# Hydrologic Connectivity, Water Quality Function, and Biocriteria of Coastal Plain Geographically Isolated Wetlands

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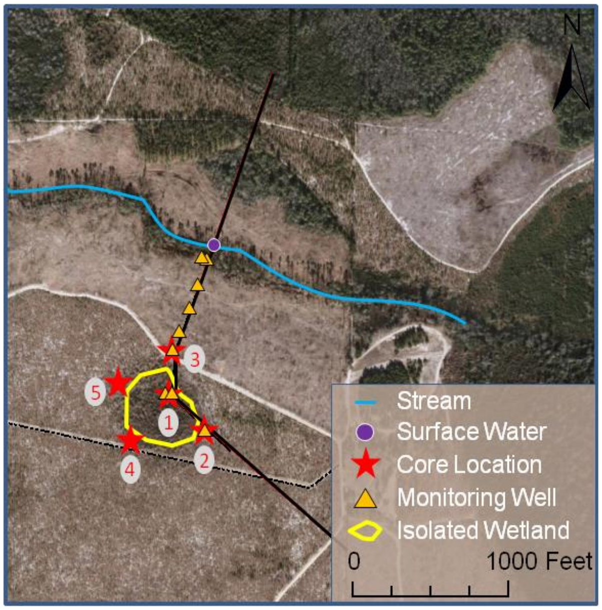


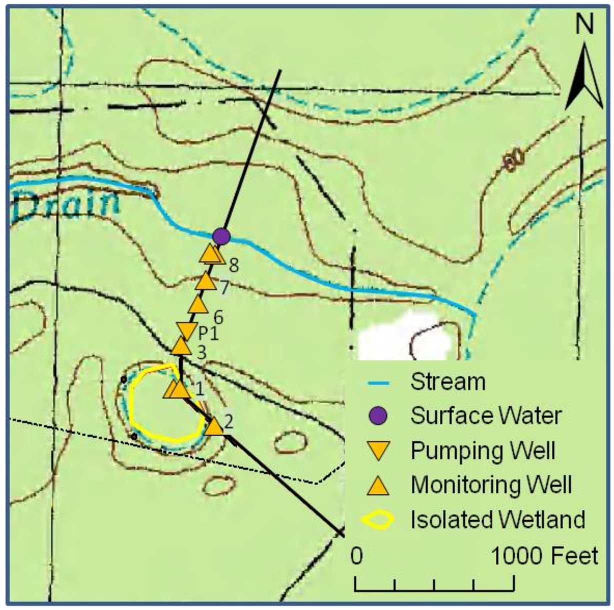


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## LIST OF ABBREVIATIONS

| Abbreviation | Description |
|---|---|
| **APS** | (NC DWQ) Aquifer Protection Section |
| **BIMS** | BasinWide Information Management System |
| **BLS** | Below Land Surface |
| **ACOE** | Army Corps of Engineers |
| **BL** | Bladen |
| **C** | Core |
| **C of C** | Coefficient of Conservatism |
| **CVS** | Carolina Vegetation Survey |
| **CWLD** | Continuous Water Level Data |
| **CZMA** | Coastal Zone Management Act |
| **D** | Deep |
| **DBH** | Diameter Breast Height |
| **DO** | Dissolved Oxygen |
| **DOC** | Dissolved Organic Carbon |
| **DTW** | Depth to Water Table |
| **DWLD** | Discrete Water Level Data |
| **DWQ** | Division of Water Quality |
| **EMC** | Environmental Management Commision |
| **FQAI** | Floristic Quality Assessment Index |
| **FGCS** | Federal Geodetic Control Subcommittee |
| **GPM** | Gallons per Minute |
| **GS** | Green Swamp |
| **GWP** | Groundwater Planning |
| **HUC** | Hydrologic Unit Code |
| **I** | intermediate |
| **IWC** | Isolated Wetland Connectivity |
| **IWs** | Isolated Wetlands |
| **JLD** | Jones Lake Drain |
| **LiDAR** | Light Detection and Ranging |
| **LDI** | Land Development Index |
| **MP** | Measuring Point |
| **MW** | Monitoring Well |
| **NLCD** | National Landcover Database |
| **NCAC** | NC Administration Code |
| **NCGS** | North Carolina Geodetic Survey |
| **NC MNS** | North Carolina Museum of Natural Science |
| **NC WAM** | North Carolina Wetland Assessment Method |
| **NCWFAT** | North Carolina Wetland Functional Assessment Team |

## LIST OF ABBREVIATIONS

| Abbreviation | Description |
|---|---|
| **Non-IW** | Non-Isolated Wetland (Jurisdictional Connected Wetland) |
| **NRCS** | Natural Resources Conservation Service |
| **NWI** | National Wetland Inventory |
| **PDU** | Program Development Unit |
| **PVC** | Polyvinyl Chloride |
| **PW** | Pumping Well |
| **OPUS** | Online Positioning User Service |
| **ORAM** | Ohio Rapid Assessment Method |
| **QA** | Quality Assurance |
| **S** | Shallow |
| **SC DHEC** | South Carolina Department of Health and Environmental Control |
| **S.E.** | Standard Error |
| **SEIWA** | Southeast Isolated Wetland Assessment |
| **SWLMS** | Surface Water Level Monitoring Station |
| **SWPS** | (NC DWQ) Surface Water Protection Section |
| **SWANCC** | Solid Waste Agency of Northern Cook County |
| **TKN** | Total Kjeldahl Nitrogen |
| **TNC** | The Nature Conservancy |
| **TOC** | Total Organic Carbon |
| **TP** | Total Phosphorus |
| **USACOE** | United States Army Corps of Engineers |
| **USC** | University of South Carolina |
| **USDA** | United States Department of Agriculture |
| **USFWS** | United States Fish and Wildlife Service |
| **USGS 24K** | US Geological Survey 1:24,000 Scale Map |
| **WQA** | Water Quality Certifications |
| **WPDG** | Wetland Program Development Grant |

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The Isolated Wetland Connectivity (IWC) project team would first like to acknowledge and thank the U.S. Environmental Protection Agency (U.S. EPA) for their continual interest and support in funding wetland monitoring and research in the Carolinas. We would especially like to recognize Rhonda Evans and Gail Harrison, the Region 4 grant technical officers who worked on this grant, Morgan Jackson, the Region 4 grant administrative officer, Diana Woods who also provides technical advice for region 4 grants and Rich Sumner, the regional liaison to the National Wetland Program. The Division of Water Quality (DWQ), Surface Water Protection (SWPS) Section, Program Development Unit (PDU) supervisors Lori Montgomery and John Dorney (currently of Atkins Environmental) and the DWQ Aquifer Protection Section (APS), Groundwater Planning (GWP) Unit supervisor Evan Kane provided both professional advice, field assistance and peer review on status reports and the final report for this project. Their feedback and efforts are greatly appreciated. We would also like to thank Breda Munoz, of RTI International for the advice and assistance she provided on statistics. Additionally we would like to thank Kathleen Farrell, of the NC Geological Survey, for sharing her expert coastal plain geological knowledge and advice. Amanda Johnson, a technician in the PDU was a great help in the developing of maps and figures for this project. The long days and tireless work of the NC DWQ APS drillers were greatly appreciated and necessary to complete the installation of the NC wells and execution of the aquifer pumping tests. The NC DWQ APS drillers include Billy Casper (Driller Supervisor, currently retired), Joseph Bailey (Driller), Stuart Bowman (Driller's Helper), Jesse Martin (Driller), Allen Mason (Driller's Helper), Dennis Foyles (Driller), and Terry Goff (Driller's Helper). We would also like to thank ARM Environmental Services for the installation of the SC wells. The time and efforts of those who volunteered for the aquifer pump tests are to be recognized as this section of the study could not have happened without them. These volunteers include NC DWQ staff members Art Barnhardt, Evan Kane, Lori Montgomery, Joan Schneier, Lori Skidmore, Michael Tutweiler, Tom Moore, Amanda Gaines, Jennifer Haynie, Eric Smith, Sarah Morrison, Chonticha McDaniel and Cory Larson and Alexis Keyworth of the University of NC Greensboro and John Dorney of Atkins Environmental. Additionally, we would also like to extend our appreciation to the land owners and land managers that allowed us to utilize their properties for this study. These include Brunswick Timber LCC, Patricia Hewett, Coastal Developers LLC, John Henry Allison, Marie Evans Watts, Mark Marlo of Horry County Municipal Airport, Bob Gordon of AC Raem Farm, Earl and Doris Helms. We are especially thankful to the NC and SC state and Nature Conservancy land managers and the SC Department of Natural Resources that provided access to their properties and also allowed us to install wells that were vital for completing the hydrology portion of this study. These land managers include Sam Stokes, Jr. of the Marsh Furniture Wildlife Management Area and Deanna Ruth of the Lewis Ocean Bay Heritage Preserve, Michael Chestnutt and Hans Rohr of Bladen Lakes State Forest, Chris Meggs and John Uber of Turnbull Creek Education State forest, and Dan Ryan and Angie Carl of the NC Nature Conservancy.

# Section 1 – REPORT INTRODUCTION AND BACKGROUND

## 1.1 Executive Summary

Isolated wetlands (IWs) are a vitally important aquatic resource in the North and South Carolina coastal plain landscape in terms of ecological value and hydrological and water quality function (Eshleman et al. 1992, Stone and Stone 1994, Whigham and Jordan 2003, Semlitsch and Bodie 1998, and Reddy and Delaune 2008). Rapid growth in NC and SC coastal plain counties (Crossette et al. 2004) in combination with the small size of IWs (median size of 0.41 acres) (RTI et al. 2011) has made this important resource susceptible to loss through urban and agricultural development. NC state regulatory protection of IWs (15A NCAC 02H .1300) was introduced following the U.S. 2001 Supreme Court ruling on the Solid Waste Agency of Northern Cook County (SWANCC). However, similar rules have not been adopted in SC; therefore IWs do not receive the same level of protection. Over 10+ years of 401 Water Quality Certification (WRC) and Isolated Wetland Permit tracking for NC IW impacts have accounted for 82.2 acres of wetland loss and 86.0 acres of mitigation, approximately a 1:1 mitigation to impact ratio (NCDENR DWQ BIMs 2011). NC Administrative Code requires a 2:1 mitigation to impact ratio, however more than half the IWs were associated with project impacts that fell below the one-acre threshold that requires mitigation (15A NCAC 2H .0506[h][2] and 15A NCAC 2H .1305 [g][2]). Additionally, it has been shown that over thirty percent of the IWs in this project's NC study area are smaller in size than the one-third of an acre NC reporting requirement (RTI et al. 2011) (15A NCAC 02H .1305 [d] [2]). NCAC also does not require an impacted IW to be replaced with a mitigated IW (i.e. IWs can be replaced with connected wetlands), therefore IWs that provide critical habitat to amphibians and other species reliant on IW conditions are still highly vulnerable to development, especially in rapidly developing coastal plain counties like Brunswick County, where 20 percent of IW impacts occurred during that 10+ year span. IWs do provide a highly important ecological niche, although the loss of IWs in NC and likely SC are not a large percent of the wetland impacts (Comer et al. 2005) (NCDENR DWQ BIMs 2011).

Isolated wetlands in the coastal plain counties of Brunswick, Bladen, Columbus, and Robeson NC and Horry, Marion, and Florence SC were evaluated for their hydrological function and pollution absorption capacity and surveyed to develop biocriteria and further verify and validate the NC Wetland Assessment Method (NCWAM). A stratified random design was employed to choose eleven high, medium, and low NCWAM rated IW sites used for the biocriteria portion of the study so that the results could be extrapolated to the entire study region. Eleven additional IW sites were selected for the hydrology and pollution absorption capacity portion of the study. These IWs were not randomly chosen due to specific requirements for equipment access and security, gradient and soil substrate characteristics, and necessary nearby proximity to a downstream connected waterbody.

The biocriteria sites were surveyed for vegetation in 2010 and amphibians and aquatic macroinvertebrates in 2011. Dry climatic conditions in 2011 resulted in limited numbers of amphibians and aquatic macroinvertebrates and therefore biocriteria could not be developed for these aquatic biota communities. The vegetation survey results were combined with results from three previous studies and used to test 43 candidate metrics for the development of a nine-metric Index of Biotic Integrity (IBI) for forested IWs. The Ohio Index of Biotic Integrity (VIBI) (Mack 2004) was used to calculate IBI values for shrub and emergent IW sites since there was not enough site data to develop shrub and emergent IBIs. The forested IBI was weighted for comparison to the 10-metric shrub and eight-metric emergent Ohio VIBI values. The comparable weighted IBI results ranged from 24 to 61.7 with a mean value of 48.6 and median value of 52.0. A generalized linear model using least squares fit was used to analyze the relationship between six sets of vegetation IBIs (forest, shrub, and emergent IBIs) and NCWAM ratings (overall and habitat function ratings). The results indicated that from one-third to three-quarters of the variation for the IBI(s) are accounted for by the NCWAM ratings in the study area. These results also showed that NCWAM can successfully rate the function of IWs and did further validate and verify the rapid assessment method.

The long term monitoring of 83 ground water wells from 2010 to 2012, three aquifer pumping tests, and water table contour maps clearly showed IWs are hydrologically connected to nearby waterbodies with surface connection to regulated streams. The long term hydrologic monitoring and drawdown data from the aquifer pumping tests indicated that IWs are hydraulically connected to the water table aquifer while the water table contour maps and long term hydrologic monitoring showed groundwater both flowed toward and discharged into downstream connected water bodies.

The pollution absorption capacity of IWs was demonstrated by the water quality and soil analysis results. Higher levels of nitrogen and organic carbon concentrations occurred in the IW than the surrounding upland monitoring wells which showed these systems have the capacity sequester these constituents before they flow into the aquifer through ground water movement. The soils results indicated that phosphorous sorption potential is also greater in the IW than surrounding upland.

The combination of ground water connection and water quality function show a continuity between IW and connected water bodies that indicate the IWs can be an integral part of these hydrologic landscapes. The site selection requirements for this phase of the study prevent quantitative extrapolation of these results to the entire study area. However, it is qualitatively clear from GIS mapping and hundreds of site visits that these geomorphic conditions likely are widespread. The landscapes are complex in terms of position of the IW relative to connected streams, soil characteristics, anthropogenic alteration, and condition of the IW which suggest there are site specific subtleties that influence these functions at the local scale.

## 1.2 Project Background

Isolated wetlands or IWs are a critically important ecosystem that provide ecological value and hydrological and water quality function for the North and South Carolina Coastal Plain regions. Although the importance of the ecological and functional value of wetlands in the landscape is well documented, there are still significant gaps in our knowledge of “isolated” wetlands, specifically in regards to water quality and hydrology. Wetland loss, in particular, has been extensive in the southeast with the loss of 44% and 27% respectively of wetland coverages in NC and SC alone (Dahl 1991). Isolated Wetlands are particularly vulnerable to losses from urbanization and agriculture because they are often surrounded by developable uplands, tend to be small in size, and have varying degrees of regulatory protection. Wetlands that are surrounded by uplands and have no obvious surface hydrologic connection have been traditionally called “isolated wetlands”. Tiner (2002) presented “geographically isolated” as a better term for describing isolated wetlands because many of these systems are hydrologically connected to other water bodies through ground-water connections or intermittent overflows.

Wetlands, including those that are geographically isolated, are highly important for aquifer recharge, flood attenuation, assimilation and processing of nutrients, carbon sequestration, water quality, habitat, and biodiversity of plants and animals including at-risk rare species (Eshleman et al. 1992, Stone and Stone 1994, Whigham and Jordan 2003, Semlitsch and Bodie, 1998, Reddy and Delaune 2008). Studies have shown that IWs provide specialized habitat for numerous plant and animal species, including many at-risk species that require specific conditions associated with isolated wetlands to survive. A study by NatureServe (Comer et al. 2005) found that nationwide there were 274 “at-risk” animal and plant species with strong associations to IWs of which 96 species have an obligate association with IWs. Of those 274, 86 are federally protected and 45 of the 86 have an obligate association with IWs, which is about 5% of all federally listed species nationwide. In the Carolinas, 3.8% and 5.9% of the at-risk species are associated with IWs in NC and SC respectively.

From an ecological perspective, the density and dispersion of small IWs in a landscape combined with the condition of the connecting upland corridors is vital for the survival of a number of wildlife species, especially amphibians that depend on geographically isolated wetlands for survival (Leibowitz 2003). Many frogs and salamanders require fish-free small depressional wetlands that dry out annually for larval stages (Leibowitz 2003). Many amphibian species are sensitive to environmental disturbances and act as indicators of the quality of their surroundings (EPA 2002*b*). North Carolina has 96 species of amphibians and is known for its diverse population of salamanders, boasting more than any other state in the Union with 54 species (Braswell 2006). Deforestation and the increase of acidic conditions and pollutants such as nitrogen and heavy metals can affect these environmentally sensitive species (Smith et al. 1994, EPA 2002*a,* Wilson and Dorcas 2003). Most amphibians spend part of their life in water and part on land or even in subterranean habitats, which consequently makes surveying especially difficult except during the yearly breeding season. Some species of amphibians can reproduce in farm ponds, lakes, ditches, puddles, or rivers, while other species have more specialized requirements, needing mature forested wetland areas that have good water quality and lack predatory fish. These conditions can occur in isolated wetlands or headwater wetlands. In North Carolina 53 species of amphibians are known to use these types of habitats during their breeding season, of which 31 species, or nearly one-third of the amphibian species in North Carolina, require these conditions solely to reproduce (A. Brasswell, pers. comm. 2006). Of those 31 species, 7 are considered state threatened or state/federal special concern and 4 more are on the state watch list (NC NHP 2010). These essential benefits for amphibian populations can be reduced or removed by wetland impacts (e.g., Harper et al 2008). Continued loss of these critical habitats in North Carolina has the potential to affect population diversity and survival of these unique and sensitive species.

Wetlands provide important habitat for a large variety of aquatic macroinvertebrates. Many of these aquatic macroinvertebrates complete their life cycles within wetlands while others utilize wetlands during part of their life cycle (U.S. EPA 2002*d*). Macroinvertebrates have proven to be useful bioindicators of aquatic environments due to their ubiquitous presence and sensitivity to environmental stressors (U.S. EPA 2002*d*). Macroinvertebrates contribute to nutrient and organic matter cycling and provide food resources for higher trophic levels (Wharton et al. 1982). Coburn et al. (2008) also found endemic macroinvertebrate taxa were associated with isolated vernal pools in the northeastern U.S.

IWs are also rarely isolated from a water quality perspective. IWs have the potential to affect water quality since studies have shown these systems to have direct hydrological interactions with other wetlands and uplands via groundwater and/or an intermittent surface water connection (Whigham and Jordan 2003). It is rare that isolated wetlands are truly isolated from a hydrologic perspective as many are connected downstream water bodies by groundwater flow. However, few studies have been done which characterize the groundwater hydrological connection and pollutant absorption capacity of geographically IWs. Studies have shown that the IW substrate has the capacity to affect the interaction of IW surface water and groundwater. IWs with an impervious clay lens will cause hydric regimes to be driven by precipitation and evapotranspiration. In contrast, other IWs that have a more impervious substrate appear to have direct connections to ground-water sources (Hendricks and Goodwin, 1952, Torak et al. 1991).

The U.S. 2001 Supreme Court ruling on the Solid Waste Agency of Northern Cook County (SWANCC) case removed jurisdiction over isolated wetlands at the federal level by the Army Corps of Engineers (SWANCC vs. USACOE et. al. 2001). The Supreme Court ruled that the USACOE could not use the Migratory Bird Rule developed in 1986 to exert authority over IWs and wetlands under the Clean Water Act (Petri et al. 2001). The June 2006 Supreme Court ruling of the Rapanos/Carabell cases further restricted jurisdiction over wetlands that lack a “significant nexus” to non-isolated water bodies (Rapanos and Carabell vs. USACOE 2006). The loss of federal protection of isolated and intermittently isolated wetlands has made the necessity of implementing state level protection of IWs absolutely crucial.

In North Carolina all 401 WQC projects that impact wetlands that are ≥ $1/3^{rd}$ of an acre to the east of I-95 and ≥ $1/10^{th}$ of an acre to the west of I-95 require the submittal of a Pre-construction Notification form to NC DWQ (15A NCAC 02H .1305 [d][2]). On October 22, 2001, following the SWANCC ruling, the NC Environmental Management Commission (EMC) adopted rules regulating the impacts (both filling and draining) to IWs (15A NCAC 02H .1300) 2001 NC The NC Administrative Code (NCAC) Section 1300 defines IWs as those waters which are inundated or saturated by an accumulation of surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support a prevalence of vegetation typically adapted to life in saturated soil conditions and under normal circumstances have no visible surface water connection to downstream waters of the state. Visible surface water connection may include but are not limited to a connection to other surface water via: "(1) continuous wetlands, (2) intermittent or perennial streams, and (3) ditches with intermittent or perennial flow." This definition of IWs was applied to the IW sites chosen for this study and the Southeast Isolated Wetland Assessment (SEIWA) study discussed later in this section. NCDWQ issues 401 WQCs for approved impacts to 404 wetlands and/or an Isolated Wetland Permit for impacts to isolated wetlands. North Carolina Administrative Code requires compensatory mitigation for projects with impacts to ≥ 1 acre of wetlands (15A NCAC 2H .0506(h)(2) and 15A NCAC 2H .1305 (g)(2)). These impacts can be IW impacts, non-IW impacts, or a combination of both. NCDWQ requires compensatory mitigation for impacts to IWs at a 2:1 mitigation:impact ratio (15A NCAC 2H .1305 (g)(2)), but the mitigated wetland is not necessarily required to be an IW. In NC the ACOE often requires mitigation at a lower impact threshold and may require higher mitigation ratios than the NC DWQ.

The SC Department of Health and Environmental Control (SC DHEC) developed regulations for the protection of IWs following the SWANCC ruling similar to NC. After meeting with stakeholders for more than a year, the SC DHEC board approved the rules in January 2004, and submitted them to the South Carolina General Assembly (in South Carolina, the General Assembly has the authority to review and approval all regulations). The General Assembly failed to approve the regulations and therefore they were never implemented. However, the debate over IWs continues in South Carolina and was the topic of two recent South Carolina Supreme Court cases. In one case a development company was denied a permit to fill IWs under the Coastal Zone Management Act (CZMA) which resulted in the requirement of IWs to be included in the permit review process for applicable coastal counties. In the second situation, the SC Supreme Court determined that IWs were waters of the State as defined by the South Carolina Pollution Control Act and, therefore, a permit would be required for a developer who wished to discharge fill in order to develop the property. In this second case, the final result was that the South Carolina General Assembly amended the SC Pollution Control Act to provide, among other things, an exemption for discharges for which there is no regulatory permitting program. Thus, the situation remains that, outside of the coastal counties, South Carolina has no regulatory authority over IWs. However, one interesting note is that with the most recent amendments to the SC Pollution Control Act, the South Carolina legislature created the "Isolated Wetlands and Carolina Bays Task Force" whose mission is to review, study and make recommendations concerning issues related to isolated wetlands and Carolina Bays in South Carolina (South Carolina Legislative Printing).

Research on IWs, along with the development of state level regulations for IWs, have increased in the last decade due to the ruling of the SWANCC case (Downing et al. 2003). Currently, there is no national assessment of the extent of IWs (Lane et. al. 2012) but various studies using Level 1 remote sensing and GIS analysis have been conducted on IWs within different states and regions, including the southeast and the Carolinas. Regional studies in the southeast and Carolinas have assessed the extent, density, abundance, area, volume and condition of IWs (Lane and D'Amico, 2010, Lane et. al. 2012, RTI Inernational et al. 2011, Comer et. al. 2005, Tiner 2003). NatureServe found that 27% of NC wetlands are isolated and 44% of SC wetlands (by number of wetlands not total area) are isolated (Comer, et al. 2005). Tiner (2002) found that the low-lying Coastal Plain region has the highest occurrence of these wetlands, covering up to 30% in some land areas of the Coastal Plain. Best professional judgment almost a decade ago estimated 20% of the contiguous U.S. wetlands to be isolated (Likens et. al. 2000). The Lane et al. 2012 study on the IWs within an eight state area in the southeast (MD, DE, VA, NC, SC, GA, AL, and FL) used a GIS process to buffer and mask the National Wetland Inventory (NWI) wetlands that intersected rivers, streams, and lakes which identified 813,163 potential isolated wetlands in the landscape. This resulted in 1,185,022.6 ha equaling 9.0 percent of the total freshwater wetland habit in the southeast. In NC 76,604 IWs were identified equaling 126,994.3 ha and 6.8% of the freshwater wetland habitat while in SC, 100,413 IWs were identified equaling 153,279.8 ha and 9.5% of the freshwater wetland habitat. The median size of wetlands in the southeast was 0.38 ha (0.94 acres). Wetland condition was determined with a Landscape Development Index (LDI) tool that was used to evaluate the surrounding 100m buffer of each IW with the 2006 National Land Cover Database (NLCD). IWs were considered to be either impaired ($LDI \geq 2.0$) or reference ($LDI < 2.0$). In the southeast approximately 50% of the IWs rated as reference while in NC and SC 39.5 and 59.8 percent of the IWs rated as reference respectively (Lane et. al 2012).

However, it is likely the above studies do not take into account the number of isolated wetlands that have been impacted in the Coastal Plain by means of logging, ditching, filling, and draining. Under the Southeast Isolated Wetland Assessment (SEIWA) Regional Environmental Monitoring and Assessment Program study a Level 1 “GIS Isolated Predictive Mapping Tool” was developed (RTI International et al. 2011). This mapping tool was used to map isolated wetlands located in eight NC and SC Coastal Plain counties and to determine the rate of destruction and modification of these systems in this area. The accuracy of the mapping tool was ground-truthed during the 2008 field season at 170 sites. During the ground-truthing process additional Level 2 information was taken on wetlands that were isolated including a rapid assessment of each site using the North Carolina Wetland Assessment Method (NCWAM; North Carolina Wetland Functional Assessment Team 2008) and Ohio Rapid Assessment Method (ORAM; Mack 2001) and a survey of depth and volume. The Level 2 portin of the SEIWA study found that of the candidate IWs mapped during the Level 1 analysis 69% were jurisdictional wetlands and only 22% were in fact IWs. During the Level 2 ground- truthing candidate IWs were often found to not be IWs due to ditching in forested areas that was not detected in the GIS process or by the LiDAR. These results indicate that the use of solely GIS and remote sensing for the mapping of isolated wetlands can over-estimate IWs on the landscape.

The SEIWA study also had a Level 3 intensive survey component that was conducted on two clusters of IWs. This intensive survey assessed the biota, soils, hydrology, and water quality characteristics of these IWs. This project expanded on the Level 3 work of the SEIWA grant to gain further knowledge about the hydrological connectivity and water quality pollution absorption capacity of isolated wetlands plus what biocriteria can be used to properly assess the condition of isolated wetlands. This important information on isolated wetlands is needed to help wetland managers make informed decisions on the management and promote the protection of these valuable ecosystems. It should also be noted that the Level 1, Level 2, Level 3 approach to monitoring NC wetlands has been implemented on other EPA grants including: 1. Development of a Wetland Monitoring Program for Headwater Wetlands in North Carolina (USEPA Grant CD 974260-01), 2. Field Verification of Wetland Functional Assessment Methods within Local Watershed Planning Areas (CD 96422105-0). 3. Implementation Grant – Wetland Functional Assessment: Expansion and enhancement of the North Carolina Wetland Assessment Method (NC WAM) (WL 9643505-1).

The SEIWA Level 3 intensive study of the biota (macroinvertebrates, amphibians, plants), soils, water quality, and how these systems interact with each other through ground water movement was completed during the 2009 and 2010 field seasons. Due to financial constraints of the SEIWA grant, not enough wetland sites could be evaluated to effectively characterize the biota, soils, pollution absorption capacity, and hydrology of these systems. This Isolated Wetland Connectivity (IWC) grant was awarded to NC DWQ in 2008 to further expand the Level 3 work completed for the SEIWA study. NC DWQ contracted University of South Carolina (USC) for portions of the SC field work and analysis and also consulted with Research Triangle Institute (RTI) on some of the statistics. This study sought to gain a better understanding of the hydrology, water quality, and biocriteria of IWs. The IWC project objectives and description are discussed further in the next section.

## 1.3 Project Study Objectives and Description

### 1.3.1 Project Study Objectives

The objective of this research is to gain a better understanding of the hydrologic connectivity, pollution absorption capacity and biocriteria of IWs through intensive field study and to determine if there has been a net-loss of IWs in NC since October, 2001, following the SWANCC decision and implementation of a permitting program for IWs in NC. Data were collected using a stratified random sample of isolated wetlands visited for the SEIWA grant. The probability sampling design allows extrapolation of the results to the population of isolated wetlands in the eight county study area. The "Hydrologic Connectivity, Water Quality Function, and Biocriteria of Coastal Plain Geographically Isolated Wetlands" called the "Isolated Wetland Connectivity" or IWC study for short had five main study objectives which are outlined below.

1. To develop biocriteria for "at-risk" Coastal Plain IWs by completing a Level 3 intensive survey of the water quality, soils, vegetation, amphibians, and macrobenthos for 10-12 isolated wetland sites combined with other available data. The results will be combined with comparable results obtained from the two clusters of IWs that were intensively surveyed for the SEIWA grant project results. Sites that were identified as small basin wetlands and identified for the Level 1 work SEIWA grant will be used for the biocriteria development. Other potential data to be used in the development of the biocriteria for IWs are the intensive survey results from isolated basin wetlands located in Brunswick County

that were collected for the "Field Verification of Wetlands Functional Assessment Methods" grant (CD-96422105-0).

2. To further validate the NCWAM by assessing the statistical significance of the correlation between the intensive survey data and the NCWAM ratings for the major type of IWs –basin wetlands.

3. To determine the pollution absorption capacity of 10 to 12 Coastal Plain IWs in order to gain a better understanding of the water quality function of these systems.

4. To identify and characterize the hydrological connectivity of 10 to 12 Coastal Plain IWs in order to improve the understanding of how these systems interact with and are connected to downstream water bodies.

5. To determine the acreage of IWs that have been impacted and mitigated in North Carolina since 2001 and find out if there has been a net loss or increase of these systems. This information is needed to work toward a net-increase rather than a net-decrease of this critically important and vulnerable natural resource.

### 1.3.2 Project Study Description

For the IWC study, 11 "biocriteria" sites (seven in NC and four in SC) and 11 "hydrology and water quality" sites (eight in North Carolina and three in South Carolina) were chosen. In order to meet the project study objectives and constraints associated with those objectives, it was necessary to have two sets of field sites. The randomly chosen biocriteria sites did not meet the study design criteria needed for the hydrology portion of the study, which included equipment access and security, gradient and soil substrate characteristics, and necessary nearby proximity a downstream connected waterbody.

**Biocriteria Sites** – The biocriteria sites were a random subset of the SEIWA Level 2 IW randomly selected sites (see Section 2.1.1 Biocriteria Site Selection). A stratified random design was used to sub-sample sites with NCWAM functional ratings of High, Medium, and Low values (see Section 2.1.7 NC Wetland Assessment Method). As mentioned before a probability sample will allow the extrapolation of the intensive study results to the entire study region. Biocriteria site results were analyzed and used to meet IWC project study goals: (1.) the development of biocriteria, and (2.) further verification and validation of the NCWAM and intensive biocriteria results extrapolation to the IWC project study area. Intensive surveys and sampling for the 11 biocriteria sites included:

1. An amphibian survey in February-March and May of 2012 at North Carolina and South Carolina biocriteria sites. (see Section 2.1.2 Amphibian Monitoring Methods).

2. Aquatic macroinvertebrate sampling in March of 2012 was performed at North Carolina and South Carolina biocriteria sites (see Section 2.1.3 Aquatic Macroinvertebrate Monitoring Methods).

3. A plant community survey using the Carolina Vegetative Survey protocol during the 2010 field season at North Carolina and South Carolina biocriteria sites (Section 2.1.4 Vegetation Monitoring Methods).

4. A water quality survey which included monitoring physical parameters in the field and collecting water quality samples for analysis during the amphibian survey in February-March 2012 at North Carolina and South Carolina biocriteria sites (Section 2.1.5 Biocriteria Water Quality Sampling Methods).

5. A soil survey which included a field description and collection of soil samples for lab analysis in the wetland and surrounding upland was also completed during the 2010 field season (Section 2.1.6 Biocriteria Soil Sampling Methods).

**Hydrology and Water Quality Sites** – The hydrology and water quality sites were chosen for several criteria, including their proximity to a downstream connected water body and accessibility for well installation. See 2.2.1 Hydrology and Water Quality Site Selection for further detail on study site criteria and a definition of downstream connected water bodies. The sites were used to study water quality characteristics at the landscape scale and to characterize IW hydrological connectivity. Study sites were identified through a desk-top review followed by site reconniassance of SEIWA Level 1 polygons on conservation lands. Intensive survey methods were applied between February 2010 and July 2012 for the 11 sites included the following procedures:

1. A shallow subsurface stratigraphy survey was done by collecting sediment cores along transects from the IW to the non-isolated water body and/or around the edge of the IW (see Section 2.2.2.1 Geology and Core Sampling Methods). These results were used to make a best professional judgment for the well placement and depth.

2. A series of 3-9 monitoring wells was installed to monitor water level and water quality. For details on well dimensions and installation methods see Section 2.2.2.2 Monitoring and Aquifer Pump Well Installation Methods.

3. A survey of well elevations was conducted to determine a measuring point for water level monitoring (see Section 2.2.2.3 Differential Level Survey Methods).

4. Monitoring wells outfitted with transducers were used to develop water table contour maps and determine hydrologic connectivity between the IW, aquifers, and downstream connected water bodies (see Section 2.2.2.4 Methods for Hydrologic Sampling of Monitoring Wells).

5. Aquifer pumping tests were conducted at three NC sites to reveal hydraulic properties of the aquifer materials such as hydraulic conductivity and specific yield (see Section 2.2.2.5 Aquifer Pumping Test Methods).

6. A water quality survey, which included monitoring physical parameters in the field and collecting samples for analysis, was conducted quarterly (see Section 2.2.3 Water Quality Sampling Methods).

7. A soil survey was conducted in the wetland and surrounding upland. This included a field description and collection of soil samples for lab analysis (see Section 2.2.4 Hydrology and Water Quality Soil Sampling Methods).

**NC IW Impact and Mitigation** - Project goal (5.) to determine acreage of IWs that have been impacted and mitigated in NC since 2001, was achieved through review of the NC DWQ Basinwide Information Management System (BIMS; DENR 1999) database, mitigation database and mitigation projects files associated with those IW impacts.

## 1.4 Study Area

Sites in four NC counties (Robeson, Bladen, Columbus, and Brunswick) and four SC counties (Dillon, Marion, Florence, and Horry) were used for the study (Figure 1) which was the same eight county study area used in the SEIWA study. The randomly chosen biocriteria sites (see Section 2.1.1 Biocriteria Site Selection, below) occurred in Robeson, Bladen, Columbus, Brunswick, Florence, and Horry counties. The non-randomly chosen hydrology and water-quality sites (see Section 2.2.1 Hydrology and Water Quality Site Selection) occurred in Bladen, Brunswick, Marion and Horry counties. The sample size was allocated to each county proportional to the land area of each county, therefore counties with large areas had more chance of having sites selected. Neither Marion nor Dillon County, which had the smallest land area and fewest IWs according to the SEIWA study (RTI et. al. 2011), had biocriteria sites chosen. However, under the assumption that the the four counties in South Carolina represent a similar region, inferences derived from the other counties can also be extended to Dillon and Marion Counties.

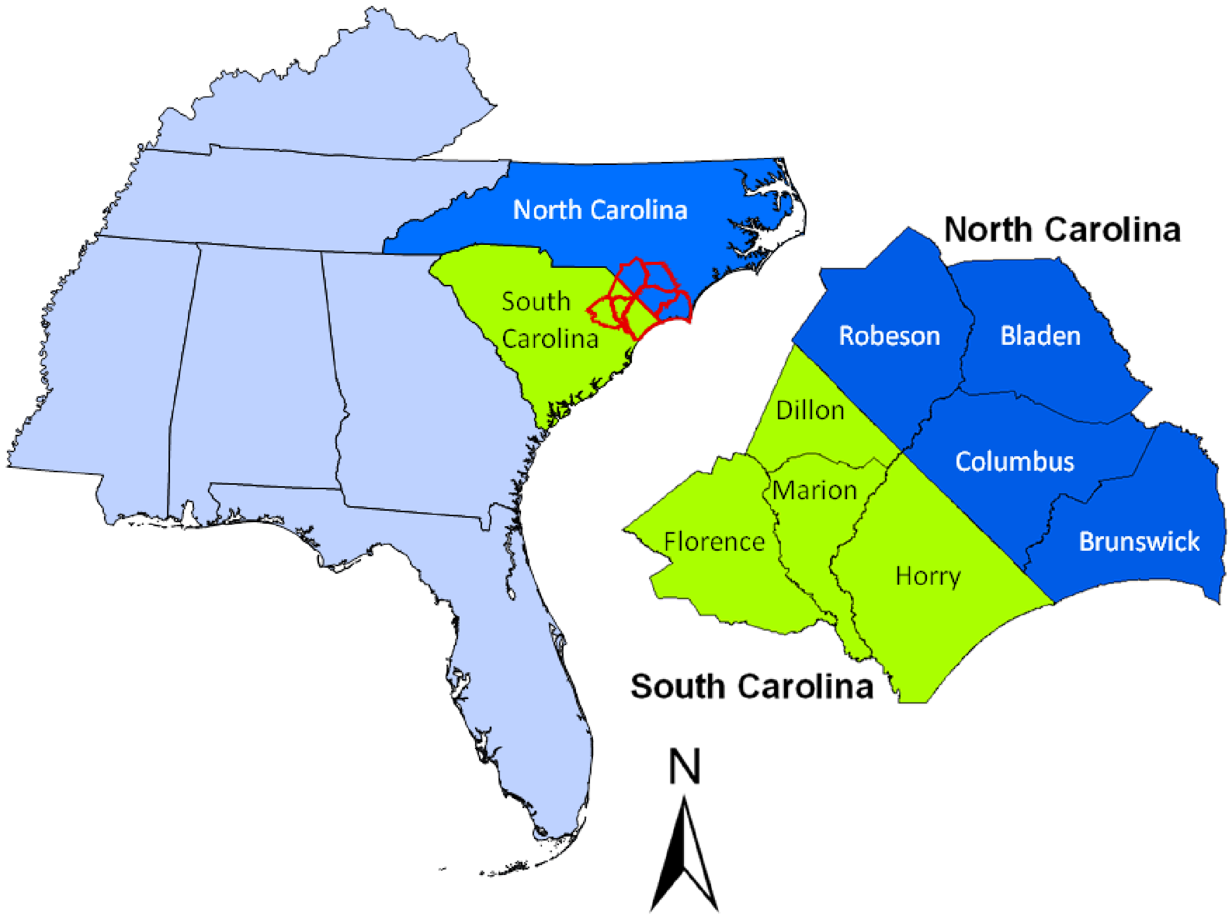


Figure 1. Project study area.

# Section 2 – METHODOLOGY

## 2.1 Biocriteria Site Field and Data Analysis Methodology

### 2.1.1 Biocriteria Site Selection

The Level 1 SEIWA study developed an isolated wetland GIS coverage (sampling frame for the SEIWA study); a tool for estimating the coverage and location of IWs in an eight county study area (NC Brunswick, Bladen, Columbus, and Robeson Counties and SC Horry, Marion, Florence, and Dillon Counties). This sampling frame contained all locations that were considered potential isolated wetlands (RTI et al. 2011) A probability-based sampling design was used to randomly select 170 sites for the Level 2 analysis. Biocriteria sites were selected at random from the SEIWA Level 2 study sites.  The SEIWA sampling design stratified the sample area by county and clustered the sites within counties using the 14-digit hydrologic unit (HUC). Half of the SEIWA sample was allocated to NC and half to SC to ensure the sample precision at the state level. Sample size within each state was allocated proportional to the number of potential isolated wetlands in each county. Counties that had a higher occurrence of potential IWs (as identified in the SEIWA Level 1 analysis) had a higher number of randomly chosen sample sites as compared to counties with fewer occurrences of potential IWs. The SEIWA samping design is a two stage sampling design. In the first stage 6 to 8 clusters (14-digit Hydrologic Unit Codes [HUC]) were selected at random from each state using probability proportional to the size, and in the second stage, sites were selected randomly from selected HUCs. Sampling using probability proportional to the size gives HUCs with larger number of potential IWs a larger likelihood of being included in the sample when compared to those HUCs with smaller number of potential IWs. The goal of this sampling approach was to improve efficiency by selecting sites with certain geographic proximity (e.g. sites within the same HUC) and to ensure that the sample of sites was distributed among those 14-digit HUCs with larger number of potential isolated wetlands. The SEIWA 170 Level 2 sites were ground-truthed by first determining accessibility, second whether the site was a wetland or not, and third whether the site's wetland was isolated or connected. The 48 IW sites found during the SEIWA Level 2 survey were also delineated using 1987 Army Corps of Engineers methods (USACOE 1987), rapidly assessed with the NC WAM (NCFAT 2008) and Ohio Rapid Assessment Method (ORAM) (Mack 2001), identified by wetland type using the NCWAM key, the *NC Third Approximation* (Schafale and Weakley, 1990) and *The Natural Communities of SC* (Nelson 1986), and surveyed for depth and volume (RTI et. al. 2011).

The SEIWA Level 2 survey resulted in the identification of 48 individual IWs, five pocosin and 43 basin IWs. Basin sites were chosen for the IWC biocriteria study since this type of wetland was most common and has a better potential for providing good habitat for amphibians than pocosins, which are typically too acidic and shrub covered. The SEIWA Level 2 study identified 25 high-rated, 16 medium-rated and two low-rated basin IWs with the NCWAM (RTI et. al. 2011). Biocriteria sites were selected from the 43 SEIWA Level 2 basin IWs.

For the IWC study 10-12 sites evenly distributed between NCWAM ratings of high, medium and low (Figure 2) were selected. Four high rated and four medium rated sites were selected using a stratified simple random sampling design. However, for the low-rated sites this was not possible since there were only two sites. Both low-rated sites, Brunswick 4 and Horry 1, were included in the study, along with an additional poor quality site, Bladen 9. Bladen 9 rated low for hydrology and habitat, medium for water quality, and medium overall. Therefore, for the purposes of this study, Bladen 9 was classified in the "low" category for NC WAM rating. The IWC biocriteria study sample design is a double-sampling or two-phase sampling design. In this type of sampling design, general measures are collected in a large sample (e.g. Level 2 data) and more expensive or time consuming measurements (e.g. intensive Level 3 data) are collected from a smaller sub-sample (Legg and Fuller, 2009).

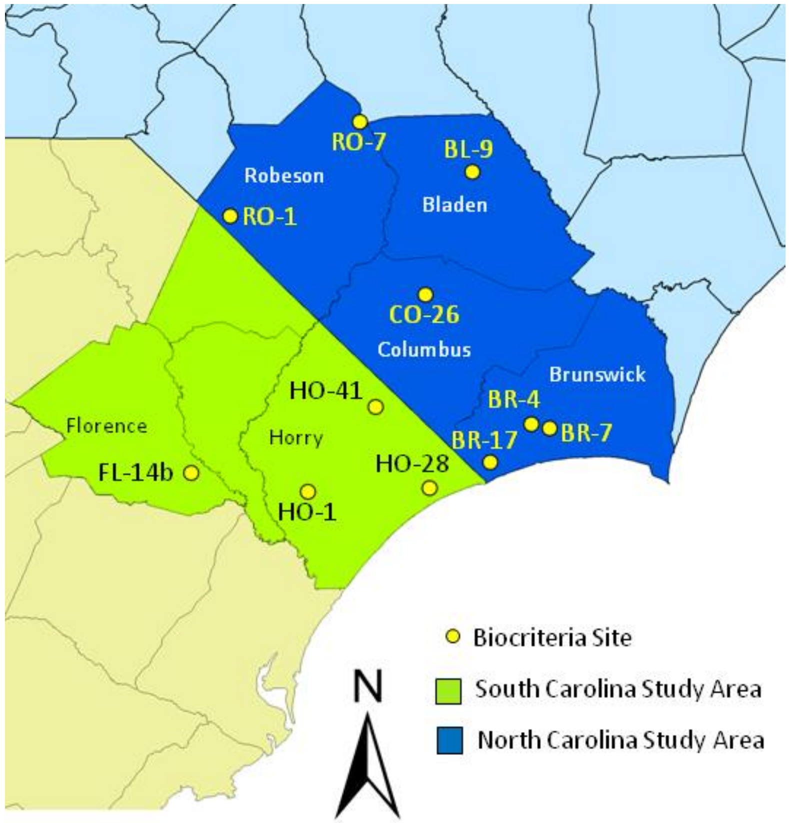


Figure 2. Biocriteria study sites located in North Carolina and South Carolina.

## 2.1.2 Amphibian Monitoring Methods

The amphibian survey work was done using both quantitative and qualitative methodology. Amphibian surveys were done at 11 sites in North Carolina and South Carolina. Surveys were performed twice at each site during the 2012 field season. The first survey was completed in February and March and a second survey was completed in May. Seasonal weather patterns that encourage spring breeding (2−4 nights of >45$^{o}$F with rain) were used to determine the exact timing of the surveys.

During both survey events, staff completed the qualitative survey by inventorying frogs, tadpoles, egg masses, and larval salamanders found in pools in the wetland site and in the surrounding 150−200’ buffer for 2 man-hours. Methods included using D-shaped sweep nets in pools and potato rakes in areas with saturated soils and leaf cover. Leaf cover near standing was lightly scraped to search for salamanders. Logs or woody debris located in the wetland or adjacent upland buffer were turned over to look for amphibians and then replaced. Additionally, all auditory calls heard during the survey period were identified when possible.

A quantitative survey for amphibians was done in conjunction with the qualitative survey using a combination of funnel traps and cover boards. Twenty to 25 plywood cover boards (1 $m^2$) were deployed throughout the IW approximately 1 year prior to the survey (see Figure 3).

Cover boards were turned over and checked for amphibians during the qualitative survey. If sufficient water was present, funnel traps (15−20 traps) were deployed in standing water at each site after the 2 hour visual survey and were then checked for amphibians after approximately 24 hours.

Field data sheets were kept for each amphibian survey event. See Appendix A for an example of the amphibian field sheet and data collected on each sheet. The water quality field parameters were taken during the qualitative and quantitative survey events. The previous 48-hour precipitation and temperature minimum and maximum levels were also taken from the nearest weather stations and recorded on field sheets. All amphibians were identified in the field. The "Distribution of Amphibians in North Carolina" (NC DENR 2003) draft document written by the NC State Museum of Natural Sciences (NC MNS) was used for genus and species nomenclature.

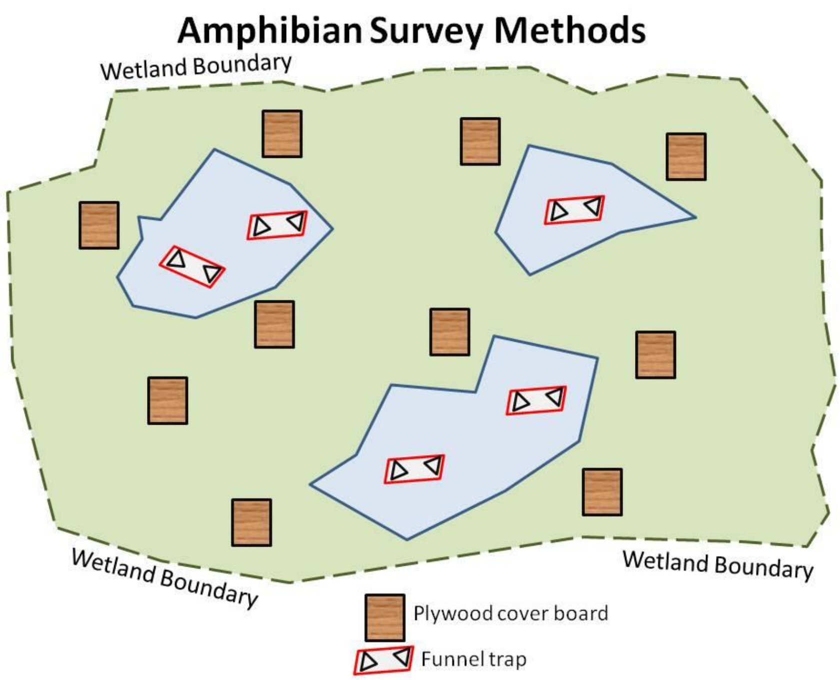


Figure 3. Amphibian survey methods (Green – wetland, blue – pools).

### 2.1.3 Aquatic Macroinvertebrate Monitoring Methods

A semi-quantitative sweep-net sampling procedure at up to five stations was used to sample for macroinvertebrates in conjunction with the early spring amphibian survey. Sweep nets, or dip nets, are a semi-quantitative method that is quick and easy to use which can collect a diverse array of representative taxa and are usable in very shallow water. In order to ensure more semi-quantitative results, D-shaped nets (500-micron) were used to sweep a 1 $m^2$ area with 3-4 sweeps per station (see Figure 4). Additionally, the five stations were located in areas with variable micro-habitats for each survey. In cases where water was present in small isolated pools, macroinvertebrate samples from up to 5 pools were collected, if possible. Leaf and woody materials were then elutriated from the net, and a visual search of leaf packs and woody debris was made before discarding. The sample was then composited and put in a labeled container. Sweep nets were rinsed thoroughly between sites. All macroinvertebrates collected in funnel traps were also collected and placed in a separate container for preservation. Macroinvertebrate samples were preserved in 70 percent non-denaturized ethanol alcohol.

A field sheet was completed for each site sampled. See Appendix A for an example of the Amphibian field sheet and data collected on each sheet. Physical water quality parameters were measured within the sample area. All sample containers were labeled in pencil with the site name, date, sample ID, container number, dye, field crew initials, sample-processing initials, and date processed.

Macroinvertebrate samples were sorted under a light by using a white picking tray. Sample contents were mixed and then deposited evenly on a 14 x 17 inch tray. All macroinvertebrates were picked from the sample first to ensure that predators and species higher on the food chain are included in the processed sample. Processed specimen vials were labeled with the site name, station ID, number of individuals picked, date of collection, and picker's initials. Trained DWQ entomologists performed identification and enumeration of each sample. Regional macroinvertebrate identification keys were used was be used for genus and species nomenclature (Merritt et al. 2008, Brigham et al. 1982).

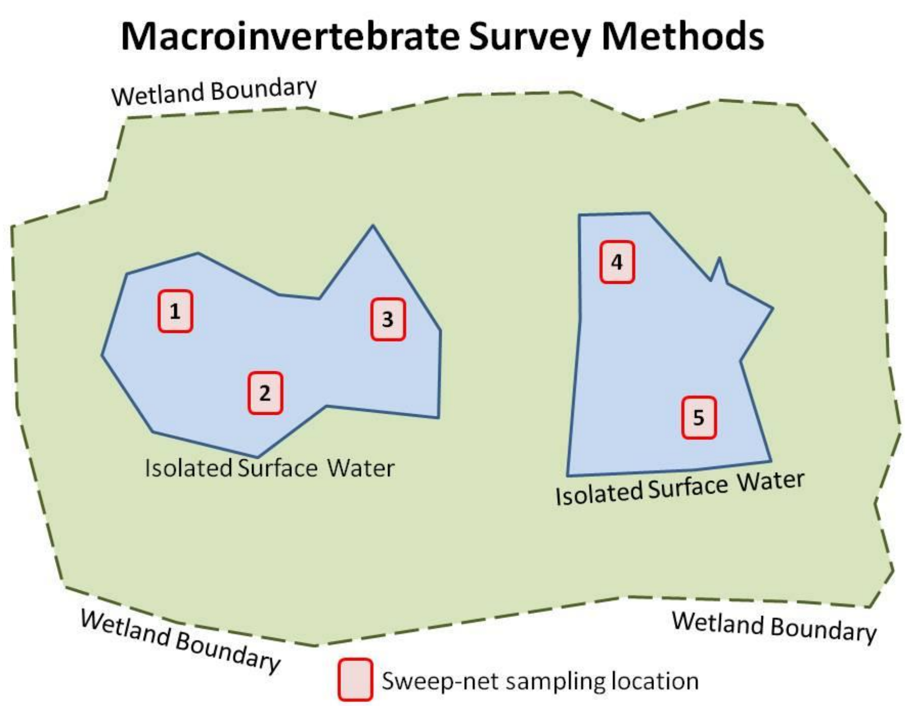


Figure 4. Macroinvertebrate survey methods (Green – wetland, blue – pools).

### 2.1.4 Vegetation Monitoring Methods

Wetland plant communities are a useful indicator of human disturbance. Intact wetland plant communities are important for maintaining water quality (U.S. Environmental Protection Agency 2006) and providing habitat to wildlife. Quantitative monitoring of IW vegetation enables us to better understand the community characteristics of these systems.

Plant community monitoring methods were devised from the *North Carolina Vegetation Survey Protocol: A Flexible, Multipurpose Method for Recording Vegetation Composition and Structure* (Peet et al. 1997) which will be referred to as the Carolina Vegetation Survey (CVS) protocol in this report. CVS protocol was developed by experienced NC botanists for the purpose of providing a quantitative description of the vegetation in a variety of Carolina habitats. This method has proved to be flexible in design and highly accurate in the 25 field seasons it has been employed by CVS staff and volunteers. Carolina Vegetation Survey protocol was used to evaluate three types of plant community characteristics: vegetation presence, cover, and woody stem size class.

CVS protocol typically consists of 10 m x 10 m modules laid out in a 5 x 2 array or a 50 m x 20 m plot. The exact layout and size of the modules can be altered according to the area chosen for the survey. For this project, eight modules in a 4 x 2 array or 40 m x 20 m plots were used at ten of the eleven sites (Figure 5). The best location and orientation for the 40 m by 20 m vegetation plot was determined in the field based on the contours of the wetland site boundary and variability of the vegetative community. Biocriteria site Florence 14b was too small (0.09 acres) to complete a full survey so just two intensive modules were surveyed. Modules were numbered counter clockwise from “1” to “8”. The four modules located in the center of the plot, 2, 3, 6, and 7, are “intensive modules” and were surveyed for vegetation presence, cover and woody stem size class. The intensive module corners are numbered clockwise from “1” to “4”. The other modules, located at either end of the plot, 1, 4, 5, and 8, are “residual modules” and were only surveyed for woody stem size class (see Figure 5).

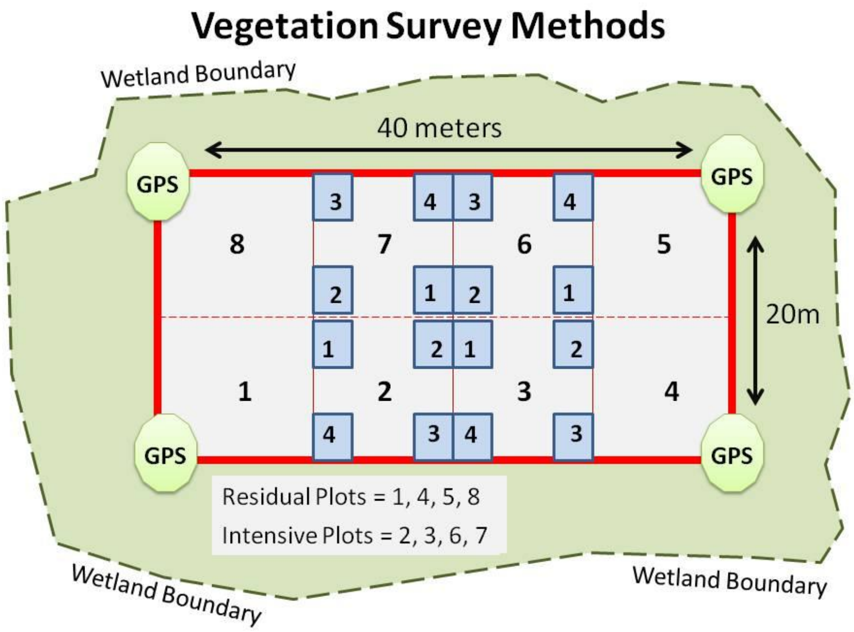


Figure 5. Vegetation survey methods.

As previously discussed, the intensive modules, modules 2, 3, 6, and 7 were surveyed for vegetation presence and cover. Species presence was first determined at one chosen corner and then cover classes were assigned to each species present within the entire module. The presence survey corner was randomly chosen in the field. Adjacent corners of adjacent modules such as module-2, corner-1 and module-7, corner 2 (see Figure 5) or corners with localized disturbance, such as a downed tree, were not used for the presence survey. Vegetation presence was determined with a series of four nested quadrats (10 cm x 10 cm, 32 cm x 32 cm, 1 m x 1 m, and 3.16 m x 3.16 m; within each 10 m x 10 m module (Figure 6). Presence in the CVS protocol is defined as “the occurrence of a species within a quadrat, where the species must be ‘rooted in the quadrat”. Species occurring within the module were given a presence class number for the smallest nested quadrat in which they first occurred: “5” for the 10 cm x 10 cm quadrat; “4” for the 32 cm x 32 cm quadrat; “3” for the 1 m x 1 m quadrat; “2” for the 3.16 m x 3.16 m quadrat; and “1” for the entire module. Species overhanging the intensive module but not rooted in the module were assigned a presence value of “0”.

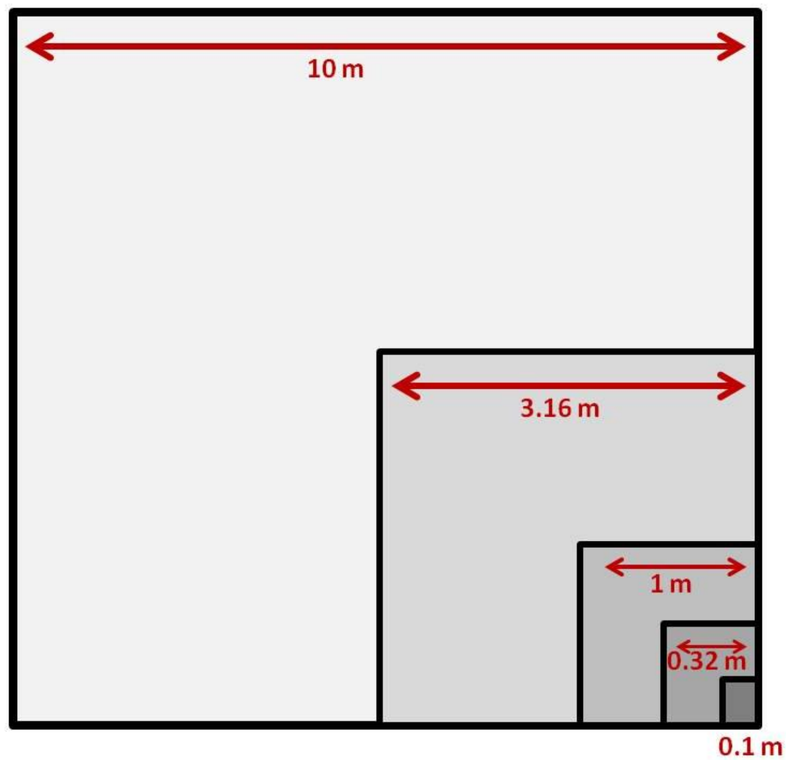


Figure 6. Nested quadrat diagram.

Cover was recorded for all species rooted in or overhanging the module, which included herbs, shrubs, vines, and trees, and was defined as "the percentage of ground surface obscured by the vertical projection of all above ground parts of a given species onto that surface." Carolina Vegetation Survey protocol was used to divide cover into cover classes based on what the human eye can detect. The cover classes were based roughly on doubling percents: trace (1–2 individuals only), 0–1% (1 $m^2$), 1–2% (1 m x 2 m), 2–5% (1 m x 5 m), 5–10% (1 m x 10 m), 10–25% (5 $m^2$), 25–50% (5 m x 10 m), 50–75% (8.7 $m^2$), 75–95% (9.7 $m^2$), and 95–100% (10 $m^2$). Species not rooted or overhanging the intensive modules but located in the residual modules, were also recorded but not assigned a cover class. A cover value was assigned for the overall herb, shrub and sapling, and canopy strata for each of the intensive modules. Additionally, presence and cover class was assigned to bryophytes which were lumped into bryophyte or sphagnum categories. See Appendix A for an example of the IWC Plant Survey Species Cover Field Sheet.

Woody stem data were recorded for every woody plant, shrub, vine or tree rooted within the module that reached breast height (BH; BH = 1.37 m above the ground). Woody stems were divided into diameter at breast height (DBH) size classes for ease of measuring and recording in the field: 0–1 cm, 1–2.5 cm, 2.5–5 cm, 5–10 cm, 10–15 cm, 15–20 cm, 20–25 cm, 25–30 cm, 30–35 cm, and $\geq$ 40. The exact DBH was also recorded for trees >35 cm DBH. A separate tally was kept for each intensive module and a combined tally was kept for the residual modules. All stems were surveyed for bifurcated saplings or shrubs that split below 1 m, while only the largest stem was surveyed for bifurcated saplings or shrubs that split above 1 m. Snags that reached a 5 cm DBH were also included in this survey. See for an example of the IWC Woody Stem Survey Field Sheet.

All plants that were observed during the survey were identified to the lowest taxonomic level possible. Voucher specimens were obtained for identification, and were processed, labeled, and kept for future reference. *Floras of the Carolinas, Virginia, Georgia, and Surrounding Areas* (Weakley, Draft January 2007), and the US Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS) National Plant Database (plants.usda.gov) were used for genus species nomenclature for all survey-related field research or databases used for this project. Other identification books included: *Trees, Shrubs, and Woody Vines of North Florida and Adjacent Georgia and Alabama* (Godfrey, 1988), *The Manual of Vascular Flora of the Carolinas* (Radford et al. 1968), and *Aquatic and Wetland Plants of the United States* (Godfrey and Wooten, 1979 and 1981). The US Fish and Wildlife (USFWS) wetland indicator status and whether the plant was native or exotic were also determined with the National Plant Database (plants.usda.gov).

### 2.1.5 Biocriteria Water Quality Sampling Methods

Water quality was assessed at the biocriteria sites based on the results of previous studies conducted by the NC DWQ that found direct correlations between water quality and amphibians and macroinvertebrate communities (Baker et. al. 2008, Savage et al. 2010). Due to funding and logistics, just one biocriteria surface water sample was collected at the biocriteria sites in February-March 2012 during the amphibian and macroinvertebrate surveys at a representative location within the IW. Standing water that was deep enough for collection (≥10cm) was collected at four of the 11 biocriteria sites, Brunswick 4 and 7 in NC and Horry 1 and 41 in SC. The other sites did not have standing water at the time of the survey.

Physical parameters (pH), dissolved oxygen (DO), specific conductivity, and temperature) were measured in the field with water meters (YSI 85 for temperature, DO, and specific conductivity and an Accumet AP61 for pH). Water quality samples were collected for chemical analysis of nutrient fractions (ammonia, $NO_2$+$NO_3$ as N, total Kjeldahl nitrogen(TKN), and total phosphorus [TP]), total organic carbon (TOC), dissolved organic carbon (DOC), and metals (copper, zinc, and lead). The NC DWQ Laboratory Section conducted the chemical analysis of collected samples. All water samples were collected, preserved, and transported in accordance with the NC DWQ Laboratory Section Sample Submission Guidance Document (NC DWQ 2009) and the NC DWQ Laboratory Section Standard Operating Procedures (NC DWQ 2005).

Meters were calibrated daily. Additional quality assurance (QA) measures taken during the laboratory analysis are explained in NC DWQ's *The Quality Assurance Manual for the NC DWQ Laboratory Section* (NC DWQ, 2004).

## 2.1.6 Soil Sampling Methods for Biocriteria sites

Soil quality, similarly to water quality, has been known to exhibit extensive variability between wetlands located in natural and urbanizing areas (Azous and Horner, 2001). Soil samples were collected from eight sample locations at each biocriteria IW site. Typically, six locations were sampled within the IW, and two locations were sampled within the surrounding upland.

At each sampling location, a 45–50 cm deep soil core was excavated with a 6-cm-diameter stainless steel auger. Soil descriptions were made for each core sample horizon. The horizon depth, location (top layer = A, second layer=B, etc.), matrix and mottle color, mottle (%) abundance, and texture were recorded for each horizon. The Munsell Soil Color Charts (Munsell Color Company 2000) was used to determine hue, value, and chroma, and the “Soil Texture by Feel Flow Chart” (Brookings Institution 2000) was used to determine texture. Information on hydric soil indicators was also noted. Natural Resource Conservation Service (NRCS) soil maps were used to determine soil map unit names, taxonomy, and drainage class. Approximately 0.5 kg of soil was collected from each horizon as determined by texture and color. Soil cores that appeared to have only one horizon had a sample collected from the top nine inches and bottom nine inches. Samples were placed in labeled zip lock bags in the field. The North Carolina Agronomic Division, Soil Testing Section, analyzed soil samples for the following parameters:

- Levels of major plant nutrients, including phosphorus, potassium, calcium, and magnesium
- Levels of plant micronutrients, including copper, manganese, sulfur, and zinc
- Aluminum and iron content
- Level of sodium
- pH and acidity
- Soil class
- Percent base saturation
- Percent humic matter
- Cation exchange capacity and weight-to-volume ratio.

See http://www.agr.state.nc.us/agronomi/stmethod.htm for further details on NC Agronomic Division lab analyses methods. The Soil Testing Section Lab uses quality control procedures specified in the NRCS National Soil Survey Handbook (http://soils.usda.gov/technical/handbook).

Soil samples were also analyzed for phosphorus adsorption capacity and oxalate-extractable iron and aluminum. This was done using methods described by Axt and Walbridge (1999). Samples also were analyzed for percent organic matter by the loss on ignition method similar to Konen et al. (2002) and Schulte and Hopkins (1996). These analyses were performed at the University of South Carolina.

### 2.1.7 NC Wetland Assessment Method Comparison to Biocriteria Sites

North Carolina Wetland Assessment Method is a rapid wetland assessment method that was developed specifically for NC wetlands to provide an accurate assessment of wetland hydrology, water quality, and habitat function. The NCWAM recognizes 16 types of NC wetlands of which two types, small basin wetlands or pocosins, could be IWs in the coastal plain region. The NCWAM form has a series of metrics that produce ratings for the three functions separately and overall for the site (NC WFAT, 2008). The completed NCWAM forms are entered into the NCWAM calculator which provides the three function and overall NCWAM rating results as “high”, “medium”, or “low”. This calculator weighs metrics differently for the 16 different wetland types. The NCWAM results were assessed using NCWAM Version 4 field form and NCWAM Version 1 calculator (NCFAT 2008) in the field in 2008 during the SEIWA Level 2 study (except for Bladen 9 which was not a part of the SEIWA Level 2 IW population and was completed in January 2012). It should also be noted that although NCWAM was developed for NC and has not been calibrated for SC it is unlikely there would be significant differences in the NCWAM results for SC. A detailed review of the wetland community descriptions in Schafale and Weakley’s *Third Approximation* (1990) and Nelson’s *Natural Communities of South Carolina: Initial Classification and Description* plus field observations during the SEIWA Level 2 study indicated there is significant ecological overlap between wetland community types in the coastal plain of the NC and SC.

The association between the NCWAM habitat function and overall ratings from the 11 biocriteria sites (see Section 2.1.1. Biocriteria Site Selection) and the intensive survey data was evaluated. A generalized linear model and least squares fit analysis was used to evaluate the association between the NCWAM habitat function and the overall ratings (NCWAM Version 1, NCWFAT 2008) with the intensive survey results. Intensive survey results were derived from metric and IBI results from the amphibian, aquatic macroinvertebrate, and vegetation surveys (see sections 3.1.2 Amphibian Monitoring Results and Discussion, 3.1.3 Aquatic Macroinvertebrate Monitoring Results and Discussion, and 3.1.4 Vegetation Monitoring Results and Discussion).

## 2.2 Hydrology and Water Quality Site Field and Data Analysis Methodology

### 2.2.1 Hydrology and Water Quality Site Selection

Sites chosen for the hydrological connectivity and water quality study had to meet the following criteria: 1.) be within a half mile of a “downstream connected water body”, 2.) have enough of a gradient change from the wetland site to the stream to allow for ground water flow direction to be quantified, 3.) have a soil substrate that will enable detectable water flow during an aquifer pumping test, 4.) be accessible for well installation from the wetland to the stream and 5.) and be secluded enough to avoid vandalism. This study defined a “downstream connected water body" as an intermittent or perennial stream, intermittent or perennial non-isolated ditch, or jurisdictional wetland that connected with a stream or non-isolated ditch. Sites randomly chosen for the biocriteria study that did not meet the above criteria were not used for the hydrological and water quality assessment. Large tracts of natural area lands owned by The Nature Conservancy and other land conservation organizations, the state of NC or SC, and logging companies were reviewed for isolated wetland locations with nearby streams that met the above criteria.

An initial site screening was conducted by ground truthing the SEIWA Level 2 study sites. SEIWA analyzed the available digital data on soil type, elevation, and drainage to identify potential isolated wetlands sites, but these had to be confirmed in the field before the hydrology and water quality assessment field work could begin. Field reconnaissance was conducted on approximately 49 potential study sites in North Carolina in July, 2009 and thirty-eight sites in South Carolina in 2010. The most significant limiting factor for selecting the hydrology and water quality assessment sites was access for drilling equipment. Hand-augured soil borings of the potential wetland sites were taken during the reconnaissance visits to confirm that wetland soil conditions were present and to ensure that the isolated wetland had reasonably permeable substrate (limited clay content). As a result of the field reconnaissance, 8 sites in North Carolina and 3 sites in South Carolina were selected for hydrology and water quality assessment (Figure 7).

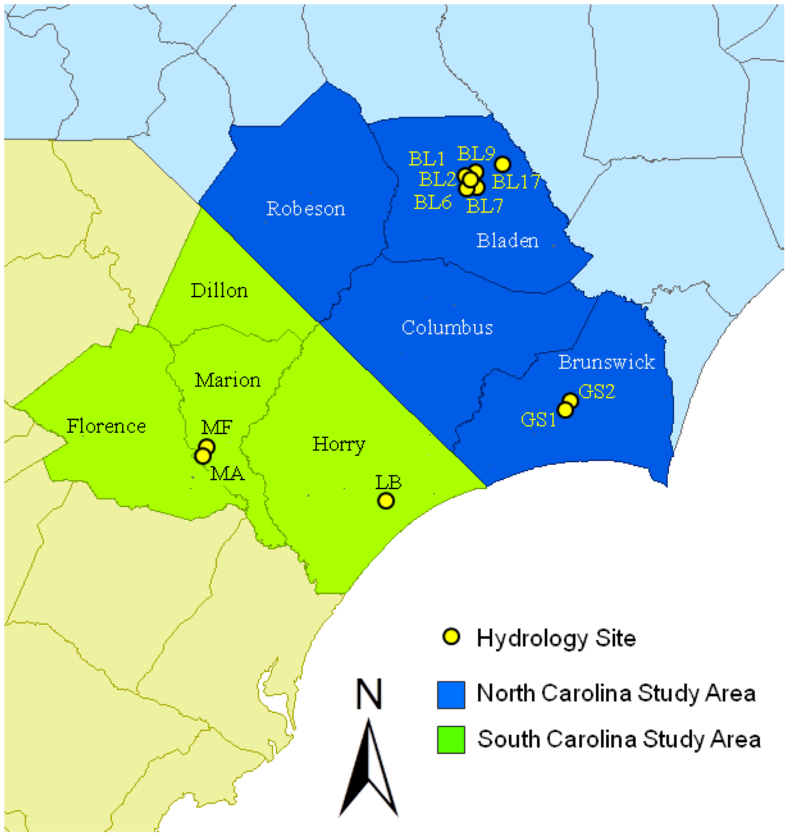


Figure 7. Hydrology study sites located in North Carolina and South Carolina.

## 2.2.2 Hydrology Monitoring Methods

### 2.2.2.1 Geology and Sediment Core Sampling Methods

Shallow subsurface stratigraphy was determined at eight IW sites chosen for the detailed survey in NC and three IW sites in SC. Sediment cores were taken with a direct push hydraulic sampler (Geoprobe®) that was mounted on a four-wheel drive truck. The sediment cores were taken at 2-4 upland sites surrounding the isolated wetland as well as along atransect from the isolated wetlands to an identified downstream connected water body (see section 2.2.1). A map of the core locations at a typical site are shown in Figure 8.

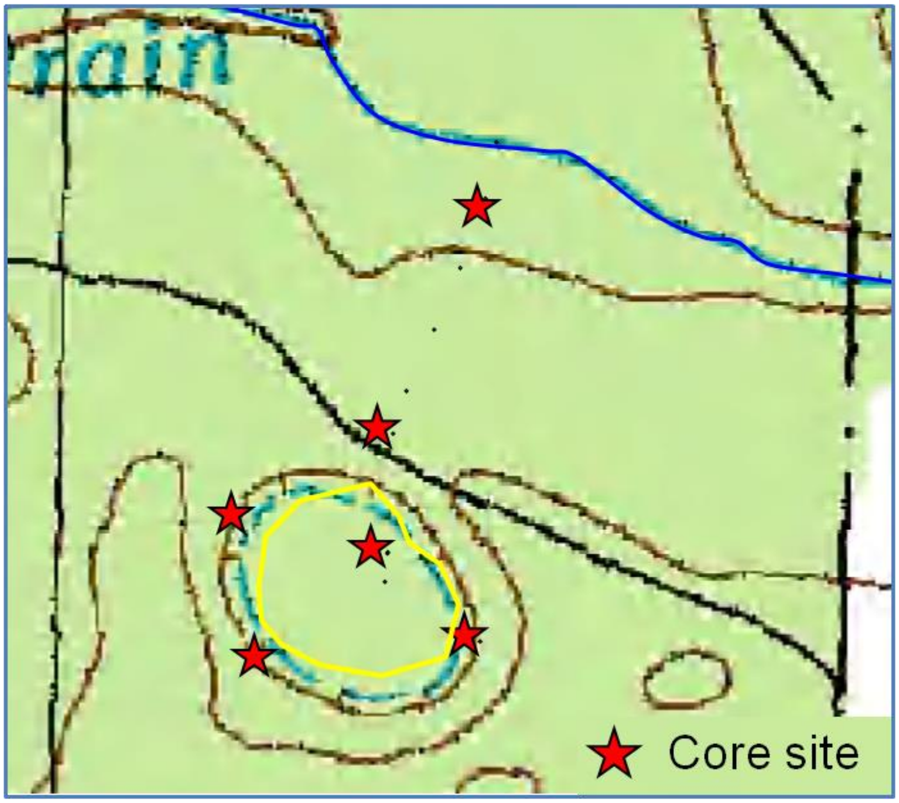


Figure 8. Typical core location layout for hydrology sites.

A clear PVC tube liner was placed into the four-foot long sediment core sampling device to facilitate extraction of an undisturbed sediment core. Sediment cores were carefully removed from the core barrel to keep them as intact as possible. The PVC tube liner was then cut open longitudinally and the top of the core sample was removed to facilitate description of the sediment core. Moisture content and the location of water bearing zones were observed as soon as possible after collection and recorded on the log sheet. The length of the recovered core was measured to the nearest tenth of a foot. The site hydrogeologist logged color; the presence of organics; grain size, sorting and rounding as well as any sedimentary structure present. Grain size was determined using the Wentworth grade scale (Wentworth, 1922). Color descriptions are based on comparison with the Munsell Soil Color Charts, 1998. After logging, the cores were re-sealed, labeled, and stored temporarily on site. The NC cores are currently being stored at the NC Geological Survey Core Repository in Raleigh, NC. In SC the cores are being stored in a research lab at the University of South Carolina.

#### 2.2.2.2 Monitoring and Aquifer Pumping Test Well Installation Methods

In NC, once the shallow stratigraphy at each site was established from the sediment cores, water table monitoring wells were installed along a transect from the IW to the downgradient connected water body. Nested wells, one shallow and one deep, were installed in the IW. The shallow well was installed across the water table and the deep well was installed at the base of the aquifer. Nested wells were also installed in locations where the stratigraphy indicated a need for it, for example where there was a change in lithology from sand to silt or clay. These wells are indicated with an “S” (shallow) or “D” (deep), and in one case an “i” (intermediate) after the monitoring well number. Well installation in NC was completed in June 2010. At the SC sites wells were installed during Autust 2011. At select sites, additional monitoring wells were installed in order to enhance groundwater level monitoring during aquifer tests. The water table monitoring wells were used to determine the direction of shallow groundwater flow and, at three sites, to measure the hydraulic response of the water table during a subsequent aquifer pumping test. The locations and final construction details of each monitoring well were determined by the site hydrogeologist based upon conditions noted in the stratigraphic borings at each site.

One-inch diameter schedule 40 PVC water table monitoring wells were installed with a hydraulic direct push (Geoprobe®) drilling rig. A two-inch diameter solid push probe was used to create a nominal two-inch diameter borehole at each water table monitoring well location. Once the supervising hydrogeologist determined that the probe had reached the desired depth for monitoring well installation, the solid probe was withdrawn from the boring to facilitate installation of the PVC monitoring well. The monitoring wells were constructed of flush-threaded PVC riser pipe and screen. No glue or solvents were used. Each monitoring well was equipped with a five-foot to ten-foot long section of PVC well screen with 0.010-inch wide slots. A solid plug was screwed into the end of the screen before being placed into the open borehole. A sufficient length of solid PVC riser was assembled to permit the PVC well to extend approximately 3 feet above the land surface. Clean filter sand compatible with the size of the well screen slots was poured into the annular space between the borehole and the PVC well until the resulting sand filter pack extended above the top of the well screen slots. A bentonite seal was placed in the remaining annular space from the top of the sand filter pack to the surface.

An expanding plug was placed at the top of the PVC to prevent foreign matter from entering the well. A 1/8-inch diameter hole was drilled in the PVC casing approximately four inches below the top to prevent water level fluctuations being hindered by pressure inside the well. Wells located in environmentally sensitive areas or areas inaccessible by the drill rig such as streams and swamplands were installed with a hand auger using 2” diameter PVC to minimize impact.

A locking steel protector pipe was installed over the PVC well casing extending approximately 3 inches above the top of the PVC casing. After the wells were completed, each well was developed to remove sediment from the well and to improve hydraulic communication between the well and the aquifer. Well development consisted of agitating the water column and pumping the well until the discharge was clear and free of suspended sediment.

Hollow-stem auger methods were used to install a four-inch diameter well at three of the sites. Four-inch diameter wells were used for the aquifer pumping tests to enable a sufficient flow rate. Once the supervising hydrogeologist determined that the augers had reached the desired depth for pumping test well installation, PVC well screen and pipe were set in the hollow of the augers. Water was piped into the well casing as the augurs were slowly withdrawn from the boring and filter pack sand was introduced to the annular space. The water prevented the formation sand from collapsing into the annular space. Fifteen to twenty feet of 0.020-inch slot size screen were used. The slot size was selected for the aquifer test wells based on sediment size. The wells were constructed and completed in a similar manner to the 1-inch monitoring wells.

Seventy-six wells in NC and eleven wells in SC were constructed for the project. All wells in NC were constructed in accordance with standards described in North Carolina Administrative Code Title 15A Department of Environment and Natural Resources, Division of Water Quality, Subchapter 2C, Section .0100 Well Construction Standards. Seven of the wells in SC were installed by a commercial driller licensed by SC DHEC. Four of the wells were in locations inaccessible to drilling equipment so were installed by hand using methods described by Sprecher (2000).

#### 2.2.2.3 Differential Level Survey Methods

The elevation of a measuring point on the top of the well casing of each monitoring well was determined using a differential level survey. The top of the well casing is measured rather than ground level because climate conditions are more likely to produce incremental changes in the ground surface than in a well anchored several feet below the ground surface. In this environment, the water table is relatively flat, thus accuracy to 0.01 feet is necessary to determine the elevation of the water table and hence determine the direction and gradient of groundwater flow. The North Carolina Geodetic Survey (NCGS) was contracted to perform the differential level survey for the NC sites. At each site, NCGS surveyors established a benchmark or control point via multiple OPUS (Online Positioning User Service) sessions. The individual well measuring point elevations were determined using a digital level and invar bar coded rods according to specifications outlined by the Federal Geodetic Control Subcommittee (FGCS) (see NGS, 2004). NCGS surveyors performed differential leveling from the benchmark control points to each well. DWQ staff surveyed any wells installed after the NCGS had completed their work using the procedures outlined in the project QAPP (NC DWQ, 2010). Wells surveyed by the NCGS surveyor were used as benchmarks for DWQ surveying. In SC the South Carolina Geodetic Survey placed temporary elevation benchmarks at the three wetland sites using the same methods as NCGS. Differential survey of the well elevations was completed by project staff.

#### 2.2.2.4 Methods for Hydrologic Sampling of Monitoring Wells

Water levels were recorded both discretely and continuously for one year. Discrete water level elevations in all monitoring wells were measured approximately monthly using a steel measuring tape graduated in feet, tenths and hundredths of feet. The lower five feet of the tape was covered in chalk and the tape was lowered into the well far enough for the lower portion to be submerged. The tape was lowered until a whole foot gradation lined up with the measuring point (MP) on the well. The foot gradation was recorded as the "MP hold". The tape was then removed from the well and the measurement of the wetted chalk mark recorded. The difference between the "MP Hold" and the "Wetted Chalk Mark" was recorded as the "Depth to Water (DTW)". This measurement was later converted to elevation above mean sea level by subtracting "Depth to Water" from MP Elevation. Discrete water level elevations in SC were measured using a Geotech Keck® water level meter graduated in feet, tenths and hundredths of feet. The water level meter was lowered until the probe at the end of the meter emitted a beep, indicating it had reached the water's surface, and the depth of the probe from the MP was read from the meter's cable. Each reading was performed three times to ensure accurate measurement.

Continuous water level data (CWLD) were recorded in 31 wells at eight IW sites in NC and 11 wells at three IW sites in SC using In-Situ Level Troll pressure transducers. In general, transducers were deployed in the shallow and deep IW monitoring wells, an upland well and a streamside well at each site. Continuous monitoring at all wells was beyond the scope of this project. The transducer was suspended at such a depth that it would remain submerged as the water table elevation changed with conditions. Vented cables were used to suspend the transducers so that the instrument was measuring true depth to water and no corrections for barometric pressure changes were necessary. The DTW reading on the transducer was calibrated to match that of the steel tape DTW measurement. Files were downloaded monthly and restarted if the DTW reading "drifted" more than 0.02 ft from the steel tape DTW measurement.

While not part of the original study design, several surface water level monitoring stations (SWLMS) were installed late in the study to better understand the relationship between the water table aquifer and the nearby surface water body. Dry conditions made it impractical to install SWLMS at all sites. Of special interest were those sites where aquifer pumping tests were to take place and locations that remained wet during most climate conditions. Surface water stations were of four types: post only, post with staff gage attached (Figure 9 - A), stilling well with staff gage attached and an In-Situ Level Troll pressure transducer installed (Figure 9 - B), or stilling well with staff gage attached and an Onset HOBO® U20 Water Level Data Logger installed (Figure 9 - C and 9 - D). The transducers (Troll® and HOBO®) were suspended at such a depth that they would remain submerged as long as there was water in the surface water feature. HOBO® transducers are not open to barometric pressure so an additional instrument was installed in a nearby well to record barometric pressure in the area. Corrections for barometric pressure were made by the associated software after the data was downloaded from the device. The water level reading was calibrated to manual measurements made on the staff gage installed on the stilling well. The elevations of all surface water monitoring stations were surveyed by DWQ staff according to the methods described in section 2.2.2.3. As with water level monitoring in wells, surface water level data was recorded discretely in all locations and continuously where transducers were installed.

Figure 9. Surface water level monitoring. A. Post with staff gage. B. Stilling well with staff gage and Level Troll®. C. HOBO® prior to installation. D. HOBO® attached to data download shuttle.

### 2.2.2.5 Aquifer Pump Test

Aquifer pumping tests were utilized to help establish the degree of hydraulic connection between the groundwater monitoring wells and surface water bodies. One aquifer pumping test was performed on a relatively homogeneous site with no known perched water conditions (BL-7), a second aquifer test was performed on a site with a thick but discontinuous silt lens that produce perched water table conditions (BL-1), and a third aquifer test was performed on a site presumed to be a limestone sinkhole that had a layer of thin, discontinuous clay lenses interbedded with sand layers (GS-1). The objective of the aquifer pumping tests at each site was to create the maximum feasible stress (water level drawdown) on the surficial aquifer and record the response that was induced on wells and surface water as a result. The tests were not designed to obtain aquifer hydraulic characteristics such as transmissivity and storativity (specific yield), however the data obtained from these tests can be used to estimate these characteristics at each site.

*Aquifer Pumping Test Preparations*

Four-inch diameter PVC wells with 0.02" size slotted screens were installed at each of the three sites where aquifer pumping tests were conducted. The four-inch diameter wells can accommodate a large submersible pump that is capable of a pumping rate of up to 50 gallons per minute. Each pumping well was installed so that the screen would rest directly on top of the first regional confining layer, except for the well at the lime sink site, which was installed at the deepest practical depth that the auger machine was capable of drilling at this site, which was 40 feet. Table 1 contains a summary of the construction details of the aquifer pumping test well at each site.

Table 1. Pumping well construction details.

| Site | Well_ID | Date | Elev of Top of Casing (feet above msl) | Total Depth (feet below land surface) | Screened interval (feet below land surface) | |
|---|---|---|---|---|---|---|
| | | | | | from | to |
| Bladen 1 | BL1-PW1 | 1/11/2011 | 70.99 | 27 | 12 | 27 |
| Bladen 7 | BL7-PW1 | 3/2/2011 | 58.15 | 32 | 17 | 32 |
| Green Swamp 1 | GS1-PW1 | 2/15/2011 | 62.62 | 40 | 20 | 40 |

A variable speed submersible pump was lowered into each pumping well at least two days before the start of each test. Water levels were measured in all wells on site prior to the installation of the pump and electronic data loggers. The pump was lowered to a depth of approximately 1 foot above the bottom of the well to avoid stirring up sediment during the test. A step drawdown test was performed to determine the optimal pumping rate for each well. The optimal pumping rate was the maximum "safe" sustainable pumping rate that would result in the largest possible water level drawdown without losing pump suction.

Due to the relatively small amount of available drawdown in the pumping wells, the initial pumping rate was relatively conservative to avoid drawing the water level down in the pumping well low enough to cause cavitation and loss of flow. Since the goal of the aquifer pumping tests was to stress the water table aquifer enough to induce drawdown in the observation wells if there was a hydraulic connection between the pumping well and the observation wells and not to determine the aquifer hydraulic parameters such as transmissivity and storage coefficients, the pumping rate was increased after twenty-four hours. This change in rate was applied at sites BL1 and GS1 where there was some available capacity for additional discharge at these locations.

Electronic pressure transducers and data loggers were installed in selected wells while the step drawdown test was being conducted. An eight channel In-Situ® Hermit data logger was connected to pressure transducers that were installed in the wells closest to the pumping well. In-Situ® Troll 500 pressure transducer/data logger combination instruments were installed in wells beyond the range of the Hermit system cables. A high range pressure transducer was lowered into a standpipe located inside the pumping well.

The actual aquifer pumping test was initiated at least two days after the completion of the step drawdown test at each site to allow the water level to recover from the step drawdown pumping. Static water levels in all on-site wells were recorded just prior to starting the pump. All water levels were recorded to within 0.01 foot using an electronic water level indicator tape or with a steel tape coated with chalk. A staff gauge was installed in the surface water body closest to the wells and measured every hour to monitor for possible changes in the elevation of the surface water body in response to pumping.

*Measuring water levels during test*

All personnel involved in the test synchronized their watches immediately prior to beginning the test. An observer was stationed at each nearby observation well to record water levels during the first two to three hours of testing.

Table 2 shows the maximum time intervals for recording water levels in the pumped well. A logarithmic sampling interval was used on the Hermit data logger to collect water level data at 0.6 seconds initially, then at logarithmically declining intervals as the test progressed. The rapid early time recording intervals facilitate the collection of the critical early time water level drawdown data. The maximum time interval for data collection from the Hermit was 10 minutes. The Troll data loggers that were installed in the more distant observation wells were not capable of a logarithmic data collection interval, so their data collection interval was set at 5 minutes at BL1 and 10 minutes at BL7 and GS1.

Manual water level data was collected in all wells during each aquifer pumping test to verify the results of the electronic water level data and to provide “fail-safe” data in case the electronic data was lost or damaged.

Table 2. Time Intervals for Aquifer Test Water Level Measurements.

| | |
|---|---|
| 0 to 3 minutes | Every 30 seconds |
| 3 to 15 minutes | Every minute |
| 5 to 60 minutes | Every 5 minutes |
| 60 to 120 minutes | Every 10 minutes |
| 120 min. to 10 hours | Every 30 minutes |
| 10 hours to shut down | Every hour |

*Monitoring discharge rate*

The discharge rate of the pumping well was measured with a pitot tube flow meter. In addition, the flow rate was checked at frequent intervals using a calibrated 5 gallon bucket and a stop watch. The pump discharged through 1,500 feet of 2" diameter schedule 40 PVC pipe. The discharge was directed into the adjacent surface water bodies downstream of the site to avoid interference with drawdown data. During the initial hour of the aquifer test, well discharge in the pumping well was monitored and recorded as frequently as practical. The pump speed was adjusted occasionally to accommodate an increasing head as the water levels in the pumping well declined to maintain a constant pumping rate. The pump discharge rate was measured and recorded at approximately 15 minute intervals after the water levels in the pumping wells began to stabilize (approximately 2 hours after the pump was turned on).

*Length of test*

Each of the three aquifer pumping test consisted of pumping periods of approximately 48 hours. BL-1 was pumped for 2,878 minutes, BL-7 was pumped for 2,879 minutes, and GS-1 was pumped for 2,919 minutes. The pumping rate for BL-1 was 36 gallons per minute (gpm), which was increased to 40 gpm for the last 24 hours of the test in order to maximize the drawdown in the pumping well and induce the greatest depression in the water table aquifer. The pumping rate for BL-7 was a constant 48 gpm. The initial pumping rate for GS-1 was 33 gpm, which was increased to 38 gpm during the last 24 hours of the test to maximize drawdown. These relatively high pumping rates for shallow wells are indicative of the sandy conditions that characterized all three sites where the aquifer pumping tests were conducted.

Water levels were also measured and recorded in the pumping and observation wells at each site after pumping ceased in order to monitor the recovery responses of the aquifers. Recovery measurements were recorded at similar frequencies as the pumping test. Recovery test measurements ceased once water levels had returned to within 5% of their pre-pumped (background) levels.

### 2.2.3 Water Quality Sampling Methods

Both groundwater and surface water quality were assessed at the hydrology and water quality sites. Groundwater samples were collected from monitoring wells and surface water samples were collected from surface water stations in the IW and the downstream non-isolated water body (either a stream or connected wetland). Figure 10 shows the surface water station and monitoring wells at one of the hydrology and water quality sites. Water quality was collected quarterly in May, August, and November 2010 and February 2011 at the NC Bladen county sites, August-September and November 2010 and January and April 2011 at the NC Brunswick county sites, and August and November 2011 and January and April 2012 at the SC Horry and Marion county sites. The inconsistency of collection times between counties and states was due to the timing of well installations and contract approvals. The NC DWQ Laboratory Section analyzed the water samples.

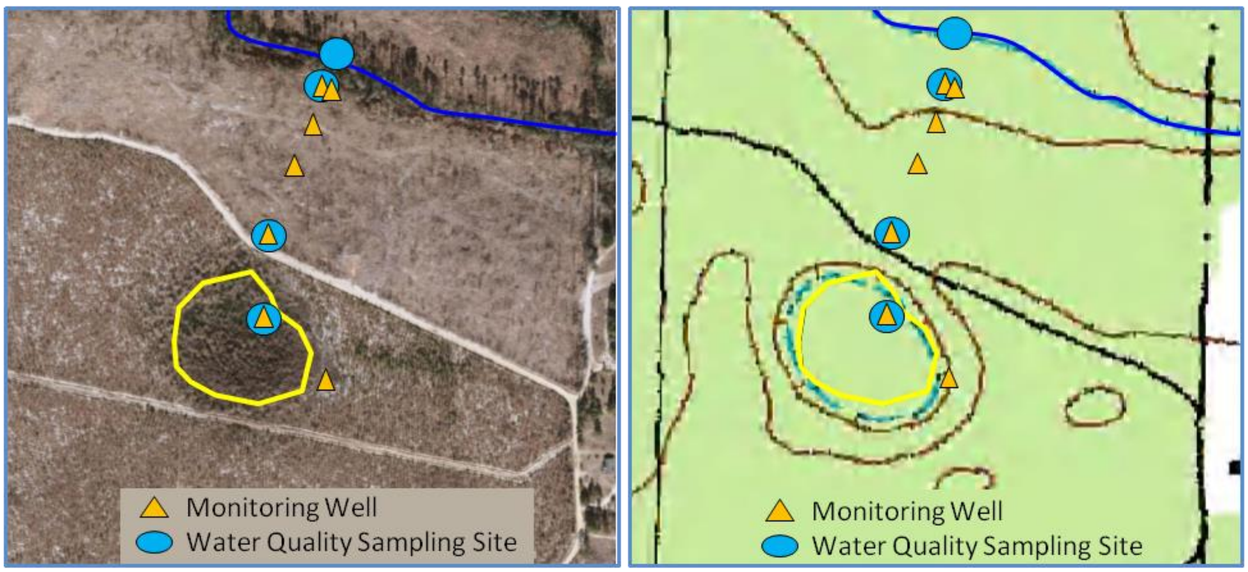


Figure 10. Water quality sampling locations at a typical hydrology/water quality site.

Water samples were collected, preserved, and transported in accordance with the NC DWQ Laboratory Section Sample Submission Guidance Document (NC DWQ, 2009) and the NC DWQ Laboratory Section Standard Operating Procedures (NC DWQ, 2005). Quality control measures included daily meter calibration, preparation of daily AM and PM quality control blanks used to check for carbon contamination of the filtering equipment and a blind and split sample duplicate collected quarterly for each sample event. Lab results indicating filtering equipment contamination were discarded. Duplicate samples that showed greater than 10% variation were also discarded. Additional DWQ Laboratory Quality Control checks are addressed in the "Quality Assurance Manual for the North Carolina Division of Water Quality Laboratory Section" (See http://h2o.enr.state.nc.us/esb/qapp/labqam.pdf).

### 2.2.3.1 Surface Water Quality Sampling Methods

Dissolved oxygen, specific conductivity, and temperature were measured in the field with a YSI Pro2030 water meter and pH was measured in the field with an Accumet AP61. Water quality samples were analyzed for ammonia, $NO_2$+$NO_3$ as N, TKN, and total phosphorus (TP), TOC, DOC, and metals (copper, zinc, and lead).

A unique station number that reflected the site name, sample location (IW or stream/connected wetland), and sample date (month and year) was assigned for each sample event. All field data was recorded on field sheets (see Appendix A). Station locations were photographed with a digital camera each time the station was sampled to make a visual record of the hydrology of the sample station (Figure 11).

Figure 11. Bladen 7 wetland (left) and Bladen 7 stream (right) on February 8, 2011.

### 2.2.3.2 Ground Water Quality Sampling Methods

Groundwater samples were collected from at least three monitoring wells at each of the IWs chosen for the hydrological section of the study – an IW well, an upland well and the well closest to the downstream water body (see Section 1.3.1 for the definition of a downstream water body). Purging and sampling equipment was decontaminated using low-lathering non-phosphate detergent (Alconox™) dissolved in de-ionized water prior to use in each well. Monitoring wells were typically purged with a peristaltic pump in NC and a 12 volt submersible pump in SC. Wells were purged until at least three times the volume of the standing water column or was withdrawn or until pH, DO, specific conductivity, and temperature stabilized. A Quanta G Hydrolab®, was used to measure the physical parameters. It was calibrated daily. Once purging was complete and parameters had stabilized, water samples were collected. See Appendix A for an example of water quality field sheets and equipment lists.

### 2.2.4 Hydrology and Water Quality Soil Sampling Methods

Soil sampling and analysis at the Hydrology and Water Quality sites was completed using the same methods to those described in Section 2.1.6. However, for the Hydrology and Water Quality sites soil was collected at only four locations, two locations in the IW and two locations directly adjacent to the IW in the surrounding upland.

## 2.3 North Carolina Isolated Wetland Impacts and Mitigation Records

Impacts to IWs permitted by NC DWQ from October 22, 2001 (the effective date for NC administrative code 15A NCAC 02H .1300, see Section 1.2 Project Introduction and Background) to December 31, 2011 were determined using the NC DWQ Basinwide Information Management System (BIMS) database (NC DENR 1999). BIMS is a database tool developed by NC DWQ to provide accessible information on permitting/certifications, monitoring, water bodies, facilities, inspections, incidents, permitted discharge facilities, enforcement, and operator training and certification. 401 Water Quality Certification (WQC) and Isolated Wetland Permit (since 2001) information were obtained from BIMS to provide details on approved impacts and required compensatory mitigation to water bodies regulated by the state. However, at this time BIMS is not capable of tracking the details of compensatory mitigation projects. The amount of required mitigation obtained from BIMS for 401 WQC projects or Isolated Wetland Permit approvals include NC DWQ permit requirements, documented voluntary mitigation or notification of completed Army Corps of Engineers (ACOE) mitigation requirements.

Since BIMS does not have the capacity to track details of compensatory mitigation projects, NC DWQ tracks the implementation and success of NC mitigation projects in a mitigation database (developed with EPA Grant WL 9643505, Hill et al. 2011). The NC DWQ mitigation database was used to determine the mitigation projects, components within projects (sections of projects divided by mitigation type, mitigation activity or construction phase), mitigation provider (In Lieu Fee, NCDOT, Private or Mitigation Bank), types of mitigation (such as riverine or non-riverine), and mitigation activity (creation, restoration, enhancement, and preservation) as well as other parameters such as project name and acreage, etc. However, the mitigation database did not provide accurate IW classification for the completed mitigation wetland type due to the fact that prior to 2006 wetland mitigation providers did not differentiate between riverine/riparian and non-riverine/riparian wetlands.

A query of the mitigation database for projects from October 22, 2001 to December 31, 2011 indicated there were 347 project component files that could have been IWs by their wetland type designation. A careful review of these projects and in some cases a field visit would be required to determine which mitigation components of the projects are IWs and which are non-IWs. Logistically, the review of 347 project components would not be feasible within the required timeframe, so the procedure was restructured.

BIMS was queried, state-wide and within the four-county project study area, to determine which approved impacts with an IW component actually required mitigation for the IW components. The wetland mitigation requirement data obtained from BIMS was cross-referenced with the Mitigation Database, in order to determine which approved impacts requiring mitigation are tracked in the mitigation database. The mitigation database provided mitigation site information for BIMS impacts with permittee-responsible (private or NC DOT) mitigation. In-lieu fee mitigation projects are tracked in the mitigation database, but the mitigation database does not have the ability to link an impact site with a particular in-lieu fee mitigation site. The DWQ project number and name in BIMS for impact approvals did not always match up with the Mitigation Database. The projects that did cross-reference between the two databases were reviewed to determine what the IW and Non-IW impacts were and what type of mitigation (IW or Non-IW) was done to compensate for those impacts.

The BIMS and Mitigation Database queries from October 22, 2001 to December 31, 2012 were conducted for the following searches statewide in NC and in the IWC four county study area (See Table 3):

1.) For all wetland types: A BIMS query for the total number of approved 401 WQCs and Isolated Wetland Permits.

    - Number of approved 401 WQC and Isolated Wetland Permits
    - Number of acres impacted

2.) For IWs only: A BIMS query for the total number of approved 401 WQCs with an IW component and Isolated Wetland Permit.

    - Number of approved 401 WQC with an IW component and Isolated Wetland Permits
    - Number of acres impacted

3.) For all wetland types: A BIMS query for the total number of approved 401 WQCs and Isolated Wetland Permits with ≥1 acre of wetland impacts that should have triggered mitigation.

    - Number of approved 401 WQC and Isolated Wetland Permits
    - Number of acres impacted

4.) For approvals with IW impacts: A BIMS query for the total number of approved 401 WQCs with an IW component and Isolated Wetland Permits with ≥1 acre of wetland impacts that should have triggered mitigation.

    - Number of approved 401 WQCs and Isolated Wetland Permits

- Number of combined acres for IW and non-IW impacts (number of IW acre impacts solely)

5.) For all wetland types: A BIMS query for the total number of approved 401 WQCs and Isolated Wetland Permits that required mitigation by NC DWQ and/or the ACOE.

- Number of approved 401 WQCs and Isolated Wetland Permits
- Number of compensatory acres required for mitigation

6.) For approvals with IW impacts: A BIMS query for the total number of approved WQCs with an IW component and Isolated Wetland Permits that did require mitigation by NC DWQ and/or the ACOE.

- Number of approved 401 WQCs and Isolated Wetland Permits
- Number of compensatory acres required for mitigation (corrected IW acres [see Section 3.3])

7.) A BIMS and Mitigation database cross-reference query for the total number of approved WQCs with an IW component and Isolated Wetland Permits that required mitigation in the BIMS database and were assigned the same project number and name in the Mitigation database.

- Number of approved 401 WQCs and Isolated Wetland Permits
- Number of compensatory mitigation acres for IW and non-IW impacts combined (number of compensatory acres for IW impacts solely)

Table 3. BIMS and NCDWQ Mitigation Database query

| WQC and IW Permit Database Search Results* | Database | NC State-wide | | IWC Four-County Study Area | |
|---|---|---|---|---|---|
| 1. All Wetland Impact approvals | BIMS | Number of WQC and IW Permits | Wetland Acres Impacted | Number of WQC and IW Permits | Wetland Acres Impacted |
| 2. IW Impact approvals | BIMS | Number of WQC with an IW Component and IW Permits | IW Acres Impacted | Number of WQC with an IW Component and IW Permits | IW Acres Impacts |
| 3. Wetland Impact approvals with ≥1-acre | BIMS | Number of WQC and IW Permits | Wetland Acres to be Mitigated | Number of WQC and IW Permits | Wetland Acres to be Mitigated |
| 4. IW Impact approvals with ≥1-acre | BIMS | Number of WQC with an IW Component and IW Permits | Wetland Acres to be Mitigated (IW Acres to be Mitigated) | Number of WQC with an IW Component and IW Permits | Wetland Acres to be Mitigated (IW Acres to be Mitigated) |

| WQC and IW Permit Database Search Results* | Database | NC State-wide | | IWC Four-County Study Area | |
|---|---|---|---|---|---|
| 5. Wetland Impact approvals that required mitigation | BIMS | Number of WQC and IW Permits | Acres of Required Mitigation | Number of WQC and IW Permits | Acres of Required Mitigation |
| 6. IW Impact approvals that required mitigation | BIMS | Number of WQC with an IW Component and IW Permits | IW and non-IW Wetland Acres Mitigated (corrected IW Acres**) | Number of WQC with an IW Component and IW Permits | IW and non-IW Wetland Acres Mitigated |
| 7. Trackable IW Mitigation Projects for BIMS permits | BIMS - Mitigation | Number of Mitigation Projects with an IW Component | IW and non-IW Acres Mitigated | Number of Mitigation Projects with an IW Component | IW and non-IW Acres Mitigated |

*BIMS queries included both 401 WQCs for impacts to 404 wetlands and/or Isolated Wetland permits for impacts to non-404 jurisdictional wetlands.
**A large portion of the wetland acres were mitigation associated with non-IW components of one project. The corrected value more accurately depicts the amount of mitigation provided for IW components of the state-wide permits, as described in Section 3.3.

# Section 3 – RESULTS AND DISCUSSION

## 3.1 Biocriteria Site Results and Discussion

### 3.1.1 Biocriteria Site Selection Results and Discussion

The 11 Biocriteria study sites in North Carolina and South Carolina were assessed using NC WAM and ORAM during initial site visits. Wetland area ranged from 0.09 − 3.17 acres across biocriteria sites (mean = 1.28 acres). These wetland sites were all defined as basin wetlands by NC WAM. Schafale and Weakley’s Classification of the Natural Communities of NC (1990) wetland type classification resulted in four classifications; Wet Pine Flatwoods (n = 3), Non-riverine Swamp Forest (n = 2), Non-riverine Wet Hardwood Forest (n = 4), and Cypress Savannah (n = 2). Nelson’s Natural Communities of SC: Initial Classification and Description (1986) resulted in three classifications; Pine Flats (n=3), Non-Alluvial Swamp Forests (n=7), and Pond Cypress Savannah N=1). These sites represented a range of conditions based on the site selection process. Overall ORAM scores ranged from 26−58 and overall NCWAM scores ranged from low to high across the study sites. Brunswick 17 and Columbus 26 had *high* scores for hydrology, water quality, and habitat function. In addition, Robeson 1 also scored *high* for habitat function, the metric most likely to correspond to amphibian, macroinvertebrate, and vegetation surveys using NCWAM. Four sites, Brunswick 4, Horry 1, Robeson 7, and Bladen 9 scored *low* for habitat function using NCWAM. The wetland delineation is shown in the site aerials. Summary information for each biocriteria study site is provided in Table 4 below and outlined in the following descriptions

.

Table 4. Biocriteria study sites assessed in North Carolina and South Carolina summary table.

| Site Name | State | Acres | Wetland Type | | | NC WAM | | | | ORAM |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Third Approximation | Communities of SC | NC WAM | Overall Rating | Hydrology Function | Water Quality Function | Habitat Function | |
| Brunswick 4 | NC | 0.49 | Cypress Savannah | Pond Cypress Savannah | Basin Wetland | Low | Low | Low | Low | 32 |
| Brunswick 7 | NC | 0.83 | Nonriverine Wet Hardwood Forest | Non-Alluvial Swamp Forest | Basin Wetland | Med | Med | Med | Med | 40 |
| Brunswick 17 | NC | 0.10 | Wet Pine Flatwoods | Pine Flatwoods | Basin Wetland | High | High | High | High | 51 |
| Horry 1 | SC | 3.17 | Nonriverine Wet Hardwood Forest | Non-Alluvial Swamp Forest | Basin Wetland | Low | Low | Low | Low | 28 |
| Horry 28 | SC | 0.17 | Nonriverine Wet Hardwood Forest | Non-Alluvial Swamp Forest | Basin Wetland | High | High | High | Med. | 58 |
| Horry 41 | SC | 0.81 | Nonriverine Wet Hardwood Forest | Non-Alluvial Swamp Forest | Basin Wetland | Med. | Med. | High | Med. | 40 |
| Florence 14b | SC | 0.09 | Nonriverine Wet Hardwood Forest | Non-Alluvial Swamp Forest | Basin Wetland | Med. | Med. | High | Med. | 26 |
| Robeson 1 | NC | 2.94 | Nonriverine Swamp Forest | Non-Alluvial Swamp Forest | Basin Wetland | Med. | Med. | High | High | 31 |
| Robeson 7 | NC | 3.75 | Wet Pine Flatwoods | Pine Flatwoods | Basin Wetland | Med. | Med. | High | Low | 35 |
| Columbus 26 | NC | 0.44 | Nonriverine Swamp Forest | Non-Alluvial Swamp Forest | Basin Wetland | High | High | High | High | 48 |
| Bladen 9 | NC | 1.32 | Wet Pine Flatwoods | Pine Flatwoods | Basin Wetland | Med. | Low | Med. | Low | 34 |

**Robeson 7 -** The Robeson 7 (3.75 acres or 1.5 Ha) is located approximately 3.4 miles northeast of St. Pauls in northern Robeson County, North Carolina (Figure 12). It is approximately 250 feet (75 m) from a paved highway and housing subdivision. The area within and immediately adjacent is forested. The site was rutted during logging. It is a forested site with a dense herb stratum and fairly sparse shrub stratum. Loblolly pine (*Pinus taeda*) was dominant and pignut hickory (*Carya glabra*) and sweet gum (*Liquidambar styraciflua*) also occurred in the canopy. The herb stratum was diverse with swamp smartweed *(Polygonum hydropiperoides*) being the most dominant followed by annual ragweed (*Ambrosia artemesiifolia*). Shrubs, although not prevalent, included exotic invasives white mulberry (*Morus alba*) and Chinese privet (*Ligustrum sinense*).

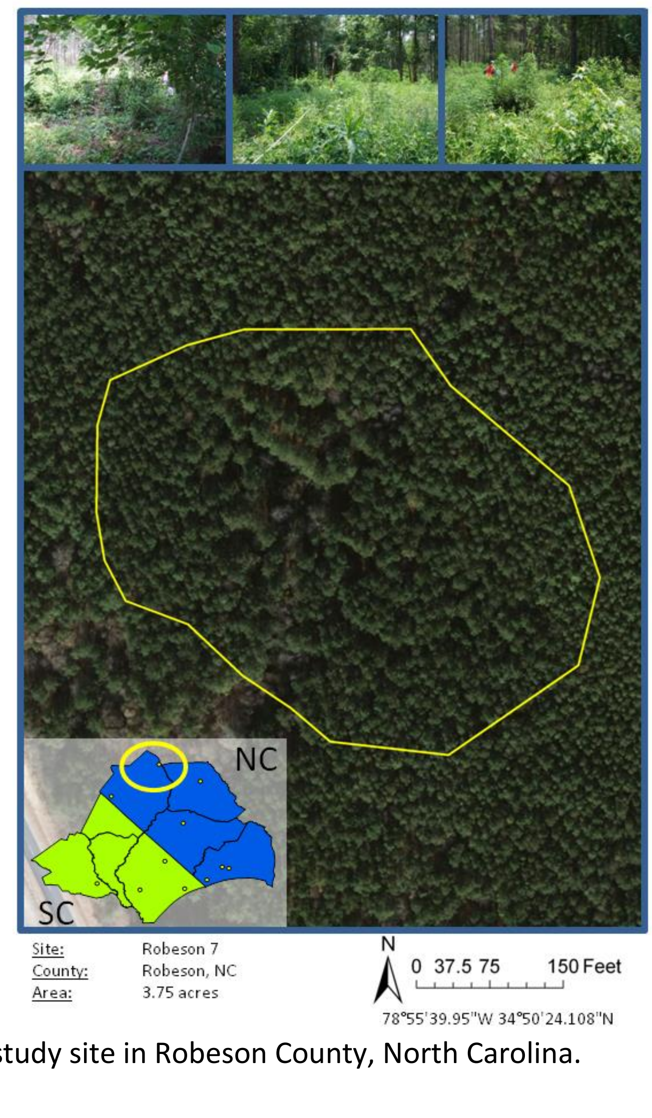


Figure 12. Robeson 7 study site in Robeson County, North Carolina.

**Robeson 1**- The Robeson 1 site (2.94 acres or 1.19 Ha) is located approximately 3.4 miles south of Raemon in southwestern Robeson County, North Carolina (Figure 13). This site is approximately 100 ft (30m) from an agricultural field. Area within and immediately surrounding the wetland is forested. The Robeson 1 site is a forested site with an extremely sparse herb stratum. Laurel oak (*Quercus laurifolia*) was most prevalent in the canopy with and swamp tupelo (*Nyssa biflora*) and sweet gum also occurring. Swamp titi (*Cyrilla racemiflora*) was dominant in the understory.

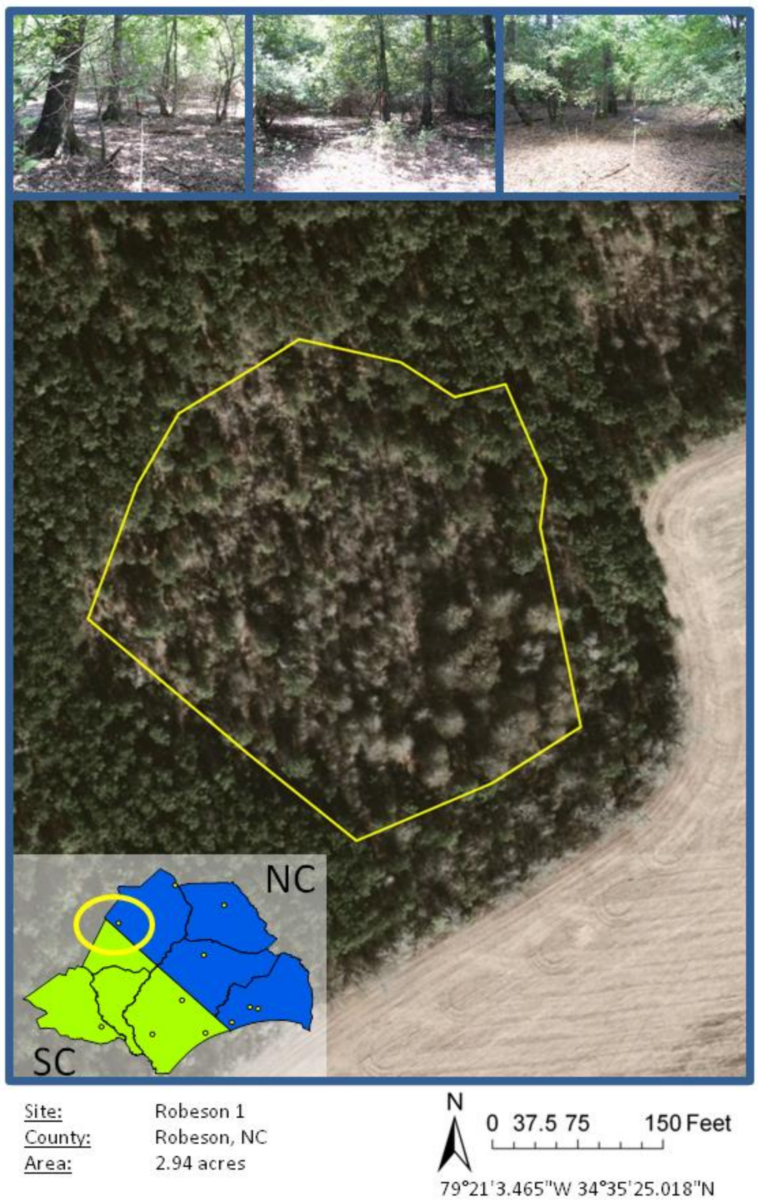


Figure 13. Robeson 1 study site in Robeson County, North Carolina.

**Horry 41** - The Horry 41 site (0.81 acres or 0.33 Ha) is located in a residential neighborhood in Loris in northern Horry County, South Carolina (Figure 14). This site is approximately 60 ft (18 m) from the nearest road and residential neighborhood. The area within and immediately adjacent to the wetland is forested. The Horry 41 site has a dense sub-canopy and shrub-sampling stratum and fairly sparse herb stratum. Red maple and lolblolly pine were the dominant trees at this site with sweet gum and water oak (*Quercus nigra*), and red bay (*Persea palustris*) also occurring. Common sweetleaf (*Symplocos tinctoria*) along with many red maple and sweet gum saplings were common in the shrub – sapling stratum. Cinnamon fern (*Osmunda cinnamomea*) and royal fern (*Osmunda regalis*) occurred in the herb stratum at the Horry 41 site. This site contained a couple of small, shallow (approximately 4 inches) pool caused by a relict tire track during March biocriteria sampling.

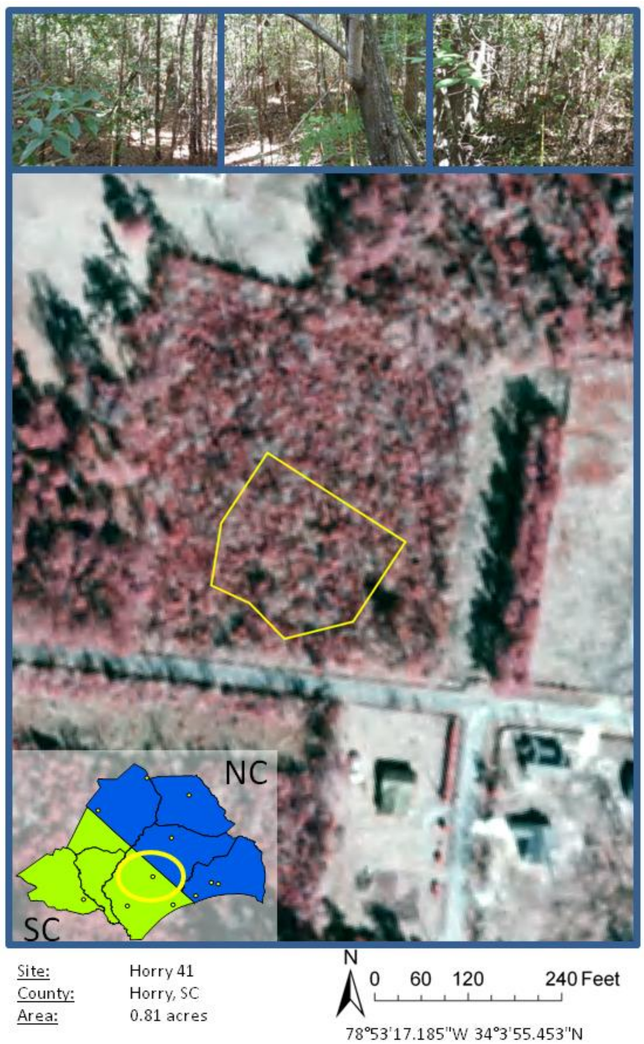


Figure 14. Horry 41 study site in Horry County, South Carolina.

**Horry 28** - The Horry 28 (0.17 acres or 0.7 Ha) is approximately three miles from North Myrtle Beach located in eastern Horry County, South Carolina (Figure 15). This wetland is 0.5 miles northwest of Carolina Bays Parkway. This site has a water treatment plant and a large cleared area used for parking and spoil piles to the north with scrubby pine upland to the east, south, and west. Horry 28 had the highest overall ORAM rating of 58 and a *high* NC WAM overall rating. Function ratings were *high* for hydrology, *high* for water quality, and *medium* for habitat. The Horry 28 site is dominated with shrubs including pond spice (*Litsea aestivalis*) and Titi. Pond cypress and a few swamp tupelos and red bays were scattered throughout the site. Patches of Carolina redroot (*Lachnanthes caroliana*) and sphagnum moss occurred in the herb stratum. The steep sides of this wetland indicated it is actually a lime sink.


Figure 15. Horry 28 study site in Horry County, South Carolina.

**Horry 1** - The Horry 1 site (3.17 acres or 1.28 Ha) is located approximately 4 miles east of Conway in southern Horry County (Figure 16). This site is partially located in the Conway Regional Airport air operations area. This wetland is divided, with 50% located on the airport managed grassy field while the other half is located in a forest adjacent to the airport property. Function ratings for Horry 1 were *low* for hydrology, water quality, and habitat. The forested portion of the site was composed of laurel oak, red maple (*Acer rubrum*), black gum (Nyssa sylvatica), sweet gum, and willow oak (*Quercus phellos*). Small trees and shrubs included the American holly (Ilex opaca), Inkberry (*Ilex glabra*) and dangleberry (*Gaylussacia frondosa*). The grassy portions of the airport operations area were dominted with Beaked panic grass (*Panicum anceps*) and smooth crabgrass (*Digitaria ischaemum*). This site contained a large pool (approximately 0.5 acres) in the open grassy portions of the site during March biocriteria sampling.

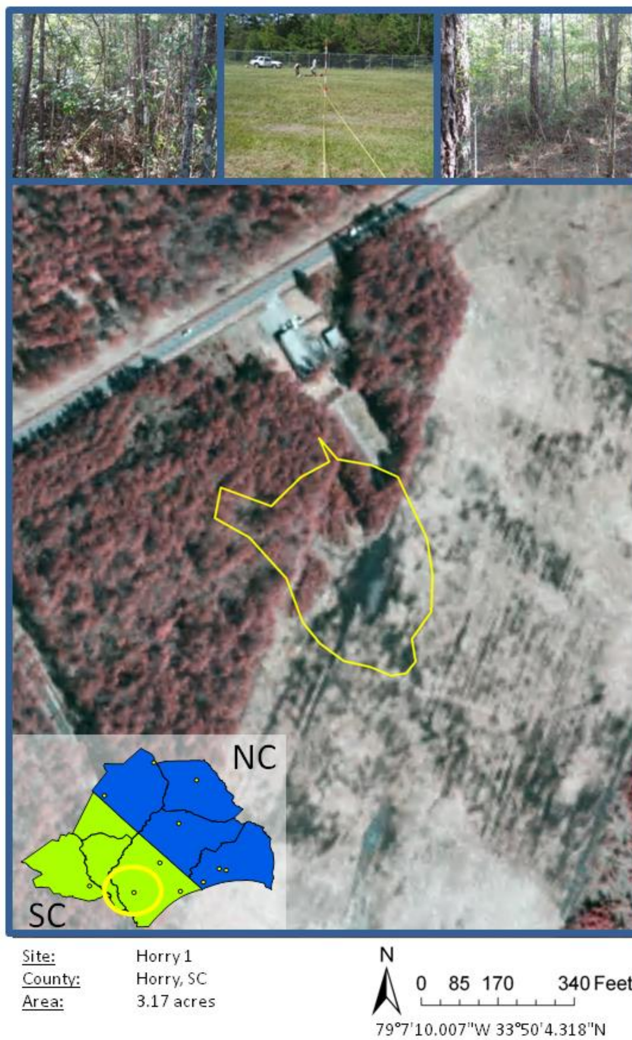


Figure 16. Horry 1 study site in Horry County, South Carolina.

**Florence 14b -** The Florence 14b (0.09 acres or 0.04 Ha) site is located approximately 5.31 miles from Gresham in southeastern Florence County, South Carolina (Figure 17). This site is 0.5 miles north of West Myrtle Beach Highway. This site was historically connected to a large 10 acre IW and is now fragmented by an adjacent gravel road to the south. An agricultural field and nearby rural homes surround this fragmented wetland on the other sides. This site had the lowest overall ORAM score of 26 and a *medium* NC WAM Overall rating. Function ratings for Florence 14b were *medium* for hydrology, *high* for water quality, and *medium* for habitat function. The Florence 14b site is forested with water oak, sweet gum, and swamp tupelo. There are scattered wax myrtle (*Morella cerifera*) shrubs and a very sparse herb stratum.


Figure 17. Florence 14b study site in Florence County, South Carolina.

**Columbus 26** - The Columbus 26 (0.44 acres or 0.18 Ha) site is located approximately 2 miles northeast of Whiteville in northern Columbus County, North Carolina (Figure 18). This IW is 0.75 miles (1.2 km) west of James B White Highway N. This site is 250 feet (75 m) from a small agricultural field and neighborhood and surrounded by mature upland forest. Water oak, sweet bay, red maple, and water tupelo were the dominant trees covering this wetland. The prevalent shrub stratum was composed of common sweetleaf (*Symplocos tinctoria*) and gallberry while the herb stratum was fairly sparse.

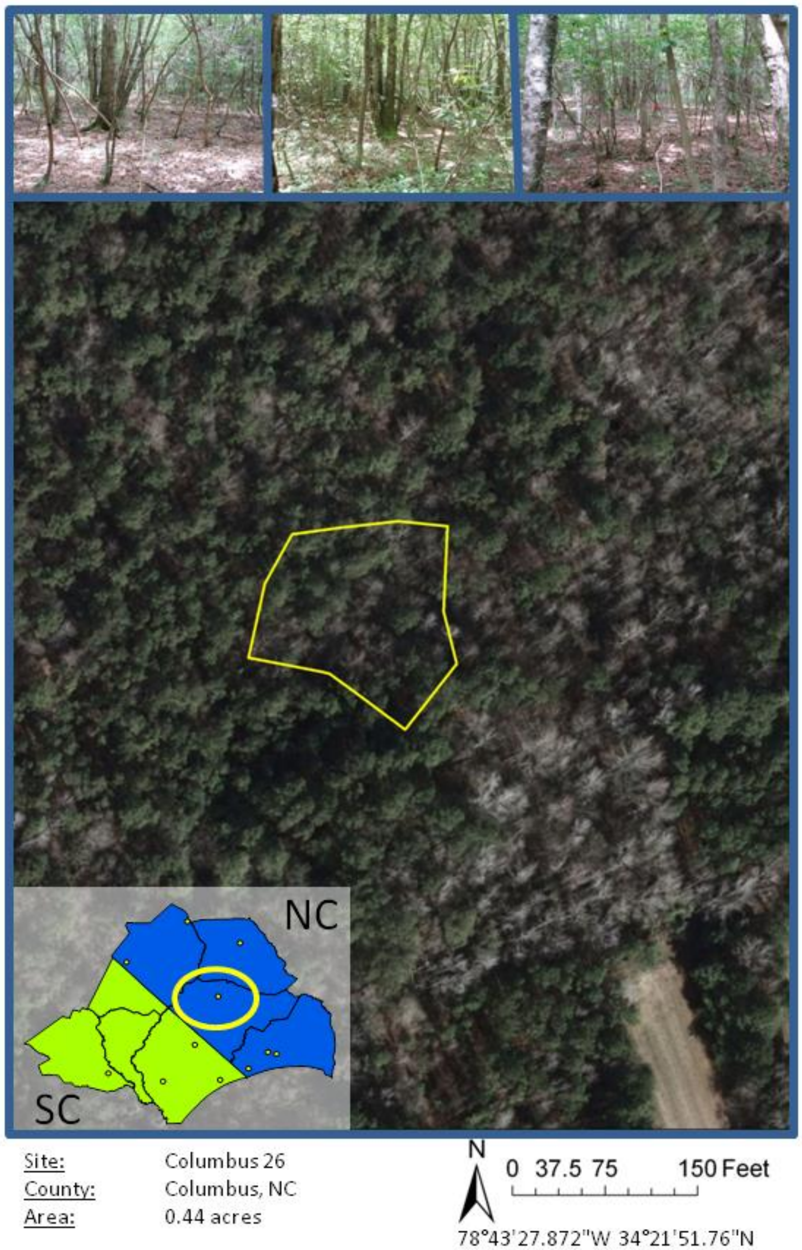


Figure 18. Columbus 26 study site in Columbus County, North Carolina.

**Brunswick 17 -** The Brunswick 17 (0.10 acres, 0.04 Ha) site is located approximately 1.8 miles from Sunset Beach in southeastern Brunswick County, North Carolina (Figure 19). This site is adjacent to Old Georgetown Road SW. This wetland borders the highway, a nearby golf course, and a housing development. This site had an open canopy of Loblolly pine (*Pinus taeda*) with scattered red bay and sweet bay (*Magnolia virginiana*) in the understory and a dense shrub cover of creeping blueberry (*Vaccimium crassifolium*), gallberry (*Ilex glabra*), and high bush blueberry (*Vaccinium corymbosum*). The understory of this site was cleared after the 2012 vegetation survey and prior to the 2012 amphibian survey.

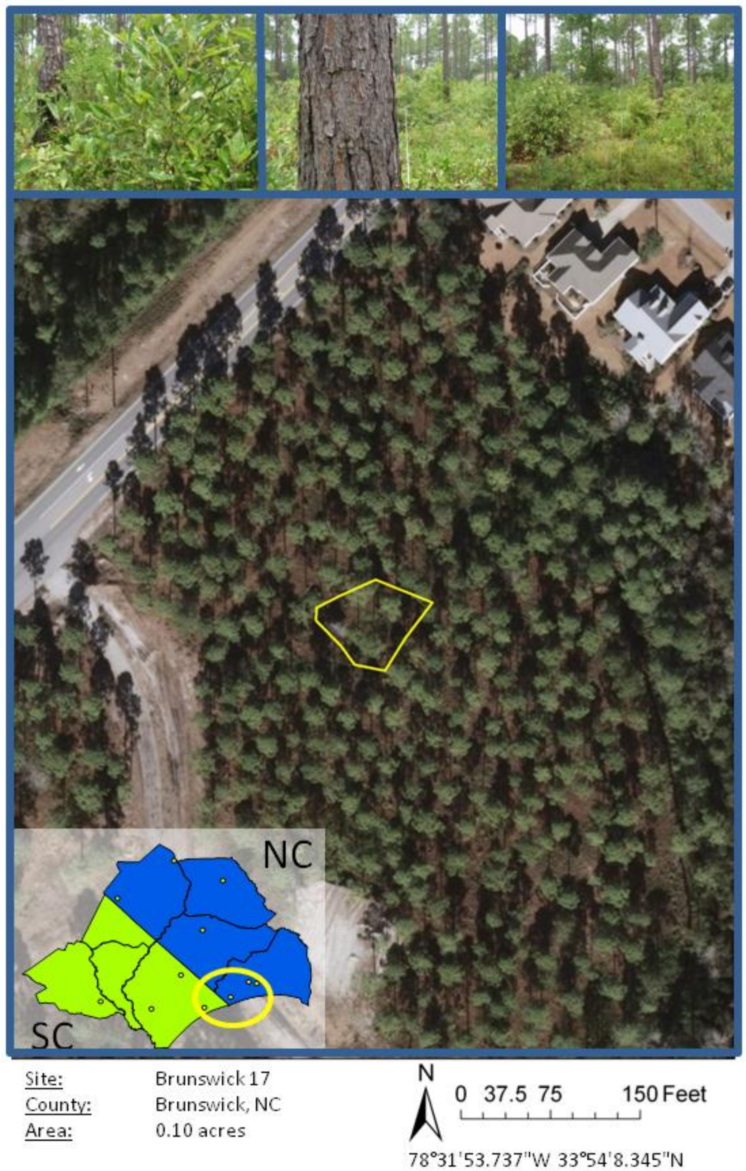


Figure 19. Brunswick 17 study site in Brunswick County, North Carolina.

**Brunswick 7 -** The Brunswick 7 site (0.83 acres, 0.34 Ha) is located approximately 3.2 miles from Shallotte in eastern Brunswick County, North Carolina (Figure 20). This site is located 300 feet (90 m) to the southeast of Ocean Highway West. There is also a residential area directly to the northeast and west of the Brunswick 7 site. Mature upland forest occurs to the south and east of the site. Brunswick 7 is a forested site with red maple, swamp tupelo, sweet gum, and tulip poplar (*Tulipifera liriodendron*) composing the canopy, American holly composing the understory, coastal doghobble (*Leucothoe axillaris*) and wax myrtle (*Myrica cerifera*) composing the shrub layer, and netted chainfern (*Woodwardia areolata*) dominating the herb layer. This site contained four small pools during March biocriteria sampling.

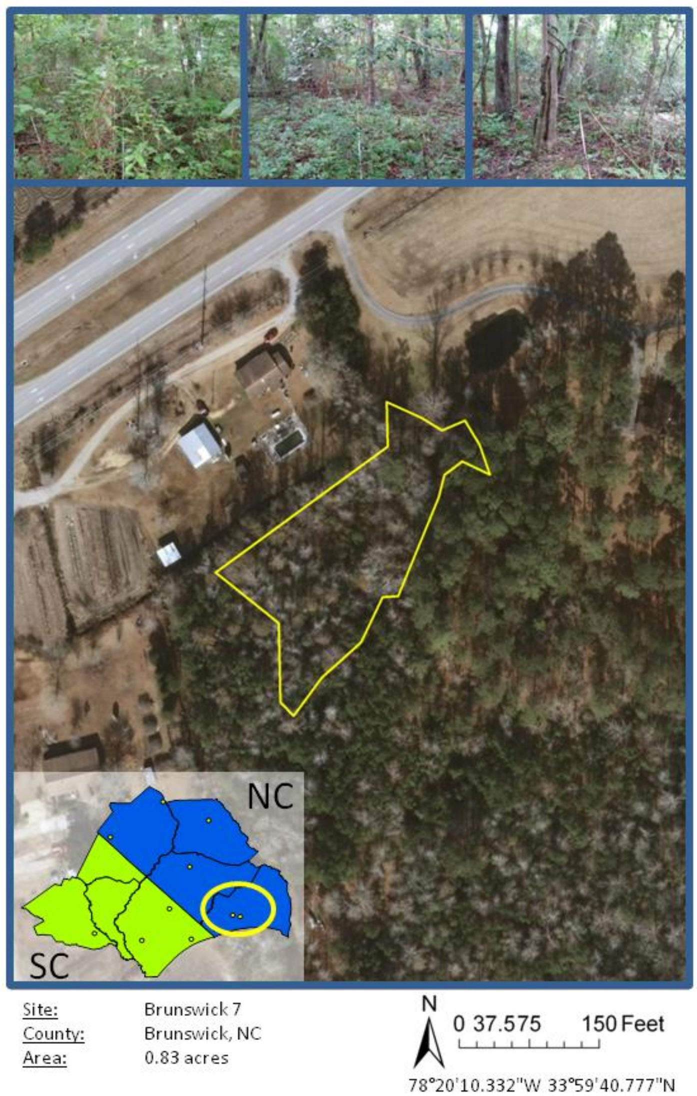


Figure 20. Brunswick 7 study site in Brunswick County, North Carolina.

**Brunswick 4 -** The Brunswick 4 (0.49 acres or 0.20 Ha) site is located approximately 2.2 miles north of Shallotte in eastern Brunswick County, North Carolina (Figure 21). This site is 1.1 miles from northwest of Ocean Highway W. Brunswick 4 is located on a managed pine plantation and is accessed through unpaved roads. The Brunswick 4 site had a dense herb stratum with a few scattered trees and shrubs including a pond pine, sweet bay, and inkberry. The herb stratum was composed primarily of Virginia chainfern (*Woodwardia virginica*) and purple bluestem (*Andropogon glaucopsis*). This site contained only one small, shallow (< 3 inches) pool during March biocriteria sampling.

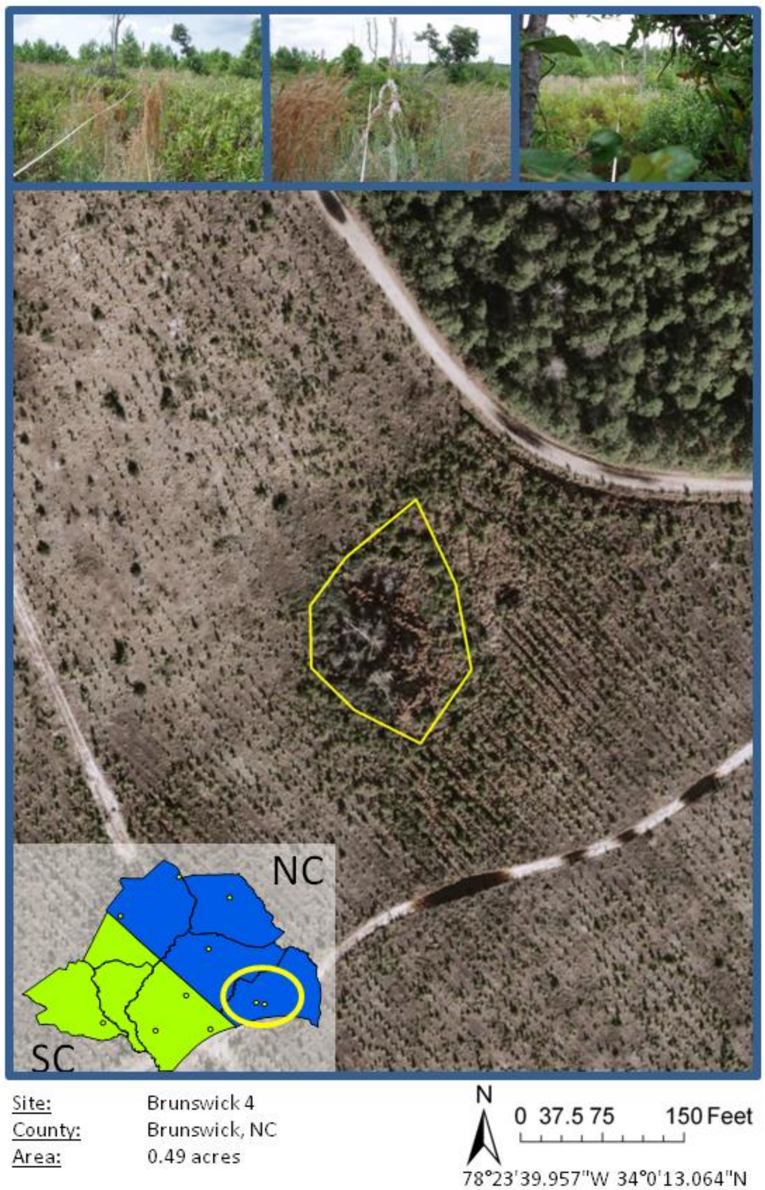


Figure 21. Brunswick 4 study site in Brunswick County, North Carolina.

**Bladen 9 -** Bladen 9 (1.32 acres, 0.5 Ha) is located approximately 5 miles northeast of Elizabethtown in northern Bladen County, North Carolina (Figure 22). This site is 500 ft (160 m) north of Sweet Home Church Road. Bladen 9 was a clear-cut site with no canopy cover and little ground cover. The area immediately surrounding this site has also been clear-cut. A few fetterbush (*Lyonia lucida*) shrubs and colonizing loblolly pine and longleaf pine (Pinus palstris) were scattered throughout the site.

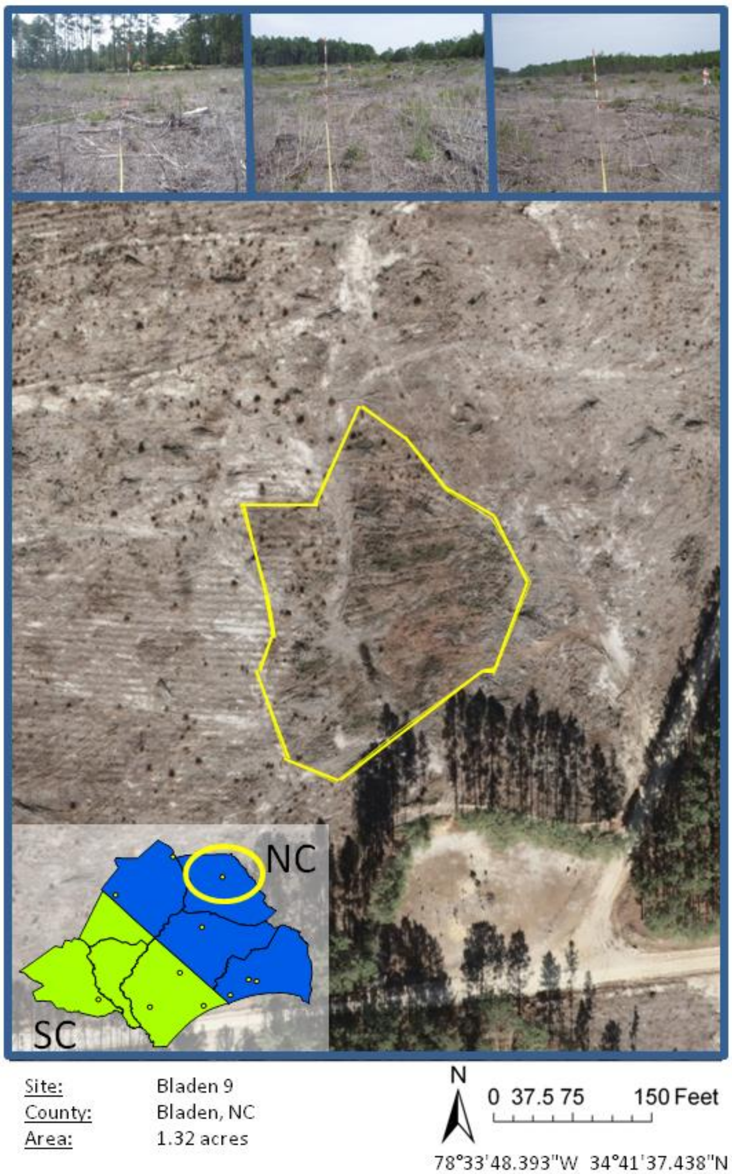


Figure 22. Bladen 9 study site in Bladen County, North Carolina.

### 3.1.2 Amphibian Monitoring Results and Discussion

Amphibian sampling occurred in February/March and again in May 2012 at 11 biocriteria sites in North Carolina and South Carolina. Amphibians were recorded from all sites except Brunswick 7, Florence 14b, Horry 28, and Robeson 1 during the February/March site visits. In May, amphibians were recorded from all sites except Brunswick 17, Brunswick 24, Florence 14b, and Horry 1. The majority (55%) of sites did not have any surface water present during both sampling events. The study area experienced below normal average rainfall and above normal average temperature. Normal precipitation between November-May is 27.95 inches while the same period in 2011-2012 received 22.46, with 8.26 inches coming in May after sampling occurred.

A total of 8 amphibian species were recorded from isolated wetland study sites over two sampling periods (see Table 5). Seven of the eight species collected were anuran taxa, mainly from the genus *Hyla*. One salamander species, the northern slimy salamander (*Plethodon glutinosus)*, was recorded from several study sites. Spring peepers (*Pseudacris crucifer*) and *northern* slimy salamanders were recorded at three of the 11 biocriteria sites during February/March sampling. One anuran species, southern cricket frogs *(Acris gryllus*), was recorded during the first sampling. May sampling yielded one salamander species, the northern slimy salamander (*Plethodon glutinosus*) and five anuran species, the American toad (*Bufo americanis),* barking treefrog (*Hyla gratiosa),* squirrel treefrog *(H. squirella),* Cope's gray treefrog (*H. chrysosocelis),* pinewoods treefrog (*H. femoralis*). The barking treefrog was recorded at three sites (Horry 28, Horry 41, Robeson 7) during the second sampling period. There were no larval or egg sac field observations. All field observations of amphibians were adults except for one juvenile American toad.

Table 5. Amphibian species recorded from isolated wetland study sites during sampling period.

| Species Name | Common Name |
|---|---|
| *Bufo americanis* | American Toad |
| *Acris gryllus* | Southern Cricket Frog |
| *Hyla chrysosocelis* | Cope's Grey Treefrog |
| *Hyla femoralis* | Pine Woods Treefrog |
| *Hyla gratiosa* | Barking Treefrog |
| *Hyla squirella* | Squirrel Treefrog |
| *Plethodon chlorobryonis* | Northern Slimy Salamander |
| *Pseudacris crucifer* | Spring Peeper |

Results from amphiban surveys at isolated wetland study sites yielded low diversity compared to the potential number of species found in this region. Savage et al. (2010) recorded 23 amphibians in small basin wetlands in North Carolina. Habitat conditions were poor at most biocriteria sites. Only four sites, Horry1, Horry 41, Brunswick 4, and Brunswick 7, had pools of standing water, all of which appeared to be fairly temporary. Several sites were located on managed forest land or maintained properties, with one (Bladen 9) being completely clear cut and another half covered with an airport air operations managed grass area. Dry conditions affected the study area and surface water was absent from most sites during the sampling period. When surface water was present, pH was acidic and below 4.0 at two sites, Horry 41 and Brunswick 4. Many species of amphibians prefer pH levels of 4.5 or higher (Smith and Braswell, 1994). Additionally, Horry 41 and Brunswick 7 had low oxygen levels. These combined factors likely created stressful conditions for breeding amphibians.

### 3.1.3 Aquatic Macroinvertebrate Monitoring Results and Discussion

Macroinvertebrate samples were collected from four of the 11 biocriteria study sites during the 2012 February/March sampling period. Samples were not collected from six sites during this period due to absence of surface water. Surface water was absent during the May sampling period at all 11 sites. The absence of surface water associated with these isolated wetlands created difficulties for the macroinvertebrate assessments which rely on at least small pools for habitation. Prior to sampling (December 2011-February 2012), there was an 8.0 inch rainfall deficit compared to normal mean b amounts (1971−2000) in the study area. Lack of precipitation during the study period created fewer inundated isolated wetlands than would be expected during a normal rainfall year. Small pools were present at several study sites and were inhabited by macroinvertebrates despite their brief hydroperiod and lack of surface connection with permanent water bodies.

A total of 23 genera from 6 orders and 12 families were recorded from isolated wetland study sites during the February/March sampling period (see Table 6). The order Coleoptera (2 families, 9 genera) and Diptera (4 families, 7 genera) were the most diverse groups collected, making up 50% of family richness and 70% of genera richness. The majority of taxa collected (67%) were from the swimmer habit guild. Two genera, *Fallicambarus* and *Cambarus* (Cambaridae), are known to burrow and survive dry surface water conditions in saturated soils in wetlands (Hobbs et al. 1991). Crayfish burrows were often visible during field sampling before and after sites were inundated. The NC DWQ Lab Biotic Index (NC DWQ 2012) indicated tolerance to organic pollution (i.e., low dissolved oxygen) of macroinvertebrates collected was high (range 7.2−9.8, scale 0−10). Results indicated that taxa found had strong dispersal characteristics with the ability to inhabit these temporary waters within an estimated 1−2 weeks after inundation.

Table 6. Macroinvertebrate species collected from isolated wetland study sites during sampling period.

| **Order (*n* = 6)** | **Family (*n* = 12)** | **Genera (*n* = 23)** |
|---|---|---|
| Amphipoda | Crangonyctidae | *Crangonyx* |
| | Hyalellidae | *Hyalella* |
| Coleoptera | Dyticidae | *Copelatus* |
| | | *Cybister* |
| | | *Laccophilus* |
| | | *Laccornis* |
| | | *Liodessus* |
| | | *Sphaeridiinae* |
| | | *Thermonectus* |
| | Hydrophilidae | *Platambus* |
| | | *Tropisternus* |
| Decapoda | Cambaridae | *Fallicambarus* |
| | | *Cambarus* |
| Diptera | Ceratopogonidae | *Dasyhelea* |
| | Chironomidae | *Hydrobaenus* |
| | | *Polypedilum* |
| | | *Pseudosmittia* |
| | | *Psilometriocnemus* |
| | | *Smittia* |
| | Culicidae | *Aedes* |
| | Dolichopodidae | |
| Hemiptera | Corixidae | *Hesperocorixa* |
| | Notonectidae | *Notonecta* |
| Isopoda | Asellidae | *Caecidotea* |

Macroinvertebrate diversity ranged from two to five families and three to 12 genera at the four study sites (Table 7). Horry 1 had the highest macroinvertebrate diversity (5 families, 12 genera) of study sites. Crangonyx (Crangonyctidae), Copelatus (Dytiscidae), Cambarus (Cambaridae), and Caecidotea (Asellidae) were the most dominant taxa based on abundance from the study sites sampled (*n* = 5). Overall, macroinvertebrates from six different functional feeding guilds were collected including herbivore, shredder, collector-gatherer, scraper, predator, and omnivore. Collector-gatherer taxa were the most abundant functional feeding guild (range 65%−80%) at Brunswick 4 and Horry 41. Predator taxa were most abundant at Brunswick 7 (40%) and omnivore taxa dominated Horry 1 (81%). Average tolerance of study sites (range 7.2−9.0) was lowest at Brunswick 4 and highest at the Horry 1 site.

Table 7. Macroinvertebrate diversity, dominant taxa and functional feeding guild (FFG), and tolerance score for biocriteria sites sampled during February/March 2012 sampling period in North Carolina and South Carolina.

| Site | No. of Families | No. of Genera | Dominant Taxa (% Dominance) | Dominant FFG (% Dominance) | Tolerance Score |
|---|---|---|---|---|---|
| Brunswick 4 | 4 | 4 | Crangonyctidae Crangonyx (29%) | Collector-Gatherer (65%) | 7.2 |
| Brunswick 7 | 5 | 7 | Dyticidae Copelatus (33%) | Predator (40%) | 8.2 |
| Horry 1 | 9 | 13 | Cambaridae Cambarus (74%) | Omnivore (81%) | 9.0 |
| Horry 41 | 3 | 3 | Asellidae Caecidotea (60%) | Collector-Gatherer (80%) | 7.8 |

In general, macroinvertebrate diversity was low across isolated wetland study sites compared to stream and permanent wetland assessments. A recent study in headwater streams in the southeastern United States identified 67 macroinvertebrate taxa from intermittent reaches (sections) and 145 taxa from perennial stream reaches (Eaton and Vander Vorste 2012). Leslie et al. (1997) documented 85 macroinvertebrate taxa from three pond cypress swamps in north central Florida. Taxa collected during this study are considered tolerant to low dissolved oxygen conditions and resistant to predictable drying disturbances. Many taxa documented in this study have mechanisms (e.g., burrowing, flying, desiccation resistance) allowing them to quickly inhabit newly inundated wetlands and emigrate or survive when drying occurs. *Crangonyx spp.* (Amphipoda), beetles (Coleoptera), and crayfish (Crustacea) have the ability to burrow into moist sediments to survive seasonal drying in wetlands. Chironomid (Diptera) larvae (e.g., *Hydrobaenus*) survive drought in a cryptobiotic state (Gore et al. 1998).

### 3.1.4 Vegetation Monitoring Results and Discussion

The vegetation communities of the IWs surveyed in this study were diverse in nature. IWs can be basin wetlands or pocosins as defined by NCWAM in the NC coastal plain region. As discussed previously, only basin wetlands were used for this study (see Section 2.1.1 Biocriteria Site Selection). The NCWAM defines basin wetlands by their landscape position, "depressions surrounded by uplands" rather than by their vegetation. This broad definition encompasses vegetation structure that "may vary widely from forest in mafic depressions and ephemeral pools, to primarily herbaceous or emergent in lime sinks, man-excavated depressions, and along the shorelines of small open waters" (NCFAT 2008). As previously discussed in Section 3.1.1, the basin wetlands were defined as Wet Pine Flatwoods (n = 3), Non-riverine Swamp Forest (n = 2), Non-riverine Wet Hardwood Forest (n = 4), and Cypress Savannah (n = 2) by Schafale and Weakely's Classification of the Natural Communities of NC (1990) and Pine Flats (n=3), Non-Alluvial Swamp Forests (n=7), and Pond Cypress Savannah (N=1) by Nelson's Natural

Communities of SC: Initial Classification and Description (1986) (see Table 4 in Section 3.1.1). These two community classifications characterize wetland types by dominant vegetation, soil type, and region, as well as landscape position.

Vegetation biocriteria also known as Indices of Biotic Integrity (IBIs) were developed for the IWs to assess the biological integrity of these sites. IBIs are an index that combine several (preferably 8-10) metrics derived from biological attributes. IBIs represent the condition of a site and provide results that are easily interpreted (USEPA 2002). Vegetation IBIs have been developed by a number of states, for various types of wetlands (Mack and Micacchion 2000, Lemly and Rocchio 2009). NC has developed vegetation IBIs for headwater wetlands (Baker et al. 2008), riverine swamp forests, bottomland hardwood forests, and basin wetlands (Savage et. al. 2010). Studies have shown that further testing and adjustment of IBIs with new datasets from the same or different regions and/or community types are an important process in the development of IBIs (Karr and Chu 1999 and Mack 2004). Studies have also shown that it is important to incorporate study sites that are representative of a human disturbance gradient from highly disturbed to reference quality in the development of IBIs (USEPA 2002 and Mack 2004).

The IWC study sites were categorized into vegetation structure categories to simplify the development of vegetation IBIs. This more general vegetation structure categorization approach, which has been used by other states (Mack 2004), provided a way to combine and organize these diverse communities of IWs. Vegetation structure was defined as "forest", "shrub", or "emergent" according to which vegetation stratum the intensive survey module results found to have the highest coverage (see Section 2.1.4 Vegetation Monitoring Methods). Additionally, the vegetation results from 38 other sites collected for three other studies (the SEIWA [RTI 2011], NCWAM Headwater and "Development of a wetland monitoring program for headwater wetlands" [CD-974260-01, Baker et al. 2008]) were combined with the corresponding results from the 11 IWC sites to make a large enough dataset to develop IBIs. There were six forest, three shrub, and two emergent categorized sites for the IWC study. The four studies combined resulted in 39 forest, seven shrub, and three emergent categorized sites (see Table 8). Vegetation IBIs were developed separately for the three vegetation structure categories.

A total of 43 candidate metrics were developed and analyzed for use in the Forest IBI. These metrics were categorized in five types: 1.) community balance, 2.) floristic quality, 3.) wetness, 4.) functional group, and 5.) community structure. The metrics are listed in Table 9 and further defined in Appendix B. The 43 forested site candidate metrics were analyzed for significance through correlation with ORAM scores (Mack, 2001), see Table 8. ORAM is a rapid assessment method developed in Ohio that provides a numeric rather than categorical wetland condition rating score and has proven useful for the development of IBIs in previous NC DWQ studies (Baker et. al 2008, Savage et. al. 2010). Pearson's Correlation was used for continuous candidate metrics (e.g. percent sensitive) and Spearman's Rho was used discrete candidate metric (e.g. species richness). The statistical analysis and expected correlation direction (positive or negative) are shown in Table 9. Observations that exceeded the 99.5 percentile were considered outliers and removed from the correlation analyses. Nine metrics showed statistical significant results at 5% of significance or less (p-value<0.05): 1.) Floristic Quality Assessment (FQAI) Count, 2.) FQAI Cover, 3.) Average Coefficient of Conservatism (C of C), 4.) Percent Tolerant, 5.) Percent Sensitive, 6.) Wetland Plant Cover, 7.) Wetland Shrub Richness, 8.) Wetland Shrub Cover, and 9.) Annual: Perennial (see Table 10). Scatter plots showing the distribution of data for the nine metrics with significant correlation, a linear model fit line (red) and the observed mean line (green) are shown in Figure 23 A to I.

Table 8. Study, vegetation structure, and ORAM score

| Study | Site | Forest, Emergent, or Shrub | ORAM Score |
|---|---|---|---|
| IWC | Brunswick 4 | Emergent | 32 |
| IWC | Robeson 7 | Emergent | 35 |
| IWC | Florence 14b | Forest | 26 |
| IWC | Horry 1 | Forest | 28 |
| IWC | Robeson 1 | Forest | 31 |
| IWC | Horry 41 | Forest | 40 |
| IWC | Brunswick 7 | Forest | 40 |
| IWC | Columbus 26 | Forest | 48 |
| IWC | Bladen 9 | Shrub | 34 |
| IWC | Brunswick 17 | Shrub | 51 |
| IWC | Horry 28 | Shrub | 58 |
| SEIWA | Marion 2B | Emergent | 69.5 |
| SEIWA | Brunswick L3.2 | Forest | 77 |
| SEIWA | Brunswick L3.1 | Forest | 78 |
| SEIWA | Marion 2A | Shrub | 53 |
| SEIWA | Marion 2C | Shrub | 75.5 |
| Headwater Wetland | Troxler | Forest | 20.5 |
| Headwater Wetland | Boddie Noell | Forest | 35.5 |
| Headwater Wetland | Hog Farm Lower | Forest | 37.67 |
| Headwater Wetland | Walmart | Forest | 38.17 |
| Headwater Wetland | Moonshine | Forest | 42 |
| Headwater Wetland | Hog Farm Upper | Forest | 42.67 |
| Headwater Wetland | Fire Tower | Forest | 45.5 |

Table 8. Study, vegetation structure, and ORAM score

| Study | Site | Forest, Emergent, or Shrub | ORAM Score |
|---|---|---|---|
| Headwater Wetland | Nahunta | Forest | 47.67 |
| Headwater Wetland | Kelly Rd | Forest | 48.33 |
| Headwater Wetland | Battle Park | Forest | 55.67 |
| Headwater Wetland | East Fayetteville South | Forest | 57 |
| Headwater Wetland | PCS | Forest | 57.17 |
| Headwater Wetland | Pete Harris | Forest | 59.67 |
| Headwater Wetland | East of Mason | Forest | 60.33 |
| Headwater Wetland | Rough Rider | Forest | 64 |
| Headwater Wetland | Black Ankle Non-Powerline | Forest | 64.17 |
| Headwater Wetland | East Fayetteville North | Forest | 65.17 |
| Headwater Wetland | Batchelor | Forest | 69.83 |
| Headwater Wetland | Umstead | Forest | 70 |
| Headwater Wetland | Spring Garden | Forest | 74.33 |
| Headwater Wetland | Cox | Shrub | 43.67 |
| NCWAM Headwater Wetland | Hog Farm New | Forest | 27 |
| NCWAM Headwater Wetland | Durham Church | Forest | 29.5 |
| NCWAM Headwater Wetland | Raleigh Beacon Hill | Forest | 33 |
| NCWAM Headwater Wetland | Wilson Cutover | Forest | 33.5 |
| NCWAM Headwater Wetland | Greensboro Jarvis | Forest | 35.5 |
| NCWAM Headwater Wetland | Wilson Target North | Forest | 37 |
| NCWAM Headwater Wetland | Durham Rockwood Park | Forest | 43 |
| NCWAM Headwater Wetland | Rocky Mount Raper | Forest | 45 |
| NCWAM Headwater Wetland | Burlington Tickle | Forest | 45.5 |
| NCWAM Headwater Wetland | Greenville Lakeview | Forest | 47.5 |
| NCWAM Headwater Wetland | Duke Forest | Forest | 53.5 |
| NCWAM Headwater Wetland | Rocky Mountain Halifax | Shrub | 38.5 |

Table 9. DWQ Forest Candidate Vegetation Metrics, ORAM correlation, and Statistical Test

| Candidate Vegetation Metric | Expected Correlation with ORAM Score | Statistical Test |
|---|---|---|
| **Community Balance Candidate Metric** | | |
| Diversity Cover Simpson Metric | Positive | Pearson's Correlation |
| Evenness Metric | Positive | Pearson's Correlation |
| Native Evenness Metric | Positive | Pearson's Correlation |
| Dominance Metric | Negative | Pearson's Correlation |
| Herb and Shrub Cover Dominance Metric | Negative | Pearson's Correlation |
| Species Richness Metric | Positive | Spearman's Rho |
| Native Species Richness Metric | Positive | Spearman's Rho |
| Vascular Plant Genera Richness Metric | Positive | Spearman's Rho |
| Vascular Plant Family Richness Metric | Positive | Spearman's Rho |
| **Floristic Quality Candidate Metrics** | | |
| FQAI Cover Metric | Positive | Pearson's Correlation |
| FQAI Species Count Metric | Positive | Pearson's Correlation |
| Average C of C Metric | Positive | Pearson's Correlation |
| Percent Tolerant Metric | Negative | Pearson's Correlation |
| Percent Sensitive Metric | Positive | Pearson's Correlation |
| Invasive Species Coverage Metric | Negative | Pearson's Correlation |
| Invasive Shrub Coverage Metric | Negative | Pearson's Correlation |
| Invasive Grass Coverage Metric | Negative | Pearson's Correlation |
| **Wetness Characteristic Candidate Metrics** | | |
| FAQWET Equation 3 Metric | Positive | Pearson's Correlation |

Table 9. DWQ Forest Candidate Vegetation Metrics, ORAM correlation, and Statistical Test

| Candidate Vegetation Metric | Expected Correlation with ORAM Score | Statistical Test |
|---|---|---|
| FAQWet Cover Metric | Positive | Pearson's Correlation |
| Wetland Plant Species Richness Metric | Positive | Spearman's Rho |
| Wetland Plant Cover Metric | Positive | Pearson's Correlation |
| Wetland Shrub Species Richness Metric | Positive | Spearman's Rho |
| Wetland Shrub Cover Metric | Positive | Pearson's Correlation |
| **Functional Group Candidate Metrics** | | |
| Cryptogram Richness Metric | Positive | Spearman's Rho |
| Cryptogram Cover Metric | Positive | Pearson's Correlation |
| Annual: Perennial Metric | Negative | Spearman's Rho |
| Bryophyte Cover Metric | Positive | Pearson's Correlation |
| Carex Richness Metric | Positive | Spearman's Rho |
| Carex Cover Metric | Positive | Pearson's Correlation |
| Cyperaceae, Poaceae and Juncaceae Metric | Positive | Pearson's Correlation |
| Cyperaceae, Poaceae and Juncaceae Coverage Metric | Positive | Pearson's Correlation |
| Dicot Richness Metric | Positive | Spearman's Rho |
| Native Herb Richness Metric | Positive | Spearman's Rho |
| Native Herb Cover Metric | Positive | Pearson's Correlation |
| Total Herb Richness Metric | Positive | Spearman's Rho |
| **Community Structure Candidate Metrics** | | |
| Shade Metric | Positive | Spearman's Rho |
| Sapling Density Metric | Negative | Pearson's Correlation |
| Large Tree Density Metric | Positive | Pearson's Correlation |

Table 9. DWQ Forest Candidate Vegetation Metrics, ORAM correlation, and Statistical Test

| Candidate Vegetation Metric | Expected Correlation with ORAM Score | Statistical Test |
|---|---|---|
| Pole Timber Density Metric | Negative | Pearson's Correlation |
| Canopy Importance Metric | Positive | Pearson's Correlation |
| Sub-Canopy Importance Metric | Positive | Pearson's Correlation |
| Shade Sub-Canopy Importance Metric | Positive | Pearson's Correlation |
| Snag Density Metric | Positive | Spearman's Rho |

Table 10. DWQ Forest Metric Correlation Results.

| Metric | $R^2$ or Spearman Rho | P-Value |
|---|---|---|
| FQAI Cover Metric* | 0.519 | 0.0008 |
| FQAI Species Count Metric | 0.561 | 0.000203 |
| Average C of C Metric | 0.495 | 0.001362 |
| Percent Tolerant Metric | -0.337 | 0.036029 |
| Percent Sensitive Metric | 0.489 | 0.001576 |
| Wetland Plant Cover Metric | 0.324 | 0.044197 |
| Wetland Shrub Species Richness Metric | 0.3409 | 0.03369 |
| Wetland Shrub Cover Metric | 0.459 | 0.003297 |
| Annual: Perennial Metric | -0.448 | 0.004227 |

* Robeson 1 - an outlier in the 99.5 % was removed for this analysis

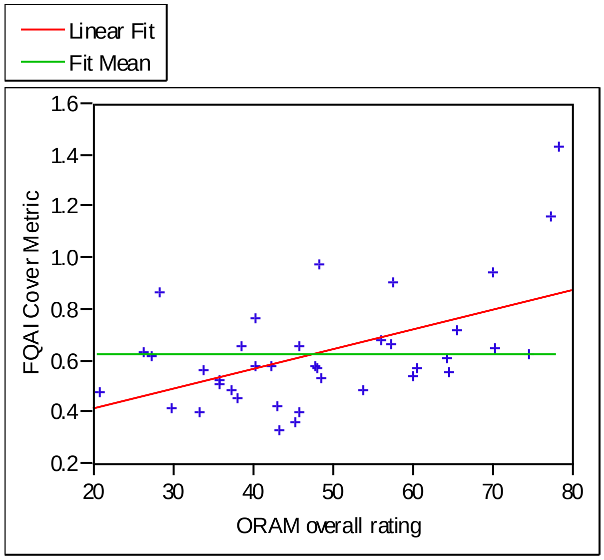


Figure A. ORAM by FQAI Cover Metric

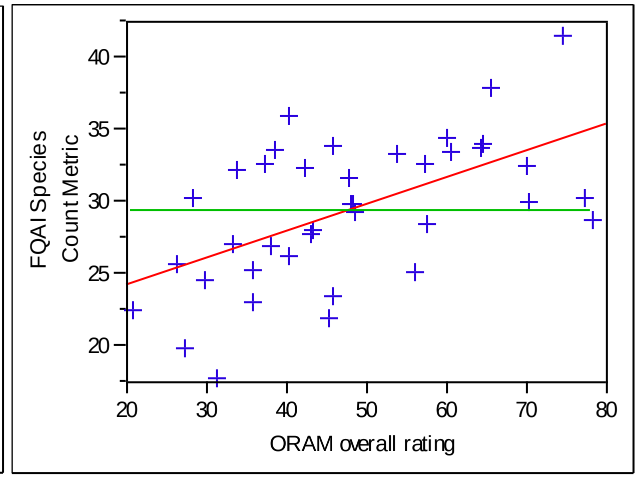


Figure B. ORAM by FQAI Species Count Metric

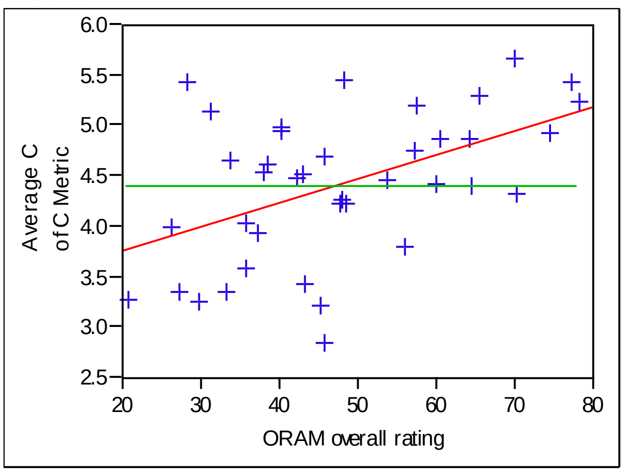


Figure C. ORAM by C of C Metric

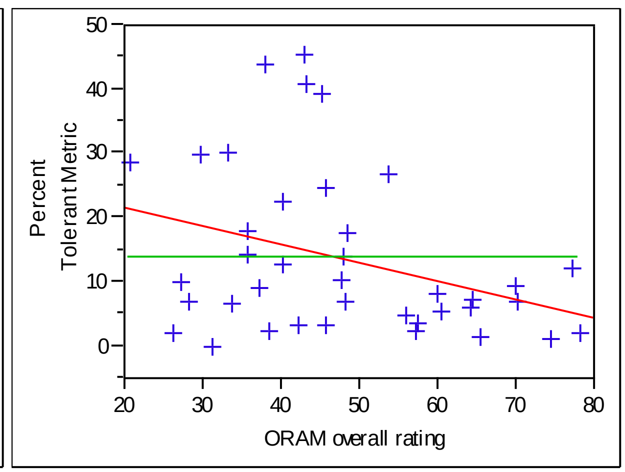


Figure D. ORAM by Percent Tolerant Metric

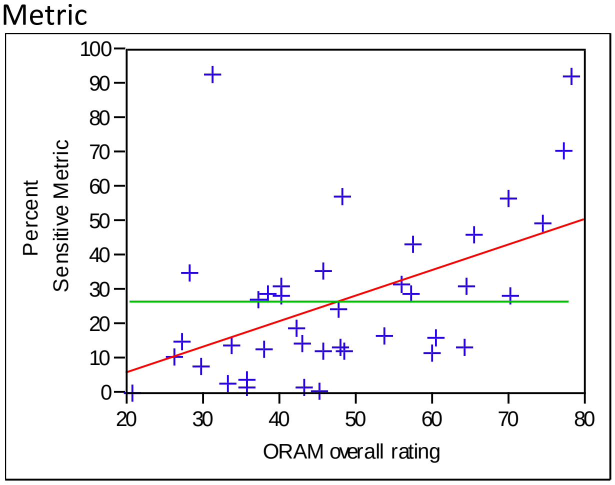


Figure E. ORAM by Percent Sensitive Metric

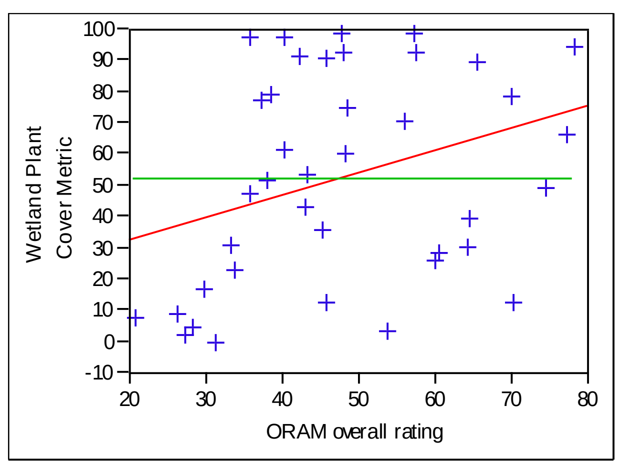


Figure F. ORAM by Wetland Plant Cover Metric

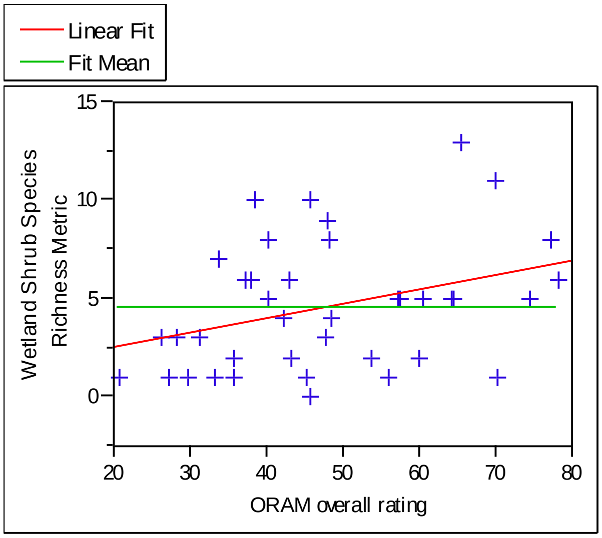


Figure G. ORAM by Wetland Shrub Richness

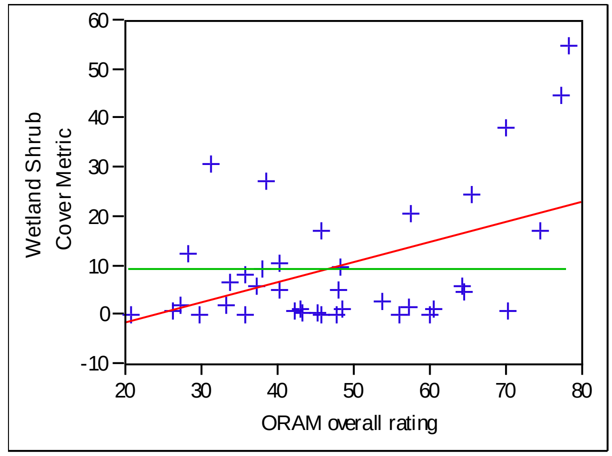


Figure H. ORAM by Wetland Shrub Cover Metric

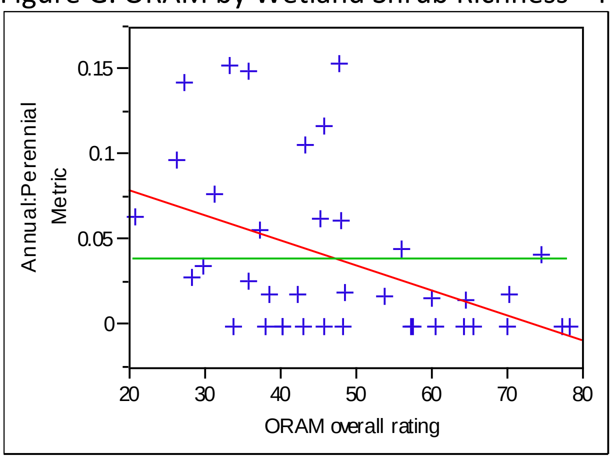


Figure I. Annual Perennial Metric

Figure 23. A – I. DWQ Forest IBI Metric Correlations

The first five significant metrics are associated with the Coefficient of Conservatism scores (C of C). C of C score assignments (0-10) are based on the affinity each plant species has for a particular ecoregion (Swink and Wilhelm, 1979, Swink and Wilhelm 1994, and Taft et al. 1997). The Floristic Quality Assessment (FQAI) Count metric has been shown to be a highly affective indicator of wetland condition by a number of states (Mack, 2004, Herman et al. 2006, Bernthal, 2003, Cohen et. al. 2003, Ervin et. al. 2006) and has been used alone or in combination with other metrics. FQAI combines the C of C score along with the number of species on a site (Taft et al. 1997). Five of the eight floristic quality candidate metrics which developed from C of C scores had significant results. Three of the six wetness characteristic candidate metrics and one of the 12 functional group candidate metrics also had significant results, while the community balance and community structure candidate metrics had no significant results. See Appendix B for further information on the development the nine metrics used for the Forest IBI.

The nine significant metrics that correlated with ORAM are on a different scales (see Table 11) and were transformed to the same scale in order to combine the nine metrics into a forest IBI. A “0-10 scaling” equation (see below) was used to transform all the significant forest metrics to the same 0-10 scale. A complement of the 0-10 scaling equation was used to transform the two metrics, Percent Tolerant and Annual: Perennial, those were expected to and did have a negative correlation with ORAM (see below). Outliers were removed from the 0-10 scaling and complement of the 0-10 scale equations prior to transformation of metric values to 0-10. The outliers were recoded with a “0” or a “10” according to which end of the data distribution they occurred and which equation (the 0-10 scale or the complement of the 0-10 scale) was appropriate to apply for metric value transformation. Table 12 shows the scaled value for each metric and the overall Forest IBI score. The six IWC Forest IBI results ranged from 28 (Florence 14b) to 59.6 (Columbus 26) with a mean of 48 and median of 50.75 while the 39 total Forest IBI results for all four studies were more diverse and ranged from 15.2 (Burlington Tickle) to 77 (Brunswick L3.1) with a mean of 42.72 and median of 44.1. The equations used for transforming the data are described below:

**0-10 scale variable** = [(Metric – Minimum of metric) / Metric Range]*10

**Complement of the 0-10 scale variable** = {1 - [(Metric – Minimum of metric) / Metric Range]*10

Table 11. DWQ Forest Vegetation Metric Results

| Site | Grant | FQAI Cover Metric | FQAI Species Count Metric | Average C of C Metric | Percent Tolerant Metric | Percent Sensitive Metric | Wetland Plant Cover Metric | Wetland Shrub Species Richness Metric | Wetland Shrub Cover Metric | Annual: Perennial Metric |
|---|---|---|---|---|---|---|---|---|---|---|
| Florence 14b | IWC | 0.63 | 25.64 | 4.00 | 2.15 | 10.53 | 8.77 | 3 | 0.81 | 0.10 |
| Horry 1 | IWC | 0.87 | 30.23 | 5.43 | 6.80 | 35.18 | 4.58 | 3 | 12.56 | 0.03 |
| Horry 41 | IWC | 0.77 | 26.23 | 4.96 | 22.65 | 31.12 | 97.53 | 5 | 4.99 | 0.00 |
| Robeson 1 | IWC | 2.04 | 17.84 | 5.15 | 0.00 | 92.87 | 0.00 | 3 | 30.73 | 0.08 |
| Brunswick 7 | IWC | 0.58 | 35.99 | 4.99 | 12.65 | 28.20 | 61.74 | 8 | 10.62 | 0.00 |
| Columbus 26 | IWC | 0.97 | 29.91 | 5.46 | 6.90 | 57.44 | 60.00 | 8 | 9.88 | 0.00 |
| Brunswick L3.2 | SEIWA | 1.16 | 30.23 | 5.43 | 12.10 | 70.54 | 66.67 | 8 | 44.85 | 0.00 |
| Brunswick L3.1 | SEIWA | 1.44 | 28.72 | 5.24 | 1.95 | 92.20 | 94.44 | 6 | 54.97 | 0.00 |
| Troxler | Headwater | 0.48 | 22.46 | 3.28 | 28.71 | 0.27 | 7.59 | 1 | 0.23 | 0.06 |
| Duke Forest | Headwater | 0.49 | 33.34 | 4.46 | 26.69 | 16.59 | 3.63 | 2 | 2.88 | 0.02 |
| Boddie Noell | Headwater | 0.51 | 25.22 | 4.04 | 18.00 | 3.87 | 97.78 | 1 | 0.00 | 0.03 |
| Umstead | Headwater | 0.65 | 29.95 | 4.32 | 6.90 | 28.30 | 12.63 | 1 | 0.76 | 0.02 |
| Hog Farm Upper | Headwater | 0.43 | 27.82 | 4.51 | 45.54 | 14.45 | 43.24 | 6 | 1.15 | 0.00 |
| Pete Harris | Headwater | 0.54 | 34.51 | 4.42 | 8.16 | 11.92 | 25.76 | 2 | 0.20 | 0.02 |
| Hog Farm Lower | Headwater | 0.46 | 26.88 | 4.54 | 43.80 | 12.65 | 51.72 | 6 | 9.34 | 0.00 |
| Kelly Rd | Headwater | 0.54 | 29.30 | 4.23 | 17.53 | 12.37 | 74.86 | 4 | 1.20 | 0.02 |
| East of Mason | Headwater | 0.57 | 33.40 | 4.87 | 5.38 | 16.19 | 28.77 | 5 | 1.16 | 0.00 |
| Black Ankle Non-Powerline | Headwater | 0.56 | 34.08 | 4.40 | 7.09 | 31.01 | 39.74 | 5 | 4.60 | 0.02 |

Table 11. DWQ Forest Vegetation Metric Results

| Site | Grant | FQAI Cover Metric | FQAI Species Count Metric | Average C of C Metric | Percent Tolerant Metric | Percent Sensitive Metric | Wetland Plant Cover Metric | Wetland Shrub Species Richness Metric | Wetland Shrub Cover Metric | Annual: Perennial Metric |
|---|---|---|---|---|---|---|---|---|---|---|
| Rough Rider | Headwater | 0.61 | 33.70 | 4.86 | 5.85 | 13.23 | 30.32 | 5 | 5.84 | 0.00 |
| Nahunta | Headwater | 0.57 | 29.93 | 4.28 | 13.82 | 13.38 | 92.51 | 9 | 5.26 | 0.06 |
| Moonshine | Headwater | 0.58 | 32.31 | 4.48 | 3.24 | 19.14 | 91.62 | 4 | 0.70 | 0.02 |
| East Fayetteville South | Headwater | 0.67 | 32.60 | 4.76 | 2.25 | 28.62 | 98.64 | 5 | 1.78 | 0.00 |
| Spring Garden | Headwater | 0.63 | 41.54 | 4.93 | 1.01 | 49.65 | 49.31 | 5 | 17.12 | 0.04 |
| Walmart | Headwater | 0.66 | 33.65 | 4.62 | 2.34 | 28.89 | 79.10 | 10 | 27.42 | 0.02 |
| PCS | Headwater | 0.91 | 28.48 | 5.20 | 3.45 | 43.45 | 92.59 | 5 | 20.61 | 0.00 |
| Fire Tower | Headwater | 0.66 | 33.84 | 4.69 | 3.37 | 35.42 | 91.13 | 10 | 17.06 | 0.00 |
| East Fayetteville North | Headwater | 0.72 | 37.88 | 5.30 | 1.57 | 45.94 | 89.36 | 13 | 24.79 | 0.00 |
| Batchelor | Headwater | 0.95 | 32.55 | 5.67 | 9.41 | 56.60 | 78.69 | 11 | 38.06 | 0.00 |
| Burlington Tickle | NCWAM Headwater | 0.40 | 23.44 | 2.84 | 24.73 | 12.02 | 12.45 | 0 | 0.00 | 0.12 |
| Raleigh Beacon Hill | NCWAM Headwater | 0.41 | 27.01 | 3.35 | 30.12 | 2.55 | 30.73 | 1 | 1.90 | 0.15 |
| Hog Farm New | NCWAM Headwater | 0.62 | 19.83 | 3.35 | 9.87 | 15.23 | 2.02 | 1 | 2.04 | 0.14 |
| Rocky Mount Raper | NCWAM Headwater | 0.36 | 21.90 | 3.23 | 39.36 | 0.50 | 35.66 | 1 | 0.34 | 0.06 |
| Durham Rockwood Park | NCWAM Headwater | 0.33 | 28.03 | 3.42 | 40.80 | 1.43 | 53.68 | 2 | 0.37 | 0.11 |
| Durham Church | NCWAM Headwater | 0.42 | 24.53 | 3.25 | 29.83 | 7.71 | 16.67 | 1 | 0.05 | 0.03 |
| Greensboro Jarvis | NCWAM Headwater | 0.52 | 22.99 | 3.59 | 14.35 | 1.45 | 47.52 | 2 | 8.23 | 0.15 |
| Greenville Lakeview | NCWAM Headwater | 0.58 | 31.67 | 4.23 | 10.28 | 24.59 | 98.80 | 3 | 0.04 | 0.15 |

Table 11. DWQ Forest Vegetation Metric Results

| Site | Grant | FQAI Cover Metric | FQAI Species Count Metric | Average C of C Metric | Percent Tolerant Metric | Percent Sensitive Metric | Wetland Plant Cover Metric | Wetland Shrub Species Richness Metric | Wetland Shrub Cover Metric | Annual: Perennial Metric |
|---|---|---|---|---|---|---|---|---|---|---|
| Battle Park | NCWAM Headwater | 0.68 | 25.18 | 3.80 | 4.90 | 31.93 | 70.59 | 1 | 0.13 | 0.05 |
| Wilson Target North | NCWAM Headwater | 0.49 | 32.70 | 3.94 | 9.09 | 27.11 | 77.44 | 6 | 5.96 | 0.06 |
| Wilson Cutover | NCWAM Headwater | 0.57 | 32.26 | 4.66 | 6.55 | 13.77 | 23.30 | 7 | 6.71 | 0.00 |

Table 12. 0-10 Scaled and Complement Scaled DWQ Forest Metric and Forest IBI Scores

| Site | Grant | FQAI Cover Metric Score (no outlier) | FQAI Species Count Score | Average C of C Score | Complement Percent Tolerant Score | Percent Sensitive Score | Wetland Plant Cover Score | Wetland Shrub Species Richness Score | Wetland Shrub Cover Score | Complement Annual: Perennial Score | Forested IBI total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Florence 14b | IWC | 2.7 | 3.3 | 4.1 | 9.8 | 1.1 | 0.9 | 2.3 | 0.1 | 3.7 | **28** |
| Horry 1 | IWC | 4.8 | 5.2 | 9.1 | 9.3 | 3.8 | 0.5 | 2.3 | 2.3 | 8.1 | **45.4** |
| Horry 41 | IWC | 3.9 | 3.5 | 7.5 | 7.6 | 3.3 | 9.9 | 3.8 | 0.9 | 10 | **50.4** |
| Robeson 1 | IWC | 10 | 0 | 8.2 | 10 | 10 | 0 | 2.3 | 5.6 | 5 | **51.1** |
| Brunswick 7 | IWC | 2.3 | 7.7 | 7.6 | 8.6 | 3 | 6.2 | 6.2 | 1.9 | 10 | **53.5** |
| Columbus 26 | IWC | 5.8 | 5.1 | 9.3 | 9.3 | 6.2 | 6.1 | 6.2 | 1.8 | 10 | **59.6** |
| Brunswick L3.2 | SEIWA | 7.5 | 5.2 | 9.1 | 8.7 | 7.6 | 6.7 | 6.2 | 8.2 | 10 | **69.2** |

Table 12. 0-10 Scaled and Complement Scaled DWQ Forest Metric and Forest IBI Scores

| Site | Grant | FQAI Cover Metric Score (no outlier) | FQAI Species Count Score | Average C of C Score | Complement Percent Tolerant Score | Percent Sensitive Score | Wetland Plant Cover Score | Wetland Shrub Species Richness Score | Wetland Shrub Cover Score | Complement Annual: Perennial Score | Forested IBI total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Brunswick L3.1 | SEIWA | 10 | 4.6 | 8.5 | 9.8 | 9.9 | 9.6 | 4.6 | 10 | 10 | **77** |
| Troxler | Headwater | 1.4 | 2 | 1.5 | 6.9 | 0 | 0.8 | 0.8 | 0 | 5.9 | **19.2** |
| Duke Forest | Headwater | 1.4 | 6.5 | 5.7 | 7.1 | 1.8 | 0.4 | 1.5 | 0.5 | 8.9 | **33.9** |
| Boddie Noell | Headwater | 1.6 | 3.1 | 4.2 | 8.1 | 0.4 | 9.9 | 0.8 | 0 | 8.3 | **36.4** |
| Umstead | Headwater | 2.9 | 5.1 | 5.2 | 9.3 | 3 | 1.3 | 0.8 | 0.1 | 8.8 | **36.5** |
| Hog Farm Upper | Headwater | 0.9 | 4.2 | 5.9 | 5.1 | 1.5 | 4.4 | 4.6 | 0.2 | 10 | **36.9** |
| Pete Harris | Headwater | 1.9 | 7 | 5.6 | 9.1 | 1.3 | 2.6 | 1.5 | 0 | 9 | **38** |
| Hog Farm Lower | Headwater | 1.2 | 3.8 | 6 | 5.3 | 1.3 | 5.2 | 4.6 | 1.7 | 10 | **39.2** |
| Kelly Rd | Headwater | 1.9 | 4.8 | 4.9 | 8.1 | 1.3 | 7.6 | 3.1 | 0.2 | 8.7 | **40.6** |
| East of Mason | Headwater | 2.2 | 6.6 | 7.2 | 9.4 | 1.7 | 2.9 | 3.8 | 0.2 | 10 | **44.1** |
| Black Ankle Non-Powerline | Headwater | 2.1 | 6.9 | 5.5 | 9.2 | 3.3 | 4 | 3.8 | 0.8 | 9 | **44.7** |
| Rough Rider | Headwater | 2.5 | 6.7 | 7.2 | 9.4 | 1.4 | 3.1 | 3.8 | 1.1 | 10 | **45.1** |
| Nahunta | Headwater | 2.2 | 5.1 | 5.1 | 8.5 | 1.4 | 9.4 | 6.9 | 1 | 6 | **45.6** |
| Moonshine | Headwater | 2.3 | 6.1 | 5.8 | 9.7 | 2 | 9.3 | 3.1 | 0.1 | 8.8 | **47.2** |
| East Fayetteville South | Headwater | 3.1 | 6.2 | 6.8 | 9.8 | 3.1 | 10 | 3.8 | 0.3 | 10 | **53.1** |
| Spring Garden | Headwater | 2.7 | 10 | 7.4 | 9.9 | 5.3 | 5 | 3.8 | 3.1 | 7.3 | **54.5** |
| Walmart | Headwater | 3 | 6.7 | 6.3 | 9.7 | 3.1 | 8 | 7.7 | 5 | 8.8 | **58.3** |

Table 12. 0-10 Scaled and Complement Scaled DWQ Forest Metric and Forest IBI Scores

| Site | Grant | FQAI Cover Metric Score (no outlier) | FQAI Species Count Score | Average C of C Score | Complement Percent Tolerant Score | Percent Sensitive Score | Wetland Plant Cover Score | Wetland Shrub Species Richness Score | Wetland Shrub Cover Score | Complement Annual: Perennial Score | Forested IBI total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PCS | Headwater | 5.2 | 4.5 | 8.3 | 9.6 | 4.7 | 9.4 | 3.8 | 3.7 | 10 | **59.3** |
| Fire Tower | Headwater | 3 | 6.7 | 6.5 | 9.6 | 3.8 | 9.2 | 7.7 | 3.1 | 10 | **59.7** |
| East Fayetteville North | Headwater | 3.5 | 8.5 | 8.7 | 9.8 | 4.9 | 9 | 10 | 4.5 | 10 | **69** |
| Batchelor | Headwater | 5.5 | 6.2 | 10 | 9 | 6.1 | 8 | 8.5 | 6.9 | 10 | **70.1** |
| Burlington Tickle | NCWAM Headwater | 0.6 | 2.4 | 0 | 7.3 | 1.3 | 1.3 | 0 | 0 | 2.4 | **15.2** |
| Raleigh Beacon Hill | NCWAM Headwater | 0.7 | 3.9 | 1.8 | 6.8 | 0.2 | 3.1 | 0.8 | 0.3 | 0.1 | **17.7** |
| Hog Farm New | NCWAM Headwater | 2.6 | 0.8 | 1.8 | 8.9 | 1.6 | 0.2 | 0.8 | 0.4 | 0.7 | **17.9** |
| Rocky Mount Raper | NCWAM Headwater | 0.3 | 1.7 | 1.4 | 5.8 | 0 | 3.6 | 0.8 | 0.1 | 5.9 | **19.5** |
| Durham Rockwood Park | NCWAM Headwater | 0 | 4.3 | 2.1 | 5.6 | 0.1 | 5.4 | 1.5 | 0.1 | 3.1 | **22.2** |
| Durham Church | NCWAM Headwater | 0.8 | 2.8 | 1.4 | 6.8 | 0.8 | 1.7 | 0.8 | 0 | 7.8 | **22.9** |
| Greensboro Jarvis | NCWAM Headwater | 1.8 | 2.2 | 2.7 | 8.5 | 0.1 | 4.8 | 1.5 | 1.5 | 0.2 | **23.3** |
| Greenville Lakeview | NCWAM Headwater | 2.2 | 5.8 | 4.9 | 8.9 | 2.6 | 10 | 2.3 | 0 | 0 | **36.8** |
| Battle Park | NCWAM Headwater | 3.2 | 3.1 | 3.4 | 9.5 | 3.4 | 7.1 | 0.8 | 0 | 7 | **37.5** |
| Wilson Target North | NCWAM Headwater | 1.4 | 6.3 | 3.9 | 9 | 2.9 | 7.8 | 4.6 | 1.1 | 6.3 | **43.3** |
| Wilson Cutover | NCWAM Headwater | 2.1 | 6.1 | 6.4 | 9.3 | 1.5 | 2.4 | 5.4 | 1.2 | 10 | **44.3** |

Thirty-nine of the 43 candidate metrics were also analyzed for the six shrub dominated sites (including the three IWC sites). The Large Tree Density, Pole Timber Density, Canopy Importance, and Snag Density candidate metrics, which are solely applicable to forested sites, were not analyzed. The Spearman's Rho statistical test was used to analyze all 39 continuous and discrete metrics since N < 15. Only one metric, the Sapling Density metric, had a significant correlation at a P-value = 0.014 and Rho of -0.86, however the Bryophyte Coverage candidate metric was borderline with a P-value = 0.052 and Rho of 0.75. Candidate metrics were not tested for the emergent sites since there were only three sites with emergent vegetation. An existing vegetation IBI that was developed for Shrub and Emergent dominated wetlands in Ohio, the "Vegetation Index of Biotic Integrity" (VIBI) (Mack 2004), was used to determine individual metric scores and IBI values for the six shrub and three emergent IWs since it was not possible to develop IBI scores for the small number of shrub and emergent sites evaluated for this study.

The Ohio shrub VIBI is derived from 10 metrics: 1.) FQAI Species Count, 2.), Percent Tolerant, 3.) Percent Sensitive, 4.) Wetland Plant Species Richness, 5.) Wetland Shrub Species Richness, 6.) Cryptogram Richness, 7.) Bryophyte Cover, 8.) Carex Cover, 9.) Dicot Richness, and 10.) Shade Sub-Canopy Importance. Eight of the ten metrics used to calculate the Ohio emergent VIBI were used for this study including: 1.) FQAI Species Count, 2.), Percent Tolerant, 3.) Percent Sensitive, 4.) Wetland Plant Species Richness, 5.) Wetland Shrub Species Richness, 6.) Annual: Perennial, 7.) Carex Cover, and 8.) Dicot Richness. The Ohio emergent VIBI also uses Percent Invasive Graminoids and Biomass. All of the emergent sites had zero coverage for invasive graminoids and were therefore dropped from the emergent IBI. The Biomass metric was also dropped since biomass data was not collected for the IWC study or the other three studies analyzed for the development of vegetation IBIs. Table 13 shows the metric site results that were used to calculate the emergent and shrub VIBI scores. VIBI score assignments of "0", "3", "7", or "10" are listed in Table 14 for each of the emergent and shrub metrics. The VIBI metric score assignment and VIBI totals for the emergent and shrub sites are shown in Table 15. The emergent site scores were 37 for Robeson 7 and 56 for Ohio Brunswick 4 and Marion 2B. The shrub sites ranged from 23, Rocky Mount Halifax to 80, Cox with a mean of 52.4 and a median of 56, see Table 15.

The 39 sites used to develop the forest IBIs were derived from a sizeable and diverse dataset. However, this dataset only included NC coastal plain and piedmont sites so further survey work, analysis, and evaluation would be needed for the forest IBI development in the mountain ecoregion of NC. In addition, more survey work, analysis and evaluation are needed to properly develop biocriteria for emergent and shrub vegetation sites statewide. It should be noted that the Ohio shrub and emergent VIBI results may not be accurate since these vegetation IBIs were developed in a different region of the country and have not been calibrated for NC.

Table 13. Ohio Emergent and Shrub Metric Results

| Site | Grant | Emergent / Shrub | FQAI Species Count Metric | Percent Tolerant Metric | Percent Sensitive Metric | Wetland Plant Species Richness Metric | Wetland Shrub Species Richness Metric | Cryptogram Cover Metric | Annual: Perennial Metric | Bryophyte Coverage Metric | Carex Richness Metric | Dicot Richness Metric | Shade Subcanopy Importance Metric |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Robeson 7 | IWC | Emergent | 20.97 | 35.54 | 6.69 | 6 | 0 | 0.00 | 0.18 | 1.99 | 1 | 36 | 118.32 |
| Brunswick 4 | IWC | Emergent | 27.14 | 1.81 | 69.17 | 5 | 6 | 67.17 | 0.00 | 0.33 | 2 | 17 | 61.39 |
| Marion 2B | SEIWA | Emergent | 25.04 | 7.14 | 27.05 | 2 | 6 | 2.10 | 0.00 | 1.27 | 2 | 13 | 0.28 |
| Cox | Headwater | Shrub | 36.88 | 3.96 | 61.19 | 6 | 11 | 71.96 | 0.02 | 15.75 | . | 43 | 0.16 |
| Bladen 9 | IWC | Shrub | 18.94 | 3.42 | 93.16 | 2 | 2 | 20.00 | 0.00 | 0.00 | . | 6 | . |
| Brunswick 17 | IWC | Shrub | 37.27 | 26.67 | 62.96 | 7 | 6 | 42.11 | 0.00 | 1.72 | . | 20 | 3.36 |
| Horry 28 | IWC | Shrub | 29.50 | 0.95 | 90.27 | 4 | 5 | 0.00 | 0.00 | 5.93 | 1 | 14 | 0.33 |
| Rocky Mountain Halifax | NCWAM Headwater | Shrub | 23.89 | 57.92 | 1.99 | 14 | 0 | 0.00 | 0.07 | 0.56 | 2 | 44 | . |
| Marion 2A | SEIWA | Shrub | 22.59 | 12.08 | 80.68 | 1 | 6 | 44.78 | 0.00 | 8.22 | . | 11 | 23.14 |
| Marion 2C | SEIWA | Shrub | 31.73 | 3.68 | 64.71 | 1 | 8 | 100.00 | 0.00 | 41.94 | . | 17 | 0.13 |

Table 14. Ohio Shrub and Emergent Vegetation Metric Score Assignment

| **Candidate Vegetation Metric** | **Shrub or Emergent** | Score 0 | **Score 3** | **Score 7** | **Score 10** |
|---|---|---|---|---|---|
| **Floristic Quality Candidate Metrics** | | | | | |
| FQAI Species Count Metric | Shrub / Emergent | 0-9.9 | 10.0-14.3 | 14.4-21.4 | ≥21.5 |
| Percent Tolerant Metric | Shrub / Emergent | 15-100 / 60-100 | 10 -15 / 40 - 60 | 5 -10 / 20 - 40 | 0 -5 / 0-20 |
| Percent Sensitive Metric | Shrub / Emergent | 0-2 / 0-2.5 | 2.1 – 6 / 2.5-10 | 6.1-13 / 10-15 | 13.1-100 / 15-100 |
| **Wetness Characteristic Candidate Metrics** | | | | | |
| Wetland Plant Species Richness Metric | Shrub / Emergent | 0-9 / 0-10 | 10-14 / 11-20 | 15-20 / 21-30 | ≥21 / ≥31 |
| Wetland Shrub Species Richness Metric | Shrub / Emergent | 0-1 | 2 | 3-4 | ≥5 |
| **Functional Group Candidate Metrics** | | | | | |
| Cryptogram Richness Metric | Shrub | 0 | 1 | 2 | ≥3 |
| Annual: Perennial Metric | Emergent | >0.48 | 0.32-0.48 | 0.20-0.32 | 0.0-0.20 |
| Bryophyte Cover Metric | Shrub | 0-1 | 1-3 | 3.1-6 | ≥6 |
| Carex Richness Metric | Shrub / Emergent | 0-1 | 2-3 | 4 | ≥5 |
| Dicot Richness Metric | Shrub / Emergent | 0-9 / 0-10 | 10-14 / 11-17 | 15-23 / 18-24 | ≥24 / ≥25 |
| **Community Structure Candidate Metrics** | | | | | |
| Shade Sub-Canopy Importance Metric | Shrub | 0-2 | 2-5 | 5-10 | ≥11 |

Table 15. Ohio Shrub and Emergent Vegetation Index of Biotic Integrity Metric Score Results

| Grant | Site | VIBI Shrub or Emergent | VIBI - FQAI Count Metric | VIBI Percent Tolerant Metric | VIBI Percent Sensitive Metric | VIBI Wetland Plant Species Richness Metric | VIBI Wetland Shrub Species Richness Metric | VIBI Cryptogram Richness Metric | VIBI Annual Perennial Metric | VIBI Bryophyte Coverage Metric | VIBI Carex Richness Metric | VIBI Dicot Richness Metric | VIBI Shade Subcanopy Importance Metric | Metric count | VIBI Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IWC | Robeson 7 | Emergent | 7 | 7 | 3 | 0 | 0 | N/A | 10 | N/A | 0 | 10 | N/A | 8 | **37** |
| IWC | Brunswick 4 | Emergent | 10 | 10 | 10 | 0 | 10 | N/A | 10 | N/A | 3 | 3 | N/A | 8 | **56** |
| SEIWA | Marion 2B | Emergent | 10 | 10 | 10 | 0 | 10 | N/A | 10 | N/A | 3 | 3 | N/A | 8 | **56** |
| IWC | Bladen 9 | Shrub | 7 | 10 | 10 | 0 | 3 | 3 | N/A | 0 | 0 | 0 | 0 | 10 | **33** |
| IWC | Horry 28 | Shrub | 10 | 10 | 10 | 0 | 10 | 3 | N/A | 7 | 0 | 3 | 0 | 10 | **53** |
| IWC | Brunswick 17 | Shrub | 10 | 0 | 10 | 0 | 10 | 7 | N/A | 3 | 0 | 7 | 10 | 10 | **57** |
| SEIWA | Marion 2A | Shrub | 10 | 3 | 10 | 0 | 10 | 3 | N/A | 10 | 0 | 3 | 10 | 10 | **59** |
| SEIWA | Marion 2C | Shrub | 10 | 10 | 10 | 0 | 10 | 3 | N/A | 10 | 0 | 7 | 10 | 10 | **70** |
| Headwater | Cox | Shrub | 10 | 10 | 10 | 0 | 10 | 10 | N/A | 10 | 0 | 10 | 10 | 10 | **80** |
| NCWAM Headwater | Rocky Mount Halifax | Shrub | 10 | 0 | 0 | 3 | 0 | 0 | N/A | 0 | 3 | 10 | 0 | 10 | **23** |

### 3.1.5 Water Quality Sampling Results and Discussion for Biocriteria sites

Water quality field parameters were measured and water samples collected for lab analysis at just four biocriteria sites during the amphibian and aquatic macroinvertebrate sampling in March 2012 (see Table 16). For the most part these point samples do not suggest anything exceptional. Many values were below the method detection limit.

Hypoxia was present in two of the wetlands, Brunswick 7 and Horry 41. Ordinarily this would be somewhat early in the season for these conditions to develop. At this time drought conditions were at varying levels of severity in much of the study area and had been that way for a few months. This could favor development of low oxygen conditions because of reduced input of higher oxygen precipitation and less mixing with air at the surface. If that is the explanation here, there clearly are site specific factors involved since only two of the wetlands developed hypoxia.

The phosphorus concentration was somewhat elevated in Brunswick 7. Given the hypoxic conditions at the surface it is possible there was phosphorus flux out of the sediment into the water column, as observed elsewhere (e.g. Fisher and Reddy 2001, Dunne et al. 2006). Additional work would be needed to determine if this may have been the case or if there is another explanation.

Dissolved organic carbon (DOC) was the largest fraction of total organic carbon (TOC). This indicates still-water conditions that allow the solids to settle out of the water column and no recent re-suspension. The DOC concentration was greater than TOC at Horry 1. This is physically impossible and is likely the result of either variability or error in the laboratory analysis.

Table 16. Results of water quality sampling at the biocriteria sites.

| Site Name | Air Temp °C | Water Temp °C | DO sat % | DO mg/L | NH4 mg/L | Qualifier* | NO2+NO3 mg/L | Qualifier* | P mg/L | TKN mg/L |
|---|---|---|---|---|---|---|---|---|---|---|
| Brunswick 4 | 32.0 | 29.9 | 54.5 | 4.25 | 0.02 | U | 0.15 | | 0.1 | 2.10 |
| Brunswick 7 | 33.0 | 19.5 | 21.6 | 1.93 | 0.06 | | 0.02 | | 0.3 | 2.50 |
| Horry 1 | 21.0 | 21.5 | | 8.35 | 0.02 | U | 0.02 | U | 0.1 | 1.30 |
| Horry 41 | 17.5 | 14.0 | 18.9 | 1.99 | 0.02 | U | 0.02 | U | 0 | 0.83 |

| Site Name | Specific Conductivity µS | pH S.U. | DOC mg/L | TOC mg/L | Cu ug/L | Qualifier* | Pb ug/L | Qualifier* | Zn ug/L | Qualifier* |
|---|---|---|---|---|---|---|---|---|---|---|
| Brunswick 4 | 68.4 | 3.46 | 76 | 79 | 2.0 | U | 2.0 | U | 10 | U |
| Brunswick 7 | 149.9 | 4.93 | 36 | 44 | 2.1 | | 2.0 | | 13 | |
| Horry 1 | 23.9 | 4.96 | 22 | 18 | 2.0 | U | 2.0 | U | 10 | U |
| Horry 41 | 91.7 | 3.95 | 26 | 30 | 2.0 | U | 5.1 | | 10 | U |

*Qualifier "U" indicates result was below the detection limit.

### 3.1.6 Hydrology and Water Quality Sites Soil Sampling Results and Discussion

Wetland soils in the biocriteria sites tended to be quite acidic, with most having a pH value of 5 or less (Figure 24). They also had fairly low organic content as seen in humic percent and loss on ignition (LOI). This is typical in primarily mineral Coastal Plain soils and the wet flats that occur there (Rheinhardt et al. 2002). The high bulk density and low cation exchange capacity (CEC) are further indications of the primarily mineral content of the soils (Mitsch and Gosselink 1993). The base saturation and exchanged acidity results are characteristic of acid soils.

There were exceptions to the general trend. At Horry 28, for example, one sample had a LOI of 71% and CEC of 12.1. Field notes said this sample had a high duff content which accounts for the analytical result. The base saturation and exchanged acidity results are further indications of the acidic character of the soils.

Upland soils near the biocriteria sites had similar characterisitcs to the soils in the wetlands (Figure 25) but there were significant differences. Two-way analysis of variance indicates the wetland soils were greater than upland soils ($p<.05$) in humic percent, cation exchange capacity, exchanged acidity, and LOI. Upland soils were greater than wetland soils ($p<.05$) in bulk density and pH. There were no differences in total phosphorus and base saturation. There were also significant differences among sites except in total phosphorus and base saturation.

Total phosphorus tended to be very low (Figure 24 and Figure 25). The reported range in North Carolina soils is 20 – 800 ppm (mg / $dm^3$ same as ppm) (http://www.ncagr.gov/agronomi/pdffiles/essnutr.pdf). Soils in the biocriteria sites are at the low end of the range, with a few exceptions. The exceptions suggest past or current use for agricultural production.

As part of the routine analysis of the soil sample, concentrations of several major and minor nutrients also were determined. These are primarily of agricultural concern and will not be discussed in this report. See Table 17 for a summary of the results.

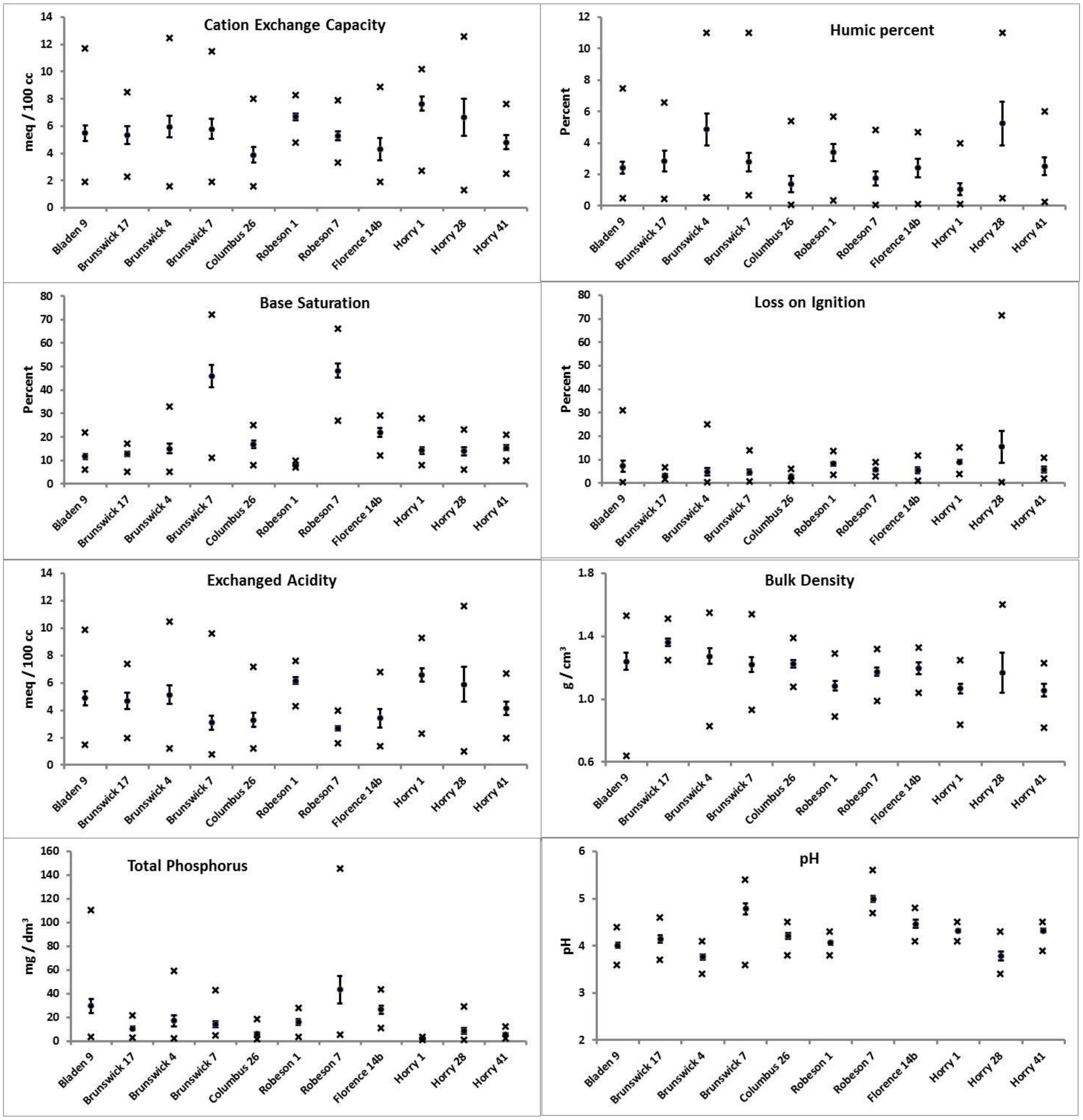


Figure 24. Results of the wetland soil analysis at the biocriteria sites. Solid dot is the mean value of all samples, bars are one standard error, X are the minimum and maximum values.

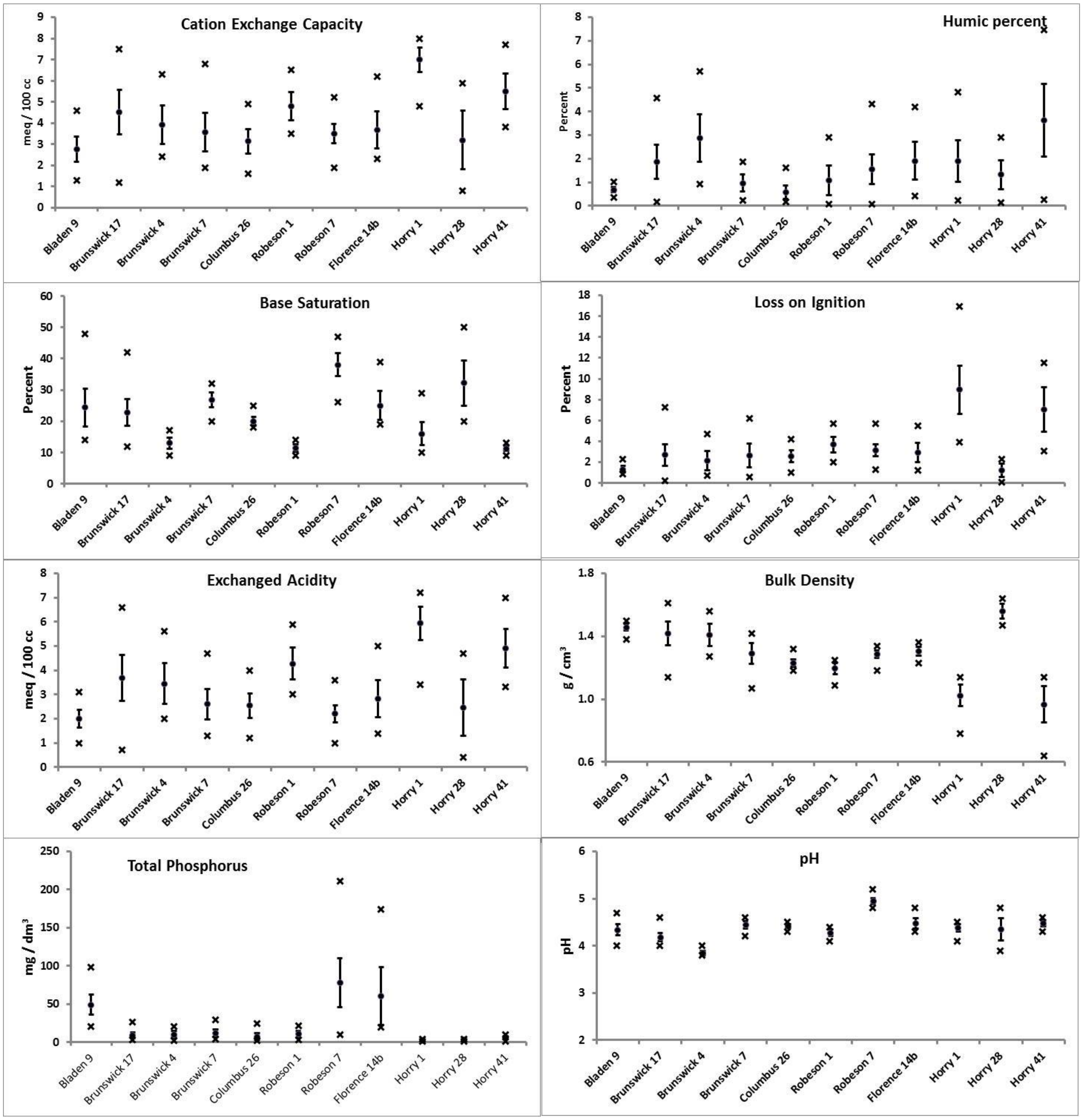


Figure 25. Results of the upland soil analysis at the biocriteria sites. Solid dot is the mean value of all samples, bars are one standard error, X are the minimum and maximum values.

Table 17. Results of the soil analysis at the biocriteria sites. Values are the sample mean, minimum, maximum, and standard error.

| Site | Wetland / Upland | Sample No. | K mg / dm³ | Ca mg / dm³ | Mg mg / dm³ | S mg / dm³ | Mn mg / dm³ | Zn mg / dm³ | Cu mg / dm³ | Na mg / dm³ | Fe mg / dm³ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bladen 9 | U | 5 | 6.2 | 131.4 | 10.4 | 11.4 | 10.48 | 0.56 | 0.46 | 6.2 | 1044.2 |
| minimum | | | 3 | 39 | 6 | 4 | 0.7 | 0.2 | 0.2 | 3 | 282 |
| maximum | | | 9 | 423 | 13 | 21 | 47.1 | 0.8 | 0.6 | 10 | 1631 |
| standard error | | | 0.97 | 73.41 | 1.60 | 2.82 | 9.16 | 0.10 | 0.07 | 1.24 | 251.47 |
| | | | | | | | | | | | |
| Bladen 9 | W | 19 | 22.3 | 76.79 | 22.21 | 12.95 | 0.78 | 0.48 | 0.19 | 10.84 | 1178.37 |
| minimum | | | 4 | 43 | 7 | 2 | 0.2 | 0.2 | 0.1 | 5 | 59 |
| maximum | | | 127 | 178 | 87 | 31 | 3.7 | 1.7 | 0.3 | 20 | 2671 |
| standard error | | | 6.42 | 8.95 | 4.41 | 2.20 | 0.18 | 0.07 | 0.01 | 0.99 | 226.51 |
| | | | | | | | | | | | |
| Brunswick 17 | U | 6 | 8.33 | 113.67 | 29.67 | 10.50 | 0.55 | 0.60 | 0.17 | 14.00 | 780.50 |
| minimum | | | 5 | 68 | 13 | 2 | 0.2 | 0.3 | 0.1 | 8 | 26 |
| maximum | | | 12 | 162 | 52 | 39 | 1.7 | 1.5 | 0.3 | 22 | 2711 |
| standard error | | | 1.05 | 16.01 | 5.71 | 5.95 | 0.24 | 0.18 | 0.03 | 2.48 | 462.68 |
| | | | | | | | | | | | |
| Brunswick 17 | W | 12 | 8.08 | 84.08 | 21.42 | 19.50 | 0.23 | 0.39 | 0.14 | 16.17 | 1509.67 |
| minimum | | | 4 | 44 | 10 | 2 | 0.1 | 0.2 | 0.1 | 7 | 38 |
| maximum | | | 12 | 144 | 37 | 44 | 0.4 | 1.2 | 0.3 | 28 | 2726 |
| standard error | | | 0.73 | 10.02 | 2.48 | 4.29 | 0.03 | 0.08 | 0.02 | 2.13 | 299.93 |
| | | | | | | | | | | | |
| Brunswick 4 | U | 4 | 6.75 | 70.50 | 13.75 | 30.75 | 0.28 | 0.48 | 0.18 | 11.00 | 1049.75 |
| minimum | | | 6.0 | 59.0 | 11.0 | 18.0 | 0.2 | 0.3 | 0.1 | 6.0 | 82.0 |
| maximum | | | 8 | 98 | 18 | 48 | 0.5 | 0.8 | 0.3 | 15 | 2290 |
| standard error | | | 0.48 | 9.21 | 1.55 | 7.59 | 0.08 | 0.11 | 0.05 | 1.87 | 568.24 |
| | | | | | | | | | | | |
| Brunswick 4 | W | 14 | 14.29 | 102.07 | 30.43 | 26.21 | 0.51 | 0.54 | 0.14 | 13.07 | 828.86 |
| minimum | | | 6 | 51 | 10 | 17 | 0.2 | 0.3 | 0.1 | 6 | 43 |
| maximum | | | 42 | 218 | 102 | 51 | 1.8 | 1.6 | 0.2 | 36 | 2298 |
| standard error | | | 3.34 | 15.94 | 7.62 | 2.54 | 0.14 | 0.10 | 0.01 | 1.90 | 230.27 |

Table 17. Results of the soil analysis at the biocriteria sites. Values are the sample mean, minimum, maximum, and standard error.

| Site | Wetland / Upland | Sample No. | K mg / dm³ | Ca mg / dm³ | Mg mg / dm³ | S mg / dm³ | Mn mg / dm³ | Zn mg / dm³ | Cu mg / dm³ | Na mg / dm³ | Fe mg / dm³ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Brunswick 7 | U | 5 | 34.6 | 139.4 | 23 | 29.2 | 0.68 | 2.62 | 0.34 | 10.2 | 814.8 |
| minimum | | | 12 | 59 | 12 | 18 | 0.2 | 0.6 | 0.2 | 8 | 72 |
| maximum | | | 97 | 292 | 42 | 37 | 1.4 | 5.8 | 0.6 | 14 | 1421 |
| standard error | | | 16.22 | 41.20 | 5.18 | 3.12 | 0.22 | 1.14 | 0.07 | 1.02 | 221.73 |
| Brunswick 7 | W | 17 | 24.47 | 446.82 | 47.29 | 33.71 | 0.48 | 1.01 | 0.21 | 14.88 | 971.88 |
| minimum | | | 5 | 90 | 14 | 19 | 0.1 | 0.3 | 0.1 | 7 | 127 |
| maximum | | | 68 | 1347 | 107 | 60 | 1.9 | 5.4 | 0.3 | 25 | 2027 |
| standard error | | | 4.74 | 90.76 | 7.39 | 3.00 | 0.11 | 0.32 | 0.01 | 1.48 | 150.44 |
| Columbus 26 | U | 5 | 12.6 | 85 | 18.8 | 40.4 | 1.34 | 0.44 | 0.16 | 9.6 | 1010.6 |
| minimum | | | 4 | 60 | 13 | 27 | 0.5 | 0.3 | 0.1 | 7 | 730 |
| maximum | | | 24 | 116 | 26 | 72 | 2.8 | 0.6 | 0.3 | 12 | 1270 |
| standard error | | | 3.31 | 10.78 | 2.22 | 8.27 | 0.44 | 0.07 | 0.04 | 0.93 | 106.39 |
| Columbus 26 | W | 13 | 13.54 | 76.92 | 19.15 | 31.00 | 0.49 | 0.46 | 0.16 | 10.08 | 997.62 |
| minimum | | | 4 | 45 | 8 | 20 | 0.2 | 0.2 | 0.1 | 5 | 613 |
| maximum | | | 40 | 137 | 34 | 57 | 1.3 | 1 | 0.3 | 14 | 2157 |
| standard error | | | 2.72 | 6.05 | 2.04 | 2.45 | 0.10 | 0.06 | 0.02 | 0.67 | 104.56 |
| Robeson 1 | U | 4 | 18.25 | 68.25 | 16.5 | 24.75 | 0.425 | 0.6 | 0.35 | 9.5 | 1548.5 |
| minimum | | | 11 | 63 | 14 | 17 | 0.3 | 0.4 | 0.2 | 9 | 1478 |
| maximum | | | 32 | 76 | 19 | 29 | 0.6 | 1 | 0.5 | 10 | 1721 |
| standard error | | | 4.84 | 2.87 | 1.19 | 2.72 | 0.08 | 0.14 | 0.06 | 0.29 | 57.73 |
| Robeson 1 | W | 13 | 19.38 | 65.62 | 16.38 | 27.69 | 0.47 | 0.60 | 0.36 | 10.46 | 1864.08 |
| minimum | | | 12 | 56 | 14 | 22 | 0.3 | 0.3 | 0.2 | 8 | 1743 |
| maximum | | | 32 | 93 | 25 | 34 | 1.2 | 1.3 | 0.6 | 14 | 2017 |
| standard error | | | 1.75 | 2.92 | 0.86 | 0.94 | 0.07 | 0.08 | 0.03 | 0.51 | 23.92 |

Table 17. Results of the soil analysis at the biocriteria sites. Values are the sample mean, minimum, maximum, and standard error.

| Site | Wetland / Upland | Sample No. | K mg / dm³ | Ca mg / dm³ | Mg mg / dm³ | S mg / dm³ | Mn mg / dm³ | Zn mg / dm³ | Cu mg / dm³ | Na mg / dm³ | Fe mg / dm³ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Robeson 7 | U | 6 | 22.17 | 204.83 | 25.50 | 14.67 | 3.93 | 0.57 | 0.70 | 9.00 | 1652.17 |
| minimum | | | 8 | 121 | 13 | 11 | 0.7 | 0.3 | 0.3 | 7 | 1353 |
| maximum | | | 39 | 276 | 42 | 21 | 12.7 | 1.1 | 1.1 | 12 | 2046 |
| standard error | | | 5.11 | 26.61 | 4.54 | 1.73 | 1.87 | 0.12 | 0.12 | 0.73 | 132.96 |
| Robeson 7 | W | 16 | 30.94 | 438.63 | 41.56 | 28.44 | 6.51 | 0.63 | 0.51 | 11.31 | 1653.31 |
| minimum | | | 14 | 172 | 17 | 13 | 1.5 | 0.3 | 0.2 | 9 | 1316 |
| maximum | | | 128 | 810 | 88 | 88 | 19.4 | 2.1 | 1.3 | 14 | 2062 |
| standard error | | | 7.41 | 47.42 | 3.95 | 5.09 | 1.50 | 0.13 | 0.08 | 0.36 | 57.15 |
| Florence 14b | U | 4 | 17.25 | 137.5 | 17.25 | 31.5 | 0.8 | 0.725 | 0.275 | 11 | 1615.5 |
| minimum | | | 14 | 87 | 15 | 18 | 0.4 | 0.5 | 0.2 | 8 | 1439 |
| maximum | | | 26 | 189 | 22 | 53 | 1.5 | 1.2 | 0.4 | 13 | 1767 |
| standard error | | | 2.93 | 22.22 | 1.65 | 7.73 | 0.25 | 0.16 | 0.05 | 1.22 | 80.72 |
| Florence 14b | W | 9 | 22.00 | 117.44 | 29.33 | 35.33 | 1.21 | 1.38 | 0.24 | 10.89 | 1937.00 |
| minimum | | | 7 | 66 | 12 | 22 | 0.2 | 0.3 | 0.2 | 7 | 1479 |
| maximum | | | 42 | 242 | 91 | 54 | 5.1 | 4.1 | 0.3 | 18 | 2325 |
| standard error | | | 4.61 | 20.58 | 8.42 | 3.66 | 0.56 | 0.45 | 0.02 | 1.30 | 99.24 |
| Horry 1 | U | 5 | 30.4 | 121.4 | 44.2 | 29.4 | 0.6 | 0.54 | 0.32 | 27.2 | 1744.8 |
| minimum | | | 25 | 64 | 32 | 15 | 0.2 | 0.3 | 0.1 | 22 | 1062 |
| maximum | | | 39 | 211 | 67 | 43 | 0.9 | 0.7 | 0.6 | 34 | 2053 |
| standard error | | | 2.44 | 26.49 | 6.24 | 4.88 | 0.12 | 0.08 | 0.09 | 2.31 | 174.50 |
| Horry 1 | W | 13 | 27.23 | 131.46 | 41.77 | 27.08 | 0.53 | 0.52 | 0.23 | 20.77 | 1940.85 |
| minimum | | | 8 | 56 | 13 | 13 | 0.2 | 0.3 | 0.1 | 7 | 952 |
| maximum | | | 40 | 382 | 66 | 39 | 1 | 0.9 | 0.5 | 31 | 2412 |
| standard error | | | 2.26 | 23.84 | 3.74 | 2.12 | 0.07 | 0.05 | 0.03 | 1.77 | 105.50 |

Table 17. Results of the soil analysis at the biocriteria sites. Values are the sample mean, minimum, maximum, and standard error.

| Site | Wetland / Upland | Sample No. | K mg / dm³ | Ca mg / dm³ | Mg mg / dm³ | S mg / dm³ | Mn mg / dm³ | Zn mg / dm³ | Cu mg / dm³ | Na mg / dm³ | Fe mg / dm³ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Horry 28 | U | 4 | 5 | 112.3 | 22.25 | 2 | 0.45 | 0.45 | 0.15 | 7.75 | 70 |
| minimum | | | 2 | 44 | 8 | 1 | 0.1 | 0.2 | 0.1 | 4 | 14 |
| maximum | | | 8 | 185 | 37 | 3 | 1.2 | 0.8 | 0.2 | 13 | 133 |
| standard error | | | 1.73 | 36.28 | 7.69 | 0.41 | 0.26 | 0.13 | 0.03 | 1.93 | 31.92 |
| | | | | | | | | | | | |
| Horry 28 | W | 11 | 12.00 | 90.64 | 35.36 | 9.18 | 0.25 | 0.36 | 0.18 | 22.91 | 450.36 |
| minimum | | | 3 | 48 | 10 | 3 | 0.1 | 0.2 | 0.1 | 6 | 40 |
| maximum | | | 38 | 196 | 89 | 36 | 0.8 | 0.7 | 0.4 | 71 | 1131 |
| standard error | | | 3.38 | 14.60 | 8.98 | 2.81 | 0.07 | 0.05 | 0.03 | 6.14 | 118.69 |
| | | | | | | | | | | | |
| Horry 41 | U | 4 | 26 | 73 | 21 | 47.25 | 0.3 | 0.5 | 0.125 | 22.75 | 1901.5 |
| minimum | | | 12 | 64 | 15 | 36 | 0.2 | 0.3 | 0.1 | 20 | 1483 |
| maximum | | | 46 | 80 | 26 | 80 | 0.5 | 0.8 | 0.2 | 31 | 2402 |
| standard error | | | 7.70 | 3.54 | 2.48 | 10.92 | 0.07 | 0.12 | 0.03 | 2.75 | 213.62 |
| | | | | | | | | | | | |
| Horry 41 | W | 13 | 20.77 | 85.00 | 22.54 | 22.31 | 0.43 | 0.58 | 0.14 | 17.46 | 1375.15 |
| minimum | | | 8 | 69 | 17 | 13 | 0.2 | 0.3 | 0.1 | 12 | 895 |
| maximum | | | 48 | 109 | 32 | 39 | 0.9 | 1.5 | 0.4 | 33 | 1965 |
| standard error | | | 3.75 | 3.20 | 1.29 | 2.03 | 0.07 | 0.09 | 0.02 | 1.48 | 86.86 |

### 3.1.7 NC Wetland Assessment Method Comparison to Biocriteria Sites Results and Discussion

The NCWAM overall results and habitat function were correlated with the DWQ Forest IBI, and Ohio emergent and shrub VIBIs to further validate NCWAM and to determine the condition of the population of IWs in the eight-county study area. As noted in Section 2.1.7, the biocriteria sites were chosen from the SEIWA Level 2 results with a probability-based random sample technique. A generalized linear model using a least square fit was used to analyze the relationship between six measures vegetation IBIs (DWQ forest IBI and Ohio shrub and emergent VIBIs) and NCWAM ratings (NCWAM overall and habitat function ratings) (see Table 18). Since the habitat function rating is derived from metrics directly associated with the vegetation community composition and structure, it is expected there would be a stronger correlation between the vegetation IBIs and the habitat function rating than the correlation between the vegetation IBIs and the NCWAM overall rating. The correlations with different types of IBIs were produced to evaluate if IBIs developed specifically for NC for forested wetlands would correlate differently than IBIs developed in Ohio for shrub and emergent dominated wetlands (see Section 3.1.4).

The DWQ forest IBI and Ohio shrub VIBI were derived from nine and 10 metrics respectively, while the Ohio emergent VIBI was derived from just eight metrics. The DWQ forest IBI and Ohio shrub VIBI were weighted to compensate for the differences in the number of metrics used to calculate the forest, shrub, and emergent IBIs (see Table 18). So for example, to weight the 10 metric DWQ Forest IBI and make it comparable to the eight metric Ohio emergent VIBI, the DWQ Forest IBI results were multiplied by 0.8. Correlations were not conducted for amphibians or aquatic macro invertebrates as it was not possible to develop IBIs for these taxa with the survey results from this study (see Sections 3.1.2 and 3.1.3).

Table 18. NCWAM Correlations with Vegetation Biocriteria

| Independent Variable | Response Variable | IBI Weighting Factor |
|---|---|---|
| NCWAM Overall Score | DWQ Forest IBI | N/A |
| NCWAM Habitat Function | DWQ Forest IBI | N/A |
| NCWAM Overall Score | Ohio weighted shrub and non-weighted emergent VIBIs | Ohio shrub VIBI was weighted by 0.8 |
| NCWAM Habitat Function | Ohio weighted shrub and non-weighted emergent VIBIs | Ohio shrub VIBI was weighted by 0.8 |
| NCWAM Overall Score | Ohio weighted shrub and non-weighted emergent VIBIs and DWQ forest IBI | Ohio shrub VIBI was weighted by 0.8 and the DWQ Forest IBI was weighted by 0.889 |
| NCWAM Habitat Function | Ohio weighted shrub and non-weighted emergent VIBIs and DWQ forest IBI | Ohio shrub VIBI was weighted by 0.8 and the DWQ Forest IBI was weighted by 0.889 |

The results of the Generalized Linear Model are shown in Table 19 and Table 20. All of the results suggest significant correlations (P-value <0.05) except for the NCWAM habitat function and the Ohio weighted shrub and non-weighted emergent VIBIs which was borderline (P-value = 0.064). The DWQ forest IBI correlation analyses with the NCWAM overall rating and with the NCWAM habitat function rating were both highly correlated (P-value of 0.0004 and 0.001 and $R^2$ value of 0.348 and 0.318 respectively). The $R^2$ value indicates that the models only explains about a third of the variation. The Ohio weighted shrub and non-weighted emergent VIBIs correlation with the NCWAM overall rating had the best results (P-value >0.007 and $R^2$ value of 0.754), indicating that the model explained more than three-quarters of the variation. The Ohio weighted shrub and non-weighted emergent VIBIs correlation with the NCWAM habitat function results were nearly significant (P-value = 0.0634). The $R^2$ value of 0.545 for this correlation indicated that the model explained more than half the observed variation. The correlations of all of the IBIs (weighted DWQ forest IBI and Ohio weighted shrub and non-weighted emergent VIBIs) with both the NCWAM overall and the NCWAM habitat function ratings were all significant (p-value=0.0002). Similar $R^2$ values ($R^2$ at 0.31 and 0.32, respectively) were obtained for both NCWAM overall and the NCWAM habitat function rating metrics. These results again indicated the models explained approximately one-third of the variation.

Interestingly, the Ohio weighted shrub and non-weighted emergent VIBIs had better results when analyzed separately than when combined with and in comparison to the NC developed forest IBIs. Five of the six correlation analyses did have significant results and the sixth correlation (Ohio weighted shrub and non-weighted emergent VIBIs X NCWAM Habitat function) had near significant results. The lower $R^2$ results for the correlation of IBIs with NCWAM may simply be due to the fact that NCWAM is a rapid assessment and does not have the level of detail that the intensive all day surveys have. Additionally, the coarse ratings of “High”, “Medium” and “Low” and uneven distribution of these wetland types (29 High, 10 Medium, and 10 Low) may have been a factor in the analysis. The following conclusions can be drawn on IWs in the 8-county study area based the probabilistic random sampling technique used in use in this study (see 2.1.1 and 2.1.7) and the results of the generalized linear model analysis.

1.) Approximately one-third of the variation for the DWQ forest IBIs (the response variable) is accounted for by the NCWAM overall ratings (the predictor variable) for IWs in the 8-county study area.
2.) Approximately one-third of the variation for the DWQ forest IBIs (the response variable) is accounted for by the NCWAM habitat ratings (the predictor variable) for IWs in the 8-county study area.
3.) Approximately three-quarters of the variation for the Ohio weighted shrub and non-weighted emergent VIBIs (the response variable) is accounted for by the NCWAM overall rating (the predictor variable) for IWs in the 8-county study area.
4.) Greater than half (55%) of the variation for the Ohio weighted shrub and non-weighted emergent VIBIs (the response variable) is accounted for by the NCWAM habitat rating (the predictor variable) for IWs in the 8-county study area.

5.) Approximately one-third of the variation for all the IBIs (Ohio weighted shrub and non-weighted emergent VIBIs and DWQ forest IBI, the response variable) is accounted for by the NCWAM overall ratings (31%) (the predictor variable) for IWs in the 8-county study area.
6.) Approximately one-third of the variation for all the IBIs (Ohio weighted shrub and non-weighted emergent VIBIs and DWQ forest IBI, the response variable) is accounted for by the the NCWAM habitat function (32%) ratings (the predictor variable) for IWs in the 8-county study area.

Table 19. NCWAM Predictor x IBI Response Least Square Fit Analysis

| Response Variable | Effect | NCWAM Level | Least Sq Mean | Std Error | Mean | N | R-Square | Root Mean Sq Error | F-Ratio | Prob > F |
|---|---|---|---|---|---|---|---|---|---|---|
| DWQ Forest IBI total | NCWAM Overall Rating | LOW | 30.8637 | 4.4105 | 30.864 | 39 | 0.348 | 13.23 | 9.622 | 0.0004 |
| DWQ Forest IBI total | NCWAM Overall Rating | MEDIUM | 42.8494 | 5.001 | 42.849 | | | | | |
| DWQ Forest IBI total | NCWAM Overall Rating | HIGH | 53.3437 | 2.759 | 53.344 | | | | | |
| DWQ Forest IBI total | Habitat Function | LOW | 35.0371 | 3.6183 | 35.037 | 39 | 0.318 | 13.539 | 8.383 | 0.001 |
| DWQ Forest IBI total | Habitat Function | MEDIUM | 45.4535 | 6.0547 | 45.454 | | | | | |
| DWQ Forest IBI total | Habitat Function | HIGH | 54.3419 | 3.0273 | 54.342 | | | | | |
| Ohio weighted shrub and non-weighted emergent VIBIs | NCWAM Overall Rating | LOW | 56 | 8.638 | 56 | 10 | 0.754 | 8.638 | 10.71 | 0.007 |
| Ohio weighted shrub and non-weighted emergent VIBIs | NCWAM Overall Rating | MEDIUM | 28.936 | 4.987 | 28.936 | | | | | |
| Ohio weighted shrub and non-weighted emergent VIBIs | NCWAM Overall Rating | HIGH | 56.593 | 3.527 | 56.593 | | | | | |

Table 19. NCWAM Predictor x IBI Response Least Square Fit Analysis

| Response Variable | Effect | NCWAM Level | Least Sq Mean | Std Error | Mean | N | R-Square | Root Mean Sq Error | F-Ratio | Prob > F |
|---|---|---|---|---|---|---|---|---|---|---|
| Ohio weighted shrub and non-weighted emergent VIBIs | Habitat Function | LOW | 35.69 | 5.87 | 35.69 | 10 | 0.545 | 11.737 | 4.196 | 0.0634 |
| Ohio weighted shrub and non-weighted emergent VIBIs | Habitat Function | MEDIUM | 47.11 | 11.74 | 47.11 | | | | | |
| Ohio weighted shrub and non-weighted emergent VIBIs | Habitat Function | HIGH | 58.49 | 5.25 | 58.49 | | | | | |
| Ohio weighted shrub and non-weighted emergent VIBIs and DWQ forest IBI | NCWAM Overall Rating | LOW | 27.821 | 3.736 | 27.82 | 49 | 0.311 | 11.81 | 10.36 | 0.0002 |
| Ohio weighted shrub and non-weighted emergent VIBIs and DWQ forest IBI | NCWAM Overall Rating | MEDIUM | 32.67 | 3.74 | 32.67 | | | | | |
| Ohio weighted shrub and non-weighted emergent VIBIs and DWQ forest IBI | NCWAM Overall Rating | HIGH | 45.55 | 2.19 | 45.55 | | | | | |
| Ohio weighted shrub and non-weighted emergent VIBIs and DWQ forest IBI | Habitat Function | LOW | 29.916 | 2.77 | 29.73 | 49 | 0.316 | 11.77 | 10.63 | 0.0002 |
| Ohio weighted shrub and non-weighted emergent VIBIs and DWQ forest IBI | Habitat Function | MEDIUM | 38.15 | 4.8 | 38.15 | | | | | |
| Ohio weighted shrub and non-weighted emergent VIBIs and DWQ forest IBI | Habitat Function | HIGH | 46.48 | 2.35 | 46.48 | | | | | |

Table 20. NCWAM Predictor x IBI Response - Coefficients

| Response Variable | Effect | NCWAM Level | Estimate | Std Error | t value | Pr (>\|t\|) |
|---|---|---|---|---|---|---|
| DWQ Forest IBI total | NCWAM Overall Rating | LOW | -22.48 | 5.202 | -4.321 | 0.00017 |
| DWQ Forest IBI total | NCWAM Overall Rating | MEDIUM | -10.494 | 5.712 | -1.837 | 0.07442 |
| DWQ Forest IBI total | NCWAM Overall Rating | HIGH-Intercept | 53.344 | 2.759 | 19.35 | <2e-16 |
| DWQ Forest IBI total | Habitat Function | LOW | -19.305 | 4.718 | -4.092 | 0.00023 |
| DWQ Forest IBI total | Habitat Function | MEDIUM | -8.888 | 6.769 | -1.313 | 0.19748 |
| DWQ Forest IBI total | Habitat Function | HIGH-Intercept | 54.342 | 3.027 | 17.95 | <2e-16 |
| Ohio weighted shrub and non-weighted emergent VIBIs | NCWAM Overall Rating | LOW | -0.5926 | 9.3305 | -0.064 | 0.9511 |
| Ohio weighted shrub and non-weighted emergent VIBIs | NCWAM Overall Rating | MEDIUM | -27.667 | 6.1082 | -4.529 | 0.0027 |
| Ohio weighted shrub and non-weighted emergent VIBIs | NCWAM Overall Rating | HIGH-Intercept | 56.5926 | 3.5266 | 16.047 | 8.87E-07 |
| Ohio weighted shrub and non-weighted emergent VIBIs | Habitat Function | LOW | -22.794 | 7.873 | -2.895 | 2.31E-02 |
| Ohio weighted shrub and non-weighted emergent VIBIs | Habitat Function | MEDIUM | -11.378 | 12.857 | -0.885 | 0.4055 |
| Ohio weighted shrub and non-weighted emergent VIBIs | Habitat Function | HIGH-Intercept | 58.489 | 5.249 | 11.143 | 1.04E-05 |
| Ohio weighted shrub and non-weighted emergent VIBIs and DWQ forest IBI | NCWAM Overall Rating | LOW | -17.733 | 4.332 | -4.093 | 0.00017 |
| Ohio weighted shrub and non-weighted emergent VIBIs and DWQ forest IBI | NCWAM Overall Rating | MEDIUM | -12.881 | 4.332 | -2.973 | 0.00468 |

Table 20. NCWAM Predictor x IBI Response - Coefficients

| Response Variable | Effect | NCWAM Level | Estimate | Std Error | t value | Pr (>\|t\|) |
|---|---|---|---|---|---|---|
| Ohio weighted shrub and non-weighted emergent VIBIs and DWQ forest IBI | NCWAM Overall Rating | HIGH-Intercept | 45.554 | 2.194 | 20.765 | < 2e-16 |
| Ohio weighted shrub and non-weighted emergent VIBIs and DWQ forest IBI | Habitat Function | LOW | -16.744 | 3.6337 | -4.604 | 3.28E-05 |
| Ohio weighted shrub and non-weighted emergent VIBIs and DWQ forest IBI | Habitat Function | MEDIUM | -8.322 | 5.349 | -1.556 | 1.27E-01 |
| Ohio weighted shrub and non-weighted emergent VIBIs and DWQ forest IBI | Habitat Function | HIGH-Intercept | 46.477 | 2.353 | 19.75 | < 2e-16 |

## 3.2 Hydrology and Water Quality Sites Site Results and Discussion

### 3.2.1 Hydrology and Water Quality Site Selection Results and Discussion

Eight sites were selected for further hydrologic and water quality study in North Carolina and three sites in South Carolina. This section describes the basic hydrologic conditions at each site that was selected for detailed investigation. The sites were selected after the field reconnaissance work described in Section 2.2.1. The hydrology sites ranged in size from .07 to 8.5 acres (Table 21). The North Carolina sites are presented first then the South Carolina Sites.

Table 21. Hydrology Sites for NC and SC

| Hydrology Site | County | State | Acres | NCWAM Type |
|---|---|---|---|---|
| Bladen 1 | Bladen | NC | 0.64 | Basin Wetland |
| Bladen 2 | Bladen | NC | 0.07 | Basin Wetland |
| Bladen 6 | Bladen | NC | 8.52 | Basin Wetland |
| Bladen 7 | Bladen | NC | 3.46 | Basin Wetland |
| Bladen 9 | Bladen | NC | 1.32 | Basin Wetland |
| Bladen 17 | Bladen | NC | 1.65 | Basin Wetland |
| Green Swamp 1 | Brunswick | NC | 0.64 | Basin Wetland |
| Green Swamp 2 | Brunswick | NC | 1 | Basin Wetland |
| MA | Marion | SC | 1.11 | Basin Wetland |
| MF | Marion | SC | 1.26 | Basin Wetland |
| LB | Horry | SC | 4.41 | Basin Wetland |

**Bladen 1 –** The Bladen 1 site (BL1) (0.64 acre) is approximately 4 miles northeast of Elizabethtown in northern Bladen County, North Carolina (Figure 26) at the Turnbull Creek Education State Forest. This site is 0.4 miles (650 m) south of Sweet Home Church Road. The BL1 IW site is a clear-cut site surrounded by pine forested uplands. No surface water was observed in the IW throughout the course of this study. Eight sediment cores were obtained at BL1. Twelve monitoring wells, one pumping well and two surface water gaging stations were installed at this site. An aquifer test was conducted at this site in March 2011. Monitoring at this site covered a transect almost 0.7 miles (1.1 km) in length from an upgradient ditch, the Jones Lake Drain (JLD) draining nearby Jones Lake, through the IW, to Turnbull Creek, downgradient from the IW. Aerial photos reveal that JLD was in place in 1950. (Michael Chesnutt, Manager of Bladen Lakes State Forest, personal communication)

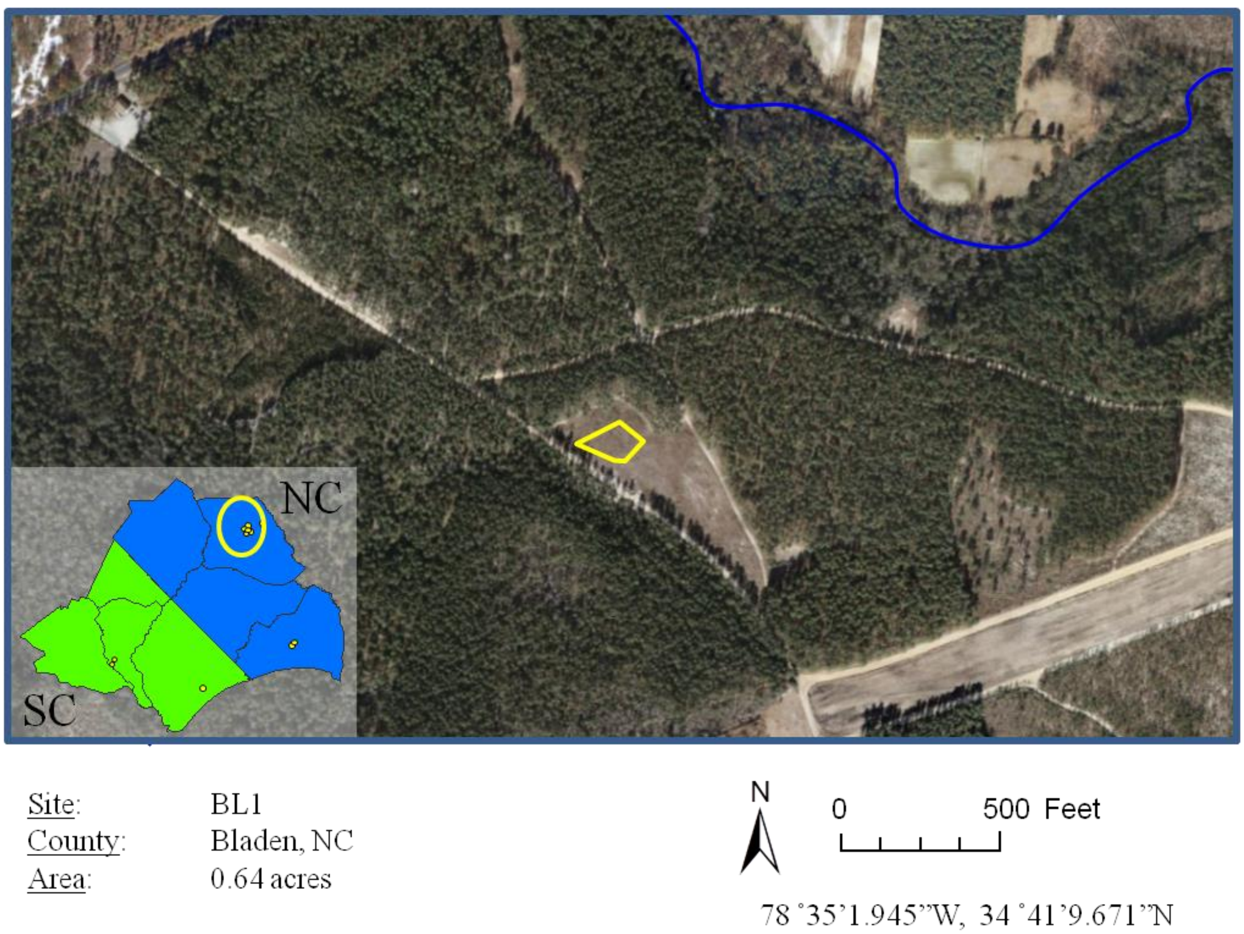


Figure 26. Bladen 1 study site in Bladen County, North Carolina

**Bladen 2** – The Bladen 2 site (BL2) (0.07 acre) is approximately 4 miles northeast of Elizabethtown in northern Bladen County, North Carolina (Figure 27) at the Turnbull Creek Education State Forest. This site is 1 mile south of Sweet Home Church Road. The BL2 IW site is surrounded by pine forested uplands. No surface water was observed in the IW throughout the course of this study. Eight sediment cores were obtained at BL2. Eight monitoring wells and one surface water gaging station were installed at this site. Monitoring at this site covered a transect 1000 ft (300 m) in length, from the IW to a downgradient ditch, the JLD. Aerial photos reveal that JLD was in place in 1950. (Michael Chesnutt, personal communication)

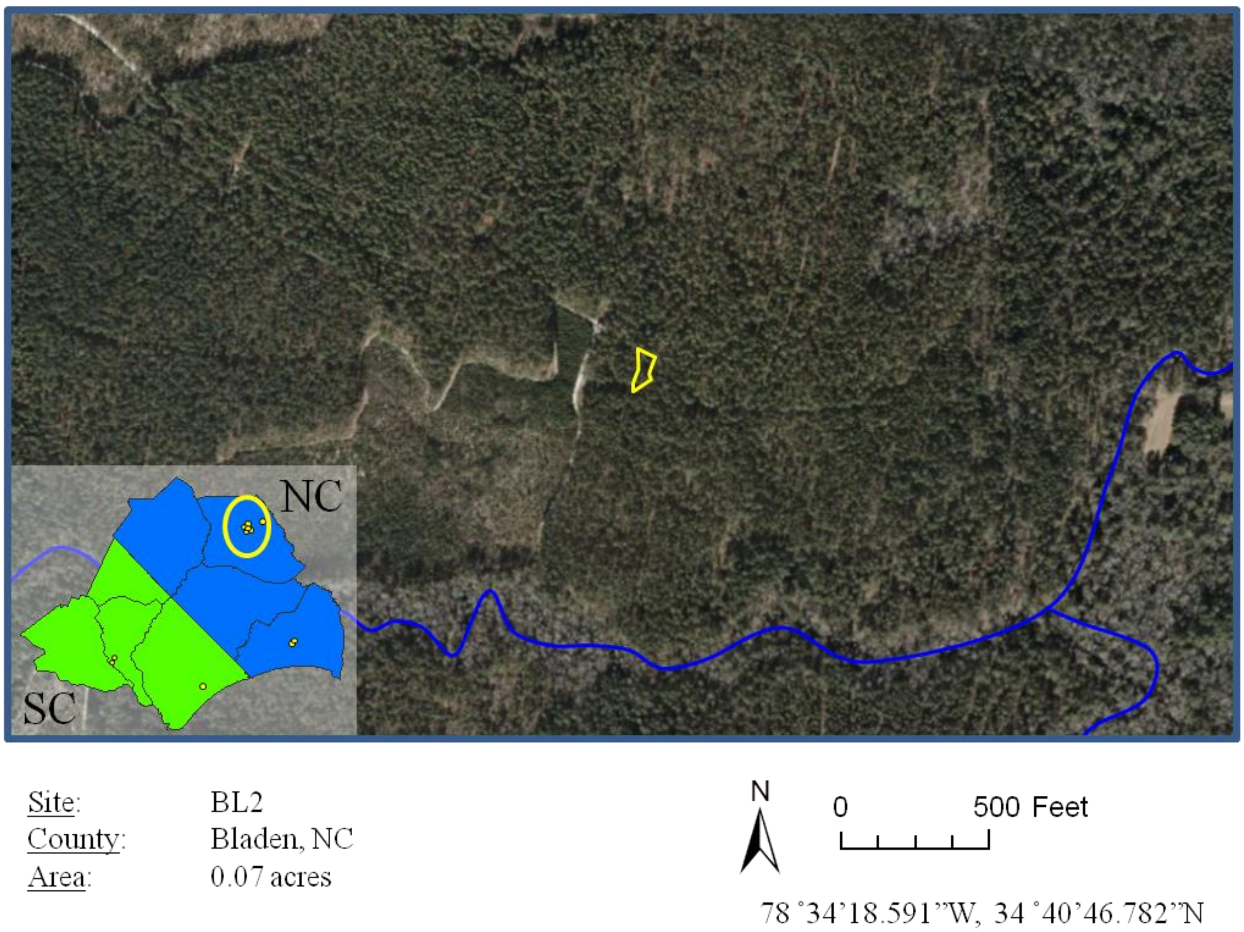


Figure 27. Bladen 2 study site in Bladen County, North Carolina

**Bladen 6** – The Bladen 6 site (BL6) (8.52 acres) is approximately 2.5 miles northeast of Elizabethtown in northern Bladen County, North Carolina (Figure 28) at Bladen Lakes State Forest Game Land. This site is approximately 0.2 miles (300 m) east of Willard Tatum Road. As viewed on the USGS 24K topographic quad map, BL6 has the landform characteristics of a Carolina Bay – an elliptical depression with a sandy ridge to the east. The BL6 IW is the largest in the hydrology study and is covered in complex vegetation that is surrounded by pine forested uplands. Surface water was periodically observed in the IW throughout the course of this study during wetter weather patterns. Six sediment cores were obtained at BL6. Ten monitoring wells and two surface water gaging stations were installed at this site. Monitoring at this site covered a transect 1050 ft (300 m) in length, from the IW to a downgradient intermittent stream.

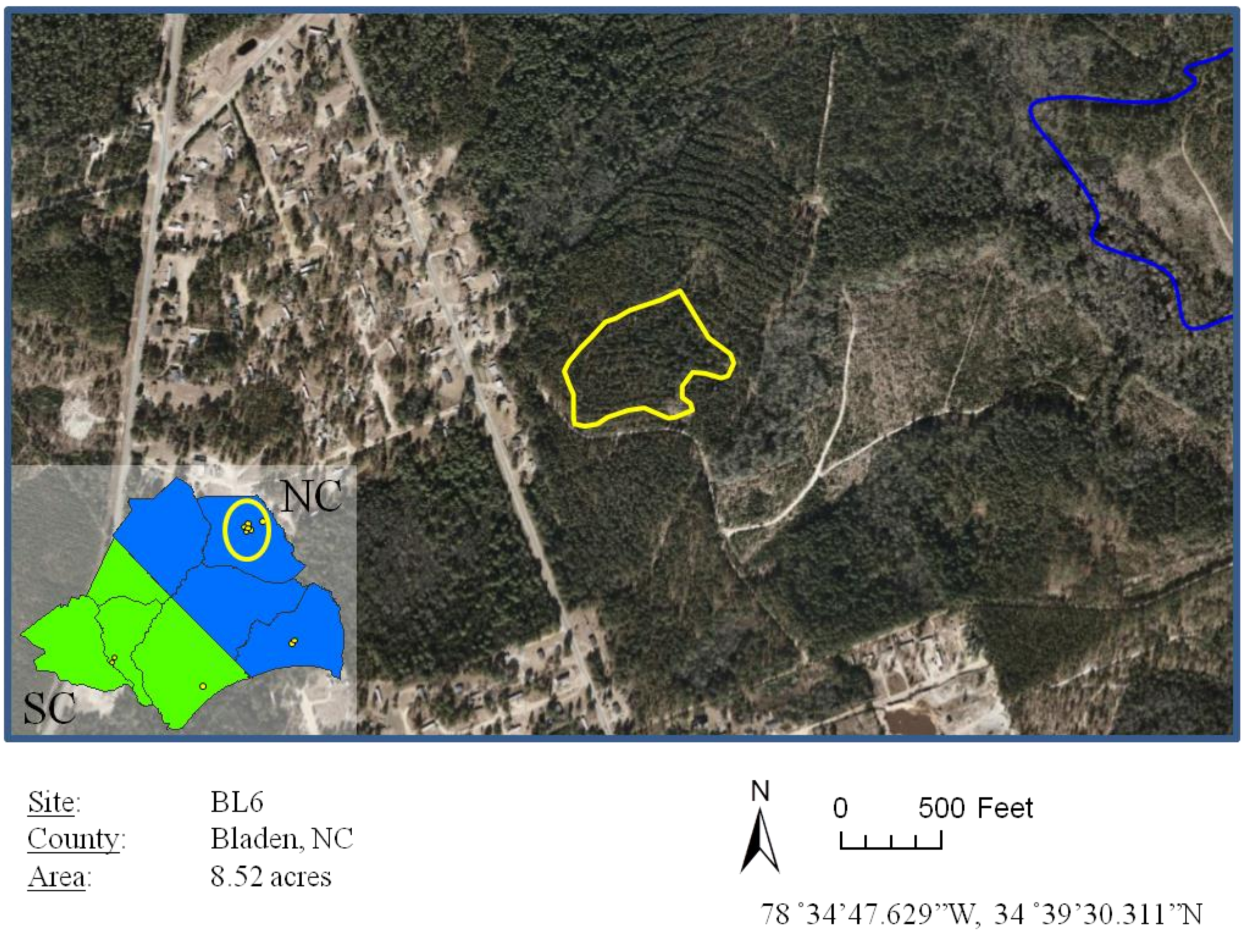


Figure 28. Bladen 6 study site in Bladen County, North Carolina

**Bladen 7** – The Bladen 7 site (BL7) (3.46 acres) is approximately 4 miles northeast of Elizabethtown in northern Bladen County, North Carolina (Figure 29) Bladen Lakes State Forest Game Land . This site is 0.25 (400 m) east of Sweet Home Church Road. As viewed on the USGS 24K topographic quad map, BL7 has the landform characteristics of a Carolina Bay – an elliptical depression with a sandy ridge to the east. The BL7 IW vegetation was shrubby. The area immediately around the IW is covered by immature pines from a clear-cut re-planting several years old. The upland between the IW and the downgradient stream was clear-cut within a year prior to initiation of field work. Surface water was periodically observed in the IW throughout the course of this study during wetter weather patterns. Five sediment cores were obtained at BL7. Seven monitoring wells, one temporary well, one pumping well and two surface water gaging stations were installed at this site. Monitoring at this site covered a transect 1300 ft (400 m) in length, from a well upgradient of the IW, through the IW to White Lake Drain, a stream which drains nearby White Lake.

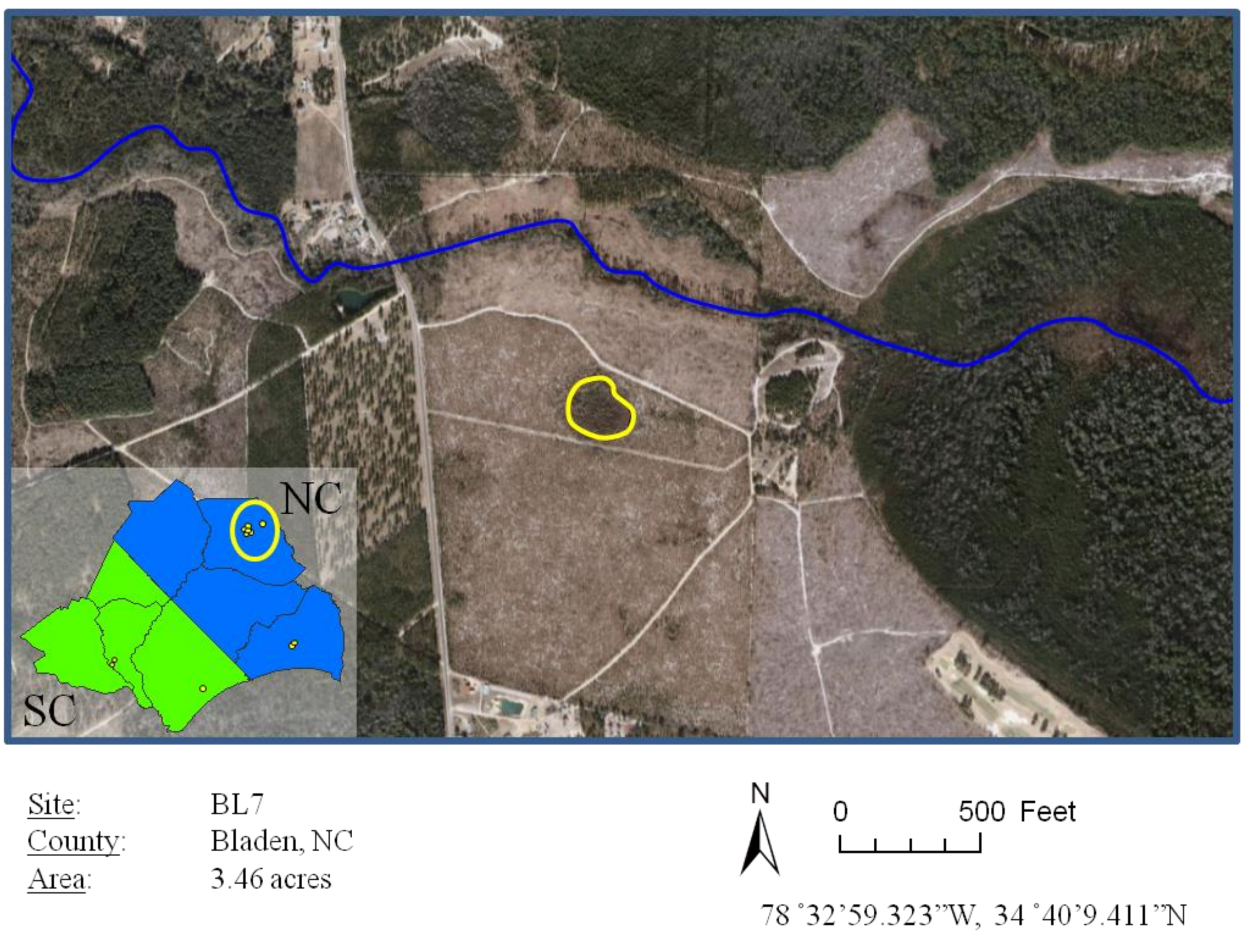


Figure 29. Bladen 7 study site in Bladen County, North Carolina

**Bladen 9** – The Bladen 9 site (BL9) (1.32 acres) is approximately 5 miles northeast of Elizabethtown in northern Bladen County, North Carolina (Figure 30) Bladen Lakes State Forest Game Land. This site is approximately 500 ft (160 m) north of Sweet Home Church Road. BL9 was a clear-cut site with no canopy cover and little ground cover adjacent to mature, managed forest land. Surface water was periodically observed in the IW throughout the course of this study during wetter weather patterns. Six sediment cores were obtained at BL9. Seven monitoring wells and one surface water gaging station were installed at this site. Monitoring at this site covered a transect 790 ft (240 m) in length, from the IW to a ditch which enters an unnamed tributary to Turnbull Creek.

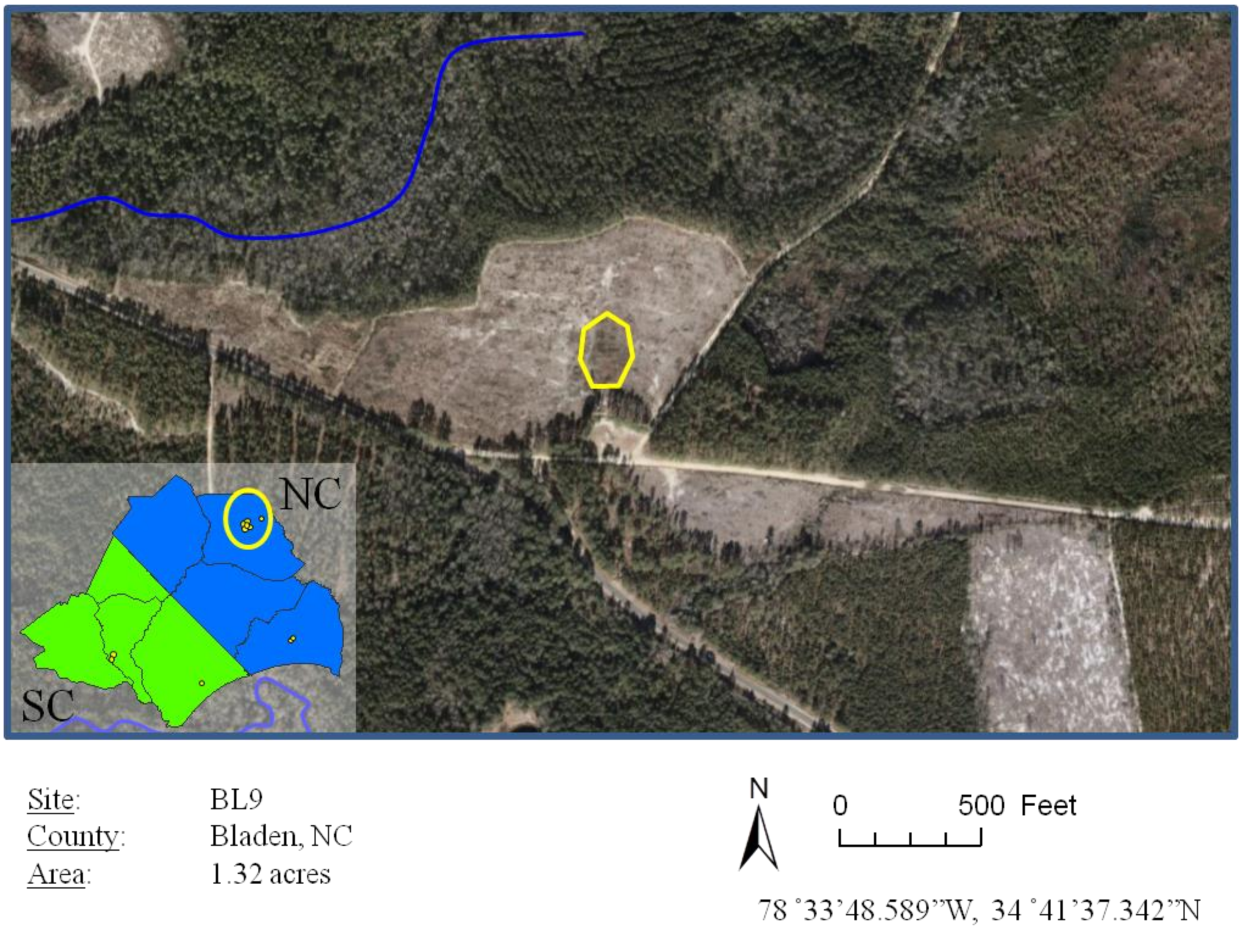


Figure 30. Bladen 9 study site in Bladen County, North Carolina

**Bladen 17 –** The Bladen 17 site (BL17) (1.65 acres) is approximately 4.5 miles northeast of White Lake in northern Bladen County, North Carolina (Figure 31)at Bladen Lakes State Forest Game Land. This site is approximately 500 ft (160 m) northwest of Highway 701. The BL17 IW is surrounded by mature, managed pine forested uplands. This IW is long and narrow. Surface water was periodically observed in the IW throughout the course of this study during wetter weather patterns. Much of the time the IW was completely dry. Eight sediment cores were obtained at BL17. Eleven monitoring wells were installed at this site. Monitoring at this site covered a transect 1050 ft (300 m) in length, from the IW to a downgradient ditch draining into Colly Creek.

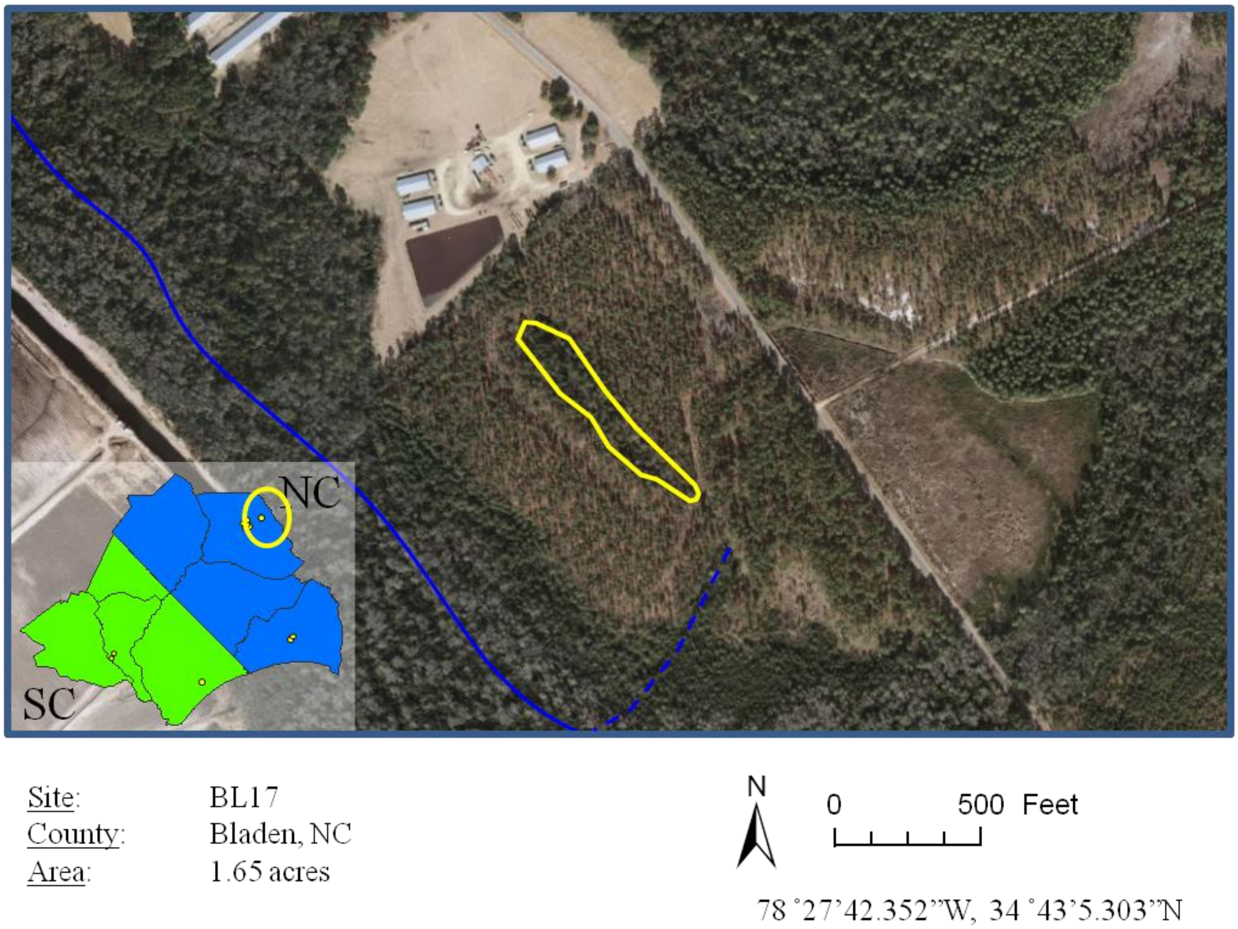


Figure 31. Bladen 17 study site in Bladen County, North Carolina

**Green Swamp 1 –** The Green Swamp 1 site (GS1) (0.64 acres) is approximately 2.5 miles north of the town of Supply in central Brunswick County, North Carolina (Figure 32) at the Nature Conservancy Green Swamp Preserve. This site is 0.75 miles (1.2 km) east of North Carolina Highway 211. The property is within the Green Swamp on land owned by The Nature Conservancy. The GS1 IW is in an area pockmarked with rounded depressions (sinkholes) and the IW is actually 4 sinkholes which have coalesced to form one IW. The IW is a Cypress swamp but the surrounding upland is pine forest. The IW was filled with several feet of surface water when the field study began in June 2010 and was completely dry for several months in the spring of 2012. Four sediment cores were obtained at GS1, including three Geoprobe® cores and one hand augered core. Eleven monitoring wells, one pumping well and two surface water gaging stations were installed at this site. Monitoring at this site covered a transect 500 ft (160 m) in length, from the IW to a downgradient wetland that is connected to Beaverdam Swamp.

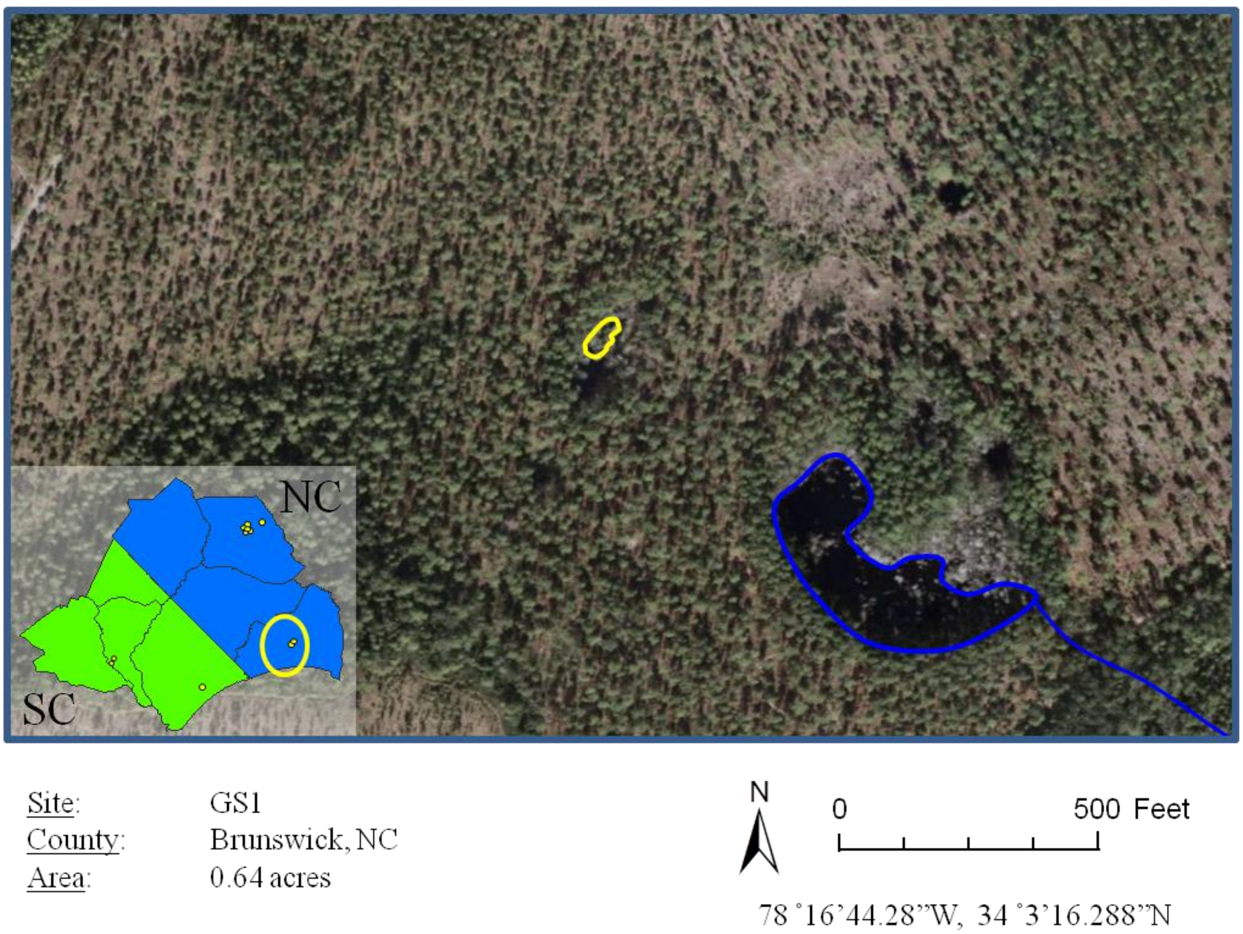


Figure 32. Green Swamp 1 study site in Brunswick County, North Carolina

**Green Swamp 2 –** The Green Swamp 2 site, ( GS2) (1.0 acre), is approximately 3 miles north of the town of Supply in central Brunswick County, North Carolina (Figure 33) at the Nature Conservancy Green Swamp Preserve. This site is 0.6 miles (960 m) north of Middle River Road. The property is in the Green Swamp on land owned by The Nature Conservancy. The GS2 site was clear cut within a year prior to the initiation of field work. Surface water was periodically observed in the IW throughout the course of this study during wetter weather patterns. Three sediment cores were obtained at GS2. Six monitoring wells were installed at this site. Monitoring at this site covered a transect 260 ft (80 m) in length, from the IW to a downgradient slough that is connected to Beaver dam Swamp.

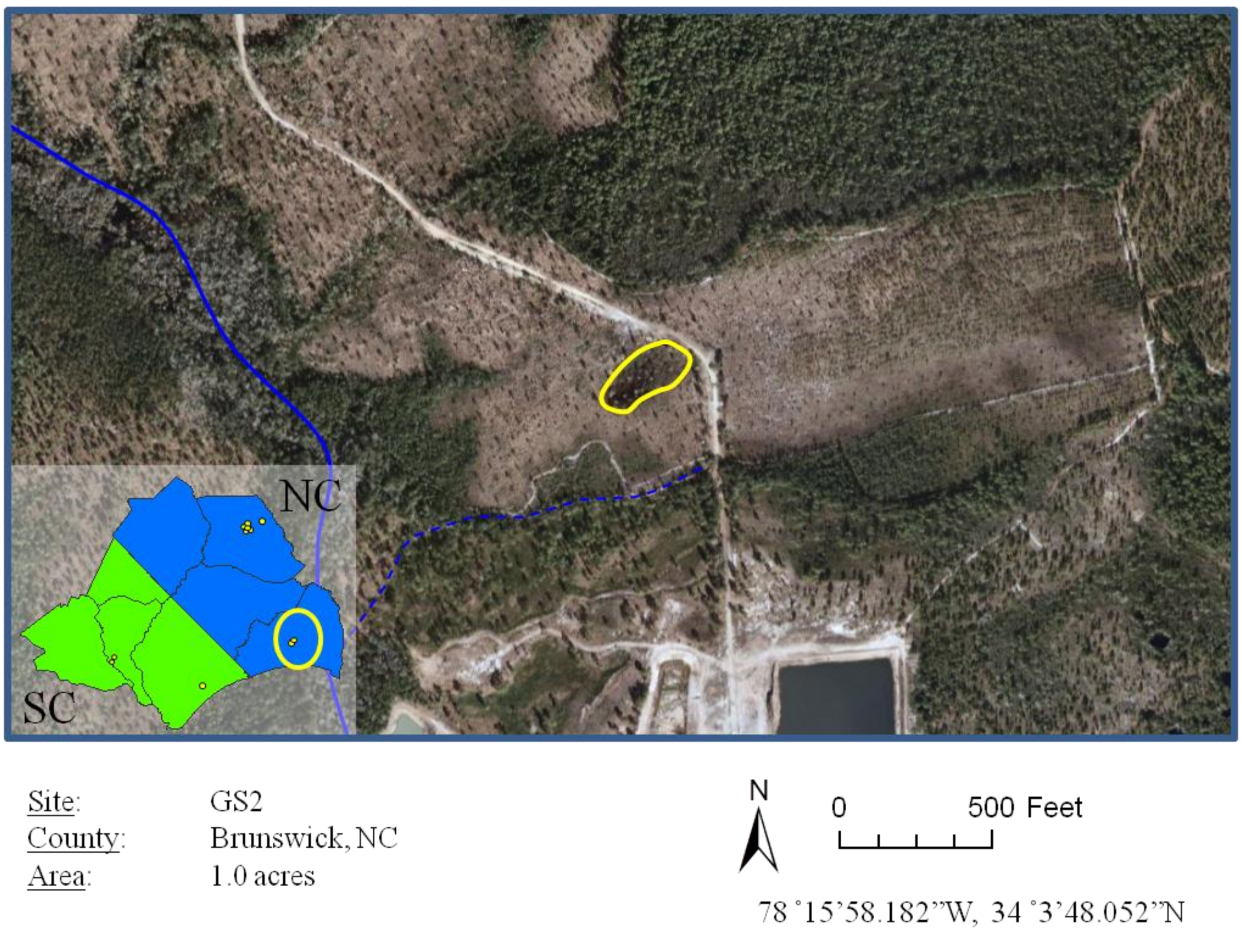


Figure 33. Green Swamp 2 study site in Brunswick County, North Carolina

**MA** - The MA site (1.11. acre) is approximately 3 miles (4.8 km) northwest of Gresham in western Marion County, South Carolina (Figure 34) at the Marsh Furniture Wildlife Management Area. This site is located just south of Bear Pond Road approximately 1.4 miles (2.3 km) west of SC Highway 9. The MA IW site is a forested basin wetland surrounded by 50 to 200 feet of upland grassland which was plowed periodically. Young upland planted pine bordered much of the upland grassland. A dirt road (Bear Pond Road) forms the northern border of the MA wetland. Surface water was periodically observed in the IW throughout the course of this study during wetter weather patterns. Three monitoring wells and two surface water monitoring stations were installed at this site. Monitoring at this site covered a transect approximately 200 feet (61 m) in length from the upgradient isolated wetland southward and downgradient to another basin wetland which had a small surface connection to a riverine swamp.

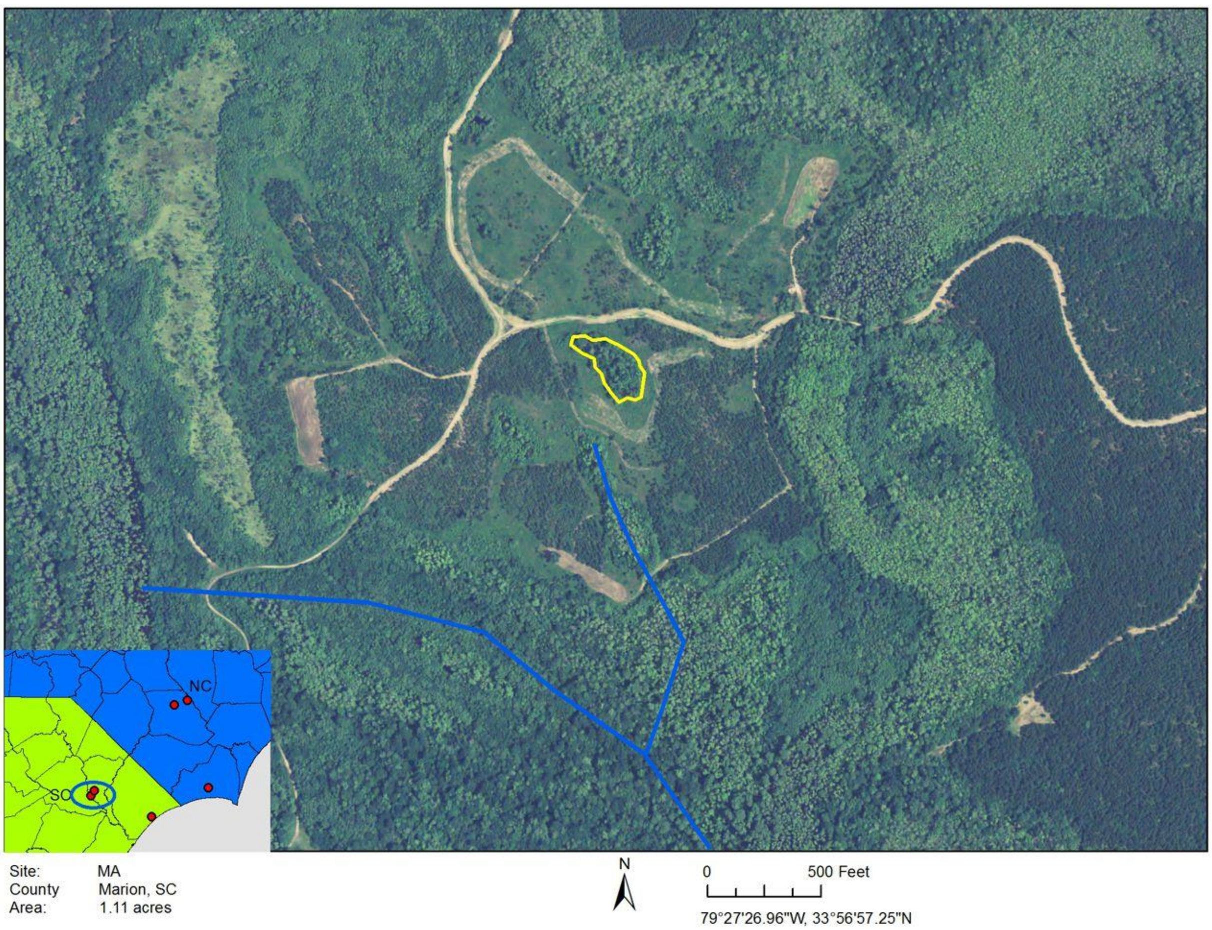


Figure 34. The MA study site in Marion County, South Carolina.

**MF** - The MF site (1.26 acres) is approximately 3.15 miles (5.1 km) northwest of Gresham in western Marion County, South Carolina (Figure 35) at the Marsh Furniture Wildlife Management Area. This site is located approximately 0.6 miles (1 km) south of Harmon Court and 0.9 miles (1.5 km) west of SC Highway 9. The MF IW site is a forested basin wetland surrounded by dense, mixed upland forest. Surface water was only observed in the IW on one or two occasions during the course of this study. Four monitoring wells and two surface water gauging stations were installed at this site. Monitoring at this site covered a transect approximately 800 feet (1450 m) in length from the upgradient isolated wetland southwestward and downgradient through the surrounding upland and connected bottomland hardwood wetland to a riverine swamp wetland.

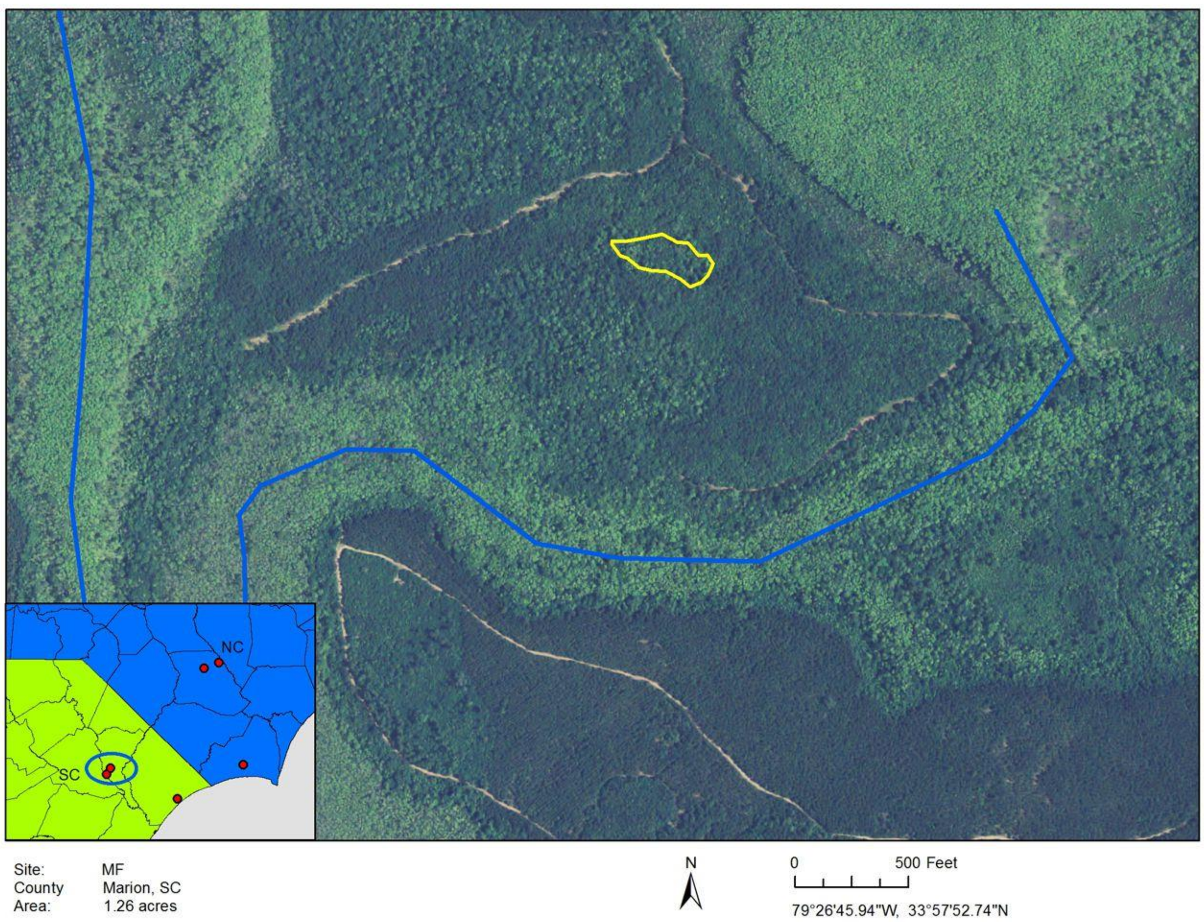


Figure 35. The MF study site in Marion County, South Carolina.

**LB** – The LB site (4.41 acres) is approximately 9 miles (14.6 km) north northeast of Myrtle Beach in southern Horry County, South Carolina (Figure 36) at the Lewis Ocean Bay Heritage Preserve site. This site is located approximately 300 feet (90 m) east of Water Tower Road and 1.5 miles (2.4 km) south of SC Highway 90. The LB wetland has the geomorphological characteristics of a Carolina Bay – a slightly elliptical depression with a sandy ridge to the east. The LB IW site is a pocosin which was burned less than a year before the commencement of this study. The surrounding upland consists mostly of fire managed mature pine forest. Surface water was only observed in the IW on one or two occasions during the course of this study. Four monitoring wells and two surface water gauging stations were installed at this site. Monitoring at this site covered a transect approximately 550 feet (170 m) in length from the upgradient isolated wetland northward and downgradient through the surrounding upland to a connected riverine swamp wetland.

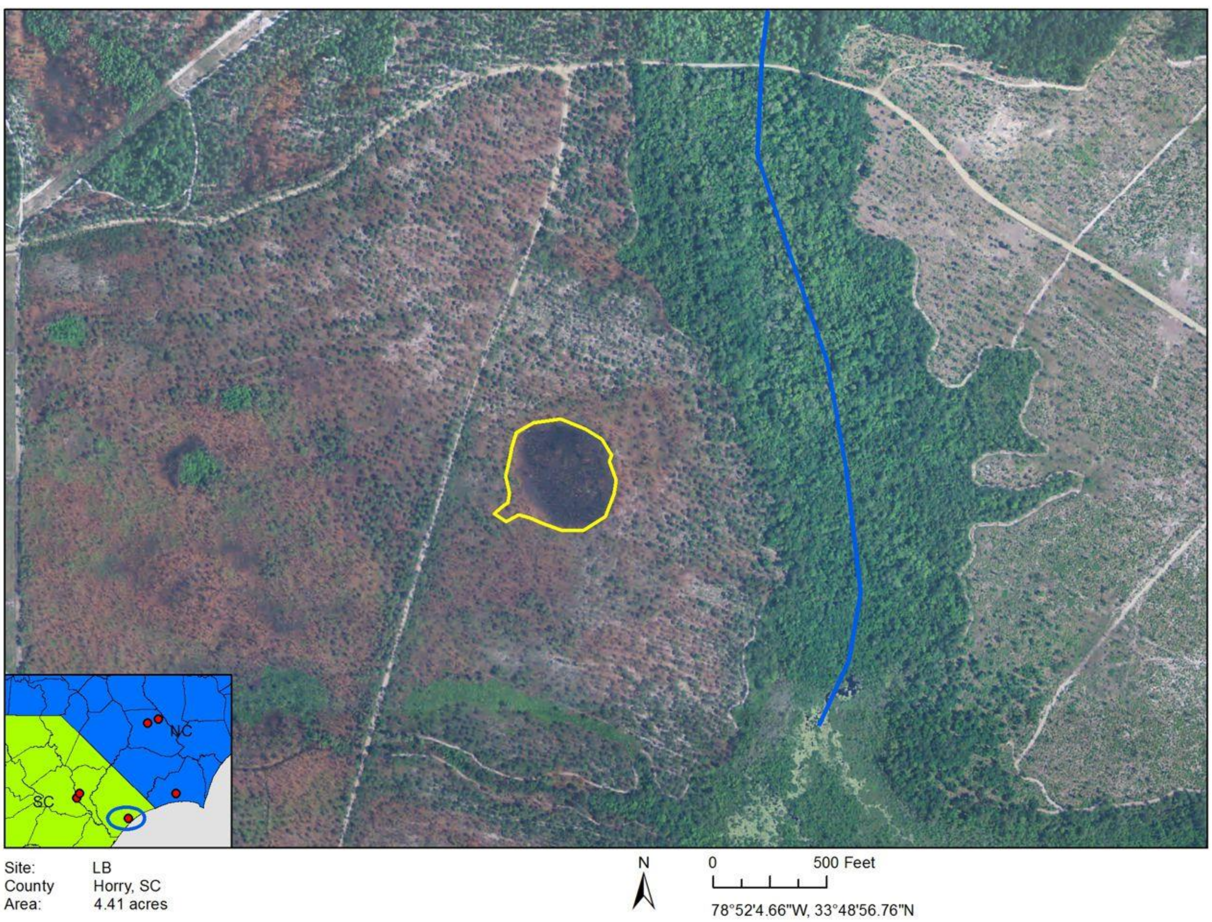


Figure 36. The LB study site in Horry County, South Carolina.

## 3.2.2 Hydrology Monitoring

### 3.2.2.1 Geology and Sediment Core Sampling Results and Discussion

**Geology and Sediment Core Site Descriptions**

As indicated in Section 2.2.2.1, shallow subsurface stratigraphy was investigated at all eleven hydrology sites in the study. Section 2.2.2.1 outlines the methods used to locate and describe the stratigraphic cores. A stratigraphic cross-section was developed using the findings of core analysis. Coring was done at each site in the wetland, the surrounding upland, and near the receiving water body. A site by site description of the findings from the stratigraphic coring follows.

**Bladen 1 -** Eight sediment cores were obtained as shown in Figure 37. As indicated in the cross-section (Figure 38) there are two units, a surficial sand unit overlying a dark gray unit. The surficial sand unit is 18’ to 25’ thick. The grain size is primarily medium sand but varies from medium to very coarse sand with gravel in some cores. The gravel is primarily granule sized though pebbles do occur, especially at the base of thicker gravel beds. There are some indications of laminated and graded bedding especially below approximately eight feet. Several cores have fining upward or coarsening upward sequences. Organic material is generally present at the surface and decreases rapidly with depth. The sand is sub-angular at the top and rounding increases with depth. The mineral content is mostly quartz with the occasional feldspar and the very rare occurrence of unidentified heavy minerals. Lignite and mica are sometimes present near the base of the surficial sand unit, and in several cores there is a gravel layer at the base of the sand. A discontinuous silt body occurs from 13’ to 17’ feet below land surface in core C6 located on the topographic ridge between the IW and the receiving stream (Figure 37). The lowermost unit at this site is a hard, dry, dark gray clay. In some cores the clay has laminae of very fine sand. This lowermost unit is presumed to be Cretaceous age sediment.

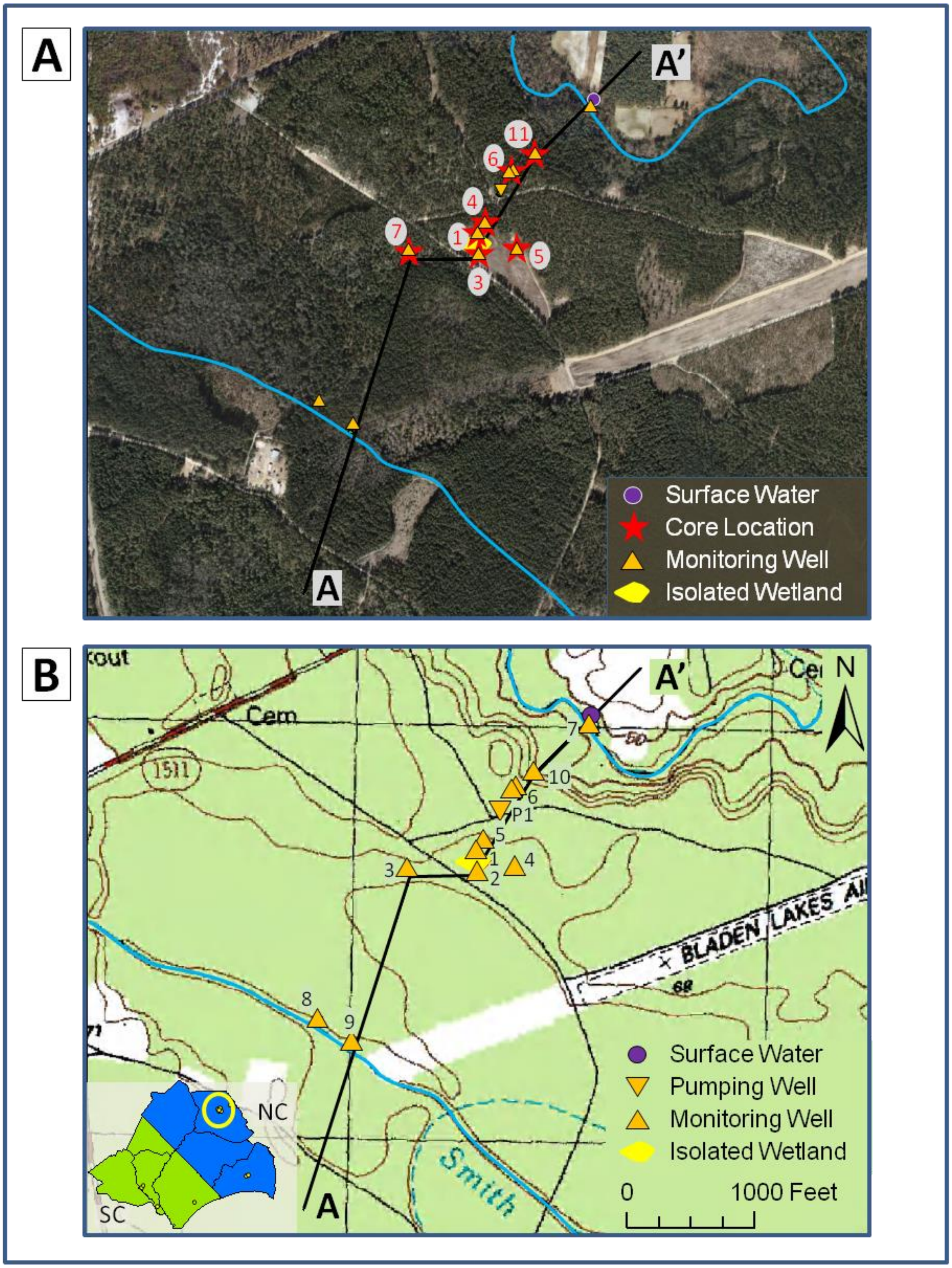


Figure 37. Site BL1: Location of wells and topographic profile (A-A') and stratigraphic cross-section lines. A. True Color aerial photograph. Core locations are numbered. B. USGS Topographic Map. Monitoring well locations are numbered.

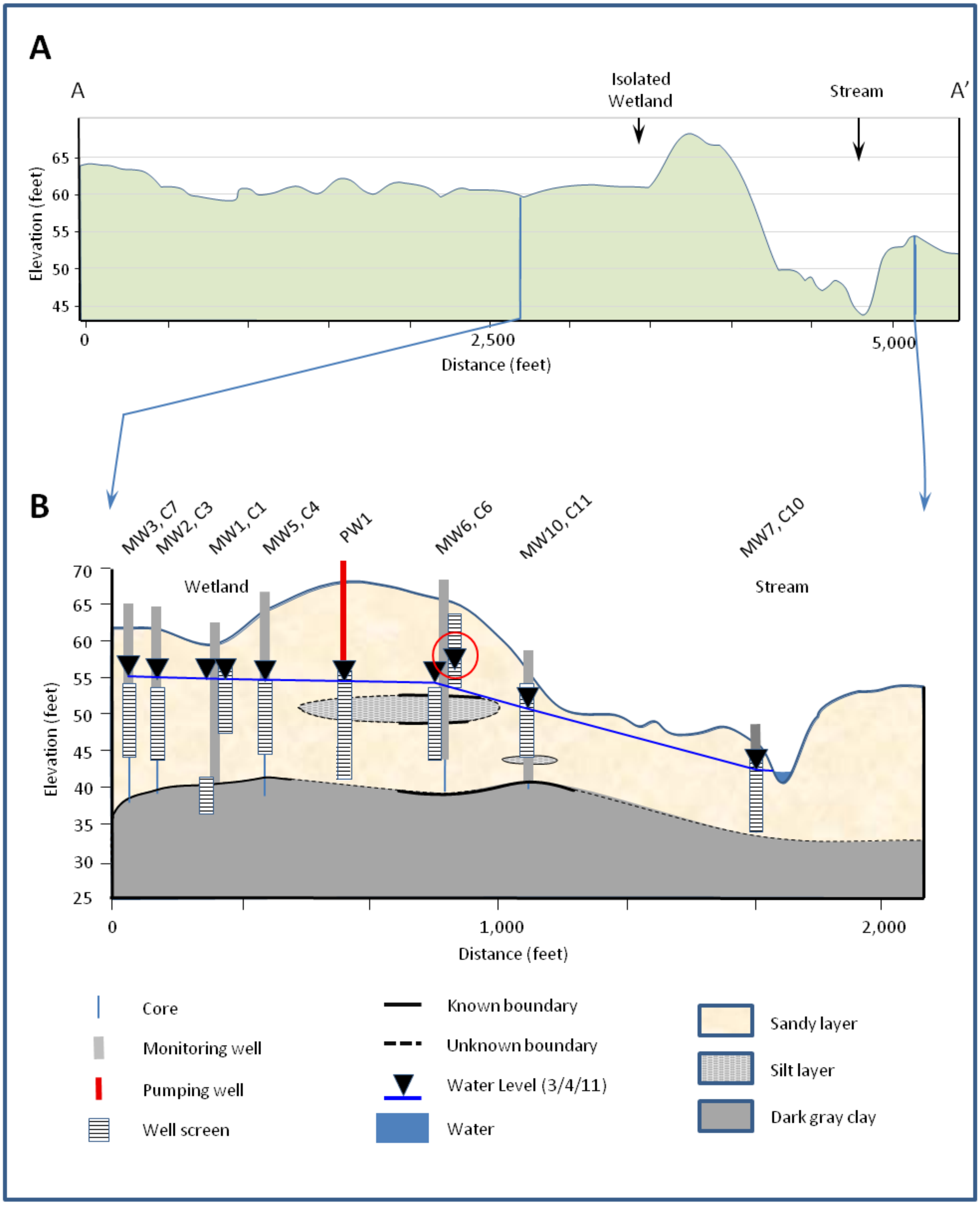


Figure 38. Site BL1 profiles along transect A-A' in Figure 37. A. Topographic profile based on LIDAR elevation data. B. Stratigraphic cross-section along a portion of the transect. Stratigraphy based on coring data.

**Bladen 2 -** Eight cores were obtained as shown in Figure 39. As indicated in the cross-section (Figure 40) there are two units, a surficial sand unit overlying a dark gray unit consisting of two lithologies. The surficial sand unit is 18’ to 27’ thick. The grain size is primarily medium sand but varies from medium to coarse sand with gravel in some cores. The gravel is primarily granule sized though pebbles do occur, especially at the base of thicker gravel beds. From 5’ to 7’ below land surface (bls) there are concentrations of very fine sand and silt in cores C1 and C6. Below approximately 5’ bls there are some indications of laminated and graded bedding in all cores at the site. Organic material is generally present near the top of each core, decreasing very quickly in the first few feet. The sand is sub-angular in the upper six feet and rounding increases with depth. The mineral content is mostly quartz with the occasional feldspar and the rare occurrence of unidentified heavy minerals. Lignite and mica are sometimes present near the base of the sand unit, and in several cores there is a gravel layer at the base of the sand. An unidentified green mineral was observed near the base of the sand unit in cores C1 and C2. There are wood chunks in core C6 at 24.5 to 27.5 feet bls. The lowermost unit at this site consists of two lithologies. In cores C2, C5 and C6, the lowermost unit is a hard, dry, dark gray clay with laminae of very fine sand, and in cores C1, C3, C4, C7 and C8 the lowermost unit is a very dark gray medium sand with lignite and mica. Both dark gray units, the sand and the clay, are presumed to be different facies of the same formation which is presumed to be Cretaceous age sediment.

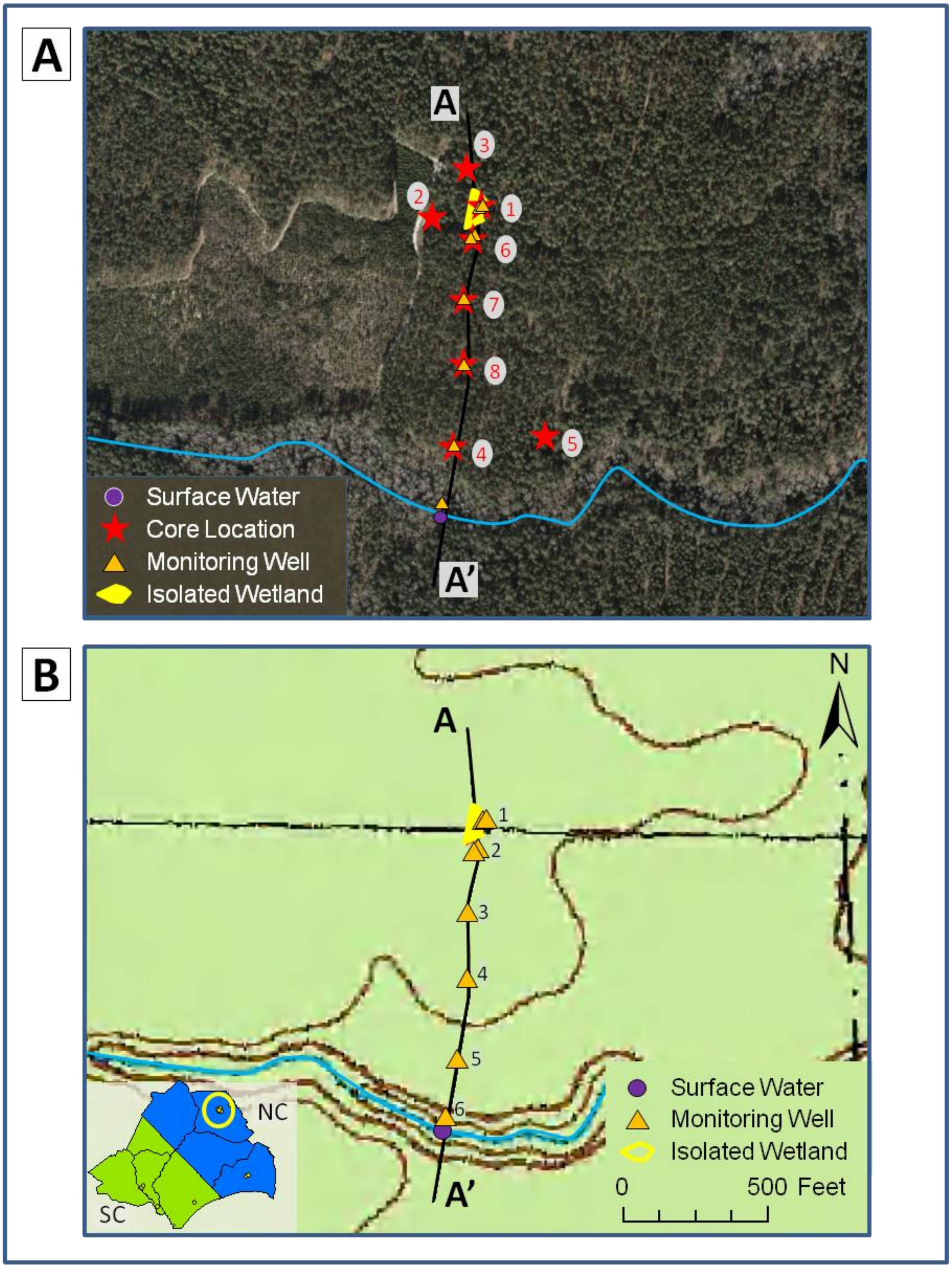


Figure 39. Site BL2: Location of wells and topographic profile (A-A') and stratigraphic cross-section lines. A. True Color aerial photograph. Core locations are numbered. B. USGS Topographic Map. Monitoring well locations are numbered.

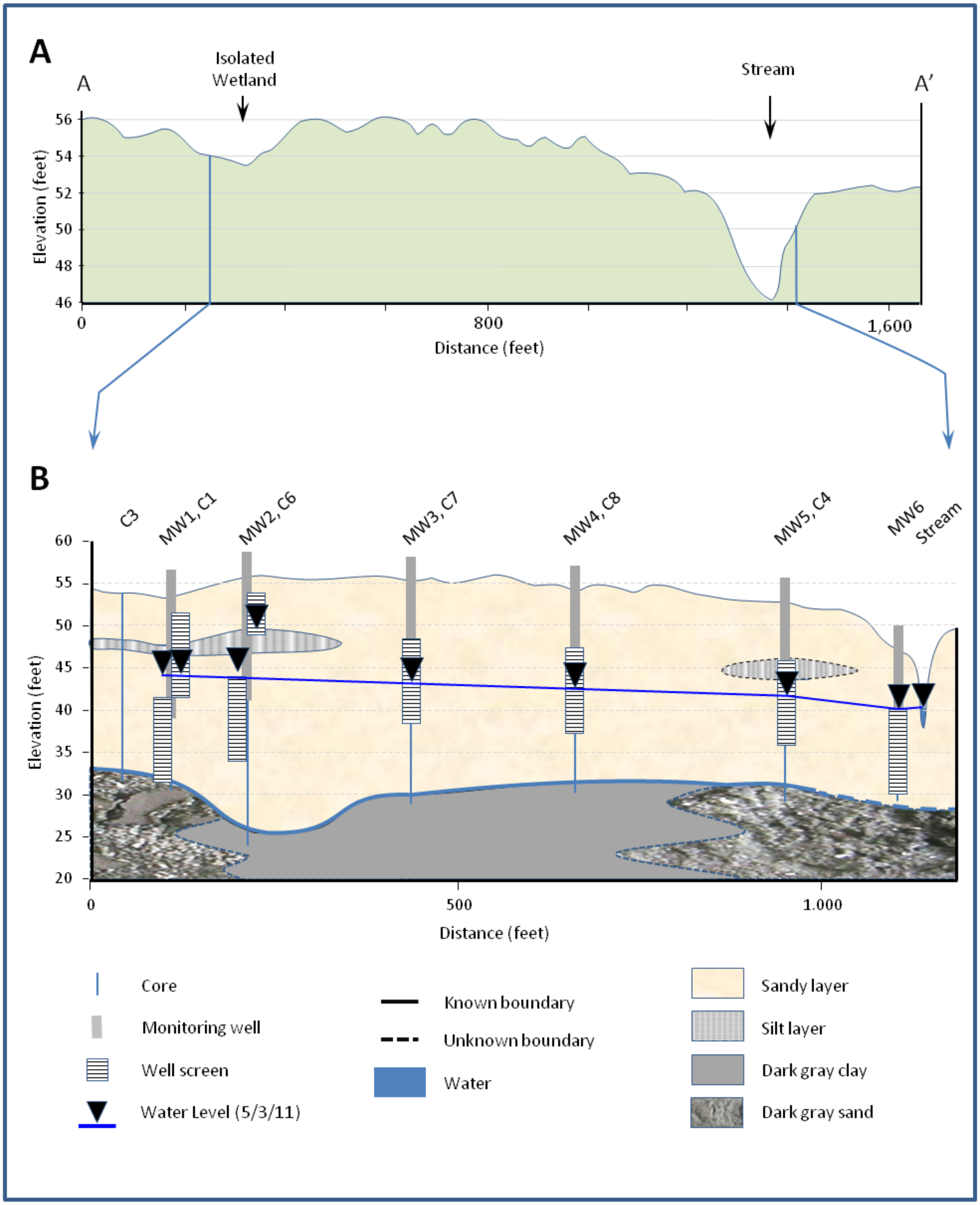


Figure 40. Site BL2 profiles along transect A-A' in Figure 39. A. Topographic profile based on LIDAR elevation data. B. Stratigraphic cross-section along a portion of the transect. Stratigraphy based on coring data.

**Bladen 6 -** Six cores were obtained as shown in Figure 41. As indicated in the cross-section (Figure 42) there are four lithologic units: an upper sand unit, a silt unit, a lower sand unit and a lowermost dark gray unit. The surficial sand unit is 9' to 20' thick. The grain size is primarily medium sand but varies from medium to coarse sand. There is no gravel in the upper sand unit and sedimentary structures are absent. Organic material is generally present near the top of each core, decreasing very quickly with depth. The sand is sub-angular at the top and rounding increases with depth. The mineral content is mostly quartz with the occasional feldspar and the rare occurrence of unidentified heavy minerals. There is an aerially extensive 4' to 6' thick silt layer underlying the surficial sand unit across much of the central portion of this site. The silt layer pinches out within 225 feet of the edge of the IW at the farthest upgradient core, C5. The lateral extent of the silt layer cannot be determined from the existing core data. The silt has a plastic texture, has laminae of very fine sand in some cores, may include green mottling and gray streaks, and contains some minor amounts of black-coated wood pieces and mica.

The lower sand unit is 13' to 18' thick and consists of several sequences fining upward from gravel to medium sand. The lower sand unit has varying amounts of granule- and small pebble-sized gravel generally concentrated at the base of fining upward sequences. Mica, silt balls, clay balls, and wood chunks are sometimes present near the base of this sand unit, and in several cores there is granule and small pebble sized gravel at the base of the sand.

The lowermost unit at this site is a hard, dry, dark gray clay. In some cores the clay has laminae of very fine sand. This unit is presumed to be Cretaceous age sediment.

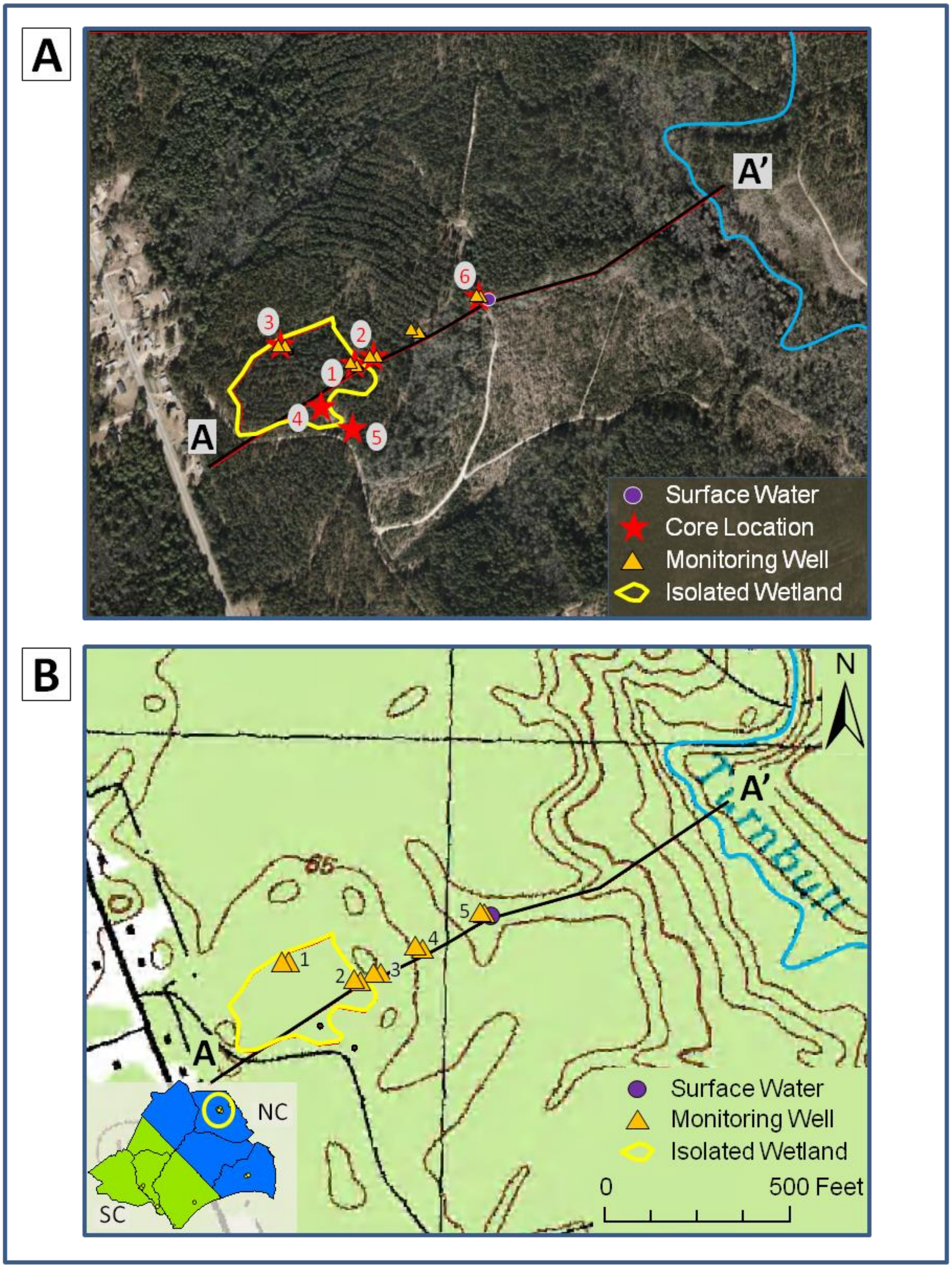


Figure 41. Site BL6: Location of wells and topographic profile (A-A') and stratigraphic cross-section lines. A. True Color aerial photograph. Core locations are numbered. B. USGS Topographic Map. Monitoring well locations are numbered.

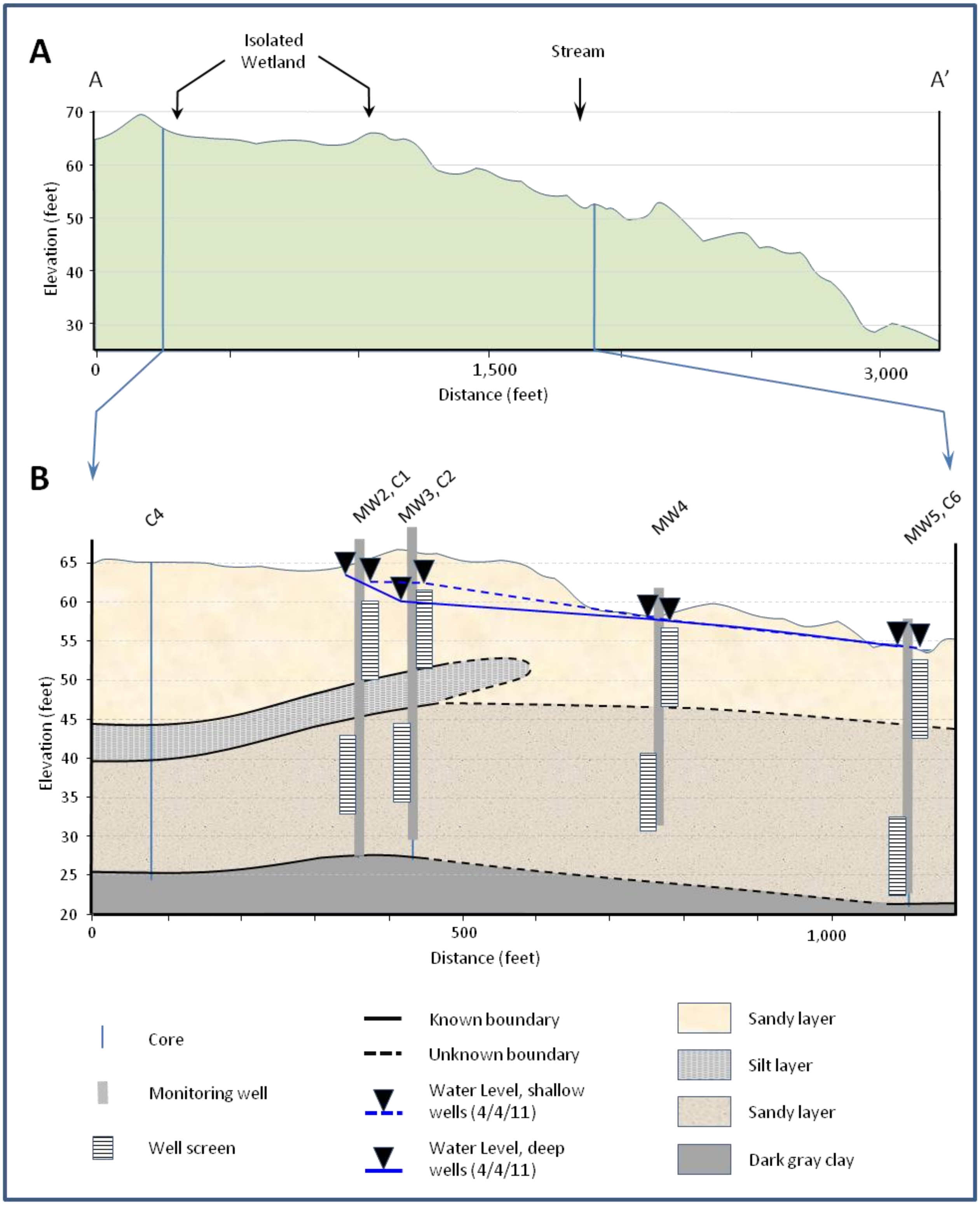


Figure 42. Site BL6 profiles along transect A-A' in Figure 41. A. Topographic profile based on LIDAR elevation data. B. Stratigraphic cross-section along a portion of the transect. Stratigraphy based on coring and hydrology data.

**Bladen 7 –** Five cores were obtained as shown in Figure 43. As indicated in the cross-section (Figure 44) there are two units, a surficial sand unit and a dark gray lowermost unit. The surficial sand unit is 18' to 27' thick. The grain size primarily medium sand but varies from fine to coarse. There are varying amounts of gravel below 15' bls, primarily granule size with the occasional occurrence of pebbles. The grain size sorting tends to be moderately sorted to well sorted throughout. Three feet bls in the easternmost core (C2) is a layer of dark, organic rich, slightly moist fine sand which may be a buried soil layer. Sedimentary structures such as bedding and fining upward and coarsening upward sequences occur below eight feet bls in most cores. The gravel layer at the base of the sand unit in the westernmost core (C5) is 2.5' thick and gravel size increases with depth. Organic material is generally present near the top of each core, decreasing very quickly in the first few feet. The sand is sub-angular in the upper six feet and rounding increases with depth. The mineral content is mostly quartz with the occasional feldspar and the rare occurrence of unidentified heavy minerals. Wood chunks, clay balls, lignite, mica and an unidentified green mineral is sometimes present near the base of the surficial sand unit, and in several cores there is a gravel layer at the base of the sand, in some cases 1' to 2.5' thick. The lowermost unit is a hard, dry, dark gray clay. In general the clay has laminae of very fine sand. The lowermost unit is presumed to be Cretaceous age sediment.

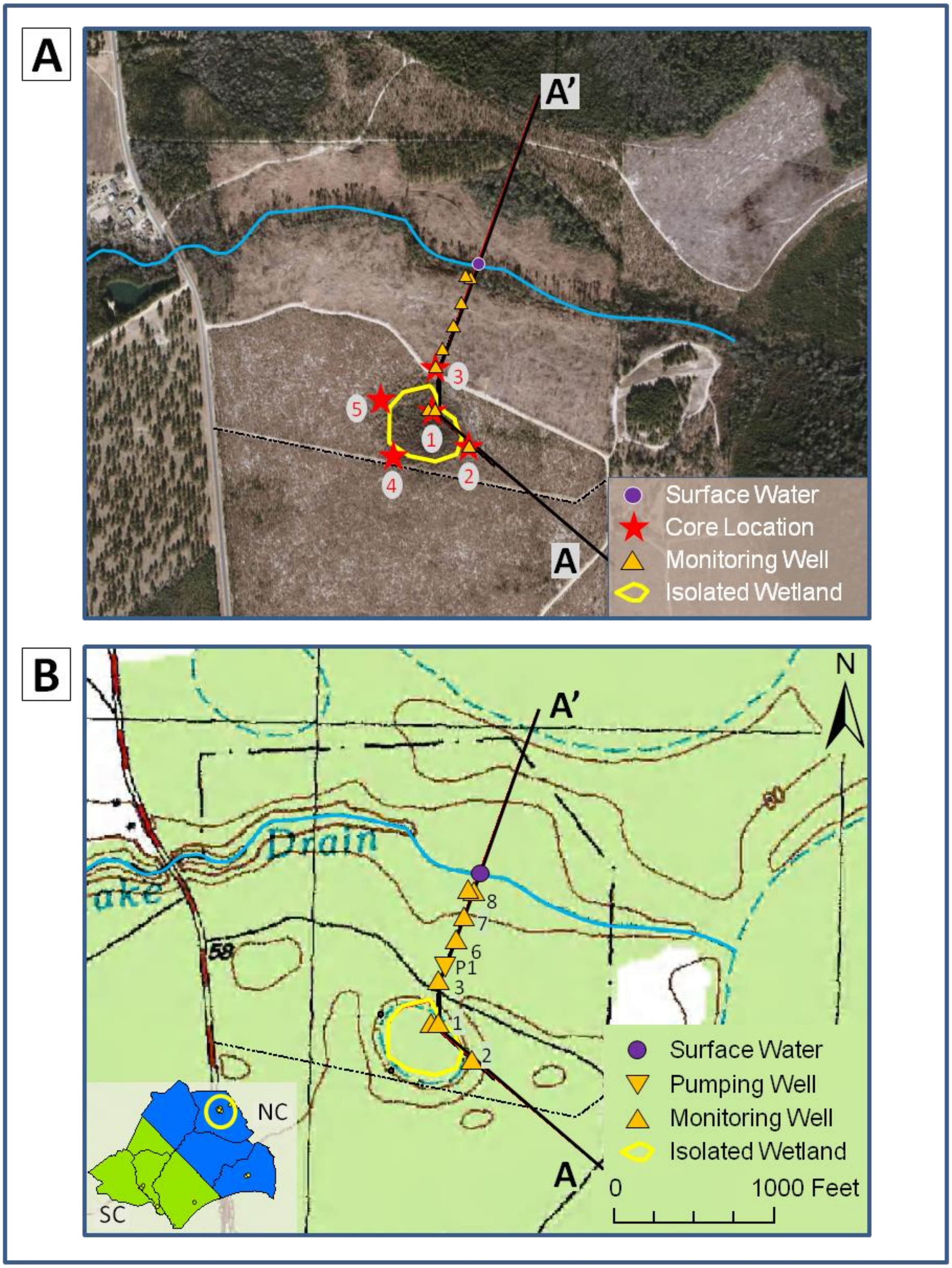


Figure 43. Site BL7: Location of wells and topographic profile (A-A') and stratigraphic cross-section lines. A. True Color aerial photograph. Core locations are numbered. B. USGS Topographic Map. Monitoring well locations are numbered.

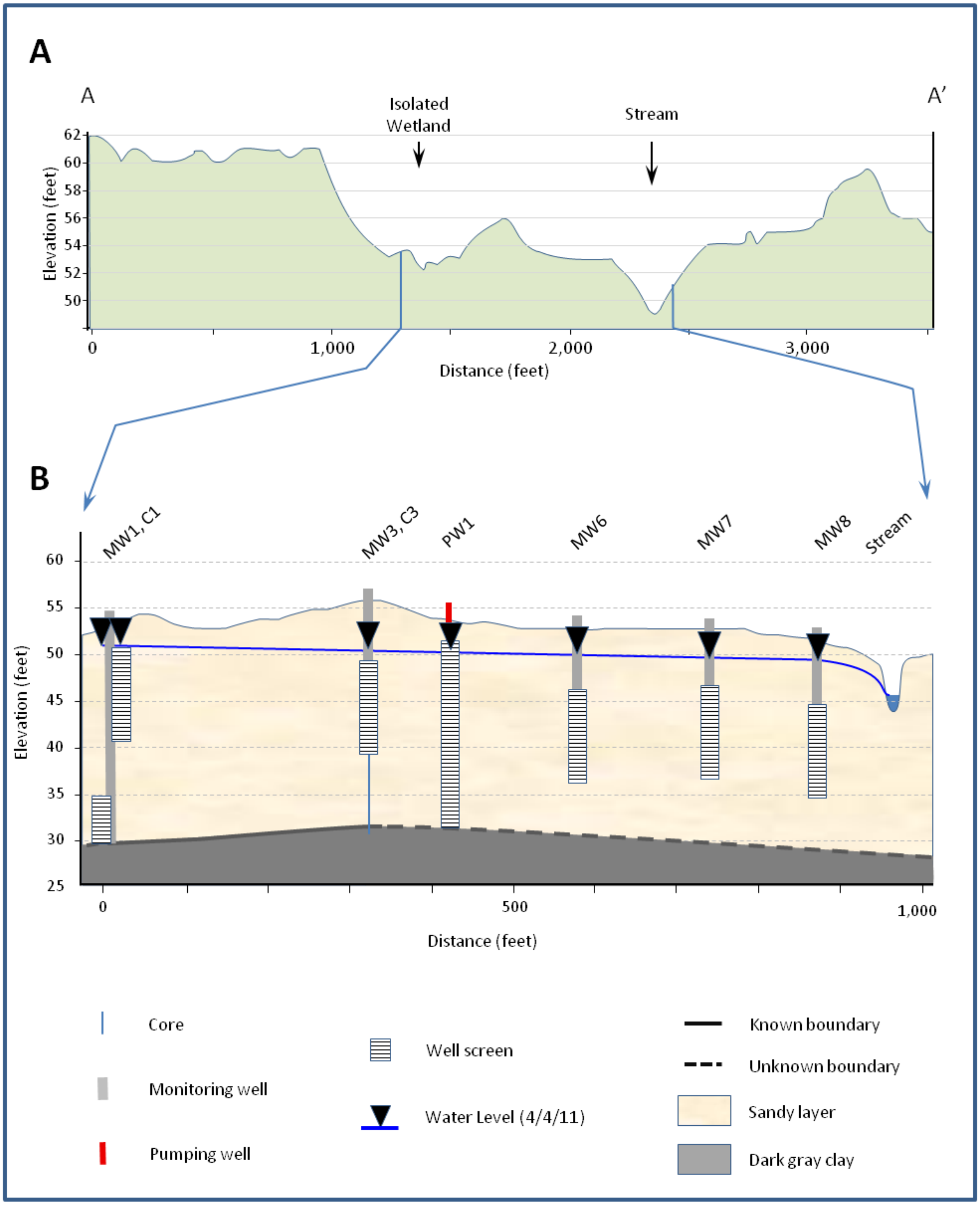


Figure 44. Site BL7 profiles along transect A-A' in Figure 43. A. Topographic profile based on LIDAR elevation data. B. Stratigraphic cross-section along a portion of the transect. Stratigraphy based on coring data.

**Bladen 9 -** Six cores were obtained as shown in Figure 45. As indicated in the cross-section (Figure 46) there are two units present, a surficial sand unit containing three lithologies and a lower dark gray unit containing two lithologies. The three lithologies in the surficial sand unit are the encompassing sand unit, a zone of cementation, and an extensive muddy dark brown sand. The two lithologies in the lower dark gray unit are a hard, dry, dark gray clay with very fine sand laminae and a dark gray sand. The units will be described in the order just listed. The surficial sand unit is 25' to 30' thick. The encompassing sand unit lithology consists of medium to coarse sand. Gravel is present below approximately 18' bls, either scattered pebble-sized gravel or in layers up to a few inches thick. Granule sized gravel is present only in the thicker gravel beds. There is pebble sized gravel at the base of this unit in all cores. In core C3, the southernmost core, a quartz cobble was encountered. While the upper 18' are somewhat sorted into laminae and beds, grain size sorting into beds, laminae and graded beds are distinct below 18'. Organic material is generally present near the top of each core, decreasing very quickly in the first few feet. The sand is sub-angular in the upper six feet and rounding increases with depth. The mineral content is mostly quartz with the occasional feldspar and the very rare occurrence of unidentified heavy minerals. The lower few inches of this unit often has clay balls, gravel, lignite, mica, and an unidentified green mineral.

A zone of cementation occurs at a depth of 6' to 9'. The zone consists of medium to coarse muddy sand, with sub-rounded sand grains and dark brown to black in color. The cemented nodules do not respond to a magnet. Cemented nuggets were recovered from the IW core (C1) and the more distant upland core (C6), but in the cores at the upland edge of the IW (C2, C3, C4, and C5) one or more coherent cemented layers were found. This layer appears to form a doughnut around the IW. At one core location (C5) the Geoprobe© could not penetrate the cemented layer and the core hole had to be abandoned and restarted several yards away (C5A). The cemented layers are probably examples of a lithified sand that many local people in the area call "sand rock".

Also at a depth of 6' to 9' is a sediment layer up to five feet thick of muddy, organic rich, dark brown, sub-round, medium to coarse sand. This unit may be a buried soil layer or may be a result of local hydrology created by the cemented zone. The sand is rounder than the lighter colored, better sorted sand above and below this unit. There is insufficient coring data to discern the lateral extent of this unit.

The lowermost unit under a portion of this site is the typical hard, dry, dark gray clay with very fine sand laminae that was found throughout the sites in Bladen County. In the westernmost core (C4), the clay unit was encountered 10' to 15' deeper than in cores C1,C 2, C3 and C5. The upper medium to coarse sand unit ended at 28.7' bls with a layer of coarse sand and pebble sized gravel. The lowermost 13 feet of core C4 were mica and lignite rich and included beds of medium and coarse sand with lignite laminae, clay balls, silt balls, and clay chips. In the northernmost core (C6), the hard, dry, dark gray clay was not encountered and coring was discontinued at 42.5' bls. The surficial sand unit ended at 25.7' bls with a layer of ½" diameter gravel. The lowermost 17 feet of this core (25.7' to 42.5') was fine sand rich in mica and lignite. Lignite occurred as both small pieces in laminae and as large chunks. There were clay laminae, clay rip-up and clay balls. An unidentified green mineral was observed. The overall color was a dark greenish gray. The lowermost units in cores C4 and C6 are thought to be a different facies of Cretaceous age sediment than seen in other cores at this site.

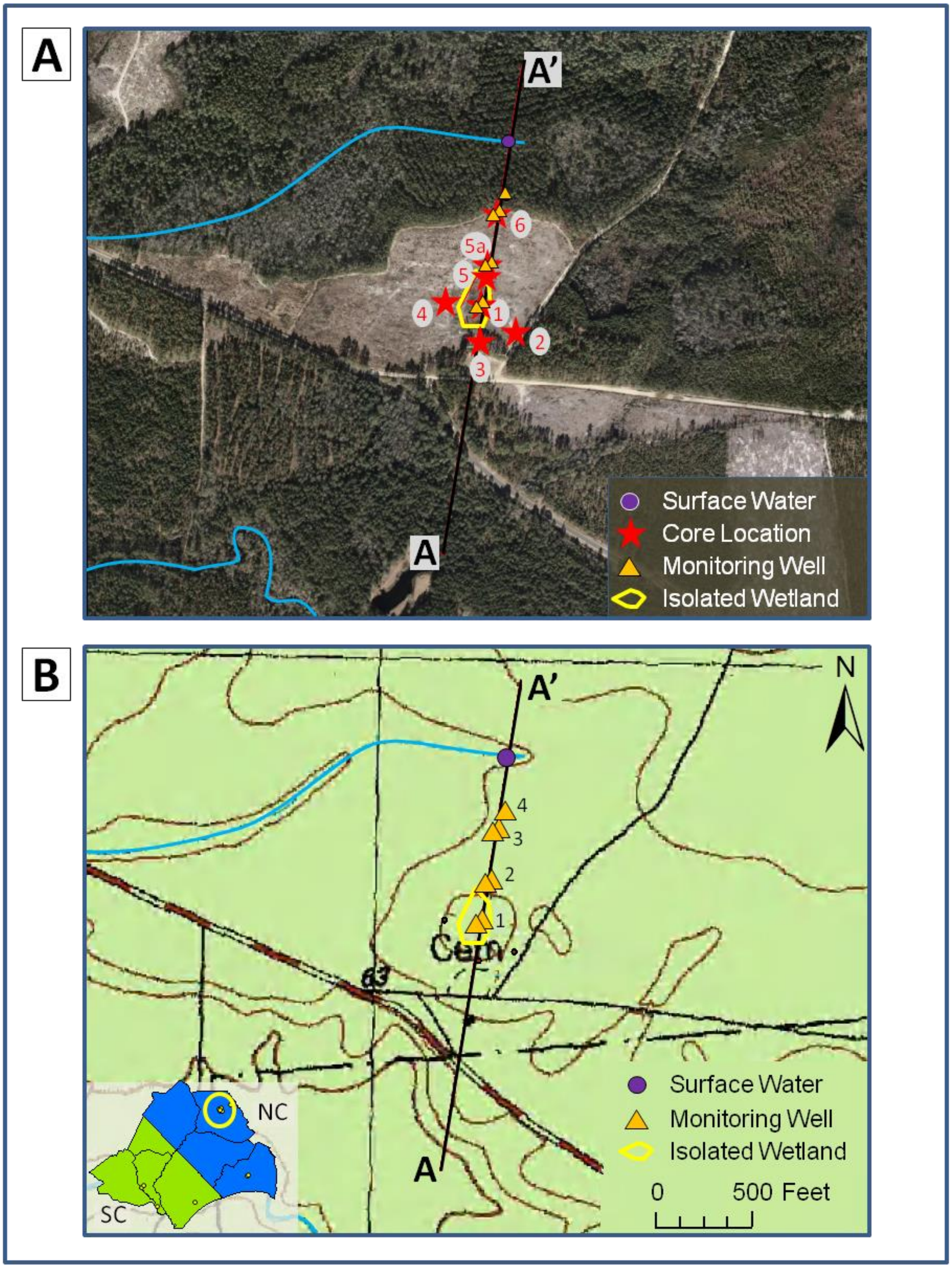


Figure 45. Site BL9: Location of wells and topographic profile (A-A') and stratigraphic cross-section lines. A. True Color aerial photograph. Core locations are numbered. B. USGS Topographic Map. Monitoring well locations are numbered.

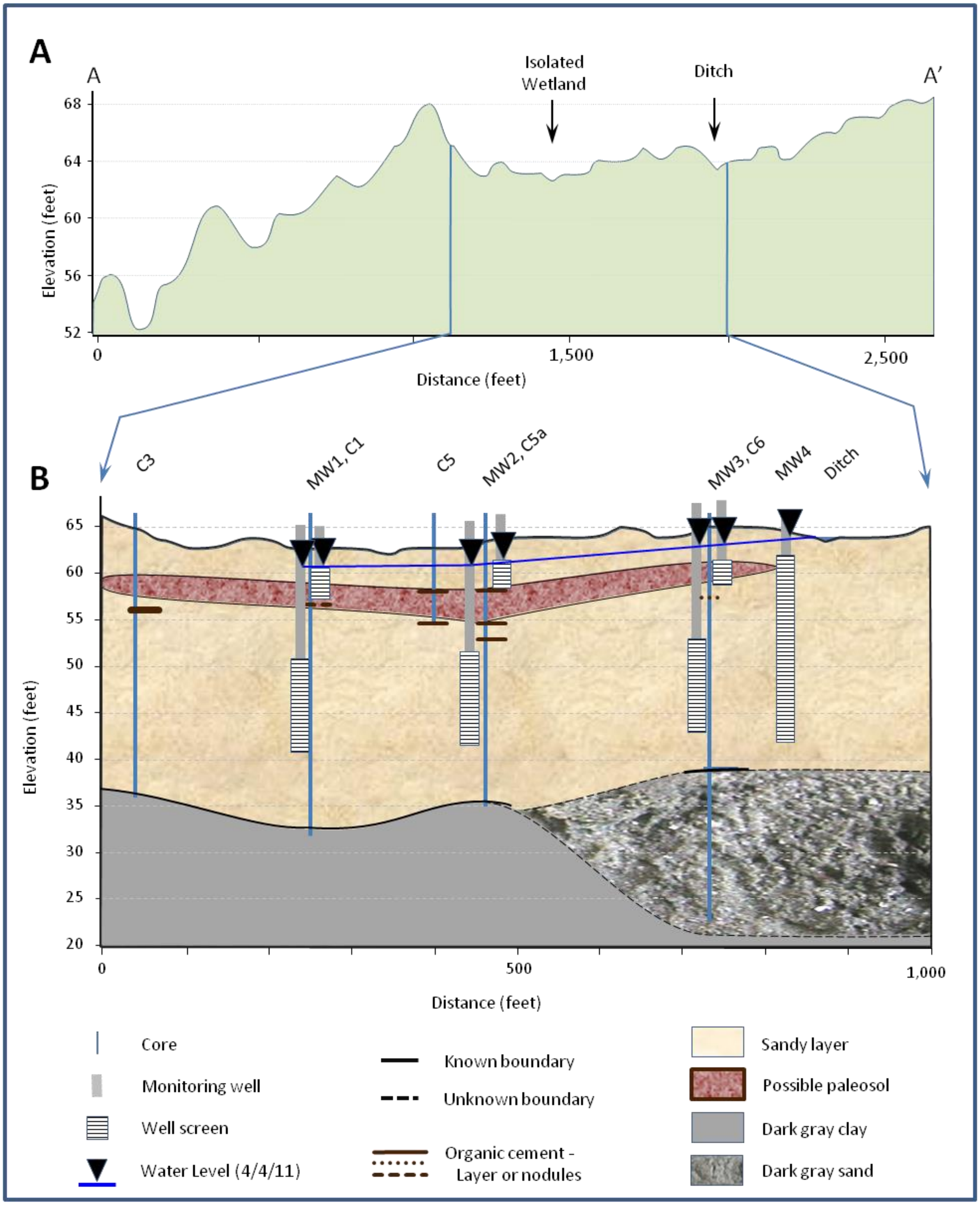


Figure 46. Site BL9 profiles along transect A-A' in Figure 45. A. Topographic profile based on LIDAR elevation data. B. Stratigraphic cross-section along a portion of the transect. Stratigraphy based on coring data.

**Bladen 17 -** Eight cores were obtained as shown in Figure 47. Cores and wells were placed to determine whether there would be differences in stratigraphy, water chemistry, or flow direction in this long, narrow IW As indicated in the cross-section (Figure 48), the stratigraphy is different than that in the cluster of sites near Jones Lake. There are four primary lithologic units. From uppermost to lowermost, there is a silty sand, which occasionally encompasses a silt layer or a buried soil layer; two distinct units of graded bedding; and the same dark gray unit seen throughout Bladen County. The units will be described in the order just listed, from the uppermost to lowermost units.

The uppermost unit is a very silty medium sand varying from 6' to 15' thick. The sand is sub-angular, poorly sorted, gray to brown and contains primarily quartz with some feldspar and unidentified heavy minerals. Cores C3, C5 and C7 contain an apparent buried soil layer from one to four feet thick, beginning at a depth of approximately six feet bls. Core C2 has a dense dry silt layer at a similar depth.

The second unit from the top exhibits various bedding structures: fining upward from gravel to medium sand, coarsening upward from medium sand to gravel, and laminae and beds well sorted by grain size. The gravel is primarily granule sized but there are pebbles sprinkled throughout. The grains are sub-angular to sub-round. The color is primarily yellowish brown. The mineral content is mostly quartz with the occasional feldspar and unidentified heavy minerals as well as the very rare occurrence of mica and wood fragments.

The third unit contains similar grain sizes and sedimentary structures as layer two, but there is less gravel and the mineralogy is different. Mica and lignite are present in significant amounts, clay balls, clay rip-up clasts and silt balls are present, and there are unidentified pink and green mineral grains in addition to the quartz, feldspar and unidentified heavy minerals.

The lowermost unit in all cores at this site is the hard, dry, dark gray clay found at the other Bladen County sites. This unit is presumed to be Cretaceous sediment.

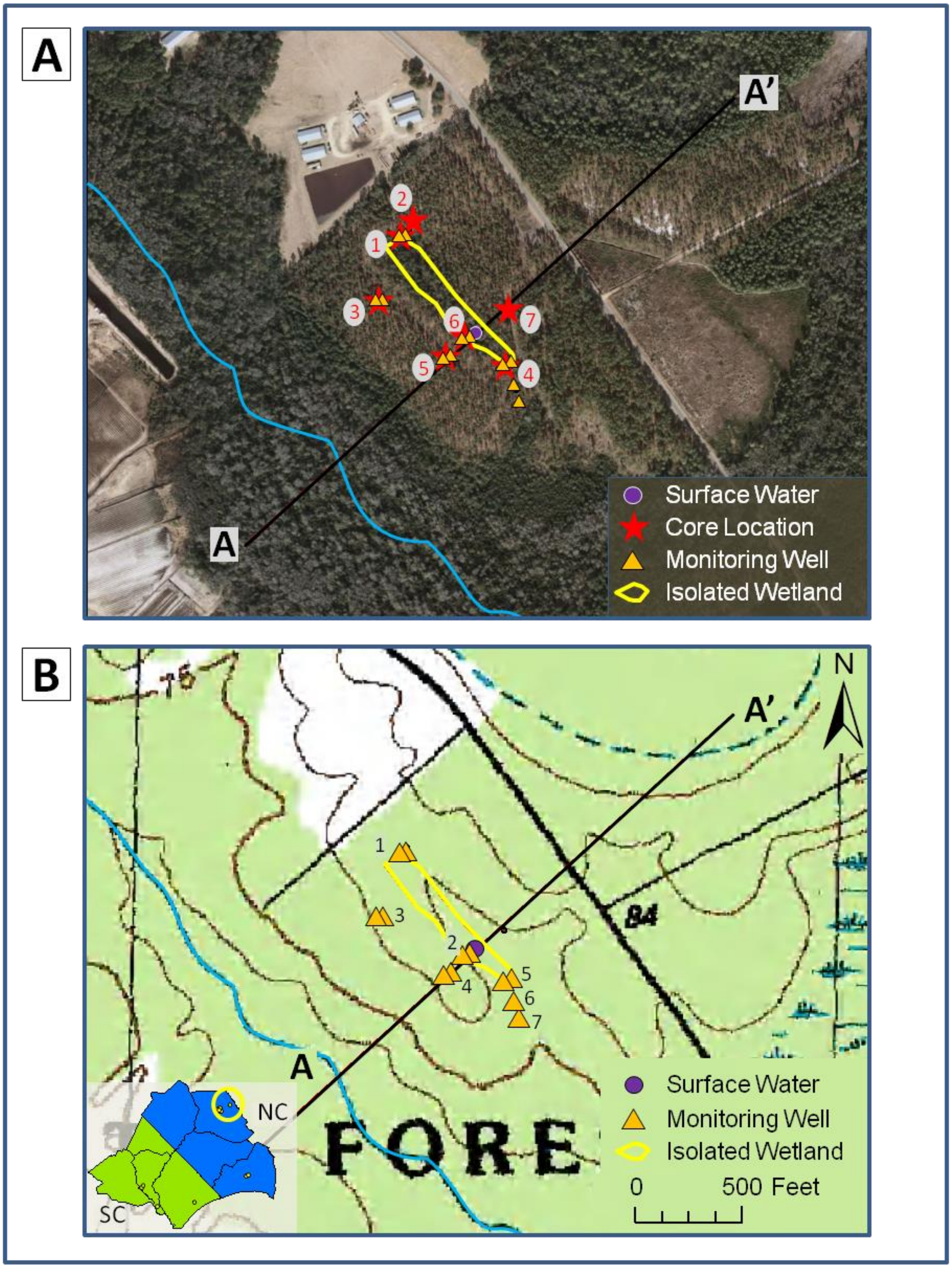


Figure 47. Site BL17: Location of wells and topographic profile (A-A') and stratigraphic cross-section lines. A. True Color aerial photograph. Core locations are numbered. B. USGS Topographic Map. Monitoring well locations are numbered.

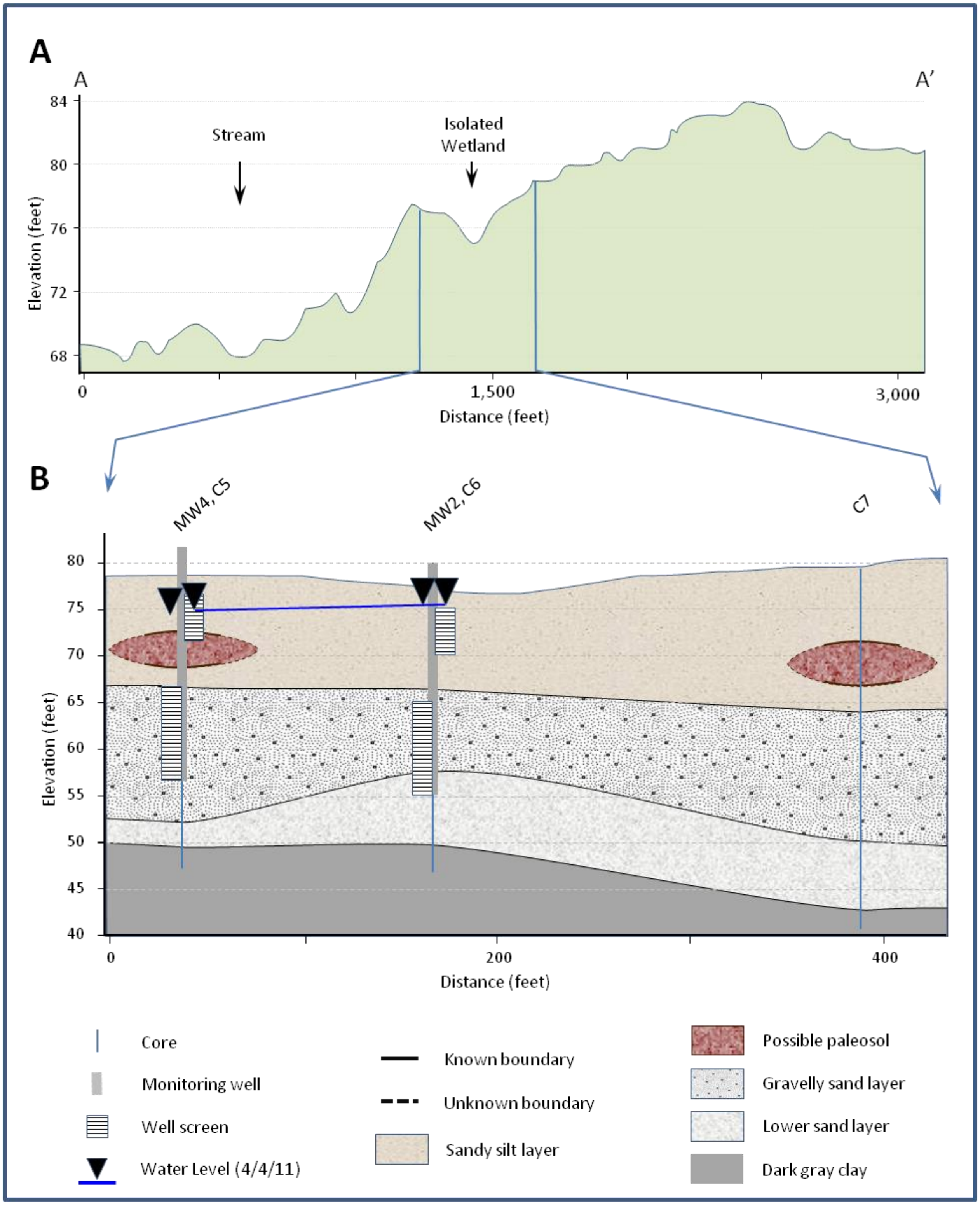


Figure 48. Site BL17 profiles along transect A-A’ in Figure 47. A. Topographic profile based on LIDAR elevation data. B. Stratigraphic cross-section along a portion of the transect. Stratigraphy based on coring data.

**Green Swamp 1 -** Four cores were obtained as shown in Figure 49. This site is pocked with rounded depressions presumed to be sinkholes, indicating that something beneath the surface has collapsed, creating some alteration of the original lithology. In order to determine the effect of this alteration on the lithology and therefore the hydrology, one upland core was located at the base of a dry sinkhole and one was located at the highest point on the transect at a location where the lithology was unlikely to be altered by collapsed sediments. As indicated in the cross-section (Figure 50), the effect of the collapse was to lower the entire section leaving the lithology intact but at a lower elevation in the area of that sinkhole.

The surficial aquifer is quite thick in this location. Coring was discontinued at 65’ bls without reaching the base of the surficial aquifer. The shallow hydrology affecting the IW could be understood with the knowledge gained in the upper forty or fifty feet, thus continuing to core below 65’ was beyond the scope of this project and would not have significantly increased our knowledge of the hydrogeologic conditions affecting the wetlands at this site. The surficial aquifer is a layered system of three units, an upper sand unit, an interbedded sand and clay unit and a lower sand unit.

The upper sand unit is 9’ to 15’ thick. The grain size of the upper sand is finer here than in Bladen County, and varies from fine to medium sand. The sand is moderately sorted though some silt is present. The sand grains are sub-rounded. Organic material is present at the top of each core, decreasing with depth. The mineral content is primarily quartz with rare unidentified heavy minerals and very rare feldspars. The color is brown-gray though where organics are present the color is golden brown to black. There are concentrations of hardened sand at approximately 7’ bls in cores C1 and C2.

The middle unit is 9’ to 18’ thick and consists of interbedded sand and clay laminae (Figure 51). The sand layers are 1” to several feet thick consisting of fine sand. The overall color is yellow-gray and olive-gray. The clay laminae are 2” to 12” thick and olive gray in color. The mineral content is primarily quartz with some unidentified heavy minerals and the rare occurrence of mica. In each core there were layers of “clay chips” (Figure 52) in a zone approximately 4’ thick. Individual clay chips were approximately ¼” thick, hard but breakable with sharp edges when broken, and olive gray in color.

The lowermost layer encountered was a fine to medium sand, which was distinguished by the presence of wood fragments and unidentified heavy minerals, the increasing presence of silt, and the lack of clay laminae. There is very rare gravel and only below 40’ bls. This unit was saturated and gray to brown in color.

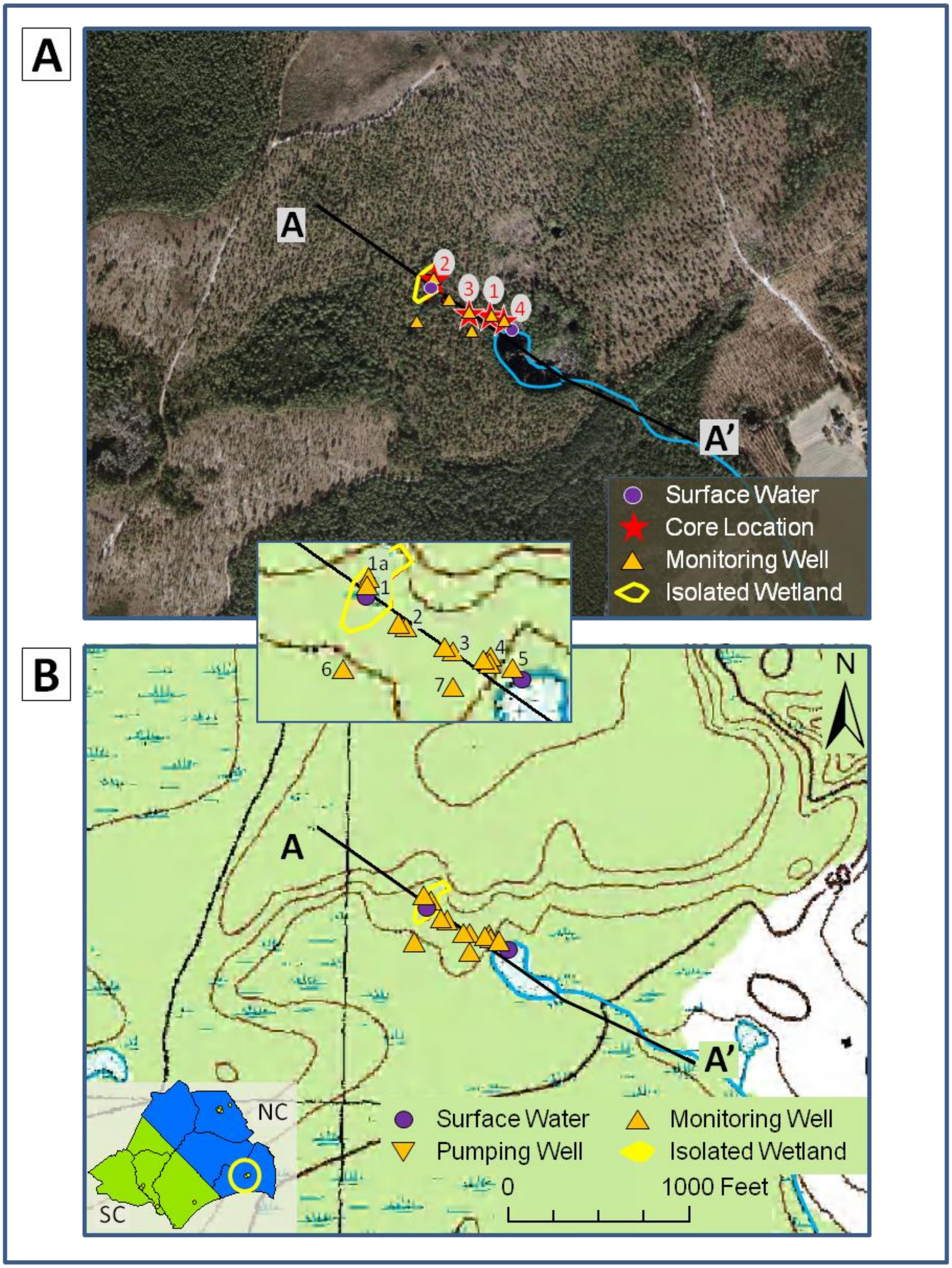


Figure 49. Site GS1: Location of wells and topographic profile (A-A') and stratigraphic cross-section lines. A. True Color aerial photograph. Core locations are numbered. B. USGS Topographic Map. Monitoring well locations are numbered.

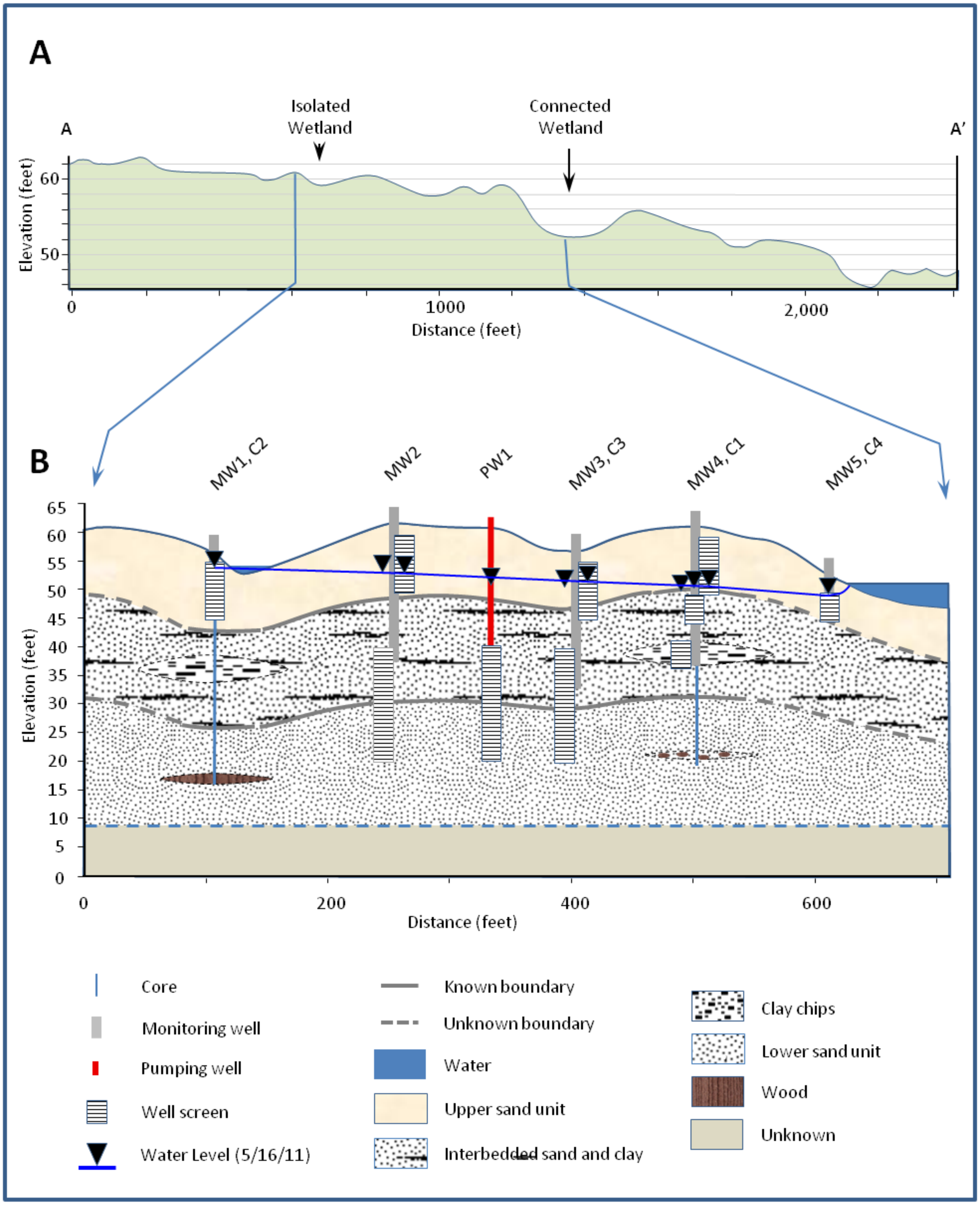


Figure 50. Site GS1 profiles along transect A-A' in Figure 49. A. Topographic profile based on LIDAR elevation data. B. Stratigraphic cross-section along a portion of the transect. Stratigraphy based on coring data.

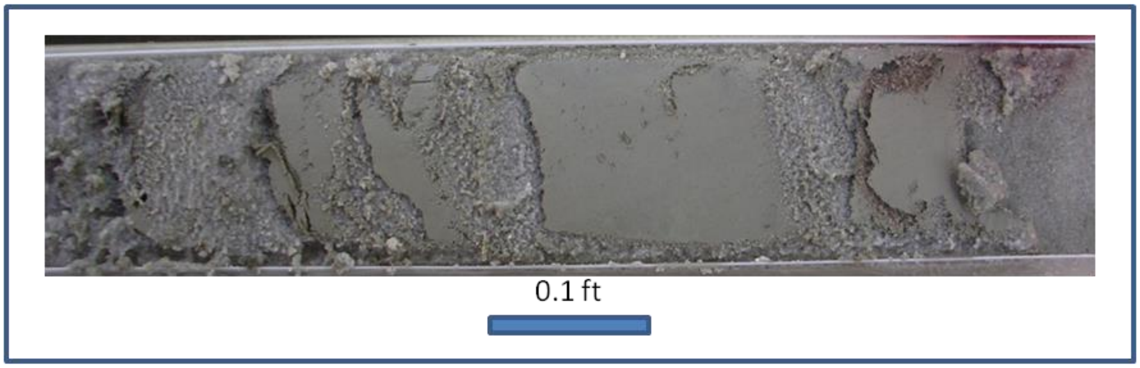


Figure 51. Interbedded sand an clay from core GS1-2 , (27.1’ – 27.9’ bls)

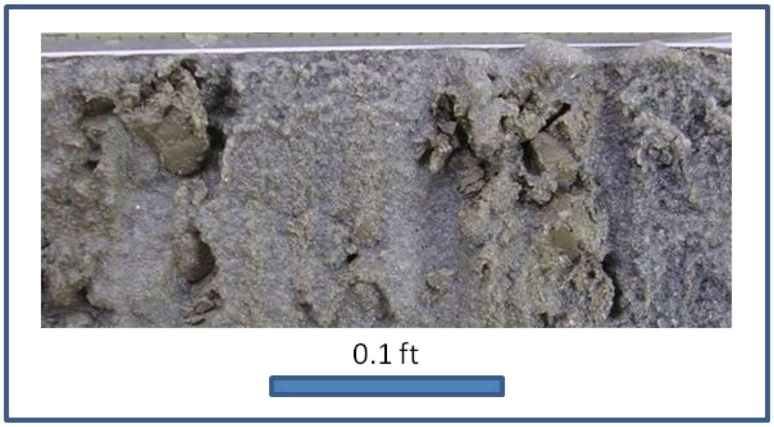


Figure 52. Clay chips from core GS1-2 , (18.4’ – 18.7’ bls)

**Green Swamp 2 -** Three cores were obtained as shown in Figure 53. As indicated in the cross-section (Figure 54), the lithology here is quite similar to that at GS1 though there are no sinkholes at this site. The surficial aquifer at GS2 is a layered system of three units, an upper sand unit similar to that at GS1, an interbedded sand and clay unit, and a lower sand unit. The units will be described in the order just listed.

The upper sand unit is 10’ to 11’ thick and very similar to the upper sand unit at GS1. The grain size is primarily medium though it varies from fine to medium sand, there is no gravel, and the sand is moderately sorted and grains are sub-rounded. Organic material is present at the top of each core and in the upland core organic material decreases quickly. The core adjacent to the slough (C1) was organic rich in the upper 11’ and contained a buried hydric soil from 3’-4’ bls. The mineral content is primarily quartz with rare unidentified heavy minerals and very rare feldspars. The color is grayish brown to yellow brown.

The interbedded sand and clay unit is different from the corresponding unit at GS1 in three ways. There are mudballs but no clay chips at GS2, the sand layers are thinner and the clay is more predominant. The sand layers are thin laminae up to 1’ thick, but are predominantly 1” to 3” thick and consist of fine sand. The clay layers are from 1” to 2’ thick. The mineral content is primarily quartz with some unidentified heavy minerals and the rare occurrence of mica.

The lowermost unit encountered was a fine to medium sand, which was distinguished by the presence of wood fragments and unidentified heavy minerals, the increasing presence of silt, and the lack of clay laminae. This unit was saturated and greenish gray to gray in color.

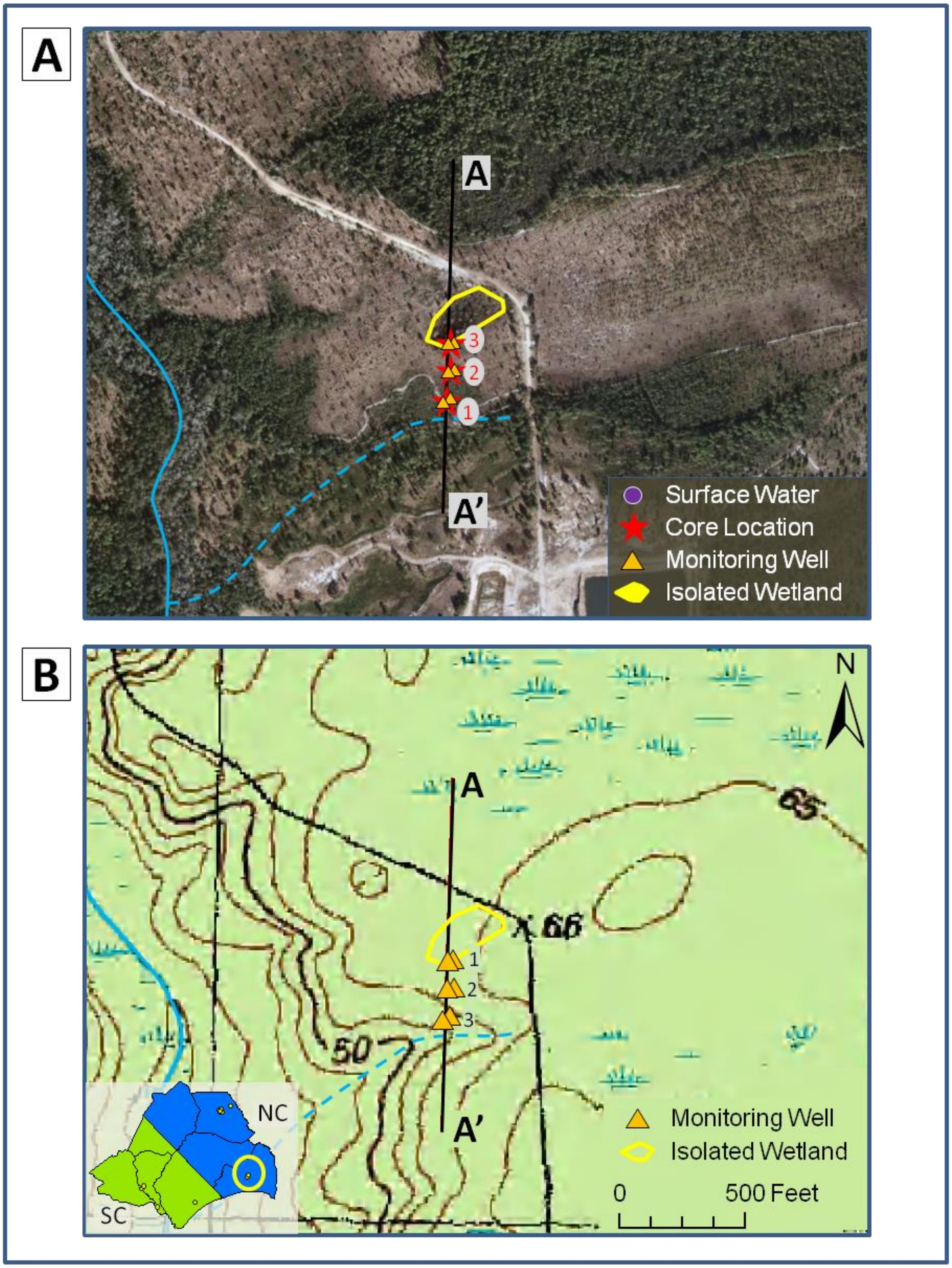


Figure 53. Site GS2: Location of wells and topographic profile (A-A') and stratigraphic cross-section lines. A. True Color aerial photograph. Core locations are numbered. B. USGS Topographic Map. Monitoring well locations are numbered.

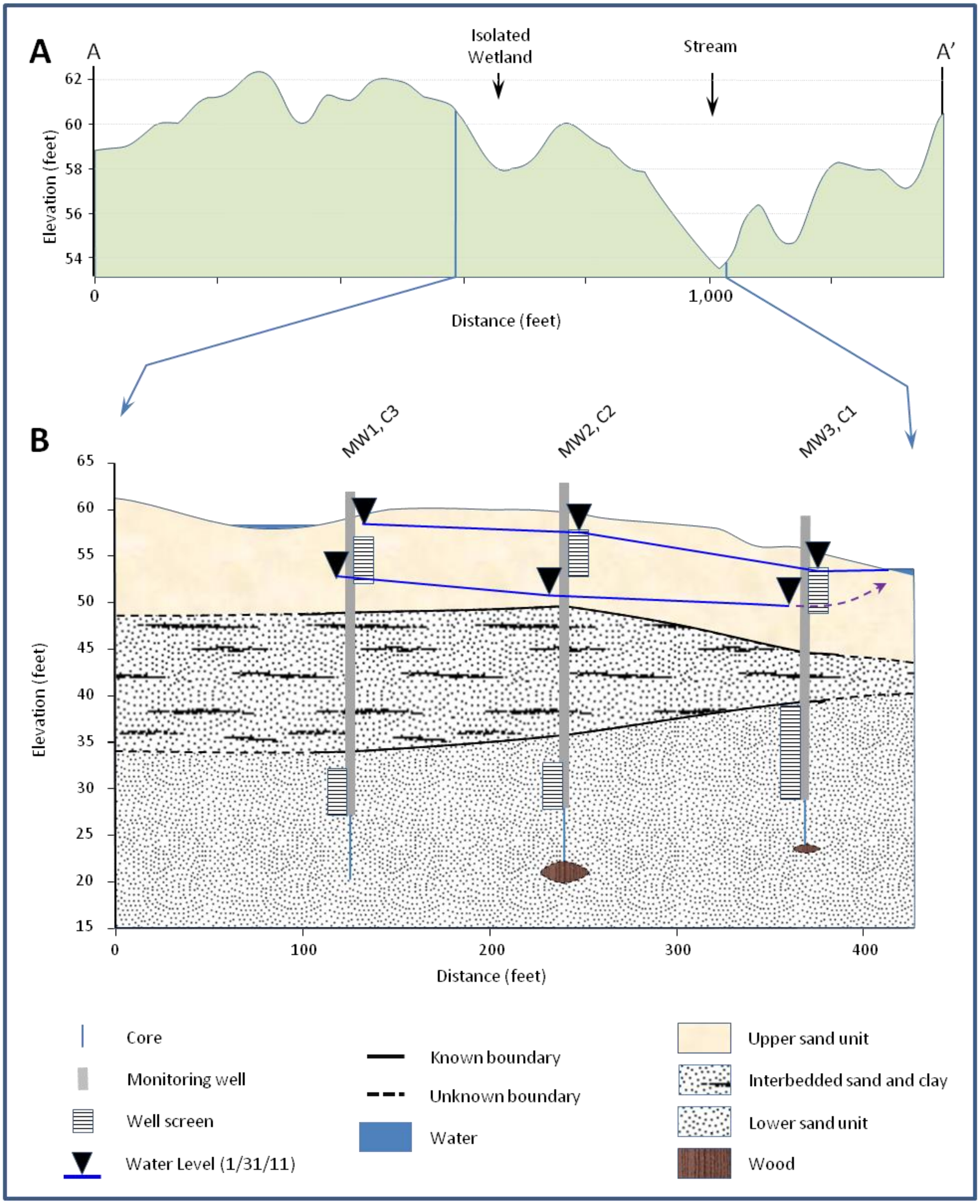


Figure 54. Site GS2 profiles along transect A-A' in Figure 53. A. Topographic profile based on LIDAR elevation data. B. Stratigraphic cross-section along a portion of the transect. Stratigraphy based on coring data.

**MA -** Soil composition at the MA site consists of layers of coarse and medium-sized sand with several areas of inclusions (Figure 55). Both the isolated wetland and the connected wetland contain a surficial layer of clay loam, which acts as an infiltration barrier and increases water retention within the wetlands. Topographic and stratigraphic cross-sections are in Figure 56.

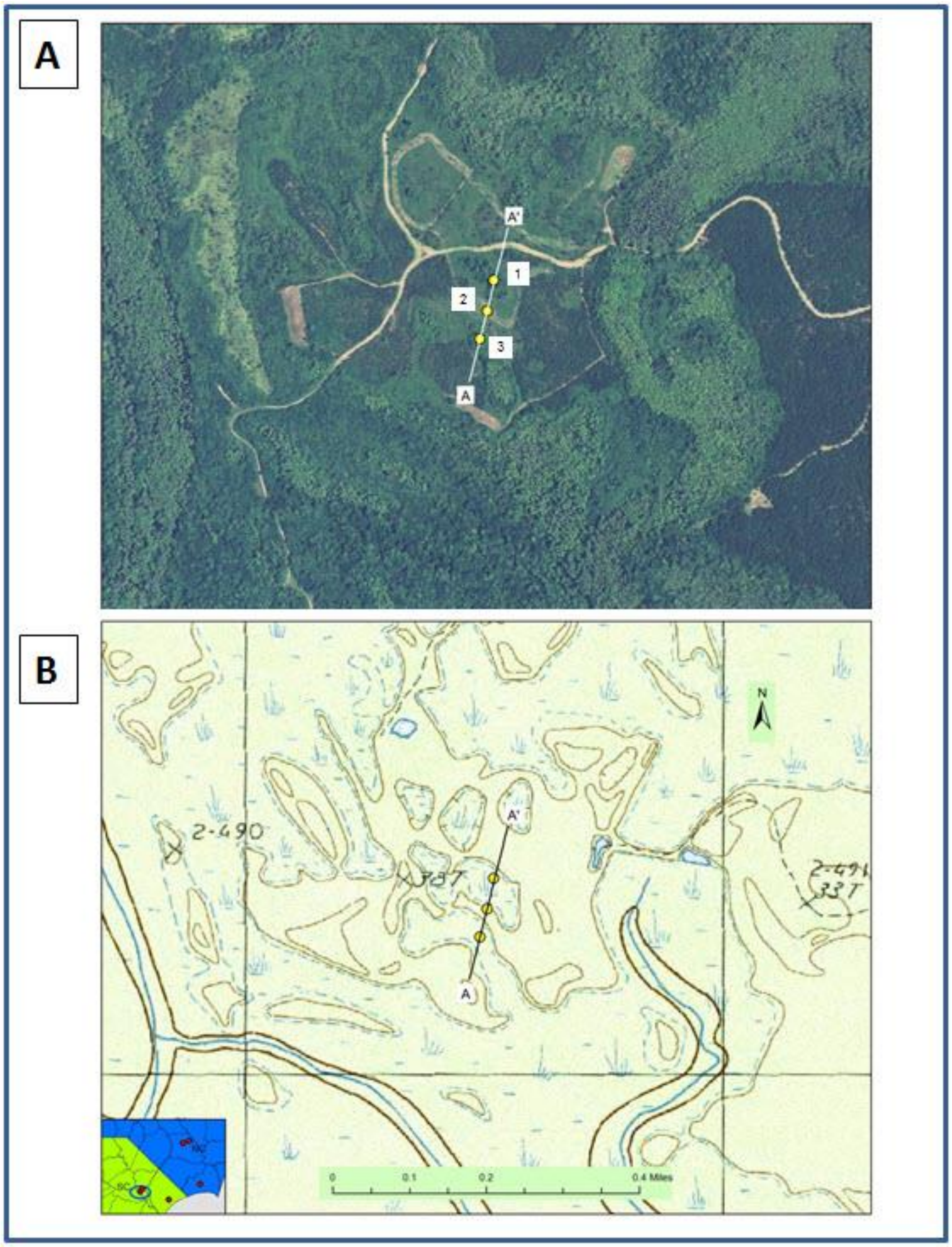


Figure 55 . Site MA: Location of wells and topographic profile (A-A') and stratigraphic cross-section lines. A. True Color aerial photograph. Well locations are numbered. B. USGS Topographic Map.

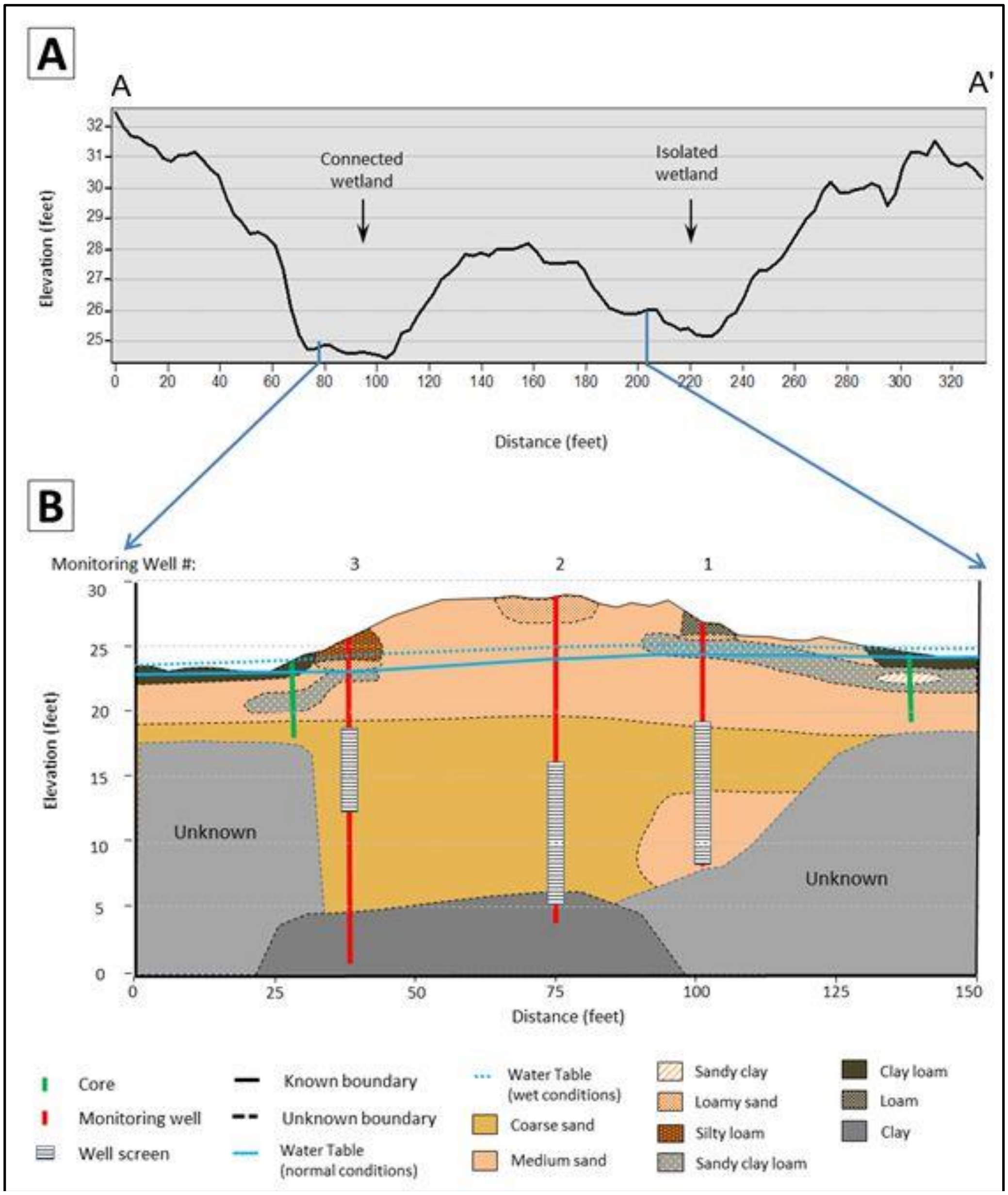


Figure 56. Site MA profiles along transect A-A' in Figure 55.
A. Topographic profile from A to A'. B. Stratigraphic cross-section from the isolated wetland to the connected wetland.

**MF -** The MF site (Figure 57) contains a layer of medium grain-sized sand followed by a layer of sandy loam, and then another layer of medium grain-sized sand. Soil cores indicated the presence of sandy clay and loamy sandy clay at the location of well 4 and well 3, respectively. A surficial layer of loam exists within the isolated wetland, while a surficial layer of clay loam exists within the connected wetland. Topographic and stratigraphic cross-sections are in Figure 58.

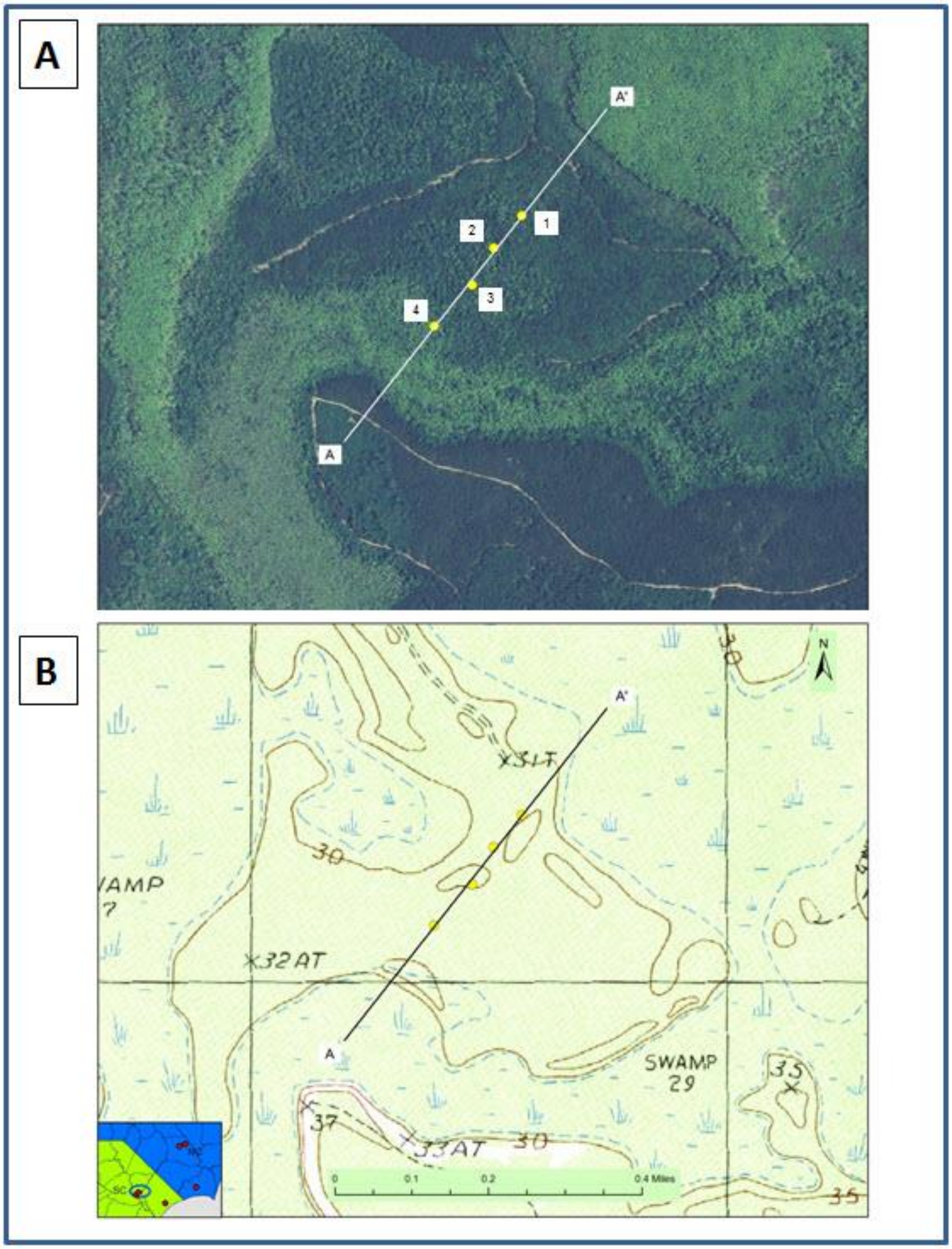


Figure 57. Site MF: Location of wells and topographic profile (A-A') and stratigraphic cross-section lines. A. True Color aerial photograph. Well locations are numbered. B. USGS Topographic Map.

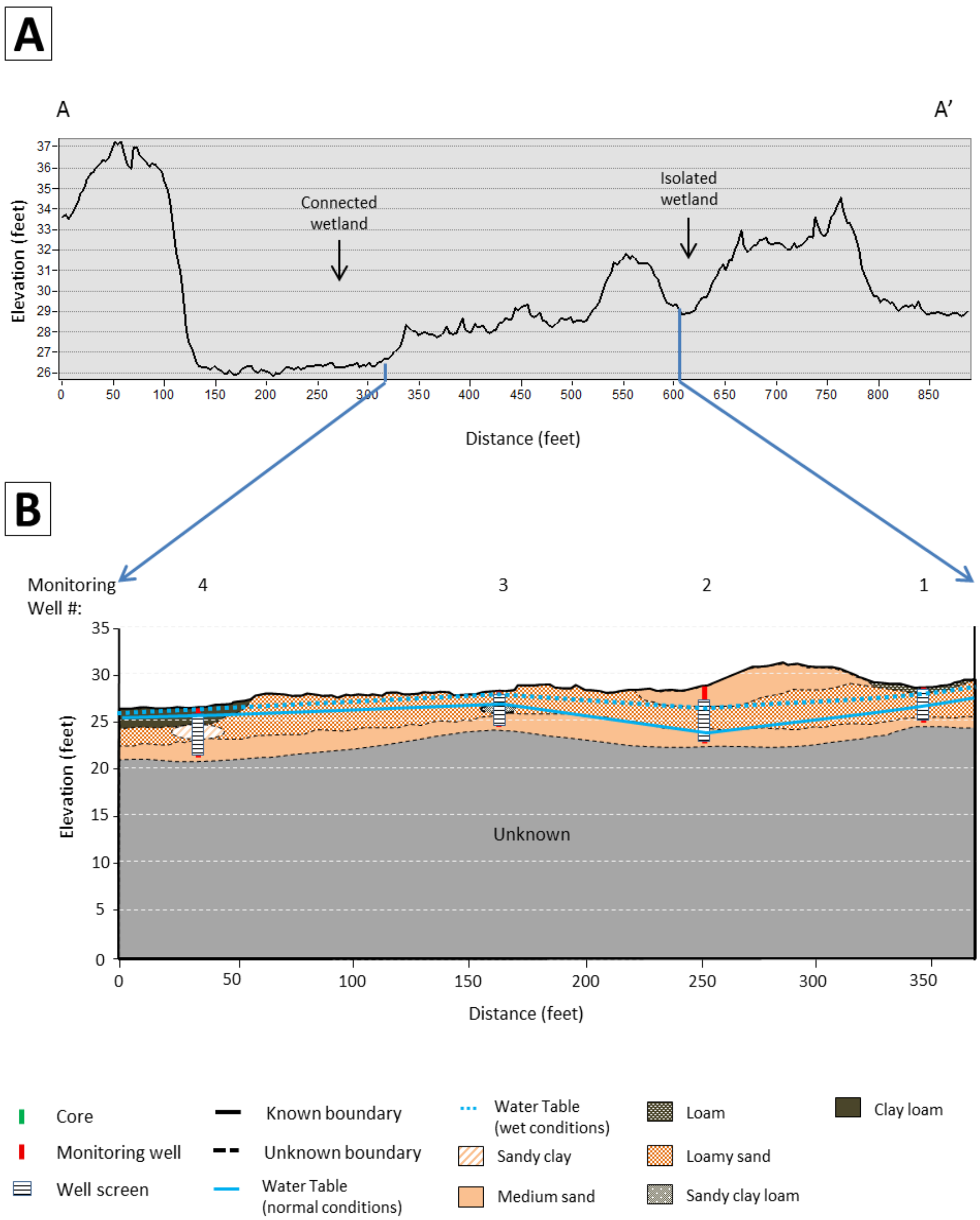


Figure 58. Site MF profiles along transect A-A' in Figure 57. A. Topographic profile from A to A'. B. Stratigraphic cross-section from the isolated wetland to the connected wetland.

**LB -** Soil profiles at the LB site in Horry County, SC indicate layers of medium grain-sized sand and fine grain-sized sand, with the presence of loamy sand inclusions (Figure 59). A surficial silty loam layer exists within the connected wetland and the isolated wetland. At this site, groundwater in the surficial aquifer flowed from the isolated wetland to the connected wetland. Topographic and stratigraphic cross-sections are in Figure 60.

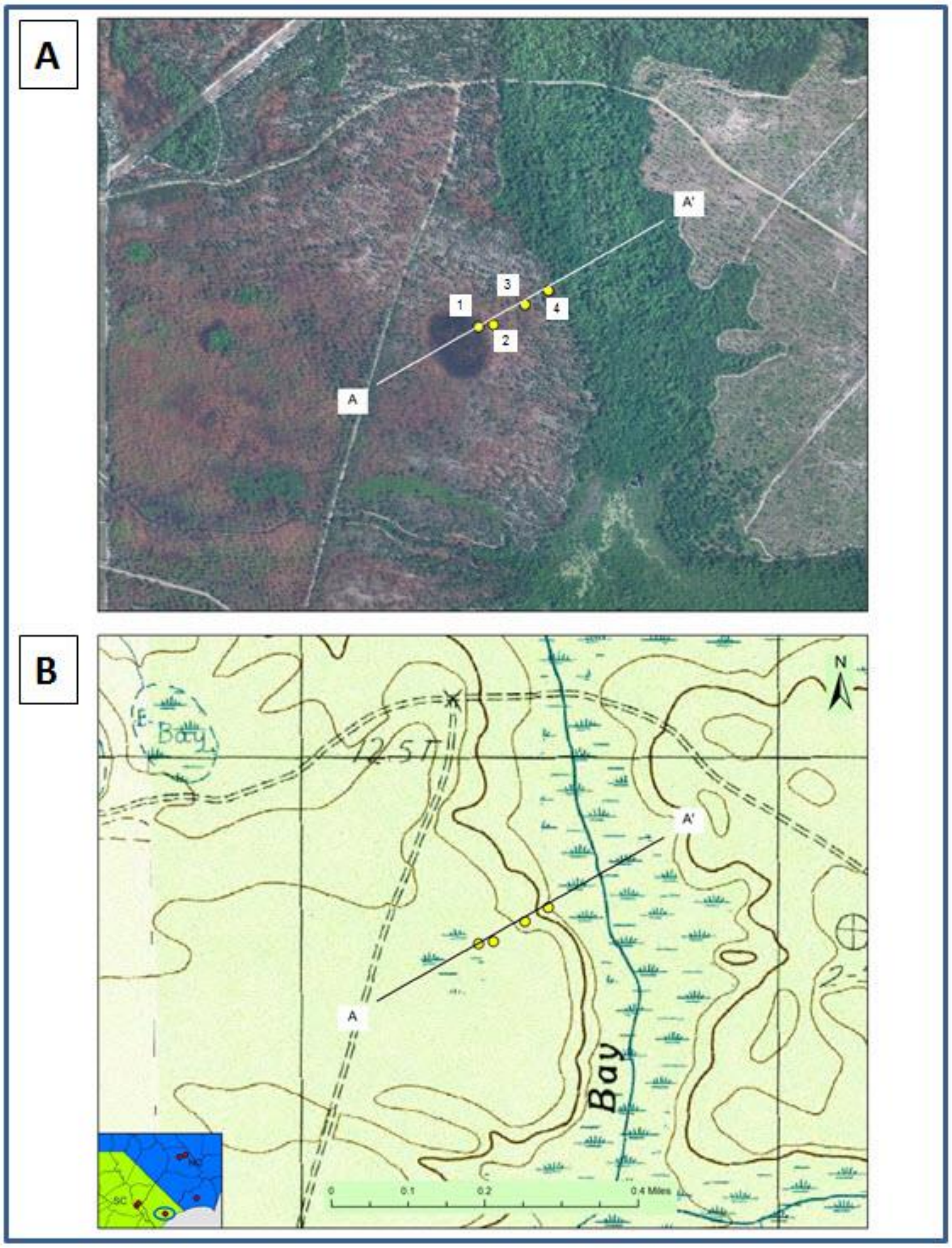


Figure 59. Site LB: Location of wells and topographic profile (A-A') and stratigraphic cross-section lines. A. True Color aerial photograph. Well locations are numbered. B. USGS Topographic Map.

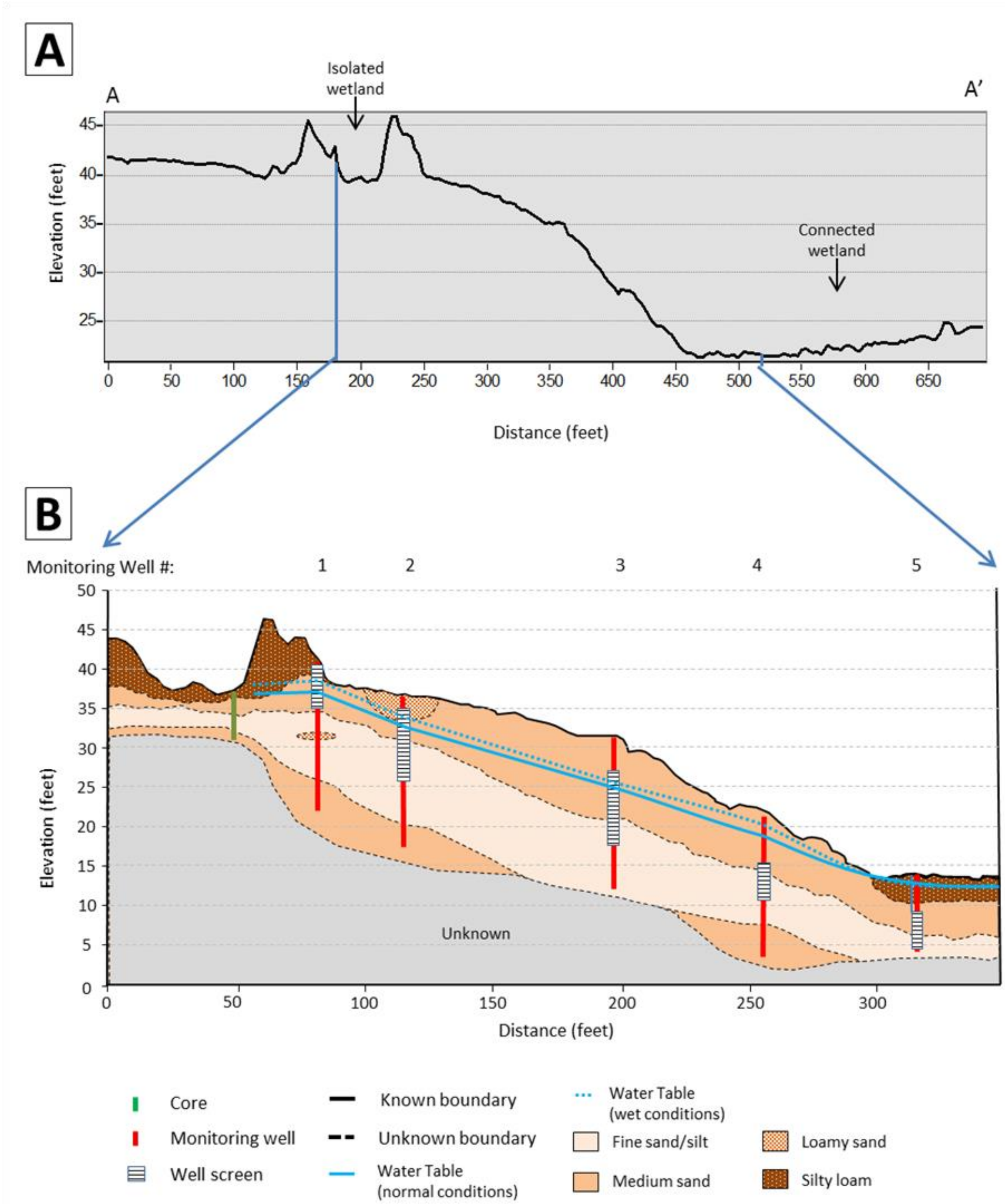


Figure 60. Site LB profiles along transect A-A' in Figure 59. A. Topographic profile from A to A'. B. Stratigraphic cross-section from the isolated wetland to the connected wetland.

**Geology and Sediment Core Summary Discussion**

The initial conceptual model developed by the investigators was that the isolated wetlands would be directly underlain by a clay layer. Instead, all of the IW's in NC are underlain by approximately twenty to forty feet of sand, overlying a hard dry clay. Within that basic framework of sand overlying clay, coring results indicate several stratigraphic conceptual models. Silt bodies of varying sizes were found, some fairly small occupying a limited area in or near the IW (BL1, BL2), and some quite large, occupying much of the aerial extent of an individual study site (BL6). One site, BL9, had an area of organic cementation surrounding the IW. The sites in Brunswick County (GS1 and GS2) had a layer of interbedded sand and clay sandwiched between sand layers. While limited mineral identification was performed in the field, visual observations indicate that the sand is primarily quartz with small amounts of feldspar and heavy minerals. The heavy minerals are most likely epidote and hornblende (Owens 1990, Weems 2011). Very rarely there is an unidentified green mineral, most likely chlorite, indicating immature detrital sediment (Selley 1988).

All eleven sites lay in areas identified as Pleistocene terrace deposits on geologic maps by Owens (1990) and Weems (2011). The sand and silt units comprising the upper 20 to 40 feet of the cores are fluvial or deltaic in origin and unconformably overlay the Cretaceous sediments at the base of each Bladen County core. Sites BL17, GS1 and GS2 are located on a higher, older Pleistocene terrace than the other Bladen County sites, explaining their different lithology. At several sites (BL7, BL9, BL17 and GS2), there is evidence of buried soil zones. These zones appeared quite similar to the hydric soil at the surface of the wetland cores – dark brown in color and with sand grains coated with organic material. It is possible that a wetland was covered by windblown sand during a particularly dry time period (Weems 2011) to produce this phenomenon in the soil/sediment. Wood found at the base of the sand units is likely to be on the order of 10,000 to 450,000 years old (middle to late Pleistocene Epoch) while lignite found in the underlying dark gray unit is likely to be 80+ million years old (Upper Cretaceous Period) (Owens 1990; Weems 2011). No macrofossils were observed. Further analyses necessary to confirm these dates and environments of deposition are beyond the scope of this project but would include dating the buried soils, wood and lignite using Carbon 14 methods, a microsope analysis of heavy minerals, and an examination of microscopic fossils.

### 3.2.2.2 Differential Level Survey Results

The elevation of a measuring point on the top of the well casing of each PVC monitoring well were determined as described in section 2.2.2.3. The results for wells in both states are presented in Table 22 and Table 23.

Table 22. Elevations of Water level monitoring locations at the North Carolina sites. (*Surveyed by DWQ staff.)

| Monitoring well | Top of Casing Elevation (feet above NAVD88) | Monitoring well | Top of Casing Elevation (feet above NAVD88) | Monitoring well | Top of Casing Elevation (feet above NAVD88) |
|---|---|---|---|---|---|
| Site BL1 | | Site BL6 (Cont) | | Site BL17 (Cont) | |
| BL1-MW1D | 62.49 | BL6-MW3S | 69.92 | BL17-MW2S | 79.97 |
| BL1-MW1S | 62.34 | BL6-MW4D | 61.22 | BL17-MW3 | 81.89 |
| BL1-MW2 | 64.69 | BL6-MW4S | 61.31 | BL17-MW4D | 81.66 |
| BL1-MW3 | 64.64 | BL6-MW5D | 58.15 | BL17-MW4S | 82.06 |
| BL1-MW4 | 64.39 | BL6-MW5S | 58.04 | BL17-MW5D | 80.92 |
| BL1-MW5 | 66.94 | BL6-Stream* | 57.11 | BL17-MW5S | 80.92 |
| BL1-PW1* | 70.99 | Site BL7 | | BL17-MW6 | 80.31 |
| BL1-MW6D | 67.51 | BL7-Wetland* | 56.5 | BL17-MW7 | 79.51 |
| BL1-MW6S | 67.82 | BL7-MW1D | 56.02 | Site GS1 | |
| BL1-MW7* | 49.8 | BL7-MW1S | 55.90 | GS1-MW1 | 59.59 |
| BL1-Stream* | 40.4 | BL7-MW2 | 58.10 | GS1-MW1A* | 62.25 |
| BL1-MW8 | 64.39 | BL7-MW3 | 59.08 | GS1-IsoWet* | 52.83 |
| BL1-MW9 | 64.46 | BL7-PW1* | 58.15 | GS1-MW2 | 64.38 |
| BL1-Ditch* | 55.24 | BL7-MW6 | 55.89 | GS1-MW2D* | 64.36 |
| BL1-MW10* | 56.28 | BL7-MW7 | 56.70 | GS1-PW1* | 62.62 |
| Site BL2 | | BL7-MW8 | 54.49 | GS1-MW3 | 59.55 |
| BL2-MW1D | 56.72 | BL7-MW8S | 52.00 | GS1-MW3D* | 59.74 |
| BL2-MW1S | 56.71 | BL7-Stream* | 44.27 | GS1-MW4D | 63.79 |
| BL2-MW2D | 58.81 | Site BL9 | | GS1-MW4i | 63.88 |
| BL2-MW2S | 58.95 | BL9-MW1D | 65.18 | GS1-MW4S | 63.76 |
| BL2-MW3 | 59.12 | BL9-MW1S | 65.04 | GS1-MW5* | 55.34 |
| BL2-MW4 | 57.77 | BL9-MW2D | 67.11 | GS1-MW6 | 62.17 |
| BL2-MW5 | 56.48 | BL9-MW2S | 67.12 | GS1-MW6-2 | 61.72 |
| BL2-MW6 | 49.53 | BL9-MW3D | 68.19 | GS1-MW7 | 62.51 |
| BL2-Stream* | 32.26 | BL9-MW3S | 68.05 | GS1-ConWet* | 48.25 |
| Site BL6 | | BL9-MW4 | 67.18 | Site GS2 | |
| BL6-MW1D | 67.87 | BL9-Ditch* | 67.78 | GS2-MW1D | 62.39 |
| BL6-MW1S | 67.70 | Site BL17 | | GS2-MW1S | 62.15 |
| BL6-Wetland* | 68.24 | BL17-MW1D | 80.78 | GS2-MW2D | 62.08 |
| BL6-MW2D | 67.46 | BL17-MW1S | 80.56 | GS2-MW2S | 62.09 |
| BL6-MW2S | 67.58 | BL17-MW2D | 79.87 | GS2-MW3D | 56.59 |
| BL6-MW3D | 69.97 | | | GS2-MW3S | 56.55 |

Table 23. Elevations of water level monitoring locations at the South Carolina sites. Surveyed by USC and DWQ staff.

| Monitoring well | Top of Casing Elevation (feet above NAVD88) |
|---|---|
| **Site MA** | |
| MA01 | 31.86 |
| MA02 | 32.00 |
| MA03 | 30.68 |
| **Site MF** | |
| MF-01 | 33.62 |
| MF-02 | 35.39 |
| MF-03 | 33.01 |
| MF-04 | 32.35 |
| **Site LB** | |
| LB-01 | 43.83 |
| LB-02 | 44.28 |
| LB-03 | 39.53 |
| LB-04 | 31.40 |

### 3.2.2.3 Hydrological Monitoring Well Sampling Results and Discussion

**Hydrology Monitoring Well Sampling Site Descriptions**

After completion of the field reconnaissance work described in Section 2.2.1, eleven sites were selected for further hydrologic and water quality study, eight in North Carolina and three in South Carolina. Wells were installed along a transect from the IW to the receiving water body based on the results of stratigraphic analysis described in Section 3.2.2.1. Water levels were monitored as described in Section 2.2.2.4. There are discrete water level data (DWLD) for all wells and continuous water level data (CWLD) for select wells at each site as explained in section 2.2.2.4. Surface water level monitoring stations were installed in select locations late in the study. Note that wells were installed in stages and water level monitoring instruments were occasionally moved to different monitoring locations. This section describes the results of hydrologic monitoring at each site that was selected for detailed investigation.

**Bladen 1**- BL1 is a large site, approximately 1 mile across from Jones Lake Drain to Turnbull Creek with the IW approximately in the middle (Figure 37). This site is intersected by an extensive network of deeply incised drainage ditches installed prior to 1950 (Michael Chesnutt, pers. comm. 2012). The ditch network does not intersect the IW but conducts water from the site to JLD and has drained the area such that the water table was never less than four feet bls during the course of this study and the IW is likely only a relict feature. In February 2010, a ditch approximately 580 ft from the IW contained several feet of water draining in a southwesterly direction toward JLD and there was some question as to the direction of groundwater outflow from the IW. Wells were installed as indicated in the site map, Figure 37

Flow direction at BL1 is from JLD through the IW to Turnbull Creek (Figure 61 - A). Drainage out of the IW appears to be in an arc toward both MW4 and MW5. Water table elevation at all wells increases rapidly in response to precipitation and is slow to decline afterward (Figure 61 - B). The hydrograph curves of the two IW wells (MW1S and 1D) indicate that there is one aquifer system with no apparent vertical gradient (Figure 61 - C). Water level data collected for wells MW6S and MW6D indicate that the silt body located beneath the surface at that location constitutes a localized confining unit allowing a local perched water table to form. The perched water table at MW6S is not part of the site-wide aquifer system (Figure 61 - D).

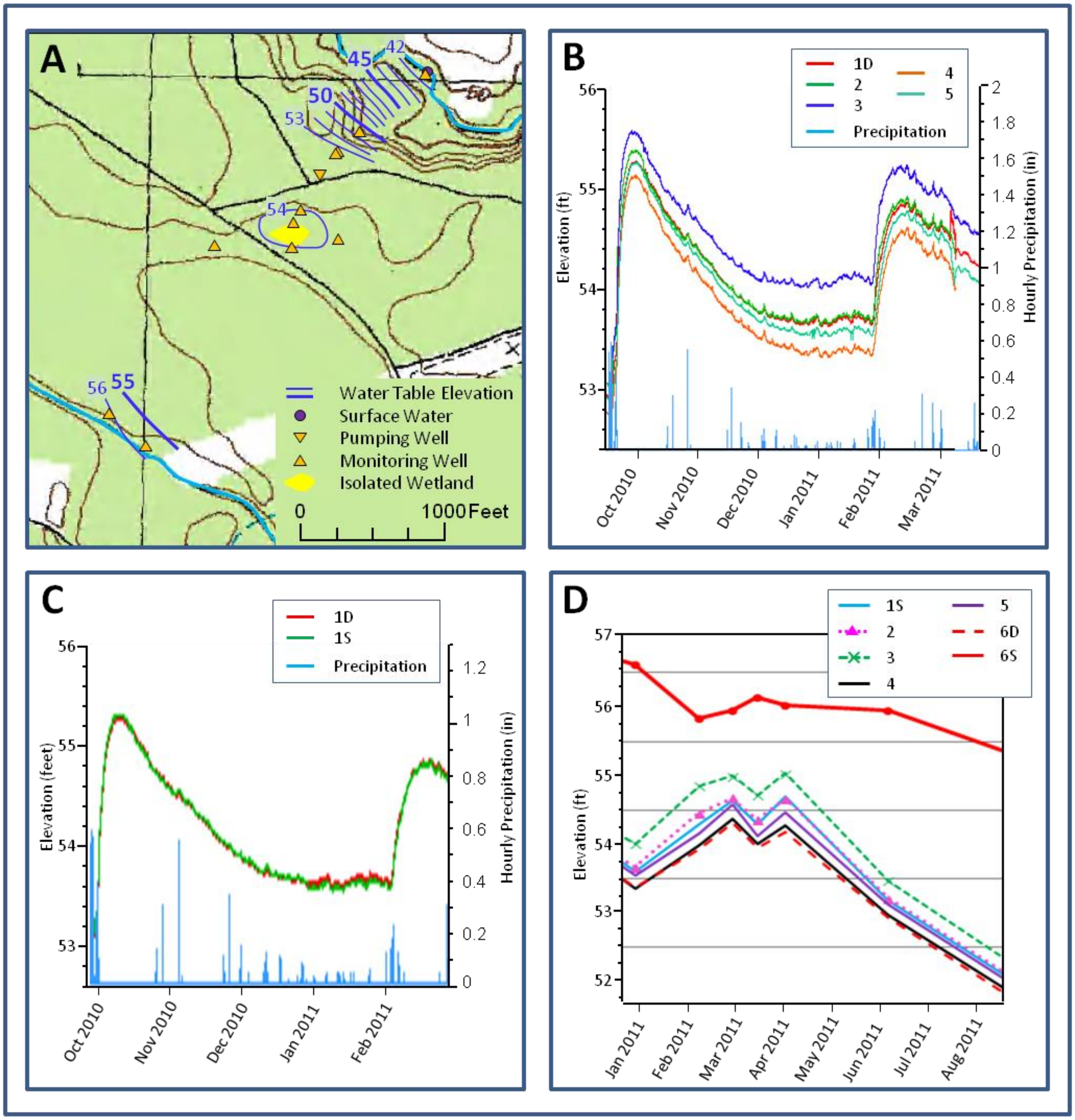


Figure 61. Hydrology at site BL1. A. Water table map showing water table elevation contours on May 3, 2011. B. A portion of the continuous hydrograph data for wells in and near the IW (1D, 2, 3, 4, 5). C. Continuous hydrograph data for wells 1S and 1D. D. Discrete (manual) water level data indicating that the water table at 6S is perched.

**Bladen 2** - BL2 appears to be another relict IW. No surface water was observed in the IW and the water table was never less than eight feet bls during the course of this study. This condition is likely the result of decades of drainage to the JLD (Figure 39). At this location JLD is a free-flowing deeply incised stream with point bars, riffles, and a channel with some sinuosity. Wells were installed as indicated in the site map (Figure 39). There was no upgradient well at this site.

Groundwater flow is from the IW to JLD (Figure 62-A). As seen in hydrographs of both CWLD and DWLD the discontinuous sandy silt bodies encountered at several locations at this site do not exert site-wide hydrologic control (Figure 62 - B and D). As with site BL1, the hydrograph curves of the two IW wells (MW1S and MW1D) indicate that there is one aquifer system with no vertical gradient (Figure 62 - C). There appears to be a perched water table at MW2S (Figure 62 - B).

Water table elevation at all wells increases in response to precipitation and is slow to decline afterward but the response is more muted than in Bladen 1 (Figure 62 – D). The water table is deeper at this site than any other in the study and precipitated water has a thicker unsaturated sand unit to infiltrate. The response at MW6 is much more immediate and “flashy” – sudden rises in water level followed by a quick decline to a somewhat static level (Figure 62 -D). The water level in the stream is higher than that in MW6 which is approximately 10 feet away. The base flow water level in JLD was fairly constant throughout the course of this study.

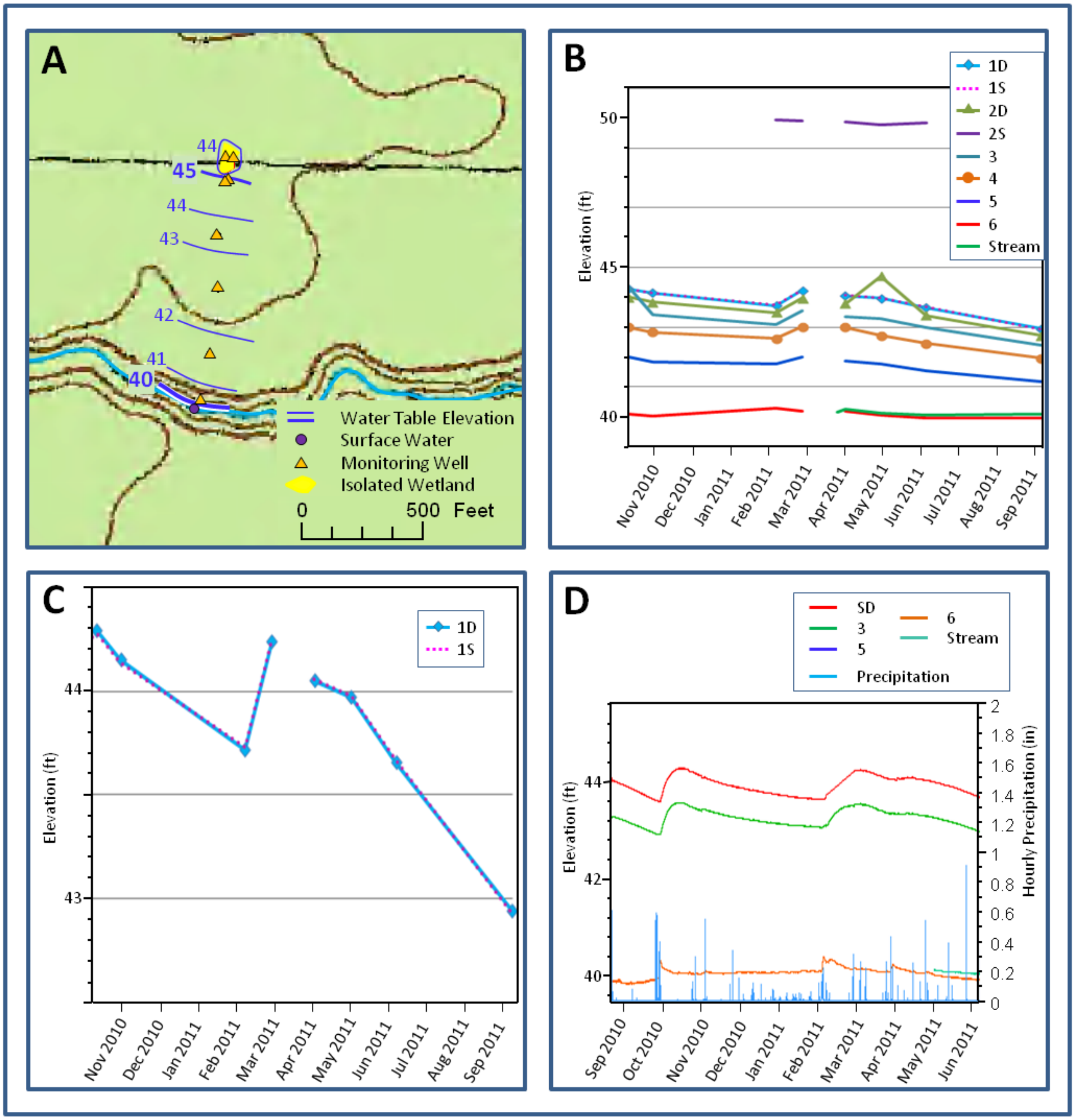


Figure 62. Hydrology at site BL2. A. Water table map showing water table elevation contours on May 3, 2011. B. A portion of the DWLD for the site. C. Discrete water level data for wells 1S and 1D. D. Continuous water level data for select wells (1S, 3, 5/6) and the stream as well as hourly precipitation data.

**Bladen 6** - BL6 is a larger IW than most in the study, is a classic Carolina Bay (Section 3.2.1), and has a layered aquifer system (Section 3.2.2.1). Wells were installed as indicated in the site map (Figure 41). At each location two wells were installed, one screened in the upper sand aquifer above the silt confining layer and one screened in the lower sand aquifer.

Water level monitoring results indicate that there are two distinct aquifers (Figure 63 - A), an unconfined surficial aquifer in the upper sand unit and a semi-confined deeper aquifer in the lower sand unit indicated by a water table in the deeper aquifer that was higher than that in the surficial aquifer. This difference decreases with distance from the IW, indicating that the silt confining unit exerts more influence in and near the IW. The silt body thins or pinches out between MW3 and MW5 (Figure 42 - B). In both aquifers, flow is from the IW to the headwater stream (MW1 and MW2 to MW5) (Figure 63 - B). The water table in the deep wells in the IW is flat but in the surficial aquifer water flows from one end (MW1) of the IW to the other (MW2) (Figure 63 - A). Water table elevation increases rapidly in response to precipitation in the surficial wells (Figure 63 - C). There is no CWLD for the deeper aquifer.

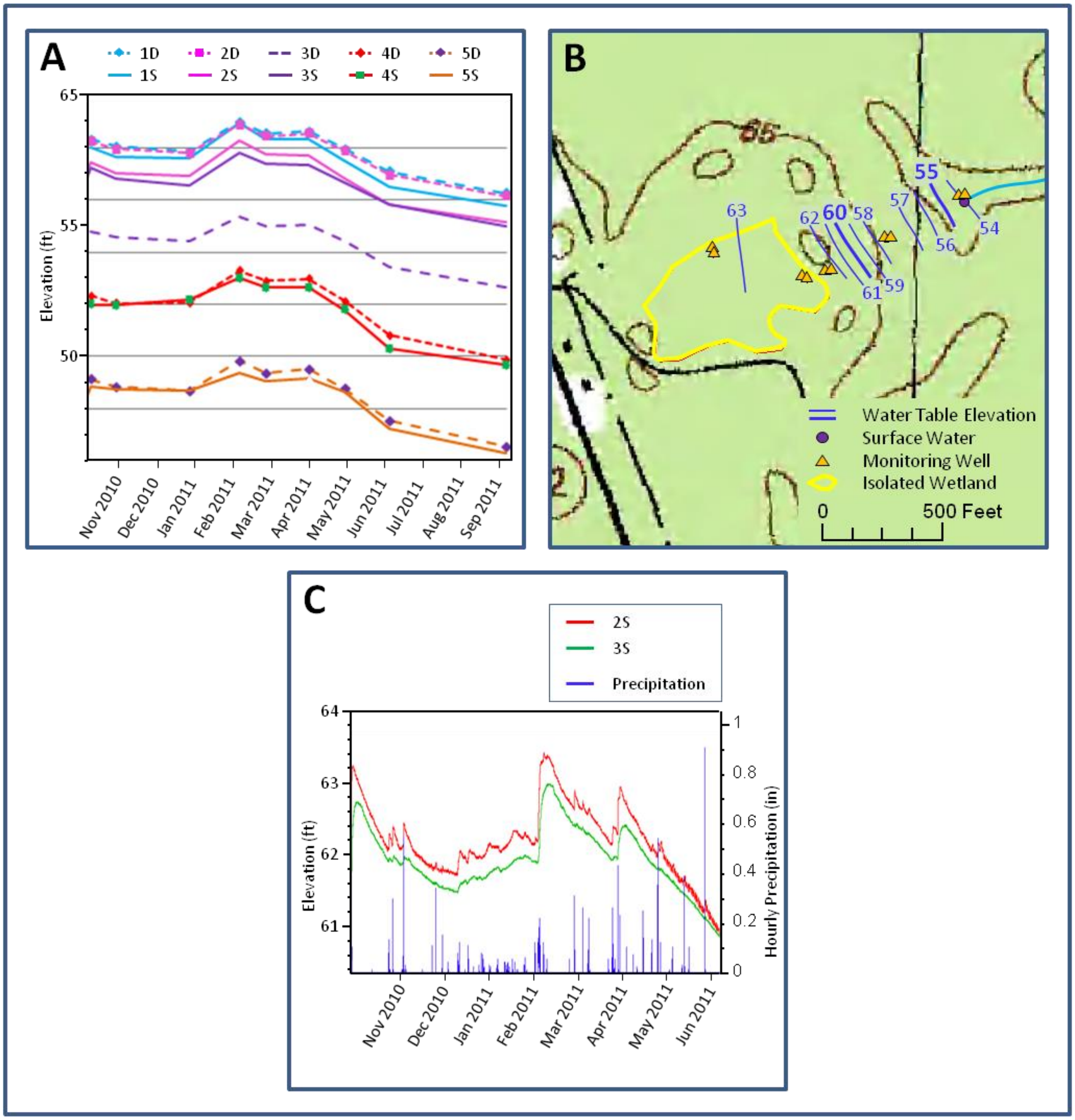


Figure 63. Hydrology at site BL6. A. Discrete water level data for all wells. B. Water table map showing water table elevation contours for shallow wells on April 4, 2011. C. Continuous water level data for wells 2S and 3S with hourly precipitation data.

**Bladen 7 -** Site BL7 has the simplest stratigraphy of any site included in this study (Section 3.2.2.1) and the site design is the closest to the model conceived in the planning phases (Sections 2.2.2.1 and 2.2.2.2). Wells were installed as indicated in the site map (Figure 43).

Groundwater flows from the upgradient area through the wetland to the stream (Figure 64 - A). Water table elevation increases rapidly in response to precipitation, is slow to decline afterward, and all the wells respond nearly simultaneously (Figure 64 - B). While there is no layering within the sand aquifer and no silt bodies were detected by coring, the shallow and deep well in the IW have slightly different responses to precipitation (Figure 64 - C). The deeper well does not experience the same magnitude of WL rise but within days of the event the recession curves equilibrate and the deeper well's WL is slightly higher than that of the shallow well, indicating a slight upward gradient

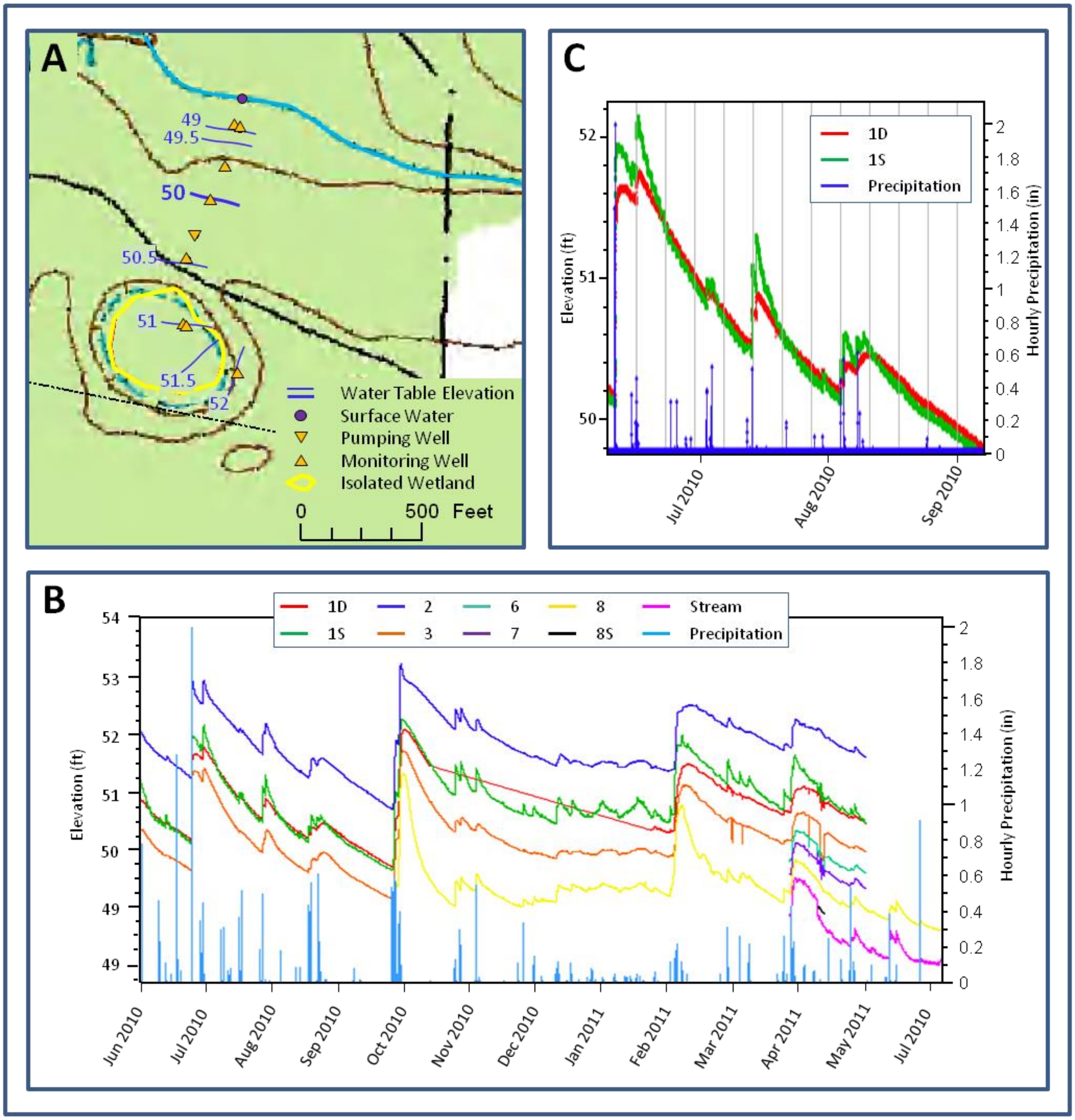


Figure 64. Hydrology at site BL7. A. Water table map showing water table elevation contours on April 4, 2011. B. Continuous water level data for wells and for the stream as well as hourly precipitation data. C. Continuous water level data for wells 1S and 1D.

**Bladen 9 -** BL9 was an interesting site for several reasons. The stratigraphy of the lowermost unit here is quite different than at other sites (see section 3.2.2.1 and Figure 46 - B), there is a cemented or "hardpan" zone affecting hydrology, this site is on the "other" side of Turnbull Creek, and, due to accessibility, the downgradient end of the well transect is at the IW and the connected surface water body is upgradient of the IW. Wells were installed as indicated in the site map (Figure 45).

Groundwater flow is from the upgradient ditch to the wetland (Figure 65 - A). Water table elevation increases rapidly in response to precipitation, is slow to decline afterward, and all the wells respond nearly simultaneously (Figure 65 - B). There is a perched water table due to the cemented zone surrounding the IW (Figure 65 - C) as seen in DWLD in Figure 65 - D. The site-wide aquifer is represented by the deep wells. The aquifer thickness changes dramatically north and west of the IW (Figure 65 – C - purple dashed line, Figure 46), but there is insufficient data to fully characterize the hydrologic effect of either the cemented zone or the change in aquifer thickness.

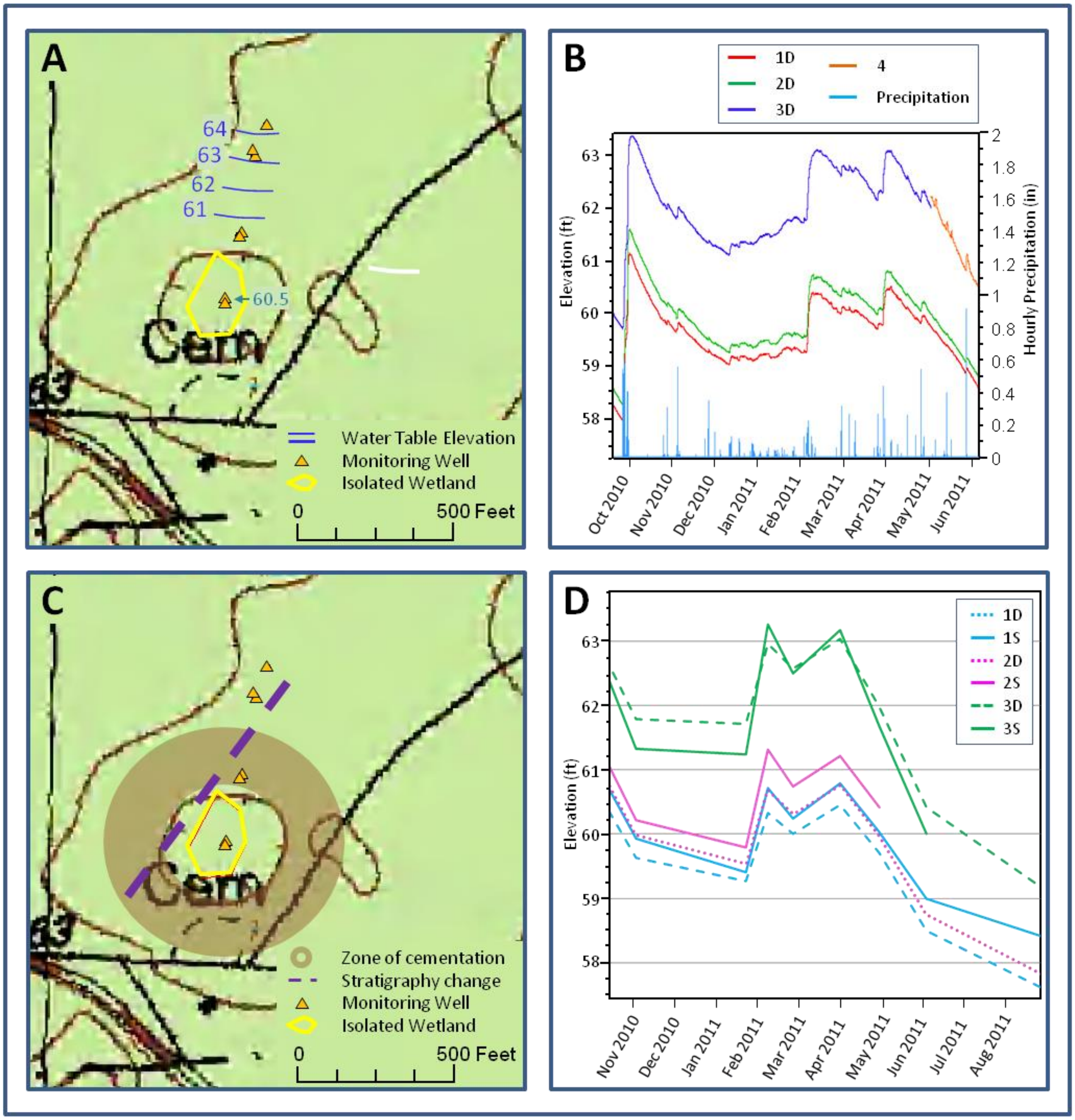


Figure 65. Hydrology at site BL9. A. Water table map showing water table elevation contours in the site-wide aquifer on April 4, 2011. B. A portion of the CWLD for the site. C. Site map showing the zone of cementation surrounding the IW and the estimated boundary between thinner and thicker aquifers based on stratigraphy at 25' bls. D. Discrete water level data comparing shallow and deep wells.

**Bladen 17 -** The IW at BL17 is long and narrow (Figure 47). Wells were installed in 3 transects, two along the short axis and one along the long axis of the IW (Figure 47). Monitoring results indicate that flow out of the IW is radial through an arc from the southwest to the southeast though the dominant flow is along the long axis (Figure 66 - A). The response to precipitation is similar to other Bladen County sites – a rapid increase in water table elevation followed by a slow decline (Figure 66 - B).

The lithology at BL17 is slightly different than that found at the other Bladen County sites (see Figure 48) and a comparison of CWLD from MW1S and MW1D indicates that the lithology does affect the hydrology (Figure 66 - B). The water table elevation in the shallow well is almost one foot higher than in the deep well indicating a downward groundwater gradient. The precipitation response in the shallow well is faster than that in the deeper well. When comparing DWLD for shallow and deep IW wells, the shallow well hydrographs indicate that flow is down the length of the IW from MW1S to MW2S to MW5S (Figure 66 - C). The hydrographs for the three deep IW wells (1D, 2D and 5D) are virtually identical (Figure 66 - D) until the spring of2011, perhaps because the system was drying out.

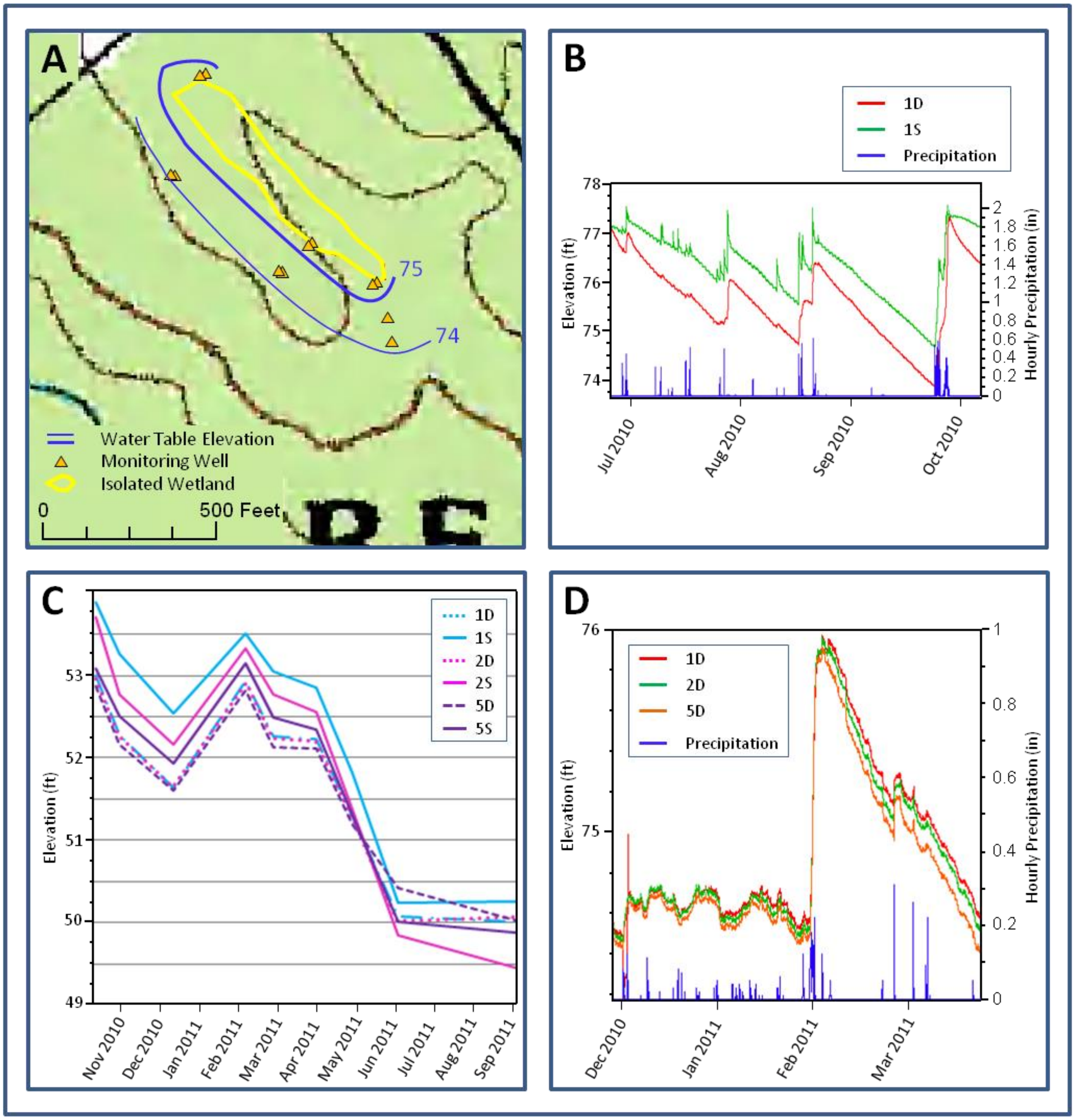


Figure 66. Hydrology at site BL17. A. Water table map showing water table elevation contours in the site-wide aquifer on April 4, 2011. B. A portion of the CWLD for the site. C. Discrete water level data in shallow and deep wells in the IW. D. Continuous water level data in deep wells in the IW.

**Green Swamp 1** - Site GS1 encompasses several sinkhole structures, some of which have intersected the groundwater table (see Figure 50). It also has a layered aquifer system (Section 3.2.2.1). Wells were installed as indicated in the site map (Figure 49).

Groundwater flows from the IW to the connected wetland (Figure 67 - A). Flow out of the IW appears to be in an arc toward both MW6 and MW2. Discrete groundwater level data recorded for the locations where there are pairs of wells, one shallow and one deep, indicate a downward vertical gradient (Figure 67 - B). As with the Bladen County sites, there is a rapid increase in water table elevation in response to precipitation followed by a slow decline (Figure 67 - C). In September 2010 the remnants of Tropical Storm Nicole, more than 17 inches of rain fell in a 4 1/2 day time span. On the last day of this event groundwater broke the surface at the IW well (MW1) and two hours later at the dry sinkhole (MW3). The water table elevation rose halfway up the IW well casing (1.6 ft) and rose nearly to the top of the casing of MW3 (2.82' above ground surface). Nine days later the recorded water level was once again below ground surface at MW3, and there was no sign of flooding in the dry sinkhole when the site was visited two weeks after flooding except that the outer casing of the well was flooded. The IW well (MW1) was in water for two months following the storm.

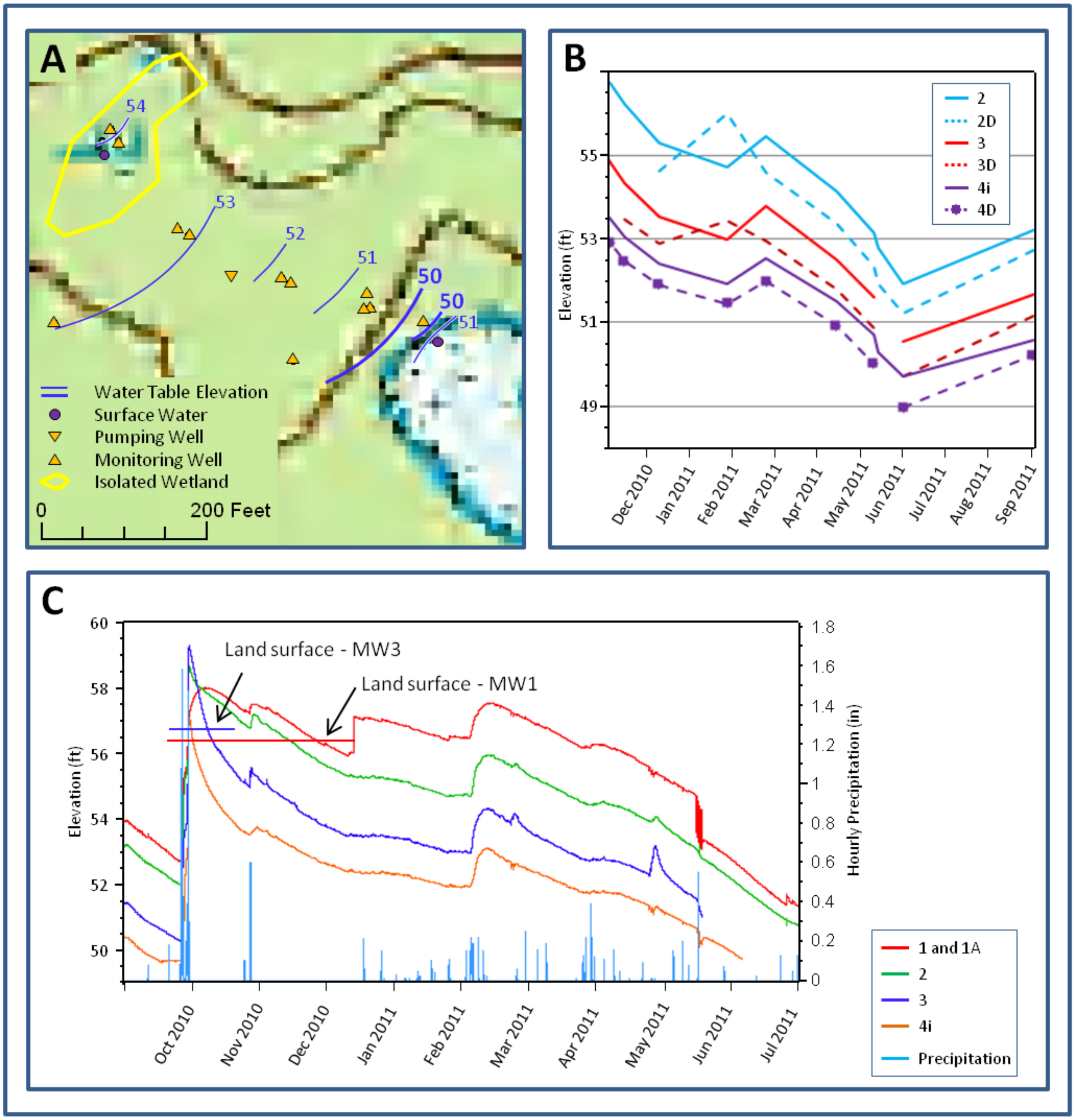


Figure 67. Hydrology at site GS1. A. Water table map showing water table elevation contours in the site-wide aquifer on May 16, 2011. B. Discrete water level data for pairs of shallow and deep wells. C. Continuous water level data in shallow and deep wells in the IW. D. Continuous water level data for select wells. The datalogger was moved from well 1 to well 1A on 12/13/10 due to flooding, and returned on 5/19/11. Well 1A is at a higher elevation than well 1, as is the water table at 1A.

**Green Swamp 2**- Site GS2 is a small site on the opposite bank of Beaverdam Swamp from GS1. Though there are no sinkholes at GS2, the stratigraphy is similar to that at GS1 and there is a layered aquifer system (Section 3.2.2.1). Wells were installed as indicated in the site map (Figure 53).

In both shallow and deep wells, groundwater flows from the IW to the slough connected to Beaverdam Swamp (Figure 68 - A). Discrete water level monitoring results indicate that there is a downward vertical gradient (Figure 68 - B). The gradient itself decreases with distance from the IW as the interbedded sand and clay layer thins toward the slough (Figure 54). As with all the other North Carolina sites, there is a rapid increase in water table elevation in response to precipitation followed by a slow decline (Figure 68 - C). There is no CWLD in the deep aquifer to assess vertical gradients or flow.

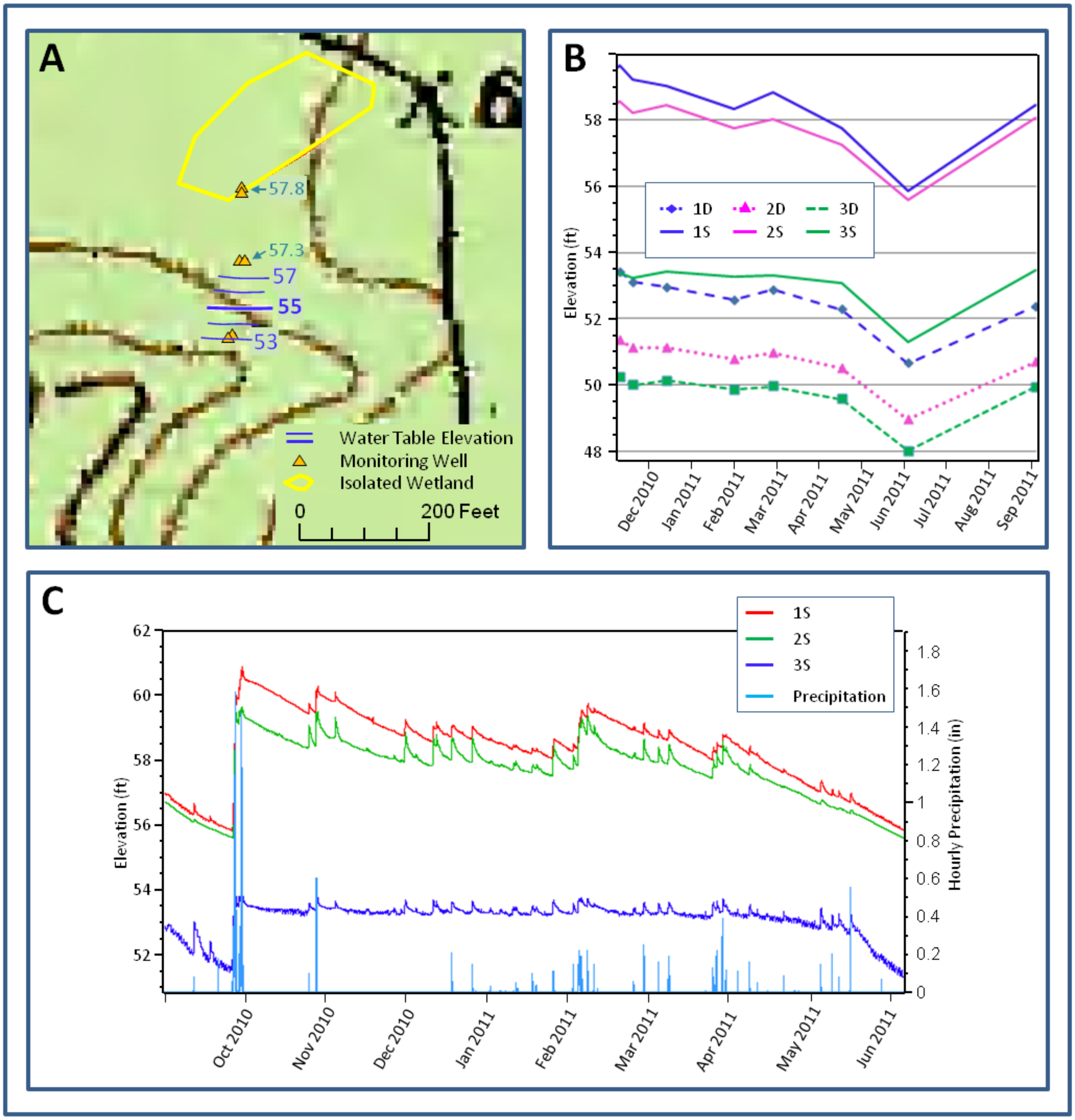


Figure 68. Hydrology at site GS2. A. Water table map showing water table elevation contours in the shallow aquifer on April 19, 2011. B. Discrete water level data in shallow and deep wells in the IW. C. Continuous water level data in shallow wells.

**MF** – In Figure 69, a hydrograph of water table elevations from July 2011 to July 2012 at the MF site shows a rapid response to rain events in addition to water table seasonal responses. Water table elevation increased in December, but with a gradual recession due to seasonal low rates of evapotranspiration. The rate of recession increased during March/April, when air temperature and evapotranspiration is high. The well located within the connected wetland (MF-04) was the only well that contained water throughout the study period, including during times of low water table elevation. The remainder of the wells began showing a water table response after rain events (>0.1 in) at the end of November 2011. Frequent and higher levels of precipitation in April and May resulted in sustained relative high water table elevations through most of the summer months. When water was detected in all four wells, groundwater flowed from the isolated wetland (MF-01) to the connected wetland (MF-04). MF-03 was somewhat anomolous a few times with higher water table elevation than MF-04. MF-03 was at the outer edge of the floodplain so during period of high water may be reflecting floodplain impacts on the water table and not just precipitation.

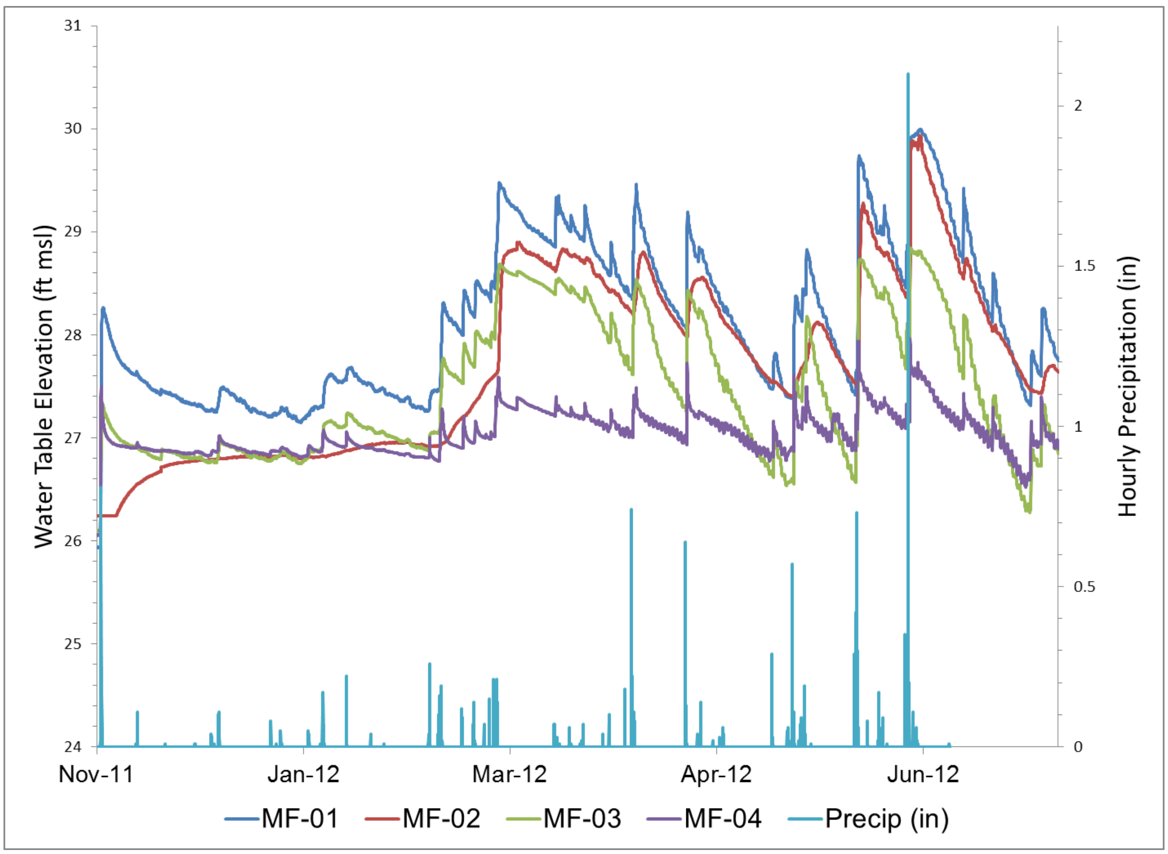


Figure 69. Hydrograph from Site MF showing water table elevations and hourly precipitation from November 2011-June 2012.

**MA -** Monitoring wells at the MA site also showed a rapid water table response to rain events. Water table elevations increased during winter months, when evapotranspiration was low, and persisted through the beginning of the summer months (Figure 70). Even as the groundwater elevation fluctuated, relative water table elevations among the wells along the transect remained relatively constant. Throughout the study period the water table at the isolated wetland (MA-01) remained higher than the remaining wells, indicating that groundwater flowed from the isolated wetland to the connected wetland.

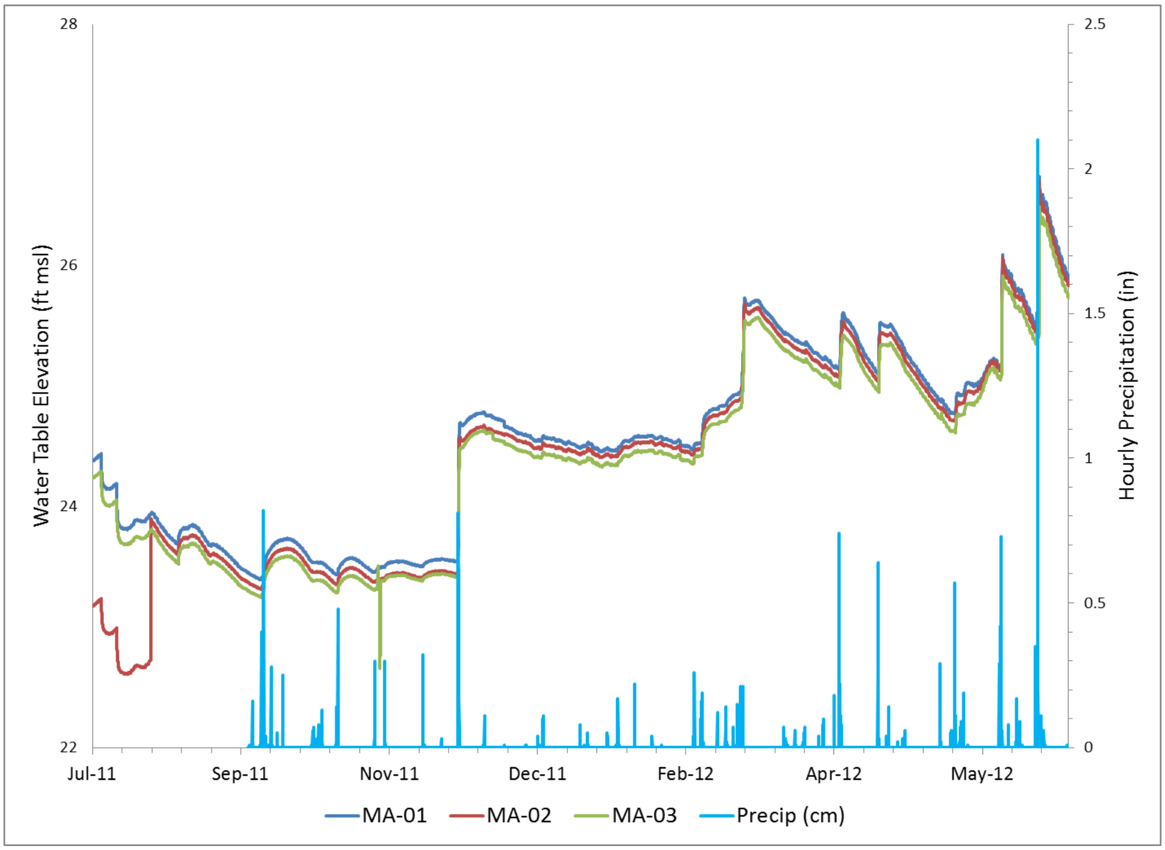


Figure 70. Hydrograph from Site MA showing water table elevations and hourly precipitation from July 2011-June 2012.

**LB** - Water table elevations at the LB site in Horry County indicated no seasonal fluctuations, as water levels remained within a fairly consistent range in each of the monitoring wells (Figure 71).Rapid response to rain events occurred. During the driest periods, the water table elevation at the isolated wetland (LB-01) and the adjacent upland area (LB-02) persisted at near-equal levels. There was one interval (November 2011) where the relative elevations revered (water table elevation at LB-02 is higher than that at LB-01). The reason is unknown but may be an effect that occurs only during dry periods. During the wettest periods the water table within the isolated wetland remained at a higher elevation than the adjacent upland area. Overall, groundwater at this site drained from the isolated wetland to the connected wetland, as seen in the other South Carolina sites.

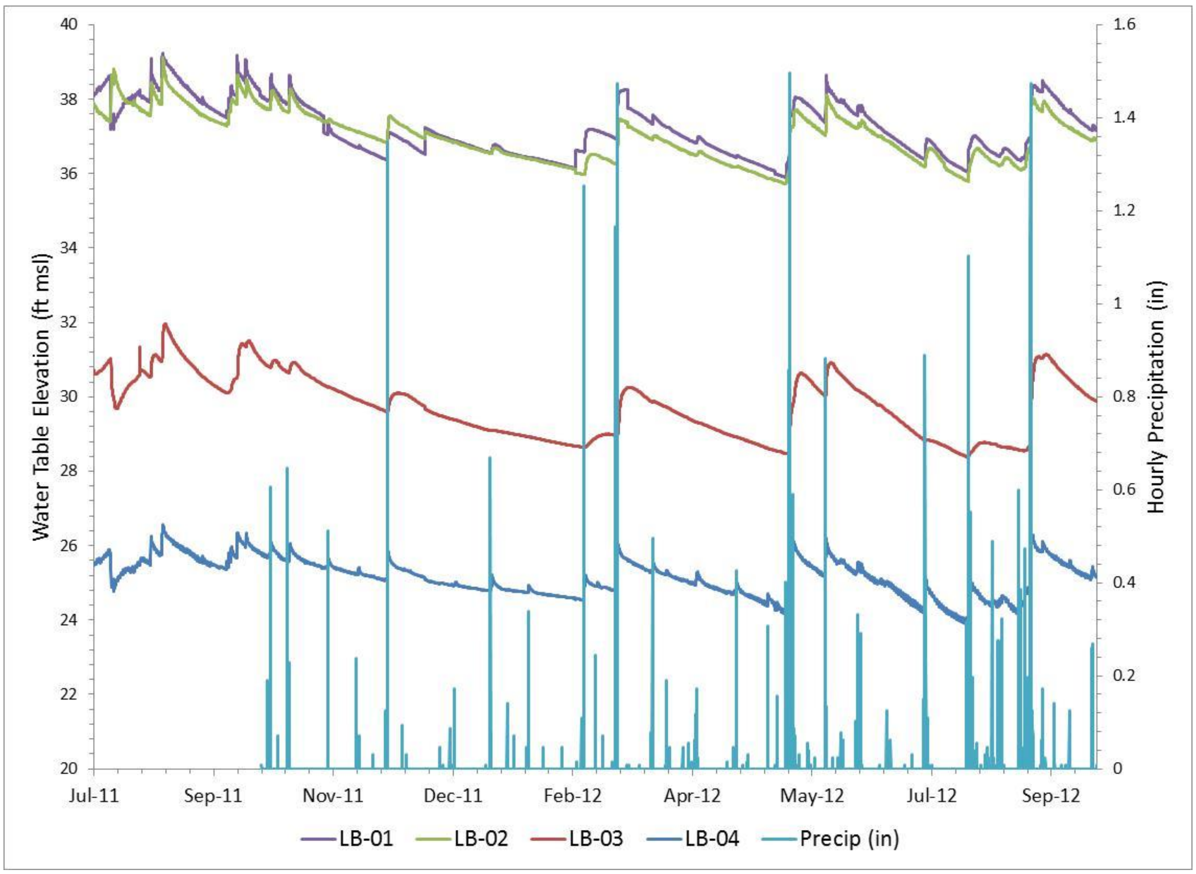


Figure 71. Hydrograph from Site LB showing water table elevations and hourly precipitation from July 2011-June 2012.

**Hydrology Monitoring Well Sampling Summary Discussion**

Groundwater flows from upgradient areas through the IW to a downgradient surface water body at all sites in this study. In some cases there is partial radial flow out of the IW, (sites BL1, BL17 and GS1). At site BL7, the topography appears to focus outward flow in one direction. There is insufficient data at other sites to whether outward flow is unidirectional or otherwise.

Water table elevation in all surficial aquifer wells at all sites rose rapidly and simultaneously in response to precipitation. Some streamside wells (BL2-MW6 and BL9-MW4) and some shallow wells in the IW (BL7-MW1S and BL17-MW1S) responded more quickly than upland or deeper wells at these sites. Since there were not enough instruments to obtain CWLD at all wells, layered systems were not fully characterized.

Though there were instances of perched water tables caused by discontinuous silt bodies with low hydraulic conductivity (BL1-MW6S and BL2-MW2) or by cementation of some sort (BL9-MW1S, BL9-MW2S and BL9-MW3S), this did not affect site hydrology and does not explain the presence of an IW. Three sites had distinct layering that did affect site hydrology. Site BL6 had two layers of sand aquifers sandwiching a thick silt confining layer that pinched out with distance from the IW. The upper sand aquifer behaved in the same manner as the surficial sand aquifers at other sites. The lower sand aquifer behaved as a confined aquifer near the IW. Sites GS1 and GS2 each had a layer of lower hydraulic conductivity than the sand aquifers above and below, but did transmit water downward. The semi-confining unit at site GS2 pinched out or thinned with distance from the IW and this affected the gradient between the upper and lower aquifers.

The vertical groundwater gradient was site specific. At sites BL17, GS1, GS2 and the upland well pair at site BL6 (BL6-MW3), the gradient was downward. The gradient at all other well pairs at site BL6 was upward. These four well pairs (BL6-MW1, BL6-MW2, BL6-MW4, and BL6-MW5) are in discharge zones - either the IW or a wetland connected to the receiving surface water. No vertical gradient was detected in the IW at sites BL1 and BL2. The vertical gradient in the IW at site BL7 changed depending on conditions, from a downward gradient during and immediately after a precipitation event to upward during baseflow. The vertical gradients at BL9 depended on the presence or absence of the cemented zone. The gradient was upward where the zone was absent and where the cemented zone was present there was either a downward gradient or a perched water table.

Monitoring surface water level was not part of the project plan, though several surface water level monitoring stations were installed late in the study. There is enough data to conclude that the water table aquifer is discharging to the downgradient surface water body at all eleven sites.

### 3.2.2.4 Aquifer Pumping Test Results and Discussion

**Aquifer Pumping Test #1 – BL1 Site:**

The aquifer pumping test at site BL1 was conducted on March 15 to March 17, 2011. There is a surficial sand unit approximately 25' thick with at least one discontinuous silt body at a depth of approximately 15 feet below land surface at this site (Refer to Section 3.2.2.1). There appears to be radial drainage out of the IW (Section 3.2.2.3). The pumping well (BL1-PW1) was screened from 12 to 27 feet, which is just above the regional basal confining layer and the majority of the monitoring wells were also screened above the confining layer. The pumping well was located on a slight topographic rise between the IW and the nearest surface water body. All but one of the monitoring wells were screened below the discontinuous silt body and were sealed from the upper portion of the water table aquifer with a bentonite grout.

Water levels were also monitored in two distant wells (BL1-MW8 and BL1-MW9) that served as background wells unaffected by pumping. BL1-MW8 was monitored manually at 2 to 4 hour intervals. Water levels in all other wells and barometric pressure were monitored at 15 minute intervals for 16 hours prior to the start of active pumping in order to ensure that water levels were stable and that there was no potential interference from any adjacent pumping wells during the test. No significant interferences were noted in the pre-test water level monitoring, and the maximum drawdown that was noted in the two background wells during the pumping test was 0.03 feet, which indicates that water levels in the background wells were most likely unaffected by the pumping from BL1-PW1, and that there was no significant regional influence on water levels that could interfere with the test.

The maximum sustainable pumping rate during the test was approximately 40 gallons per minute, which resulted in a little over 5 feet of drawdown in the pumping well. This pumping rate and drawdown is indicative of a sandy aquifer with a high transmissivity. The closest surface water feature to the pumping well is Turnbull Creek, which is located approximately 900 feet away from the pumping well. Drawdown in the nearby monitoring wells was noticed almost immediately after pumping was initiated. Drawdown was noted in all of the shallow monitoring wells that were located in and near the IW (Figure 37), and the cone of depression created by the pumping extended at least 900 feet from the pumping well (distance to BL1-MW3).

The drawdown data from the monitoring wells that were instrumented with pressure transducers connected to an electronic data logger for the aquifer pumping test at BL1 are shown on Figure 72. The highest measured induced drawdown from this test was 0.8 feet at well MW-6D, which is screened below the silt confining (perching) layer, and located approximately 200 feet from the pumping well. The drawdown was not uniform in all observation wells in a radial pattern from the pumping well suggesting that there is some degree of anisotropy and/or inhomogeneity in the water table aquifer.

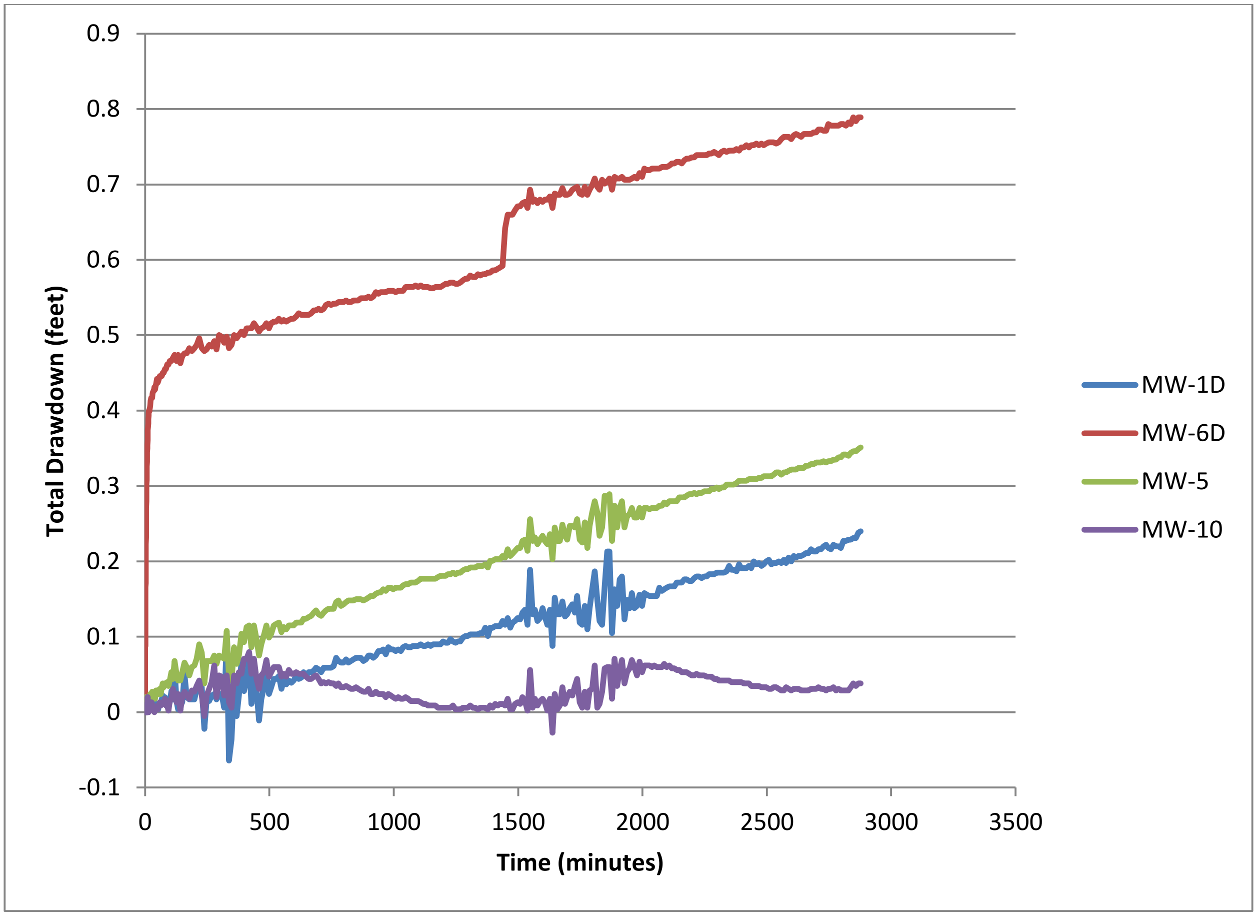


Figure 72. Drawdown graphs for the aquifer test at the BL1 site.

Due to the high sampling frequency provided by the electronic pressure transducers, short wavelength and low amplitude fluctuations in the water levels were noted in the monitoring wells during the pumping test. There were two such episodes noted in the aquifer test data; one occurred shortly after the pumping began at 8:45AM, and the other approximately 24 hours later. The exact cause for these fluctuations is unknown, however they seem to coincide with daylight hours and therefore may be a function of evapotranspiration. The fact that these fluctuations occurred at the same time in harmony in all of the instrumented wells indicates that the wells are in hydraulic communication with the same aquifer system.

No significant drawdown was noted in Turnbull Creek. However, the drawdown responses noted in the monitoring wells located in and near the IW reveals that they were significantly affected by the pumping in BL1-PW1. This drawdown response indicates that the groundwater in the water table aquifer underneath the IW is hydraulically connected to the water table aquifer in the vicinity of the pumping well.

The pre-pumping background water level data, the drawdown data for the pumping test, and the drawdown data for the recovery test are available upon request. Copies of the field notes from all phases of the aquifer pumping test are available upon request.

**Aquifer Pumping Test #2 – BL7 Site:**
The aquifer pumping test at site BL7 was conducted on April 12, 2011 to April 14, 2011. This site has a relatively homogeneous sandy water table aquifer 18 to 27 feet thick (refer to Section 3.2.2.1). The IW is located on a topographic high and groundwater in the water table aquifer appears to flow from the IW to the nearby surface water body, White Lake Drain. The pumping well (BL7-PW1) was screened from 17 to 32 feet, which is just above the regional confining layer. The pumping well was located between the IW and White Lake Drain. The shallow observation wells were screened in the upper portion of the water table aquifer and the deeper observation wells were screened just above the regional confining layer.

None of the wells installed at this site were suitable for use as background water level wells since all of the wells were within the potential cone of depression for the aquifer pumping test. Water levels in all wells and barometric pressure were monitored at 15 minute intervals for 16 hours prior to the start of active pumping in order to ensure that water levels were stable and that there was no potential interference from adjacent pumping wells during the test. No significant interferences were noted in the pre-test water level monitoring.

The maximum sustainable pumping rate during the test was approximately 50 gallons per minute, which was the maximum pumping rate for the submersible pump. This pumping rate resulted in a little over 5 feet of drawdown in the pumping well. This pumping rate and the associated drawdown are indicative of a sandy aquifer with a very high transmissivity. The closest surface water feature to the pumping well is White Lake Drain, which is approximately 500 feet away. Drawdown in the nearby monitoring wells was noticed almost immediately after pumping was initiated. The total maximum drawdown that was induced in the pumping well was 5.51 feet. Drawdown was noted in all of the shallow monitoring wells in the IW (see Figure 43), and the cone of depression extended at least 400 feet from the pumping well (distance to BL7-MW7). (Figure 73)

Since all of the observation wells in the vicinity of the pumping well responded to the drawdown in the water table aquifer, it can be inferred that groundwater in all of these observation wells is hydraulically connected. In addition, the water table contour map of this site (Figure 64 - A) indicates that groundwater is hydraulically connected to surface water since it flows towards and discharges into White Lake Drain.

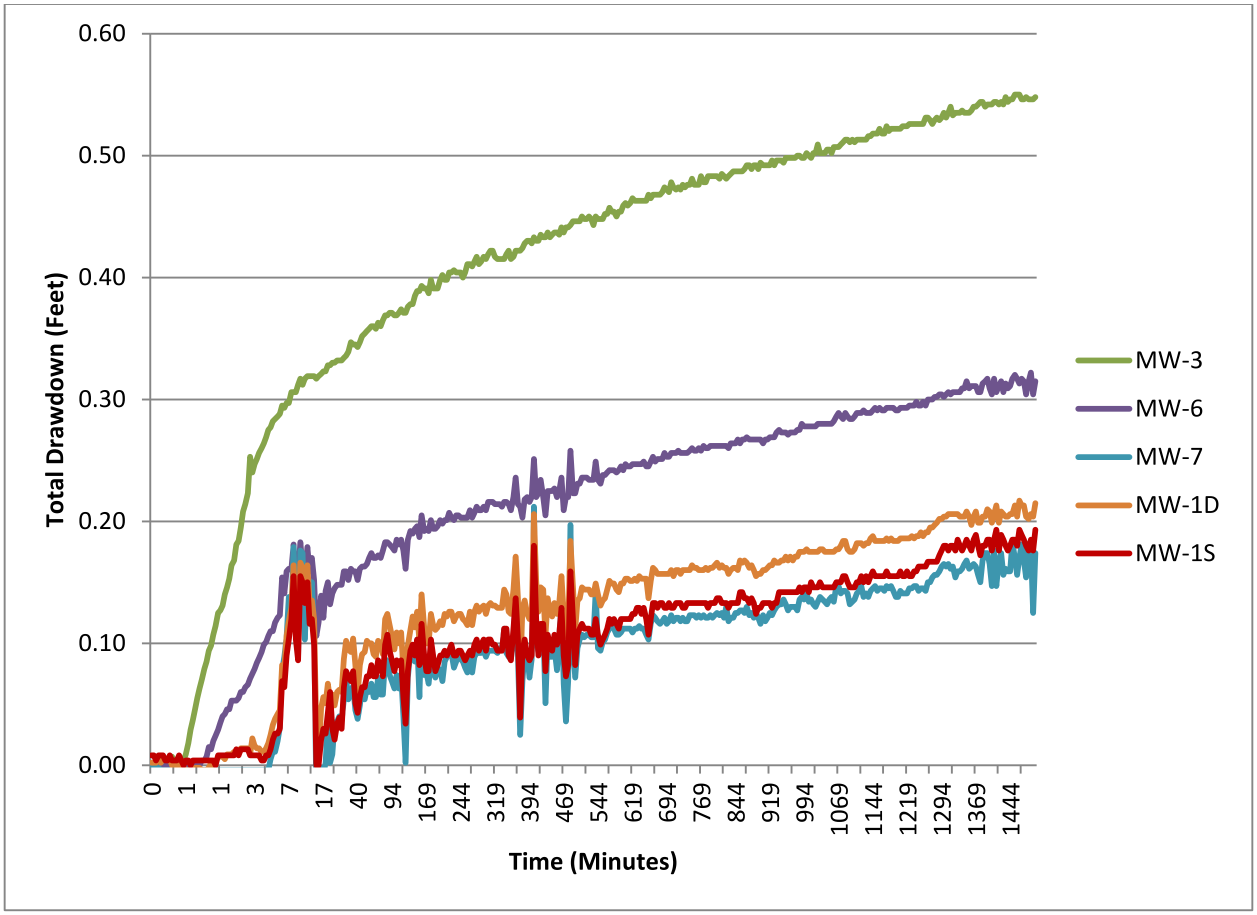


Figure 73. Drawdown graphs for the aquifer test at the BL7 site.

**Aquifer Pumping Test #3 – GS1 Site:**
The aquifer pumping test at site GS1 was conducted on May 17, 2011 to May 19, 2011. This site has a sandy water table aquifer of an unknown thickness and occasional circular depressions that appear to be sinkholes, although no limestone was encountered in any of the borings or well installations (Refer to Section 3.2.2.1). The pumping well (GS1-PW) was screened from 20 to 40 feet, just below an interbedded sand and clay layer. The pumping well was located between the IW and the nearest surface water feature (see Figure 49). The shallow observation wells were screened in the upper portion of the water table aquifer, typically from 2 to 12 feet below ground surface. The deeper observation wells were screened below the interbedded sand and clay layer, typically from 20 to 40 feet below ground surface.

Since the most distant on-site monitoring well was approximately 300 feet (GS-MW1A) from the pumping well and thus all of the wells were within the potential cone of depression for the aquifer pumping test, none of the wells installed at this site were suitable for use as background water level wells. However, monitoring wells at the GS2 site, which are approximately 1 mile from the GS1 site but are separated from the GS1 site by a drainage feature, were used to establish background trends in groundwater levels for the aquifer test at GS1.

Water levels in all instrumented wells and barometric pressure were monitored at 2 minute intervals for 17 hours prior to the start of active pumping to ensure that water levels were stable and that there was no potential interference from adjacent pumping wells during the test. No significant interferences were noted in the pre-test water level monitoring. The GS2 monitoring wells show a slight increase in the elevation of the water table aquifer during the time of the aquifer pumping test at GS1. This rise in the water table elevation at GS2 appears to be in response to a precipitation pulse that was not noted in the water level data from the GS1 pumping test.

The maximum sustainable pumping rate during the test was approximately 38 gallons per minute, which was the maximum pumping rate for the submersible pump at a depth of approximately 38 feet. The initial pumping rate was approximately 32 gpm, but this was increased to 35 gpm and finally to 38 gpm in order to maximize the drawdown in the water table aquifer. The maximum drawdown noted in the pumping well during the aquifer pumping test was 17 feet. These pumping rates and associated drawdowns are indicative of a sandy aquifer with a high transmissivity.

The closest surface water feature to the pumping well is the connected wetland, which is located approximately 150 feet away from the pumping well. Drawdown in the nearby deep monitoring wells was noticed almost immediately after pumping was initiated. However, drawdown in the shallow monitoring wells adjacent to their associated deep monitoring wells was not evident until about an hour after the pumping began. In addition, the drawdown levels in the deep monitoring wells were considerably greater than in the shallow wells. (Figure 74)
Drawdown was noted in all of the wells at the GS1 site. The cone of depression created by the pumping extended at least 300 feet from the pumping well (distance to GS1-MW1A).

Since all of the observation wells in the vicinity of the pumping well responded to the drawdown in the water table aquifer, it can be inferred that groundwater in all of these observation wells is hydraulically connected. In addition, the water table contour maps of this site (Figure 67 - A) indicate that groundwater is hydraulically connected to surface water since it flows towards and discharges into the connected wetland.

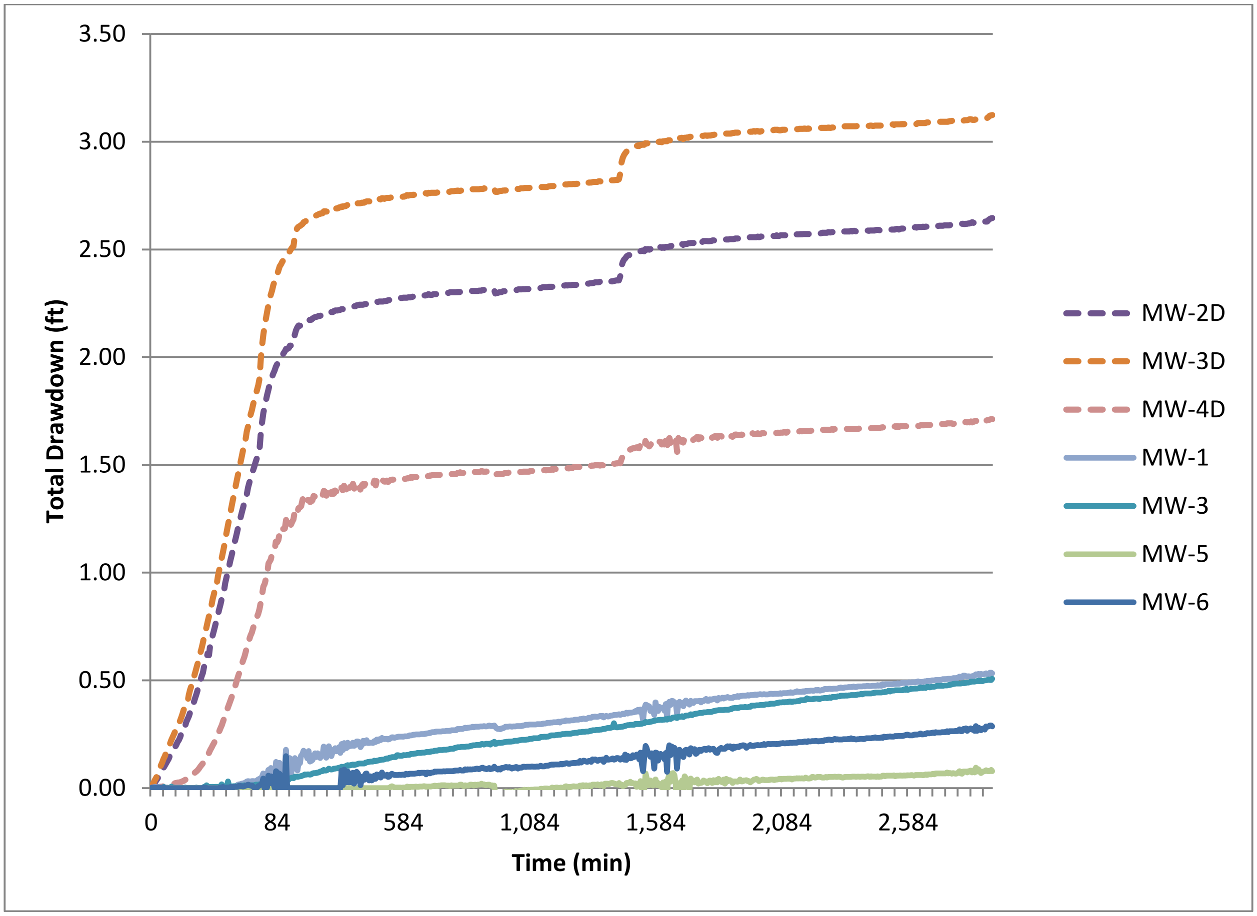

Figure 74. Drawdown graphs for the aquifer test at the GS1 site.

### 3.3.3 Water Quality Sampling Results and Discussion for Hydrology and Water Quality sites

The project plan was for water quality sampling to occur four times (seasonally) during the field year (see Section 2.2.3). Actual results were that sampling was completed from 0 – 4 times at each location (well, wetland, stream). Mixed results were due to no water (in a well or surface water in a wetland) or other problems. It is often the case that environmental systems exhibit seasonality. A single year of sampling, with some seasons missed, prevents assessment of seasonality with these data. Additionally, climatic conditions were dry, especially during the SC sampling year which prevented the collection of water samples from some of the surface water and upland well stations. This analysis will focus on overall trends and general observations.

In general, nutrient concentrations were fairly low, often below detection limits. Some general patterns are apparent using results from three IW as examples (Figure 75 and Figure 76). TKN was by far the largest fraction of total nitrogen at these sites (Figure 75 and Figure 76). TKN is all reduced forms of nitrogen, including NH4, so the small $NH_4$ fraction indicates the majority of TKN is organic. At the Bladen 6 and Green Swamp 2 site the organic fraction was at a peak in the wetland (Figure 76), decreased in the transect wells, and increased again in the stream. (Streams have constituents from upstream surface and groundwater sources unrelated to the IWs in this study.) This relationship tends to be confirmed by the concentration data (Figure 75) although the IW at the LB site had no surface water for any of the sampling trips so nothing can be said about that site.

There was a clear hydraulic gradient from the IW toward the connected stream at all three sites suggesting nutrient transformations occurred in the IW and as water moved to the stream. Additional perspective on this can be seen in the organic carbon results (Figure 77). Dissolved organic carbon was the largest fraction in all samples. At the sites where IW samples were taken the quantity of organic carbon was less in the wells than in the IW and connected stream. This suggests that a significant amount of organic carbon was either retained in the IW or mineralized during transit toward the stream or both. It appears that some mineralization occurred along the transects because the concentrations of ammonium tend to increase although not uniformly and not at all sites (Figure 75 and Figure 76).

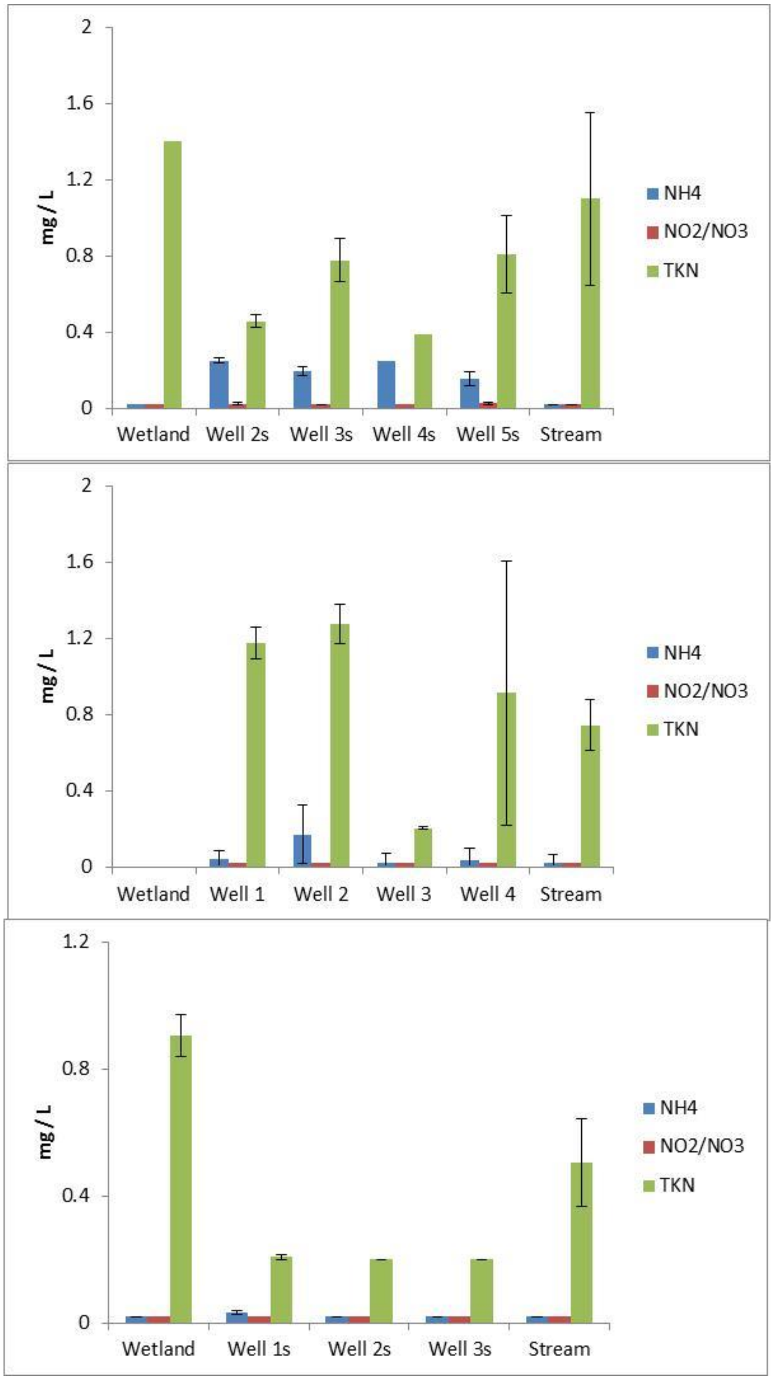


Figure 75. Mean concentrations (± standard error) of nitrogen fractions in the IW, wells, and stream at Bladen 6 (upper), LB (middle), and GS2 (lower). No samples were taken in the IW at the LB site. It is included here for consistency with the other two panels in the figure.

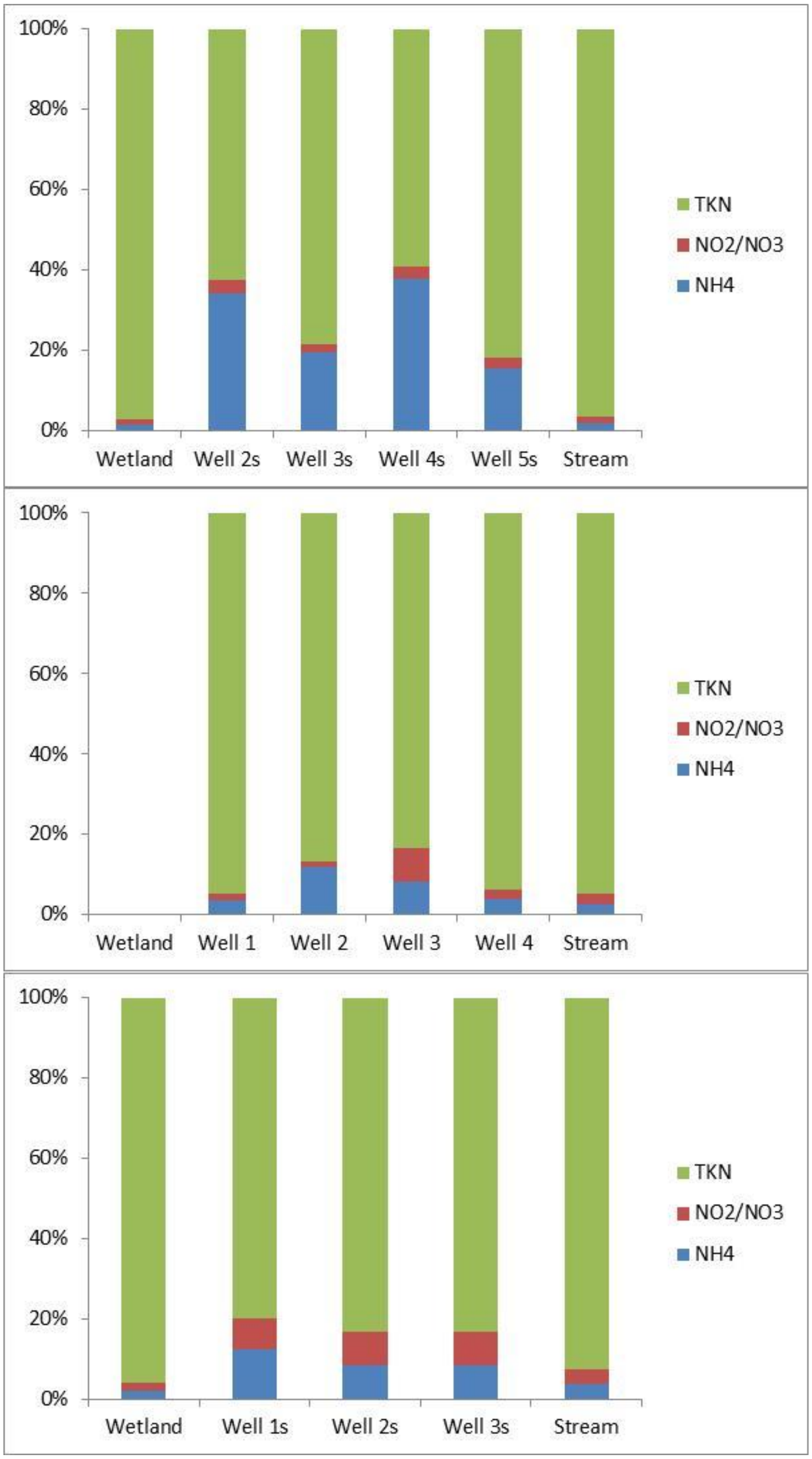


Figure 76. Mean percent of nitrogen fractions in the IW, wells, and stream at Bladen 6 (upper), LB (middle), and GS2 (lower). No samples were taken in the IW at the LB site. It is included here for consistency with the other two panels in the figure.

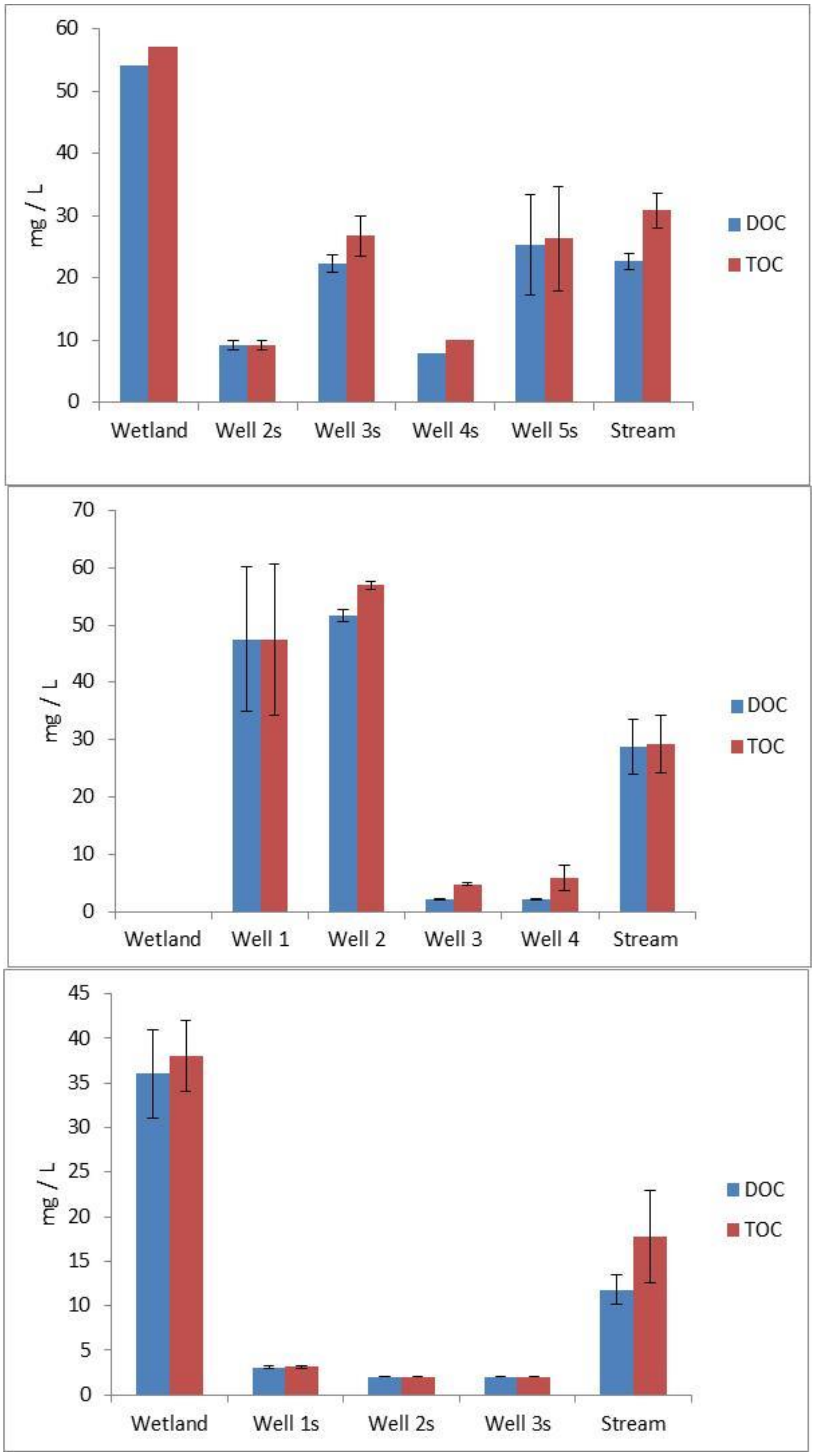


Figure 77. Mean concentrations (± standard error) of dissolved (DOC) and total (TOC) organic carbon in the IW, wells, and stream at Bladen 6 (upper), LB (middle), and GS2 (lower). No samples were taken in the IW at the LB site. It is included here for consistency with the other two panels in the figure.

The sole exceptions to the overall low concentrations of nutrients were wells 1 and 2 at the MF site in Marion County, SC. Only one sample was possible from those wells (May 2012) due to dry conditions during the field year. Both extractable phosphorus and TKN concentrations were very high (Table 24). The inorganic nitrogen ($NO_2$/$NO_3$ and $NH_4$) and TOC concentrations were also elevated but not as extreme as TKN and extractable phosphorus. As stated earlier, TKN in these sites was primarily the organic fraction of nitrogen. Taken in combination, these results could suggest an accumulation of partially decayed organic material in the soils that was mobilized due to wet conditions during May. Additional data are needed to be more certain of this or alternative explanations.

Specific conductivity in all samples was low or relatively low suggesting low concentrations of dissolved ions which was also seen in the nutrient data. Well 4 at the MF site had somewhat elevated specific conductivity. Taken together with the nutrient and TOC results mentioned above for wells 1 and 2 and the relatively high concentrations of TKN and $NH_4$ at well 4, this suggests there are dynamics at this site that may be somewhat different from the other sites. This hypothesis cannot be analyzed further with these data. The pH at all sites was acidic except in one sample. The acidic conditions are normal for Coastal Plain streams and shallow groundwater due to the presence of organic acids in higher concentrations (see DOC results) than seen in other locations in the Carolinas. The one exception to this trend was a pH of 10.9 in the IW at Bladen 17 in February 2011 (data not shown). This is the only parameter that is exceptional during that sampling period; the cause cannot be determined from these data.

Overall these data suggest the landscapes in this study were nutrient poor. The IW were sources of organic material that was mineralized and depleted either in the IW or as groundwater traveled toward the stream. Organic concentrations were again somewhat elevated in the stream but that loading must have occurred either upstream from the sample site or in the immediate riparian area. This general conceptual understanding of nutrient and organic carbon conditions and dynamics at our study sites is consistent with the literature on Coastal Plain streams (e.g. Gilliam 1988, Smock and Gilinsky 1992).

The limited amount of data available for analysis restricts the ability to draw firm conclusions or to generalize to issues outside the scope of the study. For example, based on these data we could hypothesize that IW ecosystems have developed pathways to cycle and retain nutrients in landscapes that are otherwise nutrient poor. Thus they are self-sustaining habitat for plant and animal communites both within the wetland and the immediately adjacent upland.

Table 24. Overall Mean Concentration of Water Quality Parameters at IW Study Sites

| Site* | N | Water Temp °C | s.e. | pH S.U. | s.e. | NH4 mg/L | s.e. | $NO_2/NO_3$ mg/L | s.e. | TKN mg/L | s.e. | DOC mg/L | s.e. | TOC mg/L | s.e. | Extractable P mg/L | s.e. | Specific Condo µS/cm | s.e. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bladen 1-IW | 0 | | | | | | | | | | | | | | | | | | |
| Bladen 1-well 1s | 4 | 18.4 | 1.25 | 4.44 | 0.079 | 0.02 | 0.000 | 0.07 | 0.035 | 0.20 | 0.000 | 2.1 | 0.10 | 2.2 | 0.20 | 0.06 | 0.018 | 103.5 | 59.88 |
| Bladen 1-well 3 | 1 | 16.4 | | 4.45 | | 0.02 | | 0.02 | | 0.20 | | 2.8 | | 3.1 | | 0.02 | | 36.0 | |
| Bladen 1-well 6d | 4 | 17.8 | 1.44 | 4.45 | 0.073 | 0.02 | 0.000 | 0.02 | 0.000 | 0.20 | 0.000 | 2.0 | 0.00 | 2.0 | 0.00 | 0.02 | 0.000 | 27.8 | 1.89 |
| Bladen 1-well 7 | 1 | 12.2 | | 4.53 | | 0.04 | | 0.02 | | 0.31 | | 4.5 | | 9.0 | | 0.14 | | 55.0 | |
| Bladen 1-stream | 4 | 16.4 | 3.59 | 3.83 | 0.260 | 0.06 | 0.043 | 0.02 | 0.000 | 0.64 | 0.031 | 19.5 | 2.18 | 21.8 | 3.15 | 0.02 | 0.003 | 80.0 | 14.09 |
| | | | | | | | | | | | | | | | | | | | |
| Bladen 2-IW | 0 | | | | | | | | | | | | | | | | | | |
| Bladen 2-well 1d | 3 | 17.0 | 1.11 | 4.76 | 0.075 | 0.02 | 0.000 | 0.02 | 0.000 | 0.20 | 0.000 | 2.0 | 0.00 | 2.0 | 0.00 | 0.02 | 0.000 | 147.8 | 129.54 |
| Bladen 2-well 2d | 1 | 19.6 | | 4.33 | | 0.02 | | 0.02 | | 0.20 | | 2.0 | | 2.0 | | 0.02 | | 41.0 | |
| Bladen 2-well 3 | 4 | 17.6 | 1.10 | 4.58 | 0.063 | 0.03 | 0.008 | 0.02 | 0.003 | 0.23 | 0.030 | 2.0 | 0.00 | 3.5 | 0.91 | 0.27 | 0.116 | 147.0 | 98.68 |
| Bladen 2-well 5 | 1 | 15.8 | | 4.53 | | 0.02 | | 0.02 | | 0.24 | | 5.5 | | 4.9 | | 0.02 | | 55.0 | |
| Bladen 2-well 6 | 3 | 17.0 | 1.18 | 4.64 | 0.822 | 0.15 | 0.012 | 0.05 | 0.033 | 0.22 | 0.023 | 4.4 | 0.83 | 3.8 | 0.19 | 0.25 | 0.007 | 48.3 | 3.38 |
| Bladen 2-stream | 4 | 16.0 | 1.70 | 4.32 | 0.341 | 0.04 | 0.006 | 0.11 | 0.088 | 0.23 | 0.027 | 7.9 | 1.72 | 7.8 | 1.43 | 0.02 | 0.000 | 45.5 | 9.47 |
| | | | | | | | | | | | | | | | | | | | |
| Bladen 6-IW | 4 | 7.9 | | 3.13 | | 0.02 | | 0.02 | | 1.40 | | 54.0 | | 57.0 | | 0.02 | | 108.5 | |
| Bladen 6-well 2s | 4 | 16.7 | 0.84 | 5.21 | 0.086 | 0.25 | 0.015 | 0.03 | 0.005 | 0.46 | 0.032 | 9.2 | 0.81 | 9.2 | 0.78 | 0.05 | 0.009 | 51.3 | 7.56 |
| Bladen 6-well 3s | 4 | 17.5 | 1.45 | 4.19 | 0.065 | 0.19 | 0.023 | 0.02 | 0.000 | 0.78 | 0.113 | 22.3 | 1.38 | 26.8 | 3.25 | 0.09 | 0.064 | 235.0 | 163.01 |
| Bladen 6-well 4s | 1 | 20.6 | | 4.79 | | 0.25 | | 0.02 | | 0.39 | | 7.9 | | 10.0 | | 0.04 | | 39.0 | |
| Bladen 6-well 5s | 3 | 17.6 | 2.13 | 5.03 | 0.085 | 0.15 | 0.035 | 0.03 | 0.007 | 0.81 | 0.203 | 25.3 | 8.11 | 26.3 | 8.37 | 0.04 | 0.006 | 312.0 | 245.56 |
| Bladen 6-stream | 4 | 14.0 | 2.01 | 3.35 | 0.132 | 0.02 | 0.000 | 0.02 | 0.000 | 1.10 | 0.451 | 22.7 | 1.33 | 30.8 | 2.77 | 0.17 | 0.047 | 71.3 | 6.28 |
| | | | | | | | | | | | | | | | | | | | |
| Bladen 7-IW | 4 | 9.9 | | 2.96 | | 0.02 | | 0.02 | | 1.10 | | 45.0 | | 43.0 | | 0.05 | | 86.8 | |
| Bladen 7-well 1s | 4 | 18.0 | 2.86 | 4.33 | 0.181 | 0.02 | 0.000 | 0.10 | 0.016 | 0.31 | 0.035 | 12.3 | 3.50 | 13.9 | 3.51 | 0.02 | 0.000 | 34.8 | 5.00 |

Table 24. Overall Mean Concentration of Water Quality Parameters at IW Study Sites

| Site* | N | Water Temp °C | s.e. | pH S.U. | s.e. | NH4 mg/L | s.e. | $NO_2/NO_3$ mg/L | s.e. | TKN mg/L | s.e. | DOC mg/L | s.e. | TOC mg/L | s.e. | Extractable P mg/L | s.e. | Specific Condo µS/cm | s.e. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bladen 7-well 3 | 4 | 18.6 | 1.50 | 4.71 | 0.098 | 0.03 | 0.010 | 0.38 | 0.096 | 0.35 | 0.150 | 2.0 | 0.00 | 4.8 | 2.75 | 0.37 | 0.343 | 24.8 | 3.20 |
| Bladen 7-well 8 | 3 | 18.3 | 1.63 | 4.75 | 0.030 | 0.02 | 0.000 | 0.17 | 0.040 | 0.20 | 0.000 | 2.0 | 0.00 | 2.0 | 0.00 | 0.02 | 0.000 | 47.0 | 0.00 |
| Bladen 7-stream | 4 | 16.3 | 3.24 | 3.62 | 0.173 | 0.04 | 0.011 | 0.02 | 0.000 | 0.90 | 0.226 | 35.5 | 8.94 | 38.8 | 10.27 | 0.08 | 0.023 | 73.7 | 7.54 |
| | | | | | | | | | | | | | | | | | | | |
| Bladen 9-IW | 0 | | | | | | | | | | | | | | | | | | |
| Bladen 9-well 1d | 4 | 18.0 | 0.60 | 4.54 | 0.090 | 0.02 | 0.000 | 0.56 | 0.224 | 0.20 | 0.000 | 2.0 | 0.00 | 2.0 | 0.00 | 0.03 | 0.008 | 124.0 | 84.03 |
| Bladen 9-well 2d | 4 | 18.6 | 1.59 | 4.47 | 0.172 | 0.02 | 0.000 | 0.30 | 0.124 | 0.20 | 0.000 | 2.0 | 0.00 | 2.0 | 0.00 | 0.02 | 0.000 | 120.8 | 85.45 |
| Bladen 9-well 3d | 4 | 17.4 | 0.51 | 5.04 | 0.148 | 0.07 | 0.005 | 0.02 | 0.000 | 0.20 | 0.000 | 2.7 | 0.11 | 2.6 | 0.10 | 0.06 | 0.000 | 28.0 | 1.78 |
| Bladen 9-well 4 | 3 | 15.2 | 2.22 | 4.69 | 0.281 | 0.04 | 0.012 | 0.04 | 0.023 | 0.20 | 0.000 | 4.5 | 0.64 | 4.7 | 0.69 | 0.05 | 0.018 | 44.0 | 9.87 |
| Bladen 9-stream | 3 | 11.0 | 2.55 | 3.71 | 0.375 | 0.02 | 0.000 | 0.02 | 0.000 | 0.25 | 0.005 | 9.4 | 1.60 | 10.9 | 1.15 | 0.02 | 0.000 | 43.6 | 9.00 |
| | | | | | | | | | | | | | | | | | | | |
| Bladen 17-IW | 3 | 18.6 | 7.35 | 7.20 | 3.700 | 0.02 | 0.000 | 0.02 | 0.000 | 0.68 | 0.060 | 21.5 | 3.50 | 24.5 | 4.50 | 0.06 | 0.025 | 43.9 | 1.55 |
| Bladen 17-well 1d | 1 | 16.5 | | 4.90 | | 0.02 | | 0.02 | | 0.20 | | 2.0 | | 2.0 | | 0.02 | | 33.0 | |
| Bladen 17-well 2d | 4 | 16.9 | 0.49 | 4.57 | 0.078 | 0.02 | 0.000 | 0.03 | 0.005 | 0.20 | 0.000 | 2.0 | 0.00 | 2.0 | 0.00 | 0.02 | 0.000 | 32.3 | 1.65 |
| Bladen 17-well 4d | 4 | 17.8 | 1.57 | 4.44 | 0.087 | 0.02 | 0.000 | 0.02 | 0.000 | 0.20 | 0.000 | 2.0 | 0.00 | 2.0 | 0.00 | 0.02 | 0.000 | 32.8 | 2.59 |
| Bladen 17-well 5d | 1 | 18.1 | | 4.74 | | 0.02 | | 0.03 | | 0.20 | | 2.0 | | 2.7 | | 0.11 | | 30.0 | |
| Bladen 17-well 6 | 1 | 19.0 | | 4.68 | | 0.02 | | 0.05 | | 0.20 | | 2.0 | | 2.0 | | 0.02 | | 30.0 | |
| Bladen 17-well 7 | 3 | 18.0 | 4.21 | 4.71 | 0.072 | 0.02 | 0.003 | 0.07 | 0.035 | 0.24 | 0.040 | 5.0 | 0.35 | 5.5 | 0.39 | 0.02 | 0.003 | 141.0 | 110.52 |
| Bladen 17-stream | 4 | 14.8 | 3.34 | 3.20 | 0.025 | 0.05 | 0.026 | 0.02 | 0.000 | 1.04 | 0.142 | 47.8 | 3.71 | 59.3 | 7.00 | 0.05 | 0.012 | 96.7 | 4.70 |
| | | | | | | | | | | | | | | | | | | | |
| Green Swamp 1-IW | 4 | 16.6 | 4.89 | 3.56 | 0.059 | 0.02 | 0.000 | 0.02 | 0.000 | 0.77 | 0.116 | 27.5 | 4.48 | 30.3 | 5.78 | 0.03 | 0.005 | 68.2 | 4.97 |
| Green Swamp 1-well 1 | 4 | 17.2 | 2.60 | 4.62 | 0.066 | 0.02 | 0.000 | 0.02 | 0.000 | 0.20 | 0.000 | 2.7 | 0.27 | 2.9 | 0.43 | 0.02 | 0.000 | 55.9 | 15.33 |

Table 24. Overall Mean Concentration of Water Quality Parameters at IW Study Sites

| Site* | N | Water Temp °C | s.e. | pH S.U. | s.e. | NH4 mg/L | s.e. | $NO_2/NO_3$ mg/L | s.e. | TKN mg/L | s.e. | DOC mg/L | s.e. | TOC mg/L | s.e. | Extractable P mg/L | s.e. | Specific Condo µS/cm | s.e. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Green Swamp 1-well 2 | 4 | 18.1 | 1.70 | 4.44 | 0.025 | 0.02 | 0.000 | 0.02 | 0.000 | 0.23 | 0.028 | 3.8 | 0.53 | 4.0 | 0.65 | 0.02 | 0.000 | 55.5 | 4.73 |
| Green Swamp 1-well 4i | 4 | 18.6 | 1.58 | 4.46 | 0.053 | 0.02 | 0.000 | 0.02 | 0.000 | 0.20 | 0.001 | 2.0 | 0.00 | 2.0 | 0.00 | 0.02 | 0.000 | 36.0 | 3.37 |
| Green Swamp 1-well 5 | 2 | 16.2 | 1.00 | 4.47 | 0.085 | 0.02 | 0.000 | 0.02 | 0.000 | 0.20 | 0.000 | 2.0 | | 2.0 | 0.00 | 0.02 | 0.000 | 30.5 | 1.50 |
| Green Swamp 1-Non-IW | 4 | 19.2 | 5.06 | 3.69 | 0.075 | 0.06 | 0.019 | 0.02 | 0.000 | 0.83 | 0.050 | 27.5 | 1.71 | 27.8 | 1.31 | 0.02 | 0.000 | 62.8 | 4.11 |
| Green Swamp 2-IW | 4 | 10.9 | 1.25 | 3.60 | 0.040 | 0.02 | 0.000 | 0.02 | 0.000 | 0.91 | 0.065 | 36.0 | 5.00 | 38.0 | 4.00 | 0.25 | 0.175 | 46.0 | 10.95 |
| Green Swamp 2-well 1s | 4 | 17.6 | 2.96 | 4.43 | 0.087 | 0.03 | 0.005 | 0.02 | 0.000 | 0.21 | 0.008 | 3.1 | 0.18 | 3.1 | 0.15 | 0.02 | 0.000 | 35.3 | 0.48 |
| Green Swamp 2-well 2s | 4 | 18.2 | 3.01 | 4.74 | 0.074 | 0.02 | 0.000 | 0.02 | 0.000 | 0.20 | 0.000 | 2.0 | 0.00 | 2.0 | 0.00 | 0.02 | 0.000 | 22.0 | 0.41 |
| Green Swamp 2-well 3s | 4 | 17.6 | 3.18 | 4.66 | 0.088 | 0.02 | 0.000 | 0.02 | 0.000 | 0.20 | 0.000 | 2.0 | 0.00 | 2.0 | 0.00 | 0.02 | 0.000 | 24.5 | 0.96 |
| Green Swamp 2-Non-IW | 4 | 16.4 | 3.50 | 3.78 | 0.101 | 0.02 | 0.000 | 0.02 | 0.000 | 0.51 | 0.139 | 11.8 | 1.63 | 17.8 | 5.15 | 0.05 | 0.015 | 37.8 | 7.08 |
| LB-IW | 0 | | | | | | | | | | | | | | | | | | |
| LB-well 1 | 4 | 21.7 | 3.62 | 3.98 | 0.415 | 0.04 | 0.009 | 0.02 | 0.000 | 1.18 | 0.085 | 47.5 | 12.59 | 47.5 | 13.14 | 0.04 | 0.011 | 94.0 | 66.00 |
| LB-well 2 | 4 | 22.6 | 1.48 | 4.00 | 0.210 | 0.17 | 0.031 | 0.02 | 0.000 | 1.28 | 0.103 | 51.8 | 1.03 | 57.0 | 0.71 | 0.15 | 0.073 | 87.0 | 7.00 |
| LB-well 3 | 4 | 21.2 | 0.14 | 4.63 | 0.125 | 0.02 | 0.000 | 0.02 | 0.000 | 0.21 | 0.005 | 2.1 | 0.08 | 4.8 | 0.28 | 0.05 | 0.015 | 47.0 | 1.00 |
| LB-well 4 | 4 | 20.6 | 0.15 | 4.82 | 0.315 | 0.04 | 0.018 | 0.02 | 0.000 | 0.91 | 0.696 | 2.1 | 0.08 | 5.8 | 2.27 | 0.06 | 0.031 | 46.5 | 3.50 |
| LB-Non-IW | 4 | 17.1 | 3.59 | 5.48 | 0.025 | 0.02 | 0.000 | 0.02 | 0.000 | 0.75 | 0.132 | 28.8 | 4.87 | 29.3 | 5.07 | 0.05 | 0.014 | 78.6 | 2.39 |

Table 24. Overall Mean Concentration of Water Quality Parameters at IW Study Sites

| Site* | N | Water Temp °C | s.e. | pH S.U. | s.e. | NH4 mg/L | s.e. | $NO_2/NO_3$ mg/L | s.e. | TKN mg/L | s.e. | DOC mg/L | s.e. | TOC mg/L | s.e. | Extractable P mg/L | s.e. | Specific Condo µS/cm | s.e. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MA-IW | 0 | | | | | | | | | | | | | | | | | | |
| MA-well 1 | 4 | 18.7 | 0.38 | 5.40 | 0.110 | 0.02 | 0.000 | 0.02 | 0.000 | 0.20 | 0.000 | 2.0 | 0.00 | 2.0 | 0.00 | 0.03 | 0.008 | 49.5 | 0.50 |
| MA-well 2 | 4 | 20.4 | 0.17 | 5.31 | 0.100 | 0.03 | 0.005 | 0.02 | 0.000 | 0.20 | 0.000 | 2.0 | 0.00 | 2.0 | 0.00 | 0.04 | 0.020 | 51.5 | 1.50 |
| MA-well 3 | 4 | 18.1 | 3.62 | 5.62 | 0.145 | 0.05 | 0.005 | 0.02 | 0.000 | 0.20 | 0.000 | 2.0 | 0.00 | 2.0 | 0.00 | 0.02 | 0.003 | 70.5 | 1.50 |
| MA-Non-IW | 4 | 15.1 | 6.30 | 4.82 | 0.010 | 0.02 | 0.000 | 0.02 | 0.000 | 1.85 | 0.350 | 35.5 | 10.50 | 39.0 | 10.00 | 0.19 | 0.025 | 107.1 | 103.45 |
| | | | | | | | | | | | | | | | | | | | |
| MF-IW | 0 | | | | | | | | | | | | | | | | | | |
| MF-well 1 | 1 | | | | | 0.20 | | 0.07 | | 20.00 | | | | 140.0 | | 1.20 | | | |
| MF-well 2 | 1 | | | | | 0.08 | | 0.12 | | 8.00 | | | | 76.0 | | 9.90 | | | |
| MF-well 4 | 4 | 22.9 | 3.95 | 4.81 | 0.640 | 0.04 | 0.013 | 0.02 | 0.000 | 2.18 | 0.522 | 6.1 | 1.67 | 24.0 | 8.81 | 0.64 | 0.192 | 737.5 | 107.50 |
| MF-Non-IW | 4 | 15.9 | 4.20 | 4.66 | 0.005 | 0.12 | 0.095 | 0.04 | 0.020 | 1.63 | 0.770 | 26.0 | 13.00 | 25.5 | 8.50 | 0.11 | 0.030 | 88.1 | 3.05 |

*Each Site has three Station Types - 1.) Groundwater "wells", 2.) Surface Water "Iws" (Isolated Wetlands), and 3.) Surface Water "Streams" or "Non-IWs" (Non-Isolated Wetlands/Connected Wetlands)

S.E. = Standard Error

Several metals were included in the laboratory analysis (See Appendix C) but were not a focus of this project so significant discussion is not provided here. Many of them, such as arsenic, cadmium, selenium, lead, and others, were entirely or mostly below the practical quantitation limit (PQL) of the method. Aluminum is noteworthy because of the high values. To provide context, the EPA standard for Aluminum in drinking water is 50 – 200 ug/L (http://water.epa.gov/drink/contaminants/index.cfm#Inorganic). North Carolina does not have a separate standard; the standard in South Carolina is the same as EPA has (http://www.scdhec.gov/environment/water/regs/r61-58.pdf). All but a few of the samples in this project exceeded 200 ug/L, some by orders of magnitude. The MF wells were the most extreme example of this. National standards for other parameters also are exceeded in these results, including iron and manganese.

The MF site had the highest recorded concentrations of several parameters, including Arsenic, Barium, Chromium, Copper, Iron, Lead, and others. Whether or not these represent a potential human or environmental health problem is unknown but may warrant follow-up investigation.

### 3.3.4 Hydrology and Water Quality Soil Sampling Results and Discussion

Sampling results of the soils in the hydrology/water quality sites were analyzed the same as for the biocriteria sites discussed in Section 3.1.6. Results are essentially the same, which is expected since the sites are all on the Coastal Plain with similar landscape settings. The wetland soils tend to be quite acidic, with most having a pH value of 5 or less (Figure 78). They also have fairly low organic content as seen in humic percent and LOI. This is typical in primarily mineral Coastal Plain soils and the wet flats that occur there (Rheinhardt et al. 2002). The high bulk density and low cation exchange capacity (CEC) are further indications of the primarily mineral content of the soils (Mitsch and Gosselink 1993). The base saturation and exchanged acidity results also are characteristic of acid soils.

There were exceptions to the general trend. At the LB site, for example, one sample had a LOI of 92.4% and another of 90.8%. The mean CEC at this site was highest of all. The LB wetland is a small Carolina Bay with very dense shrubs in the interior that probably result in high organic matter accumulation.

Upland soils near the hydrology/water quality sites had similar characteristics to soils in the wetlands (Figure 79) but there were significant differences. Two-way analysis of variance indicates the wetland soils were greater than upland soils ($p<.05$) in humic percent, cation exchange capacity, exchanged acidity, and LOI. Upland soils were greater than wetland soils ($p<.05$) in bulk density, base saturation, and pH. There were no differences in total phosphorus. There were also significant differences among sites except in total phosphorus

.

In both upland and wetland samples the total phosphorus tended to be very low (Figure 78 and Figure 79). The reported range in North Carolina soils is 20 – 800 ppm (mg / $dm^3$ same as ppm) (http://www.ncagr.gov/agronomi/pdffiles/essnutr.pdf). Soils in the hydrology/water quality sites are at the low end of the range except at Bladen 7 and Bladen 9. The site descriptions indicate their current use was silviculture and they were recently clearcut. Decomposition of the waste or some other related factor may be the cause of the elevated phosphorus.

As part of the routine analysis of the soil sample, concentrations of several major and minor nutrients also were determined. These are primarily of agricultural concern and will not be discussed in this report. See Table 25 for a summary of the results.

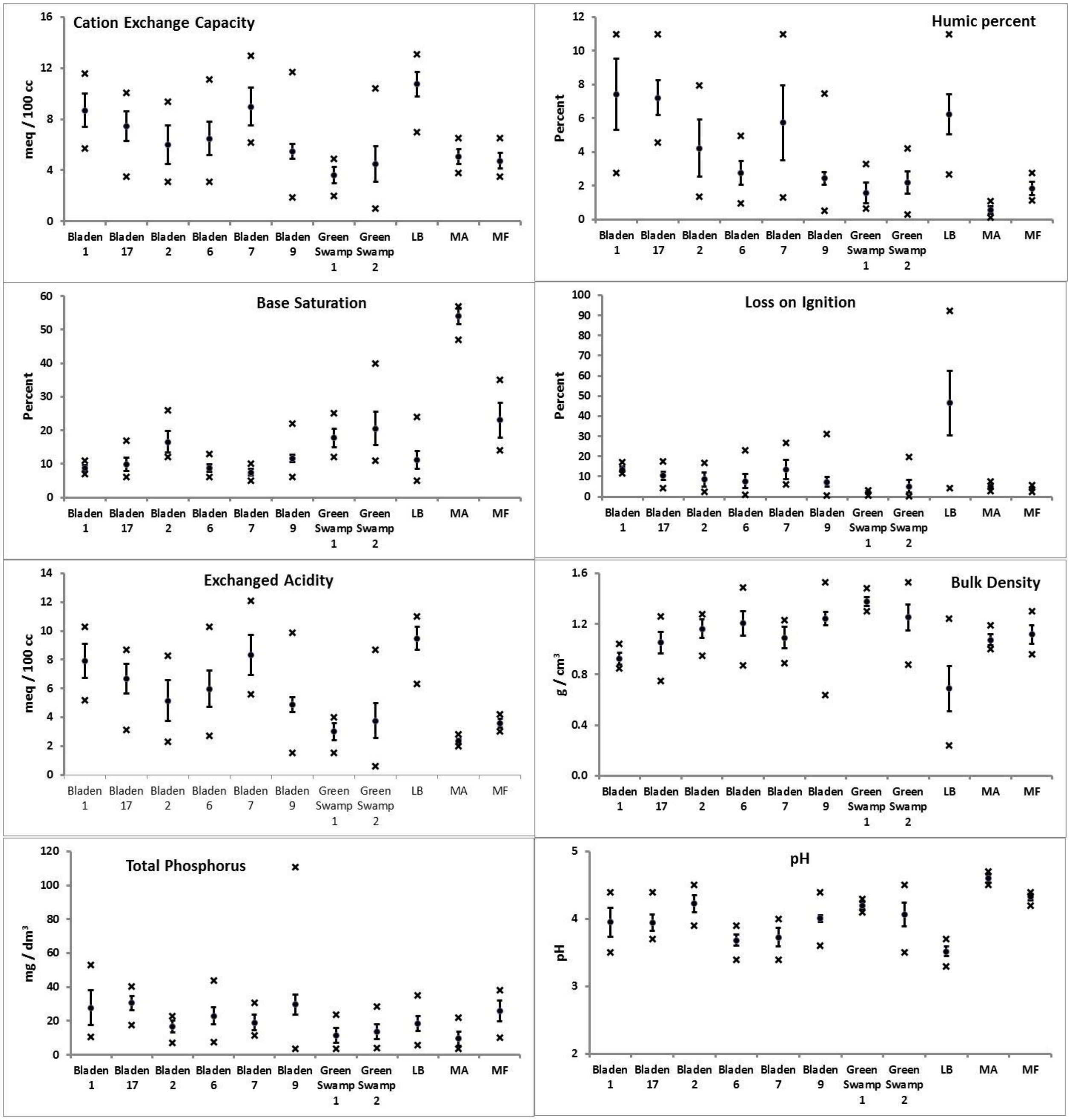


Figure 78. Results of the wetland soil analysis at the hydrology/water quality sites. Solid dot is the mean value of all samples, bars are one standard error, X are the minimum and maximum values.

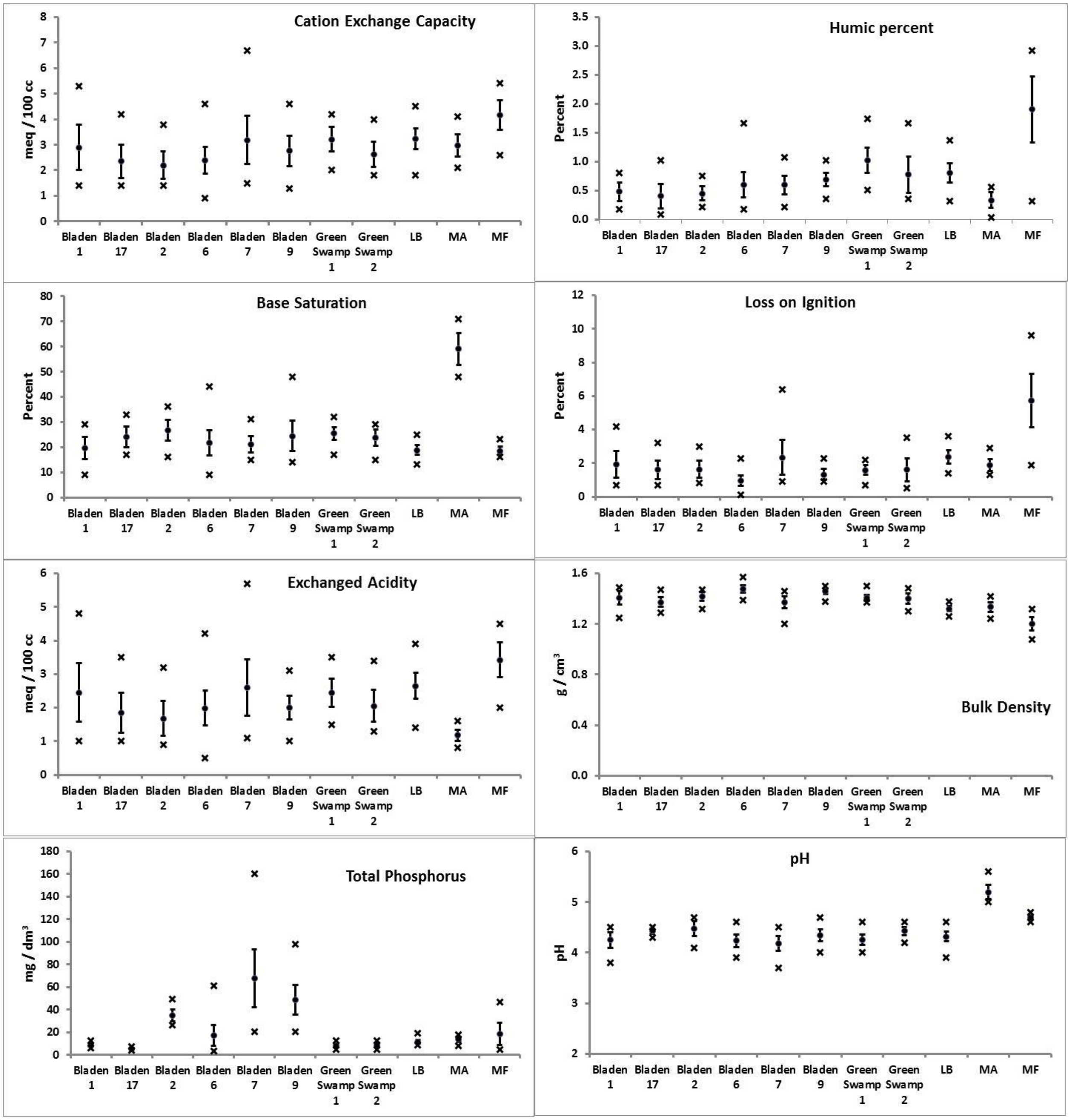


Figure 79. Results of the upland soil analysis at the hydrology/water quality sites. Solid dot is the mean value of all samples, bars are one standard error, X are the minimum and maximum values.

Table 25. Results of the soil analysis at the hydrology/water quality sites. Values are the sample mean, minimum, maximum and standard error.

| Site | Wetland / Upland | Sample No. | K mg / dm³ | Ca mg / dm³ | Mg mg / dm³ | S mg / dm³ | Mn mg / dm³ | Zn mg / dm³ | Cu mg / dm³ | Na mg / dm³ | Fe mg / dm³ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bladen 1 | U | 4 | 9.75 | 63.5 | 14 | 9.5 | 0.875 | 0.575 | 0.15 | 9.25 | 754.8 |
| minimum | | | 6 | 56 | 12 | 7 | 0.6 | 0.5 | 0.1 | 7 | 422 |
| maximum | | | 15 | 74 | 16 | 12 | 1.1 | 0.7 | 0.2 | 12 | 1007 |
| standard error | | | 1.89 | 3.77 | 0.82 | 1.04 | 0.13 | 0.05 | 0.03 | 1.11 | 122.91 |
| | | | | | | | | | | | |
| Bladen 1 | W | 4 | 37.5 | 90.5 | 25.25 | 17.25 | 0.625 | 0.45 | 0.15 | 11.75 | 2294 |
| minimum | | | 17 | 62 | 16 | 12 | 0.3 | 0.3 | 0.1 | 10 | 1901 |
| maximum | | | 62 | 158 | 38 | 24 | 0.9 | 0.6 | 0.2 | 16 | 2690 |
| standard error | | | 9.89 | 22.63 | 4.96 | 2.69 | 0.14 | 0.06 | 0.03 | 1.44 | 172.67 |
| | | | | | | | | | | | |
| Bladen 17 | U | 4 | 7.75 | 71.5 | 15 | 12.75 | 3.625 | 0.45 | 0.175 | 7.75 | 952.3 |
| minimum | | | 6 | 59 | 12 | 11 | 2.1 | 0.4 | 0.1 | 6 | 816 |
| maximum | | | 10 | 98 | 22 | 14 | 5.2 | 0.5 | 0.2 | 10 | 1137 |
| standard error | | | 1.03 | 9.21 | 2.35 | 0.75 | 0.64 | 0.03 | 0.03 | 0.85 | 67.25 |
| | | | | | | | | | | | |
| Bladen 17 | W | 5 | 22.2 | 104.4 | 22.8 | 15.8 | 1.12 | 0.98 | 0.48 | 16.2 | 1696 |
| minimum | | | 5 | 58 | 12 | 11 | 0.3 | 0.3 | 0.2 | 8 | 944 |
| maximum | | | 50 | 236 | 47 | 23 | 3.3 | 2.2 | 0.8 | 32 | 2018 |
| standard error | | | 7.52 | 33.73 | 6.19 | 2.13 | 0.55 | 0.34 | 0.12 | 4.15 | 192.84 |
| | | | | | | | | | | | |
| Bladen 2 | U | 4 | 10.25 | 72.75 | 15.5 | 10.75 | 7.375 | 0.575 | 0.225 | 8.75 | 1038 |
| minimum | | | 7 | 65 | 14 | 8 | 1.8 | 0.4 | 0.2 | 8 | 670 |
| maximum | | | 14 | 84 | 17 | 13 | 16.7 | 0.9 | 0.3 | 11 | 1231 |
| standard error | | | 1.65 | 4.33 | 0.65 | 1.03 | 3.33 | 0.11 | 0.03 | 0.75 | 125.11 |
| | | | | | | | | | | | |
| Bladen 2 | W | 4 | 24 | 116 | 27 | 25.25 | 0.95 | 0.525 | 0.3 | 13.5 | 2098 |
| minimum | | | 16 | 75 | 19 | 23 | 0.4 | 0.4 | 0.2 | 10 | 1755 |
| maximum | | | 40 | 154 | 42 | 27 | 1.9 | 0.8 | 0.4 | 17 | 2329 |
| standard error | | | 5.48 | 16.37 | 5.12 | 0.85 | 0.36 | 0.09 | 0.04 | 1.55 | 121.82 |

Table 25. Results of the soil analysis at the hydrology/water quality sites. Values are the sample mean, minimum, maximum and standard error.

| Site | Wetland / Upland | Sample No. | K mg / dm³ | Ca mg / dm³ | Mg mg / dm³ | S mg / dm³ | Mn mg / dm³ | Zn mg / dm³ | Cu mg / dm³ | Na mg / dm³ | Fe mg / dm³ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bladen 6 | U | 6 | 6.50 | 55.17 | 12.33 | 5.67 | 0.27 | 0.42 | 0.12 | 7.83 | 401.00 |
| minimum | | | 4 | 51 | 11 | 2 | 0.2 | 0.3 | 0.1 | 6 | 38 |
| maximum | | | 10 | 60 | 14 | 13 | 0.4 | 0.5 | 0.2 | 10 | 1214 |
| standard error | | | 0.89 | 1.40 | 0.42 | 1.69 | 0.03 | 0.04 | 0.02 | 0.75 | 188.75 |
| | | | | | | | | | | | |
| Bladen 6 | W | 6 | 20.33 | 64.00 | 17.83 | 9.50 | 0.35 | 0.57 | 0.10 | 18.00 | 653.50 |
| minimum | | | 5 | 53 | 11 | 3 | 0.2 | 0.3 | 0.1 | 7 | 161 |
| maximum | | | 59 | 82 | 31 | 17 | 0.8 | 1 | 0.1 | 37 | 1163 |
| standard error | | | 8.75 | 4.73 | 3.07 | 2.17 | 0.10 | 0.13 | 0.00 | 5.14 | 140.40 |
| | | | | | | | | | | | |
| Bladen 7 | U | 5 | 12 | 84.6 | 16.8 | 11.6 | 2.46 | 1.92 | 0.44 | 10 | 1122 |
| minimum | | | 8 | 62 | 14 | 8 | 1.7 | 0.5 | 0.2 | 9 | 941 |
| maximum | | | 18 | 143 | 25 | 14 | 3.4 | 4.2 | 0.8 | 13 | 1349 |
| standard error | | | 2.26 | 14.78 | 2.13 | 1.29 | 0.34 | 0.66 | 0.12 | 0.77 | 81.59 |
| | | | | | | | | | | | |
| Bladen 7 | W | 4 | 24.5 | 77.75 | 25 | 23 | 0.775 | 0.7 | 0.325 | 15 | 1994 |
| minimum | | | 12 | 60 | 14 | 14 | 0.2 | 0.3 | 0.2 | 9 | 1598 |
| maximum | | | 45 | 91 | 37 | 33 | 1.3 | 1.1 | 0.6 | 23 | 2270 |
| standard error | | | 7.60 | 6.57 | 5.21 | 4.30 | 0.26 | 0.20 | 0.09 | 3.34 | 154.92 |
| | | | | | | | | | | | |
| Bladen 9 | U | 5 | 6.2 | 131.4 | 10.4 | 11.4 | 10.48 | 0.56 | 0.46 | 6.2 | 1044 |
| minimum | | | 3 | 39 | 6 | 4 | 0.7 | 0.2 | 0.2 | 3 | 282 |
| maximum | | | 9 | 423 | 13 | 21 | 47.1 | 0.8 | 0.6 | 10 | 1631 |
| standard error | | | 0.97 | 73.41 | 1.60 | 2.82 | 9.16 | 0.10 | 0.07 | 1.24 | 251.47 |
| | | | | | | | | | | | |
| Bladen 9 | W | 19 | 22.32 | 76.79 | 22.21 | 12.95 | 0.78 | 0.48 | 0.19 | 10.84 | 1178.4 |
| minimum | | | 4 | 43 | 7 | 2 | 0.2 | 0.2 | 0.1 | 5 | 59 |
| maximum | | | 127 | 178 | 87 | 31 | 3.7 | 1.7 | 0.3 | 20 | 2671 |
| standard error | | | 6.42 | 8.95 | 4.41 | 2.20 | 0.18 | 0.07 | 0.01 | 0.99 | 226.51 |

Table 25. Results of the soil analysis at the hydrology/water quality sites. Values are the sample mean, minimum, maximum and standard error.

| Site | Wetland / Upland | Sample No. | K mg / dm³ | Ca mg / dm³ | Mg mg / dm³ | S mg / dm³ | Mn mg / dm³ | Zn mg / dm³ | Cu mg / dm³ | Na mg / dm³ | Fe mg / dm³ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Green Swamp 1 | U | 5 | 10.4 | 112.2 | 21.4 | 8.6 | 0.7 | 0.88 | 0.1 | 11.6 | 660.8 |
| minimum | | | 6 | 70 | 16 | 2 | 0.3 | 0.4 | 0.1 | 7 | 95 |
| maximum | | | 15 | 162 | 30 | 18 | 1.2 | 1.9 | 0.1 | 20 | 1504 |
| standard error | | | 1.57 | 17.12 | 2.32 | 3.46 | 0.15 | 0.27 | 0.00 | 2.23 | 281.45 |
| | | | | | | | | | | | |
| Green Swamp 1 | W | 4 | 9 | 86.5 | 20.5 | 14.75 | 0.3 | 0.55 | 0.125 | 14 | 796 |
| minimum | | | 7 | 62 | 17 | 4 | 0.2 | 0.3 | 0.1 | 13 | 76 |
| maximum | | | 12 | 135 | 28 | 29 | 0.5 | 0.8 | 0.2 | 16 | 1461 |
| standard error | | | 1.08 | 16.46 | 2.53 | 6.14 | 0.07 | 0.12 | 0.03 | 0.71 | 351.83 |
| | | | | | | | | | | | |
| Green Swamp 2 | U | 4 | 9.5 | 86.5 | 17.75 | 13.75 | 0.775 | 0.725 | 0.15 | 11.25 | 1083 |
| minimum | | | 8 | 77 | 16 | 3 | 0.5 | 0.7 | 0.1 | 8 | 66 |
| maximum | | | 11 | 93 | 19 | 30 | 1.2 | 0.8 | 0.2 | 14 | 2560 |
| standard error | | | 0.65 | 3.75 | 0.63 | 6.60 | 0.15 | 0.03 | 0.03 | 1.25 | 613.57 |
| | | | | | | | | | | | |
| Green Swamp 2 | W | 6 | 12.17 | 91.67 | 26.17 | 15.50 | 0.42 | 0.58 | 0.10 | 16.33 | 870.67 |
| minimum | | | 4 | 59 | 12 | 2 | 0.2 | 0.3 | 0.1 | 7 | 50 |
| maximum | | | 32 | 185 | 82 | 35 | 0.8 | 0.9 | 0.1 | 41 | 2748 |
| standard error | | | 4.50 | 19.12 | 11.22 | 5.25 | 0.09 | 0.10 | 0.00 | 5.41 | 406.75 |
| | | | | | | | | | | | |
| LB | U | 6 | 12.00 | 79.33 | 19.67 | 20.50 | 0.42 | 0.48 | 0.32 | 11.33 | 1233 |
| minimum | | | 6 | 53 | 13 | 4 | 0.2 | 0.3 | 0.2 | 7 | 190 |
| maximum | | | 19 | 112 | 30 | 40 | 0.7 | 0.8 | 0.4 | 14 | 2372 |
| standard error | | | 1.97 | 8.52 | 2.40 | 6.29 | 0.09 | 0.07 | 0.04 | 1.05 | 357.76 |
| | | | | | | | | | | | |
| LB | W | 6 | 46.17 | 129.33 | 62.67 | 12.83 | 1.20 | 1.23 | 0.37 | 39.33 | 935.83 |
| minimum | | | 19 | 68 | 28 | 5 | 0.4 | 0.5 | 0.2 | 20 | 320 |
| maximum | | | 102 | 385 | 118 | 21 | 4.6 | 3.1 | 0.9 | 73 | 1938 |

Table 25. Results of the soil analysis at the hydrology/water quality sites. Values are the sample mean, minimum, maximum and standard error.

| Site | Wetland / Upland | Sample No. | K mg / dm³ | Ca mg / dm³ | Mg mg / dm³ | S mg / dm³ | Mn mg / dm³ | Zn mg / dm³ | Cu mg / dm³ | Na mg / dm³ | Fe mg / dm³ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| standard error | | | 12.84 | 51.19 | 13.62 | 2.63 | 0.68 | 0.39 | 0.11 | 8.35 | 256.98 |
| MA | U | 4 | 40.5 | 266.3 | 47.5 | 14.75 | 4.475 | 0.6 | 1.025 | 9.5 | 1070 |
| minimum | | | 18 | 138 | 36 | 10 | 1.1 | 0.3 | 0.6 | 9 | 930 |
| maximum | | | 90 | 416 | 74 | 18 | 12.6 | 1.2 | 1.7 | 10 | 1225 |
| standard error | | | 17.04 | 58.18 | 8.97 | 1.70 | 2.73 | 0.20 | 0.25 | 0.29 | 61.36 |
| MA | W | 4 | 37.5 | 366.3 | 100.5 | 29.5 | 3.325 | 1.7 | 3.55 | 42.75 | 1010 |
| minimum | | | 19 | 238 | 68 | 20 | 0.7 | 0.7 | 0.5 | 19 | 780 |
| maximum | | | 59 | 505 | 125 | 37 | 5.6 | 3.6 | 11.3 | 68 | 1189 |
| standard error | | | 9.78 | 58.42 | 12.76 | 3.80 | 1.27 | 0.67 | 2.60 | 13.18 | 85.32 |
| MF | U | 4 | 27 | 85.25 | 33.5 | 33.75 | 7.225 | 0.825 | 0.7 | 11.5 | 1942 |
| minimum | | | 13 | 77 | 26 | 28 | 0.8 | 0.3 | 0.5 | 7 | 1564 |
| maximum | | | 46 | 94 | 46 | 44 | 16.9 | 1.3 | 0.9 | 15 | 2187 |
| standard error | | | 7.13 | 3.84 | 4.33 | 3.57 | 3.86 | 0.25 | 0.08 | 1.71 | 132.91 |
| MF | W | 4 | 22.75 | 178.3 | 29.25 | 23 | 0.675 | 0.85 | 0.55 | 16.25 | 1228 |
| minimum | | | 10 | 67 | 22 | 16 | 0.3 | 0.5 | 0.1 | 13 | 840 |
| maximum | | | 36 | 379 | 40 | 31 | 1.2 | 1.3 | 1 | 19 | 1605 |
| standard error | | | 6.82 | 71.41 | 4.07 | 3.08 | 0.19 | 0.18 | 0.19 | 1.25 | 185.25 |

**Phosphorus adsorption**

The analysis of factors that can influence phosphorus adsorption capacity indicate many similarities but also key differences between uplands and wetlands in the study area. In Coastal Plain landscapes high phosphorus retention is often positively correlated with high organic content. This is hypothesized to be related to a tendency for clays to settle in areas with standing water such as wetlands (Darke and Walbridge 2000) as opposed to the mostly sandy upland soils. Wetland soils in this study had significantly more organic content (as estimated by Loss on Ignition – LOI) than did upland soils (Table 26). Correlation analysis of soil results indicate a significant positive correlation of the Phosphorus Sorption Index (PSI) with LOI in upland soils but not wetland soils (Table 27). The PSI has a significant negative correlation with bulk density and positive correlation with humic matter in soils from both locations.

All of these results are consistent with expectations except the LOI to PSI correlation in wetland soils. The explanation may be that depth profiles were taken with most of the soil samples and the wetland soils tend to be more organic near the surface and become more like the upland soils with depth. This tends to reinforce the conceptual model of wet depressions on mineral landscapes and earlier discussion of the soil sampling results.

Phosphorus sorption typically occurs by Al and Fe hydrates (Walbridge and Struthers 1993) and our results indicate a significant positive correlation with oxylate extractable Al and Fe in both upland and wetland soils. Simple linear regression indicates the relationship between Al concentration and PSI is very similar in the two soil types (Figure 80) but there was almost twice as much aluminum in the wetland versus upland soils so greater capacity for phosphorus sorption. Additional analysis of our results that take soil depth into account may reveal more about these relationships.

Table 26. Descriptive statistics of Loss on Ignition (LOI) results in this study.

| LOI | Upland | Wetland |
|---|---|---|
| Number of samples | 97 | 184 |
| Mean | 2.85 | 8.10 |
| Median | 2.20 | 5.25 |
| Standard Deviation | 2.747 | 12.314 |
| Standard Error | 0.279 | 0.908 |
| Minimum | 0.1 | 0.2 |
| Maximum | 16.9 | 92.35 |

Table 27. Correlation analysis of several parameters that can influence phosphorus sorption (rho with p-value below it) in upland (top) and wetland (bottom) soils. See text for discussion. Correlations are considered significant if $p<0.05$.

| Parameter | HM | BulkDen | pH | PSI | LOI | Alox |
|---|---|---|---|---|---|---|
| **Upland** | | | | | | |
| BulkDen | -0.610 | 1 | | | | |
| | <.0001 | | | | | |
| pH | -0.216 | -0.041 | 1 | | | |
| | 0.0287 | 0.679 | | | | |
| PSI | 0.466 | -0.720 | 0.331 | 1 | | |
| | 0.0022 | <.0001 | 0.0348 | | | |
| LOI | 0.634 | -0.827 | -0.129 | 0.775 | 1 | |
| | <.0001 | <.0001 | 0.1989 | <.0001 | | |
| Alox | 0.480 | -0.594 | 0.396 | 0.778 | 0.599 | 1 |
| | 0.0017 | <.0001 | 0.0114 | <.0001 | <.0001 | |
| Feox | 0.344 | -0.503 | 0.504 | 0.692 | 0.568 | 0.508 |
| | 0.0296 | 0.0009 | 0.0009 | <.0001 | 0.0001 | 0.0008 |
| **Wetland** | | | | | | |
| BulkDen | -0.522 | 1 | | | | |
| | <.0001 | | | | | |
| pH | -0.537 | 0.259 | 1 | | | |
| | <.0001 | 0.0001 | | | | |
| PSI | 0.312 | -0.456 | 0.183 | 1 | | |
| | 0.0049 | <.0001 | 0.1033 | | | |
| LOI | 0.463 | -0.817 | -0.402 | 0.171 | 1 | |
| | <.0001 | <.0001 | <.0001 | 0.1346 | | |
| Alox | 0.275 | -0.487 | 0.159 | 0.772 | 0.366 | 1 |
| | 0.0135 | <.0001 | 0.1601 | <.0001 | 0.001 | |
| Feox | -0.115 | -0.212 | 0.193 | 0.408 | -0.021 | 0.294 |
| | 0.3079 | 0.0592 | 0.0861 | 0.0002 | 0.8558 | 0.0082 |

BulkDen = bulk density; PSI = phosphorus adsorption index; LOI = loss on ignition; Alox/ Feox = oxalate extractable aluminum and iron, respectively.

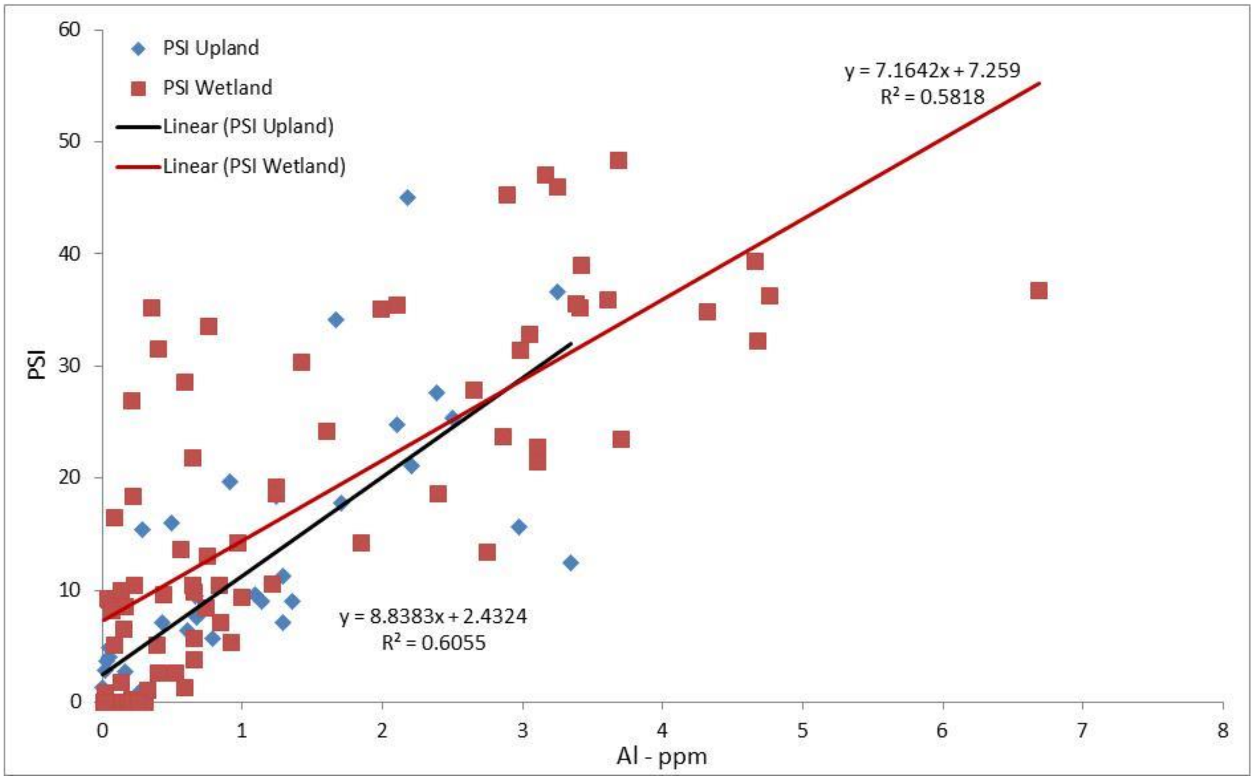


Figure 80. Plot of PSI (dependent) and oxalate extractable Aluminum (independent) for upland and wetland soils in the study area. Also shown are the simple linear regression equations and $R^2$ for the relationships.

## 3.3 North Carolina Isolated Wetland Impacts and Mitigation Records

Table 28. BIMS and NCDWQ Mitigation Database query shows the results of the BIMS and Mitigation database queries described in section 2.3. The NC statewide BIMS query showed the issuance of 3950 approvals for 6381.2 acres of wetland impacts from October 22, 2001 to December 31, 2011. One-hundred and seventy of the 3950 approvals, or 4.3%, had IW impacts as part of the project. These IW, which include both 401 WQCs and Isolated Wetland permits (see section 2.3), resulted in 82.2 acres of IW impacts or 1.2% of the total impact to wetlands in NC over the course of > 10 years of WQC and IW permit tracking. The BIMS query for the counties in the NC IWC project study area (Robeson, Bladen, Columbus, and Brunswick Counties) resulted in the issuance of 263 approvals for 351.3 acres of wetland impacts. Thirteen of those 263 approvals, or 4.9%, were issued for IW impacts in the four-county study area. These approvals with IW impacts (both 401 WQCs and IW Permits) resulted in 20.3 acres or 5.8% of the total impact to wetlands in the four-county study area.

Statewide, 263 of the 3950 issued approvals had wetland impacts ≥1 acre and should have triggered the mitigation of 5833.9 acres of wetlands according to North Carolina Administrative Code (NCAC). Due to a combination of both the NCAC and federal ACOE requirements, 792 of the 3950 permits ultimately will provide wetland mitigation in the amount of 15,401.8 acres of wetlands over the course of >10 years of WQCs and IW permit tracking. Twenty-nine of the 170 approvals for projects including IW impacts had total wetland impacts ≥1 acre. This should have triggered the mitigation for 182.0 total wetland acres under NCAC requirements of which 39.0 acres were impacts to IW components. The combination of the NCAC and federal ACOE mitigation requirements state-wide resulted in 29 approvals requiring mitigation for projects including IW impacts. One of the 29 approved projects accounted for 135 of the total 221.0 acres of required wetland mitigation to compensate only for that project's non-IW impacts. The remaining 86.0 acres of required mitigation sufficiently compensates for the 39.0 acres of IW impacts, therefore meeting the 2:1 mitigation:impact ratio for IW permits associated with projects ≥1 acre of impact.

In the four-county study area, 21 of the 263 issued approvals had total wetland impacts ≥1 acre and should have triggered the mitigation of 305.5 acres of wetlands. However, with NCAC and federal ACOE requirements 76 of the 263 approvals will provide 422.2 acres of mitigation. Additionally, in the four county area, three of the 13 IW impact approvals had wetland impacts ≥1 acre and should have triggered mitigation for 14.8 acres, but again with the combination of NCAC and ACOE requirements six approvals will provide 34.1 acres of compensatory mitigation. Of the 14.8 acres of impact that should have triggered mitigation, 12.8 were for impacts to IWs.

Table 28. BIMS and NCDWQ Mitigation Database query

| WQC and IW Permit Database Search Results* | Database** | NC State-wide* | | IWC Four-County Study Area* | |
|---|---|---|---|---|---|
| 1. All Wetland Impact approvals | BIMS | 3950 approvals | 6381.2 acres | 263 approvals | 351.3 acres |
| 2. IW Impact approvals | BIMS | 170 approvals | 82.2 acres | 13 approvals | 20.3 acres |
| 3. Wetland Impact approvals with ≥1-acre | BIMS | 263 approvals | 5833.9 acres | 21 approvals | 305.5 acres |
| 4. IW Impact approvals with ≥1-acre | BIMS | 29 approvals | 182.0-Wetland (39.0-IWs) acres | 3 approvals | 14.8 Wetland (12.8 IWs) acres |
| 5. Wetland Impact approvals that required mitigation | BIMS | 792 approvals | 15401.8 acres | 76 approvals | 422.2 acres |
| 6. IW Impact approvals that required mitigation | BIMS | 29 approvals | 221 Wetland (86.0***) acres | 6 approvals | 34.1 Wetland acres |
| 7. Trackable IW Mitigation Projects for BIMS permits | BIMS-Mitigation | 3 | 23.51 Wetland (11.13 IWs) acres | 1 | 14.85 Wetland (10.66 IWs) acres |

*BIMS queries included both 401 WRCs for impacts to 404 wetlands and/or Isolated Wetland permits for impacts to non-404 jurisdictional wetlands.
**Most accurate and up to date information is included in this Table; however some data may have been lost when the NC DWQ File Maker was converted to the BIMS database.
***135 of the 220.98 wetland acres were mitigation associated with non-IW components of one project. 86.0 acres more accurately depicts the amount of mitigation provided for IW components of the 29 state-wide permits, as described in the above text.

Table 29 summarizes the mitigation for the three BIMS permits that were tracked in the Mitigation Database. There were three wetland approvals with an IW component that cross referenced between the BIMS and Mitigation Databases (i.e. the same project number was assigned in both the BIMS and Mitigation databases). For these three approvals there were 23.51 acres of impacts to non-IWs and IWs combined, of which 11.13 acres were for impacts to just IWs. All three tracked approvals were 401 WQC projects.

The three projects with IW components that were tracked from impact to mitigation stage were examined to determine the acreage, wetland type (IW and/or non-IW) and mitigation activity (see Table 29). Both on-site and off-site mitigation were used for these projects. The on-site mitigation for the three projects resulted in the 23.23 acres of on-site mitigation for impacts to IWs through restoration, creation, and preservation. Aerials, plan sheets, and soils maps indicated that none of the on-site mitigation acres resulted in an isolated wetland type.

There were also 7.16 acres of off-site mitigation for these projects through the purchase of mitigation credits from EEP therefore it was not possible to track the wetland type. The largest project to impact IWs was the Brunswick County Airport project. This project had 14.85 acres of total wetland impacts of which 10.66 acres were impacts to IWs.

Table 29. IWs tracked for mitigation

| BIMS Project Number | Project Name | Wetland Impact (Non-IWs and IW) | IW Impact | Mitigation Type | Isolated Mitigation ? | Mitigation Activity | Mitigation Acres | Mitigation for IW | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 19930818 | South Wake Sanitary Landfill | 6.88 | 0.15 | Wetland (Riparian) | No | Enhancement | 0.72 | 0.15 | |
| | | | | Wetland | N/A | Multiple types | 6.16 | | Off-Site via EEP |
| 20030948 | Brunswick County Airport | 14.85 | 10. 66 | Wetland (Riparian) | No | Preservation | 4.2 | 21.3 | |
| | | | | Wetland | No | Restoration | 31 | | |
| 20060922 | Airport Road Retail Shopping Center | 1.78 | 0.32 | Wetland (Non-riparian, wetter) | No | Creation | 1.41 | 1.78 | |
| | | | | Wetland | No | Preservation | 0.3 | | |
| | | | | Wetland | N/A | Restoration | 1 | | Off site via EEP |

Overall impacts to IWs in the BIMS query were 82.2 acres statewide and 20.3 acres in the four-county study area while 86.0 acres of mitigation were required for approved impacts with IW components statewide and 34.1 acres in the four-county study area. These queries indicate that at a state level the IWs were mitigated at approximately a 1:1 mitigation to impact ratio (86.0 acres mitigation:82.2 acres impact) and at the four-county study area approximately a 1.7:1 mitigation to impact ratio (34.1 acres mitigation:20.3 acres impact).

IWs that were associated with project approvals that had ≥1 acre of impact, and should have triggered mitigation, were mitigated by multiple wetland types at a 2.2:1 mitigation to impact ratio (86.0 acres mitigation:39 acres impact) and at the four-county study area approximately a 2.7:1 mitigation to impact ratio (34.1 acres mitigation:12.8 acres impact). These ratios meet the 2:1 mitigation to impact ratio required for wetland project approvals that impact ≥1 acre of IWs under 15A NCAC 2H .1305 (g)(2)). These results show that for all approved IW impacts about half the IWs statewide and one-third in the four-county study area are associated with project approvals that did not require mitigation because they were below the one-acre threshold that requires mitigation. The queries did not show any IW mitigation sites (see Table 14); however, it is possible some IWs were mitigated for with the creation, restoration, enhancement or preservation of IWs. Pine flats and Carolina bays have the greatest potential for providing IW mitigation sites and can provide the large mitigation acreage usually found in mitigation banks or NC EEP projects. Vernal pools and cypress savannahs are IWs that would provide better amphibian habitat but their small size would yield fewer compensatory mitigation credits, making them less enticing to mitigation managers. IWs are non-jurisdictional wetlands and cannot be used for ACOE compensatory mitigation credits which account for the majority of the needed and required wetland mitigation statewide.

The BIMS queries on impacts to IWs also indicated that 7.6 % of the approvals (13 out of 170) and 24.7 % (20.3 out of 82.2 acres) of the acreage was in the four-county study area. These percentages show that this four-county part of the state has a disproportionately large percent of IWs as well as development. Brunswick County, NC is expected to have the largest percent increase in population of any coastal county in the Southeast (Crossett et al. 2004). It is probable the SC four-county study area (Horry, Dillon, Marion, and Florence counties) also has a disproportionately large percent of IWs that have been impacted when the distribution of Carolina bays in this part of the state and development associated with Myrtle Beach is considered. The SEIWA study also showed the NC four-county study area had IWs with an average size of 0.77 acres and median size of 0.41 acres and about one-third of the sites fell below the 1/3 acre reporting threshold (RTI International et al. 2011). These average and median values indicate that projects with impacts solely to an IW are usually large enough to be reported (≥1/3 acre east of I-95) but not large enough to require mitigation. However, some IWs are still too small to require reporting under current rules.

NC DWQ would benefit from improvements to BIMS and the mitigation database. A more accurate method for tracking mitigation, improvements in the level of project detail, improved consistencay in the classification of wetland impact and mitigation types, and the improved consistency in data entry would enhance the ability of the NC state wetland managers to access wetland resource data in NC. Even with database improvements there is still the potential to lose IWs as a vital natural resource in NC since impacts to IWs do not currently require in-kind mitigation for isolated wetlands. In SC, most IWs are not protected so there has been no tracking of IW impacts which makes the management of this natural resource all that much more difficult.

## Section 4 – CONCLUSION

### 4.1 Biocriteria Site Summary and Conclusions

IWs were evaluated in this study to better understand their ecology, water quality, and hydrology. These sites may be isolated in terms of a surface water connection, but not in terms of biota and a ground-water connection. This study sought to extend the methods of the prior SEIWA study by intensively surveying 11 biocriteria sites as well as 11 hydrology sites described in the following section. There were two study objectives associated with the biocriteria sites: 1.) To develop biocriteria for "at-risk" Coastal Plain IWs by completing a Level 3 intensive survey of the water quality, soils, vegetation, amphibians, and macrobenthos for 10-12 isolated wetland sites 2.) To further verify and validate the NC WAM (Wetlands Assessment Method) by statistically correlating the intensive survey results to the NCWAM ratings. For Objective 1, biocriteria (IBIs) were developed for the vegetation but not for the amphibian and macroinvertebrate communities due to limited field data. The field results of the amphibian and macroinvertebrate communities along with the water and soil quality attributes were summarized and characterized in this report. For objective 2, the vegetation IBIs were correlated with NCWAM.

The random sampling design used to select 10 of the 11 high, medium, and low rated IW basin sites within the eight-county study area resulted the selection of sites that were variable in quality, size, vegetation community type, and structure. It can be concluded that the flat nature of a number of the sites and dry climatic conditions during the 2012 sampling field season resulted in poor habitat for both the amphibian and aquatic macroinvertebrate communities. Only four sites, Horry 1, Horry 41, Brunswick 4, and Brunswick 7, had temporary pools of water during the March sampling and none during the May sampling. Horry 1 was the only site with a sizeable pool, although this was a poor quality, low rated site, located in the managed grassy operations area of the Horry County airport. Additionally, two of the four sites, Horry 41 and Brunswick 4, had acidic (pH < 4.0) conditions that would not attract many species of amphibians.

The aquatic macroinvertebrate survey resulted in the collection of 23 genera from 6 orders and 12 families with the orders of Coleoptera and Diptera being the most diverse. The majority of the taxa (67%) collected for this study were associated with the swimming habitat guild (e.g. order Coleopetera). Macroinvertebrates were also found to be associated with six different functional feeding guilds; herbivore, shredder, collector-gatherer, scraper, predator, and omnivore for this study. The Horry 1 site, which had the largest (20 ft X 60 ft) and deepest (> 1 foot deep in sections) pool of water, and likely the longest hydroperiod, also had the highest macroinvertebrate diversity with five families and 12 genera. Based in these results, in general, the macroinvertebrate diversity in this study was low in comparison with headwater streams and wetlands with a longer hydroperiod.

The two wetland plant community type classifications (Schafale and Weakley, 1990 and Nelson, 1986) used in this study identified several different plant communities among the 11 biocriteria IW sites. These diverse vegetation communities surveyed and analyzed in this study varied in quality and condition as was indicated by the range of IBI scores. The development of the DWQ Forest IBI and calculation of the Shrub and Emergent VIBIs provided simple numeric indices that represented the quality and condition of sites that were very different in terms of vegetation community type and structure. Weighting of the forest and shrub IBIs to make all the IBIs comparable resulted in the site IBI scores ranging from 24 (Florence 14b) to 61.7 (Columbus 26) with an average of 48.6 and median of 52.0. These scores do indicate diverse quality and condition, but suggest that none of the sites in the study were truly reference quality. Other sites from previous studies used in the development of the weidghted IBIs scored in the 70 and 80s. The future development of DWQ shrub and emergent IBIs, that have been calibrated for NC and SC IWs and other wetland types, will provide a more accurate way to compare the diverse vegetation communities associated with IWs.

The dry climatic conditions and flat physiography of a number of the sites resulted in the collection of water quality parameters at only four of the eleven sites, Brunswick 4, Brunswick 7, Horry 1, and Horry 41 which made it only possible to summarize observed trends, rather than draw sound conclusions. The drought and small pool size were probably the cause of hypoxic conditions (DO < 2.0 mg/L) at two of the sites, Brunswick 7 and Horry 41. Phosphorous was also slightly elevated at Brunswick 7, possibly due to a flux of the sediment into the water column. The water quality, as previously discussed, at these four sites was highly acidic. Additionally, the soils at all the biocriteria sites were acidic, ranging from 3.3 to 5.6 with an average of 4.2. The sites sampled in this study were primarily mineral (with the exception of Horry 28) with a low organic content which was indicated by humic percent, LOI, bulk density and cation exchange capacity levels. Many IWs, although not in this study typically have high organic soil content like pocosins.

Study Objective 2 was accomplished through running a combination of six different correlations to search for differences between the NCWAM overall and habitat function ratings and the different types of IBIs (the DWQ derived forest IBI and the Ohio derived shrub and emergent VIBIs). These results show that NCWAM can successfully rate the function of IWs based on this analysis, however, there is room for improvement as the variance accounted for ranges from 31% to about 75%. It is possible that shrub and emergent IBIs calibrated for NC wetlands or a larger data set could provide better $R^2$-values and account for more of the variance in the model. However, NCWAM is still a "rapid" assessment tool which was designed to show an estimation of wetland function, as was done in this study, not necessarily condition or quality. While NCWAM has been shown to be a useable tool for estimating function, it still does not have the accuracy of an intensive Level 3 study that would produce a data set useable for calculating IBIs.

## 4.2 Hydrology and Water Quality Site Summary and Conclusions

The intensive monitoring of the hydrology sites via pressure transducer outfitted monitoring wells, and aquifer pump test showed unequivocally that these isolated systems are connected via ground water to downstream connected water bodies. Although IWs, by definition, do not have a surface water connection to streams, non-IWs, or other connected waters, the results of this study showed that there is a hydraulic connection that transfers water ultimately to streams and rivers. The water quality analysis of surface water IWs and connected downstream water bodies and groundwater collected from monitoring wells showed trends that suggest nutrient transformations occur in the IW as water moves toward the stream. The evaluation of the soils of IWs and the surrounding upland indicated that IWs are a sink for organic carbon and nutrients. IWs are a sink for pollutants many of which are removed by the wetland as indicated by the fact that the deeper wetland horizons more closely resembled the surrounding upland soils. However, it is likely a small percent of pollutants can be transferred via ground water to the aquifer and streams. Careful management of these wetland systems is essential not just for ecological value, but also for essential water quality benefits.

There were two study objectives associated with the hydrology sites, objectives 3 and 4: 3.) To determine the pollution absorption capacity of 10 to 12 Coastal Plain IWs in order to gain a better understanding of the water quality function of these systems and 4.)To identify and characterize the hydrological connectivity of 10 to 12 Coastal Plain IWs in order to improve the understanding of how these systems interact with and are connected to downstream water bodies (see Section 1.3.1 Project Study Objectives and Description). The dry climatic conditions resulted in surface water only five of the 11 IW hydrology sites.

For Objective 3, the water quality and soils analyses both indicated IWs have pollution absorption capacity as indicated by the phosphorus adsorption results. As with the biocriteria sites, water quality data were limited in this study due to drought conditions that existed during much of the field work. The data suggest that the water in the IW was significantly higher in nutrient and organic carbon concentrations than water in the upland wells. This relationship was especially clear for nitrogen, less so for phosphorus, probably due to differences in biogeochemistry that favor dissolved forms of nitrogen and particulate forms of phosphorus in the environment. Given the shallow aquifer connection between the IW and connected water body this result indicates that nutrients and organic material are sequestered in the IW.

The vertical soil profiles in the 11 IWs, which were the focus of the hydrology and water quality portion of the IWC study, were analyzed. Results of the soils analysis indicate that phosphorus sorption potential is greater in the IW than surrounding uplands. This appears to be a consequence of the higher organic content and, in particular, higher concentrations of aluminum. In most of the IWs the characteristics that are specific to wetlands occur only in the upper horizons. In deeper layers the soils more closely resemble the surrounding upland, with increased mineral and less organic characteristics. Results suggest that the phosphorus adsorption was highest in the upper soil layers.

The data collected during this project to meet objective 4 clearly indicate a subsurface hydraulic connection between the IWs and the nearby downstream connected water body. Water table contour maps, long term hydrologic monitoring, and aquifer pumping test results showed that the all of the groundwater in the water table aquifer is hydraulically connected at each of the sites. Groundwater flows from upgradient areas through the IW to a downgradient surface water body. There was no evidence of a significant hydraulic barrier in either the horizontal or vertical directions at any of three sites where aquifer pumping tests took place. Even when "aquacludes" were present in the water table aquifer, the drawdown data produced during the aquifer pumping test reveals that groundwater can still flow between the sand units comprising the water table aquifer.

The long term hydrologic monitoring and the drawdown data from the aquifer pumping tests indicate that the isolated wetlands are hydraulically connected to the water table aquifer. Though vertical gradients in IWs generally indicated discharge, the vertical gradients were somewhat dependent on local conditions. At BL7, the vertical gradient was downward following precipitation and upward during baseflow. At BL9 the vertical gradient depended on the presence or absence of a perching zone and drought conditions. At sites that had been heavily drained for years, BL1 and BL2, no vertical gradient was measured and the IW at these sites is probably a relic of pre-drainage conditions. The water table contour maps and long-term monitoring clearly indicate that groundwater flows towards and discharges into the downgradient surface water body. At one site, BL2, long-term monitoring data may indicate bank storage rather than discharge for the majority of the observed time.

Stratigraphy did have a local influence. Perched water tables and radial flow out of some IWs were the result of local stratigraphy and topography. The drawdown data from the aquifer pumping test at BL1 shows the nature of a perching but discontinuous silt unit, while the test at GS1 indicates that while there is a geologic unit that hinders groundwater flow in the vertical direction, this unit does not provide a hydraulic barrier. Partial radial flow out of BL1, BL17 and GS2 may be related to topography since there is no stratigraphic evidence of perching. In contrast is the flow from BL7 which is focused in one direction by the topography.

The isolated wetlands appear to occur where and when the water table rises above the land surface for periods of a few days to a few weeks. Thus, the isolated wetlands at the study sites are merely a reflection of the seasonal high water table or a storm induced high water table. When present, the water in the isolated wetlands is in direct communication with the water table aquifer. Since the isolated wetlands are hydraulically connected to the water table aquifer, and the water table aquifer is hydraulically connected to adjacent surface water, the isolated wetlands are hydraulically connected to surface water via groundwater.

## 4.3 North Carolina Isolated Wetlands Impacts and Mitigation Summary and Conclusions

Objective 5 for the IWC study was to determine the acreage of IWs that have been impacted and mitigated in North Carolina since 2001 and find out if there has been a net loss or increase of these systems (see Section 1.3.1). The NC DWQ BIMS and Mitigation databases, which track approvals for projects with impacts to wetlands as well as corresponding compensatory mitigation were queried to obtain information from October 22, 2001 to December 31, 2011. The queries showed just 1.2% (82.2 acres) of the 6381.2 acres of wetland impacts have been to IWs. In the NC four county study area, 5.6% (20.3 acres) of the 351.2 acres of wetland impacts have been to IWs. Therefore 24.7 % (20.3 out of 82.2 acres) of the impacts to IWs were located in the southeastern region of NC in the four-county study area. These results suggest that there is a disproportionately large percent of IWs and high amount of development in the NC four-county study area compared to other regions of the state. It was possible to determine whether the impacted IWs had been mitigated with the database queries; however, in most cases it was not possible to determine whether the impacted IWs had been mitigated in-kind with credits from IW mitigation sites. The queries indicated that at a state level, the IWs were mitigated at approximately a 1:1 mitigation to impact ratio (86.0 acres mitigation: 82.2 acres impact) and at the four-county study area approximately a 1.7:1 mitigation to impact ratio (34.1 acres mitigation: 20.3 acres impact). The mitigation to impact ratio for project approvals involving IWs for impacts ≥1 acre were 2.2:1 at the state level (86.0 acres mitigation: 39 acres impact) and 2.7:1 at the four-county level (34.1 acres mitigation: 12.8 acres impact). These results can conclude that approximately half the statewide IWs and one-third of the four-county study area IWs that are reported are below the one acre threshold that requires mitigation.

It should also be noted that the SEIWA study showed the NC four-county study area had IWs with an average size of 0.77 acres and median size of 0.41 acres with around one-third of the sites falling below the required 1/3 acre reporting threshold and 40 percent of the sites falling above the ≥ 1 acre mitigation threshold (RTI International et al. 2011). These values indicate that projects with impacts solely to an IW are large enough to be reported two-thirds of the time but not large enough to require mitigation 60 percent of the time. The fact that IWs tend to be smaller in size jeopardizes the state's ability to achieve an overall 2:1 mitigation to impact ratio for IWs or to achieve no-net loss for IWs, given the current mitigation requirements for ≥1 acre of impact. Improvements to the impact and mitigation tracking systems in NC are needed to accurately monitor the affects of IW impact approvals and their required mitigation and consideration should be given to reporting IWs that are smaller than 1/3 of an acre.

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# APPENDICES

**Appendix A** - Division of Water Quality Isolated Wetland Field Sheets and Rapid Assessment Forms

**Appendix B** - DWQ Forest IBI Candidate Metrics and NC Coefficient of Conservatism Scores

**Appendix C** – Hydrology and Water Quality Site Water Quality Metals Analysis

## Appendix A - NC DWQ and USC Isolated Wetland Field Sheets

1. DWQ Isolated Wetland Amphibian Monitoring – Field Sheet
2. DWQ Wetland Macroinvertebrate Sampling Field Sheet
3. DWQ Isolated Wetland Connectivity Plant Survey Species Cover Field Sheet
4. DWQ Isolated Wetland Connectivity Woody Stem Survey Field Sheet
5. DWQ Isolated Wetland Connectivity-Soil Field Sheet
6. SWPS/APS DWQ Isolated Wetland Connectivity Water Quality Monitoring Project-Field Sheet
7. Division of Water Quality Chemistry Laboratory Report / Water Quality
8. Division of Water Quality Groundwater Field/Lab Form
9. Core Log Sheet – Isolated Wetlands
10. Isolated Wetlands-Green Swamp Aquifer Pumping Test-GS1
11. Isolated Wetlands-Green Swamp Aquifer Pumping Test-GS1 – Measured Flow Rate Data Sheet – Discharge Bucket
12. NC Isolated Wetlands Field Sheet – Data Loggers and GPS
13. SC Isolated Wetlands Field Sheet – Ground Water
14. NCWAM Dichotomous Key to General NC Wetland Types
15. NCWAM Assessment Form vs 4.1
16. NCWAM Rating Calculator vs 4.1
17. ORAM v 5.0

## DWQ Isolated Wetland Amphibian Monitoring Project – Field Sheet

**Site Name**: ______________________ **County**: __________________ **Observers**: __________________________

**Date**: _____________ **Time Start**: ________________ **Time Stop**: ________________ **Total Time**: ____________

**Weather**:
Air Temperature: ___________________ Wind*: ____________________ Percent Cloud Cover: _________

Rain in last 48 hrs: ________________________ Air Temperature Previous 2 days ______________________

**Water Quality**:
Time parameters taken: ___________________ Water Temperature: ______________________________

Specific Conductivity: ________________ Dissolved Oxygen: _______________ pH: _________________

Comments on hydrology (saturation, inundation, depth of water, size and duration of pools etc) __________________
_______________________________________________________________________________________
_______________________________________________________________________________________

| **Species** | **Life Stage** (egg mass, larvae, juvenile, adult) | **Number observed** (egg masses or individual larvae, juv, or Adults) | **Number of eggs in mass** (<25, 25-50, 50-100, 150-200, >200) | **Comments**** | **Specimen number** (if collected) | **Photo** number |
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* Wind – Calm (<1 mph) smoke rises, light air 1-3 mph smoke drifts, light breeze (4-7mph) leaves rustle and can feel wind on face, gentle breeze (8-12 mph) twigs and leaves move around, moderate breeze (13-18 mph) moves thin branches, raises loose papers, fresh breeze (13-18 mph) moves thing branches, raises loose paper
** Comments- Include such things as microhabitat (under log, under leaves, in moss hammock, ephemeral pool, on vegetation, etc), if this is auditory observation than note in comments, how many individuals calling, malformations observed, behavior observed (e.g. guarding eggs, mating etc), questionable ID, photo taken and number)

# DWQ Wetland Macroinvertebrate Sampling Field Sheet

Site: ______________________________
County: ____________________________

Sampler's Initials: ______________________
Start Date: ____________________________
(YYYY/MM/DD)

## Macroinvertebrate Sweep and Funnel Field Data

| ID Number (Site Abbrev _technique_#) * | Sampling Technique* | Date Start (yyyy/mm/dd) | Start Time | Date End (yyyy/mm/dd) | Time End (Fn only) | Total Hours Deployed (Fn only) | Comments |
|---|---|---|---|---|---|---|---|
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*Site Abbrev_Method_# Site Abbrev – see Methods usually first 3 letters, technique – **Sweep = SW**, **Funnel Trap = FN**, **Stove Pipe = SVP**, # (e.g. KelSW1, KelSW2, KelFN1, KelFN2, KelSVP1)
Make notes in comments if other technquique used – leaf pack, visual check of rocks or woody debris)

## Sample Station Information

**Water Chemistry (Date:______________)**

| Station ID Number(s) | Air Temp | $H_2O$ Temp | %DO | Mg of DO | Specific Condo | pH | Pic # | GPS Pt (y/n) | Comments* Camera Used________ |
|---|---|---|---|---|---|---|---|---|---|
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*Comments- Include info on- smell, presence of fish, periphyton / filamentous Algae, Fe Oxidizing Bacteria

**Station Description**

| Station ID Number(s) | Location (middle, edge) | Flow Rate** | Pool / Stream | Stream width (w') / Pool Size (W'xL') | Depth of Sample location (in) | % Veg | %Shade | Substrate Texture*** |
|---|---|---|---|---|---|---|---|---|
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** Flow Rate = No Flow, Slow, Med, Fast *** Substrate Texture = silt, sand, detritus, gravel (<2"), cobble (>2"), woody debris, sphagnum and aquatic plants include all

## DWQ Isolated Wetland Connectivity
## Plant Survey Species Cover Field Sheet

Site Name:____________ Page ____ of ____

County:____________ Date:__________(yyyy/mm/dd)

Surveyor's Initials:______

| Code | Plot Number / Stratum / Statum % Cover / Corner Number / Species (Presence / Presence / % Cover) | Collected | Module____ | | | Module____ | | | Module____ | | | Module____ | | | Res Presence / Absence |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Stratum | | H | S | C | H | S | C | H | S | C | H | S | C | |
| | Statum % Cover | | | | | | | | | | | | | | |
| | Corner Number | | C# | | | C# | | | C# | | | C# | | | |
| Code | Species (Presence / Presence / % Cover) | | | | % cov | | | % cov | | | % cov | | | % cov | |
| | | | | | | | | | | | | | | | |

Stratum Height Classes --- H-Herb (0-1m), S-Shrub (1-6m), C-Canopy (>6m)

Stratum % Cover Classes--- 0-5%, 5-10%, 10-25%, 25-50%, 50-75%, 75-95%, 95-100% or Estimate % cover

Species % Cover Classes --- T=Trace (1-2 individuals), 0-1% (1m$^2$), 1-2% (1m x 2m), 2-5%(1m x 5m), 5-10% (1m x 10m), 10-25% (5m$^2$), 25-50% (5m x 10m), 50-75% (8.7m$^2$), 75-95% (9.7m$^2$), 95-100% (10m$^2$)

Presences Classes for Nested Corner Plots --- 5= 10cm x 10cm, 4= 32cm x 32 cm, 3= 1m x 1m, 4= 3.16m x 3.16m, 5= 10m x 10m, 0= overhanging

Site Name:__________________
County:__________________

# DWQ Isolated Wetland Connectivity Woody Stem Survey Field Sheet

Page______of______
Date:____________(yyyy/mm/dd)
Observers:__________________

| | | | | Saplings / Vines | | Trees | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Code | Collected | Species | Module Number | 0-1 cm | 1-2.5 cm | 2.5- | 5- | 10- | 15- | 20- | 25- | 30- | ≥35(write dbh) |
| | | | | | | | | | | | | | |

Subsample Taken (Y/N):________

Sub-sample size:____________________

# DWQ Isolated Wetland Connectivity- Soil Field Sheet

**Site Name:** ______________ **Soil type from soil maps:** ______________ **Date:** ______________ **Page #**

**County:** ______________ **Soil type from field analysis:** ______________ ______ **OF** ______

**Sample #** ______________ **Observer initials:** ______________

| | Soil Depth (to 18 inches): | Matrix Color / Mottle Color (Munsell Moist): | Horizon | Mottle Abundance (%) | Texture | Comments | Photo # |
|---|---|---|---|---|---|---|---|
| 1 | | / | | | | | |
| 2 | | / | | | | | |
| 3 | | / | | | | | |
| 4 | | / | | | | | |
| 5 | | / | | | | | |

**Sample #** ______________ **Soil type from soil maps:** ______________

**Soil type from field analysis:** ______________

| | Soil Depth (inches, 18 max): | Matrix Color / Mottle Color (Munsell Moist): | Horizon | Mottle Abundance (%) | Texture | Comments | Photo # |
|---|---|---|---|---|---|---|---|
| 1 | | / | | | | | |
| 2 | | / | | | | | |
| 3 | | / | | | | | |
| 4 | | / | | | | | |
| 5 | | / | | | | | |

## SWPS/APS DWQ Isolated Wetland Connectivity Water Quality Monitoring Project – Field Sheet

**Site Name:**____________________ **Sampler's Initials:**________________

**SWPS Station Number:** ____________________ **County:**____________________

**APS Station Number:** ____________________ **Date:** ____________________

**Station Location** ____________________ **Daily Lab Site Number:** ________
**(Wetland, Well, Stream)**

**Weather:**

Air Temperature (Wetland/Stream only):________________

Inches of Rain in last 48 hr:____________________

**Water Quality:**

Water Level: ________________ Pump Start time:________________ Pumping rate:________________

Total Depth:________________ Purge Volume: (gal/linear ft X length of water column X 3) ________________

Probe (Hydrolab / YSI85-Accumeter):____________________

| Time | Temp | SpCond | DO mg | DO% | pH | Vol(g) |
|---|---|---|---|---|---|---|
| | | | | | | |
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Temp with pH probe (Accumeter):____________

Picture Number ________ Camera Used __________

**Water Sampled:**

Method: Direct Grab / Bailed / Pumped

Comments on water quality / hydrology (e.g. water clarity or turbidity characteristics, raining at sampling time, numerous aquatic plants, presence of algae, presence of sphagnum moss or anything that might effect water quality on sampling day, metal or plastic shovel used, if sampled at new site:)________________________________________

Preservation Time: ______________ Sample Time: ________________

| **Sample type** | **Preservative** | **Bottle Size** | **"X" if taken at this site** |
|---|---|---|---|
| Nutrients | $H_2SO_4$-Sulfuric Acid & ice | 500 ml | |
| Nitrate-Nitrite (separate) | Ice | 500 ml | |
| Metals | $HNO_3$- Nitric Acid & ice | 500 ml | |
| TOC | $H_3PO_4$- Phosphoric Acid & ice | 200 ml | |
| DOC | $H_3PO_4$- Phosphoric Acid & ice | 200 ml | |

# DIVISION OF WATER QUALITY

**Chemistry Laboratory Report / Water Quality**

**COUNTY :**
**RIVER BASIN :**
**REPORT TO :** Central Office-Parkview
2321 Crabtree Blvd, Raleigh
**Other :**
**COLLECTOR(S) :** R. Savage
IWC Project

**Estimated BOD Range:**
**Seed:** **Chlorinated:**

PRIORITY
- [ ] AMBIENT
- [ ] QA
- [ ] COMPLIANCE
- [ ] CHAIN OF CUSTODY
- [ ] EMERGENCY

VISIT ID

SAMPLE TYPE
- [ ] STREAM
- [ ] EFFLUENT
- [ ] LAKE
- [ ] INFLUENT
- [ ] ESTUARY

Lab Number :
Date Received :
Time Received :
Received By :
Data Released :
Date Reported :

**Station Location:**
**Remarks:**

| Station #/Location Code | Date Begin (yy/mm/dd) | Date End (yy/mm/dd) | Time Begin | Time End | Depth - DM, DB, DBM | Value Type - A, H, L | Composite-T, S, B | Sample Type |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | BOD 310 | mg/L | | Chloride 940 | mg/L | X | NH3 as N 610 | mg/L | | Li-Lithium 1132 | ug/L |
| | COD High 340 | mg/L | | | | X | TKN an N 625 | mg/L | | Mg- Magnesium 927 | mg/L |
| | COD Low 335 | mg/L | | Chlorophyll a EPA 445.0 modified option | ug/L | X | NO2 plus NO3 as N 630 | mg/L | | Mn-Manganese 1055 | ug/L |
| | Coliform: MF Fecal 31616 | /100ml | | | | X | P: Total as P 665 | mg/L | | Na- Sodium 929 | mg/L |
| | Coliform: MF Total 31504 | /100ml | | Color: True 80 | c.u. | | PO4 as P 70507 | mg/L | | Arsenic:Total 1002 | ug/L |
| | Coliform: tube Fecal 31615 | /100ml | | Color: (pH ) 83 pH= | c.u. | | P: Dissolved as P 666 | mg/L | | Se- Selenium 1147 | ug/L |
| | Coliform: Fecal Strep 31673 | /100ml | | Color: pH 7.6 82 | c.u. | | K-Potassium | mg/L | | Hg- Mercury 71900 | ug/L |
| | Residue: Total 500 | mg/L | | Cyanide 720 | mg/L | | Cd- Cadmium 1027 | ug/L | | Ba-Barium | ug/L |
| | Volatile 505 | mg/L | | Fluoride 951 | mg/L | | Cr-Chromium:Total 1034 | ug/L | | Organochlorine Pesticides | |
| | Fixed 510 | mg/L | | Formaldehyde 71880 | mg/L | X | Cu- Copper 1042 | ug/L | | Organophosphorus Pesticides | |
| | Residue: Suspended 530 | mg/L | | Grease and Oils 556 | mg/L | | Ni-Nickel 1067 | ug/L | | Organonitrogen Pesticides | |
| | Volatile 535 | mg/L | | Hardness Total 900 | mg/L | X | Pb- Lead 1051 | ug/L | | Acid Herbicides | |
| | Fixed 540 | mg/L | | Specific Cond. 95 | umhos/cm | X | Zn- Zinc 1092 | ug/L | | | |
| | pH 403 | units | | MBAS 38260 | mg/L | | V-Vanadium | ug/L | | Base/Neutral&Acid Extractable Organics | |
| | Acidity to pH 4.5 436 | mg/L | | Phenols 32730 | ug/L | | Ag- Silver 1077 | ug/L | | TPH Diesel Range | |
| | Acidity to pH 8.3 435 | mg/L | | Sulfate 945 | mg/L | | Al- Aluminum 1105 | ug/L | | | |
| | Alkalinity to pH 8.3 415 | mg/L | | Sulfide 745 | mg/L | | Be- Beryllium 1012 | ug/L | | Purgeable Organics (VOA bottle req'd) | |
| | Alkalinity to pH 4.5 410 | mg/L | | Boron | | | Ca- Calcium 916 | mg/L | | TPH Gasoline Range | |
| X | TOC 680 | mg/L | | Tannin & Lignin | ug/L | | Co- Cobalt 1037 | ug/L | | TPH/BTEX Gasoline Range | |
| | Turbidity 76 | NTU | | Hexavalent Chromium | ug/L | | Fe- Iron 1045 | ug/L | | Phytoplankton | |
| | Coliform Total Tube | /100 ml | | Bicarbonate | mg/L | | Mo-Molybdenum | ug/L | | | |
| | | | | Carbonate | mg/L | | Sb-Antimony | ug/L | | | |
| | | | | Total Dissolved Solids | mg/L | | Sn-Tin | ug/L | | | |
| | | | | | | | Tl-Thallium | ug/L | | | |
| | | | | | | | Ti-Titanium | ug/L | | | |
| | | | | | | | Hg-1631 | ng/L | | Temperature on arrival (°C): | |

**COMMENTS :**

# GROUNDWATER FIELD/LAB FORM

North Carolina
Department of Environment and Natural Resources
DIVISION OF WATER QUALITY-GROUNDWATER SECTION

**Location code** 2R201IWLB

County **Horry**

Quad No ______ Serial No. ______

Lat. ______ Long. ______

SAMPLE TYPE
X Water
☐ Soil
☐ Other
☐ Chain of Custody

SAMPLE PRIORITY
X Routine
☐ Emergency

Lab Number ______
Date Received ______ Time: ______
Rec'd By: From:Bus, Courier, Hand Del.,
Other: ______
Data Entry By: ______ Ck: ______
Date Reported: ______

Report To: ARO, FRO, MRO, RRO, WaRO, WiRO, WSRO, Kinston FO, Fed. Trust, **Central Off.**, Other: ______

Shipped by: Bus, Courier, Hand Del., Other: ______

Collector(s): **R.Savage** Date ______ Time ______

Purpose: Baseline, Complaint, Compliance, LUST, Pesticide Study, Federal Trust, Other: **IWC Study** (circle one)

## FIELD ANALYSES

pH 400 ______ Spec. Cond.94 ______ at 25°C

Temp.10 ______ °C Odor ______

Appearance ______

Field Analysis By: ______

Owner **NC DWQ**

Location or Site ______ LB Well ______

Description of sampling point ______

Sampling Method ______ (Pump, bailer, etc.) Sample Interval ______

Remarks ______ (Pumping time, air temp., etc.)

## LABORATORY ANALYSES

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BOD 310 | mg/L | | Diss. Solids 70300 | mg/L | X | Ag-Silver 46566 | ug/L | | Organochlorine Pesticides |
| | COD High 340 | mg/L | | Fluoride 951 | mg/L | X | Al-Aluminum 46557 | ug/L | | Organophosphorus Pesticides |
| | COD Low 335 | mg/L | | Hardness: Total 900 | mg/L | X | As-Arsenic 46551 | ug/L | | Nitrogen Pesticides |
| | Coliform: MF Fecal 31616 | /100ml | | Hardness (non-carb) 902 | mg/L | X | Ba-Barium 46558 | ug/L | | Acid Herbicides |
| | Coliform: MF Total 31504 | /100ml | | Phenols 32730 | ug/l | X | Ca-Calcium 46552 | mg/L | | PCBs |
| | X TOC 680 | mg/L | | Specific Cond. 95 | µMhos/cm | X | Cd-Cadmium 46559 | ug/L | | |
| | Turbidity 76 | NTU | | Sulfate 945 | mg/L | X | Cr-Chromium 46559 | ug/L | | |
| | Residue, Total Suspended 530 | mg/L | | Sulfide 745 | mg/L | X | Cu-Copper 46562 | ug/L | | |
| | | | | | | X | Fe-Iron 46563 | ug/L | | Semivolatile Organics |
| | | | | Oil and Grease | mg/L | X | Hg-Mercury 71900 | ug/L | | TPH-Diesel Range |
| | pH 403 | units | | | | X | K-Potassium 46555 | mg/L | | |
| | Alkalinity to pH 4.5 410 | mg/L | | | | X | Mg-Magnesium 46554 | mg/L | | |
| | Alkalinity to pH 8.3 415 | mg/L | | | | X | Mn-Manganese 46565 | ug/L | | Volatile Organics (VOA bottle) |
| | Carbonate 445 | mg/L | X | $NH_3$ as N 610 | mg/L | X | Na-Sodium 46556 | mg/L | | TPH-Gasoline Range |
| | Bicarbonate 440 | mg/L | X | TKN as N 625 | mg/L | X | Ni-Nickel | ug/L | | TPH-BTEX Gasoline Range |
| | Carbon dioxide 405 | mg/L | X | $NO_2$ + $NO_3$ as N 630 | mg/L | X | Pb-Lead 46564 | ug/L | | |
| | Chloride 940 | mg/L | X | P: Total as P 665 | mg/L | X | Se-Selenium | ug/L | | |
| | Chromium: Hex 1032 | ug/L | X | Nitrate ($NO_3$ as N) 620 | mg/L | X | Zn-Zinc 46567 | ug/L | | |
| | Color: True 80 | CU | X | Nitrite ($NO_2$ as N) 615 | mg/L | | | | | LAB USE ONLY<br>Temperature on arrival (°C): |
| | Cyanide 720 | mg/L | | | | | | | | |

Lab Comments ______

 For Dissolved Analysis-submit filtered sample and write "DIS" in block.

**CORE LOG SHEET**

Page ____ of ____

**PROJECT:** Isolated Wetlands

**DRILLING METHOD:**

**BORING ID:**

**LOGGED BY:**

**CORE DIAMETER:**

**BEGIN DATE:**

**LOCATION CODE:** 2R IW

**END DATE:**

(2R County# IW well#)

(Bladen-009, Brunswick-010)

**WATER LEVEL:**

(IW - Isolated Wetlands)

| INTERVAL | RECOVERY | SOIL HORIZON | % Saturation | COLOR | % Organics | SORTING | ROUNDING | Gravel | Sand | | | | | Mud | | DESCRIPTION<br>WL -<br>K - |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Gr | VC | C | M | F | VF | Slt | Cl | |
| TO | | | | | | | | | | | | | | | | |
| TO | | | | | | | | | | | | | | | | |
| TO | | | | | | | | | | | | | | | | |
| TO | | | | | | | | | | | | | | | | |
| TO | | | | | | | | | | | | | | | | |
| TO | | | | | | | | | | | | | | | | |

Isolated Wetlands – Green Swamp Aquifer Test - GS1 - May 16-20, 2011 P 1 of __

**Project Name:** Isolated Wetlands
**Location:** GS1 - Green Swamp
**Well Number or Name:** GS1-

Measuring point at Top of Casing
Measure to 0.01 foot

| Date | Time | MP Hold, | Wetted Chalk Mark | Depth to Water From MP | Observer Initials | Remarks (e.g., weather, well condition) |
|---|---|---|---|---|---|---|
| | | Ft. | Ft. | Ft. | | |
| | | | | | | |

**NOTES:**

Isolated Wetlands – Green Swamp Aquifer Test - GS1 - May 16-20, 2011
Measured Flow Rate Data Sheet - Discharge Bucket



| | | |
|---|---|---|
| **Project Name:** | Isolated Wetlands | time - on the clock |
| **Location:** | GS1 - Green Swamp | measured = in bucket at end of discharge pipe - gallons/second (gps) |
| **Well Number or Name:** | GS1 - Discharge Bucket | convert to gallons/minute (gpm)<br>gallons ÷ seconds X 60 = gallons per min (gpm) |

| **Date** | **Time** | **Measured Flow Rate (in bucket)** | | | **Observer Initials** | **Remarks** |
|---|---|---|---|---|---|---|
| | | **# gallons** | **fill time** | **rate (gpm)** | | |
| | | | | | | |

NOTES:

**Isolated Wetlands Field Sheet - Data Logger and GPS**

To name new Datalogger Log File: Site ID = Site Name (e.g., BL1)
Log Name = well name(i.e. BL7-MW1D)

| | Date | Operator (initials) | Well_ID | Time | Water Level before (feet) | Water Level-DL | Action (Restart, let it run, etc) | Water Level-DL | Laptop used | DL Status* (I, P, R, no DL) | DL Serial # | Cable Length | File Exported (Y/N) | Data logger file name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | |

see other side

see other side

* DL Status: I - install, P - Previously installed, U - Uninstalled, N - no Data logger

SC - Isolated Wetlands Field Sheet - Groundwater Monitoring

| | Date | Checked by: | Well ID | Time | Well Depth below land during installation (feet) | Total Depth (feet) | Riser Length (feet) | E-Tape DTW (feet) | Logger DTW (feet) | DL Status* (I, U, Re, D, N) | DL Serial # | Dessicant Status** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | MA-01 | | 17 | 21.27 | 4.25 | | | | 157042 | |
| 2 | | | MA-02 | | 18 | 22.50 | 3.21 | | | | 156662 | |
| 3 | | | MA-03 | | 10 | 14.62 | 3.74 | | | | 156943 | |
| 4 | | | LB-01 | | 7 | 11.45 | 4.10 | | | | 156502 | |
| 5 | | | LB-02 | | 12 | 16.55 | 4.20 | | | | 156646 | |
| 6 | | | LB-03 | | 15 | 19.29 | 4.10 | | | | 156670 | |
| 7 | | | LB-04 | | 12 | 15.96 | 3.87 | | | | 156718 | |
| 8 | | | MF-01 | | 4.04 | 7.85 | 3.88 | | | | 157348 | |
| 9 | | | MF-02 | | 6.41 | 9.15 | 3.29 | | | | 157366 | |
| 10 | | | MF-03 | | 3.46 | 6.92 | 4.03 | | | | 157361 | |
| 11 | | | MF-04 | | 5.17 | 9.56 | 4.21 | | | | 157355 | |
| 12 | | | BrunsL3.1a | | 7.10 | 9.95 | 2.85 | | | | 157044 | |
| 13 | | | BrunsL3.1b | | 13.84 | 15.00 | 1.16 | | | | 157299 | |
| 14 | | | BrunsL3.2a | | 4.34 | 9.78 | 5.44 | | | | 157280 | |
| 15 | | | BrunsL3.2b | | 8.75 | 9.91 | 1.16 | | | | 156902 | |
| 16 | | | BrunsL3.12 | | 10.79 | 15.31 | 4.52 | | | | 157045 | |

*DL Status: I - installed, U - uninstalled, Re - reinstalled, D - downloaded, N - new log started

**Dessicant Status based on a scale of 1-5, with 5 being good and 1 being poor.

**SC - Isolated Wetlands Field Sheet - Groundwater Monitoring**

| | Well_ID | Data logger file name | Calibrated? | Comments |
|---|---|---|---|---|
| 1 | MA-01 | | | |
| 2 | MA-02 | | | |
| 3 | MA-03 | | | |
| 4 | LB-01 | | | |
| 5 | LB-02 | | | |
| 6 | LB-03 | | | |
| 7 | LB-04 | | | |
| 8 | MF-01 | | | |
| 9 | MF-02 | | | |
| 10 | MF-03 | | | |
| 11 | MF-04 | | | |
| 12 | BR1-A | | | |
| 13 | BR1-B | | | |
| 14 | BR2-A | | | |
| 15 | BR2-B | | | |
| 16 | BR-D | | | |

see other side

**NOTES:**

make sure recordings are on the hour

## Dichotomous Key to General North Carolina Wetland Types

### Accompanies NC WAM User Manual, Version 4.1

Before using this key, the assessor should read and become familiar with descriptions of the general wetland types. The assessor should use best professional judgment to verify that the wetland type determined with the use of this key matches the written description (see User Manual page number following wetland type name).

The following rule should be used to assist in the selection of the most appropriate general wetland type. Narrative descriptions are also available to assist in this choice (see User Manual Section 3.1).

> Wetlands with alterations (man-made or natural) should generally be classified as the original, naturally occurring type if this determination can be made. However, if the full range of stable, existing, wetland parameters (vegetation, hydrology, and soils) better resembles another wetland type because of long-established, permanent alterations, the wetland should be classified as this current, more appropriate type.

If there is evidence suggesting the wetland is a type other than the keyed type, the wetland may be classified as the evidenced type. Also, if the wetland does not appear to conform to any of the following general types, the site should be evaluated based on what the assessor believes is the closest wetland type. If the wetland is "intensively managed" or "intensively disturbed," the assessor should note this fact on the field assessment form and then select the most appropriate general wetland type based on the guidance provided above.

- I. Wetland affected by lunar or wind tide, may include woody areas contiguous with tidal marsh
  - A. Wetland affected, at least occasionally, by brackish or salt water
    - i. Dominated by herbaceous vegetation – **Salt/Brackish Marsh** (p. 12)
    - ii. Dominated by woody vegetation – **Estuarine Woody Wetland** (p. 15)
  - B. Wetland primarily affected by freshwater
    - i. Dominated by herbaceous vegetation – **Tidal Freshwater Marsh** (p. 17)
    - ii. Dominated by woody vegetation – **Riverine Swamp Forest** (p. 19)
- II. Wetland not affected by tides
  - A. Not in a geomorphic floodplain or a natural topographic crenulation <u>and</u> not contiguous with an open water 20 acres or larger
    - i. On a side slope – **Seep** (p. 24)
    - ii. On interstream divides <u>or</u> on a coastal island
      1. Flats on interstream divides in Coastal Plain ecoregions
         - a. Dominated by deciduous trees
           - i. Seasonally saturated to seasonally inundated (typically dominated by sweetgum and oaks) – **Hardwood Flat** (p. 26)
           - ii. Seasonally to semi-permanently inundated (typically dominated by cypress and black gum) – **Non-Riverine Swamp Forest** (p. 28)
         - b. Dominated by evergreens
           - i. Dominated by dense, waxy shrub species (typically include gallberries, fetterbushes, honeycup, greenbriar); canopy may include pond pine, Atlantic white cedar, and bays – **Pocosin** (p. 30)
           - ii. Not dominated by dense, waxy shrub species
             1. Dominated by long-leaf or pond pine and wire grass – **Pine Savanna** (p. 32)
             2. Dominated by loblolly or slash pines – **Pine Flat** (p. 33)
      2. In depressions surrounded by uplands anywhere in the state (mafic depressions, lime sinks, Carolina bays) or contiguous with an open water

## Dichotomous Key to General NC Wetland Types, Continued

2. In depressions surrounded by uplands anywhere in the state (mafic depressions, lime sinks, Carolina bays) or contiguous with an open water (repeated from the previous page)
    a. Dominated by dense, waxy shrub species (typically include gallberries, fetterbushes, honeycup, greenbriar); canopy may include pond pine, Atlantic white cedar, and bays and not characterized by clay-based soils– **Pocosin** (p. 30)
    b. Not dominated by dense, waxy shrub species and not characterized by a peat-filled bay – **Basin Wetland** (p. 35)

B. In a geomorphic floodplain or a natural topographic crenulation or contiguous with an open water 20 acres or larger
  i. Northern Inner Piedmont or Blue Ridge Mountains ecoregions and dense herbaceous or mixed shrub/herbaceous vegetation with characteristic bog species (see wetland type description), with or without tree canopy; at least semi-permanent saturation; typically on organic or mucky soils; sphagnum moss commonly present – **Bog** (p. 37)
  ii. Anywhere in the state and not Bog
    1. Dominated by herbaceous vegetation. At least semi-permanently inundated or saturated. Includes lacustrine and riparian fringe and beaver ponds with dense herbaceous vegetation; sphagnum moss scarce or absent – **Non-Tidal Freshwater Marsh** (p. 40)
    2. Dominated by woody vegetation. Trees may be present on edges or hummocks.
        a. Localized depression and semi-permanently inundated – **Floodplain Pool** (p. 43)
        b. Not "a"
            i. Less than second-order stream or in a topographic crenulation without a stream. Diffuse surface flow and groundwater more important than overbank flooding.
                1. Seasonally to semi-permanently saturated and/or only intermittently inundated – **Headwater Forest** (p. 45)
                2. Seasonally to semi-permanently inundated – **Riverine Swamp Forest** (p. 19)
            ii. Second-order or greater stream or contiguous with an open water 20 acres or larger
                1. Intermittently to seasonally inundated (may be dominated by sweetgum, ash, sycamore, and oaks) – **Bottomland Hardwood Forest** (p. 49)
                2. Seasonally to semi-permanently inundated (may be dominated by cypress and blackgums in Coastal Plain and ash, overcup oak, and elms in Piedmont and Mountains) – **Riverine Swamp Forest** (p. 19)

[1]See stream order schematic diagrams in User Manual Appendix C.

NC WAM WETLAND ASSESSMENT FORM
Accompanies User Manual Version 4.1
Rating Calculator Version 4.1

| | | | |
|---|---|---|---|
| Wetland Site Name | | Date | |
| Wetland Type | | Assessor Name/Organization | |
| Level III Ecoregion | | Nearest Named Water Body | |
| River Basin | | USGS 8-Digit Catalogue Unit | |
| Yes No Precipitation within 48 hrs? | | Latitude/Longitude (deci-degrees) | |

**Evidence of stressors affecting the assessment area (may not be within the assessment area)**
Please circle and/or make note on last page if evidence of stressors is apparent. Consider departure from reference, if appropriate, in recent past (for instance, approximately within 10 years). Noteworthy stressors include, but are not limited to the following.

- Hydrological modifications (examples: ditches, dams, beaver dams, dikes, berms, ponds, etc.)
- Surface and sub-surface discharges into the wetland (examples: discharges containing obvious pollutants, presence of nearby septic tanks, underground storage tanks (USTs), hog lagoons, etc.)
- Signs of vegetation stress (examples: vegetation mortality, insect damage, disease, storm damage, salt intrusion, etc.)
- Habitat/plant community alteration (examples: mowing, clear-cutting, exotics, etc.)

**Is the assessment area intensively managed?** Yes No

**Regulatory Considerations (select all that apply to the assessment area)**
- Anadromous fish
- Federally protected species or State endangered or threatened species
- NCDWQ riparian buffer rule in effect
- Abuts a Primary Nursery Area (PNA)
- Publicly owned property
- N.C. Division of Coastal Management Area of Environmental Concern (AEC) (including buffer)
- Abuts a stream with a NCDWQ classification of SA or supplemental classifications of HQW, ORW, or Trout
- Designated NCNHP reference community
- Abuts a 303(d)-listed stream or a tributary to a 303(d)-listed stream

**What type of natural stream is associated with the wetland, if any? (check all that apply)**
- Blackwater
- Brownwater
- Tidal (if tidal, check one of the following boxes) Lunar Wind Both

**Is the assessment area on a coastal island?** Yes No

**Is the assessment area's surface water storage capacity or duration substantially altered by beaver?** Yes No

**Does the assessment area experience overbank flooding during normal rainfall conditions?** Yes No

1. **Ground Surface Condition/Vegetation Condition – assessment area condition metric**
**Check a box in each column.** Consider alteration to the ground surface (GS) in the assessment area and vegetation structure (VS) in the assessment area. Compare to reference wetland if applicable (see User Manual). If a reference is not applicable, then rate the assessment area based on evidence of an effect.

| GS | VS | |
|---|---|---|
| A | A | Not severely altered |
| B | B | Severely altered over a majority of the assessment area (ground surface alteration examples: vehicle tracks, excessive sedimentation, fire-plow lanes, skidder tracks, bedding, fill, soil compaction, obvious pollutants) (vegetation structure alteration examples: mechanical disturbance, herbicides, salt intrusion [where appropriate], exotic species, grazing, less diversity [if appropriate], hydrologic alteration) |

2. **Surface and Sub-Surface Storage Capacity and Duration – assessment area condition metric**
**Check a box in each column.** Consider surface storage capacity and duration (Surf) and sub-surface storage capacity and duration (Sub). Consider both increase and decrease in hydrology. Refer to the current NRCS lateral effect of ditching guidance for North Carolina hydric soils (see USACE Wilmington District website) for the zone of influence of ditches in hydric soils. A ditch ≤ 1 foot deep is considered to affect surface water only, while a ditch > 1 foot deep is expected to affect both surface and ditch sub-surface water. Consider tidal flooding regime, if applicable.

| Surf | Sub | |
|---|---|---|
| A | A | Water storage capacity and duration are not altered. |
| B | B | Water storage capacity or duration are altered, but not substantially (typically, not sufficient to change vegetation). |
| C | C | Water storage capacity or duration are substantially altered (typically, alteration sufficient to result in vegetation change) (examples: draining, flooding, soil compaction, filling, excessive sedimentation, underground utility lines). |

3. **Water Storage/Surface Relief – assessment area/wetland type condition metric (answer for non-marsh wetlands only)**
**Check a box in each column for each group below**. Select the appropriate storage for the assessment area (AA) and the wetland type (WT).

| | AA | WT | |
|---|---|---|---|
| 3a. | A | A | Majority of wetland with depressions able to pond water > 1 foot deep |
| | B | B | Majority of wetland with depressions able to pond water 6 inches to 1 foot deep |

4. **Soil Texture/Structure – assessment area condition metric**
**Check a box from each of the three soil property groups below.** Dig soil profile in the dominant assessment area landscape feature. Make soil observations within the 12 inches. Use most recent National Technical Committee for Hydric Soils guidance for regional indicators.

4a. ☐ A Sandy soil
☐ B Loamy or clayey soils exhibiting redoximorphic features (concentrations, depletions, or rhizospheres)
☐ C Loamy or clayey soils not exhibiting redoximorphic features
☐ D Loamy or clayey gleyed soil
☐ E Histosol or histic epipedon

4b. ☐ A Soil ribbon < 1 inch
☐ B Soil ribbon ≥ 1 inch

4c. ☐ A No peat or muck presence
☐ B A peat or muck presence

5. **Discharge into Wetland – opportunity metric**
**Check a box in each column.** Consider surface pollutants or discharges (Surf) and sub-surface pollutants or discharges (Sub). Examples of sub-surface discharges include presence of nearby septic tank, underground storage tank (UST), etc.

| Surf | Sub | |
|---|---|---|
| ☐ A | ☐ A | Little or no evidence of pollutants or discharges entering the assessment area |
| ☐ B | ☐ B | Noticeable evidence of pollutants or discharges entering the wetland and stressing, but not overwhelming the treatment capacity of the assessment area |
| ☐ C | ☐ C | Noticeable evidence of pollutants or discharges (pathogen, particulate, or soluble) entering the assessment area and potentially overwhelming the treatment capacity of the wetland (water discoloration, dead vegetation, excessive sedimentation, odor) |

6. **Land Use – opportunity metric**
**Check all that apply (at least one box in each column).** Evaluation involves a GIS effort with field adjustment. Consider sources draining to assessment area within entire upstream watershed (WS), within 5 miles and within the watershed draining to the assessment area (5M), and within 2 miles and within the watershed draining to the assessment area (2M). Effective riparian buffers are considered to be 50 feet wide in the Coastal Plain and Piedmont ecoregions and 30 feet wide in the Blue Ridge Mountains ecoregion.

| WS | 5M | 2M | |
|---|---|---|---|
| ☐ A | ☐ A | ☐ A | ≥ 10% impervious surfaces |
| ☐ B | ☐ B | ☐ B | < 10% impervious surfaces |
| ☐ C | ☐ C | ☐ C | Confined animal operations (or other local, concentrated source of pollutants) |
| ☐ D | ☐ D | ☐ D | ≥ 20% coverage of pasture |
| ☐ E | ☐ E | ☐ E | ≥ 20% coverage of agricultural land (regularly plowed land) |
| ☐ F | ☐ F | ☐ F | ≥ 20% coverage of maintained grass/herb |
| ☐ G | ☐ G | ☐ G | ≥ 20% coverage of clear-cut land |
| ☐ H | ☐ H | ☐ H | Little or no opportunity to improve water quality. Lack of opportunity may result from hydrologic alterations that prevent drainage or overbank flow from affecting the assessment area. |

7. **Wetland Acting as Vegetated Buffer – assessment area/wetland complex condition metric**

7a. Is assessment area within 50 feet of a tributary or other open water?
☐ Yes ☐ No If Yes, continue to 7b. If No, skip to Metric 8.
Wetland buffer need only be present on one side of the water body. Make buffer judgment based on the average width of the wetland. Record a note if a portion of the buffer has been removed or disturbed.

7b. How much of the first 50 feet from the bank is weltand? Descriptor E should be selected if ditches effectively bypass the buffer.
☐ A ≥ 50 feet
☐ B From 30 to < 50 feet
☐ C From 15 to < 30 feet
☐ D From 5 to < 15 feet
☐ E < 5 feet or buffer bypassed by ditches

7c. Tributary width. If the tributary is anastomosed, combine widths of channels/braids for a total width.
☐ ≤ 15-feet wide ☐ > 15-feet wide ☐ Other open water (no tributary present)

7d. Do roots of assessment area vegetation extend into the bank of the tributary/open water?
☐ Yes ☐ No

7e. Is tributary or other open water sheltered or exposed?
☐ Sheltered – adjacent open water with width < 2500 feet and no regular boat traffic.
☐ Exposed – adjacent open water with width ≥ 2500 feet or regular boat traffic.

8. **Wetland Width at the Assessment Area – wetland type/wetland complex metric (evaluate for riparian wetlands only)**
**Check a box in each column.** Select the average width for the wetland type at the assessment area (WT) and the wetland complex at the assessment areas (WC). See User Manual for WT and WC boundaries.

| WT | WC | |
|---|---|---|
| ☐ A | ☐ A | ≥ 100 feet |
| ☐ B | ☐ B | From 80 to < 100 feet |
| ☐ C | ☐ C | From 50 to < 80 feet |
| ☐ D | ☐ D | From 40 to < 50 feet |
| ☐ E | ☐ E | From 30 to < 40 feet |
| ☐ F | ☐ F | From 15 to < 30 feet |
| ☐ G | ☐ G | From 5 to < 15 feet |

**9. Inundation Duration – assessment area condition metric**
Answer for assessment area dominant landform.
- A Evidence of short-duration inundation (< 7 consecutive days)
- B Evidence of saturation, without evidence of inundation
- C Evidence of long-duration inundation or very long-duration inundation (7 to 30 consecutive days or more)

**10. Indicators of Deposition – assessment area condition metric**
Consider recent deposition only (no plant growth since deposition).
- A Sediment deposition is not excessive, but at approximately natural levels.
- B Sediment deposition is excessive, but not overwhelming the wetland.
- C Sediment deposition is excessive and is overwhelming the wetland.

**11. Wetland Size – wetland type/wetland complex condition metric**
**Check a box in each column.** Involves a GIS effort with field adjustment. This metric evaluates three aspects of the wetland area: the size of the wetland type (WT), the size of the wetland complex (WC), and the size of the forested wetland (FW) (if applicable, see User Manual). See the User Manual for boundaries of these evaluation areas. If assessment area is clear-cut, select "K" for the FW column.

| WT | WC | FW (if applicable) | |
|---|---|---|---|
| A | A | A | ≥ 500 acres |
| B | B | B | From 100 to < 500 acres |
| C | C | C | From 50 to < 100 acres |
| D | D | D | From 25 to < 50 acres |
| E | E | E | From 10 to < 25 acres |
| F | F | F | From 5 to < 10 acres |
| G | G | G | From 1 to < 5 acres |
| H | H | H | From 0.5 to < 1 acre |
| I | I | I | From 0.1 to < 0.5 acre |
| J | J | J | From 0.01 to < 0.1 acre |
| K | K | K | < 0.01 acre <u>or</u> assessment area is clear-cut |

**12. Wetland Intactness – wetland type condition metric (evaluate for Pocosins only)**
- A Pocosin is the full extent (≥ 90%) of its natural landscape size.
- B Pocosin is < 90% of the full extent of its natural landscape size.

**13. Connectivity to Other Natural Areas – landscape condition metric**

13a. **Check appropriate box(es) (a box may be checked in each column). Involves a GIS effort with field adjustment.** This evaluates whether the wetland is well connected (Well) and/or loosely connected (Loosely) to the landscape patch, the contiguous metric naturally vegetated area and open water (if appropriate). Boundaries are formed by four-lane roads, regularly maintained utility line corridors the width of a four-lane road or wider, urban landscapes, fields (pasture open and agriculture), or water > 300 feet wide.

| Well | Loosely | |
|---|---|---|
| A | A | ≥ 500 acres |
| B | B | From 100 to < 500 acres |
| C | C | From 50 to < 100 acres |
| D | D | From 10 to < 50 acres |
| E | E | < 10 acres |
| F | F | Wetland type has a poor or no connection to other natural habitats |

13b. **Evaluate for marshes only.**
Yes No Wetland type has a surface hydrology connection to open waters/stream or tidal wetlands.

**14. Edge Effect – wetland type condition metric (skip for all marshes)**
May involve a GIS effort with field adjustment. Estimate distance from wetland type boundary to artificial edges. Artificial edges include non-forested areas ≥ 40 feet wide such as fields, development, roads, regularly maintained utility line corridors and clear-cuts. Consider the eight main points of the compass.
- A No artificial edge within 150 feet in all directions
- B No artificial edge within 150 feet in four (4) to seven (7) directions
- C An artificial edge occurs within 150 feet in more than four (4) directions <u>or</u> assessment area is clear-cut

**15. Vegetative Composition – assessment area condition metric (skip for all marshes and Pine Flat)**
- A Vegetation is close to reference condition in species present and their proportions. Lower strata composed of appropriate species, with exotic plants absent or sparse within the assessment area.
- B Vegetation is different from reference condition in species diversity or proportions, but still largely composed of native species characteristic of the wetland type. This may include communities of weedy native species that develop after clearcutting or clearing. It also includes communities with exotics present, but not dominant, over a large portion of the expected strata.
- C Vegetation severely altered from reference in composition. Expected species are unnaturally absent (planted stands of non-characteristic species or at least one stratum inappropriately composed of a single species). Exotic species are dominant in at least one stratum.

**16. Vegetative Diversity – assessment area condition metric (evaluate for Non-tidal Freshwater Marsh only)**
- A Vegetation diversity is high and is composed primarily of native species (<10% cover of exotics).
- B Vegetation diversity is low or has > 10% to 50% cover of exotics.
- C Vegetation is dominated by exotic species (>50% cover of exotics).

**17. Vegetative Structure – assessment area/wetland type condition metric**

17a. Is vegetation present?

- Yes
- No

If Yes, continue to 17b. If No, skip to Metric 18.

17b. Evaluate percent coverage of assessment area vegetation **for all marshes only**. Skip to 17c for non-marsh wetlands.

- A ≥ 25% coverage of vegetation
- B < 25% coverage of vegetation

17c. **Check a box in each column for each stratum**. Evaluate this portion of the metric **for non-marsh wetlands**. Consider structure in airspace above the assessment area (AA) and the wetland type (WT) separately.

| | AA | WT | |
|---|---|---|---|
| Canopy | A | A | Canopy closed, or nearly closed, with natural gaps associated with natural processes |
| | B | B | Canopy present, but opened more than natural gaps |
| | C | C | Canopy sparse or absent |
| Mid-Story | A | A | Dense mid-story/sapling layer |
| | B | B | Moderate density mid-story/sapling layer |
| | C | C | Mid-story/sapling layer sparse or absent |
| Shrub | A | A | Dense shrub layer |
| | B | B | Moderate density shrub layer |
| | C | C | Shrub layer sparse or absent |
| Herb | A | A | Dense herb layer |
| | B | B | Moderate density herb layer |
| | C | C | Herb layer sparse or absent |

**18. Snags – wetland type condition metric**

- A Large snags (more than one) are visible (> 12-inches DBH, or large relative to species present and landscape stability).
- B Not A

**19. Diameter Class Distribution – wetland type condition metric**

- A Majority of canopy trees have stems > 6 inches in diameter at breast height (DBH); many large trees (> 12 inches DBH) are present.
- B Majority of canopy trees have stems between 6 and 12 inches DBH, few are > 12-inch DBH.
- C Majority of canopy trees are < 6 inches DBH or no trees.

**20. Large Woody Debris – wetland type condition metric**

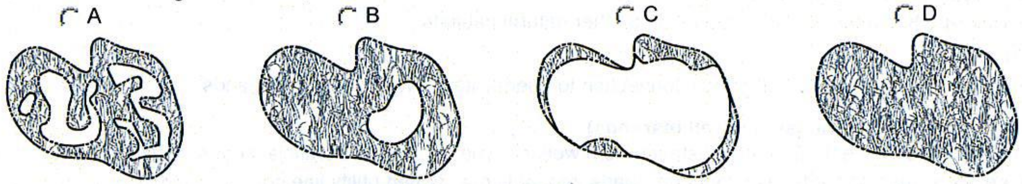
Include both natural debris and man-placed natural debris.

- A Large logs (more than one) are visible (> 12 inches in diameter, or large relative to species present and landscape stability).
- B Not A

**21. Vegetation/Open Water Dispersion – wetland type/open water condition metric (evaluate for Non-Tidal Freshwater Marsh only)**

Select the figure that best describes the amount of interspersion between vegetation and open water in the growing season. Patterned areas indicate vegetated areas, while solid white areas indicate open water.

A B C D



**22. Hydrologic Connectivity – assessment area condition metric (evaluate for riparian wetlands only)**

Examples of activities that may severely alter hydrologic connectivity include intensive ditching, fill, sedimentation, channelization, diversion, man-made berms, beaver dams, and stream incision.

- A Overbank and overland flow are not severely altered in the assessment area.
- B Overbank flow is severely altered in the assessment area.
- C Overland flow is severely altered in the assessment area.
- D Both overbank and overland flow are severely altered in the assessment area.

Notes

**NC WAM Wetland Rating Sheet**
**Accompanies User Manual Version 4.1**
**Rating Calculator Version 4.1**

Wetland Site Name ______________________ Date ______________

Wetland Type ______________________ Assessor Name/Organization ______________

| | |
|---|---|
| Notes on Field Assessment Form (Y/N) | NO |
| Presence of regulatory considerations (Y/N) | |
| Wetland is intensively managed (Y/N) | |
| Assessment area is located within 50 feet of a natural tributary or other open water (Y/N) | |
| Assessment area is substantially altered by beaver (Y/N) | |
| Assessment area experiences overbank flooding during normal rainfall conditions (Y/N) | |
| Assessment area is on a coastal island (Y/N) | |

**Sub-function Rating Summary**

| Function | Sub-function | Metrics | Rating |
|---|---|---|---|
| Hydrology | Surface Storage and Retention | Condition | |
| | Sub-Surface Storage and Retention | Condition | |
| Water Quality | Pathogen Change | Condition | |
| | | Condition/Opportunity | |
| | | Opportunity Presence? (Y/N) | |
| | Particulate Change | Condition | |
| | | Condition/Opportunity | |
| | | Opportunity Presence? (Y/N) | |
| | Soluble Change | Condition | |
| | | Condition/Opportunity | |
| | | Opportunity Presence? (Y/N) | |
| | Physical Change | Condition | |
| | | Condition/Opportunity | |
| | | Opportunity Presence? (Y/N) | |
| | Pollution Change | Condition | |
| | | Condition/Opportunity | |
| | | Opportunity Presence? (Y/N) | |
| Habitat | Physical Structure | Condition | |
| | Landscape Patch Structure | Condition | |
| | Vegetation Composition | Condition | |

**Function Rating Summary**

| Function | Metrics/Notes | Rating |
|---|---|---|
| Hydrology | Condition | |
| Water Quality | Condition | |
| | Condition/Opportunity | |
| | Opportunity Presence? (Y/N) | |
| Habitat | Conditon | |

**Overall Wetland Rating** ______________

ORAM v. 5.0 Field Form Quantitative Rating

| Site: | Rater(s): | Date: |
|---|---|---|

## Metric 1. Wetland Area (size).

max 6 pts. subtotal

Select one size class and assign score.

- [ ] >50 acres (>20.2ha) (6 pts)
- [ ] 25 to <50 acres (10.1 to <20.2ha) (5 pts)
- [ ] 10 to <25 acres (4 to <10.1ha) (4 pts)
- [ ] 3 to <10 acres (1.2 to <4ha) (3 pts)
- [ ] 0.3 to <3 acres (0.12 to <1.2ha) (2pts)
- [ ] 0.1 to <0.3 acres (0.04 to <0.12ha) (1 pt)
- [ ] <0.1 acres (0.04ha) (0 pts)

## Metric 2. Upland buffers and surrounding land use.

max 14 pts. subtotal

2a. Calculate average buffer width. Select only one and assign score. Do not double check.

- [ ] WIDE. Buffers average 50m (164ft) or more around wetland perimeter (7)
- [ ] MEDIUM. Buffers average 25m to <50m (82 to <164ft) around wetland perimeter (4)
- [ ] NARROW. Buffers average 10m to <25m (32ft to <82ft) around wetland perimeter (1)
- [ ] VERY NARROW. Buffers average <10m (<32ft) around wetland perimeter (0)

2b. Intensity of surrounding land use. Select one or double check and average.

- [ ] VERY LOW. 2nd growth or older forest, prairie, savannah, wildlife area, etc. (7)
- [ ] LOW. Old field (>10 years), shrubland, young second growth forest. (5)
- [ ] MODERATELY HIGH. Residential, fenced pasture, park, conservation tillage, new fallow field. (3)
- [ ] HIGH. Urban, industrial, open pasture, row cropping, mining, construction. (1)

## Metric 3. Hydrology.

max 30 pts. subtotal

3a. Sources of Water. Score all that apply.

- [ ] High pH groundwater (5)
- [ ] Other groundwater (3)
- [ ] Precipitation (1)
- [ ] Seasonal/Intermittent surface water (3)
- [ ] Perennial surface water (lake or stream) (5)

3b. Connectivity. Score all that apply.

- [ ] 100 year floodplain (1)
- [ ] Between stream/lake and other human use (1)
- [ ] Part of wetland/upland (e.g. forest), complex (1)
- [ ] Part of riparian or upland corridor (1)

3c. Maximum water depth. Select only one and assign score.

- [ ] >0.7 (27.6in) (3)
- [ ] 0.4 to 0.7m (15.7 to 27.6in) (2)
- [ ] <0.4m (<15.7in) (1)

3d. Duration inundation/saturation. Score one or dbl check.

- [ ] Semi- to permanently inundated/saturated (4)
- [ ] Regularly inundated/saturated (3)
- [ ] Seasonally inundated (2)
- [ ] Seasonally saturated in upper 30cm (12in) (1)

3e. Modifications to natural hydrologic regime. Score one or double check and average.

- [ ] None or none apparent (12)
- [ ] Recovered (7)
- [ ] Recovering (3)
- [ ] Recent or no recovery (1)

Check all disturbances observed

- [ ] ditch
- [ ] tile
- [ ] dike
- [ ] weir
- [ ] stormwater input
- [ ] point source (nonstormwater)
- [ ] filling/grading
- [ ] road bed/RR track
- [ ] dredging
- [ ] other____________________

## Metric 4. Habitat Alteration and Development.

max 20 pts. subtotal

4a. Substrate disturbance. Score one or double check and average.

- [ ] None or none apparent (4)
- [ ] Recovered (3)
- [ ] Recovering (2)
- [ ] Recent or no recovery (1)

4b. Habitat development. Select only one and assign score.

- [ ] Excellent (7)
- [ ] Very good (6)
- [ ] Good (5)
- [ ] Moderately good (4)
- [ ] Fair (3)
- [ ] Poor to fair (2)
- [ ] Poor (1)

4c. Habitat alteration. Score one or double check and average.

- [ ] None or none apparent (9)
- [ ] Recovered (6)
- [ ] Recovering (3)
- [ ] Recent or no recovery (1)

Check all disturbances observed

- [ ] mowing
- [ ] grazing
- [ ] clearcutting
- [ ] selective cutting
- [ ] woody debris removal
- [ ] toxic pollutants
- [ ] shrub/sapling removal
- [ ] herbaceous/aquatic bed removal
- [ ] sedimentation
- [ ] dredging
- [ ] farming
- [ ] nutrient enrichment

ORAM v. 5.0 Field Form Quantitative Rating

| Site: | Rater(s): | Date: |
|---|---|---|

subtotal this page

max 10 pts. subtotal

## Metric 5. Special Wetlands.

Check all that apply and score as indicated.

- ☐ Bog (10)
- ☐ Fen (10)
- ☐ Old growth forest (10)
- ☐ Mature forested wetland (5)
- ☐ Lake Erie coastal/tributary wetland-unrestricted hydrology (10)
- ☐ Lake Erie coastal/tributary wetland-restricted hydrology (5)
- ☐ Lake Plain Sand Prairies (Oak Openings) (10)
- ☐ Relict Wet Praires (10)
- ☐ Known occurrence state/federal threatened or endangered species (10)
- ☐ Significant migratory songbird/water fowl habitat or usage (10)
- ☐ Category 1 Wetland. See Question 1 Qualitative Rating (-10)

max 20 pts. subtotal

## Metric 6. Plant communities, interspersion, microtopography.

6a. Wetland Vegetation Communities.
Score all present using 0 to 3 scale.

- ☐ Aquatic bed
- ☐ Emergent
- ☐ Shrub
- ☐ Forest
- ☐ Mudflats
- ☐ Open water
- ☐ Other________________

6b. horizontal (plan view) Interspersion.
Select only one.

- ☐ High (5)
- ☐ Moderately high(4)
- ☐ Moderate (3)
- ☐ Moderately low (2)
- ☐ Low (1)
- ☐ None (0)

6c. Coverage of invasive plants. Refer to Table 1 ORAM long form for list. Add or deduct points for coverage

- ☐ Extensive >75% cover (-5)
- ☐ Moderate 25-75% cover (-3)
- ☐ Sparse 5-25% cover (-1)
- ☐ Nearly absent <5% cover (0)
- ☐ Absent (1)

6d. Microtopography.
Score all present using 0 to 3 scale.

- ☐ Vegetated hummucks/tussucks
- ☐ Coarse woody debris >15cm (6in)
- ☐ Standing dead >25cm (10in) dbh
- ☐ Amphibian breeding pools

**Vegetation Community Cover Scale**

| | |
|---|---|
| 0 | Absent or comprises <0.1ha (0.2471 acres) contiguous area |
| 1 | Present and either comprises small part of wetland's vegetation and is of moderate quality, or comprises a significant part but is of low quality |
| 2 | Present and either comprises significant part of wetland's vegetation and is of moderate quality or comprises a small part and is of high quality |
| 3 | Present and comprises significant part, or more, of wetland's vegetation and is of high quality |

**Narrative Description of Vegetation Quality**

| | |
|---|---|
| low | Low spp diversity and/or predominance of nonnative or disturbance tolerant native species |
| mod | Native spp are dominant component of the vegetation, although nonnative and/or disturbance tolerant native spp can also be present, and species diversity moderate to moderately high, but generallyw/o presence of rare threatened or endangered spp |
| high | A predominance of native species, with nonnative spp and/or disturbance tolerant native spp absent or virtually absent, and high spp diversity and often, but not always, the presence of rare, threatened, or endangered spp |

**Mudflat and Open Water Class Quality**

| | |
|---|---|
| 0 | Absent <0.1ha (0.247 acres) |
| 1 | Low 0.1 to <1ha (0.247 to 2.47 acres) |
| 2 | Moderate 1 to <4ha (2.47 to 9.88 acres) |
| 3 | High 4ha (9.88 acres) or more |

**Microtopography Cover Scale**

| | |
|---|---|
| 0 | Absent |
| 1 | Present very small amounts or if more common of marginal quality |
| 2 | Present in moderate amounts, but not of highest quality or in small amounts of highest quality |
| 3 | Present in moderate or greater amounts and of highest quality |

**GRAND TOTAL(max 100 pts)**

# Appendix B - DWQ Forest IBI Candidate Metrics and NC Coefficient of Conservatism Scores

## DWQ Forest Candidate IBI Metrics

Table B-1 Median Wetland Plant Class Coverages

| %Cov $m^2$ = | Median Cover $m^2$ |
|---|---|
| T | 0.25 $m^2$ |
| 0-1 $m^2$ | 0.5 $m^2$ |
| 1-2 $m^2$ | 1.5 $m^2$ |
| 2-5 $m^2$ | 3.5 $m^2$ |
| 5-10 $m^2$ | 7.5 $m^2$ |
| 10-25 $m^2$ | 17.5 $m^2$ |
| 25-50 $m^2$ | 37.5 $m^2$ |
| 50-75 $m^2$ | 62.5 $m^2$ |
| 75-95 $m^2$ | 85 $m^2$ |
| 95-100 $m^2$ | 97.5 $m^2$ |

**PLANT METRICS**

**Community Balance Candidate Metrics**

*Diversity Cover Simpson Metric* – Simpson's Index (Simpson 1949) considers the number of species, the number of individuals, and the proportion of the total of each species. A higher value of $D_s$ correlates with higher diversity within the survey area. The first equation is the standard Simpson's diversity equation ($D_s$) and the second equation ($D_{cov}$) uses coverage instead of abundance and was used as a candidate metric in this study.

$D_s = 1 - [\sum n_i (n_i - 1) / N (N - 1)]$

$D_{cov} = 1 - [\sum n_{icov} (n_{icov} - 1) / N_{cov} (N_{cov} - 1)]$

$D_s$ – Simpson's Diversity Index

$D_{cov}$ – Simpson's Diversity Index using Cover

$N$ – Total individuals

$n_i$ –Total individuals of species $_i$

$N_{cov}$ – Total cover for all species

$n_{icov}$ - Total cover for species $_i$

*Evenness Metric* and *Native Evenness Metric* – Evenness is the distribution of individuals among species. If all species are equal in distribution, then evenness is high. The first equation ($E_s$) is the standard Evenness equation (Brower and Zar 1977) and the second equation ($E_{cov}$) uses coverage instead of abundance and was used as a candidate metric in this study. *Native Evenness* was calculated with solely native species.

$E_s = D_s / D_{max}$

$E_{cov} = D_{cov} / D_{max\text{-}cov}$

$D_{max} = ( s - 1 / s ) * ( N / N - 1)$

$D_{max\text{-}cov} = ( s - 1 / s ) * (N_{cov} / N_{cov} - 1)$
$E_s$ - Evenness
$D_{max}$ – Maximum $D_s$
$D_{max\text{-}cov}$ – Maximum $D_s$ using cover
$s$ - number of species
$N$ – Total Individuals
$D_s$ – Simpson's Diversity Index
$N_{cov}$ – Total cover for all species

*Dominance Metric* and *Herb and Shrub Cover Dominance Metric* – These metrics incorporates the "distribution or concentration" of the three most dominant species cover class values for all individuals, "D", and shrub and herb classified individuals "D(hs)"(ferns, grass, sedge, rush, forb, herbaceous vines, shrubs, and small trees).

$D = (Cov_{a+b+c} / Ncov)$
$Cov_{a+b+c}$ - Total most dominant species *a, b*, or *c*.
*N*cov – Total cover for all species
$D(hs) = (Cov(hs)_{a+b+c} / Ncov(hs))$
$Cov(hs)_{a+b+c}$ - Total most dominant herb or shrub cover species *a, b*, or *c*.
*N*cov(hs) – Total cover for all herb and shrub species

*Species Richness Metric* and *Native Species Richness Metric* – Total number of vascular species and total number of native vascular species.
*Vascular Plant Genera Richness Metric* – Total number of native vascular genera.
*Vascular Plant Family Richness Metric* – Total number of vascular plant families.

**Floristic Quality Candidate Metrics**

Table B-2 Floristic Quality Index Coefficient of Conservatism Value Assignments (Taft et. al.. 1997)

| C of C Value Assignment | Criteria used to define C of C assignment |
|---|---|
| 0-1 | Taxa that are adapted to severe disturbances, particularly anthropogenic. Disturbance occurs so frequently that often only brief periods are available for growth and reproduction, generally considered ruderal species/opportunistic invaders. |
| 2-3 | Taxa within this category are associated with more stable, though degraded habitat. Generally considered ruderal-competitive species, found in a variety of habitats. |
| 4-6 | Taxa that have a high consistence of occurrence within a given community type and will include many dominant or matrix species for several habitats. Species will persist under moderate disturbance. |
| 7-8 | Taxa associated mostly with natural areas but can persist where the habitat has been somewhat degraded. Increases in the intensity or frequency of disturbance may result in reduction in population size or taxa may be subject to local extirpation. |
| 9-10 | Taxa exhibiting a high degree of fidelity to a narrow range of synecological parameters. Species within this category are restricted to relatively intact natural areas. |

See Table B3 for C of C value assignements at end of Appendix B.

*FQAI Cover Metric and FQAI Species Count Metric* - Floristic Quality Assessment Index (FQAI) is an evaluation of ecological integrity that incorporates the affinity that a species has for occurring in a natural habitat and the total number of species at the site into the calculation of the index (Taft *et al*. 1997). The $FQAI_{cov}$ metric (Mack 2004), which incorporates species cover into the equation, was used in this study. See Table B-3 for a list of NCDWQ Coefficient of Conservatism plant rankings.

$FQAI_{cov} = \sum C_i * Cov_i / \sqrt{N} * Cov_{tot}$ $FQAI = \sum C_i / \sqrt{N}$
$C_i$ - Coefficient of Conservatism for species *i*
*N* - Native Species richness
$Cov_i$ - Cover of species *i*
$Cov_{tot}$ – Total native coverage

*Average C of C Metric* – Average Coefficient of Conservatism value (see Table B-3).
*Percent Tolerant Metric* – Total relative coverage of all species, including non-natives, with a C of C value $\leq 2$.

*Percent Sensitive Metric* - Total relative coverage of all species, including non-natives, with a C of C value $\geq 6$.

*Invasive Coverage Metric* – Total relative coverage of invasive species.

*Invasive Shrub Coverage Metric* – Total relative coverage of invasive shrub species.

*Invasive Grass Coverage Metric* – Total relative coverage of invasive grasses and *Typha*.

**Wetness Characteristic Metrics**

*FAQWet Equation 3 Metric* and *FAQWet Cover Metric* - The Floristic Assessments for Wetland Plants index equation was devised by Ervin *et al*. (2006). This equation incorporate species wetness, number of species, number of native species, and cover of native species. The FAQWet metric equations are as follows:

$FAQWet\ Cover = \sum WC/\sqrt{S} * \sum Cov_{nat}/\sum Cov_{tot}$
*WC* = Wetness Coefficient
$Cov_{nat}$ = Cover of native species
*S* = All species
$Cov_{tot}$ = Cover of all species
*N* = Native Species
Wetland coefficient values in the above equations are calculated as follows: OBL = + 5, FACW = + 3, FAC = 0, FACUP = -3, UPL = - 5.

*Wetland Plant Species Richness Metric* – Number of native herb species with a FACW or OBL wetland indicator status. Herb = all forbs, ferns, grasses, sedges, rushes, and herbaceous vines.

*Wetland Plant Cover Metric* – Relative (to the herb stratum, see Total Herb Cover Metric) percent coverage of native herb species with a FACW or OBL wetland indicator status. Herb cover = all forbs, ferns, grasses, sedges, rushes, and herbaceous vines.

*Wetland Shrub Species Richness Metric* – Number of native wetland shrubs with a FACW or OBL wetland indicator status.

*Wetland Shrub Cover Metric* – Relative (to the shrub stratum) percent coverage of native wetland shrubs with a FACW or OBL wetland indicator status. Shrub cover = all shrubs and small trees.

**Function Guild Metrics**

*Cryptogram Richness Metric* – Number of fern or fern ally species.

*Cryptogram Cover Metric* – Relative (to the herb stratum, see Total Herb Cover Metric) percent cover of fern and fern allies in the herb layer. Herb cover = all forbs, cryptograms, bryophyte, Sedges, Grass, and Reeds.

*Annual : Perennial Metric* – Annual + Biennial species herb species / Perennial species herb species.

*Bryophyte Cover Metric* – Total moss coverage relative to herb coverage (see Total Herb Cover Metric).

*Carex Richness Metric* – Total number of *Carex* species.

*Carex Cover Metric* – Relative percent cover (to the herb stratum, see Total Herb Cover Metric) of *Carex* species in comparison to the herb stratum. Herb cover = all forbs, cryptograms, bryophyte, Sedges, Grass, and Reeds.

*Cyperaceae, Poaceae, and Juncaceae Metric* – Total number of native Cyperaceae, Poaceae, and Juncaceae species (sedge, grass, and reed species).

*Cyperaceae, Poaceae, and Juncaceae Coverage Metric* – Relative (to the herb stratum, see Total Herb Cover Metric) percent cover of native Cyperaceae, Poaceae, and Juncaceae in the herb layer.

*Dicot Richness Metric* – Total number of native vascular dicot species (including woody species).
*Native Herb Richness Metric* –Total native vascular herb richness. Herb = all forbs, ferns, grasses, sedges, rushes, and herbaceous vines.

*Native Herb Cover Metric* – Total native vascular herb cover. Herb = all forbs, ferns, grasses, sedges, rushes, and herbaceous vines.

*Total Herb Richness Metric* –Total herb richness. Herb = all forbs, ferns, grasses, sedges, rushes, and herbaceous vines.

**Community Structure Metrics**

*Shade Metric* – Number of native species (not including adventives or trees) with a shade rating of "shade" or "partial shade". See Table B-3 for a list of plant shade rankings.

*Sapling Density Metric* – Relative density of canopy and small tree sapling species (Canopy = tree and Small Tree = Sm tre, see Table b-3) and small tree species in the <1 cm, 1-2.5 cm, 2.5-5 cm, and 5-10 cm DBH size classes. Relative density was calculated for each sapling size class by dividing the total number of stems per size class for canopy and small tree species by all stems for canopy and small tree species. The relative density of the four sapling size classes (<1 cm, 1-2.5 cm, 2.5-5 cm, and 5-10 cm) was then summed to equal the *Sapling Density Metric*.

*Large Tree Density Metric* – Relative density of native trees > 25 cm DBH. The relative density of trees > 25 cm was calculated by dividing the total number of > 25 cm DBH canopy species stems (Canopy = Tree, see Table B-3) by the total number of all canopy species stems.

*Pole Timber Density Metric* – Relative density of trees in the 10-15, 15-20, and 20-25 cm DBH size class. Relative density of pole timber trees was calculated for each pole timber size class (10-15, 15-20, 20-25) by dividing the total number of stems per pole timber size class for canopy and small tree species ("Trees" and "Sm Tres" see Table B-3) by all stems for canopy and small tree species. The relative density of the three size classes (10-15, 15-20, and 20-25 cm) was then summed to equal the *Pole Timber Density Metric*.

*Canopy Importance Metric* - The *Canopy Metric* is the average relative importance value of native canopy species. The relative importance value is equal to the sum of relative density, relative dominance, and relative frequency. Relative density for each species was calculated by dividing the total number of canopy (Canopy = "Tree" see Table B-3) stems per species by the total number of canopy stems for all species. Species dominance per size class for size classes 0-1 cm to 30-35 cm DBH was calculated by multiplying the number of canopy stems in each species size class by the midpoint of the size class. The 0-1 cm to 30-35 cm dominance size class for each species was calculated by summing the dominance for size classes 0-1 cm to 30-35 cm. The species dominance for size classes >35 cm DBH was calculated by summing the total DBH for each canopy species >35 cm. Therefore, if two red maples each equal to 45 cm DBH and one red maple equal to 60 cm DBH were recorded during the woody vegetation survey the >35 dominance size class would be equal to 150 cm. The total dominance for each species was calculated by summing the 0-1 cm to 30-35 cm dominance and > 35 cm species dominance species size classes. Relative dominance was calculated by dividing total dominance of each canopy species by the total dominance of all canopy species. Relative frequency was calculated by dividing the number of size classes each canopy species occurred in by the total number of size classes, which were 10 (0-1, 1-2.5, 2.5-5, 5-10, 10-15, 15-20, 20-25, 25-30, 30-35, and ≥35). For example, if red maple occurred in the 0-1, 1-2.5, 2.5-5, 5-10, 20-25 and ≥35 the frequency would be 6 / 10 or 0.60.

*Sub-Canopy Importance Metric* - The *Sub-Canopy Importance Metric* is the sum of the average importance value for native shrubs and small trees (see Table B-3). The average importance values for all native shade shrubs and small trees and all native partial shade shrubs and small trees were calculated separately. The relative importance value is equal to the sum of the relative density, relative dominance, and relative frequency. Relative density for each species was calculated by dividing the total number of shrub and small tree stems per species by the total number of shrub and small tree stems for all species. Species dominance per size class was calculated by multiplying the number of shrub and small tree stems in each species size class by the midpoint of the size class. The dominance of each size class was then summed to equal total species dominance. Relative species dominance was calculated by dividing total dominance of each native shrub and small tree species by the total dominance of all shrub and small tree species. Relative species frequency was calculated by dividing the number of size classes each native shrub or small tree species occurred in by the total number of size classes, which were 10.

*Shade Sub-Canopy Importance Metric* - The *Shade Sub-Canopy Importance Metric* is the sum of the average importance value for native shade-tolerant and partial shade-tolerant shrubs and small trees (see Table B-3). The average importance values for all native shade shrubs and small trees and all native partial shade shrubs and small trees were calculated separately. The relative importance value is equal to the sum of the relative density, relative dominance, and relative frequency. Relative density for each species (shade or partial shade) was calculated by dividing the total number of shade and partial shade shrub and small tree stems per species by the total number of shrub and small tree stems for all species. Species dominance per size class was calculated by multiplying the number of shade and partial shade shrub and small tree stems in each species size class by the midpoint of the size class. The dominance of each size class was then summed to equal total species dominance. Relative species dominance was calculated by dividing total dominance of each native shade or partial shade shrub and small tree species by the total dominance of all shrub and small tree species. Relative species frequency was calculated by dividing the number of size classes each native shade or partial shade shrub or small tree species occurred in by the total number of size classes, which were 10.

*Snag Metric* – Snags ≥ 5cm DBH were counted for this metric.

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Acalypha rhomboidea | Acalypha rhomboidea | Common threeseed mercury | ACALRHOM | Euphorbiaceae | 3.0 | FAC- | Forb | AN | DI | 0 | |
| Acalypha virginica | Acalypha virginica | Virginia threeseed mercury | ACALVIRG | Euphorbiaceae | 3.0 | FACU- | Forb | AN | DI | | |
| Acer floridanum | Acer floridanum | Southern Sugar Maple | ACERFLOR | Aceraceae | 5.5 | | Tree | W | DI | Tree | |
| Acer floridanum | Acer saccharum ssp. floridanum | S. Sugar Maple, Chalk Maple | ACERSACCFL | Aceraceae | 7.7 | FACU- | Tree | W | DI | Tree | |
| Acer leucoderme | Acer saccharum ssp. leucoderme | Chalk Maple | ACERSACCLE | Aceraceae | 8.0 | FACU- | Tree | W | DI | Tree | |
| Acer negundo | Acer negundo | Box elder | ACERNEGU | Aceraceae | 4.0 | FACW | Tree | W | DI | Tree | |
| Acer rubrum | Acer rubrum | Red maple | ACERRUBR | Aceraceae | 3.0 | FAC | Tree | W | DI | Tree | |
| Acer saccharum | Acer saccharum | Sugar maple | ACERSACC | Aceraceae | 5.0 | FACU- | Tree | W | DI | Tree | |
| Aesculus sylvatica | Aesculus sylvatica | Painted buckeye | AESCSYLV | Hippocastanaceae | 7.3 | NI | Tree | W | DI | Tree | |
| Agrimonia gryposepala | Agrimonia gryposepala | tall hairy groovebur | AGRIGRYP | Rosaceae | 2.7 | FACU | Forb | PE | DI | Shade | |
| Agrimonia parviflora | Agrimonia parviflora | Small-flowered agrimony | AGRIPARV | Rosaceae | 3.0 | FAC | Forb | PE | DI | Shade | |
| Agrimonia pubescens | Agrimonia pubescens | Agrimonia | AGRIPUBE | Rosaceae | 4.0 | NG | Forb | PE | DI | Shade | |
| Agrimonia rostellata | Agrimonia rostellata | Beaked groovebur | AGRIROST | Rosaceae | 4.5 | FAC | Forb | PE | DI | Shade | |
| Agrostis hyemalis | Agrostis hyemalis | Winter bentgrass | AGROHYEM | Poaceae | 4.0 | FAC | Grass | PE | MONO | Advent | |
| Agrostis stolonifera | Agrostis stolonifera | Spreading bentgrass | AGROSTOL | Poaceae | 5.0 | FACW | Grass | PE | MONO | Advent | |
| Ailanthus altissima | Ailanthus altissima | Tree-of-heaven | AILAALTI | Simaroubaceae | 0.0 | NI | Tree | W | DI | Advent | Exotic |
| Albizia julibrissin | Albizia julibrissin | Mimosa | ALBIJULI | Mimosaceae | 0.0 | NI | Tree | W | DI | Advent | Exotic |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Allium canadense var. canadense | Allium canadense var. canadense | meadow onion | ALLCANACA | Alliaceae | 2.7 | FACU- | Forb | PE | Mono | Full | |
| Allium vineale | Allium vineale | Wild garlic | ALLIVINE | Liliaceae | 0.0 | FACU | Forb | PE | MONO | Advent | Exotic |
| Alnus serrulata | Alnus serrulata | Tag alder | ALNUSERR | Betulaceae | 5.0 | FACW | Shrub | W | DI | Full | |
| Ambrosia artemisiifolia | Ambrosia artemisiifolia | Annual ragweed | AMBRARTE | Asteraceae | 1.0 | FACU | Forb | AN | DI | Full | |
| Amelanchier arborea | Amelanchier arborea | Downy service-berry | AMELARBO | Rosaceae | 5.5 | FACU | Sm tre | PE | DI | Shade | |
| Amianthium muscitoxicum | Amianthium muscaetoxicum | Fly Poison | AMIAMUSC | Liliaceae | 7.0 | FAC | Forb | PE | MONO | Partial | |
| Amorpha fruticosa | Amorpha fruticosa | Desert false indigo | AMORFRUT | Fabaceae | 2.7 | FACW | Shrub | W | DI | Full | |
| Ampelopsis arborea | Ampelopsis arborea | Peppervine | AMPEARBO | Vitaceae | 4.0 | FAC+ | Vine | PE | DI | Shade | |
| Amsonia tabernaemontana | Amsonia tabernaemontana | Eastern slimpod | AMSOTABE | Apocynaceae | 6.5 | FACW | Forb | PE | DI | | |
| Andropogon glaucopsis | Andropogon virginicus | Broomsedge | ANDRVIRG | Poaceae | 2.5 | FAC- | Grass | PE | MONO | Full | |
| Andropogon glaucopsis | Andropogon glaucopsis | Purple Bluestem | ANDRGLAU | Poaceae | 4.0 | NG | Grass | | MONO | | |
| Andropogon ternarius | Andropogon ternarius | Splitbeard bluestem | ANDRTERN | Poaceae | 4.7 | NG | Grass | PE | MONO | | |
| Antennaria plantaginifolia | Antennaria plantaginifolia | Plantain-leaved pussy toes | ANTEPLAN | Asteraceae | 3.5 | NG | Forb | PE | DI | Full | |
| Anthoxanthum odoratum | Anthoxanthum odoratum | Sweet vernalgrass | ANTHODOR | Poaceae | 0.0 | FACU | Grass | PE | MONO | Advent | Exotic |
| Apios americana | Apios americana | American potato bean | APIOAMER | Fabaceae | 4.0 | FACW | Vine | PE | DI | Partial | |
| Aralia spinosa | Aralia spinosa | Hercules club | ARALSPIN | Araliaceae | 4.5 | FAC | Shrub | W | DI | Shade | |
| Arisaema triphyllum | Arisaema triphyllum | Jack-in-the-pulpit | ARISTRIP | Araceae | 6.5 | FACW- | Forb | PE | MONO | Shade | |
| Aristida stricta | Aristida stricta | Pineland | ARISSTRI | Poaceae | 8.0 | FAC- | Grass | PE | MONO | 1 | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | threeawn | | | | | | | | | |
| Arundinaria gigantea | Arundinaria gigantea | Switch cane | ARUNGIGA | Poaceae | 6.5 | FACW | Grass | PE | MONO | Full | |
| Arundinaria gigantea ssp. tecta | Arundinaria tecta | Switchcane | ARUNTECT | Poaceae | 9.0 | FACW | Grass | PE | MONO | | |
| Asimina triloba | Asimina triloba | Pawpaw | ASIMTRIL | Annonaceae | 6.0 | FACU+ | Sm tre | W | DI | Shade | |
| Asplenium platyneuron | Asplenium platyneuron | Bradley's spleenwort | ASPLPLAT | Aspleniaceae | 3.5 | FACU | Fern | PE | SVP | Shade | |
| Athyrium asplenioides | Athyrium filix-femina | Lady fern | ATHYFILI | Dryopteridaceae | 5.5 | FAC | Fern | PE | SVP | Shade | |
| Baccharis halimifolia | Baccharis halimifolia | Silverling | BACCHALI | Asteraceae | 2.0 | FAC | Shrub | W | DI | Full | |
| Barbarea vulgaris | Barbarea vulgaris | Garden yellowrocket | BARBVULG | Brassicaceae | 0.0 | FAC | Forb | BI | DI | Advent | Exotic |
| Berchemia scandens | Berchemia scandens | Rattan vine | BERCSCAN | Rhamnaceae | 5.0 | FACW | H-vine | PE | DI | Shade | |
| Betula nigra | Betula nigra | River birch | BETUNIGR | Betulaceae | 5.0 | FACW | Tree | W | DI | Tree | |
| Bidens aristosa | Bidens aristosa | Bearded Beggars Ticks | BIDEARIS | Asteraceae | 2.0 | FACW | Forb | AN | DI | Full | |
| Bidens frondosa | Bidens frondosa | Devil's Beggar Ticks | BIDEFRON | Asteraceae | 1.0 | FACW | Forb | AN | DI | Full | ? |
| Bidens laevis | Bidens laevis | smooth beggar-ticks | BIDELAEV | Asteraceae | 4.0 | OBL | Forb | AN/PE | DI | | |
| Bignonia capreolata | Bignonia capreolata | Crossvine | BIGNCAPR | Bignoniaceae | 5.5 | FAC | Vine | W | DI | Shade | |
| Boehmeria cylindrica | Boehmeria cylindrica | False nettle | BOEHCYLI | Urticaceae | 4.0 | FACW+ | Forb | PE | DI | Shade | |
| Botrychium biternatum | Sceptridium biternum | Sparselobe fern | BOTRBITE | Ophioglossaceae | 5.3 | FAC | Fern | PE | SVP | Shade | |
| Botrychium dissectum | Botrychium dissectum | Dissected grape fern | BOTRDISS | Ophioglossaceae | 5.0 | FAC | Fern | PE | SVP | Shade | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Brickellia eupatorioides var. eupatorioides | Kuhnia eupatorioides | False boneset | KUHNEUPA | Asteraceae | 6.5 | NG | Forb | PE | DI | Full | Syn. Brickellia eupatorioides |
| Calamagrostis coarctata | Calamagrostis cinnoides | Nuttall's small reed grass | CALACINN | Poaceae | 6.0 | FACU- | Grass | PE | MONO | Advent | |
| Callicarpa americana | Callicarpa americana | Beautyberry | CALLAMER | Verbenaceae | 3.5 | FACU- | Shrub | W | DI | Shade | |
| Callitriche heterophylla | Callitriche heterophylla | Twoheaded water-starwort | CALLHETE | Callitrichaceae | 2.7 | NI | Forb | AN | DI | Full | |
| Campsis radicans | Campsis radicans | Trumpet creeper | CAMPRADI | Bignoniaceae | 2.0 | FAC | Vine | W | DI | Full | |
| Cardamine bulbosa | Cardamine bulbosa | Bulbous bittercress | CARDBULB | Brassicaceae | 7.5 | OBL | Forb | PE | DI | Shade | |
| Cardamine hirsuta | Cardamine hirsuta | Hairy bittercress | CARDHIRS | Brassicaceae | 0.0 | FAC | Forb | AN | DI | Advent | Exotic |
| Carex alata | Carex alata | Broad-winged sedge | CAREALAT | Cyperaceae | 5.0 | NG | Sedge | PE | MONO | | |
| Carex albolutescens | Carex albolutescens | Greenwhite sedge | CAREALBO | Cyperaceae | 4.0 | FAC+ | Sedge | PE | MONO | shade | |
| Carex atlantica | Carex atlantica | Prickly bog sedge | CAREATLA | Cyperaceae | 6.5 | FACW | Sedge | PE | MONO | Full | |
| Carex atlantica ssp. capillacea | Carex atlantica ssp capillacea | Prickly bog sedge | CAREATLACA | Cyperaceae | 7.0 | FACW | Sedge | PE | MONO | full | |
| Carex atlantica ssp. capillacea | Carex howei | Howe Sedge | CAREHOWE | Cyperaceae | 3.5 | OBL | Sedge | PE | MONO | | |
| Carex comosa | Carex comosa | Bearded Sedge | CARECOMO | Cyperaceae | 6.0 | OBL | Sedge | PE | MONO | Full | |
| Carex complanata | Carex complanata | hirsute sedge | CARECOMP | Cyperaceae | 4.0 | FAC+ | Sedge | PE | Mono | | |
| Carex crinita | Carex crinita | Fringed sedge | CARECRIN | Cyperaceae | 5.0 | FACW + | Sedge | PE | MONO | Shade | |
| Carex debilis | Carex debilis | White-edge sedge | CAREDEBI | Cyperaceae | 7.0 | FACW | Sedge | PE | MONO | Shade | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Carex debilis var. pubera | Carex debilis var pubera | White edge sedge | CAREDEBIPU | Cyperaceae | 5.0 | FACW | Sedge | PE | MONO | shade | |
| Carex digitalis | Carex digitalis | Slender woodland sedge | CAREDIGI | Cyperaceae | 5.0 | FACU | Sedge | PE | MONO | shade | |
| Carex elliottii | Carex elliottii | Elliott's sedge | CAREELLI | Cyperaceae | 8.0 | OBL | Sedge | PE | MONO | | |
| Carex festucacea | Carex festucacea | fescue sedge | CAREFEST | Cyperaceae | 5.0 | FACW | Sedge | PE | Mono | Partial | |
| Carex flaccosperma | Carex flaccosperma | Thinfruit sedge | CAREFLAC | Cyperaceae | 5.5 | FAC+ | Sedge | PE | MONO | | |
| Carex flaccosperma | Carex flaccosperma | thin-fruit sedge | CAREFLAC | Cyperaceae | 6.0 | FAC+ | Sedge | PE | Mono | | |
| Carex folliculata | Carex folliculata | Northern Long Sedge | CAREFOLL | Cyperaceae | 7.0 | NG | Sedge | PE | MONO | | |
| Carex glaucescens | Carex glaucescens | Southern waxy sedge | CAREGLAU | Cyperaceae | 7.0 | OBL | Sedge | PE | MONO | Shade | |
| Carex gracilescens | Carex gracilescens | Slender looseflower sedge | CAREGRAC | Cyperaceae | 5.0 | FACU | Sedge | PE | MONO | shade | |
| Carex gracilescens | Carex gracillescens | Slender Looseflower Sedge | CAREGRAC | Cyperaceae | 4.0 | NG | Sedge | PE | MONO | Shade | |
| Carex gracillima | Carex gracillima | Graceful Sedge | CAREGRCI | Cyperaceae | 6.0 | FACU | Sedge | PE | MONO | Shade | |
| Carex intumescens | Carex intumescens | Bladder sedge | CAREINTU | Cyperaceae | 6.5 | FACW | Sedge | PE | MONO | Shade | |
| Carex joorii | Carex joorii | Cypress Swamp Sedge | CAREJOOR | Cyperaceae | 6.3 | OBL | Sedge | PE | MONO | | |
| Carex laevivaginata | Carex laevivaginata | smooth-sheath sedge | CARELAEV | Cyperaceae | 6.0 | OBL | Sedge | PE | Mono | Shade | |
| Carex leptalea | Carex leptalea | Bristly Stalk Sedge | CARELEPT | Cyperaceae | 7.0 | OBL | Sedge | PE | MONO | Full | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Carex lonchocarpa | Carex lonchocarpa | Long Sedge | CARELONC | Cyperaceae | 7.0 | OBL | Sedge | PE | MONO | | |
| Carex louisianica | Carex louisianica | Louisiana sedge | CARELOUI | Cyperaceae | 8.0 | OBL | Sedge | PE | MONO | Shade | |
| Carex lupulina | Carex lupulina | Hop sedge | CARELUPU | Cyperaceae | 4.0 | OBL | Sedge | PE | MONO | Full | |
| Carex lurida | Carex lurida | Shallow sedge | CARELURI | Cyperaceae | 3.0 | OBL | Sedge | PE | MONO | Full | |
| Carex nigromarginata | Carex nigromarginata | Black edge sedge | CARENIGR | Cyperaceae | 7.0 | FACU | Sedge | PE | MONO | Partial | |
| Carex oxylepis | Carex oxylepis | Sharp-scale sedge | CAREOXYL | Cyperaceae | 7.0 | FACW- | Sedge | PE | MONO | | |
| Carex prasina | Carex prasina | Drooping sedge | CAREPRAS | Cyperaceae | 7.0 | OBL | Sedge | PE | MONO | Shade | |
| Carex radiata | Carex radiata | | CARERADI | Cyperaceae | 6.0 | NG | Sedge | PE | Mono | Shade | |
| Carex rosea | Carex rosea | Rose sedge | CAREROSE | Cyperaceae | 3.0 | UPL | Sedge | PE | MONO | Shade | oh c of c |
| Carex scoparia var. scoparia | Carex scoparia var. scoparia | pointed broom sedge | CARESCOPSC | Cyperaceae | 5.0 | FACW | Sedge | PE | Mono | Full | |
| Carex squarrosa | Carex squarrosa | squarrose sedge | CARESQUA | Cyperaceae | 5.0 | FACW | Sedge | PE | Mono | Shade | |
| Carex stipata | Carex stipata | Awl fruit sedge | CARESTIP | Cyperaceae | 3.0 | OBL | Sedge | PE | MONO | Partial | |
| Carex stipata var. maxima | Carex stipata var maxima | Stalk-grain sedge | CARESTIPMA | Cyperaceae | 3.0 | OBL | Sedge | PE | MONO | Partial | |
| Carex tribuloides | Carex tribuloides | blunt broom sedge | CARETRIB | Cyperaceae | 4.0 | FACW + | Sedge | PE | Mono | Partial | |
| Carex tribuloides var. tribuloides | Carex tribuloides var. tribuloides | | CARETRIBTR | Cyperaceae | 4.0 | NG | Sedge | PE | Mono | | |
| Carex typhina | Carex typhina | Cat-tail sedge | CARETYPH | Cyperaceae | 5.0 | OBL | Sedge | PE | MONO | Shade | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Carex venusta | Carex venusta | Sedge | CAREVENU | Cyperaceae | 7.0 | FACW + | Sedge | PE | MONO | Shade | |
| Carex vulpinoidea | Carex vulpinoidea | fox sedge | CAREVULP | Cyperaceae | 3.0 | OBL | Sedge | PE | Mono | Full | |
| Carphephorus paniculatus | Carphephorus paniculatus | Hairy Chaffhead | CARPPANI | Asteraceae | 9.0 | FACW | Forb | PE | DI | | |
| Carphephorus tomentosus | Carphephorus tomentosus | Woolly Chaffhead | CARPTOME | Asteraceae | 9.0 | FACW- | Forb | PE | DI | | |
| Carpinus caroliniana | Carpinus caroliniana | Ironwood | CARPCARO | Betulaceae | 5.0 | FAC | Sm tre | W | DI | Shade | |
| Carya alba | Carya tomentosa | Mockernut hickory | CARYTOME | Juglandaceae | 6.0 | NG | Tree | W | DI | Tree | |
| Carya cordiformis | Carya cordiformis | Bitternut hickory | CARYCORD | Juglandaceae | 6.5 | FAC | Tree | W | DI | Tree | |
| Carya glabra | Carya glabra | Pignut hickory | CARYGLAB | Juglandaceae | 6.0 | FACU | Tree | W | DI | Tree | |
| Carya ovata | Carya ovata | Shag-bark hickory | CARYOVAT | Juglandaceae | 7.0 | FACU | Tree | W | DI | Tree | |
| Cassia fasciculata | Cassia fasciculata | Partridge pea | CASSFASC | Fabaceae | 1.5 | FACU | Forb | AN | DI | Partial | |
| Catalpa speciosa | Catalpa speciosa | Indian cigar tree | CATASPEC | Bignoniaceae | 0.0 | FAC- | Tree | W | DI | Advent | |
| Cathartolinum curtissii | Linum medium var. texanum | stiff yellow flax | LINUMEDITE | Linaceae | 5.3 | FAC | Forb | PE | DI | Full | |
| Celtis laevigata | Celtis laevigata | Hackberry | CELTLAEV | Ulmaceae | 4.5 | FACW | Tree | W | DI | Tree | |
| Centella asiatica | Centella asiatica | Asian coinleaf | CENTASIA | Apiaceae | 3.5 | FACW | Forb | PE | DI | Advent | Exotic |
| Cephalanthus occidentalis | Cephalanthus occidentalis | Buttonbush | CEPHOCCI | Rubiaceae | 5.5 | OBL | Shrub | W | DI | Full | |
| Cercis canadensis | Cercis canadensis | Redbud | CERCCANA | Caesalpiniaceae | 5.5 | FACU | Sm tre | W | DI | Shade | |
| Chaerophyllum tainturieri | Chaerophyllum tainturieri | Hairyfruit chervil | CHAETAIN | Apiaceae | 2.0 | FAC | Forb | AN | DI | | |
| Chamaecyparis thyoides | Chamaecyparis thyoides | Atlantic white cedar | CHAMTHYO | Cupressaceae | 9.0 | OBL | Tree | W | GYMN | Tree | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Chasmanthium latifolium | Uniola latifolia | River oats | UNIOLATI | Poaceae | 4.5 | FAC- | Grass | PE | MONO | Partial | |
| Chasmanthium laxum | Chasmanthium laxum | Spike chasmanthium | CHASLAXU | Poaceae | 4.5 | FACW- | Grass | PE | MONO | Shade | |
| Chasmanthium sessiliflorum | Chasmanthium sessiliflorum var. sessiliflorum | long-leaf spikegrass | CHASSESSSE | Poaceae | 6.0 | FAC+ | Grass | PE | Mono | | |
| Chelone glabra | Chelone glabra | White Turtlehead | CHELGLAB | Scrophulariaceae | 7.0 | OBL | Forb | PE | DI | Partial | |
| Chimaphila maculata | Chimaphila maculata | Spotted wintergreen | CHIMMACU | Pyrolaceae | 7.0 | NG | Forb | PE | DI | Shade | |
| Chionanthus virginicus | Chionanthus virginicus | White Fringetree | CHIOVIRG | Oleaceae | 6.0 | FACU | SmTre | PE | DI | | |
| Cicuta bulbifera | Cicuta bulbifera | Bulb bearing water hemlock | CICUBULB | Apiaceae | 5.5 | NI | Forb | PE | DI | Full | |
| Cicuta maculata | Cicuta maculata | Spotted water hemlock | CICUMACU | Apiaceae | 5.5 | OBL | Forb | PE | DI | Full | |
| Cinna arundinacea | Cinna arundinacea | Stout wood reed grass | CINNARUN | Poaceae | 5.0 | FACW | Grass | PE | MONO | Shade | |
| Cirsium horridulum | Cirsium horridulum | Yellow thistle | CIRSHORR | Asteraceae | 3.7 | NG | Forb | AN | DI | | |
| Claytonia virginica | Claytonia virginica | Narrow leaf spring beauty | CLAYVIRG | Portulaceae | 6.0 | FACU- | Forb | PE | DI | Shade | |
| Clematis crispa | Clematis crispa | Swamp Virgin's Bower | CLEMCRIS | Ranunculaceae | 7.0 | FACW+ | H-vine | | DI | | |
| Clematis viorna | Clematis viorna | | CLEMVIOR | Ranunculaceae | 5.3 | NG | Forb | PE | DI | Partial | |
| Clematis virginiana | Clematis virginiana | Virgin's bower | CLEMVIRG | Ranunculaceae | 3.5 | FAC+ | Forb | PE | DI | Partial | |
| Clethra alnifolia | Clethra alnifolia | Sweet pepperbush | CLETALNI | Clethraceae | 5.5 | FACW | Shrub | W | DI | Advent | |
| Commelina communis | Commelina communis | Asiatic dayflower | COMMCOMM | Commelinaceae | 0.0 | FAC | Forb | AN | DI | Advent | Exotic |
| Commelina virginica | Commelina virginica | Virginia Dayflower | COMMVIRG | Commelinaceae | 5.0 | FACW | Forb | PE | DI | Full | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Conium maculatum | Conium maculatum | Poison Hemlock | CONIMACU | Apiaceae | 0.0 | FACW | Forb | BI | DI | Advent | |
| Conoclinium coelestinum | Conoclinium coelestinum | Blue mistflower | CONOCOEL | Asteraceae | 2.7 | NG | Forb | PE | DI | | |
| Conyza canadensis | Conyza canadensis | Canadian horseweed | CONYCANA | Asteraceae | 1.0 | FACU | Forb | AN/BI | DI | Full | |
| Cornus amomum | Cornus amomum | Silky Dogwood | CORNAMOM | Cornaceae | 4.3 | FACW + | Shrub | W | DI | Full | |
| Cornus florida | Cornus florida | Flowering dogwood | CORNFLOR | Cornaceae | 5.0 | FACU | Sm tre | W | DI | Shade | |
| Cornus foemina | Cornus stricta | Stiff Dogwood | CORNSTRI | Cornaceae | 5.0 | FACW- | Sm tre | W | DI | | |
| Corylus americana | Corylus americana | American hazelnut | CORYAMER | Betulaceae | 5.0 | FACU | Shrub | W | DI | Full | |
| Crataegus crus-galli | Crataegus crus-galli | Cockspur hawthorn | CRATCRUS | Rosaceae | 4.7 | FAC- | Sm tre | W | DI | Full | |
| Crataegus marshallii | Crateagus marshallii | Parsley hawthorn | CRATMARS | Rosaceae | 6.5 | FAC | Sm tre | W | DI | Shade | |
| Cuscuta gronovii | Cuscuta gronovii | Scaldweed | CUSCGRON | Cuscutaceae | 3.0 | NI | Vine | PE | DI | | |
| Cyperus echinatus | Cyperus echinatus | Globe flatsedge | CYPEECHI | Cyperaceae | 4.0 | NG | Sedge | PE | MONO | | |
| Cyperus erythrorhizos | Cyperus erythrorhizos | Red-root flatsedge | CYPEERYT | Cyperaceae | 2.0 | OBL | Sedge | AN | MONO | Full | |
| Cyperus odoratus | Cyperus odoratus | Fragrant Flatsedge | CYPEODOR | Cyperaceae | 3.0 | FACW | Sedge | AN/PE | MONO | Full | |
| Cyperus pseudovegetus | Cyperus pseudovegetus | Marsh flatsedge | CYPEPSEU | Cyperaceae | 4.0 | FACW | Sedge | PE | MONO | | |
| Cyperus strigosus | Cyperus strigosus | Straw-color flatsedge | CYPESTRI | Cyperaceae | 3.0 | FACW | Sedge | PE | MONO | Full | |
| Cyrilla racemiflora | Cyrilla racemiflora | Titi | CYRIRACE | Ericaceae | 8.0 | FACW | Shrub | W | DI | Advent | |
| Danthonia spicata | Danthonia spicata | | DANTSPIC | Poaceae | 5.0 | NG | Grass | PE | Mono | Shade | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Decodon verticillatus | Decodon verticillatus | Hairy swamp loosestrife | DECOVERT | Lythraceae | 6.5 | OBL | Forb | PE | DI | Full | |
| Decumaria barbara | Decumaria barbara | Southeast decumaria | DECUBARB | Hydrangaceae | 6.5 | FACW | Vine | PE | DI | Shade | |
| Desmodium paniculatum | Desmodium paniculatum | Panicled Tick-Treefoil | DESMPANI | Fabaceae | 4.0 | FACU | Forb | PE | DI | Shade | |
| Dichanthelium aciculare | Dichanthelium aciculare | Needleleaf rosette grass | DICHACIC | Poaceae | 4.0 | FACU | Grass | PE | MONO | | |
| Dichanthelium auburne | Dichanthelium acuminatum var acuminatum | Tapered rosette grass | DICHACUMAC | Poaceae | 5.0 | FAC | Grass | PE | MONO | | |
| Dichanthelium commutatum | Dichanthelium commutatum | Variable panicgrass | DICHCOMM | Poaceae | 5.5 | FAC | Grass | PE | MONO | | |
| Dichanthelium dichotomum | Dichanthelium dichotomum | Velvet panicum | DICHDICH | Poaceae | 5.0 | FACW | Grass | PE | MONO | | |
| Dichanthelium laxiflorum | Dichanthelium laxiflorum | Lax-flower witchgrass | PANILAXI | Poaceae | 6.0 | FAC | Grass | PE | MONO | Shade | |
| Dichanthelium laxiflorum | Panicum laxiflorum | Lax-flower witchgrass | PANIDILAXI | Poaceae | 4.0 | FAC | Grass | PE | MONO | Shade | |
| Dichanthelium laxiflorum | Dichanthelium laxiflorum | Openflower rosette grass | DICHLAXI | Poaceae | 4.0 | FAC | Grass | PE | MONO | | |
| Dichanthelium scabriusculum | Dichanthelium scabriusculum | Woolly rossette grass | DICHSCAB | Poaceae | 3.0 | OBL | Grass | PE | MONO | | |
| Dichanthelium scoparium | Dichanthelium scoparium | Cypress panic grass | DICHCSCOP | Poaceae | 4.0 | FAC | Grass | PE | MONO | | |
| Dichanthelium scoparium | Dichanthelium scoparium | Velvet panicum | DICHSCOP | Poaceae | 5.7 | FACW | Grass | PE | MONO | Full | |
| Dicliptera brachiata | Dicliptera brachiata | wild mudwort | DICLBRAC | Acanthaceae | 7.3 | FACW | Forb | AN/PE | DI | | |
| Digitaria ciliaris | Digitaria sanguinalis | hairy crabgrass | DIGISANG | Poaceae | 0.0 | FACW | Grass | AN | Mono | Advent | |
| Digitaria ischaemum | Digitaria ischaemum | Smooth crabgrass | DIGIISCH | Poaceae | 2.0 | UPL | Grass | AN | MONO | Advent | |
| Digitaria leptoloma | Digitaria cognata | Witch grass spp C | DIGICOGN | Poaceae | 3.0 | | Grass | PE | MONO | | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diodia virginiana | Diodia virginiana | Virginia Buttonweed | DIODVIRG | | 3.0 | FACW | Forb | | DI | | |
| Dioscorea villosa | Dioscorea villosa | Wild Yamroot | DIOSVILL | Dioscoreaceae | 5.5 | FAC | Vine | PE | DI | Partial | |
| Diospyros virginiana | Diospyros virginiana | Common persimmon | DIOSVIRG | Ebenaceae | 3.5 | FAC | Sm tre | W | DI | Shade | |
| Drosera capillaris | Drosera capillaris | Pinksundew | DROSCAPI | Droseraceae | 7.3 | OBL | Forb | PE | DI | Full | |
| Drosera intermedia | Drosera intermedia | Spoon-leafed Sundew | DROSINTE | Droseraceae | 8.3 | OBL | Forb | PE | DI | Full | |
| Dryopteris cristata | Dryopteris cristata | Crested shield-fern | DRYOCRIS | Dryopteridaceae | 8.0 | OBL | Fern | PE | SVP | Shade | Natural Heritage Program - Watch Category W1, S3, G5 |
| Dryopteris ludoviciana | Dryopteris ludoviciana | Southern Wood Fern | DRYOLUDO | Dryopteridaceae | 7.5 | FACW | Fern | PE | SVP | Shade | |
| Duchesnea indica | Duchesnea indica | Indian strawberry | DUCHINDI | Rosaceae | 0.0 | NI | Forb | PE | DI | Advent | Exotic |
| Echinochloa crus-galli | Echinochloa crus-galli | Barnyard grass | ECHICRUS | Poaceae | 1.5 | FACW- | Grass | AN | MONO | Advent | |
| Elaeagnus angustifolia | Elaeagnus angustifolia | Russian olive | ELAEANGU | Elaeagnaceae | 0.0 | FAC | Sm tre | W | DI | Advent | Exotic, Check species all sites, E. umbellata? |
| Elaeagnus pungens | Elaeagnus pungens | Thorny olive | ELAEPUNG | Elaeagnaceae | 0.0 | NG | Shrub | W | DI | Advent | Exotic |
| Elaeagnus umbellata | Elaeagnus umbellata | Autumn olive | ELAEUMBE | Elaeagnaceae | 0.0 | NG | Sm tre | W | DI | Advent | |
| Eleocharis tortilis | Eleocharis tortillis | Twisted spikerush | ELEOTORT | Cyperaceae | 7.0 | FACW | Sedge | PE | MONO | | |
| Elephantopus nudatus | Elephantopus nudatus | Smooth elephant foot | ELEPNUDA | Asteraceae | 3.5 | FAC | Forb | PE | DI | Partial | |
| Elephantopus tomentosus | Elephantopus tomentosus | Devil's Grandmother | ELEPTOME | Asteraceae | 3.5 | NG | Forb | PE | DI | Full | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Elymus virginicus | Elymus virginicus | Virginia wild-rye | ELYMVIRG | Poaceae | 6.5 | FAC | Grass | PE | MONO | | |
| Erechtites hieraciifolia | Erechtites hieraciifolia | Fireweed American / Burn | ERECHIER | Asteraceae | 2.3 | FAC- | Forb | PE | DI | | |
| Erianthus contortus | Saccharum brevibarbe var contortum | Sortbeard Plumegrass | SACCBREVCO | Poaceae | 5.0 | FAC | Grass | PE | MONO | | |
| Eubotrys racemosa | Leucothoe racemosa | Fetterbush | LEUCRACE | Ericaceae | 7.0 | FACW | Shrub | W | DI | Advent | |
| Euonymus americanus | Euonymus americanus | Strawberry bush | EUONAMER | Celastraceae | 5.0 | FAC- | Shrub | W | DI | Partial | |
| Euonymus fortunei | Euonymus fortunei | Winter creeper | EUONFORT | Celastraceae | 0.0 | NG | Vine | W | DI | Advent | Exotic |
| Eupatorium capillifolium | Eupatorium capillifolium | Small dog fennel | EUPACAPI | Asteraceae | 2.0 | FACU | Forb | PE | DI | Partial | |
| Eupatorium compositifolium | Eupatorium compositifolium | Dog fennel | EUPACOMP | Asteraceae | 2.0 | FAC- | Forb | PE | DI | Partial | |
| Eupatorium dubium | Eupatorium dubium | Coastal Joe-pye-weed | EUPADUBI | Asteraceae | 5.5 | FACW | Forb | PE | DI | Advent | |
| Eupatorium fistulosum | Eupatorium fistulosum | Hollow-stemmed Joe-pye-weed | EUPAFIST | Asteraceae | 5.5 | FAC+ | Forb | PE | DI | Partial | |
| Eupatorium hyssopifolium | Eupatorium hyssopifolium | Hyssop thoroughwort | EUPAHYSS | Asteraceae | 4.0 | NG | Forb | PE | DI | Partial | |
| Eupatorium leucolepis | Eupatorium leucolepis | | EUPALEUC | Asteraceae | 8.0 | FAC- | Forb | PE | DI | | |
| Eupatorium perfoliatum | Eupatorium perfoliatum | Common boneset | EUPAPERF | Asteraceae | 4.5 | FACW + | Forb | PE | DI | Full | |
| Eupatorium purpureum | Eupatorium purpureum | Unscented Joe-pye weed | EUPAPURP | Asteraceae | 5.0 | FAC | Forb | PE | DI | Partial | |
| Eupatorium rotundifolium | Eupatorium rotundifolium | Round-leaved thoroughwort | EUPAROTU | Asteraceae | 4.0 | FAC | Forb | PE | DI | Shade | |
| Eupatorium serotinum | Eupatorium serotinum | Late flowering thoroughwort | EUPASERO | Asteraceae | 2.0 | UPL | Forb | PE | DI | Shade | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Eurybia divaricata | Eurybia divaricata (Weakley) | White wood aster | EURYDIVA | Asteraceae | 5.5 | NG | Forb | PE | DI | Shade | old nomenclature - Aster divaricatus |
| Euthamia caroliniana | Euthamia caroliniana | Slender goldentop | EUTHCARO | Asteraceae | 3.5 | FAC | Forb | PE | DI | | |
| excluded | Sanicula spp. | Sanicle | SANISPPB | Apiaceae | 6.0 | x | Forb | PE | DI | | |
| excluded | Liriope spp | Turf Lily | LIRISPP | Liliaceae | 0.0 | NG | Forb | PE | MONO | Advent | Exotic |
| Fagus grandifolia | Fagus grandifolia | American beech | FAGUGRAN | Fagaceae | 7.0 | FACU | Tree | W | DI | Tree | |
| Festuca subverticillata | Festuca subverticillata | | FESTSUBV | Poaceae | 6.3 | FACU | Grass | PE | MONO | Shade | |
| Festuca subverticillata | Festuca obtusa | Nodding obtusa | FESTOBTU | Poaceae | 4.0 | FACU- | Grass | PE | MONO | | |
| Fothergilla gardenii | Fothergilla gardenii | Dwarf witch alder | FOTHGARD | Hamamelidaceae | 7.5 | FACW | Shrub | W | DI | Partial | ?? |
| Fragaria virginiana | Fragaria virginiana | Virginia strawberry | FRAGVIRG | Rosaceae | 1.7 | FAC- | Forb | PE | DI | Full | |
| Fraxinus americana | Fraxinus americana | White ash | FRAXAMER | Oleaceae | 4.7 | FACU | Tree | PE | DI | Tree | |
| Fraxinus caroliniana | Fraxinus caroliniana | Carolina ash | FRAXCARO | Oleaceae | 5.7 | OBL | Tree | W | DI | Tree | |
| Fraxinus pennsylvanica | Fraxinus pennsylvanica (Weakley) | Green ash | FRAXPENN | Oleaceae | 5.0 | FACW | Tree | W | DI | Tree | |
| Fraxinus profunda | Fraxinus profunda (Weakley) | Pumkin ash | FRAXPROF | Oleaceae | 7.0 | OBL | Tree | W | DI | Tree | |
| Galium aparine | Galium aparine | Catchweed bedstraw | GALIAPAR | Rubiaceae | 2.0 | FACW + | Forb | AN | DI | Partial | |
| Galium circaezans | Galium circaezans | Wild licorice | GALICIRC | Rubiaceae | 4.5 | FACU- | Forb | PE | DI | Shade | |
| Galium obtusum | Galium obtusum | Blunt leaf bedstraw | GALIOBTU | Rubiaceae | 5.5 | FACW- | Forb | PE | DI | Full | |
| Galium parisiense | Galium | Lamarck's | GALIPARI | Rubiaceae | 0.0 | FACU | Forb | AN | MONO | | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | parisiense | bestraw | | | | | | | | | |
| Galium pilosum | Galium pilosum | Hairy bedstraw | GALIPILO | Rubiaceae | 5.0 | NG | Forb | PE | DI | Shade | |
| Galium tinctorium | Galium tinctorium | Stiff marsh bedstraw | GALITINC | Rubiaceae | 2.5 | FACW | Forb | PE | DI | Full | |
| Gaylussacia dumosa | Gaylussacia dumosa | Dwarf huckleberry | GAYLDUMO | Ericaceae | 7.0 | FAC | Shrub | PE | DI | | |
| Gaylussacia frondosa | Gaylussacia frondosa | Dangleberry | GAYLFRON | Ericaceae | 5.5 | FAC | Shrub | W | DI | Advent | |
| Gelsemium sempervirens | Gelsemium sempervirens | Yellow jessamine | GELSSEMP | Loganiaceae | 4.0 | FAC | Vine | PE | DI | Advent | |
| Gentiana crinita | Gentiana crinita | Fringed gentian | GENTCRIN | Gentianaceae | 9.0 | FACW + | Forb | PE | DI | Full | or Sabatia sp ? |
| Geum canadense | Geum canadense | White avens | GEUMCANA | Rosaceae | 5.0 | FAC | Forb | PE | DI | Shade | |
| Glechoma hederacea | Glecoma hederacea | Ground ivy | GLECHEDE | Lamiaceae | 0.0 | FACU | Forb | PE | DI | Advent | |
| Glyceria striata | Glyceria striata | Fowl manna grass | GLYCSTRI | Poaceae | 4.5 | OBL | Grass | PE | MONO | Shade | |
| Glyceria striata | Glyceria striata var striata | Fowl manna grass | GLYCSTRIST | Poaceae | 4.5 | OBL | Grass | PE | MONO | Shade | |
| Goodyera pubescens | Goodyera pubescens | Rattlesnake orchid | GOODPUBE | Orchidaceae | 7.0 | UPL | Forb | PE | MONO | Shade | |
| Gordonia lasianthus | Gordonia lasianthus | Loblolly bay | GORDLASI | Theaceae | 8.5 | FACW | Sm tre | W | DI | Tree | |
| Gratiola pilosa | Gratiola pilosa (Radford) | Shaggy Hedge Hissop | GRATPILO | Scrophulariaceae | 4.7 | FACW- | Forb | PE | DI | | |
| Hamamelis virginiana | Hamamelis virginiana | Witchhazel | HAMAVIRG | Hamamelidaceae | 5.3 | FACU | Sm tre | W | DI | Shade | |
| Hedera helix | Hedera helix | English ivy | HEDEHELI | Araliaceae | 0.0 | NI | Vine | W | DI | Advent | Exotic |
| Heliopsis helianthoides | Heliopsis helianthoides | Smooth Oxeye | HELIHELI | Asteraceae | 4.5 | FACU | Forb | PE | DI | Full | |
| Hepatica nobilis var. obtusa | Hepatica americana | Round-lobe Hepatica | HEPAAMER | Ranunculaceae | 7.0 | UPL | Forb | PE | DI | Shade | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | (Radford) | | | | | | | | | | |
| Hexastylis arifolia | Hexastylis arifolia | Wild ginger | HEXAARIF | Aristolochiaceae | 7.0 | FAC- | Forb | PE | DI | Shade | |
| Hexastylis virginica | Hexastylis virginica | Wild ginger | HEXAVIRG | Aristolochiaceae | 7.0 | FACU | Forb | PE | DI | Shade | |
| Holcus lanatus | Holcus lanatus | Common velvetgrass | HOLCLANA | Poaceae | 0.0 | FACU- | Grass | PE | MONO | Adven t | Exotic |
| Hydrocotyle ranunculoides | Hydrocotyle ranunculoides | Floating Pennywort | HYDRRANU | Apiaceae | 3.0 | OBL | Forb | PE | DI | Adven t | |
| Hydrocotyle verticillata | Hydrocotyle verticillata | Whorled Pennywort | HYDRVERT | Apiaceae | 4.0 | OBL | Forb | PE | DI | | |
| Hymenocallis palmeri | Hymenocallis pygmaea | Alligatorlily | HYMEPYGM | Amaryllidaceae | 9.0 | OBL | Forb | PE | MONO | | |
| Hypericum crux-andreae | Hypericum crux-andreae | St. Peterswort | HYPECRUX | Clusiaceae | 6.0 | FACW- | Shrub | PE | DI | | |
| Hypericum hypericoides | Hypericum hypericoides | St. Andrew's-cross | HYPEHYPE | Clusiaceae | 5.0 | FAC | Shrub | W | DI | Full | Old nomenclature-Ascyrum hypericoides |
| Hypericum hypericoides ssp. multicaule | Hypericum hypericoides ssp multicaule | St. Andrew's-cross | HYPEHYPEMU | Clusiaceae | 5.7 | NG | Forb | PE | DI | Full | |
| Hypericum majus | Hypericum majus | Large St. Johnswort | HYPEMAJU | Clusiaceae | 7.0 | NI | Forb | AN | DI | Full | |
| Hypericum mutilum | Hypericum mutilum | Slender St. John's Wort | HYPEMUTI | Clusiaceae | 2.7 | FACW | Forb | W | DI | Full | |
| Hypochaeris radicata | Hypochaeris radicata | Hairy cat's ear | HYPORATI | Asteraceae | 0.0 | FACU | Forb | PE | DI | Adven t | Exotic |
| Ilex amelanchier | Ilex amelanchier | Sarvis holly | ILEXAMEL | Aquifoliaceae | 8.0 | OBL | Shrub | W | DI | Partial | ???? |
| Ilex cassine | Ilex cassine | Dahoon holly | ILEXCASS | Aquifoliaceae | 7.0 | FACW | Sm tre | W | DI | Full | NC Natural Heritage - W7, S2, G5 |
| Ilex coriacea | Ilex coriacea | Gallberry | ILEXCORI | Aquifoliaceae | 7.5 | FACW | Shrub | W | DI | Adven t | |
| Ilex cornuta | Ilex cornuta | Chinese holly | LLEXCORN | Aquifoliaceae | 0.0 | NG | Tree | PE | DI | Adven t | Exotic |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ilex decidua | Ilex decidua | Deciduous holly | ILEXDECI | Aquifoliaceae | 6.0 | FACW- | Shrub | W | DI | Full | |
| Ilex glabra | Ilex glabra | Gallberry | ILEXGLAB | Aquifoliaceae | 6.0 | FACW | Shrub | W | DI | Advent | |
| Ilex myrtifolia | Ilex myrtifolia | Myrtle holly | ILEXMYRT | Aquifoliaceae | 7.5 | FACW | Shrub | W | DI | Full | |
| Ilex opaca | Ilex opaca | American Holly | ILEXOPAC | Aquifoliaceae | 5.0 | FAC- | Sm tre | W | DI | Shade | |
| Ilex verticillata | Ilex verticillata | Winter berry | ILEXVERT | Aquifoliaceae | 6.5 | FACW | Shrub | W | DI | Shade | |
| Ilex vomitoria | Ilex vomitoria | Yaupon holly | ILEXVOMI | Aquifoliaceae | 7.0 | FAC | Shrub | W | DI | | |
| Impatiens capensis | Impatiens capensis | Jewelweed | IMPACAPE | Balsaminaceae | 4.0 | FACW | Forb | AN | DI | Partial | |
| Iris virginica | Iris virginica | Virginia Blueflag | IRISVIRG | Iridaceae | 6.7 | OBL | Forb | PE | MONO | Partial | |
| Itea virginica | Itea virginica | Virginia willow | ITEAVIRG | Grossulariaceae | 7.0 | FACW + | Shrub | W | DI | Advent | |
| Juglans nigra | Juglans nigra | Black walnut | JUGLNIGR | Juglandaceae | 4.7 | FACU | Tree | W | DI | Tree | |
| Juncus abortivus | Juncus abortivus | Pinebarren rush | JUNCABOR | Juncaceae | 5.0 | OBL | Rush | PE | MONO | | |
| Juncus acuminatus | Juncus acuminatus | Taper-tip rush | JUNCACUM | Juncaceae | 3.5 | OBL | Forb | PE | MONO | Full | |
| Juncus biflorus | Juncus biflorus | turnflower rush | JUNCBIFL | Juncaceae | 5.0 | FACW | Forb | PE | Mono | | |
| Juncus canadensis | Juncus canadensis | Canada rush | JUNCCANA | Juncaceae | 5.0 | OBL | Forb | PE | Mono | Full | |
| Juncus coriaceus | Juncus coriaceus | Leathery Rush | JUNCCORI | Juncaceae | 6.0 | FACW | Rush | PE | MONO | | |
| Juncus dichotomus | Juncus dichotomus | Forked Rush | JUNCDICH | Juncaceae | 3.0 | FACW | Rush | PE | MONO | Full | |
| Juncus effusus | Juncus effusus | Soft rush | JUNCEFFU | Juncaceae | 2.5 | FACW + | Forb | PE | MONO | Full | |
| Juncus effusus var. solutus | Juncus effusus ssp solutus | Soft rush | JUNCEFFUSO | Juncaceae | 5.0 | FACW + | Rush | PE | MONO | Full | |
| Juncus marginatus | Juncus marginatus | Grassleaf rush | JUNCMARG | Juncaceae | 3.0 | FACW | Forb | PE | MONO | Full | |
| Juncus repens | Juncus repens | Creeping Rush | JUNCREPE | Juncaceae | 5.0 | OBL | Rush | | MONO | | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Juncus scirpoides | Juncus scirpoides | Needle-pod rush | JUNCSCIR | Juncaceae | 4.0 | FACW + | Grass | PE | MONO | Full | |
| Juncus tenuis | Juncus tenuis | Slender rush | JUNCTENU | Juncaceae | 3.5 | FAC | Rush | PE | MONO | Partial | |
| Juniperus virginiana | Juniperus virginiana | Eastern red cedar | JUNIVIRG | Cupressaceae | 3.5 | FACU- | Tree | W | GYMN | Tree | |
| Krigia virginica | Krigia virginica | Virginia dwarfdandelio n | KRIGVIRG | Asteraceae | 4.0 | FACU- | Forb | AN | DI | Full | |
| Kummerowia striata | Lespedeza striata | Japonese clover | KUMMSTRI | Fabaceae | 0.0 | FACU | Forb | PE | DI | Adven t | |
| Lachnanthes caroliana | Lachnanthes caroliana | Red Root | LACHCARO | Haemodoraceae | 4.0 | OBL | Forb | PE | MONO | Partial | |
| Lachnocaulon anceps | Lachnocaulon anceps | Whitehead bogbutton | LACHANCE | Eriocaulaceae | 7.0 | OBL | Forb | PE | MONO | Partial | |
| Lamium purpureum | Lamium purpureum | Purple deadnettle | LAMIPURP | Lamiaceae | 0.0 | NG | Forb | AN | DI | Adven t | Exotic |
| Leersia virginica | Leersia virginica | Whitegrass | LEERVIRG | Poaceae | 5.0 | FACW | Grass | PE | MONO | Shade | |
| Lemna valdiviana | Lemna valdiviana | Pale Duckweed | LEMNVALD | Lemnaceae | 6.7 | OBL | Forb | AN | MONO | Full | |
| Lepidium virginicum | Lepidium virginicum | Poor man's pepper grass | LEPIVIRG | Brassicaceae | 2.0 | FACU | Forb | AN | DI | Full | |
| Lespedeza capitata | Lespedeza capitata | Roundhead lespedeza | LESPCAPI | Fabaceae | 5.0 | FACU | Forb | PE | DI | | |
| Lespedeza cuneata | Lespedeza cuneata | Chinese bushclover | LESPCUNE | Fabaceae | 0.0 | NI | Forb | PE | DI | Adven t | Exotic |
| Lespedeza virginica | Lespedeza virginica | Slender bushclover | LESPVIRG | Fabaceae | 3.0 | NG | Forb | PE | DI | Full | |
| Leucothoe axillaris | Leucothoe axillaris | Coastal dog-hobble | LEUCAXIL | Ericaceae | 7.0 | FACW | Shrub | W | DI | Shade | |
| Ligustrum japonicum | Ligustrum japonicum | Japanese privet | LIGUJAPO | Oleaceae | 0.0 | NG | Shrub | W | DI | Adven t | Exotic |
| Ligustrum sinense | Ligustrum sinense | Chinese privet | LIGUSINE | Oleaceae | 0.0 | FAC | Shrub | W | DI | Adven t | Exotic |
| Lindera benzoin | Lindera benzoin | Northern spicebush | LINDBENZ | Lauraceae | 6.5 | FACW | Shrub | W | DI | Shade | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Liquidambar styraciflua | Liquidambar styraciflua | Sweet gum | LIQUSTYR | Hamamelidaceae | 3.0 | FAC+ | Tree | W | DI | Tree | |
| Liriodendron tulipifera | Liriodendron tulipifera | Tulip tree | LIRITULI | Magnoliaceae | 4.0 | FAC | Tree | W | DI | Tree | |
| Litsea aestivalis | Litsea aestivalis | Pondspice | LITSAEST | Lauraceae | 9.0 | OBL | Shrub | PE | DI | 1 | |
| Lobelia cardinalis | Lobelia cardinalis | Cardinalflower | LOBECARD | Campanulaceae | 5.0 | FACW + | Forb | PE | DI | Partial | |
| Lobelia elongata | Lobelia elongata | elongated lobelia | LOBEELON | Campanulaceae | 6.0 | OBL | Forb | PE | DI | | |
| Lobelia inflata | Lobelia inflata | Indian tobacco | LOBEINFL | Campanulaceae | 2.0 | FAC | Forb | AN | DI | Full | |
| Lonicera japonica | Lonicera japonica | Japanese honeysuckle | LONIJAPO | Caprifoliaceae | 0.0 | FAC- | Vine | W | DI | Advent | Exotic |
| Lonicera sempervirens | Lonicera sempervirens | Trumpet honeysuckle | LONISEMP | Caprifoliaceae | 0.0 | FAC | Vine | W | DI | | |
| Ludwigia alternifolia | Ludwigia alternifolia | Bushy seedbox | LUDWALTE | Onagraceae | 4.0 | OBL | Forb | PE | DI | Full | |
| Ludwigia palustris | Ludwigia palustris | Marsh seedbox | LUDWPALU | Onagraceae | 4.0 | OBL | Forb | AN | DI | | |
| Luzula bulbosa | Luzula bulbosa | Bulbous woodrush | LUZUBULB | Juncaceae | 5.0 | FACU | Rush | PE | MONO | shade | |
| Luzula echinata | Luzula echinata | Hedgehog woodrush | LUZUECHI | Campanulaceae | 5.0 | FACU | Rush | PE | MONO | shade | |
| Lycopodium digitatum | Lycopodium flabelliforme | Fan clubmoss | LYCOFLAB | Lycopodiaceae | 4.5 | NG | Forb | PE | DI | Shade | Syn. Lycopodium digitatum |
| Lycopodium obscurum | Lycopodium obscurum | Tree clubmoss | LYCOOBSC | Lycopodiaceae | 5.5 | FACU- | Fern | PE | SVP | Shade | |
| Lycopus virginicus | Lycopus virginicus | Virginia bugleweed | LYCOVIRG | Lamiaceae | 4.0 | OBL | Forb | PE | DI | Full | |
| Lyonia ligustrina | Lyonia ligustrina | Maleberry | LYONLIGU | Ericaceae | 7.0 | FACW | Shrub | W | DI | Advent | |
| Lyonia lucida | Lyonia lucida | Fetterbush | LYONLUCI | Ericaceae | 7.0 | FACW | Shrub | W | DI | Advent | |
| Lyonia mariana | Lyonia mariana | Piedmont Staggerbush | LYONMARI | Ericaceae | 6.7 | FAC | Shrub | W | DI | | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lysimachia nummularia | Lysimachia nummularia | Creeping Jenny | LYSINUMM | Primulaceae | 0.0 | FACW + | Forb | PE | DI | | |
| Magnolia grandiflora | Magnolia grandiflora | Southern magnolia | MAGNGRAN | Magnoliaceae | 1.0 | FAC+ | Tree | W | DI | Tree | |
| Magnolia tripetala | Magnolia tripetala | Umbrella magnolia | MAGNTRIP | Magnoliaceae | 7.5 | FAC | Tree | W | DI | Tree | |
| Magnolia virginiana | Magnolia virginiana | Sweetbay magnolia | MAGNVIRG | Magnoliaceae | 7.0 | FACW + | Tree | W | DI | Tree | |
| Mecardonia acuminata | Mecardonia acuminata | Axilflower | MECAACUM | Scrophulariaceae | 3.0 | FACW | Forb | PE | DI | | |
| Medeola virginiana | Medeola virginiana | Indian cucumber root | MEDEVIRG | Liliaceae | 6.5 | NG | Forb | PE | MONO | Shade | |
| Melia azedarach | Melia azedarach | Chinaberry | MELIAZED | Meliaceae | 0.0 | NG | Tree | W | DI | Adven t | Exotic |
| Microstegium vimineum | Microstegium vimineum | Nepalese browntop | MICRVIMI | Poaceae | 0.0 | FAC+ | Grass | AN | MONO | Adven t | Exotic |
| Mikania scandens | Mikania scandens | Climbing hempweed | MIKASCAN | Asteraceae | 3.0 | FACW + | Vine | PE | DI | Shade | |
| Mimulus ringens var. ringens | Mimulus ringens var. ringens | alleghany monkey-flower | MIMURINGRI | Lamiaceae | 3.7 | OBL | Forb | PE | DI | Full | |
| Mitchella repens | Mitchella repens | Partridgeberry | MITCREPE | Rubiaceae | 6.0 | FACU+ | Forb | PE | DI | Shade | |
| Monotropa uniflora | Monotropa uniflora | Indian pipe | MONOUNIF | Monotropaceae | 5.5 | FACU- | Forb | PE | DI | Shade | |
| Morella caroliniensis | Myrica heterophylla | Black bayberry | MYRIHETE | Myricaceae | 7.0 | FACW | Shrub | W | DI | Partial | |
| Morella cerifera | Myrica cerifera | Wax mytle | MYRICERI | Myricaceae | 4.0 | FAC+ | Shrub | W | DI | Full | |
| Morus alba | Morus alba | White mulberry | MORUALBA | Moraceae | 0.0 | FACU- | Sm tre | W | DI | Adven t | Exotic |
| Morus rubra | Morus rubra | Red mulberry | MORURUBR | Moraceae | 4.0 | FAC | Sm tre | W | DI | Tree | |
| Murdannia keisak | Aneilema keisak | Marsh Dewflower | ANEIKEIS | Commelinaceae | 0.0 | OBL | Forb | PE | DI | | Exotic |
| Myosotis macrosperma | Myosotis macrosperma | Large-seed Forget-me-not | MYOSMACR | Boraginaceae | 5.0 | FAC | Forb | AN | DI | Shade | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Myriophyllum aquaticum | Myriophyllum aquaticum | Parrot feather | MYRIAQUA | Haloragaceae | 0.0 | OBL | Forb | PE | DI | Adven t | Exotic |
| Nandina domestica | Nandina domestica | Nandina | NANDDOME | Poaceae | 0.0 | NG | Grass | W | MONO | Adven t | Exotic |
| none | Ophioglossum vulgatum var. pychasticum | Northern Adder's Tongue | OPHIVUPYCH | Ophioglossaceae | 6.7 | FACW | Fern | PE | SVP | Full | |
| none | Rhynchospora cephalantha var cephalantha | Clustered beakrush | RHYNCEPHCE | Cyperaceae | 7.0 | OBL | Sedge | PE | MONO | | |
| Nymphaea odorata | Nymphaea odorata | Fragrant water lily | NYMPODOR | Nymphaceae | 6.5 | OBL | Forb | PE | DI | Full | |
| Nyssa biflora | Nyssa biflora | Swamp tupelo | NYSSBIFL | Cornaceae | 7.0 | OBL | Tree | W | DI | Tree | |
| Nyssa sylvatica | Nyssa sylvatica | Black gum | NYSSSYLV | Cornaceae | 6.0 | FAC | Tree | W | DI | Tree | |
| Onoclea sensibilis | Onoclea sensiblis | Sensitive Fern | ONOCSENS | Dryopteridaceae | 2.3 | FACW | Fern | PE | SVP | Full | |
| Opuntia humifusa | Opuntia humifusa | Prickly pear | OPUNHUMI | Cataceae | 8.0 | NG | Shrub | W | DI | Full | |
| Osmanthus americanus | Osmanthus americanus | Devil-wood | OSMAAMER | Oleaceae | 8.0 | FAC | Tree | PE | DI | Shade | |
| Osmunda cinnamomea | Osmunda cinnamomea | Cinnamon fern | OSMUCINN | Osmundaceae | 6.5 | FACW + | Fern | PE | SVP | Partial | |
| Osmunda regalis | Osmunda regalis | Royal fern | OSMUREGA | Osmundaceae | 7.5 | OBL | Fern | PE | SVP | Shade | |
| Ostrya virginiana | Ostrya virginiana | American hornbeam | OSTRVIRG | Betulaceae | 6.0 | FACU- | Tree | W | DI | Tree | |
| Oxalis dillenii | Oxalis dillenii | Slender Yellow Woodsorrel | OXALDILL | Oxalidaceae | 0.0 | FACU | Forb | PE | DI | Full | |
| Oxalis stricta | Oxalis stricta | Yellow wood sorrel | OXALSTRI | Oxalidaceae | 2.5 | FACU | Forb | PE | DI | Full | |
| Oxydendrum arboreum | Oxydendrum arboreum | Sourwood | OXYDARBO | Ericaceae | 5.0 | NI | Tree | W | DI | Tree | |
| Oxypolis rigidior | Oxypolis rigidior | Stiff cowbane | OXYPRIGI | Apiaceae | 6.5 | OBL | Forb | PE | DI | Full | |
| Panicum amarum | Panicum amarum | Bitter panic grass | PANIAMAR | Poaceae | 5.5 | FAC | Grass | PE | MONO | | |
| Panicum anceps | Panicum anceps | Beaked panic | PANIANCE | Poaceae | 4.5 | FAC- | Grass | PE | MONO | Full | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | grass | | | | | | | | | |
| Panicum anceps | Panicum anceps var. rhizomatum | Beaked panic grass | PANIANCERH | Poaceae | 5.5 | FAC- | Grass | PE | MONO | Full | |
| Panicum capillare | Panicum capillare | Witchgrass | PANICAPI | Poaceae | 1.0 | FAC | Grass | AN | MONO | Full | |
| Panicum hemitomon | Panicum hemitomon | Maiden-cane | PANIHEMI | Poaceae | 5.0 | OBL | Grass | PE | MONO | | |
| Panicum verrucosum | Panicum verrucosum | Warty Panicgrass | PANIVERR | Poaceae | 5.0 | FACW | Grass | AN | MONO | | |
| Parthenocissus quinquefolia | Parthenocissus quinquefolia | Virginia creeper | PARTQUIN | Vitaceae | 4.0 | FAC | Vine | W | DI | Shade | |
| Passiflora incarnata | Passiflora incarnata | Purple Passionflower | PASSINCA | Passifloriaceae | 3.0 | NG | Vine | PE | DI | 1 | |
| Passiflora lutea | Passiflora lutea | Yellow passion flower | PASSLUTE | Passifloriaceae | 3.5 | NG | Vine | PE | DI | Partial | |
| Peltandra virginica | Peltandra virginica | Arrow arum | PELTVIRG | Araceae | 6.0 | OBL | Forb | PE | MONO | Full | |
| Persea borbonia | Persea borbonia | Red Bay | PERSBORB | Lauraceae | 7.0 | FACW | Sm tre | W | DI | Shade | |
| Persea palustris | Persea palustris | Swamp Bay | PERSPALU | Lauraceae | 7.3 | NG | Sm tre | W | DI | Shade | |
| Phaseolus polystachios var. sinuatus | Phaseolus sinuatus | Thicket bean | PHASSINU | Fabaceae | 7.0 | NG | Forb | PE | DI | Partial | (may be Amphicarpa bracteolata) |
| Phoradendron leucarpum | Phoradendron serotinum | Mistle toe | PHORSERO | Viscaceae | 5.5 | NG | Epi | W | DI | Full | Syn. Phoradendron leucarpum |
| Photinia melanocarpa | Aronia melanocarpa | Black chokeberry | ARONMELA | Rosaceae | 7.0 | FAC | Shrub | W | DI | Partial | |
| Photinia pyrifolia | Aronia arbutifolia | Red chokeberry | ARONARBU | Rosaceae | 7.5 | FACW | Shrub | W | DI | Partial | |
| Phragmites australis | Phragmites communis | Common reed | PHRACOMM | Poaceae | 0.0 | FACW | Grass | PE | MONO | Full | |
| Phragmites australis | Pragmites australis | Common reed | PHRAAUST | Poaceae | 0.0 | FACW | Grass | PE | DI | Full | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Phyllostachys aurea | Phyllostachys aurea | Golden bamboo | PHYLAURE | Poaceae | 0.0 | NG | Grass | W | MONO | Advent | Exotic |
| Phytolacca americana | Phytolacca americana | Common Pokeweed | PHYTAMER | Phytolaccaceae | 2.0 | FACU+ | Forb | PE | DI | Full | |
| Pilea pumila | Pilea pumila | Clearweed | PILEPUMI | Urticaceae | 4.0 | FACW | Forb | AN | DI | Partial | |
| Pinus echinata | Pinus echinata | Southern Yellow Pine | PINUECHI | Pinaceae | 6.5 | NG | Tree | W | GYMN | Tree | |
| Pinus palustris | Pinus palustris | Longleaf pine | PINUPALU | Pinaceae | 8.0 | FACU+ | Tree | W | GYMN | Tree | |
| Pinus serotina | Pinus serotina | Pond pine | PINUSERO | Pinaceae | 8.0 | FACW + | Tree | W | GYMN | Tree | |
| Pinus taeda | Pinus taeda | Loblolly pine | PINUTAED | Pinaceae | 2.0 | FAC | Tree | W | GYMN | Tree | |
| Pinus virginiana | Pinus virginiana | Virginia pine | PINUVIRG | Pinaceae | 3.5 | NG | Tree | W | GYMN | Tree | |
| Plantago rugelii | Plantago rugelii | Blackseed plantain | PLANRUGE | Plataginaceae | 1.0 | FACU | Forb | PE | DI | | |
| Platanthera cristata | Platanthera cristata | Yellow crested orchid | PLATCRIS | Orchidaceae | 8.0 | OBL | Forb | PE | MONO | Full | |
| Platanus occidentalis | Platanus occidentalis | Sycamore | PLATOCCI | Platanaceae | 5.0 | FACW- | Tree | W | DI | Tree | |
| Pluchea camphorata | Pluchea camphorata | Salt marsh camphor-weed | PLUCCAMP | Asteraceae | 4.5 | FACW | Forb | AN | DI | Partial | |
| Pluchea foetida | Pluchea foetida | Stinking Camphor-weed | PLUCFOET | Asteraceae | 5.0 | OBL | Forb | PE | DI | | |
| Poa annua | Poa annua | Annual bluegrass | POAANNU | Poaceae | 0.0 | FAC | Grass | AN | MONO | | Exotic |
| Poa autumnalis | Poa autumnalis | autumn bluegrass | POAAUTU | Poaceae | 5.0 | FACW- | Grass | PE | MONO | | |
| Poa pratensis | Poa pratensis | Kentucky bluegrass | POAPRAT | Poaceae | 0.0 | FACU+ | Grass | PE | MONO | Advent | |
| Podophyllum peltatum | Podophyllum peltatum | May-apple | PODOPELT | Berberidaceae | 4.5 | FACU | Forb | PE | MONO | Shade | |
| Polygala cymosa | Polygala cymosa | Tall Pinebarren Milkweed | POLYCYMO | Polygalaceae | 8.0 | OBL | Forb | BI | DI | | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Polygala lutea | Polygala lutea | Orange lutea | POLYLUTE | Polygalaceae | 5.0 | FACW + | Forb | BI | DI | | |
| Polygonatum biflorum | Polygonatum biflorum | small Solomon's-seal | POLYBIFL | Ruscaceae | 6.0 | FAC- | Forb | PE | Mono | Shade | |
| Polygonum cespitosum var. longisetum | Polygonum cespitosum | Cespitose knotweed | POLYCESP | Polygonaceae | 0.0 | FACW- | Forb | AN | DI | Adven t | |
| Polygonum erectum | Polygonum erectum | Erect knotweed | POLYEREC | Polygonaceae | 3.0 | FACU | Forb | AN | DI | Full | |
| Polygonum hydropiperoides | Polygonum hydropiperoides | Swamp smartweed | POLYHYDR | Polygonaceae | 3.5 | OBL | Forb | PE | DI | Full | |
| Polygonum lapathifolium | Polygonum lapathifolium | Willow-weed | POLYLAPA | Polygonaceae | 3.0 | FACW | Forb | AN | DI | Full | |
| Polygonum persicaria | Polygonum persicaria | Lady's thumb | POLYPERS | Polygonaceae | 0.0 | FACW | Forb | AN | DI | Adven t | Exotic |
| Polygonum punctatum | Polygonum punctata | dotted smartweed | POLYPUNC | Polygonaceae | 3.7 | FACW + | Forb | PE | DI | Full | |
| Polygonum sagittatum | Polygonum sagittatum | Arrowleaf tearthumb | POLYSAGI | Polygonaceae | 0.0 | OBL | Forb | PE | DI | | |
| Polygonum setaceum | Polygonum setaceum | Bristly Smartweed | POLYSETA | Polygonaceae | 5.0 | FAC+ | Forb | PE | DI | Full | |
| Polygonum virginianum | Tovara virginiana | Jumpseed | TOVAVIRG | Polygonaceae | 5.0 | FAC | Forb | AN | DI | Shade | Syn. Polygonum virginianum |
| Polypodium polypodioides | Polypodium polypodioides | Resurrection fern | POLYPOLY | Polypodiaceae | 7.0 | NG | Fern | PE | SVP | Shade | Syn. Pleopeltis polypodioides |
| Polystichum acrostichoides | Polystichum acrostichoides | Christmas fern | POLYACRO | Dryopteridaceae | 4.5 | FAC | Fern | PE | SVP | Shade | |
| Poncirus trifoliata | Poncirus trifoliata | Hardy orange | PONCTRIF | Rutaceae | 0.0 | NG | Tree | PE | DI | | Exotic |
| Pontederia cordata | Pontederia cordata | Pickelelweed | PONTCORD | Pontederiaceae | 6.7 | OBL | Forb | PE | DI | Full | |
| Populus deltoides | Populus | Eastern | POPUDELT | Salicaceae | 5.0 | FAC+ | Tree | W | DI | Tree | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | deltoides | cottonwood | | | | | | | | | |
| Potentilla canadensis | Potentilla canadensis | Dwarf cinquefoil | POTECANA | Rosaceae | 2.7 | NG | Forb | PE | DI | Full | |
| Potentilla simplex | Potentilla simplex | Old field cinquefoil | POTESIMP | Rosaceae | 3.5 | FACU | Forb | PE | DI | Full | |
| Prenanthes altissima | Prenanthes altissima | Tall white lettuce | PRENALTI | Asteraceae | 4.5 | UPL | Forb | PE | DI | Shade | |
| Proserpinaca palustris | Proserpinaca palustris | Marsh mermaid-weed | PROSPALU | Haloragaceae | 6.0 | OBL | Forb | PE | DI | Full | |
| Prunus americana | Prunus americana | American plum | PRUNAMER | Rosaceae | 5.7 | FACU- | Tree | PE | DI | Partial | |
| Prunus caroliniana | Prunus caroliniana | Carolina laurel cherry | PRUNCARO | Rosaceae | 4.0 | NG | Sm tre | PE | DI | Tree | |
| Prunus serotina | Prunus serotina | Black cherry | PRUNSERO | Rosaceae | 4.0 | FACU | Tree | W | DI | Tree | |
| Pseudognaphalium obtusifolium | Gnaphalium obtusifolium | Rabbit tobacco | GNAPOBTU | Asteraceae | 3.5 | NG | Forb | BI | DI | Partial | Syn. Pseudognaphalium obtusifolium |
| Pteridium aquilinum | Pteridium aquilinum | Bracken fern | PTERAQUI | Dennstaedtiaceae | 3.5 | FACU | Fern | PE | SVP | Partial | |
| Ptilimnium capillaceum | Ptilimnium capillaceum | Hair-like mock bishop-weed | PTILCAPI | Apiaceae | 3.0 | OBL | Forb | AN | DI | | |
| Ptilimnium nodosum | Ptilimnium nodosum | Piedmont mock bishopweed | PTILNODO | Apiaceae | 8.5 | OBL | Forb | AN | DI | | State Endangered |
| Pueraria lobata | Pueraria montana | Kudzu | PUERMONT | Fabaceae | 0.0 | NG | Vine | W | DI | Advent | Exotic |
| Pyrus calleryana | Pyrus calleryana | Bradford pear | PYRUCALL | Rosaceae | 0.0 | NG | Sm tre | W | DI | Advent | Exotic |
| Quercus alba | Quercus alba | White oak | QUERALBA | Fagaceae | 6.0 | FACU | Tree | W | DI | Tree | |
| Quercus falcata | Quercus falcata | Southern red oak | QUERFALC | Fagaceae | 5.5 | FACU- | Tree | W | DI | Tree | Also rated as FAC+ |
| Quercus geminata | Quercus geminata | Sandlive Oak | QUERGEMI | Fabaceae | 7.0 | NG | Tree | W | DI | 1 | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Quercus laurifolia | Quercus laurifolia | Laural oak | QUERLAUR | Fagaceae | 7.0 | FACW | Tree | W | DI | Tree | |
| Quercus lyrata | Quercus lyrata | Overcup oak | QUERLYRA | Fagaceae | 6.3 | OBL | Tree | W | DI | | |
| Quercus marilandica | Quercus marilandica | Black Jack Oak | QUERMARI | Fagaceae | 6.0 | NG | Tree | W | DI | Tree | |
| Quercus michauxii | Quercus michauxii | Swamp chestnut oak | QUERMICH | Fagaceae | 7.0 | FACW- | Tree | W | DI | Tree | |
| Quercus michauxii | Quercus prinus | Chestnut oak | QUERPRIN | Fagaceae | 6.5 | UPL | Tree | W | DI | Tree | |
| Quercus nigra | Quercus nigra | Water oak | QUERNIGR | Fagaceae | 4.0 | FAC | Tree | W | DI | Tree | |
| Quercus pagoda | Quercus pagoda | Cherry bark oak | QUERPAGO | Fagaceae | 7.0 | FAC+ | Tree | W | DI | Tree | |
| Quercus phellos | Quercus phellos | Willow oak | QUERPHEL | Fagaceae | 5.0 | FACW- | Tree | W | DI | Tree | |
| Quercus rubra | Quercus rubra | Red oak | QUERRUBR | Fagaceae | 6.5 | FACU | Tree | W | DI | Tree | |
| Quercus stellata | Quercus stellata | Post Oak | QUERSTEL | Fagaceae | 6.5 | FACU | Tree | W | DI | Tree | |
| Quercus velutina | Quercus velutina | Black oak | QUERVELU | Fagaceae | 5.5 | NG | Tree | W | DI | Tree | |
| Quercus virginiana | Quercus virginiana | Live oak | QUERVIRG | Fagaceae | 7.0 | FACU+ | Tree | W | DI | Tree | |
| Ranunculus abortivus | Ranunculus abortivus | Littleleaf buttercup | RANUABOR | Ranunculaceae | 3.3 | FAC | Forb | BI | DI | Shade | |
| Ranunculus hispidus | Ranunculus hispidus | Bristly buttercup | RANUHISP | Ranunculaceae | 5.5 | FAC | Forb | PE | DI | Shade | |
| Rhexia alifanus | Rhexia alifanus | Savannah meadowbeaut y | RHEXALIF | Melastomataceae | 8.0 | FACW + | Forb | PE | DI | 1 | |
| Rhexia mariana | Rhexia mariana | Maryland Meadow beauty | RHEXMARI | Melastomataceae | 4.0 | FACW + | Forb | PE | DI | | |
| Rhexia virginica | Rhexia virginiana | Virginia Meadow Beauty | RHEXVIRG | Melastomataceae | 5.0 | FACW + | Forb | PE | DI | Full | |
| Rhododendron atlanticum | Rhododendron atlanticum | Coastal azalea | RHODATLA | Ericaceae | 6.5 | FAC+ | Shrub | W | DI | Partial | |
| Rhododendron canescens | Rhododendron canescens | Piedmont azalea | RHODCANE | Ericaceae | 6.5 | FACW- | Shrub | W | DI | Shade | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rhododendron periclymenoides | Rhododendron nudiflorum | Pink azalea | RHODNUDI | Ericaceae | 6.5 | FAC | Shrub | PE | DI | Shade | |
| Rhododendron viscosum | Rhododendron viscosum | Swamp Azalea | RHODVISC | Ericaceae | 7.5 | FACW + | Shrub | W | DI | Adven t | |
| Rhus copallinum | Rhus copallina | Winged sumac | RHUSCOPA | Anacardiaceae | 3.5 | NI | Shrub | W | DI | Full | |
| Rhynchospora capitellata | Rhynchospora capitellata | Brownish beakrush | RHYNCAPI | Cyperaceae | 8.0 | OBL | Sedge | PE | MONO | Full | |
| Rhynchospora chalarocephala | Rhynchospora chalarocephala | Loose-head beakrush | RHYNCHAL | Cyperaceae | 3.0 | OBL | Grass | PE | MONO | Partial | |
| Rhynchospora corniculata | Rhynchospora corniculata var. corniculata | Short-bristle beakrush | RHYNCORNC O | Cyperaceae | 5.0 | OBL | Sedge | PE | MONO | | |
| Rhynchospora elliottii | Rhynchospora elliotii | Elliott's beakrush | RHYNELLI | Cyperaceae | 6.0 | FACW | Sedge | PE | Mono | | |
| Rhynchospora filifolia | Rhynchospora filifolia | Threadleaf Beaksedge | RHYNFILI | Cyperaceae | 6.0 | FACW- | Grass | PE | Mono | | |
| Rhynchospora globularis | Rhynchospora globularis | globe beakrush | RHYNGLOB | Cyperaceae | 5.0 | FACW | Sedge | AN/P E | Mono | | |
| Rhynchospora glomerata | Rhynchospora glomerata | Clustered beakrush | RHYNGLOM | Cyperaceae | 4.0 | OBL | Sedge | PE | MONO | Partial | |
| Rhynchospora gracilenta | Rhynchospora gracilenta | Slender beakrush | RHYNGRAC | Cyperaceae | 8.0 | OBL | Sedge | PE | MONO | | |
| Rhynchospora inexpansa | Rhynchospora inexpansa | Nodding beakrush | RHYNINEX | Cyperaceae | 2.0 | FACW | Sedge | PE | MONO | | |
| Rhynchospora inundata | Rhynchospora inundata | Narrowfruit Horned Beaksedge | RHYNINUN | Cyperaceae | 6.0 | OBL | Grass | PE | MONO | | |
| Rhynchospora latifolia | Dichromena latifolia | Giant White Topped Sedge | DICHLATI | Cyperaceae | 8.3 | FACW + | Sedge | PE | MONO | | |
| Rhynchospora miliacea | Rhynchospora miliacea | millet beakrush | RHYNMILI | Cyperaceae | 6.0 | OBL | Sedge | PE | Mono | | |
| Rhynchospora mixta | Rhynchospora mixta | Mingled beakrush | RHYNMIXT | Cyperaceae | 9.0 | OBL | Sedge | PE | MONO | | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rhynchospora nitens | Rhynchospora nitens | Shortbeak Beaksedge | RHYNNITE | Cyperaceae | 6.0 | OBL | Sedge | PE | MONO | | |
| Rhynchospora oligantha | Rhynchospora oligantha | Few-flower beakrush | RHYNOLIG | Cyperaceae | 8.0 | OBL | Grass | PE | MONO | Partial | |
| Rhynchospora pusilla | Rhynchospora pusilla | Humble beakrush | RHYNPUSI | Cyperaceae | 6.0 | FACW | Sedge | PE | MONO | | |
| Rosa carolina | Rosa carolina | Carolina rose | ROSACARO | Rosaceae | 6.5 | FACU | Shrub | W | DI | Full | |
| Rosa laevigata | Rosa laevigata | Cherokee rose | ROSALAEV | Rosaceae | 0.0 | NG | Vine | PE | DI | Advent | Exotic |
| Rosa multiflora | Rosa multiflora | Multiflora rose | ROSAMULT | Rosaceae | 0.0 | UPL | Shrub | W | DI | Advent | |
| Rosa palustris | Rosa palustris | Swamp rose | ROSAPALU | Rosaceae | 6.5 | OBL | Shrub | W | DI | Full | |
| Rotala ramosior | Rotala ramosior | Lowland Rotala | ROTARAMO | Lythraceae | 4.0 | OBL | Forb | AN | DI | | |
| Rubus argutus | Rubus argutus | Highbush blackberry | RUBUARGU | Rosaceae | 2.0 | FACU+ | Shrub | W | DI | Full | |
| Rubus cuneifolius | Rubus cuneifolius | sand blackberry | RUBUCUNE | Rosaceae | 3.0 | FACU | Shrub | PE | DI | | |
| Rubus flagellaris | Rubus flagellaris | Prickly dewberry | RUBUFLAG | Rosaceae | 3.0 | UPL | Shrub | W | DI | Full | |
| Rubus hispidus | Rubus hispidus | Bristly blackberry | RUBUHISP | Rosaceae | 6.0 | FACW | Forb | PE | DI | Partial | |
| Ruellia caroliniensis | Ruellia caroliniensis | Hairy ruellia | RUELCARO | Acanthaceae | 4.5 | NG | Forb | PE | DI | Full | |
| Rumex crispus | Rumex crispus | Curly dock | RUMECRIS | Polygonaceae | 0.0 | FAC | Forb | PE | DI | | Exotic |
| Rumex obtusifolius | Rumex obtusifolius | Bitter dock | RUMEOBTU | Polygonaceae | 0.0 | FACW- | Forb | PE | DI | | Exotic |
| Sabal minor | Sabal minor | Dwarf palmetto | SABAMINO | Arecaceae | 8.0 | FACW | Shrub | PE | MONO | Shade | |
| Sabatia calycina | Sabatia calycina | Coast Rose Gentian | SABACALY | Gentianaceae | 8.0 | FACW | Forb | PE | DI | | |
| Saccharum giganteum | Saccharum giganteum | Sugarcane plumegrass | SACCGIGA | Poaceae | 4.0 | FACW | Grass | PE | MONO | | |
| Sagittaria lancifolia | Sagittaria lancifolia | Bull-tongue arrow-head | SAGILANC | Alismataceae | 7.0 | FACW | Forb | PE | MONO | Full | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sagittaria latifolia | Sagittaria latifolia | Broad-leaf arrow-head | SAGILATI | Alismataceae | 4.5 | OBL | Forb | PE | MONO | Full | |
| Salix nigra | Salix nigra | Black willow | SALINIGR | Salicaceae | 3.0 | OBL | Tree | W | DI | Tree | |
| Sambucus nigra spp. canadensis | Sambucus canadensis | American elder | SAMBCANA | Caprifoliaceae | 4.0 | FACW- | Shrub | W | DI | Full | |
| Samolus valerandi ssp. parviflorus | Samolus parviflorus (Radford) | Water Pimpernel | SAMOPARV | Caprifoliaceae | 6.0 | OBL | Forb | PE | DI | | |
| Sanicula canadensis | Sanicula canadensis | Snakeroot | SANICANA | Apiaceae | 4.0 | FACU | Forb | PE | DI | Shade | |
| Sarracenia flava | Sarracenia flava | Yellow pitcher-plant | SARRFLAV | Sarraceniaceae | 9.0 | OBL | Forb | PE | DI | Partial | |
| Sassafras albidum | Sassafras albidum | Sassafras | SASSALBI | Lauraceae | 3.5 | FACU | Tree | W | DI | Tree | |
| Saururus cernuus | Saururus cernuus | Lizard's tail | SAURCERN | Saururaceae | 4.5 | OBL | Forb | PE | MONO | Shade | |
| Schedonorus pratensis | Schedonorus pratensis | Meadow fescue | SCHEPRAT | Poaceae | 0.0 | FACU | Grass | PE | MONO | | |
| Schizachyrium scoparium | Schizachyrium scoparium | Little Bluestem | SCHISCOP | Poaceae | 4.5 | FACU | Grass | PE | MONO | Full | |
| Schoenoplectus tabernaemontani | Scirpus validus (Radford) | Soft stem bulrush | SCIRVALI | Cyperaceae | 5.0 | OBL | Sedge | PE | MONO | | |
| Scirpus atrovirens | Scirpus atrovirens | Green bulrush | SCIRATRO | Cyperaceae | 4.0 | OBL | Sedge | PE | MONO | Full | |
| Scirpus cyperinus | Scirpus cyperinus | Woolgrass | SCIRCYPE | Cyperaceae | 3.0 | OBL | Sedge | PE | MONO | Full | |
| Scutellaria integrifolia | Scutellaria integrifolia | Hyssop skullcap | SCUTINTE | Lamiaceae | 5.0 | FAC | Forb | PE | DI | Partial | |
| Scutellaria lateriflora | Scutellaria lateriflora | Blue skullcap | SCUTLATE | Lamiaceae | 5.0 | FACW + | Forb | PE | DI | Partial | |
| Setaria parviflora | Setaria parviflora | | SETAPARV | Poaceae | 3.0 | FAC | Grass | PE | Mono | | |
| Sisyrinchium fuscatum | Sisyrinchium fuscatum | Coastal Plain Blue-eyed grass | SISYFUSC | Iridaceae | 5.0 | FACU | Forb | PE | MONO | Full | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sium suave | Sium suave | Hemlock water parsnip | SIUMSUAV | Apiaceae | 5.0 | OBL | Forb | PE | DI | Partial | |
| Smilacina racemosa | Smilacina racemosa | False Solomon seal | SMILRACE | Liliaceae | 6.5 | FACU | Forb | PE | MONO | Shade | |
| Smilax auriculata | Smilax auriculata | Earleaf Greenbriar | SMILAURI | Liliaceae | 6.0 | FACU | Shrub | PE | MONO | | |
| Smilax bona-nox | Smilax bona-nox | Saw greenbrier | SMILBONA | Smilaceae | 4.0 | FAC | Vine | W | MONO | Advent | |
| Smilax glauca | Smilax glauca | Cat greenbrier | SMILGLAU | Smilaceae | 4.5 | FAC | Vine | W | MONO | Shade | |
| Smilax laurifolia | Smilax laurifolia | Laurel-leaf greenbrier | SMILLAUR | Smilaceae | 5.5 | FACW+ | Vine | W | MONO | Advent | |
| Smilax rotundifolia | Smilax rotundifolia | Common greenbrier | SMILROTU | Smilaceae | 4.0 | FAC | Vine | W | MONO | Shade | |
| Smilax smallii | Smilax smallii | Lanceleaf Greenbriar | SMILSMAL | Liliaceae | 6.0 | FACU | Shrub | PE | MONO | | |
| Smilax walteri | Smilax walteri | Coral greenbrier | SMILWALT | Smilaceae | 6.3 | FACW | Vine | W | MONO | | |
| Solanum americanum | Solanum americanum | American Black Nightshade | SOLAAMER | Solanaceae | 1.0 | FACU+ | Forb | PE | DI | 1 | |
| Solanum carolinense | Solanum carolinense | Stinging Nettle | SOLACARO | Solanaceae | 2.0 | FACU | Forb | PE | DI | Advent | |
| Solidago altissima | Solidago altissima | Tall goldenrod | SOLIALTI | Asteraceae | 3.5 | FACU+ | Forb | PE | DI | Full | |
| Solidago caesia | Solidago caesia | wreath golden-rod | SOLICAES | Asteraceae | 7.7 | FACU | Forb | PE | DI | Shade | |
| Solidago gigantea | Solidago gigantea | Giant goldenrod | SOLIGIGA | Asteraceae | 2.7 | FACW | Forb | PE | DI | Full | |
| Solidago latissimifolia | Solidago elliottii | Elliot's goldenrod | SOLIELLI | Asteraceae | 7.0 | FACU+ | Forb | PE | DI | Full | |
| Solidago patula | Solidago patula | Rough-leaf golddenrod | SOLIPATU | Asteraceae | 7.5 | OBL | Forb | PE | DI | Full | |
| Solidago rugosa | Solidago rugosa | Rough-stemmed goldenrod | SOLIRUGO | Asteraceae | 3.0 | FAC | Forb | PE | DI | Full | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Solidago sempervirens | Solidago sempervirens | Seaside goldenrod | SOLISEMP | Asteraceae | 5.0 | FACW | Forb | PE | DI | Advent | |
| Solidago sempervirens var. mexicana | Solidago sempervirens var. mexicana | seaside golden-rod | SOLISEMPME | Asteraceae | 7.7 | FACW | Forb | PE | DI | Advent | |
| Sparganium americanum | Sparganium americanum | American bur-reed | SPARAMER | Sparganiaceae | 5.5 | OBL | Forb | PE | MONO | Full | |
| Spiraea prunifolia | Spiraea prunifolia | Bridalwreath spirea | SPIRPRUN | Rosaceae | 0.0 | NG | Shrub | W | DI | Advent | Exotic |
| Spiranthes cernua | Spiranthes cernua | Nodding ladies'-tresses | SPIRCERN | Orchidaceae | 8.5 | FACW | Forb | PE | MONO | Full | |
| Spirodela polyrrhiza | Spirodela polyrrhiza | Greater duckweed | SPIRPOLY | Lemnaceae | 4.0 | OBL | Forb | AN | MONO | Full | |
| Stellaria media | Stellaria media | Common chickweed | STELMEDI | Caryophyllaceaea | 0.0 | FACU | Forb | AN | DI | Full | |
| Streptopus lanceolatus | Streptopus roseus | Rose twisted stalk | STREROSE | Liliaceae | 9.0 | FAC | Forb | PE | MONO | Shade | |
| Symphyotrichum dumosum | Symphyotrichum dumosum | Rice button aster | SYMPDUMO | Asteraceae | 3.0 | FAC- | Forb | PE | DI | | |
| Symphyotrichum elliotii | Aster elliottii | Elliott's aster | ASTEELLI | Asteraceae | 7.5 | OBL | Forb | PE | DI | | |
| Symphyotrichum lateriflorum | Aster lateriflorus | Calico aster | ASTELATE | Asteraceae | 3.5 | FAC | Forb | PE | DI | Shade | |
| Symphyotrichum lateriflorum | Aster vimineus | Small White Aster | ASTEVIMI | Asteraceae | 5.0 | FAC | Forb | PE | DI | Advent | |
| Symphyotrichum patens | Symphyotrichum patens | Late purple aster | SYMPPATE | Asteraceae | 7.0 | NG | Forb | PE | DI | Partial | old nomenclature-Aster patens |
| Symphyotrichum pilosum | Symphyotrichum pilosum | Hairy white oldfield aster | SYMPPILO | Asteraceae | 3.0 | FAC- | Forb | PE | DI | | |
| Symphyotrichum puniceum var. puniceum | Aster puniceus | Swamp aster | ASTEPUNI | Asteraceae | 6.5 | OBL | Forb | PE | DI | Full | |
| Symplocos | Symplocos | Horse sugar | SYMPTINC | Symplocaceae | 6.5 | FAC | Shrub | W | DI | Shade | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| tinctoria | tinctoria | | | | | | | | | | |
| Taraxacum officinale | Taraxacum officinale | Common dandelion | TARAOFFI | Asteraceae | 0.0 | FACU | Forb | PE | DI | | |
| Taxodium ascendens | Taxodium ascendens | Pond cypress | TAXOASCE | Taxodiaceae | 9.0 | OBL | Tree | W | GYMN | Tree | |
| Taxodium distichum | Taxodium distichum | Bald cypress | TAXODIST | Taxodiaceae | 8.0 | OBL | Tree | W | GYMN | Tree | |
| Thalictrum revolutum | Thalictrum revolutum | Wax-leaf meadow-rue | THALREVO | Ranunculaceae | 7.0 | FAC+ | Forb | PE | DI | Full | |
| Thalictrum thalictroides | Thalictrum thalictroides | Rue anemone | THALTHAL | Ranunculaceae | 6.5 | NG | Forb | PE | DI | Shade | |
| Thelypteris palustris var. pubescens | Thelypteris palustris | Eastern Marsh Fern | THELPALU | Thelypteridaceae | 6.0 | FACW + | Fern | PE | SVP | Full | |
| Tiarella cordifolia | Tiarella cordifolia | Foam flower | TIARCORD | Saxifagaceae | 6.5 | FAC- | Forb | PE | DI | Shade | |
| Tiarella cordifolia L. var. collina Wherry | Tiarella wherryi | | TIARWHER | Saxifragaceae | 7.0 | | Forb | PE | DI | | |
| Tilia americana var. caroliniana | Tilia caroliniana | American basswood | TILICARO | Tiliaceae | 8.5 | FACU | Tree | PE | DI | Tree | |
| Tilia americana var. heterophylla | Tilia heterophylla | White basswood | TILIHETE | Tiliaceae | 7.5 | FACU | Tree | W | DI | Tree | |
| Tillandsia usneoides | Tillandsia usneoides | Spanish moss | TILLUSNE | Bromeliaceae | 7.0 | NG | Epi | PE | MONO | Shade | |
| Tipularia discolor | Tipularia discolor | Cranefly orchid | TIPUDISC | Orchidaceae | 6.5 | FACU | Forb | PE | MONO | Shade | |
| Toxicodendron radicans | Toxicodendron radicans | Poison ivy | TOXIRADI | Anacardiaceae | 2.0 | FAC | Vine | W | DI | Partial | |
| Toxicodendron vernix | Rhus vernix | Poison sumac | RHUSVERN | Anacardiaceae | 7.5 | OBL | Shrub | W | DI | Full | |
| Trachelospermum difforme | Trachelospermu m difforme | Climbing dogbane | TRACDIFF | Apocynaceae | 4.5 | FACW | Vine | PE | DI | Shade | |
| Triadenum virginicum | Triadenum virginicum | Marsh St. John's Wort | TRIAVIRG | Clusiaceae | 5.7 | OBL | Forb | PE | DI | Full | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Triadenum walteri | Triadenum walteri | Larger marsh St. John's wort | TRIAWALT | Clusiaceae | 5.5 | OBL | Forb | PE | DI | Partial | |
| Trichostema dichotomum | Trichostema dichotomum | Blue curls | TRICDICH | Lamiaceae | 3.0 | NG | Forb | AN | DI | Full | |
| Trifolium repens | Trifolium repens | White clover | TRIFREPE | Fabaceae | 0.0 | FACU | Forb | PE | DI | | exotic |
| Typha angustifolia | Typha angustifolia | Narrow leaf Cattail | TYPHANGU | Typhaceae | 4.0 | OBL | Forb | PE | MONO | Adven t | |
| Typha latifolia | Typha latifolia | Broad-leaf cattail | TYPHLATI | Typhaceae | 2.0 | OBL | Forb | PE | MONO | Full | |
| Ulmus alata | Ulmus alata | Winged elm | ULMUALAT | Ulmaceae | 4.0 | FACU+ | Tree | W | DI | Tree | |
| Ulmus americana | Ulmus americana | American elm | ULMUAMER | Ulmaceae | 5.5 | FACW | Tree | W | DI | Tree | |
| Ulmus rubra | Ulmus rubra | Slippery elm | ULMURUBR | Ulmaceae | 5.5 | FAC | Tree | W | DI | Tree | |
| Uvularia perfoliata | Uvularia perfoliata | Perfoliate bellwort | UVULPERF | Liliaceae | 6.5 | FACU | Forb | PE | MONO | Shade | |
| Uvularia sessilifolia | Uvularia sessifolia | Sessile leaf bellwort | UVULSESS | Liliaceae | 7.0 | FAC+ | Forb | PE | MONO | Shade | |
| Vaccinium arboreum | Vaccinium arboreum | Sparkleberry | VACCARBO | Ericaceae | 6.5 | FACU | Shrub | W | DI | Partial | |
| Vaccinium corymbosum | Vaccinium corymbosum | Highbush blueberry | VACCCORY | Ericaceae | 6.5 | FACW | Shrub | W | DI | Partial | |
| Vaccinium crassifolium | Vaccinium crassifolim | Creeping blueberry | VACCCRAS | Ericaceae | 9.0 | FAC+ | Shrub | PE | DI | 1 | |
| Vaccinium elliottii | Vaccinium elliottii | Elliot blueberry | VACCELLI | Ericaceae | 7.0 | FAC+ | Shrub | W | DI | Shade | |
| Vaccinium fuscatum | Vaccinium fuscatum | Highbush blueberry | VACCFUSC | Ericaceae | 6.5 | FAC+ | Shrub | W | DI | Shade | |
| Vaccinium myrsinites | Vaccinium myrsinites | Shiny blueberry | VACCMYRS | Ericaceae | 8.0 | FACU | Shrub | W | DI | Partial | |
| Vaccinium stamineum | Vaccinium stamineum | Deer berry | VACCSTAM | Ericaceae | 5.0 | FACU | Shrub | W | DI | Shade | |
| Vaccinium tenellum | Vaccinium tenellum | Slender blueberry | VACCTENE | Ericaceae | 8.0 | FACU- | Shrub | W | DI | Partial | |
| Verbena urticifolia | Verbena urticifolia | White vervain | VERBURTI | Verbenaceae | 3.0 | FAC+ | Forb | PE | DI | Full | |
| Verbesina alternifolia | Verbesina alternifolia | Wingstem | VERBALTE | Asteraceae | 3.0 | FAC | Forb | PE | DI | Partial | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Vernonia gigantea ssp. gigantea | Vernonia altissima | Giant ironweed | VERNALTI | Asteraceae | 2.0 | FAC+ | Forb | PE | DI | Full | |
| Vernonia noveboracensis | Vernonia noveboracensis | New York ironweed | VERNNOVE | Asteraceae | 5.0 | FAC+ | Forb | PE | DI | Full | |
| Veronica arvensis | Veronica arvensis | Corn speedwell | VEROARVE | Scrophulariaceae | 0.0 | NI | Forb | AN | DI | | exotic |
| Viburnum acerifolium | Viburnum acerfolium | Maple-leaved viburnum | VIBUACER | Caprifoliaceae | 6.5 | FACU | Shrub | W | DI | Shade | |
| Viburnum dentatum | Viburnum dentatum | Arrow-wood | VIBUDENT | Caprifoliaceae | 5.0 | FAC | Shrub | W | DI | Full | |
| Viburnum nudum | Viburnum nudum | Possum-haw | VIBUNUDU | Caprifoliaceae | 6.0 | FACW + | Shrub | W | DI | Adven t | |
| Viburnum prunifolium | Viburnum prunifolium | Black-haw | VIBUPRUN | Caprifoliaceae | 6.0 | FACU | Shrub | W | DI | Shade | |
| Viburnum rafinesqueanum | Viburnum rafinesquianum | Downy Arrowhead | VIBURAFI | Caprifoliaceae | 6.7 | UPL | Shrub | PE | DI | Shade | |
| Viburnum rufidulum | Viburnum rufidulum | Rusty blackhaw | VIBURUFI | Caprifoliaceae | 7.0 | FACU | Shrub | W | DI | Partial | |
| Vinca major | Vinca major | Bigleaf periwinkle | VINCMAJO | Apocynaceae | 0.0 | NG | Vine | PE | DI | Adven t | exotic |
| Viola affinis | Viola affinis | Sand violet | VIOLAFFI | Violaceae | 4.7 | FACW | Forb | AN | DI | | |
| Vitis aestivalis | Vitis aestivalis | Summer grape | VITIAEST | Vitaceae | 5.0 | FAC- | Vine | W | DI | Shade | |
| Vitis rotundifolia | Vitis rotundifolia | Muscadine grape | VITIROTU | Vitaceae | 4.5 | FAC | Vine | W | DI | Adven t | |
| Wisteria frutescens | Wisteria frutescens | American wisteria | WISTFRUT | Fabaceae | 6.5 | FACW | Vine | W | DI | Shade | |
| Wisteria sinensis | Wisteria sinensis | Chinese wisteria | WISTSINE | Fabaceae | 0.0 | NG | Vine | W | DI | Adven t | Exotic |
| Wolffia columbiana | Wolffia columbiana | Columbia water-meal | WOLFCOLU | Lemnaceae | 4.3 | OBL | Forb | AN | MONO | Full | |
| Wolffia gladiata | Wolffia gladiata | Florida mudmidget | WOLFGLAD | Lemnaceae | 4.5 | OBL | Forb | PE | MONO | Full | |
| Woodwardia areolata | Woodwardia areolata | Netted chain fern | WOODAREO | Blechnaceae | 5.0 | OBL | Fern | PE | SVP | Full | |
| Woodwardia | Woodwardia | Virginia chain | WOODVIRG | Blechnaceae | 8.0 | OBL | Fern | PE | SVP | Full | |

Table B-1 - NC Plant Survey Species Codes - Coefficient of Conservatism (C of C), NWI Wetland Indicator, Form, Habit, Group, and Shade

| USDA Scientific Name | Scientific Name-Radford/Weakley | Common Name | Species Code | Family | NC Cof C | NWI Reg 2 Ind | Form | Habit | Group | Shade | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| virginica | virginiana | fern | | | | | | | | | |
| Xyris caroliniana | Xyris caroliniana | Carolina Yelloweyed Grass | XYRICARO | Xyridaceae | 9.0 | FACW + | Forb | PE | MON O | | |

## Appendix C – Hydrology and Water Quality Site Water Quality Metals Analysis

Table 9 Values of metal analysis for hydrology site water quality

| Site Name - Station Type | Date | Al ug/L | As ug/L | Ba ug/L | Cd ug/L | Ca ug/L | Cr ug/L | Cu ug/L | Fe ug/L | Pb ug/L | Mg ug/L | Mn ug/L | Hg ug/L | Ni ug/L | K ug/L | Se ug/L | Ag ug/L | Na ug/L | Zn ug/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Practical Quantitation Limit** | | 50 | 2 | 10 | 1 | 0 | 10 | 2 | 50 | 10 | 0.1 | 10 | 0 | 10 | 0 | 5 | 5 | 0.1 | 10 |
| Bladen 1-well 1s | 05/18/10 | 3800 | 2 | 46 | 1 | 0 | 10 | 2 | 310 | 10 | 0.4 | 10 | 0 | 10 | 0 | 5 | 5 | 3.5 | 10 |
| Bladen 1-well 1s | 08/24/10 | 1100 | 2 | 42 | 1 | 0 | 10 | 2 | 50 | 10 | 0.41 | 10 | 0 | 10 | 0 | 5 | 5 | 2.7 | 10 |
| Bladen 1-well 1s | 11/01/10 | 2000 | 2 | 38 | 1 | 0 | 10 | 2 | 140 | 10 | 0.32 | 10 | 0 | 10 | 0 | 5 | 5 | 2.6 | 10 |
| Bladen 1-well 1s | 02/08/11 | 1900 | 2 | 35 | 1 | 0 | 10 | 2 | 190 | 10 | 0.43 | 10 | 0 | 10 | 0 | 5 | 5 | 2.3 | 10 |
| Bladen 1-well 3 | 05/18/10 | 1300 | 2 | 39 | 1 | 1 | 10 | 2 | 720 | 10 | 0.25 | 18 | 0 | 10 | 0 | 5 | 5 | 1.8 | 10 |
| Bladen 1-well 6d | 05/18/10 | 1200 | 2 | 54 | 1 | 1 | 10 | 2 | 720 | 10 | 0.43 | 15 | 0 | 10 | 0 | 5 | 5 | 2.1 | 10 |
| Bladen 1-well 6d | 08/24/10 | 390 | 2 | 53 | 1 | 1 | 10 | 2 | 50 | 10 | 0.3 | 28 | 0 | 10 | 0 | 5 | 5 | 2.1 | 10 |
| Bladen 1-well 6d | 11/01/10 | 380 | 2 | 51 | 1 | 1 | 10 | 2.5 | 50 | 10 | 0.26 | 27 | 0 | 10 | 0 | 5 | 5 | 2.2 | 11 |
| Bladen 1-well 6d | 02/08/11 | 430 | 2 | 42 | 1 | 0 | 10 | 2 | 50 | 10 | 0.3 | 21 | 0 | 10 | 0 | 5 | 5 | 2.2 | 10 |
| Bladen 1-well 7 | 02/08/11 | 2100 | 2 | 48 | 1 | 1 | 10 | 2 | 2900 | 10 | 1.1 | 25 | 0 | 10 | 1 | 5 | 5 | 5.9 | 10 |
| Bladen 1-stream | 05/18/10 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Bladen 1-stream | 08/24/10 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Bladen 1-stream | 11/01/10 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Bladen 1-stream | 02/08/11 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Bladen 17-wetland | 08/25/10 | | | | | | | 5 | | 10 | | | | | | | | | 10 |
| Bladen 17-wetland | 02/09/11 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Bladen 17-well 1d | 05/11/10 | 540 | 2 | 19 | 1 | 1 | 10 | 2 | 380 | 10 | 0.36 | 14 | 0 | 10 | 0 | 5 | 5 | 2.4 | 10 |
| Bladen 17-well 2d | 05/11/10 | 1400 | 2 | 14 | 1 | 0 | 10 | 2 | 620 | 10 | 0.1 | 10 | 0 | 10 | 0 | 5 | 5 | 1.4 | 10 |
| Bladen 17-well 2d | 08/25/10 | 810 | 2 | 25 | 1 | 0 | 10 | 2 | 420 | 10 | 0.15 | 10 | 0 | 10 | 0 | 5 | 5 | 2.2 | 10 |
| Bladen 17-well 2d | 11/03/10 | 750 | 2 | 28 | 1 | 0 | 10 | 2 | 360 | 10 | 0.14 | 10 | 0 | 10 | 0 | 5 | 5 | 2.4 | 10 |
| Bladen 17-well 2d | 02/09/11 | 980 | 2 | 27 | 1 | 0 | 10 | 2 | 380 | 10 | 0.12 | 10 | 0 | 10 | 0 | 5 | 5 | 2.4 | 10 |
| Bladen 17-well 4d | 05/11/10 | 740 | 2 | 34 | 1 | 1 | 10 | 2 | 330 | 10 | 0.4 | 10 | 0 | 10 | 0 | 5 | 5 | 2.4 | 10 |
| Bladen 17-well 4d | 08/25/10 | 390 | 2 | 34 | 1 | 1 | 10 | 2 | 200 | 10 | 0.46 | 10 | 0 | 10 | 0 | 5 | 5 | 2.4 | 10 |
| Bladen 17-well 4d | 11/03/10 | 390 | 2 | 37 | 1 | 1 | 10 | 2.5 | 170 | 10 | 0.46 | 10 | 0 | 10 | 0 | 5 | 5 | 2.5 | 10 |
| Bladen 17-well 4d | 02/09/11 | 470 | 2 | 29 | 1 | 1 | 10 | 2 | 160 | 10 | 0.44 | 10 | 0 | 10 | 0 | 5 | 5 | 2.3 | 10 |

Table 9 Values of metal analysis for hydrology site water quality

| Site Name - Station Type | Date | Al | As | Ba | Cd | Ca | Cr | Cu | Fe | Pb | Mg | Mn | Hg | Ni | K | Se | Ag | Na | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ug/L | ug/L | ug/L | ug/L | ug/L | ug/L | ug/L | ug/L | ug/L | ug/L | ug/L | ug/L | ug/L | ug/L | ug/L | ug/L | ug/L | ug/L |
| Bladen 17-well 5d | 08/25/10 | 1400 | 2 | 19 | 1 | 1 | 10 | 2 | 120 | 10 | 0.41 | 10 | 0 | 10 | 1 | 5 | 5 | 2.5 | 10 |
| Bladen 17-well 6 | 08/25/10 | 540 | 2 | 22 | 1 | 1 | 10 | 2.5 | 100 | 10 | 0.34 | 10 | 0 | 10 | 0 | 5 | 5 | 2.4 | 10 |
| Bladen 17-well 7 | 08/25/10 | 700 | 2 | 17 | 1 | 0 | 10 | 2 | 2100 | 10 | 0.25 | 18 | 0 | 10 | 0 | 5 | 5 | 3.5 | 15 |
| Bladen 17-well 7 | 11/03/10 | 690 | 2 | 16 | 1 | 0 | 10 | 2 | 1500 | 10 | 0.27 | 15 | 0 | 10 | 0 | 5 | 5 | 3.3 | 10 |
| Bladen 17-well 7 | 02/09/11 | 1200 | 2 | 21 | 1 | 1 | 10 | 2 | 920 | 10 | 0.29 | 18 | 0 | 10 | 0 | 5 | 5 | 4.1 | 10 |
| Bladen 17-stream | 05/11/10 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Bladen 17-stream | 08/25/10 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Bladen 17-stream | 11/02/10 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Bladen 17-stream | 02/09/11 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Bladen 2-well 1d | 05/18/10 | 640 | 2 | 35 | 1 | 1 | 10 | 2 | 160 | 10 | 0.44 | 15 | 0 | 10 | 0 | 5 | 5 | 2.1 | 10 |
| Bladen 2-well 1d | 08/23/10 | 460 | 2 | 39 | 1 | 1 | 10 | 2 | 200 | 10 | 0.48 | 15 | 0 | 10 | 0 | 5 | 5 | 2.3 | 10 |
| Bladen 2-well 1d | 02/07/11 | 400 | 2 | 42 | 1 | 1 | 10 | 2 | 120 | 10 | 0.53 | 14 | 0 | 10 | 1 | 5 | 5 | 3 | 10 |
| Bladen 2-well 2d | 11/01/10 | 750 | 2 | 58 | 1 | 1 | 10 | 3 | 50 | 10 | 0.57 | 10 | 0 | 10 | 0 | 5 | 5 | 4.3 | 11 |
| Bladen 2-well 3 | 05/18/10 | 10000 | 2 | 66 | 1 | 2 | 10 | 3 | 1100 | 10 | 0.7 | 22 | 0 | 10 | 1 | 5 | 5 | 2.8 | 10 |
| Bladen 2-well 3 | 08/23/10 | 2600 | 2 | 54 | 1 | 1 | 10 | 2 | 220 | 10 | 0.43 | 13 | 0 | 10 | 0 | 5 | 5 | 2.3 | 10 |
| Bladen 2-well 3 | 11/01/10 | 4200 | 2 | 55 | 1 | 2 | 10 | 2 | 380 | 10 | 0.47 | 19 | 0 | 10 | 0 | 5 | 5 | 2.2 | 10 |
| Bladen 2-well 3 | 02/07/11 | 2200 | 2 | 58 | 1 | 1 | 10 | 2 | 190 | 2.3 | 0.42 | 5 | 10 | 15 | 0 | 10 | 5 | 0.46 | 10 |
| Bladen 2-well 5 | 05/18/10 | 970 | 2 | 53 | 1 | 2 | 10 | 2 | 720 | 10 | 0.62 | 24 | 0 | 10 | 1 | 5 | 5 | 3.7 | 10 |
| Bladen 2-well 6 | 08/23/10 | 3800 | 2 | 30 | 1 | 3 | 10 | 3.5 | 2400 | 10 | 0.89 | 65 | 0 | 10 | 1 | 5 | 5 | 5.8 | 10 |
| Bladen 2-well 6 | 11/01/10 | 1500 | 2 | 26 | 1 | 3 | 10 | 2 | 1900 | 10 | 0.79 | 62 | 0 | 10 | 1 | 5 | 5 | 5.5 | 10 |
| Bladen 2-well 6 | 02/07/11 | 500 | 2 | 23 | 1 | 3 | 10 | 2 | 1700 | 10 | 0.76 | 59 | 0 | 10 | 1 | 5 | 5 | 6 | 10 |
| Bladen 2-stream | 05/18/10 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Bladen 2-stream | 08/23/10 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Bladen 2-stream | 11/01/10 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Bladen 2-stream | 02/07/11 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Bladen 6-wetland | 02/07/11 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Bladen 6-well 2s | 05/10/10 | 2700 | 2 | 27 | 1 | 1 | 10 | 2 | 6800 | 10 | 0.56 | 42 | 0 | 10 | 1 | 5 | 5 | 4.2 | 58 |

Table 9 Values of metal analysis for hydrology site water quality

| Site Name - Station Type | Date | Al ug/L | As ug/L | Ba ug/L | Cd ug/L | Ca ug/L | Cr ug/L | Cu ug/L | Fe ug/L | Pb ug/L | Mg ug/L | Mn ug/L | Hg ug/L | Ni ug/L | K ug/L | Se ug/L | Ag ug/L | Na ug/L | Zn ug/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bladen 6-well 2s | 08/23/10 | 300 | 2 | 17 | 1 | 1 | 10 | 2 | 5300 | 10 | 0.46 | 34 | 0 | 10 | 1 | 5 | 5 | 3.5 | 10 |
| Bladen 6-well 2s | 11/02/10 | 770 | 2 | 35 | 1 | 1 | 10 | 2 | 5700 | 10 | 0.65 | 36 | 0 | 10 | 1 | 5 | 5 | 6 | 10 |
| Bladen 6-well 2s | 02/07/11 | 990 | 2 | 29 | 1 | 1 | 10 | 2 | 4600 | 10 | 0.52 | 29 | 0 | 10 | 1 | 5 | 5 | 4.9 | 10 |
| Bladen 6-well 3s | 05/10/10 | 8000 | 2 | 74 | 1 | 1 | 19 | 4.7 | 5000 | 10 | 0.87 | 27 | 0 | 10 | 1 | 5 | 5 | 5.6 | 10 |
| Bladen 6-well 3s | 08/23/10 | 1300 | 2 | 67 | 1 | 1 | 10 | 2 | 1600 | 10 | 0.71 | 14 | 0 | 10 | 1 | 5 | 5 | 5.7 | 10 |
| Bladen 6-well 3s | 11/02/10 | 1300 | 2 | 77 | 1 | 1 | 10 | 5.2 | 1500 | 10 | 0.66 | 14 | 0 | 10 | 1 | 5 | 5 | 5.3 | 15 |
| Bladen 6-well 3s | 02/07/11 | 1300 | 2 | 60 | 1 | 1 | 10 | 2 | 1200 | 10 | 0.6 | 14 | 0 | 10 | 1 | 5 | 5 | 5.2 | 10 |
| Bladen 6-well 4s | 08/23/10 | 1300 | 2 | 27 | 1 | 1 | 10 | 2 | 1600 | 10 | 0.32 | 15 | 0 | 10 | 1 | 5 | 5 | 6.3 | 10 |
| Bladen 6-well 5s | 08/23/10 | 2600 | 2 | 44 | 1 | 2 | 10 | 2 | 3100 | 10 | 0.76 | 28 | 0 | 10 | 1 | 5 | 5 | 4.6 | 10 |
| Bladen 6-well 5s | 11/02/10 | 2500 | 2 | 95 | 1 | 3 | 10 | 2 | 6000 | 10 | 1.1 | 31 | 0 | 10 | 2 | 5 | 5 | 6.2 | 10 |
| Bladen 6-well 5s | 02/07/11 | 1800 | 2 | 71 | 1 | 2 | 10 | 2 | 6300 | 10 | 1.1 | 24 | 0 | 10 | 1 | 5 | 5 | 7 | 10 |
| Bladen 6-stream | 05/11/10 | | | | | | | 2 | | 10 | | | | | | | | | 13 |
| Bladen 6-stream | 11/02/10 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Bladen 6-stream | 02/07/11 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Bladen 7-wetland | 02/08/11 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Bladen 7-well 1s | 05/12/10 | 1600 | 2 | 18 | 1 | 0 | 10 | 2 | 190 | 10 | 0.4 | 12 | 0 | 10 | 0 | 5 | 5 | 1.2 | 10 |
| Bladen 7-well 1s | 08/24/10 | 2200 | 2 | 32 | 1 | 0 | 10 | 2 | 52 | 10 | 0.21 | 10 | 0 | 10 | 0 | 5 | 5 | 1.2 | 10 |
| Bladen 7-well 1s | 11/02/10 | 3300 | 2 | 26 | 1 | 0 | 10 | 8.1 | 190 | 10 | 0.22 | 10 | 0 | 10 | 0 | 5 | 5 | 1.2 | 10 |
| Bladen 7-well 1s | 02/07/11 | 3000 | 2 | 17 | 1 | 0 | 10 | 2 | 62 | 10 | 0.23 | 10 | 0 | 10 | 0 | 5 | 5 | 1.5 | 10 |
| Bladen 7-well 3 | 05/11/10 | 33000 | 2.1 | 57 | 1 | 1 | 17 | 7.1 | 4500 | 10 | 0.71 | 28 | 0 | 10 | 1 | 5 | 5 | 1.4 | 26 |
| Bladen 7-well 3 | 08/24/10 | 770 | 2 | 42 | 1 | 1 | 10 | 2 | 210 | 10 | 0.34 | 18 | 0 | 10 | 1 | 5 | 5 | 1.5 | 10 |
| Bladen 7-well 3 | 11/02/10 | 590 | 2 | 49 | 1 | 1 | 10 | 2 | 50 | 10 | 0.34 | 18 | 0 | 10 | 1 | 5 | 5 | 1.5 | 10 |
| Bladen 7-well 3 | 02/08/11 | 640 | 2 | 28 | 1 | 0 | 10 | 2 | 50 | 10 | 0.25 | 19 | 0 | 10 | 1 | 5 | 5 | 1.2 | 10 |
| Bladen 7-well 8 | 08/24/10 | 380 | 2 | 49 | 1 | 2 | 10 | 2 | 78 | 10 | 0.91 | 10 | 0 | 10 | 1 | 5 | 5 | 2.4 | 10 |
| Bladen 7-well 8 | 11/01/10 | 450 | 2 | 59 | 1 | 2 | 10 | 2 | 90 | 10 | 0.59 | 10 | 0 | 10 | 1 | 5 | 5 | 2.7 | 10 |
| Bladen 7-well 8 | 02/08/11 | 300 | 2 | 62 | 1 | 3 | 10 | 2 | 50 | 10 | 1.1 | 13 | 0 | 10 | 2 | 5 | 5 | 3.1 | 11 |
| Bladen 7-stream | 05/12/10 | | | | | | | 2 | | 10 | | | | | | | | | 10 |

Table 9 Values of metal analysis for hydrology site water quality

| Site Name - Station Type | Date | Al ug/L | As ug/L | Ba ug/L | Cd ug/L | Ca ug/L | Cr ug/L | Cu ug/L | Fe ug/L | Pb ug/L | Mg ug/L | Mn ug/L | Hg ug/L | Ni ug/L | K ug/L | Se ug/L | Ag ug/L | Na ug/L | Zn ug/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bladen 7-stream | 08/24/10 | | | | | | | 2 | | 10 | | | | | | | | | 13 |
| Bladen 7-stream | 11/02/10 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Bladen 7-stream | 02/08/11 | | | | | | | 2 | | 10 | | | | | | | | | 11 |
| Bladen 9-well 1d | 05/12/10 | 1600 | 2 | 28 | 1 | 0 | 10 | 2 | 470 | 10 | 0.63 | 12 | 0 | 10 | 0 | 5 | 5 | 3.2 | 10 |
| Bladen 9-well 1d | 08/24/10 | 1100 | 2 | 30 | 1 | 0 | 10 | 2 | 50 | 10 | 0.6 | 13 | 0 | 10 | 0 | 5 | 5 | 3.2 | 10 |
| Bladen 9-well 1d | 11/03/10 | 1200 | 2 | 30 | 1 | 0 | 10 | 2.2 | 50 | 10 | 0.29 | 10 | 0 | 10 | 0 | 5 | 5 | 3.6 | 10 |
| Bladen 9-well 1d | 02/09/11 | 880 | 2 | 24 | 1 | 0 | 10 | 2 | 140 | 10 | 0.46 | 10 | 0 | 10 | 0 | 5 | 5 | 3.4 | 10 |
| Bladen 9-well 2d | 05/12/10 | 1000 | 2 | 22 | 1 | 0 | 10 | 2 | 120 | 10 | 0.14 | 10 | 0 | 10 | 0 | 5 | 5 | 3.9 | 10 |
| Bladen 9-well 2d | 08/24/10 | 650 | 2 | 26 | 1 | 0 | 10 | 2 | 89 | 10 | 0.15 | 10 | 0 | 10 | 0 | 5 | 5 | 3.2 | 10 |
| Bladen 9-well 2d | 11/03/10 | 680 | 2 | 35 | 1 | 0 | 10 | 2.3 | 67 | 10 | 0.18 | 10 | 0 | 10 | 0 | 5 | 5 | 3.6 | 10 |
| Bladen 9-well 2d | 02/09/11 | 910 | 2 | 31 | 1 | 0 | 10 | 2 | 50 | 10 | 0.34 | 18 | 0 | 10 | 0 | 5 | 5 | 3.2 | 10 |
| Bladen 9-well 3d | 05/12/10 | 150 | 2 | 15 | 1 | 1 | 10 | 2 | 1300 | 10 | 0.36 | 20 | 0 | 10 | 1 | 5 | 5 | 2.5 | 10 |
| Bladen 9-well 3d | 08/24/10 | 120 | 2 | 15 | 1 | 1 | 10 | 2 | 1300 | 10 | 0.37 | 18 | 0 | 10 | 1 | 5 | 5 | 2.4 | 10 |
| Bladen 9-well 3d | 11/03/10 | 100 | 2 | 17 | 1 | 1 | 10 | 2 | 1200 | 10 | 0.37 | 18 | 0 | 10 | 1 | 5 | 5 | 2.7 | 10 |
| Bladen 9-well 3d | 02/09/11 | 120 | 2 | 14 | 1 | 1 | 10 | 2 | 1100 | 10 | 0.32 | 16 | 0 | 10 | 1 | 5 | 5 | 2.9 | 10 |
| Bladen 9-well 4 | 08/24/10 | 220 | 2 | 16 | 1 | 1 | 10 | 2 | 1200 | 10 | 0.32 | 14 | 0 | 10 | 1 | 5 | 5 | 2.7 | 10 |
| Bladen 9-well 4 | 11/03/10 | 380 | 2 | 28 | 1 | 2 | 10 | 2 | 2400 | 10 | 0.51 | 24 | 0 | 10 | 1 | 5 | 5 | 3.2 | 10 |
| Bladen 9-well 4 | 02/09/11 | 2500 | 2 | 41 | 1 | 1 | 10 | 2 | 1600 | 10 | 0.51 | 15 | 0 | 10 | 0 | 5 | 5 | 4.8 | 10 |
| Bladen 9-stream | 11/03/10 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Bladen 9-stream | 02/09/11 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Green Swamp 1-wetland | 08/31/10 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Green Swamp 1-wetland | 11/08/10 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Green Swamp 1-wetland | 01/31/11 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Green Swamp 1-wetland | 04/19/11 | | | | | | | 2 | | 2 | | | | | | | | | 10 |
| Green Swamp 1- | 09/01/10 | 990 | 2 | 14 | 1 | 0 | 10 | 2 | 730 | 10 | 0.47 | 10 | 0 | 10 | 0 | 5 | 5 | 5.8 | 10 |

Table 9 Values of metal analysis for hydrology site water quality

| Site Name - Station Type | Date | Al ug/L | As ug/L | Ba ug/L | Cd ug/L | Ca ug/L | Cr ug/L | Cu ug/L | Fe ug/L | Pb ug/L | Mg ug/L | Mn ug/L | Hg ug/L | Ni ug/L | K ug/L | Se ug/L | Ag ug/L | Na ug/L | Zn ug/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| well 1 | | | | | | | | | | | | | | | | | | | |
| Green Swamp 1-well 1 | 11/08/10 | 920 | 2 | 12 | 1 | 0 | 10 | 2 | 1100 | 10 | 0.43 | 10 | 0 | 10 | 0 | 5 | 5 | 6 | 16 |
| Green Swamp 1-well 1 | 01/31/11 | 980 | 2 | 10 | 1 | 0 | 10 | 2 | 920 | 10 | 0.49 | 10 | 0 | 10 | 0 | 5 | 5 | 5.4 | 10 |
| Green Swamp 1-well 1 | 04/19/11 | 750 | 2 | 10 | 1 | 0 | 10 | 2 | 570 | 2 | 0.42 | 10 | 0 | 2 | 0 | 5 | 5 | 4.2 | 10 |
| Green Swamp 1-well 2 | 09/01/10 | 1500 | 2 | 15 | 1 | 0 | 10 | 2 | 330 | 10 | 0.98 | 10 | 0 | 10 | 0 | 5 | 5 | 6.2 | 10 |
| Green Swamp 1-well 2 | 11/08/10 | 1200 | 2 | 15 | 1 | 0 | 10 | 2 | 260 | 10 | 0.68 | 10 | 0 | 10 | 0 | 5 | 5 | 4.5 | 10 |
| Green Swamp 1-well 2 | 01/31/11 | 1800 | 2 | 12 | 1 | 0 | 10 | 2.6 | 450 | 10 | 0.65 | 10 | 0 | 10 | 0 | 5 | 5 | 5.9 | 13 |
| Green Swamp 1-well 2 | 04/19/11 | 1700 | 2 | 10 | 1 | 0 | 10 | 2 | 430 | 2 | 0.48 | 10 | 0 | 2 | 0 | 5 | 5 | 4.8 | 10 |
| Green Swamp 1-well 4d | 08/31/10 | 960 | 2 | 10 | 1 | 1 | 10 | 3.3 | 170 | 10 | 0.49 | 10 | 0 | 10 | 0 | 5 | 5 | 4.6 | 10 |
| Green Swamp 1-well 4i | 11/08/10 | 440 | 2 | 10 | 1 | 1 | 10 | 2 | 50 | 10 | 0.43 | 10 | 0 | 10 | 0 | 5 | 5 | 4 | 10 |
| Green Swamp 1-well 4i | 01/31/11 | 500 | 2 | 10 | 1 | 1 | 10 | 2.6 | 50 | 10 | 0.44 | 10 | 0 | 10 | 0 | 5 | 5 | 3.6 | 11 |
| Green Swamp 1-well 4i | 04/19/11 | 535 | 2 | 10 | 1 | 1 | 10 | 2.05 | 50 | 2 | 0.465 | 10 | 0 | 2 | 0 | 5 | 5 | 3.6 | 10 |
| Green Swamp 1-well 5 | 01/31/11 | 620 | 2 | 10 | 1 | 0 | 10 | 2 | 170 | 10 | 0.47 | 10 | 0 | 10 | 0 | 5 | 5 | 3.2 | 10 |
| Green Swamp 1-well 5 | 04/19/11 | 580 | 2 | 10 | 1 | 0 | 10 | 4.7 | 160 | 2 | 0.45 | 10 | 0 | 2 | 0 | 5 | 5 | 2.8 | 15 |
| Green Swamp 1-stream | 08/31/10 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Green Swamp 1-stream | 11/08/10 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Green Swamp 1-stream | 01/31/11 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Green Swamp 1- | 04/19/11 | | | | | | | 2 | | 2 | | | | | | | | | 10 |

Table 9 Values of metal analysis for hydrology site water quality

| Site Name - Station Type | Date | Al ug/L | As ug/L | Ba ug/L | Cd ug/L | Ca ug/L | Cr ug/L | Cu ug/L | Fe ug/L | Pb ug/L | Mg ug/L | Mn ug/L | Hg ug/L | Ni ug/L | K ug/L | Se ug/L | Ag ug/L | Na ug/L | Zn ug/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| stream | | | | | | | | | | | | | | | | | | | |
| Green Swamp 2-wetland | 11/09/10 | | | | | | | 2 | | 10 | | | | | | | | | 12 |
| Green Swamp 2-wetland | 01/31/11 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Green Swamp 2-well 1s | 09/01/10 | 350 | 2 | 11 | 1 | 0 | 10 | 2 | 260 | 10 | 0.28 | 10 | 0 | 10 | 0 | 5 | 5 | 2.5 | 10 |
| Green Swamp 2-well 1s | 11/09/10 | 560 | 2 | 18 | 1 | 1 | 10 | 2 | 990 | 10 | 0.5 | 10 | 0 | 10 | 0 | 5 | 5 | 4 | 14 |
| Green Swamp 2-well 1s | 01/31/11 | 790 | 2 | 12 | 1 | 0 | 10 | 2 | 650 | 10 | 0.45 | 10 | 0 | 10 | 0 | 5 | 5 | 3.5 | 10 |
| Green Swamp 2-well 1s | 04/19/11 | 760 | 2 | 15 | 1 | 0 | 10 | 3.5 | 630 | 2 | 0.49 | 10 | 0 | 2 | 0 | 5 | 5 | 4.1 | 10 |
| Green Swamp 2-well 2s | 09/01/10 | 140 | 2 | 10 | 1 | 0 | 10 | 2 | 240 | 10 | 0.29 | 10 | 0 | 10 | 0 | 5 | 5 | 2 | 10 |
| Green Swamp 2-well 2s | 11/09/10 | 240 | 2 | 10 | 1 | 1 | 10 | 2 | 160 | 10 | 0.53 | 10 | 0 | 10 | 0 | 5 | 5 | 2.9 | 10 |
| Green Swamp 2-well 2s | 01/31/11 | 390 | 2 | 10 | 1 | 1 | 10 | 2 | 120 | 10 | 0.52 | 10 | 0 | 10 | 0 | 5 | 5 | 2.5 | 10 |
| Green Swamp 2-well 2s | 04/19/11 | 240 | 2 | 10 | 1 | 1 | 10 | 2 | 170 | 2 | 0.48 | 10 | 0 | 2 | 0 | 5 | 5 | 2.5 | 10 |
| Green Swamp 2-well 3s | 09/01/10 | 160 | 2 | 10 | 1 | 0 | 10 | 2 | 730 | 10 | 0.31 | 10 | 0 | 10 | 0 | 5 | 5 | 2.7 | 10 |
| Green Swamp 2-well 3s | 11/09/10 | 120 | 2 | 10 | 1 | 0 | 10 | 2 | 510 | 10 | 0.48 | 10 | 0 | 10 | 0 | 5 | 5 | 3.1 | 10 |
| Green Swamp 2-well 3s | 01/31/11 | 160 | 2 | 10 | 1 | 0 | 10 | 2 | 550 | 10 | 0.51 | 10 | 0 | 10 | 0 | 5 | 5 | 2.9 | 10 |
| Green Swamp 2-well 3s | 04/19/11 | 160 | 2 | 10 | 1 | 0 | 10 | 2 | 640 | 2 | 0.47 | 10 | 0 | 2 | 0 | 5 | 5 | 3 | 10 |
| Green Swamp 2-stream | 09/01/10 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Green Swamp 2-stream | 11/09/10 | | | | | | | 2 | | 10 | | | | | | | | | 10 |
| Green Swamp 2- | 01/31/11 | | | | | | | 2 | | 10 | | | | | | | | | 10 |

Table 9 Values of metal analysis for hydrology site water quality

| Site Name - Station Type | Date | Al ug/L | As ug/L | Ba ug/L | Cd ug/L | Ca ug/L | Cr ug/L | Cu ug/L | Fe ug/L | Pb ug/L | Mg ug/L | Mn ug/L | Hg ug/L | Ni ug/L | K ug/L | Se ug/L | Ag ug/L | Na ug/L | Zn ug/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| stream | | | | | | | | | | | | | | | | | | | |
| Green Swamp 2-stream | 04/19/11 | | | | | | | 2 | | 2 | | | | | | | | | 10 |
| LB-well 1 | 08/17/11 | 1800 | 2 | 10 | 1 | 0 | 10 | 2 | 1200 | 2 | 0.69 | 10 | 0 | 2 | 0 | 5 | 5 | 7 | 14 |
| LB-well 1 | 11/02/11 | 1800 | 2 | 10 | 1 | 0 | 10 | 2 | 1100 | 2 | 0.82 | 10 | 0 | 2 | 0 | 5 | 5 | 8 | 10 |
| LB-well 1 | 02/15/12 | 2400 | 2 | 10 | 1 | 0 | 10 | 2 | 1300 | 3.8 | 1.2 | 10 | 0 | 2 | 0 | 5 | 5 | 9 | 10 |
| LB-well 1 | 05/08/12 | 2000 | 2 | 10 | 1 | 0 | 10 | 2 | 1400 | 2.9 | 1.4 | 10 | 0 | 2 | 0 | 5 | 5 | 9.9 | 10 |
| LB-well 2 | 08/17/11 | 1500 | 2 | 14 | 1 | 0 | 10 | 3.7 | 5500 | 2 | 0.91 | 31 | 0 | 8.9 | 0 | 5 | 5 | 6.3 | 48 |
| LB-well 2 | 11/02/11 | 1300 | 2 | 11 | 1 | 0 | 10 | 2 | 1600 | 2 | 0.76 | 10 | 0 | 2.5 | 0 | 5 | 5 | 5.3 | 27 |
| LB-well 2 | 02/15/12 | 2000 | 2 | 13 | 1 | 0 | 10 | 3.4 | 2000 | 2 | 0.92 | 16 | 0 | 3.2 | 0 | 5 | 5 | 6.3 | 71 |
| LB-well 2 | 05/08/12 | 1700 | 2 | 13 | 1 | 0 | 10 | 2.5 | 1700 | 2 | 0.88 | 15 | 0 | 2.1 | 0 | 5 | 5 | 6.6 | 29 |
| LB-well 3 | 08/17/11 | 2100 | 2 | 12 | 1 | 0 | 10 | 2 | 2800 | 2 | 0.46 | 18 | 0 | 3.5 | 0 | 5 | 5 | 3.9 | 52 |
| LB-well 3 | 11/02/11 | 910 | 2 | 10 | 1 | 0 | 10 | 2 | 1200 | 2 | 0.4 | 10 | 0 | 3 | 0 | 5 | 5 | 3.9 | 16 |
| LB-well 3 | 02/15/12 | 2400 | 2 | 10 | 1 | 0 | 16 | 5.5 | 4200 | 2 | 0.44 | 10 | 0 | 2 | 0 | 5 | 5 | 3.9 | 25 |
| LB-well 3 | 05/08/12 | 1600 | 2 | 11 | 1 | 0 | 10 | 2.3 | 4100 | 2 | 0.42 | 10 | 0 | 2 | 0 | 5 | 5 | 4.2 | 10 |
| LB-well 4 | 08/17/11 | 2900 | 2 | 15 | 1 | 1 | 27 | 7.8 | 4300 | 2 | 0.55 | 21 | 0 | 7 | 0 | 5 | 5 | 5.3 | 30 |
| LB-well 4 | 11/02/11 | 1300 | 2 | 10 | 1 | 1 | 17 | 4.7 | 520 | 2 | 0.43 | 10 | 0 | 2.2 | 0 | 5 | 5 | 4.3 | 11 |
| LB-well 4 | 02/15/12 | 430 | 2 | 10 | 1 | 1 | 10 | 2 | 340 | 2 | 0.485 | 10 | 0 | 2 | 0 | 5 | 5 | 4.2 | 10 |
| LB-well 4 | 05/08/12 | 470 | 2 | 10 | 1 | 1 | 10 | 2 | 370 | 2 | 0.47 | 10 | 0 | 2 | 0 | 5 | 5 | 4.2 | 10 |
| LB-stream | 08/17/11 | | | | | | | 2 | | 2 | | | | | | | | | 10 |
| LB-stream | 11/02/11 | | | | | | | 2 | | 2 | | | | | | | | | 10 |
| LB-stream | 02/15/12 | | | | | | | 2 | | 2 | | | | | | | | | 10 |
| LB-stream | 05/08/12 | | | | | | | 2 | | 2 | | | | | | | | | 10 |
| MA-well 1 | 08/17/11 | 71.5 | 2 | 14 | 1 | 2 | 10 | 2 | 1700 | 2 | 1.1 | 33 | 0 | 2 | 1 | 5 | 5 | 4 | 10 |
| MA-well 1 | 11/01/11 | 53 | 2 | 17 | 1 | 2 | 10 | 2 | 1300 | 2 | 1.1 | 36 | 0 | 2 | 1 | 5 | 5 | 4.8 | 10 |
| MA-well 1 | 02/16/12 | 62 | 2 | 16 | 1 | 2 | 10 | 2 | 1900 | 2 | 1.1 | 42 | 0 | 2 | 0 | 5 | 5 | 4.4 | 10 |
| MA-well 1 | 05/09/12 | 190 | 2 | 13 | 1 | 2 | 10 | 2 | 1900 | 2 | 1.1 | 41 | 0 | 2 | 0 | 5 | 5 | 3.8 | 10 |

Table 9 Values of metal analysis for hydrology site water quality

| Site Name - Station Type | Date | Al ug/L | As ug/L | Ba ug/L | Cd ug/L | Ca ug/L | Cr ug/L | Cu ug/L | Fe ug/L | Pb ug/L | Mg ug/L | Mn ug/L | Hg ug/L | Ni ug/L | K ug/L | Se ug/L | Ag ug/L | Na ug/L | Zn ug/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MA-well 2 | 08/17/11 | 420 | 2 | 20 | 1 | 2 | 10 | 2 | 3700 | 2 | 1 | 50 | 0 | 2 | 0 | 5 | 5 | 3.9 | 10 |
| MA-well 2 | 11/01/11 | 50 | 2 | 17 | 1 | 2 | 10 | 2 | 3100 | 2 | 0.97 | 56 | 0 | 2 | 0 | 5 | 5 | 3.7 | 10 |
| MA-well 2 | 02/16/12 | 82 | 2 | 17 | 1 | 2 | 10 | 2 | 2900 | 2 | 1.1 | 68 | 0 | 2 | 0 | 5 | 5 | 4.1 | 10 |
| MA-well 2 | 05/09/12 | 103.5 | 2 | 16 | 1 | 2 | 10 | 2 | 2800 | 2 | 0.96 | 58 | 0 | 2 | 0 | 5 | 5 | 3.7 | 10 |
| MA-well 3 | 08/17/11 | 870 | 2 | 17 | 1 | 2 | 10 | 2 | 10000 | 2 | 0.92 | 28 | 0 | 2 | 1 | 5 | 5 | 4 | 14 |
| MA-well 3 | 11/01/11 | 50 | 2 | 14 | 1 | 2 | 10 | 2 | 8200 | 2 | 0.93 | 24 | 0 | 2 | 1 | 5 | 5 | 3.7 | 10 |
| MA-well 3 | 02/16/12 | 197 | 2 | 15 | 1 | 2 | 10 | 2 | 8900 | 2 | 1.1 | 29 | 0 | 2 | 0 | 5 | 5 | 4 | 10 |
| MA-well 3 | 05/09/12 | 160 | 2 | 13 | 1 | 2 | 10 | 2 | 8600 | 2 | 0.92 | 23 | 0 | 2 | 0 | 5 | 5 | 3.5 | 10 |
| MA-stream | 02/16/12 | | | | | | | 2.3 | | 2 | | | | | | | | | 10 |
| MA-stream | 05/09/12 | | | | | | | 2 | | 2 | | | | | | | | | 10 |
| MF-well 1 | 05/09/12 | 160000 | 3.4 | 1500 | 1 | 2 | 71 | 30 | 36000 | 98 | 4.6 | 120 | 0 | 29 | 2 | 6.5 | 5 | 9.9 | 41 |
| MF-well 2 | 05/09/12 | 150000 | 14 | 260 | 1 | 2 | 110 | 23 | 90000 | 34 | 3.3 | 82 | 0 | 40 | 1 | 5 | 5 | 4.7 | 52 |
| MF-well 4 | 08/16/11 | 27000 | 2 | 360 | 1 | 4 | 21 | 7.8 | 6400 | 15 | 2.1 | 67 | 0 | 5.6 | 1 | 5 | 5 | 7.6 | 10 |
| MF-well 4 | 11/01/11 | 56000 | 2 | 480 | 1 | 4 | 47 | 43 | 12000 | 31 | 3.1 | 100 | 0 | 13 | 2 | 5 | 5 | 6.4 | 29 |
| MF-well 4 | 02/16/12 | 25000 | 2 | 280 | 1 | 3 | 20 | 5.5 | 7100 | 17 | 1.9 | 49 | 0 | 5.1 | 1 | 5 | 5 | 8.3 | 15 |
| MF-well 4 | 05/09/12 | 96000 | 2 | 780 | 1 | 8 | 85 | 31 | 29000 | 69 | 4.8 | 150 | 1 | 22 | 2 | 5 | 5 | 7.6 | 38 |
| MF-stream | 02/16/12 | | | | | | | 2 | | 2 | | | | | | | | | 10 |
| MF-stream | 05/09/12 | | | | | | | 2.4 | | 2 | | | | | | | | | 10 |