Field Verification of Wetland Functional Assessment Methods within Local Watershed Planning Areas Draft Report

Report to the U. S. Environmental Protection Agency in Fulfillment of EPA Wetlands Program Development Grant - CD 96422105-0

Department of Environment and Natural Resources
North Carolina Division of Water Quality

April 2010

Prepared by Rick Savage, Virginia Baker, Mike Turner, and Sarah Schwarzer

Acknowledgements

The project coordinators, Rick Savage and Virginia Baker, would like to acknowledge the U.S. Environmental Protection Agency for their continued interest and support of the North Carolina Wetlands Monitoring Program. Without that support this project would not have been possible. We would also like to thank our supervisor, John Dorney, who has always found time to provide valuable professional feedback and advice on this project no matter how full his schedule was. We would also like to offer appreciation and thanks to the immensely hard work provided by our technicians Mike Turner and Caroline Reddy and our summer intern Sarah Schwarzer. Mike and Sarah also did some of the research and writing for some of the background information sections. Lastly we would like to acknowledge and thank Alvin Braswell of the North Carolina Museum of Natural History for his expert assistance with the identification of amphibians and Alan Weakley of the University of North Carolina for his expert assistance with the identification of plant vouchers.

Field Verification of Wetland Functional Assessment Methods within Local Watershed Planning Areas

Table of Contents

List of Figures

List of Tables

Appendices

Section 1 - Report Introduction

Section 1.1 Executive Summary

The objectives of this study were to (1) expand the NC wetland monitoring program that originated with the EPA Grant, "Development of a Wetland Monitoring Program for Headwater Wetlands in North Carolina" (CD 974260-01) to additional wetland types, (2) to conduct a field verification of the newly developed Level II North Carolina Rapid Assessment Method (NCWAM) through comparison with the intensive Level III survey results, and (3) to provide information on the condition of wetlands in the Fishing Creek and Lockwood Folly River watersheds for the NC Ecosystem Enhancement Program (EEP) which will potentially be used in the development of EEP's Local Watershed Plans for these watersheds. The North Carolina Division of Water Quality (NCDWQ) has collected Level I (remote GIS spatial analysis), Level II (rapid on-the-ground assessments), and Level III (intensive chemical, physical, and biological surveys) wetland survey information on two types of riverine wetlands, (Riverine Swamp Forest and Bottomland Hardwood Forest wetlands), and depressional wetlands, (Small Basin wetlands) in this report. This study was conducted in the Piedmont Fishing Creek watershed located in Granville County and the Coastal Plain Lockwood Folly River watershed located in Brunswick County. This study monitored seven Riverine Swamp Forests and six Small Basin wetlands in the Lockwood Folly River watershed and six Bottomland Hardwood Forests and six Small Basin wetlands in the Fishing Creek watershed for a total monitoring effort at 25 sites.

Level III chemical and physical monitoring of the three wetland types examined the water quality, soils, and hydrology. Water quality data were collected from one to three stations depending on wetland type in order to assess how the water quality changed as it flowed through the wetland system. The Riverine Swamp water quality results showed these systems clearly improved water quality while the bottomland hardwood results were more variable with some parameters improving and some not improving. Similarly, two Small Basins with outlets were assessed for changes in water quality resulting in one site showing improvement and the other not showing improvement. The Small Basins wetlands in the Lockwood Folly River watershed also had better water quality then in the Fishing Creek watershed. However, system inputs were not measured as a possible explanation for the difference. The analysis of the surrounding upland and wetland soil samples showed that all three wetland types are acting as sinks for nutrients and metals, thereby, improving water quality. The soils assessment is consistent with the water quality results in that Fishing Creek sites had more pollutants in the soil than Lockwoods Folly River sites. Monitoring wells outfitted with pressure transducers were installed at each wetland site. The hydroperiod of the three wetland types was variable, partly due to differences between the wetland systems and partly due to the more severe effects of drought in the Lockwood Folly River watershed.

Level III biological monitoring results were used to develop Amphibian and Plant Indices of Biotic Integrity (IBIs). Level I and Level II (Ohio Rapid Assessment Method scores) results were correlated with each wetland type's amphibian and plant metrics separately. Level III (soil and water quality) results were also correlated with amphibian metrics for each wetland type. Different wetland types, regions of the state, and specific site stressors caused considerable variation within the Riverine Swamp Forest, Bottomland Hardwood Forest and Small Basin wetland amphibian and plant communities which resulted in the significance of different metrics for different wetland types. The IBIs with the most significant metric correlations were the Small Basin wetland Plant IBI, the Riverine Swamp Forest Plant IBI, and the Bottomland Hardwood Forest Amphibian IBI. Notably, five plant metrics and the Plant IBI for the Small Basin wetlands, two plant metrics and the Plant IBI for the Riverine Swamp Forests, and four amphibian metrics and one plant metric for the Bottomland Hardwood Forest wetlands also were significantly correlated with some of the NCWAM results. Further monitoring of additional sites and more diverse wetlands (with respect to condition) for all three wetland types in other areas of the Piedmont and Coastal Plain will be needed to fully develop these IBIs and to ensure their accuracy. Some of this effort will probably be done with a recently awarded Wetland Monitoring Intensification Grant to North Carolina, South Carolina, and Alabama.

Statistical correlations were made by comparing overall NCWAM ratings and the NCWAM function ratings (Water Quality, Hydrology, and Habitat) with the Level III intensive results. Additionally comparisons were made with a second rapid assessment Method (Ohio Rapid Assessment Method) and the GIS Level I analysis. Significant correlations were found between the NCWAM scores and some of the Level III results including some of the amphibian and plant metrics and plant IBIs, the water and soil quality results (dissolved oxygen, some nutrients and metals). Some of the NCWAM scores also correlated with the Level II ORAM scores, but not the Level I LDI scores. The correlation of the Small Basin Wetland and Riverine Swamp Plant IBI with the NCWAM Habitat function is a particularly significant correlation as this indicates this function is working appropriately. The non-significant correlations may have occurred since there was not a wide range of NCWAM ratings for the sample sites (most sites rated high value and some rated medium value) and the fact that there was a small sample size for each wetland type. Further testing with a larger sample size and more diverse NCWAM ratings of these wetland types is needed and is currently being done for Headwater Wetlands (EPA Grant - WL 9643505-1).

The quality and function of the wetlands that were surveyed in both the Fishing Creek and Lockwood Folly River watersheds had some variation in terms of quality due to logging, the presence of invasive vegetation, ditching, and buffer impacts. However, overall these wetlands appeared to be maintaining their water quality and hydrological functional benefits. Both the Fishing Creek and Lockwood Folly River watersheds have large expanses of open space, although impending development in these watersheds (especially in the Lockwood Folly River watershed) have the potential to impact these wetlands and stress the ability of these systems to properly function. Continued long term monitoring of six of these sites (two Riverine Swamp, two Bottomland Hardwood Forests, and four Small Basin wetlands [two Coastal Plain and two Piedmont]) will provide invaluable information on the affects of developmental impacts on wetland quality and function in a rapidly growing region of the country.

This study has provided a better understanding of the quality and function of three types of wetlands, Riverine Swamp Forest, Bottomland Hardwood Forest, and Small Basin wetlands within the Lockwood Folly River and Fishing Creek watersheds. The intensive Level III monitoring results have showed these types of wetlands are diverse systems comprised of a variety of vegetation in each strata and that these systems are home to numerous types of amphibians. Additionally, the Riverine Swamp Forests and to a lesser degree Bottomland Hardwood Forests can improve water quality by lowering the levels of nutrients and metals. The nutrients and metals in the soils are lower in the uplands indicating that these wetlands act as a sink for these potential pollutants. The development of IBI's was largely successful, especially for the plant data.

Regional, wetland type and site specific stressors caused variability of water quality, hydrology and soil type which contributed to biota differences between the wetland types in the Coastal Plain and Piedmont. The Coastal Plain Small Basin wetlands had better water quality than the Piedmont Small Basin wetlands. The hydrology of Riverine Swamp Forests showed these wetlands are very wet and stay that way year round while Bottomland Hardwood Forest are drier during the during the growing season. Piedmont Small Basin wetlands also tended to be more drought tolerant than Coastal Plain Small Basin wetlands. The soils in Bottomland Hardwood Forests were typically mineral while Riverine Swamp Forests contained organic muck. Small Basin wetlands had organic soils with a higher sand content in the Coastal Plain. The Coastal Plain Small Basin wetlands had the highest diversity of amphibian species while the Riverine Swamps had the least diversity; however the Piedmont wetlands had the greatest abundance of individuals. Coastal Plain Riverine Swamp vegetation was the most diverse while the Small Basin wetlands in this region had the least diversity and a dense shrub layer. Species variability between wetland type was related to regional, soil, and physiographic differences.

Section 1.2 Purpose and Goals

This grant proposed to accomplish several goals: (1) continue the process of establishing a wetlands monitoring program in North Carolina, as stated in a previous EPA grant (CD# 9754260-01), by monitoring different wetland types; (2) continue to provide Level III data for the verification and validation of the North Carolina Wetlands Assessment Method (NCWAM) and (3) focus on wetland monitoring within watersheds that are having management plans developed by the NC Ecosystem Enhancement Program (NC EEP). The focus of this monitoring project concentrated on two watersheds; Fishing Creek watershed in Granville County located in the north central Piedmont, and Lockwood Folly River Watershed in Brunswick County located in the southeastern Coastal Plain. This wetlands monitoring effort will provide useful information for NC EEP and could contribute to the development of the local watershed plans. The previous monitoring project (Baker and Savage, 2008) focused on Headwater Wetlands randomly selected in the Piedmont (12 sites) and in the Coastal Plain (11 sites). The current monitoring project focuses on three wetland types; Small Basin wetlands, Bottomland Hardwood Forests, and Riverine Swamp Forests. Specifically six Small Basin wetlands and six Bottomland Hardwood Forests were monitored in the Fishing Creek watershed and six Small Basin wetlands and seven Riverine Swamp Forests were monitored in the Lockwood Folly River watershed for a total of 25 sites.

Section 1.3 Level I, Level II, and Level III Wetland Monitoring

Monitoring methodologies used in the previous wetlands monitoring project (Baker and Savage, 2008) were used in the current project with a few modifications. Level I (remote sensing, spatial analysis), Level II (rapid assessments), and Level III (intensive assessments) monitoring have been completed for the wetland sites. The Level I analysis involved a spatial land cover analysis of the watershed and 100 m buffer of each site. This analysis was used to create a land-use development index (LDI) (Vivas and Brown, 2003) which will be used to determine the effect of land-use development on the Level III monitoring data. Level II monitoring involved completing rapid assessments; NCWAM and Ohio Rapid Assessment Method (ORAM, Mack 2001) on each site. The primary use of the ORAM results was as a disturbance gradient for the analysis of the Level III monitoring data as well as to allow comparisons to the NCWAM results. Level III monitoring involved intensive wetland monitoring surveys of amphibians, aquatic macroinvertebrates, vegetation, water quality, hydrology, and soils. Water quality data included physical measurements and chemical measurements. Soil data included soil composition of nutrients and metals as well as soil chemical and physical characteristics. Hydrological data was collected with monitoring wells over time intervals for the duration of the project (June 2007 – December, 2008).

Section 2 - Wetland Monitoring, IBI Development, and Data Analysis

Section 2.1 Level I GIS Assessment

A Land Development Index (LDI) value was calculated for each site's watershed and 300m buffer using a method similar to that described in Brown and Vivas (2003). The LDI value estimates the potential impacts from anthropomorphic influences on land cover by evaluating land cover in a designated area. LDI values are essentially a human-related disturbance score that is associated with intensity of the land-use based on non-renewable energy flow. US Geographical Survey topographical quad maps were used to determine the watershed boundaries for each site. Land cover parcels were delineated and assigned a land cover type value (see Table 2.1-1) with ArcGIS. A 2006 DOQQ aerial and on the ground observations were used to delineate the land parcel polygons for all land area located within each site's 100m buffer or watershed. Each land parcel type was digitized and assigned a land cover code and associated LDI coefficient (see Table 2.1-1). The following equation was used to determine the Land Use Index value for the watershed and 100m buffer of each site.

$$\mathrm{LDI}_{Total} = \sum \%\mathrm{Lu}i * \mathrm{LDI}i$$

LDI_{Total} = LDI ranking for landscape unit
$\%\mathrm{Lu}_i$ = percent of the total area of influence in the land use i
LDI_i = landscape development intensity coefficient for land use i

Table 2.1-1 Fishing Creek and Lockwood Folly River Wetland Land Cover Type and Index Values

Land Cover Types for wetland study site watersheds and one-mile buffers	LDI Coefficient
Natural Areas	1
Water Bodies	1
Unmanaged Herbaceous Upland	2
Unmanaged Herbaceous Wetland	2
Managed Herbaceous Upland	3
Pine Plantation	3
Cultivated	5
Low Intensity Developed	6
High Intensity Developed	8

LDI values with a higher score indicated that land use for the watershed and 100m buffer were more heavily impacted by human usage (see Table 2.1-2). LDI value of 100 indicates the buffer or watershed land coverage contained only natural areas or water bodies. The LDI values used in this study were similar to the values used in the Brown and Vivas 2003 study in Florida. The ranges and averages of each of the wetland types for 100 M and Watershed LDI I values are showen in Table 2.1-2.

Table 2.1-2 LDI Results Table

Watershed	Wetland Type	Site Name	LDI Value		Averages and Ranges	
			100 M	Watershed	100 M	Watershed
Fishing Creek	Bottomland Hardwood	Fairport	165	342	Range = 100-263 Ave = 143.7	Range = 179-342 Ave = 251.3
		Gray	100	237		
		Hancock	109	284		
		Kim Brooks	263	181		
		Munn	125	285		
		Powers	100	179		
	Small Basin Wetland	Belton Creek	184	131	Range = 118-228 Ave = 286	Range = 100-317 Ave = 284
		Dargan	124	100		
		Dean	164	282		
		Eastwood	228	317		
		Goldston	118	136		
		Hart	216	232		
Lockwood Folly	Riverine Swamp	Doe Creek	100	249	Range = 100-284 Ave = 172.4	Range = 132-390 Ave = 262.6
		Hewitt	100	293		
		Lockwood	162	161		
		Mercer Seawatch	162	223		
		Rourk	120	132		
		Winding River Pond	279	390		
		Winding River Townhouse	284	390		
	Small Basin Wetland	Bluegreen Golf	286	284	Range = 103-286 Ave = 174	Range = 102-284 Ave = 197
		Martin Amment	152	178		
		Mill Creek	157	174		
		Seawatch Bay	209	277		
		Seawatch Nautica	103	102		
		Sikka	147	154		

Section 2.2 Level II Rapid Assessment

Section 2.2.1 North Carolina Wetland Assessment Method (NCWAM)

The newly developed North Carolina Wetlands Assessment Method (NC WAM) was performed on each wetland study site (see Appendix A for a copy of the NCWAM form and NCWAM Dichotomous Key to General NC Wetland Types). NCWAM is a Level II, rapid assessment of wetlands based on functional value. The primary objective of NCWAM was to provide an accurate, rapid assessment of wetland function requiring no more than 15 minutes of on-site time. The development of NCWAM occurred over a five year period (2003-2007) with participation from the NC Division of Water Quality, NC Department of Transportation, NC Natural Heritage Program, US Environmental Protection Agency, the US Army Corps of Engineers, the US Federal Highways Administration, US Fish and Wildlife Service, NC Wildlife Resource Commission, and the NC Ecosystem Enhancement Program which made up the Wetlands Functional Assessment Team (WFAT). NCWAM depends on wetland type to assess function. Therefore, 16 general wetland types were defined by WFAT and a dichotomous key was developed to help the assessor determine the correct wetland type (WFAT development committee, 2006).

Three functions are assessed by the method; hydrology, water quality, and habitat. The hydrology function is further broken down into surface and subsurface storage capacity and retention. The water quality function is assessed by the sub-functions of pathogen, particulate, soluble, physical, and pollution changes. Finally, the habitat function uses the sub-functions of physical structure, landscape patch structure, and vegetation composition. A single form is filled out by the assessor, which includes office time (GIS, map consultation for some of the metrics) and field time. Several scores are generated from the completed form which is entered into a Excel spreadsheet which calculates the results. All the scores take on the values of “high”, “medium”, or “low”. There is an overall score all the rated wetland as well as scores for each of the three major functions. The sub-functions for each function also receive a score, of high, medium, or low. NCWAM also contains opportunity metrics, which are scored high, medium, or low. Opportunity metrics are an assessment of the ability of the wetland to perform a function based on watershed condition. The opportunity metrics are not automatically used to calculate any of the function scores or overall score, but are provided as additional information for the assessor to use at his/her discretion as the underlying regulatory structure allows or requires.

The two researchers for this work (Rick Savage and Virginia Baker) completed the assessment forms two times each, in fall of 2006 and the fall of 2008 in the months of October and November. The forms were completed two times for each site (except Hart due to loss of access), once prior to and once post the Level III intensive survey work in order to assess whether further knowledge and familiarity with the site would change the NCWAM score. Additionally, the forms were completed independently to avoid bias. Both individuals have successfully completed the four-day NCWAM training class. The 2006 forms completed were version 2.10 dated March 27, 2006 and the 2008 forms completed were version 4.0 dated May 12, 2008. The calculator version 1.0 dated June 12, 2008 was used to calculate the NCWAM scores for both the 2006 and 2008 rapid assessments.

Correlations were performed on the overall NCWAM score between the two researchers. Numeric scores were assigned to the NCWAM valus (high = 10, medium = 5, and low = 1, see discussion below). The Pearson's correlation resulted in a significant correlation of 0.5678 ($p<0.0001$) and the Spearmans also had a significant correlation 0.6014 ($p<0.0001$). Also, a t-test was performed on the two set of scores and there was no significant difference between the two researchers. These correlations are strong and very significant indicating that the two researchers were in good agreement in their rating of the sites with NCWAM.

Table 2.2.1-1 shows the NCWAM results for each site. For the Bottomland Hardwood Forests in the Fishing Creek watershed, the predominant overall scores were high for three of the sites, medium for two sites, and low for the Gray site. The major difference was the results for Virginia Baker for the Fairport and Kim-Brooks sites where they were rated low on the first assessment and high on the second. The main reason for this difference was due to the observation of overland flooding and inundation of these sites on the second visit since. One critical question on the NCWAM form dealing with the issue of overland or overbank flooding could swing the rating from high to low (or low to high) based on how it was answered. The answer to that question accounted for this difference. For the Small Basin wetlands in the Fishing Creek watershed, four were rated high and the Eastwood and Hart sites were rated medium and in this case there were no differences between raters or time periods. For the Small Basin wetlands in the Lockwood Folly River watershed, all scored high on NCWAM except for the Bluegreen Golf site, which was rated medium. Again there were no differences between raters or time periods. In addition, the Small Basin wetlands were rated similarly in both watersheds on NCWAM. Finally, the Riverine Swamp Forest in the Lockwood Folly River watershed all received an overall score of high with consistent results between raters and time periods with exception of the Winding River Townhouse site. Again this difference was primarily triggered by the one question on NCWAM dealing with overland and overbanks flooding (this discrepancy is dicussed at the end of this section). On many of the sites, there was some variation with the individual functions which can be seen in Table 2.2.1-1.

The results for the NCWAM ratings show very good consistency between the raters and within the raters over time such that more familiarity with the site did not typically change the overall ratings. The major cause of any differences in ratings was the question dealing with overland and overbank flooding. A "no" answer to this question could bring the rating for the entire wetland to low and a "yes" answer would result in a high rating. This question only affected the Riverine Swamp Forests and Bottomland Hardwood Forests. The WFAT has noted this problem and have changed this question to reduce the ability of this question to so dramatically adjust the site's rating (J. R. Dorney, personal, 2009).

To evaluate NCWAM, the high, medium, and low scores had to be assigned numbers to allow correlations to be performed. Therefore, a value of high was given a score of "10", medium was given a "5", and a low NCWAM rating was given a score of "1". This numerical assignment is the same method that the developers of the National Rapid Assessment Method are using (USA-RAM) used (Collins and Fennessey, USA-RAM draft manual, 2009, http://www.epa.gov/oamhpod1/adm_placement/sapcbd/rapid.htm). The USA-RAM also scores parameters with values of High, Medium, and Low which are assigned the numeric values of 10, 5, and 1, respectively, when values need to be summed to acquire cumulative scores. For current purposes, the logic used by Collins and Fennessy was to provide some variance and “separation” between the ratings. Since future evaluations of NCWAM will include the use and evaluation of USA-RAM, it made logical sense to use the same numeric assignment. These numerical assignments for NCWAM were done for the overall score and for the functions of hydrology, water quality, and habitat.

As was previously mentioned, NCWAM was completed on all the wetland sites (except Hart due to loss of access half way through the study) two times by two different researchers, once at the beginning of the study and once at the end in order to assess how further knowledge and familiarity with the site would change the ratings. Therefore, correlations using Spearman’s rho and Pearson’s correlation tests were performed on the raw data with both the pre and post study NCWAM results. The average of the three function scores and the overall score for the two researchers were calculated for both the pre and post study NCWAM results and used in the correlation. These averaged NCWAM results for both the pre and post study were correlated against Level I, Level II, and Level III monitoring results. For the Level I, results the LDI score for the three wetland types was used (see Section 2.1). For the Level II results, a second rapid assessment method, the Ohio Rapid Assessment Method (ORAM, Mack 2001) was also evaluated and is described further in the following section. The ORAM average score of the two researchers was used for this correlation. For Level III analysis, the results from the intensive chemical, physical, and biological surveys for each wetland type were used. The average water quality parameter values (except water temperature) and the average values for wetland soil potassium, phosphorus, calcium, magnesium, sulfur, manganese, zinc, lead, copper, sodium, and NO3-N were used in the correlations and are described further in sections 4.1 and 4.3. The IBI scores and associated significant metrics that were developed for each wetland type for both amphibians and plants were used in the correlation for the Level III biological results. The development of these metrics are described further in sections 4.4 (amphibians) and 4.6 (plants) and the significant metrics used in the IBI and IBI scores are described further in sections 5.2.5, 5.2.7 (riverine swamps), 5.3.5, 5.3.7 (bottomland hardwoods), 6.6 and 6.8 (Small Basin wetlands). The correlations of the NCWAM results and Level I, Level II, and Level III survey results were analyzed separately for each wetland type. Overall, one of the seven bottomland hardwood sites was rated low, two were rated medium and three were high quality. For the Riverine Swamp Forests, all were rated high. Finally, for the Small Basin wetlands, three were rated medium and and nine were rated high.

As mentioned earlier, there was a significant discrepancy between the two researchers on the Lockwood Folly Riverine Swamp Forest Winding River Townhouse site. The NCWAM question dealt with whether there was overbank or overland flooding and answering this question, “yes” or “no”, could result in the rating going form high to low or low to high. This question clearly carried too much weight (see Appendix A, last item on question 13, NCWAM Form vs 4.0, May 2008). The NCWAM Functional Assessment Team (pers. comm. Dorney, 2009) changed the form where overbank or overland flooding is assumed for Riverine Systems and the question now asks whether the overland or overbank flooding, or both, are severly altered. The weight of the answer in the underlying boolean logic, which is used by the NCWAM calculator (version. 3.0) to calculate the score, has also been reduced such that fluctuation in the overall rating would not go from high to low or from low to high when the answer to this question is changed (see Appendix A, NCWAM Form version 3.0). The newest version of the NCWAM Form and calculator resulted in both researchers scoring medium for the Winding River Townhouse site (meaning that the overland flooding had been altered by the adjacent development) which would have been the same as the averaged score of both researchers (high + low = medium) used in the correlation analysis.

Table 2.2.1-1 - NCWAM Results for the Fishing Creek and Lockwood Folly Watershed Wetlands

Watershed	Wetland Type	Site	Date	Observer	Function					Overall NCWAM Wetland Rating
					Hydrology Condition	Water Quality Condition	Water Quality Condition / Opportunity	Water Quality Opportunity Presence? Y/N	Habitat Condition	
Fishing Creek	Bottomland Hardwood Forest	Fairport	10/12/2006	RS	high	high	high	yes	high	**high**
		Fairport	9/2/2008	RS	medium	high	high	yes	high	**high**
		Fairport	10/12/2006	VB	low	low	low	yes	high	**low**
		Fairport	9/2/2008	VB	medium	high	high	yes	high	**high**
		Gray	10/12/2006	RS	low	low	low	yes	medium	**low**
		Gray	9/2/2008	RS	low	low	low	yes	high	**low**
		Gray	11/21/2006	VB	low	low	low	yes	high	**low**
		Gray	9/2/2008	VB	low	low	low	yes	high	**low**
		Hancock	11/1/2006	RS	medium	medium	high	yes	high	**medium**
		Hancock	9/2/2008	RS	medium	medium	high	yes	high	**medium**
		Hancock	11/1/2006	VB	medium	medium	high	yes	high	**medium**
		Hancock	9/2/2008	VB	medium	medium	high	yes	high	**medium**
		Kim-Brooks	10/30/2006	RS	high	high	high	yes	high	**high**
		Kim-Brooks	9/2/2008	RS	medium	high	high	yes	high	**high**
		Kim-Brooks	10/30/2006	VB	low	low	low	yes	high	**low**
		Kim-Brooks	9/2/2008	VB	medium	high	high	yes	high	**high**
		Munn	10/30/2006	RS	medium	high	high	yes	high	**high**
		Munn	9/2/2008	RS	medium	high	high	yes	high	**high**
		Munn	10/30/2006	VB	medium	high	high	yes	high	**high**
		Munn	9/2/2008	VB	medium	high	high	yes	high	**high**
		Powers	11/29/2006	RS	medium	high	high	yes	high	**high**
		Powers	9/2/2008	RS	medium	medium	high	yes	high	**medium**
		Powers	11/29/2006	VB	medium	medium	high	yes	high	**medium**
		Powers	9/2/2008	VB	medium	medium	high	yes	high	**medium**
	Small Basin Wetland	Belton Creek	10/12/2006	RS	medium	high	high	no	high	**high**
		Belton Creek	9/3/2008	RS	medium	high	high	no	high	**high**
		Belton Creek	10/12/2006	VB	medium	high	high	no	high	**high**
		Belton Creek	9/2/2008	VB	medium	high	high	no	high	**high**

RS = Rick Savage and VB = Virginia Baker

Table 2.2.1-1 - NCWAM Results for the Fishing Creek and Lockwood Folly Watershed Wetlands

Watershed	Wetland Type	Site	Date	Observer	Function					Overall NCWAM Wetland Rating
					Hydrology Condition	Water Quality Condition	Water Quality Condition / Opportunity	Water Quality Opportunity Presence? Y/N	Habitat Condition	
Fishing Creek	Small Basin Wetland	Dargan	10/11/2006	RS	high	high	high	no	high	**high**
		Dargan	9/2/2008	RS	high	high	high	no	high	**high**
		Dargan	10/11/2006	VB	high	high	high	no	high	**high**
		Dargan	9/3/2008	VB	high	high	high	no	high	**high**
		Dean	11/1/2006	RS	high	high	high	no	high	**high**
		Dean	9/2/2008	RS	high	high	high	no	high	**high**
		Dean	11/1/2006	VB	high	high	high	no	high	**high**
		Dean	9/2/2008	VB	high	high	high	yes	high	**high**
		Eastwood	10/26/2006	RS	medium	high	high	no	low	**medium**
		Eastwood	09/02//08	RS	medium	high	high	no	low	**medium**
		Eastwood	10/12/2006	VB	medium	high	high	no	low	**medium**
		Eastwood	9/2/2008	VB	medium	high	high	no	low	**medium**
		Goldston	11/1/2006	RS	medium	high	high	no	high	**high**
		Goldston	9/2/2008	RS	medium	high	high	no	high	**high**
		Goldston	11/1/2006	VB	medium	high	high	no	high	**high**
		Goldston	9/2/2008	VB	medium	high	high	no	high	**high**
		Hart	11/21/2006	RS	medium	medium	medium	no	low	**medium**
		Hart	0/0/2008	RS	medium	medium	medium	no	low	**medium**
		Hart	11/21/2006	VB	medium	medium	medium	no	low	**medium**
Lockwood Folly	Riverine Swamp Forest	Doe Creek	10/18/2006	RS	high	high	high	no	high	**high**
		Doe Creek	10/15/2008	RS	high	high	high	yes	high	**high**
		Doe Creek	10/18/2006	VB	high	high	high	yes	high	**high**
		Doe Creek	10/16/2008	VB	high	high	high	yes	high	**high**
		Hewett Wildlife	11/16/2006	RS	high	high	high	no	high	**high**
		Hewett Wildlife	10/15/2008	RS	high	high	high	yes	medium	**high**
		Hewett Wildlife	11/16/2006	VB	high	high	high	yes	high	**high**
		Hewett Wildlife	10/15/2008	VB	high	high	high	yes	medium	**high**

RS = Rick Savage and VB = Virginia Baker

Table 2.2.1-1 - NCWAM Results for the Fishing Creek and Lockwood Folly Watershed Wetlands

Watershed	Wetland Type	Site	Date	Observer	Function					Overall NCWAM Wetland Rating
					Hydrology Condition	Water Quality Condition	Water Quality Condition / Opportunity	Water Quality Opportunity Presence? Y/N	Habitat Condition	
Lockwood Folly	Riverine Swamp Forest	Lockwood	11/14/2006	RS	high	high	high	yes	high	**high**
		Lockwood	10/15/2008	RS	high	high	high	yes	high	**high**
		Lockwood	11/14/2006	VB	high	high	high	yes	high	**high**
		Lockwood	10/15/2008	VB	high	high	high	yes	high	**high**
		Mercer Seawatch	11/15/2006	RS	high	high	high	no	high	**high**
		Mercer Seawatch	10/15/2008	RS	high	high	high	no	high	**high**
		Mercer Seawatch	11/15/2006	VB	high	high	high	no	high	**high**
		Mercer Seawatch	10/15/2008	VB	high	high	high	no	high	**high**
		Rourk	10/19/2006	RS	high	high	high	no	high	**high**
		Rourk	10/15/2008	RS	high	high	high	no	high	**high**
		Rourk	10/19/2006	VB	high	high	high	no	high	**high**
		Rourk	10/15/2008	VB	high	high	high	no	high	**high**
		Winding River Pond	10/20/2006	RS	high	high	high	yes	high	**high**
		Winding River Pond	10/15/2008	RS	high	high	high	yes	high	**high**
		Winding River Pond	10/22/2006	VB	high	high	high	yes	medium	**high**
		Winding River Pond	10/15/2008	VB	high	high	high	yes	high	**high**
		Winding River Townhouse	11/14/2006	RS	high	high	high	yes	medium	**high**
		Winding River Townhouse	10/15/2008	RS	high	high	high	yes	medium	**high**
		Winding River Townhouse	11/14/2006	VB	low	low	low	yes	medium	**low**
		Winding River Townhouse	10/15/2008	VB	low	low	low	yes	medium	**low**
	Small Basin Wetland	Bluegreen Golf	11/16/2006	RS	medium	high	high	yes	medium	**medium**
		Bluegreen Golf	10/16/2008	RS	medium	high	high	yes	medium	**medium**
		Bluegreen Golf	10/18/2006	VB	medium	high	high	yes	medium	**medium**
		Bluegreen Golf	10/16/2008	VB	medium	high	high	yes	medium	**medium**
		Martin-Amment	10/19/2006	RS	high	high	high	no	high	**high**
		Martin-Amment	10/16/2008	RS	high	high	high	no	high	**high**
		Martin-Amment	10/19/2006	VB	high	high	high	no	high	**high**
		Martin-Amment	10/16/2008	VB	high	high	high	no	high	**high**

RS = Rick Savage and VB = Virginia Baker

Table 2.2.1-1 - NCWAM Results for the Fishing Creek and Lockwood Folly Watershed Wetlands

Watershed	Wetland Type	Site	Date	Observer	Function					Overall NCWAM Wetland Rating
					Hydrology Condition	Water Quality Condition	Water Quality Condition / Opportunity	Water Quality Opportunity Presence? Y/N	Habitat Condition	
Lockwood Folly	**Small Basin Wetland**	Mill Creek	10/20/2006	RS	medium	high	high	yes	high	**high**
		Mill Creek	10/16/2008	RS	medium	high	high	no	high	**high**
		Mill Creek	10/20/2006	VB	medium	high	high	no	high	**high**
		Mill Creek	10/16/2008	VB	medium	high	high	no	nigh	**high**
		Seawatch Bay	11/15/2006	RS	high	high	high	no	high	**high**
		Seawatch Bay	10/10/2008	RS	high	high	high	no	high	**high**
		Seawatch Bay	11/15/2006	VB	high	high	high	no	high	**high**
		Seawatch Bay	10/16/2008	VB	high	high	high	no	high	**high**
		Seawatch Nautica	11/30/2006	RS	high	high	high	no	high	**high**
		Seawatch Nautica	10/15/2008	RS	high	high	high	no	high	**high**
		Seawatch Nautica	11/30/2006	VB	high	high	high	no	high	**high**
		Seawatch Nautica	10/16/2008	VB	high	high	high	no	high	**high**
		Sikka	11/30/2006	RS	high	high	high	no	high	**high**
		Sikka	10/16/2008	RS	high	high	high	no	high	**high**
		Sikka	11/30/2006	VB	high	high	high	no	high	**high**
		Sikka	10/16/2008	VB	high	high	high	no	high	**high**

RS = Rick Savage and VB = Virginia Baker

Section 2.2.2 Ohio Rapid Assessment Method

The Ohio Rapid Assessment Method v. 5.0 (Mack, 2001, see Appendix C for copy of ORAM form) was used for the Level II monitoring and to calculate a disturbance score for each of the wetland sites which is described further in Section 2.4. ORAM is an existing conditional evaluation tool that was suggested for use by the EPA since ORAM had been used in Ohio since 2001. ORAM contains six rapid assessment metrics: 1. wetland area, 2. upland buffers and surrounding land use, 3. hydrology, 4. habitat alteration and development, 5. special wetlands, 6. plant communities, interspersion, and microtopography. Metric 5, which was specific to Ohio wetlands, was not used in the assessment. ORAM has not been specifically calibrated to NC. However, the five metrics that were used (wetland area, upland buffer and surrounding land-use, hydrology, habitat, and plant communities) are believed to be important factors in determining the quality of NC wetlands. Again the project researchers, (Rick Savage and Virginia Baker) completed the assessment forms two times each, in fall of 2006 and the fall of 2008 in the months of October and November at the same time the NCWAM forms were completed. Similar to NCWAM, the forms were completed two times for each site (except Hart due to loss of access), once prior to and once post to the Level III intensive survey work. Additionally, the forms were completed independently to avoid bias.

Correlations were performed on the ORAM scores between the two researchres. Pearson's correlation resulted is a strong correlation with $r = 0.932$ ($p<0.0001$) and the Spearman's Rho correlation was also significant with $r = 0.9076$ ($p<0.0001$). A t-test between the two sets of scores also was not significant indicating no significant differences between the two researchers. The strong correlations indicate that there was very good agreement between the two researchers on their ORAM rating of the sites.

The maximum score for a high quality wetland in NC would be 90 without the use of metric 5. Using both the sets of scores from the 2006 and 2008 assessments for Fishing Creek bottomland hardwood sites and Small Basin wetlands sites resulted each of these regional wetland types having a normal distribution of scores. The score range for the Fishing Creek Bottomland Hardwood Forests is 45.5 to 76 with a mean of 61.7 and median of 61.8. The score range for the Fishing Creek Small Basin wetland is 32 to 82.5 with a mean of 57.7 and median of 55.5. The Fishing Creek median scores for both the bottomland hardwood and Small Basin wetland were lower in 2006 than in 2008 (bottomland hardwood 2006 = 57 and 2008 = 64.3, Small Basin wetland 2006 = 65.5 and 2008 = 76.5). Using the both sets of scores from 2006 and 2008 resulted in a non-normal distribution for both the Lockwood Folly Riverine Swamp Forest and Small Basin wetland sites. The Lockwood Folly Riverine Swamp scores ranged from 50.5 to 84 with a mean of 71.2 and median of 72.3, while the Lockwood Folly River Small Basin wetlands ranged from 28.5 to 90.5 with a mean of 69.1 and median of 73.5. Combining the Small Basin wetland ORAM scores from both watersheds also resulted in a non-normal distribution with a mean of 63.8 and median of 68.5. The Lockwood Folly River median score for riverine swamps decreased from 2006 to 2008 from 76.5 to 71.3 while the Small Basin wetland score stayed about the same; 73.8 in 2006 and 73 in 2008.

Table 2.2.2-1 ORAM Results for the Fishing Creek and Lockwood Folly Watershed Wetlands

Watershed	Wetland Type	Site	Area	Buffer	Hydrology	Habitat	Community	Total	Observer	Date	Min	Max	Range	Mean
Fishing Creek	Bottomland Hardwood Forest	Fairport	2	10	26	19	14.5	71.5	RS	09/02/08	50	71.5	21.5	**62.13**
		Fairport	2	8	19	11	10	50	RS	10/12/06				
		Fairport	2	10	26	18	13.5	69.5	VB	09/02/08				
		Fairport	2	10	22	17	6.5	57.5	VB	10/12/06				
		Gray	1	14	20	19	11	65	RS	09/02/08	55.5	65	9.5	**61.00**
		Gray	1	9	25	19	8	62	RS	10/12/06				
		Gray	1	13	20	19	8.5	61.5	VB	09/02/08				
		Gray	1	8	22.5	18	6	55.5	VB	10/12/06				
		Hancock	2	9	20	14	14	59	RS	09/02/08	45.5	59	13.5	**52.38**
		Hancock	2	4	17.5	11	14	48.5	RS	11/01/06				
		Hancock	2	9	19	13	13.5	56.5	VB	09/02/08				
		Hancock	2	4.5	15	11.5	12.5	45.5	VB	11/01/06				
		Kim-Brooks	2	4	20	11.5	13	50.5	RS	09/02/08	50.5	60.5	10	**55.88**
		Kim-Brooks	2	7	20.5	14.5	12.5	56.5	RS	10/30/06				
		Kim-Brooks	2	7	24	13.5	14	60.5	VB	09/02/08				
		Kim-Brooks	2	7	19	15	13	56	VB	10/30/06				
		Munn	2	14	26.5	19	14	75.5	RS	09/02/08	69.5	76	6.5	**72.88**
		Munn	2	14	26.5	18.5	15	76	VB	09/02/08				
		Munn	2	12	23.5	16	16	69.5	VB	10/30/06				
		Munn	2	12	24	16.5	16	70.5	VB	10/30/06				
		Powers	2	12	21	16.5	13	64.5	RS	09/02/08	64	69	5	**65.88**
		Powers	2	10	23.5	17	16.5	69	RS	11/21/06				
		Powers	2	12	21	16.5	12.5	64	VB	09/02/08				
		Powers	2	10	22	16	16	66	VB	11/21/06				
	Small Basin Wetland	Belton Creek	2	13	19	13	20	67	RS	09/02/08	50.5	67	16.5	**60.25**
		Belton Creek	2	12	18.5	11	16	59.5	RS	10/12/06				
		Belton Creek	2	12	19	11.5	19.5	64	VB	09/02/08				
		Belton Creek	2	8	16	10	14.5	50.5	VB	10/12/06				
		Dargan	2	14	26	19	18	79	RS	09/02/07	79	82.5	3.5	**80.13**
		Dargan	2	13	24.5	19	21	79.5	RS	10/11/06				
		Dargan	2	14	26	17	20.5	79.5	VB	09/02/08				
		Dargan	2	13	24.5	20	23	82.5	VB	10/11/06				

RS = Rick Savage and VB = Virginia Baker

Table 2.2.2-1 ORAM Results for the Fishing Creek and Lockwood Folly Watershed Wetlands

Watershed	Wetland Type	Site	Area	Buffer	Hydrology	Habitat	Community	Total	Observer	Date	Min	Max	Range	Mean
Fishing Creek	Small Basin Wetland	Dean	2	9	24.5	19	20	74.5	RS	09/02/08	64	76	12	**69.75**
		Dean	2	10	22.5	14.5	15.5	64.5	RS	11/01/06				
		Dean	2	9	24.5	19	21.5	76	VB	09/02/08				
		Dean	2	13	20.5	14	14.5	64	VB	11/01/06				
		Eastwood	3	12	14	7	11	47	RS	09/02/08	32	49.5	17.5	**41.38**
		Eastwood	3	4	14.5	6.5	9	37	RS	10/12/06				
		Eastwood	3	12	15	8	11.5	49.5	VB	09/02/08				
		Eastwood	3	4	12.5	5.5	7	32	VB	10/12/06				
		Goldston	2	11	16.5	12	10	51.5	RS	09/02/08	40	51.5	11.5	**45.25**
		Goldston	2	8	17.5	11	8.5	47	RS	11/01/06				
		Goldston	2	10	13	11	6.5	42.5	VB	09/02/08				
		Goldston	2	8	15.5	8.5	6	40	VB	11/01/06				
		Hart	2	5	14.5	8	11.5	41	RS	11/21/06	41	41	0	**41.00**
		Hart	2	5	13	9	12	41	VB	11/21/06				
Lockwood Folly	Riverine Swamp Forest	Doe Creek	2	9	28.5	16	18	73.5	RS	10/15/08	70.5	84	13.5	**77.00**
		Doe Creek	2	9	31.5	17.5	20	80	RS	10/18/06				
		Doe Creek	2	9	26.5	15.5	17.5	70.5	VB	10/15/08				
		Doe Creek	2	11	32	18	21	84	VB	10/18/06				
		Hewett Wildlife	2	12	29	19	18.5	80.5	RS	11/16/06	77	83.5	6.5	**80.13**
		Hewett Wildlife	2	13	33	19	16.5	83.5	RS	15/15/08				
		Hewett Wildlife	2	13	31	17.5	16	79.5	VB	10/15/08				
		Hewett Wildlife	2	11	29	17	18	77	VB	11/16/06				
		Lockwood	3	9	24.5	17	17	70.5	RS	10/15/08	70.5	79.5	9	**74.75**
		Lockwood	3	10	25	18	16.5	72.5	RS	10/15/08				
		Lockwood	3	10	30.5	17	16	76.5	RS	11/14/06				
		Lockwood	3	10	30.5	18.5	17.5	79.5	VB	11/14/06				
		Mercer Seawatch	3	14	26	19	15.5	77.5	RS	10/15/08	76.5	80.5	4	**78.25**
		Mercer Seawatch	3	14	28	18	15.5	78.5	RS	11/15/06				
		Mercer Seawatch	3	14	26	19	18.5	80.5	VB	10/15/08				
		Mercer Seawatch	3	14	27	18	14.5	76.5	VB	11/15/06				
		Rourk	2	13	24.5	15.5	7.5	62.5	RS	10/15/08	57	71.5	14.5	**64.50**
		Rourk	2	12	29.5	14	14	71.5	RS	10/19/06				

RS = Rick Savage and VB = Virginia Baker

Table 2.2.2-1 ORAM Results for the Fishing Creek and Lockwood Folly Watershed Wetlands

Watershed	Wetland Type	Site	Area	Buffer	Hydrology	Habitat	Community	Total	Observer	Date	Min	Max	Range	Mean
Lockwood Folly	Riverine Swamp Forest	Rourk	2	13	23	12	7	57	VB	10/15/08	57	71.5	14.5	**64.50**
		Rourk	2	12	30	10.5	12.5	67	VB	10/19/06				
		Winding River Pond	2	8	26	17	16	69	RS	10/15/08	65.5	72	6.5	**68.88**
		Winding River Pond	2	4	29	14.5	16	65.5	RS	10/20/06				
		Winding River Pond	2	8	26.5	18	17.5	72	VB	10/15/08				
		Winding River Pond	2	7	29	13.5	17.5	69	VB	10/20/06				
		Winding River Townhouse	2	8	20	14	13	57	RS	10/15/08	50.5	57	6.5	**55.00**
		Winding River Townhouse	2	7	19.5	9	13	50.5	RS	11/14/06				
		Winding River Townhouse	2	8	19	13.5	13.5	56	VB	10/15/08				
		Winding River Townhouse	2	8	23	9	14.5	56.5	VB	11/14/06				
	Small Basin Wetland	Bluegreen Golf	2	3	15	12	12.5	44.5	RS	10/16/08	44.5	50	5.5	**46.50**
		Bluegreen Golf	2	3	16.5	11	13.5	46	RS	11/16/06				
		Bluegreen Golf	2	3	16	12	12.5	45.5	VB	10/16/08				
		Bluegreen Golf	2	3	17.5	13.5	14	50	VB	11/16/06				
		Martin-Amment	3	9	26	19	19	76	RS	10/16/08	75	78.5	3.5	**77.00**
		Martin-Amment	3	9	24	16.5	22.5	75	RS	10/19/06				
		Martin-Amment	3	10	26	19	20.5	78.5	VB	10/16/08				
		Martin-Amment	3	10	24.5	16.5	24.5	78.5	VB	10/19/06				
		Mill Creek	2	10	21	18	10	61	RS	10/16/08	61	74.5	13.5	**67.88**
		Mill Creek	2	9	32	18	12	73	RS	10/20/06				
		Mill Creek	2	10.5	24	18	8.5	63	VB	10/16/08				
		Mill Creek	2	9	33	19	11.5	74.5	VB	10/20/06				
		Seawatch Bay	3	14	32	19	20	88	RS	10/16/08	88	90.5	2.5	**89.25**
		Seawatch Bay	3	14	32	20	19.5	88.5	RS	11/15/06				
		Seawatch Bay	3	14	32	20	21.5	90.5	VB	10/16/08				
		Seawatch Bay	3	14	32	20	21	90	VB	11/15/06				
		Seawatch Nautica	2	14	24	18	16	74	RS	10/16/08	70	74	4	**71.63**
		Seawatch Nautica	2	14	22.5	16	16	70.5	RS	11/30/06				
		Seawatch Nautica	2	14	24	15.5	16.5	72	VB	10/16/08				
		Seawatch Nautica	2	14	21.5	16	16.5	70	VB	11/30/06				
		Sikka	3	10	23	17	18	71	RS	10/16/08	71	88.5	17.5	**80.63**
		Sikka	3	12	30.5	18.5	22	86	RS	11/30/06				

RS = Rick Savage and VB = Virginia Baker

Table 2.2.2-1 ORAM Results for the Fishing Creek and Lockwood Folly Watershed Wetlands															
Watershed	**Wetland Type**	**Site**	**Area**	**Buffer**	**Hydrology**	**Habitat**	**Community**	**Total**	**Observer**	**Date**	**Min**	**Max**	**Range**	**Mean**
Lockwood Folly	**Small Basin Wetland**	Sikka	3	10	24.5	17.5	22	77	VB	10/16/08	71	88.5	17.5	**80.63**
		Sikka	3	12	30.5	19.5	23.5	88.5	VB	11/30/06				

RS = Rick Savage and VB = Virginia Baker

Section 2.3 Level III Intensive Survey Methodology Outline

Field data were collected on water quality, hydrology, soils, amphibians, aquatic macroinvertebrates, and plants. The following provides a brief description of the methods, which are described in detail in Section 4. Results are found in Sections 5 and 6.

1. **Water Quality** – Water quality was monitored quarterly for 15 months from early February 2007 to late April 2008. The pH, dissolved oxygen, specific conductivity, and temperature were taken each quarter and water samples were collected for total suspended solids, turbidity, fecal coliform, nutrients (NO_2+NO_3, phosphorous, ammonia, and total Kjeldahl), metals (lead, copper, zinc, calcium, and magnesium), total organic carbon, and dissolved organic carbon. Water quality was typically collected from three stations at the Riverine Swamp sites ("up-river", "down-river", and "buffer" stations), two stations in the bottomland hardwood sites ("upstream" and "downstream" stations) and one station in the Small Basin sites ("wetland" station). Due to extreme drought conditions, surface water samples were unattainable after April 2007 at some of the basin sites and not always available at other wetland sites (see Section 4.1).

2. **Hydrology –** Hydrological data were collected at each site from one or two 1.8 feet deep surface water monitoring wells for 16-17 months from June of 2007 to October 2008. Typically two automated wells were installed at the Riverine Swamp and bottomland hardwood sites and one automated and one non-automated were installed at the Small Basin wetlands. Automated wells were outfitted with Level Troll 500 vented pressure transducers. Data from the pressure transducers were collected in the field and downloaded to a spreadsheet program every three months. Pressure transducer water level readings were always field proofed with measurements taken by hand every three months (see Section 4.2).

3. **Soils –** Core samples were taken at 6-10 stations within each wetland: 4-6 in the wetland and 2-4 in the surrounding upland. Each soil core was examined in the field for the number of horizons and color, texture and width of each identified horizon. Soil samples were collected for each horizon at each station for all sites and analyzed for nutrients (phosphorus, nitrate, nitrogen, potassium, calcium, magnesium, and sodium), metals (also called micronutrients- manganese, zinc, and copper), weight/volume, exchangeable acidity, sum of the cation, cation exchange capacity, base saturation, and humic matter. All samples were analyzed at the North Carolina Division of Agronomy, Soils Testing Lab I Raleigh, North Carolina (see Section 4.3).

4. **Amphibians –** A semi-qualitative amphibian survey of approximately three man hours per site was performed in March and June of 2007. Two funnel traps were also set out at most sites for approximately 24 hours during the March survey and a 10 minute auditory night survey was also conducted in June 2007. All visual and auditorial observations of amphibians were recorded. Voucher specimens and / or photographs were taken for identification and record purposes for all captured amphibians that were not identifiable in the field. Dip-nets for standing water areas, potato rakes for moving logs, and a tape recorder were used with the amphibian survey work (see Section 4.4).

5. **Aquatic macroinvertebrates** – Up to five (depending on specific site condition) macroinvertebrate sample stations were established at each site. Macroinvertebrate samples were collected with sweep nets and funnel traps in March of 2007 in conjunction with the amphibian survey (see Section 4.5).

6. **Plants** – A qualitative presence / absence plant survey was performed at all sites in the fall of 2006. A quantitative survey was performed during the spring or summer of 2007 or 2008 using methodology derived from the Carolina Vegetative Survey (Peet et. al. 1997). This methodology included surveying the presence and coverage of all plant species and diameter at breast height of the woody species (see Section 4.6).

Section 2.4 Index of Biotic Integrity Development

Section 2.4.1 – Water Quality Disturbance Measures

Disturbance measurements for water quality parameters were developed with average site surface water quality results for 18 water quality parameters. These include ammonia, calcium, copper, dissolved organic carbon (DOC), dissolved oxygen (percent and mg/L), lead, magnesium, nitrite + nitrate (NO_2+NO_3), phosphorous, specific conductivity, total kjeldahl (TKN), total organic carbon (TOC), total suspended solids (TSS), turbidity, zinc and pH. A "combination" water quality disturbance measurement was also developed by first determining the relative average for each parameter for nutrients, metals (copper, zinc, and lead only), specific conductivity, and TSS for each site. Relative averages were determined by wetland type and by wetland type by region. The relative averages of these nine parameters were then summed which resulted in a water quality combination disturbance measurement for each site. The different measurements, including the average surface water quality results and the combination disturbance measurement were tested for normality using the Shapiro-Wilk W Test ($P > 0.05$ indicated a normal distribution). The water quality disturbance combination score is shown in table 2.4-1.

Section 2.4.2 - Soil Disturbance Measures

At each wetland site, 6 to 10 soil samples were collected and analyzed for a number of parameters including pH, copper, and zinc. As explained in Section 2.3 and 4.3, 2 to 4 samples were collected in the upland and 4 to 6 samples were collected in the wetland. The average value for each site's wetland samples was calculated for pH, copper, lead, and zinc at each site. These average results were used as disturbance measurements for soil pH, soil copper and soil zinc (see Table 2.4-1). These metals can be particularly toxic to amphibians. Upland soil samples were not used as disturbance measurements or in the disturbance measurement calculation since all macroinvertebrate samples were collected within the wetland (See Section 4.5). In addition, many of the amphibians were observed in the wetland rather than the upland buffer during the amphibian survey (see Section 4.4). The soil disturbance mean values are shown in table 2.4.2-1.

Table 2.4.1-1 Water Quality Disturbance Measurements

Wetland Type	Site Name	Water Quality Combo	Ammonia (mg/L)	Calcium (mg/L)	Copper (ug/L)	DOC (mg/L)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Lead (ug/L)
Bottomland Hardwood	Fairport	62.8	0.05	10.2	2.56	22.33	20.75	2.15	10
	Gray	268.99	0.22	10.5	29	8.75	25.95	3.4	78
	Hancock	139.73	0.08	25.58	12.55	16.79	28.1	3.1	27.13
	Kim Brooks	127.56	0.03	43.67	10.3	22	5.57	0.65	11
	Munn	190.97	0.22	8.27	19.68	11.59	33.97	5.24	27.08
	Powers	109.95	0.16	11.06	9.06	35.42	17.34	1.93	15.2
Small Basin Wetland	Belton Creek	37.44	0.03	4.1	2.85	60.5	17.93	1.78	10
	Dargan	44.34	0.03	2.63	2.8	44.17	30.03	3.3	10
	Dean	170.23	1.41	9.12	7.48	30.17	10.73	1.19	10
	Eastwood	93.23	0.38	7.84	6.7	24.24	47.7	7.5	10.71
	Goldston	85.11	0.23	8.5	8.1	38.33	15.64	1.34	12.6
	Hart	110.32	0.04	5.6	4.43	33.63	85.07	8.08	14.67
Riverine Swamp	Doe Creek	113.27	0.15	82.06	13.38	12.78	48.31	4.74	19.06
	Hewitt	50.02	0.17	31.58	4.94	14.03	23.9	2.98	20.59
	Lockwood	243.34	0.83	122.76	18.33	22.22	25.78	2.75	39
	Mercer Seawatch	163.18	0.73	36.83	13.72	13.58	33.96	3.56	62.04
	Rourk	213.76	0.17	49.8	52.1	11.03	13.36	1.47	101.4
	Winding River Pond	57.09	0.06	38.14	5.37	18.61	22.65	2.44	28.06
	Winding River Townhouse	59.34	0.04	21.11	5.24	10.15	9.74	1.04	15.9
Small Basin Wetland	Bluegreen Golf	26.66	0.02	4	2	4.9	45.8	5.6	10
	Martin Amment	35.29	0.17	1.15	2	38	25.9	2.85	10
	Mill Creek	27.39	0.02	3.38	2	17.25	15.85	1.95	10
	Seawatch Bay	67.53	0.92	1.9	2.05	33.38	74.23	6.62	10
	Seawatch Nautica	147.2	0.69	2.07	10.33	37.33	28.47	3.13	25.33
	Sikka	108.88	0.83	8.51	4.11	39.78	78.61	6.94	10.89

Table 2.4.2-1 Soil Disturbance Table for IBI Development

Wetland Type	**Site Name**	Mean		
		Mean pH	Zn mg/dm^3	Cu mg/dm^3
Bottomland Hardwood	Fairport	5.27	2.37	1.5
	Gray	4.88	1.26	0.61
	Hancock	5.16	2.51	1.86
	Kim Brooks	5.15	1.9	1.98
	Munn	4.84	0.89	1.56
	Powers	4.96	2.21	1.29
Small Basin Wetland	Belton Creek	4.41	2.88	1.45
	Dargan	4.39	1.64	1.05
	Dean	4.67	1.13	0.86
	Eastwood	4.68	1.43	0.77
	Goldston	4.48	1.2	0.65
Riverine Swamp	Doe Creek	4.86	2.61	0.34
	Hewitt	4.57	1.6	0.23
	Lockwood	5.23	0.93	0.23
	Mercer Seawatch	4.88	1.35	0.23
	Rourk	4.77	1.38	0.36
	Winding River Pond	4.87	0.64	0.24
	Winding River Townhouse	5.44	1.14	0.25
Small Basin Wetland	Bluegreen Golf	4.62	0.44	0.34
	Martin Amment	3.65	0.66	0.86
	Mill Creek	4.5	0.39	0.33
	Seawatch Bay	4.09	1.23	0.36
	Seawatch Nautica	3.81	0.8	0.37
	Sikka	4.05	0.4	0.33

Section 2.4.3 Statistical Analyses of Biotic Data for Indices of Biotic Integrity Development

Indices of Biotic Integrity (IBIs) were developed for the two biotic sections- amphibians and plants of the Wetlands Monitoring Grant (methods used to evaluate the abiotic sections of the grant are described in section 3.5). A set of biological attributes were identified and evaluated for use as candidate metrics in taxa specific IBIs (i.e. amphibians and plants). Different types of biological attributes were evaluated for each taxa group such as species richness, percent tolerant species, and percent sensitive species. The exact biological attributes that were evaluated and chosen as candidate metrics for each taxa group are described further in Sections 5 and 6.

Various wetland disturbance measurements were produced in order to test candidate metrics for each taxa group. Disturbance measurements used to test metrics include a Level 1 GIS assessment (LDI – Land Development Index), Level 2 wetland rapid assessment (ORAM – Ohio Rapid Assessment Method), and Level 3 summary of the intensive survey of each site's water quality and soils. The development of the disturbance measurements were described in detail in Sections 2.1, 2.2.2, 2.4.1, and 2.4.2.

Disturbance measurements (the independent X variable) and candidate metrics (the dependent Y variable) for each taxon group were tested for normality by plotting normal quartile plots and using the Shapiro-Wilk W Goodness of Fit test (p-value < 0.05 indicated a normal distribution). Pairwise comparisons using correlation analyses, including Spearman's Rho (a non-parametric test) and Pearson's correlations, were run for the candidate metrics of each taxon group of candidate metrics against the disturbance measurements. For the Pearson's correlation, disturbance measurement and candidate metrics that did not have a normal distribution were transformed using a log 10 transformation prior to running a Pearson's correlation. Correlation results of candidate metrics and disturbance measurements that had a p-value < 0.15 were considered significant and therefore potentially usable as a metric in the taxon group's IBI (ultimately, the metrics that were used in the plant and amphibian IBIs had a p-value < 0.10) Correlation tests were run for each wetland type (Riverine Swamp Forest, Bottomland Hardwood Forest and Small Basin Wetland) separately. For the Small Basin wetlands correlations were run on all sites together and then using the Coastal Plain and Piedmont regional data separately (See Sections 4, 5 and 6).

Section 2.5 Statistical Analysis of Wetland Monitoring Data

Summaries of all the results for the wetland types are given where appropriate. Specifically, results are summarized for each monitoring site and then for each wetland type, such that overall comparisons can be made between the sites and between the wetland types. For the Riverine Swamp Forests, water quality samples were taken upriver and downriver, so the analysis looked for any improvements in water quality as the surface water flowed though the wetland. Samples were also taken in the buffer areas of the Riverine Swamp Forests, so the analysis will evaluate differences in the buffer samples with the samples taken upriver and downriver. For the Bottomland Hardwood Forests, four of the sites had water quality samples taken at upstream locations and downstream locations, so the analysis looked for improvements in water quality as water flowed through the system. Two Bottomland Hardwood Forests sites (Gray and Kim-Brooks) did not have readily defined outlets, so no downstream samples were taken. Finally, water quality was analyzed between the wetland types to determine what differences may exist between them such as which pollutants may be more revalent in a Small Basin wetland versus a Bottomland Hardwood Forest or Riverine Swamp Forest. This analysis may be an indication of how the wetland types may perform in terms of improving water quality. The water quality analyses also compareed the Small Basin wetlands between the two watersheds (and physiographic regions) to look at potential differences in their function.

Soil data were also compared between wetland types. A comparison between the Small Basin wetlands in the two watersheds (and physiographic regions) was performed to look at those potential differences in soil characteristics. Finally, upland soil samples were compared with wetland soil samples to analyze differences and this will be analyzed across wetland type also.

Hydrology data were analyzed over time for each wetland type. Differences between the wetland types will be noted with a comparison of the Small Basin wetlands between the two watersheds. During the study period, drought conditions were experienced and this effect on hydrology will be noted and how the wetlands and wetland types tended to be affected and how they recovered. Emphasis will be given to comparing the recovery of the Small Basin wetlands between the two watersheds.

Level III data were analyzed using the level II ORAM scores as a disturbance gradient. Water quality data, soil data, and hydrology data were compared with ORAM scores to determine the characteristics of least disturbed wetlands with wetlands that are more disturbed. For example, do higher levels of pollutants occur in the water or soil samples in disturbed wetlands versus non-disturbed wetlands based on ORAM scores? Does the hydrology tend to be different in disturbed wetlands in terms of flashiness or water levels? This same type of analysis will be performed with the Level I Land Development Index (LDI). Again, determination of whether levels of water or soil pollutants are higher in more developed watersheds versus less developed watersheds was analyzed.

Another purpose of this wetland monitoring research was to continue to evaluate NCWAM with Level III data. Therefore, correlations with the Level III data for each wetland type were conducted with NCWAM scores. Water quality data was correlated with the NCWAM overall score and water quality sub-function of NCWAM. The results will be a basis for an initial calibration of NCWAM for these three wetland types. A more extensive evaluation of NCWAM for Headwater Wetlands is being conducted with Level III monitoring data by NC DWQ with statistical assistance from the Research Triangle Institute (Development of a Wetland Monitoring Program for Headwater Wetlands in North Carolina, grant CD# 9754260-01 and Wetland Functional Assessment: Expansion and enhancement of the North Carolina Wetland Assessment Method, (NC WAM) (grant WL 9643505-1).

Biological data (vegetation, amphibian, [and macroinvertebrate at a later time]) will be used to develop Indices of Biological Integrity (IBI's) as described in section 2.5. The IBI results will determine if there are relationships between the biological data and disturbance scores or LDI scores. Biological data will also be analyzed by wetland type to look at differences between them. In other words, what are the vegetation characteristics of each wetland type? What types of amphibians inhabit each wetland type? In particular, are there differences between the Small Basin wetlands in the two watersheds? Biological data will also be correlated with NCWAM, particularly the habitat sub-function. This will help further calibrate NCWAM for these wetland types.

Two Riverine Swamp Forests, two Bottomland Hardwood Forests, and four Small Basin wetlands (two in the Lockwood Folly River watershed and two in the Fishing Creek watershed) will continue to be monitored. Six Headwater Wetlands are also continuing to be monitored from the first wetlands monitoring project (grant CD# 9754260-01). These long term monitoring sites will serve as a basis for establishing a long term wetland monitoring project in North Carolina. Separate analysis of the long term data will be conducted and reported in a future report. Trends in the data over time will be analyzed to determine any changes in the monitored wetlands.

One Statistical concern that needs to be addressed is the use of the p-value of 0.15. We use a more liberal probablility value due to the nature of our research in that it is field data and not laboratory data, small samples sizes, missing data, not always normally distributed, and being natural systems in a natural setting makes data collection more variable. We also have a desire (goal) not to miss any potential significant results. Given the exploratory nature of the research, we want to be sure we uncover all potential significant results and let the test of time prove them to be correct (or not). This is part of the analysis that will occur with our long term wetland monitoring sites.

The development of the IBI's however, uses a stricter p-value of 0.1. It was felt that a stricter p-value was needed for any kind of model development.

Section 3 - Site Selection, Site Delineation, and Watershed and Site Description

Section 3.1.1 Site Selection Methods

Wetland study sites were located during the summer and early fall of 2006 in both the Fishing Creek and Lockwood Folly River watersheds. In the Lockwood Folly River, watershed GIS layers including North Carolina Coastal Region Evaluation of Wetland Significance (NC-CREWS), National Resource Conservation Service (NRCS) Soils, Brunswick County 2006 infrared aerial, and USGS 1:24,000 topographical quads were used to develop reconnaissance maps to search for Riverine Swamp Forests and Small Basin wetlands for use in this study. GIS layers used to develop reconnaissance maps in the Fishing Creek watershed included National Wetland Inventory, NRCS Soils, 1998 DOQQs and USGS 1:24,000 topographical quad. Reconnaissance maps were used to make field visits in both watersheds where potential sites were accessed for usability in this study. In the Fishing Creek Watershed, a couple of non-mapped Small Basin wetlands (the Hart and Dean sites) were found while trying to access other sites. For each site, a wetland determination was made by reviewing soil, hydrology, and dominant plant species. Wetland type was determined with the NCWAM Dichotomous Key to General North Carolina Wetland Types (v5.12). In addition general notes were made on the condition of the wetland, dominant plant species and accessibility. Sites were chosen based on accessibility, size, land-owner permission, and site condition. Sites that appeared to be variable in quality (for example clear cut as opposed to forested with mature trees) were chosen. In addition in Brunswick County, some of the sites were located in new development areas in the pre-construction stage. Some of these sites (e.g. the Seawatch and Mill Creek sites) were chosen for this study and with the goal of long-term monitoring to detect changes.

Section 3.1.2 Site Delineation and Features Recorded with GPS

All wetlands were delineated using methods described in the US Army Corps of Engineers Wetland Delineation Manual, 1987 (Environmental Laboratory 1987). The upland wetland delineation line determined the site boundary for most of the Small Basin wetlands in the Fishing Creek and Lockwood Folly River watersheds. In Fishing Creek, two of the wetlands had natural outlets, one that continued to a stream (Eastwood) and one that entered a ditch that ended some yards from the wetland. The outlets were not included within the site boundary for the Fishing Creek sites. Similarly, in the Lockwood Folly River watershed, three of the sites had connecting ditches or outlets (Bluegreen Golf, Mill Creek and Seawatch Nautica) that were not included in the delineation. Two other sites in the Lockwood Folly River watershed were too large to use the entire basin (Seawatch Bay and Sikka) therefore a portion of these two sites which included open water areas was utilized.

The bottomland hardwood wetland sites, located in the Fishing Creek Watershed, were delineated along the upland wetland boundary or a habitat boundary as was the case at the Hancock Site. The sites were either adjacent or close to a river or stream (second order or greater) or associated with one. In some situations (Hancock and Powers), a sewage line was located between the site and the stream so the sewage line was used as the boundary along one side of the site.

The Riverine Swamp wetlands of Lockwood Folly River are generally extensive systems that were too large in size for the entire wetland to be used as a research study site. Approximately 300-400 feet of Riverine Swamp (measured along the upland wetland boundary of one side of the swamp) was used at each site. Both sides of the river or stream associated with the 400 feet of Riverine Swamp were used if accessible. However, this was usually not the case. At the Doe Creek site, 200 feet on either side of Stone Chimney Rd, on both sides of Doe Creek were delineated for the assessment area. At the Mercer Seawatch site, 200 feet on either side of the proposed right-of-way for the bridge crossing of Mill Creek were delineated on just the north side of the creek. Both sides of the proposed right-of-way were surveyed for the Mercer Seawatch site. At Hewitt Wildlife and Lockwood sites a section of Riverine Swamp was delineated on just the south side of Sandy Branch and the Lockwood Folly River respectively. The Winding River sites were delineated approximately 300 feet on either side of Zion Hill Road. Both sides of the Sandy Branch were delineated for Winding River Pond site on the east side of Zion Hill Road. For Winding River Townhouse site just the north side of Sandy River Branch was delineated on the west side of Zion Hill Road (Townhouses were on the south side of Sandy Branch). For the Rourk site, both side of the stream were delineated, although only the west side was 300 – 400 feet in length due to curves in the stream and changes in habitat. The Rourk site transitioned to fresh water tidal marsh at the south end of the site.

GPS points were recorded along contours in the wetland boundary, at water quality sampling stations, wells, macroinvertebrate sampling stations, and at the corners of the vegetation sampling plot.

Section 3.2 Watershed and Site Descriptions (Wetland Types as defined by NCWAM)

Watershed Descriptions

Fishing Creek Watershed

The Fishing Creek watershed (see Figure 3.2-1) is located in the north central part of the state within the Tar-Pamlico River Basin (Catalog Unit 03020101) in Granville (primarily ~93%), Vance (~5%), and Franklin (~2%) counties, near the town of Oxford. The watershed itself is 69.7 square miles in size. The NC Department of Transportation has three roadway improvement projects planned for this region of the state. Fishing Creek is a major and important tributary of the Tar River and is also considered to be impaired due to having a poor aquatic macroinvertebrate community and has been placed on the North Carolina’s 303(d) list. This impairment may be related to the Oxford wastewater treatment plant, which is situated just to the south of Oxford at the headwaters of Fishing Creek (http://www.nceep.net/services/lwps/Fishing/Fishing_Creek.pdf). The town of Oxford has a population of 24,040. Most of the area surrounding Oxford within the watershed is composed of pastureland, cropland and low-density housing. Most of the section of the Tar River that runs through the Fishing Creek watershed has been designated as a Significant Natural Heritage Area by the NC Natural Heritage Program since it provides habitat for rare aquatic and wetland species (e.g. mussels). The Tar River Land Conservancy also maintains two significant easements along the Tar River in the study area (http://www.nceep.net/services/lwps/Fishing/Fishing_Creek.pdf).

Lockwood Folly River Watershed

The Lockwood Folly River watershed is located the southeastern part of the state (see Figure 3.2-2) entirely within the Coastal Plain county Brunswick in the Lumber River Basin (Catalog Unit 03040207). The watershed used in this study was 55 square miles in size. The Lockwood Folly River starts near the town of Bolivia and drains into the Atlantic at the Lockwood Folly River Inlet. Much of the watershed is forested. However, that is quickly changing due to the pressures of residential golf course development in the region. Similar to Fishing Creek, the Lockwood Folly River is impaired due to the presence of fecal coliform that has impacted the shellfish population causing this river to be placed on the 303(d) list. High nutrient levels have been a recorded in the Lockwood Folly River watershed (http://www.nceep.net/services/lwps/Upper_Neuse/Lake_Rogers.pdf). Development has been rapid along US Highway 17, NC Highway 211 and in other areas to the south. However there are large tracts of land to the north which have remained undeveloped mainly in the Green Swamp although there have been extensive silviculture activities in this area (http://www.nceep.net/services/lwps/Upper_Neuse/Lake_Rogers.pdf).

Figure 3.2-1 Fishing Creek Watershed

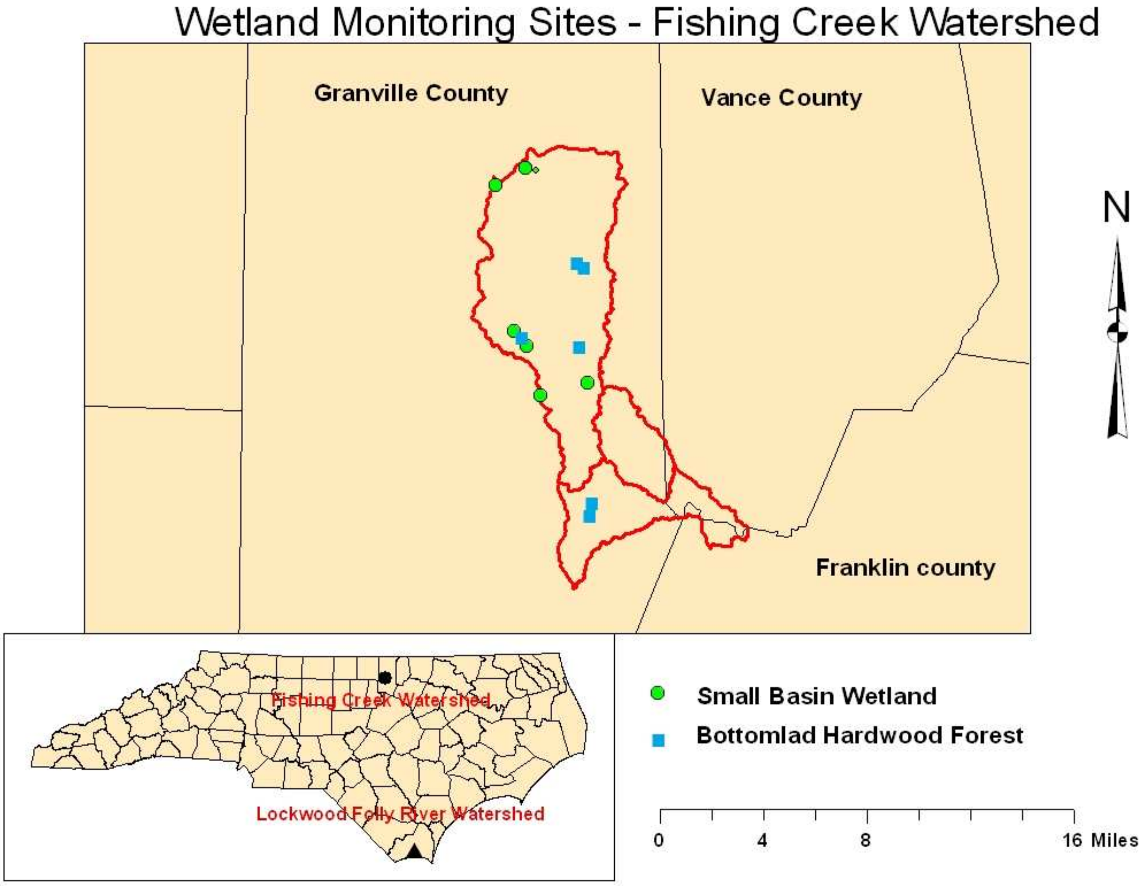
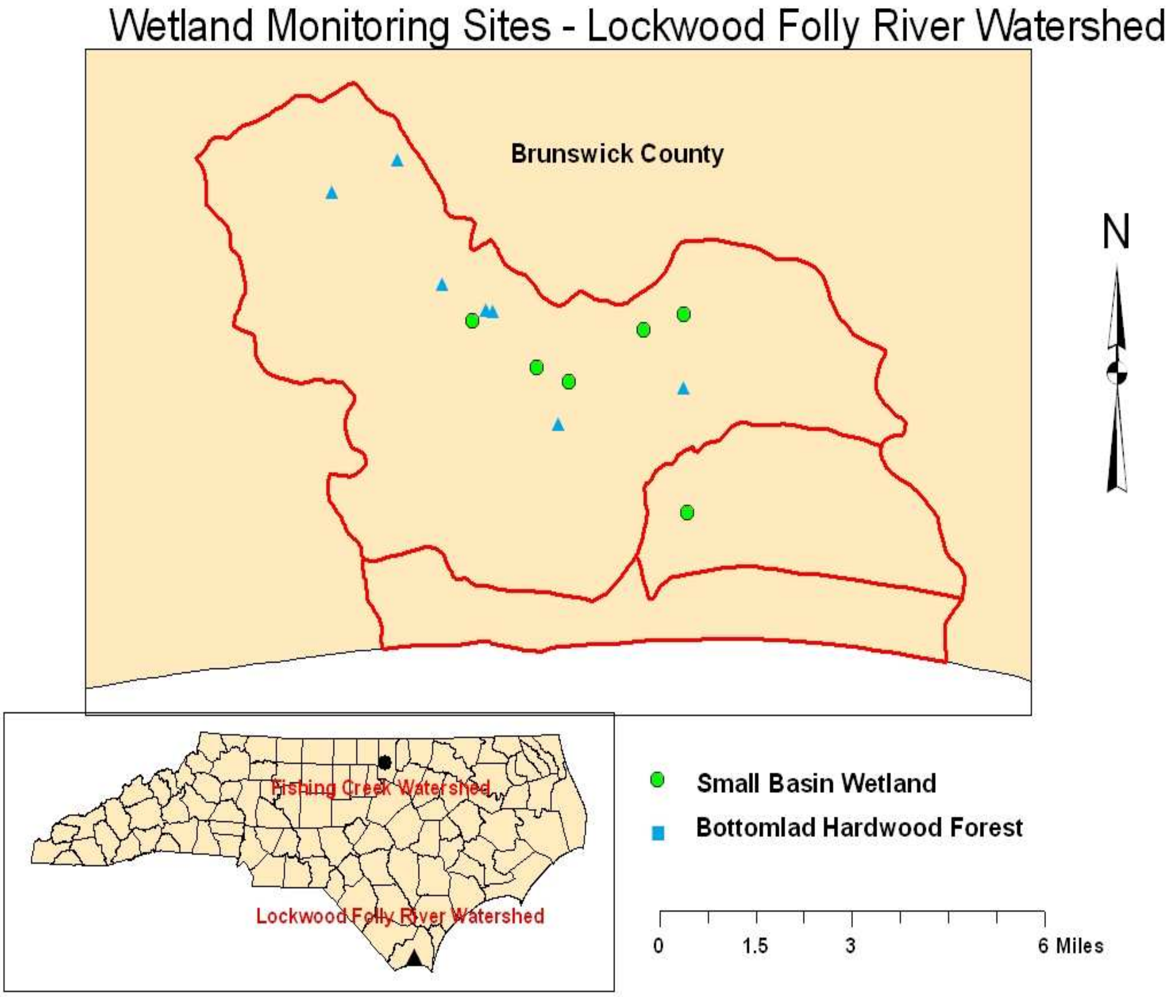


Figure 3.2-2 Lockwood Folly River Watershed



Site Descriptions

Site descriptions for the Fishing Creek Small Basin wetlands and Bottomland Hardwood Forests and Lockwood Folly River Small Basin wetlands and Riverine Swamp Forests are listed below. Infrared aerial maps and photos for each site can be found in Appendix B. Table 3.2-1 shows the acreage and the latitude and longitude for each site.

Table 3.2-1 Site Acreage, Longitude, and Latitude

Watershed	Wetland Type	Site Name	Acres	Longitude	Latitude
Fishing Creek	Bottomland Hardwood	Fairport	1.72	78°34'5.23"W	36°16'14.124"N
		Gray	0.14	78°33'33.769"W	36°10'57.736"N
		Hancock	2.09	78°33'51.719"W	36°18'55.307"N
		Kim Brooks	1.27	78°36'22.095"W	36°16'28.113"N
		Munn	1.76	78°33'38.484"W	36°10'31.769"N
		Powers	2.80	78°34'29.779"W	36°19'15.798"N
	Small Basin Wetland	Belton Creek	0.70	78°35'40.441"W	36°14'35.767"N
		Dargan	0.91	78°37'31.266"W	36°21'43.561"N
		Dean	1.05	78°36'47.623"W	36°16'47.893"N
		Eastwood	3.07	78°36'13.378"W	36°22'13.241"N
		Goldston	0.78	78°36'17.018"W	36°16'18.271"N
		Hart	0.42	78°33'4.565"W	36°13'19.921"N
Lockwood Folly	Riverine Swamp	Doe Creek	2.67	78°16'48.518"W	34°0'15.078"N
		Hewitt	1.39	78°15'3.377"W	33°59'10.183"N
		Lockwood	5.80	78°15'44.181"W	34°0'40.404"N
		Mercer Seawatch	3.24	78°11'6.786"W	33°57'52.311"N
		Rourk	1.18	78°13'11.658"W	33°57'28.816"N
		Winding River Pond	0.91	78°14'13.273"W	33°58'50.885 "N
		Winding River Townhouse	0.59	78°14'19.056"W	33°58' 50.34"N
	Small Basin Wetland	Bluegreen Golf	1.82	78°14'34.143"W	33°58'42.936"N
		Martin Amment	3.18	78°11'45.318"W	33°58'35.399"N
		Mill Creek	1.02	78°13'0.431"W	33°57'56.657"N
		Seawatch Bay	3.01	78°11'5.585"W	33°56'22.771"N
		Seawatch Nautica	2.05	78°11'7.009"W	33°58'46.077"N
		Sikka	4.33	78°13'29.713"W	33°58'7.554"N

Fishing Creek Watershed – Small Basin wetlands (SmBW)

Belton Creek – The Belton Creek site is a 0.70 acre isolated Small Basin wetland in southeast Granville County about four miles south of Oxford, North Carolina. Approximately 70 percent of the wetland and area immediately surrounding it were logged in the last 10 to15 years. The wetland is buffered by mature forest to the north and 15 to 20 year old second-growth forest on all other sides. There is a logging road located 110 feet south of the Belton Creek site, otherwise the buffer is greater than 500 feet on all sides. Major disturbances are the aforementioned logging and canopy gaps created by windthrow- the amount of which is significant. Canopy consists of sweet gum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), and along the sunnier edges, loblolly pine (*Pinus taeda*). Hydrology has had minor affects by the ruts and ditching associated with the use of heavy equipment in logging operations. The wetland is a bowl-shaped depression with good herb cover and was a productive site for breeding amphibians during amphibian surveys in March 2007. Schafale and Weakley's "Classification of the Natural Communites of North Carolina, Third Approximation" (1990) would define the Belton Creek site as primarily Upland Depression Swamp Forest with a section of Upland Pool in the interior of the site.

Dargan – The Dargan site is a 0.91 acre isolated Small Basin wetland located in north-central Granville County about three miles northwest of Oxford, North Carolina. The wetland is buffered on all sides by at least 200 feet of mature hardwood forest. The wetland itself is approximately 1000 feet west of Sterl Carrington Road, a two-lane paved road. The canopy is open with red maple, sweet gum, and black gum (*Nyssa sylvatica*) dominant around the edge of the wetland. The shrub layer is substantial and consists mainly of black highbush blueberry (*Vaccinium fuscatum*). Dargan appears to be a high quality Small Basin reference site with little human impact. The "Third Approximation" (Schafale and Weakley, 1990) would define the Belton Creek site as Upland Depression Swamp Forest with a section of Upland Pool located in the interior of the site.

Dean – The Dean site is a 1.05 acre isolated Small Basin wetland in central Granville County about two miles southeast of Oxford, North Carolina. The north side of the wetland has not been recently disturbed though agricultural fields buffer the wetland to the northwest and are found within 75 feet of the wetland. The southern fifth of the wetland was logged in the past 15 years. The remaining buffers on all sides are forested. The wetland lies approximately 500 feet west of Hatcher's Run Creek. No obvious signs of altered hydrology are present though nearby agricultural probably probably contribute runoff to the wetland. There are downed trees and canopy gaps created by windthrow. Canopy consists of sweet gum, willow oak (*Quercus phellos*), and red maple. Non-native invasive species include Japanese stilt-grass (*Microstegium vimineum*), Chinese privet (*Ligustrum sinense*), and tree-of-heaven (*Ailanthus altissima*). The "Third Approximation" (Schafale and Weakley, 1990) would define the Dean site as an Upland Depression Swamp Forest.

Eastwood – The Eastwood site is a 3.07 acre non-isolated Small Basin wetland in north-central Granville County about three miles north of Oxford, North Carolina. The Eastwood site has a natural hydrological conveyance (zero-order stream) that drains to the northeast and connects with an unnamed tributary of Coon Creek. The entire Eastwood site buffer was clearcut within the last five years which has undoubtedly affected the hydrology of this site and caused it to become wetter. An agricultural field is also located 120 feet south of the site. There are few non-native invasive plant species though the area is heavily populated with “pioneering” species that are often first invaders in recently disturbed areas [e.g., red maple, sweet gum, common dog fennel (*Eupatorium capillifolium*), blackberry (*Rubus* sp.), etc.]. There are no tree species taller than 15 feet at the site or within the adjacent buffer except in the hedgerows between fields, and the area is dominated by grasses, sedges, rushes, and small shrubs. The “Third Approximation” (Schafale and Weakley, 1990) would define the Eastwood site as an Upland Depression Swamp Forest.

Goldston – The Goldston site is a shallow 0.78 acre Small Basin wetland in central Granville County about three miles south of Oxford, North Carolina. It is buffered by at least 500 feet of mature second-growth forest on all sides, with I-85 located 500 feet to the west. The nearly closed canopy is dominated by sweet gum and red maple with winged elm (*Ulmus alata*) and black gum co-dominating the understory. The herb layer is very sparse. There are remnants of narrow, shallow ditches through and at the edge of the wetland. The shallow ditching and silviculture bedding located in the buffer may alter the hydrology of the Goldston site. The “Third Approximation” (Schafale and Weakley, 1990) would define the Goldston site as an Upland Depression Swamp Forest.

Hart – The Hart site is a 0.42 acre isolated Small Basin wetland in southeastern Granville County about six miles south of the town of Oxford, North Carolina. This wetland resembles the Eastwood site since half of the Hart site and the entire buffer were logged extensively within the last 5 years. Some mature red maple, sweetgum, elm, green ash (*Fraxinus pennsylvatica*), willow oak (*Quercus phellos*), and mockernut hickory (*Carya tomentosa*) trees were left behind probably due to parts of the site being too wet to log. There is also a mature pine plantation 50 feet to the west of the Hart site. Tree removal and ruts left from logging have most likely affected the hydrology of this site. In early 2008, before NC DWQ personnel could complete a quantitative vegetation survey, ownership of this parcel changed hands and the new owner removed the well and piezometer. Therefore, a hydrological monitoring, vegetation survey and water quality monitoring were not completed due to denied site access. The “Third Approximation” (Schafale and Weakley, 1990) would define the Hart site as an Upland Depression Swamp Forest.

Fishing Creek Watershed – Bottomland Hardwood Forests (BLH)

Fairport – The Fairport site is a 1.72 acre Bottomland Hardwood wetland in east-central Granville County about three miles southeast of Oxford, North Carolina. Fairport Road is located 30-200 feet west of the site with a narrow strip of forested upland between it and the site. There is a narrow strip of upland along the south which then grades back into Bottomland Hardwood and mature forest is located along the north side. Mature forest extends to the east of Coon Creek. Coon Creek runs along the eastern edge of the buffer with a natural levee between it and the water. The wetland slopes down hill in an eastward direction with the deepest sections located closest to the river. Fairport receives overland flooding but rarely over riverbank flooding due to the deep incision of Coon Creek. There is a nearly closed canopy here consisting of green ash (*Fraxinus pennsylvanica*), sycamore (*Platanus occidentalis*), American elm (*Ulmus* *americana*), and sweet gum. Herb cover is sparse due to the standing water present through much of the year. The "Third Approximation" (Schafale and Weakley, 1990) would define the Fairport site as Piedmont / Mountain Bottomland Forest.

Gray – The Gray site is a 0.14 acre Bottomland Hardwood Forest wetland in southeast Granville County about 10 miles south of the town of Oxford and about one mile north of the Munn site, which itself is situated on Sandy Creek. The wetland is buffered on all sides by at least 125 feet of forest and stream. A 3rd order stream, Sandy Creek, and a 1st order unnamed tributary to Sand Creek lie to the east and north, respectivey. In addition, Phyllo White Rd (SR1623) is 140 feet to the northeast. The wetland lies at the base of a wooded slope, much resembling a hillside seep, but there is not enough lateral seepage from this slope to classify it as such. The dense canopy consists of red maple, white oak (*Quercus alba*), tulip-tree (*Liriodendron tulipifera*), with American elm and American hornbeam (*Carpinus caroliniana*) co-dominating the understory. The herbaceous layer is diverse and covers most of the wetland area. Non-native invasive species such as Japanese honeysuckle (*Lonicera japonica*), Japanese stilt-grass, and Chinese privet are present but not yet a significant threat to the wetland. "Third Approximation" (Schafale and Weakley, 1990) would define the Gray site as Piedmont / Mountain Bottomland Forest. This site appeared to be fairly dry, only a small portion of the site was observed to have standing water during the survey.

Hancock – The Hancock site is a 2.09 acre Bottomland Hardwood Forest wetland in east-central Granville County about one mile east of Oxford, North Carolina. A busy two-lane paved road, Williamsboro Street (SR158), abuts about 100 feet along its southern edge. The eastern edge is bordered by a wide sewer-line right-of-way which impedes natural flow to and from Coon Creek which is located just to the east of the sewer-line. On the southeast side about twenty percent of the wetland has been filled. Most likely this is old fill that was installed for residential yard reasons. To the west of the site, there is a residential home and to the north is a shrubby section dominated with Chinese privet. Natural habitat associated with the Coon Creek riparian corridor continues to the north. The existence of the sewer right-of-way seems to have raised the water table in this area. The canopy is extensive and consists of green ash, sweet gum, American elm, and red maple. The herb layer is dense but scattered and is mostly common woodreed (*Cinna arundinacea*) and sedges of the genus *Carex* spp. Due to the wetland's proximity to the sewerline right-of-way and the disturbance it receives through frequent maintenance efforts, invasive, non-native species are creeping into the wetland from the sewerline's edge. Present non-native invasives are Chinese privet, creeping-charlie (*Lysimachia nummularia*), ground-ivy (*Glechoma hederacea*), Japanese stilt-grass, Japanese honeysuckle, common water-purslane (*Ludwigia palustris*), and multiflora rose (*Rosa multiflora*). The fill and proximity to the sewer-line and road have probably contributed to the introduction of non-native invasives at the Hancock site. The "Third Approximation" (Schafale and Weakley, 1990) would define the Hancock site as Piedmont / Mountain Bottomland Forest.

Kim-Brooks – The Kim-Brooks site is a 1.27 acre Bottomland Hardwood Forest wetland in central Granville County about two miles south of Oxford, North Carolina. It is buffered by a strip of 100 to 150 feet of upland on all but the northeast side where forested upland continues to the north-northeast for another 1000 feet. Hatchers Run, (a 3rd order stream) is located to the north-northwest of the site. I-85, is located just outside the forested buffer to the east and south and NC 15, which is a busy a two-lane road, is located just outside the forested buffer to the west. At present, there are few non-native invasive species but there are small patches of Japanese stilt-grass that were noted during a vegetation survey in late-summer 2008. Additionally, poison ivy (*Toxicodendron radicans*), a native species that in large quantity can indicate disturbance, is highly dominant at this site. Poison ivy was well-represented throughout the vegetation plot by close to 100 individual plants reaching well into the canopy with branches extending out to 20' from the trunks of their host trees. The tree canopy is well-developed and consists of green ash, sweet gum, and American elm. The understory is also well-developed with American hornbeam and winged elm co-dominating. Some hydrological alterations may have occurred due to the incised stream. Additionally runoff from the highways in the form of polluted water is probably significant. The "Third Approximation" (Schafale and Weakley, 1990) would define the Kim-Brooks site as Piedmont / Mountain Bottomland Forest.

Munn – The Munn site is a 1.76 acre Bottomland Hardwood Forest Wetland with a section of Floodplain Pool in southeast Granville County about nine miles south of the town of Oxford and one mile south of another site, (the Gray site), which is also on Sandy Creek. The Munn site is buffered by 100 to 150 feet of wooded slope to the east. There is greater than 600 feet of forest on all other sides. Sandy Creek is located approximately 200 feet to the west of the Munn site. It has a nearly closed canopy of red maple, American elm, tulip-tree, and sweet gum. Non-native invasive plant species are the exotics Japanese stilt-grass, Japanese honeysuckle, and Chinese privet. The wetland is far enough away from the nearby residential area and any roads that there have probably been few man-made disturbances, though along the outer edges of the wetland windthrow has downed a few trees and created a few canopy gaps. The Munn site for the most part appears to be a quality representative bottomland hardwood site. There are no evident hydrological modifications. The hydrology of the area is influenced mainly by overbank flooding from nearby Sandy Creek (a third order stream). The "Third Approximation" (Schafale and Weakley, 1990) would define the Munn site as Piedmont / Mountain Bottomland Forest with a section of Floodplain Pool with a section of floodplain pool.

Powers – The Powers site is a 2.80 acre Bottomland Hardwood Forest wetland in east-central Granville County about one mile northeast of the town of Oxford, North Carolina. It is buffered by greater then 200 feet of mature forest to the north and east. Located to the west and south is a sewer-line adjacent to Coon Creek. The Powers site is less than one mile from the Hancock site which is also along Coon Creek. The Powers site has a dense canopy of American elm, red maple, green ash, and sweet gum. The ground layer is dominated by non-native invasive species such as Japanese stilt-grass, Japanese honeysuckle, ground-ivy, is the shrub Chinese privet. The stilt-grass is extensive and a major, and noxious, component of this site. The existence of the sewer-line and incised stream hinders natural overland flow to and from Coon Creek. There is also a ditch on the south side of the site that may have negatively altered the hydrology. The "Third Approximation" (Schafale and Weakley, 1990) would define the Powers site as Piedmont / Mountain Bottomland Forest.

Lockwood Folly River – Small Basin wetlands (SmBW)

Bluegreen Golf – The Bluegreen Golf site is a 1.82 acre non-isolated Small Basin wetland in southern Brunswick County about four miles south-southeast of Supply, North Carolina. The wetland itself is open and dominated with switchgrass (*Panicum virgatum*) and another *Panicum* spp (possibly *Panicum hemitomon*). The wetland is completely void of a natural buffer. There is a golf course associated with a residential area to the northeast and west of the site and Goley Hewett Rd, a two-lane residential street, is located directly to the south. Chemical runoff from the adjacent golf course and road is probably significant. There are narrow shallow ditches draining the eastern portion of the wetland. The Bluegreen Golf site has remained dry since the drought of 2007. The only canopy trees are approximately 25-year-old loblolly pine at the outer boundary of the wetland, and a row of shrub-sized swamp black gum (*Nyssa biflora*) which bisects the wetland. The shrubs along the interior edge of the wetland are thick and consist of ti-ti (*Cyrilla racemiflora*) and myrtle holly (*Ilex myrtifolia*). Other pocosin species such as fetterbush (*Lyonia lucida*) and highbush blueberry (*Vaccinium fuscatum*) are dominant around the edges of the wetland. The "Third Approximation" (Schafale and Weakley, 1990) would define the Bluegreen Golf site as a Vernal Pool surrounded by Small Depression Pocosin.

Martin-Amment – The Martin-Amment site is a 3.18 acre Small Basin isolated wetland in southern Brunswick County about eight miles southeast of Supply, North Carolina. It is buffered on all sides, except for 300 feet along the southeast edge, by an even-aged loblolly pine forest ranging from 50 to 150 feet deep. The southeast buffer is an area that was selectively logged fairly recently leaving scattered, mature, loblolly pines. There is also a residential home at the edge of the southeast side of the wetland. The Martin-Amment site is a Carolina Bay with a mature and moderately dense canopy of red maple, pond-cypress (*Taxodium ascendens*), and swamp black gum. In NC DWQ's quantitative plant survey done in July 2008, six individual swamp black gum were larger than 35cm in diameter and one pond-cypress was 56.5cm in diamater, indicating the advanced age of these typical bay species. The Martin-Amment site has also remained dry since the drought of 2007. The "Third Approximation" (Schafale and Weakley, 1990) would define the Martin Amment site Cypress Savannah surrounded by High Pocosin.

Mill Creek – The Mill Creek site is a 1.02 acre Small Basin non-isolated wetland in southern Brunswick County about nine miles southeast of Supply, North Carolina. It is buffered by a new residential neighborhood that is in the process of being constructed. Within 15 feet of its southwest edge is a busy two-lane paved road, Sunset Harbor Road SE. There is approximately 70 feet of wooded vegetation between Sunset Harbor Road and the western side of the wetland. Forested vegetation continues to the north and east of the site while the area to the south and southeast is slated for development. The Mill Creek site has a ditch draining water from the wetland on the northeast side and a culvert draining water from the wetland on the southeast side. The Mill Creek site has remained dry since the drought of 2007. The canopy consists solely of pond-cypress and swamp black gum, with myrtle holly the only component of the sparse sub-canopy. The herb cover is fairly sparse as the wetland is normally inundated for much of the year. This year's quantitative vegetation survey yielded no non-native invasive plant species and few weedy natives. Other then the ditch, the Mill Creek site is fairly well preserved. This is likely attributed to the newness of the neighborhood; though roads and infrastructure are in place the lots are largely undeveloped. The “Third Approximation” (Schafale and Weakley, 1990) would define the Mill Creek site as Cypress Savannah surrounded by High Pocosin.

Seawatch Bay – The Seawatch Bay site is a 3.01 acre section of an isolated Small Basin wetland in southern Brunswick County about 11 miles southeast of Supply, NC. It is a Carolina bay rimmed with large pond-cypress and swamp black gum, medium-sized red maples, and shrubs such as myrtle holly, shining fetterbush (*Lyonia lucida*), and southern maleberry (*Lyonia ligustrina* var. *foliosiflora*). In the vegetation survey that the DWQ completed in June of 2008, the herb layer comprised less than 1% of the cover. This is another undisturbed wetland in an rapidly developing part of Brunswick County that is itself one of North Carolina’s most rapidly developing counties. The extensive buffers consist of some natural wooded areas and mature planted pine. However, planned road construction adjacent to the bay and the development of a community park associated with the Seawatch development plan will impact some of the existing buffers. There is a set of dirt roads that circle the bay and range from immediately adjacent to greater than 1000 feet away. At present, the Seawatch Bay site is an example of a quality Coastal Plain Small Basin Reference site. Water levels have dropped drastically since the 2007 drought, at least 7-8 feet as indicated by water stains on pond cypress trees. Dried out areas once flooded with water are now colonized with dog fennel (*Eupatorium caprifollium*). “Third Approximation” (Schafale and Weakley, 1990) would define the Seawatch Bay site as Cypress Savannah surrounded by High Pocosin. The NC Natural Heritage program considers the Seawatch Bay site to be a state natural heritage site with a mix of high quality and good quality habitat that is rated as being one of the best Cypress Savannahs within the region. The entire bay, including the research site area, is in the process of being deeded by Seawatch Development Community to the NC Deparment of Environment and Natural Resources (NC DENR) as a conservation easement as of February 2010.

Seawatch Nautica – The Seawatch Nautica site is a 2.05 acre Small Basin effectively isolated wetland in southern Brunswick County about nine miles east-southeast of Supply, North Carolina. There is a ditch on the east side of the wetland that does not appear to have held water in a long time by the size of the trees. Due to the presence of the ditch, it is likely that the Army Corps of Enginears (ACOE) would deem this site non-isolated. The canopy is nearly closed and consists of large pond-cypress and swamp black gums. The common shrub is ti-ti and the herb layer cover is less than 1%. There is a non-functioning old ditch that connects to the west side of Seawatch Nautica with mature trees in the ditch which indicate the lack of regular water flow. A future residential neighborhood is slated to be built along the edges of Seawatch Nautica. Road building and house site selection has begun though most of the roads are still dirt or sand. Seawatch Nautica is currently buffered with extensive mature forest and sandy dirt roads located within 60 feet of the wetland site. There are no obvious signs of alteration to hydrology, though it seems likely this wetland will be utilized as a means of stormwater management for this neighborhood. The Seawatch Nautica site has remained dry even in the deepest sections since the 2007 drought. The “Third Approximation” (Schafale and Weakley, 1990) would define the Seawatch Nautica site as Cypress Savannah surrounded by High Pocosin.

Sikka – The Sikka site is a 4.33 acre section of Small Basin non-isolated wetland in southern Brunswick County about six miles southeast of Supply, North Carolina. Zion Road is located 50 feet to the southeast of Sikka while a grassy church lawn is located within five feet to the east side of the site. The rest of the bay extends to the northeast. The wetland is a large Carolina bay with an open canopy of scattered pond-cypress, a moderate shrub layer of myrtle holly, and a dense herb layer of ferns, sedges, rushes, and grasses. There are few signs of altered hydrology, such as ruts located through parts of the wetland left by heavy equipment or large trucks most likely from a selective logging operation. Additionally, there appears to be a fire break line along the edge of of the wetland. Except for one small 20 by 20 foot section, Sikka has been dry since June of 2007. A deep water section that was once vegetated with aquatics like white lily pads (*Nymphaea odorata*) is now vegetated with a volunteer unidentified grass like species. The “Third Approximation” (Schafale and Weakley, 1990) would define the Sikka site as Cypress Savannah surrounded by High Pocosin.

Lockwood Folly River – Riverine Swamp Forest Wetlands (Riverine Swamp Forests)

Doe Creek – The Doe Creek site is a 2.67 acre section of a more extensive tidal Riverine Swamp Forest wetland in southern Brunswick County about three miles southwest of Supply, North Carolina. This site is split into two parcels by Stone Chimney Road SW, one on each side of the road. The majority of the site is buffered by mature upland forest or contiguous Riverine Swamp Forest on all sides except the northeast side which is approximately 100 feet from a residence and the southeast side which is approximately 300 feet from another residence. This disturbance necessitated DWQ personnel doing one 2 x 2 array of 10 x 10 m module vegetative survey in each parcel instead of the preferred contiguous 2 x 4 array of 10 x 10 m module survey (see Section 4.6). The canopy is approximately 50% aerial cover and consists of swamp black gum and bald-cypress. Sub-canopy species are Carolina ash (*Fraxinus caroliniana*), American hornbeam, and small red maples. The herb layer is substantial and lizard’s tail (*Saururus cernuus*) dominates. Hydrological alterations stem from interruptions to natural stream flow due to the bridge over Doe Creek and the earthen road causeway constructed to elevate Stone Chimney Road SW above the floodplain. The “Third Approximation” (Schafale and Weakley, 1990) would define the Doe Creek site as a Cypress Gum Swamp – Blackwater subtype.

Hewett Wildlife – The Hewett Wildlife site is a 1.39 acre section of non-tidal Riverine Swamp Forest wetland in southern Brunswick County about four miles south of Supply, North Carolina. Hewett is a large wetland that has been made deeper by the damming of Sandy Branch Creek by beavers. The canopy is open and becoming more open as trees die from the high water levels and prolonged hydroperiod. The sparse canopy is composed of red maple, pumpkin ash (*Fraxinus profunda*), and swamp black gum. The herbaceous layer is thick and made up of forbs and emergents such as heartleaf pickerelweed (*Pontederia cordata* var. *cordata*), green arrow-arum (*Peltandra virginica*), lizard’s tail (*Saururus cernuus*), American bur-reed (*Sparganium americanum*), and swamp loosestrife (*Decodon verticillatus*), and graminoids such as giant cane (*Arundinaria gigantea*), bottlebrush sedge (*Carex comosa*), and soft rush (*Juncus effusus* spp. *solutus*). The southern border of this site is buffered by an approximately four-acre clear-cut that has been replanted with longleaf (*Pinus palustris*) seedlings, on its narrow eastern edge by a short 15-foot wide pathway and beaver dam which separates the study site from another section of the river. The Riverine Swamp Forest continues to the west of the site and to the north bank which is buffered by mature forest. The presence of beavers are the only evident hydrological alteration. The lack of a vegetated buffer along the southern edge, where the clear-cut lies, coupled with it being on a slight slope, undoubtedly contributes increased sediment loads to the wetland. On the other side of the clear-cut are scattered homes with large yards, but it is unlikely that chemical runoff reaches the wetland since these rural yards are not well maintained and the roads and driveways leading to these homes are not paved. The “Third Approximation” (Schafale and Weakley, 1990) would define the Hewitt Wildlife site as a Cypress Gum Swamp – Blackwater subtype. The NC Natural Heritage program considers the Hewitt Wildlife site be a state natural heritage site with high quality habitat that is rated as being one of the best Cypress Gum Swamps within the state. Hewitt Wildlife was considered to be part of the Lockwood Folly tidal wetland natural heritage site, however we did not observe tidal conditions on this site. Hewitt Wildlife is a Coastal Carolina Land Trust land easement.

Lockwood – The Lockwood site is a 5.80 acre section of an extensive Riverine Swamp Forest wetland in southern Brunswick County about one mile southeast of Supply, North Carolina. Lockwood is nestled in a meander of the tidally influenced Lockwood Folly River. This river buffers approximately 950 feet of the site along the northern edge. The west – southwest side of the site is buffered by the road causeway built for NC 211 which is located approximately 100 feet from the edge of the wetland. The causeway has altered the hydrology on this side of the site by inhibiting normal sheet flow resulting in ponding and an open canopy on the NC 211 side of the site. The mature Riverine Swamp Forest wetland continues along the eastern site boundary. The southern buffer is upland, wooded with loblolly pines, that extends for more than 2000 feet to the south. The canopy is moderately dense and rapidly becoming more open as these canopy trees die off probably as a result of tidal saltwater intrusion. This was most evident with the dying ash trees (*Fraxinus* spp). As a testament to tree mortality due to intrusion, DWQ personnel recorded 52 snags greater than 10 cm in diameter in their June 2008 quantitative vegetation survey. The tallest remaining live trees are red maple, ash, bald-cypress, and swamp black gum. The upland edge of the vegetation plots was thick with the shrub of common wax-myrtle (*Morella cerifera*) and swamp bay (*Persea palustris*). The herb layer was dense in places, usually at the upland edges of our plots, and composed of royal fern (*Osmunda regalis* var. *spectabilis*), millet sedge (*Rhynchospora miliacea*), and lizard’s tail. Poison ivy is also a significant contributor to the aerial cover of this site with many vines reaching up into the canopy. The “Third Approximation” (Schafale and Weakley, 1990) would define the Lockwood site as a Cypress Gum Swamp – Blackwater subtype. The NC Natural Heritage program considers the Lockwood site be a state natural heritage site with high quality habitat that is rated as being one of the best Cypress Gum Swamps within the state. The Lockwood site is part of the larger Lockwood Folly tidal wetlands natural heritage site.

Mercer Seawatch – The Mercer Seawatch site a 4.43 acre section of an extensive Riverine Swamp Forest wetland along Mercer Mill Creek in southern Brunswick County about 10 miles southeast of Supply, North Carolina. There is some tidal influence at the Mercer Seawatch site as stream levels were observed increasing and decreasing, however, the tidal influence is not nearly as significant as at the Doe Creek and Lockwood Folly River sites. The right-of-way for a future bridge project to connect two neighborhoods in the Seawatch development bisects the Seawatch Mercer site. This site has experienced natural wind damage as indicated by downed trees, an open canopy, and shrubby understory. The bridge right-of-way section of the site has the least impacted canopy, a more open understory, and a diverse herb layer. The number of species identified by NC DWQ personnel during their June 2008 vegetation survey was the highest of any of the study sites. At least 10 species of sedge in the genus *Carex* were found in the plot and made up a substantial portion of the ground cover, along with ferns and *Juncus* spp. With qualitative surveys performed by NC DWQ personnel, at least nine genera of sedge were found within the wetland area, though not all were within our survey plot. Canopy-sized trees that are most prevalent in the bridge right-of-way consist of large bald cypress and swamp black gum, and smaller, near canopy-sized red maple. This site is bordered to the south by the tidally influenced Mercer's Mill Creek (at this point 20 feet wide) with extensive woods on the opposite side of the creek. Impending development has the potential to greatly reduce the natural buffer and alter the hydrology of this quality riverine site. Along the north central section of the site, there is a natural spring that emerges from the sloped upland. Water quality buffer samples (see Section 4.1) were taken from this spring. The "Third Approximation" (Schafale and Weakley, 1990) would define the Mercer Seawatch site as a Cypress Gum Swamp – Blackwater subtype. The NC Natural Heritage program considers the Mercer Seawatch site be a state natural heritage site with high quality habitat that is rated as being one of the best Cypress Gum Swamps within the state. The Mercer Seawatch site is part of the larger Boiling Springs Lakes Wetland Complex natural heritage site. Boiling Springs is known of which Mercer Seawatch is not, therefore this ranking may not be accurate or up to date as there has been conserable wind damage in portions of the Mercer Seawatch site. The floodplain area of Mercer Seawatch located on the Seawatch property, including the research site area, is in the process of being deeded by Seawatch Development Community to the NC Deparment of Environment and Natural Resources (NC DENR) as a conservation easement as of February 2010.

Rourk – The Rourk site is a 1.18 acre section of a non-tidal Riverine Swamp wetland in southern Brunswick County about eight miles south-southeast of Supply, North Carolina. To the southeast, there is a tidal freshwater marsh that extends 230 feet to a salt marsh associated with Mercer Mill Creek. In all other directions, there is a wooded buffer at least 540 feet in width. Throughout the 2006-2008 survey, flooding was noted in sections of the site, but not throughout, indicating that this site really was a border-lined Riverine Swamp Forest with hydrology more comparable to a Bottomland Hardwood Forest. The wooded buffer is densely vegetated with young trees and was probably logged in the last 20 years. The nearly closed canopy of the wetland is comprised of red maple, sweet gum, green ash, and American elm. The shrub layer is thick, with wax myrtle (*Morella cerifera*) and American holly (*Ilex opaca*) the most common. Ground cover is sparse, about 5% across the vegetation plot. There were no evident changes to hydrology at this site, or disturbance, but less than one-quarter mile away is a two-lane paved road, Rourk's Landing Road SW (CR1200), where many development efforts may happen over time. The "Third Approximation" (Schafale and Weakley, 1990) would define the Rourk site as a Coastal Plain Small Stream Swamp – Blackwater subtype.

Winding River Pond – The Winding River Pond site is a 0.91 acre section of Riverine Swamp Forest wetland in southern Brunswick County about five miles southeast of Supply, North Carolina. This site is separated from the Winding River Townhouse site (see below) by a north-south running two-lane paved road, Zion Hill Road SE (CR1114). The Winding River Pond site is on the east side of Zion Hill Road and the Winding River Townhouse site is on the west side of Zion Hill Road. Both Riverine Swamp Forest sites are associated with Sandy Branch. The northeast buffer is a 40 to 100 feet wide section of wooded upland and lies between the wetland site and a residential neighborhood while along the southeast border there is a range of 20 to 30 feet of wooded buffer between the wetland and residential homes. Additionally, these residences are nestled among the greens and fairways of Carolina National Golf Club. The Riverine Swamp Forest continues upstream to the northeast another 600 feet. The dense canopy of the Winding River Pond site consists of red maple, ash, swamp black gum, and sweet gum. The sub-canopy layer is well-developed with tag alder (*Alnus serrulata*), ti-ti, and wax myrtle. The herb layer is sparse, owing to the prolonged hydroperiod and high water levels caused by beaver activity. A narrow buffer, in combination with runoff from the golf course and treated lawns has potentially influenced the water quality. Through their damming activities, beavers have recently increased the hydroperiod and water levels during the 2008 field season. The "Third Approximation" (Schafale and Weakley, 1990) would define the Winding River Pond site as a Cypress Gum Swamp – Blackwater subtype.

Winding River Townhouse – The Winding River Townhouse site is a 0.59 acre section of Riverine Swamp Forest / Bottomland Hardwood Forest wetland in southern Brunswick County about five miles southeast of Supply, North Carolina. There is a forested buffer that ranges from 10 to 100 feet wide on the north – northwest side of the site. On the southeast side of the site, Sandy Branch flows through a straightened and incised section of the channelized basin. Townhouses are located directly on the other side of the Sandy Branch. Along the west side of the Winding River Townhouse site, there is contiguous Riverine Swamp that ultimately connects with the Hewitt Wildlife site. The straightened stream and crossing of Zion Road has reduced the hydrology in this section of the swamp. During survey work, flooding was observed in sections of the site, but not throughout, indicating this site was a borderline Riverine Swamp Forest with hydrology more comparable to a Bottomland Hardwood Forest. Additionally, canopy disturbance has resulted in a high density of sampling growth on the east side of the site. The canopy is nearly closed with red maple, green ash, and swamp black gum dominant. The sub-canopy layer was dense with large specimens of tag alder, wax myrtle, sweet bay (*Magnolia virginiana*), swamp bay (*Persea palustris*), and American hornbeam. The ground layer surveyed in NC DWQ's quantitative plant surveys ranged from sparse to dense in our plot, with millet sedge being the most prevalent. Potential water quality impacts here are much the same as at the Winding River Pond site. The "Third Approximation" (Schafale and Weakley, 1990) would define the Winding River Townhouse site as a – Cypress Gum Swamp – Blackwater subtype.

Section 4 – Field Methodology

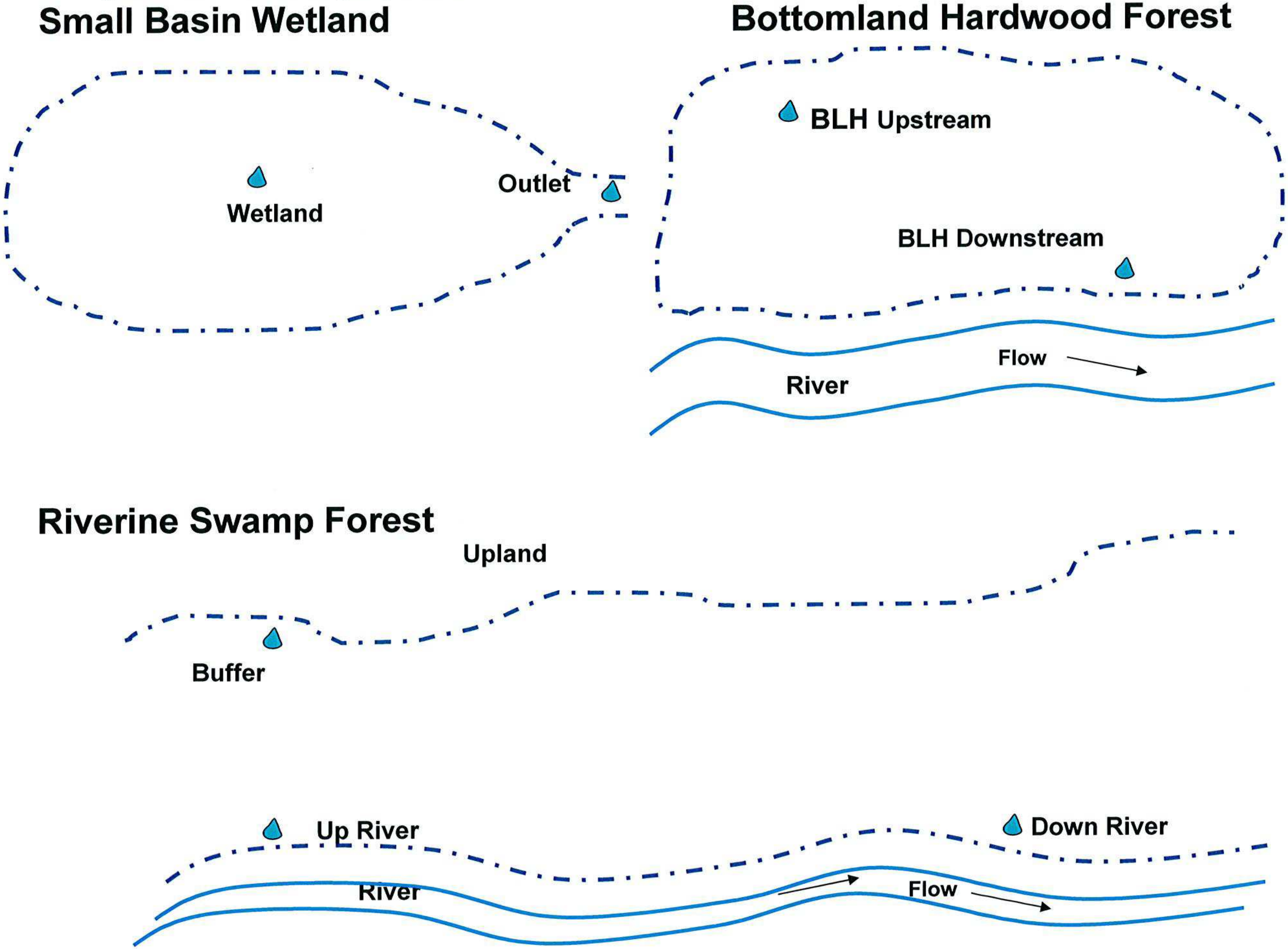
Section 4.1 Water Quality Monitoring

Water quality parameters were sampled on a quarterly basis six times during the study period; February 2007, April 2007, July 2007, October 2007, January 2008, and April 2008. Sampling during these times allowed DWQ to obtain information on water quality during the dry season, wet season, and transition periods. Due to loss of site access, the last quarter of sampling was not completed at the Hart site. Additionally, eight sites, two Riverine Swamp (Lockwood and Seawatch Mercer), two bottomland hardwood ([Munn and Hancock], and four Small Basin wetland sites [two Piedmont- Dargan and Dean and two Coastal Plain- Sikka and Seawatch Bay]) were chosen for long term monitoring. The long-term sites were monitored in October 2008, Febuary 2009, May-June 2009 and will continue to be monitored bi-annually. A total of up to 19 water quality parameters was monitored during each sample period. Physical parameters (pH, DO, specific conductivity, and temperature) were taken in the field with an Accumet AP61 pH meter and YSI model 85 meter and recorded on "DWQ Wetland Field Verification Water Quality Monitoring" field sheets (see Appendix C). All water samples were collected, preserved, and transported in accordance with Division of Water Quality Laboratory Standard Operating Procedures (NCDWQ 2003) and DWQ Laboratory Sample Submission guidelines (NCDWQ 2005). Water samples were always analyzed for nutrients (P, NO_2+NO_3 as N, total Kjeldahl nitrogen [TKN], NH_3-N), heavy metals (Mg, Ca, Cu, Pb, and Zn), dissolved organic carbon (DOC), total organic carbon (TOC), total suspended solids (TSS), and fecal coliform. Chlorine was tested in the field using chlorine strips during the first sample period. All results were negative and no additional samples were analyzed at the lab for chlorine.

The wetland type (Riverine Swamp Forest, Bottomland Hardwood Forest, or Small Basin Wetland) determined the number and location of the water quality sample stations. Riverine Swamp Forest wetland sites typically had three water quality sample stations; one located close to the river but within the wetland (up river station), one located down stream in the buffer but close to the wetland (down river station) and one located further inland in the buffer (buffer station, see Figure 4.1-1). The Rourk site was the exception with only two sample stations, one up river and one down river. Bottomland Hardwood Forests typically had two sample stations with one located up stream and one located down stream (upstream Bottomland Hardwood Forests and downstream Bottomland Hardwood Forests stations), Gray and Kim-Brooks just had one station (see Figure 4.1). Small Basin wetlands typically had just one station located in the middle of the wetland (wetland station). Basin sites that drained to an outlet had a second sample station as was the case with Eastwood and Goldston (outlet station, see Figure 4.1). Sample station locations were recorded with GPS and marked in the field with flagging. Additionally, station locations were photographed with a digital camera each time the station was sampled in order to make a visual record of the station's hydrology. The best sampling methodology was chosen according to the hydrological conditions on the sampling day; direct-grab or bail. Bail bottles were tripled rinsed with station water prior to use. Field data sheets were completed for each station as well as DWQ lab sheets and labels for sample bottles (see DWQ Wetland Field Verification Water Quality Monitoring field sheet, Appendix C). A unique station number that reflected the site name, sample location (UpRiver, DownRiver, Bottomland Hardwood Forests Upstream, Bottomland Hardwood Forests Downstream, Wetland, Outlet), and sample time (month and year) was assigned for each sample event. Field data sheets included information on physical parameters, sample location, station number, 48-hour precipitation history from the nearest weather station, wetland site name, date, sampler's initials, air temperature, sample method, chlorine strip results, picture number, sample method, comments on hydrology, water quality, and details on the microhabitat of station location, sample time, preservation time, and which lab tests were to be performed. All samples were analyzed at the Division of Water Quality Laboratory Section in Raleigh, North Carolina. Lab sheets (see DWQ Wetland Field Verification Water Quality Monitoring field sheet, Appendix C) and bottle labels are used by the DWQ Lab to identify the proper lab test to perform on each water sample.

Meters were calibrated at the beginning and end of each day and during the day if deemed necessary. Probes were rinsed with deionized water before and after each use. To avoid contamination of samples, gloves were worn for sampling, filtering, and preservation. For DOC samples, 200 ml of water collected in the field was suction-filtered through 0.45-micron filters within half an hour of collection. DOC filtering equipment was triple-rinsed with deionized water before and after each sample was filtered and filters were changed between samples. Filtering blanks were prepared at the beginning and end of each sample day to test for DOC contamination. Additionally, one set of unlabeled duplicates was sent to the lab during each sample period to check for accuracy. DWQ Standard Operating Procedure and Laboratory Sample Submission Guidelines were followed to ensure that sample preservation, storage, labeling, and hold times are met. The DWQ Lab was responsible for selection and preparation of sample containers, sample volumes needed for each chemical analysis, and decontamination of any lab equipment. Details of these processes are explained in “The Quality Assurance Manual for the North Carolina DWQ Laboratory section” (NCDWQ 2003b).

Figure 4.1-1 Wetland Water Quality Stations

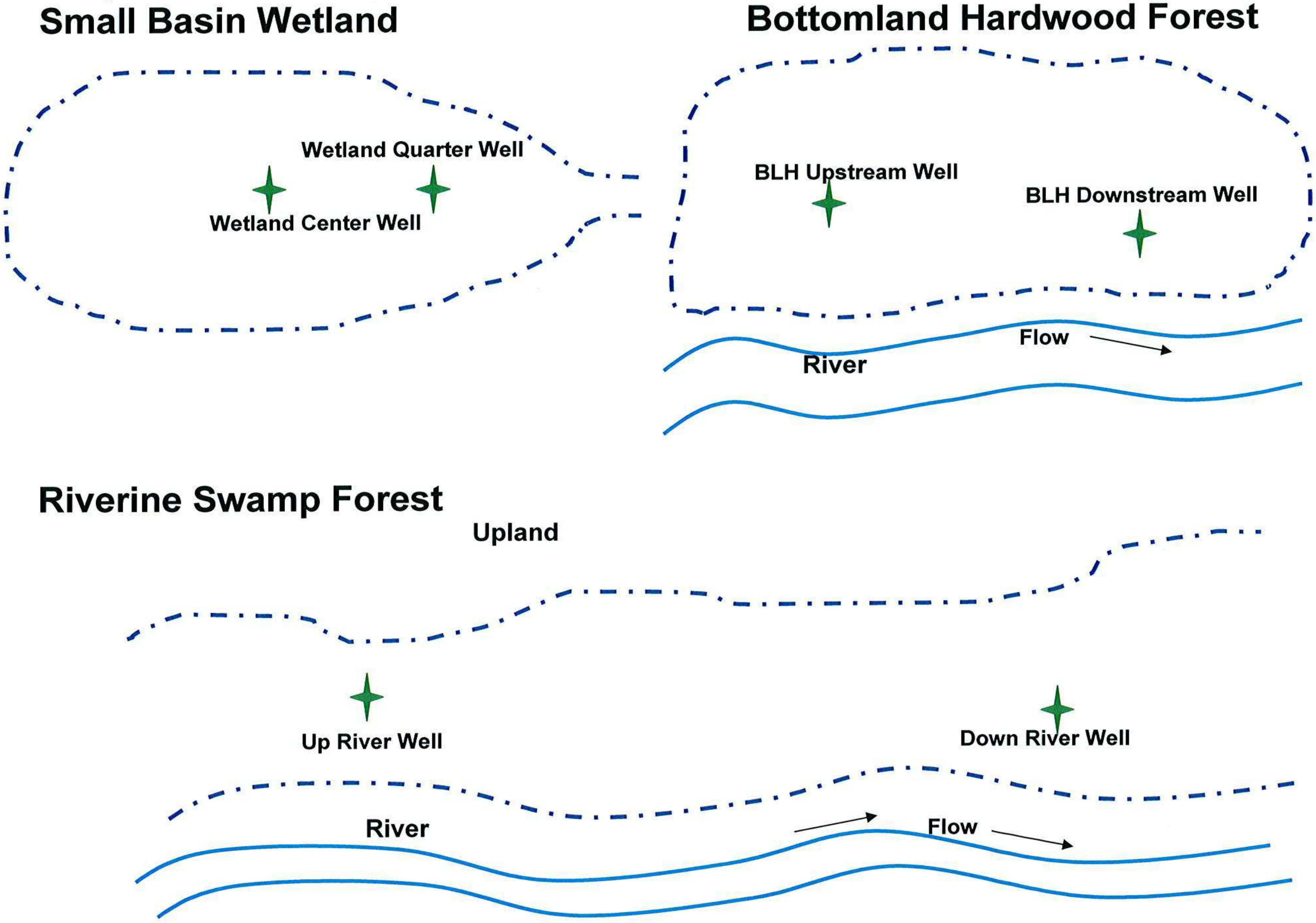


Section 4.2 Hydrology Monitoring

Monitoring wells were installed in June of 2007. Typically two monitoring wells were installed at each wetland site. However, only one automated well was installed at the Small Basin wetland sites. Wells with transducers were installed at an upstream location and downstream location within the Riverine Swamp Forest and Bottomland Hardwood Forest wetlands (see figure 4.2-1). The Kim-Brooks, Rourk, and Winding River Townhouse sites had just one automated well installed while the Gray site had just one non-automated well installed. The Small Basin sites had one automated well installed in the center of the wetland and one non-automated well installed half way between the center and edge of the wetland (see Figure 4.2-1). Methods outlined in the Army Corps of Engineers document entitled, "Wetlands Regulatory Assistance Program (WRAP) for Installing Monitoring Wells/piezometer in Wetlands" (http://el.erdc.usace.army.mil/elpubs/pdf/ tnwrap00-2.pdf) was used to install monitoring wells. The wells had 0.01 inch slats along the lower 18 inches for water flow and vented caps to prevent a vacuum from forming and allow the water to flow freely. Wells were typically installed approximately 1.8 to 2 feet below the ground surface. Sand was used in the bottom of the installation hole and around the circumference of the well up to four to six inches from the ground surface where bentonite was used for a seal. Bentonite was piled around the well four to six inches above the ground surface and covered with wet soil. Wells were installed for at least 24 hours before the first water level readings were taken. The well location was recorded with GPS and later imported into a GIS project/database.

Before installation in the field, transducers were checked for accuracy in a controlled indoor environment. In-situ vented Level-Troll 500 transducers were installed in June 2007 at 12 of the well locations (six in the Piedmont and six in the Coastal Plain) to record information on duration, frequency, and seasonal timing of wetland inundation. Transducers were hung with the sensors located a couple inches from the bottom of the well. The transducer sensor depths at the sites ranged from 1.7 ft to 2.1 ft. Data were collected from June 2007 to October 2008 at all the sites except for Hart which was terminated in early 2007 due to loss of site access. Eight sites, the same as for water quality monitoring (see Section 4.1), were chosen for long-term monitoring, two riverine (Lockwood and Seawatch Mercer), two bottomland hardwood (Munn and Hancock), and four Small Basin wetland sites (two Piedmont- Dargan and Dean and two Coastal Plain- Sikka and Seawatch Bay) were chosen for long term monitoring. In the field, transducers were set to record every 30 minutes in the Riverine Swamp Forest Wetlands and every hour in the Bottomland Hardwood Forest and Small Basin wetlands. Hand measured water level readings were compared to automated-water levels in order to check for accuracy every time well water level data was downloaded (at least every three months). Automated well water level data that was more than 0.08 feet different than water levels measured by hand in the field was discounted. Hand measurements were taken at least two times to ensure accuracy. Monitoring wells that did not contain transducers were measured by hand during each field visit. Appendix C contains an example of the well level recording field sheets for hand measurements and In-situ transducer automated measurements. Data from the automated transducers were downloaded using an interface cable from the transducer to a laptop computer. The data were downloaded and immediately backed up by converting the existing data format to an Excel format. The last depth recording from the transducer was used to verify accuracy compared to the hand measurements.

Figure 4.2-1 Wetland Monitoring Well Locations



Section 4.3 Soils Monitoring

A total of six to ten soil cores were extracted at each wetland site. In the wetland, four to six cores were taken and in the upland two to four cores were taken. Sample locations were based on the plant survey plot layout (see Figure 4.3-1). Typically two cores were taken inside the vegetation plot, four cores were taken approximately half way between the plot and wetland delineation line, and lastly, two to four cores were taken in the upland areas surrounding the plot. Figure 4.3 shows the soil sample design for basin and riverine wetlands.

Each soil core was extracted with a 2.5” diameter bucket auger. Soil horizons were identified within each core based on changes in color and texture. The horizon width, order (“A” = top layer, “B”= middle layer, and “C” = to bottom layer), matrix and mottle color, percent mottle abundance, and texture were recorded for each horizon. Munsell Soil Book color charts (Munsell Soil Color Charts) were used to determine Hue, Value, and Chroma. Texture was determined for each layer using the flow diagram adapted from Thien (1979). Each sample was coded with the site abbreviation, sample number and layer (e.g., KIMS2B = Kim-Brooks Sample 2 B). An example of the “DWQ Wetland Field Verification Monitoring Study Field Sheet” can be found in Appendix C. Approximately one cup of sample from each layer was collected for analysis in zip lock bags labeled with the corresponding sample abbreviation. Samples were later placed in labeled boxes for analysis by the North Carolina Agronomic Division after air drying. Soil Testing Section lab sheets were completed for each sample (see http://www.ncagr.com/agronomi/pdffiles/issoil.pdf).

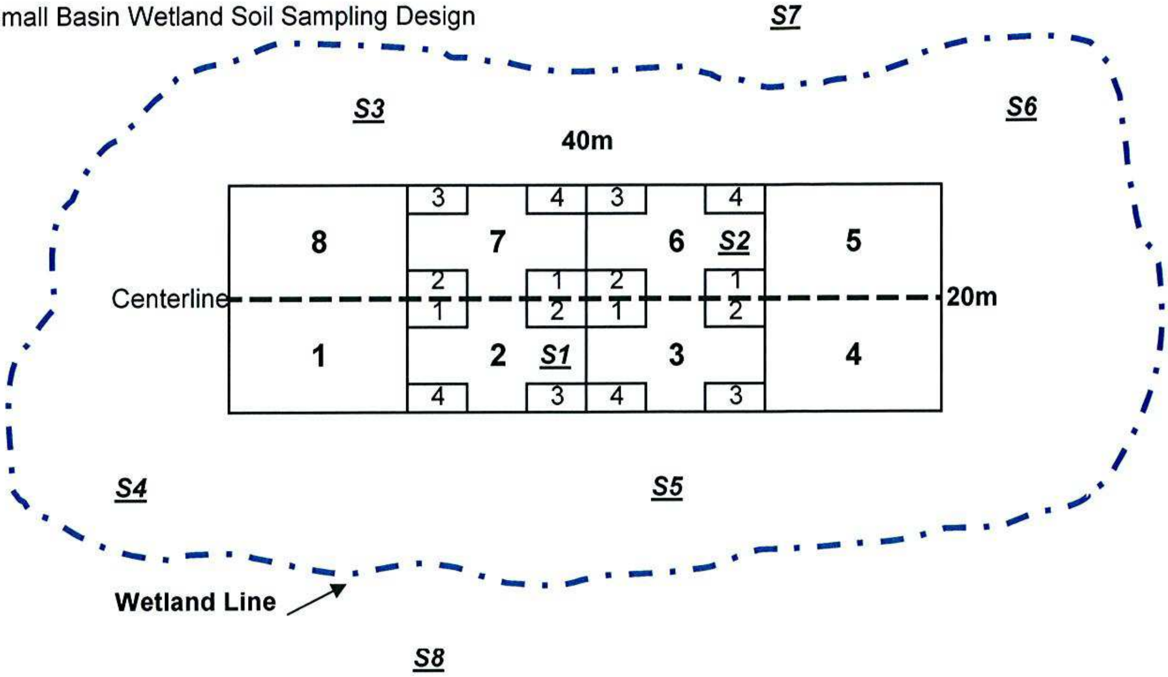
Soil samples were tested by the Soils Testing Section of the North Carolina Agronomic Division in Raleigh, North Carolina using methodologies described at http://www.ncagr.com/agronomistmethod.com. Soil samples were tested for the following:

- Levels of major plant nutrients, including phosphorus, potassium, calcium and magnesium
- Levels of plant micronutrients, including copper, manganese, sulfur and zinc
- Levels of sodium
- pH
- Exchangeable Acidity (Ac - ability of soil to absorb aluminum and hydrogen ions)
- Sum Cation (sum of the charged particles in the soil, related to salinity)
- Percent base saturation (soils with low base saturation are considered to be leached and are often acid, whereas neutral and alkaline soils tend to have high base saturation)
- Percent humic matter (percent of soil organic matter)
- Cation exchange capacity (CEC, storage capacity for plant nutrients)
- Weight-to-volume ratio (used to classify soil type, normally inversely related to CEC)

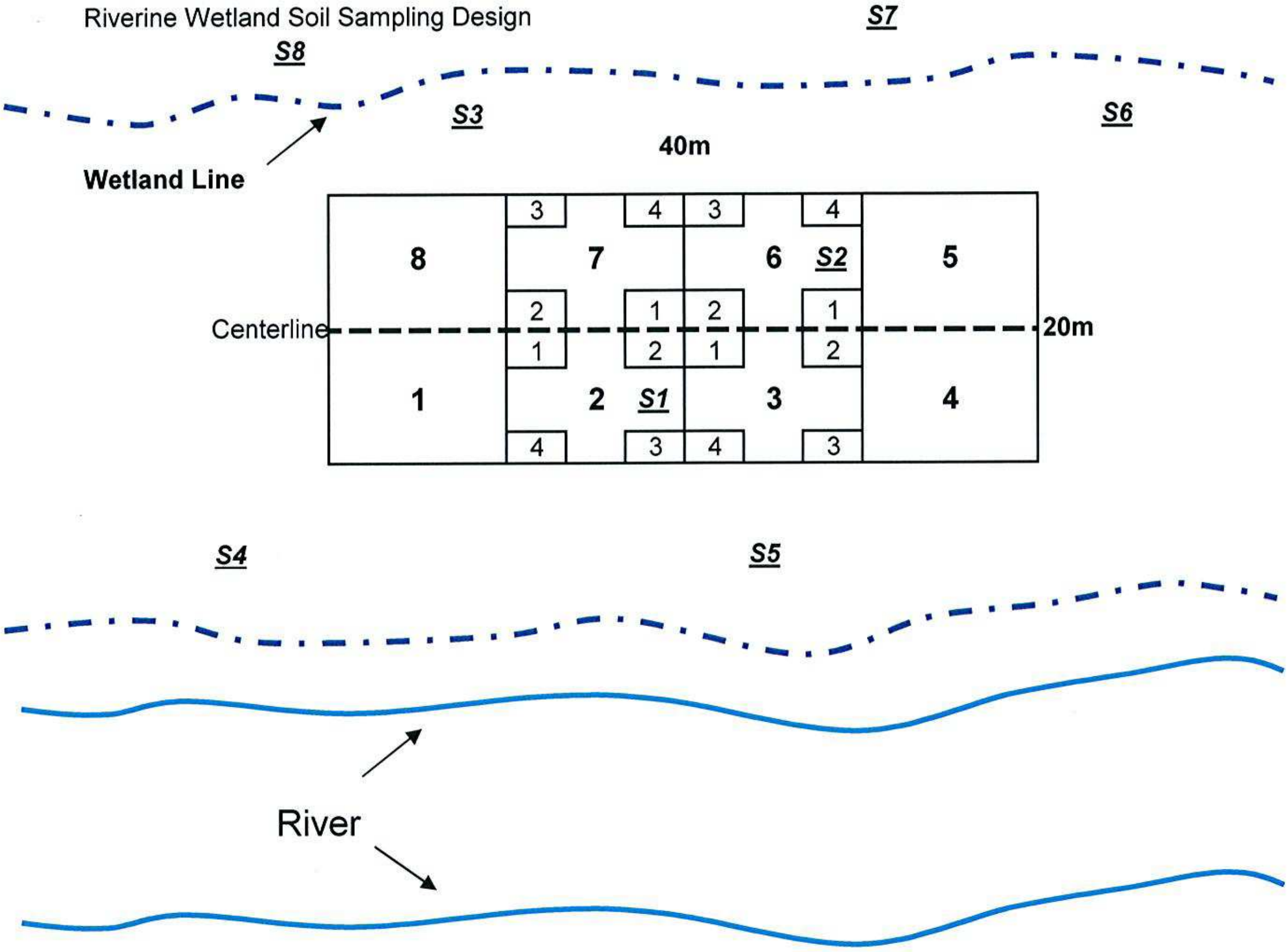
Results from the field survey were entered into an Excel database. Electronic results from the lab were received and formatted and copied into an Excel database.

Figure 4.3-1 Soil Sampling Design

Small Basin Wetland Soil Sampling Design



Riverine Wetland Soil Sampling Design



Section 4.4.1 Amphibian Field Monitoring

A qualitative survey for amphibians was performed twice at each wetland site during March and June 2007. Typically, three man-hours of survey work were completed at each site in March and June. In addition, a 10 minute auditory night survey was completed at each site in June. Sites were systematically searched for amphibians with the use of dip nets and potato rakes. Sweep nets were used to search for amphibians (frogs, tadpoles, egg masses, and larval salamanders) in areas with standing water. Potato rakes were used to turn over logs and woody debris in the wetland and surrounding upland buffer area. Leaf debris adjacent to wetlands was lightly scraped to search for salamanders. Moss hammocks overhanging water or within a few feet of water were searched by for cavities and than peeled back on three sides and replaced to search for female salamanders guarding eggs. Crayfish holes were also searched for salamanders. All auditory frog calls were noted and recorded. The macroinvertebrate survey was performed on the same day in March as the amphibian survey (see Section 4.5). All amphibians that were collected at the macroinvertebrate stations either in a funnel-trap or sweep net was also recorded on field sheets.

"DWQ Wetland Field Verification Amphibian Wetland Monitoring Field Sheets" (see Appedix C) were completed for both the March and June amphibian sampling survey events. Information on the field data sheets included site name, county, observers, date, start and stop time, water quality parameters, current air temperature, wind speed, percent cloud cover, air temperature range and rain in last 48 hours, comments on the hydrology of the site, and a table with records for each separate observation. Each record included species, life-stage, the number observed, specimen number, photo number, and comments on microhabitat, behavior, malformations, auditory or visual observation, identification information and size (head to tail for salamanders and head to anus for frogs and toads). The previous 48-hour precipitation and temperature (minimum and maximum) were taken from the nearest weather stations and recorded on field sheets. Usually surveys were avoided when temperatures were below 4.4^{o}C (40^{o}F) the previous night or below 15.6^{o}C (60^{o}F) during the survey. Air temperature was taken on site and recorded during the survey. A specimen list sheet (see Appendix C) was also kept with records of each specimen collected. Specimens collected for identification were assigned a specimen number. Specimens were preserved in 10% formaldehyde solution and labeled with the specimen number, site name, and date. The "Distribution of Amphibians in North Carolina" (2003) Draft document written by the NC State Museum of Natural Sciences was be used for Genus species nomenclature. All specimens collected for this project were donated to the NC State Museum of Natural Sciences herpivarium collection.

Section 4.4.2 Amphibian IBI Development and Analysis

In this study, six biological attributes were tested for usage as metrics in the development of an amphibian Index of Biotic Integrity (IBI) for wetlands in this study. The biological attributes tested were an Amphibian Quality Assessment Index (AQAI), percent tolerant species, percent sensitive species, percent ephemeral – headwater – seepage wetland (EW-HW-SW) species, species richness, and percent Urodela (Salamander / Newt Order). All six candidate metrics were tested for the Small Basin wetlands and all but the EW-HW-SW metric were tested for the Riverine Swamp and Bottomland Hardwood Forest. A description of how each potential metric was calculated is discussed later in this section. Wetland disturbance measures as determined by the Ohio Rapid Assessment Method (ORAM), Land Development Index (LDI) for the watershed and 100 m buffers were used as were water quality parameters as well as soil pH, copper, and zinc. Amphibians are sensitive to low pH levels (Kutka and Bachman, 1995) and species richness can be affected by pH since only certain species can survive in lower pH levels (Alvin Braswell 2009). Amphibians area also particulary sensitive to heavy metals like mercury, cadmium, zinc and copper (Lefcort et al, 1998, Garbrino et al. 1995). The six metrics (see Section 2) tested for correlations with Pearson's Correlation and Spearman's rho non-parametric correlation test. Correlations were run using amphibian data results from both regions and from each region separately.

Field data observations were used to develop an amphibian database with Excel 2000 spreadsheets. In order to develop an amphibian IBI, each site's larvae and egg stage tally for each species needed to be converted to an adult tally. Table 4.4.2.-1 shows the calculations used to convert each egg and larval species that were observed during the survey to adult species. In most cases, 20% of the larvae were counted as one adult and every egg mass were counted as two adults (see Table 4.4.2 - 1). Amphibian C of C (Coefficient of Conservation) rankings for each species were assigned from 1-10 with "1" being species that were considered to be generalist with the least specific habitat requirements such as the American toad (*Bufo americanus*) and "10" being species that had the most specific habitat requirements and sensitivity to stress plus a state listing such as the four toed salamander (*Hemidactylium scutatum*). Table 4.4.2 -1 shows the C of C rankings for the 35 species, genera, and orders observed during this study. Species with a C of C $\leq$ 3 were considered tolerant while species with a C of C $\geq$ 6 were considered sensitive (see Table 4.4.2 -1). Species that require ephemeral wetlands, headwater wetlands, or seepage wetlands (i.e. the absence of predatory fish) are also denoted in Table 4.4.2-1. Table 4.4.2-1, specifically the C of C ratings and adult conversion calculations, was developed with the assistance of Alvin Braswell (Lab Director and Curator for Herpetology at the N.C. State Museum of Natural Sciences) in 2005 and updated in 2008 and 2009. It should be noted the adult conversion methodology as well as the C of C scores are based on the best professional judgment of an experienced herpetologist (Alvin Braswell, 2009).

The number of adults for each site was determined and then used to calculate the AQAI value, species richness, percent tolerant species, percent sensitive species, percent EW-HW-SW species, and percent Urodela species. The AQAI value for each site was determined using the following equation-

$$\mathrm{AQAI} = \frac{\sum S_i * S_{i\ \mathrm{c\ of\ c}}}{N}$$

S_i = Adult number of species i
$S_{i\ \mathrm{c\ of\ c}}$ = C of C value for species i
N = Total number of adults

Spearman’s rho correlation coefficient, a non-parametric correlation test, was used to test each candidate metric. Correlations were run with each candidate metric against each site’s Land Disturbance Index (LDI), Ohio Rapid Assessment Method (ORAM), soil pH and water quality disturbance measures (see Section 2 for an in-depth description of the disturbance measures). Pearson’s pairwise correlations were also performed on the transformed candidate metrics verses transformed disturbance measurements (Land Disturbance Index (LDI), Ohio Rapid Assessment Method (ORAM), soil pH and water quality disturbance measures). The candidate metric correlations were tested using data from both regions and with the Coastal Plain and Piedmont regions separately. A p-value of 0.15 was considered significant. In addition, Pearson’s correlation was also used to test transformed candidate metrics and disturbance measures.

Table 4.4.2 -1 Amphibian Ratings and Adult Conversion Table

Species	Common Name	Adults C of C	Juv C of C	Larvae = 1 Adult	Eggs or Egg Masses = 1 Adult	Tolerant Species (C of C ≤3)	Sensitive Species (C of C ≥6)	*EW, HW, Seep Species Specific	Comments
Acris crepitans	Eastern Cricket Frog	2	2	20%= 1 Adult	5% of eggs = 1 female	1			Generalist- open grassy pond margins, ditches, marshy areas w/ shallow h2o
Acris gryllus	Coastal Plain Cricket Frog	2	2	20%= 1 Adult	5% of eggs = 1 female	1			Generalist-grassy margins of ponds, streams or ditches
Acris sp.	Cricket Frog Species	2	2	20%= 1 Adult	5% of eggs = 1 female	1			Generalist-grassy margins of ponds, streams or ditches
Ambystoma maculatum	Spotted Salamander	8	8	20%= 1 Adult	250 eggs = 1 female		1	0.5	Spotted salamanders tend to use isolated or deeper headwater site with semi permanent pools, will sometimes use other areas.
Ambystoma opacum	Marbled Salamander	8	8	20%= 1 Adult	5% of eggs = 1 female		1		
Anura sp.	Frog or Toad Species	1	1	20%= 1 Adult	5% of eggs = 1 female	1			generalist for non-identified frog calls
Bufo americanus	Eastern American Toad	1	1	20%= 1 Adult	5% of eggs = 1 female	1			generalist for non-identified frog calls
Bufo fowleri	Fowler's Toad	1	1	20%= 1 Adult	5% of eggs = 1 female	1			Generalist with eggs develop fast and can tolerate disturbances. [pmds ;ales. Streams shallow water
Bufo quercicus	Oak Toad	4	4	20%= 1 Adult	5% of eggs = 1 female				
Bufo sp.	Toad Species	1	1	20%= 1 Adult	5% of eggs = 1 female	1			Generalist, eggs develop fast and can tolerate disturbances
Bufo terrestris	Southern Toad	1	1	20%= 1 Adult	5% of eggs = 1 female	1			Generalist- eggs develop fast, and can tolerate disturbances, temporary pools, shallowy water, sandy areas, flooded meadows
Desmognanthus auriculatus	Southern Dusky Salamander	6	6	20%= 1 Adult	5% of eggs = 1 female		1	1	Site specific to seepage areas, do not tolerate poor water quality as well as other species do, under leaf litter logs, eggs in moss cavities in summer, smal streams, eggs in cavities of rotton logs, under rock surfaces
Hemidactylium scutatum	Four Toed Salamander	10	10	20%= 1 Adult	Each cluster of eggs = 1 female		1	1	Seepage area specific habitat, need mature forest developed moss cavities to lay eggs, found in bogs, NC species of Special Concern.
Hyla chrysoscelis	Cope's Gray Tree Frog	5	5	20%= 1 Adult	5% of eggs = 1 female			1	Site specific to ephemeral ponds or deeper water headwater wetlands, adults rarely found -
Hyla cinera	Green Tree Frog	3	3	20%= 1 Adult	5% of eggs = 1 female	1			
Hyla femoralis	Pine Woods Tree Frog	5	5	20%= 1 Adult	5% of eggs = 1 female				
Hyla squirella	Squirrel Treefrog	6	6	20%= 1 Adult	5% of eggs = 1 female		1		Will use ephemeral wetlands deeper water headwater wetlands can also use ditches and other areas, found in urban settings
Necturus punctatus	Dwarf Mudpuppy	6	6	20%= 1 Adult	5% of eggs = 1 female		1		

Table 4.4.2 -1 Amphibian Ratings and Adult Conversion Table

Species	**Common Name**	**Adults C of C**	**Juv C of C**	**Larvae = 1 Adult**	**Eggs or Egg Masses = 1 Adult**	**Tolerant Species (C of C ≤3)**	**Sensitive Species (C of C ≥6)**	***EW, HW, Seep Species Specific**	**Comments**
Notophthalmus viridescens	Eastern Newt	1	1	20%= 1 Adult	5% of eggs = 1 female	1			
Plethodon cylindraceus	White-spotted Slimy Salamandar	4	4	20%= 1 Adult	5% of eggs = 1 female				
Pseudacris brimleyi	Brimley's Chorus Frog	6	6	20%= 1 Adult	5% of eggs = 1 female		1		
Pseudacris crucifer	Northern Spring Peeper	3	3	20%= 1 Adult	5% of eggs = 1 female	1			Will use ephemeral wetlands deeper water headwater wetlands can also use ditches and other areas, woodland areas, forest litter, brush areas, swamps, ponds , and ditches
Pseudacris feriarum	Upland Chorus Frog	4	4	20%= 1 Adult	5% of eggs = 1 female			1	Site specific to ephemeral ponds or deeper water headwater wetlands, use semi perminant pools, Pseudocris feriarum synonym
Pseudacris ocularis	Little Grass Frog	6	6	20%= 1 Adult	5% of eggs = 1 female		1	1	Site specific to ephemeral ponds or deeper water headwater wetlands, Limnaedus ocularis synonym
Pseudacris ornata	Ornate Chorus Frog	6	6	20%= 1 Adult	5% of eggs = 1 female		1		
Pseudacris sp.	Chorus Frog Species	4	6	20%= 1 Adult	5% of eggs = 1 female		1		If not identified to species then 4
Pseudacris nigrita	Southern Chorus Frog	4	4	20%= 1 Adult	5% of eggs = 1 female		1		
Rana catesbeiana	American Bullfrog	1	1	20%= 1 Adult	5% of eggs = 1 female	1			Generalist
Rana clamitans	Northern Green Frog	2	2	20%= 1 Adult	5% of eggs = 1 female	1			Generalist
Rana palustris	Pickerel Frog	3	3	20%= 1 Adult	5% of eggs = 1 female	1			Generalist
Rana sp.	Frog species	1	1	20%= 1 Adult	5% of eggs = 1 female	1			Consider generalist if not identified to species
Rana sphenocephala	Southern Leopard Frog	3	3	20%= 1 Adult	5% of eggs = 1 female	1			Ephemeral pond or other areas, ponds, ditches and swamps, lake and stream margins
Sterochilus marginatus	Many-lined Salamander	7	7	20%= 1 Adult	5% of eggs = 1 female				Remove if no pic
Urodela sp.	Salamander or Newt Species	4	4	20%= 1 Adult	5% of eggs = 1 female				If not identified to species consider to be a 4

*EW = Ephemeral Wetland, HW = Headwater Wetland

Ambystoma maculatum requires ephemers, headwater, or seepage specific wetlands half the time, but can also be found in less pristine environments such as road-side ditches or small retention areas.

Section 4.5 Macroinvertebrate Monitoring

Section 4.5.1 Macroinvertebrate Field Methods

Macroinvertebrates were sampled in conjunction with the amphibian survey in March of 2007. Each site was first scouted for appropriate sample station locations with the goal of finding variable microhabitats and deep enough water (greater than five inches deep) to deploy funnel trap at two stations. Typically five macroinvertebrate stations were sampled at each site with either a funnel trap or sweep net. Optimally, funnel traps were used at two stations and a sweep net at three stations. However, some sites did not have deep enough standing water to utilize the funnel trap at two stations. Table 4.5.1-1 summarizes the sampling stations located at each site.

The “DWQ Wetland Field Verification Macroinvertebrate Sampling Field Sheet” was completed for each site sampled (see Appendix C). The site name, county, sampler’s initials, Station ID Numbers, sample technique, date, start time, funnel trap deployment time, and station description were recorded on the field sheet. Physical water quality parameters of water temperature and pH were also recorded on the field sheet. Station description information was recorded on each macroinvertebrate field sheet. Station description information included the appropriate Sample ID Number, location (middle or edge of the wetland), flow rate, pool / stream, stream width, depth, percent vegetation cover, percent shade, and substrate texture. Flow Rate (No Flow, Slow, Med, Fast) at most sites was “No Flow” or “Slow”. For pools, the width x length was estimated and for streams only the width was recorded (i.e. continuous water in stream bed). The “percent vegetation”, “percent shade”, and “substrate texture” solely referred to the microhabitat where the macroinvertebrate sample stations were located (see DWQ Wetland Field Verification Macroinvertebrate Sampling Field Sheet in Appendix C). Station ID numbers were labeled at the corresponding field station with yellow pin flagging. GPS was used to record the location of the sampling stations. Photos were also taken of each sample station. Sample methods for funnel traps and sweep nets are described in the following sections.

Table 4.5.1-1 Macroinvertabrate Stations

Site	funnel	sweep	Total
Belton Creek	2	3	5
Bluegreen Golf	2	3	5
Dargan	2	3	5
Dean	2	3	5
Doe Creek	2	3	5
Eastwood	1	4	5
Fairport	4	3	7
Goldston	2	3	5
Gray	.	3	3
Hancock	2	3	5
Hart	2	3	5
Hewett Wildlife	2	3	5
Kim-Brooks	2	3	5
Lockwood	2	3	5
Martin-Amment	2	3	5
Mercer Seawatch	2	3	5

Site	funnel	sweep	Total
Mill Creek	2	3	5
Munn	2	3	5
Powers	2	3	5
Rourk	1	4	5
Seawatch Bay	2	3	5
Seawatch Nautica	2	3	5
Sikka	2	3	5
Winding River Pond	2	3	5
Winding River Townhouse	2	3	5

Sample Methods

FUNNEL TRAP STATIONS

The funnel trap is a semi-quantitative method used for sampling macroinvertebrates. Funnel traps are easy to use activity traps that collect a clean sample and require little processing time; however, funnel traps do not collect as wide a range of taxa as some of the other methods. Logistically, they are difficult to plan. They require two site visits approximately 24 hours apart, higher water levels than for the other methods, and predation may occur in the trap by macroinvertebrates or amphibians (U.S. EPA 2002d).

The funnel traps used at the headwater wetland sample stations were 18 x 6 inch cylinders with inverse funnels located on either side with 2” openings to allow macroinvertebrates easy entry (See Figures 4.5.1a and 4.5.1b). Each trap was made with a layer of window screen and 300-micron nitex netting. Funnel traps were deployed for approximately 24 hours (+/-2 hours). Care was taken when deploying the funnel traps to ensure that air pockets existed for any amphibian that might enter the trap and that the openings remained open and were completely under water. As needed, sediment and debris were removed to ensure the traps were placed deep enough in the water to be effective. Traps were kept horizontal when retrieving and then placed vertically in the washbasin where water was used to rinse the macroinvertebrates from the traps into the washbasin. The contents of the washbasin were then decanted through a sieve (250-micron or smaller) to remove excess water or sediment from the sample. Lastly, the sample was put in a labeled container. Funnel traps were rinsed thoroughly between site usages.

SWEEP STATIONS

Sweep nets, or dip nets, are another semi-quantitative method that is quick and easy to use. They can collect a diverse array of representative taxa and are usable in very shallow water. Unlike funnel traps, sweep nets are not as useful for collecting motile and nocturnal species, require a longer processing time, and may result in user variability (U.S. EPA 2002c). In order to ensure more semi-quantitative results, D-shaped nets (600-micron) were used to sweep a 1-meter area with 3-4 sweeps per station (see Figures 4.5.1-1a and 4.5.1-1b). The 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 put in a labeled container. Sweep nets were rinsed thoroughly between wetland study sites.

All sample containers were labeled in pencil with site name, date, sample ID, container number, dye, field crew initials, sample-processing initials, and date processed. Rose bengal dye was used when there was excessive sediment in the sample, which included all stove-pipe samples, and some sweep-net samples and a few funnel trap samples. For preservation, 70 percent non-denaturized ethanol alcohol was added to each sample bottle.

Figure 4.5.1-1a Funnel Trap

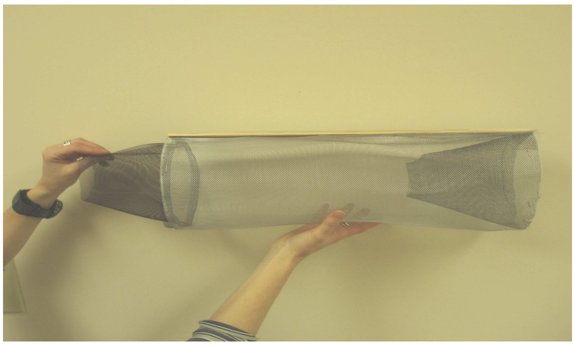


Figure 4.5.1-1b Funnel Trap in the Field

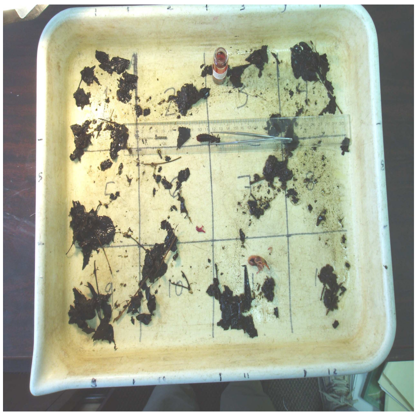
Figure 4.5.1-2a Sweep Net

Figure 4.5.1-2b Sweep Net in Field

Section 4.5.2 Macroinvertebrate Sample Processing Procedure

Macroinvertebrate samples were picked randomly under a light by using a picking tray with 12 grid cells (see Figure 4.5.2-1). Sample contents were stirred and then deposited evenly on a 14 x 17 inch tray. All macroinvertebrates that were greater than one cm in length were picked from the sample first to ensure that predators and species higher on the food chain were included in the processed sample. Grid cells were randomly chosen for picking after taxa greater than one cm in length were removed from the sample. Each grid cell was entirely picked prior to starting the next randomly chosen grid cell. A total of 200 individuals or the entire sample (if less than 200 individuals found) was picked for each sample. Processed specimen sample jars were labeled with the site name, station ID, number of individuals picked, date of collection, and picker's initials.

Figure 4.5.2-1 Macroinvertebrate Picking Tray



Section 4.5.3 Aquatic Macroinvertebrate IBI Development and Analysis

A total of 125 samples were collected in four different abundance classes: 34 samples in the 0-50 abundance class, 25 samples in the 51-100 abudance class, 18 in the 101-150 abundance class, and 47 in the 151-200 abundance class. The process of finding a contractor to enumerate and identify the taxa in each sample was begun in June 2008 after the samples had been processed as the exact count per sample was needed to post the Request for Proposal. Due to state budget constraints, the identification and enumeration of the 125 samples will be done in 2010 using DWQ staff. The following section provides the potential analysis of the macroinvertebrate data after the samples are enumerated and identified. Candidate metrics may be changed after the samples have been enumerated, identified, and entered into a database.

Approximately 36 biological attributes will potentially be tested as metrics for the NC Wetland Index of Biotic Integrity for Riverine Swamp Forest, Bottomland Hardwood Forest, and Small Basin Wetland. The candidate metrics will be chosen by reviewing data with the assistance of NC DWQ aquatic macroinvertebrate biologists and a literature review of other stream and wetland IBI development studies by Rader *et al*. (2001), Ohio EPA (2004), U.S. EPA (2002c), Reiss and Brown (2005), Chirhart (2003), and Stribling *et al*. (1998). Wetland disturbance measures as determined by the Ohio Rapid Assessment Method (ORAM), Land Development Index (LDI) for the watershed and 100m buffer, water quality, soil pH, zinc, and copper will be used to test the 36 candidate metrics (see Section 2). Table 4.5.3-1 lists the potential candidate metrics and the expected response (positive or negative) with the various disturbance measures. Candidate metrics are listed in Table 4.5.3-1 according to metric type: Taxonomic Richness, Taxonomic Composition, Trophic Structure, and Tolerance / Sensitive.

Table 4.5.3-1 Candidate Macroinvertebrate Metrics with Expected Response to Disturbance Measures

Metric Type	Candidate Metric	LDI, Water Quality, Soils Metals	ORAM, soil and water pH, DO
Taxonomic Richness	Species Richness	Negative	Positive
	Genera Richness	Negative	Positive
	Family Richness	Negative	Positive
	Chironomidae Richness	Negative	Positive
	EPT Richness	Negative	Positive
	OET Richness	Negative	Positive
	POET Richness	Negative	Positive
Taxonomic Composition	Percent Decapoda	Negative	Positive
	Percent Oligochaeta	Positive	Negative
	Percent Chironomidae	Positive	Negative
	Percent Coleoptera	Negative	Positive
	Percent Corixidae	Positive	Negative
	Percent Crustacea	Negative	Positive
	Percent Diptera	Positive	Negative
	Percent Dytiscidae	Negative	Positive
	Percent Hemiptera	Positive	Negative
	Percent Leech	Positive	Negative
	Percent Microcrustacea	Variable	Variable
	Percent Mollusk	Negative	Positive
	Percent Orthocladiinae	Positive	Negative
	Percent Terrestrial	Variable	Variable
	Percent Trichoptera	Negative	Positive
	Percent Trombidiformes	Negative	Positive
	Percent EPT*	Negative	Positive
	Percent OET**	Negative	Positive
	Percent POET***	Negative	Positive
	Percent of Top 3 Dominants	Positive	Negative
	Evenness	Negative	Positive
	Simpson's Index of Diversity	Negative	Positive
	Site Abundance	Negative	Positive

Table 4.5.3-1 Candidate Macroinvertebrate Metrics with Expected Response to Disturbance Measures

Metric Type	Candidate Metric	LDI, Water Quality, Soils Metals	ORAM, soil and water pH, DO
Trophic Structure	Percent Predators	Negative	Positive
	Predator Richness	Negative	Positive
Tolerance / Sensitive	Percent Sensitive	Negative	Positive
	Percent Tolerant	Positive	Negative
	Sensitive : Tolerant	Negative	Positive
	Macroinvertebrate Biotic Index Score****	Positive	Negative

*EPT=Ephemeroptera, Plecoptera, Trichoptera

**OET=Odonata, Ephemeroptera, Trichoptera

***POET=Plecoptera, Odonata, Ephemeroptera, Trichoptera

**** The Macroinvertebrate Biotic Index metric uses a method created by David Lenat of the NC DENR Division of Environmental Management for use in southeastern streams (Lenat 1990). The Macroinvertebrate Biotic Index is calculated as follows:

$$\mathrm{MBI} = \frac{\sum \mathrm{TV}_i \mathrm{N}_i}{\mathrm{N}}$$

MBI = Macroinvertebrate Biotic Index
TVi = Tolerance Value of ith taxa
Ni = Abundance of ith taxa
N = Total Number of individuals in taxa

Metrics using aquatic macroinvertebrate data will be tested against the disturbance measures using both Spearman’s rho and Pearson’s Correlation Coefficient with pairwise comparisons. Non-parametric data will be transformed as needed for the Pearson’s Correlation Coefficient test. Correlations will be performed on each wetland type separately and on wetland type by region for the Small Basin wetlands.

Section 4.6 Plant Monitoring

Section 4.6.1 Plant Monitoring Field Survey Methods

The field survey methods for plant monitoring are described below.

Section 4.6.1.1 Presence-Absence Species Lists

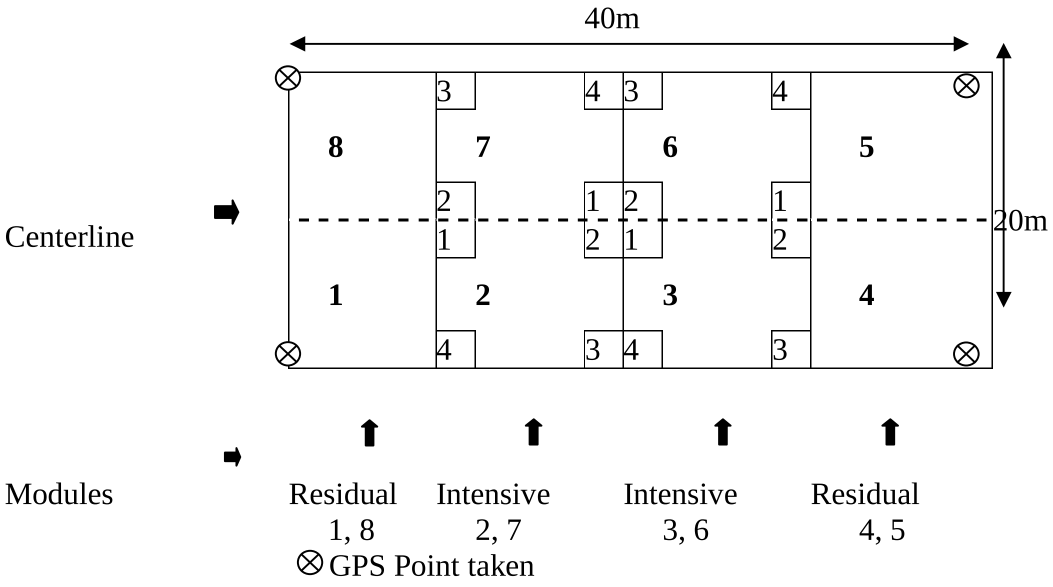
In order to generate a species list for the site, all vascular plant species located within the study area boundary were identified to species, if possible. Species lists were recorded in field notebooks and transferred to a database. Voucher specimens were obtained for identification. All taxa were identified to the lowest practical taxonomic level. Voucher specimens were collected and identified resulting in the modification of site species lists, field survey sheets, and the plant list database as needed. Voucher specimens were processed, labeled, and catalogued for future reference. The University of North Carolina Herbarium was contracted to identify some of the more difficult voucher specimens such as grass and sedge species. The “Flora of the Carolinas, Virginia, Georgia, and Surrounding Areas, Draft January 2007 (Weakley 2007) was used for genus and species nomenclature for all survey-related field research or databases used for this project.

Section 4.6.1.2 Community Plant Survey

Plant community monitoring methods were developed with a survey design similar to “The North Carolina Vegetative Survey Protocol (Peet *et al*. 1997), also known as the Carolina Vegetative Survey (CVS). The CVS was developed by experienced North Carolina botanists and ecologists for the purpose of providing a quantitative description of the vegetation in a variety of habitats throughout the Carolinas. However, this method was developed to be used in high quality references sites that have a fairly consistent homogenous plant community. The sites chosen for the Wetland Verification project are variable in quality and function and are not always homogenous in plant community type, either due to wetland size or past disturbance. The sampling plot design also differs from the CVS design in that eight Modules rather than ten modules were typically surveyed for presence, cover, and woody stem DBH (see Figure 4.6.1.2-1). Plant surveys were completed on all sites during the 2007 and 2008 field season except for the Hart site due to loss of access to the site.

Plot Description

Figure 4.6.1.2-1 Normal Plot Layout



Plot Layout for Normal Plots

Typically a plot consisted of eight modules (or subplots) that were 10x10 m in size and numbered counter clockwise from one to eight (See Figure 4.6.1.2-1). Modules were arranged in a 2 x 4 array with a 40 m centerline located along the long axis line between modules 1 and 8 and 4 and 5 (see Figure 4.6.2.1-1 or the DWQ Wetland Field Verification Plot Layout Sheet located in Appendix B). The best orientation for the plot was chosen in the field according to the contours of the wetland boundary and consistency of site vegetative community. GPS points were taken at the four corners of the plot (see Figure 4.6.2.1-1). The corners of the modules 2, 3, 6, 7, are intensive modules and were surveyed for vegetation cover and woody stem density while modules 1, 4, 5, and 8 are residual modules and were surveyed for woody stem density only. The vegetation cover and woody stem density surveys are described later in this section

Plot Layout for Varied Plots

For some wetland sites, the 2 x 4 array of modules were not feasible due to the site size, contours of the site boundary, proposed development, road intersections, or condition of the habitat. In these situations a varied plot layout was used instead. Varied plots consisted of 10 x 10 modules, laid out in the most practical way to allow up to eight modules to be surveyed within site's wetland habitat boundary. Within variable plots, the four most centrally located modules, or those four modules that were most representative of the site's vegetative community were intensively surveyed, while additional modules were considered residual. For example, the Gray site in Granville County was too small to allow for a 2 x 8 array of modules, therefore a 2 x 2 array of modules were surveyed. Chimney Rock Road intersects the Doe Creek site and there is a proposed road that insects the Mercer Seawatch site. In these two situations, a 2 x 2 array of modules was surveyed on either side of the existing / proposed road crossing with two intensive and two residual modules being surveyed in each 2 x 2 array of modules. Other sites (Bluegreen Golf and Hewett Wildlife) also required a varied plot layout. The layout of the varied plot was drawn on the lower half of the "DWQ Wetland Field Verification Plot Layout Sheet" (see Appendix C).

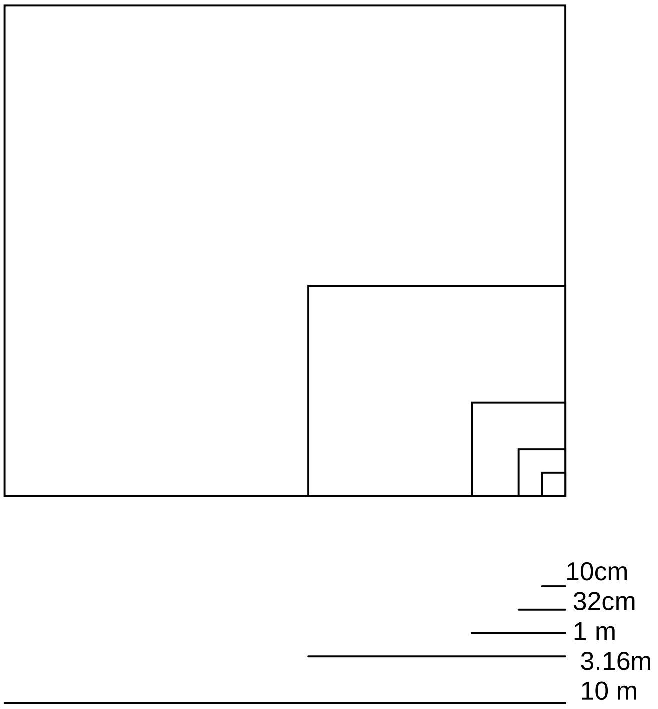
Plot Survey Methods

The "DWQ Wetland Field Verification Plant Survey Species Cover Field Sheet" and the "DWQ Wetland Field Verification Woody Stem Survey Field Sheet" were completed for the vegetation cover and woody stem density survey respectively (see Appendix C). The first column on both field sheets referred to the species code, which was filled out in the office and used in the plant database later. The species code was typically the first four letters of the Genus followed by the first four letters of the species (e.g. *Acer rubrum* = acerrubr). For species identified to genus (or family) only, the code would be the first four letters of the genus (or family) followed by spp (e.g. Acer species = acerspp or Poaceae species = poacspp). All other columns on both field sheets were filled out in the field. For both the plant and woody stem survey, the scientific name for the species was written down as accurately and quickly as possible in the species column. Vouchers of plants that could not be identified in the field were collected and later identified in the office or by the University of NC Herbarium and then the corrections to datasheets were made accordingly.

Plant Species Coverage Survey

As previously discussed, modules 2, 3, 6, 7 were intensively surveyed for plant coverage. Each intensive module had corners numbered from "1" to "4" counter-clockwise in which a series of nested quadrats was surveyed (see the labeled corners in Figure 4.6.1.2-1 and nested quadrats in Figure 4.6.1.2-2). The species presence was determined at one chosen corner within each intensive module first and then cover classes were assigned to each species present within the module. One corner was chosen in the field for each intensive module to be surveyed for presence. Adjacent corners of adjacent modules such as module-2, corner-1 and module-7, corner 2 (see Figure 4.6.1.2-1) or corners with localized disturbance, such as a downed tree were not chosen to survey presence.

Figure 4.6.1.2-2. Nested Quadrats Diagram



A series of nested quadrats (see Figure 4.6.1.2-2) were surveyed for presence at the chosen survey corner. The nested quadrats were composed of five nested quadrats that increased in size from 10 x 10 cm to 10 x 10 m exponentially. “Presence” for a plant species is defined as being rooted within the boundary of the survey quadrat. “Presence class” is defined by the smallest of the nested quadrats the plant is rooted in. The quadrat size and presence class are as follows: class 5 – 10 cm x 10 cm, class 4 – 32 cm x 32 cm, class 3 – 1 m^2, class 2- 3.16 m x 3.16 m, and class 1 – the entire 10 m x 10 m module (see Figure 4.6.1.2-2). Each nested quadrat was surveyed in order by size from the smallest quadrat (10 cm x 10 cm or presence class 5) to the largest quadrat (10 m x 10 m or presence class 1). Any individual plant species that over hung the intensive module, but was rooted within the module was given a presence class of “0”. The presence class of “0”, “1”, “2”, “3”,”4”, or “5” were recorded under the appropriate corner number (c#) and module number. A cover class was assigned to every species rooted in or overhanging the intensive module after all presence values had been assigned. Cover is defined as “The percentage of ground surface obscured by the vertical projection of all above ground parts of a given species onto that surface.” Cover classes are: 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), 95-100% (10 m^2). The cover class was recorded in the percent cover (%cov) column for each species under the appropriate module number. The overall cover for the herb (H), shrub (S), and Canopy (C) vertical stratums for each module was recorded last, directly under the module number. The vertical stratums classes are herb = 0-1m, shrub = 1-6 m, and canopy = >6 m. The residual modules were surveyed for any species that was not present in the intensive modules after the intensive modules survey was completed. The species code, Genus species, and collected (when applicable) columns were completed for any new species surveyed in the residual modules (see DWQ Wetland Field Verification Plant Survey Species Cover Field Sheet, Appendix C).

Woody Stem Survey

The survey of the woody plants (primarily trees, shrubs and vines) was recorded on the "DWQ Wetland Field Verification Woody Stem Survey Field Sheet" (see Appendix C). Every individual live stem that was rooted within the plot and reached Diameter at Breast Height (DBH =1.37m) was surveyed and tallied on this field sheet. Two separate lines and therefore a separate tally needed to be used if the same species occurred in two separate intensive Modules (one for each Module). Each individual stem was measured and tallied as one of the following size classes: <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 >35 cm. DBH rounded to the nearest centimeter was recorded for trees ≥ 35 cm DBH. For bifurcated saplings or shrubs, "Individual stems" were defined as stems that split below 1 meter in height. 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 1m. Snags that were ≥5 cm and reached DBH level were also be included in this survey.

Section 4.6.2 Plant IBI Development and Analysis

An overall species list database was developed. The "Species list" database contained fields for the species code (see section 4.6.1.2), genus species, common name, family, NWI Region 2 Wetland Indicator Status (Resource Management Group, Inc. 1999), physiognomic form (fern, forb, grass, moss, sedge, shrub, small tree, tree, and vine), habit (annual, perennial, cryptogram, woody species), group (monocot or dicot), shade tolerance (shade species, light species, partial light species, or adventive) and coefficient of conservative value (C of C). Three botanists (Dr. Alan Weakely, Dr. Peter White, and Dr. Johnny Randall) from the University of North Carolina, Chapel Hill, were contracted to evaluate each plant species and assign C of C values based on Taft et al. (1997), which is summarized in Table 4.6.2-1 below. An average value of the C of C ratings of the three botanists was calculated for the species list database (see Appendix D).

Information from the "DWQ Wetland Field Verification Wetland Woody Stem Survey Field Sheet" and "DWQ Wetland Field Verification Plant Survey Species Cover Sheet" was also entered into a "Coverage and woody stem survey" database in Excel. The median cover value for each cover class (see Table 4.6.2-2) was calculated for all coverage records on the "DWQ Wetland Species Plant Survey Species Cover Sheet" and entered in the database. Voucher species identifications were used to modify and correct the field sheets and databases prior to analysis.

Table 4.6.2-1 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.

Table 4.6.2-2 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

CANDIDATE METRICS

A total of 40 candidate metrics were identified for use as potential metrics for the Riverine Swamp Forest, bottomland hardwood, and Small Basin wetland wetland Plant IBIs (Indices of Biotic Integrity). The candidate metrics assessed for the study were different types of vegetative parameters (or different types of metrics): community balance metrics, floristic quality metrics, wetness metrics, functional group metrics, or community structure metrics. All metrics were calculated and statistically tested with JMP v. 6.0 software. Spearman’s Rho correlation coefficient, a non-parametric correlation test, was used to test each candidate metric. Plant metrics were tested for normality using the Shapiro-Wilk W Goodness of Fit test (see Section 2). Spearman’s Rho was used since the candidate metric data and disturbance measures were not always normally distributed. In addition, the candidate metrics and disturbance measures were transformed and tested for correlation using Pearson's pairwise correlations. The ORAM and LDI disturbance measurements were used to test the candidate metrics (see Section 2). The candidate metric correlations were tested separately for the three different wetland types. A p-value of 0.15 was considered significant. ORAM and LDI are believed to provide a better overall indicator of site disturbance then water quality and soil characteristics and were therefore use to test plant metrics.

The following is a list and description of each metric. The metrics are organized according to vegetative parameter (or metric type). Table 4.6.2-3 lists the candidate metrics and the expected correlation (positive or negative) with the various disturbance measurements.

Community Balance Candidate Metrics

Simpson's Diversity Index 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. The Simpson's diversity using cover (D_{cov}) was also calculated and tested as a candidate metric.

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

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 and *Native Species Evenness Metrics*– 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. Evenness using coverage and just native species was also calculated and tested as a candidate metric.

$$E_s = D_s / D_{max}$$

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

$$D_{max} = (s - 1 / s) * (N / N - 1) \qquad D_{max\text{-}cov} = (s - 1 / s) * (N_{cov} / N_{cov} - 1)$$

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 and Dominance for Herb and Shrub cover metrics – These metrics incorporates the "distribution or concentration" of the three most dominant species cover class values for all individuals and shrub and herb classified individuals.

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

Species Richness Metric – Total Number of Species

Vascular Plant Genera Richness Metric – Total number of vascular plant genera.

Floristic Quality Candidate Metrics

FQAI and *FQAI Cover Metrics* - 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 metric used in this study also includes non-natives in the species total (Fennessy *et al*. 1998a and 1998b, Lopez and Fennessy 2002, Mack 2004). The FQAI_{cov} metric, which incorporates species cover into the equation, was used in this study. See Table D in Appendix D for a list of NCDWQ Coefficient of Conservatism plant rankings.

$$\mathrm{FQAI} = \sum \mathrm{C}_i / \sqrt{\mathrm{N}} \qquad \mathrm{FQAI}_{cov} = \sum \mathrm{C}_i * Cov_i / \sqrt{N} * \mathrm{Cov}_{tot}$$

C_i - Coefficient of Conservatism for species i
N - Species richness (including non-natives)
Cov_i - Cover of species i
Cov_{tot} – Total Coverage including non-native species

Average C of C Metric – Average Coefficient of Conservation value (see Appendix F).

Percent Tolerant Metric – Total relative coverage of all species, including non-natives, with a C of C value ≤ 2.

Percent Sensitive Metric - Total relative coverage of all species, including non-natives, with a C of C value ≥ 7.

Invasive Coverage Metric – Total relative cover of all non-native invasive species.

Invasive Shrub Coverage Metric – Total relative cover, within the shrub stratum only, of non-native invasive shrubs.

Invasive Grass Coverage Metric – Total relative cover, within the herb stratum only, of non-native invasive grasses.

Wetness Characteristics

FAQWet Metrics (FAQWet Equation 3 Metric and *FAQWet Cover Metric)* – The Floristic Assessments for Wetland Plants index equations "3" and "4" were devised by Ervin *et al*. (2006). These equations incorporate species wetness, number of species, number of native species, and frequency of native species. For this study, the FAQWet equation "3" was tested; however, the FAQWet equation "4" was revised to include coverage (FAQWet Cover Metric) rather than frequency as a factor in the equation. Frequency values are typically calculated by the number of times a specific plant species occurs within survey plots. Therefore the more survey plots in a study, the more variable the value for frequency. FAQWet equation "4" was not used in this study since there were only four large survey plots (i.e., four intensive modules). The FAQWet metric equations are as follows:

$$\text{FAQWet equation 3} = \sum WC/\sqrt{S} * N/S$$

$$\text{FAQWet equation 4} = \sum WC/\sqrt{\text{S}} * \sum f/\sum F$$

$$\text{FAQWet Cover} = \sum WC/\sqrt{\text{S}} * \sum \text{Cov}_{\text{nat}}/\sum \text{Cov}_{tot}$$

WC = Wetness Coefficient
S = All species
N = Native Species
F = Frequency of all species
f = Frequency of 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.

Wetland Plant Cover Metric – Coverage of native herb species with a FACW or OBL wetland indicator status.

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

Wetland Shrub Cover Metric – Coverage of native wetland shrubs with a FACW or OBL wetland indicator status.

Functional Groups

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

Cryptogram Coverage Metric – Total relative cover of fern and fern allies in the herb layer.

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

Bryophyte Coverage Metric – Total relative coverage of moss in the herb layer.

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

Carex Coverage Metric – Total relative cover of *Carex* species.

Cyperaceae, Poaceae, and Juncaceae Metric – Total number of native Cyperaceae, Poaceae, Juncaceae.

Cyperaceae, Poaceae, and Juncaceae Coverage Metric – Total relative cover of native Cyperaceae, Poaceae, and Juncaceae in the herb layer.

Dicot Richness Metric – Total number of native dicot herb species.

Dicot Coverage Metric – Relative percent cover of native dicot herb stratum species in the herb layer.

Community Structural

Native Herb Species Richness – Total number of native herb species.

Native Herb Cover Metric – Total herb cover for native species.

Total Herb Species Richness (Native and Exotic) Metric –Total herb richness for both native and exotic species.

Total Herb Cover (native and exotic) Metric –Total herb cover for both native and exotic species.

Shade Metric – Number of native species (not including adventives or trees) with a shade rating of “shade” or “partial shade”. See Appendix D, Table D for a list of plant shade rankings.

Sapling Density Metric – Relative density of canopy and small tree sapling species 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 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 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 trees ≥ 25 cm DBH. The relative density of trees ≥25 cm was calculated by dividing the total number of ≥ 25 cm DBH canopy and small tree species stems by the total number of all canopy and small tree 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 size class (10-15, 15-20, 20-25) 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 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 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.

Average Importance Shrub Metric - The *Average Importance Shrub Metric* is the sum of the average importance value for native shade-tolerant and partial shade-tolerant shrubs and small trees. 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 shrub and small tree stems per species by the total number of woody 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 shade or partial shade shrub and small tree species by the total dominance of all woody 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.

Standing Snag Importance – Snags provide habitat for wildlife. This candidate refers to the Relative Importance of Snags. Relative Importance = Relative Frequency + Relative Dominance + Relative Density.

Table 4.6.2-3 Candidate Plant Metrics and expected Correlation with Disturbance Measurements

Candidate Metric	ORAM Score	LDI Scores
Community Balance Candidate Metrics		
Simpson's Diversity Index Metric	Positive	Negative
Evenness Metric	Positive	Negative
Dominance Metric	Negative	Positive
Herb and Shrub Dominance Metric	Negative	Positive
Species Richness Metric	Positive	Negative
Vascular Plant Genera Richness Metric	Positive	Negative
Floristic Quality Candidate Metrics		
FQAI Cover Metric	Positive	Negative
Average C of C Metric	Positive	Negative
Percent Tolerant Metric	Negative	Positive
Percent Sensitive Metric	Positive	Negative
Invasive Coverage Metric	Negative	Positive
Invasive Shrub Coverage Metric	Negative	Positive
Invasive Grass Coverage Metric	Negative	Positive
Wetness Characteristic Metrics		
FAQWet Equation 3 Metric	Positive	Negative
FAQWet Cover Metric	Positive	Negative
Wetland Plant Species Richness Metric	Positive	Negative
Wetland Plant Cover Metric	Positive	Negative
Wetland Shrub Species Richness Metric	Positive	Negative
Wetland Shrub Cover Metric	Positive	Negative
Functional Groups		
Cryptogram Richness Metric	Positive	Negative
Cryptogram Coverage Metric	Positive	Negative
Annual : Perennial Metric	Negative	Positive
Bryophyte Coverage Metric	Positive	Negative

Table 4.6.2-3 Candidate Plant Metrics and expected Correlation with Disturbance Measurements

Candidate Metric	**ORAM Score**	**LDI Scores**
Carex Richness Metric	Positive	Negative
Carex Coverage Metric	Positive	Negative
Cyperaceae, Poaceae, and Juncaceae Metric	Positive	Negative
Cyperaceae, Poaceae, and Juncaceae Coverage Metric	Positive	Negative
Dicot Richness Metric	Positive	Negative
Dicot Coverage Metric	Positive	Negative
Community Structural		
Native Herb Richness Metric	Positive	Negative
Native Herb Cover Metric	Positive	Negative
Total Herb Richness (Native and Exotic) Metric	Positive	Negative
Total Herb Cover (Native and Exotic) Metric	Positive	Negative
Shade Metric	Positive	Negative
Sapling Density Metric	Negative	Positive
Large Tree Density Metric	Positive	Negative
Pole Timber Density Metric	Negative	Positive
Canopy Importance Metric	Positive	Negative
Average Importance Shrub Metric	Positive	Negative
Standing Snag Importance	Positive	Negative

Section 5 – Results: Riverine Swamp Forests and Bottomland Hardwood Forests

Section 5.1 Riverine Swamp Forests and Bottomland Hardwood Forests: Introduction and Background

Bottomland hardwood and Riverine Swamp Forests occur in extensive mosaics North Carolina's rivers and streams. Riverine Swamp Forests are more common in the Coastal Plain, and occupy many positions in the landscape; stream headwaters, saturated areas along large rivers, floodplains, fresh- and brackish-water tidal forests, and large lakes where enough wind fetch occurs to produce wind tides that effectively function as overbank flooding (generally larger than 20 acres). Riverine Swamp Forests can also be created or augmented by beaver impoundments in the Coastal Plain and Piedmont ecoregions as was the case with two of the Coastal Plain project sites (Winding River Pond and Hewitt Wildlife).

Both riverine and bottomland systems receive inputs from overbank flooding, groundwater, and surface runoff, but the frequency and amount of all of these inputs is increased in Riverine Swamp Forests causing them to remain inundated seasonally to semi-permanently. Bottomland Hardwood Forests are common on the floodplains of second-order and larger streams and rivers throughout the state and are usually intermittently to seasonally inundated (see NCWAM User Manual, 2008, http://h2o.enr.state.nc.us/ncwetlands/pdu.htm). It is possible to progress from a Bottomland Hardwood Forests downslope to a Riverine Swamp Forests, or to have only one type present. If both types are present, differences in topographic relief and hydrology can cause the borders of the two systems to undulate and intersperse.

In second or higher order streams, local hydrology and sedimentation are important factors in determining whether and Riverine Swamp Forests or Bottomland Hardwood Forests will be present in a given area. These factors influence plant community type and inundation period which in turn define wetland type. Flow regime plays an important part in nutrient and sediment inputs, which also in turn affect plant community type (Hodges 1997). Soils in the Riverine Swamp Forests are both organic and mineral, while Bottomland Hardwood Forests tend to be mineral only. Riverine Swamp Forests in the Piedmont and Blue Ridge regions are characterized by a canopy of overcup oak (*Quercus lyrata*), ashes (*Fraxinus* spp.), and American Elm (*Ulmus americana*) while the Coastal Plain canopy is dominated by bald-cypress (*Taxodium ascendens*) and/or pond-cypress (*Taxodium distichum*), and water tupelo (*Nyssa biflora*). The herbaceous layer ranges from nearly absent to moderate but is most always obligate (Schafale and Weakley 1990). In Bottomland Hardwood Forests, canopy tree species consist of hardwoods such as oaks (*Quercus* spp.), red maple (*Acer rubrum*), ashes (*Fraxinus* spp.), and other hardwoods (NCFAT 2008). The herbaceous layer in Riverine Swamp Forests is sparse to moderate with native herbs such as false-nettle (*Boehmeria cylindrica*), sedges of the genus *Carex*, river oats (*Chasmanthium latifolium*), are often suppressed by exotic invasive plant species such as Japanese stilt-grass (*Microstegium vimineum*) and Japanese honeysuckle (*Lonicera japonica*), particularly in the Piedmont and mountains (Schafale and Weakley 1990). The role of sediment and organic debris (seeds and decomposed leaves etc) inputs and deposition on species distribution will be discussed in more detail below.

Though patterns of flooding and inundation differ between Bottomland Hardwood Forests and Riverine Swamp Forests, their formation is due to many of the same processes. Common landscape features found in southeastern floodplains include meandering river channels, oxbow lakes created when river meanders change course, natural levees, and areas of ponded water inside meanders called sloughs. Oxbows and sloughs, because of their increased water retention, are likely sites for the formation of bald cypress-tupelo Riverine Swamp Forests in the Coastal Plain (Mitsch and Gosselink 2000). The levees and drier areas would likely support Bottomland Hardwood Forests or non-wetland vegetation. Sediment deposition during overbank flooding is greater on levees and swales, while the semi-permanently flooded Riverine Swamp Forests receive less nutrient input. The same inundation pattern also leads to an accumulation of organic material in Riverine Swamp Forests due to reduced decomposition and increased residence time. Bottomland Hardwood Forests on blackwater streams also receive less sediment and nutrients than their brownwater counterparts (NCFAT 2008). Brownwater streams that arise in uplands are high energy systems that often carry large sediment loads (Hupp 2000). Streams associated with these communities may be quite old, but the sediments deposited in these floodplains are of recent geologic origin, and consist of soil material derived from the Piedmont and mountains of North Carolina (Hodges 1997). Blackwater streams are generally low gradient and lack the energy for significant sediment transport (Hupp 2000).

Forested wetlands act as natural basins during heavy precipitation events. Excess rainwater from upland areas backs up into backwaters such as sloughs and oxbows and adjacent bottomlands, lessening the severity of downstream flooding as this water is slowly released downstream. In addition, this backwater flooding is often laden with pollution and nutrient-rich sediments, which are deposited in these bottomland and riverine basins far from stream and river channels, thus improving downstream water quality (Kellison and Young 1997). This pollution removing function of Bottomland Hardwood Forests was quantified as a monetary value in a 1990 study of a bottomland hardwood swamp at present day Congaree National Park in central South Carolina. Researchers found that the pollutants removed by these wetlands were equivalent to the function of a $5 million wastewater treatment plant (USEPA 1995).

Wetland processes play an important role in transforming nutrients and releasing them into the atmosphere. In particular, Bottomland Hardwood Forests and Riverine Swamp Forests have high productivity and decomposition rates because of their flowing water and pulsing hydrological regimes, allowing for the rapid exchange of nutrients. Wetland inputs of nutrients derive from precipitation and river flooding; outflows distribute nutrients and organic matter to downstream habitats (Mitsch and Gosselink 2000).

As mentioned above, hydrology and sedimentation are the key differences between Bottomland Hardwood Forests and Riverine Swamp Forests. They are both highly productive and diverse systems as a result of episodic flooding which provides inputs of organic and mineral suspended materials. Disturbances play a large role in the successional pattern in a wetland, with intermediate magnitude and frequency of disturbances favoring the presence of fast-growing pioneer species. Reduced connectivity to rivers and streams will decrease the disturbance regime, allowing less competitive species to thrive. It should be noted that extreme isolation can increase diversity by preserving past vegetation patterns that are now atypical in a region (e.g. upland plants from the mountains in now-isolated floodplains) (Bornette 1998). Unlike upland sites, bottomland succession is very dependent on both internal (plant-mediated) and external processes such as soil deposition and floods (Hodges 1997). Another major factor in the succession of North Carolina's forested wetlands is the frequency of hurricanes. Windthrow due to these storms opens up the canopy and allows increasing amounts of sunlight into the forest floor, letting sun-tolerant trees such as sweetgums, red oaks, and pines flourish (Batzer and Sharitz, 2006).

The cypress-tupelo swamps of the Coastal Plain experience a naturally longer successional cycle because of the longevity of the trees. With stands able to reach 200-300 years of age, succession can become arrested on these sites, barring significant disturbances (Hodges 1997). Schafale and Weakley identify six types of ecosystems that are considered to be Riverine Swamp Forests wetland by the NCWAM method. Those six types are: 1. Cypress-Gum Swamp (Blackwater subtype), 2. Cypress-Gum Swamp (Brownwater subtype), 3. Coastal Plain Stream Small Stream Swamp (part), 4. Piedmont/Mountain Swamp Forest, 5. Tidal Cypress-Gum Swamp, 6. Natural Lake Shoreline (Schafale and Weakley, 1990, NCFAT 2008). The Riverine Swamp Forests sites that were surveyed in the Lockwood Folly River Watershed for this study were all Cypress-Gum Swamp (Blackwater subtype). The understory of blackwater Riverine Swamp Forests ("Cypress-gum swamp [blackwater subtype]" from Schafale and Weakley 1990) is characterized by Carolina ash (*Fraxinus caroliniana*), swamp tupelo, and red maple (*Acer rubrum*), while ti-ti (*Cyrilla racemiflora*), sweet pepperbush (*Clethra alnifolia*) and fetterbush (*Lyonia lucida*) make up the shrub layer. Though generally sparse, the understory may be quite dense in areas. "The herb layer ranges from nearly absent to moderate cover." (Hodges 1997) Common species include lizard's-tail (*Saururus cernuus*), giant sedge (*Carex gigantea*), dotted smartweed (*Persicaria punctatum*), *Centella asiatica*, *Hydrocotyle verticillata* var. *triradiata*, threeway sedge (*Dulichium arundinaceum*), and netted chain fern (*Woodwardia areolata*).

The Riverine Swamp Forests of the Lockwood Folly River watershed were generally dominated with bald cypress and gum or swamp tupelo trees. However, cypress trees were rarer at a few of the sites. Ash, red maple, sweet bay (*Magnolia Virginian*), swamp bay (*Persia palustris*), and sweet gum (*Liquidambar styraciflua*) were also present in the canopy with ti-ti, wax myrtle (*Morella cerifera*), and tag alder (*Alnus serrulata*) in the shrub layer, and lizard's tail, royal fern (*Osmunda regalis*), and various sedges and rushes in the herb layer. Of the seven sites, three were tidally influenced (Doe Creek, Lockwood Folly River, and Mercer Seawatch). However, the tidal influence at the Mercer Seawatch site was fairly insignificant, and while at the Lockwood Folly River, site salt intrusion appeared to be causing the die-back of ash trees.

Bottomland hardwood succession and species distribution varies greatly depending on the rate and type of sediment deposition, as well as ecoregion. Schafale and Weakley (1990) list eight types of plant communities that are considered to be Bottomland Hardwood Forests wetlands with the NC WAM method (NCFAT 2008). The eight community types identified by Schafale and Weakley (1990) are: 1. Coastal Plain Bottomland Hardwoods (Blackwater subtype), 2. Coastal Plain Bottomland Hardwoods (Blackwater subtype), 3. Coastal Plain Levee Forest (Blackwater subtype), 4. Coastal Plain Levee Forest (Brownwater subtype), 5. Piedmont/Mountain Levee Forest, 6. Piedmont/Mountain Bottomland Forest, 7. Montane Alluvial Forest, 8. Piedmont/Low Mountain Alluvial Forest (Part). There are Bottomland Hardwood Forests communities throughout the state, however, the Bottomland Hardwood

Forests communities surveyed in the Fishing Creek watershed would be considered to be "Piedmont/Mountain Bottomland Forest" according to Schafale and Weakley (1990).

The portions of a Bottomland Hardwood Forests situated lowest in the floodplain, such as oxbow lakes, are almost always flooded, except during times of extreme drought. Small Riverine Swamp Forests often occur in these situations. In the Coastal Plain, these pockets of standing water support a canopy of baldcypress and water tupelo (*Nyssa aquatica*), species adapted to life in standing water and anoxic soil conditions. On river levees receiving inputs of fine sediment, a community of trees less adapted to inundation and soil anoxia can prevail, such as black willow (*Salix nigra*). Slow accumulations in areas with soils which are only semi-permanently saturated or inundated allow species such as overcup oak (*Quercus lyrata*), water hickory (*Carya aquatica*), and sweetgum to predominate (Batzer and Sharitz 2006, Hodges 1997). More rapid accumulation of these fine sediments will support an elm-ash-sugarberry (*Celtis laevigata*) community. Deposition of sandy and loamy materials will favor boxelder (*Acer negundo*) and sugarberry (Hodges 1997). Sweetgum (*Liquidambar syraciflua*), sycamore (*Platanus occidentalis*), swamp chestnut oak and cherry bark oak are also common on these sites (Schafale and Weakley 1990). Highly disturbed areas will be pioneered by river birch (*Betula nigra*) and as these short-lived trees die back and the canopy opens, a transitory sweetgum, yellow poplar (*Liriodendron tulipifera*) community can be found on the more well-drained flats and ridges. Old floodplains, considered to be terraces, will exhibit the regional oak-hickory climax about 200 years after flooding and sedimentation cease (Hodges 1997). Herbaceous Bottomland Hardwood Forests species on levees are often dense and tall because of the higher elevation and fertile deposits left behind by flooding. In North Carolina, river oats (*Chasmanthium latifolium*), bottlebrush grass (*Elymus hystrix*), violets (*Viola* spp.) sedges, particularly *Carex* spp., and false nettle (*Boehmeria cylindrica*) are most common (Schafale and Weakley 1990, and Weakley 2008). Other herbs found on these sites include Christmas fern (*Polystichum acrostichoides*) jack-in-the-pulpit (*Arisaema triphyllum*), and axillary goldenrod (*Solidago caesia*). These sites often have a prominent vine community including poison ivy, Virginia creeper (*Parthenocissus quinquefolia*), cross-vine and *Smilax* spp. These areas are prone to invasion by Japanese stilt-grass and Japanese honeysuckle which can suppress the native herb layer (Schafale and Weakley 1990).

The Bottomland Hardwood Forests sites that were surveyed in the Fishing Creek watershed tended to have a canopy and sub-canopy dominated with American elm (*Ulmus Americana*), sweet gum, red maple (*Acer rubrum*), American hornbeam (*Carpinus caroliniana*), and tulip tree (*Liriodendron tulipifera*). Similar to the Schafale and Weakley's (1990) description, non-natives such as Japanese stilt-grass and Japanese honeysuckle along with Chinese privet (*Ligustrum sinense*) were very common at the Fishing Creek sites, even the sites that did not have obvious human impacts. Poison ivy (*Toxicodendron radicans*) was also prevalent especially at the more disturbed sites.

Mature southern bottomland and swamp riverine communities have a flora and fauna as diverse as any in the continental United States. Especially diverse are the species of birds (water birds in particular) that use these areas for wintering and breeding habitat and as stopovers during migration. Diversity of trees in these bottomland and riverine communities rival those of the tropics, and mammals such as whitetail deer, beavers, black bears, bobcats, and river otters use forested wetlands as their primary habitat. Amphibians and reptiles are plentiful and diverse, especially frogs, toads, and salamanders who require ponded water of varying durations to complete their life cycle (Kellison and Young 1997).

National wetland loss in the continental United States has been well documented, with over 116,000,000 acres-over half of all wetlands-being lost since the early seventeenth century (Dahl and Johnson 1991). Regionally, from the mid-1970 to the mid-1980, 89 percent of national wetland loss in the conterminous U.S. occurred in the southeast. Of that percentage, 3.1 million acres of southeastern forested wetlands were lost, with 887,000 of those losses occurring in North Carolina alone. In total, North Carolina lost a total of 1.2 million acres of wetlands of all types over that time span, primarily for conversion due to silvicultural and agricultural uses (Hefner et al., 1994). According to The Nature Conservancy (1992), from 1883-1991, the south lost 77 percent (over 16,000,000) acres-of southern Bottomland Hardwood Forests. A NC collaborative study by the NC Department of Transportation, NC DENR, and Duke University (Cashin et al, 1992) found that 51.35 of the NC coastal palin wetlands had been impacted to such an extent the original wetland function and value no longer exitsed. Palustrine wetlands experienced the greatest loss during this time frame due primarily to conversion to forestry and agricultural land use (Cashin et al, 1992).

Historically, the major reason for the loss of North Carolina's forested wetlands was due to draining and cutting for agriculture and timber. By the late 19th-century, virtually all land suitable for cultivation along the south's larger rivers (which could include Riverine Swamp Forests and Bottomland Hardwood Forests) had been converted to cropland. This practice held until landowners and forestry managers realized that conversion to cropland was not the most valuable use of these riverine systems. Among these newfound efficiencies were pollution removal, flood control, sediment retention, nutrient cycling, and wildlife habitat provided by these sponge-like riverine wetlands (Kellison and Young 1997).

Current and future threats to forested wetlands in North Carolina are draining and clearing for agriculture, development, roads, silviculture operations, timber harvesting and mining of phosphate and other mineral products—the latter has caused the loss and/or conversion of many acres of wetlands in coastal North Carolina .

The Lockwood Folly River watershed is located in one of the fastest growing counties in the NC, Brunswick County. This part of NC is located half way between Wilmington and Myrtle Beach and has been a popular area to develop golf course retirement communities. Brunswick County is still relatively undeveloped; however, numerous tracts of land have been acquisitioned by developers (Lockwood Folly River Watershed Strategy, http://www.southeastwaterforum.org /files/2-Stone%20-%20Lockwood%20Folly%20Watershed %20Strategry.pdf, 2009). The water quality in the Lockwoods Folly watershed has decreased since the 1980s due to higher turbidity and fecal coliform levels. Fecal coliform levels, which are typically associated with waste products from warm blooded animals, have been on the rise. Increased ditching, urbanization, and failing or poorly maintained septic tanks have also had negative affects on turbidity and fecal coliform levels in the Lockwood Folly River watershed (Lockwood Folly River Round Table Report, 2007). The rapid development and recent decrease in water quality have resulted in the

NC Ecosystem Enhancement Program targeting the Lockwood Folly River watershed as a priority for watershed planning.

The Fishing Creek Watershed (where the Bottomland Hardwood Forests sites were located) is currently a fairly undeveloped watershed other then the town of Oxford. Low density housing is interspersed with cropland and pastureland. Fishing Creek is a primary tributary of the Tar River and has been rated as impaired by the NCDWQ due to having a poor benthic community and is currently on the 303(d) list of impaired waters. The condition of the Tar River can likely be contributed to a combination of factors including the Oxford wastewater treatment plant located at the headwaters of Fishing Creek and urban runoff. The NC Department of Transportation is also planning highway improvements in and around Oxford (N.C. State University Department of Agricultural and Resource Economics, 2009). These planned improvements and the existing condition of the Tar River have prompted the NC Ecosystem Enhancement Program (NC EEP) to develop a watershed management plan for the Fishing Creek Watershed.

A major goal of local watershed plans is to locate stream and wetland restoration projects that can provide mitigation credit while improving the function of the watershed. Watershed planning also strives to educate and engage the public and encourage developers to decrease development density while maximizing areas where stormwater can infiltrate groundwater or be treated thus improving water quality (N.C. State University Department of Agricultural and Resource Economics, Lockwood Folly River Round Table Report, 2007). The results from this research can provide information on riverine wetland systems to the NC EEP for both the Fishing Creek and Lockwood Folly River watershed areas. This valuable baseline information can be used in future watershed planning efforts by NC EEP.

Section 5.2 Riverine Swamp Forests: Results

Section 5.2.1 Riverine Swamp Forests: Summary of NCWAM Results

Table 5.2.1-1 shows the metrics, IBIs, water quality site parameter means, and site ORAM scores that correlated with the NCWAM overall score and Hydrology, Water Quality, and Habitat NCWAM Functions for Riverine Swamp Forests. The first column of Table 5.2.1-1 shows “Round” which refers to the pre (Round “1”) and post (Round “2”) survey results. Correlations with p-values that are < 0.05 and have $r > 0.5$ are shown in bold red to show the strongest relationships. The Riverine Swamp Forest NCWAM habitat function and overall score correlated well with two of the plant metrics and the Riverine Swamp Forest Plant IBI (see Table 5.2.1-1). The NCWAM overall scores and the three functions (habitat, hydrology, and water quality [WQ]) had statistically significant correlations with dicot cover (dicot coverage metric, which is the relative percent cover of native dicot herb species). The NCWAM Habitat function also correlated with pole timber density metric (the density of poor quality timber in the 10-15 cm, 15-20 cm, and 20-25cm DBH size classes). The habitat function also correlated significantly with the riverine plant IBI scores. However, the pre-survey NCWAM results (round 1) had more significant correlations then the post-survey NCWAM results (round 2). These differences occurred with the habitat function correlations with dicot cover and the Riverine Swamp Forest plant IBI results which only correlated during round 1. The plant IBI results and the habitat function correlation is a logical correlation and makes sense, although this would be a better result if the correlation also occurred during the round 2, post-survey analyses. The habitat function had the strongest correlations with p-values of <0.05. All of these correlations were in the correct direction, positive correlations for the Plant IBIs and the dicot cover metric and negative correlations for the pole timber density metric. The NCWAM Overall Score, Water Quality Function, and Habitat Function correlated weakly with the dissolved oxygen site water quality parameter and no other water quality parameters. The ORAM site scores also correlated with the Overall NCWAM Score, the Hydrology Function and Water Quality Function at a p-value < 0.05 for the Pearson's correlation for both rounds. The Spearman's Rho correlation had weaker results with the same correlations as well as with the Habitat Function (round 1 only). The results of the two correlation analyses, Spearman's Rho and Pearson's correlation, overall produced similar results. There were no statistically significant correlation results of any NCWAM scores with any of the amphibian metrics, the soil parameters or with the Land Density Index (LDI) scores.

These results evaluating NCWAM had were somewhat disappointing since only a few of the plant metrics and plant IBI correlated significantly with the NCWAM rating scores as well as the significant correlations with the ORAM site means. However, it is important to note that there were only seven Riverine Swamp Forest sites that were monitored in this study and that is a small sample size for this type of evaluation. Also, the NCWAM ratings for these Riverine Swamp Forests did not have much variability. In Table 2.2.1-1, all the scores for the water quality function, the hydrology function, and the overall scores were all rated high with the exception of one site. However the habitat function did vary more in that three sites had some low and medium scores but there was still not great variability, still the habitat function had the most and strongest correlations. So it is also evident that not only was there a sample size problem, but there needed to be more variability in the NCWAM ratings. In other words, there need to be several sites that rated high and several sites that rated medium and several sites that rated low to allow for a proper evaluation and calibration of NCWAM. Therefore, given the small number of Riverine Swamp Forests from which Level III data was collected and the lack of variability in the NCWAM ratings, it could be argued that any statistically significant correlations are encouraging and that with more data, more significant correlations could result. In addition, note that two of these Riverine Swamp Forest sites (Lockwood and Mercer Seawatch) are still being monitored and that more Level III data are being collected and more analysis with NCWAM will occur. The second is that a more extensive evaluation of NCWAM will be performed with a larger sample of Headwater Wetlands (N=33) so this will provide better evaluation of the data **(**Wetland Functional Assessment: Expansion and enhancement of the North Carolina Wetland Assessment Method, (NC WAM), grant WL 9643505-1). Similarly a more intensive analysis will probably be done using the recently awarded Intensification Grant (National Wetland Conditional Assessment Study of the Alabama, South Carolina and North Carolina Wetlands [Southeast Wetlands Monitoring and Assessment]).

Table 5.2.1-1 NCWAM Correlation with Level III Significant Results for Riverine Swamp Forest Wetlands

Round	Wetland Type	NCWAM Total / - Function	L2, L3	IBI/ Metric/ Water Quality/ ORAM	r	Prob>|ρ|	Analysis
1	Riverine Swamp	Habitat-Function	L2	ORAM Mean	**0.8164**	**0.0251**	Pearson's Correlation
1	Riverine Swamp	Habitat-Function	L2	ORAM Mean	0.6682	0.1009	Spearman's Rho Correlation
1	Riverine Swamp	Habitat-Function	L2-WQ	Dissolved Oxygen (%)	0.6682	0.1009	Spearman's Rho Correlation
1	Riverine Swamp	Habitat-Function	L2-WQ	Dissolved Oxygen (%)	0.6124	0.1438	Spearman's Rho Correlation
2	Riverine Swamp	Habitat-Function	L2-WQ	Dissolved Oxygen (%)	0.6124	0.1438	Spearman's Rho Correlation
1	Riverine Swamp	Habitat-Function	L2-WQ	Dissolved Oxygen (mg/L)	0.6682	0.1009	Spearman's Rho Correlation
1	Riverine Swamp	Habitat-Function	L2-WQ	Dissolved Oxygen (mg/L)	0.6135	0.1429	Pearson's Correlation
1	Riverine Swamp	Habitat-Function	L2-WQ	Dissolved Oxygen (mg/L)	0.6124	0.1438	Spearman's Rho Correlation
2	Riverine Swamp	Habitat-Function	L2-WQ	Dissolved Oxygen (mg/L)	0.6124	0.1438	Spearman's Rho Correlation
1	Riverine Swamp	Habitat-Function	L3-Plants	Dicot Cover	**0.8018**	**0.0301**	Spearman's Rho Correlation
1	Riverine Swamp	Habitat-Function	L3-Plants	Dicot Cover	**0.7631**	**0.0460**	Pearson's Correlation
1	Riverine Swamp	Habitat-Function	L3-Plants	Pole Timber Density	**-0.7971**	**0.0318**	Pearson's Correlation
1	Riverine Swamp	Habitat-Function	L3-Plants	Pole Timber Density	**-0.7572**	**0.0487**	Spearman's Rho Correlation
1	Riverine Swamp	Habitat-Function	L3-Plants	Plant IBI	**0.7866**	**0.0359**	Spearman's Rho Correlation
1	Riverine Swamp	Habitat-Function	L3-Plants	Plant IBI	0.6192	0.1381	Pearson's Correlation
1	Riverine Swamp	Hydrology -Function	L2	ORAM Mean	**0.7925**	**0.0336**	Pearson's Correlation
2	Riverine Swamp	Hydrology -Function	L2	ORAM Mean	**0.7925**	**0.0336**	Pearson's Correlation
1	Riverine Swamp	Hydrology -Function	L2	ORAM Mean	0.6124	0.1438	Spearman's Rho Correlation
2	Riverine Swamp	Hydrology -Function	L2	ORAM Mean	0.6124	0.1438	Spearman's Rho Correlation
1	Riverine Swamp	Hydrology -Function	L3-Plants	Dicot Cover	0.6552	0.1101	Pearson's Correlation
2	Riverine Swamp	Hydrology -Function	L3-Plants	Dicot Cover	0.6552	0.1101	Pearson's Correlation
1	Riverine Swamp	Hydrology -Function	L3-Plants	Dicot Cover	0.6124	0.1438	Spearman's Rho Correlation
2	Riverine Swamp	Hydrology -Function	L3-Plants	Dicot Cover	0.6124	0.1438	Spearman's Rho Correlation
1	Riverine Swamp	NCWAM OverAll Score	L2	ORAM Mean	**0.7925**	**0.0336**	Pearson's Correlation
2	Riverine Swamp	NCWAM OverAll Score	L2	ORAM Mean	**0.7925**	**0.0336**	Pearson's Correlation
1	Riverine Swamp	NCWAM OverAll Score	L2	ORAM Mean	0.6124	0.1438	Spearman's Rho Correlation
2	Riverine Swamp	NCWAM OverAll Score	L2	ORAM Mean	0.6124	0.1438	Spearman's Rho Correlation
1	Riverine Swamp	NCWAM Overall Score	L2-WQ	Dissolved Oxygen (%)	0.6124	0.1438	Spearman's Rho Correlation

Table 5.2.1-1 NCWAM Correlation with Level III Significant Results for Riverine Swamp Forest Wetlands

Round	Wetland Type	NCWAM Total / -Function	L2, L3	IBI/ Metric/ Water Quality/ ORAM	r	Prob>|ρ|	Analysis
2	Riverine Swamp	NCWAM Overall Score	L2-WQ	Dissolved Oxygen (%)	0.6124	0.1438	Spearman's Rho Correlation
1	Riverine Swamp	NCWAM Overall Score	L2-WQ	Dissolved Oxygen (mg/L)	0.6124	0.1438	Spearman's Rho Correlation
2	Riverine Swamp	NCWAM Overall Score	L2-WQ	Dissolved Oxygen (mg/L)	0.6124	0.1438	Spearman's Rho Correlation
1	Riverine Swamp	NCWAM OverAll Score	L3-Plants	Dicot Cover	0.6552	0.1101	Pearson's Correlation
2	Riverine Swamp	NCWAM OverAll Score	L3-Plants	Dicot Cover	0.6552	0.1101	Pearson's Correlation
1	Riverine Swamp	NCWAM OverAll Score	L3-Plants	Dicot Cover	0.6124	0.1438	Spearman's Rho Correlation
2	Riverine Swamp	NCWAM OverAll Score	L3-Plants	Dicot Cover	0.6124	0.1438	Spearman's Rho Correlation
1	Riverine Swamp	WQ Function	L2-WQ	Dissolved Oxygen (%)	0.6124	0.1438	Spearman's Rho Correlation
2	Riverine Swamp	WQ Function	L2-WQ	Dissolved Oxygen (%)	0.6124	0.1438	Spearman's Rho Correlation
1	Riverine Swamp	WQ Function	L2-WQ	Dissolved Oxygen (mg/L)	0.6124	0.1438	Spearman's Rho Correlation
2	Riverine Swamp	WQ Function	L2-WQ	Dissolved Oxygen (mg/L)	0.6124	0.1438	Spearman's Rho Correlation
1	Riverine Swamp	WQ -Function	L2	ORAM Mean	**0.7925**	**0.0336**	Pearson's Correlation
2	Riverine Swamp	WQ -Function	L2	ORAM Mean	**0.7925**	**0.0336**	Pearson's Correlation
1	Riverine Swamp	WQ -Function	L2	ORAM Mean	0.6124	0.1438	Spearman's Rho Correlation
2	Riverine Swamp	WQ -Function	L2	ORAM Mean	0.6124	0.1438	Spearman's Rho Correlation
1	Riverine Swamp	WQ -Function	L3-Plants	Dicot Cover	0.6552	0.1101	Pearson's Correlation
2	Riverine Swamp	WQ -Function	L3-Plants	Dicot Cover	0.6552	0.1101	Pearson's Correlation
1	Riverine Swamp	WQ -Function	L3-Plants	Dicot Cover	0.6124	0.1438	Spearman's Rho Correlation
2	Riverine Swamp	WQ -Function	L3-Plants	Dicot Cover	0.6124	0.1438	Spearman's Rho Correlation

Bold Red = Probility ≤ 0.05 , L2-Level 2, L3-Level 3, WQ-Water Quality

Section 5.2.2 Riverine Swamp Forests: Water Quality Results and Discussion

Riverine Swamp Forests water quality samples were analyzed for each parameter that was collected. The summary of the 18 parameters for each site is shown in Table 5.2.2-1. The table shows the mean and median for each water quality parameter and then for each of the seven Riverine Swamp Forests. The Mercer Seawatch and Lockwood sites had the highest ammonia levels. The Lockwood and Doe Creek sites had the highest levels of calcium and for copper, the Rourk site has the highest level. For dissolved oxygen (DO), the Doe Creek site has the highest level whereas the Winding River Townhouse site had the lowest. The Lockwood site had the highest level of dissolved organic carbon (DOC) and the Winding River Townhouse site had the lowest. Mercer Seawatch and Rourk sites had fecal colliform levels quite a bit higher than the other sites, and the same was true for the levels of lead in the water samples. For magnesium, the Lockwood site had the highest level and the Doe Creek site had the second highest levels; both levels were quite a bit higher than the other sites. The levels of Nitrate+Nitrite (NO2+NO3) varied very little between sites. For pH, the Mercer Seawatch site was the most acidic site and the two Winding River sites were the next most acidic. The Rourk site had levels of phosphorus quite large relative to the other sites. The Hewett Wildlife site and the two Winding River sites had the lowest levels of phosphorus. Lockwood and Doe Creek sites had specific conductivity levels much larger that the other sites. This is likely associated with salt water intrusion as both the Lockwood and Doe Creek sites are tidal sites. The Lockwood site also had the highest levels of TKN while Mercer Seawatch and Rourk sites had the next highest levels. For total organic carbon (TOC), the highest levels were at the Rourk site, while Lockwood and Mercer Seawatch sites had the second highest levels. For total suspended residue (TSS), Lockwood, Rourk, and Mercer Seawatch sites had the highest levels. Water temperature was pretty equal for six of the sites, but the Rourk site was about four degrees C^{o} cooler. For zinc, the Rourk site had the highest level and the Mercer Seawatch, Lockwood, and Doe Creek sites had the next highest levels. With respect to the overall water quality, the Rourk, Mercer Seawatch and Lockwood sites have the most problems with high levels of potential pollutants (metals, nutrients, etc.) and the Hewitt Wildlife and the Winding River sites had the best water quality.

Table 5.2.2-2 shows the same (site means and medians) data but broken out by station location. For the Riverine Swamp Forests, water samples were taken at buffer locations, and at Up-River and Down-River locations. One assumption would be that water quality sould improve (reduction in levels of metals and nutrients, for example) as water flows from the Up-River station to the Down-River station. Generally it would also be assumed that the buffer should have better water quality since water flows from a somewhat upland station toward the center of the wetland. Table 5.2.2-3 shows the same data but averaged across sites. From observing the table, it appears that copper is lower in the buffer and down-river and higher in the up-river. Dissolved Organic Carbon also appears to be lower down-river and lower still in the buffer, with the highest levels being, again, up-river. Lead and TKN have the same pattern, being lowest in the buffer, and down-river being lower than up-river. Interestingly, Fecal Coliform levels are highest in the buffer, but the down-river is still lower than up-river. From the observation of Table 5.2.2-3, there are several indications of water quality improving as water flows down river through the Riverine Swamp Forest.

The statistical test, Analysis of Variance (ANOVA) and the Rank Sums tests (Kruskall-Wallis) were performed on these data to determine statistical significance between the station locations for the Riverine Swamp Forests. Parametric and non-Parametric tests were performed for completeness (to allow for some potential distribution problems to be tested non-Parametrically), so significant results from both test are noted. Also, as previously noted, a p-value of 0.15 or less is considered significant. Ammonia was statistically significant (Kruskall-Wallis, p=0.0116) with the lowest levels in the buffer and the down-river being lower that the up-river. Dissolved oxygen (DO, percent) was also statistically significant (Kruskall-Wallis, p=0.1075 and ANOVA, p=0.0933) as was DO mg/L (Kruskall-Wallis, p=0.1285, ANOVA, p=0.0985). The DO was highest in the buffer regions with the up-river and down-river being about the same. DOC was lowest in the buffer and the down-river was lower than the up-river and was statistically significant (Kruskall-Wallis, p=0.018, ANOVA, p=0.0017). Phosphorus was statistically significant (Kruskall-Wallis, p=0.0247) with the buffer and down-river being lower than up-river. The levels of TKN were lower in the buffer and down-river with the highest level being up-river and this difference was again statistically significant (Kruskall-Wallis, p=0.0351). Total Organic Carbon was also lower in the buffer and down-river and higher up-river and was statistically significant, (Kruskall-Wallis, p=0.0514, ANOVA, p=0.1263). Finally, zinc levels were statistically significant (Kruskall-Wallis, p=0.0511) with lower levels in the down-river and buffer. All of the results for ammonia, DO, DOC, phosphorus, TKN, TOC, and zinc showed lower levels down-river indicating that water quality is improving as water flows downstream past and through the Riverine Swamp Forest. Two other results are of note. The pH was lower in the buffer (more acidic) whereas the up-river and down-river were about the same (still acidic, but less) [and was statistically significant (Kruskall-Wallis, p=0.0885, ANOVA, p=0.0454)]. Magnesium was highest down-river and lower in the buffer and up-river and was statistically significant (Kruskall-Wallis, p=0.1367). This result is somewhat inconsistent with the other results in that the levels were higher downstream than upstream, but was marginally significant.

In summary, these results show that there are several water quality parameters for Riverine Swamp Forest that shows significant changes from upstream locations to downstream locations which indicate a significant reduction in certain pollutants. This result is an example of one ecosystem service that is provided by this type of wetland. As previously noted the Rourk, Mercer Seawatch and Lockwood sites have the most problems with high levels of potential pollutants (metals, nutrients, etc.) and were not in densely populated or even particularly developed areas. The Rourk site was the most distant from development of all the sites and the Mercer Seawatch site was in an area where development was just beginning. The Lockwood site was near a busy intersection of NC 211 and US 17 which would probably account for some of its water quality problems. The Hewitt Wildlife and the Winding River sites had the best water quality. The Hewitt Wildlife site is located in a nature preserve (land easement by the landowner with the Carolina Coastal Land Trust), however, the Winding River sites were in the middle of an established development with the same name. This would be an indication that wetlands can still be functional and be in good condition in this type of residential development. These results indicate the location (alone) of these sites do not appear to control water quality in these wetlands.

Table 5.2.2-1 Lockwood Folly Riverine Swamp Forest Water Quality Mean and Median Results by site.

Site Name	N	Parameter	Mean	Median	Units
Doe Creek	17	Ammonia	0.15	0.02	mg/L
Hewett Wildlife	17	Ammonia	0.17	0.02	mg/L
Lockwood	21	Ammonia	0.83	0.52	mg/L
Mercer Seawatch	23	Ammonia	0.73	0.02	mg/L
Rourk	5	Ammonia	0.17	0.06	mg/L
Winding River Pond	16	Ammonia	0.06	0.02	mg/L
Winding River Townhouse	10	Ammonia	0.04	0.02	mg/L
Doe Creek	17	Calcium	82.06	55	mg/L
Hewett Wildlife	17	Calcium	31.58	32	mg/L
Lockwood	21	Calcium	122.76	95	mg/L
Mercer Seawatch	23	Calcium	36.83	20	mg/L
Rourk	5	Calcium	49.8	29	mg/L
Winding River Pond	16	Calcium	38.14	27.75	mg/L
Winding River Townhouse	10	Calcium	21.11	22.5	mg/L
Doe Creek	17	Copper	13.38	2	ug/L
Hewett Wildlife	17	Copper	4.94	2	ug/L
Lockwood	21	Copper	18.33	11	ug/L
Mercer Seawatch	23	Copper	13.72	2.4	ug/L
Rourk	5	Copper	52.1	28	ug/L
Winding River Pond	16	Copper	5.37	2	ug/L
Winding River Townhouse	10	Copper	5.24	2	ug/L
Doe Creek	14	Dissolved Oxygen (%)	48.31	49.9	%
Hewett Wildlife	17	Dissolved Oxygen (%)	23.9	14	%
Lockwood	18	Dissolved Oxygen (%)	25.78	11.85	%
Mercer Seawatch	22	Dissolved Oxygen (%)	33.96	37.7	%
Rourk	5	Dissolved Oxygen (%)	13.36	10.3	%
Winding River Pond	13	Dissolved Oxygen (%)	22.65	14.1	%
Winding River Townhouse	8	Dissolved Oxygen (%)	9.74	9.35	%
Doe Creek	14	Dissolved Oxygen (mg/L)	4.74	4.3	mg/L
Hewett Wildlife	17	Dissolved Oxygen (mg/L)	2.98	1.8	mg/L
Lockwood	18	Dissolved Oxygen (mg/L)	2.75	1.25	mg/L
Mercer Seawatch	22	Dissolved Oxygen (mg/L)	3.56	4	mg/L
Rourk	5	Dissolved Oxygen (mg/L)	1.47	1.3	mg/L
Winding River Pond	13	Dissolved Oxygen (mg/L)	2.44	1.34	mg/L
Winding River Townhouse	8	Dissolved Oxygen (mg/L)	1.04	0.9	mg/L
Doe Creek	17	DOC	12.78	11	mg/L
Hewett Wildlife	17	DOC	14.03	13	mg/L
Lockwood	21	DOC	22.22	18	mg/L
Mercer Seawatch	23	DOC	13.58	10	mg/L
Rourk	3	DOC	11.03	12	mg/L
Winding River Pond	16	DOC	18.61	15.5	mg/L

Table 5.2.2-1 Lockwood Folly Riverine Swamp Forest Water Quality Mean and Median Results by site.

Site Name	N	Parameter	Mean	Median	Units
Winding River Townhouse	10	DOC	10.15	7.9	mg/L
Doe Creek	17	Fecal Colliform	524.12	140	CFU/100 ml
Hewett Wildlife	17	Fecal Colliform	430.65	96	CFU/100 ml
Lockwood	21	Fecal Colliform	738.05	160	CFU/100 ml
Mercer Seawatch	23	Fecal Colliform	6955.52	20	CFU/100 ml
Rourk	5	Fecal Colliform	8411.8	2000	CFU/100 ml
Winding River Pond	16	Fecal Colliform	1192.13	600	CFU/100 ml
Winding River Townhouse	10	Fecal Colliform	464.3	345	CFU/100 ml
Doe Creek	17	Lead	19.06	10	ug/L
Hewett Wildlife	17	Lead	20.59	10	ug/L
Lockwood	21	Lead	39	10	ug/L
Mercer Seawatch	23	Lead	62.04	10	ug/L
Rourk	5	Lead	101.4	21	ug/L
Winding River Pond	16	Lead	28.06	10	ug/L
Winding River Townhouse	10	Lead	15.9	10	ug/L
Doe Creek	17	Magnesium	45.78	5.8	mg/L
Hewett Wildlife	17	Magnesium	2.62	2.4	mg/L
Lockwood	21	Magnesium	151.29	110	mg/L
Mercer Seawatch	23	Magnesium	5.64	2.6	mg/L
Rourk	5	Magnesium	16.08	17	mg/L
Winding River Pond	16	Magnesium	3.15	2.35	mg/L
Winding River Townhouse	10	Magnesium	3.69	1.6	mg/L
Doe Creek	17	NO2+NO3	0.06	0.02	mg/L
Hewett Wildlife	17	NO2+NO3	0.02	0.02	mg/L
Lockwood	21	NO2+NO3	0.03	0.02	mg/L
Mercer Seawatch	23	NO2+NO3	0.02	0.02	mg/L
Rourk	5	NO2+NO3	0.04	0.02	mg/L
Winding River Pond	16	NO2+NO3	0.03	0.02	mg/L
Winding River Townhouse	10	NO2+NO3	0.04	0.02	mg/L
Doe Creek	17	pH	6.31	6.25	S.U.
Hewett Wildlife	17	pH	6.15	6.14	S.U.
Lockwood	21	pH	6.1	6.16	S.U.
Mercer Seawatch	23	pH	4.84	4.7	S.U.
Rourk	5	pH	5.97	5.98	S.U.
Winding River Pond	16	pH	5.57	5.73	S.U.
Winding River Townhouse	10	pH	5.52	5.91	S.U.

Table 5.2.2-1 Lockwood Folly Riverine Swamp Forest Water Quality Mean and Median Results by site.

Site Name	N	Parameter	Mean	Median	Units
Doe Creek	17	Phosphorus	0.83	0.16	mg/L
Hewett Wildlife	17	Phosphorus	0.37	0.11	mg/L
Lockwood	21	Phosphorus	1.23	0.36	mg/L
Mercer Seawatch	23	Phosphorus	1.11	0.29	mg/L
Rourk	5	Phosphorus	2.59	2.4	mg/L
Winding River Pond	16	Phosphorus	0.48	0.13	mg/L
Winding River Townhouse	10	Phosphorus	0.59	0.16	mg/L
Doe Creek	14	Specific Conductivity	2404.73	243.25	uS/cm
Hewett Wildlife	17	Specific Conductivity	197.08	215	uS/cm
Lockwood	18	Specific Conductivity	5767.54	4005	uS/cm
Mercer Seawatch	20	Specific Conductivity	91.09	58.05	uS/cm
Rourk	5	Specific Conductivity	261.82	267	uS/cm
Winding River Pond	13	Specific Conductivity	172.14	197.2	uS/cm
Winding River Townhouse	8	Specific Conductivity	124.49	116.05	uS/cm
Doe Creek	17	TKN	1.33	1	mg/L
Hewett Wildlife	17	TKN	1.41	0.83	mg/L
Lockwood	21	TKN	21.64	3.5	mg/L
Mercer Seawatch	23	TKN	12.8	2.4	mg/L
Rourk	5	TKN	6.26	4.2	mg/L
Winding River Pond	16	TKN	1.38	1.25	mg/L
Winding River Townhouse	10	TKN	1.17	0.85	mg/L
Doe Creek	20	TOC	134.25	18.5	mg/L
Hewett Wildlife	17	TOC	65.2	20	mg/L
Lockwood	21	TOC	474.67	52	mg/L
Mercer Seawatch	23	TOC	390.71	84	mg/L
Rourk	3	TOC	533.33	570	mg/L
Winding River Pond	19	TOC	73.89	24	mg/L
Winding River Townhouse	12	TOC	76.44	14	mg/L
Doe Creek	17	Total Suspended Residue	350.41	37	mg/L
Hewett Wildlife	17	Total Suspended Residue	256.13	8.8	mg/L
Lockwood	21	Total Suspended Residue	1048.24	181	mg/L
Mercer Seawatch	23	Total Suspended Residue	1276.54	365	mg/L
Rourk	5	Total Suspended Residue	1420	1500	mg/L
Winding River Pond	16	Total Suspended Residue	514.27	32.5	mg/L
Winding River Townhouse	10	Total Suspended Residue	538.84	48.5	mg/L
Doe Creek	17	Water, Temperature	16.78	15.5	oC
Hewett Wildlife	17	Water, Temperature	16.75	17.5	oC

Table 5.2.2-1 Lockwood Folly Riverine Swamp Forest Water Quality Mean and Median Results by site.

Site Name	N	Parameter	Mean	Median	Units
Lockwood	23	Water, Temperature	17.65	19.5	oC
Mercer Seawatch	23	Water, Temperature	16.71	15.5	oC
Rourk	5	Water, Temperature	12	10.3	oC
Winding River Pond	16	Water, Temperature	16.53	16.75	oC
Winding River Townhouse	10	Water, Temperature	16.09	17.3	oC
Doe Creek	18	Zinc	59.06	12.5	ug/L
Hewett Wildlife	17	Zinc	26.47	10	ug/L
Lockwood	21	Zinc	62.43	17	ug/L
Mercer Seawatch	23	Zinc	67.39	12	ug/L
Rourk	5	Zinc	118.4	64	ug/L
Winding River Pond	16	Zinc	29.94	10	ug/L
Winding River Townhouse	10	Zinc	37.9	10	ug/L

Table 5.2.2-2 Lockwood Folly Riverine Swamp Forest Water Quality Mean Results by Station within Site.

Site Name	Parameter	N - Buffer	Buffer Station Mean	N-Up River	Up River Station Mean	N Down River	Down River Station Mean	Units
Doe Creek	Ammonia	5	0.06	6	0.04	6	0.34	mg/L
Hewett Wildlife	Ammonia	5	0.46	6	0.03	6	0.07	mg/L
Lockwood	Ammonia	6	0.13	6	1.53	9	0.84	mg/L
Mercer Seawatch	Ammonia	9	0.02	8	2.06	6	0.04	mg/L
Rourk	Ammonia	.	.	4	0.2	1	0.06	mg/L
Winding River Pond	Ammonia	5	0.03	5	0.04	6	0.11	mg/L
Winding River Townhouse	Ammonia	.	.	4	0.06	6	0.02	mg/L
Doe Creek	Calcium	5	55.4	6	92.17	6	94.17	mg/L
Hewett Wildlife	Calcium	5	35.4	6	30.8	6	29.17	mg/L
Lockwood	Calcium	6	113.7	6	143.8	9	114.8	mg/L
Mercer Seawatch	Calcium	9	1.11	8	44.63	6	80	mg/L
Rourk	Calcium	.	.	4	57	1	21	mg/L
Winding River Pond	Calcium	5	71	5	17.64	6	27.83	mg/L
Winding River Townhouse	Calcium	.	.	4	13.53	6	26.17	mg/L
Doe Creek	Copper	5	18.1	6	7.83	6	15	ug/L
Hewett Wildlife	Copper	5	11.4	6	2.5	6	2	ug/L
Lockwood	Copper	6	13.98	6	20.52	9	19.78	ug/L
Mercer Seawatch	Copper	9	2	8	21.88	6	20.42	ug/L
Rourk	Copper	.	.	4	63.1	1	8.1	ug/L
Winding River Pond	Copper	5	11.24	5	3.54	6	2	ug/L
Winding River Townhouse	Copper	.	.	4	10.1	6	2	ug/L
Doe Creek	Dissolved Oxygen (%)	4	33.65	5	74.38	5	33.98	%
Hewett Wildlife	Dissolved Oxygen (%)	5	14.24	6	32.55	6	23.3	%
Lockwood	Dissolved Oxygen (%)	5	57.08	5	4.9	8	19.26	%
Mercer Seawatch	Dissolved Oxygen (%)	9	44.39	8	21.16	5	35.66	%
Rourk	Dissolved Oxygen (%)	.	.	4	12.63	1	16.3	%
Winding River Pond	Dissolved Oxygen (%)	4	31.83	4	12.55	5	23.4	%
Winding River Townhouse	Dissolved Oxygen (%)	.	.	3	8.13	5	10.7	%
Doe Creek	Dissolved Oxygen (mg/L)	4	3.88	5	6.52	5	3.65	mg/L
Hewett Wildlife	Dissolved Oxygen (mg/L)	5	2.05	6	3.42	6	3.33	mg/L
Lockwood	Dissolved Oxygen (mg/L)	5	6.11	5	0.5	8	2.05	mg/L
Mercer Seawatch	Dissolved Oxygen (mg/L)	9	4.3	8	2.81	5	3.42	mg/L
Rourk	Dissolved Oxygen (mg/L)	.	.	4	1.43	1	1.6	mg/L
Winding River Pond	Dissolved Oxygen (mg/L)	4	3.53	4	1.31	5	2.49	mg/L
Winding River Townhouse	Dissolved Oxygen (mg/L)	.	.	3	0.83	5	1.16	mg/L
Doe Creek	DOC	5	13	6	12.2	6	13.18	mg/L
Hewett Wildlife	DOC	5	16.69	6	12.68	6	13.15	mg/L
Lockwood	DOC	6	16.1	6	33.33	9	18.89	mg/L
Mercer Seawatch	DOC	9	6.06	8	22.5	6	12.98	mg/L
Rourk	DOC	.	.	3	11.03	.	.	mg/L
Winding River Pond	DOC	5	8.94	5	33.4	6	14.33	mg/L
Winding River Townhouse	DOC	.	.	4	8	6	11.58	mg/L
Doe Creek	Fecal Colliform	5	201.6	6	1038	6	279.2	CFU/100 ml

Table 5.2.2-2 Lockwood Folly Riverine Swamp Forest Water Quality Mean Results by Station within Site.

Site Name	Parameter	N - Buffer	Buffer Station Mean	N-Up River	Up River Station Mean	N Down River	Down River Station Mean	Units
Hewett Wildlife	Fecal Colliform	5	413.2	6	230.2	6	645.7	CFU/100 ml
Lockwood	Fecal Colliform	6	490.8	6	1197	9	597.1	CFU/100 ml
Mercer Seawatch	Fecal Colliform	9	16718	8	577.8	6	815	CFU/100 ml
Rourk	Fecal Colliform	.	.	4	10500	1	59	CFU/100 ml
Winding River Pond	Fecal Colliform	5	1089	5	1494	6	1027	CFU/100 ml
Winding River Townhouse	Fecal Colliform	.	.	4	440	6	480.5	CFU/100 ml
Doe Creek	Lead	5	19.4	6	18.17	6	19.67	ug/L
Hewett Wildlife	Lead	5	46	6	10	6	10	ug/L
Lockwood	Lead	6	12.5	6	50.33	9	49.11	ug/L
Mercer Seawatch	Lead	9	10	8	129	6	50.83	ug/L
Rourk	Lead	.	.	4	116.8	1	40	ug/L
Winding River Pond	Lead	5	41	5	36.8	6	10	ug/L
Winding River Townhouse	Lead	.	.	4	24.75	6	10	ug/L
Doe Creek	Magnesium	5	4.16	6	60.83	6	65.4	mg/L
Hewett Wildlife	Magnesium	5	3.03	6	2.2	6	2.7	mg/L
Lockwood	Magnesium	6	174.1	6	149.3	9	137.4	mg/L
Mercer Seawatch	Magnesium	9	1.17	8	7.98	6	9.23	mg/L
Rourk	Magnesium	.	.	4	17.1	1	12	mg/L
Winding River Pond	Magnesium	5	4.46	5	2.74	6	2.4	mg/L
Winding River Townhouse	Magnesium	.	.	4	6.95	6	1.52	mg/L
Doe Creek	NO2+NO3	5	0.04	6	0.05	6	0.08	mg/L
Hewett Wildlife	NO2+NO3	5	0.02	6	0.02	6	0.02	mg/L
Lockwood	NO2+NO3	6	0.03	6	0.02	9	0.03	mg/L
Mercer Seawatch	NO2+NO3	9	0.02	8	0.03	6	0.02	mg/L
Rourk	NO2+NO3	.	.	4	0.04	1	0.02	mg/L
Winding River Pond	NO2+NO3	5	0.04	5	0.02	6	0.02	mg/L
Winding River Townhouse	NO2+NO3	.	.	4	0.06	6	0.02	mg/L
Doe Creek	pH	5	5.92	6	6.57	6	6.37	S.U.
Hewett Wildlife	pH	5	6.01	6	6.15	6	6.27	S.U.
Lockwood	pH	6	5.87	6	6.15	9	6.23	S.U.
Mercer Seawatch	pH	9	4.12	8	5.72	6	4.73	S.U.
Rourk	pH	.	.	4	5.88	1	6.31	S.U.
Winding River Pond	pH	5	6.07	5	4.74	6	5.85	S.U.
Winding River Townhouse	pH	.	.	4	5.22	6	5.72	S.U.
Doe Creek	Phosphorus	5	1.11	6	0.34	6	1.09	mg/L
Hewett Wildlife	Phosphorus	5	0.87	6	0.15	6	0.18	mg/L
Lockwood	Phosphorus	6	0.35	6	2.33	9	1.09	mg/L
Mercer Seawatch	Phosphorus	9	0.06	8	2.06	6	1.42	mg/L
Rourk	Phosphorus	.	.	4	2.63	1	2.4	mg/L
Winding River Pond	Phosphorus	5	0.99	5	0.39	6	0.12	mg/L
Winding River Townhouse	Phosphorus	.	.	4	1.26	6	0.14	mg/L

Table 5.2.2-2 Lockwood Folly Riverine Swamp Forest Water Quality Mean Results by Station within Site.

Site Name	Parameter	N - Buffer	Buffer Station Mean	N-Up River	Up River Station Mean	N Down River	Down River Station Mean	Units
Doe Creek	Specific Conductivity	4	264.3	5	3639	5	2883	uS/cm
Hewett Wildlife	Specific Conductivity	5	192.2	6	193.1	6	205.2	uS/cm
Lockwood	Specific Conductivity	5	6353	5	5142	8	5792	uS/cm
Mercer Seawatch	Specific Conductivity	8	50.09	7	163.4	5	55.46	uS/cm
Rourk	Specific Conductivity	.	.	4	260.5	1	267	uS/cm
Winding River Pond	Specific Conductivity	4	219.4	4	114.2	5	180.7	uS/cm
Winding River Townhouse	Specific Conductivity	.	.	3	85.73	5	147.7	uS/cm
Doe Creek	TKN	5	1.51	6	1.25	6	1.27	mg/L
Hewett Wildlife	TKN	5	2.18	6	1.01	6	1.17	mg/L
Lockwood	TKN	6	3.95	6	65.6	9	4.12	mg/L
Mercer Seawatch	TKN	9	0.57	8	6.85	6	39.07	mg/L
Rourk	TKN	.	.	4	6.78	1	4.2	mg/L
Winding River Pond	TKN	5	1.08	5	2.14	6	0.98	mg/L
Winding River Townhouse	TKN	.	.	4	1.85	6	0.71	mg/L
Doe Creek	TOC	6	208.7	7	97.54	7	107.2	mg/L
Hewett Wildlife	TOC	5	176.5	6	18.15	6	19.5	mg/L
Lockwood	TOC	6	62.33	6	1315	9	189.4	mg/L
Mercer Seawatch	TOC	9	93.27	8	588	6	573.8	mg/L
Rourk	TOC	.	.	3	533.3	.	.	mg/L
Winding River Pond	TOC	6	157.2	6	55.67	7	18.14	mg/L
Winding River Townhouse	TOC	.	.	5	163.3	7	14.39	mg/L
Doe Creek	Total Suspended Residue	5	534.5	6	130.8	6	416.7	mg/L
Hewett Wildlife	Total Suspended Residue	5	795	6	26.2	6	37.03	mg/L
Lockwood	Total Suspended Residue	6	176.2	6	2451	9	694.4	mg/L
Mercer Seawatch	Total Suspended Residue	9	124.9	8	574.7	6	3940	mg/L
Rourk	Total Suspended Residue	.	.	4	1400	1	1500	mg/L
Winding River Pond	Total Suspended Residue	5	1330	5	264.2	6	42.75	mg/L
Winding River Townhouse	Total Suspended Residue	.	.	4	1308	6	25.9	mg/L
Doe Creek	Water, Temperature	5	13.72	6	19.32	6	16.78	oC
Hewett Wildlife	Water, Temperature	5	13.82	6	17.97	6	17.98	oC
Lockwood	Water, Temperature	7	14.99	7	20.23	9	17.71	oC
Mercer Seawatch	Water, Temperature	9	17.68	8	15.7	6	16.6	oC
Rourk	Water, Temperature	.	.	4	12.75	1	9	oC
Winding River Pond	Water, Temperature	5	15.8	5	15.98	6	17.6	oC
Winding River Townhouse	Water, Temperature	.	.	4	15.18	6	16.7	oC
Doe Creek	Zinc	5	88.4	6	41.5	7	53.14	ug/L
Hewett Wildlife	Zinc	5	61.4	6	11.5	6	12.33	ug/L
Lockwood	Zinc	6	14	6	91.67	9	75.22	ug/L
Mercer Seawatch	Zinc	9	10	8	149.3	6	44.33	ug/L
Rourk	Zinc	.	.	4	141.3	1	27	ug/L
Winding River Pond	Zinc	5	68.4	5	15.4	6	10	ug/L
Winding River Townhouse	Zinc	.	.	4	79.5	6	10.17	ug/L

Table 5.2.2-3 Lockwood Folly Riverine Swamp Forest: Water Quality Means by Station Location

Parameter	N	Mean (Buffer)	Mean (Down River)	Mean (Up River)
Ammonia (mg/L)	109	0.123	0.277	0.698
Calcium (mg/L)	109	50.034	64.950	59.695
Copper (ug/L)	109	10.187	10.865	17.196
Dissolved Oxygen (%)	97	37.704	23.683	25.317
Dissolved Oxygen (mg/L)	97	4.039	2.617	2.615
DOC (mg/L)	107	11.475	14.394	20.037
Fecal Colliform (CFU/100 ml)	109	5397.567	622.925	1811.256
Lead (ug/L)	109	23.233	27.125	57.769
Magnesium (mg/L)	109	37.111	43.413	37.115
NO2+NO3 (mg/L)	109	0.028	0.031	0.033
pH (S. U.)	109	5.409	5.898	5.825
Phosphorus (mg/L)	109	0.585	0.749	1.304
Specific Conductivity (uS/cm)	95	1348.596	1833.437	1410.679
TKN (mg/L)	109	1.759	7.514	13.003
TOC (mg/L)	115	134.088	148.640	393.544
Total Suspended Residue (mg/L)	109	515.977	863.078	830.744
Water, Temperature (oC)	111	15.506	17.060	17.063
Zinc (ug/L)	110	42.167	37.488	77.487

Section 5.2.3 Riverine Swamp Forests: Hydrology Results and Discussion

Hydrographs for the Riverine Swamp Forests at the Lockwood Folly River watershed are shown in Figures 5.2.3-1 thru 5.2.3-13. The hydrographs show the electronic depth of the water in the well, where zero on the y-axis is the bottom of the well as measured by the transducer. The red line on the hydrograph indicates ground level and the blue line on the hydrograph indicates one foot below the surface for the Riverine Swamp Forest hydrographs. As the water level increases, it approaches the surface as indicated by the curves. Surface ground levels varied slightly between the sites, but were generally at about 21-25 inches as shown on the graphs. Some gaps in the data exist that are caused by technical difficulties with the transducers or errors in downloading the data. Six of the seven sites had two automated transducers, one located up-river (up-flow) and one located down-river (down-flow). The Winding River Townhouse site had only one automated transducer. The Doe Creek hydrographs are shown in Figures 5.2.3-1 and 2, for the down flow and up flow. The pattern between the two hydrographs is very similar, with the lower levels being during the summer months and the higher levels during the winter months. The Hewitt site had much less variability than the Doe Creek site (see Figures 5.2.3-4 and 5) and did not show any seasonal pattern, at either of the transducers. The Hewitt site always had high water levels and was influenced by beaver dams. The Lockwood site also did not show a seasonal pattern (see Figures 5.2.3-5 and 6) and generally had high water levels. However, there were differences between the down-river and up-river transducers. The up-river transducer had more variability in the water depths where the down-river transducer had very consistent water depth. The Mercer Seawatch site (see Figures 5.2.3-7 and 8) also did not show a seasonal pattern and the two transducers (up-flow and down-flow) were fairly consistent. There was no seasonal pattern at the Rourk site also (Figures 5.2.3-9 and 10), and the two transducers were also very similar with consistent water levels. The Winding River Pond site (see Figures 5.2.3-11 and 12) also showed no seasonal pattern and was very consistent between the two transducers. This site also was influenced by beavers. The Winding River Townhouse site was just across a residential road and down stream from the Winding River Pond site. In Figure 5.2.3-13, this site also did not display a seasonal pattern and was also very consistent with the Winding River Pond water levels.

Table 5.2.3-1 shows the percent of the time the water depth at each site was within one foot of the surface. The second column is for the growing season. The Riverine Swamp Forest averaged just over 90% within one foot of the surface during the growing season with the range being from 25.7% at the Doe Creek site to 100% for the Hewitt (down-river), Lockwood (down-river), Mercer (down-river), and Winding River Pond (down-river and up-river).

Hydrographs for the Riverine Swamp Forest at the Lockwood Folly River watershed showed no seasonal variation except for the Doe Creek site and even that site did not exhibit a strong trend. The Riverine Swamp Forests generally have very consistent high water levels throughout the year with trends being more daily that seasonal. Doe Creek and Lockwood were tidal and Mercer Seawatch had some tidal influence also, but to a lesser degree.

Figure 5.2.3 -1 Riverine Swamp Forest -- Doe Creek: Down Flow

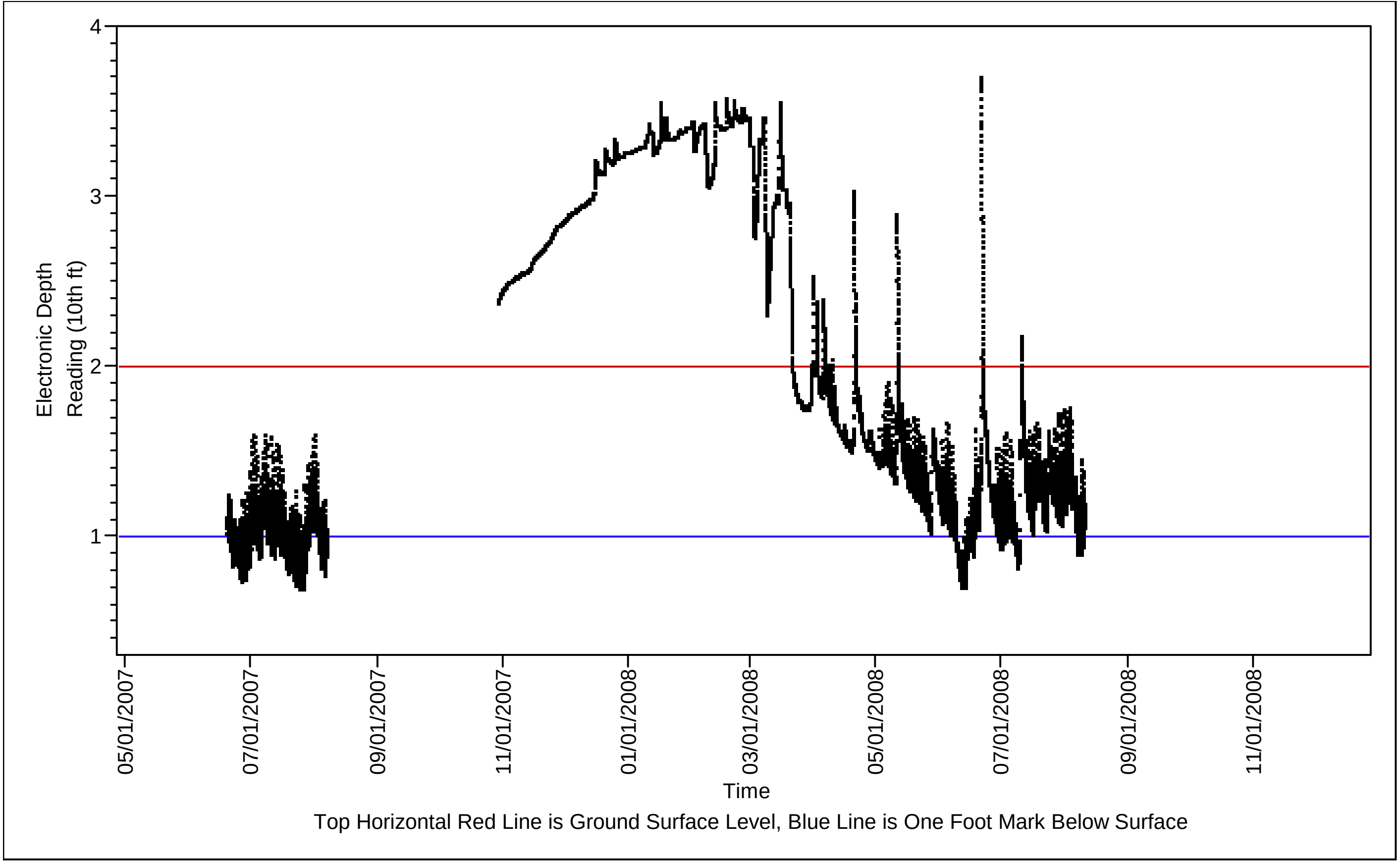


Figure 5.2.3 -2 Riverine Swamp Forest -- Doe Creek: Up Flow

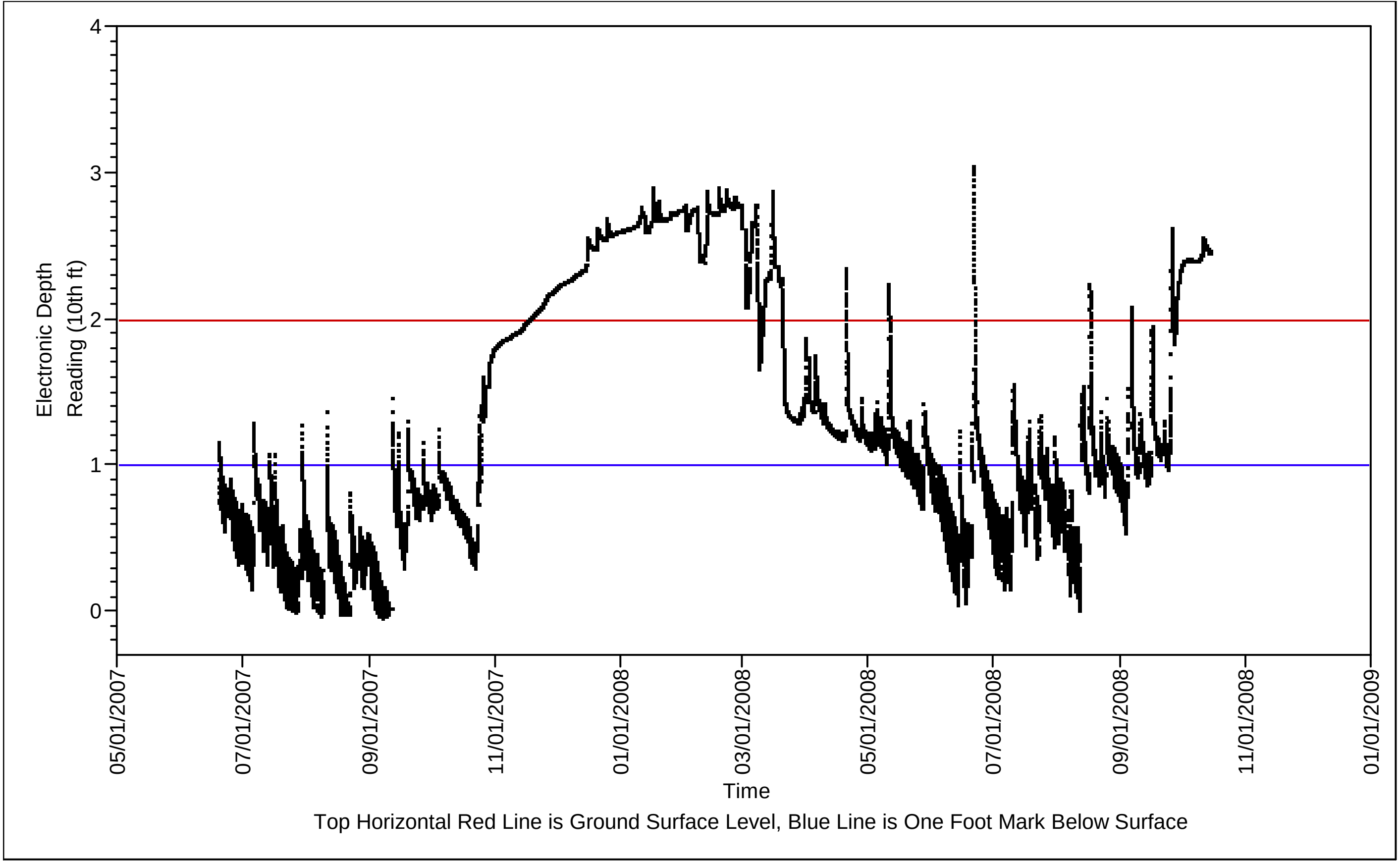


Figure 5.2.3 -3 Riverine Swamp Forest -- Hewett: Down Flow

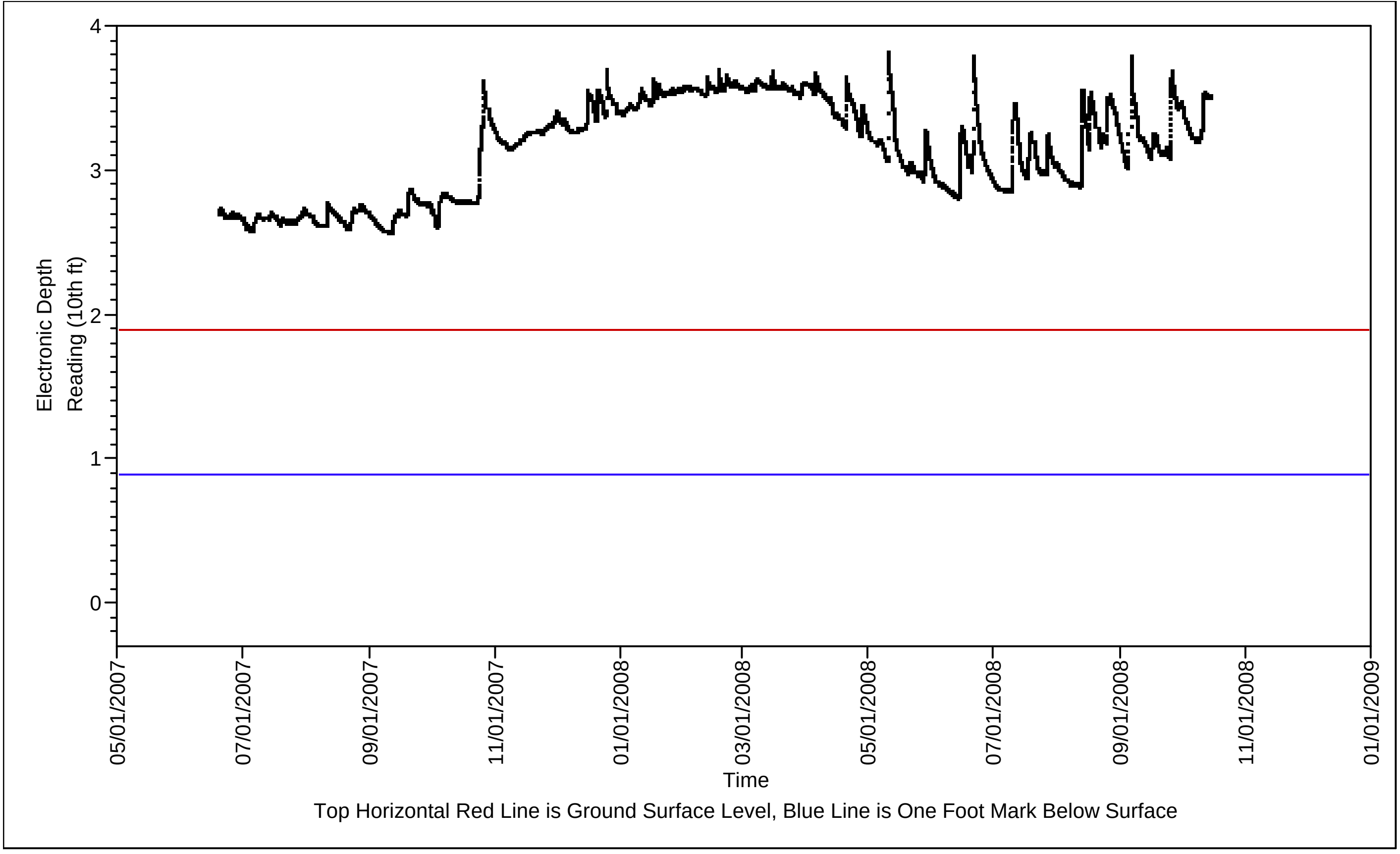


Figure 5.2.3 -4 Riverine Swamp Forest -- Hewett: Up Flow

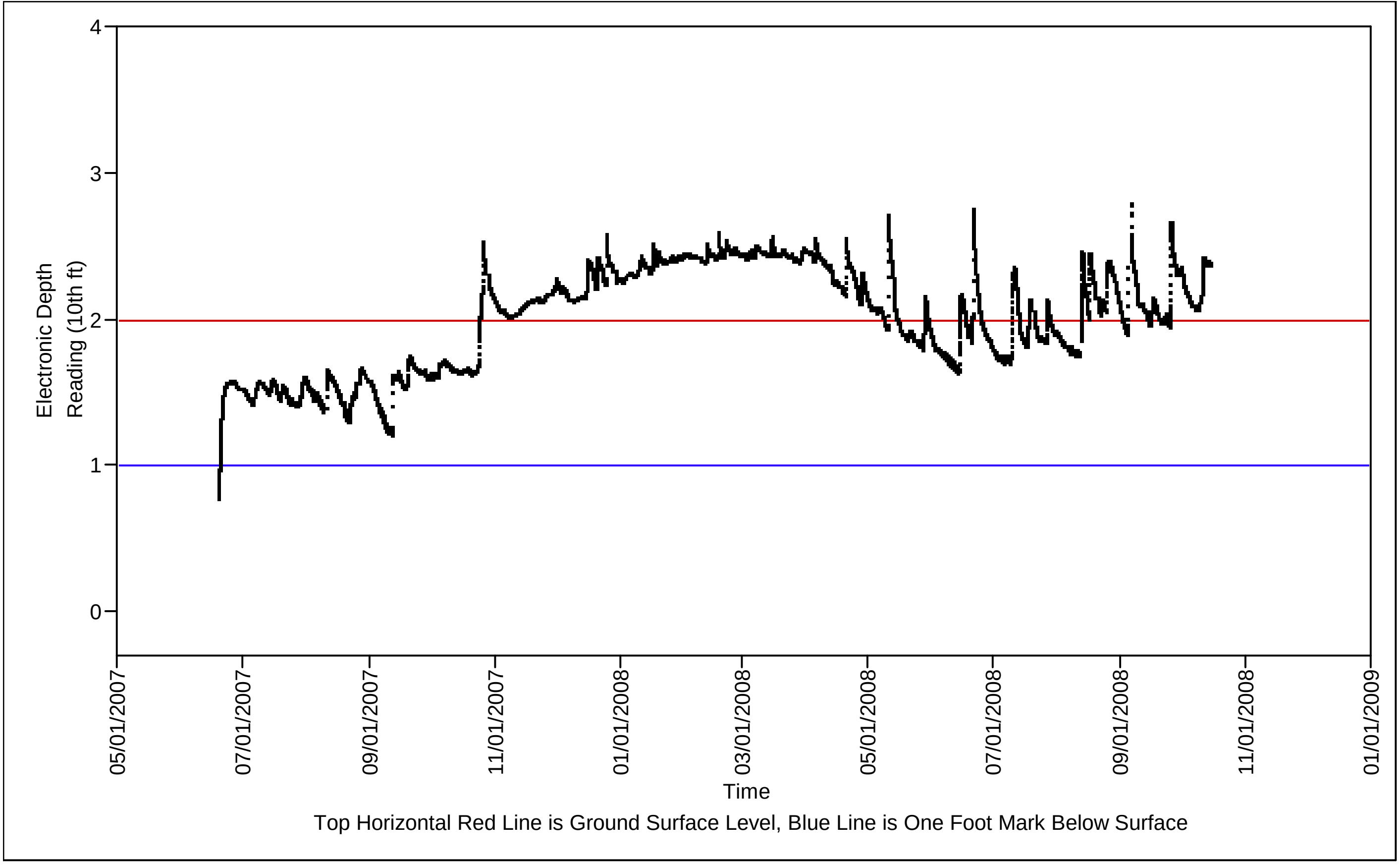


Figure 5.2.3 -5 Riverine Swamp Forest -- Lockwood: Down Flow

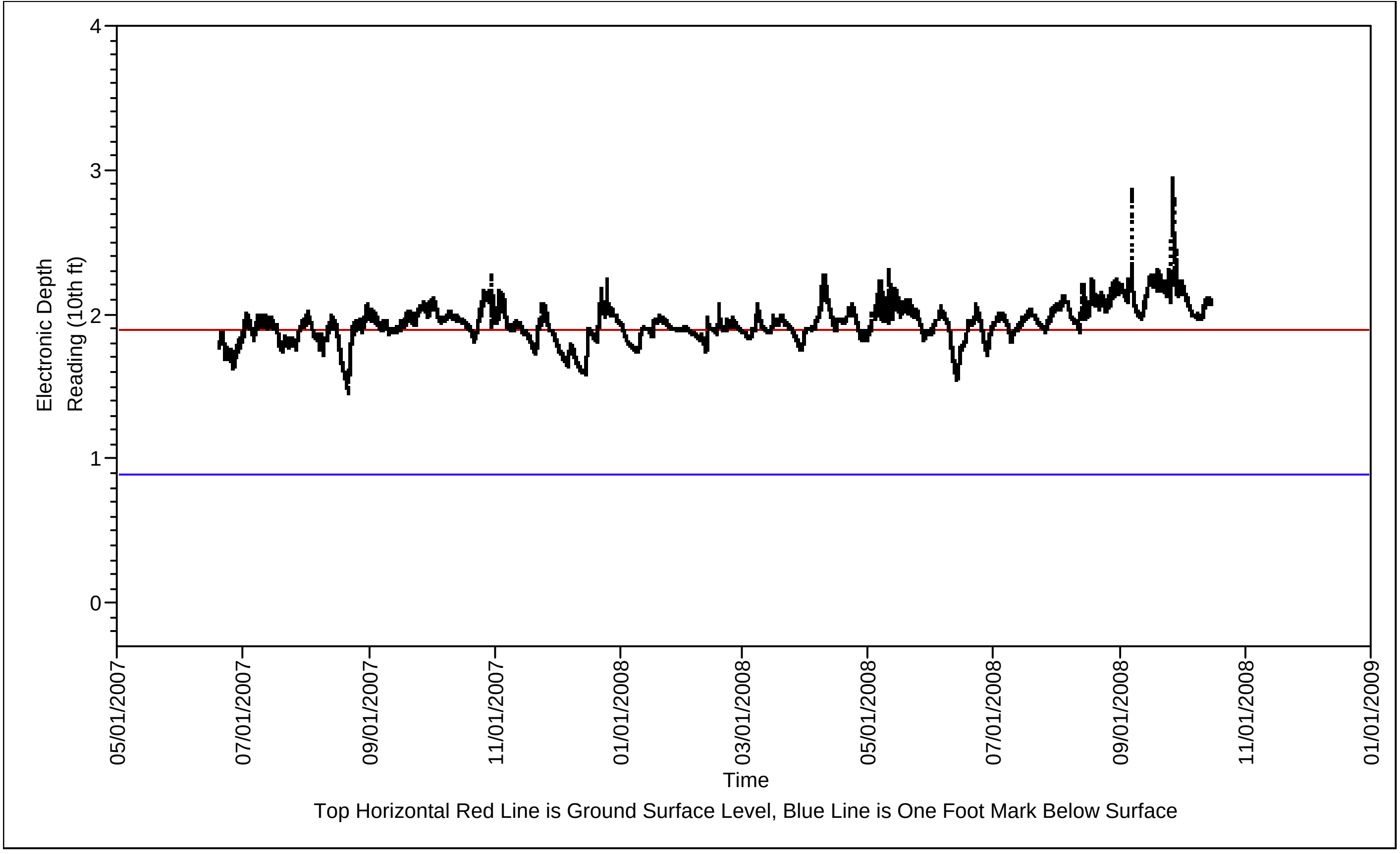


Figure 5.2.3 -6 Riverine Swamp Forest -- Lockwood: Up Flow

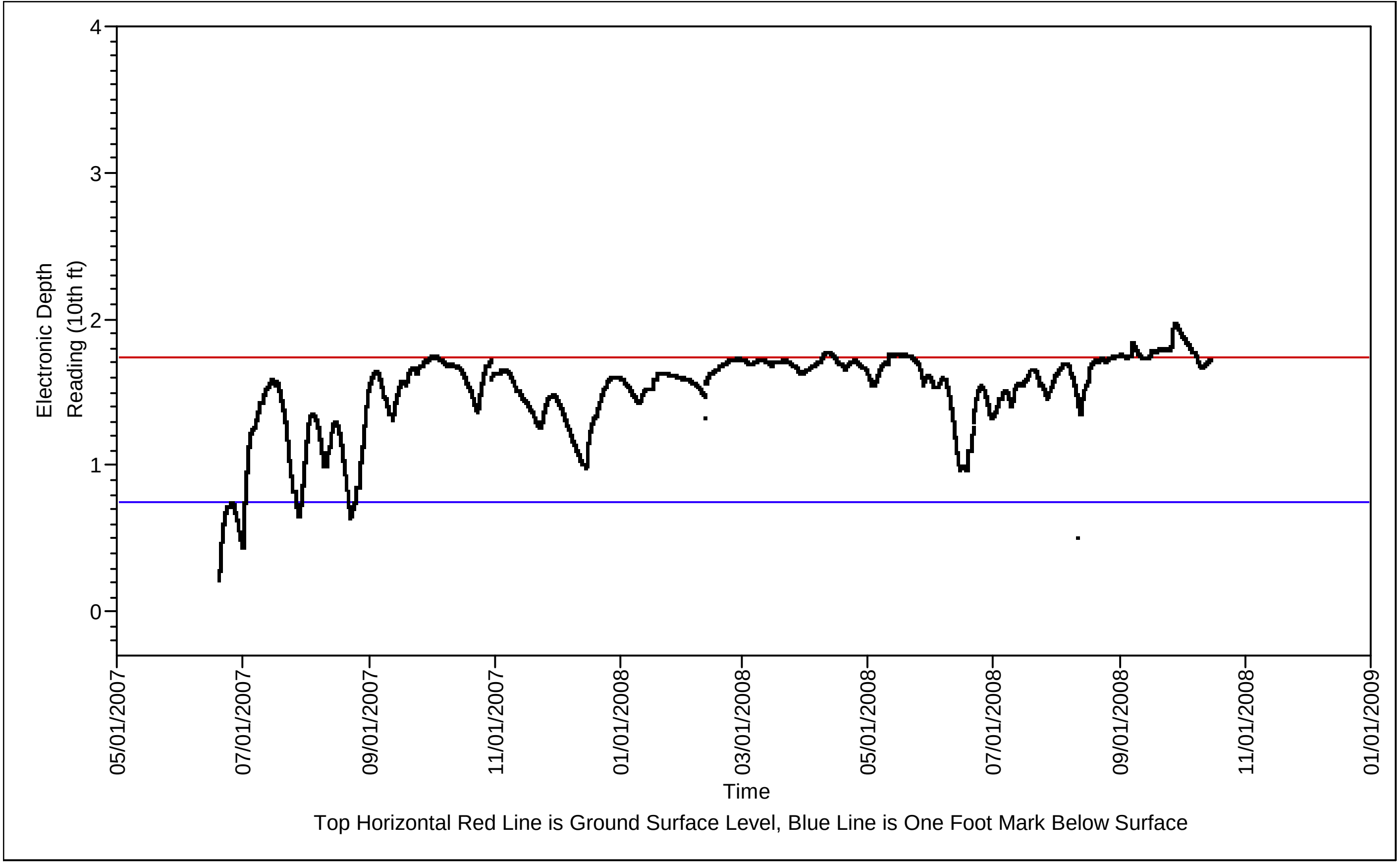


Figure 5.2.3 -7 Riverine Swamp Forest -- Mercer: Down Flow

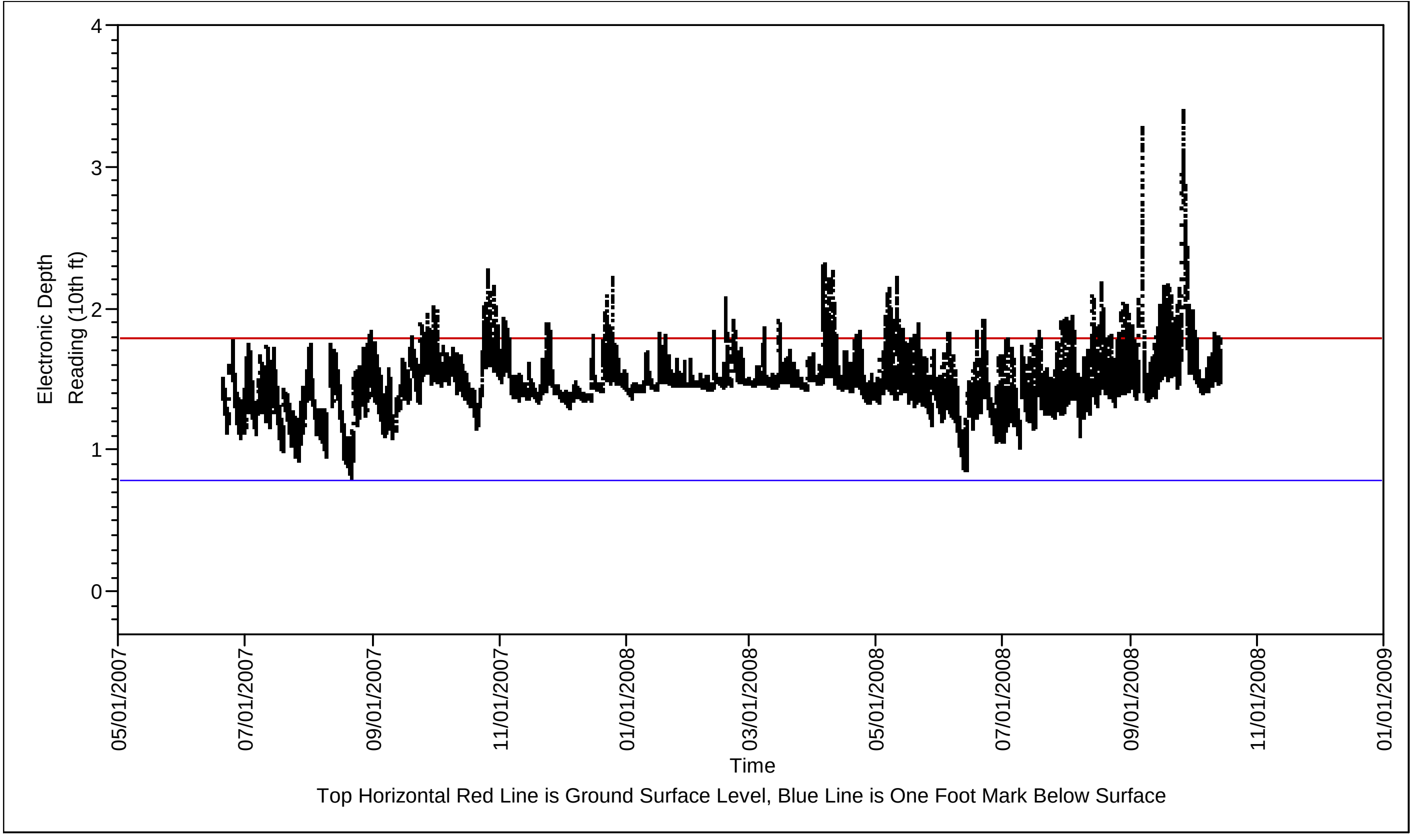


Figure 5.2.3 -8 Riverine Swamp Forest -- Mercer: Up Flow

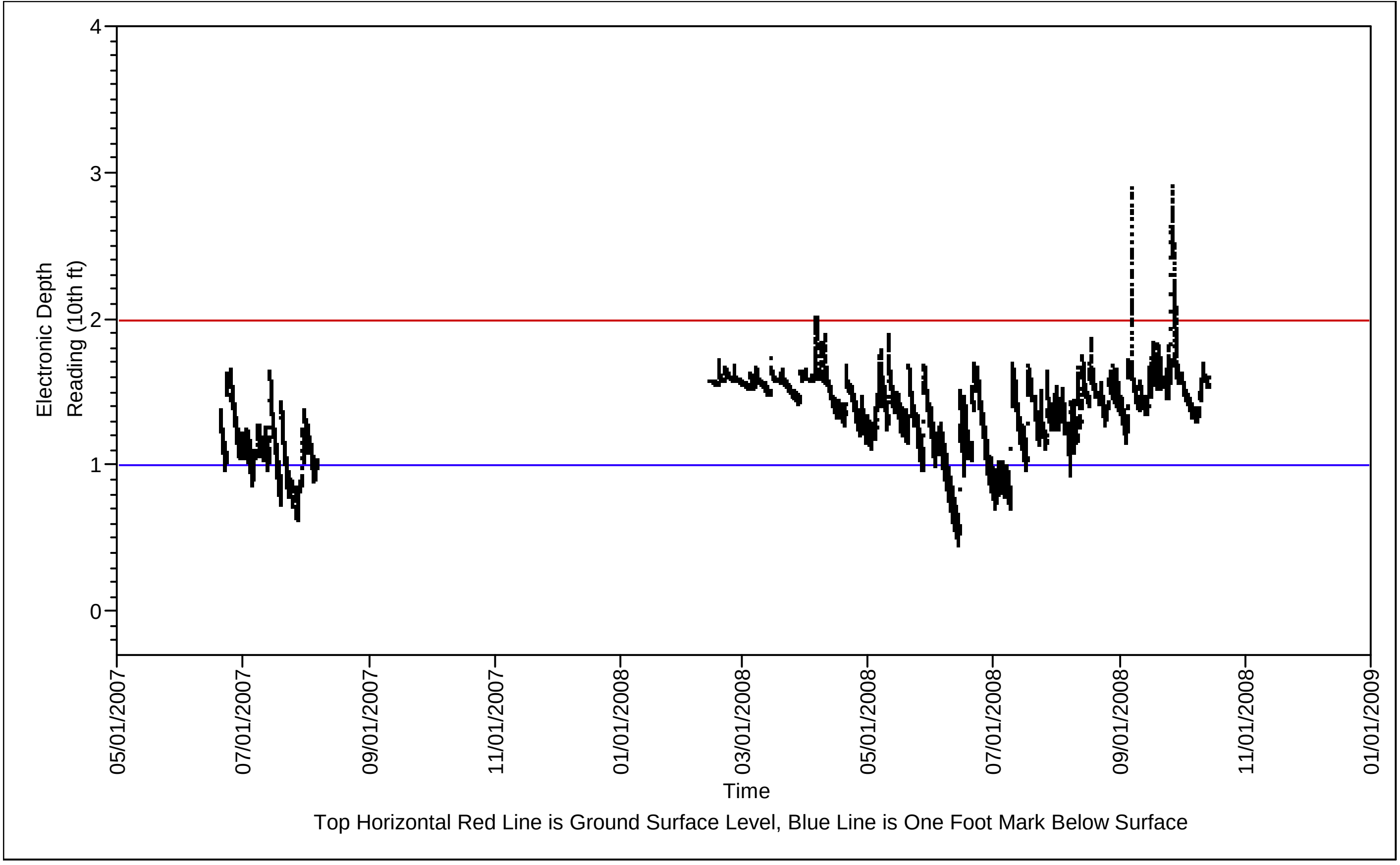
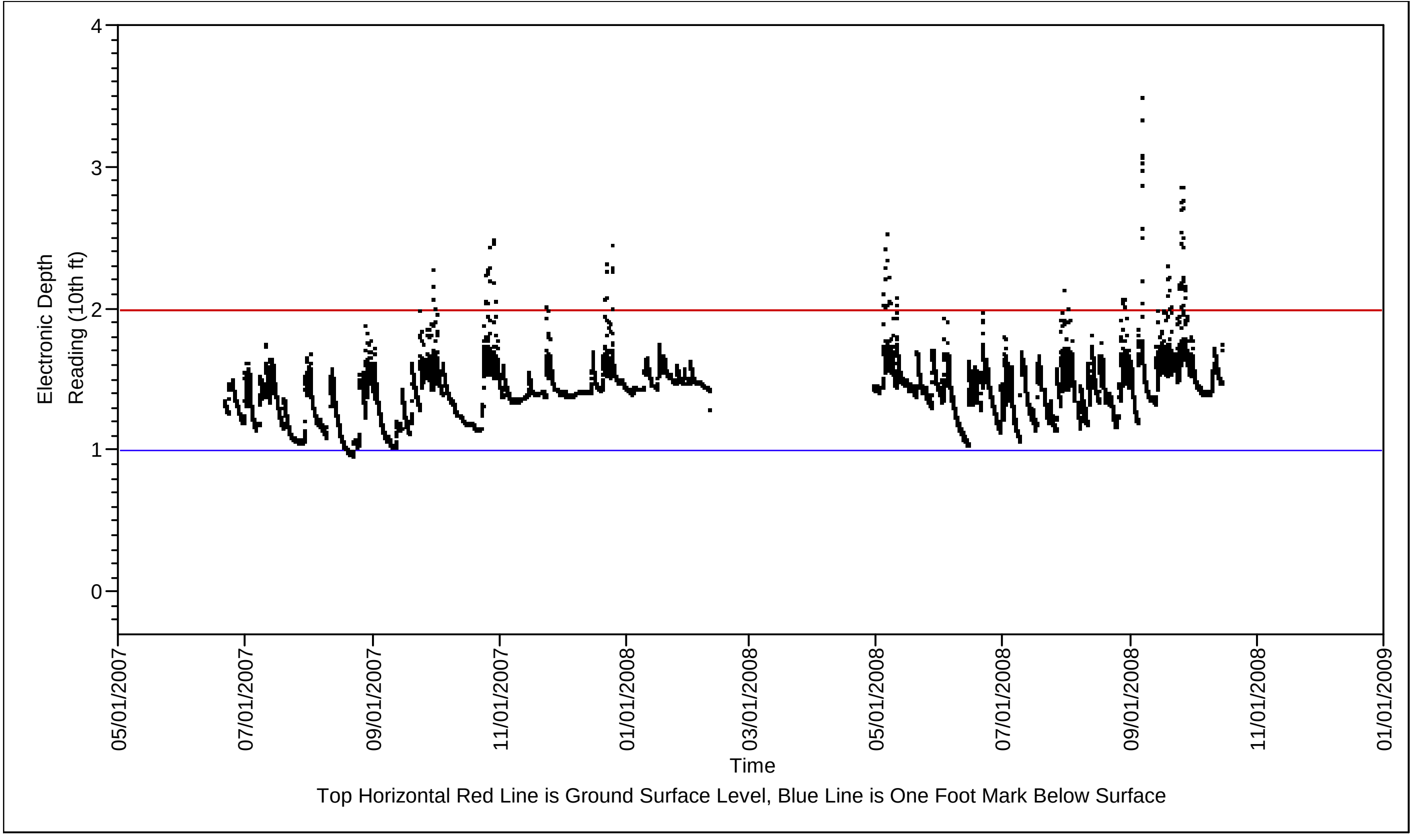
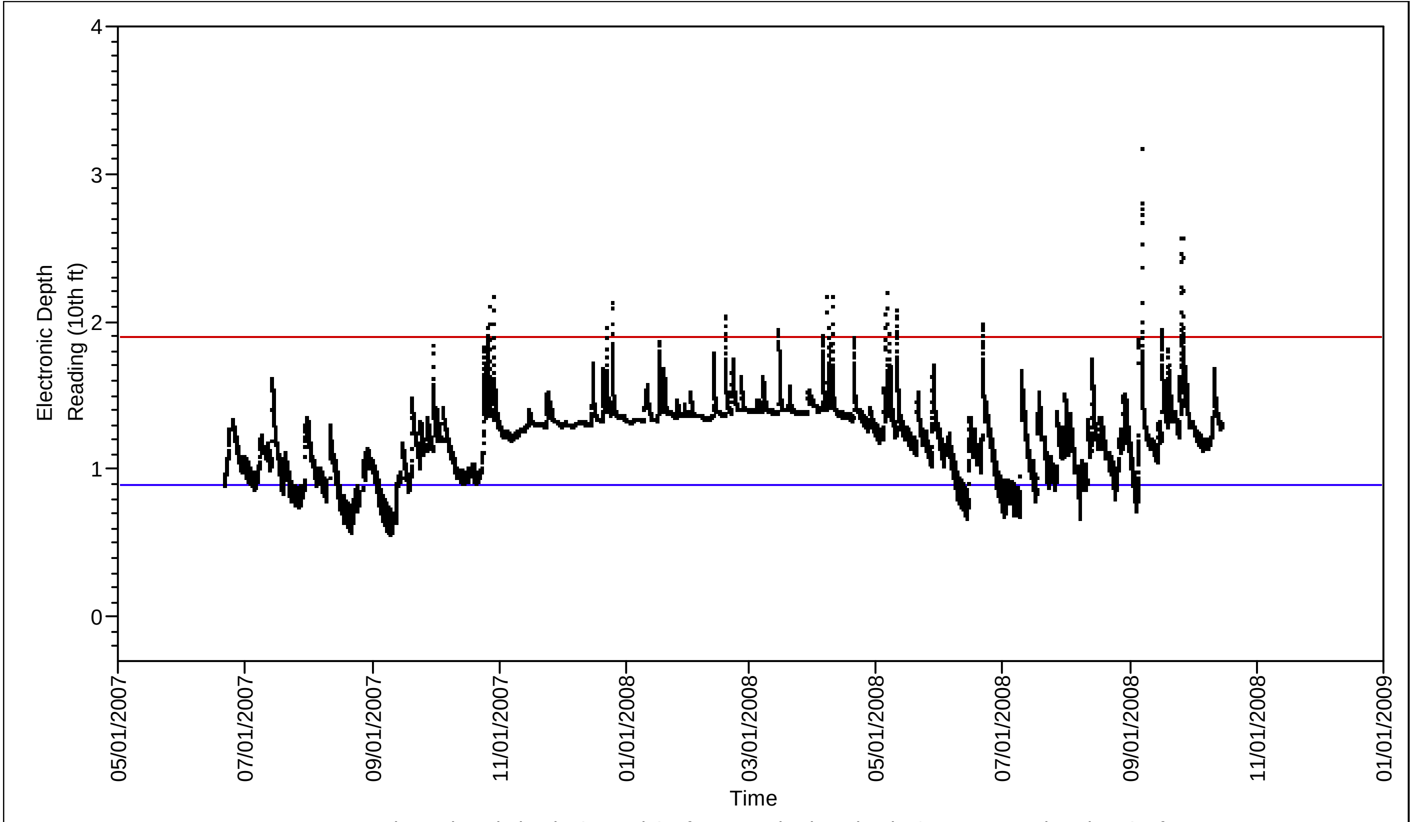


Figure 5.2.3 -9 Riverine Swamp Forest -- Rourk: Down Flow



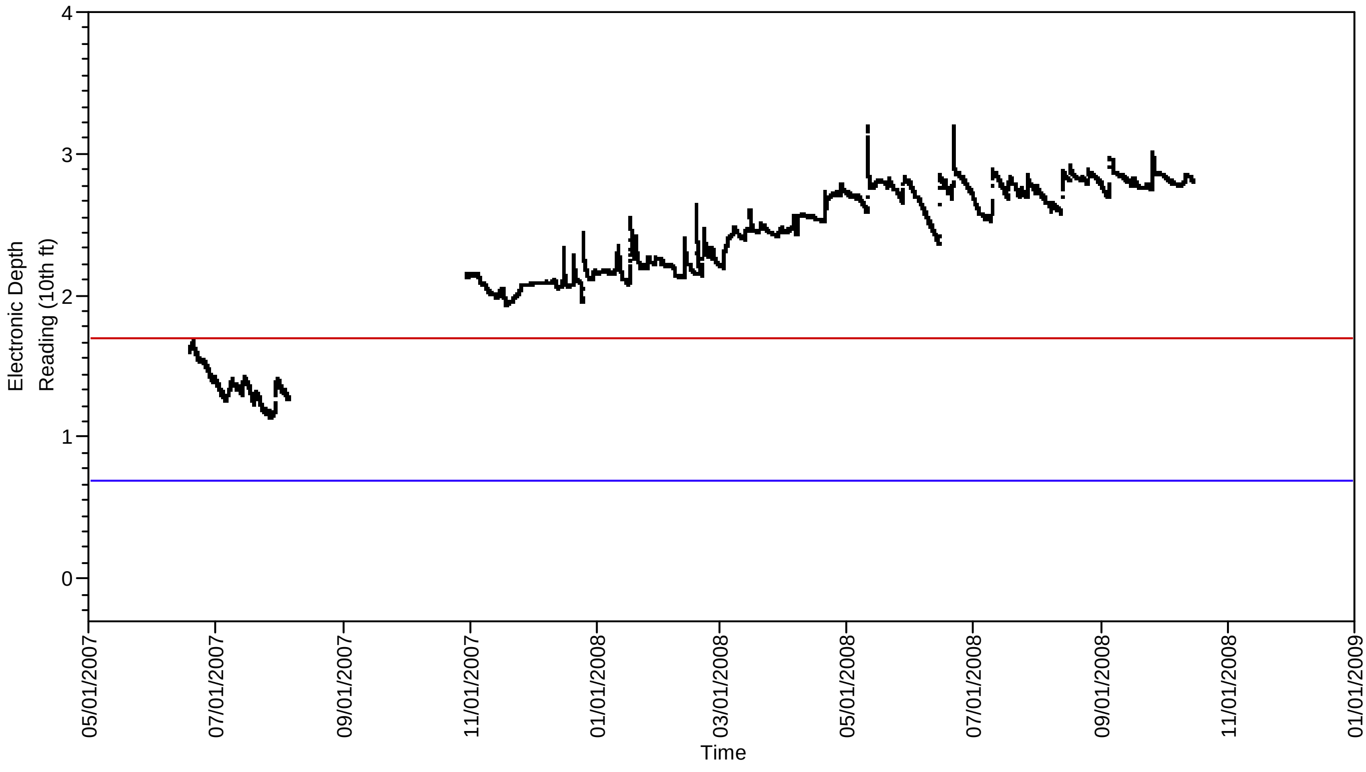
Top Horizontal Red Line is Ground Surface Level, Blue Line is One Foot Mark Below Surface

Figure 5.2.3 -10 Riverine Swamp Forest -- Rourk: Up Flow



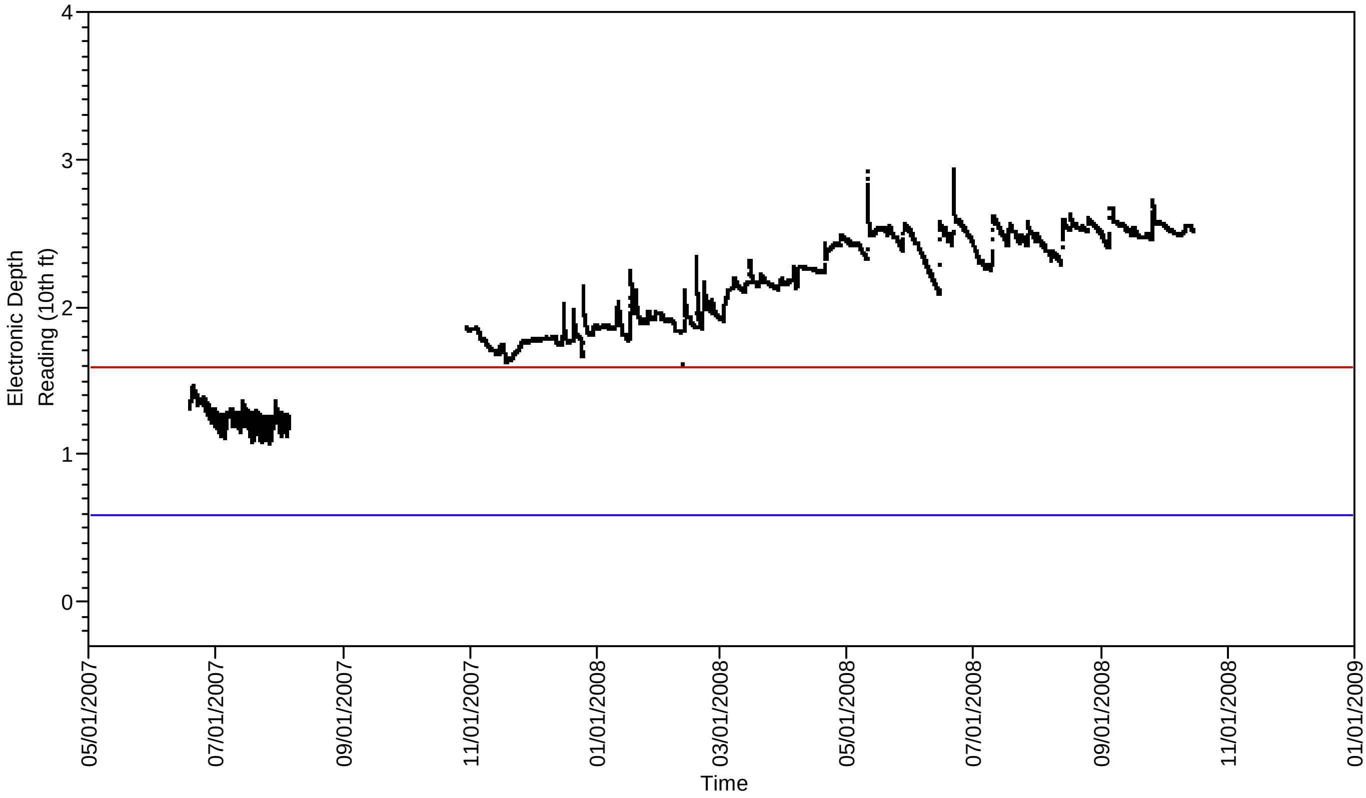
Top Horizontal Red Line is Ground Surface Level, Blue Line is One Foot Mark Below Surface

Figure 5.2.3 -11 Riverine Swamp Forest -- Winding River Pond: Down Flow



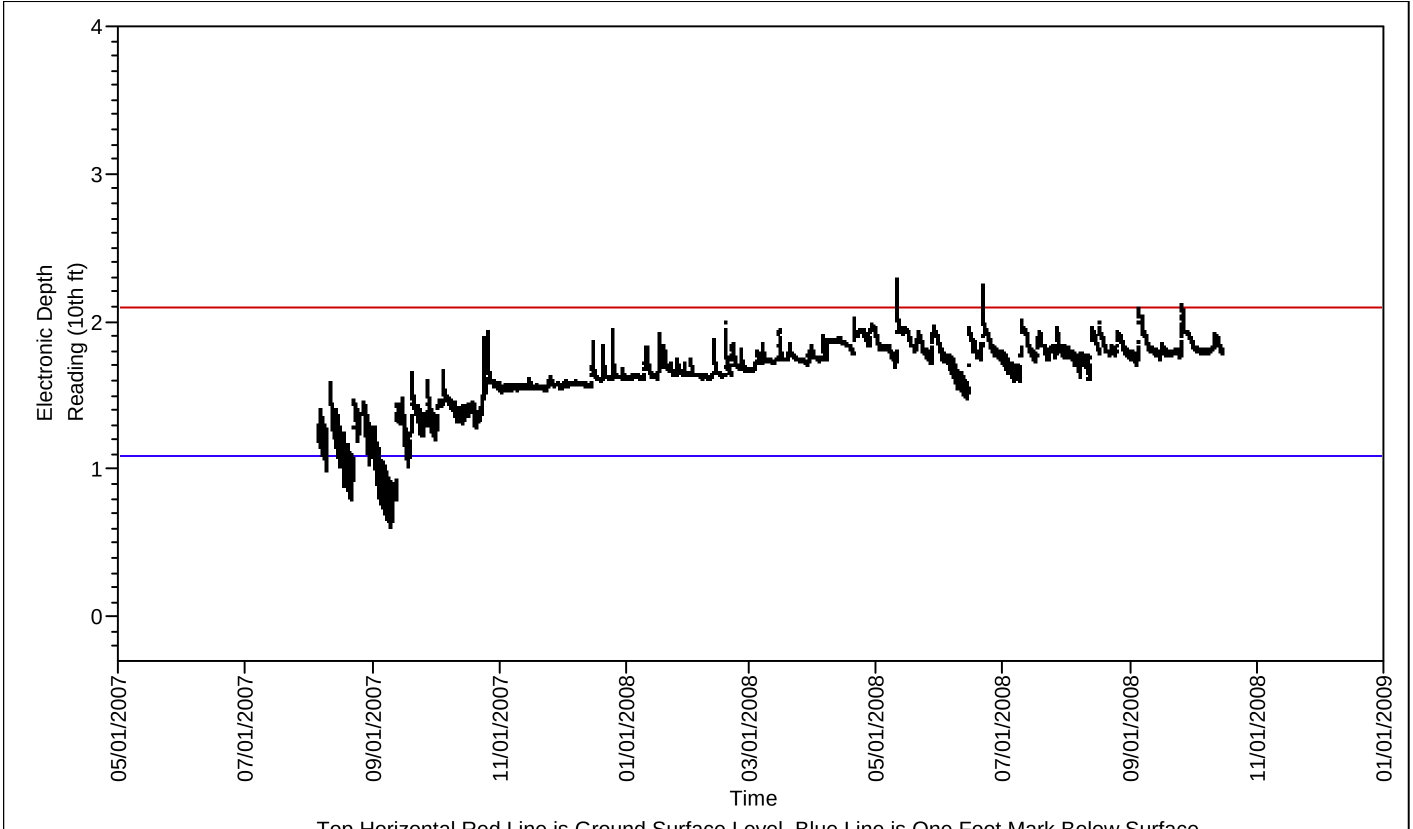
Top Horizontal Red Line is Ground Surface Level, Blue Line is One Foot Mark Below Surface

Figure 5.2.3 -12 Riverine Swamp Forest -- Winding River Pond: Up Flow



Top Horizontal Red Line is Ground Surface Level, Blue Line is One Foot Mark Below Surface

Figure 5.2.3 -13 Riverine Swamp Forest -- Winding River Townhouse



Top Horizontal Red Line is Ground Surface Level, Blue Line is One Foot Mark Below Surface

Table 5.2.3-1 Riverine Swamp Forest – Water Depth: percent within One Foot of Surface

Site / Well Station	Percent within one foot from surface	Percent within one foot of surface - growing season
Doe Creek / Down	90.5	85.1
Doe Creek / Up	50.3	25.7
Hewitt / Down	100.0	100.0
Hewitt / Up	99.9	99.8
Lockwood / Down	100.0	100.0
Lockwood / Up	96.2	95.0
Mercer / Down	100.0	100.0
Mercer / Up	91.0	90.5
Rourk / Down	98.6	98.2
Rourk / Up	91.2	88.3
Winding River Pond / Down	100.0	100.0
Winding River Pond / Up	100.0	100.0
Winding River Townhouse / Down	96.8	95.6
Mean	**93.4**	**90.6**

Section 5.2.4 Riverine Swamp Forests: Soil Results and Discussion

When soil samples were taken from each site (in wetland and upland locations), texture and soil color was recorded. Each soil core sample was taken with a bucket augur and was laid out on the surface. Different layers/horizons were measured, and each layer/horizon was then compared with the Munsell soil color chart to determine the hue, chroma, and value. Soil texture was also determined in terms of the clay, silt, sandy or loam content of the soil. These results are shown in Table E-1 in Appendix E for the Riverine Swamp Forest in the Lockwood Folly watershed.

For the Doe Creek site, the soil was primarily a muck soil with the deeper layers becoming sandier. The Hewitt site was primarily a muck even at deeper levels. A couple of the sample cores did find sandier soil at the deeper levels. Soil at the Lockwood site was again a muck soil even at the deeper levels. Some of the sample cores did find a loamy sand soil. Soil samples at the Mercer Seawatch site were more varied with most of the samples being a muck mixture with loam and sand. Rourk had an organic muck soil at all levels with one sample finding some sandy muck and a loamy sand at the deepest level. The Winding River Pond site also had a muck soil but with a lot more sand and sandy loam, especially at the deeper levels. The Winding River Townhouse site (which was down river form the Winding River Pond site) had more organic muck soil with the deeper levels becoming more of a sandy loam.

Overall the soil texture of the Riverine Swamp Forests in the Lockwood Folly watershed was primarily a muck, often organic, but several sites had sandier soils at the deeper levels. The

Munsell soil color of these wetland soils was very dark with 10YR 2/1 and 10YR 3/1 being typical.

Soil samples were collected in the wetland (usually four to six samples) and up to four samples were collected in the uplands surrounding the wetland (see Soils Field Methodology, section 4.3). Table 5.2.4-1 shows the means for all of the soil parameters for each riverine swamp forest site for the upland samples and wetland samples (note that no upland samples were collected at the Winding River sites, due to the need to have to sample in mowed lawns). Table 5.2.4-2 shows the mean results for the upland samples and the wetland samples averaged across sites. From Table 5.2.4-1, the percent humic matter is higher in the wetland and lower in the upland as would be expected. The Winding River Pond and Mercer Seawatch sites had the highest levels of percent humic matter. The weight per volume is more in the upland. The Doe Creek and Winding River Townhouse sites had the largest weight per volume with Lockwood and Winding River Townhouse sites next. The cation exchange capacity (CEC) is four times higher in the wetland than the upland indicating the wetland's larger capacity to hold plant nutrients. The Hewitt Wildlife site had the highest levels of CEC with the Rourk, Mercer Seawatch, and Lockwood sites having the next highest levels of CEC. As would be expected, the base saturation is much higher in the wetland. The Lockwood site had the highest level of percent base saturation whereas the Winding River Pond site had the lowest. While the pH is a little higher in the wetland, the Ac (exchangeable acidity) is higher in the wetland indicating more organic soils and better absorption of aluminum and hydrogen. The Winding River Townhouse and Lockwood sites were the least acidic sites (pH about 5.4 and 5.2 respectably) while the other five sites were more acidic (pH ranging from 4.56 to 4.87). The Hewitt Wildlife site had the highest level of exchangeable acidity (Ac) and the Rourk and Mercer Seawatch sites had the next highest levels.

Phosphorus was higher in the uplands as indicated in Table 5.2.4-2 but potassium, calcium, sulfur, and magnesium were higher in the wetland. Referring to Table 5.2.4-1, the Mercer Seawatch and Rourk sites had the highest levels of phosphorus with the Doe Creek site next. The Rourk, Lockwood, and Mercer Seawatch sites had at least twice the levels of potassium than the other four sites. The Hewitt Wildlife site had the highest levels of calcium with the Mercer Seawatch and Lockwood sites next. The Hewitt Wildlife and Rourk sites had the highest levels of magnesium while the two Winding River sites had the lowest levels. The Hewitt Wildlife site also had the highest levels of sulfur which was about three times as much as the next highest which was the Lockwood site. The Winding River Pond site has the lowest level of sulfur. Manganese levels were higher in the upland. Again, the Hewitt Wildlife site had the highest levels of manganese which was about twice the level of the next highest sites, Lockwood and Mercer Seawatch. Zinc, copper, sodium, and nitrogen are higher in the wetland. The Doe Creek site had the highest levels of zinc and the Winding River Pond site had the lowest level. The highest level of copper occurred at the Doe Creek and Rourk sites. The Rourk and Lockwood sites had the highest levels of sodium by a large amount whereas the two Winding River sites had the lowest levels also by a large margin. The Rourk and Mercer Seawatch sites had the highest levels of nitrogen and the Hewitt Wildlife and Winding River Townhouse sites had the lowest levels. Given that since the majority of the nutrient and micro-nutrients (metals) have higher levels in the wetland, this indicates they may function as a sink for these potential pollutants in response to filtering of the water.

From the soil results, the Rourk site had the highest levels of potential pollutants with the Mercer Seawatch and Lockwood sites next. These same three sites had the highest levels of potential pollutants in the water quality results. The Winding River sites had the lowest levels of potential pollutants with the Doe Creek site being next. The Winding River sites also had the lowest levels of potential pollutants in the water quality results. There is a definite potential correlation between the water quality results and the soil results as one would expect.

Statistical tests, (ANOVA and Wilcoxon) were performed to determine the statistical significance of the upland and wetland soil characteristic differences. The weight per volume was statistically significant (both the Wilcoxon and ANOVA, $p<0.0001$) with the higher levels in the upland. Percent humic matter, CEC, and base saturation were all statistically significant (both the Wilcoxon and ANOVA, $p<0.0001$) with the higher levels being in the wetland as would be expected. The Ac was significantly higher in the wetland (organic soil) and was significant (Wilcoxon, $p=0.0336$, ANOVA, $p=0.0344$). The pH was slightly higher in the wetland (less acidic) and this difference was significant statistically, (Wilcoxon, $p=0.1122$, ANOVA, $p=0.0225$). Higher levels of phosphorus occurred in the upland and this again was statistically significant (ANOVA, $p=0.033$). Potassium, calcium, magnesium, and sulfur had higher levels in the wetland and was statistically significant (both the Wilcoxon and ANOVA, all at $p<0.03$). Manganese was higher in the upland and this difference was significant statistically (ANOVA, $p=0.0476$). Zinc, sodium, and nitrogen were higher in the wetland and this difference was statically significant (both the Wilcoxon and ANOVA, all at $p<0.04$).

For the Riverine Swamp Forest in the Lockwood Folly River watershed, the results for the soils are consistent with the conclusion that the wetlands are acting as a sink for nutrients and metals and thereby perform important water quality functions. The soil results for the Riverine Swamp Forests were also consistent with the water quality results in that the sites with most problems with potential pollutants were the same. This implies, and not unexpectedly, a relationship between the water quality parameters and the soil parameters.

Table 5.2.4-1 Means by site for Riverine Swamp Forests Upland and Wetland Soil Samples

Site	N	Mean(HM %, Up)	Mean(HM %, Wet)	Mean (WV g/cc, Up)	Mean (WV g/cc, Wet)	Mean (CEC meq/100cc, Up)	Mean (CEC meq/100cc, Wet)
Doe Creek	13	0.298	1.364	1.403	0.982	3.375	11.456
Hewitt Wildlife	5	0.395	2.003	1.315	0.403	1.600	30.200
Lockwood	7	1.107	1.523	1.333	0.840	3.833	18.150
Mercer Seawatch	9	2.390	2.708	1.153	0.462	8.600	20.583
Rourk	13	0.715	1.832	1.375	0.584	4.075	21.444
Winding River Pond	7		3.537		0.801		12.386
Winding River Townhouse	10		1.741		0.982		11.580

Site	N	Mean(BS %, Up)	Mean (BS %, Wet)	Mean (Ac meq/100cc, Up)	Mean (Ac meq/100cc, Wet)	Mean(pH, Up)	Mean(pH, Wet)
Doe Creek	13	43.000	63.333	1.800	3.067	4.775	4.856
Hewitt Wildlife	5	48.000	77.333	0.850	6.633	5.100	4.567
Lockwood	7	31.333	84.000	2.633	2.825	4.533	5.225
Mercer Seawatch	9	28.000	71.000	6.200	5.667	4.000	4.883
Rourk	13	36.000	72.222	2.575	5.867	4.775	4.767
Winding River Pond	7		58.429		4.057		4.871
Winding River Townhouse	10		76.800		2.690		5.440

Site	N	Mean (P mg/dm3, Up)	Mean (P mg/dm3, Wet)	Mean (K mg/dm3, Up)	Mean (K mg/dm3, Wet)	Mean (Ca mg/dm3, Up)	Mean (Ca mg/dm3, Wet)
Doe Creek	13	11.100	17.689	15.425	53.289	263.900	1291.678
Hewitt Wildlife	5	5.150	8.267	13.050	50.500	109.850	2830.000
Lockwood	7	15.333	13.850	16.600	111.975	185.033	1955.425
Mercer Seawatch	9	12.067	21.617	26.833	94.533	334.933	2217.500
Rourk	13	60.150	20.022	24.575	168.356	220.125	1389.589
Winding River Pond	7		12.486		49.643		1509.643
Winding River Townhouse	10		11.290		27.200		1634.010

Table 5.2.4-1 Means by site for Riverine Swamp Forests Upland and Wetland Soil Samples

Site	N	Mean (Mg mg/dm3, Up)	Mean (Mg mg/dm3, Wet)	Mean (S mg/dm3, Up)	Me an (S mg/dm3, Wet)	Mean (Mn mg/dm3, Up)	Mean (Mn mg/dm3, Wet)
Doe Creek	13	27.550	219.811	9.250	204.344	3.650	2.011
Hewitt Wildlife	5	20.250	1130.700	14.550	1707.967	2.250	6.733
Lockwood	7	28.300	640.875	10.800	554.325	1.267	3.200
Mercer Seawatch	9	82.400	434.267	7.533	151.117	2.733	3.150
Rourk	13	41.400	997.389	18.275	323.333	7.025	2.200
Winding River Pond	7		79.057		28.114		1.671
Winding River Townhouse	10		79.070		106.790		1.870

Site	N	Mean (Zn mg/dm3, Up)	Mean (Zn mg/dm3, Wet)	Mean (Cu mg/dm3, Up)	Mean (Cu mg/dm3, Wet)	Mean (Na mg/dm3, Up)	Mean (Na mg/dm3, Wet)
Doe Creek	13	0.850	2.611	0.250	0.344	13.000	443.667
Hewitt Wildlife	5	0.400	1.600	0.200	0.233	23.500	555.000
Lockwood	7	0.600	0.925	0.233	0.225	21.667	1861.000
Mercer Seawatch	9	1.133	1.350	0.200	0.233	27.333	381.500
Rourk	13	0.525	1.378	0.300	0.356	23.000	2365.222
Winding River Pond	7		0.643		0.243		54.286
Winding River Townhouse	10		1.140		0.250		55.400

Site	N	Mean (NO3--N mq/dm3, Up)	Mean (NO3--N mq/dm3, Wet)
Doe Creek	13	1.250	2.111
Hewitt Wildlife	5	0.000	0.667
Lockwood	7	4.667	10.500
Mercer Seawatch	9	0.333	27.500
Rourk	13	0.000	29.778
Winding River Pond	7		4.000
Winding River Townhouse	10		1.100

Table 5.2.4-2 Riverine Swamp Forest Soil Mean Results for Upland and Wetland soil Samples

Up / Wet	N	Mean (HM %)	Mean (WV g/cc)	Mean (CEC meq/100cc)	Mean (BS %)	Mean (Ac meq/100cc)	Mean (pH)
Up	16	0.958	1.325	4.394	36.875	2.856	4.625
Wet	48	2.069	0.768	16.360	70.646	4.185	4.979

Up / Wet	N	Mean (P mg/dm3)	Mean (K mg/dm3)	Mean (Ca mg/dm3)	Mean (Mg mg/dm3)	Mean (S mg/dm3)	Mean (Mn mg/dm3)
Up	16	23.594	19.775	232.231	40.525	12.138	3.700
Wet	48	15.617	78.769	1680.327	434.585	297.119	2.504

Up / Wet	N	Mean(Zn mg/dm3)	Mean(Cu mg/dm3)	Mean(Na mg/dm3)	Mean(NO3--N mq/dm3)
Up	16	0.719	0.244	21.125	1.250
Wet	48	1.425	0.281	783.583	11.146

Section 5.2.5 Riverine Swamp Forest: Amphibian Results and Discussion

The amphibian surveys in the Riverine Swamp Forest's of the Coastal Plain located in the Lockwood Folly River watershed resulted in the positive identification of 14 species of amphibians, 12 of which were in the anuran order (frogs and toads). The wetter hydrological conditions of riverine swamps during warmer months did provide accessible habit for frogs primarily in the *Rana* and *Hyla* genera as well as a few others, although the presence of predatory fish does hinder a number of amphibians species, especially, those in the urodela order (salamanders and newts) from utilizing Riverine Swamp Forest wetland habitat. The species of amphibians that were either observed or heard during the Riverine Swamp Forest survey included the green tree frog (*Hyla cinerea*), Cope's grey tree frog (*Hyla chrysoscelis*), pinewoods tree frog (*Hyla femoralis*), squirrel tree frog (*Hyla squirella*), southern leopard frog (*Rana sphenocephala*), bullfrog (*Rana catesbeiana*), northern green frog (*Rana clamitans*) pickerel frog (*Rana palustris*), southern cricket frog (*Acris gryllus*), little grass frog (*Pseudacris ocularis*), Ornate chorus frog (*Pseudacris ornata*), southern toad (*Bufo terrestris*), southern dusky salamander (*Desmognanthus auriculatus*), and dwarf mudpuppy (*Necturus punctata*). Some of these species such as the little grass tree frog, Cope's grey tree frog, and dusky salamander, which are fish sensitive and uncommon, were observed or heard in drier sites (Rourk and Winding River Townhouse sites) or the buffer areas of the riverine swamps. One dead mudpuppy was found adjacent to the creek where it had washed up at the Seawatch Mercer site.

Table 5.2.5-1 shows the significant correlation results (p-value $\leq$ 0.15) for the Spearman's Rho and Pearson's pairwise correlation analyses with a suite of water quality, soil, rapid assessment, and landscape disturbance gradients. Results that had a more significant p-value of < 0.05 and Pearson's correlation or Spearman's $\rho > 0.5$ are listed in bold blue while results that had a p-value of < 0.1 and $\geq$ 0.5 are listed in bold red. Three metrics were chosen for use in the Riverine Swamp Forest amphibian IBI: Percent Urodela, Abundance, and Species Richness. These metrics had significant correlations with the most disturbance measurements (four to eight disturbance measurements for each metric) including ORAM, soil Cu and pH, and water quality Ca, Mg, specific conductivity, dissolved oxygen, P, TOC, TSS, NO2+NO3, zinc, and the water quality combination disturbance measurement). Percent Ephemeral wetland – Headwater wetland – Seep (%EW-HW-Seep, percent species associated with fish free habitats), Percent Tolerant, Percent Sensitive and AQAI (Amphibian Quality Assessment Index) only correlated with Watershed LDI.

Table 5.2.5-2 shows the metric results for each of the Riverine Swamp wetland sites. The metric results to be used in the Riverine Swamp amphibian IBI are shown in bold red. Species richness ranged from 3 (Doe Creek site) to 9 (Hewett Wildlife site), abundance ranged from 8 (Rourk) to 122 (Hewett Wildlife), and percent Urodela ranged from 0% (Doe Creek, Lockwood, Rourk, and Winding River Pond) to 10.5% (Winding River Townhouse). Metric score assignments of "0" "3", "7", "10" were made according to the data distribution and are shown in Table 5.2.5-3. Table 5.2.5-4 shows the metric score assigned for the species richness, abundance, and percent Urodela metrics as well as the total Riverine Swamp Forest amphibian IBI score for each Riverine Swamp Forest site. The total amphibian IBI scores ranged from 7 to 23. The Rourk and Lockwood sites had the lowest score of 7. The Rourk site was a lower quality site while the Lockwood site was not. However, the Lockwood site is tidally influenced as well as the Doe Creek site (which scored 13). Both these sites had high conductivity values probably due to salinity levels. The Lockwood site also had a very busy road near by which made the night survey difficult. The Hewett Wildlife site, which appears to be a high quality site, scored the highest with 23. It should be noted that the term “quality”, either high or low when referenced this context is a best professional judgement of the site, and not in reference to survey results. The Winding River Townhouse site, although not as high a quality site due to the habitat and lack of upland buffer scored 20. This site is drier, but does have pools of water that would provide fish free habitat, with one adult southern dusky salamander was found at this site. The Seawatch Mercer site, a higher quality site scored 16 while the Winding River Pond site, which has higher quality habitat, but no upland buffer, scored second highest at 20.

Table 5.2.5-1 Riverine Swamp Forest (RS) Significant Correlation Results with Disturbance Measures

Wetland Type	Cadidate Metric	Disturbance Measurement	Correlation / Spearman ρ	p-value	Analysis
RS	%EW-HW-Seep	Watershed of LDI JMP Data	-0.6636	0.1041	Spearman’s Rho Correlation
RS	%Sensitive	Watershed of LDI JMP Data	-0.6545	0.1107	Spearman’s Rho Correlation
RS	%Tolerance	Watershed of LDI JMP Data	**0.6795**	**0.0931**	Pearson’s Correlation
RS	%Tolerance	Watershed of LDI JMP Data	**0.7000**	**0.0799**	Spearman’s Rho Correlation
RS	%Urodela	Calcium	**-0.7521**	**0.0511**	Pearson’s Correlation
RS	%Urodela	Calcium	**-0.8669**	**0.0115**	Spearman’s Rho Correlation
RS	%Urodela	Magnesium	-0.6063	0.1489	Pearson’s Correlation
RS	%Urodela	Soils Mean(pH)	**0.7241**	**0.0657**	Pearson’s Correlation
RS	%Urodela	Soils Median(pH)	**0.7798**	**0.0387**	Pearson’s Correlation
RS	%Urodela	Specific Conductivity	-0.6487	0.1150	Pearson’s Correlation
RS	%Urodela	Specific Conductivity	**-0.7684**	**0.0436**	Spearman’s Rho Correlation
RS	Abundance	Copper	**-0.6786**	**0.0938**	Spearman’s Rho Correlation
RS	Abundance	Dissolved Oxygen (%)	0.6054	0.1498	Pearson’s Correlation
RS	Abundance	Dissolved Oxygen (mg/L)	0.6487	0.1150	Pearson’s Correlation
RS	Abundance	Dissolved Oxygen (mg/L)	**0.7143**	**0.0713**	Spearman’s Rho Correlation
RS	Abundance	ORAM Mean	**0.7857**	**0.0362**	Spearman’s Rho Correlation
RS	Abundance	Phosphorus	**-0.6811**	**0.0921**	Pearson’s Correlation
RS	Abundance	Phosphorus	**-0.7143**	**0.0713**	Spearman’s Rho Correlation
RS	Abundance	TOC	-0.6275	0.1314	Pearson’s Correlation
RS	Abundance	TOC	**-0.7143**	**0.0713**	Spearman’s Rho Correlation
RS	Abundance	Total Suspended Residue	**-0.8088**	**0.0276**	Pearson’s Correlation
RS	Abundance	Total Suspended Residue	**-0.7857**	**0.0362**	Spearman’s Rho Correlation
RS	Abundance	WQ Combo(w/o fc by WT)	**-0.6786**	**0.0938**	Spearman’s Rho Correlation
RS	Abundance	Zinc	-0.6071	0.1482	Spearman’s Rho Correlation
RS	AQAI	Watershed of LDI JMP Data	**-0.6845**	**0.0898**	Pearson’s Correlation
RS	AQAI	Watershed of LDI JMP Data	**-0.7388**	**0.0579**	Spearman’s Rho Correlation
RS	Species Richness	Calcium	**-0.6708**	**0.0991**	Pearson’s Correlation
RS	Species Richness	Calcium	**-0.7783**	**0.0393**	Spearman’s Rho Correlation
RS	Species Richness	Magnesium	-0.6534	0.1115	Pearson’s Correlation
RS	Species Richness	Magnesium	-0.6671	0.1016	Spearman’s Rho Correlation
RS	Species Richness	NO2+NO3	**-0.7938**	**0.0331**	Pearson’s Correlation
RS	Species Richness	NO2+NO3	**-0.7412**	**0.0566**	Spearman’s Rho Correlation

Table 5.2.5-1 Riverine Swamp Forest (RS) Significant Correlation Results with Disturbance Measures

Wetland Type	**Cadidate Metric**	**Disturbance Measurement**	**Correlation / Spearman ρ**	**p-value**	**Analysis**
RS	Species Richness	Soils Mean(Cu mg/dm3)	-0.6310	0.1286	Pearson's Correlation
RS	Species Richness	Specific Conductivity	**-0.6745**	**0.0965**	Pearson's Correlation
RS	Species Richness	Specific Conductivity	-0.6301	0.1294	Spearman's Rho Correlation

Bold Red = Probility ≤ 0.05 and **Bold Blue** = Probility > 0.05 and ≤ 0.10, RS=Riverine Swamp Forest

Table 5.2.5-2 Riverine Swamp Forest Candidate Metric Results

Site Name	Species Richness	Abundance	%Tolerance	%Sensitive	%Urodela	AQAI	%EW-HW-Seep
Doe Creek	**3**	**110.5**	90.5	0	**0**	1.38	6.33
Hewett Wildlife	**9**	**121.7**	99.84	0	**0.16**	2.74	0.00
Lockwood	**5**	**10**	20	30	**0**	4.9	40.00
Mercer Seawatch	**8**	**38**	73.68	2.63	**2.63**	2.79	10.53
Rourk	**5**	**8**	50	50	**0**	3.5	37.50
Winding River Pond	**5**	**33**	92.42	0	**0**	1.45	0.00
Winding River Townhouse	**7**	**19**	73.68	15.79	**10.53**	2.37	15.79

Bold Red = Metrics to be used in Riverine Swamp IBIs, %EW-HW-Seep=%Ephemeral Wetland-Headwater Wetland-Seep

Table 5.2.5-3 Metric Score Assignments for Riverine Swamp Forests

Metric	0	3	7	10
Species Richness	<3	<5	<8	≥8
Abundance	<15	<40	<60	≥60
%Urodela	0	<3	<10	≥10

Table 5.2.5-4 Amphibian IBI Score for Riverine Swamp Forest Sites

Site Name	Species Richness	Abundance	%Urodela	Total
Lockwood	7	0	0	**7**
Rourk	7	0	0	**7**
Winding River Pond	7	3	0	**10**
Doe Creek	3	10	0	**13**
Mercer Seawatch	10	3	3	**16**
Winding River Townhouse	7	3	10	**20**
Hewett Wildlife	10	10	3	**23**

Section 5.2.6 Riverine Swamp Forests: Macroinvertebrate Results and Discussion

Section 5.2.6 will be presented at a later time when the macroinvertebrate samples have been identified, enumerated, and analyzed.

Section 5.2.7 Riverine Swamp Forests: Vegetation Survey Results and Discussion

The seven Riverine Swamp Forest wetland communities surveyed for vegetation in 2008 found a diverse array of plant species. A total of 200 different vascular plants species composed of trees, shrubs, forbs, grasses, sedges, rushes, vines, and epiphytes were observed. Red maples (*Acer rubrum*), swamp tupelo (*Nyssa biflora*), and bald cypress (*Taxodium distichum*) were the most dominant and widely occurring trees species, other common species of trees included ash (*Fraxinus* spp), American elm (*Ulmus americana*), sweet gum (*Liquidambar styraciflua*), sweet bay (*Magnolia virginiana*), American holly (*Ilex opaca*), and Ironwood (*Carpinus caroliniana*). Wax myrtle (*Morella cerifera*) and tag alder (*Alnus serrulata*) were the most common types shrubs, other shrubs that were less common included fetter bush (*Lyonia lucida*), button bush

(*Cephalanthus occidentalis*), and titi (*Cyrilla racemiflora*). The herbaceous strata was composed of ferns, sedges, especially beakrush *(Rhynchospora*) and *Carex* spp., and forbs. The herb strata included species such as royal fern (*Osmunda regalis*), eastern marsh fern (*Thelypteris palustris*), netted chain fern (*Woodwardia areolata*), lizard tail (*Saururus cernuus*, most dominant forb), arrow arum (*Peltandra virginica*), pickerel weed (*Pontederia cordata*), Virginia dayflower (*Commelina virginica*), hairy swamp loosestrife *(Decodon verticillatus),* jack-in-the-pulpit *(Arisaema triphyllum),* soft rush *(Juncus effuses*), millet beak rush (*Rhynchospora miliacea*), howe sedge (*Carex howei*), bearded sedge (*Carex comosa*), shallow sedge (*Carex lurida*), and fringed sedge (*Carex crinita*). Riverine Swamp Forest vines are also an important part of the structure of this vegetative community. Poison ivy (*Toxicodendron radicans*) had the most important presence in Riverine Swamp communities. Other vines that occurred were Virginia creeper (*Parthenocissus quinquefolia*), muscadine grape (*Vitis rotundifolia*), southeast decumaria (*Decumaria Barbara*), trumpet vine (*Campsis radicans*), Japonese honeysuckle (*Lonicera japonica*), and laural-leaf greenbriar (*Smilax laurifolia*).

Table 5.2.7-1 shows the significant correlation results (p-value $\leq$ 0.15) for the Spearman's Rho and Pearson's pairwise correlation analyses. Results that had a more significant p-value of < 0.05 and Pearson's correlation or Spearman's ρ > 0.5 are listed in bold blue while results that had a p-value of < 0.1 and $\geq$ 0.5 are listed in bold red. The following factors were considered a priority in choosing metrics for the Riverine Swamp plant IBI: 1. Metrics with lower probabilities, 2. metrics that were significant for both Pearson's correlation and Spearman's Rho, 3. metrics that correlated with more then one disturbance measurement, 4. metrics that were not measuring similar biological attributes (e.g. Native Herb Richness and Herb Richness), 5. metrics that correlated with ORAM which was a better measurement of site condition, 6. types of metrics that measured different aspects of the vegetation community (i.e. Community Balance Structure, Wetness, Functional Groups, and Community Structure). There were a total of 15 plant metrics with significant results (see Table 5.2.7-1). However seven metrics using the above criteria were chosen for the Riverine Swamp Forest plant IBI. The Riverine Swamp metrics chosen were Herb and Shrub Dominance for the Community Balance metric type, FAQWet Equation 3 and Wetland Plant Species Richness for the Wetness Characteristic metric type, Carex Richness and Dicot Cover for the Functional Group metric type, and Total Herb Richness and Pole Timber Density for the Community Structure metric type. These metrics had the more significant results (lower p-value), were representative of four of the different metric types, and correlated with ORAM or ORAM and LDI in one or both statistical correlations.

Table 5.2.7-2 shows the metric results for each of the Riverine Swamp wetland sites. Metric results ranged from 0.29 (Hewitt Wildlife and Seawatch Mercer sites) to 0.90 (Rourk site) for the Herb and Shrub Dominance metric, which indicated only a few shrubs and herbs were dominant at the Rourk site while the Hewitt Wildlife and Seawatch Mercer sites had a more evenly diversified shrub and herb cover. Metric scores ranged from 10.5 (Rourk site) to 26.7 (Hewitt Wildlife site) for the FAQWet Equation 3 and 11 (Rourk and Winding River Pond sites) to 37 (Hewitt Wildlife and Doe Creek sites) for the wetland plant metric, which indicated the Hewitt Wildlife and Doe Creek sites had wetter and more diverse wetland species then the Rourk and Winding River Pond sites. Metric scores ranged from 0 (Lockwood site) to 11 (Mercer Seawatch site) for the Carex richness metric and 5 (Winding River Townhouse site) to 32 (Hewett Wildlife site) for the dicot cover metric which indicated there was higher diversity of Carex at the Mercer

Seawatch site than the Lockwood site and higher cover of dicots at the Hewett Wildlife site than the Winding River Townhouse site. Metric scores ranged from 17 (Winding River Pond site) to 56 (Mercer Seawatch site) for the total herb richness metric and 0.09 (Doe Creek and Hewitt Wildlife sites) to 0.28 (Rourk site) for the pole timber density metric. These results indicated that the Winding River Pond site had the least diverse herb richness, while the Mercer Seawatch site had the most and that the Rourk site's canopy structure had the highest density of pole timber (low quality timber in the 10-15 cm, 15-20 cm and 20-25 cm DBH size class) as compared to the Doe Creek and Hewitt Wildlife sites which had the least density of pole timber.

Metric score assignments of "0", "3", "7", and "10" were made according to the data results distribution and are shown in Table 5.2.7-3. Table 5.2.7-4 shows the metric score assigned for the seven individual metrics chosen for the Riverine Swamp Forest plant IBI and the total IBI score. The total Riverine Swamp Forest plant IBI scores ranged from 12 to 67. The Hewett Wildlife site scored the highest with a value of 67 followed by the Doe Creek site at 61 and the Mercer Seawatch site at 57. These three sites did appear to be fairly good quality sites ("quality" again referring only to best professional judgement). The Hewett Wildlife site has had some impacts from beaver; the impacts were worse upstream outside of the site boundary and sampling area. The Doe Creek site has a road bisecting the site, however this site had mature trees and diverse flora, and the Mercer Seawatch site is still in a very natural state although sections of this site (outside of the vegetation survey area) had received some storm damage in the past. The Winding River Townhouse site scored a 12, the Winding River Pond site scored a 12, the Rourk site scored 17, and the Lockwood site scored 26. The Lockwood site is for the most part a fairly high quality site, although a number of dead ash trees were observed during the plant study, probably due to salt intrusion. The Rourk and Winding River Townhouse sites did not appear to be high quality sites so the lower score seems reasonable. The Winding River Pond site, although primarily absent of a buffer did appear to be better quality, although the plant survey was done after some recent beaver impacts had raised the water level and this may have contributed to the lower plant diversity and a lower score.

Table 5.2.7-1 Riverine Swamp Forest (RS) Significant Correlation Results with Disturbance Measures

Wetland Type	**Metric**	**Disturbance Measurement**	**Correlation / Spearman ρ**	**p-value**	**Analysis**
Community Balance Metrics					
Riverine Swamp	Vascular Plant Genera Richness	ORAM Mean	0.6071	0.1482	Spearman’s Rho Correlation
Riverine Swamp	Herb and Shrub Dominance	ORAM Mean	-0.6461	0.1169	Pearson’s Correlation
Riverine Swamp	Herb and Shrub Dominance	ORAM Mean	**-0.9286**	**0.0025**	Spearman’s Rho Correlation
Riverine Swamp	Species Richness	ORAM Mean	0.6322	0.1277	Pearson’s Correlation
Riverine Swamp	Species Richness	ORAM Mean	0.6429	0.1194	Spearman’s Rho Correlation
Wetness Characteristic Metrics					
Riverine Swamp	FAQWet Equation 3	ORAM Mean	**0.7170**	**0.0698**	Pearson’s Correlation
Riverine Swamp	FAQWet Equation 3	ORAM Mean	**0.9286**	**0.0025**	Spearman’s Rho Correlation
Riverine Swamp	FAQWet Cover	100M LDI	-0.6667	0.1019	Spearman’s Rho Correlation
Riverine Swamp	FAQWet Cover	ORAM Mean	**0.8214**	**0.0234**	Spearman’s Rho Correlation
Riverine Swamp	Wetland Plant Cover	ORAM Mean	0.6429	0.1194	Spearman’s Rho Correlation
Riverine Swamp	Wetland Plant Species Richness	100M LDI	-0.6239	0.1343	Spearman’s Rho Correlation
Riverine Swamp	Wetland Plant Species Richness	ORAM Mean	**0.7175**	**0.0695**	Pearson’s Correlation
Riverine Swamp	Wetland Plant Species Richness	ORAM Mean	**0.8183**	**0.0244**	Spearman’s Rho Correlation
Functional Group Metrics					
Riverine Swamp	Carex Richness	ORAM Mean	**0.7092**	**0.0743**	Spearman’s Rho Correlation
Riverine Swamp	Cyperaceae, Poaceae, Juncaceae Richness	ORAM Mean	0.6547	0.1106	Spearman’s Rho Correlation
Riverine Swamp	Dicot Coverage	100M LDI	**-0.8612**	**0.0128**	Pearson’s Correlation
Riverine Swamp	Dicot Coverage	100M LDI	**-0.9370**	**0.0019**	Spearman’s Rho Correlation
Riverine Swamp	Dicot Coverage	ORAM Mean	**0.7176**	**0.0694**	Pearson’s Correlation
Riverine Swamp	Dicot Richness	ORAM Mean	0.6071	0.1482	Spearman’s Rho Correlation
Community Balance Metrics					
Riverine Swamp	Total Herb Cover	ORAM Mean	0.6071	0.1482	Spearman’s Rho Correlation
Riverine Swamp	Total Herb Richness	ORAM Mean	0.6191	0.1382	Pearson’s Correlation
Riverine Swamp	Total Herb Richness	ORAM Mean	**0.7500**	**0.0522**	Spearman’s Rho Correlation
Riverine Swamp	Native Herb Cover	ORAM Mean	0.6071	0.1482	Spearman’s Rho Correlation
Riverine Swamp	Native Herb Richness	ORAM Mean	0.6188	0.1385	Pearson’s Correlation
Riverine Swamp	Native Herb Richness	ORAM Mean	**0.7500**	**0.0522**	Spearman’s Rho Correlation
Riverine Swamp	Pole Timber Density	100M LDI	**0.9487**	**0.0011**	Pearson’s Correlation
Riverine Swamp	Pole Timber Density	100M LDI	**0.9190**	**0.0034**	Spearman’s Rho Correlation
Riverine Swamp	Pole Timber Density	ORAM Mean	-0.6429	0.1194	Spearman’s Rho Correlation

Bold Red = Probility ≤ 0.05 and **Bold Blue** = Probility > 0.05 and ≤ 0.10

Table 5.2.7-2 Riverine Swamp Forest Plant Metric Results

Site	Herb and Shrub Dominance	FAQWet Equation 3	Wetland Plant Richness	Carex Richness	Dicot Cover	Total Herb Richness	Pole Timber Density
Doe Creek	0.67	22.76	37.00	7.00	21.19	53.00	0.09
Hewett Wildlife	0.29	26.70	37.00	7.00	31.93	43.00	0.09
Lockwood	0.77	16.50	22.00	0.00	18.69	34.00	0.19
Mercer Seawatch	0.29	19.38	35.00	11.00	13.34	56.00	0.11
Rourk	0.90	10.45	11.00	2.00	25.58	23.00	0.10
Winding River Pond	0.74	14.70	11.00	3.00	12.77	17.00	0.28
Winding River Townhouse	0.78	14.51	16.00	2.00	5.15	28.00	0.25

Table 5.2.7-3 Plant Metric Score Assignments for Riverine Swamp Forests

Metric	0	3	7	10
Herb and Shrub Dominance	≥0.90	<0.90	<0.70	<0.50
FAQWet Equation 3	<12	<18	<22	≥22
Wetland Plant Richness	<15	<20	<25	≥25
Carex Richness	<3	<5	<8	≥8
Dicot Cover	<10	<20	<30	≥30
Total Herb Richness	<20	<30	<40	≥40
Pole Timber Density	≥0.20	<0.20	<0.15	<0.10

Table 5.2.7-4 Plant IBI Score for Riverine Swamp Forest Sites

Site	Herb and Shrub Dominance	FAQWet Equation 3	Wetland Plant Richness	Carex Richness	Dicot Cover	Total Herb Richness	Pole Timber Density	Total
Doe Creek	7	10	10	7	7	10	10	61
Hewett Wildlife	10	10	10	7	10	10	10	67
Lockwood	3	3	7	0	3	7	3	26
Mercer Seawatch	10	7	10	10	3	10	7	57
Rourk	0	0	0	0	7	3	7	17
Winding River Pond	3	3	0	3	3	0	0	12
Winding River Townhouse	3	3	3	0	0	3	0	12

Section 5.3 – Bottomland Hardwood Forests

Section 5.3.1 Bottomland Hardwood Forests: Summary of NCWAM Results

Table 5.3.1-1 shows the metrics, IBIs, water and soil quality site parameter means, and site ORAM scores that correlated with the NCWAM overall score and hydrology, water quality, and habitat NCWAM functions for Bottomland Hardwood Forests. The first column of Table 5.3.1-1 shows "Round" which refers to the pre (Round "1") and post (Round "2") survey results. Correlations with p-values that are < 0.05 and have r > 0.5 are shown in bold red and correlations with p-values > 0.05 and < 0.10 and have r > 0.5 are shown in bold blue. For the metrics and IBIs significant correlations occurred with four of the six Bottomland Hardwood Forest amphibian metrics, the Bottomland Hardwood Forest Amphibian IBI and with just one of the eight Bottomland Hardwood Forest plant metrics, the wetland shrub cover metric. These correlations were all positive correlations except for the percent tolerant metric which was negative as would be expected. The habitat function had only one significant correlation and that was with amphibian species richness. The hydrology function also correlated with the amphibian species richness with both the pre and post survey results (round 1 and 2). The water quality function correlated with the amphibian percent tolerance metric (percent of species with a tolerant quality index rating), with the amphibian percent sensitive metric (percent of species with a sensitive quality index rating), and with the Amphibian IBI. There was also a statistically significant correlation of the water quality function with the amphibian percent Urodela (salamanders and newts). The overall NCWAM score had a statistically significant correlation with three amphibian metrics; percent tolerance, percent sensitive, and percent Urodela and the Amphibian IBI. There were two statistically significant correlations with wetland shrub cover correlating well with the NCWAM overall score and with the NCWAM water quality function.

The NCWAM habitat function correlated significantly with the water quality parameter site means for ammonia (round 1 only), copper, lead, TKN, TOC, TSS, and zinc. This function also had a weak correlation with water quality parameter site means for pH and fecal coliform (between 0.1 < p-value < 0.15). The NCWAM overall score and water quality function for Bottomland Hardwood Forests also correlated significantly with water quality site means for lead, TSS, and zinc as well as soil quality parameter site means for NO3—N. There was also a weak correlation with the water quality site mean for magnesium and soil quality site mean for phosphorus and potassium with the NCWAM overall score and water quality function (see Table 5.3.1-1). Lastly the ORAM site scores correlated with the NCWAM overall score and water quality function significantly for round 1 (Spearman's rho correlation only). Similar to the Riverine Swamp Forest NCWAM analysis, there was little difference between the correlations tests and there were more significant correlations during the pre-survey NCWAM (round 1) then during the post survey NCWAM (round 2). There were also no significant correlations with the LDI Level II data.

As was discussed in the Riverine Swamp Forests NCWAM evaluation (see Section 5.2.1), these results are limited by the small sample size with only six Bottomland Hardwood Forests used in this evaluation. The variation of the ratings was better than for the Riverine Swamp Forest with three Bottomland Hardwood Forest being generally rated high, two medium, and one low on the overall scores. The habitat function varies a lot less and had only one significant result. There was pretty good variation with the hydrology and water quality functions and they also had more correlations. With only six Bottomland Hardwood Forests in the sample, a larger sample is needed, with good representation in each of the three NCWAM score categories, in order to do an effective evaluation of NCWAM.

Table 5.3.1-1 NCWAM Correlation with Level III Significant Results for Bottomland Hardwood Forest Wetlands

Round	Wetland Type	NCWAM Total / Function	L2, L3	IBI/ Metric/ Water Quality/ Soils/ ORAM	r	Prob>|p|	Analysis
1	Bottomland Hardwood	Habitat-Function	L3-Amphibs	Amphib Species Richness	**0.8788**	**0.0211**	Pearson's Correlation
1	Bottomland Hardwood	Habitat-Function	L3-WQ	Ammonia	-0.9258	**0.0080**	Spearman's Rho Correlation
2	Bottomland Hardwood	Habitat-Function	L3-WQ	Copper	-0.8016	**0.0551**	Pearson's Correlation
1	Bottomland Hardwood	Habitat-Function	L3-WQ	Copper	-0.8485	**0.0327**	Pearson's Correlation
1	Bottomland Hardwood	Habitat-Function	L3-WQ	Copper	-0.8016	**0.0551**	Pearson's Correlation
1	Bottomland Hardwood	Habitat-Function	L3-WQ	Copper	-0.7715	**0.0723**	Spearman's Rho Correlation
1	Bottomland Hardwood	Habitat-Function	L3-WQ	Fecal Colliform	-0.6884	**0.1305**	Pearson's Correlation
2	Bottomland Hardwood	Habitat-Function	L3-WQ	Fecal Colliform	-0.6884	0.1305	Pearson's Correlation
2	Bottomland Hardwood	Habitat-Function	L3-WQ	Lead	-0.9553	**0.0030**	Pearson's Correlation
1	Bottomland Hardwood	Habitat-Function	L3-WQ	Lead	-0.9799	**0.0006**	Pearson's Correlation
1	Bottomland Hardwood	Habitat-Function	L3-WQ	Lead	-0.9553	**0.0030**	Pearson's Correlation
1	Bottomland Hardwood	Habitat-Function	L3-WQ	Lead	-0.9258	**0.0080**	Spearman's Rho Correlation
1	Bottomland Hardwood	Habitat-Function	L3-WQ	pH	0.6789	0.1381	Spearman's Rho Correlation
1	Bottomland Hardwood	Habitat-Function	L3-WQ	TKN	-0.8910	**0.0172**	Pearson's Correlation
2	Bottomland Hardwood	Habitat-Function	L3-WQ	TKN	-0.8910	**0.0172**	Pearson's Correlation
1	Bottomland Hardwood	Habitat-Function	L3-WQ	TKN	-0.8817	**0.0202**	Pearson's Correlation
1	Bottomland Hardwood	Habitat-Function	L3-WQ	TOC	-0.8820	**0.0201**	Pearson's Correlation
2	Bottomland Hardwood	Habitat-Function	L3-WQ	TOC	-0.8820	**0.0201**	Pearson's Correlation
1	Bottomland Hardwood	Habitat-Function	L3-WQ	TOC	-0.8728	**0.0232**	Pearson's Correlation
1	Bottomland Hardwood	Habitat-Function	L3-WQ	Total Suspended Residue	-0.9889	**0.0002**	Pearson's Correlation
1	Bottomland Hardwood	Habitat-Function	L3-WQ	Total Suspended Residue	-0.9870	**0.0003**	Pearson's Correlation
2	Bottomland Hardwood	Habitat-Function	L3-WQ	Total Suspended Residue	-0.9870	**0.0003**	Pearson's Correlation
1	Bottomland Hardwood	Habitat-Function	L3-WQ	Zinc	-0.9258	**0.0080**	Spearman's Rho Correlation
1	Bottomland Hardwood	Habitat-Function	L3-WQ	Zinc	-0.8971	**0.0153**	Pearson's Correlation
1	Bottomland Hardwood	Habitat-Function	L3-WQ	Zinc	-0.8451	**0.0341**	Pearson's Correlation
2	Bottomland Hardwood	Habitat-Function	L3-WQ	Zinc	-0.8451	**0.0341**	Pearson's Correlation
2	Bottomland Hardwood	Hydrology Function	L3-Amphibs	Amphib Species Richness	**0.8788**	**0.0211**	Pearson's Correlation

Table 5.3.1-1 NCWAM Correlation with Level III Significant Results for Bottomland Hardwood Forest Wetlands

Round	Wetland Type	NCWAM Total / Function	L2, L3	IBI/ Metric/ Water Quality/ Soils/ ORAM	r	Prob>|p|	Analysis
1	Bottomland Hardwood	Hydrology Function	L3-Amphibs	Amphib Species Richness	**0.8645**	**0.0263**	Pearson's Correlation
1	Bottomland Hardwood	NCWAM OverAll Score	L2-ORAM	ORAM Mean	**0.7827**	**0.0657**	Spearman's Rho Correlation
1	Bottomland Hardwood	NCWAM OverAll Score	L3-Amphibs	Amphib Percent Tolerance	-0.6957	0.1248	Spearman's Rho Correlation
1	Bottomland Hardwood	NCWAM OverAll Score	L3-Amphibs	Amphib Percent Tolerance	-0.6822	0.1355	Pearson's Correlation
1	Bottomland Hardwood	NCWAM OverAll Score	L3-Amphibs	Amphib Percent Sensitive	**0.8986**	**0.0149**	Spearman's Rho Correlation
1	Bottomland Hardwood	NCWAM OverAll Score	L3-Amphibs	Amphib Percent Sensitive	**0.8408**	**0.0360**	Pearson's Correlation
2	Bottomland Hardwood	NCWAM OverAll Score	L3-Amphibs	Amphib Percent Sensitive	**0.7715**	**0.0723**	Spearman's Rho Correlation
1	Bottomland Hardwood	NCWAM OverAll Score	L3-Amphibs	Amphib Percent Urodela	**0.8986**	**0.0149**	Spearman's Rho Correlation
1	Bottomland Hardwood	NCWAM OverAll Score	L3-Amphibs	Amphib Percent Urodela	**0.8515**	**0.0315**	Pearson's Correlation
2	Bottomland Hardwood	NCWAM OverAll Score	L3-Amphibs	Amphib Percent Urodela	**0.7715**	**0.0723**	Spearman's Rho Correlation
1	Bottomland Hardwood	NCWAM OverAll Score	L3-Amphibs	Amphibian IBI	**0.7556**	**0.0823**	Pearson's Correlation
1	Bottomland Hardwood	NCWAM OverAll Score	L3-Amphibs	Amphibian IBI	**0.7500**	**0.0859**	Spearman's Rho Correlation
1	Bottomland Hardwood	NCWAM OverAll Score	L3-Plants	Wetland Shrub Cover	0.6898	0.1294	Pearson's Correlation
1	Bottomland Hardwood	NCWAM OverAll Score	L3-Soils	K mg/dm3	-0.6957	0.1248	Spearman's Rho Correlation
2	Bottomland Hardwood	NCWAM OverAll Score	L3-Soils	NO3--N mq/dm3	**-0.8332**	**0.0394**	Spearman's Rho Correlation
2	Bottomland Hardwood	NCWAM OverAll Score	L3-Soils	NO3--N mq/dm3	**-0.7729**	**0.0715**	Pearson's Correlation
1	Bottomland Hardwood	NCWAM OverAll Score	L3-Soils	P mg/dm3	-0.6957	0.1248	Spearman's Rho Correlation
2	Bottomland Hardwood	NCWAM OverAll Score	L3-Soils	P mg/dm3	-0.6789	0.1381	Spearman's Rho Correlation
2	Bottomland Hardwood	NCWAM Overall Score	L3-WQ	Lead	-0.7892	**0.0619**	Pearson's Correlation

Table 5.3.1-1 NCWAM Correlation with Level III Significant Results for Bottomland Hardwood Forest Wetlands

Round	**Wetland Type**	**NCWAM Total / Function**	**L2, L3**	**IBI/ Metric/ Water Quality/ Soils/ ORAM**	**r**	**Prob>|p|**	**Analysis**
2	Bottomland Hardwood	NCWAM Overall Score	L3-WQ	Lead	-0.7715	**0.0723**	Spearman's Rho Correlation
1	Bottomland Hardwood	NCWAM Overall Score	L3-WQ	Lead	-0.6670	0.1479	Pearson's Correlation
1	Bottomland Hardwood	NCWAM Overall Score	L3-WQ	Magnesium	-0.6667	0.1481	Spearman's Rho Correlation
2	Bottomland Hardwood	NCWAM Overall Score	L3-WQ	Total Suspended Residue	-0.7320	**0.0981**	Pearson's Correlation
1	Bottomland Hardwood	NCWAM Overall Score	L3-WQ	Total Suspended Residue	-0.6940	0.1261	Pearson's Correlation
2	Bottomland Hardwood	NCWAM Overall Score	L3-WQ	Zinc	-0.7862	**0.0637**	Pearson's Correlation
2	Bottomland Hardwood	NCWAM Overall Score	L3-WQ	Zinc	-0.7715	**0.0723**	Spearman's Rho Correlation
2	Bottomland Hardwood	WQ Function	L3-WQ	Lead	-0.7892	**0.0619**	Pearson's Correlation
2	Bottomland Hardwood	WQ Function	L3-WQ	Lead	-0.7715	**0.0723**	Spearman's Rho Correlation
1	Bottomland Hardwood	WQ Function	L3-WQ	Lead	-0.6670	0.1479	Pearson's Correlation
1	Bottomland Hardwood	WQ Function	L3-WQ	Magnesium	-0.6667	0.1481	Spearman's Rho Correlation
2	Bottomland Hardwood	WQ Function	L3-WQ	Total Suspended Residue	-0.7320	**0.0981**	Pearson's Correlation
1	Bottomland Hardwood	WQ Function	L3-WQ	Total Suspended Residue	-0.6940	0.1261	Pearson's Correlation
2	Bottomland Hardwood	WQ Function	L3-WQ	Zinc	-0.7862	**0.0637**	Pearson's Correlation
2	Bottomland Hardwood	WQ Function	L3-WQ	Zinc	-0.7715	**0.0723**	Spearman's Rho Correlation
1	Bottomland Hardwood	WQ Function	L2-ORAM	ORAM Mean	**0.7827**	**0.0657**	Spearman's Rho Correlation
1	Bottomland Hardwood	WQ Function	L3-Amphibs	Amphib Percent Tolerance	-0.6957	0.1248	Spearman's Rho Correlation
1	Bottomland Hardwood	WQ Function	L3-Amphibs	Amphib Percent Tolerance	-0.6822	0.1355	Pearson's Correlation
1	Bottomland Hardwood	WQ Function	L3-Amphibs	Amphib Percent Sensitive	**0.8986**	**0.0149**	Spearman's Rho Correlation
1	Bottomland Hardwood	WQ Function	L3-Amphibs	Amphib Percent Sensitive	**0.8408**	**0.0360**	Pearson's Correlation
2	Bottomland Hardwood	WQ Function	L3-Amphibs	Amphib Percent Sensitive	**0.7715**	**0.0723**	Spearman's Rho Correlation
1	Bottomland Hardwood	WQ Function	L3-Amphibs	Amphib Percent Urodela	**0.8986**	**0.0149**	Spearman's Rho Correlation
1	Bottomland Hardwood	WQ Function	L3-Amphibs	Amphib Percent Urodela	**0.8515**	**0.0315**	Pearson's Correlation
2	Bottomland Hardwood	WQ Function	L3-Amphibs	Amphib Percent Urodela	**0.7715**	**0.0723**	Spearman's Rho Correlation
1	Bottomland Hardwood	WQ Function	L3-Amphibs	Amphibian IBI	**0.7556**	**0.0823**	Pearson's Correlation

Table 5.3.1-1 NCWAM Correlation with Level III Significant Results for Bottomland Hardwood Forest Wetlands

Round	Wetland Type	NCWAM Total / Function	L2, L3	IBI/ Metric/ Water Quality/ Soils/ ORAM	r	Prob>|ρ|	Analysis
1	Bottomland Hardwood	WQ Function	L3-Amphibs	Amphibian IBI	**0.7500**	**0.0859**	Spearman's Rho Correlation
1	Bottomland Hardwood	WQ Function	L3-Amphibs	Wetland Shrub Cover	**0.6898**	**0.1294**	Pearson's Correlation
1	Bottomland Hardwood	WQ Function	L3-Soils	K mg/dm3	-0.6957	0.1248	Spearman's Rho Correlation
2	Bottomland Hardwood	WQ Function	L3-Soils	NO3--N mq/dm3	**-0.8332**	**0.0394**	Spearman's Rho Correlation
2	Bottomland Hardwood	WQ Function	L3-Soils	NO3--N mq/dm3	**-0.7729**	**0.0715**	Pearson's Correlation
1	Bottomland Hardwood	WQ Function	L3-Soils	P mg/dm3	-0.6957	0.1248	Spearman's Rho Correlation
2	Bottomland Hardwood	WQ Function	L3-Soils	P mg/dm3	-0.6789	0.1381	Spearman's Rho Correlation

Bold Red = Probility ≤ 0.05 and **Bold Blue** = Probility > 0.05 and ≤ 0.10, L2- Level 2, L3-Level 3, WQ-Water Quality

Section 5.3.2 Bottomland Hardwood Forests: Water Quality Results and Discussion

The Bottomland Hardwood Forest water quality samples in the Fishing Creek watershed were analyzed for each parameter that was used to indicate water quality. The summary of the 18 parameters for each site is shown in Table 5.3.2-1. The table shows the mean and median for each water quality parameter for each of the six Bottomland Hardwood Forest sites. For ammonia, the Gray, Munn, and Powers sites had levels quite a bit higher than the other three sites. The Kim-Brooks and Hancock sites had the highest levels of calcium while the other four sites were about the same. Copper was highest in the Gray and Munn sites whereas the Fairport site was quite a bit lower. Percent DO was between 17% and 34% for all sites but the Kim-Brooks site had lower levels (6%). The DO as measured by mg/L shows this same result, with the Kim-Brooks site having very low levels. The Powers site had the highest level of DOC with the Fairport and Kim-Brooks sites having the next highest levels and the Gray site had the lowest levels. For fecal colliform, the Gray and Kim-Brooks sites had the highest levels by a large margin. The other four sites were quite a bit lower, but the Fairport site was the lowest. For lead, the Gray site had almost three times the levels of the next highest sites (Munn and Hancock sites). The Kim-Brooks site had at least four times the levels of magnesium then the rest of the sites which had similar levels. For NO2+NO3, the Munn site had the highest level and the Hancock site was next, while the rest of the sites were about the same. The pH levels were all slightly acidic, with the Munn site being the most acidic at a pH of 5.55 and the Kim-Brooks site being the least acidic at a pH of 6.48. The Hancock and Munn sites had the highest levels of phosphorus while the other four sites were about the same. The Kim-Brooks site had the highest level of specific conductivity, more than twice the level of the next, which was the Hancock site. The Gray site had the lowest level of specific conductivity. For TKN, the Gray site had the highest levels by quite a bit with the other sites having similar levels with the Hancock site having the lowest levels. The Gray site had the highest level of TOC, more than twice the level of the next highest which were the Kim-Brooks and Munn sites. The Fairport site was had the lowest level of TOC. The Gray site also had the highest levels of TSS, more than four times the level of the Munn site. The Fairport site was quite low in TSS and the other three sites were about the same. Water temperature varied less the two-degrees Celsius between the six sites. Finally, for zinc, the Gray site again had the highest level and the Hancock and Munn sites were next. The Fairport site had the lowest levels of zinc. Overall, for water quality, the Powers and Fairport sites had the best water quality and the Gray and Kim-Brooks sites had the worst water quality with the Munn site close behind.

Table 5.3.2-2 shows the same (site means and medians) data but broken out by station location. For the Bottomland Hardwood Forests, water samples were taken at Upstream and Downstream locations at four of the sites; Hancock, Munn, Powers, and Fairport. Two sites (Gray and Kim-Brooks) had water quality samples taken only at one station (see Section 4.1). As with the Riverine Swamp Forests, an assumption would be that water quality would be improving (reduction in metals and nutrients, for example) as water flows from the upstream station to the downstream station. Table 5.3.2-3 shows the same data but averaged across sites. From these means, Ammonia and NO2+NO3 is lower downstream and DO is higher downstream which are consistent with the idea that water quality would improve downstream. On the other hand, from Table 5.3.2-2, calcium, copper, TOC, and TSS are clearly higher downstream which is not consistent with improving water quality downstream. Statistically however, of these potential pollutants, only calcium was significantly higher downstream (ANOVA, p=0.0538). pH was also significantly higher downstream indicating lower acidity (ANOVA, p=0.1181, Wilcoxon, p=0.112).

From these results, it appears Bottomland Hardwood Forests can improve water quality; however some of the indicators of water quality are inconsistent with this conclusion. Relative to Riverine Swamp Forests, it could be concluded that Bottomland Hardwood Forests do not improve water quality as well. While that may be true, it is important to realize that such a conclusion is difficult to make, especially given the locational differences between the two wetland types (northern Piedmont for the Bottomland Hardwood Forests and southern Coastal Plain for the Riverine Swamp Forests). Another factor is that water flow through a Bottomland Hardwood Forest is not as pronounced as with the typical Riverine Swamp Forest, so the filtering process may be different. Just considering the Bottomland Hardwood Forest results, it was noted previously that the Powers and Fairport sites had the best water quality. The Powers site is located in the town of Oxford, NC along a sewer line. The Fairport site on the other hand, is more rural. The worst sites in terms of water quality were the Gray site, a very rural site and the Kim-Brooks site, located just outside of Oxford at a very busy highway intersection (I 85 and US 15). Therefore, no definitive conclusions can be made about the location of the sites and water quality from these results.

Table 5.3.2-1 Fishing Creek Bottomland Hardwood Forest Water Quality Mean and Median Results by Site.

Site Name	N	Parameter	Mean	Median	Units
Fairport	6	Ammonia	0.05	0.04	mg/L
Gray	2	Ammonia	0.22	0.22	mg/L
Hancock	8	Ammonia	0.08	0.02	mg/L
Kim-Brooks	3	Ammonia	0.03	0.02	mg/L
Munn	11	Ammonia	0.22	0.02	mg/L
Powers	5	Ammonia	0.16	0.08	mg/L
Fairport	6	Calcium	10.2	9.95	mg/L
Gray	2	Calcium	10.5	10.5	mg/L
Hancock	8	Calcium	25.58	22.5	mg/L
Kim-Brooks	3	Calcium	43.67	46	mg/L
Munn	12	Calcium	8.27	4.65	mg/L
Powers	5	Calcium	11.06	12	mg/L
Fairport	6	Copper	2.56	2.33	ug/L
Gray	2	Copper	29	29	ug/L
Hancock	8	Copper	12.55	5.85	ug/L
Kim-Brooks	3	Copper	10.3	9.6	ug/L
Munn	12	Copper	19.68	3.55	ug/L
Powers	5	Copper	9.06	6.3	ug/L
Fairport	6	Dissolved Oxygen (%)	20.75	21	%
Gray	2	Dissolved Oxygen (%)	25.95	25.95	%
Hancock	8	Dissolved Oxygen (%)	28.1	23.55	%
Kim-Brooks	3	Dissolved Oxygen (%)	5.57	7	%
Munn	12	Dissolved Oxygen (%)	33.97	32.35	%
Powers	5	Dissolved Oxygen (%)	17.34	20.1	%
Fairport	6	Dissolved Oxygen (mg/L)	2.15	2	mg/L
Gray	2	Dissolved Oxygen (mg/L)	3.4	3.4	mg/L
Hancock	8	Dissolved Oxygen (mg/L)	3.1	2.7	mg/L
Kim-Brooks	3	Dissolved Oxygen (mg/L)	0.65	0.9	mg/L
Munn	12	Dissolved Oxygen (mg/L)	5.24	5.43	mg/L
Powers	5	Dissolved Oxygen (mg/L)	1.93	2.13	mg/L
Fairport	6	DOC	22.33	21	mg/L
Gray	2	DOC	8.75	8.75	mg/L
Hancock	8	DOC	16.79	14	mg/L
Kim-Brooks	2	DOC	22	22	mg/L
Munn	12	DOC	11.59	12	mg/L
Powers	5	DOC	35.42	42	mg/L
Fairport	6	Fecal Colliform	15.67	10	CFU/100 ml
Gray	2	Fecal Colliform	820	820	CFU/100 ml
Hancock	8	Fecal Colliform	52	24	CFU/100 ml
Kim-Brooks	3	Fecal Colliform	724.67	670	CFU/100 ml
Munn	10	Fecal Colliform	169.4	95.5	CFU/100 ml
Powers	5	Fecal Colliform	117.2	31	CFU/100 ml
Fairport	6	Lead	10	10	ug/L
Gray	2	Lead	78	78	ug/L

Table 5.3.2-1 Fishing Creek Bottomland Hardwood Forest Water Quality Mean and Median Results by Site.

Site Name	N	Parameter	Mean	Median	Units
Hancock	8	Lead	27.13	10	ug/L
Kim-Brooks	3	Lead	11	10	ug/L
Munn	12	Lead	27.08	10	ug/L
Powers	5	Lead	15.2	11	ug/L
Fairport	6	Magnesium	4.37	4.35	mg/L
Gray	2	Magnesium	6.1	6.1	mg/L
Hancock	7	Magnesium	5.09	5.7	mg/L
Kim-Brooks	3	Magnesium	26.7	31	mg/L
Munn	12	Magnesium	3.09	2.3	mg/L
Powers	3	Magnesium	4.93	5.5	mg/L
Fairport	6	NO2+NO3	0.02	0.02	mg/L
Gray	2	NO2+NO3	0.02	0.02	mg/L
Hancock	8	NO2+NO3	0.06	0.02	mg/L
Kim-Brooks	3	NO2+NO3	0.02	0.02	mg/L
Munn	11	NO2+NO3	0.12	0.02	mg/L
Powers	5	NO2+NO3	0.02	0.02	mg/L
Fairport	6	pH	6.16	6.27	S.U.
Gray	2	pH	6.03	6.03	S.U.
Hancock	8	pH	6.03	6.15	S.U.
Kim-Brooks	3	pH	6.48	6.88	S.U.
Munn	12	pH	5.55	5.7	S.U.
Powers	5	pH	5.92	6.23	S.U.
Fairport	6	Phosphorus	0.52	0.42	mg/L
Gray	2	Phosphorus	0.6	0.6	mg/L
Hancock	8	Phosphorus	0.93	0.48	mg/L
Kim-Brooks	3	Phosphorus	0.65	0.38	mg/L
Munn	11	Phosphorus	0.83	0.1	mg/L
Powers	5	Phosphorus	0.48	0.45	mg/L
Fairport	6	Specific Conductivity	100.87	110	uS/cm
Gray	2	Specific Conductivity	52.8	52.8	uS/cm
Hancock	7	Specific Conductivity	204.34	269.9	uS/cm
Kim-Brooks	2	Specific Conductivity	544.5	544.5	uS/cm
Munn	12	Specific Conductivity	88.58	83.35	uS/cm
Powers	4	Specific Conductivity	150.45	103.9	uS/cm
Fairport	6	TKN	1.84	1.35	mg/L
Gray	2	TKN	3.95	3.95	mg/L
Hancock	8	TKN	1.36	1.2	mg/L
Kim-Brooks	3	TKN	2.2	2.6	mg/L
Munn	11	TKN	2.13	0.9	mg/L
Powers	5	TKN	2.56	2.9	mg/L
Fairport	6	TOC	31.08	29.75	mg/L
Gray	2	TOC	257	257	mg/L
Hancock	8	TOC	32.81	18	mg/L
Kim-Brooks	3	TOC	121.33	22	mg/L
Munn	12	TOC	119.13	15.5	mg/L
Powers	5	TOC	75.4	71	mg/L

Table 5.3.2-1 Fishing Creek Bottomland Hardwood Forest Water Quality Mean and Median Results by Site.

Site Name	N	Parameter	Mean	Median	Units
Fairport	6	Total Suspended Residue	26.97	24	mg/L
Gray	2	Total Suspended Residue	2786.5	2786.5	mg/L
Hancock	8	Total Suspended Residue	242.03	41	mg/L
Kim-Brooks	3	Total Suspended Residue	295.67	42	mg/L
Munn	12	Total Suspended Residue	549.04	73.5	mg/L
Powers	5	Total Suspended Residue	225.8	50	mg/L
Fairport	6	Water, Temperature	14.33	17.85	oC
Gray	2	Water, Temperature	13	13	oC
Hancock	8	Water, Temperature	12.39	9.1	oC
Kim-Brooks	3	Water, Temperature	12.83	12.7	oC
Munn	12	Water, Temperature	12.8	15.1	oC
Powers	5	Water, Temperature	13.64	12.4	oC
Fairport	6	Zinc	12.75	10.25	ug/L
Gray	2	Zinc	109.5	109.5	ug/L
Hancock	8	Zinc	62.63	23.5	ug/L
Kim-Brooks	3	Zinc	29.67	20	ug/L
Munn	12	Zinc	56.21	14	ug/L
Powers	5	Zinc	34	38	ug/L

Table 5.3.2-2 Fishing Creek Bottomland Hardwood Forest Water Quality Mean Results by Station within Site

Site Name	Parameter	N - Down Stream	Down Stream Station Mean	N - Up Stream	Up Stream Station Mean	Units
Fairport	Ammonia	3	0.07	3	0.02	mg/L
Hancock	Ammonia	3	0.02	5	0.11	mg/L
Munn	Ammonia	6	0.22	5	0.22	mg/L
Powers	Ammonia	2	0.1	3	0.21	mg/L
Fairport	Calcium	3	10.13	3	10.27	mg/L
Hancock	Calcium	3	46.33	5	13.12	mg/L
Munn	Calcium	6	12.48	6	4.05	mg/L
Powers	Calcium	2	12.5	3	10.1	mg/L
Fairport	Copper	3	2.6	3	2.52	ug/L
Hancock	Copper	3	3.37	5	18.06	ug/L
Munn	Copper	6	29.42	6	9.93	ug/L
Powers	Copper	2	11.1	3	7.7	ug/L
Fairport	Dissolved Oxygen (%)	3	18.17	3	23.33	%
Hancock	Dissolved Oxygen (%)	3	34.83	5	24.06	%
Munn	Dissolved Oxygen (%)	6	38.73	6	29.2	%
Powers	Dissolved Oxygen (%)	2	23.2	3	13.43	%
Fairport	Dissolved Oxygen (mg/L)	3	1.97	3	2.33	mg/L
Hancock	Dissolved Oxygen (mg/L)	3	3.52	5	2.84	mg/L
Munn	Dissolved Oxygen (mg/L)	6	5.74	6	4.73	mg/L
Powers	Dissolved Oxygen (mg/L)	2	2.35	3	1.64	mg/L
Fairport	DOC	3	27.33	3	17.33	mg/L
Hancock	DOC	3	14.32	5	18.28	mg/L
Munn	DOC	6	10.92	6	12.27	mg/L
Powers	DOC	2	48	3	27.03	mg/L
Fairport	Fecal Colliform	3	19	3	12.33	CFU/100 ml
Hancock	Fecal Colliform	3	66.33	5	43.4	CFU/100 ml
Munn	Fecal Colliform	6	206	4	114.5	CFU/100 ml
Powers	Fecal Colliform	2	30	3	175.33	CFU/100 ml
Fairport	Lead	3	10	3	10	ug/L
Hancock	Lead	3	10	5	37.4	ug/L
Munn	Lead	6	37.67	6	16.5	ug/L
Powers	Lead	2	19	3	12.67	ug/L
Fairport	Magnesium	3	4.43	3	4.3	mg/L
Hancock	Magnesium	2	6.15	5	4.66	mg/L
Munn	Magnesium	6	3.63	6	2.54	mg/L
Powers	Magnesium	1	5.5	2	4.65	mg/L
Fairport	NO2+NO3	3	0.02	3	0.02	mg/L

Table 5.3.2-2 Fishing Creek Bottomland Hardwood Forest Water Quality Mean Results by Station within Site

Site Name	Parameter	N - Down Stream	Down Stream Station Mean	N - Up Stream	Up Stream Station Mean	Units
Hancock	NO2+NO3	3	0.02	5	0.08	mg/L
Munn	NO2+NO3	6	0.09	5	0.16	mg/L
Powers	NO2+NO3	2	0.02	3	0.02	mg/L
Fairport	pH	3	6.2	3	6.11	S.U.
Hancock	pH	3	6.59	5	5.7	S.U.
Munn	pH	6	5.58	6	5.53	S.U.
Powers	pH	2	6.28	3	5.69	S.U.
Fairport	Phosphorus	3	0.62	3	0.43	mg/L
Hancock	Phosphorus	3	0.45	5	1.22	mg/L
Munn	Phosphorus	6	1.22	5	0.36	mg/L
Powers	Phosphorus	2	0.61	3	0.39	mg/L
Fairport	Specific Conductivity	3	110.67	3	91.07	uS/cm
Hancock	Specific Conductivity	3	314.67	4	121.6	uS/cm
Munn	Specific Conductivity	6	75.53	6	101.62	uS/cm
Powers	Specific Conductivity	2	103.9	2	197	uS/cm
Fairport	TKN	3	1.81	3	1.87	mg/L
Hancock	TKN	3	1.09	5	1.51	mg/L
Munn	TKN	6	2.75	5	1.37	mg/L
Powers	TKN	2	2.9	3	2.33	mg/L
Fairport	TOC	3	26.33	3	35.83	mg/L
Hancock	TOC	3	29.33	5	34.9	mg/L
Munn	TOC	6	191	6	47.25	mg/L
Powers	TOC	2	52	3	91	mg/L
Fairport	Total Suspended Residue	3	26.93	3	27	mg/L
Hancock	Total Suspended Residue	3	94	5	330.84	mg/L
Munn	Total Suspended Residue	6	806.67	6	291.42	mg/L
Powers	Total Suspended Residue	2	138	3	284.33	mg/L
Fairport	Water, Temperature	3	14.37	3	14.3	oC
Hancock	Water, Temperature	3	13.67	5	11.62	oC
Munn	Water, Temperature	6	12.93	6	12.67	oC
Powers	Water, Temperature	2	14.5	3	13.07	oC
Fairport	Zinc	3	15.33	3	10.17	ug/L
Hancock	Zinc	3	19.33	5	88.6	ug/L
Munn	Zinc	6	84	6	28.42	ug/L
Powers	Zinc	2	31	3	36	ug/L

Table 5.3.2-3 Fishing Creek Bottomland Hardwood Forests Water Quality Mean Results by Station

Parameter	N	Mean (Downstream)	Mean (Upstream)
Ammonia (mg/L)	30	0.127	0.147
Calcium (mg/L)	31	19.236	8.882
Copper (ug/L)	31	15.471	10.621
Dissolved Oxygen (%)	31	31.271	23.871
Dissolved Oxygen (mg/L)	31	3.971	3.207
DOC (mg/L)	31	20.461	17.535
Fecal Colliform (CFU/100 ml)	29	110.857	82.533
Lead (ug/L)	31	23.143	20.824
Magnesium (mg/L)	28	4.408	3.797
NO2+NO3 (mg/L)	30	0.049	0.083
pH (S. U.)	31	6.026	5.712
Phosphorus (mg/L)	30	0.835	0.648
Specific Conductivity (uS/cm)	29	138.357	117.553
TKN (mg/L)	30	2.216	1.689
TOC (mg/L)	31	101.214	49.324
Total Suspended Residue (mg/L)	31	391.343	255.100
Water, Temperature (oC)	31	13.621	12.718
Zinc (ug/L)	31	47.857	44.235

Section 5.3.3 Bottomland Hardwood Forests: Hydrology Results and Discussion

Hydrographs for the Bottomland Hardwood Forests at the Fishing Creek watershed are shown in Figures 5.3.3-1 thru 5.3.3-5. Again, the hydrographs show electronic depth of the water in the well, where zero on the y-axis is the bottom of the well as measured by the transducer. The red line indicates ground level and the blue line indicates one foot below the surface on the Bottomland Hardwood Forest hydrographs. As the water level increases, it approaches the surface as indicated by the curves. The surface ground levels varied slightly between the sites, but were generally at about 21-25 inches. Some gaps in the data exist that are caused by technical difficulties with the transducers or errors in downloading the data. The hydrograph for the Fairport site can be seen in Figure 5.3.3-1. This site shows a generally flat water level, with a few exceptions, during the first half of the recordings, which then stated increasing during the spring, then decreased during the summer months, with some spikes during the fall, probably due to precipitation. The Hancock site shows almost the identical pattern, but its water levels start increasing earlier, during January (see Figure 5.3.3-2). The hydrograph for Kim-Brooks site (Figure 5.3.3-3) also shows a potential seasonal pattern, but there is a block of missing data. The spikes in the water levels clearly indicate the flashiness of this site and reflects the fact that it is located at a major highway intersection just southeast of Oxford, NC. The Munn site shows a seasonal pattern as can be seen in Figure 5.3.3-4. The highest water levels clearly occurring during the winter and spring months, with the spikes in water levels due to precipitation. In Figure 5.3.3-5, the Powers site clearly shows the same seasonal pattern, with precipitation spikes during the fall months in particular.

Table 5.3.3-1 shows the percent of the time the water depth is within one foot of the surface. The second column shows the percent of the time the water levels are within a foot of the surface during the growing season. The Bottomland Hardwood Forests were within one foot the surface during the growing season just over 28% of the time with the range being 16.85% for the Kim-Brooks sites to 36.6% for the Hancock site. An interesting point to note is that the differences between the growing season and the entire year are very small, just over one percent on the average.

The Bottomland Hardwood Forests in the Fishing Creek watershed had very similar hydrographs, which is expected since they are in the same general physiographic area (and watershed) with similar precipitation. It is also clear that Bottomland Hardwood Forests are much more influenced by precipitation and overbank and overland flooding than are the Riverine Swamp Forests which had much more consistent water levels.

Figure 5.3.3 – 1 Bottomland Hardwood Forest: Fairport

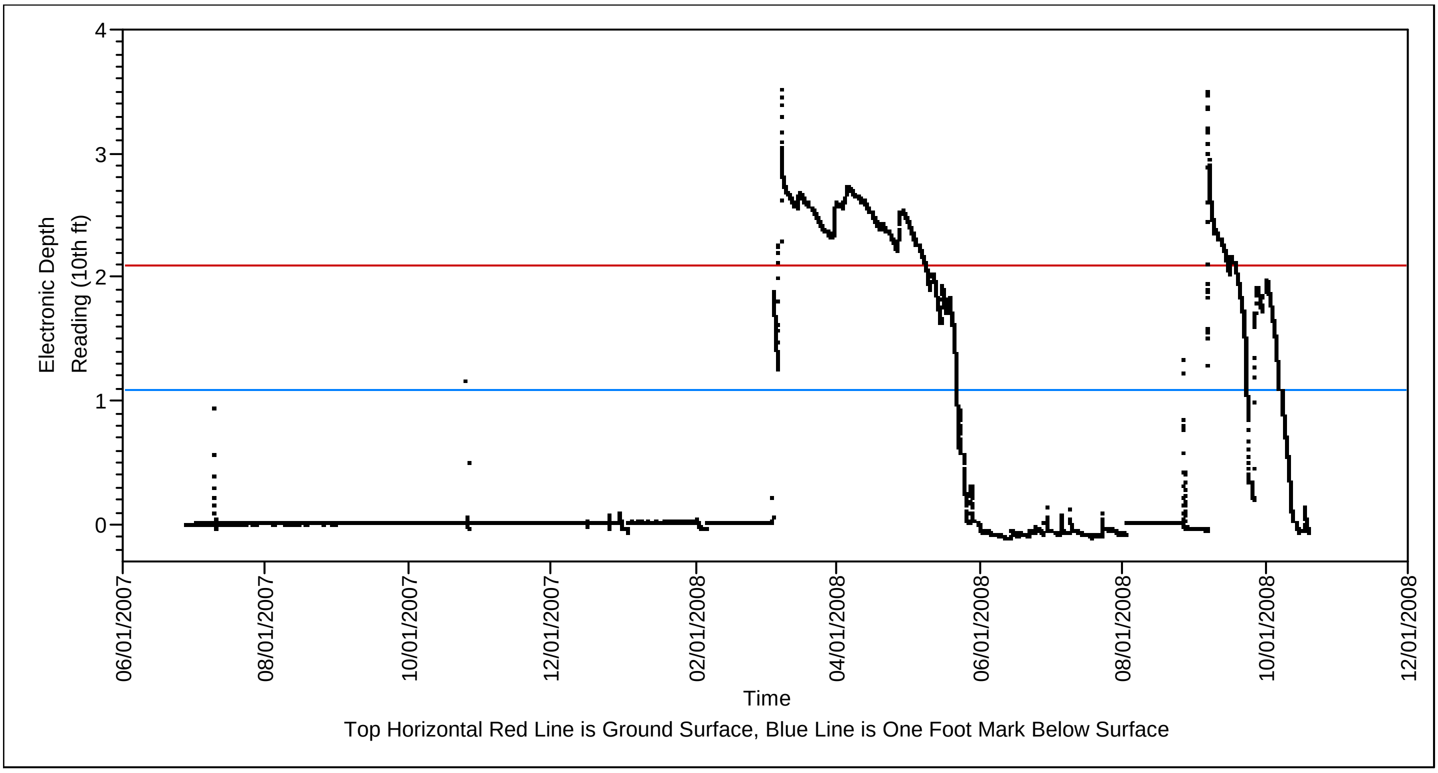


Figure 5.3.3 – 2 Bottomland Hardwood Forest: Hancock

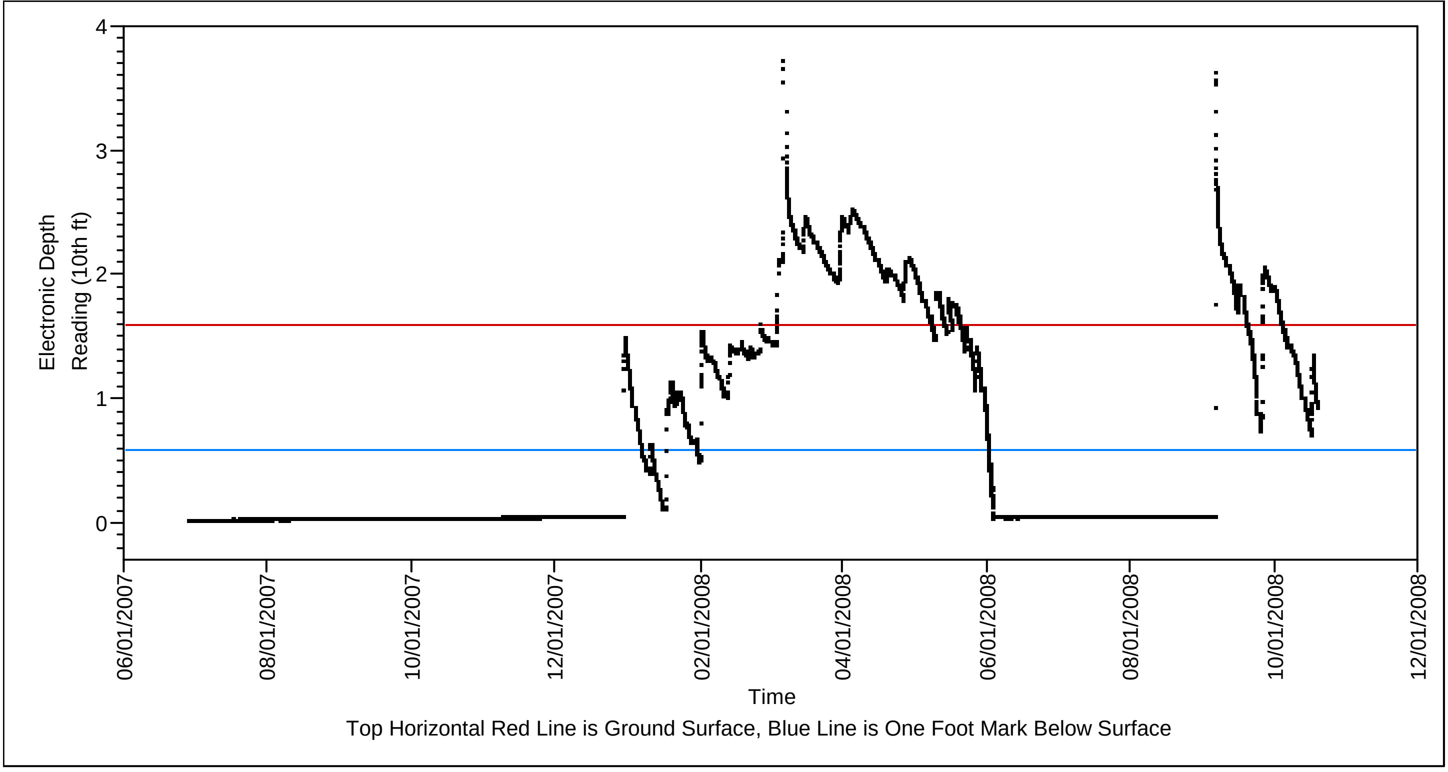
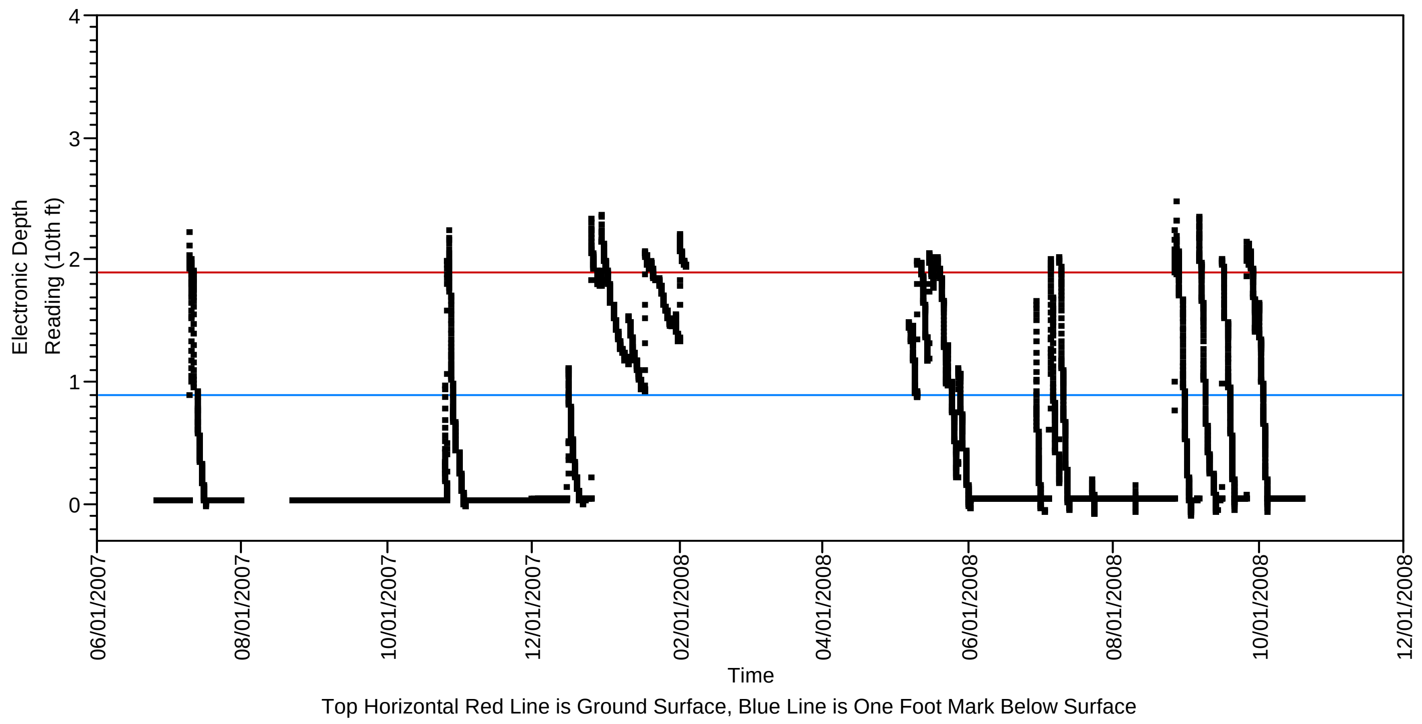
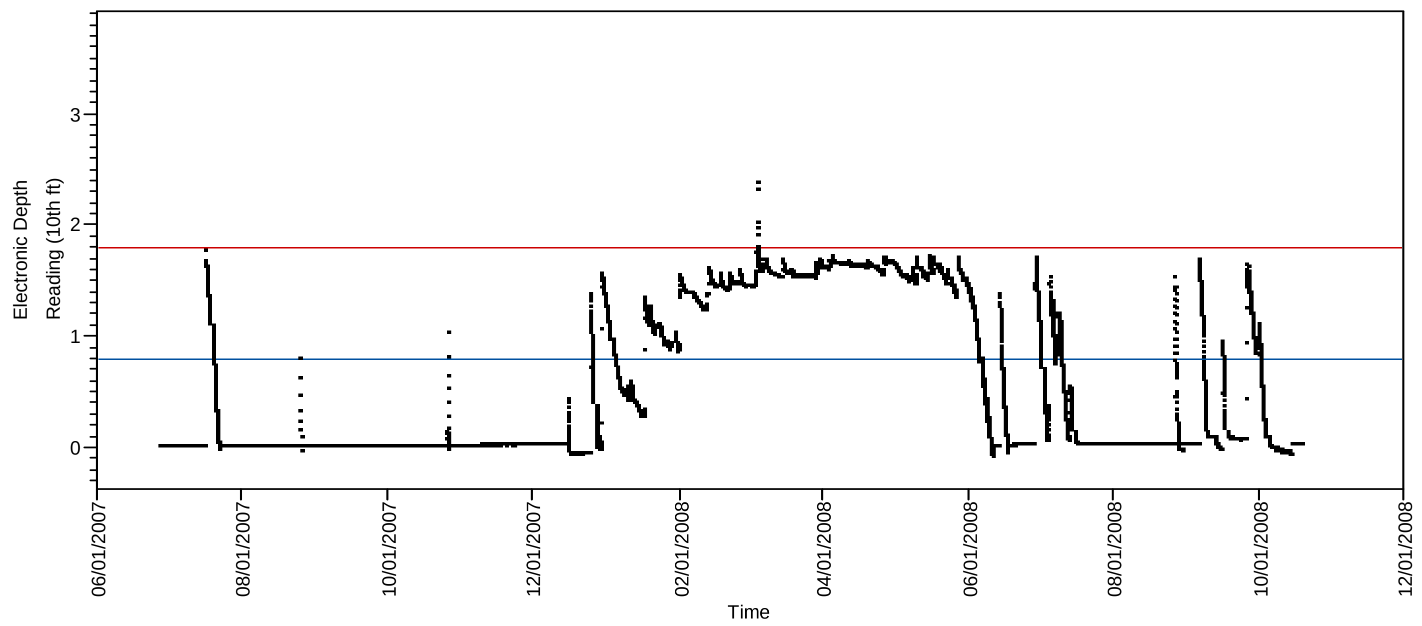


Figure 5.3.3 – 3 Bottomland Hardwood Forest: Kim-Brooks



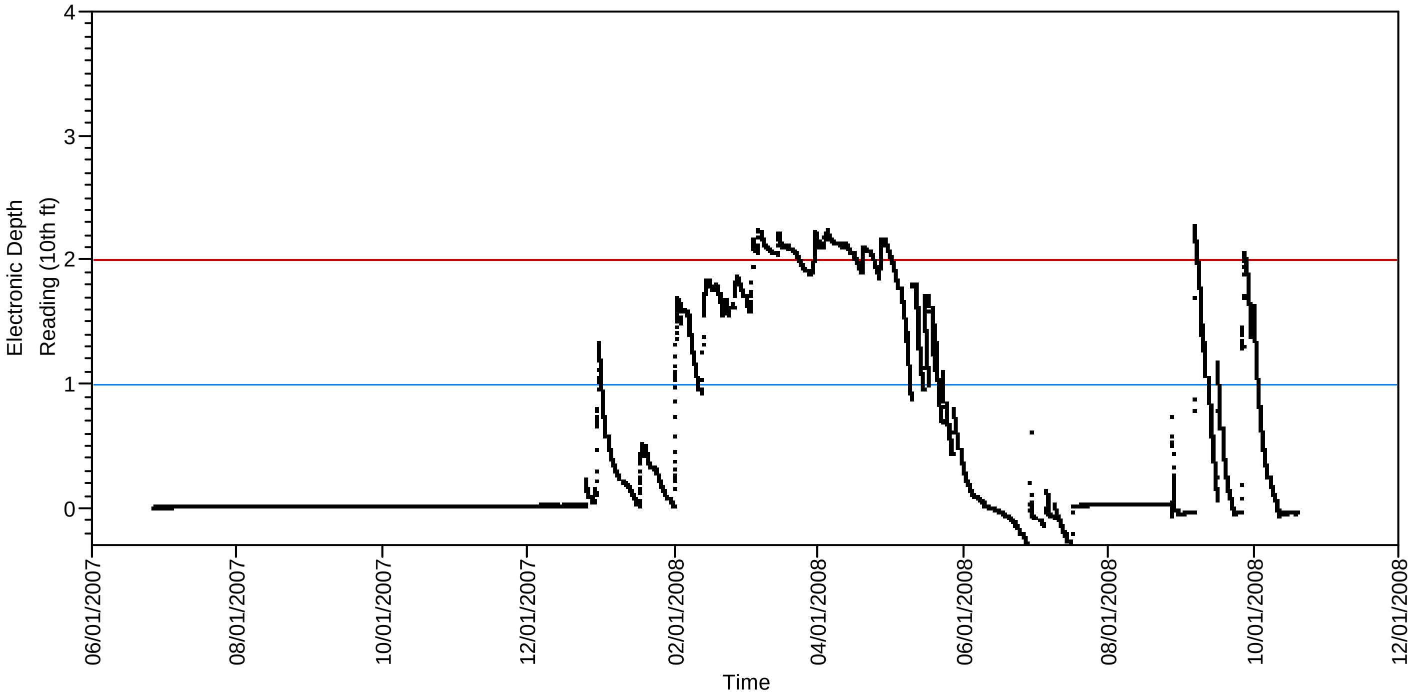
Top Horizontal Red Line is Ground Surface, Blue Line is One Foot Mark Below Surface

Figure 5.3.3 – 4 Bottomland Hardwood Forest: Munn



Top Horizontal Red Line is Ground Surface, Blue Line is One Foot Mark Below Surface

Figure 5.3.3 – 5 Bottomland Hardwood Forest: Powers



Top Horizontal Red Line is Ground Surface, Blue Line is One Foot Mark Below Surface

Table 5.3.3-1 Bottomland Hardwood Forests – Water Depth: percent within One Foot of Surface

Site	Percent within one foot from surface	Percent within one foot of surface - growing season
Fariport	22.50	30.10
Hancock	39.00	36.60
Kim-Brooks	23.40	16.85
Munn	35.50	32.40
Powers	25.60	24.50
Mean	**29.20**	**28.09**

Section 5.3.4 Bottomland Hardwood Forests: Soil Results and Discussion

When soil samples were taken from each site (in wetland and upland locations), texture and soil color was recorded. Each soil core sample taken had the different layers/horizons were measured, and each layer/horizon was then compared with the Munsell soil color chart to determine hue, chroma, and value. Soil texture was also determined in terms of clay, silt, sandy or loam content of the soil. These results are shown in Table E-3 in Appendix E for Bottomland Hardwood Forests in the Fishing Creek watershed. The upper soil layers at the Munn site was primarily a clay loam with the soil becoming more sandy (sandy clay loam) at the deeper levels. The soil color was typically 10YR 4/6, but was heavily mottled. One sample was gleyed. Soil at the Powers site varied ranging from a sandy clay loam with the soil typically becoming a little sandier at the deeper levels. The soil color typically 10YR or 7.5YR 4/6 and heavily mottled. The Fairport site soil also was variable, but primarily clay based. There were some samples that were sandy clay, sandy clay loam, and some with silt. The soil was heavily mottled and the Munsell color was typically 7.5YR 4/2 or 5/3 with one sample being gleyed. Soil samples at the Hancock site were primarily a sandy loam or a clay loam with the typical Munsell color being 10YR at 5/4 or 6/4 with two samples being gleyed at the deeper layers. The soil also was very mottled. The Gray site was the smallest and was next to a large embankment, so some erosion from the embankment was probably being deposited onto the site. The soil was sandy clay loam or sandy loam with the typical Munsell color being 10YR at 3/2 or 4/2, with mottles. The Kim-Brooks site was mostly a clay loam with a few samples being sandier. The typical Munsell color was 10YR 3/2 or 4/2 with mottles. Overall, soils at the Fishing Creek watershed for the Bottomland Hardwood Forest were variable, but primarily sandy clay loam or variants thereof. The soil was typically moderately dark with extensive mottling

Soil samples were collected in the wetland (usually four to six samples) and up to four samples were collected in the uplands surrounding the wetland (see Soils Field Methodology, section 4.3). Table 5.3.4-1 shows the means for all of the soil parameters for each Bottomland Hardwood Forest site for the upland samples and wetland samples (note that no upland samples were collected at the Winding River sites, due to having to core in maintained lawns). Table 5.3.4-2 shows the mean results for the upland samples and the wetland samples averaged across sites. Upland soils were not collected for the Hancock site due to physical barriers and having to core samples in the lawns of landowners. From Table 5.3.4-1, the Gray site had the highest percent humic matter with the rest of the sites about the same levels. The highest weight by volume occurred at the Munn site, but all sites were very similar. The Kim-Brooks site had the highest level of CEC whereas the Munn and Gray sites had the lowest levels. For percent base saturation, two groupings did appear with the highest levels being the Kim-Brooks, Fairport, and Hancock sites, respectively and the lowest levels occurred at the other three sites (the Munn site with the lowest levels, followed by the Gray and Powers sites). The exchangeable acidity was highest at the Powers site with the other five sites having similar levels. The least acidic site (pH) was the Fairport site, but the range was from a pH of 5.3 at the Fairport site to a pH of 4.8 at the Munn site. The highest levels of phosphorus occurred at the Hancock site and whereas the Kim-Brooks site had the lowest levels. The Hancock site also had the highest levels of potassium with the Kim-Brooks site having the next highest. The Munn site has the lowest levels of potassium. For calcium, the Kim-Brooks site had the highest levels by a large margin and the Munn and Gray sites had the lowest levels of calcium. The Kim-Brooks site also had the highest levels of magnesium at twice the levels of the next highest, the Hancock site. The Gray and Munn sites again had the lowest levels. For sulfur, the highest levels occurred at the Powers site, with the Kim-Brooks and Hancock sites having the next highest levels. For manganese, the Hancock site had the highest levels whereas the Munn site had the next highest. The Gray site had the lowest levels of manganese. The highest levels of zinc occurred at The Hancock site with the Fairport and Powers sites being next, respectively. The Munn site had the lowest levels of zinc. The Kim-Brooks and Hancock sites had the highest levels of copper with the Gray site having the lowest levels. The levels of sodium were highest at the Powers site and the lowest levels occurred at the Fairport and Munn sites. For nitrogen levels, the Hancock site had the highest, followed by the Gray and Powers sites.

These soil results show that two sites (Hancock and Kim-Brooks) had the highest levels of potential pollutants (nutrients and metals). The other four sites had much lower levels. Relative to the water quality results, the Gray and Kim-Brooks sites had the worst water quality. Therefore soil results for the Kim-Brooks site are consistent whereas the Gray site had few problems with potential pollutants in the soil. The Powers and Fairport sites had the best water quality and this is consistent with the overall soil results. As with the Riverine Swamp Forest, there appears to be a relationship with soil quality and water quality, but for Bottomland Hardwood Forests, the Gray site had poor water quality but good soil quality. The Gray site was in a very natural setting but was the smallest site and was situated next to a large embankment and washing of water and soil down the embankment into the wetland may have had some influence on the inconsistent results for soil and water quality.

Table 5.3.4-2 shows the results of the soil data by upland and wetland. The percent humic matter and percent base saturation was higher in the wetland as opposed to the upland as would be expected. The weight per volume was higher in the upland, again as would be expected. Potassium and phosphorus appear to be a little higher in the upland rather than the wetland. However, calcium, magnesium, sulfur, manganese, zinc, copper, sodium, and nitrogen all are higher in the wetland. These soil results (as with the water quality results) show that the Bottomland Hardwood Forest wetlands are again acting as a sink for excess nutrients and metals to allow the wetland systems to improve the water quality.

Statistical tests (ANOVA and Wilcoxon) were performed on the soil results on the upland versus wetland samples. Percent base saturation and percent humic matter were statistically significant (Wilcoxon and ANOVA, $p<0.053$) showing the higher levels in the wetland. Weight by volume was higher in the upland and was statistically significant (Wilcoxon, $p<=.001$ and ANOVA, $p=0.0003$). The soils would generally be expected to be more compacted in the upland thus accounting for this result. The CEC was significant statistically with the higher levels in the wetland (Wilcoxon, $p=0.0031$). Calcium was statistically significant (Wilcoxon, $p=0.0025$) with the higher levels occurring in the wetland. Magnesium was statistically significant (Wilcoxon, $p=0.0031$) as was sulfur (Wilcoxon, $p=0.0181$) with the higher levels of both being in the wetland as opposed to the upland. The higher levels of zinc occurred in the wetland and this difference was statistically significant (Wilcoxon, $p=0.0721$, ANOVA, $p=0.0422$) as was copper (Wilcoxon, $p=0.0743$, ANOVA, $p=0.0822$), again with the higher levels occurring in the wetland. Sodium was also higher in the wetland and was statistically significant (Wilcoxon, $p<0.0001$, ANOVA $p=0.0005$). Nitrogen was also higher in the wetland, but just beyond statistical significance (ANOVA, $p=0.154$).

These statistically significant results show that higher levels of soil nutrients and metals occur in the wetland as opposed to the upland. As with the water quality for Bottomland Hardwood Forest and the soil and water quality data for the Riverine Swamp Forest, these results show that these wetlands act as a sink for nutrients and metals and provide the opportunity for improving the water quality as water flows through the wetland system.

Table 5.3.4-1 Means by Site for Bottomland Hardwood Forests Upland and Wetland Soil Samples

Site	N	Mean (HM %, Up)	Mean (HM %, Wet)	Mean (WV g/cc, Up)	Mean (WV g/cc, Wet)	Mean (CEC meq/100cc, Up)	Mean (CEC meq/100cc, Wet)
Fairport	14	0.435	0.436	1.380	1.108	4.950	7.308
Gray	10	0.490	0.640	1.190	1.118	3.800	4.325
Hancock	14		0.410		0.996		7.800
Kim-Brooks	13	0.245	0.357	1.210	1.139	19.600	11.418
Munn	20	0.403	0.481	1.103	1.153	5.188	4.892
Powers	19	0.153	0.352	1.288	1.000	4.617	7.908

Site	N	Mean(BS %, Up)	Mean (BS %, Wet)	Mean (Ac meq/100cc, Up)	Mean (Ac meq/100cc, Wet)	Mean(pH, Up)	Mean(pH, Wet)
Fairport	14	72.500	74.917	1.350	1.817	5.200	5.267
Gray	10	53.000	56.000	1.800	1.888	5.150	4.875
Hancock	14		71.786		2.143		5.157
Kim-Brooks	13	88.500	79.909	2.200	2.045	5.600	5.145
Munn	20	47.625	51.500	2.625	2.325	4.913	4.842
Powers	19	47.500	60.308	2.083	3.115	4.967	4.962

Site	N	Mean (P mg/dm3, Up)	Mean (P mg/dm3, Wet)	Mean (K mg/dm3, Up)	Mean (K mg/dm3, Wet)	Mean (Ca mg/dm3, Up)	Mean (Ca mg/dm3, Wet)
Fairport	14	3.850	7.950	19.150	27.608	496.650	760.792
Gray	10	7.150	8.100	66.550	29.863	268.550	326.100
Hancock	14		8.607		37.271		733.693
Kim-Brooks	13	13.000	6.518	59.400	33.555	2182.000	1118.764
Munn	20	4.563	7.758	23.050	20.825	324.938	334.408
Powers	19	14.283	7.808	31.083	29.492	339.200	635.646

Table 5.3.4-1 Means by Site for Bottomland Hardwood Forests Upland and Wetland Soil Samples

Site	N	Mean (Mg mg/dm3, Up)	Mean (Mg mg/dm3, Wet)	Mean (S mg/dm3, Up)	Mean (S mg/dm3, Wet)	Mean (Mn mg/dm3, Up)	Mean (Mn mg/dm3, Wet)
Fairport	14	128.650	196.375	7.150	19.650	55.600	94.450
Gray	10	61.950	88.963	17.000	14.838	61.300	21.825
Hancock	14		229.586		23.114		174.829
Kim-Brooks	13	773.700	447.336	7.500	23.573	60.050	87.964
Munn	20	104.763	102.933	24.238	13.300	126.088	137.725
Powers	19	89.600	186.492	19.583	26.831	64.667	88.992

Site	N	Mean (Zn mg/dm3, Up)	Mean (Zn mg/dm3, Wet)	Mean (Cu mg/dm3, Up)	Mean (Cu mg/dm3, Wet)	Mean (Na mg/dm3, Up)	Mean (Na mg/dm3, Wet)
Fairport	14	0.600	2.367	0.950	1.500	13.000	24.333
Gray	10	1.250	1.263	0.700	0.613	35.000	32.250
Hancock	14		2.514		1.864		35.357
Kim-Brooks	13	2.350	1.900	2.200	1.982	20.000	32.636
Munn	20	1.100	0.892	1.325	1.558	16.750	25.917
Powers	19	1.267	2.208	1.083	1.292	16.667	40.154

Site	N	Mean (NO3--N mq/dm3, Up)	Mean (NO3--N mq/dm3, Wet)
Fairport	14	0.000	0.667
Gray	10	1.500	5.250
Hancock	14		7.929
Kim-Brooks	13	3.000	1.091
Munn	20	1.500	0.750
Powers	19	2.000	3.077

Table 5.3.4-2 Bottomland Hardwood Forest Soil Mean Results for Soil Upland and Wetland Samples

Up / Wet	N	Mean (HM %)	Mean (WV g/cc)	Mean (CEC meq/100cc)	Mean (BS %)	Mean (Ac meq/100cc)	Mean (pH)
Up	20	0.324	1.206	6.295	54.700	2.210	5.050
Wet	70	0.434	1.079	7.409	66.186	2.254	5.051

Up / Wet	N	Mean (P mg/dm3)	Mean (K mg/dm3)	Mean (Ca mg/dm3)	Mean (Mg mg/dm3)	Mean (S mg/dm3)	Mean (Mn mg/dm3)
Up	20	8.510	33.055	526.455	165.215	18.735	87.530
Wet	70	7.814	29.920	665.610	212.324	20.654	107.611

Up / Wet	N	Mean(Zn mg/dm3)	Mean(Cu mg/dm3)	Mean(Na mg/dm3)	Mean(NO3--N mq/dm3)
Up	20	1.240	1.240	18.500	1.650
Wet	70	1.914	1.519	31.957	3.171

Section 5.3.5 Bottomland Hardwood Forests: Amphibian Results and Discussion

Amphibian surveys in the Fishing Creek bottomland forest wetlands found twelve types of amphibians to the level of species, eight were anurans and four were urodelas. The following amphibian species were identified during the Bottomland Hardwood Forest survey: American toad (*Bufo americanus*), Fowler's toad (*Bufo fowleri*), upland chorus frog (*Pseudacris feriarum*), northern spring peeper (*Pseudacris crucifer*), northern cricket frog (*Acris crepitans*), bull frog, northern green frog, Cope's grey tree frog, spotted salamanders (*Ambystoma maculatum*), marbled salamanders (*Ambystoma opacum*), eastern newt (*Notophthalmus viridescens*), and state special concern four-toed salamander (*Hemidactylium scutatum*) of which two larval specimens were found at the Munn site. The observation of the larvae or eggs of fish sensitive species such as spotted salamanders, marbled salamanders, and the one four-toed salamander at the Munn, Powers, Hancock, Kim-Brooks, and Fairport sites during the March 2007 survey indicate that these sites do not receive regular flooding from their associated rivers, but rather overland flow from adjacent uplands. The American toad, which was found at the Hancock and Powers sites was the most abundant species in the Bottomland Hardwood Forest amphibian survey. The spotted salamander and upland chorus frog which were observed at four sites and northern cricket frog, which was observed at six sites, were the next most abundant species of amphibian.

Table 5.3.5-1 shows the significant correlation results (p-value ≤ 0.15) for the Spearman's Rho and Pearson's pairwise correlation analyses between amphibians and various parameters. Similarly to the Riverine Swamp Forest analysis, results that had a more significant p-value of < 0.05 and Pearson's correlation or Spearman's $\rho > 0.5$ are listed in bold blue while results that had a p-value of < 0.1 and ≥ 0.5 are listed in bold red. Five metrics were chosen for use in the Bottomland Hardwood Forest amphibian IBI: percent EW-HW-seep, percent sensitive, percent Urodela, AQAI, and species richness. These metrics had significant correlations with the most disturbance measurements (three to seven disturbance measurements for each metric) including ORAM, 100M LDI, soil pH, ORAM, and water quality Ca, Mg, specific conductivity, dissolved oxygen, TOC, TSS, TKN, Zn, Cu, Pb, fecal coliform and the water quality combination disturbance measurement. Abundance only correlated with the 100M LDI.

Table 5.3.5-2 shows the metric results for each of the Bottomland Hardwood Forest wetland sites. The metric results to be used in the Bottomland Hardwood Forest IBI are shown in bold red. species richness ranged from 4 (the Gray site) to 10 (the Hancock site), percent tolerance ranged from 17% (the Fairport and Powers sites) to 95% (the Gray site), percent sensitive ranged fro 0% (the Gray site) to 67% (the Munn site), percent Urodela ranged from 0% (the Gray site) to 67% (the Munn site), AQAI ranged from 1.5 (the Kim-Brooks site, the Hancock site was 1.6) to 34.2 (the Fairport site), and percent EW-HW-seep ranged from 0% (the Kim-Brooks site) to 68% (Powers site). Metric score assignments of "0" "3", "7", "10" were made according to the data distribution and are shown in Table 5.3.5-3. Table 5.2.5-4 shows the metric score assigned for the species richness, percent tolerant, percent sensitive, percent Urodela, AQAI and percent EW-HW-seep metrics as the as the total Bottomland Hardwood Forest amphibian IBI score for each Bottomland Hardwood Forest site. The total amphibian IBI scores ranged from 3 to 51. The Gray site had the lowest score of 3. This may partly be due to the fact that the Gray site was the smallest site at 0.14 acres. However the lack of surface hydrology at this site was likely an influencing factor. Very little standing water was observed on this site indicating the lack of overland flow or flooding from the adjacent stream. The Kim-Brooks site scored the next lowest score of 7. Based on best professional judgement, this site is not of the highest quality since there is a predominance of poison ivy (*Toxicodendron radicans*) on the site and roads, I-85 and US 15 are located in the surrounding buffer areas. The Hancock site, an urban site, scored only a 16 although ten species of amphibians were observed at this site. This site had the highest abundance due to a thriving population of American toads. American toads are a highly tolerant species with a C of C score of 1, which affected the metric score for percent tolerant, percent sensitive, percent Urodela, AQAI, and percent EW-HW-seep. The Munn site scored the highest, with a score of 54. The Munn site is a high quality Bottomland Hardwood Forest, both in terms of habitat and buffer. Floodplain pools that receive overland flow rather then stream flooding provided habitat for larval salamanders. The Fairport site, which scored 51, and the Powers site which scored 50, also have large areas with pooled water that provided habitat for larval salamanders which would have influenced the metric scores for percent tolerance, percent sensitive, percent Urodela, AQAI, and percent EW-HW-seep.

Table 5.3.5-1 Bottomland Hardwood Forest Significant Correlation Results with Disturbance Measures

Wetland Type	Cadidate Metric	Disturbance Measurement	Correlation / Spearman ρ	p-value	Analysis
BLH	%EW-HW-Seep	100M	**-0.7924**	**0.0602**	Pearson’s Correlation
BLH	%EW-HW-Seep	Calcium	**-0.8484**	**0.0327**	Pearson’s Correlation
BLH	%EW-HW-Seep	Dissolved Oxygen (%)	**0.8704**	**0.0241**	Pearson’s Correlation
BLH	%EW-HW-Seep	Dissolved Oxygen (mg/L)	**0.8017**	**0.0551**	Pearson’s Correlation
BLH	%EW-HW-Seep	Magnesium	**-0.9673**	**0.0016**	Pearson’s Correlation
BLH	%EW-HW-Seep	Magnesium	**-0.7714**	**0.0724**	Spearman’s Rho Correlation
BLH	%EW-HW-Seep	Specific Conductivity	**-0.7711**	**0.0726**	Pearson’s Correlation
BLH	%Sensitive	Lead	**-0.7995**	**0.0563**	Pearson’s Correlation
BLH	%Sensitive	Magnesium	**-0.8286**	**0.0416**	Spearman’s Rho Correlation
BLH	%Sensitive	ORAM Mean	**0.7714**	**0.0724**	Spearman’s Rho Correlation
BLH	%Sensitive	Total Suspended Residue	**-0.7307**	**0.0990**	Pearson’s Correlation
BLH	%Sensitive	WQ Combo (w/o fc by WT)	-0.6658	0.1488	Pearson’s Correlation
BLH	%Tolerance	Copper	0.7143	0.1108	Spearman’s Rho Correlation
BLH	%Tolerance	Fecal Coliform	0.7143	0.1108	Spearman’s Rho Correlation
BLH	%Tolerance	Magnesium	0.7143	0.1108	Spearman’s Rho Correlation
BLH	%Tolerance	ORAM Mean	-0.6889	0.1301	Pearson’s Correlation
BLH	%Tolerance	TOC	0.7143	0.1108	Spearman’s Rho Correlation
BLH	%Tolerance	Total Suspended Residue	**0.7714**	**0.0724**	Spearman’s Rho Correlation
BLH	%Tolerance	WQ Combo(w/o fc by WT)	0.7143	0.1108	Spearman’s Rho Correlation
BLH	%Urodela	Lead	**-0.8147**	**0.0483**	Pearson’s Correlation
BLH	%Urodela	Magnesium	**-0.8286**	**0.0416**	Spearman’s Rho Correlation
BLH	%Urodela	ORAM Mean	**0.7714**	**0.0724**	Spearman’s Rho Correlation
BLH	%Urodela	Total Suspended Residue	**-0.7309**	**0.0989**	Pearson’s Correlation
BLH	%Urodela	WQ Combo (w/o fc by WT)	-0.6678	0.1472	Pearson’s Correlation
BLH	%Urodela	Zinc	-0.6646	0.1499	Pearson’s Correlation
BLH	Abundance	100M	-0.6667	0.1481	Spearman’s Rho Correlation
BLH	AQAI	Calcium	**-0.8930**	**0.0166**	Pearson’s Correlation
BLH	AQAI	Calcium	**-0.9429**	**0.0048**	Spearman’s Rho Correlation
BLH	AQAI	Magnesium	-0.7188	0.1075	Pearson’s Correlation
BLH	AQAI	Magnesium	**-0.9429**	**0.0048**	Spearman’s Rho Correlation
BLH	AQAI	ORAM Mean	**0.9159**	**0.0103**	Pearson’s Correlation
BLH	AQAI	ORAM Mean	**0.8857**	**0.0188**	Spearman’s Rho Correlation

Table 5.3.5-1 Bottomland Hardwood Forest Significant Correlation Results with Disturbance Measures

Wetland Type	**Cadidate Metric**	**Disturbance Measurement**	**Correlation / Spearman ρ**	**p-value**	**Analysis**
BLH	Species Richness	Fecal Coliform	-0.6833	0.1346	Pearson’s Correlation
BLH	Species Richness	Fecal Coliform	**-0.8407**	**0.0361**	Spearman’s Rho Correlation
BLH	Species Richness	Lead	**-0.7903**	**0.0613**	Pearson’s Correlation
BLH	Species Richness	Soils Mean(pH)	0.6736	0.1425	Pearson’s Correlation
BLH	Species Richness	Soils Mean(pH)	**0.7537**	**0.0835**	Spearman’s Rho Correlation
BLH	Species Richness	TKN	-0.6957	0.1248	Spearman’s Rho Correlation
BLH	Species Richness	TOC	**-0.8580**	**0.0288**	Pearson’s Correlation
BLH	Species Richness	TOC	**-0.8407**	**0.0361**	Spearman’s Rho Correlation
BLH	Species Richness	Total Suspended Residue	**-0.7997**	**0.0562**	Pearson’s Correlation
BLH	Species Richness	Total Suspended Residue	**-0.8117**	**0.0499**	Spearman’s Rho Correlation
BLH	Species Richness	WQ Combo (w/o fc by WT)	**-0.7622**	**0.0781**	Pearson’s Correlation

Bold Red = Probility ≤ 0.05 and **Bold Blue** = Probility > 0.05 and ≤ 0.10, BLH=Bottomland Hardwood Forests

Table 5.3.5-2 Bottomland Hardwood Forest Candidate Metric Results

Site Name	Species Richness	Abundance	%Tolerance	%Sensitive	%Urodela	AQAI	%EW-HW-Seep
Fairport	**9**	41.8	**17.94**	**31.82**	**34.21**	**4.96**	**65.19**
Gray	**4**	42	**95.24**	**0**	**0**	**2.62**	**4.76**
Hancock	**10**	500.35	**89.14**	**4.53**	**5.77**	**1.56**	**7.18**
Kim-Brooks	**8**	34	**91.18**	**4.71**	**8.82**	**1.48**	**0.00**
Munn	**7**	51.2	**28.32**	**66.8**	**66.8**	**6.1**	**34.96**
Powers	**9**	77.55	**17.02**	**26.24**	**26.24**	**4.83**	**68.44**

Bold Red = Metrics to be used in Bottomland Hardwood IBIs, %EW-HW-Seep = %Ephemeral Wetland-Headwater Wetland-Seep

Table 5.3.5-3 Metric Score Assignments for Bottomland Hardwood Forests

Metric	0	3	7	10
Species Richness	<5	<7	<9	≥9
%Tolerance	≥50	<50	<30	<20
%Sensitive	<5	<30	<50	≥50
%Urodela	<10	<30	<50	≥50
AQAI	<2	<4	<6	≥6
%EW-HW-Seep	<5	<30	<50	≥50

Table 5.3.5-4 Amphibian IBI Scores for Bottomland Hardwood Forest Sites

Site Name	Species Richness	%Tolerance	%Sensitive	%Urodela	AQAI	%EW-HW-Seep	Total
Kim-Brooks	7	0	0	0	0	0	**7**
Gray	0	0	0	0	3	0	**3**
Hancock	10	0	0	0	3	3	**16**
Powers	10	10	3	3	7	10	**43**
Fairport	10	10	7	7	7	10	**51**
Munn	7	7	10	10	10	7	**51**

Section 5.3.6 Bottomland Hardwood Forests: Macroinvertebrate Results and Discussion

Section 5.3.6 will be delivered to the EPA at a later time when the macroinvertebrate samples have been identified, enumerated, and analyzed.

Section 5.3.7 Bottomland Hardwood Forest: Vegetation Survey Results and Discussion

Bottomland Hardwood Forests of the Fishing Creek watershed contained over 150 vascular species of trees, shrubs, grasses, sedges, rushes, ferns, and forbs. These systems were forested with mature trees with American elm, sweet gum, red maple, and green ash (*Fraxinus pennsylvatica*) dominating. Other tree species included winged elm (*Ulmus alata*), tulip tree (*Liriodendron tulipifera*), hackberry (*Celtis laevigata*), willow oak (*Quercus phellos*), and box elder (*Acer negundo*). The most dominant shrub species was tag alder followed by the invasive exotic Chinese privet (*Ligustrum sinense*), which is a common problem species in the Piedmont of NC. The most dominant herb layer species is also a problem exotic invasive, Nepalese browntop (*Microstegium vimineum*). Other common herb stratum species were jewelweed (*Impatiens capensis*), false nettle (*Boehmeria cylindrical*), Virginia bugelweed (*Lycopus virginicus*) and various species of *Carex*. Ferns were less common in the Bottomland Hardwood Forests than Riverine Swamp Forests. Species observed were Christmas fern (*Polystichum acrostichoides*), lady fern (*Athyrium filix-femina*), and netted chain fern (*Woodwardia areolata*). Poison ivy was highly dominant at a couple of the sites (Kim-Brooks, Hancock, Powers) and occurred at all of the Bottomland Hardwood Forest sites. Other vine species that occurred in the bottomland hardwoods included trumpet vine, common greenbriar, Japonese honeysuckle, Virginia creeper, and muscadine grape.

Table 5.3.7-1 shows the significant correlation results (p-value $\leq$ 0.15) for the Spearman's Rho and Pearson's pairwise correlation analyses. Results that had a more significant p-value of < 0.05 and Pearson's correlation or Spearman's ρ > 0.5 are listed in bold blue while results that had a p-value of < 0.1 and $\geq$ 0.5 are listed in bold red. The following factors were considered a priority in choosing metrics for the Bottomland Hardwood Forest plant IBI: 1. Metrics with lower probabilities: 2. metrics that were significant for both Pearson's correlation and Spearman's Rho, 3. metrics that correlated with more then one disturbance measurement, 4. metrics that were not measuring similar biological attributes (e.g. native herb richness and herb richness), 5. metrics that correlated with ORAM which was a better measurement of site condition, 6. types of metrics that measured different aspects of the vegetation community (i.e. community balance structure, wetness, functional groups, and community structure). There were a total of 14 plant metrics with significant results (see Table 5.3.7-1), however eight metrics were chosen for the Bottomland Hardwood Forest plant IBI. The Bottomland Hardwood Forest metrics chosen were dominance for the community balance metric type, FAQWet cover and wetland shrub cover for the wetness characteristic metric type, Bryophyte cover, Carex richness and Cyperaceae, Poaceae, and Juncaceae richness for the functional froup metric type, and native herb richness and standing snag importance for the community structure metric type. These metrics had the more significant results (lower p-value) and were representative of four of the different metric types. Few of these metrics correlated with ORAM and none of the metrics correlated with both statistical tests as was the case with the Riverine Swamp Forest analysis, which indicates the

Bottomland Hardwood Forest analysis has fewer significant results than the Riverine Swamp Forest data.

Table 5.3.7-2 shows the metric results for each of the Bottomland Hardwood Forest wetland sites. Metric results ranged from 0.43 (the Powers site) to 0.75 (the Fairport site) for the dominance metric which indicated that the Fairport site had a couple of species that were more dominant while the Powers site had species that were more evenly distributed. Metric results ranged from –0.11 (the Gray site) to 3.08 (the Hancock site) for the FAQWet cover metric and 0.75 (the Fairport site) to 61.5 (the Munn site) for the wetland shrub metric which indicates gray has a more dominant coverage of upland plants as compared to the Hancock site which is the most dominantly covered with wetland plants and that the Fairport site has the least coverage of wetland shrubs as compared to the Munn site which has the most. Metric results ranged from 0 (the Kim-Brooks site) to 7.6 (the Fairport site) for the Bryophyte cover metric, 4 (the Fairport site) to 7 (the Powers site) for the Carex richness metric, and 6 to 13 for the Cyperaceae, Poaceae, and Juncaceae richness metric. These results indicate that the Fairport site has the highest cover of moss as compared to the Kim-Brooks site, which has no cover, the Powers site has the highest number of Carex species and the Fairport site the least, and the Powers site has the highest richness of sedges, grasses, and rushes as compared to the Fairport site which, again, has the least. Metric results ranged from 14 (the Fairport site) to 37 (the Gray site) for native herb richness and 0 (the Kim-Brooks site) to 1.19 (the Fairport site) for standing snag importance. These results indicated that the Fairport site had the fewest species of native herbs while the Gray site had the most and that the Fairport site had the highest number of snags and therefore, better wildlife habitat in terms of nesting cavities while the Kim-Brooks site had the least. The vegetation survey of the Gray site may have picked up some upland due to the small size of the site thus increasing the herb diversity. The Fairport site had the least ground cover probably due to winter flooding and therefore scored lowest under a number of the metric types.

Metric score assignments of “0”, “3”, “7”, and “10” were made according to the data results distribution and are shown in Table 5.3.7-3. Table 5.3.7-4 shows the metric score assigned for the eight individual metrics chosen for the Bottomland Hardwood Forest Plant IBI and the total IBI score. The total Bottomland Hardwood Forest Plant IBI scores ranged from 29 to 55. The Munn site scored 55 with the Powers site being second at 46 and the Hancock site being third at 40. The Munn site is a mature forested Bottomland Hardwood Forest with little sign of disturbance. The Powers and Hancock sites are also mature forested Bottomland Hardwood Forests. However, they are both near a sewage line and the Hancock site is adjacent to a busy road and had a more disturbed buffer than the Powers site. The Fairport site scored the lowest with 29 while the Kim-Brooks site scored second lowest with 30. The Fairport site is a mature forested Bottomland Hardwood Forest but the understory shrubs and herbaceous vegetation was minimal which would have lowered the overall plant IBI score for this site. The Kim-Brooks site is also a mature forested Bottomland Hardwood Forest. However poison ivy is highly invasive here, diversity is not as high, and I-85 and US 15 are located in the buffer.

Table 5.3.7-1 Bottomland Hardwood Forest (BLH) Significant Correlation Results with Disturbance Measures

Wetland Type	**Metric**	**Disturbance Measurement**	**Correlation / Spearman ρ**	**p-value**	**Analysis**
Community Balance Metrics					
Bottomland Hardwood	Dominance	Watershed LDI	**0.7477**	**0.0875**	Pearson’s Correlation
Bottomland Hardwood	Species Richness	100M LDI	-0.6957	0.1248	Pearson’s Correlation
Floristic Quality Metrics					
Bottomland Hardwood	Average C of C	Watershed LDI	-0.7143	0.1108	Spearman's Rho Correlation
Wetness Characteristics Metrics					
Bottomland Hardwood	FAQWet Cover	100M LDI	**-0.8271**	**0.0841**	Spearman's Rho Correlation
Bottomland Hardwood	Wetland Shrub Species Richness	ORAM Mean	**0.7527**	**0.0842**	Pearson’s Correlation
Funtional Metrics Groups					
Bottomland Hardwood	Carex Richness	Watershed LDI	**-0.9344**	**0.0063**	Spearman's by Wetland Type
Bottomland Hardwood	Cyperaceae, Poaceae, Juncaceae Richness	Watershed LDI	**-0.8659**	**0.0258**	Pearson’s Correlation
Bottomland Hardwood	Dicot Richness	100M LDI	-0.6765	0.1401	Pearson’s Correlation
Bottomland Hardwood	Cryptogram Richness	Watershed LDI	-0.6665	0.1483	Spearman's Rho Correlation
Bottomland Hardwood	Bryophyte Cover	100M LDI	**-0.7666**	**0.0753**	Pearson’s Correlation
Community Structure Metrics					
Bottomland Hardwood	Total Herb Cover	100M LDI	**-0.7301**	**0.0995**	Spearman's Rho Correlation
Bottomland Hardwood	Total Herb Richness	100M LDI	**-0.8697**	**0.0244**	Pearson’s Correlation
Bottomland Hardwood	Native Herb Cover	100M LDI	**-0.7440**	**0.0899**	Pearson’s Correlation
Bottomland Hardwood	Native Herb Richness	100M LDI	**-0.8697**	**0.0244**	Pearson’s Correlation
Bottomland Hardwood	Standing Snag Importance	100M LDI	**-0.7789**	**0.0679**	Pearson’s Correlation

Bold Red = Probility ≤ 0.05 and **Bold Blue** = Probility > 0.05 and ≤ 0.10

Table 5.3.7-2 Bottomland Hardwood Forest Plant Metric Results

Site	Dominance	FAQWet Cover	Wetland Shrub Cover	Bryophyte Cover	Carex Richness	Cyperaceae, Poaceae, and Juncaceae Richness	Native Herb Richness	Standing Snag Importance
Fairport	0.75	0.25	0.75	7.58	4.00	6.00	14.00	1.19
Gray	0.57	-0.11	3.25	3.18	5.00	11.00	37.00	0.17
Hancock	0.62	3.08	2	0.67	5.00	10.00	24.00	0.85
Kim-Brooks	0.56	0.07	6	0.00	6.00	12.00	22.00	0.00
Munn	0.51	0.52	61.5	0.88	5.00	10.00	30.00	0.65
Powers	0.43	0.48	2.25	0.65	7.00	13.00	31.00	0.35

Table 5.3.7-3 Plant Metric Score Assignments for Bottomland Hardwood Forests

Metric	0	3	7	10
Dominance	≥0.70	<0.70	<0.60	<0.50
FAQWet Cover	<0.20	<0.50	<3	≥3
Wetland Shrub Cover	<5	<20	<30	≥30
Bryophyte Cover	<0.5	<2	<5	≥5
Carex Richness	<3	<5	<7	≥7
Cyperaceae, Poaceae, and Juncaceae Richness	<6	<9	<12	≥12
Native Herb Richness	<15	<25	<35	≥35
Standing Snag Importance	<0.30	<0.50	<1	≥1

Table 5.2.7-4 Plant IBI Score for Bottomland Hardwood Forest Sites

Site	Dominance	FAQWet Cover	Wetland Shrub Cover	Bryophyte Cover	Carex Richness	Cyperaceae, Poaceae, and Juncaceae Richness	Native Herb Richness	Standing Snag Importance	Total
Fairport	0	3	0	10	3	3	0	10	29
Gray	7	0	0	7	7	7	10	0	38
Hancock	3	10	0	3	7	7	3	7	40
Kim-Brooks	7	0	3	0	7	10	3	0	30
Munn	7	7	10	3	7	7	7	7	55
Powers	10	3	0	3	10	10	7	3	46

Section 6 – Results: Coastal Plain and Piedmont Small Basin Wetlands

Section 6.1 Small Basin Wetlands Introduction and Background

Small Basin wetlands are found throughout the Southeast and comprised a highly diverse array of wetlands that have variable soils, plant associations, and geologic histories. Small Basin wetlands are often considered isolated with no surface water connection to downstream waters. Wetlands, including those that are isolated, can be highly important for aquifer recharge, flood attenuation, water quality, habitat, and biodiversity of plants and animals including at-risk rare species (Eshleman et al. 1992, Stone and Lindley Stone 1994, Whigham and Jordan 2003, Semlitsch and Bodie, 1998). Development, logging, and agriculture have caused the diminishment of these critical ecosystems in the landscape. Additionally, isolated wetlands are not protected at the national level. There are numerous classification systems for identifying wetlands, including Small Basin wetlands (both isolated and non-isolated). This review of Small Basin wetlands will discuss the ways in which Small Basin wetlands are defined in North Carolina and how that description compares with study sites chosen for this project. Four of the wetland sites studied in the Coastal Plain are Carolina Bays, which are a unique type of basin wetland named aptly for the region of the country where they predominate. The geologic history and formation, soil type, vegetation, hydrology, and water chemistry of Carolina bays will also be discussed in detail. The geology, formation, vegetation and soils of Piedmont wetlands will also be examined in this section. In addition, the importance of isolated Small Basin wetlands, how they have been impacted, and associated federal and state regulations will also be discussed.

Basin wetlands have been categorized in different ways within the U.S. and North Carolina. The two methodologies that will be discussed in this section are specific to North Carolina, the North Carolina Wetland Assessment Method (NCWAM) and the “Classification of Natural Communities of North Carolina, Third Approximation” (Schafale and Weakley, 1990). The North Carolina Wetland Assessment Method (NCWAM), which was used to identify Small Basin wetlands for this study, defines these wetlands as depressions found on interstream divides or coastal islands that are surrounded by uplands and not dominated solely by dense, waxy, pocosin type vegetation. This definition also includes wetlands that occur on the fringes of small water bodies (< 20 acres in size). Small Basin wetlands are located throughout the state of North Carolina but are the most concentrated in the Coastal Plain due to the predominance of Carolina Bays which will be described below. Small Basin wetlands are surrounded by uplands, but there may be a natural or man-made hydric conveyance associated with the wetland. Small Basin wetlands, according to NCWAM, tend to be seasonally to semi-permanently inundated with fluctuating water tables that often result in seasonal high water marks on vegetation (NCWAM 2008). Soils are often mineral based but can be organic in the Coastal Plain. The NCWAM definition of the Small Basin wetland is a general category that encompasses six types of wetlands that are defined in more detail according to plant associations and soil type by the NC Natural Heritage Program (NC NHP) and the “Classification of the Natural Communities of North Carolina, Third Approximation” (Schafale and Weakley, 1990). These six types of Small Basin wetlands recognized by the Natural Heritage Program and the “Third Approximation” are Upland Depression Swamp Forest, Upland Pool wetlands (located primarily in the Piedmont wetlands), and Vernal Pool, Cypress Savanna, Small Depression Pond, and Inner Dune Pond wetlands (located primarily in the Coastal Plain).

In “The Third Approximation”, Upland Pools and Upland Depression Swamp Forest are both found in the Piedmont. However, Upland Pools are found solely in the Piedmont and Mountains whereas the Upland Depression Swamp Forests are also found in the eastern and central Piedmont and possibly the upper Coastal Plain. Both types of wetlands are seasonally flooded and have a hard pan of clay or rock that hinders drainage. Hydrology is primarily related to rainwater input and evaporation and evapotranspiration. Upland Pools typically have an open canopy, often do not show up on soil surveys, and have a longer hydro-period then the flatter Upland Depression Swamp Forests. Dominant canopy species of these two Small Basin Wetland types are black gum (*Nyssa sylvatica*), willow oak (*Quercus phellos*), red maple (*Acer rubrum*), sweet gum (*Liquidambar styraciflua*), tulip tree (*Liriodendron tulipifera*), and swamp chestnut oak (*Quercus michauxii*) (Schafale and Weakley, 1990). “The Third Approximation’s” description of Upland Pools and Upland Depression Swamp Forests suggest that all of the Fishing Creek watershed Small Basin wetland sites would be defined as Upland Depression Swamp Forests by this classification system. However, the longer hydroperiod and open canopy in the center sections of the Dargan and Belton Creek sites indicate portions of these sites are Upland Pools that transition into Upland Depression Swamp Forests. Upland Pools and Upland Depression Swamp Forests in other regions of the country are sometimes referred to as “vernal pools” (Zedler 2003) which “The Third Approximation” defines differently.

The Natural Heritage Program and “The Third Approximation” defined vernal pools, cypress savannahs, small depression ponds and inner dune ponds and states they are distributed in the NC Coastal Plain. Vernal Pools, as defined by the NHP and “The Third Approximation” (Schafale and Weakley, 1990), are distributed in the Coastal Plain only and are seasonally flooded gently sloping depressions found in sandy soil vegetated with species such as little bluestem (*Schizachyrium scoparioum)*, *Panicum* spp., clubhead cutgrass *Leersia hexandra*, *Carex* spp., and Virginia chain fern (*Woodwardia virginica)*. Small Depression Ponds are permanently flooded sinkholes, small Carolina bays, and other upland depressions. Concentric zoned Small Depression Pond vegetation typically include species such as white water lily (*Nyphaea odorata)*, big floating-heart (*Nymphoides aquatica)*, yellow cow-lily (*Nuphar lutea)*, comb-leaf mermaid-weed (*Prosperpinaca pectinata)* and bladderwort (*Utricularia* spp.) outlined by maidencane (*Panicum hemitomon*), *Panicum* spp., spikerush (*Eleocharis* spp.), beakrush (*Rhynchospora* spp.), and Asian coinleaf (*Centella asiatica)*. Cypress Savannas are clay-based Carolina bays that are seasonally to temporarily flooded. Cypress Savannas have an open to sparse canopy dominated with pond cypress (*Taxodium ascendens*) and may also have swamp tupelo (*Nyssa biflora*), loblolly pine (*Pinus taeda*), pond pine (*Pinus serotina*), and sweet gum with shrubs such as sarvis holly (*Ilex amelanchier)*, fetter-bush (*Leucothoe racemosa)*, ti-ti (*Cyrilla racemiflora*), and fetter-bush (*Lyonia lucida*) also present. Interdune Ponds, also a type of Coastal Plain Small Basin wetland, are wetland depressions in active or relict dunes of barrier islands (Schafale and Weakley, 1990). In the Lockwood Folly River watershed, the Seawatch Bay, Sikka, Martin-Amment, and Seawatch Nautica sites are Carolina bays that most closely resemble Cypress Savannah descriptions as defined by Schafale and Weakley’s “Third Approximation” (1990). Mill Creek is also a Cypress Savannah but not oriented in the typical northwest-southeast direction of Carolina bays which are described further in this section. The

Seawatch Bay, Mill Creek and Sikka sites have open water sections that are normally flooded year round (although severe drought conditions in 2007 and 2008 dried these areas) and appear to be more closely defined by the Third Approximation's, Small Depression Pond description. The Seawatch Bay, Mill Creek, and Sikka sites also grade into Pocosin-like vegetation around the edges. The interior of the Bluegreen golf site is most similar to a vernal pool, as described by the Third Approximation, with its open grassy interior while the shrubby exterior appears to be more indicative of a Small Depression Pocosin.

A number of wetland studies have been conducted on Coastal Plain Carolina bays due to their prevalence in the mid-Atlantic Coastal Plain and the shape and northwest-southeast orientation of this wetland type. Carolina bays can either be a Pocosin or a Small Basin Wetland as defined by NCWAM. Carolina bays are elliptical shaped wetlands with a northwest-southeast long-axis that range in size from 50 m to 8 km in length (Tiner 2003, Messina and Conner, 1998, Sharitz 2003). Carolina bays are found from New Jersey to Florida but are concentrated in southeastern North Carolina and the mid-coastal range of South Carolina (Sharitz 2003). These Carolina bays occur between elevations of a few meters to 200 m in the extreme upper Coastal Plain (Sharitz 2003). Variable theories on the formation of Carolina Bays have been suggested, the most generally accepted attributes the shape and orientation of these uniquely identifiable wetlands to historic modification of shallow ponds through action of waves generated by southerly winds (Sharitz 2003, Messina and Conner, 1998). The consistency of age among Carolina bays is doughtful, however radiocarbon dates from organic sediments indicate bays were formed 16,000 to 48,000 before present (bp) (Sharitz 2003). Strategraphic studies have also indicated that bays have been gradually filling for the last 4000-4500 years.

Carolina Bay plant associations are variable due to differing soils, water depth, hydroperiods, and successional history. Droughts every 10 to 30 years can shift species from aquatic macrophytes to wetland emergents and / or invasive upland species. Fires during times of drought can also burn holes in the peat layer and result in the establishment of new plant communities such as cane breaks and even Atlantic white cedar communities (*Chamaecyparis thyoides*) (Messina and Conner, 1998). NCWAM (2008) considers two wetland types to be associated with Carolina Bays (Small-Basin Wetland and Pocosin) while Schafale and Weakley (1990) recognizes nine wetland communities to be associated with Carolina Bays (Small Depression Pocosin, High Pocosin, Low Pocosin, Cypress Savannah, Bay Forests, Peatland Atlantic White Cedar Forest, Pond Pine Woodland, Small Depression Pond, and Natural Lake Shore. [Schafale and Weakley, 1990]). In the Lockwood Folly River watershed, the 2007 and 2008 drought has enabled upland volunteers (e.g. *Eupatorium caprillifollium*, *Erechtites hieraciifolia* and *Pinus taeda* seedlings) to establish themselves in areas that had once deep open water or populations of aquatics plants (such as water lily [*Nymphaea odorata*] at the Seawatch and Sikka sites. The basin sites have been dry or nearly dry since the summer of 2007. Figures 6.1-1a and 6.1-1b show pre-drought conditions and 2007-2008 existing drought conditions at the Seawatch site.

Carolina Bay soils range from highly organic to predominantly mineral. Most Bays are underlain with sand, alternating with layers of impervious clay, which hinder groundwater movement. Bays can have stagnant or very slow sheet flow. It is rare that bays are flushed completely thus organic matter such as peats and mucks accumulate (Messina and Connor, 1998). Soils are generally histosols or fine to course textured mineral soils. Bay soils can have loam overlying loamy sand or sand. Additionally farther into the interior of the Coastal Plain loam, often sand clay loam, clay loam or clay are prevalent. Organic peat deposits range from less than 1cm thick to 200 cm thick with thicker deposits found closer to the coast (Sharitz 2003). Organic deposits also tend to be thicker in the center of bays. All bays also have a characteristic southeastern, upland, sandy rim. Organic histosol bays occur on the Croatan, Mattamuskeet, and Pamlico soil series while the more mineral Coastal Plain interior bays tend to be of the Byars, Pantego, Torhunta, Coxville, McColl or Rains soil series. The Lockwood Folly River sites were all mapped on sand or loamy soils including hydric soils Murville and Rains and upland soils with hydric inclusions; Kureb, Blanton, Baymeade, and Foreston.

The majority of bays receive hydrological inputs through precipitation. Also evidence suggests suggests that some bays have subsurface lateral flow and a few have artesian water sources. Bays store surface water during storm events and periods of heavy rainfall thereby reducing local flooding and slowly releasing surface water inputs into local groundwater. Some bays are seasonally wet or have permanent to semi-permanent ponds that dry only during droughts (Sharitz 2003). Water levels fluctuate between season and among years depending on rainfall pattern. The fluctuating inputs and losses of Carolina Bays result in a water table that fluctuates between one to two meters above to one meter below the surface (Messina and Conner, 1998). The 2007 and 2008 drought easily had fluctuations within this range at the Lockwood Folly River Carolina Bay study sites. The Seawatch Bay site probably had the most drastic water table fluctuations as indicated by 10-foot high water marks in the cypress trees and dry monitoring wells (see Figure 6.1-1a and 6.1-1b). Carolina Bays typically fill with water during the cooler winter season when there are moderate rain levels, which is followed by a decline in the water table as the warmer weather promoting evaporation and growing season evapotranspiration. Sometimes late summer and early fall storm events re-flood the bays (Messina and Connor, 1998). However, timing and duration of hydroperiods can differ greatly among bays, even those in close proximity and hydroperiod is not necessarily a function of the size of the depression (Sharitz 2003). Ditching also has the capacity to alter the hydroperiod of Carolina Bays or any Small Basin wetland via surface drainage.

Various factors influence the water chemistry of bays including the location of the bay within the Coastal Plain, landscape and variation in shallow groundwater chemistry, weathering of underlying mineral substrates, paludification and associated accrual of organic substrates and the degree to which precipitation verses runoff or shallow ground water dominated hydrology. In addition, ditching into or out of a Carolina Bay or other Small Basin wetland can cause an unnatural rapid influx or output of contaminants. A heavy rainfall could cause rapid water movement into or out of a Carolina Bay or other Small Basin wetland without providing for proper diffuse flow of overland runoff or slow water retention that allows for transformation of pollutants. Carolina Bays generally contain ombrotrophic ponds that are acidic (median pH 4.6), variable in conductivity (32-320 µmhos/cm), and have dissolved organic carbon (DOC) values that range from 2.1 to 70 mg/L (Sharitz 2003, Messina and Connor 1998). The Lockwood Folly River Carolina bay sites were similar with a median pH of 4.1, specific conductivity was variable (46.6-243.5 µmhos/cm), and DOC values ranged from 17 to 100 mg/L. The Bluegreen Golf and Mill Creek sites, although not bays, fell within the ranges of the other sites for specific conductivity and DOC with pH being slightly more basic.

In the Piedmont, Small Basin wetlands are smaller more irregular in shape, and fewer in number. Piedmont upland pools, which are rarer then Piedmont Upland Depression Swamp Forests, are believed to slowly fill in over time and succeed to Upland Depression Swamp Forests. Upland Depression Swamp Forests are considered to be a climax community by Schafale and Weakley that form on mafic igneous or metamorphic rock parent material. High base levels in mafic rocks promote the formation of montmorillonite clays which inhibit drainage. These Small Basin wetlands can also form over acidic shales or harder rocks (Schafale and Weakley, 1990). In the Piedmont, Small Basin wetlands have variable soil types. Piedmont basins are commonly found in mafic depressions including two of the Fishing Creek sites; Belton Creek and Eastwood (NCWAM, 2008). The Fishing Creek sites occurred in hydric inclusions of upland soils that were mapped as Iredell, Lignun, Vance, Enon, Cecil, and Helena along interstream divides. In the Piedmont Small Basin wetlands, the median value of pH was more basic, 5.17, and specific conductivity ranged from 26.46-202.0 µmhos/cm, while DOC values ranged from 7.4-97 mg/L.

Small Basin wetlands are usually isolated although some do have natural stream inlets or outlets and many have been ditched, especially in the Coastal Plain. A study of 2651 SC bays showed that 97% had been disturbed, primarily by agriculture (71 %), logging (34%), or both. In some rapid growing areas like Brunswick County, development threats are a greater risk to the Carolina bays (Sharitz 2003). There are few unaltered bays in the Coastal Plain and preservation of many of those remaining will require natural fire or prescription burns to maintain their vegetation (Messina and Conner, 1998). Ditching of Small Basin wetlands is more unusual in the Piedmont. However basin wetlands are lost to development, due to their small size. The Fishing Creek watershed, as was discussed in Section 5.1, although not experiencing the population growth of the Lockwood Folly River watershed, is slated for roadway expansion work by NCDOT. Additionally, the North Carolina Department of Agriculture & Consumer Services near the city of Oxford plans $35,000 for the development of a biodiesel Feedstock Research plant. Others areas of the Piedmont, such as the Triangle, Triad, and Charlotte are experiencing faster population growth and development than in the Fishing Creek watershed around Oxford. At the Fishing Creek sites, one shallow ditch bisects the Goldston site, however this ditch does not connect with downstream waters. None of the other Fishing Creek Small Basin wetlands were ditched, although three of the sites (Eastwood, Belton Creek, and Hart sites) had been partially or completely logged. The Eastwood site also had a first order stream connection to downstream waters. In the Coastal Plain Lockwood Folly River sites, just one of the basin wetlands (the Sikka site) had a natural connection. The Mill Creek and Blue Green Golf sites had ditches that connected to downstream waters. The Seawatch Nautica site had an old and no longer hydrologically connected ditch on the West side.

Small Basin wetlands are a common type of isolated wetland in the Piedmont and Coastal Plain. Other types of potentially isolated NCWAM wetlands include some pocosins and seeps. Small Basin wetlands are often considered to be historically isolated wetlands but are no longer isolated due to ditching. Isolated wetlands are critically important ecosystems that can provide ecological value and hydrological function. 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, especially in regards to water quality and hydrology. Wetlands that are surrounded by uplands and have no obvious surface hydrologic connection have been traditionally called “isolated wetlands”. Tiner (2003) 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. Tiner also points out that there are no ecologically isolated wetlands as all ecosystems are connected. Studies have shown that isolated wetlands provide specialized habitat for numerous plant and animal species, including many at-risk species that require specific conditions associated with isolated wetlands to survive (Conner et al 2005).

A regional isolated wetland study of eight counties in the NC and SC Coastal Plain is currently being completed by RTI International (RTI 2009), the NC Center for Geographic Information and Analysis (CGIA), and the NC DWQ. This study found that of 170 sites that were potentially thought to be isolated 64 were historically isolated, 87 were never isolated, and 19 were never wetlands. Currently, 48 of the 170 sites were found to be isolated, however seven of those 48 were not historically isolated and had become isolated due to roadway or some other kind of development. Therefore only 41 of the 64 historically isolated wetlands were still isolated. This study plans to use this information to extrapolate the actual percentage of land coverage of isolated wetlands in this eight county NC and SC Coastal Plain area. NCDWQ's review of wetland 401 permits indicates that only 2.80 percent of permit applications in the last seven years are, in fact, for isolated wetlands, however only impacts greater than one acre require mitigation.

Isolated Small Basin wetlands rarely are completely isolated hydrologically as many of these systems are connected by groundwater flow. The degree of isolation is primarily controlled by the hydraulic conductivity of the geologic materials through which the groundwater flows from and to the wetland. Water can flow freely as if through pipes when passing through limestone, or gravel aquifers, while the rate may seem nearly imperceptible when passing through silt and clay. It should be noted, though, that isolated wetlands with the most impermeable sediments, as can be the case with Carolina bays, are the most likely to fill and spillover during times of high precipitation (Winter and LaBaugh 2003).

Isolated Small Basin wetlands can also have important water quality functions. Isolated wetlands have the potential to affect water quality since studies have shown these systems have direct hydrological interactions with other wetlands and uplands via groundwater and an intermittent surface water connection (Whigham and Jordan 2003). A survey of 49 bays in North and South Carolina (Newman and Schalles 1990) suggested that their waters were strongly influenced by shallow ground water. Water solutes (including contaminants) can seep from isolated wetlands into groundwater systems over weeks, months, or years (Winter and LaBaugh 2003). Isolated wetlands can act as a nutrient sink and alterations could cause negative impacts to downstream surface and groundwater quality (Whigham and Jordan 2003). Additionally, isolated wetlands that are ditched and receive upstream pollutant inputs at a higher rate due to the ditching may not be able properly filter and attenuate these pollutants thus resulting in impacts to the downstream water quality and aquatic habitat.

From an ecological perspective, the density and dispersion of Small Basin isolated wetlands in a landscape combined with the condition of the connecting upland corridor is vital for the survival of a number of wildlife species, especially amphibians that depend on geographically isolated wetlands for survival. Many frogs and salamanders require fish-free small depressional wetlands that dry out annually for larval stages (Leibowitz 2003). Nearly one-third of the 96 amphibian species found in NC need wetlands void of predators to survive (Braswell 2006). Many amphibians live terrestrial or fossorial lives in upland habitats and usually return to their natal wetlands. One study noted that of 93% amphibians return to their natal wetlands to breed while 7% dispersed (Scott, 1994). Many amphibians that depend on isolated wetlands for breeding also need healthy adjacent forested terrestrial habitat for some or all of their life cycles for nesting, hibernating aestivation, foraging, and migration (Gibbons, 2003). Small isolated depressional wetlands can support enormous numbers of metamorphosing amphibians. A one year study of two 2.5 ac clay-based bays in SC resulted in the capture of 72,000 immigrating or emigrating amphibians including nine species of salamander and sixteen species of frogs (Gibbons and Semlitsch, 1981; Messina and Conner 1998). These findings show that amphibians are a key wetland ecosystem component and have the potential to transfer significant amounts of energy between aquatic wetland systems and surrounding terrestrial habitats (Gibbons et al. 2005).

A number of factors related to isolated wetlands have been shown to affect wetland amphibian population density and diversity. Amphibian richness has a positive relationship between wetland hydroperiod but not wetland size (Sharitz, 2003). However, amphibian richness has been found to decrease with greater wetland isolation because a series of wetland complexes aid in the dispersal and recolonization of amphibians. The destruction of small isolated wetlands can have especially detrimental affects on amphibian dispersion, migration, and ultimately population size (Semlitsch and Bodie 1998). The condition of the wetland and surrounding habitat and connectivity to other nearby small isolated wetlands also can have a direct affect on species richness and population density. Ditching of wetlands, commonly been done in Carolina bays, has caused the potential introduction of predatory fish (Gibbons, 2003, NRCS, 2006). A dead fish was observed at the Mill Creek site in the Lockwood Folly River watershed, likely due to ditching. Mosquito control spraying and the use of wetlands for stormwater basins can also degrade water chemistry and have negative affects on existing amphibian populations (Tiner 2003).

Small Basin isolated wetlands can provide habitat for a rich array invertebrates. Many aquatic invertebrates also lay eggs in or near water and have larvae stages that require a fish-free wetland environment similar to amphibians. Invertebrates in particular are vital to the survival of a wetland habitat due to being at the base of the food chain (NRCS, 2006). Mahoney et al. (1990) researched 23 bays along the Savannah River and found 44 species of cladocerans and seven species of calanoid copepods plus a variety of aquatic and semi-aquatic insects. In another study, one bay was found to have more than 100 taxa (Leeper and Taylor, 1998; Sharitz 2003). In general, larger bays with longer hydroperiods support more taxa. Also, similarly to amphibians, ditching of isolated Small Basin wetlands and the use of mosquito control measures may negatively affect aquatic invertebrate populations and thus species higher on the food chain such as foraging amphibians, reptiles and birds that rely on aquatic invertebrates for food.

Many other species also utilize bays and other Small Basin wetlands and the contiguous upland habitat. Gibbons and Semlitsch (1981) found six species of turtles, nine species of lizards, 19 kinds of snakes, and 13 small mammal species during their one-year study of just two bays. Waterfowl utilize shallow isolated wetlands for high-energy seeds, tubers, and protein rich invertebrates. In colder climates, small isolated basins are of particular importance as they melt sooner than larger lakes and can provide habitat for migrating birds (NRCS, 2006). Isolated wetlands also support a significant number of rare species and have promoted a high degree of endemism in some regions of the country (Tiner 2003). A study by NatureServe (Comer 2005) cross referenced by the Natural Heritage Program (2009) indicated there is one obligate isolated wetland rare plant species and three facultative isolated wetland rare plant species (obligate – always associated with isolated wetlands, facultative – often associated with isolated wetlands) that are associated with isolated basin wetlands in Brunswick County (Lockwood Folly River) watershed. No rare isolated obligate or facultative species were found to exist in Granville County in this cross-referenced study (Comer 2005, NCNHP 2009).

The U.S. 2001 Supreme Court ruling on the Solid Waste Agency of Northern Cook County (SWANCC) case removed federal jurisdiction over isolated wetlands (SWANCC vs. ACOE et. al. 2001). The June 2006 Supreme Court ruling of the Rapanos/Carabell cases has further restricted jurisdiction over wetlands that lack a “significant nexus” to non-isolated water bodies (Rapanos and Carabell vs. ACOE 2006). A field definition of “significant nexus” is being implemented by the ACOE and EPA. The loss of federal protection of isolated and intermittently isolated wetlands has made implementing state level protection of isolated wetlands crucial. The North Carolina Environmental Management Commission (NC EMC) has adopted rules regulating the fill of isolated wetlands and isolated waters (15A NCAC 2H .1300). However, mitigation thresholds for all wetland types for NC are one-acre where as the mitigation threshold for ACOE isolated wetlands was generally 0.1 acre historically.

In the Lockwood Folly River watershed in Brunswick County, one of the sites (the Sikka site) has a natural connection, and two of the sites have man-made connections via ditching, (the Mill Creek and Bluegreen Golf sites). The Mill Creek site is close to the one-acre threshold at 1.02 acres. The previously discussed isolated wetland study being completed by RTI, CGIA, and DWQ found that of the 48 delineated wetlands only 17 (35%) were greater than one acre in size. Isolated wetlands in this study ranged in size from 0.002 acres to 20.9 acres with an average of 1.66 acres and median of 0.49 acres (RTI 2008). In the Fishing Creek watershed in Granville County, four of the six study sites are isolated. The Eastwood and Goldston sites were the only sites with a natural wetland connection. The Eastwood site was the largest Fishing Creek Small Basin wetland at 3.07 acres. The other four isolated Small Basin wetlands in the Fishing Creek study ranged from 0.42 to 1.05 acres; the Dean site was the only isolated wetland site that was greater than the one-acre mitigation threshold in Granville County. The continual impact and loss of isolated wetlands which provide a critical ecological and water quality function to the landscape can have significant affects on certain species of amphibians, rare plant species, and water quality. Additional scientific knowledge and understanding of these systems can be used to provide better protection and management.

Figure 6.1-1a Seawatch Bay August 2006, Pre-Drought Condition

Figure 6.1-1b Seawatch Bay October 2008, Drought Condition

Section 6.2 Small Basin Wetlands: Summary NCWAM Results

Table 6.2-1 shows the metrics, IBIs, and site ORAM scores that correlated with the NCWAM overall score and hydrology, water quality, and habitat NCWAM functions for Small Basin wetlands. The first column of Table 5.3.1-1 shows "Round" which refers to the pre (Round "1") and post (Round "2") survey results. Correlations with p-values that are < 0.05 and have r > 0.5 are shown in bold red and correlations with p-values > 0.05 and < 0.10 and have r > 0.5 are shown in bold blue. Plant metrics correlations occurred between NCWAM scores and four of the seven Small Basin wetland plant metrics and the plant IBI but not with any of the amphibian metrics or amphibian IBI. The NCWAM habitat function correlated significantly with sapling density, large tree density, and standing snag importance (standing snags that provided habitat) and with the Small Basin wetland plant IBI score. The hydrology function also had significant correlations with sapling density, large tree density, and the plant IBI. In addition, the hydrology function also correlated with the FQAI (Floristic Quality Assessment Index), although weakly. Finally, the overall NCWAM score correlated with large tree density, standing snag importance, and with the plant IBI. Most of these correlations were positive correlations except sapling density which would be expected. The ORAM site mean score also correlated significantly with the NCWAM overall score, habitat and hydrology functions for both statistical tests and rounds (see Table 6.2-1). There were no significant correlations with the water quality, soil, or amphibian Level III data or with the LDI Level III data. Similar to the NCWAM results for the Riverine Swamp Forest and Bottomland Hardwood Forest, there was little difference between the two statistical analyses for the "rounds" (pre and post survey). However, with the Small Basin wetlands, the pre and post survey results (round 1 and 2) were exactly the same. Metrics for plant community structure that are more easily observable during a rapid assessment like sapling density, large tree density, and standing snag importance had significant results which indicates the habitat function NCWAM metric is working appropriately. Also the fact that the habitat function correlated with the overall plant IBI is a significant finding.

The variation of the scores for the Small Basin wetlands was not very broad with the overall NCWAM score being high for nine Small Basin wetlands and medium for three others. The water quality function varied for only one site and there were not significant correlations. There was some variation in the scores for the habitat function and the hydrology functions as there were several statistically significant correlations. Again the results taken "as is" could be considered disappointing. However, a larger sample size with more wetlands needed at the low value will be needed. DWQ plans to collect these data with the new EPA grant (on monitoring and determining the connectivity of Isolated Wetlands and is underway) in order to calibrate NCWAM for this wetland type.

Table 6.2-1 NCWAM Correlation with Level III Significant Results for Small Basin Wetlands

Round	Wetland Type	NCWAM Total / Function	L2, L3	Metric / IBI/ ORAM	r	Prob>|p|	Analysis
1	Small Basin Wetland	Habitat-Function	L2-ORAM	ORAM Mean	**0.7486**	**0.0051**	Pearson's Correlation
2	Small Basin Wetland	Habitat-Function	L2-ORAM	ORAM Mean	**0.7486**	**0.0051**	Pearson's Correlation
1	Small Basin Wetland	Habitat-Function	L2-ORAM	ORAM Mean	**0.7135**	**0.0092**	Spearman's Rho Correlation
2	Small Basin Wetland	Habitat-Function	L2-ORAM	ORAM Mean	**0.7135**	**0.0092**	Spearman's Rho Correlation
1	Small Basin Wetland	Habitat-Function	L3-Plants	Sapling Density	-0.4719	0.1428	Spearman's Rho Correlation
2	Small Basin Wetland	Habitat-Function	L3-Plants	Sapling Density	-0.4719	0.1428	Spearman's Rho Correlation
1	Small Basin Wetland	Habitat-Function	L3-Plants	Large Tree Density	**0.6690**	**0.0244**	Spearman's Rho Correlation
2	Small Basin Wetland	Habitat-Function	L3-Plants	Large Tree Density	**0.6690**	**0.0244**	Spearman's Rho Correlation
1	Small Basin Wetland	Habitat-Function	L3-Plants	Plant IBI	**0.5662**	**0.0694**	Pearson's Correlation
2	Small Basin Wetland	Habitat-Function	L3-Plants	Plant IBI	**0.5662**	**0.0694**	Pearson's Correlation
1	Small Basin Wetland	Habitat-Function	L3-Plants	Plant IBI	0.4719	0.1428	Spearman's Rho Correlation
2	Small Basin Wetland	Habitat-Function	L3-Plants	Plant IBI	0.4719	0.1428	Spearman's Rho Correlation
1	Small Basin Wetland	Habitat-Function	L3-Plants	Standing Snag Importance	**0.6690**	**0.0244**	Spearman's Rho Correlation
2	Small Basin Wetland	Habitat-Function	L3-Plants	Standing Snag Importance	**0.6690**	**0.0244**	Spearman's Rho Correlation
1	Small Basin Wetland	Habitat-Function	L3-Plants	Standing Snag Importance	**0.5531**	**0.0776**	Pearson's Correlation
2	Small Basin Wetland	Habitat-Function	L3-Plants	Standing Snag Importance	**0.5531**	**0.0776**	Pearson's Correlation
1	Small Basin Wetland	Hydrology Function	L2-ORAM	ORAM Mean	**0.8690**	**0.0002**	Spearman's Rho Correlation
2	Small Basin Wetland	Hydrology Function	L2-ORAM	ORAM Mean	**0.8690**	**0.0002**	Spearman's Rho Correlation
1	Small Basin Wetland	Hydrology Function	L2-ORAM	ORAM Mean	**0.8529**	**0.0004**	Pearson's Correlation
2	Small Basin Wetland	Hydrology Function	L2-ORAM	ORAM Mean	**0.8529**	**0.0004**	Pearson's Correlation
1	Small Basin Wetland	Hydrology Function	L3-Plants	FQAI	0.5196	0.1014	Spearman's Rho Correlation
2	Small Basin Wetland	Hydrology Function	L3-Plants	FQAI	0.5196	0.1014	Spearman's Rho Correlation
1	Small Basin Wetland	Hydrology Function	L3-Plants	FQAI	0.4912	0.1249	Pearson's Correlation
2	Small Basin Wetland	Hydrology Function	L3-Plants	FQAI	0.4912	0.1249	Pearson's Correlation
1	Small Basin Wetland	Hydrology Function	L3-Plants	Sapling Density	**-0.5786**	**0.0622**	Pearson's Correlation
2	Small Basin Wetland	Hydrology Function	L3-Plants	Sapling Density	**-0.5786**	**0.0622**	Pearson's Correlation
1	Small Basin Wetland	Hydrology Function	L3-Plants	Large Tree Density	**0.8101**	**0.0025**	Spearman's Rho Correlation
2	Small Basin Wetland	Hydrology Function	L3-Plants	Large Tree Density	**0.8101**	**0.0025**	Spearman's Rho Correlation
1	Small Basin Wetland	Hydrology Function	L3-Plants	Large Tree Density	**0.7066**	**0.0151**	Pearson's Correlation
2	Small Basin Wetland	Hydrology Function	L3-Plants	Large Tree Density	**0.7066**	**0.0151**	Pearson's Correlation
1	Small Basin Wetland	Hydrology Function	L3-Plants	Plant IBI	**0.6121**	**0.0453**	Pearson's Correlation

Table 6.2-1 NCWAM Correlation with Level III Significant Results for Small Basin Wetlands

Round	Wetland Type	NCWAM Total / Function	L2, L3	Metric / IBI/ ORAM	r	Prob>|ρ|	Analysis
2	Small Basin Wetland	Hydrology Function	L3-Plants	Plant IBI	**0.6121**	**0.0453**	Pearson's Correlation
1	Small Basin Wetland	Hydrology Function	L3-Plants	Plant IBI	0.5196	0.1014	Spearman's Rho Correlation
2	Small Basin Wetland	Hydrology Function	L3-Plants	Plant IBI	0.5196	0.1014	Spearman's Rho Correlation
1	Small Basin Wetland	NCWAM OverAll Score	L2-ORAM	ORAM Mean	**0.7562**	**0.0044**	Pearson's Correlation
2	Small Basin Wetland	NCWAM OverAll Score	L2-ORAM	ORAM Mean	**0.7562**	**0.0044**	Pearson's Correlation
1	Small Basin Wetland	NCWAM OverAll Score	L2-ORAM	ORAM Mean	**0.6969**	**0.0118**	Spearman's Rho Correlation
2	Small Basin Wetland	NCWAM OverAll Score	L2-ORAM	ORAM Mean	**0.6969**	**0.0118**	Spearman's Rho Correlation
1	Small Basin Wetland	NCWAM OverAll Score	L3-Plants	Large Tree Density	**0.6724**	**0.0234**	Spearman's Rho Correlation
2	Small Basin Wetland	NCWAM OverAll Score	L3-Plants	Large Tree Density	**0.6724**	**0.0234**	Spearman's Rho Correlation
1	Small Basin Wetland	NCWAM OverAll Score	L3-Plants	Plant IBI	0.5058	0.1124	Pearson's Correlation
2	Small Basin Wetland	NCWAM OverAll Score	L3-Plants	Plant IBI	0.5058	0.1124	Pearson's Correlation
1	Small Basin Wetland	NCWAM OverAll Score	L3-Plants	Standing Snag Importance	**0.6724**	**0.0234**	Spearman's Rho Correlation
2	Small Basin Wetland	NCWAM OverAll Score	L3-Plants	Standing Snag Importance	**0.6724**	**0.0234**	Spearman's Rho Correlation
1	Small Basin Wetland	NCWAM OverAll Score	L3-Plants	Standing Snag Importance	**0.5800**	**0.0614**	Pearson's Correlation
2	Small Basin Wetland	NCWAM OverAll Score	L3-Plants	Standing Snag Importance	**0.5800**	**0.0614**	Pearson's Correlation

Bold Red = Probility ≤ 0.05 and **Bold Blue** = Probility > 0.05 and ≤ 0.10, L2-Level 2, L3-Level 3

Section 6.3 Small Basin Wetlands: Water Quality Results and Discussion

For Small Basin wetlands, water quality samples were taken in the wetland. Where there was an obvious outlet, a second sample was taken at this location. Table 6.3-1 shows the means for each water quality parameter for each Small Basin wetland site by watershed. In looking at the table for the Lockwood Folly River (Brunswick County, Coastal Plain) Small Basin wetland sites, the ammonia levels were highest for the Seawatch Bay, Sikka, and Seawatch Nautica sites while the other three sites were quite a bit lower. Calcium had the highest levels at the Sikka site which was more than twice the level of the next highest, the Bluegreen Golf and Mill Creek sites. The Seawatch Nautical site had the highest levels of copper which was more than twice as high as the Sikka site, the next highest level. The rest of the sites have less than half the copper levels of the Sikka site. The Sikka and Seawatch Bay sites had the highest level of DO (percent and mg/L) with the Mill Creek site having the lowest level. For DOC, the lowest levels were recorded at the Bluegreen Golf site with the Mill Creek site having the next lowest. The other four sites were similar and had about twice the level of DOC as the Mill Creek site. The fecal coliform results had very large variation with the Sikka site having more that 10 times the level of the next highest, the Seawatch Nautica site. The Seawatch Nautica site had the highest lead level while the other five Small Basin wetlands in the Lockwood Folly River watershed had about the same levels. The Sikka site had the highest levels of magnesium with the Seawatch Nautica site the next highest. The highest levels of NO2+NO3 occurred at the Sikka site and the other five sites had virtually the same levels. The Martin Amment, Seawatch Nautica, and Seawatch Bay sites were the most acidic sites whereas the Bluegreen Golf site was the least acidic. Phosphorus levels were highest at the Seawatch Nautica site with the Sikka and Seawatch Bay sites having the next highest levels. Specific conductivity was highest at the Seawatch Nautica site, with the Sikka and Martin Amment sites with the next highest levels. For TKN, the Seawatch Nautica, Sikka, and Seawatch Bay sites had the highest levels respectively while the other three sites were similar and had lower levels. The Sikka site had the highest level of TOC which was about three times the levels of the other five sites. The highest level of TSS was at the Seawatch Nautica site which was more than four times the level of the next highest site, the Seawatch Bay site. Water temperatures varied quite significantly for a high of average of about 20^o C at the Seawatch Bay and Sikka sites to 6.7^o C at the Bluegreen Golf site. The higher water temperatures can be explained by greater exposure to sunlight by having largely open canopies. Finally, the Sikka and Seawatch Bay sites had the highest levels of zinc with the other four sites had less than half this level.

From these results for the Lockwood Folly River Small Basin wetlands, it appears that the lowest water quality was present at the Sikka and Seawatch Nautica sites. The best water quality was recorded at the Martin Amment, Bluegreen Golf, and Mill Creek sites. The Seawatch Bay site was about in the middle with respect to water quality. The most rural sites were the Martin Amment and Sikka sites while the Bluegreen Golf site is in the middle of the established community of Winding River. As with the previous results for Riverine Swamp Forests in Lockwood Folly River, location (rural, developed, etc.) does not seem to explain the water quality results.

Table 6.3-1 also shows the mean water quality results for the Small Basin wetlands in the Fishing Creek Watershed (Granville County, Piedmont). The ammonia levels were highest at the Dean site with the Eastwood and Goldston sites being next but significantly lower. For calcium, the same three sites had the highest levels, the Dean, Goldston, and Eastwood sites respectively with the Dargan site with the lowest level. The same three sites had the highest levels of copper, with order from highest being the Goldston, Dean, and Eastwood sites. The Dargan and Belton Creek sites had the lowest levels of copper. The percent DO was highest at the Hart site at about 85% with the Eastwood site next at just over 47% and the Dargan site at 30% (the same result occurs for DO in mg/L). The highest levels of DOC occurred at the Belton Creek site with the Dargan and Goldston sites having the next highest levels. The Eastwood site had the highest level of fecal coliform, nearly three times the level of the next highest site, the Belton Creek site. The Hart and Dargan sites had the lowest levels. Lead was highest at the Hart site with the Goldston site being the next highest. The Eastwood site had the highest level of magnesium with the Belton Creek site having the lowest. For NO2+NO3, the Dean site had the highest level with the Eastwood site having next highest. The most acidic sites were the Belton Creek and Dargan sites at a pH of 4.61 and the least acidic sites were the Eastwood (pH at 5.81) and Hart (pH at 5.73) sites. The Dean site had the highest level of phosphorus, which was more than twice the levels of the next highest, the Eastwood and Goldston sites. Specific conductivity was highest at the Eastwood and Dean sites and lowest at the Dargan and Belton Creek sites. The levels of TKN were highest at the Dean and Eastwood sites with the other four sites having similar, but lower results. The Goldston site had the highest level of TOC with the Belton Creek and Dargan sites having the next highest levels. The levels of TSS were highest at the Dargan site with the Hart and Eastwood site being next. Water temperature varied by 10^{o} C among the sites, with the Hart and Dargan sites being the warmest and the Goldston site having the lowest water temperature. For zinc, the Goldston site had significantly higher levels with the rest of the sites being more similar. The Dargan site had the lowest level of zinc.

The results for the Fishing Creek Small Basin wetlands showed the lowest water quality occurred at the Eastwood, Goldston, and Dean sites. Of these three sites, the Goldston site was the most urban, located near the busy intersection of I-85 and US 15. The Dean site was a ways upslope from this intersection and directly adjacent to a corn field on the East side. The Eastwood site was very rural, but had been recently logged. The best water quality occurred at the Hart and Dargan sites with the Belton Creek site being a little lower. All three of these sites were very rural and the Dargan site had the most intact buffer.

Small Basin wetlands were next compared between the two watersheds (and ecoregions) to see how they differed in terms of the water quality parameters. Table 6.3-2 shows the means for each water quality parameter by watershed. From observing this table, it appears that Ammonia, fecal coliform, and TSS are higher in Small Basin wetlands in the Lockwood Folly River watershed. DO is also higher in the Lockwood Folly River watershed. For Fishing Creek, calcium, copper and zinc appear to be higher. The pH is lower in the Lockwood Folly River watershed. The statistical analysis (again ANOVA and Wilcoxon) show a statistically significant result for calcium, with the lower levels in the Lockwood Folly River watershed (Wilcoxon, p-0.0005). Copper was also statistically significant and also with the lower levels in the Lockwood Folly River watershed (Wilcoxon, p=0.0001). DO was significantly higher, statistically, in the Lockwood Folly River watershed both in terms of percent (Wilcoxon, p=0.0029, ANOVA, p-0.0031) and mg/L (Wilcoxon, p=0.0187, ANOVA, p=0.0956). Magnesium was also statistically significant (Wilcoxon, p=0.0681) with the lower levels again in the Lockwood Folly River watershed, but the differences were very small. The Lockwood Folly River watershed also had the lower levels of phosphorus and was statistically significant (Wilcoxon, p=0.442). Zinc also was lower in the Lockwood Folly River watershed and was statistically significant compared to the Fishing Creek watershed (Wilcoxon, p=0.0003, ANOVA, p=0.0744). All of these results indicate that the Small Basin wetlands in the Lockwood Folly River watershed had better water quality than the Fishing Creek Small Basin wetlands as measured by these parameters. However, TOC was higher in the Lockwood Folly River watershed, which is inconsistent with better water quality (marginally significant, Wilcoxon, p=0.1455). Two other results of note is that specific conductivity was higher in the Lockwood Folly River watershed, being statistically significant (Wilcoxon, p=0.0272, ANOVA, p=0.0727). This result makes sense in that higher level of salinity (therefore causing the conductivity to be higher) would be expected on the Coastal Plain. Small Basin wetlands in the Lockwood Folly River watershed were also more acidic with a pH of 4.306 compared to Fishing Creek at a pH of 5.176. This result was also statistically significant (Wilcoxon, p=0.0001, ANOVA, p=0.0001).

The results comparing the Small Basin wetlands in the different watershed tend to indicate that the Small Basin Wetlands in the Lockwood Folly River watershed have better water quality than in the Fishing Creek watershed. Whether that indicates that the Small Basin wetlands are functioning better than the Fishing Creek Small Basin wetlands is difficult to conclude because the input into these systems is not known and only two Small Basin wetlands had clear outlet where water samples were collect, (see below). It is also interesting to note that the Lockwood Folly River watershed is being more intensely developed than the Fishing Creek watershed so it would seem somewhat surprising that the water quality appears to be better. However it could be that the development that has occurred in the Fishing Creek watershed is older whereas the development in Lockwood Folly River is more recent, so this could be a factor in the results. This result also could be a characteristic that exists between the Piedmont and Coastal Plain, and future research will need to note this difference and determine if such a difference exists. Two Small Basin wetlands in Fishing Creek (the Dean and Dargan sites) and two Small Basin wetlands in Lockwood Folly River (the Sikka and Seawatch Bay sites) are still being monitored and may shed some light on this difference as more data is collected.

One additional comparison can be made with the Small Basin wetlands in Fishing Creek for the Eastwood and Goldston sites. These two sites had water samples taken at a clearly defined outlet, so some conclusions can be made about water quality as it flows though these Small Basin wetlands. Lower levels of potential pollutants would be expected at the outlet. It is also interesting to note that these two sites (along with the Dean site) had lower water quality. Table 6.3-3 shows the results by station (wetland versus outlet) for each water quality parameter for the Eastwood and Goldston sites. From this table, it can be seen that ammonia is higher at the outlet. Calcium is lower at the outlet for the Goldston site and copper is lower at the outlet for both sites. The levels of copper are much lower at the outlet, especially for the Eastwood site. DO is higher at the outlet for the Eastwood site. DOC is lower at the outlet for the Eastwood site, but higher for the Goldston site. Fecal colliform is quite a bit lower at the outlet for the Eastwood site, but slightly higher for the Goldston site. Lead was a little higher at the outlet for the Goldston site whereas the magnesium levels were about the same. The level of NO2+NO3 was higher at the outlet for the Eastwood site. Phosphorus was significantly lower at the outlet for the Eastwood site. The levels of TKN and TOC were lower at the outlet for the Eastwood site and TOC was a higher at the outlet for the Goldston site. The levels of TSS was much lower at the outlet for the Eastwood site, but higher for the Goldston site. Zinc was also lower at the outlet for the Eastwood site. These results suggest that the Eastwood site is in fact improving the water quality where the results for Goldston are mixed at best. Given that these are Small Basin wetlands, flow through the system is slow and probably irregular. The slope at the Eastwood site was a little more obvious that at the Goldston site, so this may affect the results.

Table 6.3-4 shows the same water quality results for the wetland and outlet stations, but averaged across the two sites. This was done so that a statistical analysis can be done in order to draw some conclusions about Small Basin wetlands (at least in the Piedmont or Fishing Creek watersheds) rather than as individual systems as the previous results were showing (see Table 6.3-2). From this table, calcium is lower at the outlet and copper is much lower at the outlet. Fecal colliform is much lower at the outlet whereas lead is a little higher at the outlet. NO2+NO3 is higher at the outlet, but phosphorus is lower at the outlet. TKN and TOC are both lower at the outlet. Zinc is also a little lower at the outlet. Therefore it appears that Small Basin wetlands can improve water quality when there is some flow with an obvious outlet. Statistically, only two of the parameters were significant [Copper was lower at the outlet (Wilcoxon, p=0.0435) and Phosphorus was also lower at the outlet (Wilcoxon, p=0.1495)].

Overall for Small Basin wetlands, the Lockwood Folly River sites had better water quality that the Fishing Creek Small Basin sites. This result could be due the differences in wetlands, difference in location (different watersheds and ecoregion), differences in the type of adjacent development, or differences in the number of samples collected (there were more samples taken at the Fishing Creek sites). Two Small Basin wetlands in Fishing Creek had water samples taken at an outlet and the results indicate that some water quality parameters were improved (reduction in potential pollutants) s they flowed through the wetland system.

Table 6.3-1 Fishing Creek and Lockwood Folly Small Basin Wetland Mean and Median Results by Site.

Watershed	Site Name	N	Parameter	Mean	Median	Units
Lockwood Folly	Bluegreen Golf	1	Ammonia	0.02	0.02	mg/L
	Martin Amment	2	Ammonia	0.17	0.17	mg/L
	Mill Creek	2	Ammonia	0.02	0.02	mg/L
	Seawatch Bay	8	Ammonia	0.92	0.63	mg/L
	Seawatch Nautica	3	Ammonia	0.69	0.04	mg/L
	Sikka	9	Ammonia	0.83	0.02	mg/L
	Bluegreen Golf	1	Calcium	4	4	mg/L
	Martin Amment	2	Calcium	1.15	1.15	mg/L
	Mill Creek	2	Calcium	3.38	3.38	mg/L
	Seawatch Bay	8	Calcium	1.9	2.1	mg/L
	Seawatch Nautica	3	Calcium	2.07	1.4	mg/L
	Sikka	9	Calcium	8.51	5.5	mg/L
	Bluegreen Golf	1	Copper	2	2	ug/L
	Martin Amment	2	Copper	2	2	ug/L
	Mill Creek	2	Copper	2	2	ug/L
	Seawatch Bay	8	Copper	2.05	2	ug/L
	Seawatch Nautica	3	Copper	10.33	2	ug/L
	Sikka	9	Copper	4.11	2	ug/L
	Bluegreen Golf	1	Dissolved Oxygen (%)	45.8	45.8	%
	Martin Amment	2	Dissolved Oxygen (%)	25.9	25.9	%
	Mill Creek	2	Dissolved Oxygen (%)	15.85	15.85	%
	Seawatch Bay	8	Dissolved Oxygen (%)	74.23	64.8	%
	Seawatch Nautica	3	Dissolved Oxygen (%)	28.47	25.3	%
	Sikka	8	Dissolved Oxygen (%)	78.61	73.15	%
	Bluegreen Golf	1	Dissolved Oxygen (mg/L)	5.6	5.6	mg/L
	Martin Amment	2	Dissolved Oxygen (mg/L)	2.85	2.85	mg/L
	Mill Creek	2	Dissolved Oxygen (mg/L)	1.95	1.95	mg/L
	Seawatch Bay	8	Dissolved Oxygen (mg/L)	6.62	6.45	mg/L
	Seawatch Nautica	3	Dissolved Oxygen (mg/L)	3.13	2.3	mg/L
	Sikka	8	Dissolved Oxygen (mg/L)	6.94	6.9	mg/L
	Bluegreen Golf	1	DOC	4.9	4.9	mg/L
	Martin Amment	2	DOC	38	38	mg/L
	Mill Creek	2	DOC	17.25	17.25	mg/L
	Seawatch Bay	8	DOC	33.38	34	mg/L
	Seawatch Nautica	3	DOC	37.33	38	mg/L
	Sikka	9	DOC	39.78	34	mg/L
	Bluegreen Golf	1	Fecal Colliform	1	1	CFU/100 ml
	Martin Amment	2	Fecal Colliform	1	1	CFU/100 ml
	Mill Creek	2	Fecal Colliform	9	9	CFU/100 ml
	Seawatch Bay	8	Fecal Colliform	29.88	8.5	CFU/100 ml
	Seawatch Nautica	3	Fecal Colliform	246.33	8	CFU/100 ml
	Sikka	9	Fecal Colliform	37951.44	73	CFU/100 ml
	Bluegreen Golf	1	Lead	10	10	ug/L
	Martin Amment	2	Lead	10	10	ug/L
	Mill Creek	2	Lead	10	10	ug/L
	Seawatch Bay	8	Lead	10	10	ug/L
	Seawatch Nautica	3	Lead	25.33	10	ug/L
	Sikka	9	Lead	10.89	10	ug/L
	Bluegreen Golf	1	Magnesium	1.2	1.2	mg/L
	Martin Amment	2	Magnesium	1.6	1.6	mg/L
	Mill Creek	2	Magnesium	0.85	0.85	mg/L
	Seawatch Bay	8	Magnesium	1.24	1.35	mg/L
	Seawatch Nautica	3	Magnesium	2.8	2	mg/L

Table 6.3-1 Fishing Creek and Lockwood Folly Small Basin Wetland Mean and Median Results by Site.

Watershed	Site Name	N	Parameter	Mean	Median	Units
Lockwood Folly	Sikka	9	Magnesium	3.91	3.4	mg/L
	Bluegreen Golf	1	NO2+NO3	0.02	0.02	mg/L
	Martin Amment	2	NO2+NO3	0.02	0.02	mg/L
	Mill Creek	2	NO2+NO3	0.02	0.02	mg/L
	Seawatch Bay	8	NO2+NO3	0.03	0.02	mg/L
	Seawatch Nautica	3	NO2+NO3	0.02	0.02	mg/L
	Sikka	9	NO2+NO3	0.64	0.02	mg/L
	Bluegreen Golf	1	pH	5.41	5.41	S.U.
	Martin Amment	2	pH	3.77	3.77	S.U.
	Mill Creek	2	pH	4.72	4.72	S.U.
	Seawatch Bay	8	pH	4.06	4.04	S.U.
	Seawatch Nautica	3	pH	3.86	3.89	S.U.
	Sikka	9	pH	4.58	4.65	S.U.
	Bluegreen Golf	1	Phosphorus	0.03	0.03	mg/L
	Martin Amment	2	Phosphorus	0.05	0.05	mg/L
	Mill Creek	2	Phosphorus	0.06	0.06	mg/L
	Seawatch Bay	8	Phosphorus	0.23	0.11	mg/L
	Seawatch Nautica	3	Phosphorus	0.71	0.12	mg/L
	Sikka	9	Phosphorus	0.44	0.18	mg/L
	Bluegreen Golf	1	Specific Conductivity	62.6	62.6	uS/cm
	Martin Amment	2	Specific Conductivity	100.3	100.3	uS/cm
	Mill Creek	2	Specific Conductivity	53.4	53.4	uS/cm
	Seawatch Bay	7	Specific Conductivity	71.87	74.9	uS/cm
	Seawatch Nautica	3	Specific Conductivity	157.93	131.8	uS/cm
	Sikka	9	Specific Conductivity	136.83	142.1	uS/cm
	Bluegreen Golf	1	TKN	0.77	0.77	mg/L
	Martin Amment	2	TKN	1.32	1.32	mg/L
	Mill Creek	2	TKN	0.93	0.93	mg/L
	Seawatch Bay	8	TKN	3.05	2.15	mg/L
	Seawatch Nautica	3	TKN	4.09	2	mg/L
	Sikka	9	TKN	3.88	2.4	mg/L
	Bluegreen Golf	2	TOC	11.45	11.45	mg/L
	Martin Amment	2	TOC	38	38	mg/L
	Mill Creek	2	TOC	19.75	19.75	mg/L
	Seawatch Bay	8	TOC	47	44	mg/L
	Seawatch Nautica	3	TOC	178.33	48	mg/L
	Sikka	9	TOC	58	40	mg/L
	Bluegreen Golf	1	Total Suspended Residue	20	20	mg/L
	Martin Amment	2	Total Suspended Residue	16.6	16.6	mg/L
	Mill Creek	2	Total Suspended Residue	10	10	mg/L
	Seawatch Bay	8	Total Suspended Residue	110.81	63	mg/L
	Seawatch Nautica	3	Total Suspended Residue	439	12	mg/L
	Sikka	9	Total Suspended Residue	51.33	29	mg/L
	Bluegreen Golf	1	Water, Temperature	6.7	6.7	oC
	Martin Amment	2	Water, Temperature	16.2	16.2	oC
	Mill Creek	2	Water, Temperature	11.25	11.25	oC
	Seawatch Bay	8	Water, Temperature	20.85	22.7	oC
	Seawatch Nautica	3	Water, Temperature	13.23	15.5	oC
	Sikka	9	Water, Temperature	20.23	18.9	oC
	Bluegreen Golf	1	Zinc	10	10	ug/L
	Martin Amment	2	Zinc	10.5	10.5	ug/L
	Mill Creek	2	Zinc	13	13	ug/L
	Seawatch Bay	8	Zinc	10.5	10	ug/L
	Seawatch Nautica	3	Zinc	24.33	10	ug/L
	Sikka	9	Zinc	23.56	15	ug/L

Table 6.3-1 Fishing Creek and Lockwood Folly Small Basin Wetland Mean and Median Results by Site.

Watershed	Site Name	N	Parameter	Mean	Median	Units
Fishing Creek	Belton Creek	4	Ammonia	0.03	0.02	mg/L
	Dargan	7	Ammonia	0.03	0.02	mg/L
	Dean	5	Ammonia	1.41	0.07	mg/L
	Eastwood	7	Ammonia	0.38	0.05	mg/L
	Goldston	5	Ammonia	0.23	0.05	mg/L
	Hart	3	Ammonia	0.04	0.02	mg/L
	Belton Creek	4	Calcium	4.1	3.9	mg/L
	Dargan	7	Calcium	2.63	2.5	mg/L
	Dean	6	Calcium	9.12	7.65	mg/L
	Eastwood	7	Calcium	7.84	5.7	mg/L
	Goldston	5	Calcium	8.5	6.9	mg/L
	Hart	3	Calcium	5.6	5.1	mg/L
	Belton Creek	4	Copper	2.85	2.05	ug/L
	Dargan	7	Copper	2.8	2.9	ug/L
	Dean	6	Copper	7.48	4.55	ug/L
	Eastwood	7	Copper	6.7	2.9	ug/L
	Goldston	5	Copper	8.1	4.6	ug/L
	Hart	3	Copper	4.43	4	ug/L
	Belton Creek	4	Dissolved Oxygen (%)	17.93	18.55	%
	Dargan	7	Dissolved Oxygen (%)	30.03	19.5	%
	Dean	6	Dissolved Oxygen (%)	10.73	9.5	%
	Eastwood	7	Dissolved Oxygen (%)	47.7	41.8	%
	Goldston	5	Dissolved Oxygen (%)	15.64	4.8	%
	Hart	3	Dissolved Oxygen (%)	85.07	92.2	%
	Belton Creek	4	Dissolved Oxygen (mg/L)	1.78	1.75	mg/L
	Dargan	7	Dissolved Oxygen (mg/L)	3.3	1.8	mg/L
	Dean	6	Dissolved Oxygen (mg/L)	1.19	0.94	mg/L
	Eastwood	7	Dissolved Oxygen (mg/L)	7.5	6.1	mg/L
	Goldston	5	Dissolved Oxygen (mg/L)	1.34	0.67	mg/L
	Hart	3	Dissolved Oxygen (mg/L)	8.08	9.8	mg/L
	Belton Creek	4	DOC	60.5	51.5	mg/L
	Dargan	6	DOC	44.17	44.5	mg/L
	Dean	6	DOC	30.17	29.5	mg/L
	Eastwood	7	DOC	24.24	16	mg/L
	Goldston	3	DOC	38.33	27	mg/L
	Hart	3	DOC	33.63	42	mg/L
	Belton Creek	4	Fecal Colliform	81.75	3	CFU/100 ml
	Dargan	7	Fecal Colliform	11.71	6	CFU/100 ml
	Dean	6	Fecal Colliform	32.83	11	CFU/100 ml
	Eastwood	7	Fecal Colliform	213.71	64	CFU/100 ml
	Goldston	5	Fecal Colliform	20.8	11	CFU/100 ml
	Hart	3	Fecal Colliform	6.67	8	CFU/100 ml
	Belton Creek	4	Lead	10	10	ug/L
	Dargan	7	Lead	10	10	ug/L
	Dean	6	Lead	10	10	ug/L
	Eastwood	7	Lead	10.71	10	ug/L
	Goldston	5	Lead	12.6	10	ug/L
	Hart	3	Lead	14.67	10	ug/L
	Belton Creek	4	Magnesium	1.43	1.25	mg/L
	Dargan	7	Magnesium	1.99	1.7	mg/L
	Dean	6	Magnesium	2.47	2.15	mg/L
	Eastwood	7	Magnesium	3.09	2.2	mg/L
	Goldston	5	Magnesium	2.64	2.4	mg/L
	Hart	2	Magnesium	2.8	2.8	mg/L
	Belton Creek	4	NO2+NO3	0.02	0.02	mg/L

Table 6.3-1 Fishing Creek and Lockwood Folly Small Basin Wetland Mean and Median Results by Site.

Watershed	Site Name	N	Parameter	Mean	Median	Units
Fishing Creek	Dargan	7	NO2+NO3	0.02	0.02	mg/L
	Dean	5	NO2+NO3	1.32	0.02	mg/L
	Eastwood	7	NO2+NO3	0.33	0.02	mg/L
	Goldston	5	NO2+NO3	0.02	0.02	mg/L
	Hart	3	NO2+NO3	0.02	0.02	mg/L
	Belton Creek	4	pH	4.61	4.65	S.U.
	Dargan	7	pH	4.61	4.6	S.U.
	Dean	6	pH	5.42	5.58	S.U.
	Eastwood	7	pH	5.81	6	S.U.
	Goldston	5	pH	4.91	5.2	S.U.
	Hart	3	pH	5.73	5.98	S.U.
	Belton Creek	4	Phosphorus	0.12	0.13	mg/L
	Dargan	7	Phosphorus	0.14	0.12	mg/L
	Dean	5	Phosphorus	1.02	0.74	mg/L
	Eastwood	7	Phosphorus	0.42	0.11	mg/L
	Goldston	5	Phosphorus	0.42	0.22	mg/L
	Hart	3	Phosphorus	0.25	0.22	mg/L
	Belton Creek	4	Specific Conductivity	48.6	44.15	uS/cm
	Dargan	6	Specific Conductivity	35.73	42.95	uS/cm
	Dean	6	Specific Conductivity	122.98	103.45	uS/cm
	Eastwood	3	Specific Conductivity	157.83	169	uS/cm
	Goldston	5	Specific Conductivity	72.5	72.8	uS/cm
	Hart	3	Specific Conductivity	61.67	61	uS/cm
	Belton Creek	4	TKN	1.83	1.85	mg/L
	Dargan	7	TKN	2.33	2.3	mg/L
	Dean	5	TKN	4.78	2.3	mg/L
	Eastwood	7	TKN	3.62	2.6	mg/L
	Goldston	5	TKN	2.66	2.4	mg/L
	Hart	3	TKN	2.16	2.6	mg/L
	Belton Creek	4	TOC	65.25	59	mg/L
	Dargan	7	TOC	58.43	60	mg/L
	Dean	6	TOC	43.17	32	mg/L
	Eastwood	8	TOC	38.93	14.5	mg/L
	Goldston	5	TOC	67.6	46	mg/L
	Hart	3	TOC	42.67	46	mg/L
	Belton Creek	4	Total Suspended Residue	32.7	29	mg/L
	Dargan	7	Total Suspended Residue	105.29	63	mg/L
	Dean	6	Total Suspended Residue	32.17	18	mg/L
	Eastwood	7	Total Suspended Residue	76.29	37	mg/L
	Goldston	5	Total Suspended Residue	121	60	mg/L
	Hart	3	Total Suspended Residue	86.67	26	mg/L
	Belton Creek	4	Water, Temperature	14.05	16.4	oC
	Dargan	7	Water, Temperature	17.81	17.8	oC
	Dean	6	Water, Temperature	11.55	10.8	oC
	Eastwood	7	Water, Temperature	11.07	7.7	oC
	Goldston	5	Water, Temperature	9.96	11.7	oC
	Hart	3	Water, Temperature	19.03	17.2	oC
	Belton Creek	4	Zinc	19.25	19.5	ug/L
	Dargan	7	Zinc	17.14	17	ug/L
	Dean	6	Zinc	27.92	28.5	ug/L
	Eastwood	7	Zinc	20.29	19	ug/L
	Goldston	5	Zinc	47.2	27	ug/L
	Hart	3	Zinc	24.67	18	ug/L

Table 6.3-2 Mean Water Quality Results for Small Basin Wetlands by Watershed

Parameter	Lockwood Folly N	Mean (Lockwood Folly River)	Fishing Creek N	Mean (Fishing Creek)
Ammonia (mg/L)	25	0.693	31	0.366
Calcium (mg/L)	25	4.442	32	6.366
Copper (ug/L)	25	3.776	32	5.519
Dissolved Oxygen (%)	24	59.892	32	31.675
Dissolved Oxygen (mg/L)	24	5.544	32	3.774
DOC (mg/L)	25	34.096	29	37.021
Fecal Colliform (CFU/100 ml)	25	13702.48	32	69.563
Lead (ug/L)	25	12.16	32	11
Magnesium (mg/L)	25	2.385	31	2.413
NO2+NO3 (mg/L)	25	0.245	31	0.3
pH (S. U.)	25	4.306	32	5.176
Phosphorus (mg/L)	25	0.329	31	0.398
Specific Conductivity (uS/cm)	24	107.433	27	80.284
TKN (mg/L)	25	3.074	31	2.988
TOC (mg/L)	26	60.438	33	51.709
Total Suspended Residue (mg/L)	25	109.548	32	76.869
Water, Temperature (oC)	25	18.008	32	13.581
Zinc (ug/L)	25	17.04	32	25.516
Zinc	25	0.693	31	0.366

Table 6.3-3 Fishing Creek Water Quality Comparison of Means for Small Basin Wetland and Outlet Results

Site Name	**Parameter**	**N - Wetland**	**Wetland Mean**	**N - Wetland Outlet**	**Wetland Outlet Mean**	**Units**
Eastwood	Ammonia	4	0.4	3	0.37	mg/L
Goldston	Ammonia	2	0.05	3	0.36	mg/L
Eastwood	Calcium	4	8.03	3	7.6	mg/L
Goldston	Calcium	2	9.95	3	7.53	mg/L
Eastwood	Copper	4	10.23	3	2	ug/L
Goldston	Copper	2	9.8	3	6.97	ug/L
Eastwood	Dissolved Oxygen (%)	4	39	3	59.3	%
Goldston	Dissolved Oxygen (%)	2	19.65	3	12.97	%
Eastwood	Dissolved Oxygen (mg/L)	4	7.53	3	7.47	mg/L
Goldston	Dissolved Oxygen (mg/L)	2	1.67	3	1.12	mg/L
Eastwood	DOC	4	28.33	3	18.8	mg/L
Goldston	DOC	1	27	2	44	mg/L
Eastwood	Fecal Colliform	4	350	3	32	CFU/100 ml
Goldston	Fecal Colliform	2	10	3	28	CFU/100 ml
Eastwood	Lead	4	11.25	3	10	ug/L
Goldston	Lead	2	10	3	14.33	ug/L

Table 6.3-3 Fishing Creek Water Quality Comparison of Means for Small Basin Wetland and Outlet Results

Site Name	Parameter	N - Wetland	Wetland Mean	N - Wetland Outlet	Wetland Outlet Mean	Units
Eastwood	Magnesium	4	2.9	3	3.33	mg/L
Goldston	Magnesium	2	2.75	3	2.57	mg/L
Eastwood	NO2+NO3	4	0.13	3	0.61	mg/L
Goldston	NO2+NO3	2	0.02	3	0.02	mg/L
Eastwood	pH	4	5.8	3	5.84	S.U.
Goldston	pH	2	4.72	3	5.03	S.U.
Eastwood	Phosphorus	4	0.68	3	0.07	mg/L
Goldston	Phosphorus	2	0.36	3	0.46	mg/L
Eastwood	Specific Conductivity	2	136.45	1	200.6	uS/cm
Goldston	Specific Conductivity	2	76	3	70.17	uS/cm
Eastwood	TKN	4	5.2	3	1.52	mg/L
Goldston	TKN	2	2.95	3	2.47	mg/L
Eastwood	TOC	4	60.48	4	17.38	mg/L
Goldston	TOC	2	58	3	74	mg/L
Eastwood	Total Suspended Residue	4	117.5	3	21.33	mg/L
Goldston	Total Suspended Residue	2	57.5	3	163.33	mg/L
Eastwood	Water, Temperature	4	10.78	3	11.47	oC
Goldston	Water, Temperature	2	7.35	3	11.7	oC
Eastwood	Zinc	4	28	3	10	ug/L
Goldston	Zinc	2	45.5	3	48.33	ug/L

Table 6.3-4 Water Quality Means by Station (Eastwood and Goldston)

Parameter	N	Mean(Outlet)	Mean(Wetland)
Ammonia (mg/L)	12	0.363	0.280
Calcium (mg/L)	12	7.567	8.667
Copper (ug/L)	12	4.483	10.083
Dissolved Oxygen (%)	12	36.133	32.550
Dissolved Oxygen (mg/L)	12	4.295	5.572
DOC (mg/L)	10	28.880	28.060
Fecal Colliform (CFU/100 ml)	12	30.000	236.667
Lead (ug/L)	12	12.167	10.833
Magnesium (mg/L)	12	2.950	2.850
NO2+NO3 (mg/L)	12	0.317	0.090
pH (S. U.)	12	5.435	5.437
Phosphorus (mg/L)	12	0.265	0.575
Specific Conductivity (uS/cm)	8	102.775	106.225
TKN (mg/L)	12	1.992	4.450
TOC (mg/L)	13	41.643	59.650
Total Suspended Residue (mg/L)	12	92.333	97.500
Water, Temperature (oC)	12	11.583	9.633
Zinc (ug/L)	12	29.167	33.833

Section 6.4 Small Basin Wetlands: Hydrology Results and Discussion

Hydrographs for the Small Basin Wetlands at the Lockwood Folly River watershed are shown in Figures 6.4-1 thru 6.4-6. The hydrographs show electronic depth of the water in the well, where zero on the y-axis is the bottom of the well as measured by the transducer. The red line indicates ground level and the blue line indicates one foot below the surface in the Small Basin wetland hydrographs. As the water level increases, it approaches the surface as indicated by the curves. The surface ground levels varied slightly between the sites, but were generally at about 21-25 inches. Some gaps in the data exist that are caused by technical difficulties with the transducers or errors in downloading the data. In Figure 6.4-1, the Bluegreen Golf site generally shows a flashy pattern, driven by precipitation and possibly by the maintenance of the golf course surrounding the site. The rest of the Small Basin wetland sites at Lockwood Folly River watershed show the effects of a significant drought that started soon after the well transducers were installed. The Martin-Amment site is very dry except for a period between February and June of 2008. Figure 6.4-3 for the Mill Creek site and Figure 6.4-4 for the Seawatch Bay site show that there were water levels when the recording first started, but then the drought started and they have no water during the rest of the recording period. The Seawatch Nautica site (see Figure 6.4-5) reflects the drought, but has a nearly identical increase in water levels as did the Martin-Amment site during late winter to the late spring months. Finally, the Sikka site (see Figure 6.4-6) shows there was a big drop at the start of the drought, but does show some variations due to precipitation.

Table 6.4-1 shows the Small Basin wetland hydrology as the percent of the time the water depth was within on foot of the surface, with the second column showing the growing season only. These Small Basin wetlands were within one foot of the surface during the growing season just over 12% on average with the range being 0.03% minimum at the Mill Creek site and just over 22% maximum at the Martin-Amment site. The drought clearly affected these wetlands, so the data are probably not reflective of their true nature. Two of these wetlands (the Sikka and Seawatch Bay sites) are still being monitored (part of the long term monitoring effort), so future hydrology data from these two site may result in more accurate data.

For the Small Basin wetlands at the Lockwood Folly River watershed, the Mill Creek, Seawatch Bay, and Sikka sites clearly show the big drops in water levels when the drought started. The Bluegreen Golf site hydrograph shows some initial signs of drought; however, this wetland appears to be very flashy and is in the middle of a golf course and residential development where irrigation may have supplemented its hydrology. The Martin-Amment and Seawatch Nautica sites seem to show the drought pattern, but had an interesting period with water levels being recorded during the spring of 2008 even during the drought.

Figure 6.3 – 1 Small Basin Wetland: Bluegreen

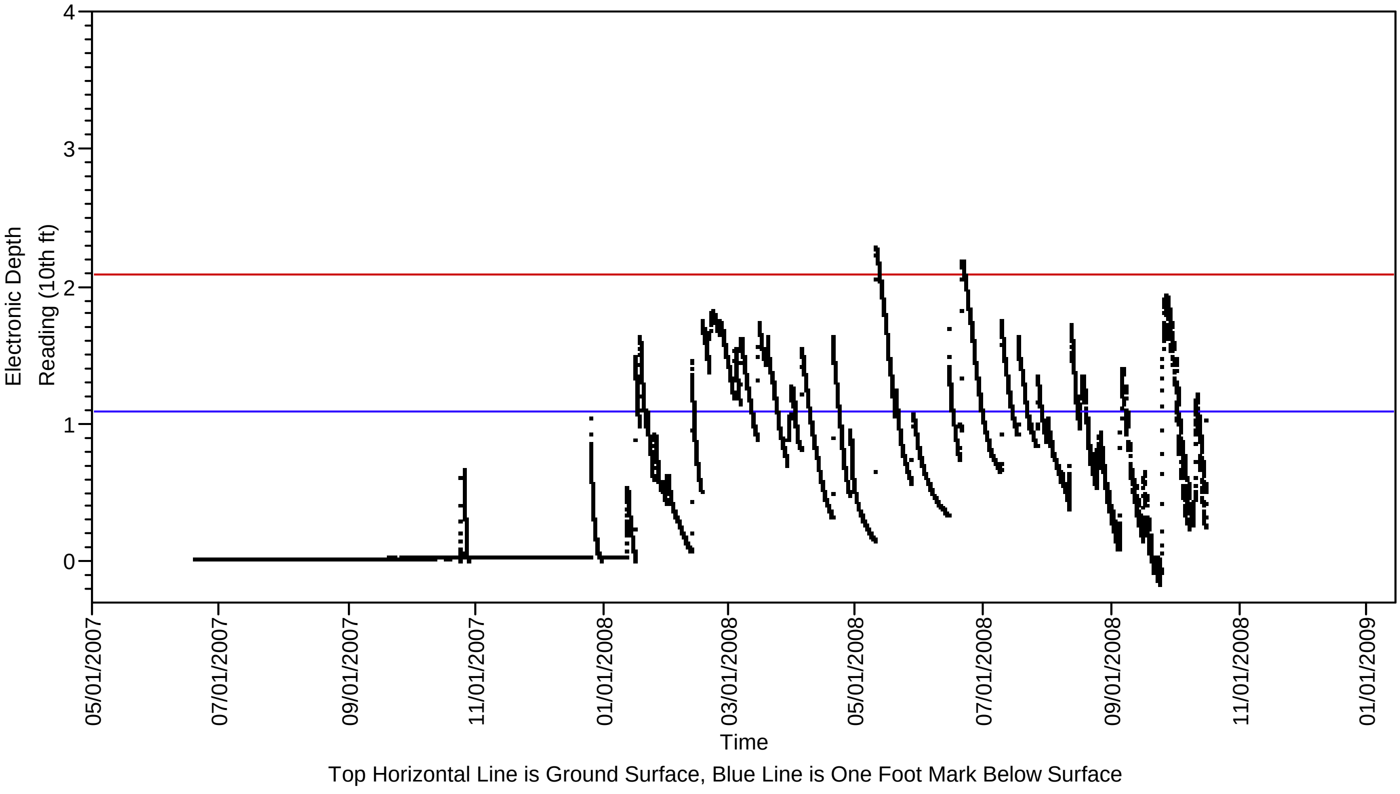


Figure 6.3 – 2 Small Basin Wetland: Martin-Amment

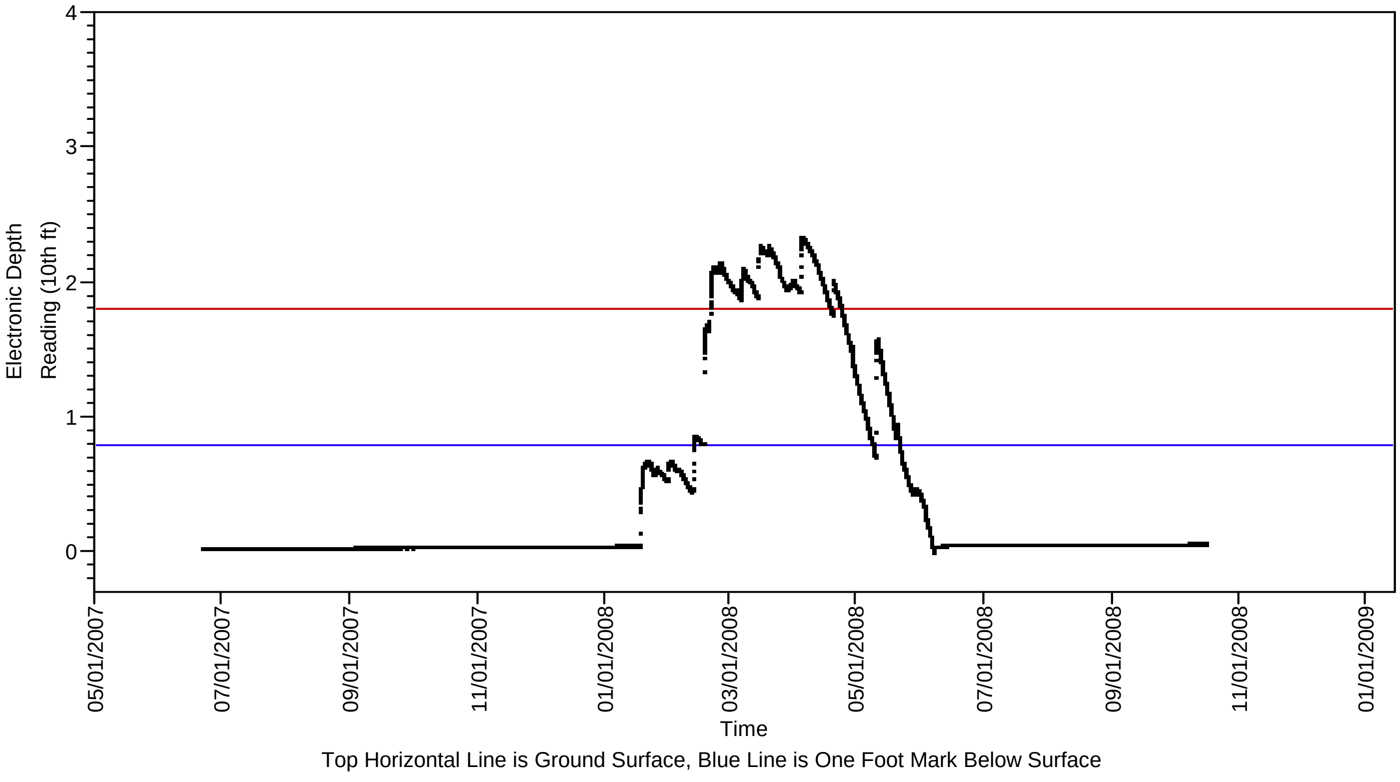


Figure 6.3 – 3 Small Basin Wetland: Mill Creek

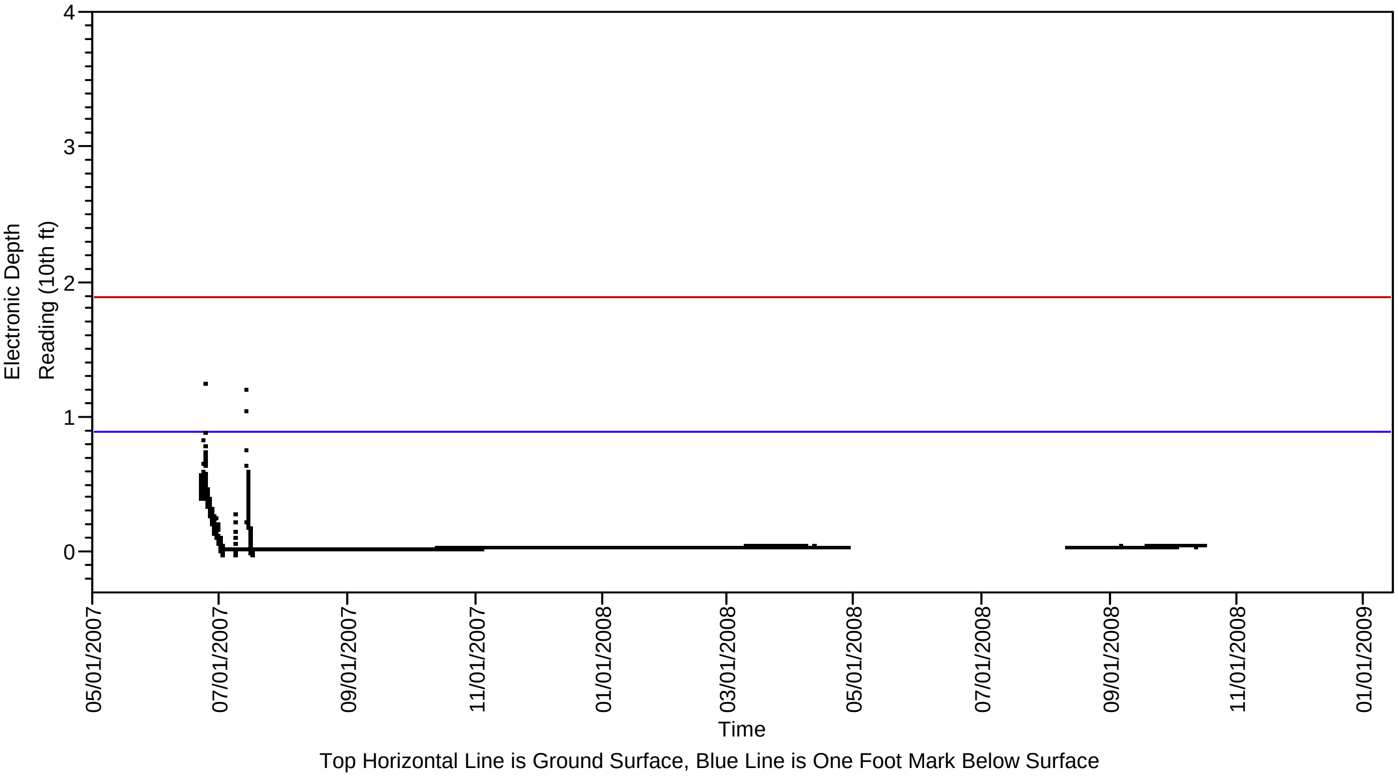


Figure 6.3 – 4 Small Basin Wetland: Seawatch Bay

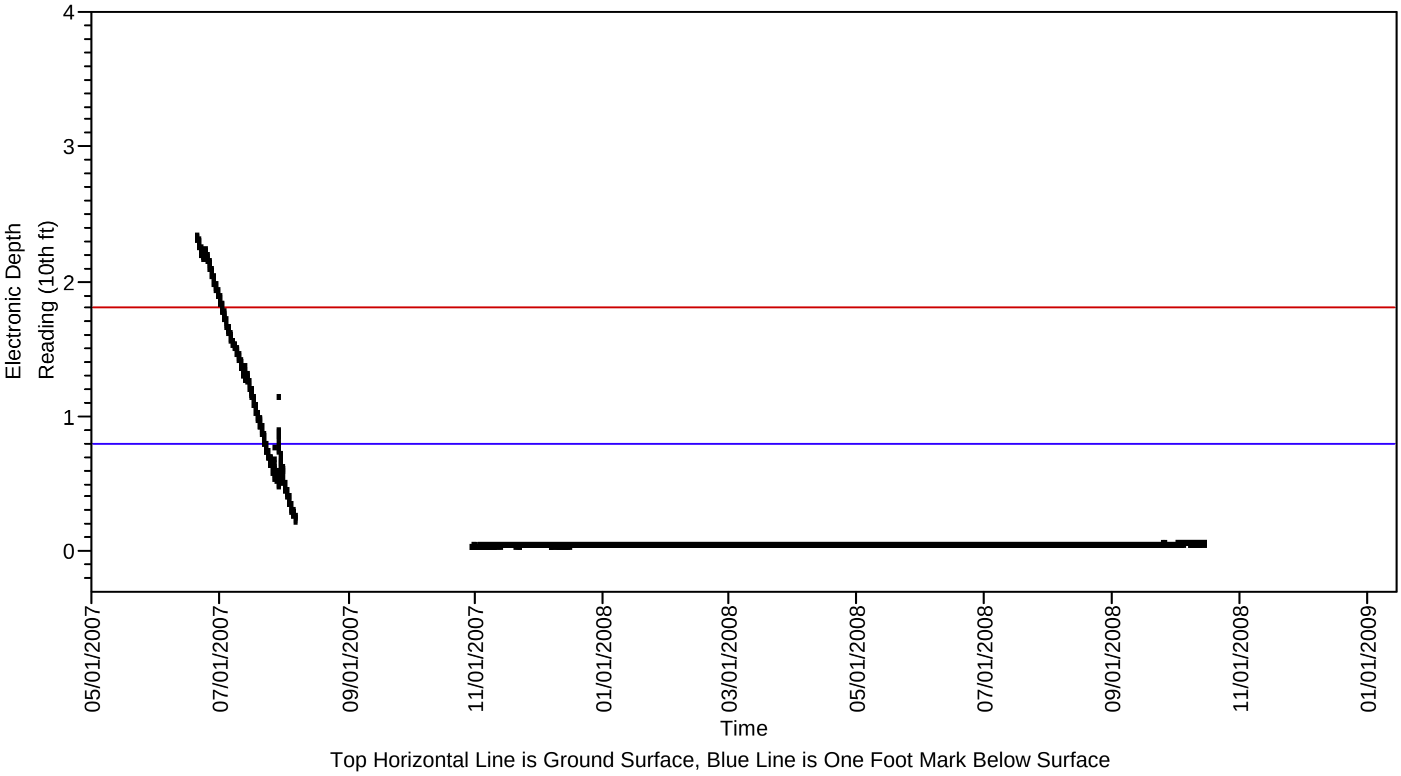


Figure 6.3 – 5 Small Basin Wetland: Seawatch Nautica

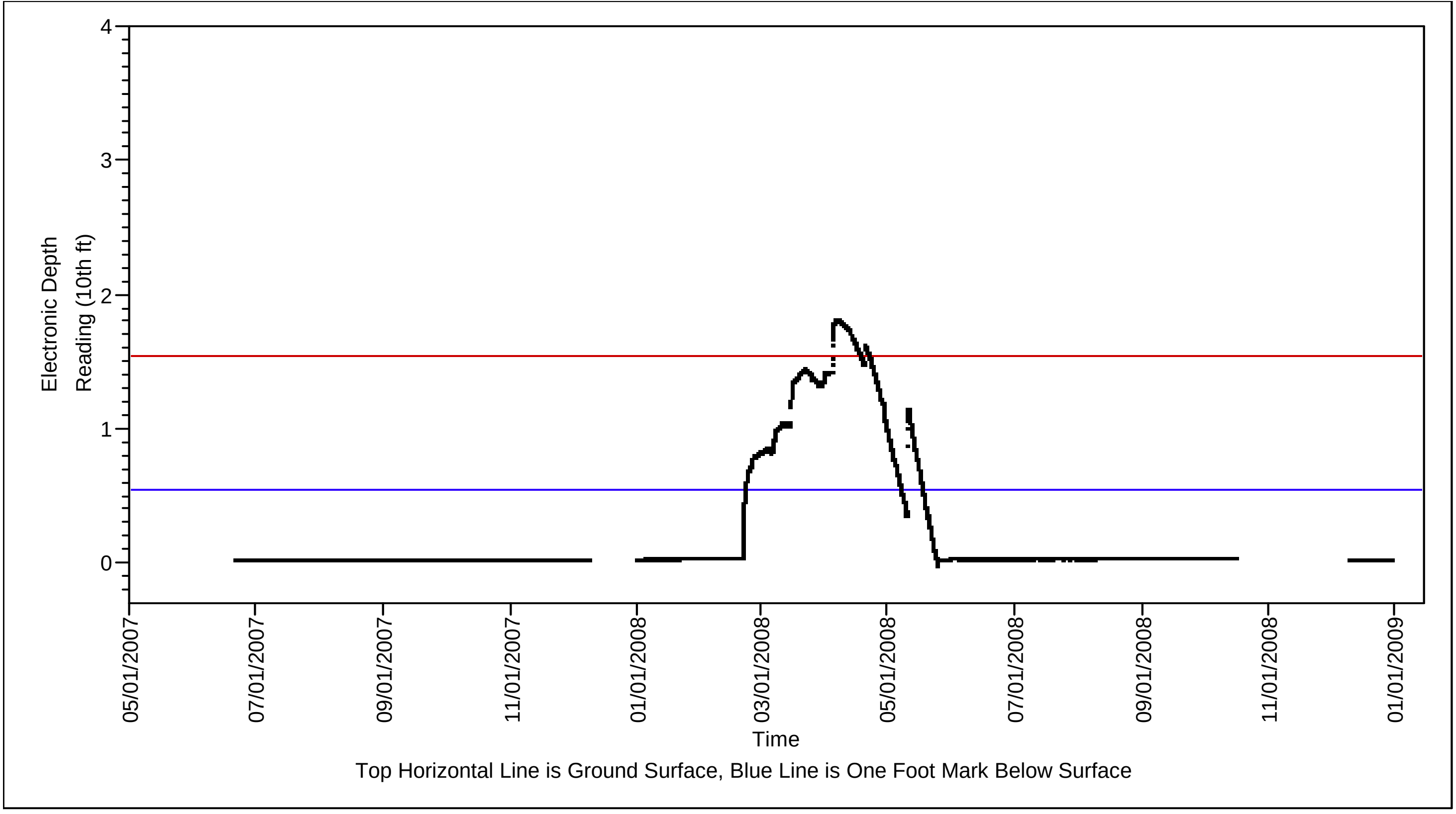
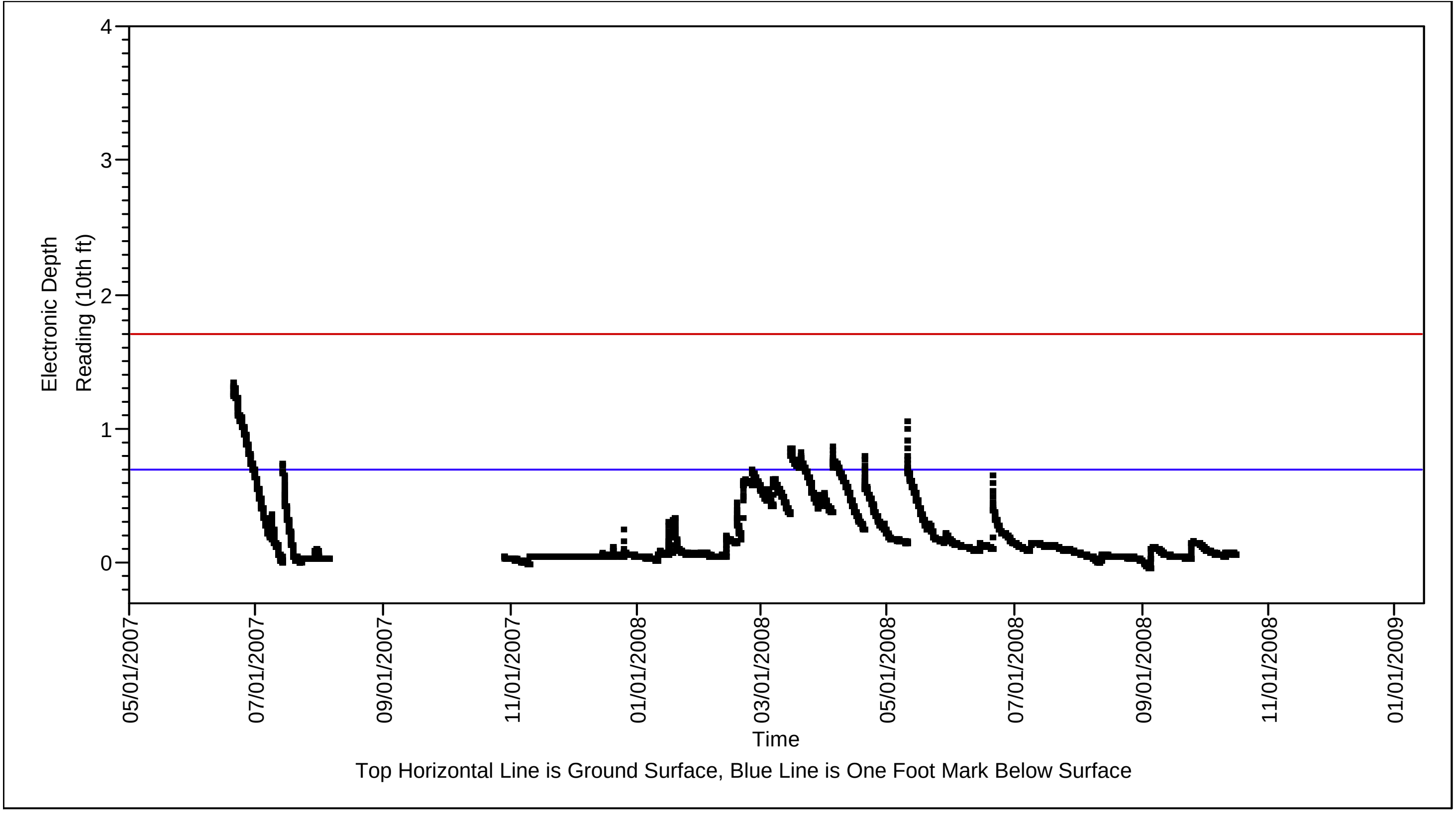


Figure 6.3 –6 Small Basin Wetland: Sikka



Hydrographs for the Small Basin wetlands at the Fishing Creek watershed are shown in Figures 6.4-7 thru 6.4-12. There are some gaps in the data that are due to technical difficulties with the transducers or errors in downloading the data. The Hart site (see Figure 6.4-12) had data collected for only a short time period (two months) due to the lost of landowner permission to monitor the site. Figure 6.4-7 shows the hydrograph for the Belton Creek site. There is a block of missing data, but a seasonal pattern can be seen with the higher water levels during the non-summer months. The Dargan site (see Figure 6.4-8) shows a seasonal pattern, with the highest water levels during the winter and spring months, but there is some variation during the summer months during 2007. In Figure 6.4-9, the hydrograph for the Dean site again show the highest water levels during the winger and spring months but there was again some variation probably due to precipitation. The Eastwood site, in Figure 6.4-10 (with some missing data), also shows a small seasonal pattern with plenty of variation. Finally the Goldston site (see Figure 6.4-11) shows a stronger seasonal pattern with the highest water levels during the winter and spring months and the lowest levels during the summer months.

Table 6.4-1 shows the percent of the time the water depth was within one foot of the surface and the second column showing the growing season only. These Small Basin wetlands' water levels in the Fishing Creek watershed were within one foot of the surface just over 52% of the time with the range being 26.6% at the Goldston site to 64.4% at the Dargan site. The differences between the growing season and the year round results are not very different, just over 5%.

Small Basin wetlands in the Fishing Creek watershed showed some seasonal pattern with higher levels in the winter and also patterns due to precipitation. The drought that affected the Small Basin wetlands at Lockwood Folly did affect the Fishing Creek Small Basin Wetlands, but the affect is not as clear in the Fishing Creek hydrographs and they tended to recover much better possibly due to their more clayey soils (versus the more sandy-muck soils) in the Coastal Plain.

Figure 6.3 – 7 Small Basin Wetland: Belton Creek

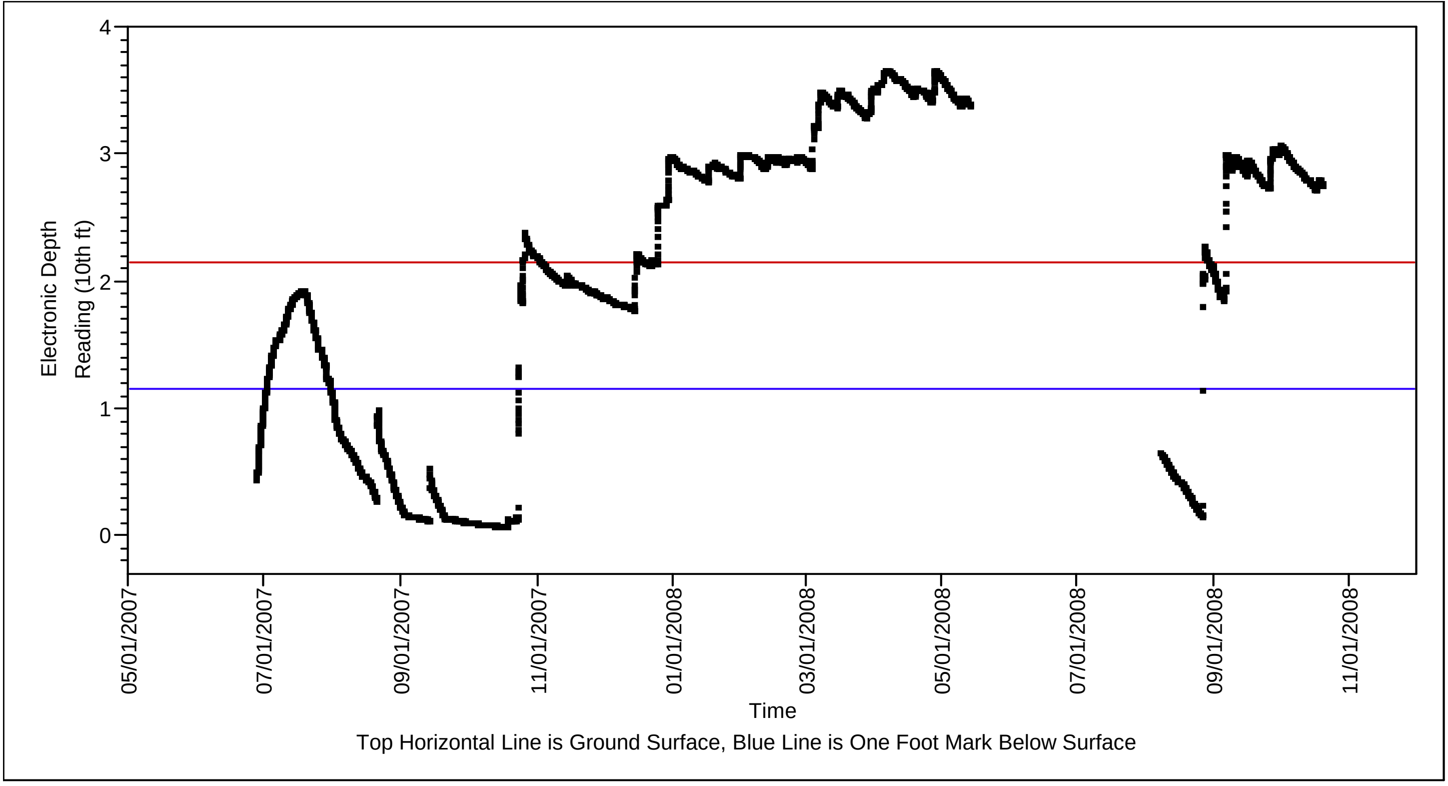


Figure 6.3 – 8 Small Basin Wetland: Dargan

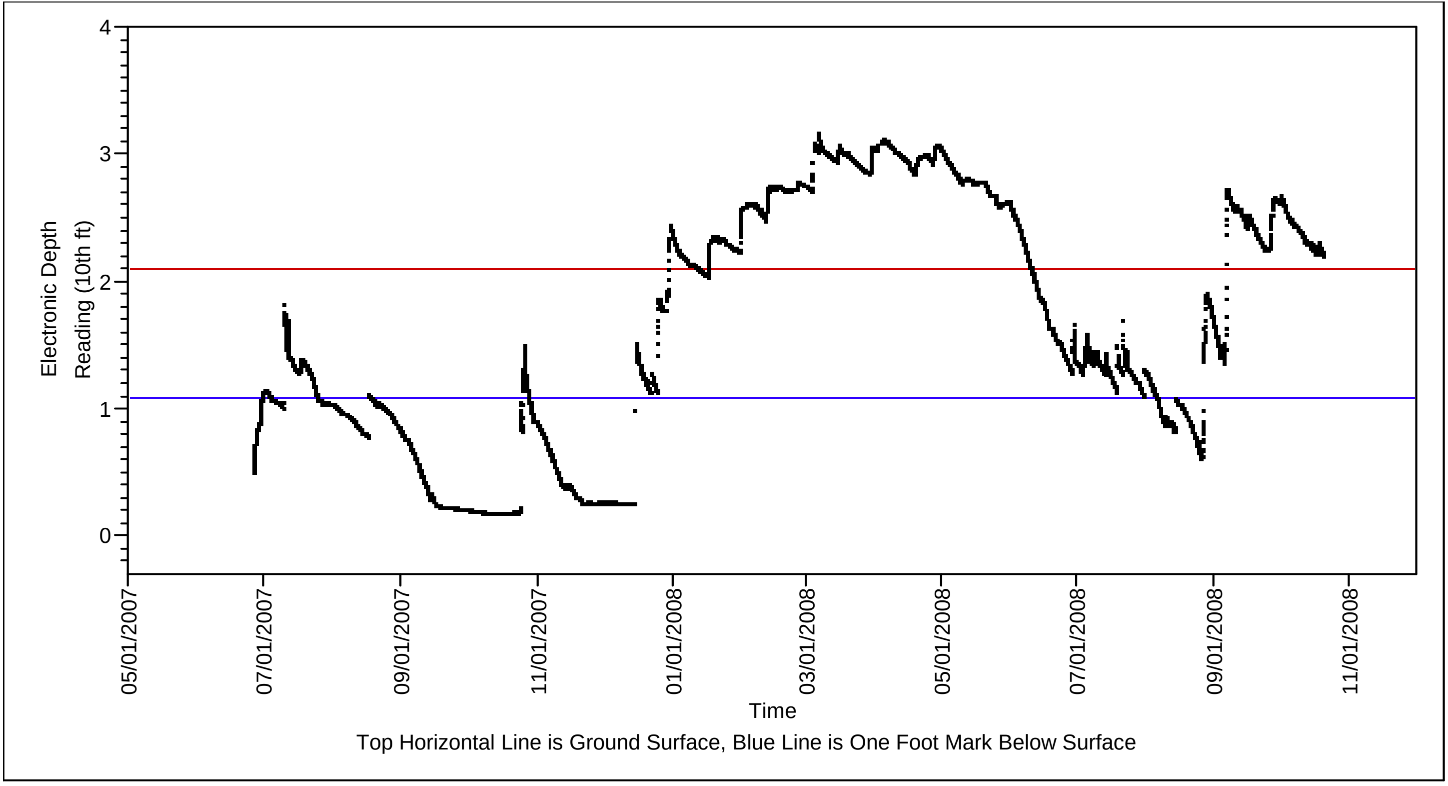


Figure 6.3 – 9 Small Basin Wetland: Dean

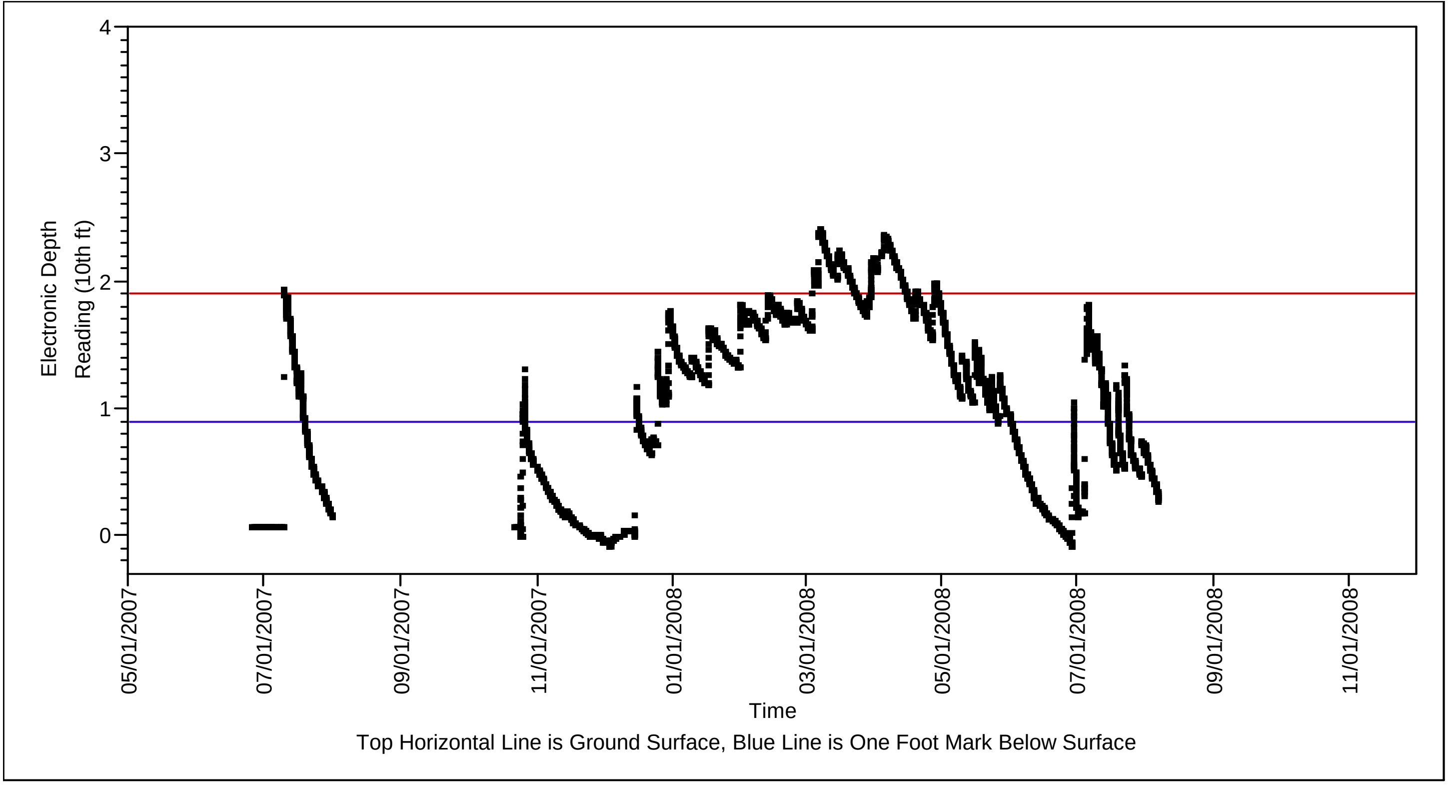


Figure 6.3 – 10 Small Basin Wetland: Eastwood

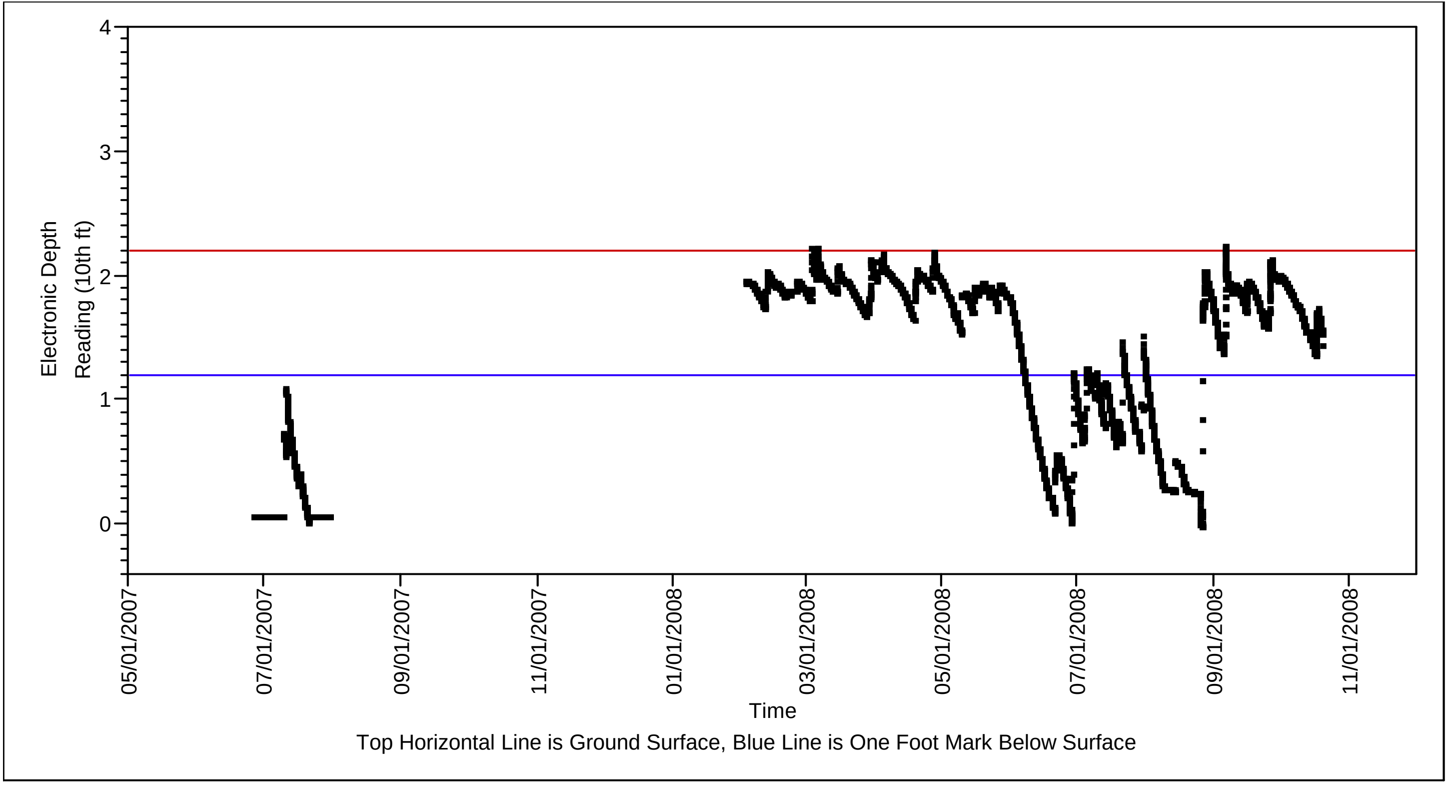


Figure 6.3 – 11 Small Basin Wetland: Goldston

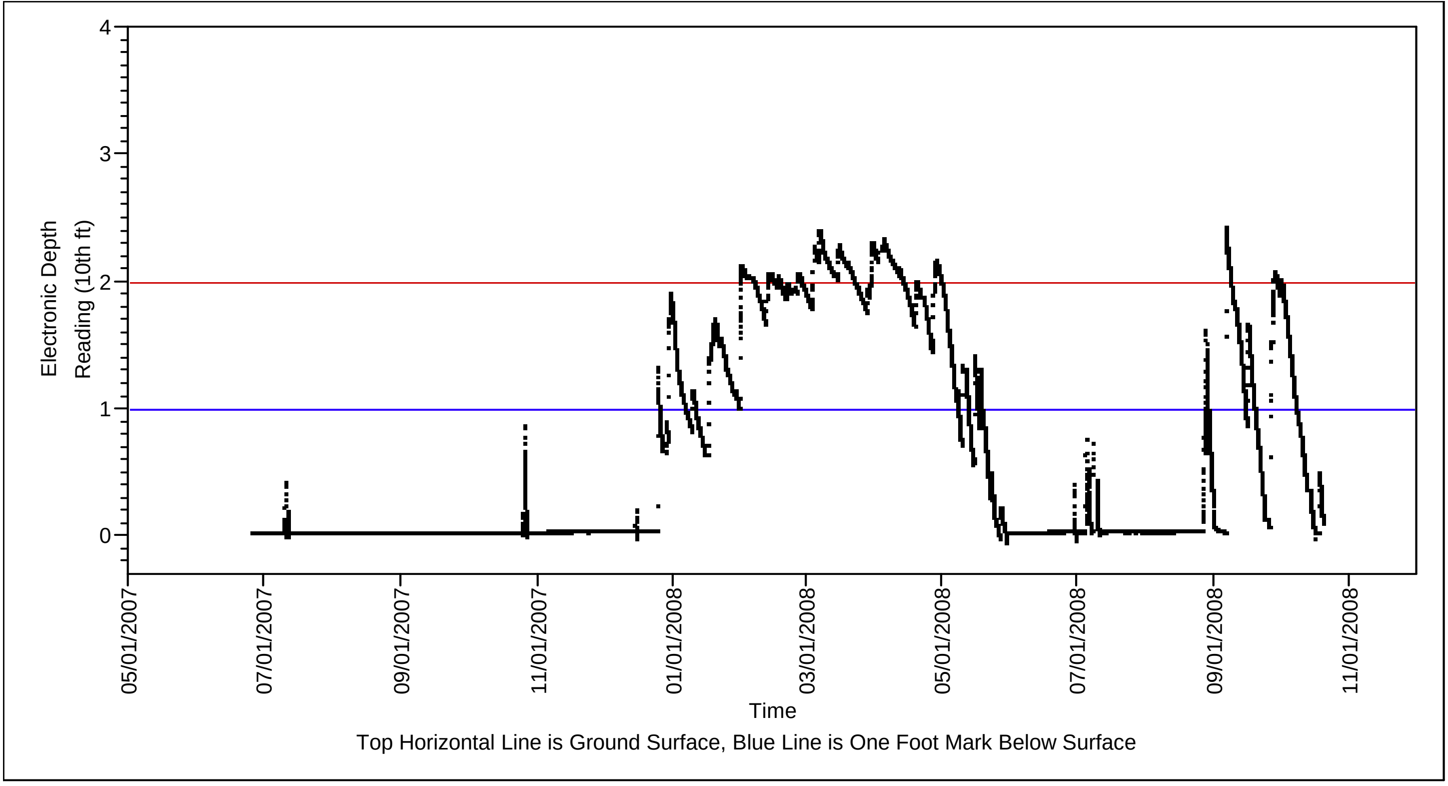


Figure 6.3 – 12 Small Basin Wetland: Hart

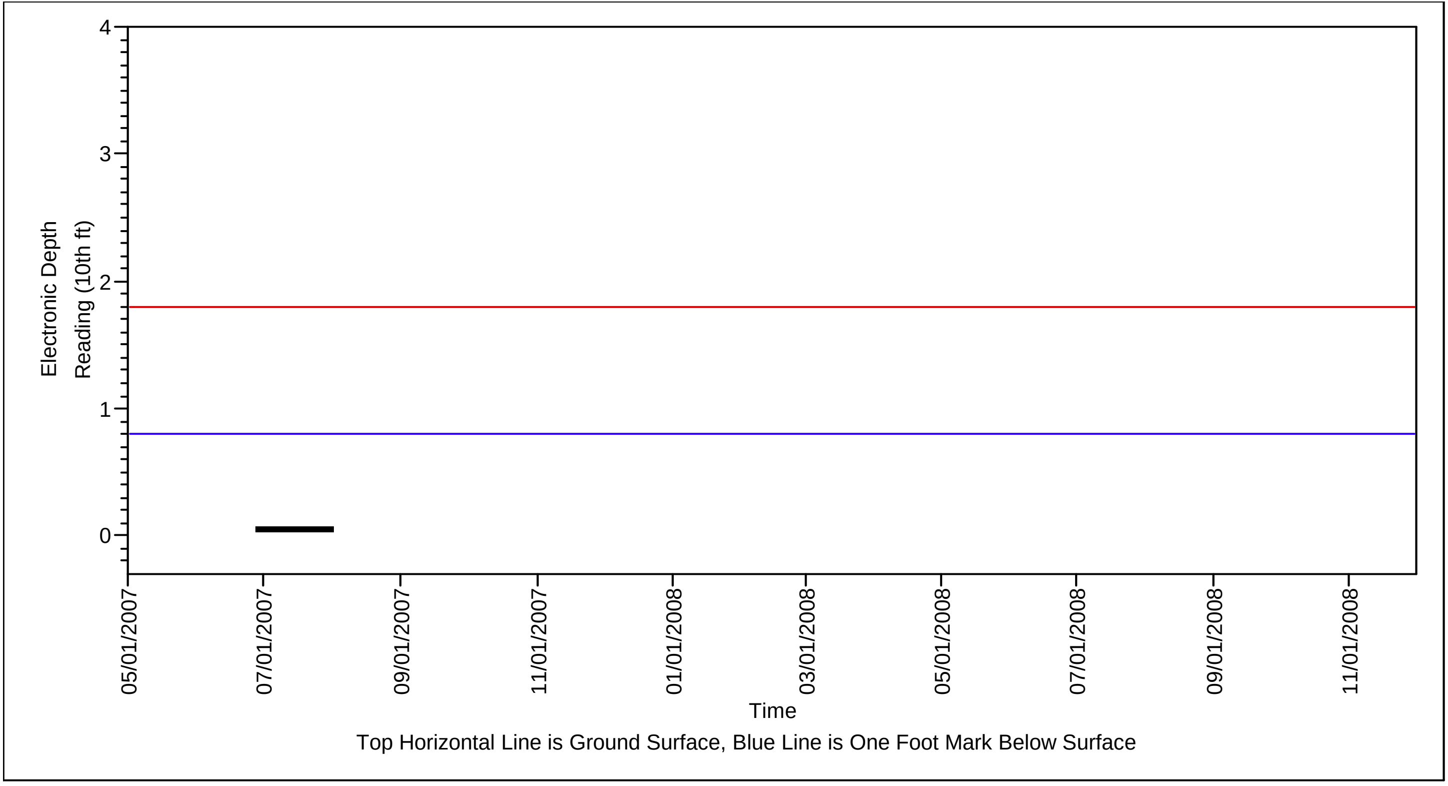


Table 6.4-1 Small Basin Wetlands – Water Depth: percent within One Foot of Surface

Site	Percent within one foot from surface	Percent within one foot of surface - growing season
Lockwood Folly: Bluegreen Golf	16.00	16.70
Lockwood Folly: Martin-Amment	19.90	22.40
Lockwood Folly: Mill Creek	0.03	0.03
Lockwood Folly: Seawatch Bay	8.10	8.10
Lockwood Folly: Seawatch Nautica	17.00	20.90
Lockwood Folly: Sikka	4.42	4.42
Mean	**10.91**	**12.09**
Fishing Creek: Belton Creek	72.40	57.80
Fishing Creek: Dargan	63.80	64.40
Fishing Creek: Dean	55.00	53.80
Fishing Creek: Eastwood	64.80	59.40
Fishing Creek: Goldston	32.20	26.60
Mean	**57.64**	**52.40**

Section 6.5 Small Basin Wetlands: Soil Results and Discussion

As with the riverine wetlands, texture and soil color were recorded when the soil cores were collected for the Small Basin wetlands. Different layers/horizons were measured, and each layer/horizon was then compared with the Munsell soil color chart to determine the hue, chroma, and value. Soil texture was also determined in terms of the clay, silt, sandy or loam content of the soil. These results are in Table E-4 in Appendix D for the Small Basin wetlands in the Fishing Creek watershed and in Table E-2 also in Appendix E for the Small Basin wetlands in the Lockwood Folly River watershed. For the Small Basin wetlands in Lockwood Folly River watershed, the Bluegreen Golf site was primarily a sandy loam with some muck presence. The typical Munsell color was dark at 10YR 2/1, 3/1, 3/2, and so on. The Martin-Amment site was primarily organic muck, but with some samples becoming more loamy (with sand, clay and silt presence) at the deeper levels. The Munsell color was typically dark with 10YR 2/1 and 10 YR 2/2 being typical. The Mill Creek site had a muck presence, but was mostly a loamy sand. This soil was also dark with a Munsell color being about 10YR 2/1 to 4/1. Soils at the Seawatch Bay site had a muck presence, but were mostly a sandy loam. The soil was dark with the Munsell color being 10YR 2/1 or 3/1. The Seawatch Nautica site had a very similar make-up in soil texture with a muck presence but mostly sandy loam. The Munsell color was dark being about 10YR 2/1. The soil at the Sikka site also had a mucky soil, but more than a presence with sand and sandy loam being typical. The soil was again dark with a Munsell color typically at 10YR 2/1 at the upper layers.

Overall, soils for the Small Basin wetlands in Lockwood Folly River watershed were very similar in texture with often a muck presence with sandy loam being the typical texture. The Munsell color was typically very dark. Soils in the Small Basin wetlands at the Fishing Creek watershed (see Table E4, Appendix E), did not have the muck that was characteristic of the Small Basin wetlands at the Lockwood Folly River watershed. The Goldston site was primarily a clay loam with some samples being sandy clay loam. The soil was very mottled with the typical Munsell color being 10YR 3/2, 4/2, and 6/2. Soil at the Dean site was much more of a silty loam with many samples being a silty clay loam. A few samples had some sand. The soil was very mottled and the Munsell color generally about 2.5YR 5/1, 5/2, 6/2 or 10YR 5/3 or 5/4. The Dargan Small Basin Wetland had a silty clay loam as being the typical texture with variants from that. The Munsell color was typically 10YR 7/1 with mottles. The Eastwood site was predominately clay loam with strong mottling. The Munsell color was typically gleyed. Finally the Belton Creek site was primarily a clay loam with some silt and sand mixed in some of the soil samples. The Munsell color was about 10YR 3/1, 4/1, 3/2, being darker than most of the other Small Basin Wetlands at Fishing Creek. Overall, the Fishing Creek Small Basin wetlands were different form the Small Basin wetlands at the Lockwood Folly River watershed since the Piedmont wetlands had no muck and therefore the soil was typically not as dark. The soil was primarily a clay loam with a silty clay loam or silty loam being also common, with some sand mixed in some samples.

Soil samples were collected in the wetland (usually four to six samples) and up to four samples were collected in the uplands surrounding the wetland (see Soils Field Methodology, section 4.3). Table 6.5-1 shows the means for all of the soil parameters for each Small Basin wetland site for the upland samples and wetland samples (note that not upland samples were collected at the Winding River sites, due to having to core in maintained lawns). Table 6.5-2 shows the mean results for the upland samples and the wetland samples averaged across sites. From Table 6.5-1, the Martin-Amment and Seawatch Nautica sites had the highest levels of humic mater (percent) and the Bluegreen Golf and Mill Creek sites had the lowest levels. Just the opposite was true for the weight per volume, with the Bluegreen Golf and Mill Creek sites having the highest levels and the Martin-Amment and Seawatch Nautica sites having the lowest levels. The highest levels of CEC were recorded at the Martin-Amment site, then the Seawatch Nautica and Seawatch Bay sites respectively. For percent base saturation, the Mill Creek, Seawatch Bay, and Bluegreen Golf sites had the highest percent. Exchangeable Acidity (Ac) had the highest levels recorded at the Martin-Amment and Seawatch Nautica sites whereas the lowest levels occurred at the Mill Creek and Bluegreen Golf sites. All of these Small Basin wetland soils were quite acidic, with the most acidic being the Martin-Amment (pH=3.7) and Seawatch Nautica (pH=3.8) sites. The least acidic site was the Bluegreen Golf site (pH=4.6). Phosphorus levels were quite high at the Martin-Amment and Seawatch Nautica sites with the other four sites having similar levels. The same two sites also had the highest levels of potassium (the Seawatch Nautica and Martin-Amment sites respectively) with the rest of the sites having much lower levels. Calcium, however, was highest at the Seawatch Bay site which was almost three times the level of the next highest, the Bluegreen Golf site. The Seawatch Bay site also had the highest levels of magnesium, more than twice the levels of the Seawatch Nautica site. The lowest levels of magnesium were recorded at the Mill Creek site. Sulfur was highest at the Martin-Amment site with the Seawatch Nautica site having the next highest levels. The lowest levels of sodium were recorded at the Mill Creek and Seawatch Bay sites. The Seawatch Bay site had the highest levels of manganese in the soil whereas the lowest levels occurred at the Mill Creek site. The same was true for zinc, with the Seawatch Bay site having the highest levels and the Mill Creek site having the lowest levels of zinc in the soil. There was very little difference in the levels of copper with the exception of the Martin-Amment site, having more than twice the levels of the other five sites. The highest levels of sodium occurred at the Seawatch Nautica site with the Martin-Amment site being next. The lowest levels were recorded at Mill Creek. Finally, for nitrogen, Seawatch Nautica had the highest levels, much higher than the next two sites, the Martin-Amment and Seawatch Bay sites respectively. The levels of nitrogen at the Sikka site were quite low.

From the results shown in Table 6.5-1, three sites had the most problems with potential pollutants in the soils (metals and nutrients); the Martin-Amment, Seawatch Nautica, and Seawatch Bay sites, in that order. The Martin-Amment site was located in the most rural area, while the Seawatch Nautica and Seawatch Bay sites were at the very early stages of residential development. When comparing the soil results to the water quality results, the Seawatch Nautica and Sikka sites had the lowest water quality. However, the lower water quality is consistent for the Seawatch Nautica site, but the Sikka site had good soil quality. The Sikka site is a large site and the soil quality could be due to where the samples were collected in the wetland or how water flows through the system. The Bluegreen Golf and Mill Creek sites also had the best water quality and their soil results are consistent with this. The Martin-Amment site was also inconsistent since the site had good water quality, but poorer soil quality and again this could be due to where the samples were collected in the wetland or how water flows through the system.

Table 6.5-2 shows the results for the upland and wetland soil samples for the Small Basin wetland in Lockwood Folly River (Brunswick County). The highest level of percent humic matter was in the wetland, but somewhat surprisingly, the percent base saturation was highest in the upland. The weight per volume was lower in the wetland. The CEC was higher in the wetland as was exchangeable acidity. Wetland soils were more acidic that upland soils. Levels of phosphorus were more than twice as high in the wetland and the potassium and magnesium levels were also higher in the wetland. Calcium was slightly higher in the upland. Sulfur was higher in the wetland soils, but manganese had higher levels in the upland as was zinc. Copper and sodium had recorded levels higher in the wetland than the upland. For nitrogen levels, the wetland had much higher levels than the upland.

Statistical test were performed on the wetland and upland results. Percent humic matter was statistically significant with the higher levels in the wetland (Wilcoxon and ANOVA, $p<0.0001$), and the weight by volume was also statistically significant with the higher weight in the upland soil samples (Wilcoxon, $p=0.0002$, ANOVA, $p=0.0012$). Percent base saturation was statistically significant with the higher percent being in the upland (Wilcoxon and ANOVA, $p<0.0001$). This is not an expected result as one would generally expect the wetland to have a higher base saturation. The Sikka and Seawatch Bay sites are still being monitored and future results may clarify this result. CEC was also different statistically with higher CEC being recorded in the wetland (Wilcoxon, $p=0.003$, ANOVA, $p=0.0036$). The pH and Ac were both statistically significant (Wilcoxon and ANOVA at $p<0.0044$) with the wetlands being more acidic and having a higher exchangeable acidity. Potassium was not statistically significant, but phosphorus was with the higher levels being in the wetland (Wilcoxon, p=0.0035, ANOVA, p=0.022). Calcium and magnesium levels also were not significantly different, but sulfur was (Wilcoxon, p=0.0764) with the wetland having the higher levels. Zinc was not statistically significant but manganese was (Wilcoxon, p=0.0217) with the soil samples in the wetland having the higher levels. Copper were statistically different (Wilcoxon, p=0.585) as was sodium (Wilcoxon, p=0.0006, ANOVA, p=0.0046), with the wetland having higher levels than the upland. Finally, nitrogen levels were statistically significant with the wetland soils samples having the higher levels (Wilcoxon, p=0.1068, ANOVA, p=0.1429).

The statistically significant results confirm that most of the soil parameters that are potential pollutants (metals and nutrients) occur in the wetland. This is consistent with the water quality results and indicates that the Small Basin wetlands in the Lockwood Folly River watershed are acting as a sink for the potential pollutants and have the opportunity to improve the water quality.

Table 6.5-3 shows the soil results for the Small Basin wetlands in the Fishing Creek watershed (Granville, County, Piedmont ecoregion) for upland and wetland soil samples. No soil samples were collected from the Hart site due to the property changing landowners. From this table, it can be seen that the highest levels of humic matter (percent) occurred at the Belton Creek site with the Dargan site next. The Dean site had the lowest level. The weight per volume was highest at the Eastwood site whereas the lowest weight was at the Belton Creek site, but these were small differences. The highest levels of CEC were recorded at the Belton Creek site with the Dean and Eastwood sites having the lowest levels. For percent base saturation, the Belton Creek site was much higher than the other four sites (57% versus less that 48% for the other sites). The highest levels of Ac occurred at the Belton Creek and Dargan sites with the lowest levels at the Dean and Eastwood sites. All of the sites were acidic and with similar pH, ranging from 4.4 to 4.7 with the Eastwood and Dean sites being slightly more acidic. The levels of phosphorus were very high at the Belton Creek site, nearly twice the levels at the Dargan site which had the next highest level. The Eastwood site had the lowest level of phosphorus. The Belton Creek site also had the highest levels of potassium with the Goldston site having the lowest level. For calcium, the Belton Creek site again had the highest level at twice the level recorded at the Goldston and Dargan sites. The Dargan and Belton Creek sites had the highest levels of magnesium with the Eastwood site having the lowest. The Dean site had the highest level of sulfur with the other four sites having similar levels. The manganese was much higher at the Dean and Eastwood sites than the other sites. Zinc was highest at the Belton Creek site with the Dean site being the lowest. The Belton Creek site also had the highest levels of copper with the Goldston site having the lowest level. For sodium, the Dargan site had the highest levels with the Eastwood and Belton Creek sites having the lowest levels. Finally for nitrogen, the highest level was much higher at the Dean and Eastwood sites than the other three sites. The Goldston site had the lowest level of nitrogen.

From these results, the Eastwood and Goldston sites had the lowest levels of potential pollutants (nutrients and metals) in the soil. The Belton Creek site had the most problems followed by the Dargan and Dean sites. The Goldston site was the most urban of these sites located at a major interaction of I-85 and US 15. In relating to the water quality results, the Dargan site had the best water quality which is not consistent with the soil results. The Eastwood and Goldston sites also had more water quality problems, but had better soil quality. These results, like the Small Basin wetland results in the Lockwood Folly River watershed did not have very consistent results in terms of soil and water quality. In contrast, the Riverine Swamp Forest and Bottomland Hardwood Forest wetland sites had fairly consistent results between the soil results and water quality. Therefore, the Small Basin wetlands, regardless of watershed, appear to be quite variable. In addition, this may also reflect the fact that the watersheds of Small Basin wetlands are miniscule in comparison to the other wetland types.

Table 6.5-4 shows the results for the Small Basin wetlands at Fishing Creek for the upland and wetland soils samples. The percent humic matter was higher in the wetland as was the CEC. The weight by volume was higher in the upland. The percent base saturation was higher in the upland which was not expected. The Ac was higher in the wetland and the pH was slightly more acidic in the wetland also. Phosphorus was higher in the upland, but potassium and calcium were higher in the wetland. Magnesium and manganese were higher in the upland but the wetland soil sample had higher levels of sulfur and zinc. The levels of copper were about the same, but there were much higher levels of sodium and nitrogen in the wetland.

Statistical tests were performed on the upland and wetland soil samples to determine which levels were statistically significant. Percent human matter was statistically significant (Wilcoxon, $p<0.0001$, ANOVA, $p=0.0019$), with the wetland having the higher levels. The upland had the higher weight per volume which was statistically significant (Wilcoxon, ANOVA, $p<0.0001$). The percent base saturation was unexpectedly higher in the upland and this result was also statistically significant (Wilcoxon, $p=0.0665$, ANOVA, $p=0.0629$). As noted earlier, long term monitoring of two of these sites may clarify this result. CEC was also significant statistically (Wilcoxon, $p=0.0099$), with the higher levels in the wetland soil samples. The levels of Ac and the pH were both statistically significant (Wilcoxon, ANOVA, both at $p<0.0015$), with the higher Ac recorded in the wetland and the wetland being more acidic. The levels of phosphorus and calcium were not statistically significant, but potassium levels were significantly different with the higher levels being in the wetland (Wilcoxon, $p=0.1087$, ANOVA $p=0.0704$). Magnesium was not different statistically, but sulfur was (Wilcoxon, $p=0.0081$) with the wetland having the higher levels. Manganese was higher in the upland and again was different statistically (Wilcoxon, $p=0.0319$, ANOVA, $p=0.0002$). Zinc levels were different statistically (Wilcoxon, $p=0.0649$, ANOVA, $p=0.0397$) as was copper (Wilcoxon, $p=0.0878$), with the soil samples in the wetland having the higher levels. Sodium levels were also significantly different with the higher levels again in the wetland (Wilcoxon, $p<0.0001$, ANOVA, $p=0.0439$). Finally, the levels for nitrogen were higher in the wetland and this difference was statistically significant (Wilcoxon, $p=0.0234$).

These results for the upland and wetland soil samples for the Small Basin wetlands in the Fishing Creek watershed show that most of the potential pollutants (nutrients and metals) had higher levels in the wetland as opposed to the upland. Again this indicates that these Small Basin wetlands act as sinks for these potential pollutants. Therefore, these wetlands appear to have the potential for improving water quality.

Next, comparisons were made between the two watersheds (and ecoregions) for the Small Basin wetlands. Table 6.5-5 shows the means for each soil parameter by watershed. From the table, the Lockwood Folly River Small Basin wetlands had the highest percent humic matter as one would expect from the Coastal Plain. The weight by volume was virtually identical. The CEC was higher in Fishing Creek as was the percent base saturation. The Lockwood Folly River watershed sites were more acidic and therefore had a higher Ac. The level of phosphorus was higher at the Small Basin wetland in Lockwood Folly River. Potassium was highest at Fishing Creek at nearly twice the level as the Lockwood Folly River sites. Calcium was more than three times higher at Fishing Creek and magnesium as was more that four times higher at Fishing Creek. Sulfur was also higher at Fishing Creek and levels of zinc and copper were more than twice as high at Fishing Creek. Sodium was almost twice as high at Fishing Creek. However, the levels of nitrogen were only slightly higher at Fishing Creek.

Statistical tests were performed on the soils data to evaluate the significance of the differences between the two watersheds (and ecoregions). The percent humic matter was statistically significant with the higher levels at Lockwood Folly River (Wilcoxon, ANOVA, $p<0.0001$). The weight per volume was also significant statistically (Wilcoxon, $p=0.0199$) with Lockwood Folly River having a slightly higher weight. Fishing Creek had the higher level of CEC which was statistically significant (Wilcoxon, $p=0.0009$, ANOVA, $p=0.0004$). Percent base saturation was higher at Fishing Creek and this difference was statistically significant (Wilcoxon, ANOVA, $p=0.0001$). Ac and pH were both significant statistically (for Ac, Wilcoxon=0.1097, ANOVA, $p<0.0299$ and for pH, Wilcoxon, ANOVA, $p<0.0001$). Lockwood Folly River wetlands were more acidic and therefore had the higher level of Ac. The level of phosphorus was higher at Lockwood Folly River wetlands (Wilcoxon, $p=0.0003$, ANOVA, $p=0.0347$). Potassium and calcium were both higher at Fishing Creek (Wilcoxon, ANOVA, all at $p<0.0001$). The levels of magnesium were also significant with the highest levels again at Fishing Creek (Wilcoxon, ANOVA, $p<0.0001$). Sulfur levels were also statistically significant (Wilcoxon, $p=0.0142$, ANOVA, $p=0.1294$) with the higher levels at Fishing Creek. Fishing Creek sites also had the higher levels of zinc, manganese, and copper and all three were statistically significant at $p<0.0001$ (both the Wilcoxon and ANOVA). Sodium was statistically significant (Wilcoxon, $p=0.0165$, ANOVA, $p=0.0038$), with Fishing Creek again having the higher levels. Finally, nitrogen levels were also statistically significant (Wilcoxon, $p=0.0150$), again with Fishing Creek having the higher levels.

These results comparing the soil parameters of the two watersheds with the Small Basin wetlands show that soils in the Lockwood Folly River Small Basin wetlands generally had lower levels of potential pollutants than the Fishing Creek wetlands. This result is consistent with the water quality results which also showed that the Lockwood Folly River Small Basin wetland had better water quality than the Fishing Creek Small Basin wetlands. Again, as pointed out with the water quality results, one could conclude that the Small Basin wetlands in Lockwood Folly River may do a better job of improving water quality (ultimately resulting in soils with lower levels of potential pollutants) than the Fishing Creek wetlands, but without better a understanding of the inputs into the systems and how the development pressures differ, it is difficult to substantiate that conclusion. The fact that two Small Basin wetlands in Fishing Creek (the Dean and Dargan sites) and two Small Basin wetlands in Lockwood Folly River (the Sikka and Seawatch Bay sites) are still being monitored and may shed some light on this difference as more data are collected.

Table 6.5-1 Means by Site for Lockwood Folly River Watershed Small Basin Wetlands for Upland and Wetland Soil Samples

Site	N	Mean (HM %, Up)	Mean (HM %, Wet)	Mean (WV g/cc, Up)	Mean (WV g/cc, Wet)	Mean (CEC meq/100cc, Up)	Mean (CEC meq/100cc, Wet)
Bluegreen Golf	19	0.890	2.264	1.285	1.118	3.450	4.206
Martin-Amment	18	0.913	7.261	1.303	0.554	4.475	10.886
Mill Creek	14	0.560	2.636	1.460	1.268	2.700	2.942
Seawatch Bay	17	0.595	4.705	1.420	1.139	4.100	9.213
Seawatch Nautica	12	2.520	6.034	1.190	0.685	5.600	10.082
Sikka	16	0.225	3.933	1.380	1.227	2.200	5.971

Site	N	Mean(BS %, Up)	Mean (BS %, Wet)	Mean (Ac meq/100cc, Up)	Mean (Ac meq/100cc, Wet)	Mean(pH, Up)	Mean(pH, Wet)
Bluegreen Golf	19	37.500	26.118	2.150	3.165	4.650	4.618
Martin-Amment	18	33.000	10.786	2.925	9.693	4.450	3.650
Mill Creek	14	41.000	29.083	1.600	2.200	4.450	4.500
Seawatch Bay	17	41.000	27.447	2.500	6.333	4.450	4.093
Seawatch Nautica	12	41.000	12.364	3.300	8.836	4.700	3.809
Sikka	16	26.500	17.000	1.600	5.114	4.450	4.050

Site	N	Mean (P mg/dm3, Up)	Mean (P mg/dm3, Wet)	Mean (K mg/dm3, Up)	Mean (K mg/dm3, Wet)	Mean (Ca mg/dm3, Up)	Mean (Ca mg/dm3, Wet)
Bluegreen Golf	19	4.000	9.824	10.700	16.794	201.950	155.341
Martin-Amment	18	9.825	40.036	26.050	49.657	222.100	134.093
Mill Creek	14	6.150	11.042	9.000	9.075	174.900	111.750
Seawatch Bay	17	4.700	12.460	11.650	16.473	236.050	413.473
Seawatch Nautica	12	28.100	30.591	18.800	56.818	370.800	134.973
Sikka	16	4.700	13.764	5.650	10.736	85.250	108.136

Site	N	Mean (Mg mg/dm3, Up)	Mean (Mg mg/dm3, Wet)	Mean (S mg/dm3, Up)	Mean (S mg/dm3, Wet)	Mean (Mn mg/dm3, Up)	Mean (Mn mg/dm3, Wet)
Bluegreen Golf	19	31.900	26.306	10.200	31.494	1.950	0.794
Martin-Amment	18	46.150	48.629	23.700	64.943	1.700	1.064
Mill Creek	14	24.350	18.217	57.850	19.225	0.900	0.608
Seawatch Bay	17	44.000	115.847	1.500	12.440	2.450	2.200
Seawatch Nautica	12	46.400	53.518	15.700	51.436	1.000	1.309
Sikka	16	17.100	34.400	11.100	10.179	0.800	0.621

Table 6.5-1 Means by Site for Lockwood Folly River Watershed Small Basin Wetlands for Upland and Wetland Soil Samples

Site	N	Mean (Zn mg/dm3, Up)	Mean (Zn mg/dm3, Wet)	MeanB(Cu g/dm3, Up)	Mean (Cu mg/dm3, Wet)	Mean (Na mg/dm3, Up)	Mean (Na mg/dm3, Wet)
Bluegreen Golf	19	0.500	0.441	0.400	0.335	14.500	32.000
Martin-Amment	18	1.200	0.664	0.300	0.857	19.750	54.000
Mill Creek	14	0.550	0.392	0.200	0.333	17.500	17.333
Seawatch Bay	17	0.750	1.233	0.250	0.360	18.500	35.933
Seawatch Nautica	12	0.900	0.800	0.400	0.373	35.000	64.545
Sikka	16	0.350	0.400	0.250	0.329	10.000	27.143

Site	N	Mean (NO3--N mq/dm3, Up)	Mean (NO3--N mq/dm3, Wet)
Bluegreen Golf	19	1.500	2.000
Martin-Amment	18	1.250	9.929
Mill Creek	14	0.000	1.500
Seawatch Bay	17	0.000	6.467
Seawatch Nautica	12	2.000	16.545
Sikka	16	0.000	0.286

Table 6.5-2 Lockwood Folly River Watershed Small Basin wetlands Soil Mean Results for Upland and Wetland Samples

Up / Wet	N	Mean (HM %)	Mean (WV g/cc)	Mean (CEC meq/100cc)	Mean (BS %)	Mean (Ac meq/100cc)	Mean (pH)
Up	13.000	0.824	1.345	3.723	35.769	2.362	4.500
Wet	83.000	4.383	1.009	7.131	20.840	5.780	4.140

Up / Wet	N	Mean (P mg/dm3)	Mean (K mg/dm3)	Mean (Ca mg/dm3)	Mean (Mg mg/dm3)	Mean (S mg/dm3)	Mean (Mn mg/dm3)
Up	13.000	8.192	15.154	204.269	35.823	20.908	1.538
Wet	83.000	18.989	25.446	181.443	50.055	30.966	1.106

Up / Wet	N	Mean(Zn mg/dm3)	Mean(Cu mg/dm3)	Mean(Na mg/dm3)	Mean(NO3--N mq/dm3)
Up	13.000	0.769	0.292	18.077	0.769
Wet	83.000	0.655	0.431	37.795	5.711

Table 6.5-3 Means by Site for Fishing Creek Watershed Small Basin Wetlands for Upland and Wetland Soil Samples

Site	N	Mean (HM %, Up)	Mean (HM %, Wet)	Mean (WV g/cc, Up)	Mean (WV g/cc, Wet)	Mean (CEC meq/100cc, Up)	Mean (CEC meq/100cc, Wet)
Belton Creek	16.000	0.385	1.192	1.013	0.875	17.925	14.892
Dargan	17.000	0.223	1.035	1.180	0.879	9.225	11.238
Dean	25.000	0.203	0.384	1.114	0.982	5.613	6.912
Eastwood	14.000	0.300	0.558	1.140	1.007	3.550	6.542
Goldston	20.000	0.150	0.538	1.265	1.104	6.613	9.675

Site	N	Mean(BS %, Up)	Mean (BS %, Wet)	Mean (Ac meq/100cc, Up)	Mean (Ac meq/100cc, Wet)	Mean(pH, Up)	Mean(pH, Wet)
Belton Creek	16.000	76.250	57.250	3.700	6.108	5.050	4.408
Dargan	17.000	42.250	42.308	3.625	6.062	4.550	4.392
Dean	25.000	60.125	47.529	2.175	3.365	4.963	4.671
Eastwood	14.000	36.000	45.917	2.250	3.608	4.700	4.675
Goldston	20.000	49.500	42.917	3.125	5.033	4.613	4.483

Site	N	Mean (P mg/dm3, Up)	Mean (P mg/dm3, Wet)	Mean (K mg/dm3, Up)	Mean (K mg/dm3, Wet)	Mean (Ca mg/dm3, Up)	Mean (Ca mg/dm3, Wet)
Belton Creek	16.000	4.250	25.383	42.000	75.492	1345.550	1238.867
Dargan	17.000	5.675	13.992	21.325	45.223	424.900	505.746
Dean	25.000	12.050	10.235	57.325	44.294	470.413	404.741
Eastwood	14.000	4.400	6.267	34.550	49.725	120.550	353.192
Goldston	20.000	35.575	8.992	25.638	33.250	530.225	612.933

Site	N	Mean (Mg mg/dm3, Up)	Mean (Mg mg/dm3, Wet)	Mean (S mg/dm3, Up)	Mean (S mg/dm3, Wet)	Mean (Mn mg/dm3, Up)	Mean (Mn mg/dm3, Wet)
Belton Creek	16.000	898.850	290.367	18.075	27.867	179.750	18.600
Dargan	17.000	413.575	307.154	20.225	33.338	6.400	11.385
Dean	25.000	114.300	170.759	36.363	51.076	111.288	45.076
Eastwood	14.000	71.050	127.042	66.700	30.208	47.500	31.367
Goldston	20.000	95.525	181.167	30.013	37.750	14.563	8.750

Table 6.5-3 Means by Site for Fishing Creek Watershed Small Basin Wetlands for Upland and Wetland Soil Samples

Site	N	Mean (Zn mg/dm3, Up)	Mean (Zn mg/dm3, Wet)	Mean (Cu mg/dm3, Up)	Mean (Cu mg/dm3, Wet)	Mean (Na mg/dm3, Up)	Mean (Na mg/dm3, Wet)
Belton Creek	16.000	1.875	2.883	3.500	1.450	38.500	42.250
Dargan	17.000	0.825	1.638	0.600	1.046	73.250	112.462
Dean	25.000	1.088	1.129	0.663	0.859	15.625	55.647
Eastwood	14.000	1.100	1.425	0.650	0.767	10.500	38.250
Goldston	20.000	0.913	1.200	0.538	0.650	27.000	78.833

Site	N	Mean (NO3--N mq/dm3, Up)	Mean (NO3--N mq/dm3, Wet)
Belton Creek	16.000	1.000	4.750
Dargan	17.000	0.500	2.000
Dean	25.000	5.375	11.176
Eastwood	14.000	5.500	9.750
Goldston	20.000	1.375	0.750

Table 6.5-4 Fishing Creek Watershed Small Basin Wetlands Soil Mean Results for Upland and Wetland Samples

Up / Wet	N	Mean (HM %)	Mean (WV g/cc)	Mean (CEC meq/100cc)	Mean (BS %)	Mean (Ac meq/100cc)	Mean (pH)
Up	26.000	0.225	1.157	8.212	54.731	2.931	4.785
Wet	66.000	0.719	0.969	9.650	47.136	4.742	4.535

Up / Wet	N	Mean (P mg/dm3)	Mean (K mg/dm3)	Mean (Ca mg/dm3)	Mean (Mg mg/dm3)	Mean (S mg/dm3)	Mean (Mn mg/dm3)
Up	26.000	16.519	37.927	589.538	271.938	31.446	71.015
Wet	66.000	12.782	49.129	604.776	213.315	37.145	24.529

Up / Wet	N	Mean(Zn mg/dm3)	Mean(Cu mg/dm3)	Mean(Na mg/dm3)	Mean(NO3--N mq/dm3)
Up	26.000	1.115	1.050	31.115	2.731
Wet	66.000	1.615	0.948	65.455	6.045

Table 6.4-5 Soil Means by Watershed for Small Basin Wetlands

Watershed	N	Mean (HM %)	Mean (WV g/cc)	Mean (CEC meq/100cc)	Mean (BS %)	Mean (Ac meq/100cc)	Mean (pH)
Fishing Creek	66.000	0.719	0.969	9.650	47.136	4.742	4.535
Lockwood Folly	83.000	4.383	1.009	7.131	20.840	5.780	4.140

Watershed	N	Mean (P mg/dm3)	Mean (K mg/dm3)	Mean (Ca mg/dm3)	Mean (Mg mg/dm3)	Mean (S mg/dm3)	Mean (Mn mg/dm3)
Fishing Creek	66.000	12.782	49.129	604.776	213.315	37.145	24.529
Lockwood Folly	83.000	18.989	25.446	181.443	50.055	30.966	1.106

Watershed	N	Mean(Zn mg/dm3)	Mean(Cu mg/dm3)	Mean(Na mg/dm3)	Mean(NO3--N mq/dm3)
Fishing Creek	66.000	1.615	0.948	65.455	6.045
Lockwood Folly	83.000	0.655	0.431	37.795	5.711

Section 6.6 Small Basin Wetlands: Amphibian Results and Discussion

The Small Basin wetland survey resulted in a total of 23 amphibians being identified to species. There were 17 species of amphibians identified to species in the Coastal Plain Lockwood Folly River sites of which 13 were anurans and 14 were urodela including: green tree frog, pinewoods tree frog, Cope's gray tree frog, squirrel tree frog, southern cricket frog, little grass frog, southern chorus frog (*Pseudacris nigrita*), Brimley's chorus frog (*Pseudacris brimleyi*), southern leopard frog, northern green frog, bullfrog, southern toad, oak toad (*Bufo quercicus*), eastern newt, marbled salamander, white-spotted slimy salamander (*Plethodon cylindraceus*), and the many-lined salamander (*Sterochilus marginatus*). In the Piedmont Fishing Creek sites, 13 amphibians were identified to species, (10 anurans and 3 urodela), similarly to the Coastal Plain, Cope's gray tree frog, squirrel tree frog, northern green frog, bullfrog, southern leopard frog, eastern newt and marbled salamander were observed, in addition, the American toad, Fowler's toad, northern cricket frog, upland chorus frog, spring peeper, and spotted salamander were also observed. The Coastal Plain Small Basin wetlands were more acidic due to the presences of pond cypress (*Taxodium ascendens*) and a lack of fire. Most Piedmont sites yielded more abundance results (44 to 250) then the Coastal Plain amphibian surveys, which ranged from 21 to 77. The most common species by far in the Coastal Plain was the southern cricket frog with 136 occurrences at five sites followed by the southern toad (19 occurrences), *Rana* sp. (16 occurrences) and green tree frog (10 occurrences) which were found at three, three, and one site. respectively. The most common species in the Piedmont species were the southern leopard frog (232 occurrences), spotted salamander (147 occurrences), and spring peeper (70 occurrences). The southern leopard frog was found 5 sites, the spotted salamander was found at all six sites, and the spring peeper was found at 3 sites.

The Small Basin wetlands were analyzed two ways, by combining both regions together and separating the regions. The results were slightly better by separating the two regions; however, the Piedmont result only had two usable metrics for the IBI. Table 6.6-1 shows the significant correlation results (p-value $\leq$ 0.15) for the Spearman's Rho and Pearson's pairwise correlation analyses. Similarly to the previous amphibian analyses, results that had a more significant p-value of < 0.05 and Pearson's correlation or Spearman's ρ > 0.5 are listed in bold blue while results that had a p-value of < 0.1 and $\geq$ 0.5 are listed in bold red. Three metrics were chosen for the Coastal Plain Small Basin wetland IBI: Percent Tolerance, Percent Urodela, and Species Richness. Percent Tolerance and Percent Urodela were chosen for the Piedmont Small Basin wetland Amphibian IBI. The Coastal Plain metrics correlated with four to seven disturbance measurements including soil pH, Cu, and Zn and water quality Ca, Mg, Ammonia NO2+NO3, Cu, fecal Coliform, DOC, and TSS. There were no correlations with either ORAM or LDI. Percent EW-HW-Seep, Percent Sensitive, Percent Urodela, and Abundance correlated with just one or two disturbance measurements. The Piedmont metrics correlated with three to six disturbance measurements, including ORAM. Species Richness correlated with TSS and Percent Sensitive correlated with TSS, otherwise there were no other correlations for the Piedmont Small Basin wetlands.

Table 6.6-2 shows the metric results for both the Coastal Plain (shown in bold red) and Piedmont (shown in bold blue) Small Basin wetland sites. For the Coastal Plain, species richness ranged from four (the Martin-Amment site, a highly acidic site) to ten (the Bluegreen Golf and Mill Creek sites), percent tolerance ranged from 35% (the Mill Creek site) to 92% (the Sikka site), and percent Urodela ranged from 0% (the Sikka site) to 7.3% (the Mill Creek site). For the

Piedmont, abundance ranged from 44 (the Goldston site) to 250 (the Belton Creek site) and 245 (the Dargan site) and percent EW-HW-seep ranged from 14% (the Dargan site) to 43% (the Eastwood and Goldston sites). Metric score assignments of “0” “3”, “7”, “10” were made according to the data distribution and are shown in Table 6.6-3 (bold red for the Coastal Plain and bold blue for the Piedmont). Table 6.6-4 shows the metric score assigned for the species richness, percent tolerant, percent Urodela for the Coastal Plain (bold red) and abundance and percent EW-HW-seep for the Piedmont (bold blue). The total amphibian IBI scores ranged from 7 to 23 in the Coastal Plain and 13 to 17 in the Piedmont. In the Coastal Plain, the Sikka site, which was not a low quality (quality again referring to best professional judgment in this context) site scored 7 and the Mill Creek site which was also not a low quality site, although Sunset Harbor Road is located in the buffer of one side of this site, scored 23. The Seawatch Bay site, which was probably the highest quality site in the Coastal Plain, had a score of 14 while the Bluegreen Golf site, the lowest quality site, had a score of 17. The lack of diversity in the ratings for the Piedmont is likely due to only two metrics being chosen for the IBI. It is apparent from the results that further evaluation of these sites and evaluation of additional sites that are variable in quality would be needed to develop a more representative IBI to be used in both the Coastal Plain and Piedmont.

Table 6.6-1 Small Basin Wetland Significant Correlation Results with Disturbance Measures

Region	Wetland Type	Cadidate Metric	Disturbance Measurement	Correlation / Spearman ρ	p-value	Analysis
Both	Small Basin Wetland	%Sensitive	NO2+NO3	-0.4535	0.1387	Spearman’s Rho Correlation
Both	Small Basin Wetland	%Sensitive	Total Suspended Residue	**-0.5455**	**0.0666**	Spearman’s Rho Correlation
Both	Small Basin Wetland	%Urodela	Fecal Coliform	**-0.7360**	**0.0064**	Pearson’s Correlation
Both	Small Basin Wetland	%Urodela	pH	**0.6294**	**0.0283**	Spearman’s Rho Correlation
Both	Small Basin Wetland	%Urodela	Soils Mean(pH)	**0.5229**	**0.0989**	Pearson’s Correlation
Both	Small Basin Wetland	%Urodela	Soils Mean(pH)	**0.5455**	**0.0827**	Spearman’s Rho Correlation
Both	Small Basin Wetland	%Urodela	Soils Median(pH)	0.5162	0.1041	Pearson’s Correlation
Both	Small Basin Wetland	%Urodela	Soils Median(pH)	**0.5434**	**0.0841**	Spearman’s Rho Correlation
Both	Small Basin Wetland	AQAI	Fecal Coliform	-0.4466	0.1456	Pearson’s Correlation
Both	Small Basin Wetland	Species Richness	pH	**0.5794**	**0.0484**	Pearson’s Correlation
Both	Small Basin Wetland	Species Richness	pH	**0.6138**	**0.0338**	Spearman’s Rho Correlation
Both	Small Basin Wetland	Species Richness	Soils Mean(pH)	**0.6362**	**0.0354**	Pearson’s Correlation
Both	Small Basin Wetland	Species Richness	Soils Mean(pH)	**0.7032**	**0.0158**	Spearman’s Rho Correlation
Both	Small Basin Wetland	Species Richness	Soils Median(pH)	**0.6900**	**0.0188**	Pearson’s Correlation
Both	Small Basin Wetland	Species Richness	Soils Median(pH)	**0.7615**	**0.0065**	Spearman’s Rho Correlation
cp	Small Basin Wetland	%EW-HW-Seep	NO2+NO3	**-0.7775**	**0.0687**	Spearman’s Rho Correlation
cp	Small Basin Wetland	%Sensitive	Ammonia	-0.6667	0.1481	Spearman’s Rho Correlation
cp	Small Basin Wetland	%Sensitive	NO2+NO3	**-0.7775**	**0.0687**	Spearman’s Rho Correlation
cp	Small Basin Wetland	%Tolerance	Ammonia	0.7023	0.1197	Pearson’s Correlation
cp	Small Basin Wetland	%Tolerance	Ammonia	**0.8986**	**0.0149**	Spearman’s Rho Correlation
cp	Small Basin Wetland	%Tolerance	Copper	0.6983	0.1228	Spearman’s Rho Correlation
cp	Small Basin Wetland	%Tolerance	NO2+NO3	**0.7775**	**0.0687**	Spearman’s Rho Correlation
cp	Small Basin Wetland	%Tolerance	Soils Median(Zn mg/dm3)	0.6667	0.1481	Spearman’s Rho Correlation
cp	Small Basin Wetland	%Tolerance	Total Suspended Residue	**0.8286**	**0.0416**	Spearman’s Rho Correlation
cp	Small Basin Wetland	%Urodela	Ammonia	**-0.8407**	**0.0361**	Spearman’s Rho Correlation
cp	Small Basin Wetland	%Urodela	Calcium	**-0.7415**	**0.0916**	Pearson’s Correlation
cp	Small Basin Wetland	%Urodela	Copper	**-0.7590**	**0.0801**	Spearman’s Rho Correlation
cp	Small Basin Wetland	%Urodela	Fecal Coliform	**-0.8723**	**0.0234**	Pearson’s Correlation
cp	Small Basin Wetland	%Urodela	Fecal Coliform	**-0.7537**	**0.0835**	Spearman’s Rho Correlation
cp	Small Basin Wetland	%Urodela	Magnesium	**-0.7432**	**0.0904**	Pearson’s Correlation
cp	Small Basin Wetland	%Urodela	Magnesium	-0.7143	0.1108	Spearman’s Rho Correlation
cp	Small Basin Wetland	%Urodela	NO2+NO3	**-0.9977**	**0.0000**	Pearson’s Correlation
cp	Small Basin Wetland	%Urodela	NO2+NO3	**-0.8452**	**0.0341**	Spearman’s Rho Correlation
cp	Small Basin Wetland	%Urodela	Total Suspended Residue	**-0.7714**	**0.0724**	Spearman’s Rho Correlation

Table 6.6-1 Small Basin Wetland Significant Correlation Results with Disturbance Measures

Region	Wetland Type	Cadidate Metric	Disturbance Measurement	Correlation / Spearman ρ	p-value	Analysis
cp	Small Basin Wetland	Abundance	Dissolved Oxygen (%)	0.7143	0.1108	Spearman’s Rho Correlation
cp	Small Basin Wetland	Abundance	Dissolved Oxygen (mg/L)	0.7143	0.1108	Spearman’s Rho Correlation
cp	Small Basin Wetland	AQAI	Ammonia	-0.6667	0.1481	Spearman’s Rho Correlation
cp	Small Basin Wetland	AQAI	NO2+NO3	**-0.7775**	**0.0687**	Spearman’s Rho Correlation
cp	Small Basin Wetland	Species Richness	DOC	-0.6957	0.1248	Spearman’s Rho Correlation
cp	Small Basin Wetland	Species Richness	pH	**0.7494**	**0.0863**	Pearson’s Correlation
cp	Small Basin Wetland	Species Richness	Soils Mean(Cu mg/dm3)	**-0.7556**	**0.0823**	Pearson’s Correlation
cp	Small Basin Wetland	Species Richness	Soils Mean(pH)	**0.7688**	**0.0740**	Pearson’s Correlation
cp	Small Basin Wetland	Species Richness	Soils Mean(pH)	**0.7537**	**0.0835**	Spearman’s Rho Correlation
cp	Small Basin Wetland	Species Richness	Soils Median(pH)	**0.8099**	**0.0508**	Pearson’s Correlation
cp	Small Basin Wetland	Species Richness	Soils Median(pH)	**0.7537**	**0.0835**	Spearman’s Rho Correlation
cp	Small Basin Wetland	Species Richness	Soils Median(Zn mg/dm3)	-0.7059	0.1170	Spearman’s Rho Correlation
pd	Small Basin Wetland	%EW-HW-Seep	DOC	-0.6902	0.1291	Pearson’s Correlation
pd	Small Basin Wetland	%EW-HW-Seep	pH	0.6724	0.1434	Pearson’s Correlation
pd	Small Basin Wetland	%EW-HW-Seep	Soils Mean(Cu mg/dm3)	**-0.8315**	**0.0809**	Pearson’s Correlation
pd	Small Basin Wetland	%EW-HW-Seep	Soils Mean(Cu mg/dm3)	**-0.9000**	**0.0374**	Spearman’s Rho Correlation
pd	Small Basin Wetland	%EW-HW-Seep	Soils Median(Cu mg/dm3)	**-0.9669**	**0.0072**	Pearson’s Correlation
pd	Small Basin Wetland	%EW-HW-Seep	Soils Median(Cu mg/dm3)	**-0.8721**	**0.0539**	Spearman’s Rho Correlation
pd	Small Basin Wetland	%Sensitive	Total Suspended Residue	-0.6993	0.1220	Pearson’s Correlation
pd	Small Basin Wetland	Abundance	Calcium	**-0.7681**	**0.0744**	Pearson’s Correlation
pd	Small Basin Wetland	Abundance	Copper	**-0.8075**	**0.0520**	Pearson’s Correlation
pd	Small Basin Wetland	Abundance	Copper	**-0.7714**	**0.0724**	Spearman’s Rho Correlation
pd	Small Basin Wetland	Abundance	Lead	**-0.7583**	**0.0806**	Pearson’s Correlation
pd	Small Basin Wetland	Abundance	Lead	**-0.7590**	**0.0801**	Spearman’s Rho Correlation
pd	Small Basin Wetland	Abundance	Magnesium	**-0.7688**	**0.0740**	Pearson’s Correlation
pd	Small Basin Wetland	Abundance	ORAM Mean	0.6855	0.1328	Pearson’s Correlation
pd	Small Basin Wetland	Abundance	Zinc	**-0.8515**	**0.0314**	Pearson’s Correlation
pd	Small Basin Wetland	Abundance	Zinc	**-0.8857**	**0.0188**	Spearman’s Rho Correlation
pd	Small Basin Wetland	Species Richness	Total Suspended Residue	**-0.8792**	**0.0210**	Pearson’s Correlation
pd	Small Basin Wetland	Species Richness	Total Suspended Residue	**-0.8407**	**0.0361**	Spearman’s Rho Correlation

Bold Red = Probility ≤ 0.05 and **Bold Blue** = Probility > 0.05 and ≤ 0.10

Table 6.6-2 Small Basin Wetland Candidate Metric Results

Region	Site Name	Species Richness	Abundance	%Tolerance	%Sensitive	%Urodela	AQAI	%EW-HW-Seep
Coastal Plain	Bluegreen Golf	**10**	23.4	**65.81**	14.1	**4.7**	3.03	**9.4017**
	Martin-Amment	**4**	21	**42.86**	47.62	**4.76**	4.1	**47.619**
	Mill Creek	**10**	41	**35.37**	45.12	**7.32**	3.55	**12.1951**
	Seawatch Bay	**5**	61.5	**96.75**	1.63	**1.63**	1.98	**3.252**
	Seawatch Nautica	**8**	59	**67.8**	25.42	**3.39**	3.15	**28.8136**
	Sikka	**7**	77	**92.21**	7.79	**0**	2.16	**6.4935**
Piedmont	Belton Creek	14	**249.95**	51.21	43.79	27.01	3.99	**17.3035**
	Dargan	6	**245.1**	79.87	12.18	12.18	3.72	**14.0045**
	Dean	11	**95**	53.42	39.84	40.26	4.47	**24.7632**
	Eastwood	9	**107.15**	48.06	9.47	8.54	3.8	**42.8138**
	Goldston	8	**44.4**	39.41	20.05	17.79	4.06	**42.9054**
	Hart	8	**62.35**	54.05	29.91	45.95	3.62	**30.5132**

Bold Red = Metrics to be used in Coastal Plain Amphibian Small Basin Wetland IBI, **Bold Blue** = Metrics to be used in Piedmont Amphibian Small Basin IBI

%EW-HW-Seep = Percent Ephemeral Wetland - Headwater Wetland – Seep

Table 6.6-3 Metric Score Assignments for Small Basin wetlands

Metric	0	3	7	10
Species Richness	**<3**	**<5**	**<8**	**≥8**
%Tolerance	**≥50**	**<50**	**<30**	**<10**
%Urodela	**0**	**<2**	**<5**	**≥5**
Abundance	**<20**	**<50**	**<200**	**≥200**
%EW-HW-Seep	**<5**	**<20**	**<40**	**≥40**

Bold Red = Metrics to be used in Coastal Plain Amphibian Small Basin Wetland IBI, **Bold Blue** = Metrics to be used in Piedmont Amphibian Small Basin IBI, %EW-HW-Seep = % Ephemeral Wetland - Headwater Wetland –Seep

Table 6.6-4 Amphibian IBI Scores for Small Basin Wetland Sites

Region	Site Name	Species Richness	Abundance	%Tolerance	%Urodela	%EW-HW-Seep	Total
Coastal Plain	Bluegreen Golf	10		0	7		**17**
	Martin-Amment	3		3	7		**13**
	Mill Creek	10		3	10		**23**
	Seawatch Bay	7		0	7		**14**
	Seawatch Nautica	10		0	3		**13**
	Sikka	7		0	0		**7**
Piedmont	Belton Creek		10			3	**13**
	Dargan		10			3	**13**
	Dean		7			7	**14**
	Eastwood		7			10	**17**
	Goldston		3			10	**13**
	Hart		7			7	**14**

Section 6.7 Small Basin Wetlands: Macroinvertebrate Results and Discussion

Section 6.7 will be delivered to the EPA at a later time when the macroinvertebrate samples have been identified, enumerated, and analyzed.

Section 6.8 Small Basin Wetland: Vegetation Survey Results and Discussion

The vegetation survey of Small Basin wetlands in the Lockwoods Folly watershed yielded about 80 vascular species of trees, shrubs, grass, ferns, sedges, and vines. The Small Basin wetlands were more open than the Riverine Swamp Forests, often with trees dominating the edges and scattered through the middle. Swamp tupelo was by far the most common tree species followed by pond cypress (*Taxodium ascendens*), and red maple. Loblolly pine (*Pinus taeda*), red bay (*Persea borbonia*), and sweet gum also occurred in these Small Basin wetlands. Shrubs were very dominant while herbaceous vegetation was more sparse at most sites except Sikka. Titi was the most dominant shrub followed by Myrtle holly (*Ilex myrtifolia*), fetter bush, and highbush blueberry (*Vaccinium fuscatum*). Witch grass (*Dicanthelium* spp) was the most dominant herb, other herb species that occurred were Virginia chain fern (*Woodwardia virginiana*), red-root (*Lachnanthes caroliana*), and loose head beakrush (*Rhychospora chalarocephala*). Vine species that occurred (although not as prominently as in the Riverine Swamp systems) were laurel-leaf greenbriar and poison ivy.

The vegetation survey of the Fishing Creek Small Basin wetlands showed in more diversity then in Lockwoods Folly River sites with 110 species of vascular plants. Only five of the six sites were surveyed due to loss of access to the Hart site, which probably would have identified a few more grass species. One of the sites had been completely logged (the Eastwood site), while both the Hart and Belton Creek sites had been partially logged. Otherwise these sites were forested with mature trees. The Dargan and Dean sites, which were not logged, had more open canopies then the other type of wetland (Bottomland Hardwood Forests) studied in Fishing Creek. Ground vegetation also tended to be more sparse in the less disturbed sites. Trees that were common in the Fishing Creek Small Basin wetlands were sweet gum, red maple, willow oak, black gum (*Nyssa sylvatica*), and winged elm, other tree species including American elm, loblolly pine, and green ash. Highbush blueberry was the most dominant shrub followed by fetterbush (*Leucothoe racemosa*), other shrub species included blackberry (*Rubus* spp) and buttonbush. Nepalese browntop occurred at three of the sites, but it was not nearly as dominant as it was in the Bottomland Hardwood Forest sites. Ground vegetation was variable between the different Small Basins surveyed. Wool grass (*Scirpus cyperinus*) did occur at three of the sites, otherwise the more dominant species tended to only occur at one or two of the sites. Some of these species included creeping sedge (*Juncus repens*), Autumn bluegrass (*Poa autumnalis*), fringed sedge, southern waxy sedge (*Carex glaucescens*), and various other species of *Carex*. Poison ivy, muscadine grape, trumpet vine, and japonese honeysuckle were vines that occurred but did not dominate these sites. Moss was also more of an important presence in the Fishing Creek Small Basin wetlands than the Small Basin wetlands in the Coastal Plain or riverine community types.

Statistical correlations were run by separating the Small Basin wetland by region and by keeping both regions together thus having a larger sample size (N = 11). Better correlation results were achieved by combining the regions so it made sense to develop the IBIs with both regions together rather then separately as was done with the Small Basin wetland Amphibian IBI. Table 6.8-1 shows the significant correlation results (p-value $\leq$ 0.15) for the Spearman's Rho and Pearson's pairwise correlation analyses. Results that had a more significant p-value of < 0.05 and Pearson's correlation or Spearman's ρ > 0.5 are listed in bold blue while results that had a p-value of < 0.1 and $\geq$ 0.5 are listed in bold red. The following factors were considered a priority in choosing metrics for the Small Basin wetland plant IBI: 1. Metrics with lower probabilities, 2. metrics that were significant for both Pearson's correlation and Spearman's Rho, 3. metrics that correlated with more then one disturbance measurement, 4. metrics that were not measuring similar biological attributes (e.g. Native Herb Richness and Herb Richness), 5. metrics that correlated with ORAM which was a better measurement of site condition, 6. types of metrics that measured different aspects of the vegetation community (i.e. Community Balance Structure, Wetness, Functional Groups, and Community Structure). There were a total of 11 plant metrics with significant results (see Table 6.8-1), however eight metrics using the above criteria were chosen for the Small Basin wetland plant IBI. The Small Basin wetland swamp metrics chosen were Evenness for the Community Balance metric type, FQAI cover and Invasive Coverage for the Floristic Quality metric type, Wetland Shrub Richness for the Wetness Characteristics metrics, and Sapling Density, Large Tree Density, and Standing Snag Importance for the Community Structure metric type. These metrics had the more significant results (lower p-value), were representative of four of the different types metric types, and correlated with ORAM or ORAM and LDI in one or both statistical correlations.

Table 6.8-2 shows the metric results for each of the Small Basin wetland sites. Metric scores ranged from 0.08 (the Eastwood site) to 0.35 (the Seawatch Nautica site) for the evenness metric, which suggests that the Seawatch Nautica site had the most even distribution of species while the Eastwood site had the least even distribution. Metrics scores ranged from 7.7 (the Eastwood site) to 30.9 (the Seawatch Nautica and Seawatch Bay sites had 30.6) for the FQAI Cover metric, 1.2 (the Seawatch Bay, Seawatch Nautica, and Sikka sites were 1.4, and the Dargan site was 1.8) to 33.3 (the Mill Creek site) for the percent tolerance metric, and 0 (the Martin-Amment, Mill Creek, Seawatch Bay, Seawatch Nautica, Belton Creek, and Dargan sites) to 3.5 (the Goldston site) for the invasive coverage metric. The FQAI results suggest that the Eastwood site was dominated with the lowest quality vegetation. The Eastwood site was dominated with ruderals (weedy species) due to recently being cutover while the Seawatch Bay and Seawatch Nautica sites had the highest quality vegetation. The Goldston site, a low quality Piedmont site ("quality" here again refers to best profession judgement) had exotic invasives such as Nepalese browntop grass, Japonese honeysuckle and multiflora rose (*Rosa multiflora*) while the Martin-Amment, Mill Creek, Seawatch Bay, Seawatch Nautica, Belton Creek, and Dargan sites did not have any exotic invasives occur in the vegetation survey. Scores ranged from 0 (the Eastwood site) to 8 (the Seawatch Nautica site) for the wetland shrub richness metric, which indicates the Seawatch Nautica site had the most diverse coverage of wetland shrubs while the Eastwood site had none. Metric scores ranged from 0.3 (the Seawatch Nautica site) to 1 (the Eastwood site) for the sapling density metric, 0 (the Bluegreen Golf and Eastwood sites) to 0.4 (the Seawatch Nautica site) for the large tree density metric, and 0 (the Bluegreen Golf and Eastwood sites) to 1.5 (the Dargan site) for the standing snag importance metric. These results indicated that the Seawatch Nautica site had the lowest density of sapling-sized trees (trees < 10 cm DBH) while the Eastwood site only had sampling-sized trees, additionally the Bluegreen Golf and Eastwood sites only had the lowest density of large trees (trees $\geq$ 25 cm) while the Seawatch Nautica site had the greatest. The Seawatch Nautica site was dominated by pond cypress that had buttressing bases, which would have caused a greater value for the Large Tree Density Metric. The Bluegreen Golf and Eastwood sites also had the lowest importance value for standing snags while the Dargan site had the greatest indicating this site likely had the best wildlife habitat in terms of nesting cavities.

Metric score assignments of “0”, “3”, “7”, and “10” were made according to the data results distribution and are shown in Table 6.8-3. Table 6.8-4 shows the metric score assigned for the eight individual metrics chosen for the Small Basin wetland Plant IBI and the total IBI score. The total Small Basin wetland Plant IBI scores ranged from 23 to 67 in the Coastal Plain and 3 to 50 in the Piedmont. The Sikka site was the lowest quality site with a score of 23 and the Bluegreen Golf site was close behind with a score of 27 in the Coastal Plain. The Bluegreen Golf site named for the fact that it is located in the middle of a Golf Course did appear to be a lower quality site than the Sikka site which has had some selective logging. It should be noted that although only four modules were surveyed for the Bluegreen Golf site. The Mill Creek site, which scored next lowest with 31, was surveyed in the middle of the site where the water levels hinder shrub growth, however there was a ring of shrubs around the edge of this site. Therefore the score for this site may have been higher if some of these shrubs were picked up in the survey. Historically, the Mill Creek site was probably logged more recently then the other sites since the pond cypress was not as mature as at sites like Seawatch Bay and Seawatch Nautica. The Seawatch Nautica, Martin-Amment, and Seawatch Bay sites, which scored 67, 55, and 54 respectively, are high quality sites with mature trees and a well developed shrub stratum. The herbaceous layer is mostly non-existent at these sites. However, there were not any exotics present. If wetland size were to be considered, the Seawatch Bay site would certainly have rated highest. The Eastwood site, which was recently clear-cut, was not surprisingly the lowest scoring site in the Piedmont and of all the Small Basin wetlands with a score of 3. Another Piedmont site (Goldston) was second lowest with a score of 19. This is not a high quality site either so the low score was also not surprising. The Dargan site had the highest Piedmont score of 50. The Dargan site is a high quality site with an intact buffer and diverse vegetation therefore a higher plant IBI score is logical. Overall there were lower quality sites in the Piedmont than in the Coastal Plain. The differing scores between the Piedmont (average score of 25) and the Coastal Plain (average score of 43) were also likely affected by the lack of invasives in the Coastal Plain basins and buttressing bases of cypress trees.

Table 6.8-1 Small Basin Wetland Significant Correlation Results with Disturbance Measures

Wetland Type	**Metric**	**Disturbance Measurement**	**Correlation / Spearman ρ**	**p-value**	**Analysis**
Community Balance Metrics					
Small Basin Wetland	Simpson's Diversity Index	ORAM Mean	**0.5437**	**0.0839**	Pearson’s Correlation
Small Basin Wetland	Evenness	ORAM Mean	**0.5560**	**0.0757**	Pearson’s Correlation
Floristic Quality Metrics					
Small Basin Wetland	Average C of C	ORAM Mean	**0.6125**	**0.0452**	Pearson’s Correlation
Small Basin Wetland	Average C of C	ORAM Mean	**0.6636**	**0.0260**	Spearman's Rho Correlation
Small Basin Wetland	Invasive Coverage	ORAM Mean	**-0.5532**	**0.0775**	Pearson’s Correlation
Small Basin Wetland	Invasive Coverage	ORAM Mean	-0.4957	0.1210	Spearman's Rho Correlation
Small Basin Wetland	Invasive Grass Coverage	ORAM Mean	**-0.5663**	**0.0693**	Pearson’s Correlation
Small Basin Wetland	Invasive Grass Coverage	ORAM Mean	**-0.5608**	**0.0727**	Spearman's Rho Correlation
Small Basin Wetland	Invasive Shrub Coverage	ORAM Mean	**-0.7442**	**0.0086**	Pearson’s Correlation
Small Basin Wetland	Invasive Shrub Coverage	ORAM Mean	**-0.6607**	**0.0269**	Spearman's Rho Correlation
Small Basin Wetland	FQAI Cover	ORAM Mean	**0.6125**	**0.0452**	Pearson’s Correlation
Small Basin Wetland	FQAI Cover	ORAM Mean	**0.5909**	**0.0556**	Spearman's Rho Correlation
Wetness Characteristic Metrics					
Small Basin Wetland	Wetland Shrub Richness	ORAM Mean	**0.6609**	**0.0375**	Pearson’s Correlation
Small Basin Wetland	Wetland Shrub Richness	ORAM Mean	**0.7707**	**0.0055**	Spearman's Rho Correlation
Community Structure Metrics					
Small Basin Wetland	Large Tree Density	100M LDI	**-0.5968**	**0.0526**	Spearman's Rho Correlation
Small Basin Wetland	Large Tree Density	ORAM Mean	**0.6469**	**0.0314**	Spearman's Rho Correlation
Small Basin Wetland	Large Tree Density	100M LDI	**-0.7461**	**0.0084**	Pearson’s Correlation
Small Basin Wetland	Large Tree Density	ORAM Mean	**0.7832**	**0.0044**	Pearson’s Correlation
Small Basin Wetland	Large Tree Density	Watershed LDI	**-0.6186**	**0.0425**	Pearson’s Correlation
Small Basin Wetland	Sapling Density	100M LDI	**0.5598**	**0.0733**	Pearson’s Correlation
Small Basin Wetland	Sapling Density	100M LDI	0.5182	0.1025	Spearman's Rho Correlation
Small Basin Wetland	Sapling Density	Watershed LDI	**0.5336**	**0.0909**	Pearson’s Correlation
Small Basin Wetland	Standing Snag Importance	100M LDI	**-0.7338**	**0.0101**	Pearson’s Correlation
Small Basin Wetland	Standing Snag Importance	ORAM Mean	**0.6905**	**0.0187**	Pearson’s Correlation
Small Basin Wetland	Standing Snag Importance	ORAM Mean	0.5194	0.1016	Spearman's Rho Correlation
Small Basin Wetland	Standing Snag Importance	Watershed LDI	**-0.6582**	**0.0277**	Pearson’s Correlation

Bold Red = Probility ≤ 0.05 and **Bold Blue** = Probility > 0.05 and ≤ 0.10

Table 6.8-2 Small Basin Wetland Plant Metric Results

Region	Site	Evenness	FQAI Cover	Invasive Coverage	Wetland Shrub Richness	Sapling Density	Large Tree Density	Standing Snag Importance
CP	Bluegreen Golf	0.21	20.35	0.10	3.00	0.82	0.00	0.00
CP	Martin-Amment	0.35	21.34	0.00	4.00	0.51	0.21	0.65
CP	Mill Creek	0.26	19.30	0.00	4.00	0.92	0.01	0.16
CP	Seawatch Bay	0.22	30.56	0.00	5.00	0.54	0.12	1.13
CP	Seawatch Nautica	0.35	30.94	0.00	8.00	0.31	0.38	0.72
CP	Sikka	0.15	14.41	1.88	5.00	0.95	0.04	0.23
PD	Belton Creek	0.19	12.61	0.00	2.00	0.81	0.06	1.13
PD	Dargan	0.17	17.80	0.00	3.00	0.47	0.31	1.45
PD	Dean	0.18	14.18	2.67	2.00	0.84	0.13	0.20
PD	Eastwood	0.08	7.72	2.01	0.00	1.00	0.00	0.00
PD	Goldston	0.14	13.72	3.52	1.00	0.71	0.03	1.08

Table 6.8-3 Plant Metric Score Assignments for Small Basin wetlands

Metric	0	3	7	10
Evenness	<0.10	<0.20	<0.30	≥0.30
FQAI Cover	<10	<15	<25	≥25
Invasive Coverage	≥3	<3	<2	<1
Wetland Shrub Cover	<2	<4	<7	≥7
Sapling Density	≥0.90	<0.90	<0.60	<0.35
Large Tree Density	<0.10	<0.20	<0.30	≥0.30
Standing Snag Importance	<0.20	<0.50	<1	≥1

Table 6.8-4 Plant IBI Score for Small Basin Wetland Sites

Region	Site	Evenness	FQAI Cover	Invasive Coverage	Wetland Shrub Richness	Sapling Density	Large Tree Density	Standing Snag Importance	Total
CP	Bluegreen Golf	7	7	7	3	3	0	0	27
CP	Martin-Amment	10	7	10	7	7	7	7	55
CP	Mill Creek	7	7	10	7	0	0	0	31
CP	Seawatch Bay	7	10	10	7	7	3	10	54
CP	Seawatch Nautica	10	10	10	10	10	10	7	67
CP	Sikka	3	3	7	7	0	0	3	23
PD	Belton Creek	3	3	10	3	3	0	10	32
PD	Dargan	3	7	10	3	7	10	10	50
PD	Dean	3	3	3	3	3	3	3	21
PD	Eastwood	0	0	3	0	0	0	0	3
PD	Goldston	3	3	0	0	3	0	10	19

Section 7 - Wetland Type Comparisons and Final Conclusions

7.1 Wetland Type Comparisons

Physical, chemical and biological characteristics of the three different wetland types (Riverine Swamp Forests, Bottomland Hardwood Forests, and Small Basin wetlands) are summarized and compared in the following section. These characteristics of water quality and soils, along with the hydrology of these wetland types will be examined first followed by the biological characteristics. Lastly, the NCWAM correlations with the Level I, Level II, and Level III results will be compared and contrasted among the three wetland types.

Water Quality

For water quality, samples were taken quarterly at each site. The water quality parameters included chemical measures (nutrients and metals) and physical measures (pH, specific conductivity, dissolved oxygen, and suspended solids). For the Riverine Swamp Forest, water quality samples were statistically compared by location of the water sample; up-river, down-river, and in the buffer. It would be expected that the quality of the water would improve (lower levels of nutrients and metals) as it flowed down river. The buffer would be expected to have lower levels as the water would flow from the buffer to the wetland center. Generally these results were confirmed for several of the water quality parameters (ammonia, DO, DOC, phosphorus, TKN, TOC, and zinc). These results show that Riverine Swamp Forest do improve the water quality as it flows down river through the system. The Bottomland Hardwood Forests also had water quality samples taken at upstream and downstream locations. The results indicate that ammonia and NO2+NO3 are lower downstream and DO is higher downstream which are consistent with water quality improving as it flows downstream. However, several parameters actually increased downstream. Overall, the results for the Bottomland Hardwood Forest were not as significant as for the Riverine Swamp Forests. Water samples were collected for six Small Basin wetland in the Fishing Creek (Piedmont) watershed and six Small Basin wetlands in the Lockwood Folly River watershed (Coastal Plain). The water quality results were compared between the Small Basin wetland in the two watersheds (and different ecoregions). The results showed that for most of the water quality parameters, the Coastal Plain wetlands had better water quality than the Piedmont wetlands. The results comparing the Small Basin wetlands in the different watersheds tend to indicate that the Lockwood Folly River wetlands had better water quality. Whether that indicates that Small Basin wetlands have a better water quality function than the Fishing Creek Small Basin wetlands is difficult to conclude because the input into the wetlands are not known. Even with the riverine wetlands, the Lockwood Folly Riverine Swamp Forests appeared to improve water quality better that the Bottomland Hardwood Forests at Fishing Creek. The wetlands in the Lockwood Folly River watershed are clearly different from the wetlands in the Fishing Creek watershed. One other result of note was that two Small Basin wetlands (Eastwood and Goldston sites) in the Fishing Creek watershed had water quality samples taken at a clearly defined outlet from the wetland. When the water quality parameters were evaluated for the two different sample locations, the results suggest that the Eastwood site is in fact improving water quality where the results for the Goldston site are mixed at best. Given that these are Small Basin wetlands, flow through the system is slow and probably irregular. The slope at the Eastwood site was a little more pronounced and obvious than at Goldston, so this may be a factor in the results.

Overall, Riverine Swamp Forests showed statistically significant improvements for several water quality parametrs while the Bottomland Hardwood Forests showed significant improvement, but for far fewer paramenters. The Small Basin wetlands had mixed results. These conclusions are consistent with the regular flow through of water in the Riverine Swamp Forest and with the less frequent flow though in the Bottomland Hardwood Forests. Small Basin wetlands, especially those that are isolated from surface flow, generally have very small watersheds and therefore have less significant surface water quality improvements than systems with larger watersheds. Work has begun to examine the ground water connectivity of these wetlands which may reveal a significant water quality benefit though filtration to ground water.

Soil Characteristics

Soil samples were collected in the wetland and the surrounding upland. Generally, the soil texture of the Riverine Swamp Forests in the Lockwood Folly watershed was primarily a muck, often organic, but several sites had sandier soils at the deeper levels. The soil color of these wetland soils was very dark. The soils at the Fishing Creek watershed in the Bottomland Hardwood Forest were variable, but primarily sandy clay loam or variants thereof. The soil was typically moderately dark with extensive mottling. Soils for the Small Basin wetlands at Lockwood Folly River watershed were very similar in texture with there often typically being a muck presence with sandy loam being the typical texture. The color was typically very dark. The Fishing Creek Small Basin wetlands were different since Piedmont wetlands had no muck and therefore the soil was typically not as dark. The soil was primarily a clay loam with a silty clay loam or silty loam being also common.

Comparisons were made between the upland samples and the wetland samples for all three wetland types. It would be expected that soil parameters that were potential pollutants (such as nutrients and metals) would be higher in the wetland than the surrounding upland, indicating the wetlands are acting as a sink for the potential pollutants and that the wetlands have the opportunity to filter the water and improve its quality (lower levels of nutrients and metals in the water). The results confirmed this assumption since many of the soil parameters (nutrients and metals) had higher levels in the wetland samples than the upland samples for the Riverine Swamp Forests, Bottomland Hardwood Forest, and the Small Basin wetlands. Comparisons were also made between the Small Basin wetland between the two watersheds. These results comparing the soil parameters of the two watersheds with the Small Basin wetlands show that the Lockwood Folly River wetlands had fewer potential pollutants in the soil than the Fishing Creek wetlands. This result is consistent with the water quality results which also showed that the Lockwood Folly River Small Basin wetlands had better water quality than the Fishing Creek Small Basin wetlands.

Hydrology

Hydrographs for the Riverine Swamp Forest in the Lockwood Folly River watershed showed no seasonal variation except for the Doe Creek site and even that site did not exhibit a strong trend. The Riverine Swamp Forests generally have very consistent high water levels throughout the year with trends being more daily that seasonal. The Doe Creek and Lockwood sites were tidal and the Mercer Seawatch site had some tidal influence also, but to a lesser degree. The

Bottomland Hardwood Forests in the Fishing Creek watershed all had very similar hydrographs, which is expected since they are in the same general physiographic area (and watershed) with similar precipitation. It is also clear that Bottomland Hardwood Forests are much more influenced by precipitation and periodic overbank and overland flooding than are the Riverine Swamp Forests which had much more consistent water levels. For the Small Basin wetlands at the Lockwood Folly River watershed, the Mill Creek, Seawatch Bay, and Sikka sites clearly show the big drops in water levels when the drought started. For the Bluegreen Golf site, the signs of drought were less obvious. This wetland's hydrology was flashy and is in the middle of a golf course and residential development where irrigation may have supplemented its hydrology. The Martin-Amment site and Seawatch Nautica sites seem to show the drought pattern, but has an interesting period with water levels being recorded during the spring of 2008 even during the drought. Small Basin wetlands in the Fishing Creek watershed showed some seasonal pattern with higher levels in the winter and also patterns due to precipitation. The drought that affected the Small Basin wetlands at Lockwood Folly did affect the Fishing Creek Small Basin Wetlands, but the affect is not as clear and they tended to recover much better possibly due to their more clayey soils (versus the more sandy-muck soils). Overall, the Riverine Swamp Forest wetlands were more consistently inundated with much higher water levels than either the Bottomland Hardwood Forests or the Small Basin wetlands. The Bottomland Hardwood Forests also had more consistent water levels than the Small Basin wetlands. The Small Basin wetlands tend to vary greatly in their water levels and are more influenced by climatic conditions like drought.

Amphibian Communities

The surveys for amphibians and vegetation showed there was variability between the wetland types and regions. The different regions of the state combined with the presence of predatory fish in the wetter sections of the Riverine Swamp Forest sites resulted in variation between the types of amphibians that were present at each wetland type. Additionally, specific site characteristics and stressors at the different sites likely influenced the types of amphibian species and the quantity of each type that were observed during the survey. Amphibian surveys resulted in the observation of 14 species, primarily anurans (frogs and toads), in the Coastal Plain Riverine Swamp Forests while 12 species, four of which were urodela (salamander or newts) were found in the Bottomland Hardwood Forests. Riverine Swamp Forest amphibians tended to be generalist (e.g. *Rana clamitans* or *R. catesbeina*) that could tolerate the presence of predatory fish while in the Bottomland Hardwood Forests overland flooding rather then regular overbank flooding created pools of fish free water that allowed more sensitive species like the marbled salamander (*Ambystoma opacum*) to thrive. The higher Coastal Plain acidity levels in addition to regional affects on the distribution of species may have caused some of the differences between Coastal Plain and Piedmont Small Basin amphibian species populations. There were 17 Small Basin wetland Coastal Plain amphibian species and 13 Small Basin wetland Piedmont species, of which seven of these species occurred in both regions. The overall abundance was substantially higher in the Piedmont (Small Basin Piedmont wetland abundance was 804, Bottomland Hardwood Forest wetland abundance was 747, Coastal Plain Small Basin wetland abundance was 283 and Riverine Swamp Forest abundance was 340) even though the species richness was higher in the Coastal Plain. A larger portion of the Piedmont abundance was also Urodela.

Overall, the amphibian pattern that was observed appears to relate stongly to the presence or absence of predatory fish, length of indundation, and acidity. Riverine Swamp Forests receive regular overbank flooding from the adjacent stream and it is very likely that predatory fish are able to forage in these wetlands and they strongly affect amphibian species distribution. In contrast, Bottomland Hardwood Forests mostly receive overland flow which concentrates in small low lying areas in the floodplain which are relatively fish-free. Finally, the Riverine Swamp Forest and Bottomland Hardwood Forest have water pH levels closer to neutral than the Small Basin wetlands which can make them more condusive for amphibian reproduction. Small Basin wetlands often dry up in the summer (and for longer periods during droughts) and are therefore fish-free. These systems often have lower pH levels which can affect amphibian usage. Therefore, water pH also affects the pattern of amphibian use of these wetland types. Overall, the Piedmont Small Basin and Bottomland Hardwood wetlands with seasonal flooding and more neutral pH levels provided better habitat for amphibians then did the Riverine Swamp Forest and Coastal Plain Small Basin wetlands. It is likely that a less acidic open and grassy Coastal Plain wetland would also provide decent habitat for amphibian species.

Vegetation Communities

Similarly to amphibian communities, the different regions of the state combined with wetland type and site-specific stressors resulted in variation in the wetland plant communities that were surveyed. Coastal Plain Riverine Swamp Forests have diverse herb strata with bald cypress (*Taxodium distichum*), swamp tupelo (*Nyssa biflora*), and red maple (*Acer rubrum*) dominating the canopy and numerous forbs, ferns, and sedges, especially *Carex*, in the herb layer. Piedmont Bottomland Hardwood Forests, although less diverse then riverine swamps forests, were forested with American elm (*Ulmus americana*), sweet gum (*Liquidambar styraciflua*), red maples, and green ash (*Fraxinus pennsylvatica*). Exotic invasives, Chinese privet (*Ligustrum sinense*) and Nepolese browntop (*Microstegium viminium*) were most problematic in this wetland type. Coastal Plain Lockwood Folly River Small Basin wetlands were the least diverse of the wetland types and were often composed of a canopy of pond cypress (*Taxodium ascendens*), a dense ericaceous shrub layer, and a sparse herb layer. The more diverse Piedmont Fishing Creek Small Basin wetlands had canopies composed of sweet gum, red maple, willow oak (*Quercus phellos*), and black gum (*Nyssa sylvatica*) with high bush blueberry dominant in the shrub layer and a more pronounce herb layer then in the Coastal Plain. Three of the Fishing Creek Piedmont Small Basin Wetland sites had been partially or completely logged whereas all of the Coastal Plain Lockwood Folly River Small Basin wetlands were intact.

Overall, the Riverine Swamp Forests had the greatest diversity in vegetation speices while the Small Basin wetland in the Lockwood Folly River watershed had the least diversity. For the Piedmont wetlands, the Bottomland Hardwood Forests were the second most diverse and the Small Basin wetlands were less diverse. The lower diversity for the Small Basin wetlands could be attributed to longer periods of stagnant water and higher acididy. The Small Basin wetlands in the Piedmont were more diverse than the Coastal Plain Small Basin wetlands and could be partly attributed to the logging that has occurred on three of the sites, thereby allowing newer and successional species to invade. The greater diversity of the Riverine Swamp Forests is interesting in that they have relatively high water levels year round, but flow does occur, keeping the water replenished and less acidic.

Indices of Biological Integrity

The variation between wetland type, both in terms of regional location and the affects of river flooding and specific site characteristics and stressors, also resulted in different amphibian metrics with significant correlation with Level I (LDI), Level II (ORAM) and Level III (intensive surveys for water quality and soils) disturbance measurements for the three different wetland types. For the Riverine Swamp wetlands, the metrics for amphibian species richness, abundance, and percent Urodela (salamanders and newts) were significant and used in the Riverine Swamp Forest amphibian IBI. Riverine Swamp Forest amphibian IBI scores range from seven to 23 for the seven sites. For Bottomland Hardwood Forests, metrics for amphibian species percent tolerance, percent sensitive, percent Urodela, AQAI (Amphibian Quality Assessment Index - a quality index that weighs amphibian rareness and abundance), and percent ephemeral wetland-headwater wetland-seep (amphibian tax associated with fish-free environments) were significant and used in the bottomland hardwood amphibian IBI. Bottomland Hardwood Forest IBI scores ranged from three to 51. For Small Basin wetlands, the amphibian metrics were evaluated separately for the two regions. The results showed, although not as significant (but still with p-values < 0.1), as with the riverine wetlands, that species richness, percent tolerant and percent Urodela were the best metrics for indicating wetland quality in the Coastal Plain while abundance and percent ephemeral wetland – headwater wetland – seep were the best metrics for indicating wetland quality in the Piedmont. Small Basin wetland amphibian IBI scores ranged from seven to 23 in the Coastal Plain and 13 to 17 in the Piedmont.

Different plant metrics correlated significantly with the disturbance measurements, (ORAM and LDI), for the different types of wetlands. Again, as with amphibian metrics, the different plant communities that are found in the different regions and wetland types in combination with specific site stressors, likely caused these differences. For Riverine Swamp Forests, plant metrics for herb and shrub dominance, FAQWet equation 3 (a metric that incorporates species wetness and diversity) and wetland plant richness (number of obligate and facultative wet species), Carex richness, dicot cover, total herb richness, and pole timber density (density of low quality timber) were the best indicators for differentiating between high quality and low quality sites. Riverine Swamp Forest plant IBI scores ranged from 12 to 67. For Bottomland Hardwood Forests, plant metrics for dominance, FAQWet cover (a metric that incorporates species wetness and percent cover), wetland shrub cover, bryophyte cover, Carex richness, sedge, grass, and rush richness, native herb richness, and the importance of standing snags were the best indicators for differentiating between high quality and low quality sites. Bottomland Hardwood Forest plant IBI scores ranged from 29 to 55. Both regions were analyzed together for the Small Basin wetland IBI plant analysis, which found that the metrics for evenness, floristic quality assessment index cover, invasive coverage, wetland shrub richness, sapling density, and standing stag importance were the best indicators of wetland quality for Small Basin wetlands. Small Basin wetland plant IBI scores ranged from 27 to 67 in the Coastal Plain and three to 50 in the Piedmont.

For the amphibian metrics the Bottomland Hardwood Forest metrics had the best correlations with Level I, Level II, and Level III disturbance measurements which resulted in 43 significant correlations with the two statistical tests Pearson’s pairwise correlations and Spearman’s Rho. This resulted in the use of five of the seven candidate metrics in the amphibian IBI. The Piedmont Small Basin wetlands had the fewest correlations with the same disturbance measurements and analyses with 18 significant correlations. This resulted in the use of only two metrics in the amphibian IBI for Small Basin wetlands and very little range (13-17) between the resulting scores. The Bottomland Hardwood Forest amphibian metrics also correlated with NCWAM while the other two wetland type amphibian metrics did not, which will be discussed further in the next section.

For the plant metrics, the Riverine Swamp analyses had the most significant correlations with the Level I and Level II disturbance measurements which resulted in 28 correlations with the two statistical tests. However, the Small Basin wetland correlations were close behind with 26 significant correlations. These analyses resulted in the use of seven of the 40 candidate metrics in the plant IBI for both Riverine Swamp Forests and Small Basin wetlands. Plant IBI scores ranged from 12 to 67 for the Riverine Swamp Forest plant IBI and from three to 67 (27 to 67 in the Coastal Plain and three to 50 in the Piedmont) for the Small Basin Wetland IBI. The Bottomland Hardwood Forest wetlands had the fewest correlations with the same disturbance measurements and analyses with 15 significant correlations. This resulted in the use of eight metrics in the Bottomland Hardwood Forest plant IBI. Bottomland Hardwood Forest plant IBI ranged from 29 to 55. Both the Riverine Swamp Forests and especially the Small Basin wetlands had a number of plant metrics and the plant IBI correlate with NCWAM.

Overall, plant IBI’s were more successful than amphibian IBI’s. The amphibian IBI’s were most successful for the Bottomland Hardwood Forests as they tend to provide the best habitat for amphibians. This is most likely due to the more neutral pH levels and the absence of predatory fish that would be more likely in the Riverine Swamp Forests. The Bottomland Hardwood Forests also have more moderate and seasonal water levels which allow amphibians to reproduce and deposit their egg masses. The Small Basin wetlands often suffer from higher acidic levels especially in the Coastal Plain which are not conducive to most amphibian species and their water levels are more unpredictable and more affected by drought conditions which would make it difficult for most amphibian species to breed. The plant IBI’s were the most successful with the Riverine Swamp Forests which also had the greatest plant diversity. The Small Basin wetlands had the next most correlations and resulted in plant IBI ranges from three to 67 (both Coastal Plain and Piedmont together). While the Bottomland Hardwood Forests had the fewest correlations, the plant IBI range was still good. The reason that the plant IBIs’s were more successful that the amphibian IBI’s was that the amphibian populations were not very diverse in the Riverine Swamp Forests and Small Basin wetlands which made it difficult to develop good IBI’s for amphibians.

The North Carolina Rapid Assessment Method - NCWAM

The NCWAM ratings were completed twice at each of the sites. The differences between the two ratings were minimal and indicate that NCWAM ratings are not subject to observer error. The overall NCWAM ratings for the Riverine Swamp Forest were high for six of the seven sites with the Winding River Townhouse site getting a high and low rating. The ORAM scores for the Riverine Swamp Forests range from 55 to 80. The two sites rating the lowest were the Rourk site and the Winding River Townhouse site (this being somewhat consistent with NCWAM). The Bottomland Hardwood Forests had three sites being rated high overall (the Fairport, Kim-Brooks, and Munn sites), two sites were rated medium, and one site was rated low (the Gray site). The ORAM scores for the Bottomland Hardwood Forest were generally high ranging from

52 to just over 73. The site rated the lowest on ORAM was the Hancock site and it was rated Medium overall on NCWAM. The Gray site was rated low on NCWAM and had the third lowest ORAM score. The other site that was rated medium with NCWAM was the Powers site and it had the second highest ORAM score. The Small Basin wetlands at the Lockwood Folly River watershed had five of the six sites rated high overall and one site was rated medium overall (the Bluegreen Golf site). The ORAM scores for these Small Basin wetlands range from 46 to 89. The Bluegreen Golf site was rated lowest on ORAM which is consistent with NCWAM's overall low rating. The Fishing Creek Small Basin wetlands had overall NCWAM scores of high for four of the sites and medium for two sites (the Eastwood and Hart sites). For ORAM scores, the range was about 40 to 80 for these Small Basin wetlands. The two sites that rated the lowest were the Hart and Eastwood sites, and this is consistent with NCWAM's overall rating of medium for these two sites.

Statistical correlations showed there was some correlation between the two rapid assessment methods which was variable based on wetland type as well as round (the first round of assessment was at the beginning of the project in October-November 2006 and the second round was at the end of the project in November 2008) and statistical method (see Tables 5.2.1-1, 5.3.1-1, and 6.2-1). For the Riverine Swamp Forest there was significant correlation between the NCWAM overall score, hydrology, water quality, and habitat fuctions (habitat function had correlation in round 1 only). For the Bottomland Hardwood Forest there was significant correlation for the NCWAM overall score and water quality function (round 1 only) with the ORAM site means (averaged score of assessors). Small Basin Wetland NCWAM overall scores, hydrology function, and habitat function correlated significantly for both rounds and both statistical tests with ORAM site mean scores.

The agreement between NCWAM and ORAM is varied and this should not be unexpected for two reasons: (1) the small sample size with the result of little variation for NCWAM scores; and (2) the two rapid assessment methods were developed for different purposes. NCWAM was developed to determine the functional value of a wetland based on wetland type and uses an ordinal scale with only three values (high, medium, and low). ORAM on the other hand, was developed to assess wetland condition and uses a numeric (ordinal) scale with a much wider range of scores (0-100), regardless of wetland type. Therefore to expect a direct correlation between the two rapid assessments may be unrealistic, however some significant correlations did occur. Future wetlands monitoring and assessments by DWQ will attempt to clarify the relationship between the two rapid assessments (and others, such as USA-RAM).

Correlations were also performed with the NCWAM ratings and the Level I LDI data and Level III monitoring data (plant and amphibian metrics and IBIs and water and soil quality site parameter means) collected for each wetland type. There were no significant correlations with the Level I LDI data for any wetland type however some of the Level III data did correlate significantly with the NCWAM ratings for each of the wetland types (see Tables 5.2.1-1, 5.3.1-1, and 6.2-1).

For the Riverine Swamp Forests, the NCWAM overall scores and the three functions (habitat, hydrology, and water quality) had statistically significant correlations with dicot cover. The NCWAM Habitat function also correlated with the pole timber density metric significantly and with the riverine plant IBI scores. There were weak correlations ($0.15 > \text{p-value} > 0.10$) with NCWAM overall score, water quality and hydrology function and dicot cover and with the NCWAM overall score and water quality and habitat functions with dissolved oxygen.

For Bottomland Hardwood Forests, correlations of the NCWAM ratings resulted in additional significant results, with three amphibian metrics, the amphibian IBI, seven water quality parameters and one soil quality parameter plus weak correlations with one plant metric and four other water and soil quality parameters. The overall NCWAM score correlated significantly with three amphibian metrics; percent tolerance, percent sensitive, and percent Urodela, the Amphibian IBI and the water quality parameters for lead, TSS and Zinc and the soil parameter NO3--N. The habitat function correlated significantly with amphibian species richness. The NCWAM hydrology fuction correlated significantly with amphibian species richness while the NCWAM habitat function correlated with the amphibian species richness and the water quality parameters copper, lead, TKN, TOC, TSS and Zinc. The water quality function correlated with the amphibian percent Urodela and percent sensitive metrics, the amphibian IBI, the water quality parameter's lead, TSS and zinc and the soil quality parameters NO3--N. The weaker correlations between the NCWAM overall score and/or functions occurred with the wetland shrub cover metric, the water quality parameters for fecal coliform and pH and soil quality parameters for potassium and phosphorus.

For the Small Basin Wetlands there were significant correlations between the NCWAM ratings and three plant metrics and the plant IBI plus a weak correlation with one other plant metric. There were no correlations with any of the amphibian metrics, the amphibian IBI, or any water or soil quality parameters. The NCWAM overall score correlated significantly with large tree density, standing snag importance, and weakly with the plant IBI. The NCWAM habitat function correlated significantly with large tree density, standing snag importance, the plant IBI and weakley with sapling density. The hydrology function also correlated with sapling density, large tree density, and the plant IBI and weakley with the FQAI metric. Small Basin Wetland water quality function did not correlate with any of the plant metrics or the plant IBI or other results and the there were no other Level I, Level II, or Level III data results that correlated with the Small Basin wetland NCWAM ratings.

Overall, correlations with the NCWAM results were variable by wetland type. The Bottomland Hardwoods Forests had the most number of correlations with the NCWAM ratings primarily with the Level II ORAM scores and Level III amphibian and water quality and soils data. The Bottomland Hardwood Forest wetlands also have more significant correlations with the water quality parameters in the amphibian IBI development process then the other two types of wetlands. The Riverine Swamp Forests had fewer correlations and only with the Level III plant data, water quality dissolved oxygen, and Level II ORAM scores. The Small Basin Wetlands also had fewer correlations with just the Level III plant data but strongly significant correlations with the Level II ORAM scores.

The correlations with NCWAM ratings and the Level II, and III results were significant for some of the correlations and not at all for the Level I results. It should be noted that these variable results may be related to the small sample size and the lack of variability of the NCWAM ratings. First, the sample size for each wetland type was small with seven Riverine Swamp Forests, six Bottomland Hardwood Forests, and 12 Small Basin wetlands were small. Secondly, the ratings of the sites did not vary much as most of the wetlands were rated high (18 sites or 72%) and only five sites were rated medium (28%) and only one site was rated low. The functions of hydrology, water quality, and habitat did vary more than the overall score for most of the wetland types. However, given these two limitations, significant correlations across the board with all of the NCWAM ratings and Level I, II, and III results were difficult to achieve.

Therefore, it could be argued that any significant correlations at all are in fact encouraging for an initial/early evaluation of NCWAM with these wetland types. A follow-up study on Coastal Plain Small Basin wetlands will address both of these limitations and provide a larger sample size to calibrate NCWAM for this wetland type.

Headwater Forest Wetland Comparison

The previous wetlands monitoring project (CD 974260-01) focused on monitoring 23 Headwater Forest wetland sites in the Piedmont and the Coastal Plain. Some general comparisons can be made between wetland types in this current study to the Headwater Forested wetlands in the previous study. There are a few minor differences between the Level III measurements in the two studies, such as the placement of water quality stations and hydrology monitoring wells; however these differences still allow for some general comparisons to be made. In terms of water quality, Headwater wetlands successfully reduce potential pollutants as water flows from the wetland to downstream channels, which is similar to Riverine Swamp Forests. Both Riverine Swamp Forests and Headwater wetlands successfully reduced many of the nutrient pollutants as water flowed though the wetland from upstream to downstream. In terms of reducing metals however, the Headwater Forested wetlands reduced more types of metals than did Riverine Swamp Forests. The difference between the systems is that for Headwater wetlands, the water flow is from the wetland to the stream channel and with the Riverine Swamp Forest, the water flow is through the wetland, from upstream to downstream. Headwater wetlands reduced potential pollutants better than Bottomland Hardwood Forests and Small Basin wetlands. Headwater Forest wetland soil is saturated seasonally, similar to Bottomland Hardwood Forests. However, the ground water hydrology was very different in this study. Headwater wetlands have ground water within one foot of the surface 73% of the time while Bottomland Hardwood Forests have ground water within one foot of the surface 28% of the time. The hydrology of Riverine Swamp Forests were within one foot of the surface about 90% of the time while Small Basin wetlands were more varied with the Piedmont Small Basin wetlands recording water levels within one foot of the surface about 52% of the time and Coastal Plain Small Basin wetlands recording water levels within one foot of the surface 12% of the time. It should be noted that these results may have been different if the two studies had been done during the same year. Precipitation levels were more normal for the Headwater wetland study while drought conditions, especially in the Coastal Plain, existed for the Riverine Swamp Forest, Bottomland Hardwood Forest, and Small Basin wetland study. The soils of Headwater wetlands were primarily mineral in the Piedmont but more varied in the Coastal Plain where the soil tended to be more of a mixture of organic and mineral. The soils of Headwater wetlands are more similar to Bottomland Hardwood Forest, and less similar to Riverine Swamp Forests and Small Basin wetlands.

The comparison of Headwater wetlands amphibian communities to Riverine Swamp Forests, Bottomland Hardwood Forests, and Small Basin wetland amphibian communities resulted in similarities and differences that were likely caused both by region and wetland physiography. Diversity was highest in the Headwater wetland sites with 17 species in the Coastal Plain and 19 in the Piedmont. In the Coastal Plain, there were 14 amphibian species identified in the Riverine Swamps and 17 in the Small Basin wetlands while in the Piedmont there were 12 species identified in both the Bottomland Hardwood Forest and Small Basin wetlands. There was lower diversity in this study as compared to the headwater wetland study but abundance was comparable or greater and only half as many sites were assessed. Similarly to the Headwater wetland study, the amphibian survey resulted in higher levels of abundance in the Piedmont wetlands then in the Coastal Plain wetlands. The abundance of Coastal Plain Headwater wetlands was 123 while the abundance of Piedmont Headwater wetlands was 883. In the Coastal Plain, Riverine Swamp Forest abundance was 340 and Small Basin wetland swamp forest abundance was 283 while in the Piedmont, Bottomland Hardwood Forest abundance was 747 and Small Basin wetland abundance was 804. Amphibian species associated with fish free environments or EW-HW-Seep species (see Section 4.4.2) were found in all four wetland types but diversity was slightly higher in the Piedmont (six - Piedmont Headwater wetland species, five Bottomland Hardwood Forest species, and three Small Basin wetland species) then in the Coastal Plain (five Headwater wetland species, three Riverine Swamp Species, and two Small Basin wetland Species). A few EW-HW-Seep individuals (*Desmognanthus auriculatus, Pseudocris ocularis,* and *Hyla chrysoscelis*) were found or heard in the buffer areas of the Riverine Swamp Forest sites; however the abundance was higher in the Coastal Plain Small Basin wetlands (21 in the Riverine Swamp Forest sites and 41 in the Small Basin wetland sites). The EW-HW-Seep abundance was six in the Coastal Plain Headwater wetlands, 39 in the Piedmont Headwater wetlands, 185 in the Piedmont Small Basin wetlands and 135 in the Piedmont Bottomland Hardwood wetlands. The lower acidity levels in the Coastal Plain Small Basin wetlands and presence of fish within much of the Riverine Swamp Forest assessment areas likely caused the lower abundance of HW-EW-Seep amphibians at these sites. It should also be noted that the assessment area of the Headwater wetlands was generally smaller then the assessment area of the sites in this study and a 10 minute auditory night survey was conducted in this study but not the Headwater wetland study.

The similarities and differences of the vegetation of Coastal Plain Riverine Swamp Forests and Small Basin wetlands and Piedmont Bottomland Hardwood Forests and Small Basin wetland Forests were caused both by region and specific differences between wetland types. Coastal Plain Small Basin and Headwater wetlands both had a denser presence of shrubs then Piedmont Small Basin and Headwater wetlands however there were some species differences. Pond cypress trees were common in the Coastal Plain Small Basin wetlands but not the Coastal Plain Headwater wetlands. Bald cypress also occurred in the Coastal Plain Riverine Swamps and not the Coastal Plain Headwater wetlands. Other canopy trees such as red maple, American elm, sweet gum, and green ash were found in all four wetland types. Herbaceous flora species such as lizard tail, *Carex*, and various species of ferns were prevalent in all wetland types but the Coastal Plain Small Basin wetlands. The exotic invasive Chinese privet was more prevalent in the Coastal Plain Headwater wetlands then in the Piedmont Headwater wetlands; however it did not occur in any of the Coastal Plain Small Basin wetlands and was very sporadic within the Riverine Swamp Forest sites. This may have been a regional difference in the study as Headwater wetlands were assessed in eight Coastal Plain counties and Small Basin wetlands were only assessed in one outer Coastal Plain County. There were eight 10m x 10m modules surveyed in both studies, however the survey design in this study was a 2 x 4 array of adjacent modules located in the middle of the wetland while in the Headwater wetland study the design was a 2 x 3 array of modules located upstream in the wetland and then a 2 x 1 array of modules located 20m downstream. There also tended to be more upland plants in the headwater wetland study.

Section 7.2 Final Conclusions

North Carolina continues to be impacted by watershed development. Urbanization, agriculture and silviculture have altered the quality of stormwater runoff that flows into wetlands and impacts surrounding upland buffers and wildlife corridors. Wetlands can act as a natural filtering system for water quality by removing, reducing, or transforming pollutants. These wetlands also reduce downstream erosion by retaining stormwater runoff and releasing it more slowly after a heavy rain. Wetlands provide important habitat for macroinvertebrates and amphibians, both of which are sensitive to stressors in their environment such as impacts to water quality and wetland habitat, and deforestation of the surrounding upland buffer. Maintaining the ecological integrity of these wetland systems is necessary not only to protect wildlife habitat but also to protect the water quality of the entire downstream watershed.

This study has provided a better understanding of the quality and function of three types of wetlands - Riverine Swamp Forest, Bottomland Hardwood Forest, and Small Basin wetlands - within the Lockwood Folly River (Coastal Plain) and Fishing Creek (Piedmont) watersheds. The intensive Level III monitoring results have showed these types of wetlands are diverse systems comprised of a variety of vegetation in each strata and provide habitat for numerous amphibians. Additionally, the Riverine Swamp Forests and to a lesser degree Bottomland Hardwood Forests can improve water quality by lowering the levels of nutrients and metals. The nutrients and metals in the soils are lower in the uplands indicating that these wetlands act as a sink for these potential pollutants. The development of IBI’s was largely successful, especially for the plant data.

Future research will address several issues. A followup EPA grant to determine the possible ground water connectivity of isolated wetlands will concentrate on Small Basin wetlands. It is intended to have an equal number of Small Basin wetlands that rate high, medium, and low on the overall NCWAM score and to collect Level III monitoring data. These new Small Basin wetlands will provide a balanced sample from which to calibrate NCWAM for this wetland type. The sample size will still be small, so it can be combined with the data in this study to increase the sample size. Another followup EPA grant is an intensification study for the National Wetlands Condition Assessment (NCWA) being corrdinated by the EPA. This grant will work with Alabama and South Carolina to perform Level III monitoring of 20 wetlands in each state, with half being in the Piedmont and half in the Coastal Plain. The type of wetlands will be determined by the sample draw being done by the EPA, but it is expected that many if not most will be riverine wetlands (such as Riverine Swamp Forests and Bottomland Hardwood Forests) and this can provide a larger sample size when combined with the riverine wetlands from the current study. Also, the use of the USA-RAM on these wetlands for the NCWA will provide an opportunity to compare the national rapid assessment with results from NCWAM and ORAM. Another effort to calibrate NCWAM is with headwater wetlands where a reasonable number of headwater wetlands (N=32) have Level III monitoring data and with at least six in each category of NCWAM overall scores. Furthermore, data from both of these grants will continue to build the the wetlands monitoring data collected in North Carolina and the additional data will help to further develop IBI’s. Finally, eight of the sites from this study will be continued to be monitored on a long term basis. The eight sites are two Riverine Swamp Forests and two Small Basin wetlands in the Lockwood Folly River watershed and two Bottomland Hardwood Forests and two Small Basin wetlands in the Fishing Creek watershed. Level III monitoring data will continue to be collected on these six sites and some of the differences between the two ecoregions will continue to be evaluated.

Section 8 – Literature Cited

Batzer, D.P. and R.R. Sharitz, Eds. 2006. Ecology of freshwater and estuarine wetlands. Berkeley, California University of California Press. 568 p.

Bornette, Gurun, Clause Amoros, and Nicholas Lamaroux. 1998. Aquatic plant diversity in riverine wetlands: the role of connectivity. Freshwater Biology. 39:267-283.

Boynton, A.C. 1994. Wildlife use of Southern Appalachian wetlands in North Carolina. Journal Water, Air, & Soil Pollution 77:3-4 pp. 349-358.

Braccia, A. and D.P. Batzer. 2001. Invertebrates associated with woody debris in a southeastern U.S. forested floodplain wetland. Wetlands 21:1 pp.18-31.

Braswell, A., Lab Director and Curator for Herpetology, NC State Museum of Natural Sciences Research Laboratory (NCDENR). Personal interview. 28 March 2006, 2008, 2009.

Brower, J.E. and J.H. Zar. 1977. Field and laboratory methods for general ecology. Wm. Brown Company, Dubuque, Iowa.

Brown, M.T. and M.B. Vivas. 2003. A Landscape Development Intensity Index. Center for Environmental Policy, Department of Environmental Engineering Sciences, University of Florida. Technical Report Submitted to the Florida Department of Environmental Protection.

Chirhart, J. 2003. Development of a Macroinvertebrate Index of Biological Integrity (MIBI) for Rivers and Streams of the St. Croix River Basin in Minnesota. Minnesota Pollution Control Agency Biological Program. St. Paul, MN.

Collins and Fennessey, USA-RAM draft manual, 2009, (http://www.epa.gov/oamhpod1/adm_placement/sapcbd/rapid.htm)

Comer, P., K. Goodwin, A. Tomaino, G. Hammerson, G. Kittel, S. Menard, C. Nordman, M.Pyne, M. Reid, L. Sneddon, and K. Snow. 2005. “Biodiversity Values of Geographically Isolated Wetlands in the United States”. NatureServe, Arlingtion, VA.

Cashin, Gordon G., John R. Dorney, and Curtis J. Richardson, 1992, Wetland Alteration Trends in the North Carolina Coastal Plain, Wetlands 12(2): 63-71.

Dahl, T.E., and Johnson, C.E. 1991. Wetlands--Status and trends in the conterminous United States, mid-1970's to mid-1980's: Washington, D.C., U.S. Fish and Wildlife Service, 22 p.

J. R. Dorney, personal communication, 2009, North Carolina Division of Water Quality.

Environmental Laboratory. 1987. US Army Corps of Engineers Wetlands Delineation Manual. U.S. Army Engineers Waterways Experiment Station, Vicksburg, MS.

Ervin, G.N., B.D. Herman, J.T. Bried, and D.C. Holly. 2006. Evaluating non-native species and wetland indicator status as components of wetlands floristic assessment. Wetlands 26:1114-1129.

Esheleman. K. N., J.S. Pollard, and A. Kuebler. 1992. “Interactions between Surface Water and Groundwater in a Virginia Coastal Plain Watershed.” Virginia Water Resources Research Center.

Fennessy, M.S., R. Geho, B. Elifritz, and R.D. Lopez. 1998a. Testing the floristic quality assessment index as an indicator of riparian wetland quality. Final Report to U.S. EPA. Ohio Environmental Protection Agency, Division of SurfaceWater, Columbus, Ohio, USA.

Garbarino, John R., Heidy C Hays, David Rogh, Ronald Antweiler, Terry Brinton, and Howard Taylor. 1995. Contamination in the Mississippi River. *USGS Circular 113* (https://pubs.USGS.gov/circ/circ1133/heavy-metals.html)

Gibbons, J. W. and R. D. Semlitsch. 1981. “Terrestrial drift fences with pitfall traps: an effective technique for quantitative sampling of animal populations” *Brimleyana* 7: 1-16

Gibbons, Whitfield J. 2003. “Terrestrial Habitat: A Vital Component for Herpetofauna of Isolated” *Wetlands*. 23: 630-635.

Gibbons, Whitfield J. Christopher T. Winne, David E. Scott, John D. Willson, Xavier Glaudas, Kimberly M. Andrews, Brian D. Todd, Luke A. Fedewa, Lucas Wilkinson, Ria N Tsaliagos, Steven J. Harper, Judith L. Greene, Tracey D. Tuberville, Brian S. Metts, Michael E. Dorcas, John P. Nestor, Cameron A. Young, Tom Akre, Robert N. Reed, Kurt A. Buhlmann, Jason Norman, Dean A. Croshaw, Cris Hagen, and Betsie B. Rothermal. 2005. “Remarkable Amphibian Biomass and Abundance in an Isolated Wetland: Implications for Wetland Conservation”. *Conservation.* 20: 1457-1465.

Hefner, J.M., B.O. Wilen, T.E. Dahl and WE. Frayer. 1994. Southeast Wetlands; Status and Trends, Mid-1970's to Mid-1980's. U .S. Department of the Interior, Fish and Wildlife Service, Atlanta, Georgia. 32 pages.

Hodges, J.D. 1997. Development and ecology of bottomland hardwood sites. *Forest Ecology and Management*. 90: 117- 125.

Hupp, C.R. 2000. Hydrology, geomorphology and vegetation of Coastal Plain rivers in the south-eastern USA. *Hydrological Processes* 14: 2991-3010.

Kellison, R.C. and M.J. Young.1997. The Bottomland Hardwood Forest of the southern United States. *Forest Ecology & Management* 90: 101-115.

Kutka Franz, Marilyn Bachman. 1990. Acid sensitivity and water chemistry correlates in Northern WI, USA. *Hydrobiologia*. V 208. N3.

Leeper, D. A. and B. E. Taylor. 1998. “Insect emergence from South Carolina (USA) temporary pond, with emphasis on the Chironomidae (Diptera)”. *Journal of the North American Benthological Society*. 17:54-72.

Lefcort, H. RA Meguire, LH Wilson and W F Ettinger. 1998. Heavy metals alter the survival, growth, metamorphasis, and anti predatory behavior of Columbia Spotted Frog (*Rana luteivenstris*) tadpoles. *Archives of Environmental Contamination and Toxicology*. V. 35, N3. http.nap.edu/openbook.php?record_id=661&page=46.

Leibowitz, Scott G. 2003. Isolated Wetlands and their Functions: an Ecological Perspective. *Wetlands*: 23:517-531.

Lenat, D.R. 1990. A biotic index for the southeastern United States: derivation and list of tolerance values, with criteria for assigning water quality ratings. *Journal of North American Benthological Society* 12(3):279-290.

Lockwood Folly Round Table Report. Lockwood Folly River Water Quality Strategy, Report to Brunswick County Board of Commissioners. http://www.nceep.net/services/lwps/Lockwood/Lockwoods%20Folly%20DA-TM%20Report%20Appendix%20D%20Final%2006-26-07.pdf, February 2007

Lockwood Folly Watershed Strategy. http://www.southeastwaterforum.org/files/2-Stone%20-%20Lockwood%20Folly%20Watershed%20Strategy.pdf, Accessed August 2009

Lopez, R.D. and M.S. Fennessy. 2002. Testing the Floristic Quality Assessment Index as an indicator of wetland condition. *Ecological Applications* 12:487-497.

Mack, J.J. 2004. Integrated wetland assessment program. Part 9: Field manual for the vegetation index of biotic integrity for wetlands v. 1.3. Ohio EPA Technical Report WET/2004-9. Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water, Columbus, Ohio.

Mack, J.J. 2001. Ohio Rapid Assessment Method for Wetlands, Manual for Using Version 5.0. Ohio EPA Technical Bulletin Wetland/2001-1-1. Ohio Environmental Protection Agency, Division of Surface Water, 401 Wetland Ecology Unit, Columbus, Ohio.

Mahoney, D. S., M. A. Mort and B. E. Taylor. 1990. “Species richness of calanoid copepods, cladocerans and other branchiopods in Carolina bay temporary ponds”. *American Midland Naturalist.* 123:244-258.

Meade, R.H., T.R. Yuzyk, and T.J. Day. 1990. Movement and storage of sediment in rivers of the United States and Canada. In Surface Water Hydrology, the Geology of North America, Wolman, M.G. and H.C. Riggs (Eds.). Geological Society of America: Boulder, Colorado; 225-280

Messina, Michael G., and William H. Conner. *Southern Forested Wetlands.* Boca Raton. CRC Press LLC. 1998.

Mitsch, W.J. and J.G. Gosselink. 2000. Wetlands, Third Edition. John Wiley & Sons, Inc. New York, New York. 920pp.

Munsell Soil Color Charts. 1994. Macbeth Division of Kollmorgen Instruments Corporation. New Winsor, NY

The Nature Conservancy. 1992. The forested wetlands of the Mississippi River: An ecosystem in crisis. Nature Conservancy, Baton Rouge. 25pp.

Newman, M. C. and J. F. Schalles. 1995. “The Water Chemistry of Carolina Bays: a Regional Study.” *Archive für Hydrobiologie* 118:147-168.

NC_CREWS: North Carolina Coastal Region Evaluation of Wetland Significance, 1999. North Carolina Department of Environment and Natural Resources, Division of Coastal Mangement.

(NC DENR) N.C. Department of the Environment and Natural Resources. NC Natural Heritage Program. Natural Heritage Data. Accessed 3/4/2009. http://www.ncnhp.org

(NCDA&CS) N.C. Department of Agriculture and Consumer Services, Soil Testing Section. Soil Sample Information Lab Sheet. http://www.ncagr.com/agronomi/pdffiles/issoil.pdf. Oct 2007.

(NCDA&CS) N.C. Department of Agriculture and Consumer Services, Soil Testing Section. http://www.ncagr.com/agronomistmethod.htm. July 2006.

(NC DENR) N.C. Department of the Environment and Natural Resources. 2003. NC Museum of Natural Sciences. Distribution of amphibians in North Carolina draft document. January 2003.

(NCDWQ) North Carolina Division of Water Quality (2005). Laboratory Section: Sample Submission Guidance Document. North Carolina Division of Water Quality, Raleigh, NC. June 1. Available: http://h2o.enr.state.nc.us/lab/qa.htm.

(NCDWQ) North Carolina Division of Water Quality (2003). Intensive Survey Unit Standard Operating Procedures. North Carolina Division of Water Quality, Raleigh, NC. Available: http://h2o.enr.state.nc.us/esb/isu.html.

(NCDWQ) North Carolina Division of Water Quality (2003b). Quality Assurance Manual for the North Carolina Division of Water Quality Laboratory Section. Available: http://h2o.enr.state.nc.us/esb/qapp/labqam.pdf.

North Carolina and the Global Economy. Spring 2004. Hog Farming. Accessed 4 March, 2009. < http://www.duke.edu/web/mms190/hogfarming/>

N.C. State University Department of Agricultural and Resource Economics, Fishing Creek Local Watershed Planning Situation Assessment. http://www.ces.ncsu.edu/depts/agecon/WECO/fishing/Fishing_Sit_Assess.pdf. Accessed August 2009

N.C. Wetland Functional Assessment Team. N. *C. Wetland Assessment Method User Manuel*. 2008 (http://h2o.enr.state.nc.us/ncwetlands/pdu.htm).

N.C. Wetland Functional Assessment Team. Committee to develop the N. C. Wetland Assessment Method, 2006.

Wetland Functional Assessment: Expansion and enhancement of the North Carolina Wetland Assessment Method, (NC WAM), grant WL 9643505-1.

Ohio EPA (Environmental Protection Agency). 2004. Integrated Wetland Assessment Program. Part 8: Initial Development of Wetland Invertebrate Community Index for Ohio. Ohio EPA Technical Report WET/2004-8. Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water, Columbus, Ohio.

Osmond, D.L., D.E. Line, J.A. Gale, R.W. Gannon, C.B. Knott, K.A. Bartenhagen, M.H. Turner, S.W. Coffey, J. Spooner, J. Wells, J.C. Walker, L.L. Hargrove, M.A. Foster, P.D. Robillard, and D.W. Lehning. 1995. Wetlands Loss and Degradation. WATERSHEDSS: Water, Soil and Hydro-Environmental Decision Support System,. Accessed 3 March, 2009. <http://www.water.ncsu.edu/watershedss/info/wetlands/wetloss.html#tree>

Peet R.K., T.R. Wentworth, R.P. Duncan, and P.S. White. 1997. The North Carolina vegetation survey protocol: A flexible, multipurpose method for recording vegetation composition and structure. *Castanea* 63:262–274.

Rader, R.B., D.P. Batzer, and S.A. Wissinger (eds.). 2001. Bioassessment and management of North American freshwater wetlands. John Wiley and Sons, New York, NY, USA.

Rapanos, John A. et ux., Petitioners v. United States (Case No. 04-1034) and *June Carabell et. al., petitioners v. United States Army Corps of Engineers et al.* (Case No. 04-1384), Supreme Court of the United States, Washington, DC (20006). http://www.supremcourtus.gov/oral_arguments/argument_transcripts/04-1034.pdf

Reiss, K.C. and M.T. Brown. 2005. The Florida Wetland Condition Index (FWCI): Developing biological indicators for isolated depressional forested wetlands. Final Report to the Florida Department of Environmental Protection, under contract #WM-683.

Resource Management Group, Inc., 1999. National list of plant species that occur in wetlands, Region 2, Southeast, B.J. Sabine (ed.), Dickinson Press, USA, 90 pp.

RTI International, 2009. “Geographically Isolated Wetlands in Eastern Carolina: Southeast Isolated Wetland Assessment.” – Data Analysis of 2008 Field Work. Research Triangle Park, NC.

Schafale, M.P. and A.S. Weakley. 1990. *Classification of the natural communities of North Carolina. Third approximation.* North Carolina Department of Environment, Health, and Natural Resources, Division of Parks and Recreation, Natural Heritage Program, Raleigh.

Scott, D. E. 1994. “The effect of larval density on adult demographic traits in *Ambystoma opacum*”. *Ecology* 75:1383-1396.

Sharitz, Rebecca R. 2003. “Carolina Bay Wetlands: Unique Habitats of the Southeastern United States” *Wetlands*. 23: 550-562.

Semlitsch, Raymond D. and J. Russell Bodie. 1998. “Are Small, Isolated Wetlands Expendable?” *Conservation Biology*. 12:1129-1133.

Simpson, E.H. 1949. Measurement of diversity. *Nature* 163:688.

Solid Waste Agency of Northern Cook County v. United States Army Corps of Engineers et. al. Supreme Court of the United States, Case No. 99-1178, 531 U.S. 159 (2001), 191 F. 3d 845, reversed. http://www.law.cornell.edu/supct/html/99-1178.ZS.html.

Stone, A.W. and A.J. Lindley Stone. 1994. “Wetlands and Ground Water in the United States.” The American Ground Water Trust, Dublin, OH.

Stribling, J.B., B.K. Jessup, J.S. White, D. Boward, and M. Hurd. 1998. Development of a Benthic Index of Biotic Integrity for Maryland streams. Prepared by Tetra Tech, Inc., Owings Mills, MD and Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Program. CBWP-MANTA-EA-98-3

Taft, J.B., G.S. Wilhelm, D.M. Ladd, and L.A. Masters. 1997. Floristic quality assessment for vegetation in Illinois, a method for assessing vegetation integrity. *Erigenia* 15:3-95.

Thien, S. J. 1979. A flow diagram for teaching texture by feel analysis. *Journal of Agronomy Education* 8:54-55.

Tiner, Ralph Tiner. 2003. Geographically Isolated Wetlands of the United States. *Wetlands*. 23: 494:516.

Tiner, R. W., H. C. Berquist, G.P. DeAlessio, and M.J. Starr. 2002. “Geographically Isolated Wetlands: A Preliminary Assessment of their Characteristics and Status in Selected Areas of the United States”. U.S. Department of the Interior, Fish and Wildlife Service, Northeast Region, Hadley, MA.

(UMass a) http://www.umass.edu/nrec/pdf_files/checklist_and_instructions.pdf

(UMass b) http://www.umass.edu/nrec/pdf_files/whe_form_and_instructions.pdf

From http://www.umass.edu/nrec/onlinedocs.html (Accessed July 24, 2009)

U.S. Army Corps of Engineers. 2000. Installing Monitoring Wells/Piezometers in Wetlands. Wetland Regulatory Assistance Program. http://el.erdc.usace.army.mil/elpubs/pdf/tnwrap-2.pdf

U.S. EPA 1995. America's wetlands: Our vital link between land and water. Office of Water, Office of Wetlands, Oceans and Watersheds. EPA843-K-95-001.

U.S. EPA (U.S. Environmental Protection Agency). Invertebrates as Indicators of Prairie Wetland Integrity. 6 November 2007. U.S. Environmental Protection Agency. September 1995. http://www.epa.gov/owow/wetlands/wqual/pph2_4.html#4.4.4.

U.S. EPA (U.S. Environmental Protection Agency). Polluted Runoff (Nonpoint Source Pollution). What is nonpoint source (NPS) pollution. 29 November 2006. U.S. Environmental Protection Agency. 8 November 2007. http://www.epa.gov/owow/nps/qa.html

U.S. Natural Resource Conservation Service. 2006. “Ecologically Isolated Wetlands”. *Fish and Wildlife Habitat Management Leaflet.* Number 38.

Weakley, A.S. Working draft as of 7 April 2008. Flora of the Carolinas, Virginia, Georgia, northern Florida, and Surrounding Areas. The University of North Carolina Herbarium. http://www.herbarium.unc.edu/flora.htm

Whigham, Dennis F. and Thomas E. Jordan. 2003. Isolated Wetlands and Water Quality. *Wetland*s: 23: 541-549.

Winter, Thomas C. and James LaBaugh. 2003. “Hydrologic Considerations in Defining Isolated Wetlands.” *Wetlands*. 23: 532-539.

Zedler, Paul H. 2003. “Vernal Pools and the Concept of “Isolated Wetlands”” *Wetlands*. 23:597-607

.