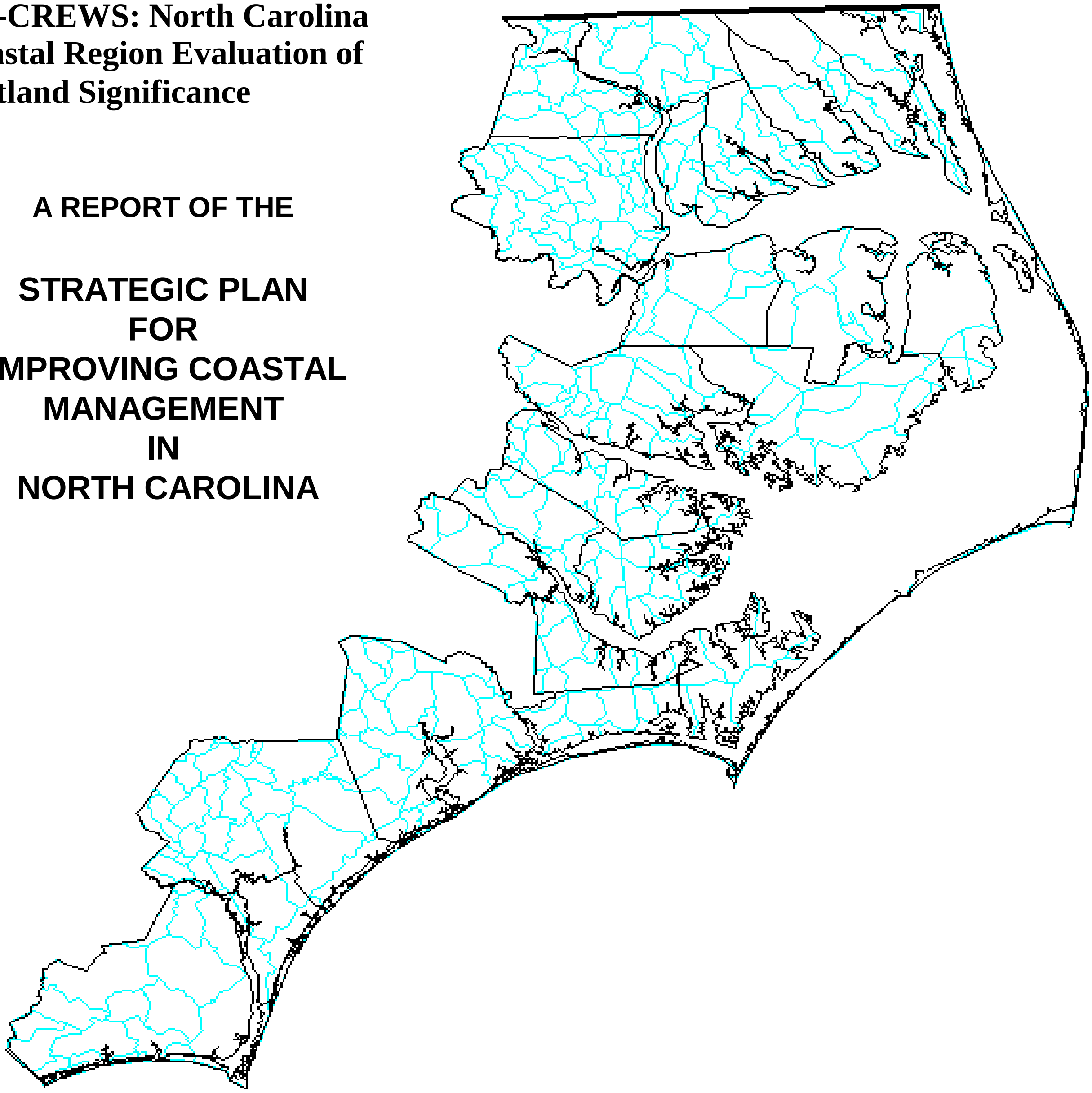
NC-CREWS: North Carolina Coastal Region Evaluation of Wetland Significance

A REPORT OF THE

STRATEGIC PLAN FOR IMPROVING COASTAL MANAGEMENT IN NORTH CAROLINA



Performed Under The Coastal Zone Enhancement Grants Program

Division of Coastal Management
North Carolina Department of Environment and Natural Resources

May 1999
(please see note in Executive Summary)

NC-CREWS: North Carolina Coastal Region Evaluation of Wetland Significance

Prepared by

Lori A. Sutter
NOAA Coastal Services Center
Formerly of the
North Carolina Division of Coastal Management
Department of Environment and Natural Resources

James B. Stanfill
North Carolina Division of Coastal Management
Department of Environment and Natural Resources

Dale M. Haupt
North Carolina Wetlands Restoration Program
Formerly of the
North Carolina Division of Coastal Management
Department of Environment and Natural Resources

Christopher J. Bruce
North Carolina Division of Coastal Management
Department of Environment and Natural Resources

James E. Wuenscher
Formerly of the
North Carolina Division of Coastal Management
Department of Environment and Natural Resources

with assistance from
US Environmental Protection Agency, Region IV
US Army Corps of Engineers, Wilmington District, Wilmington, NC
NOAA National Marine Fisheries, Beaufort, NC
North Carolina Division of Water Quality, Wetlands/401 Unit
North Carolina Division of Water Quality, North Carolina Wetlands Restoration Program
and
US Fish & Wildlife Service

May 1999
(please see note in Executive Summary)

The preparation of this report was financed by funds provided by the United States Environmental Protection Agency (EPA), Wetlands, Coastal and Water Quality Branch. The views expressed herein are those of the authors and do not necessarily reflect the views of the EPA or any of its sub-agencies or those of the North Carolina Department of Environment and Natural Resources.

A publication of the North Carolina Department of Environment and Natural Resources pursuant to the United States Environmental Protection Agency Award No. 994548-94-5.

NC-CREWS: North Carolina Coastal Region Evaluation of Wetland Significance

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The North Carolina Coastal Region Evaluation of Wetland Significance (NC-CREWS) is a watershed and landscape-based wetlands functional assessment model that uses Geographic Information Systems (GIS) software and GIS-based data to assess the level of water quality, wildlife habitat, and hydrologic functions of individual wetlands and the potential risk to watershed integrity if those wetlands were "lost" by evaluating 39 separate characteristics of the wetland and its watershed.

NC-CREWS uses a hierarchical structure in which individual parameters are combined to produce an overall wetland rating that indicates each wetland's functional importance. NC-CREWS produces 3 possible overall wetland rating scores: Exceptional Significance, Substantial Significance, or Beneficial Significance. Using GIS analysis, a High, Medium, or Low rating is assigned to each of the 39 parameters that describe the landscape and internal wetland characteristics. The parameter ratings are successively combined to produce ratings (H, M, or L) for subfunctions and primary functions. The primary functions are combined to form an overall wetland rating of the wetland's ecological significance.

NC-CREWS was primarily developed during the Carteret County Wetlands Advance Identification (ADID) project. The Carteret County Wetlands ADID project was funded by the Environmental Protection Agency under the authority of the Clean Water Act §404. The mission of the Carteret County ADID project was to provide information and planning tools for the protection of wetland resources in Carteret County, North Carolina for use by wetland property owners, industrial, commercial, and residential developers, non-profit organizations, forestry and agriculture industries, and local, county, state, and federal government agencies. NC-CREWS was one of the many tools developed during the ADID project.

Local, state, and federal agencies, citizens, and organizations contributed throughout the design of NC-CREWS. The federal and state agencies that review §404 wetland permit applications were involved in the project. The primary federal agencies involved were the US Environmental Protection Agency, US Army Corps of Engineers, National Marine Fisheries, and US Fish & Wildlife Service. The primary state agencies involved were the Division of Water Quality, Division of Parks and Recreation, and the Division of Coastal Management.

***Note: This document was originally published in May 1999. It has been reformatted and edited for the web and color figures have been added to enhance readers' understanding of the NCCREWS procedure. Some additional text has also been added as clarification. Hardcopies of the 1999 document can be requested from DCM, but they will not include these additional figures or text. Also, this mapping procedure has been extended into the North Carolina Inner Coastal Plain counties so that a total of 37 counties have been evaluated. This document focuses on the project originally confined to the 20 Coastal Counties, but the methods used for the Inner Coastal Plain were not changed.*

ACKNOWLEDGMENTS

Numerous organizations, agencies, and individuals gave their time and effort to develop the North Carolina Coastal Region Evaluation of Wetland Significance (NC-CREWS) model and report. Most of NC-CREWS was developed during the Carteret County Wetlands Advance Identification Project. Dr. Mark Brinson of East Carolina University, Dr. Robert Evans of North Carolina State University, Dr. Christopher Craft of the Jones Ecological Research Center, Dr. Hans Paerl of the University of North Carolina Institute of Marine Sciences, and Dr. Gordon Thayer of National Oceanic and Atmospheric Administration's National Marine Fisheries participated in the Carteret County Wetlands Advance Identification (ADID) Technical Support Team that contributed greatly in providing assistance in the original development of the wetland mapping and NC-CREWS evaluation methodologies.

The Carteret County ADID Project Team consisted of Rosalind Moore, Eric Hughes, Lee Pelej, and Jennifer Derby of the US Environmental Protection Agency, Wayne Wright and Scott Mclendon of the US Army Corps of Engineers, Larry Hardy and Don Field of NOAA's National Marine Fisheries, Kevin Moody of the US Fish & Wildlife Service, John Dorney, Cherri Smith, and Pete Colewell of the North Carolina Division of Water Quality, Laura Jones of the North Carolina Division of Water Quality Wetlands Restoration Program, Linda Pearsall of the North Carolina Natural Heritage Program, and Jim Stanfill, Kathy Vinson, and Lori Sutter of the North Carolina Division of Coastal Management. The Carteret County ADID Project Team was responsible for overseeing the development, review, and implementation of the Carteret County ADID Project, which included NC-CREWS and its corresponding documentation.

Jim Stanfill, Jim Wuenscher, Lori Sutter, Christopher Bruce, and Mac Haupt of the North Carolina Division of Coastal Management each wrote sections of the NC-CREWS document. The Division of Coastal Management's Greg Meyer, Sean McGuire, Christopher Bruce, Chase Barnard, Lori Sutter, Jim Stanfill, Brian Bledsoe, Steven Stichter, and others contributed to the development of the Geographic Information System and Arc Marco Language programming that were essential to the successful completion of the Carteret County ADID project. Mike Wood, Cherri Smith, Mac Haupt, Lori Sutter, Lonnie N. Shull III, Jim Stanfill, and Brian Mitchell each spent hundreds of hours in the field evaluating the accuracy of the Wetland Functional Significance Maps produced using NC-CREWS.

We would also like to collectively thank the citizens, interested organizations and agencies and others that contributed throughout the development of NC-CREWS. The support, cooperative effort, and assistance of all the parties has made NC-CREWS a valuable, comprehensive wetlands assessment tool that will be useful for all persons interested in wetland function evaluations.

INTRODUCTION

Section 1

Context

The coastal area of North Carolina encompasses twenty counties and more than 9000 square miles of land area, or about 20 percent of the state. It also includes more than 87 percent of the state's surface water. The North Carolina Coastal Management Program (NC CMP) is responsible for managing this area to meet the goals set forth in the Coastal Area Management Act (CAMA - NCGS 113A, Article 7). These goals provide a broad mandate to protect the overall environmental quality of the coastal area and to guide growth and development in a manner "consistent with the capability of the land and water for development, use, or preservation based on ecological considerations" (NCGS 113A-102(b)(2)).

Much of the North Carolina coastal area is occupied by wetlands, which, in many areas, comprise 50 percent or more of the landscape. These wetlands are of great ecological importance, in part because they occupy so much of the area and are significant components of virtually all coastal ecosystems, and in part because of their relationships to coastal water quality, estuarine productivity, wildlife habitat, and the overall character of the coastal area.

Historically, approximately 50 percent of the original wetlands of the coastal area have been drained and converted to other land uses (Hefner and Brown, 1985; Dahl, 1990; DEM, 1991). Although agricultural conversion, the largest historical contributor to wetlands loss, has largely stopped, wetlands continue to be lost as they are drained or filled for development. Conflicts between economic development and wetlands protection continue to be a major concern, with many coastal communities considering wetlands protection to be a major barrier to needed economic development.

Since wetlands are such a dominant part of the coastal landscape and are vitally important to many aspects of the area's ecology, their management and protection is a major concern of the NC CMP. Salt and brackish marshes, or "coastal wetlands" as they are referred to in law and administrative rules, are stringently protected by the State Dredge and Fill Act (NCGS 113-229) and the CAMA regulatory program. Coastal wetlands are designated Areas of Environmental Concern (AECs), with the management objective "to give highest priority to the protection and management of coastal wetlands so as to safeguard and perpetuate their biological, social, economic and aesthetic values; and to coordinate and establish a management system capable of conserving and utilizing coastal wetlands as a natural resource essential to the functioning of the entire estuarine system" (15A NCAC 7H .0205).

Non-tidal, freshwater wetlands, on the other hand, have not been specifically protected under North Carolina law. State involvement in protection of freshwater wetlands is limited to enforcement of state water quality standards and to the regulatory authority given under federal laws for state agency review of federal permits, in this case §404 permits granted by the United States Army Corps of Engineers. Under §401 of the Federal Water Pollution Control Act (33 USC 1341), a Water Quality Certification from the NC Division of Water Quality (DWQ, formerly Division of Environmental Management, or DEM) is required for a §404 permit to discharge fill material into wetlands. Section 307 of the Federal Coastal Zone Management Act (CZMA - 16 USC 1451 *et seq.*) also requires that §404 permits be consistent with the enforceable rules and policies of the NC CMP. The standards for consistency are the “use standards” for AECs and wetland policies stated in the applicable local land use plan. Outside of AECs, there are no consistent policies in the NC CMP regarding wetlands. A few local land use plans include policies to protect freshwater wetlands, but most do not.

Wetlands Conservation Plan

The NC CMP’s lack of specific protection for non-tidal wetlands was recognized in the CZMA §309 Assessment of the NC CMP performed during 1991 (DCM, 1992a). During the assessment, it was apparent that both opponents and proponents of wetlands protection felt that the current system was inadequate. Economic development interests found the §404 regulatory program to be unpredictable and inconsistent, often resulting in the loss of needed economic growth in coastal counties. Environmental interests felt that it allowed the continued loss of ecologically important wetlands. As a result, wetlands management and protection was chosen as one of the primary program areas in need of enhancement.

The North Carolina Division of Coastal Management (DCM) developed a five-year Strategy (DCM, 1992b) and a three-year Strategy (DCM, 1997) for improving wetlands protection and management in the coastal area using funds provided under the Coastal Zone Enhancement Grants Program established by 1990 amendments to §309 of the federal CZMA. The §309 Program is administered by the Office of Ocean and Coastal Resources Management (OCRM) in the National Oceanographic and Atmospheric Administration (NOAA), United States Department of Commerce. Funds provided under this Program, particularly Project of Special Merit awards for fiscal years 1992 and 1993, were used for the work reported here. The work was also funded by a separate grant from the United States Environmental Protection Agency (EPA) for a Wetlands Advance Identification project in Carteret County, NC.

The key element of DCM's Strategy for improving wetlands protection is the development of a Wetlands Conservation Plan for the North Carolina coastal area. The main objective of DCM's Wetland Conservation Plan is to improve the management and protection of freshwater wetlands in North Carolina. The Plan has several components.

Wetlands Mapping & Inventory
Functional Assessment of Wetlands
Wetland Restoration Identification & Prioritization
Coordination with Wetland Regulatory Agencies
Coastal Area Wetland Policies
Local Land Use Planning

The obvious first step toward a Wetlands Conservation Plan is describing the wetland resource. This is being accomplished by an extensive geographic information system (GIS)-based wetlands mapping program, which has produced GIS data of wetlands by wetland type for the entire coastal area. Using the GIS coverage, paper maps can be generated for areas within any boundaries available in GIS format.

One of the weaknesses of the §404 Program is that, for individual permits, it attempts to apply the same rules and procedures equally to all wetlands, regardless of the wetland type and location in the landscape. This approach can result in permits being granted for fill of wetlands of high ecological significance or permits being denied to protect wetlands of lesser significance. Either result is undesirable, since either vital wetland functions or beneficial economic activity can be lost. In an area like the North Carolina coastal area, where a high proportion of the land is wetland, many of the wetlands are vital to the area's environmental agencies for use in their own planning quality, and yet economic stimulation is sorely needed. This is an unsatisfactory way to manage the wetland resource.

To help overcome this weakness in the current wetland regulatory framework, the Wetlands Conservation Plan includes an assessment of the ecological significance of all wetlands to determine which of them are the most important in maintaining the environmental integrity of the area. This will result in a designation of each wetland polygon in the GIS coverage as being of exceptional, substantial, or beneficial functional significance in the watershed in which it exists. The procedure by which this is done is the subject of this report.

The remaining components of the Wetlands Conservation Plan are the means by which the results of the wetland mapping and functional assessment steps will be used to improve wetland protection and management. Close coordination with other state and federal agencies involved in wetlands protection and management has been an important component of the entire effort. Agency representatives have been involved in the development of the methods used, and the resulting data and maps will be provided to the agencies for use in their own planning and decision-making. Policies for protection of wetlands of varying functional significance may be proposed to the NC Coastal Resources Commission representatives to serve as the basis for consistency review of §404 permit applications. Wetland maps and functional assessment results also will be provided to local governments for use in local land use planning, and DCM will work with the local governments to increase local involvement in the wetlands regulatory structure.

While the wetland data and maps themselves are useful for land use planning, restoration planning and helping to find sites suitable for development, simply knowing where the wetlands are is insufficient information for many purposes. Any area for which a §404 permit application is in process has been officially delineated as a wetland by the Corps of Engineers. The value of wetland data to the regulatory review agencies at this stage is limited to determining the relationship of the site to the surrounding landscape mosaic, and other wetlands in the area. While, ideally, all wetlands should be avoided in planning development, it is difficult in the coastal area to avoid wetlands altogether, and virtually impossible to avoid all wetland impacts given current design techniques and econometric methods.

The results of the functional assessment will provide additional information about the ecological significance of wetlands. This information will be valuable to wetland regulatory review agencies in determining the importance to an area's environmental integrity of protecting a particular site for which a permit to fill has been requested. It will enable the public, planners, developers, and managers to rapidly select suitable classes, types, or categories of activities for each wetland type to maintain and protect the biological, chemical, and physical integrity of those ecosystems and the coastal landscape. Where no alternative exists, and it is still clearly in the public interest to proceed with a proposal, the assessment tool can significantly improve planners' ability to avoid or minimize significant and irreversible adverse impacts to the valuable wetland ecosystems. Properly matching wetland types with the activities permitted, or avoiding impacts entirely, are vitally important means of ensuring that future generations inherit functional assemblages and communities of native and endemic plants and animals. An accurate functional assessment of wetland significance, then, is the most valuable component of the Wetlands Conservation Plan.

During its development, the procedure came to be known as the “FAP,” for Functional Assessment Procedure. In the interest of using a more descriptive acronym, for acronyms seem inevitable, the final version of the procedure is called the **N**orth **C**arolina **C**oastal **R**egion **E**valuation of **W**etland **S**ignificance, or “**NC-CREWS**.”

DEVELOPMENT OF THE PROCEDURE

Section 2

Initial Considerations

Certain initial considerations shaped the approach and methods used in developing a wetlands functional assessment procedure. The procedure needed to fit within the context and objectives of the Wetlands Conservation Plan for the North Carolina coastal area as previously described. This context, and the opportunities and limitations it imposed, had considerable influence on the specific methodologies developed.

Since we were dealing with a large geographic area with many wetlands, it was obvious from the outset that we needed a method that could be applied to large land areas without site visits to each individual wetland. This ruled out the many site-specific functional assessment methods that have been applied in other contexts. Almost out of necessity, a GIS-based approach was needed. That meant the procedure would have to use information available in GIS format and make use of GIS analytical techniques. Since the wetland mapping on which the functional assessment is based was performed using a GIS, the basic digital data were available.

The primary objective was to produce information about the relative ecological importance of wetlands that would be useful for planning and overall management of wetlands rather than to serve as the basis for regulatory decisions. While not every wetland could be visited, the goal was to predict the significant functions that would be determined by a detailed, site-specific method. DCM wanted to be able to predict in advance what the wetland regulatory agencies would determine a wetland's significant functions to be so that the resulting maps would identify those wetlands where a §401, 402, 403, or 404 permit or certification might be difficult or impossible to obtain. The resulting information would then be useful in determining where development should not be planned, or where certain types of development are best suited for and compatible with the habitat. This would benefit potential permit applicants by preventing ill-advised plans that would not be likely to be permitted and simultaneously serve to protect the most ecologically sensitive wetlands. The result of the procedure, then, is not a substitute for a site visit in making regulatory decisions, but a predictor of what a site visit would determine.

A primary consideration was that the procedure be ecologically sound and scientifically valid, based on the best information available about the functions of wetlands. It needed to be based on fundamental principles of wetlands and landscape ecology rather than on arbitrary or subjective decisions.

Finally, the procedure was to be watershed-based because consideration of a wetland's role in its watershed is the most scientifically sound basis for determining its ecological significance and the other components of the Wetlands Conservation Plan are based on watershed units. The watersheds being used are 5,000 to 50,000 acre hydrologic units delineated by the Soil Conservation Service (now the Natural Resource Conservation Service) as illustrated in Figure 1. There are 348 of these hydrologic units (HUs) in the North Carolina coastal area. Watershed units of any size, however, could be used without changing the validity of the watershed-based considerations used in the procedure.

These initial considerations result in a summary definition of DCM’s functional assessment procedure. NC-CREWS is a GIS-based, landscape-scale procedure for predicting the relative ecological significance of wetlands throughout a region using fundamental ecological principles to determine the functions of wetlands within their watersheds.

Basic Concepts

A GIS-Based Procedure

The functional assessment procedure is meant to be used with GIS data for regional application. It is not a field-oriented, site-specific method that involves visiting individual wetlands and recording information. A GIS-based procedure is the only practical approach for dealing with a large geographic area containing many wetlands within a limited amount of time.

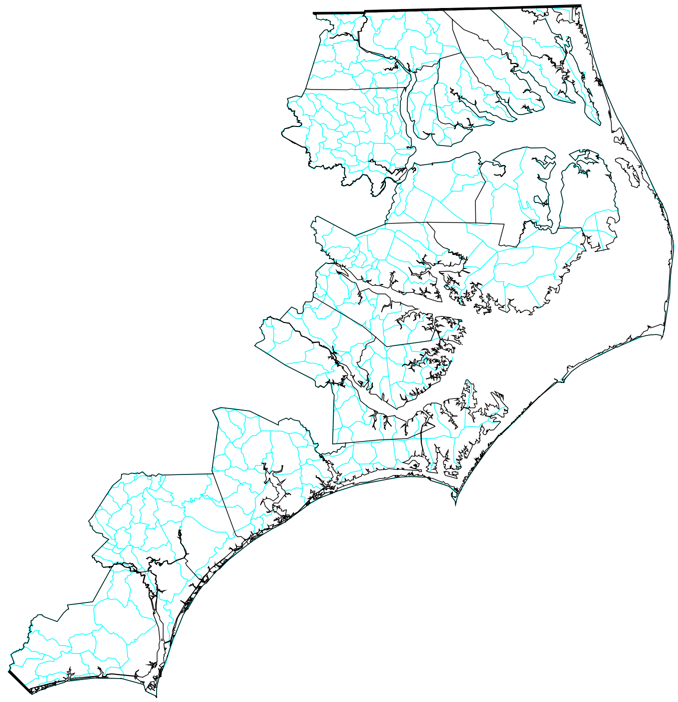


Figure 1. Hydrologic Unit and County Boundaries in the North Carolina Coastal Area

This GIS-based approach can make information on wetland functional significance available for broad regions in advance of specific development plans. The information is then available for planning so that impacts to the most ecologically important wetlands can be avoided. In this sense, the North Carolina procedure is unique and unlike other functional assessment techniques that are designed to be used in a regulatory context or that require field data for each wetland. Since the procedure uses GIS analysis, it requires digital information in GIS format. GIS data layers used in the procedure include the following.

(1) wetland boundaries and types
(2) soils data
(3) land use/land cover
(4) hydrography
(5) watershed boundaries
(6) endangered species occurrences
(7) estuarine primary nursery areas
(8) water quality classifications
(9) NC unique natural ecosystem and special wildlife habitat areas
(10) anadromous fish spawning areas

In the North Carolina coastal area, these data layers either already existed and were available from the North Carolina Center for Geographic Information and Analysis (CGIA) or were developed as parts of the Wetlands Conservation Plan. Since most of the data acquisition and digitization was funded by other projects, developing the necessary GIS databases was not a major cost.

The wetlands coverage was from DCM's GIS wetlands mapping which used digital NWI maps, soils maps, and land use/land cover layers (Figure 2). The resulting coverage is essentially an expansion and update of NWI maps with wetland types reclassified to a more manageable system. Specifics of the techniques used are described in a separate publication (Sutter, 1999).

The soils coverage consists of digitized detailed county soils maps produced by NRCS (formerly SCS) and digitized by CGIA or NRCS with the partnership of the US Geologic Survey, DCM and the NOAA Coastal Services Center. The soil series underlying a wetland are

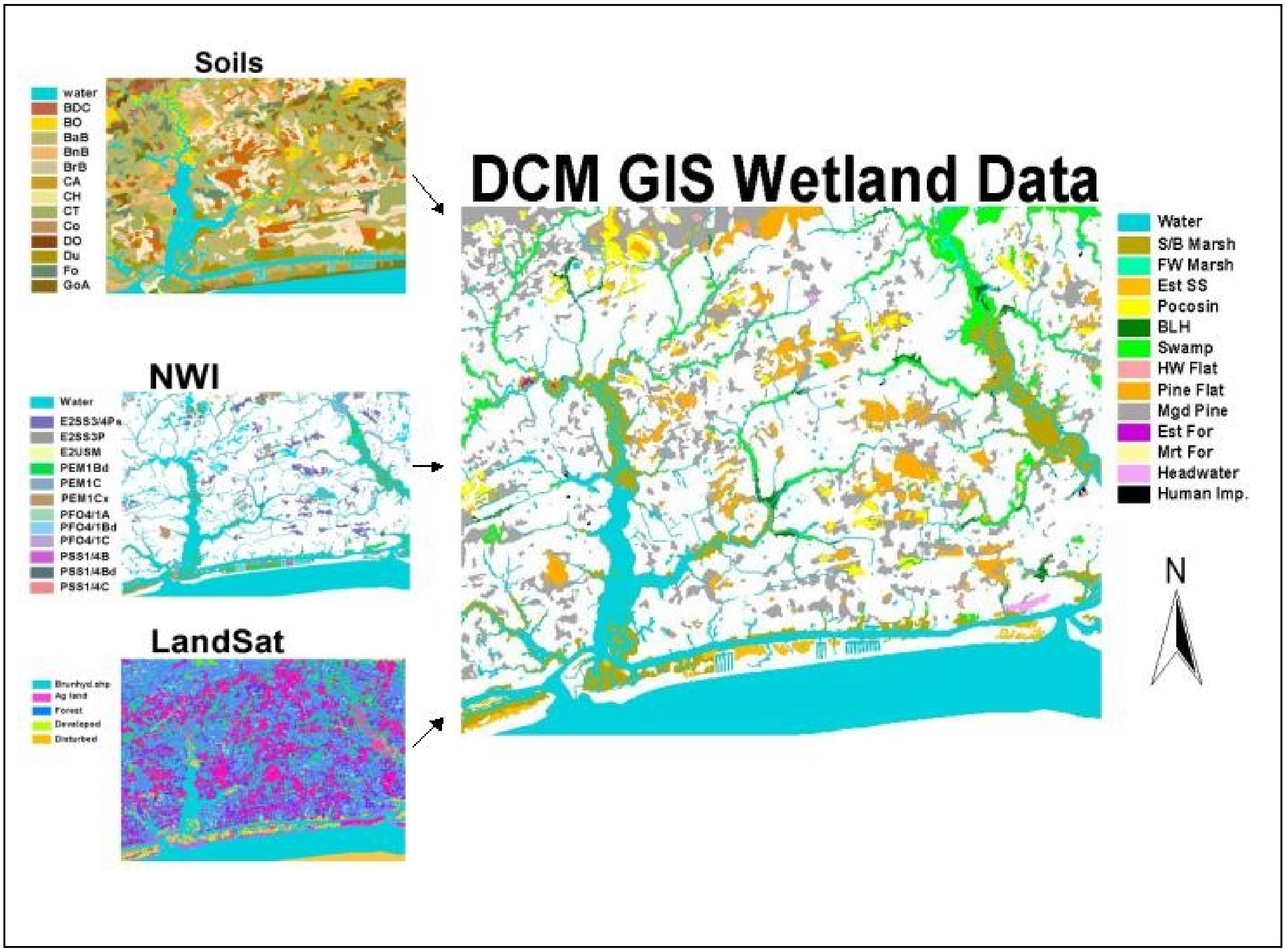


Figure 2. DCM's Wetland Type Mapping Overlay Analysis

identified from the soils coverage, and the properties of the series are used to determine soil capacity for facilitating the wetland's capability to perform various functions.

The land use/land cover data layer was produced for the Albemarle/Pamlico Estuarine Study (APES) from interpretation of satellite TM imagery (Khorram et al., 1992). It is used to determine land cover and uses surrounding each wetland and in the watershed. Both unfiltered and five by five pixel filtered data are employed.

The basic hydrography coverage consists of 1:24,000 scale USGS digital line graphs (DLGs) converted to Arc. Since the functional assessment procedure uses stream order as an indicator of watershed position, stream order according to the Strahler system was determined manually and added to the attribute files. Additional attributes also were added to the coverage.

As described above, the watersheds used in the procedure are relatively small hydrologic units delineated by NRCS. DCM contracted with CGIA to have these boundaries digitized for the coastal area. During the digitization process the watershed boundaries were rectified to USGS and DEM boundaries of larger sub-basins to ensure that the HUs could be combined into larger watershed units.

Data layers produced by the NC Natural Heritage Program are used to identify threatened and endangered species occurrences and exemplary or unique natural ecosystems or special wildlife habitats. The NC Division of Marine Fisheries maintains the coverages of primary nursery areas and anadromous fish spawning areas. The Division of Water Quality developed water quality classification data based on 1:100,000 scale hydrography. This was digitized by CGIA with some streams added from 1:24,000 scale data.

The ways in which these data layers are used to determine values for various parameters in the functional assessment procedure are complex. The procedure uses the Arc, ArcPlot, ArcEdit, Grid, and Info modules of ESRI's ARC/INFO software. The procedures have been automated using ARC/INFO Arc Macro Language (AML) on a Sun Workstation. The AML programs are available from DCM on request for anyone planning to use the procedure elsewhere. Since the assessment procedure was designed for GIS analysis, the choice and expression of individual parameters has been shaped to some extent by the GIS data available and the capabilities and limitations of ARC/INFO techniques and AML automation. DCM was fortunate in having a relatively large amount of GIS data readily available. For use in other areas, the procedure could be modified to use other GIS coverages, but at least the first five databases listed above are essential to its basic propositions.

Hydrogeomorphic Classes

The hydrogeomorphic (HGM) classification system for wetlands (Brinson, 1993) classifies wetlands into categories based on landscape position (geomorphic setting), water sources, and hydrodynamics (direction of water flow and strength of water movement). It is being increasingly used as the basis for wetland classification and functional assessment systems. HGM classification focuses on the abiotic features of wetlands rather than on the species composition of wetland vegetation on which most of the more traditional wetland classification schemes are based.

Several features of the HGM classification system make it a useful starting point for an assessment of wetland functions. Since the HGM system is based on geomorphic, physical, and chemical properties of wetlands, its result is to aggregate wetlands with similar functions into classes. The HGM class of a wetland, in itself, indicates much about the ecosystem functions of the wetland. The HGM approach also forces consideration of factors external to the wetland site, such as water source. This helps relate the wetland to the larger landscape of which it is a part and puts consideration of the wetland's functions into a landscape and watershed context.

Three HGM classes are used as the starting point for NC-CREWS. All wetlands are first classified as (1) riverine, (2) headwater, or (3) depressional/wet flat. Riverine wetlands are those in which hydrology is determined or heavily influenced by proximity to a perennial stream of any size or order. Over bank flow from the stream exerts considerable influence on their hydrology. Headwater wetlands exist in the uppermost reaches of local watersheds upstream of perennial streams. Headwater systems may contain channels with intermittent flow, but the primary sources of water input are precipitation, overland runoff, and groundwater discharge rather than over bank flow from a stream. Depressional wetlands, including wet flats and pocosins, are generally not in direct proximity to surface water. While they may be either isolated from or hydrologically connected to surface water, the hydrology of depressional wetlands is primarily determined by groundwater discharge, overland flow, and precipitation.

The functions of wetlands in these different HGM classes differ significantly. Riverine wetlands regularly receive over bank flow from flooding streams and, thus, perform the functions of removing sediment and pollutants that may be present in the stream water and providing temporary floodwater storage. Headwater and depressional wetlands cannot perform these functions, since they do not receive overbank flow. Headwater wetlands occur at landscape interfaces where groundwater and surface runoff coalesce to form streams. Since they provide a buffer between uplands and stream channels, headwater wetlands can perform significant water quality and hydrology functions. While depressional wetlands do not generally perform buffer functions, they often store large amounts of precipitation and/or surface runoff waters that otherwise would more rapidly enter streams. Wetlands in all HGM classes can perform important habitat functions.

Since the wetlands in these different HGM classes are functionally different, their functional significance is assessed using different, though similar, procedures. If the same procedure were used for all HGM classes, depressional wetlands would always be considered of lower functional significance simply because they are not in a landscape position to perform some of the water quality and hydrologic functions of riverine and headwater wetlands. Specific differences in assessment procedures for different HGM classes will be described in Section 3.

Wetland Types

In addition to HGM classes, wetland types identified by dominant vegetation and landscape position are used at several points in the functional assessment. This reflects the idea that the biological properties of a wetland site considered together with its hydrogeomorphic properties can provide a more detailed indication of its functions than either property taken alone. The HGM class of a wetland, as a broad functional indicator, determines which assessment procedure is used. Within each HGM class and corresponding assessment procedure, wetland type is used to determine the level or extent of specific parameters.

The wetland types used are those typical of the North Carolina coastal area. They result from a grouping of the Cowardin (1979) classes used on the digital NWI maps into fewer types with more intuitively obvious type names, such as swamp forest, pocosin, etc. A list and definitions of the wetland types used is included in Appendix A. These wetland attributes are used in the wetland data that form the starting point for the functional assessment.

Wetland types are used in NC-CREWS as indicators of functional characteristics. Correlations between wetland type and wetland functions were determined from statistical analysis of field data from nearly 400 sites. At each site the presence or absence of a list of functional indicators was recorded. The functional indicators lists were developed by Dr. Mark Brinson of East Carolina University, who served as primary scientific consultant in developing the HGM classification system and the field sampling methodology. Details of field sampling and data analysis are given in Appendix B.

Since wetland types will differ in other geographic areas, their inclusion in the procedure limits its use in its current form to the southeastern coastal plain. Adaptation of the procedure for use in other areas would require either extensive field sampling as was performed in coastal North Carolina or a more arbitrary clumping of wetland types based on best professional judgment. Other methods of wetland classification could be used, as long as wetlands are classified in such a way that functional characteristics of the wetland types are constant and can be determined by field sampling, literature values, and/or professional judgment. The procedure could be applied directly to NWI polygons if these are the only wetland database available.

Other Parameters

In addition to wetland type and HGM class, several other parameters are used as indicators of the existence or level of specific wetland functions. These include both site-specific parameters, such as wetland size and soil characteristics, and landscape considerations such as watershed position, water sources, land uses, and landscape patterns. Values for these parameters are determined by GIS analyses based on the data layers discussed above. They could be determined manually, but the process would be very labor intensive.

Unlike assessment procedures that depend solely on information that can be collected within a wetland, this procedure relies heavily on factors external to the wetland site itself. Relationships between a wetland and the landscape within which it exists are integral considerations in determining wetland functional significance. Characteristics of the landscape surrounding a wetland are often more important determinants of its functional significance than are the characteristics of the wetland itself. Of the 39 parameters evaluated in the procedure, 21 are landscape characteristics, and 18 are internal characteristics of the wetland itself.

While we believe this emphasis on a wetland's landscape context is a more ecologically sound approach to functional assessment than site-specific methods, it requires a great deal more information than could be collected within the wetland itself. The procedure is based on GIS data and analysis not only to make it suitable for regional application, but because GIS provides the most practical way to analyze the spatial relationships of landscape elements and their properties.

Structure of NC-CREWS

NC-CREWS uses a hierarchical structure in which individual parameters are rated and successively combined until the wetland's overall functional significance is determined. The complete hierarchical structure is illustrated in Figure 3. It consists of four levels: (1) overall functional significance of the wetland; (2) specific functions; (3) subfunctions; and (4) parameters and subparameters evaluated to determine the level and extent of functions.

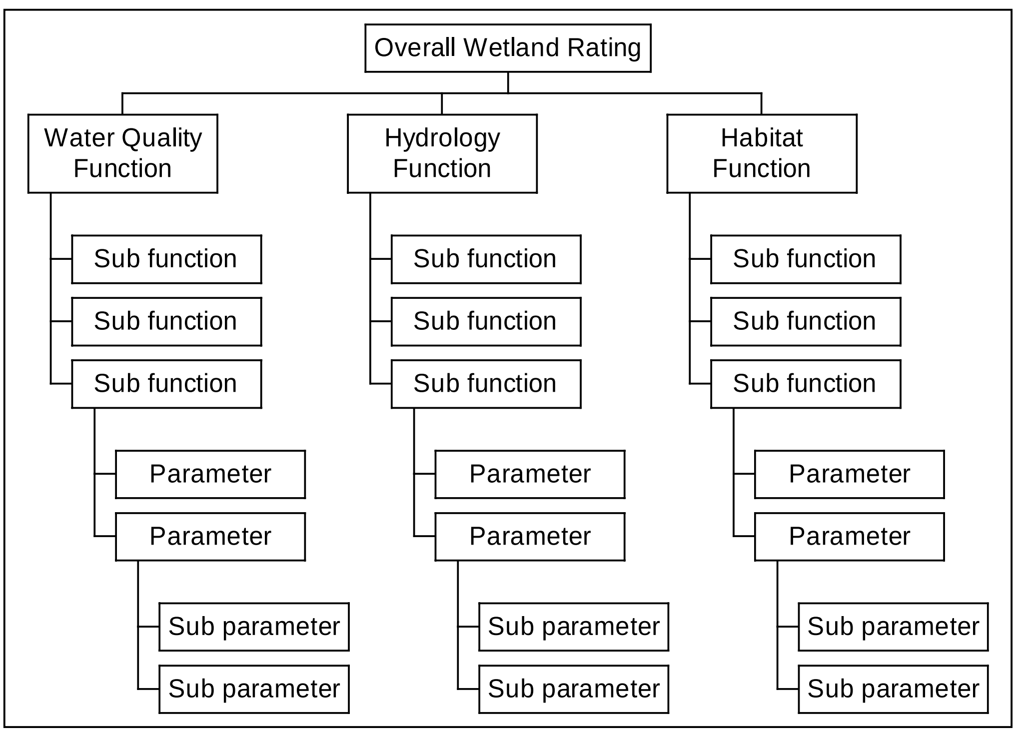


Figure 3. Overall Hierarchical Structure of NC-CREWS

The objective of functional assessment is to determine an individual wetland's ecological significance in its watershed and in the larger landscape. The highest hierarchical level, or end result of applying the procedure, then, is the wetland's overall functional significance or OWR, Overall Wetland Rating. The second hierarchical level includes the three primary functions that are considered in determining the wetland's functional significance. The overall functional significance of a wetland is determined by the degree to which it performs, or has the capacity to perform, specific functions. The broadest grouping of wetland functions includes water quality functions, hydrology functions, and habitat functions (Figure 4). Water quality, hydrology and habitat functions and their subfunctions, parameters, and subparameters are shown in Figures 5 through 7.

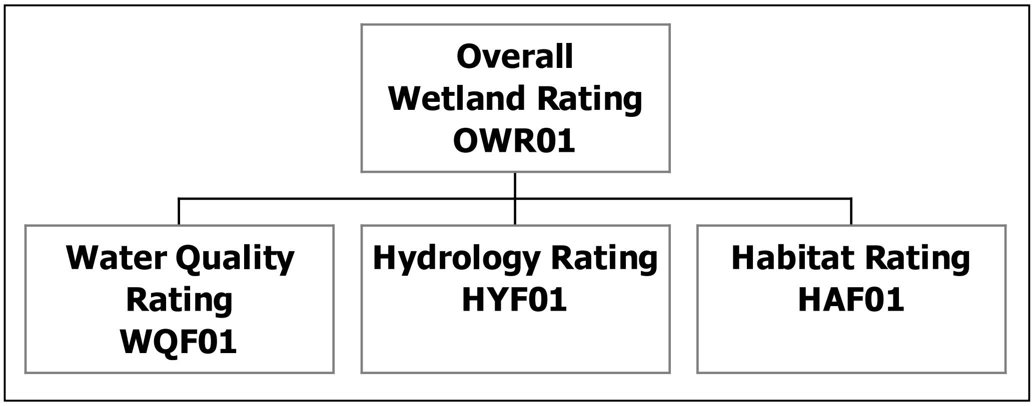


Figure 4. NC-CREWS Level Two: Primary Wetland Functions

A wetland's ecological significance is also determined, to some extent, by the nature of the landscape and the water characteristics of the watershed in which a wetland functions. These factors determine the potential risk to watershed and landscape integrity if the wetland functions were lost. Including a "risk factor" as a basic consideration in ecological assessment can provide a means of considering cumulative impacts and the practicality of replacing lost functions through compensatory mitigation. NC-CREWS calculates "Potential Risk of Wetland Loss" at the function level, but it is not used in the automated process to determine the overall functional significance of individual wetlands. Potential Risk is not used to influence a wetland's overall functional rating because it is an abiotic function of wetlands. Instead, Potential Risk is an estimation of the potential loss of function and risk to a watershed if individual wetlands ceased to continue to perform existing functions. Potential Risk can be used to help determine a wetland's overall ecological significance in the watershed. Consequently, Potential Risk is calculated and designed to be used in conjunction with the functional significance ratings. Wetland managers, local governments, developers, and others who use the results of NC-CREWS are encouraged to consider both the Overall Functional Significance and the Potential Risk ratings whenever making wetland decisions.

Each of the primary functions and potential risk of wetlands is actually a combination of separate, more specific subfunctions. Water quality subfunctions include the removal of nonpoint source pollutants from surface runoff and the removal of suspended or dissolved pollutants from flooding streams. Hydrology subfunctions include storage of precipitation and surface runoff, storage of floodwater from streams, and shoreline stabilization. Habitat subfunctions include providing habitat for both terrestrial species and aquatic life. The risk factor is also determined by several considerations that, while not truly wetland functions, are called subfunctions for parallelism (Figure 8).

The extent to which a wetland performs these different subfunctions is determined by various properties of the wetland and its surrounding landscape. These properties are called "parameters" in the NC-CREWS procedure. Parameters make up the levels in the hierarchical structure that are actually evaluated based on fundamental ecological considerations. Parameter values, in turn, are combined to produce ratings for the various subfunctions. All of the parameters evaluated in NC-CREWS are explained in detail and documented for scientific validity in later sections of this report. The parameters under the nonpoint source removal subfunction of the Water Quality Function will be discussed here for illustration.

The first parameter determining a wetland's significance in removing nonpoint source pollutants from surface runoff is whether the water contains sediment, nutrients, or toxins in significant quantities. This is evaluated in the "Proximity to Sources" parameter based on the land uses surrounding the wetland polygon. If the wetland is surrounded by agricultural fields or developed areas from which pollutants are likely to enter surface runoff, the wetland's potential for removing nonpoint source pollutants is high. If, on the other hand, the wetland is mostly surrounded by natural vegetation from which runoff is likely to be largely unpolluted, its potential for removing significant pollutants is low.

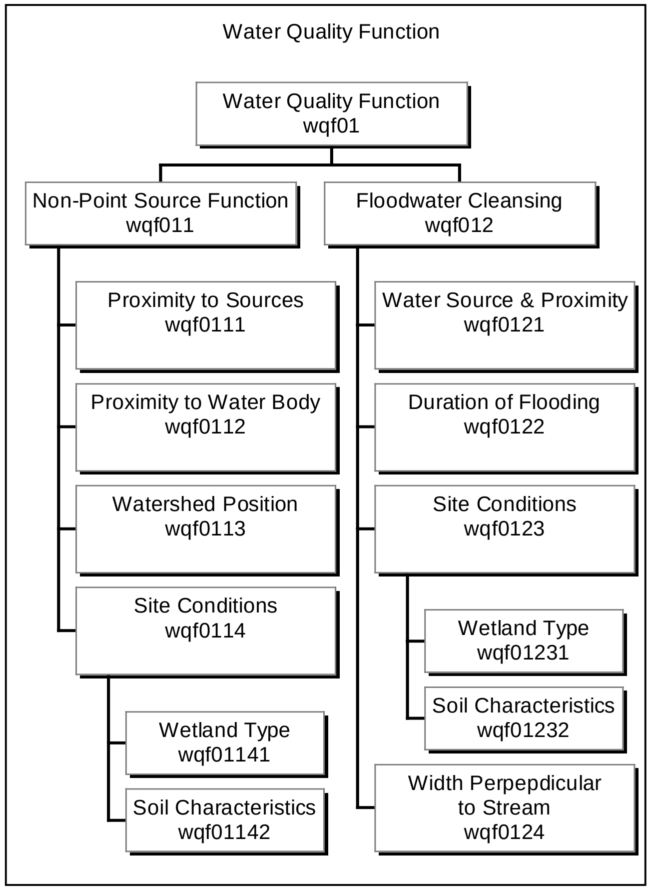


Figure 5. NCCREWS Water Quality Function, Subfunctions, Parameters and Subparameters.

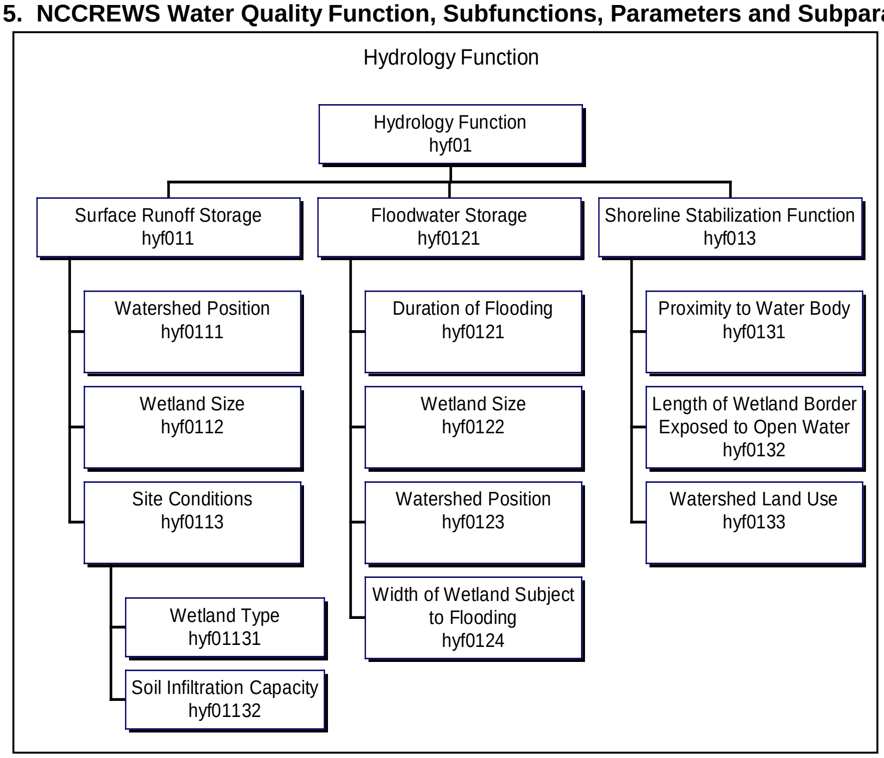


Figure 6. NCCREWS Hydrology Quality Function, Subfunctions, Parameters and Subparameters.

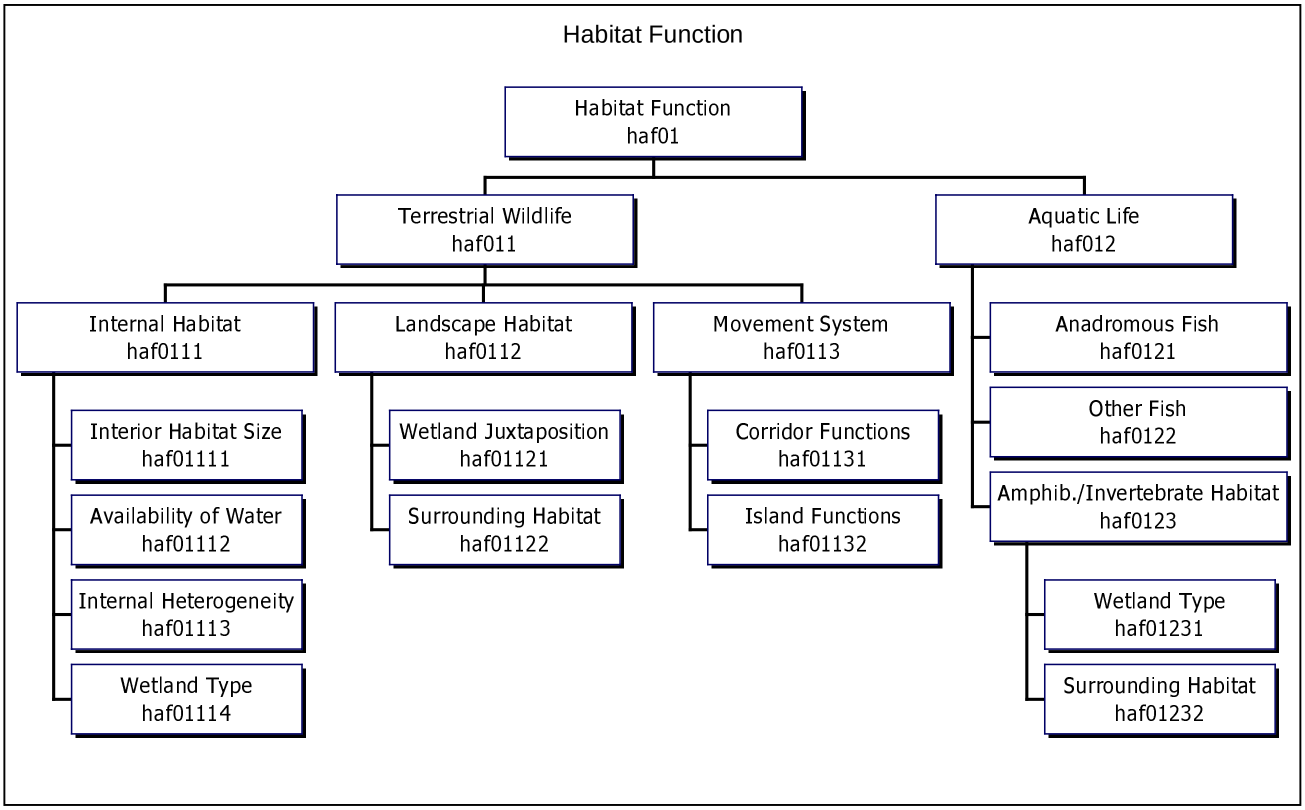


Figure 7. NCCREWS Habitat Function, Subfunctions, Parameters and Subparameters.

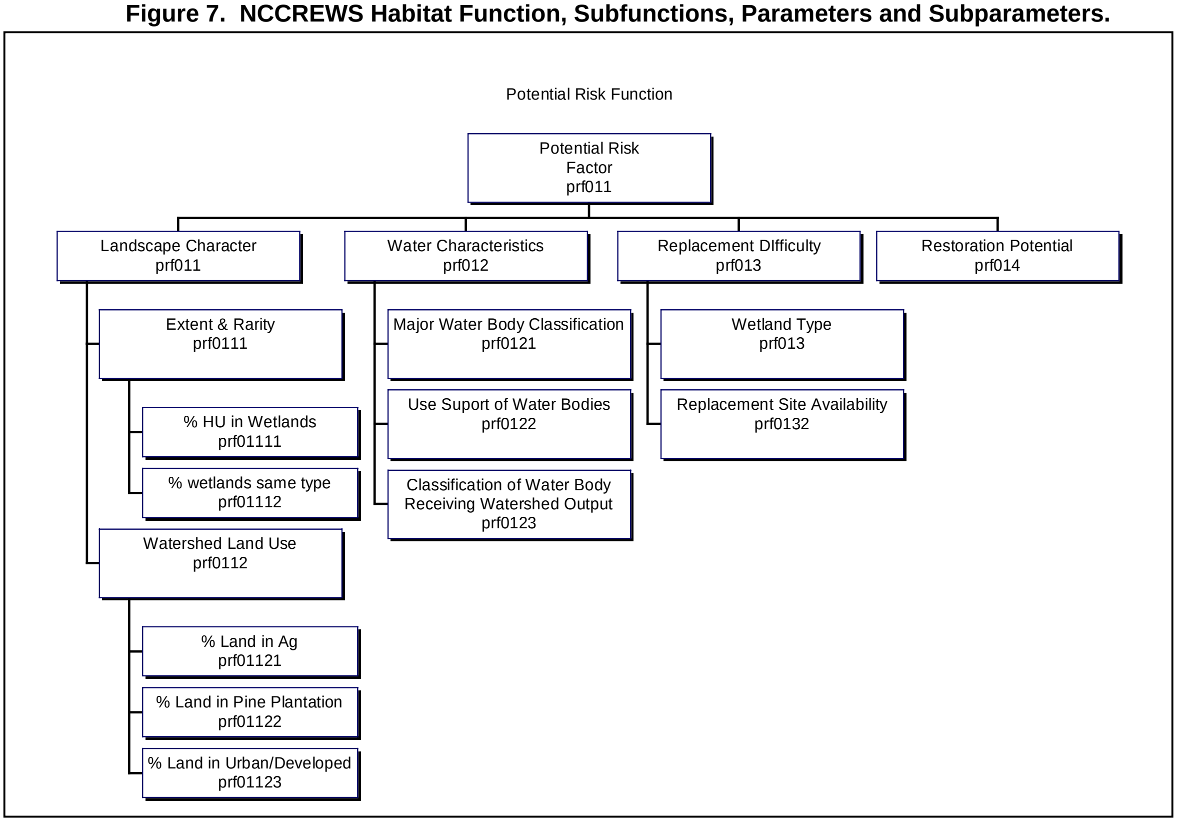


Figure 8. NCCREWS Potential Risk Factor, Subfunctions, Parameters and Subparameters.

Proximity to Sources is an "opportunity" parameter. That is, it determines whether a wetland has the opportunity to remove pollutants from surface runoff by considering how likely the runoff water is to be polluted. The other parameters for this subfunction are "capacity" parameters that measure the wetland's ability to perform the function *if* the opportunity is present. Opportunity and capacity parameters are treated differently in determining a wetland's overall significance. Wetlands are never downgraded in functional rating because of present lack of opportunity; however, if an opportunity is shown to exist in the present, the wetland may be upgraded. This is discussed in more detail later in this report.

The second parameter considered in determining a wetland's significance in nonpoint source removal is its proximity to a surface water body. If runoff entering a wetland would otherwise directly enter surface water, the wetland's significance as a filter is greater than if the wetland is far removed from surface water. In that case, pollutants in runoff could either settle out or be removed by other means before they enter surface water as pollutants.

The third parameter is the position of the wetland in its watershed. Several studies have documented that headwater wetlands are most effective in removing nonpoint source pollutants (Leopold et al., 1964; Whigham et al., 1988; Novitzki, 1979). Thus, the model assumes that the higher in its watershed a wetland is located, the higher is its significance in nonpoint source removal.

The value of the fourth parameter, Site Conditions, is determined by two subparameters, Wetland Type and Soil Characteristics. By virtue of their typical microtopography, hydrology, and vegetative structure, some wetland types are more effective in retaining and filtering surface runoff than are other types. Some soil series are more effective than others in retaining and chemically transforming pollutants. Each of these subparameters is rated, and their values are combined to produce a rating for the Site Conditions parameter.

A similar evaluation of specific parameters is performed to derive significance ratings for other wetland subfunctions. In all cases, parameter values are determined by GIS analysis based on the data layers described previously. Some parameters, such as Wetland Type in the nonpoint source illustration, are surrogates or indicators of other wetland properties that actually determine the wetland's functional capacity. The use of indicator parameters is necessitated by the limitations of GIS data and techniques.

Evaluation Procedure

The objective of NC-CREWS is to determine an individual wetland's overall functional significance in the watershed in which it exists. Functional significance is divided into three broad classes rather than attempting to derive a specific numerical "score." This is partly because of the procedure's initial application in an EPA Wetlands Advance Identification (ADID) project performed by DCM in Carteret County, NC. Standard ADID procedure is to classify wetlands into three groups: (1) areas generally unsuitable for the discharge of dredged or fill material; (2) areas where a project-by-project determination is needed; (3) possible future disposal sites for dredged or fill material.

The three broad classes of ratings that NC-CREWS uses to describe a wetland's functional significance are ***Exceptional*** functional significance, ***Substantial*** functional significance, and ***Beneficial*** functional significance. The approach of classifying wetlands into three broad functional significance classes is used because it works well with our current understanding of wetland function. Attempting to assign a specific value along a numeric continuum of functional significance exaggerates the precision with which current knowledge can realistically be applied. The three significance classes used in NC-CREWS provide the information necessary to meet the procedure's objectives without going beyond the realm of reasonable scientific validity for remotely sensed data. As scientific understanding increases, however, it is reasonable to expect that specific numerical assignments can be integrated into NC-CREWS.

As explained above, the basic evaluation is performed at the parameter level. A High (H), Moderate (M), or Low (L) value is assigned to each parameter as it relates to the performance of the wetland subfunction being considered. For example, if the soils underlying a wetland have properties that are highly conducive to the function being considered, the Soil Characteristics parameter is rated H; if soil properties are less conducive to performing the function, the parameter is rated M; and if soil properties are not at all conducive to the function, the parameter is rated L. All individual parameters under a given subfunction are similarly rated.

The individual parameter ratings are then combined to give an H, M, or L rating for each subfunction. The subfunction ratings are combined into a rating of the wetland's significance in performing each of the primary wetland functions. And finally, the ratings for primary functions are combined into an overall rating of the wetland's functional significance.

The process of successively combining ratings up the structural hierarchy is the most complex aspect of the NC-CREWS procedure. The combining, as well as the evaluation of individual parameters, is based on fundamental ecological principles about how wetlands and landscapes function. Since the ecological processes themselves interact in complex ways, combining ratings is much more complex than a simple summation of individual ratings. Some parameters are normally more important than others in determining the level at which a wetland performs a specific function and, thus, must be weighed more heavily in determining the combined value. In some cases, there are different combinations of individual parameter ratings that result in the same level of functional significance. Each of the possible combinations of parameters must then be considered.

The automated version of NC-CREWS maintains all of the individual parameter ratings and combinations in a database. Since the combining process is complex, it may not be obvious why a wetland receives an overall Exceptional, Substantial, or Beneficial rating. The database makes it possible to trace through the subparameter, parameter, subfunction, and primary function ratings that result in a wetland's overall rating.

This database also makes it possible to consider specific wetland functions individually. For example, in a watershed targeted for nonpoint source pollution reduction, it might be a management objective to give the highest level of protection to wetlands most important in performing this function. The database makes it possible to examine each wetland for its significance in nonpoint source removal and to produce a map of wetlands rated according to their significance for this single subfunction.

Individual function ratings in the database can also be used to improve planning, impact assessment, and mitigation for development projects that impact wetlands. If alternative sites are available, such as alternative corridors for a highway, the alternative with the least impact on the wetland function considered most important in the watershed can be identified. Rather than simply minimizing acres of wetland impact, the objective would be to minimize impacts to the most important wetland functions. Environmental assessment of wetland impacts can identify specific functions to be lost. Mitigation can be improved by giving priority to sites with the highest potential for performing the same functions.

Detailed procedures for evaluating individual parameters and combining them into functional ratings are explained in later sections. Here, just the water quality nonpoint source removal subfunction will be illustrated. The rating system for this subfunction is summarized in Table 1.

Four parameters are evaluated to determine the significance of the nonpoint source removal subfunction. Since (d), the Site Conditions parameter, has subparameters below it, it is evaluated first using a relatively simple procedure. If conditions typical of the

Parameters

- (a) Proximity to Sources
- (b) Proximity to Surface Water
- (c) Watershed Position
- (d) Site Conditions
  - **Subparameters**
    - (1) Wetland Type
    - (2) Soil Characteristics

Evaluation Procedures

Site Conditions

- H Both parameters H
- M Other combinations
- L One parameter L and neither H

NPS Subfunction

- H (a) & (b) H and (d) at least M **OR**
  (c) & (d) H and (b) at least M
- M Other combinations
- L Two of (b), (c), & (d) L

Table 1. Summary of Non Point Source Subfunction Evaluation Procedure

wetland type and characteristics of the underlying soil are both highly conducive to removal of pollutants in runoff water entering the wetland, the Site Conditions parameter is H. If either the wetland type or the soil is not at all conducive to pollutant removal and the other subparameter is no more than somewhat conducive, the Site Conditions parameter is L. Any other combination results in an M.

After all the parameters are evaluated, they are combined to evaluate the significance of the wetland in removing nonpoint source pollutants. There are two combinations that result in the wetland's being evaluated as Highly significant in performing this subfunction. First, if the wetland is adjacent to both a significant source of polluted runoff (a=H) and a permanent surface water body into which the runoff would flow if the wetland were not there (b=H), and has site conditions that are at least reasonably efficient in catching, holding, and removing pollutants from the runoff (d at least M), it receives an H. Alternatively, even if the wetland is not adjacent to a pollutant source, it receives an H if it is in the headwaters of the watershed (c=H), site conditions are highly conducive to pollutant removal (d=H), and is at least close to an intermittent stream (b at least M).

On the other hand, if any two of parameters (b), (c), and (d) are evaluated L, the significance of the wetland for nonpoint source pollutant removal is Low. That is, the wetland is evaluated as L for this function if: (1) the wetland is not close to surface water (b=L) and downstream in the watershed (c=L); (2) the wetland is not close to surface water (b=L) and its site conditions are poor for pollutant removal (d=L); or (3) the wetland is downstream in the watershed (c=L) and has poor site conditions (d=L).

Any combination of parameter evaluations other than those resulting in an H or L results in the wetland being evaluated as of Moderate significance for removing nonpoint source pollutants. This example is typical of evaluation procedures used for all subfunctions, which are explained in later sections. More often than not, the evaluation procedures are complex and multifarious in their reasoning and application. All of them are, however, based on the best available scientific understanding of wetland ecology.

Opportunity and Capacity

The concepts of opportunity and capacity for a wetland to perform a given function were briefly discussed above. For a wetland to actually perform a function it must have both the opportunity and the capacity for the function. In terms of the nonpoint source example, there must be a source of potentially polluted runoff entering the wetland to provide an opportunity, and the wetland must have the internal capacity to hold the runoff and remove the pollutants before releasing the water. Opportunity to perform a function is usually determined by factors external to the wetland, while capacity to perform the function is determined by properties of the wetland itself along with its landscape position.

Since NC-CREWS is a landscape scale procedure that evaluates the functions a wetland performs in relation to its surroundings, opportunity parameters are included under essentially every subfunction. A functional assessment that is too heavily dependent on opportunity parameters, however, is static and will rapidly become invalid as land uses change. A wetland that is bordered by natural forest today can be bordered by a young pine plantation or a subdivision under construction by next year. The fact that a wetland does not have the opportunity to perform certain functions today does not mean that it will not have the opportunity in the future. If an assessment of wetland significance is to remain valid over time in a landscape subject to change, opportunity parameters alone cannot be determinative.

The evaluation procedure for the nonpoint source subfunction explained above is an example of how NC-CREWS handles this situation. The opportunity for a wetland to receive polluted runoff water from surrounding lands (a=H) can result in an evaluation of H for this subfunction if other properties are also present, but it does not have to be present for a wetland to be evaluated H. Other parameters (c & d = H and b at least M) that give a wetland a high capacity to remove nonpoint source pollutants can also result in an H. Conversely, lack of present opportunity (a=L) does not necessarily result in an evaluation of Low significance for this function. At least two of the other parameters must be L for the wetland to be evaluated as L.

These conventions hold throughout the NC-CREWS evaluation procedure. A present high opportunity to perform a function can result in an evaluation of High significance for the function, but high capacity can also result in an H evaluation even if present opportunity is lacking. Lack of present opportunity alone never results in an evaluation of Low significance for a function. High opportunity is treated essentially as a "bonus" consideration that can result in a higher evaluation for a wetland than its capacity alone would indicate but that will never result in a lower evaluation because of its absence.

Overriding Considerations

Several considerations are of such importance in the North Carolina coastal area that their presence alone will result in an overall wetland rating of Exceptional functional significance. These parameters are evaluated first as either true or false, and if one or more of them is true, the rest of the evaluation procedure is not performed.

The first overriding consideration is whether the wetland is an estuarine wetland. Estuarine wetlands include salt/brackish marsh, estuarine shrub scrub and estuarine forested wetlands. Each of these wetland types are likely to be located in an Area of Environmental Concern (AEC) as defined by the North Carolina General Statutes and Administrative Code. All development within AECs is required to meet state Use Standards and require a Coastal Area Management Act (CAMA) permit prior to development.

Most salt or brackish marshes in North Carolina also meet the definition of "coastal wetlands" as set forth in North Carolina statute (NCGS 113-229(n)(3)) and rule (NCAC 7H .0205(a)). Coastal wetlands in North Carolina are designated by law as highly significant. Consequently, NC-CREWS evaluates them automatically as Exceptional and includes no considerations for differentiating among the functional significance of these wetland types.

Estuarine shrub scrub wetlands normally exist in close proximity with salt/brackish marsh wetlands. Because of their buffering function and close affinity to coastal wetlands, these wetland types are also automatically rated of Exceptional functional significance. Estuarine Forested wetlands are rated of Exceptional functional significance primarily because these systems are one of the rarest wetland types found in the North Carolina Coastal Plain and are typically located in Areas of Environmental Concern.

The second overriding consideration is whether the wetland is adjacent to an officially designated Primary Nursery Area (PNAs). All designated PNAs are included in Areas of Environmental Concern in the NC Coastal Management Program and are protected by a specific set of regulations. PNAs are areas where initial post larval development of finfish and crustaceans takes place and, thus, are critical to estuarine fish and shellfish populations. Wetlands adjacent to PNAs are highly important in maintaining water quality and appropriate salinity gradients in these critical areas and are automatically evaluated as of Exceptional functional significance.

The third overriding consideration is whether the wetland contains threatened or endangered species or includes all or part of an exemplary or unique natural ecosystem or special wildlife habitat as designated by the NC Natural Heritage Program. If a known occurrence of a threatened or endangered plant or animal species on either federal or state lists is present in the wetland, it is evaluated to be of Exceptional functional significance. Likewise if the wetland includes all or part of an exemplary or unique natural ecosystem or special wildlife habitat, it is rated Exceptional. The determination is based on information obtained from the NC Natural Heritage Program.

Verification

Careful attention has been given throughout the development and initial application of NC-CREWS to check and verify its validity. Parameter evaluations and combination procedures are based on the best wetland science available in scientific literature and extensive review by a team of wetland scientists. The validity and accuracy of the GIS databases used to apply the procedure have been verified to the greatest extent possible. When assumptions are made about wetland ecology, GIS data, or GIS analytical techniques, they are fully documented in following sections of this report.

An advisory panel of wetland scientists familiar with the wetlands of coastal North Carolina and representatives of several state and federal wetland-related agencies have reviewed every step of the procedure's development. The institutions and agencies and the individuals involved in reviewing and commenting on the procedure are listed in Appendix C. While this does not represent an endorsement of the procedure or its results by the agencies or individuals included, it does indicate the level of peer review to which the procedure has been subjected.

During development of the procedure, field visits were made to nearly 400 wetland sites to gather data on functional indicators as explained in Appendix B. On these same site visits, a field-based functional assessment procedure, the "Wetland Rating System" developed by the North Carolina Division of Environmental Management (currently the Division of Water Quality), was applied. This provides the basis for a field verification of NC-CREWS. In addition, the Division of Coastal Management is performing an extensive accuracy assessment funded by a grant from US EPA. Statistical results of this accuracy assessment will be reported in a separate publication after the completion of that study.

THE NCCREWS PROCEDURE

Section 3

As explained in Section 2, application of NC-CREWS is a hierarchical process in which individual parameters are first evaluated and then successively combined to produce ratings for subfunctions, major functions, and overall functional significance of the wetland. The processes of evaluating parameters and then combining them are two separate steps. There also are two different versions of the parameter evaluation and combining procedures, one for riverine and headwater wetlands and one for depressional wetlands. Each step of parameter evaluation and combination is based on ecological principles and/or assumptions based on best professional judgment.

Since the procedure is long and complex, it is difficult to explain the determination of parameter values, combination procedures, and rationale for each step all together. In order to convey as clear a picture of the NC-CREWS procedure as possible, the basics of parameter evaluation and combination are presented in semi-outline form and briefly explained in this Section. More detailed explanations, scientific rationale, and assumptions involved for each step are given in Section 4.

Overriding Considerations

For both Riverine/Headwater and Depressional HGM classes, if any of the following conditions exists, the overall wetland rating is Exceptional. Individual parameters need not be rated, although it may be useful to do so to document other wetland functions.

(1) The wetland is salt or brackish marsh, estuarine scrub shrub, or estuarine forest.

(2) The wetland is adjacent to (within 300 feet of) a designated Primary Nursery Area.

(3) The wetland contains a known occurrence of a threatened or endangered species of terrestrial or aquatic animal or plant on either federal or state lists or contains occurrences of exemplary or unique natural ecosystems or special wildlife habitat areas as designated by the NC Natural Heritage Program

If a wetland is immediately adjacent to (forming part of the border of) a wetland with an overall rating of "Exceptional functional significance", it is not to be rated lower than "Substantial functional significance," regardless of the values for individual sub functions.

The reminder of this section outlines each function, subfunction, parameter, and subparameter for the three primary wetland functions and the potential risk factor. The left hand column lists the items while the right hand column provides a brief explanation of each item. In addition, the left hand column provides an explanation of how each item is combined to get a rating at each level and also lists the codes for each item. The codes correspond to the file name for each AML routine used in the procedure.

.

Riverine and Headwater Wetlands

Parameter Evaluation and Combination

I. Water Quality Functions (wqf01)

A. Nonpoint Source Function (wqf011)

1. Proximity to Sources (wqf0111)

H > 20% perimeter agriculture + developed

M > 20% perimeter agriculture + developed + pine plantation

L ≤ 20% perimeter agriculture + developed + pine plantation

2. Proximity to Water Body (wqf0112)

H Within 300 ft. of permanent surface water

M Within 300 ft. of intermittent stream

L > 300 ft. from permanent or intermittent surface water

3. Watershed Position (wqf0113)

H Intermittent or first order stream

M Second or third order stream

L Higher than third order stream

4. Site Conditions (wqf0114)

a. Wetland Type (wqf01141)

H Bottomland hardwood, swamp forest, headwater swamp

M Freshwater marsh, pine flat, hardwood flat, pocosin maritime forest

L Pine plantation, altered sites

b. Soil (wqf01142)

H Histosol or frequently flooded mineral soil with high clay and organic matter

M Infrequently flooded mineral soil with high clay and organic matter

L Infrequently flooded mineral soil with low clay and organic matter

RATING SYSTEM FOR SITE CONDITIONS

H Both (a) & (b) rated H

M Other combinations

L At least one L and neither H

RATING SYSTEM FOR NPS FUNCTION

H (1) and (2) H and (4) at least M or (3) and (4) H and (2) at least M

M Other combinations

L Any two of (2), (3) & (4) rated L

Brief Explanations

The functions, subfunctions, parameters, and subparameters are earmarked in the following outlines with the corresponding arc macro language (aml) program names (e.g. wqf01) for persons reviewing the actual computer aml programs. "Wqf01" stands for "water quality function 01."

IA. The first broad category of wetland functions is the maintenance and improvement of water quality. The first water quality subfunction is the nonpoint source function, which is the removal of particulates and nutrients from surface runoff water.

1. Proximity to sources is an "opportunity" parameter. It considers the likelihood of polluted runoff entering the wetland based on predominant adjacent land uses. The more of the perimeter of the wetland surrounded by NPS-producing land uses, the higher the rating.

2. Proximity to surface water body is an indicator of the likelihood that polluted runoff entering the wetland would otherwise enter surface water. Wetlands close to permanent surface water are rated H; those close to intermittent streams are rated M; and those not close to any surface water are rated L.

3. Wetlands that are "higher" in a watershed have a greater potential effect on NPS removal and on overall watershed water quality. The order of the nearest stream is an indicator of watershed position.

4. Site conditions are determined by the biotic and physical structure typical of the wetland type and by the properties of the predominant underlying soil.

4a. Wetland type breakdowns are based on field data on indicators of wetland capacity for nutrient transformation and processing and removal of sediments and dissolved materials.

4b. The finer the texture and the higher the organic matter content of the soil, the higher its cation exchange capacity is and the more effective it is in retaining and transforming nutrients.

RATING SYSTEM - Site Conditions: Since both physical and biotic structure of the wetland and properties of the underlying soil are critical factors in determining a wetland's capacity to perform nonpoint source removal functions, both must be evaluated as highly conducive to retention and removal of particulates and nutrients for site conditions to be rated H. If either of the parameters are rated L and the other is not H, site conditions for NPS removal are rated L.

RATING SYSTEM - Nonpoint Source Function: The wetland is rated H for the NPS removal function if it is located between a NPS pollutant generating area and surface water (1 & 2 rated H) and if site conditions are reasonably conducive to retention and removal (4 not L). This provides an H rating when the opportunity is very high even though the capacity may be only moderate. The wetland is also rated H if it is high in its watershed (3 H), site conditions are highly favorable (4 H), and it is close to an intermittent or perennial stream or water body (2 at least M). This provides an H rating based on capacity alone. Thus, the opportunity consideration is, in effect, a "bonus" and does not penalize a wetland without present opportunity. The opportunity factor is not considered in determining an L rating, so a wetland cannot be rated L simply due to lack of opportunity to perform the function.

Parameter Evaluation and Combination

B. Floodwater Cleansing Function (wqf012)

Rated only for riverine systems. Headwater systems are rated L for this subfunction.

1. Water Source and Proximity to Sources (wqf0121)

For streams entering the HU from outside:

- H In floodplain of Piedmont-draining stream **or** upstream HU > 50% agricultural plus developed land
- M In floodplain of coastal plain draining stream with upstream HU < 50% agriculture plus developed land
- L Not in floodplain

For streams originating in the HU:

- H > 25% of stream length in HU bordered by agricultural or developed land
- M 5-25% of stream length bordered by agricultural or developed land
- L < 5% of stream length bordered by agricultural or developed land

2. Duration of Flooding (wqf0122)

- H Wetland is flooded 'long to very long' periods
- M Wetland is flooded 'brief' periods
- L Wetland is flooded 'very brief' periods or not at all

If the stream is channelized, the rating is reduced by one level for adjacent wetlands.

3. Site Conditions (wqf0123)

a. Wetland Type (wqf01231)

- H Bottomland hardwood, swamp forest
- L Other wetland types

b. Soil (wqf01232)

- H Histosol or frequently flooded mineral soil with high clay and organic matter
- M Infrequently flooded mineral soil with high clay and organic matter
- L Infrequently flooded mineral soil with low clay and organic matter

4. Width of Wetland Perpendicular to Stream (wqf0124)

- H > 100 feet
- M 50-100 feet
- L < 50 feet

RATING SYSTEM FOR SITE CONDITIONS

- H Both (a) and (b) rated H
- M Other combinations
- L Both (a) and (b) rated L

RATING SYSTEM FOR FLOODWATER CLEANSING FUNCTION

- H (1) H and (2), (3), and (4) at least M **or** (2), (3), and (4) rated H
- M Other combinations
- L (2) or (3) rated L

OVERALL RATING SYSTEM FOR WATER QUALITY FUNCTIONS

- H Either subfunction (nonpoint source removal or floodwater cleansing rated H
- M Other combinations
- L Both subfunctions rated L

Brief Explanations

IB. The second water quality subfunction of wetlands is removal of sediments, nutrients, and toxins that have already entered surface water that enter the wetland by over bank flow from a flooding stream. Headwater systems do not receive over bank flow of water from upstream sources and do not perform this function. Although they are commonly flooded during part of the year, the water comes from overland runoff and groundwater.

1. Water Source and Proximity to Sources is an "opportunity" parameter that indicates whether pollutants are likely to be present in a stream. If the stream enters the hydrologic unit from outside the HU boundary, it is most likely to contain pollutants if it originates in the Piedmont or if the upstream HU is heavily agricultural or developed. If the stream originates in the HU, its pollutant load is determined by the land uses bordering it upstream of the wetland site.

2. The longer floodwaters remain in a wetland, the greater the level of pollutant removal is. Parameters are based on the flooding duration typical of the predominant underlying soil as reported in the appropriate soil survey.

3. Site conditions are determined by the biotic and physical structure typical of the wetland type and by the properties of the predominant underlying soil.

3a. Wetland type breakdowns are based on field data of indicators of capacity for nutrient transformation and processing, removal of dissolved materials, organic carbon export, and retention of woody materials to provide on-site energy sources for microbial activity.

3b. The finer the texture and the higher the organic matter content of the soil, the higher is its cation exchange capacity and the more effective it is in retaining and transforming nutrients and toxins.

4. The wider a wetland is along a stream, the more area there is available for water retention and pollutant removal.

RATING SYSTEMS - Site **Conditions:** As with the nonpoint source removal subfunction, both wetland type and soil characteristics must be rated H to give the wetland an H rating. In this case, however, both of the parameters must be rated L to result in an L rating for site conditions. This reflects the lack of a moderate range for the wetland type parameter.

RATING SYSTEM - Floodwater Cleansing Function: The wetland is rated H for the floodwater cleansing function if floodwater entering it is likely to carry heavy pollutant loads and if its internal conditions are at least moderately conducive to pollutant retention and removal. It is also rated H if it holds floodwaters for long periods, has significant width in which it can hold water, and has site conditions amenable to pollutant removal. As with the nonpoint source function, the opportunity factor of whether the floodwater contains pollutants is treated as a "bonus" rather than as a determining factor. The wetland is rated L for this subfunction if the stream seldom or never floods or floods for only brief periods and there is very little width along the stream into which floodwaters can flow. Neither site conditions nor pollutant loading of the stream are sole determinants of an L rating for this subfunction.

OVERALL RATING SYSTEM - Water Quality Functions: Both nonpoint source removal from surface runoff and removal of pollutants from in-stream waters are important water quality functions of wetlands. If either one of them is rated H, the wetland is rated H for the significance of its overall water quality function. If either of these functions is rated M, the wetland will receive an M rating even though the other function may be rated L. Only if both functions are rated L will the wetland be rated L for its significance in performing water quality functions.

Parameter Evaluation and Combination

II. Hydrology Functions (hyf01)

A. Surface Runoff Storage (hyf011)

If wetland size is > 2.7% of HU area, Runoff Storage Function is rated at least M.

1. **Watershed Position (hyf0111)**
   - H Intermittent or first order stream
   - M Second or third order stream
   - L > third order stream

2. **Wetland Size (hyf0112)**
   - H Wetland is > 0.54% of total HU area
   - M Wetland is 0.05-0.54% of HU area
   - L Wetland is < 0.05% of HU area

3. **Site Conditions (hyf0113)**

   a. Wetland Type (hyf01131)
   - H Bottomland hardwood, swamp forest, headwater swamp, freshwater marsh
   - M Hardwood flat, pocosin, maritime forest
   - L Pine flat, pine plantation, altered site

   b. Soil infiltration capacity (hyf01132)
   - H Soil hydrologic group A, B, or A/D
   - M Soil hydrologic group C or B/D
   - L Soil hydrologic group D

RATING SYSTEM FOR SITE CONDITIONS
- H (a) or (b) rated H and the other rated at least M
- M Other combinations
- L At least one L and no H

RATING SYSTEM FOR SURFACE RUNOFF STORAGE FUNCTION
- H (1) and (3) rated H and (2) at least M
- M Surface runoff storage not H, but wetland size > 2.7% of HU area; other combinations
- L (1) and (2) rated L **or** (3) rated L

Brief Explanations

IIA. Wetland hydrologic functions result in attenuation of peak high and low stream flows due to storage and slow release of water. One of the primary ways in which water enters wetlands is by overland storm water runoff. The principal determinant of a wetland's capacity to hold runoff water is its size; all other conditions being equal, the larger a wetland, the more water it can store. If a wetland is large enough that its removal would likely result in an increase in peak discharge from the watershed of greater than 5%, the wetland will receive no lower than an M for this subfunction.

1. Wetlands along headwater streams receive proportionately more overland runoff than downstream wetlands, and their position high in the watershed results in their water storage capacity having greater impact on overall watershed hydrology. Stream order breakdowns are by the Strahler system, which numbers the smallest streams as first order.

2. Based on hydrologic modeling explained in more detail in Section 4, the water storage capacity of a wetland equal in size to 0.54% of total watershed area will result in a decrease in peak discharge of 1%. Water storage in a wetland less than 0.05% of the watershed area will result in a decrease in peak discharge of less than 0.1%.

3. Site conditions are determined by the biotic and physical structure typical of the wetland type and by the properties of the predominant underlying soil

3a. Wetland type breakdowns are based on field data on such indicators of surface water storage capacity as microtopographic complexity, evidence of soil reduction, and evidence of standing water.

3b. The infiltration capacity of the underlying soil determines the amount of water the soil can receive and store before additional water will run off. Hydrologic groups are used in soil surveys to indicate a soil's capacity for water intake when the soils are wet and receive precipitation from long-duration storms.

RATING SYSTEM - Site Conditions: Either a wetland type that, because of its structural characteristics, can hold large amounts of water or a soil that can allow large amounts of water to infiltrate can result in a high water storage capacity for a wetland, provided that the other parameter is not so low as to counteract it. If either parameter is rated L, and the other is not H, the wetland is rated L.

RATING SYSTEM - Surface Runoff Storage Function: Watershed position and site conditions are the primary determinants of runoff storage. If both of these are rated H, the wetland is rated H unless it is very small. If site conditions are poor for water storage or if the wetland is very small and far downstream in the watershed, it is rated L. If the wetland is of such size that its removal would result in a 5% or greater increase in watershed peak discharge, it is rated at least M for this subfunction.

Parameter Evaluation and Combination

B. Floodwater Storage (hyf012)

Rated only for riverine systems. Headwater systems are rated L for this subfunction.

1. Duration of Flooding (hyf0121)

- H Wetland is flooded 'long to very long' periods
- M Wetland is flooded 'brief' periods
- L Wetland is flooded 'very brief' periods or not at all

If the stream is channelized, the rating is reduced by one level for adjacent wetlands.

2. Wetland Size (hyf0122)

- H Wetland is > 0.54% of total HU area
- M Wetland is 0.05-0.54% of HU area
- L Wetland is < 0.05% of HU area

3. Watershed Position (hyf0123)

- H > third order stream
- M Second or third order stream
- L Intermittent or first order stream

4. Width of Wetland Subject to Flooding (hyf0124)

- H > 100 feet
- M 50 to 100 feet
- L < 50 feet

RATING SYSTEM FOR FLOODWATER STORAGE FUNCTION

- H Any 3 or more parameters rated H and none L
- M Other combinations
- L Any 2 or more parameters rated L and (4) < H

Brief Explanations

IIB. This is a rating of the wetland's significance in providing temporary storage of floodwaters to alleviate downstream flooding. It is applicable only to riverine wetlands that receive floodwater by over bank flow.

1. Duration of flooding, taken from soil survey information for the underlying soil series, is a measure of the length of time the soil surface is covered by flowing water from overflowing streams. The longer the time during which a wetland holds floodwater, the greater its significance in performing this subfunction is.

2. Even if a wetland is relatively narrow along a stream, if it is of considerable length, it can store significant amounts of water.

3. Wetlands along large streams further downstream in a watershed are the most significant in receiving and holding in-stream floodwaters.

4. The wider a wetland is along a stream, the more area is available over which flood waters can spread.

RATING SYSTEM - Floodwater Storage Function: Three of the four parameters must be rated H and the fourth one at least M for the wetland to receive an H rating for this subfunction. Thus, a wetland's size alone will not result in an H rating unless its watershed position and duration of flooding are favorable. Similarly, favorable position and flooding duration characteristics cannot rate a wetland H unless at least one of the size parameters is high. Only two parameters need be rated L, however, to rate a wetland L unless the wetland is quite large. These rating systems emphasize the importance of wetland size in performing this function.

Parameter Evaluation and Combination

C. Shoreline Stabilization Function (hyf013)

1. Proximity to Water Body (hyf0131)

- H < 50 feet from shoreline of a second or higher order stream or of an estuary or lake shoreline
- M < 50 feet from first order stream or between 50 and 300 feet from an estuary shoreline
- L ≥ 50 feet from any stream or lake or > 300 feet from an estuary shoreline

2. Length of Wetland Border Exposed to Open Water (hyf0132)

- H > 500 feet of wetland perimeter borders open water
- M 100-500 feet of perimeter borders open water
- L < 100 feet of perimeter borders open water

3. Watershed Land Use (hyf0133)

- H ≥ 1% developed <u>or</u> > 20% developed + agriculture
- L < 1% developed and < 20% developed + agriculture

RATING SYSTEM - SHORELINE STABILIZATION

- H Two or more parameters rated H
- M Other combinations
- L Two or more parameters rated L <u>or</u> (1) rated L

OVERALL RATING SYSTEM FOR HYDROLOGIC FUNCTIONS

- H Surface runoff or floodwater storage rated H <u>**or**</u> shoreline stabilization H and other two at least M
- M Other combinations
- L Runoff & floodwater L, shoreline stabilization not H

Brief Explanations

IIC. This is a rating of a wetland's significance in holding the soil and location of a shoreline in place in the face of the erosive forces of flowing stream water or wave action. The intent is to evaluate the potential energy of water movement in a watershed.

1. If a wetland is not located on a shoreline, it cannot perform this function. If the wetland does occupy a shoreline, the larger the stream or the greater the fetch of open water is, the more erosive force there is likely to be.

2. The longer the length of shoreline that the wetland occupies, the more significant this function is in relation to other wetland functions.

3. This is an "opportunity" parameter based on the assumption that the flow rate and erosive force of a stream are increased by more rapid runoff of storm water from cleared and developed land than from forested land.

RATING SYSTEM - Shoreline Stabilization Function: If two or more of the parameters are rated H and none of them is rated L, the wetland is rated H for this function. If the wetland is not along a shoreline (1=L), its stabilization function is obviously of little significance, and it is rated L. It is also rated L if it is along a shoreline but all other parameters are rated L.

OVERALL RATING SYSTEM - Hydrologic Functions: If either of the major hydrologic functions of wetlands, storage of surface runoff or floodwater, is rated H, the wetland is of high hydrologic significance. Shoreline stabilization is a "bonus" factor that can result in an H rating, but its absence does not penalize the wetland.

Parameter Evaluation and Combination

III. Habitat Functions (haf01)

A. Endangered Species/Significant Natural Areas

H Occurrence of Threatened or Endangered species or a Natural Heritage exemplary or unique natural ecosystem or special wildlife habitat

B. Terrestrial Wildlife Habitat (haf011)

1. Internal Habitat (haf0111)

a. Interior Size of Habitat Complex (haf01111)

H > 74 acres
M 0 - 74 acres
L No interior habitat

b. Association with Surface Water (haf01112)

H Adjacent to permanent surface water
M Adjacent to intermittent stream
L Not adjacent to surface water

c. Internal Heterogeneity of Habitat Complex (haf01113)

H > 8 vegetation types within complex
M 5-8 vegetation types within complex
L 1-4 vegetation types make up entire complex

d. Wetland Type (haf01114)

H Bottomland hardwood, freshwater marsh, hardwood flat, swamp forest
M Headwater swamp, pocosin, pine flat, maritime forest
L Pine plantation, altered site

RATING SYSTEM FOR INTERNAL HABITAT

H Two or more parameters rated H and (a) not L (except for freshwater marsh where (a) is not considered; **or** (d) rated H and (a) not L
M Other combinations
L Two or more parameters rated L and none H

Brief Explanations

IIIA. These are overriding considerations that result in either an overall wetland rating of Exceptional functional significance or in an H rating for the habitat function. If threatened or endangered species on either federal or state lists are verified as present or if the area is identified as a exemplary or unique natural ecosystem or special wildlife habitat by the State Natural Heritage Program, the wetland as a whole is rated as having Exceptional functional significance.

IIIB. Since the objective is to generalize about habitat quality, the more habitat requirements the wetland fills for the greatest number of species, the higher is its habitat significance rating. The bias in this analysis is toward faunal species because of the lack of GIS data and understanding of floral species.

1. This series of parameters examines the internal characteristics of the wetland in providing habitat without considering the relation of the wetland to surrounding habitat conditions.

1a. For interior-dwelling species, as opposed to 'edge' species, the larger the area of unbroken habitat the better it is. Evaluation of this parameter is based on the internal area of contiguous, unbroken wetlands and intact upland forests. Internal area is calculated as the area remaining after the total size of the habitat complex is reduced inward 100 meters from its boundaries to compensate for edge effects.

1b. Availability of surface water is important to many species and limiting to some. Even if species live elsewhere and visit the wetland to drink, the presence of water results in the area being more heavily used and having high habitat significance.

1c. Areas with higher internal heterogeneity generally provide suitable habitat for more species and often better habitat for individual species due to greater food sources, nesting sites and cover. Internal heterogeneity is measured by the number of vegetation types present in the habitat complex.

1d. The wetland type breakdown is based on analysis of field data for food and cover values typical of different wetland environments and on available literature on the habitat value of different wetland types.

RATING SYSTEM - Internal Terrestrial Habitat Function: For all wetland types other than freshwater marsh, if at least two of the parameters are rated H and the habitat complex is large enough that it provides some interior habitat (a > L), the wetland is rated H. Freshwater marshes need not be large to be rated H. Alternatively, if the wetland type provides very good habitat (d = H) the wetland will be rated H unless it is very small. If two or more parameters are rated L, the wetland is rated L for its significance in providing internal habitat.

Parameter Evaluation and Combination

2. Landscape Habitat (haf0112)

a. Wetland Juxtaposition (haf01121)

- H > 50% of wetland bordered by other wetlands
- M < 50% of wetland bordered by other wetlands
- L Isolated from other wetlands

b. Surrounding Habitat (haf01122)

- H > 50% of land cover within ½ mile composed of natural vegetation
- M > 50% of land cover within ½ mile buffer composed of a combination of natural vegetation, pine plantations, and agriculture
- L > 20% of land within ½ mile developed or < 10% natural vegetation

RATING SYSTEM FOR LANDSCAPE HABITAT

- H Both parameters rated H
- M Other combinations
- L Either parameter rated L and neither rated H

3. Movement System Value (haf0113)

a. Corridor Value (haf01131)

- H Corridor > 600 feet wide connected to contiguous natural vegetation
- M Corridor < 600 feet wide connected to contiguous natural vegetation
- L Isolated from other natural vegetation

b. Wetland Island Function (haf01132)

- H Isolated wetland > 5 acres in size within ½ mile of a wetland
- M Isolated wetland < 5 acres within ½ mile of a wetland
- L Wetland < 1 acre in size or > ½ mile from nearest wetland

RATING SYSTEM FOR MOVEMENT SYSTEM FUNCTIONS

- H Either parameter rated H
- M Other combinations
- L Both parameters rated L

RATING SYSTEM FOR TERRESTRIAL WILDLIFE HABITAT FUNCTION

- H (1) and (2) rated high **or** (3) rated H
- M Other combinations
- L Two parameters rated L, and none H

Brief Explanations

2. This is an examination of the quality of habitat provided by the wetland, as it exists in the context of its surrounding landscape. Compatible adjacent habitats provide wildlife access to additional food and cover, safer dispersal into other areas, and refuge from temporarily adverse conditions in the wetland.

2a. This parameter reflects the significance of connected wetland complexes in providing habitat.

2b. A distance of ½ mile is within the movement range of most wildlife species and within the distance even small species might move if seeking refuge. The more compatible habitat there is within this distance, the more suitable the overall habitat could be.

RATING SYSTEM - Landscape Habitat: If the wetland is surrounded along more than half its perimeter by other wetlands and more than 50% of the surrounding area within ½ mile is in natural vegetation, the landscape habitat value is rated H. If either the wetland is isolated from other wetlands or surrounded by low quality habitat, the rating is L.

3. This is an evaluation of the wetland's capacity for providing movement or dispersal pathways.

3a. A wildlife corridor is a potential movement pathway through areas of unsuitable habitat such as agricultural or developed land. The corridor can include natural upland vegetation as well as wetlands.

3b. Non-continuous islands of habitat can also provide movement pathways for wildlife, provided that these islands are of sufficient size and within reasonable travel distance of one another.

RATING SYSTEM - Movement System Parameters: If the wetland has the capacity to perform either a high corridor function or island function to allow wildlife movement, it is rated H. If it performs neither function, it is rated L.

RATING SYSTEM - Terrestrial Wildlife Habitat Subfunction: A wetland with high internal habitat quality in a landscape providing good habitat receives an H value. If the wetland provides a good movement system it is also rated H, even though its actual habitat value may be low. A wetland is rated low for terrestrial habitat when no high habitat qualities are present and either the internal habitat and landscape habitat are low, the internal habitat and movement systems are low, or the landscape habitat and movement system functions are low.

Parameter Evaluation and Combination

C. Aquatic Life Habitat (haf012)

1. Anadromous Fish (haf0121)

- H Adjacent to a river or tributary of a river harboring anadromous fish; annual flooding; not channelized
- M Adjacent to a river or tributary harboring anadromous fish; stream is channelized
- L Not adjacent to stream harboring anadromous fish

2. Other Fish Species (haf0122)

- H Adjacent to > third order stream with annual flooding
- M Adjacent to a first to third order stream with annual flooding or a channelized stream of > third order
- L Not adjacent to a stream or stream has infrequent or nonexistent flooding

3. Amphibians and Invertebrates (haf0123)

a. Wetland Type (haf01231)

- H Bottomland hardwood, headwater swamp, or freshwater marsh, swamp forest
- M Hardwood flat, pocosin, or maritime forest
- L Pine flat, pine plantation, altered site

b. Surrounding Habitat (haf01232)

- H > 50% of land cover within ½ mile composed of natural vegetation
- M > 50% of land cover within ½ mile buffer composed of a combination of natural vegetation, pine plantations, and agriculture
- L > 20% of land within ½ mile developed <u>or</u> < 10% natural vegetation

RATING SYSTEM FOR AMPHIBIAN/INVERTEBRATE HABITAT

- H Both parameters rated H
- M Other combinations
- L Either parameters rated L

RATING SYSTEM FOR AQUATIC LIFE HABITAT

- H At least one parameter rated H
- M Other combinations
- L (2) and (3) rated L

OVERALL RATING SYSTEM FOR HABITAT FUNCTIONS

- H Probable threatened/endangered species habitat or either terrestrial or aquatic habitat rated H
- M Other combinations
- L Both terrestrial and aquatic habitat rated L

Brief Explanations

IIIC. This considers the wetland's significance in providing habitat for aquatic species, including fish, amphibians, and invertebrates.

1. Wetlands along streams harboring anadromous fish can provide breeding habitat for these important species. Anadromous species often move far up tributary streams to breed. Floodwater must enter the wetland, however, to provide access and habitat, and channelization inhibits this process. Streams that are not channelized, diked, impounded or otherwise artificially altered are assumed to flood annually.

2. Many stream-dwelling fish species utilize flooded wetlands for food, cover, and breeding. The larger the stream, the more significant this function is due to the greater numbers of fish and longer periods of flooding.

3. Best habitat for amphibians and aquatic invertebrates exists in areas that provide water for egg-laying and larval development yet exclude predatory fish. This occurs in wetlands where isolated vernal pools persist long enough to allow larval development to maturity. Optimum habitat must also include adjacent non-aquatic areas for adult stages.

3a. The wetland type breakdown is based on field data on existence or evidence of vernal pools.

3b. This sub-parameter measures the availability of non-aquatic habitat within a feasible movement range for adult amphibians.

RATING SYSTEM - Amphibian/Invertebrate Habitat: If the wetland is a type in which vernal pools commonly occur and suitable habitat for adult amphibians is available, it is rated H. If either of these habitat requirements is absent, the wetland is rated L.

RATING SYSTEM - Aquatic Life Habitat: If the habitat quality is rated H for any one of the animal groups, the wetland is rated H for its significance in providing aquatic life habitat. If habitat quality is L for both fish and amphibians, the wetland is rated L. Since anadromous fish are limited to certain river systems, parameter (1) may be rated L without decreasing a wetland's rating. Anadromous fish habitat is a "bonus" for areas that perform this function.

OVERALL RATING SYSTEM - Habitat Function: A wetland is automatically rated H for habitat if a threatened or endangered species is located within the wetland polygon or if the wetland has been identified as an exemplary or unique natural ecosystem or special wildlife habitat by the Natural Heritage Program. A wetland is also rated H for habitat if it provides excellent Terrestrial Habitat (H) or Aquatic Life Habitat (H).

Wetlands are not penalized for providing habitat for only terrestrial or only aquatic wildlife. However, wetlands that provide only low levels of habitat for both terrestrial and aquatic wildlife are rated low (L).

Parameter Evaluation and Combination

IV. Potential Risk of Wetland Loss (prf01)

A. Landscape Character (prf011)

1. Wetland Extent and Rarity (prf0111)

a. Percent of hydrologic unit composed of wetlands (prf01111)

H < 20%
M 20-50%
L > 50%

b. Percent of wetlands in larger area unit composed of this type (prf01112)

H < 10%
M 10 - 25%
L > 25%

RATING SYSTEM FOR WETLAND EXTENT AND RARITY

H Either (a) or (b) rated H
M Other combinations
L Both (a) and (b) rated L

2. Land use in hydrologic unit (prf0112)

a. Percent of land in agricultural use (prf01121)

H > 40%
M 10 - 40%
L < 10%

b. Percent of land in pine plantations (prf01122)

H > 30%
M 10-30%
L < 10%

c. Percent of land in urban/developed uses (prf01123)

H > 1%
M 0.1-1%
L < 0.1%

RATING SYSTEM FOR LAND USE

H Any one parameter rated H with at least one other rated M or higher
M Other combinations
L Two or more parameters rated L with none rated H

RATING SYSTEM FOR LANDSCAPE CHARACTER

H Either parameter rated H
M Other combinations
L Both parameters rated L

Brief Explanations

IV. Potential Risk of Wetland Loss: This factor evaluates the wetland's significance in relation to the land use and water characteristics of the landscape in which it functions to determine the relative risk to watershed integrity posed by the wetland's loss.

IVA. These parameters evaluate the wetland's significance in terms of its role in the landscape. The fewer wetlands there are and the more intensively used the land is in the watershed, the more significant is the wetland's function.

1. The wetland extent and rarity parameter measures how common wetlands are in the landscape.

1a. The higher the proportion of a watershed's land area that is occupied by wetlands, the less vital to the watershed's integrity one particular wetland is. Values are based on conditions in the NC coastal area, where wetlands often comprise 50% or more of the land area. Values would be different for other landscapes with fewer wetlands.

1b. This is a rating of the rarity of this type of wetland in the larger landscape. In terms of its contribution to landscape diversity, the more rare the wetland type, the greater its significance is.

RATING SYSTEM - Wetland Extent and Rarity: If either the proportion of wetlands in the watershed is low or the wetland is a rare type, the rating is H. If wetlands are widespread in the landscape and this wetland type is common, the rating is L.

2. The more intensive land uses that exist in a watershed, the greater the significance of the functions of remaining wetlands is. The predominant anthropogenic land uses in the coastal area are agriculture, intensive forestry, and urban/residential development.

2a. Agricultural land is a significant source of nonpoint source pollution. The more agricultural land in the landscape, the more significant the wetlands are in removing pollutants before they enter surface waters.

2b. Pine plantations are the most common form of intensive forest management. During the harvest and regeneration stages of the management cycle, they can be significant sources of nonpoint source pollution.

2c. Land development increases surface runoff, increases pollutant loadings, and destroys wildlife habitat. As development increases, all the functions of remaining wetlands become more significant. Since this is the most intensive land use with the most adverse impacts, only a small proportion of the landscape needs to be developed to give wetlands an H rating.

RATING SYSTEM - Land Use: If any one of the intensive land uses occupies a significant portion of the watershed and the other two are not both L, the land use parameter is rated H. If two or more of the land uses are of low intensity and none is high, the landscape is largely in natural vegetation, and the rating is L.

RATING SYSTEM - Landscape Character: If the extent of wetlands in the watershed is small or the wetland is of a rare type, the functions of remaining wetlands are highly significant. Similarly, if the land use is intensive, the functions of remaining wetlands are highly significant. If, on the other hand, wetlands are common, this particular wetland is a common type, and most of the landscape is in natural vegetation, the loss of this wetland would probably not have a significant detrimental impact on landscape functions.

Parameter Evaluation and Combination

B. Watershed Water Quality Characteristics (prf012)

1. Classification of Major Water Body in the Watershed (prf0121)

- H SA, ORW, HQW, WS-I, WS-II, NSW, URW
- M B, WS-III, SB
- L C, SC

2. Use Support of Water Bodies in Watershed (prf0122)

- H > 25% of stream miles or water body area in watershed less than fully supporting
- M 10-25% of stream miles or water body area in watershed less than fully supporting
- L < 10% of stream miles or water body area in watershed less than fully supporting

3. Classification of Water Body Receiving Watershed Output (prf0123)

- H SA, ORW, HQW, WS-I, WS-II, NSW, URW
- M B.WS-III, SB
- L C, SC

RATING SYSTEM FOR WATERSHED WATER QUALITY CHARACTERISTICS

- H Any one parameter rated H
- M Other combinations
- L Any two parameters rated L, none rated H

C. Replacement Difficulty for Wetland Functions (prf013)

1.Wetland Type (prf0131)

- H Pocosin, maritime forest
- M Bottomland hardwood, swamp forest, headwater swamp, hardwood or pine flat
- L Freshwater marsh, pine plantation

2. Replacement Site Availability (prf0132)

- H No replacement site identified in watershed
- M Non-wetland restoration site available in watershed
- L Degraded wetland site of same type identified in watershed

RATING SYSTEM FOR REPLACEMENT DIFFICULTY

- H (2) rated H **<u>or</u>** (1) rated H and (2) rated M
- M Other combinations
- L Both parameters rated L **<u>or</u>** (1) rated L and (2) rated M

Brief Explanations

IVB. This series of parameters considers water quality within and downstream of the watershed containing the wetland. The water quality functions of a wetland become more significant as the assimilative capacity of receiving waters decreases.

1. This is an indication of how important water quality considerations are in the watershed. If water bodies have a high classification, maintaining their quality is an important consideration. If waters are subject to high nutrient concentrations or have been identified as impaired waters where uses can be restored, prevention of pollutant additions is significant.

2. Use support designations indicate water quality impairment in relation to use classifications. The more impaired waters exist in a watershed, the more significant are wetland functions in maintaining water quality.

3. This parameter considers the watershed in the context of what lies downstream. If the water body receiving the output from the watershed is classified such that prevention of additional pollutant loading is highly significant, then wetlands in the watershed are of greater significance in maintaining water quality.

RATING SYSTEM - Watershed Water Quality Characteristics: If the water in a watershed or in the downstream watershed has a high quality classification, is nutrient sensitive, or is targeted for use restoration, the water quality functions of wetlands in the watershed are highly significant. If water quality in the watershed is impaired as indicated by its failure to support intended uses, wetlands are significant in preventing further impairment.

IVC. If the functions of this wetland could be replaced relatively easily by restoration of another wetland within the same watershed, its loss is less significant than if its functions cannot be replaced. This consideration assumes implementation of compensatory mitigation for any wetland permit granted.

1. Wetland types in the lowest group are relatively easy to restore. Those in the middle group are more difficult to restore hydrologically, and their vegetation takes a long time to mature. Wetlands in the highest group are very difficult to restore due to the peculiar nature of their hydrology and the unique site requirements of their vegetation.

2. If a degraded wetland of the same type exists in the watershed, it would be relatively simple to restore it to replace this wetland's functions. Restoring a site that has been completely converted but is otherwise suitable is more difficult, but still possible. If there is no suitable restoration site in the watershed, replacing this wetland's functions is essentially impossible. Potential restoration sites are located and classified by DCM's restoration site mapping which is done in conjunction with mapping existing wetlands.

RATING SYSTEM - Wetland Replacement Potential: If no restoration site is available in the watershed, the difficulty of replacing the wetland's functions in the local landscape is high. If the wetland is in the most difficult group to restore and no degraded site of the same type is available for enhancement, replacement difficulty is rated H. If the wetland type is relatively easy to restore and any restoration site is available in the watershed, replacement difficulty is rated L

Parameter Evaluation and Combination

D. Enhancement Potential of Site (prf014)

This parameter is considered only if the wetland is rated of low value for the primary wetland functions.

- H Drained or partially drained wetland with natural vegetation intact
- M Drained or partially drained and converted to pine plantation or other intensively-managed forest type
- L Wetland intact, but of low functional significance

OVERALL RATING SYSTEM FOR RISK CONSIDERATIONS

- H At least two of (A), (B), & (C) rated H
- M (D) rated H **or** other combinations
- L Any two of (A), (B), & (C) rated L with no parameters rated H

Brief Explanations

IV. D. If a wetland has low functional significance because it is degraded due to drainage or other disturbance, it may still have the potential to be restored to higher levels of function to replace functions lost elsewhere. The closer the wetland is to its fully functioning state, i.e., the less it has been disturbed, the more practical its restoration is and the higher its significance as a potential restoration site. This is a "bonus" parameter for wetlands that have been degraded by past human activity. If the wetland is simply of low significance in and of itself, it rates L on this parameter as well.

OVERALL RATING SYSTEM - Risk Considerations: If any two of the risk parameters other than restoration potential are rated H, the risk to watershed functional integrity of losing the wetland is rated H. This occurs if land use is intense and water quality is impaired, if land use is intense and the wetland's functions would be very difficult to replace, or if water quality is impaired and replacement difficulty is high. If any two of these same considerations are rated L and the third is not rated H, the risk factor is rated L. Restoration potential is treated as a "bonus" parameter; not of enough significance by itself to give a wetland an H risk rating but as a way of recognizing the importance of protecting potential restoration sites by preventing their receiving an L rating for all considerations simply because they have been degraded by human activity.

Depressional Wetlands

Parameter Evaluation and Combination

I. Water Quality Functions (wqf01)

A. Nonpoint Source Function (wqf011)

1. Proximity to Sources (wqf0111)

H > 20% perimeter agriculture + developed
M > 20% perimeter agriculture + developed + pine plantation
L ≤ 20% perimeter agriculture + developed + pine plantation

2. Proximity to Water Body (wqf0112)

H Within 300 ft. of permanent surface water
M Within 300 ft. of intermittent stream
L > 300 ft. from permanent or intermittent surface water

3. Watershed Position (wqf0113)

H Intermittent or first order stream
M Second or third order stream
L Higher than third order stream

4. Site Conditions (wqf0114)

a. Wetland Type (wqf01141)

H Swamp forest
M Freshwater marsh, pine flat, hardwood flat, pocosin, maritime forest
L Pine plantation, altered sites

b. Soil (wqf01142)

H Histosol or frequently flooded mineral soil with high clay and organic matter
M Infrequently flooded mineral soil with high clay and organic matter
L Infrequently flooded mineral soil with low clay and organic matter

RATING SYSTEM FOR SITE CONDITIONS

H Both (a) & (b) rated H
M Other combinations
L At least one L and neither H

RATING SYSTEM FOR NPS FUNCTION

H (1) and (2) H and (4) at least M <u>or</u> (3) and (4) H and (2) at least M
M Other combinations
L Any two of (2), (3) & (4) rated L

B. Floodwater Cleansing Function (wqf012)

L All depressional wetlands are rated L for this function

OVERALL RATING SYSTEM FOR WATER QUALITY FUNCTIONS

H Nonpoint Source Function rated H
M Nonpoint Source Function rated M
L Nonpoint Source Function rated L

Brief Explanations

IA. Removal of pollutants from overland runoff and precipitation is the principal water quality function of depressional wetlands. The parameters for evaluating the nonpoint source removal function of depressional wetlands are the same as those for riverine/headwater wetlands and are evaluated in a similar manner.

1. Proximity to sources is an "opportunity" parameter that considers the likelihood of polluted runoff entering the wetland based on adjacent land uses. It is evaluated the same as for riverine/headwater wetlands.

2. Proximity to surface water is an indicator of the likelihood that polluted runoff entering the wetland would otherwise enter surface water. Unless close to a stream but not subject to flooding from it, depressional wetlands generally receive a Low rating for this parameter.

3. Watershed position for depressional wetlands is determined by the order of the closest stream to the wetland, with the assumption that the closest stream would receive any runoff from the area of the wetland. In the flat topography of the North Carolina coastal area, this is a reasonable assumption. When topography data become available, a modeling approach to determine watershed position may be more appropriate.

4. Both wetland type and soil characteristics are evaluated in the same way as for riverine/headwater systems. The list of wetland types includes only those likely to occur as depressional/flat wetlands, excluding riverine wetland types.

RATING SYSTEM - Site Conditions: Since both physical and biotic structure of the wetland and properties of the underlying soil are critical factors in determining a wetland's capacity to perform nonpoint source removal functions, both must be evaluated as highly conducive to retention and removal of particulates and nutrients for site conditions to be rated H. This is the same rating system as for riverine/headwater wetlands.

RATING SYSTEM - Nonpoint Source Function: The rating system for this function is the same for depressional as for riverine/headwater wetlands. Since depressional wetlands are less likely to be adjacent to surface waters and more likely to be in the lower-rated wetland types, the rating system adequately reflects the fact that depressional wetlands are, in general, less effective at performing water quality functions than are riverine wetlands.

I.B. Since depressional/flat wetlands are not in direct proximity to major surface water bodies, they do not receive water from over bank flow and, thus, cannot perform the floodwater cleansing function.

OVERALL RATING SYSTEM - Water Quality Functions: Removal of nonpoint source pollutants from surface runoff is the best-documented water quality function of depressional wetlands. The overall water quality rating, therefore, is the same as its NPS function rating. This rating system reflects the significant nonpoint source pollutant removal function of some depressional wetlands by rating a wetland H for water quality even though other water functions are absent. In effect, this rating system is identical to the one used for the water quality functions of riverine/headwater wetlands.

Parameter Evaluation and Combination

II. Hydrology Functions (hyf01)

A. Surface Runoff Storage (hyf011)

If wetland size is > 2.7% of HU area, Runoff Storage Function is rated at least M.

1. **Watershed Position (hyf0111)** - based on nearest stream
   - H Intermittent or first order stream
   - M Second or third order stream
   - L greater than third order stream

2. **Wetland Size (hyf0112)**
   - H Wetland is > 0.54% of total HU area
   - M Wetland is 0.05-0.54% of HU area
   - L Wetland is < 0.05% of HU area

3. **Site Conditions (hyf0113)**

a. Wetland Type (hyf01131)
   - H Swamp forest, freshwater marsh
   - M Hardwood flat, pocosin, maritime forest, Pine flat
   - LPine plantation, altered site

b. Soil infiltration capacity (hyf01132)
   - H Soil hydrologic group A, B, or A/D
   - M Soil hydrologic group C or B/D
   - LSoil hydrologic group D

RATING SYSTEM FOR SITE CONDITIONS
- H (b) rated H and (a) rated at least M
- M Other combinations
- L At least one L and no H

RATING SYSTEM FOR SURFACE RUNOFF STORAGE FUNCTION
- H (1) and (3) rated H and (2) at least M; **<u>or</u>** (1) and (2) rated H and (3) at least M
- M Surface runoff storage not H, but wetland size > 2.7% of HU area; **<u>or</u>** other combinations
- L (1) and (2) rated L **<u>or</u>** (3) rated L with no parameter rated H

B. Floodwater Storage (hyf012)
- L All depressional wetlands rated L for this function

C. Shoreline Stabilization (hyf013)
- L All depressional wetlands rated L for this function

OVERALL RATING SYSTEM FOR HYDROLOGY FUNCTIONS
- H Surface Runoff Storage Function rated H
- M Surface Runoff Storage Function rated M
- L Surface Runoff Storage Function rated L

Brief Explanations

IIA. Surface Runoff Storage: This is the only hydrologic function of depressional wetlands, since they do not receive floodwater from streams. Due to their larger size, distribution, and typical landscape positions, however, runoff water storage in depressional wetlands is often greater than that for riverine wetlands. All parameter values for depressional wetlands are assigned in the same way as for riverine/headwater wetlands, but the rating systems are different.

1. The further upstream in a watershed, the greater is the impact of water storage on overall watershed hydrology. The stream order of the nearest stream is used as a measure of watershed position.

2. Based on hydrologic modeling explained in more detail in Section 4, the water storage capacity of a wetland equal in size to 0.54% of total watershed area will result in a decrease in peak discharge of 1%. Water storage in a wetland less than 0.05% of the watershed area will result in a decrease in peak discharge of less than 0.1%.

3. Site conditions are determined by the biotic and physical structure typical of the wetland type and by the properties of the predominant underlying soil

3a. Wetland type breakdowns are based on field data of surface water storage capacity indicators such as microtopographic complexity, evidence of soil redoxomorphic condition, and evidence of standing water. Typically riverine wetland types are omitted.

3b. The infiltration capacity of the underlying soil determines the amount of water the soil can receive and store before additional water will run off. Hydrologic groups are taken from soil surveys to indicate a soil's capacity for water intake when the soils are wet and receive precipitation from long-duration storms.

RATING SYSTEM - Site Conditions: For depressional wetlands, soil storage capacity is considered to be more important in determining functional significance than wetland type; in riverine wetlands the opposite holds. In riverine wetlands, the effectiveness of the vegetation structure in impeding overland flow before it enters a stream is the determining factor. In depressional wetlands flow is impeded simply by entering the depression. The more significant factor in determining how much water will be stored before the depression "fills up" is the storage capacity of the soil.

RATING SYSTEM - SURFACE RUNOFF STORAGE FUNCTION: The rating system for depressional wetlands differs from that for riverine wetlands, reflecting the potentially great significance of large depressional wetlands in storing water. Any large depressional wetland high in a watershed is rated H, regardless of wetland type. No single parameter being rated low will result in an L rating if any other parameter is rated H.

IIB. Floodwater Storage: Depressional wetlands do not perform this function, since they do not receive floodwater.

IIC. Shoreline Stabilization: Depressional wetlands do not perform this function, since they are not located on shorelines.

OVERALL RATING SYSTEM FOR HYDROLOGY FUNCTIONS: Due to their landscape positions, depressional wetlands normally have the potential to perform only one of the three hydrologic functions. In the North Carolina coastal area, however, surface runoff storage is such a significant function of depressional wetlands that it is used as the sole determinant of the wetland's hydrologic significance.

Parameter Evaluation and Combination

III. Habitat Functions (haf01)

A. Endangered Species/Significant Natural Areas

H Occurrence of Threatened or Endangered species or a Natural Heritage exemplary or unique natural ecosystem or special wildlife habitat

B. Terrestrial Wildlife Habitat (haf011)

1. Internal Habitat (haf0111)

a. Interior Size of Habitat Complex (haf01111)

H > 74 acres
M 0 - 74 acres
L No interior habitat

b. Association with Surface Water (haf01112)

H Adjacent to permanent surface water
M Adjacent to intermittent stream
L Not adjacent to surface water

c. Internal Heterogeneity of Habitat Complex (haf01113)

H > 8 vegetation types within complex
M 5-8 vegetation types within complex
L 1-4 vegetation types make up entire complex

d. Wetland Type (haf01114)

H Bottomland hardwood, freshwater marsh, hardwood flat, swamp forest
M Headwater swamp, pocosin, maritime forest, Pine flat,
L Pine plantation, altered site

RATING SYSTEM FOR INTERNAL HABITAT

H Two or more parameters rated H and (a) not L (except for freshwater marsh where (a) is not considered; **or** (d) rated H and (a) not L
M Other combinations
L Two or more parameters rated L and none H

Brief Explanations

III. Habitat Functions: The habitat rating system for depressional wetlands is basically the same as for riverine/headwater wetlands. Nothing about the landscape position of depressional wetlands affects their habitat functions for terrestrial species. Aquatic habitat, however, is limited to amphibians and invertebrates.

IIIA. These are overriding considerations that result in either an overall wetland rating of Exceptional functional significance or in an H rating for the habitat function. If threatened or endangered species on either federal or state lists are verified as present or if the area is identified as a significant natural area by the State Natural Heritage Program, the wetland as a whole is rated as having Exceptional functional significance.

IIIB. Since the objective is to generalize about habitat quality, the more habitat requirements the wetland fills for the greatest number of species, the higher is its habitat significance rating.

1. This series of parameters examines the internal characteristics of the wetland in providing habitat without considering the relation of the wetland to surrounding habitat conditions.

a. For interior-dwelling species (as opposed to 'edge' species), the larger the area of unbroken habitat the better. Habitat complexes are contiguous unbroken areas of wetlands and intact upland forests remaining after interior area reduction by edge effects and fragmentation by primary and secondary roads. Choice of the specific size thresholds is explained in Section 4.

b. Availability of surface water is important to many species and limiting to some. Even if species live elsewhere and visit the wetland to drink, the presence of water results in the area being more heavily used and having high habitat significance.

c. Areas with higher internal heterogeneity generally provide suitable habitat for more species and often better habitat for individual species because of greater food sources, nesting sites and cover. Internal heterogeneity is measured by the number of vegetation types present in the habitat complex.

d. The wetland type breakdown is based on analysis of field data for food and cover values typical of different wetland environments and on available literature on the habitat value of different wetland types.

RATING SYSTEM - Internal Terrestrial Habitat Function: For all wetland types other than freshwater marsh, if at least two of the parameters are rated H and the habitat complex is large enough that it provides some interior habitat (a > L), the wetland is rated H. Freshwater marshes need not be large to be rated H. Alternatively, if the wetland type provides very good habitat (d = H) the wetland will be rated H unless it is very small. If two or more parameters are rated L, the wetland is rated L for its significance in providing internal habitat.

Parameter Evaluation and Combination

2. Landscape Habitat (haf0112)

a. Wetland Juxtaposition (haf01121)

- H > 50% of wetland bordered by other wetlands
- M < 50% of wetland bordered by other wetlands
- L Isolated from other wetlands

b. Surrounding Habitat (haf01122)

- H > 50% of land cover within ½ mile composed of natural vegetation
- M > 50% of land cover within ½ mile buffer composed of a combination of natural vegetation, pine plantations, and agriculture
- L > 20% of land within ½ mile developed or < 10% natural vegetation

RATING SYSTEM FOR LANDSCAPE HABITAT

- H Both parameters rated H
- M Other combinations
- L Either parameter rated L and neither rated H

3. Movement System Value (haf0113)

a. Corridor Value (haf01131)

- H Corridor > 600 feet wide connected to contiguous natural vegetation
- M Corridor < 600 feet wide connected to contiguous natural vegetation
- L Isolated from other natural vegetation

b. Wetland Island Function (haf01132)

- H Isolated wetland > 5 acres in size within ½ mile of the other wetland areas
- M Isolated wetland < 5 acres within ½ mile
- L Wetland < 1 acre in size or > ½ mile from nearest wetland

RATING SYSTEM FOR MOVEMENT SYSTEM FUNCTIONS

- H Either parameter rated H
- M Other combinations
- L Both parameters rated L

RATING SYSTEM FOR TERRESTRIAL WILDLIFE HABITAT FUNCTION

- H (1) and (2) rated high **or** (3) rated H
- M Other combinations
- L Two parameters rated L and none H

Brief Explanations

2. This is an examination of the quality of habitat provided by the wetland, as it exists in the context of its surrounding landscape. Compatible adjacent habitats provide wildlife access to additional food and cover, safer dispersal into other areas, and refuge from temporarily adverse conditions in the wetland.

a. This parameter reflects the significance of connected wetland complexes in providing habitat.

b. A distance of ½ mile is within the movement range of most wildlife species and within the distance even quite small species might move if seeking refuge. The more compatible habitat within this distance, the more suitable the overall habitat is.

RATING SYSTEM - Landscape Habitat: If the wetland is surrounded along more than half its perimeter by other wetlands and more than 50% of the surrounding area within ½ mile is in natural vegetation, the landscape habitat value is rated H. If the wetland is either isolated from other wetlands or surrounded by low quality habitat, the rating is L.

3. This is an evaluation of the wetland's capacity for providing movement or dispersal pathways. The Landscape Habitat Value is a "bonus" consideration applicable to wetlands that might otherwise have low habitat values, and its absence does not lower the wetland's habitat rating.

a. A wildlife corridor is a potential movement pathway through areas of unsuitable habitat such as agricultural or developed land. The corridor can include natural upland vegetation as well as wetlands.

b. Non-continuous islands of habitat can also provide movement pathways for wildlife, provided that these islands are of sufficient size and within reasonable travel distance of one another.

RATING SYSTEM - Movement System Functions: If the wetland has the capacity to perform either a high corridor function or island function to allow wildlife movement, it is rated H. If it performs neither function, it is rated L.

RATING SYSTEM - Terrestrial Wildlife Habitat Function: A wetland with high internal habitat quality in a landscape providing good habitat receives an H value. If the wetland provides a good movement system it is also rated H, even though its actual habitat value may be low. A wetland is rated low for terrestrial habitat when no high habitat qualities are present and either the internal habitat and landscape habitat are low, the internal habitat and movement systems are low, or the landscape habitat and movement system functions are low.

Parameter Evaluation and Combination

C. Aquatic Life Habitat (haf012)

1. Anadromous Fish (haf0121)

L Not adjacent to stream harboring anadromous fish

2. Other Fish Species (haf0122)

L Not adjacent to a stream

3. Amphibians and Invertebrates (haf0123)

a. Wetland Type (haf01231)

H Freshwater marsh, swamp forest

M Hardwood flat, pocosin, or maritime forest

L Pine flat, pine plantation, altered site

b. Surrounding Habitat (haf01232)

H > 50% of land cover within ½ mile composed of natural vegetation

M > 50% of land cover within ½ mile buffer composed of a combination of natural vegetation, pine plantations, and agriculture

L > 20% of land within ½ mile developed or < 10% natural vegetation

RATING SYSTEM FOR AMPHIBIAN/INVERTEBRATE HABITAT

H Both parameters rated H

M Other combinations

L Either parameters rated L

RATING SYSTEM FOR AQUATIC LIFE HABITAT

H Amphibian/invertebrate habitat rated H

L Amphibian/invertebrate habitat not rated H

OVERALL RATING SYSTEM FOR HABITAT FUNCTIONS

H Probable threatened/endangered species habitat **or** either terrestrial or aquatic habitat rated H

M Other combinations

L Both terrestrial and aquatic habitat rated L

Brief Explanations

IIIC. Aquatic Life Habitat: This considers the wetland's significance in providing habitat for aquatic species, including fish, amphibians, and invertebrates. Since depressional wetlands are, by definition, not adjacent to water bodies that flood regularly, they normally do not provide habitat for any fish.

1. Depressional wetlands do not perform this habitat function, since they do not receive floodwaters from adjacent streams.

2. Depressional wetlands do not perform this habitat function, since they do not receive floodwaters from adjacent streams.

3. The best habitat for amphibians and aquatic invertebrates exists in areas that provide water for egg-laying and larval development yet exclude predatory fish. This occurs in wetlands where isolated vernal pools persist long enough to allow larval development to maturity. Optimum habitat must also include adjacent non-aquatic areas for adult stages.

a. The wetland type breakdown is based on field data on existence or evidence of vernal pools.

b. This sub-parameter measures the availability of non-aquatic habitat within a feasible movement range for adults.

RATING SYSTEM - Amphibian/Invertebrate Habitat: If the wetland is a type in which vernal pools commonly occur and suitable habitat for adult amphibians is available, it is rated H. If either of these habitat requirements is absent, the wetland is rated L.

RATING SYSTEM - Aquatic Life Habitat: As for riverine/headwater wetlands, if the habitat quality is rated H for any one of the animal groups, the wetland is rated H. Since amphibian/invertebrate habitat is the only aquatic habitat provided by depressional wetlands, if it is H, the wetland is rated H for aquatic habitat. If amphibian/invertebrate habitat is not rated H the aquatic habitat value is rated L to reflect the absence of fish habitat.

OVERALL RATING SYSTEM - Overall Habitat Functions: A wetland is automatically rated H for habitat if a threatened or endangered species is located within the wetland polygon or if the wetland has been identified as an exemplary or unique natural ecosystem or special wildlife habitat by the Natural Heritage Program. A wetland is also rated H for habitat if it provides excellent Terrestrial Habitat (H) or Aquatic Life Habitat (H). Wetlands are not penalized for providing habitat for only terrestrial or only aquatic wildlife. However, wetlands that provide only low levels of habitat for both terrestrial and aquatic wildlife are rated low (L).

Parameter Evaluation and Combination

IV. Potential Risk of Wetland Loss (prf01)

A. Landscape Character (prf011)

1. Wetland Extent and Rarity (prf0111)

a. Percent of hydrologic unit composed of wetlands (prf01111)

H	< 20%
M	20 - 50%
L	> 50%

b. Percent of wetlands in larger area unit composed of this type (prf01112)

H	< 10%
M	10 - 25%
L	> 25%

RATING SYSTEM FOR WETLAND EXTENT AND RARITY

H	Either (a) or (b) rated H
M	Other combinations
L	Both (a) and (b) rated L

2. Land use in hydrologic unit (prf0112)

a. Percent of land in agricultural use (prf01121)

H	> 40%
M	10 - 40%
L	< 10%

b. Percent of land in pine plantations (prf01122)

H	> 30%
M	10 - 30%
L	< 10%

c. Percent of land in urban/developed uses (prf01123)

H	> 1%
M	0.1-1%
L	< 0.1%

RATING SYSTEM FOR LAND USE

H	Any one parameter rated H with at least one other rated M or higher
M	Other combinations
L	Two or more parameters rated L with none rated H

RATING SYSTEM FOR LANDSCAPE CHARACTER

H	Either parameter rated H
M	Other combinations
L	Both parameters rated L

Brief Explanations

IV. Potential Risk of Wetland Loss: This factor evaluates the wetland's significance (in relation to the land use and water characteristics of the landscape in which it functions) to determine the relative risk to watershed integrity posed by the wetland's loss. Parameter evaluation and rating systems are the same for depressional as for riverine/headwater wetlands.

IVA. These parameters evaluate the wetland's significance in terms of its role in the landscape. The fewer wetlands there are and the more intensively used is the land in the watershed, the more significant is the wetland's function.

1a. The higher the proportion of a watershed's land area that is occupied by wetlands, the less vital to the watershed's integrity is one particular wetland. Values are based on conditions in the NC coastal area, where wetlands often comprise 50% or more of the land area. Values would be different for other landscapes with fewer wetlands.

1b. This is a rating of the rarity of this type of wetland in the larger landscape. In terms of its contribution to landscape diversity, the rarer the wetland type, the greater is its significance.

RATING SYSTEM - Wetland Extent and Rarity: If either the proportion of wetlands in the watershed is low or the wetland is a rare type, the rating is H. If wetlands are widespread in the landscape and this wetland type is common, the rating is L.

2. The more intensive land use is in the watershed, the greater the significance of the functions of remaining wetlands is. The predominant anthropogenic land uses in the coastal area are agriculture, intensive forestry, and urban/residential development.

2a. Agricultural land is a significant source of nonpoint source pollution. The more agricultural land there is in the landscape, the more significant the wetlands are in removing pollutants before they enter surface waters.

2b. Pine plantations are the most common form of intensive forest management. During the harvest and regeneration stages of the management cycle, they can be significant sources of nonpoint source pollution.

2c. Land development increases surface runoff, increases pollutant loadings, and destroys wildlife habitat. As development increases, all the functions of remaining wetlands become more significant. Since this is the most intensive land use with the most adverse impacts, only a small proportion of the landscape needs to be developed to give wetlands an H rating.

RATING SYSTEM - Land **Use:** If any one of the intensive land uses occupies a significant portion of the watershed and the other two are not both L, the land use parameter is rated H. If two or more of the land uses are of low intensity and none is high, the landscape is largely in natural vegetation, and the rating is L.

RATING SYSTEM - Landscape Character: If the extent of wetlands in the watershed is small or the wetland is of a rare type, the functions of remaining wetlands are highly significant. Similarly if the land use is intensive, the functions of remaining wetlands are highly significant. If, on the other hand, wetlands are common, this particular wetland is a common type, and most of the landscape is in natural vegetation, the loss of this wetland would probably not have a significant detrimental impact on landscape functions.

Parameter Evaluation and Combination

B. Watershed Water Quality Characteristics (prf012)

1. Classification of Major Water Body in the Watershed (prf0121)

H SA, ORW, HQW, WS-I, WS-II, NSW, URW
M B, WS-III, SB
L C, SC

2. Use Support of Water Bodies in Watershed (prf0122)

H > 25% of stream miles or water body area in watershed less than fully supporting
M 10-25% of stream miles or water body area in watershed less than fully supporting
L < 10% of stream miles or water body area in watershed less than fully supporting

3. Classification of Water Body Receiving Watershed Output (prf0123)

H SA, ORW, HQW, WS-I, WS-II, NSW, URW
M B. WS-III, SB
L C, SC

RATING SYSTEM FOR WATERSHED WATER QUALITY CHARACTERISTICS

H Any one parameter rated H
M Other combinations
L Any two parameters rated L, none rated H

C. Replacement Difficulty for Wetland Functions (prf013)

1. Wetland Type (prf0131)

H Pocosin, maritime forest
M Swamp forest, headwater swamp, hardwood or pine flat
L Freshwater marsh, pine plantation

2. Replacement Site Availability (prf0132)

H No replacement site identified in watershed
M Non-wetland restoration site available in watershed
L Degraded wetland site of same type identified in watershed

RATING SYSTEM FOR REPLACEMENT DIFFICULTY

H (2) rated H **or** (1) rated H and (2) rated M
M Other combinations
L Both parameters rated L **or** (1) rated L and (2) rated M

Brief Explanations

IVB. This series of parameters considers water quality within and downstream of the watershed containing the wetland. The water quality functions of a wetland become more significant as the assimilative capacity of receiving waters decreases.

1. This is an indication of how important water quality considerations are in the watershed. If water bodies have a high classification, maintaining their quality is an important consideration. If waters are subject to high nutrient concentrations or have been identified as impaired waters where uses can be restored, prevention of pollutant additions is significant.

2. Use support designations indicate water quality impairment in relation to use classifications. The more impaired waters exist in a watershed, the more significant are wetland functions in maintaining water quality.

3. This parameter considers the watershed in the context of what lies downstream. If the water body receiving the output from the watershed is classified such that prevention of additional pollutant loading is highly significant, then wetlands in the watershed are of greater significance in maintaining water quality.

RATING SYSTEM - Watershed Water Quality Characteristics: If the water in a watershed or in the downstream watershed has a high quality classification, is nutrient sensitive, or is targeted for use restoration, the water quality functions of wetlands in the watershed are highly significant. If water quality in the watershed is impaired as indicated by its failure to support intended uses, wetlands are significant in preventing further impairment.

IVC. If the functions of this wetland could be relatively easily replaced by restoration or creation of another wetland within the same watershed, its loss is less significant than if its functions cannot be replaced. This consideration assumes implementation of compensatory mitigation for any wetland permit granted.

1. Wetland types in the lowest group are relatively easy to restore. Those in the middle group are more difficult to restore hydrologically, and their vegetation takes a long time to mature. Wetlands in the highest group are very difficult to restore due to the peculiar nature of their hydrology and the unique site requirements of their vegetation.

2. If a degraded wetland of the same type exists in the watershed, it would be relatively simple to restore it to replace this wetland's functions. Restoring a site that has been completely converted but is otherwise suitable is more difficult, but still possible. If there is no suitable restoration site in the watershed, replacing this wetland's functions is essentially impossible. Potential restoration sites are located and classified by DCM's restoration site mapping which is done in conjunction with developing the wetland data.

RATING SYSTEM - Wetland Replacement Potential: If no restoration site is available in the watershed, the difficulty of replacing the wetland's functions in the local landscape is high. If the wetland is in the most difficult group to restore and no degraded site of the same type is available for enhancement, replacement difficulty is rated H. If the wetland type is relatively easy to restore and any restoration site is available in the watershed, replacement difficulty is rated L.

Parameter Evaluation and Combination

D. Wetland Enhancement Potential of Site (prf014)

This parameter is considered only if the wetland is rated of low value for the primary wetland functions.

- H Drained or partially drained wetland with natural vegetation intact
- M Drained or partially drained and converted to pine plantation or other intensively-managed forest type
- L Wetland intact, but of low functional significance

OVERALL RATING SYSTEM FOR POTENTIAL RISK OF WETLAND LOSS

- H At least two of (A), (B), & (C) rated H
- M (D) rated H **or** other combinations
- L Any two of (A), (B), & (C) rated L with no parameters rated H

Brief Explanations

IVD. If a wetland has low functional significance because it is degraded because of drainage or other disturbance, it may still have the potential to be restored or enhanced to higher levels of function to replace functions lost elsewhere. The closer the wetland is to its fully functioning state, i.e., the less it has been disturbed, the more practical is its enhancement or restoration and the higher is its significance as a potential restoration or enhancement site. This is a "bonus" parameter for wetlands that have been degraded by past human activity. If the wetland is simply of low significance in and of itself, it rates L on this parameter as well.

OVERALL RATING SYSTEM - Potential Risk of Wetland Loss: If any two of the risk parameters other than enhancement potential are rated H, the risk to watershed functional integrity of losing the wetland is rated H. This occurs if land use is intense and water quality is impaired, if land use is intense and the wetland's functions would be very difficult to replace, or if water quality is impaired and replacement difficulty is high. If any two of these same considerations are rated L and the third is not rated H, the risk factor is rated L. Restoration potential is treated as a "bonus" parameter, not of enough significance by itself to give a wetland an H risk rating but as a way of recognizing the importance of protecting potential restoration sites by preventing their receiving an L rating for all considerations simply because they have been degraded by human activity.

Overall Wetland Rating System

The previously described considerations rate the significance of the wetland in performing water quality, hydrologic, and habitat functions and the potential risk to landscape functional integrity of removing the wetland from its watershed. All ratings are assigned on a watershed basis for the 14-digit hydrologic unit. Of these four considerations, water quality, hydrology, and habitat functions are combined to determine one overall wetland functional significance rating. NC-CREWS places wetlands into one of three overall wetland ratings: Exceptional functional significance, Substantial functional significance, and Beneficial functional significance. The combination determinations are summarized below:

Exceptional	Meet one of the overriding considerations listed below
Exceptional	Two primary functions (water quality, hydrology, and habitat) are rated H
Substantial	Buffer to Exceptional rated wetland; other combinations
Beneficial	Two of the primary wetland functions rated L and none rated H

Wetlands receive an Exceptional functional significance rating if two o the primary wetland functions are rated High. Also, if the wetland meets any one of the overriding considerations, it is rated as being of Exceptional functional significance. Overriding considerations are:

1. Meets the North Carolina statutory definition of a "coastal wetland," or is an estuarine forested or estuarine scrub-shrub wetland
2. Is adjacent to a primary nursery area or
3. Is known habitat for threatened or endangered species, or is identified by the Natural Heritage Program as a unique natural ecosystem or special wildlife habitat

Wetlands receive a Substantial functional significance rating whenever only one of the wetland functions is highly functioning or when no more than one of the functions is rated low (i.e. two of the functions are performing at moderate or higher levels). Wetlands that perform functions at low levels, but also are located adjacent to wetlands of Exceptional functional significance receive a Substantial significance rating because of their buffering capabilities. Wetlands receive a Beneficial functional significance rating whenever any two primary functions are of low significance for the wetland and none are high. Sample NCCREWS maps are shown in Figure 9 and 10.

The overall wetland rating system gives more weight to the functional characteristics of the wetland than to the potential risk factor. In fact, the overall wetland rating system does not even consider “Potential Risk of Wetland Loss” in determining the overall functional significance of individual wetlands. Potential Risk is not used to influence a wetland’s overall functional rating because it is not an abiotic function of wetlands. Instead, Potential Risk is an estimation of the potential loss of function and risk to a watershed if individual wetlands ceased to continue to perform existing functions.

Nevertheless, since Potential Risk can be used to help determine a wetland’s ecological significance in the watershed, it is calculated and designed to be used in conjunction with the functional significance ratings. Wetland managers, local governments, developers, and others who use the results of NC-CREWS are encouraged to consider both the “Overall Functional Significance” and the Potential Risk ratings whenever making wetland decisions. When the Division of Coastal Management publishes maps showing the NC-CREWS functional assessment results, the Potential Risk estimations are commonly co-displayed with the overall wetland ratings as hatch patterns. By using the data in this way, wetland decision makers can readily identify wetlands that are functionally exceptional and those whose loss might pose a high risk to watershed integrity.

The overall wetland rating system works the same way for depressional wetlands as for riverine/headwater wetlands. Differences in the rating systems for each function reflect the differing functional roles of these different hydrogeomorphic classes of wetlands. Because of the more limited water quality and hydrologic functions of depressional wetlands, it may be less likely that their overall functional significance will be rated Exceptional, but it is no less likely to receive a Substantial functional significance rating.

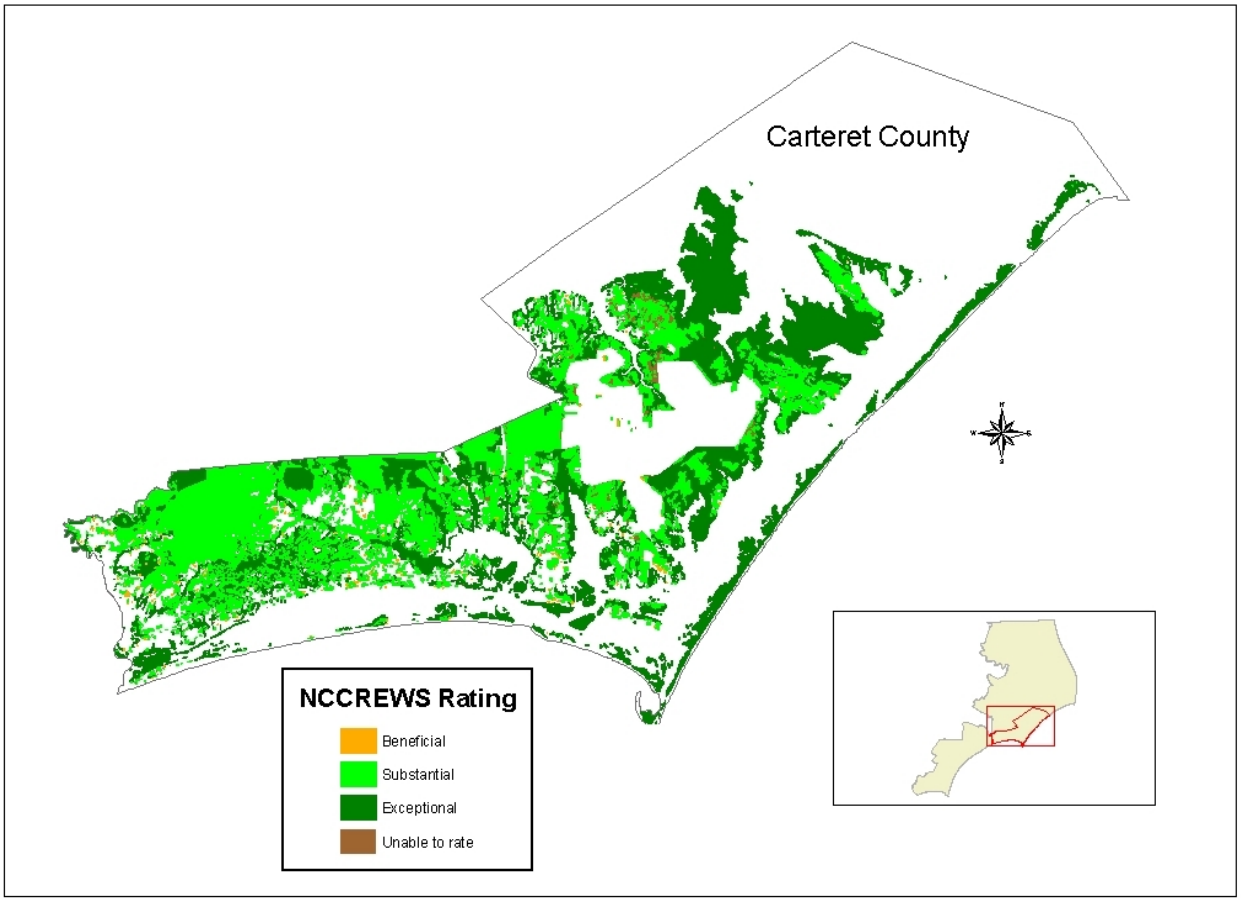


Figure 9: NCCREWS Map for Carteret Co., NC

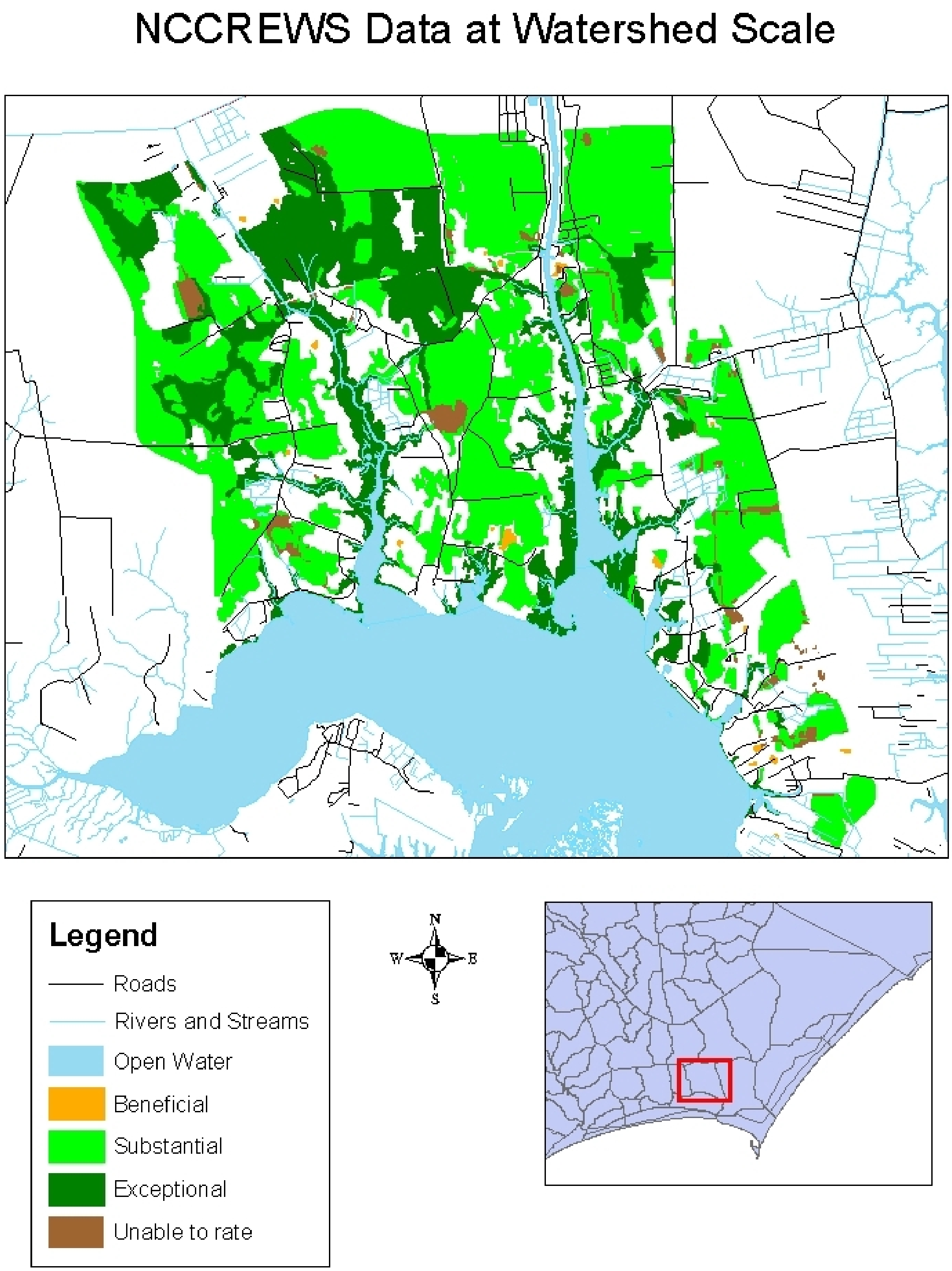


Figure 10. Watershed level NCCREWS Map, Carteret Co., NC

ECOLOGICAL BASIS AND ASSUMPTIONS

Section 4

Each of the parameter evaluation and combination steps in NC-CREWS is based on certain assumptions regarding wetland functions in relation to the surrounding landscape. To the greatest extent possible, these assumptions are based on fundamental principles of wetland and landscape ecology derived from studies reported in the scientific literature. This Section reviews the assumptions involved in each step of the procedure and documents the scientific basis for them.

Since current understanding of many aspects of wetland ecology and landscape function is rudimentary, some of the assumptions may prove to be inaccurate as further study increases knowledge about these processes. Some of the assumptions may also be invalid in other geographic areas with climatic, topographic, or biological differences from the North Carolina Coastal Plain. This explanation and documentation of the assumptions implicit in each step of the functional assessment procedure will help to identify which steps may need revision to fit different conditions or increased understanding of the underlying processes.

Basic Considerations

Landscape Context

Most traditional wetland functional assessment procedures are site-based. Evaluation decisions are derived from a static view of the site in its present condition with little or no consideration of the dimensions of time and space (Gosselink and Lee, 1986). The NC-CREWS procedure, in contrast, heavily weighs the spatial and temporal dynamics of wetland function. The majority of the parameters consider watershed and landscape rather than site characteristics (see page 7), and the separate evaluation of opportunity and capacity parameters accounts for temporal changes in surrounding land use (see page 13).

The underlying assumption of this approach is that wetland functions are not primarily the product of particular wetland sites but of the relationships between a particular site and its surroundings (Patience and Klemas, 1993). The occurrence and maintenance of wetlands and the processes that occur within them are a result of a combination of large-scale, long-term characteristics of watersheds, landscapes, and regional climatic regimes and of more local processes (Winter, 1988; Siegel, 1988; O'Brien, 1988). Local, site-specific characteristics of a wetland must be evaluated within the context of the landscape in which it exists to truly begin to understand the ecological significance of the wetland's functions. These functions are more accurately viewed as landscape functions rather than functions of individual wetlands (Leibowitz, et al., 1992).

Inadequate consideration of the landscape context in functional assessment can also lead to erroneous evaluations of wetland significance. For example, a wetland that has recently been cut over or burned may lack many of the site-specific characteristics of ecological integrity that would lead to a high evaluation under many site-based methods. Such a highly disturbed site may, indeed, be performing some functions at a lower level than if it were undisturbed. But even at below optimum levels, those functions may be of high significance in maintaining overall landscape integrity.

Functions and Values

In assessing wetland significance, a distinction is often made between the terms "function" and "value." Wetland functions are a result of physical, chemical, and biological processes that operate independently of any real or perceived benefit to human society (Adamus et al., 1991). Values may be considered as goods and services that result from wetland attributes or functions and that are considered to be of some social or economic benefit to society (Taylor et al., 1990).

The distinction between wetland functions and values is often fuzzy, since any assessment procedure evaluates wetlands from a human perspective. The fact that wetland fill is regulated by the §404 Program reflects a political decision that wetlands have value to society. Society has often made the decision that it is worth foregoing some potential land uses in order to maintain functions or characteristics that we find valuable. This concept is universal in that it has been applied to both wetlands and other types of lands. In relation to wetland protection, the purpose of functional assessment is to identify those wetlands that are of most value and that, therefore, should be most stringently protected. So even though we may be attempting to evaluate "functions," we are doing so because we have defined them as "valuable."

In reality, most of the recognized functions of wetlands have easily identified societal values (Brinson, 1993). That is particularly true when the functions being considered are landscape functions of wetlands as opposed to internal ecosystem functions. As discussed above, NC-CREWS focuses on the landscape functions of wetlands rather than the site-specific functions of individual wetland ecosystems. The ecosystem being evaluated is an entire watershed, of which each individual wetland is a component, and the functions being evaluated are the roles of the individual wetland in the watershed. The wetlands rated as most highly significant are those that play the most significant roles in maintaining the stability and integrity of watershed processes. With this approach, the distinction between functions and values is not particularly useful.

NC-CREWS, however, deliberately omits consideration of some wetland attributes that have been included in other functional assessment procedures. Attributes that are solely "values" in the sense of actual or potential human uses of a wetland, such as recreation, education, and timber harvesting, are not included. While these may be socially valuable uses of some wetlands, they bear no necessary relationship to the wetland's landscape functions or ecological significance. If certain wetland sites are considered to be sufficiently valuable for these uses, mechanisms other than regulatory protection can be used to protect them for that purpose.

Primary Wetland Functions

The ecological functions of wetlands are commonly grouped into three general categories (Leibowitz, et al., 1992).

Water Quality Functions
Water quality improvement, nutrient cycling and supply

Hydrologic Functions
Flood attenuation and moderation of hydrologic flow

Habitat Functions
Support for wildlife and fish, including food, shelter, and breeding sites

This grouping into functional categories has become a standard and well-accepted means of summarizing wetland functions and is used as the basis for the hierarchical structure of NC-CREWS. Assumptions upon which evaluation of the significance of a wetland in performing each of these functional categories is based are discussed below.

Water Quality Functions

It is well documented that the presence or absence of wetlands in a watershed can have significant effects on water quality (Jones et al., 1976; Whigham et al., 1988; Detenbeck et al., 1988; Johnston et al., 1990). Water quality functions of wetlands are the result of a variety of biogeochemical processes acting collectively to alter and improve the quality of surface waters (Hemond and Benoit, 1988). Wetlands function within a landscape as sinks or transformers of suspended inorganic sediments, inorganic phosphorus, nitrate, sulfate, and toxins (Leibowitz et al., 1992; Adamus et al., 1991; Johnston, 1991;). By buffering surface and ground waters from these potentially damaging substances, wetlands can play a highly significant role in maintaining water quality (Brinson, 1988).

Water bearing potentially polluting substances can enter wetlands as overland runoff or by overbank flow. Water entering wetlands by overland runoff has not yet entered surface waters, while overbank flow comes from streams. These two distinctly different water sources and the water quality functions of wetlands in relation to them are treated separately in NC-CREWS.

Nonpoint Source Function

This water quality subfunction of wetlands consists of the removal of particulates, nutrients, and toxins from surface runoff water before the water enters streams, lakes, or estuaries. Many studies have documented this function of wetlands, including several performed specifically in the North Carolina coastal plain (Cooper et al., 1986; Gilliam et al., 1986). Four parameters are used in NC-CREWS to evaluate wetland significance in performing this function: (1) proximity of the wetland to pollutant sources; (2) proximity of the wetland to surface water bodies; (3) watershed position of the wetland; and (4) on-site conditions.

Proximity to Sources

H	> 20% perimeter agriculture + developed
M	> 20% perimeter agriculture + developed + pine plantation
L	≤ 20% perimeter agriculture + developed + pine plantation

This parameter considers the likelihood that polluted runoff water will enter a wetland based on predominant adjacent land uses. Agricultural and developed land are assumed to be the greatest potential contributors of pollutants. Areas that are not agriculture, developed, or pine plantation are in natural vegetation, open water, and other classes. Of these, natural vegetation is assumed to contribute the least. Managed pine plantations are considered as greater contributors than natural vegetation but less than agricultural or developed lands.

Agriculture is a ground-disturbing activity that has a large potential as a sediment source. Use of fertilizers and pesticides and field applications of animal wastes increase the likelihood that runoff from agricultural fields will contain potentially harmful concentrations of nutrients, toxins, and bacteria that may pollute surface and groundwater (Stewart et al., 1976; Leonard, 1980; Daniel et al., 1982; Canter, 1987). Agriculture is generally accepted as the major source of nonpoint source pollutants in the North Carolina coastal area (Natural Resources Conservation Service, 1994).

Land development and urbanization involve site clearing, grading, and increases in impervious surfaces and maintained landscapes (Schueler, 1987). These landscape changes, together with increasing population density, result in increased runoff and pollutant loadings. Major pollutants found in runoff from developed areas include sediment, nutrients, oxygen-demanding substances, road salts, heavy metals, petroleum hydrocarbons, bacteria, and viruses (US EPA, 1993). While dense urban development occupies only a small proportion of the North Carolina coastal area, population increases and tourism are resulting in increases in developed land with a corresponding increase in the significance of urban runoff as a pollutant source.

Intensive silviculture, particularly road construction, timber harvesting, and site preparation, can result in increased runoff with heavy sediment and nutrient loads (Pardo, 1980; Coats and Miller, 1981). Fertilization of forest stands during the rotation can also result in temporary increases in nitrogen and phosphorus in surface runoff (Campbell, 1989). The impacts of forestry on surface runoff, however, are transient, and even intensively managed pine plantations have little impact on water quality during much of the rotation (Shepard, 1994). While pine plantations currently occupy a large proportion of the North Carolina coastal landscape, they are a relatively minor source of pollutants compared with agricultural and developed lands.

Naturally vegetated lands in the North Carolina coastal plain are typically covered by woody plants, either forest or shrub-scrub. While essentially none of the area is truly undisturbed, naturally vegetated areas are minor sources of pollutants and are considered the baseline condition against which other land covers are compared.

Proximity to Surface Water Bodies

H	Within 300 ft. of permanent surface water
M	Within 300 ft. of intermittent stream
L	> 300 ft. from permanent or intermittent surface water

Proximity to surface water is an indicator of the likelihood that polluted runoff entering a wetland would otherwise enter surface water. While wetlands anywhere in the landscape can remove pollutants from runoff water entering them, the significance of this function in maintaining water quality is greatest where the water would otherwise flow directly into a surface water body. In evaluation of this parameter, wetlands are considered to be of most significance if they are within 300 feet of permanent surface water and of lower significance if they are within 300 feet of an intermittent stream. Wetlands greater than 300 feet from any surface water are considered of lowest significance.

The assumption that wetlands closer to surface water are more significant in performing the nonpoint source removal function is based primarily on best professional judgment rather than scientific studies. The role of riparian areas in removing pollutants from runoff is, however, well documented (Cooper et al., 1986, 1987; DEHNR, 1991). Riparian wetlands serve as natural buffers between uplands and adjacent water bodies, and loss of these systems allows for a more direct contribution of nonpoint source pollutants to receiving waters (US EPA, 1993).

The 300 foot distance, unfortunately, is arbitrary. There have been many studies on the effects of buffer width, but no conclusive results (DEHNR, 1991). It should be noted that, in order to receive an H rating for this parameter, a wetland need only be within 300 feet of surface water, not necessarily a full 300 feet in width. This is a measure of proximity to water, not of wetland width, making the buffer width literature largely irrelevant. In coastal North Carolina, a wetland within 300 feet of surface water is likely to be immediately adjacent to the water, i.e., to be a riverine, lacustrine, or fringe wetland (Brinson, 1988). The objective of this parameter is to differentiate the role of these wetlands from that of depressional or flat wetlands that are likely to be a greater distance from surface water.

<u>Watershed Position</u>

H	Intermittent or first order stream
M	Second or third order stream
L	Higher than third order stream

Evaluation of this parameter is based on the assumption that headwater wetlands are more significant in removing nonpoint source pollutants than are wetlands further downstream in a watershed. Order of the stream nearest the wetland is used as an indicator of watershed position.

This assumption is quite well documented in the literature. As water runs off uplands, it first encounters wetlands in riparian areas associated with small streams (Whigham et al., 1988). In coastal North Carolina, these headwater riparian areas are commonly bordered by agricultural fields, and wetlands immediately below the source of nonpoint pollution are the most effective filters (Cooper et al., 1986; Lowrance et al., 1983; Phillips, 1989b). Because of the much greater length of small tributary (lower order) streams than higher order main-stem streams in a watershed (Leopold et al., 1964), a higher proportion of runoff water flows through upstream riparian wetlands than through wetlands further downstream (Brinson, 1988).

<u>Site Conditions</u>

The internal characteristics of an individual wetland site are also important determinants of its ability to remove and retain nonpoint source pollutants. Biological and physical properties of vegetation and soils affect water flow-through rates and detention time, as well as a wetland's capacity for nutrient transformation and long-term storage of nutrients and toxins (Adamus et al., 1991). These factors are evaluated based on wetland type and predominant underlying soil.

a. Wetland Type

H	Bottomland hardwood, swamp forest, headwater swamp
M	Freshwater marsh, pine flat, hardwood flat, pocosin, maritime forest,
L	Managed pine plantation, human impacted sites

The approach taken in this parameter is to rate wetlands by the classification used in DCM's wetland mapping. It is based on the assumption that all wetlands of a given type are similar enough in structure and general characteristics that they will have the same capacity for removing nonpoint source pollutants.

The grouping of wetland types by high, moderate or low capacity is based on statistical analysis of field data, as explained in Appendix B. Data were collected on the presence or absence of various indicators of capacity for runoff water retention, nutrient transformation and processing, detrital storage, etc. In general, wetland types with typically high vegetation density, organic matter accumulation, and long-term water storage capacity rate highest. Wetland types with generally high levels of disturbance and relatively little vegetational structure rate lowest.

b. Soil

H	Histosol or frequently flooded mineral soil with high clay and organic matter
M	Infrequently flooded mineral soil with high clay and organic matter
L	Infrequently flooded mineral soil with low clay and organic matter

In addition to wetland type, characteristics of the predominant soil series underlying the wetland are used to evaluate site suitability for nonpoint source pollutant removal. While vegetation and site structure as indicated by wetland type bear on the removal of both sediments and non-particulates, soil characteristics have little bearing on a wetland's capacity for sediment removal. Soil characteristics can be very important, however, in determining a site's effectiveness in holding and transforming nutrients and toxins (Adamus et al., 1991).

The primary assumptions in evaluating soil characteristics for this function are that soils with high cation exchange capacity and are subject to frequent anaerobic conditions are the most effective in holding and transforming chemical compounds. Cation exchange capacity is a measure of a soil's ability to adsorb nutrients and is normally highest in soils with high organic matter or clay content. Alternating aerobic and anaerobic conditions lead to most rapid rates of denitrification, the microbial conversion of nitrate to gaseous nitrogen.

Fine textured mineral soils, which normally have high concentrations of aluminum and iron, have high capacities to retain phosphorus (Richardson, 1985). Fine textured soils also have high pore volume and surface area and, therefore, more contact between water and soil and higher cation exchange capacities than coarser textured soils.

High soil organic matter absorbs metals more effectively than do clays. Mercury, copper, lead, and cadmium have all been shown to be retained by wetland organic sediments (Hart, 1982). Organochloride pesticides are also readily degraded in anaerobic, sulfide-rich, fine sediment organic soils typical of many wetlands (Adamus, 1991).

Organic matter also is required for denitrification but is probably not limiting in most hydric soils (Brinson et al., 1984). Since denitrification, which occurs under anaerobic conditions, is coupled with nitrification, which occurs under aerobic conditions, the highest rates of denitrification occur with fluctuations between aerobic and anaerobic conditions (Reddy and Patrick, 1976).

Given this combination of soil-related processes which influence nutrient and toxin retention and transformation, soils most effective in performing these functions will be those with high clay and/or organic matter contents and which undergo frequent flooding. The specific soil series that exhibit these characteristics are selected from the county soil survey for the area being evaluated. For the Carteret County, NC, area in which the functional assessment procedure was developed and first applied, the soils falling in the H, M, and L groups are shown in Table 2.

Class	Soil Series
H Histosols or frequently flooded mineral soils with high clay & organic matter content	Belhaven, Carteret, Croatan, Dare, Deloss (Dm), Dorovan, Duckston, Hobucken, Lafitte, Masontown, Masontown-Muckalee, Ponzer
M Infrequently flooded mineral soils with high clay & organic matter	Arapahoe, Bayboro, Deloss (De), Grantham, Murville, Pantego, Rains, Tomotley, Torhunta, Wasda
L Infrequently flooded mineral soils with low clay & organic matter	Leaf, Leon, Meggett, Roanoke

Table 2. Carteret County Soil series falling into H, M, and L classes for water quality functions.

Floodwater Cleansing Function

This water quality subfunction consists of the removal of sediments, nutrients, and toxins from water that enters a wetland by overbank flow from a flooding stream. Of the three hydrogeomorphic classes used in NC-CREWS, only riverine wetlands perform this function, since neither headwater nor depressional wetlands are normally in landscape positions to receive overbank flow (Brinson, 1988; 1993). While riverine wetlands can also remove nonpoint source pollutants from upland runoff, overbank flow so dominates in floodplain wetlands along larger streams that floodwater cleansing is a key water quality function (Brinson, 1988).

The dominant hydrologic feature of riverine wetlands is periodic flooding. During high water periods in which water from streams enters riverine floodplains, substances in the water, including sediments, nutrients, and toxins, are deposited in riparian wetlands, removing them from surface waters (Mitsch et al., 1979; Kuenzler et al., 1980; Yarbro et al., 1984; Kuenzler and Craig, 1986; Whigham et al., 1988). Several factors determine the extent to which this pollutant removal occurs. The specific parameters considered in NC-CREWS include: (1) the source of in-stream water and the proximity of the wetland to sources; (2) the duration of flooding; (3) the width of wetland subject to flooding; and (4) site conditions within the wetland.

<u>Water Source and Proximity to Sources</u>

For streams entering the HU from outside:
H In floodplain of Piedmont-draining stream **<u>or</u>** upstream HU > 50% agricultural plus developed land
M In floodplain of coastal plain draining stream with upstream HU < 50% agriculture plus developed
L Not in floodplain

For streams originating in the HU:
H > 25% of stream length in HU bordered by agricultural or developed land
M 5-25% of stream length bordered by agricultural or developed land
L < 5% of stream length bordered by agricultural or developed land

This parameter evaluates the opportunity for a wetland to perform flood water cleansing based on the likelihood that in-stream water contains significant amounts of pollutants. One or the other of the above evaluations is used, depending upon whether the stream adjacent to the wetland arises within the hydrologic unit being evaluated or enters it from outside the HU boundary.

In either case, it is assumed that the more intensive land use activities that occur upstream of the wetland, the higher the likelihood of increased pollutant concentration in stream water. It is well documented that densely vegetated watersheds export less sediment, suspended toxins, and nutrients than disturbed watersheds (Bormann et al., 1974; Ostry, 1982; Duda, 1982; Chang et al., 1983; Cooper et al., 1986; Adamus et al., 1991). Fertilization of agricultural land, livestock raising, and land development increase nutrient and sediment loadings (Jones et al., 1976; Kuenzler and Craig, 1986). Table 3 illustrates typical differences in nutrient exports from different land covers (reproduced from Adamus, 1991; based on studies reviewed by Farnworth et al., 1979).

Land Cover	**Mean Export** (kg/ha/year)	
	Total N	**Total P**
Forest	3.10	0.10
Forest & Pasture	4.70	0.28
Agricultural	10.60	0.18
Urban	6.70	4.80

Table 3. Mean nutrient exports from different land covers.

It is further assumed that, for streams entering from outside the HU boundaries, streams that originate in the more heavily urbanized Piedmont region will carry substantial pollution loads. The validity of this assumption, however, depends on upstream pollutant loadings being carried downstream into the coastal area, which is questioned by Phillips (1989a, 1991). The percentages of stream length bordered by various land uses that are used to determine H, M or L values are based on best professional judgment for conditions typical of the North Carolina coastal plain and are subject to change for other areas or if better information becomes available.

Duration of Flooding

H Wetland is flooded 'long to very long' periods
M Wetland is flooded 'brief' periods
L Wetland is flooded 'very brief' periods or not at all
If the stream is channelized, the rating for adjacent wetlands is reduced by one level.

The assumption is made that wetlands that are subject to seasonal flooding of long duration are more likely to retain sediments, nutrients, and toxins. The longer the period of flooding, the greater the settling time for suspended sediments and the more sediment deposition is likely to occur (Adamus et al., 1991; Jordan et al., 1986). Since phosphorus and toxins are normally associated with suspended particulates rather than being in solution (Froelich, 1988), retention time can be significant in removal of these substances. Since denitrification occurs under anaerobic conditions, longer periods of flooding can also result in greater total nitrogen conversion by the wetland (Reddy and Patrick, 1976).

This parameter is qualified by the presence or absence of channelization of the stream, a common situation in the North Carolina coastal plain. Channelization has been performed to accelerate water movement downstream to alleviate flooding problems in areas bordering the stream. By so doing, channelization decreases the flow of flood water into riverine wetlands and shortens the duration of flooding, decreasing the wetlands' effectiveness in removing sediments and nutrients from the water (Adamus, 1991). Watersheds with channelized streams and drainage ditches are significantly less effective for removing nutrients than those with natural drainage and undisturbed wetlands (Bedient et al., 1976; Chescheir et al., 1987).

Site Conditions

a. Wetland Type
H Bottomland hardwood, swamp forest
L Other wetland types

As with all wetland type evaluations in NC-CREWS, the grouping of wetland types used in this parameter is based on review of field data, as explained in Appendix B. Wetland type characteristics relevant to flood water cleansing include indicators of capacity for sediment capture, nutrient transformation, removal of dissolved materials, and retention of woody materials.

In the field sampling, just two of the wetland types, bottomland hardwood and swamp forest, occupied 95 percent of the riverine sites capable of performing the flood water cleansing function. Both of these types have similar characteristics in regard to their capacity for sediment, nutrient, and toxin removal, and both are included in the H category. No basis exists for further division of other wetland types between M and L categories. For those rare instances in which a wetland type other than bottomland hardwood or swamp forest occupies a site subject to overbank flooding from a stream, the wetland type rating for the site is L.

b. Soil
H Histosol or frequently flooded mineral soil with high clay and organic matter
M Infrequently flooded mineral soil with high clay and organic matter
L Infrequently flooded mineral soil with low clay and organic matter

The same soil characteristics that favor nonpoint source pollutant removal also favor flood water pollutant removal, i.e., high cation exchange capacity and frequent anoxia. Consequently, the soil characteristics breakdown and soil series included in each category are the same as those given on page 41.

Width of Wetland Perpendicular to Stream

H > 100 feet
M 50-100 feet
L < 50 feet

Evaluation of this parameter assumes that wider wetlands that allow flood water to spread out over a larger area are more effective at removing pollutants from the water. The wider the area into which flood waters flow, the greater is the reduction in flow velocity and the shallower is the water depth, both of which increase pollutant removal. The width values used are meant more to distinguish between narrow strips of riparian wetlands and more extensive wetland areas rather than to have absolute significance in themselves.

Riverine wetlands exert their influence on in-stream water quality primarily through slowing the flow rate of flood water. Wider wetlands reduce flow rates more than narrow ones by decreasing channel restriction and by offering greater frictional resistance to flow. Most resistance to flow is provided by vegetation, and the wider the wetland the more vegetation is exposed to flowing water. Water depth will also be less in wider wetlands, and the shallower the water, the greater the frictional resistance provided by the vegetation (Adamus, 1991).

Flow velocity is the single most important factor affecting sediment trapping efficiency (Dendy, 1974; Karr and Schlosser, 1977). The slower the flow velocity, the more likely nutrients will be retained by sedimentation (Knight et al., 1984.). Longer residence times resulting from lower flow rates also favor nutrient removing processes such as plant uptake and denitrification (Mulholland, 1981). Yarbro et al. (1984) determined in the North Carolina coastal plain that the wider the area of floodplain inundated, the greater the proportion of incoming phosphorus was retained.

Hydrology Functions

The hydrologic functions of wetlands are the result of water storage, in which peak flows from runoff, surface flow, ground water discharge, and precipitation enter a wetland and are delayed in their down slope movement (Adamus, 1991). This temporary storage of water in wetlands results in desynchronization of downstream flow which, under most circumstances, decreases downstream flood peaks (Thomas and Benson, 1970; Novitski, 1979; Verry and Boelter, 1979; Kittelson, 1988). Comparisons of watersheds before and after wetland drainage (Brun et al., 1981) and of watersheds with drained versus undrained wetland acreage (Moore and Larson, 1979) show the importance of wetlands in desynchronizing peak flows.

A significant aspect of the flow desynchronization resulting from wetland water storage in coastal areas is the prevention of freshwater dilution of brackish water in estuaries (Street and McClees, 1981). If large areas of wetlands are drained or converted to other land uses, rapid influxes of freshwater can substantially dilute the salinity of estuarine areas (Daniel, 1981), resulting in rapid fluctuations in salinity in nursery areas important for shellfish and finfish productivity. Salinity fluctuations have been shown to decrease productivity of shrimp (Pate and Jones, 1981) and potentially of other important shellfish and finfish populations (Street and McClees, 1981).

Water will flow into depressions anywhere they occur in the landscape. Wetlands not already filled to capacity with surface water are generally effective for water storage. In addition to water entering directly in precipitation, water may flow into wetlands as overland runoff or overbank flow. Since wetland and landscape characteristics determining the significance of storage of water entering from these two sources are different, they are evaluated independently.

Surface Runoff Storage

This hydrologic subfunction includes storage of water that enters a wetland as precipitation or as runoff from adjacent areas. The surface runoff storage subfunction evaluates the wetlands capacity to slow or stop the rate at which water enters a stream network. Since much of the water entering wetlands from these sources never enters a stream at all, but infiltrates to the ground water or is returned to the atmosphere through evapotranspiration, this subfunction can have great impact on downstream flow rates (Adamus, 1991).

The significance of wetlands for surface runoff storage is evaluated by considering three parameters: (1) position of the wetland in the watershed; (2) size of the wetland; and (3) site conditions within the wetland as indicated by wetland type and soil properties.

Watershed Position

H Intermittent or first order stream
M Second or third order stream
L > third order stream

The order of the stream nearest the wetland is used as an indicator of the effective position of the wetland in the hydrologic unit. Strahler stream order is used, which numbers the smallest streams as first order. The assumption used in ranking is that wetlands further upstream in a watershed have greater significance in storing surface runoff than do downstream wetlands.

The first phenomenon on which this assumption is based is the fact that precipitation and surface flow are the predominant water sources for upstream wetlands, while hydrology of downstream wetlands is dominated by overbank flow (Brinson, 1988). The percentage of total overland runoff that enters wetlands decreases as stream order increases (Whigham et al., 1988). This fact, together with the greater length of low order than high order streams in a watershed (Leopold et al., 1964) gives wetlands along low order streams a greater significance in storing runoff water.

The second phenomenon involved in the importance of upstream wetlands in surface runoff storage is their role in desynchronizing flood flows. Water storage in wetlands located in headwaters desynchronizes peak flows in tributaries, resulting in lower peak flows downstream (Carter et al., 1979). A study by Novitski (1979) found that 50 percent of the reduction in flood peaks results from the first five percent of wetland area in a watershed, and Flores et al. (1981) determined by simulation that detention basins are most effective if located in the upper portion of a watershed. Wetlands located in the uppermost portions of a watershed, where the total acreage of wetlands and surface waters upstream of them is less than 7 percent of total wetland and surface water acreage of the watershed, are the most effective (Ogawa and Male, 1983).

Wetland Size

H Wetland is > 0.54% of total HU area
M Wetland is 0.05-0.54% of HU area
L Wetland is < 0.05% of HU area

One of the primary determinants of a wetland's significance in influencing the hydrology of a watershed is the wetland's size. In simplest terms, the larger a wetland is, the more water it can store. Many studies have confirmed this assumption for the total area of wetlands in a watershed (Novitski, 1979; Ogawa and Male, 1983; Verry and Boelter, 1979; Edgerton, 1973). Kittelson (1988) extended the analysis to single wetland sites with the same conclusion.

Starting with the assumptions, then, that any wetland will store some water, and the larger a wetland is the more water it can store, the question remains as to how large an individual wetland must be to have an appreciable effect on watershed hydrology. The studies cited above all examined wetland size as a percentage of total watershed area, and it is obvious that this is the soundest approach. It was impossible, however, to find applicable values in the literature on which to base a wetland size - hydrologic significance relationship for eastern North Carolina.

To determine these values for NC-CREWS, simulation modeling was used to determine the effect of wetland size on watershed peak discharge. Several models were explored for applicability and tried on trial data sets, including AGNPS (Young et al., 1989), TR-55, ANSWERS (Beasley and Huggins, 1981), SWRRB (Arnold et al., 1990), and HEC-1 (US Army Corps of Engineers, 1990). HEC-1 proved most useful for this purpose and was used to arrive at the wetland size figures used in this parameter.

Simulation results were used to develop a relationship between the percentage of watershed area converted from wetlands to agriculture and the percentage increase in watershed peak discharge. This relationship is shown in Figure 11. Cutoff points were selected at 0.1, 1.0, and 5.0 percent change in peak runoff. These correspond to wetland areas of 0.05, 0.54, and 2.7 percent of watershed area. An effect on watershed peak discharge of 0.1 percent or less is considered insignificant, while an effect of 1.0 percent or more is considered highly significant. If a wetland occupies such a proportion of its watershed that its loss would result in a 5 percent or greater increase in peak discharge, the wetland is rated at least M for this subfunction, regardless of its rating for each parameter.

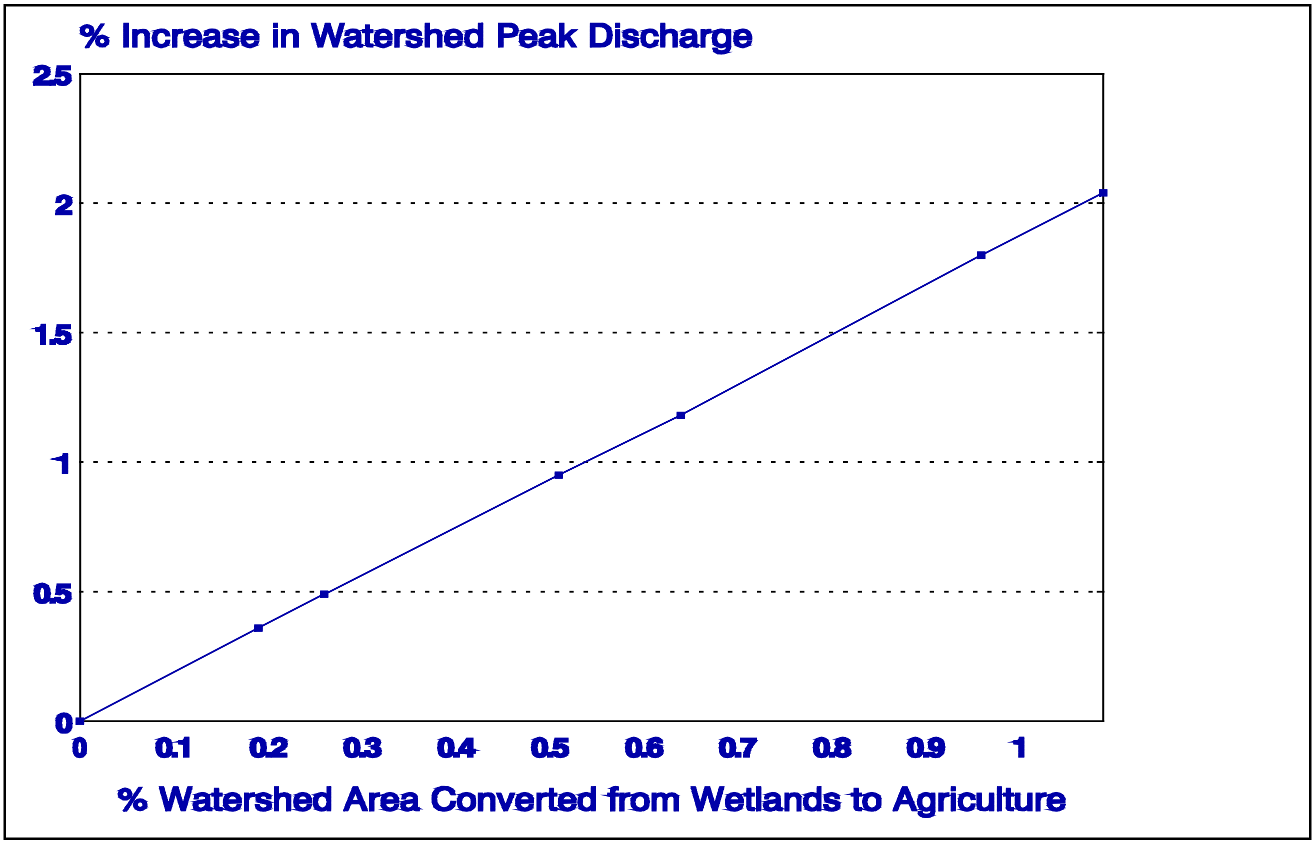


Figure 11. Relationship between wetland area and change in watershed peak discharge as determined with HEC-1.

<u>Site Conditions</u>

a. Wetland Type

H Bottomland hardwood, swamp forest, headwater swamp, freshwater marsh
M Hardwood flat, pocosin, maritime forest,
L Pine flat, pine plantation, altered site

Complexity of vegetative structure, surface roughness, and internal ponding increase a wetland's capacity to store water (Adamus, 1991). The bottomland hardwood, swamp forest, and headwater swamp types in the H category have maximum values for these characteristics. Freshwater marsh is included in the H group because marshes typically act as ponds to hold and retain water. Wetland types in the M and L categories have a lower degree of surface roughness and internal ponding. Although pine communities, both natural and managed, have high rates of evapotranspiration, they have low internal roughness and vegetative structure.

b. Soil infiltration capacity

H Soil hydrologic group A, B, or A/D
M Soil hydrologic group C or B/D
L Soil hydrologic group D

Wetlands continue to store runoff water until they become filled to capacity with surface water. Since wetlands normally occur in depressions, surface ponding stores water until the depression fills (Carter et al., 1979; Adamus, 1991). Surface runoff normally enters a wetland relatively slowly compared with floodwater from a stream, allowing time for infiltration into the soil. The faster the soil infiltration rate, the more runoff water can be stored before a wetland fills with surface water and begins to overflow.

Soil series are categorized into hydrologic groups according to the soil's capacity for water intake when the soil is wet and receives additional water from long-duration storms. The hydrologic groups are defined as follows (Goodwin, 1987).

Group A
Soils having a high infiltration rate when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands.

Group B
Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture.

Group C
Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture.

Group D
Soils having a very slow infiltration rate when thoroughly wet. These consist chiefly of clays that have high shrink-swell potential, soils that have a permanent high water table, soils that have a clay pan or clay later at or near the surface, and some organic soils.

Group A/D
A dual hydrologic group is given for certain wet, sandy soils that have a thin infiltration rate if drained. The first letter applies to the drained condition, and the second letter applies to the undrained condition.

Group B/D
A dual hydrologic group is given for certain wet soils that can be adequately drained. The first letter applies to the drained condition, and the second letter applies to the undrained condition.

Soils in the Carteret County area falling into each hydrologic group are shown in Table 4.

Class	Soil Series
H Hydrologic Groups A, B, and A/D	Beaches-Newhan, Murville, Duckston
M Hydrologic Groups C and B/D	Arapahoe, Deloss, Leon, Pantego, Rains, Tomotley, Torhunta, Wasda
L Hydrologic Group D	Belhaven, Carteret, Croatan, Dare, Deloss, Dorovan, Hobucken, Lafitte, Masontown, Ponzer, Roanoke

Table 4. Carteret County Soil series falling into each hydrologic group.

Floodwater Storage

Riverine wetlands, particularly those on higher order streams, receive most of their water from overbank flow when stream flow exceeds channel capacity (Brinson, 1988). The process of overbank flow into these wetlands spreads flood water over larger areas and slows its flow, resulting in less severe flooding downstream. Since floodwater storage, by definition, occurs only in riverine wetlands that receive overbank flow, headwater and depressional wetlands are assigned an automatic "L" rating for this subfunction. The significance of individual riverine wetlands in performing floodwater storage is evaluated by examining four parameters: (1) long-term average duration of flooding; (2) total wetland size; (3) position of the wetland in the watershed; and (4) width of the wetland subject to flooding.

Duration of Flooding

H Wetland is flooded 'long to very long' periods
M Wetland is flooded 'brief' periods

L Wetland is flooded 'very brief' periods or not at all

Evaluation of this parameter is based on the assumption that the longer the period of time floodwater is retained in a wetland, the more significant a wetland is in desynchronizing and lessening the severity of downstream flood peaks. Long water residence times are more likely to occur in watersheds with gradual topography, such as those of the North Carolina Coastal Plain, than in steeper watersheds (Adamus, 1991), but, in either case, is a valid measure of flood storage effectiveness.

Values used to determine parameter ratings are the duration of flooding ratings for the predominant underlying soil series taken from the appropriate soil survey. Duration of flooding is an indicator of the length of time the soil surface is covered by flowing water from overflowing streams. It is determined by examination of the soil profile and consideration of local information about the extent and levels of flooding. This measure does not include shallow standing water after intense rainfall or semi-permanent ponding, but is based on actual flood events (Goodwin, 1987).

Using this soil series measure as the basis of parameter evaluation has some shortcomings. Characteristics of the soil profile are the result of a soil's history, and may not reflect current flooding conditions, especially if land cover or hydrologic conditions in the watershed have substantially changed from their historic condition. It is also impossible to clearly distinguish between water remaining for long periods after a single flood event and frequent, short-lived flooding from repeated flood events. In either case, however, floodwater storage could be significant. In the absence of specific, site-level measurements of flood duration, this soil characteristic is the most appropriate measure for evaluating this parameter.

Wetland Size

H Wetland is > 0.54% of total HU area
M Wetland is 0.05-0.54% of HU area
L Wetland is < 0.05% of HU area

The ability of a wetland to alter flood flows depends on its storage capacity and hydraulic length (Adamus, 1991), which are functions of wetland area, depth, and surface roughness. This size parameter, combined with width perpendicular to the stream, is used as indicators of those direct characteristics that determine wetland significance in flood attenuation. This parameter also recognizes the flood storage potential of even narrow strips of riparian wetlands if they extend for long distances along a stream. The size breakdowns are the same as those used in the size parameter for runoff storage and are based on the results of simulation modeling as explained above (p. 44-45).

Watershed Position

H Greater than third order stream
M Second or third order stream
L Intermittent or first order stream

As with the other watershed position parameters, Strahler stream order is used as an indicator. In this case, however, higher significance is assigned to wetlands further downstream in a watershed. In the North Carolina coastal area, these are the bottomland hardwoods and extensive swamp forests that occupy the broad floodplains of major coastal rivers. These downstream floodplains are of great significance in floodwater storage for several reasons. They occupy large areas and, at least under natural conditions, are usually quite broad, allowing them to store large amounts of water. Since these wetlands occur along major rivers, their significance in floodwater storage is greatest during major flood events. The simulation studies of Ogawe and Male (1983) indicated that wetlands low in a watershed reduced flooding over a greater downstream area than did upstream wetlands and that these downstream wetlands were important regardless of the total amount of other storage available in the watershed.

Width of Wetland Subject to Flooding

H > 100 feet
M 50 to 100 feet
L < 50 feet

This parameter and the preceding one are related measures of a wetland's size. The critical factor is the size of the floodplain, since that is the area in which floodwater is actually stored. In the absence of digital floodplain maps, however, these two parameters are used as indirect measures of available water storage area.

Width is important not only as a measure of area, but also as an indicator of frictional resistance to flow, which slows flood velocity and increases storage time. Frictional resistance is provided by wetland vegetation, ground structure such as logs and hummocks, and by the soil surface itself. The frictional drag provided by vegetation is proportional to stem density (Marble, 1992), with at least 70 percent vegetation coverage required for most effective flow resistance (Adamus et al., 1987). Woody debris underlying floodplain forests also increases surface roughness and decreases flood flow (Burkham, 1976; Taylor and Barclay, 1985). In all cases, the wider the wetland is, the more these factors come into play.

Shoreline Stabilization Function

This well-accepted function of wetlands could be considered either a water quality or a hydrologic function, since it includes both sediment stabilization and dissipation of erosive forces (Adamus, 1991). In NC-CREWS it is included as a hydrologic subfunction, since it is closely related to watershed hydrology, which determines the erosive forces present.

Wetland plants bind soil with their root systems and, thus, help to hold the soil in place in the face of erosive forces from waves and currents (Allen, 1979; Benner et al., 1982;). Wetlands also reduce wave and current energies through frictional resistance and by allowing space for energy dissipation before water hits upland soils (Wayne, 1976). This effect can reduce erosion elsewhere in the watershed. Although the shoreline stabilization function is perhaps of greatest significance in marshes along estuarine or large lake shorelines, wetlands can also be important in stabilizing stream banks.

Three parameters are used to evaluate wetland significance in shoreline stabilization: (1) proximity to surface water bodies; (2) the length of wetland border exposed to open water; and (3) land use in the watershed.

<u>Proximity to Surface Water</u>

H < 50 feet from shoreline of a second or higher order stream or of an estuary or lake shoreline
M < 50 feet from first order stream or between 50 and 300 feet from an estuary shoreline
L ≥ 50 feet from any stream or lake or > 300 feet from an estuary shoreline

This parameter indicates whether a wetland is in an appropriate landscape position to perform shoreline stabilization. Obviously, if it is not located on a shoreline, a wetland cannot perform this function. If the wetland is on a shoreline, its stabilizing significance depends on the erosive force of the water body. Estuaries and lakes, with large fetch, and higher order streams have greater erosive forces than small streams. The erosive force of wave action is greatest where the fetch exceeds three miles (Knutson et al., 1982), but a one-half mile fetch is sufficient to generate waves capable of re-suspending sediments (Carper and Bachmann, 1984). Obviously, the higher the current velocity of flowing water, the greater is its erosive potential (Karr and Schlosser, 1977).

<u>Length of Border Exposed to Open Water</u>

H > 500 feet of wetland perimeter borders open water
M 100-500 feet of perimeter borders open water
L < 100 feet of perimeter borders open water

If exposure to open or flowing surface water is a prerequisite for a wetland to perform shoreline stabilization, then the greater the extent of exposure, the higher is the wetland's potential significance. The length values used are arbitrary, based simply on conditions typical of the North Carolina coastal area.

<u>Watershed Land Use</u>

H ≥ 1% developed <u>or</u> > 20% developed + agriculture
M < 1% developed <u>and</u> < 50% developed + agriculture
L < 1% developed and < 20% agriculture

This is an opportunity parameter based on the assumption that the flow rate and erosive force of a stream will be greater when watershed runoff is more rapid. The larger the amount of cleared land and the larger the proportion of impervious surface in a watershed, the more runoff there is and the faster it will reach streams. The percentages of developed and agricultural land uses in the watershed are arbitrary, although Adamus (1987) uses 10 percent impervious surface as the threshold for significance for this function.

Habitat Functions

The role of wetlands in providing habitat for both terrestrial and aquatic wildlife is a well-known and widely accepted wetland function. Wetlands function as feeding, roosting and staging sites, dispersal corridors, shelters, and refuges for many different species. Some of these species are dependent on wetlands to meet one or more life cycle requirements and would not exist in a landscape without wetlands. Other species use wetlands for water, food, or shelter, but could exist just as well in natural upland habitat.

In either case, wetlands are attractive to many wildlife species. The high productivity of many wetlands provides nutrients and other resources used by diverse wildlife populations (Tiner, 1984), and the structural diversity of wetlands and wetland-upland habitat complexes provides unique habitats necessary for many species (Weller, 1988). In many regions, more species are restricted to wetlands than to any other habitat (Williams and Dodd, 1978). Nationwide, about one-third of the species listed as threatened or endangered are dependent on wetlands, and more than 50 percent of the species of protected migratory birds depend upon or frequent wetland habitats (USFWS, 1990). Among various types of undeveloped lands, wetlands often make the largest contribution to regional biodiversity (Brinson, et al., 1981).

In the North Carolina coastal area, wetlands are particularly significant to wildlife populations because the wetlands are the primary remaining large areas of natural or semi-natural habitat. Fertile upland areas were long ago converted to agricultural use, and many of them have subsequently been developed. Forested wetlands where drainage was impractical or the soils were too wet or highly organic to farm remain as refuges for wetland and upland wildlife populations. Some coastal area wetlands, particularly those that hold floodwater from streams, also provide significant spawning habitat for fish.

The habitat function of wetlands is particularly difficult to assess, since good habitat for one species may be poor habitat for another. Nearly any vegetated area can provide habitat for some species of animal life, and picking a particular species or group of species is a matter of management objectives or personal preference. In the NC-CREWS assessment of wetland wildlife habitat, two principles are considered most important:

(1) *Overall habitat quality is highest where biodiversity is highest, i.e., the more habitat requirements a wetland fills for the greatest number of species, the higher its habitat significance is.*

(2) *In a landscape in which remaining habitat is highly fragmented, internal habitat is more ecologically significant than edge habitat is.*

These two principles may conflict in some cases, since there are normally more edge-dwelling species than interior-dwelling species. The first principle comes into play in parameters such as association with surface water and wetland type, while the second principle predominates in consideration of wetland size. In cases where the two principles may conflict, the predominant assumption used is that the coastal landscape provides plenty of edge habitat exclusive of wetlands. Thus, the primary habitat value of wetlands in the North Carolina coastal area is for those species that require either the specific habitat characteristics provided by wetlands or relatively large unbroken habitat areas.

Overriding Considerations

Three of the overriding considerations that result in a wetland being automatically rated of Exceptional functional significance are habitat-related. Any wetland immediately adjacent to a Primary Nursery Area, vital spawning habitat for estuarine fisheries, is rated Exceptional; any wetland providing habitat for a documented population of rare or endangered species is rated Exceptional; and any wetland designated by the Natural Heritage Program as an exemplary or unique natural ecosystem or special wildlife habitat area is rated Exceptional.

In the event that a wetland that has a Beneficial functional significance rating is immediately adjacent to a wetland rated Exceptional, the Beneficial rating is increased to a rating of Substantial. This gives the Exceptional wetland a buffer area since the adjacent area will certainly have an impact on the functionality of its neighboring wetland.

Terrestrial Wildlife Habitat

The first habitat subfunction assessed is the significance of the wetland in providing habitat for terrestrial wildlife species. The quality of terrestrial habitat is determined by characteristics internal to the habitat and by the relationship of the wetland to its surrounding landscape.

Internal Habitat

This series of parameters assesses the quality of habitat provided internal to the "habitat complex." The basic unit of assessment, i.e., the "habitat complex," includes not only the wetland itself, but also all contiguous unbroken areas of unmodified wetlands, drained wetlands, and intact upland areas. This represents the total area available for terrestrial wildlife activity provided by natural vegetation. Most terrestrial species utilize more than the interior of a wetland itself for parts of their life cycles, and this approach assesses the total available habitat, of which the wetland is a part.

a. Interior Size of Habitat Complex

H > 74 acres
M 0 - 74 acres
L No interior habitat

In determining the extent of the habitat complex, primary and secondary roads are assumed to be effective breaks in habitat. Areas unfragmented by roads are reduced inward 100 meters from the boundaries to compensate for edge effects. If any of the complex area remains after these reductions, it is assumed that the complex provides some interior habitat.

The significance of interior habitat is well documented. When compared to forest interiors, forest edges typically have an altered plant species composition and community structure, higher temperature, more light, and lower humidity (Fraver, 1993). In general, habitat fragmentation leads to loss of wide-ranging species, loss of interior or area sensitive species, erosion of genetic diversity in rare species, and increased abundance of species that prosper in human-dominated landscapes (Harris, 1988, 1989). Many species of rare plants and animals depend on forest interiors beyond the influence of edge for essential habitat. Nest predation and brood parasitism of interior dwelling songbirds increases with proximity to edge (Wilcove, 1985).

The 100 meter inward reduction and the habitat complex size breakdowns are based on several studies reported in the literature. The zone of negative influence associated with openings and edges has been quantified in several different regions and is known to extend at least 100 meters into the forest. Climatic and subtle species composition effects may extend 1000 meters (Brittingham and Temple, 1983; Wilcove, 1985; Lovejoy et al., 1986). Even if they occur in a forested landscape, individual forest tracts need to be at least 30-40 hectares (74-99 acres) in size in order to abate the negative consequences of edge effects (Harris, 1989). Bird species diversity has been shown to decrease rapidly with stand sizes less than 30-40 hectares.

b. Association with Surface Water

H Adjacent to permanent surface water
M Adjacent to intermittent stream
L Not adjacent to surface water

Availability of surface water is important to many species and limiting to some. For example, surface water availability, at least during critical periods of the year, determines whether a wetland will be used by waterfowl. While wide-ranging terrestrial species may travel long distances to reach water, the presence of surface water tends to concentrate use. Even if species live elsewhere and merely visit the wetland to drink, the presence of surface water increases an area's use by wildlife and, thus, its habitat significance. Water-vegetation transition zones also provide habitat for both open-water species and those inhabiting adjacent vegetation (Weller and Spatcher, 1965; Willard, 1977).

c. Internal Heterogeneity of Habitat Complex

H > 8 vegetation types within complex
M 5-8 vegetation types within complex
L 1-4 vegetation types make up entire complex

Areas with numerous interspersed vegetation forms normally support a higher wildlife diversity and abundance than homogeneous areas because of the increased number of ecological niches available (Landers et al., 1977; Flake, 1979). Continuous unbroken habitat containing a mixture of vegetation types can fulfill habitat requirements for both interior-dwelling and edge species. In forested areas, bird use in particular is strongly related to diversity of vegetation forms and tree species (Tramer and Suhrweir, 1975; Swift et al., 1984).

Habitat heterogeneity is assessed in NC-CREWS by determining the number of vegetation types included within the habitat complex associated with each wetland. Vegetation types are identified using the Cowardin classes on the underlying NWI maps and different classes in the satellite-based land cover data layer. The numbers used for the breakdown are based on empirical experimentation to arrive at situations typical of eastern North Carolina.

d. Wetland Type

H Bottomland hardwood, freshwater marsh, hardwood flat, swamp forest
M Headwater swamp, pocosin, maritime forest, Pine flat
L Pine plantation, altered site

As with other wetland type evaluations, these groupings are based on analysis of field data on the presence of habitat-related indicators in wetlands of various types. Indicators measured such factors as food supply, vertical habitat structure, and maintenance of food web support (see Appendix B).

In general, the greater the internal structural diversity of a plant community, the more animal species it can support. Forested and shrub-scrub vegetation provide habitat structure through vertical layering and patchiness resulting from horizontal overlap of layers (Roth, 1976). The presence of several vertical vegetative strata is particularly significant to breeding bird use (Kantrud and Stewart, 1984), and bird species diversity has been shown to increase as the number and density of foliage layers increase (MacArthur, et al., 1964; Karr and Roth, 1971). The presence of standing dead trees further increases habitat provision for cavity-nesting birds and mammals (Porter, 1981).

The availability of food supplies, particularly fruit and mast, is also an important determinant of habitat quality and use (Robinson and Bolen, 1984). Although these food supplies are often supplied by adjacent uplands, wetlands with fruit and mast bearing trees and shrubs are rated higher than those without them.

In the rating of wetland types, the obvious exception to the above general principles is freshwater marsh. This wetland type is included in the highest habitat value group because it is relatively rare in eastern North Carolina compared with several of the other wetland types. When freshwater marshes occur, they provide habitat for waterfowl and other wildlife that only rarely utilize more densely vegetated wetlands with little open water. The field methodologies were developed with woody landscapes in mind, so it is likely that the freshwater marshes were underrated in the field evaluations.

Landscape Habitat

Although the life-support needs of sedentary species may be met within a single wetland, many species are mobile and require a mix of wetland types or wetland and upland habitat for optimum success (Weller, 1988). The relationship of a wetland to habitat conditions in adjacent areas may be more significant in determining habitat value than conditions within the wetland itself (Leibowitz, et al., 1992). Both the juxtaposition of other wetlands and the availability of nearby naturally vegetated habitat are used to evaluate this characteristic.

a. Wetland Juxtaposition

H > 50% of wetland bordered by other wetlands
M < 50% of wetland bordered by other wetlands
L Isolated from other wetlands

For many animal species, no single wetland can provide all of their needs over their entire life cycle. For these species' success, several wetlands of various types must exist in the same area (Leibowitz, 1992). Since many wetlands exhibit considerable temporal variability in water depth and general "wetness," adjacent wetlands with different hydrologic regimes provide alternative habitat when the primary habitat becomes too dry or too wet. The proximity of different wetland types also increases overall habitat diversity, leading to increases in wildlife species richness (Brown and Dinsmore, 1986).

b. Surrounding Habitat

H > 50% of land cover within ½ mile composed of natural vegetation
M > 50% of land cover within ½ mile buffer composed of a combination of natural vegetation, pine plantations, and agriculture
L > 20% of land within ½ mile developed or < 10% natural vegetation

Naturally vegetated areas in the near vicinity of a wetland can provide additional food sources and refuge that enhance the habitat value of the wetland (Weller, 1988). Natural vegetation, pine plantation, agricultural land, and developed areas make up a descending hierarchy of habitat values. The more of the former and the less of the latter in the area surrounding a wetland, the higher is its potential habitat significance.

Movement System Value

Some wetlands that are of relatively low significance as primary habitat may still perform important functions as movement or dispersal pathways between more favorable habitat areas. Continuous corridors through areas of otherwise unsuitable habitat, such as agricultural or developed land, may provide regularly used movement pathways. Small wetland patches within reasonable movement distance of one another may also provide cover for wildlife movement and population dispersal.

While small wetland patches or narrow alluvial strips may provide only limited permanent habitat, they can often be quite significant in providing temporary cover for moving animals. The absence of significance as a movement pathway does not lower the overall habitat significance of a wetland if its internal and landscape habitat significance is high.

a. Corridor Value

H Corridor > 600 feet wide connected to contiguous natural vegetation
M Corridor < 600 feet wide connected to contiguous natural vegetation
L Isolated from other natural vegetation

This assessment is applied to a wetland to determine if it is, in effect, a corridor through otherwise inhospitable habitat that connects two or more areas of natural vegetation. Corridor width values are based on studies of habitat buffers and riparian buffer strips (Brinson et al., 1981; Brown et al., 1990).

b. Wetland Island Function

H Isolated wetland > 5 acres in size within ½ mile of the same
M Isolated wetland < 5 acres within ½ mile
L Wetland < 1 acre in size or > ½ mile from nearest wetland

Provided that intervening areas are not effectively impassable, many wildlife species do not require continuous cover for movement and dispersal. A series of isolated wetland "islands" can enable animals to move so long as the wetlands are large enough to provide temporary cover and are close enough to be within the range of reasonable movement for a species. Obviously, both of these parameters will differ for different species. The sizes and distances used in the model are typical values for small mammals and most amphibians.

Aquatic Life Habitat

While wetlands provide significant habitat for terrestrial wildlife, naturally vegetated uplands often provide as good or better habitat and can substitute for wetland habitats for many species. For species that are mainly confined to water or saturated soils or that require shallow, slow-moving water during part of their life cycles, however, wetlands provide essential habitat. Aquatic organisms that are wetland-dependent include many species of fish, amphibians, reptiles, and invertebrates.

Nearly all freshwater and many saltwater fish require shallow water such as that provided by wetlands at some stage of their lives. Fish use wetlands for spawning, predator avoidance, shelter from extreme conditions, and feeding (Adamus et al., 1991). Except for large freshwater marshes and swamps, which may support a permanent fish population of their own, a wetland must be connected to surface water to perform these functions.

Amphibians and invertebrates, on the other hand, are more successful when they are not subject to predation by fish. Consequently, ephemeral wetlands with no connection to permanent surface water provide better habitat for these life forms (Bradshaw, 1991). Since the habitat requirements for these two groups of aquatic organisms are so different, wetlands are evaluated separately for fish and other aquatic life.

Fish Habitat

1. Anadromous Fish

H Adjacent to a river or tributary of a river harboring anadromous fish; annual flooding; not channelized
M Adjacent to a river or tributary harboring anadromous fish; stream is channelized
L Not adjacent to stream harboring anadromous fish

Several species of anadromous fish are commercially important in mid-Atlantic fisheries. Because of their importance, wetlands that provide potential anadromous fish habitat are evaluated as more significant than those that do not.

While anadromous fish species live their adult lives in saltwater, they move up freshwater rivers and streams to spawn in shallow water. Flooded wetlands along these streams provide ideal spawning habitat. For a wetland to provide this function, it must be along a stream used by anadromous fish, and it must be flooded during the early spring spawning season. Virtually all streams in the coastal area flood into adjacent floodplains during late winter and early spring in years with normal precipitation. Channelization, however, can lessen or prevent this flooding and lowers wetland significance for fish habitat.

2. Other Fish Species

- H Adjacent to > third order stream with annual flooding
- M Adjacent to a first to third order stream with annual flooding or a channelized stream of > third order
- L Not adjacent to a stream or stream has infrequent or nonexistent flooding

Seasonally flooded wetlands adjacent to southeastern streams are used by nearly all species of fish present in the stream for feeding, spawning, and protection during juvenile periods (Larson et al., 1981). Wetlands along higher order streams are most significant, since both large fish populations and annual flooding are more likely to occur in streams further down a watershed (Adamus et al., 1991). Invertebrate species richness and fish productivity are generally higher in third and higher order streams (Minshall et al., 1985; Lotrich, 1973). As in the previous parameter, stream channelization is used as an indicator of decreased flooding.

<u>Amphibian and Invertebrate Habitat</u>

Many species of amphibians are dependent on ephemeral wetlands for reproduction (Bradshaw, 1991). Wetlands with isolated pools of standing water for a few months in spring and early summer (vernal pools) followed by dry conditions in late summer provide ideal amphibian habitat. Because this type of habitat is relatively uncommon outside of wetlands, and several species of wetland-dwelling amphibians are rare, this is an important wetland function.

Invertebrate fauna, including insects, nematodes, and mollusks are important processors of organic material and sources of food to higher level consumers (Brinson et al., 1995). While invertebrates are common in all natural ecosystems, some species require the saturated soils and ponded water of wetlands. Since invertebrates are also subject to fish predation, their optimal habitat is similar to that of amphibians.

a. Wetland Type

- H Bottomland hardwood, headwater swamp, or freshwater marsh, swamp forest
- M Hardwood flat, pocosin, or maritime forest
- L Pine flat, pine plantation, human impacted wetland

This breakdown of wetland types is based on the likelihood of vernal pool presence as determined from field studies (Appendix B). The wetland types in the "H" group include those in which shallow water habitat is most likely to exist without connection to surface waters with fish populations. The "M" group includes both wetlands that are likely to be connected to surface waters and those in which ephemeral pools rarely occur. The wetland types in the "L" group rarely have standing water long enough to allow amphibian reproduction.

b. Surrounding Habitat

- H Wetland within ½ mile of upland natural area or temporarily flooded wetland
- L Wetland > ½ mile from upland or temporarily flooded natural area

While amphibians require water for reproduction and larval development, mature animals require terrestrial habitat. Wetlands that are flooded most or all of the time do not provide satisfactory amphibian habitat unless drier areas are available within the movement range of these animals. There is no "M" rating for this parameter, since the habitat requirements are either met or not met, with no meaningful in-between condition.

Potential Risk Considerations

The above considerations - water quality, hydrology, and habitat - are all functions that wetlands perform. Their significance in a particular wetland is assessed on the basis of the level at which each function is currently performed and the level at which the wetland has the capacity to perform each function.

The considerations included under "Potential Risk" extend the assessment of local wetland functions by evaluating their significance in relation to the watershed of which the wetland is a part. This may be considered a measure of the relative risk to watershed and landscape functional integrity posed by loss of the wetland's functions. Regardless of the wetland's level of functioning, this factor attempts to evaluate whether it would make a significant difference beyond the site itself if those functions were not there.

The overall ecological significance of a wetland is derived from the wetland's role as a component of larger scale systems (Bedford and Preston, 1988). It is not so much a characteristic of a particular wetland as of the relationships between the wetland and other ecosystems and land uses. Those relationships are largely determined by characteristics of the landscape outside of the wetland. These characteristics are evaluated in the first two subfunctions under Potential Risk, *i.e.*, landscape character and watershed water quality.

Landscape Character

The loss of a highly functional wetland in a landscape filled with other wetlands may not be as ecologically significant as the loss of a minimally functioning wetland in a highly degraded landscape. For example, losses of wetlands from watersheds with large percentages of their area in lakes and wetlands have less impact on stream flow than wetland losses in watersheds with few wetlands (Conger, 1971). Wetlands in predominantly disturbed watersheds have more opportunity to receive sediments and associated pollutants than wetlands in relatively pristine watersheds and will, therefore, be more critical in protecting downstream water quality (DEM, 1993). Although habitat fragmentation may have already eliminated many species from highly disturbed landscapes, remaining wetlands serve as refuge. The loss of these remaining habitats can have more adverse impacts on wildlife populations than the loss of a similar area in the midst of alternative habitat.

The landscape of the watershed in which a wetland exists is characterized in NC-CREWS by evaluating two parameters: the relative abundance of wetlands and of wetlands of this particular type; and the relative areas of various land uses in the watershed.

<u>Wetland Extent and Rarity</u>

a. Percent of hydrologic unit composed of wetlands

H < 20%
M 20-50%
L > 50%

As discussed previously, a watershed with lower total area comprised of wetlands will receive a greater impact if a given wetland area were lost. The particular values used are based on conditions in the North Carolina coastal area, where few watersheds have less than 20 percent wetland area, and watersheds with 35-45 percent wetlands are common. These numbers would be much too high in regions, such as the North Carolina Piedmont, in which wetlands comprise a much smaller proportion of the landscape.

b. Percent of wetlands in larger area unit composed of this type

H < 10%
M 10 - 25%
L > 25%

Evaluation of this parameter is based on an objective of maintaining biotic diversity in the landscape. Even if the hydrologic, water quality, and habitat functions of a wetland are relatively insignificant, rare community types within the region will receive a high rating for this parameter.

The "larger area unit" may be a larger watershed or river basin in which the individual hydrologic unit is located, an arbitrarily or politically defined area such as a county, or an entire ecoregion. The objective of evaluating the relative rarity of the ecosystem type in the overall landscape is achieved with any of these larger units. The primary consideration is that the local hydrologic unit is too small to adequately assess landscape rarity. NC-CREWS uses the 14-digit watersheds as defined by the Natural Resource Conservation Service.

In addition to providing a contextual basis for the assessment of wetland significance, these parameters provide a means of considering the cumulative impacts of wetland loss. The greater the proportion of wetlands lost relative to wetland abundance and distribution prior to European settlement, the greater the probability that cumulative impacts have occurred and will be increased by additional losses (Bedford and Preston, 1988). If the numerical values used to determine the groupings realistically reflect the abundance of pre-settlement wetlands in the region, the more loss of wetland area that has occurred, the higher will be the significance rating of remaining wetland.

Land Use in Hydrologic Unit

The second consideration in evaluating the effects of landscape character on wetland significance is the mix of land uses within the watershed. Natural vegetation in eastern North Carolina, whether wetland or upland, consists primarily of dense forest and shrub communities. Densely vegetated watersheds in flat terrain have little surface water runoff and export relatively little sediment or nutrients (Cooper et al., 1986). Naturally vegetated areas provide essentially continuous wildlife habitat. As the degree and intensity of land disturbance increase, surface water runoff, sediment and nutrient export, and habitat fragmentation all increase. The functional significance of wetlands, thus, increases with increasing land use intensity because of both increases in exports from other land uses and decreases in alternative naturally vegetated land areas.

a. Percent of land in agricultural use

H > 40%
M 10 - 40%
L < 10%

The predominant human land uses in the North Carolina coastal area are agriculture, intensive forestry, and urban and residential development. Agricultural uses include cultivated lands and livestock operations, both of which result in increased runoff and nutrient exports. While croplands provide a food source for some wildlife species, intensive agriculture results in habitat fragmentation and loss of suitable habitat for wide-ranging and interior forest species. The higher the percentage of the land in a watershed in agricultural use, the more significant are the functions of remaining wetlands. The percentages used as breaking points between H, M and L evaluations are typical of the area.

b. Percent of land in pine plantations

H > 30%
M10 - 30%
L < 10%

The most common form of intensive forest management in the coastal area is pine monoculture. Timber companies manage vast acreage of pine plantations on relatively short rotations. Mature stands are clear-cut, and intensive site preparation, bedding, planting, and fertilizing are common regeneration practices. Many intensively managed pine plantations are on sites that were former wetlands or, if water control structures are in place, retain many wetland functions.

There have been many studies of the impacts of silvicultural practices on water quality, several of which were reviewed by Shepard (1994). Most of these studies report increased export of sediments and nutrients following silvicultural operations in comparison with undisturbed areas. These effects are relatively short-lived, however, and diminish in a few months to a few years as the stand develops. Over time, intensively managed pine lands export more nutrients and sediments than naturally vegetated areas but much less than the more intensive land disturbances associated with agriculture and development.

The same generalization applies to the habitat functions of pine plantations. While the habitat provided by pine monoculture is less desirable for some species than a mix of natural vegetation, it is certainly better habitat than a similar area of agricultural cropland or development. For these reasons, the percentage of the watershed occupied by pine plantations must be higher than the percentage occupied by agriculture or development for the significance of wetlands to be evaluated as high.

c. Percent of land in urban/developed uses

H > 1%
M 0.1 - 1%
L < 0.1%

Of the three land uses, land development for urban or residential purposes provides the greatest stress in terms of increased runoff and habitat destruction. Runoff from disturbed soil, grass lawns, and impervious surfaces is markedly greater than that from natural vegetation and carries a much larger sediment, nutrient, and toxicant load (Arnold et al., 1987; Wolman and Schick, 1967). The multiple impacts of development cause radical changes in wildlife habitat and normally entirely eliminate suitable habitat for some species (Brooks, et al., 1990; Croonquist and Brooks, 1991). Development of only a relatively small portion of a watershed greatly increases the functional significance of remaining wetlands.

Watershed Water Quality Characteristics

This series of parameters evaluates the potential risk to water quality if the wetland's water quality functions were lost. Three aspects of water quality are evaluated: the water quality classification of the major water body in the watershed; the degree of water quality impairment existing in the watershed; and the water quality classification of the water body downstream of the watershed.

In all cases, the basic assumption is that the water quality functions of wetlands become more significant as the assimilative capacity of receiving waters decreases. Assimilative capacity may be limited in quite different ways, and surface waters that are of presently very high quality, that support economically or socially important uses, or that are currently significantly impaired are all considered to have limited assimilative capacities.

1. Classification of Major Water Body in the Watershed

- H SA, ORW, HQW, WS-I, WS-II, NSW, URW
- M B, WS-III, SB
- L C, SC

Waters that are of exceptionally high quality (Outstanding Resource Waters and High Quality Waters) could be degraded by any increase in pollutant loading. These waters have been so classified by the North Carolina Environmental Management Commission with the objective of maintaining their outstanding high water quality. Similarly, avoidance of water quality impairment is a management goal for waters supporting important uses, such as SA waters that support saltwater fisheries and water supply watersheds. Any significant loss of wetlands in the watersheds of surface waters with these high classifications poses a high risk of water quality impairment.

2. Use Support of Water Bodies in Watershed

- H > 5% of stream miles or water body area in watershed less than fully supporting
- M 1 - 5% of stream miles or water body area in watershed less than fully supporting
- L < 1% of stream miles or water body area in watershed less than fully supporting

Waters that are already significantly impaired also have little capacity to assimilate additional pollutants. Water quality impairment is indicated by either an impaired quality classification (Nutrient Sensitive Waters and Use Restoration Waters) or lack of full support of uses intended by their water quality classifications.

3. Classification of Water Body Receiving Watershed Output

- H SA, ORW, HQW, WS-I, WS-II, NSW, URW
- M B. WS-III, SB
- L C, SC

Receiving water bodies of the water in a stream must also be considered. If the downstream watershed is considered of high quality, or if the stream is degraded, the wetlands upstream are critical in providing clean water downstream. If the waterways are not considered exceptional waters for protection or for clean up, the wetlands are less vital.

Replacement Difficulty

The objective of compensatory mitigation for a wetland's loss, as applied in wetland regulatory programs, is the replacement of wetland functions that will be lost as a result of the permitted activity. If the primary functions of a wetland could be relatively easily replaced by wetland restoration on a site within the same watershed, the risk to overall watershed integrity of the wetland's loss is relatively small. On the other hand, if it is very unlikely that a wetland's functions, if lost, could be compensated for by wetland restoration, then the risk of that wetland's loss is relatively high. The feasibility of restoring wetland functions is determined by the practicality of restoring a wetland of the given type and by the availability of a suitable restoration site.

1. Wetland Type

- H Pocosin, maritime forest
- M Bottomland hardwood, swamp forest, headwater swamp, hardwood or pine flat
- L Freshwater marsh, managed pine

Some wetland types are inherently difficult to restore or create because of their specific site requirements and/or biotic characteristics. Of the wetland types found in eastern North Carolina, organic soil pocosins and the dune and swale wetlands of maritime forests fall in this category. Other wetland types, such as freshwater marshes and pine plantations on wetlands, are less complex and therefore less difficult to restore. The Wetland Type parameter under the Replacement Difficulty heading evaluates the difficulty of replacing the functions of existing wetlands by grouping wetland types into three categories based on the feasibility of restoring a wetland of that type.

2. **Replacement Site Availability**

H No replacement site identified in watershed
M Non-wetland restoration site available in watershed
L Degraded wetland site of same type identified in watershed

The second parameter evaluates the practicality of restoring lost functions in terms of the availability of a suitable restoration site in the same watershed, a necessity if functions of local significance are to be replaced. If no suitable restoration site is available, either a site in another watershed must be used or restoration of the desired functions is impractical. Evaluation of this parameter is dependent on the existence of GIS potential wetland restoration site maps, which were produced by DCM in a related project (Bledsoe et al., 1997). If these data are not available, this parameter could be eliminated or a surrogate parameter could be used.

Enhancement Potential of Site

In a wetland management system in which wetland restoration is part of the overall management scheme, the availability of potential restoration and enhancement sites is an important consideration. If a wetland is rated to have only beneficial functional significance because it is degraded due to drainage or other disturbance, it may have the potential to be enhanced or restored to higher levels of functions. Its loss, even though minimal in terms of lost functions, would result in lost opportunity for restoration and, thus, poses some risk to future wetland management options.

H Drained or partially drained wetland with natural vegetation intact
M Drained or partially drained and converted to pine plantation or other intensively-managed forest type
L Wetland intact, but of low functional significance

This parameter is meaningful in the overall evaluation only if the wetland is rated as being of Beneficial functional significance. Thus, it is a "bonus" consideration for wetlands that have been degraded by past human activity. If the wetland is not necessarily degraded, but simply provides only Beneficial wetland functions, it will rate low on this parameter as well. If the wetland is a potential enhancement site, however, the closer the wetland is to its fully functioning state, i.e., the less it has been disturbed, the higher is its significance as a potential enhancement site.

GIS TECHNIQUES

Section 5

Description of Coverages

All coverages are clipped to the boundary of the current hydrologic unit unless otherwise noted with an asterisk (*). The asterisk denotes that an identical coverage exists except that it extends 1 mile beyond the hydrologic unit boundary to accommodate analyses not related to water that require a broader scale. The extended area coverages have an additional attribute, IN_HU, which shows which areas of the coverage are actually within the boundary of the hydrologic unit.

wetlands: Polygon coverage of DCM wetlands data. The polygon attribute table (PAT) of this coverage contains the DCM wetland type, hydrogeomorphic (HGM) classification, as well as other attributes used in the DCM wetland mapping process.

soils: Polygon coverage of soil series as delineated in the county soil surveys. The PAT contains one attribute:

soil: Character representing the soil series as described in the county soil survey.

*__hydrography__: Polygon and arc coverage of hydrological features. This coverage contains the following attributes in the PAT and AAT:

order: Number representing the Strahler stream order.

origin: Number representing whether the headwaters of the stream originated in the Mountains, Piedmont, or Coastal Plain.

flow: Number representing whether the stream is perennially or intermittently flooded.

ditch: Number representing whether the stream appeared to be ditched or channelized.

anadfish: Number representing whether the stream is a known spawning area for anadromous fish or a tributary to those spawning areas.

open: PAT only. This indicates whether polygons are truly open water or simply polygons where arcs happened to enclose an area.

*__covtyp__: Polygon coverage of cover types for all areas of the hydrologic unit. The user has an opportunity during the initialization process to add arcs to break up large wetland polygons or divide the wetland polygons where the geomorphology suggests a division is reasonable. The PAT of this coverage contains the following items:

dis_item: Character representing whether the land is occupied by open water, wetland, other natural vegetation, or pine, agriculture, or developed areas.

dis_type: Number equivalent to the wetland type.

wh_id: A unique identifier assigned to each wetland polygon.

hgm: Character representing whether the hydrogeomorphic classification of the wetlands polygon is riverine (r) or flat/depressional (f).

***habcov**: Polygon coverage of vegetated areas not distinguished by wetland or non-wetland. All areas of wetland and natural vegetation are dissolved.

***master**: Polygon coverage of all wetlands with the results of each parameter in the assessment procedure. Also contains the wetland type, HGM classification, and wh_id.

wh_id: Polygon coverage of each individual wetland showing the wetland polygon's unique identifier and no other data.

Water Quality Function

Proximity to Sources (wqf0111)
Coverages used: covtyp

Description of process: Relates are established that link the unique polygon identifier (covtyp# in the PAT) with the items in an associated arc table (AAT) that list the polygons to the right or left of each arc (RPOLY# & LPOLY#). An item is added to the covtyp PAT that contains the length of the shared arc of a particular item value. Polygons with adjacent neighbors to the left or right with cover type equal to 'wetland,' for example, will contain the length of the shared arc. This is repeated for cover types 'agriculture,' 'developed,' 'non-wetland vegetated,' 'open water,' and 'pine.' When complete, the covtyp coverage (or copy of it) will contain several additional items, including:

type_a (length of appropriate polygons that border agriculture),
type_d (length of appropriate polygons that border developed areas),
type_n (length of appropriate polygons that border natural, upland vegetation),
type_o (length of appropriate polygons that border open water),
type_p (length of appropriate polygons that border pine), and
type_w (length of appropriate polygons that border wetland areas).

The length of each cover type is then divided by the total length of the polygon perimeter that is NOT the boundary of the watershed to determine the percentage of the polygon immediately adjacent to sources of pollution. Those polygons that share 50% or more of their boundaries with agriculture or developed lands are rated high. Polygons sharing 50% or more of their borders with agriculture, developed or pine areas are rated moderately. Polygons with 50% or more of their borders with upland vegetated areas, wetlands or open water are rated minimally. Remaining polygons that do not meet any of these criteria are rated minimally.

Assumptions: Pollutants are not shared between watershed boundaries.

Proximity to water bodies (wqf0112)
Coverages used: hydrography, wetlands

Description of process: Perennial and intermittent streams are buffered by 300 feet in two independent BUFFER operations. Resulting polygons are coded as areas surrounding intermittent or perennial streams. These polygon coverages are overlaid with the wetland polygon coverage. Wetland areas that fall within perennial stream buffers are rated highly and those falling within intermittent streams are rated moderately. All other wetland areas are rated minimally.

Each wetland polygon is then assigned a final rating depending on the weighted average of its areas that fall within each of the buffered stream areas.

Assumptions: A wetland polygon that has areas within 300 feet of both intermittent and perennial streams is assigned the rating for the largest area.

Watershed position (wqf0113)
Coverages used: *hydrography, wetlands, neatline

A GRID is created of the hydrography using stream order as the grid's attribute. Within the GRID module of Arc/Info, a grid is created of the Euclidian distance of areas from each stream, based upon the stream's order. That grid is then converted to a vector coverage and overlaid with the wetland coverage. Using a weighted average, wetlands are rated based on the amount of area within the wetland polygon that falls within the area of the closet stream order.

Assumptions: Headwater wetlands are more significant in removing non-point source pollutants than are wetlands further downstream in a watershed.

Wetland Type (wqf01141)
Coverages Used: wetlands

Description of process: Using simple ARCPLOT reselects, wetlands are rated based on their classified wetland type.

Assumptions: none

Soil Characteristics (wqf01142)
Coverages Used: wetlands, soils

Description of process: Wetland and soil coverages are overlaid into a single coverage. Based on soil type, resulting polygons are assigned ratings appropriate for that soil's biogeochemical activity, which reflects its capacity to assist in non-point source pollution abatement.

Assumptions: Wetlands polygons having more than one soil type supporting them are rated based on a weighted average of the ratings of all soil types occupying the polygon.

Site Conditions (wqf0114)
Coverages Used: master

Description of process: Using ARCPLOT, the results of WQF01141 and WQF01142 are reviewed and combined appropriately.

Assumptions: WQF01141 and WQF01142 have been successfully completed.

Nonpoint Source (wqf011)
Coverages Used: master

Description of process: Using ARCPLOT, the results of WQF0111, WQF0112, WQF0113 and WQF0114 are reviewed and combined appropriately.

Assumptions: WQF0111, WQF0112, WQF0113 and WQF0114 have been successfully completed.

Water Source & Proximity to Sources (wqf0121)
Coverages Used: wetlands, hydrography, covtyp

Description of process: Streams that originate within the current hydrologic unit are first rated. These streams are buffered by 50 feet and the resulting polygons are overlaid with the vegetative cover coverage. The sum of agricultural and developed areas within these buffers is then calculated. All wetland polygons in the hydrologic unit which have a riverine hydrogeomorphic (HGM) classification are first given the same rating based on the percentage of agricultural plus developed land in the buffered areas. Wetlands bordering streams that originate outside the hydrologic unit may be given different ratings based on the results of the next section. Note that all wetland polygons which have an HGM classification other than riverine are rated minimally for this parameter.

Streams that originate from outside the hydrologic unit are evaluated next. Wetlands bordering these streams may receive a different rating from those which border streams that originate within the current hydrologic unit A relate is established to link an INFO table containing the percent of agricultural and developed land for each hydrologic unit to the hydrologic unit coded as the one nearest the current hydrologic unit that the stream also runs through. These streams are overlaid with the wetlands coverage. Using ARCPLOT reselects, a new item is calculated for all wetland polygons with these streams running through them. The overall rating of these polygons is determined by ARCPLOT reselects considering both the value just assigned to the new item and the origin of the headwaters of the stream.

Finally, to eliminate duplicate ratings for any wetland that may have been divided due to overlays, a weighted average is performed to assign a single rating to each polygon.

Assumptions: 1) Interactive process to label hydrologic unit origin of each stream has been complete. 2) The fifty foot buffer around each stream represents land area immediately adjacent to streams.

Duration of Flooding (wqf0122)
Coverages Used: wetlands, soils, hydrography

Description of process: Same as soil characteristics described above, but with alternative breakdowns for each soil's capability to attenuate downstream floods.

Assumptions: Soil groupings were determined based on flooding durations provided in county soil surveys. Soils with long or very long flooding received a high rating, brief or very brief, moderate, and soils with no flooding received the minimal rating.

Wetland Type (wqf01231)
Coverages Used: wetlands

Description of process: Based on simple ARCPLOT reselects, wetland polygons are rated based on their classified wetland type.

Assumptions: none

Soil Conditions (wqf01232)
Coverages Used: master

Description of process: Copies the results of WQF01142

Assumptions: Same as WQF01142

Site Conditions (wqf0123)
Coverages Used: master

Description of process: Using ARCPLOT, the results of WQF01231 and WQF01232 are reviewed and combined appropriately.

Assumptions: WQF01231 and WQF01232 have been successfully completed.

Width of Wetland Perpendicular to Stream (wqf0124)
Coverages Used: wetlands, hydrography

Description of process: Arcs and polygons representing streams are buffered by both 50 and 100 feet. All wetlands that pass through the 50 foot buffers (using the ARCPLOT reselect...overlap...passthru command) are initially assigned the highest rating. Those wetlands that fall completely within the 50-foot buffer are re-assigned the lowest rating (ARCPLOT reselect...overlap...within). Those wetland polygons that initially received the highest rating that also fall entirely within the 100 foot buffer are reassigned a moderate rating. Only those wetland polygons that had area within the 50-foot buffer that extend beyond the 100 foot buffer remain with the highest rating.

Assumptions: Wetlands that are at least partially within the 50-foot buffer are adjacent to streams.

Floodwater Cleansing (wqf012)
Coverages Used: master

Description of process: Using ARCPLOT, the results of WQF0121, WQF0122, WQF0123 and WQF0124 are reviewed and combined appropriately.

Assumptions: WQF0121, WQF0122, WQF0123 and WQF0124 have been successfully completed.

Water Quality (wqf01)
Coverages Used: master

Description of process: Using ARCPLOT, the results of WQF011 and WQF012 are reviewed and combined appropriately.

Assumptions: WQF011 and WQF012 have been successfully completed.

Hydrology Function

Watershed Position (hyf0111)
Coverages Used: master

Description of process: Copies the results of wqf0113, water quality, nonpoint source, watershed position.

Assumptions: Same as WQF0113

Wetland Size (hyf0112)
Coverages Used: wetlands

Description of process: The land area of the hydrologic unit is calculated by invoking a separate AML that performs this calculation. Individual wetland polygons with areas greater than 0.54% of the hydrologic unit area receive the highest rating, those within 0.05%-0.54% receive a moderate rating and < 0.05% receive the minimal rating.

Assumptions: none

Wetland Type (hyf01131)
Coverages Used: wetlands

Description of process: Based on simple ARCPLOT reselects, wetland polygons are rated based on their classified wetland type.

Assumptions: none

Soil Infiltration Capacity (hyf01132) Coverages Used: wetlands, soils

Description of process: Wetland and soil coverages are overlaid into a single coverage. Based on soil type, resulting polygons are assigned ratings appropriate for that soil's infiltration capacity.

Assumptions: Wetlands polygons having more than one soil type supporting them are rated based on a weighted average of the ratings of all soil types occupying the polygon.

Site Conditions (hyf0113)
Coverages Used: master

Description of process: Using ARCPLOT, the results of HYF01131 and HYF01132 are reviewed and combined appropriately.

Assumptions: HYF01113 and HYF01132 have been successfully completed.

Surface Runoff Storage (Flood attenuation) (hyf011)
Coverages Used: master

Description of process: Using ARCPLOT, the results of HYF0111, HYF0112, and HYF0113 are reviewed and combined appropriately.

Assumptions: HYF0111, HYF0112, and HYF0113 have been successfully completed.

Duration of Flooding (hyf0121)
Coverages Used: master

Description of process: copies results from wqf0122, water quality, floodwater cleansing, and duration of flooding.

Assumptions: Same as WQF0122.

Wetland Size (hyf0122)
Coverages Used: master

Description of process: Copies results from hyf0112, hydrology, attenuation of flooding, wetland size.

Assumptions: Same as HYF0112

Watershed Position (hyf0123)
Coverages Used: master

Description of process: Using methodology similar to wqf0113, wetlands with the majority of their areas located nearest streams higher than third order are rated most significantly. Second or third order streams receive a moderate rating, and intermittent or first order streams receive the lowest significance rating.

Assumptions: none

Width Perpendicular to Stream (hyf0124)
Coverages Used: master

Description of process: Copies results from wqf0124, water quality, floodwater cleaning, and width perpendicular to stream.

Assumptions: Same as WQF0124

Floodwater (overbank) Storage (hyf012)
Coverages Used: master

Description of process: Using ARCPLOT, the results of HYF0121, HYF0122, HYF0123, and HYF0124 are reviewed and combined appropriately.

Assumptions: HYF0121, HYF0122, HYF0123, and HYF0124 have been successfully completed.

Proximity to Water Body (hyf0131)
Coverages Used: hydrography

Description of process: Streams which are second order and greater (this includes estuarine shorelines) and lakes are buffered by 50 feet. Additionally, first order streams are buffered by 50 feet and estuarine shorelines are buffered by 300 feet. All wetlands are initialized to a low rating, and then the wetland polygons that intersect the buffers are rated accordingly. First, areas within the 50-foot buffers of first order streams, and within the 300 foot buffers of estuarine shorelines receive medium ratings. Then, areas within the 50-foot buffers of lake and estuarine shorelines and second order or greater streams are rated high. The wetlands are then evaluated for a majority of their areas. The rating for the majority of the area prevails for the entire polygon.

Assumptions: none

Length of Shoreline Border (hyf0132)
Coverages Used: covtyp, hydrography

Description of process: The hydrography coverage is joined with the covtyp coverage. Wetlands are then evaluated for the length of their perimeter that borders open water. Depressional wetlands are reassigned an L rating.

Assumptions: none

Watershed Land Use (hyf0133)
Coverages Used: covtyp

Description of process: Basic ARCPLOT reselects are performed on each of the land uses referenced in this parameter. Based on the land area of the selected land use types, all wetlands within the hydrologic unit receive the same rating. Depressional wetlands are reassigned an L rating.

Assumptions: none

Shoreline Stabilization (hyf013)
Coverages Used: master

Description of process: Using ARCPLOT, the results of HYF0131, HYF0132, and HYF0133 are reviewed and combined appropriately.

Assumptions: HYF0131, HYF0132, and HYF0133 have been successfully completed.

Hydrology Function (hyf01)
Coverages Used: master

Description of process: Using ARCPLOT, the results of HYF01, HYF012, and HYF013 are reviewed and combined appropriately.

Assumptions: HYF01, HYF012, and HYF013 have been successfully completed.

Habitat Function

Interior Size of Habitat Complex (haf01111)
Coverages Used: wh_id, habcov, roads

Description of process: A temporary coverage is created from the havcov that contains only those polygons that have natural vegetation (including pine forests/managed pineland). These natural vegetation polygons are then buffered inward by 100 meters to account for edge effects. Additionally, a 1:24k roads coverage is clipped by the buffered hydrologic unit boundary and the resulting coverage is buffered by 100 meters. This coverage is combined with the buffered natural areas coverage to create a coverage where interior habitat is present and road corridors are not present. In the resulting coverage, the polygons which have an interior habitat size of greater than 74 acres are given an H rating, and those interior habitat polygons smaller than 74 acres are given an M rating.

This interior habitat coverage is then combined with the wetlands coverage. Wetland polygons that have no interior habitat are given an L rating. Other wetland polygons are rated according to the size of the interior habitat polygons within which they fall. Finally, to eliminate duplicate ratings for any wetland polygon that may have been divided because of overlays, a weighted average is performed to assign a single rating to each wetland polygon.

Assumptions: Continuous habitat within polygons.

Availability of Surface Water (haf01112)
Coverages Used: wh_id, hydrography

Description of process: Perennial and intermittent stream arcs are independently removed from the master hydrography coverage, and INTERSECTed with the wetland polygons. The length of the streams is summed by wetland polygon. Wetlands with perennial streams in their boundaries are rated as H, those with intermittent streams are rated as M, and those wetlands without any streams are rated L.

Assumptions: all hydrography arcs are correctly labeled as permanent or intermittent.

Internal Heterogeneity of Habitat Complex (haf01113)
Coverages Used: habcov, wetlands

Description of process: the wetland coverage is dissolved to include only wetland and land cover polygon boundaries. Habcov & the new dissolved coverage are joined (IDENTITY) and statistics are computed by habitat type. Statistics summarizing the habitat polygon by land use and wetland types are created. If a habitat polygon has more than 8 different cover or wetland types, it receives an H, 5-8 types receive an M, and 1-4 types receive an L. Habitat polygons that do not have unique identifiers (same wh_id code exists in more than one polygon) are assigned the value from the majority of the polygon.

Assumptions: none

Wetland Type (haf01114)
Coverages Used: wetlands

Description of process: Using simple ARCPLOT reselects, wetlands are rated based on their classified wetland type.

Assumptions: none

Internal Habitat (haf0111)
Coverages Used: master

Description of process: Using ARCPLOT, the results of HAF01111, HAF01112, HAF01113, and HAF01114 are reviewed and combined appropriately.

Assumptions: HAF01111, HAF01112, HAF01113, and HAF01114 have been successfully completed.

Wetland Juxtaposition (haf01121)
Coverages Used: covtyp, wh_id

Description of process: Evaluates the habitat type of the adjacent polygon. If the adjacent polygon is classified as a wetland, then the length of border is divided by the perimeter of the boundary. Those polygons with 50% or more of the boundary sharing an arc with another wetland are rated H. If there is some shared boundary (but less than 50%), the wetland is given an M. Wetlands that do not abut another wetland are rated L.

Assumptions: none

Surrounding Habitat (haf01122)
Coverages Used: covtyp

Description of process: GRIDS of wetland polygons and landcover/habitat types are created from the covtyp coverage. For each wetland area, the area is expanded by 28 cells (approximately 0.5 miles) and statistics are performed to count the percentage of this surrounding area comprised of each of the major habitat types (agriculture, developed, pine, natural). Those wetland areas with 50% of their surrounding area in natural vegetation receive an H, while those wetland areas with less than 10% of their surrounding area in natural vegetation or greater than 20% of their surrounding area developed receive an L rating. All other wetlands receive an M rating.

Assumptions: Land cover data is accurate.

Landscape Habitat (haf0112)
Coverages Used: master

Description of process: Using ARCPLOT, the results of HAF01121 and HAF01122 are reviewed and combined appropriately.

Assumptions: HAF01121 and HAF01122 have been successfully completed.

Corridor Function (haf01131)
Coverages Used: habcov, wh_id

Description of process: A UNIONed coverage of habitat type and wetland type is dissolved by pine plantation/natural habitat. The natural areas are shown on-screen with agricultural and developed areas displayed in the background. The user is prompted to select polygons that appear to be corridors. This is done for corridors wider than 600 feet and those less than 600 feet wide. The corridor polygons wider than 600 feet are assigned an H rating, and the corridor polygons less than 600 feet wide are assigned an M rating. All other polygons receive an L.

Assumptions: User understands definition of corridor

Wetland Island Function (haf01132)

Coverages Used: covtyp

Description of process: Selects wetland polygons that have adjacent polygons that are wetlands and rates those as an L. Of the remaining wetlands that do not share a wetland boundary, those less than one acre are also rated as L. All remaining 'isolated' wetlands greater than one acre are extracted and put into a new coverage (the island polygon coverage) for the remaining analyses. These polygons are buffered by 0.25 miles (only half the distance of the parameter to consider overlap), and the buffered coverage is UNIONed with the island polygon coverage. If more than the original polygon is found to fall within the buffer, then the polygon is measured for size. Those that are five acres or greater are rated H, the others receive an M.

Assumptions: none

Potential Movement System (haf0113)
Coverages Used: master

Description of process: Using ARCPLOT, the results of HAF01131 and HAF01132 are reviewed and combined appropriately.

Assumptions: HAF01131 and HAF01132 have been successfully completed.

Terrestrial Wildlife Habitat (haf011)
Coverages Used: master

Description of process: Using ARCPLOT, the results of HAF0111, HAF0112 and HAF0113 are reviewed and combined appropriately.

Assumptions: HAF0111, HAF0112 and HAF0113 have been successfully completed.

Anadromous Fish (haf0121)
Coverages Used: hydrography, wh_id

Description of process: The two coverages are INTERSECTed, and statistics are established for any polygon that contains a hydrographic arc. If a wetland contains an anadromous fish arc that is not annotated as ditched, it receives an H. Wetlands containing channelized anadromous fish arcs receive an M. Polygons without any anadromous fish stream arcs in them are rated L.

Assumptions: anadromous fish attribute correctly carried over from 1:100K coverage (manual process completed by DCM).

Other Fish Species (haf0122)
Coverages Used: hydrography, wh_id

Description of process: Statistical summaries of the cover created in the anadromous fish parameter are created for streams greater than third order, first through third order streams, and for ditched streams. Polygons that contain non-ditched, third order or larger streams are rated H, while wetland polygons containing smaller and/or channelized streams receive an M. Wetland polygons that have no stream arcs are assigned an L for this parameter.

Assumptions: Anadromous fish unioned coverage was created successfully in haf0121 and still remains in the workspace.

Wetland Type (haf01231)
Coverages Used: wetlands

Description of process: Using simple ARCPLOT reselects, wetlands are rated based on their classified wetland type.

Assumptions: none

Surrounding Habitat (haf01232)
Coverages Used: master

Description of process: copies the results from haf01122
Assumptions: Same as HAF01122

Amphibian/Invertebrate Habitat (haf0123)
Coverages Used: master

Description of process: Using ARCPLOT, the results of HAF01231 and HAF01232 are reviewed and combined appropriately.

Assumptions: HAF01231 and HAF01232 have been successfully completed.

Aquatic Life Habitat (haf012)
Coverages Used: master

Description of process: Using ARCPLOT, the results of HAF0121 and HAF0122 are reviewed and combined appropriately.

Assumptions: HAF0121 and HAF0122 have been successfully completed.

Habitat Function (haf01)
Coverages Used: master

Description of process: Using ARCPLOT, the results of HAF011 and HAF012 are reviewed and combined appropriately.

Assumptions: HAF011 and HAF012 have been successfully completed.

Potential Risk Function

Percentage of Wetlands in Hydrologic Unit (prf01111)
Coverages Used: covtyp

Description of process: Statistics are calculated for the area that contains wetlands versus the land area of the entire hydrologic unit. If less than 20% of the watershed is wetland, all polygons receive an H for this parameter. If 20-50% of the watershed is in wetland, the polygons receive an M. If there is more than 50% wetland then all polygons receive an L.

Assumptions: none

Percentage of Specific Wetland Type in Larger Hydrologic Unit (prf01112)
Coverages Used: wh_id, master wetland coverage

Description of process: The program looks at the 14-digit watershed code for the hydrologic unit, and extracts the 11-digit code for the larger hydrologic unit. The 11-digit code boundary is pulled from a master coverage and used to clip out the wetlands within that boundary from the master wetlands coverage. Once this new coverage is created, statistics are calculated by wetland type. Next, wetland polygons with rare occurrence in the larger watershed (< 10%) are rated as H, those occurring in the 10-25% range receive an M, and common types (> 25%) receive an L.

Assumptions: Master wetland coverage has basic wetland data complete for all the land area in the larger watershed.

Wetland Extent and Rarity (prf0111)
Coverages Used: master

Description of process: Using ARCPLOT, the results of PRF01111 and PRF01112 are reviewed and combined appropriately.

Assumptions: PRF01111 and PRF01112 have been successfully completed.

Percentage Agricultural Use in Hydrologic Unit (prf01121)
Coverages Used: covtyp

Description of process: Statistics are calculated on the percentage of agricultural area in the hydrologic unit and divided by total land area in the hydrologic unit. If the agricultural area exceeds 40% of the total area, all wetland polygons receive an H rating. If agricultural areas are 10 - 40 % of the hydrologic unit, the polygons all receive an M. If less than 10% of the area is agricultural, all wetland polygons are assigned an L.

Assumptions: The land cover data accurately reflect the amount of agricultural land in the hydrologic unit.

Percentage Pine Silvicultural Use in Hydrologic Unit (prf01122)
Coverages Used: covtyp

Description of process: Statistics are calculated on the percentage of pine area in the hydrologic unit and divided by total land area in the hydrologic unit. If the pine area exceeds 30% of the total area, all wetland polygons receive an H rating. If pine dominates 10 - 30 % of the hydrologic unit, the polygons all receive an M. If less than 10% of the hydrologic unit is pine dominated, all wetlands receive an L.

Assumptions: The land cover data accurately reflect the amount of pine areas in the hydrologic unit.

Percentage Developed Area in Hydrologic Unit (prf01123)
Coverages Used: covtyp

Description of process: Statistics are calculated on the percentage of developed area in the hydrologic unit and divided by total land area in the hydrologic unit. If the developed area exceeds 1% of the total area, all wetland polygons receive an H rating. If developed land takes 0.1 - 1% of the hydrologic unit, the polygons all receive an M. If less than 0.1% is developed, all wetland polygons receive an L.

Assumptions: The land cover data accurately reflect the amount of developed area in the hydrologic unit.

Land Use In Hydrologic Unit (prf0112)
Coverages Used: master

Description of process: Using ARCPLOT, the results of PRF01121, PRF01122 and PRF01123 are reviewed and combined appropriately.

Assumptions: PRF01121, PRF01122 and PRF01123 have been successfully completed.

Landscape Character (prf011)
Coverages Used: master

Description of process: Using ARCPLOT, the results of PRF0111 and PRF0112 are reviewed and combined appropriately.

Assumptions: PRF0111 and PRF0112 have been successfully completed.

Major Water Body Classification (prf0121)
Coverages Used: master

Description of process: This parameter is evaluated after an interactive session with the user. The watershed is drawn on-screen depicting the water body classification as designated by the North Carolina Division of Water Quality. The user determines the classification of the major water body in the hydrologic unit and assigns an H, M or L based on the classification (The decision rules are also shown on-screen).

Assumptions: Classifications have been made on the water bodies and correctly represented in the coverage.

Major Water Body Use Support (prf0122)
Coverages Used: wh_id, master

Description of process: Again, the user enters an interactive session to evaluate the wetlands for this parameter. Based on data from the Division of Water Quality, the user is asked to assign a rating based on linear and areal figures provided on the screen.

Assumptions: Classifications have been made on the water bodies and correctly represented in the coverage.

Receiving Water Body Classification (prf0123)
Coverages Used: master

Description of process: This parameter is evaluated after an interactive session with the user. The watershed and all surrounding hydrologic units are drawn on-screen depicting water body classifications as designated by the North Carolina Division of Water Quality. The user determines the classification of the major water body that receives input from the currently evaluated watershed and assigns an H, M or L based on the classification (The decision rules are also shown on-screen). If two or more streams depart from the watershed, the user selects the rating for the downstream watershed that would result in the higher evaluation.

Assumptions: Classifications have been made on the water bodies and correctly represented in the coverage.

Watershed Water Quality Characteristics (prf012)
Coverages Used: master

Description of process: Using ARCPLOT, the results of PRF0121, PRF0122, and PRF0123 are reviewed and combined appropriately.

Assumptions: PRF0121, PRF0122, and PRF0123 have been successfully completed.

Wetland Type (prf0131)
Coverages Used: wetlands

Description of process: Using simple ARCPLOT reselects, wetlands are rated based on their classified wetland type.

Assumptions: none

Replacement Site Availability (prf0132)
Coverages Used: wetlands, wh_id

Description of process: Based on wetland restoration site identification completed prior to initiating this assessment, wetland types are compared to restoration or enhancement sites available in the watershed. If no restoration sites occur within the watershed supporting the replacement of a similar wetland type, the wetlands of that type receive an H. If a true restoration site of that type exists in the watershed, it is rated M. If an enhancement site exists, the wetlands of the type are given an L. This procedure is repeated for each wetland type.

Assumptions: Restoration site location data has been completed for the hydrologic unit.

Replacement Difficulty (prf013)
Coverages Used: master

Description of process: Using ARCPLOT, the results of PRF0131 and PRF0132 are reviewed and combined appropriately.

Assumptions: PRF0131 and PRF0132 have been successfully completed.

Restoration Potential of Site (prf014)
Coverages Used: master

Description of process: If any of the polygons are rated low in all the primary functions, this AML looks to find any of the wetland types that were designated as severely ditched or drained in DCM's wetland data development efforts. Drained wetlands that fall out as L for the primary functions are rated H for this parameter; pine plantations are rated M. All other wetlands receive an L for this parameter.

Assumptions: none

Potential Risk of Wetland Loss (prf011)
Coverages Used: master

Description of process: Using ARCPLOT, the results of PRF011, PRF012 and PRF013 are reviewed and combined appropriately.

Assumptions: PRF011, PRF012 and PRF013 have been successfully completed.

Overriding Considerations

Estuarine Wetlands (orc01)
Coverages Used: master

Description of process: Any wetlands classified salt/brackish marsh, estuarine scrubshrub or forested wetland (w-types 1,21,41,3,23,43,15,35,55) are given a rating of Exceptional functional significance.

Assumptions: none

Adjacent to Primary Nursery Area (orc02)
Coverages Used: wh_id

Description of process: Using ARCPLOT reselects, the wetlands are analyzed to see if the boundary crosses into a designated primary nursery area (PNA). If this occurs, the wetland is rated Exceptional functional significance for the overall significance.

Assumptions: The PNA data received from the North Carolina Division of Marine Fisheries is accurate and up-to-date.

Threatened or Endangered Species or Natural Heritage Exemplary or Unique Natural Ecosystem or Special Wildlife Habitat Area (orc03)

Coverages Used: wh_id

Description of process: Using an ARCPLOT reselect, polygons are queried to determine if a threatened or endangered species point lies within its boundary. If so, the wetland receives an H rating for the overall significance. Only T/E occurrences with a given degree of accuracy are accepted for this evaluation.

Assumptions: The endangered/threatened species data received from the North Carolina Natural Heritage Program is accurate and up-to-date.

Overall Wetland Rating

Overall Wetland Functional Significance (owr1)
Coverages Used: master

Description of process: Using ARCPLOT, the results of WQF01, HYF01, HAF01, ORC01, ORC02, ORC03 and ORC04 are reviewed and combined appropriately.

Assumptions: WQF01, HYF01, HAF01, PRF011, ORC01, ORC02, ORC03 and ORC04 have been successfully completed.

REFERENCES CITED

Adamus, P.R., L.T. Stockwell, E.J. Clairain, Jr., M.E. Morrow, L.P. Rozas, and R.D. Smith. 1991.
Wetland Evaluation Technique (WET) Volume I: Literature Review and Evaluation Rationale. Wetlands Research Program Technical Report WRP-DE-2. US Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.

Adamus, P.R., E.J. Clairain, R.D. Smith, and R.E. Young. 1987. *Wetland Evaluation Technique (WET) Volume II: Methodology*. US Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.

Allen, H.H. 1979. Role of Wetland Plants in Erosion Control of Riparian Shorelines. pp. 403-414 in P.E. Greeson, J.R. Clark and J.E. Clark (eds.) *Wetland Functions and Values: The State of Our Understanding*. American Water Resources Association. Minneapolis, MN.

Arnold, J.G., M.D. Bircket, J.R. Williams, W.F. Smith, and H.N. McGill. 1987. Modeling the Effects of Urbanization on Basin Water Yield and Reservoir Sedimentation. *Water Resources Bulletin* 23:1101-1107.

Arnold, J.G., J.R. Williams, A.D. Nicks, and N.B. Sammons. 1990. *SWRRB: A Basin Scale Simulation Model for Soil and Water Resources Management*. Texas A&M Press.

Beasley, D.B. and L.F. Huggins. 1981. *ANSWERS User's Manual.* EPA 905/9-82-001. US Environmental Protection Agency, Region V. Chicago, IL.

Bedford, B.L. and E.M. Preston. 1988. Developing the Scientific Basis for Assessing Cumulative Effects of Wetland Loss and Degradation on Landscape Functions: Status, Perspectives, and Prospects. *Environmental Management* 12:751-771.

Bedient, P.P., W.C. Huber, and J.P. Heaney. 1976. Modeling Hydrologic-Land Use Interactions in Florida. pp. 362-366 in W.R. Ott (ed.), *Proceedings, Conference on Environmental Modeling and Simulation*. EPA 600/9-76-016. US Environmental Protection Agency. Washington, DC.

Bledsoe, B.P., D.M. Haupt, L.A. Sutter, J.E. Wuenscher. 1997. A Geopraphic Information System for Targeting Wetland Restoration. North Carolina Department of Environment and Natural Resources, Raleigh, NC.

Benner, C.S., P.L. Knutson, R.A. Brochu, and A.R. Hurme. 1982. Vegetative Erosion Control in an Oligohaline Environment, Currituck Sound, North Carolina. *Wetlands* 2:105-117.

Bormann, F.H., G.E. Likens, T.G. Siccama, R.S. Pierce and J.S. Eaton. 1974. The Export of Nutrients and Recovery of Stable Conditions Following Deforestation at Hubbard Brook. *Ecological Monographs* 44:255-277.

Bradshaw, J.G. 1991. *A Technique for the Functional Assessment of Nontidal Wetlands in the Coastal Plain of Virginia.* Special Report No. 315. Virginia Institute of Marine Science.

Brinson, M.M. 1993. *A Hydrogeomorphic Classification for Wetlands*. Wetlands Research Program Technical Report WRP-DE-3, US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

Brinson, M.M. 1988. Strategies for Assessing the Cumulative Effects of Wetland Alteration on Water Quality. *Environmental Management* 12(5):655-662.

Brinson, M.M., F.R Hauer, L.C. Lee, W.L. Nutter, R.D. Smith, and D. Whigham. 1995. *Guidebook for Application of Hydrogeomorphic Assessments to Riverine Wetlands - Draft.* US Army Corps of Engineers Waterways Experiment Station. Vicksburg, MS.

Brinson, M.M., H.D. Bradshaw, and E.S. Kane. 1984. Nutrient Assimilative Capacity of an Alluvial Floodplain Swamp. *Journal of Applied Ecology* 21:1041-1057.

Brinson, M.M., B.L. Swift, R.C. Plantico, and J.S. Barclay. 1981. *Riparian Ecosystems: Their Ecology and Status*. FWS/OBS-81/17. US Fish and Wildlife Service. Washington, DC.

Brittingham, M.C. and S.A. Temple. 1983. Have Cowbirds Caused Forest Songbirds to Decline? *Bioscience* 33:31-35.

REFERENCES CITED

Brooks, R.P., D.E. Arnold, E.D. Bellis, C.S. Keener, and M.J. Croonquist. 1990. *A Methodology for Biological Monitoring of Cumulative Impacts on Wetland, Stream, and Riparian Components of Watersheds.* Association of Wetland Managers, Inc. Berne, NY.

Brown, M.T., J. Schaefer, and K. Brandt. 1990. *Buffer Zones for Water, Wetlands, and Wildlife in East Central Florida.* University of Florida Center for Wetlands. Gainesville, FL.

Brown, M. and J.J. Dinsmore. 1986. Implications of Marsh Size and Isolation for Marsh Bird Management. *Journal of Wildlife Management* 50:392-397.

Brun, L.J., J.L. Richardson, J.W. Enz, and J.K. Larsen. 1981. Stream flow Changes in the Southern Red River Valley of North Dakota. *North Dakota Farm Research* 38:11-14.

Burkham, D.E. 1976. *Hydraulic Effects of Changes in Bottomland Vegetation on Three Major Floods*. Paper 655-J. US Geological Survey. Reston, VA.

Campbell, R.G. 1989. *Water Quality Mid-year Report.* Weyerhaeuser Research and Development Report. New Bern Forestry Research Station. New Bern, NC.

Canter, L.W. 1987. Nitrates and Pesticides in Groundwater: An Analysis of a Computer-Based Literature Search. pp. 153-174 in D.M. Fairchild (ed.). *Ground Water Quality and Agricultural Practices.* Lewis Publishers. Chelsea, MI.

Carper, G.L. and R.W. Bachman. 1984. Wind Resuspension of Sediments in a Prairie Lake. *Canadian Journal of Fisheries and Aquatic Science* 41:1763-1767.

Carter, V., M.S. Bedinger, R.P. Novitski, and W.O. Wilen. 1979. Water Resources and Wetlands. pp. 344-376 in P.E. Greeson, J.R. Clark and J.E. Clark (eds.) *Wetland Functions and Values: The State of Our Understanding*. American Water Resources Association. Minneapolis, MN.

Chang, M., J.D. McCullough, and A.B. Granillo. 1983. Effects of Land Use and Topography on Some Water Quality Variables in Forested East Texas. *Water Resources Bulletin* 19:191-196.

Chescheir, G.M., J.W. Gilliam, R.W. Skaggs, and R.G. Broadhead. 1987. *The Hydrology and Pollutant Removal Effectiveness of Wetland Buffer Areas Receiving Pumped Agricultural Drainage Water.* Project No. 70028/70029. Water Resources Research Institute of the University of North Carolina. Raleigh, NC.

Coats, R.N. and T.O. Miller. 1981. Cumulative Silvicultural Impacts on Watersheds: A Hydrologic and Regulatory Dilemma. *Environmental Management* 5(2):147-160.

Conger, D.H. 1971. *Estimating Magnitude and Frequency of Floods in Wisconsin.* Open-File Report. US Geological Survey. Madison, WI.

Cooper, J.R., J.W. Gilliam, R.B. Daniels, and W.P. Robarge. 1987. Riparian Areas as Filters for Agricultural Sediment. *Journal of the Soil Science Society of America* 51:416-420.

Cooper, J.R., J.W. Gilliam, and T.C. Jacobs. 1986. Riparian Areas as a Control of Non-point Pollutants. pp. 166-192 in D.L. Correll (ed.), *Watershed Research Perspectives*. Smithsonian Institution Press, Washington, DC.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. US Fish and Wildlife Service Report. FWS/OSB-79/31. 131 p.

Croonquist, M.J. and R.P. Brooks. 1991. Use of Avian and Mammalian Guilds as Indicators of Cumulative Impacts in Riparian-Wetland Areas. *Environmental Management* 15:701-714.

REFERENCES CITED

Dahl, T.E. 1990. *Wetland Losses in the United States 1780's to 1980's*. US Department of the Interior, Fish and Wildlife Service, Washington, DC.

Daniel, C.C. III. 1981. Hydrology, Geology, and Soils of Pocosins: A Comparison of Natural and Altered Systems. pp. 69-108 in C.J. Richardson (ed.) *Pocosin Wetlands*. Hutchinson Ross Publishing. Stroudsburg, PA.

Daniel, T.C., R.C. Wendt, P.E. McGuire and D. Stoffel. 1982. Nonpoint Source Loading Rates From Selected Land Uses. *Water Resources Bulletin* 18(1):117-120.

DCM. 1992a. Final Assessment of the North Carolina Coastal Management Program. Coastal Zone Enhancement Grants Program. Section 309, Coastal Zone Management Act. Raleigh, NC.

DCM. 1992b. Final Strategy for Achieving Enhancements to the North Carolina Coastal Management Program. Coastal Zone Enhancement Grants Program. Section 309, Coastal Zone Management Act. North Carolina Division of Coastal Management. Raleigh, NC.

DCM. 1997. Final Assessment and Strategy of the North Carolina Coastal Management Program. Coastal Zone Enhancement Grants Program. Section 309, Coastal Zone Management Act. North Carolina Division of Coastal Management. Raleigh, NC.

DEHNR. 1991. *An Evaluation of Vegetative Buffer Areas for Water Quality Protection*. NC Department of Environment, Health and Natural Resources, Division of Environmental Management. Raleigh, NC.

DEM, 1991. *Original Extent, Status and Trends of Wetlands in North Carolina*. Report No. 91-01. NC Department of Environment, Health and Natural Resources, Division of Environmental Management, Raleigh, NC.

DEM, 1993. *Indicators of Freshwater Wetland Function and Value for Protection and Management*. Report No. 93-01. North Carolina Department of Environment, Health and Natural Resources, Division of Environmental Management. Raleigh, NC.

Dendy, F.E. 1974. Sediment Trap Efficiency of Small Reservoirs. *Transactions A.S.A.E.* 17:898-901.

Detenbeck, N.E., C.A. Johnston, and G.J. Niemi. 1988. *The Effect of Wetlands on Lake Water Quality: A Landscape Approach*. Natural Resources Research Institute, Univ. of Minnesota, Duluth.

Duda, A.M. 1982. Municipal Point Source and Agricultural Non-Point Source Contributions to Coastal Eutrophication. *Water Resources Bulletin* 18:397-406.

Edgerton, C.R. 1973. *Handbook of Design for Highway Surface Drainage Structures*. North Carolina Department of Transportation. Raleigh, NC.

Farnworth, E.G., M.C. Nichols, C.N. Vann, L.G. Wolfson, R.W. Bosserman, P.R. Hendrix, F.B. Gallery, and J.L. Cooley. 1979. *Impacts of Sediment and Nutrients on Biota in Surface Waters of the United States*. EPA-600/3-79-105. US Environmental Protection Agency. Washington, DC.

Flake, L.D. 1979. Wetland diversity and waterfowl. pp. 312-319 in P.E. Greeson, J.R. Clark and J.E. Clark, eds.) *Wetland Functions and Values: The State of Our Understanding*. American Water Resources Association. Minneapolis, MN.

Flores, A.C., P.B. Bedient, and L.W. Mays. 1981. Method for Optimizing Size and Location of Urban Detention Storage. pp. 357-365 in *Proceedings of the International Symposium of Urban Hydrology, Hydraulics and Sediment Control*. ASCE. New York, NY.

Fraver, S. 1993. *Edge Effects in the Mixed Hardwood Forests of the Roanoke River Basin.* M.S. Thesis. Department of Forestry, North Carolina State University. Raleigh, NC.

Froelich, P.N. 1988. Kinetic control of dissolved phosphate in natural rivers and estuaries: a primer on the phosphate buffer mechanism. *Limnol. Oceanogr.* 33:649-668.

REFERENCES CITED

Gilliam, J.W., R.W. Skaggs, and C.W. Doty. 1986. Controlled Agricultural Drainage: An Alternative to Riparian Vegetation. pp. 225-243 in D.L. Correll (ed.), *Watershed Research Perspectives*. Smithsonian Institution Press, Washington, DC.

Goodwin, R.A. 1987. *Soil Survey of Carteret County, North Carolina*. USDA Soil Conservation Service. Raleigh, NC.

Gosselink, J.G. and L.C. Lee. 1986. Cumulative Impact Assessment Principles. *Proceedings of National Wetland Symposium: Mitigation of Impacts and Losses*, pp. 196-203. Association of State Wetland Managers, Berne, NY.

Harris, L.D. 1988. The Nature of Cumulative Impacts on Biotic Diversity of Wetland Vertebrates. *Environmental Management* 12:675-693.

Harris, L.D. 1989. The Faunal Significance of Fragmentation in Southeastern Bottomland Forests. *Proceedings of the Symposium: The Forested Wetlands of the Southern United States.* Southeastern Forest Experiment Station Gen Tech. Report SE-50. US Forest Service, USDA.

Hart, J.T. 1982. Uptake of Trace Metals by Sediments and Suspended Particulates: A Review. *Hydrobiology* 91:299-313.

Hefner, J.M. and J.D. Brown. 1985. Wetland Trends in the Southeastern United States. *Wetlands* 4:1-12.

Hemond, H.F. and J. Benoit. 1988. Cumulative Impacts on Water Quality Functions of Wetlands. *Environmental Management* 12(5):639-653.

Johnston, C.A., N.E. Detenbeck, J.P. Bonde, and G.J. Niemi. 1990. The Cumulative Effect of Wetlands on Stream Water Quality and Quantity: A Landscape Perspective. *Biogeochemistry* 10:105-141.

Johnston, C.A. 1991. Sediment and Nutrient Retention by Freshwater Wetlands: Effects on Surface Water Quality. *Critical Reviews in Environmental Control* 21:491-565.

Jones, J.R., B.P. Borofka, and R.W. Bachmann. 1976. Factors Affecting Nutrient Loads in Some Iowa Streams. *Water Resources Bulletin* 10:117-122.

Jordan, T.E., D.L. Correll, W.T. Peterjohn, and D.E. Weller. 1986. Nutrient Flux in a Landscape: The Rhode River Watershed and Receiving Waters. pp. 57-76 in D.L. Correll (ed.), *Watershed Research Perspectives*. Smithsonian Institution Press, Washington, DC.

Kantrud, H.A. and R.F. Stewart. 1984. Ecological Distribution and Crude Density of Breeding Birds on Prairie Wetlands. *Journal of Wildlife Management* 48:426-437.

Karr, J.R. and I.J. Schlosser. 1977. *Impact of Near-stream Vegetation and Stream Morphology on Water Quality and Stream Biota*. EPA 600/3-77-097. US Environmental Protection Agency. Washington, DC.

Karr, J.R. and R.R. Roth. 1971. Vegetation Structure and Avian Diversity in Several New World Areas. *American Naturalist* 105:423-435.

Khorram, S., H. Cheshire, K. Siderelis, and Z. Nagy. 1992. *Mapping and GIS Development of Land Use and Land Cover Categories for the Albemarle-Pamlico Drainage Basin*. Albemarle-Pamlico Estuarine Study Project 91-08. NC Department of Environment, Health and Natural Resources, Raleigh, NC.

Kittelson, J.M. 1988. Analysis of Flood Peak Moderation by Depressional Wetland Sites. in D.D. Hook (ed.) *The Ecology and Management of Wetlands, Volume I: Ecology of Wetlands*. Timber Press. Portland, OR.

Knight, R.L., B.R. Winchester, and J.C. Higman. 1984. Carolina Bays - Feasibility for Effluent Advanced Treatment and Disposal. *Wetlands* 4:177-204.

Knutson, P.L., R.A. Brochu, W.N. Seelig, and M. Inskeep. 1982. Wave Dampening in *Spartina alterniflora* Marshes. *Wetlands* 2:87-104.

REFERENCES CITED

Kuenzler, E.J. and N.J. Craig. 1986. Land Use and Nutrient Yields of the Chowan River Watershed. pp. 77-107 in D.L. Correll (ed.), *Watershed Research Perspectives*. Smithsonian Institution Press, Washington, DC.

Kuenzler, E.J., P.J. Mulholland, L.A. Yarbro, and L.A. Smock. 1980. *Distributions and Budgets of Carbon, Phosphorus, Iron and Manganese in a Floodplain Swamp Ecosystem*. Report No. 157. Water Resources Research Institute, University of North Carolina, Raleigh, NC.

Landers, J.L. T.T. Fendley, and A. Johnson. 1977. Feeding Ecology of Wood Ducks in South Carolina. *Journal of Wildlife Management* 41:118-127.

Larson, J.S. M.S. Bedinger, C.F. Bryan et al. 1981. Transition From Wetlands to Uplands in Southeastern Bottomland Hardwood Forests. pp. 225-273 in J.R. Clark and J. Benforado (eds.) *Wetlands of Bottomland Hardwood Forests.* Elsevier Scientific Publishing Co., New York.

Leibowitz, S.G., B. Abbruzzese, P.R. Adamus, L.E. Hughes, and J.T. Irish. 1992. *A Synoptic Approach to Cumulative Impact Assessment: A Proposed Methodology*. EPA/600/R-92/167, US EPA Environmental Research Laboratory, Corvallis, OR.

Leonard, R.A. 1980. Herbicides in Surface Waters. pp. 45-87 in R. Grover (ed.) *Environmental Chemistry of Herbicides Volume I*. CRC Press. Boca Raton, FL.

Leopold, L.B., M.G. Wolman, and J.P. Miller. 1964. *Fluvial Processes in Geomorphology*. W.H. Freeman. San Francisco, CA.

Lotrich, V.A. 1973. Growth, Production and Community Composition of Fishes Inhabiting a First, Second, and Third Order Stream of Eastern Kentucky. *Ecological Monographs*,43:337-397.

Lovejoy, T.E., R.O. Bierregaard, A.B. Rylands, et al. 1986. Edge and Other Effects of Isolation on Amazon Forest Fragments. In *Conservation Biology: the Science of Scarcity and Diversity*. M.E. Soule, ed. Sinauer Associates. Sunderland, MA.

Lowrance, R.R., R.L. Todd, and L.E. Asmussen. 1983. Waterborne Nutrient Budgets for the Riparian Zone of an Agricultural Watershed. *Agriculture, Ecosystems and Environment* 10:371-384.

MacArthur, R.H., J.W. MacArthur, and J. Preer. 1964. On Bird Species Diversity: II, Prediction of Bird Census From Habitat Measurements. *American Naturalist* 96:167-171.

Marble, A.D. 1992. *A Guide to Wetland Functional Design*. Lewis Publishers. Boca Raton, FL.

Minshall, W.J., R.C. Petersen, Jr., and C.F. Nimz. 1985. Species Richness in Streams of Different Size from the Same Drainage Basin. *American Naturalist* 125:16-38.

Mitsch, W.J.., C.L. Dorge, and J.R. Wiemhoff. 1979. Ecosystem Dynamics and a Phosphorus Budget of an Alluvial Cypress Swamp in Southern Illinois. *Ecology* 60:1116-1124.

Moore, I.D. and D.L. Larson. 1979. *Effects of Drainage Projects on Surface Runoff from Small Depressional Watersheds in the North-central Region*. Minnesota Water Resources Research Center Bulletin 99.

Mulholland, P.J. 1981. Organic Carbon Flow in a Swamp Stream Ecosystem. *Ecological Monographs* 51:307-322.

Natural Resources Conservation Service. 1994. *Draft Eastern North Carolina River Basin Study*. USDA Soil Conservation Service. Raleigh, NC.

Novitski, R.P. 1979. The Hydrologic Characteristics of Wisconsin Wetlands and Their Influence on Floods, Streamflow, and Sediment. pp. 377-388 in P.E. Greeson, J.R. Clark, and J.E. Clark (eds.) *Wetland Functions and Values: The State of Our Understanding*. American Water Resources Association. Lake Buena Vista, FL.

REFERENCES CITED

O'Brien, A.L. 1988. Evaluating the Cumulative Effects of Alteration on New England Wetlands. *Environmental Management* 12(5):627-636.

Ogawa, H. and J.W. Male. 1983. *The Flood Mitigation Potential of Inland Wetlands*. University of Massachusetts Water Resources Research Center. Amherst, MA.

Ostry, R.C. 1982. Relationship of Water Quality and Pollutant Loads to Land Uses in Adjoining Watersheds. *Water Resources Bulletin* 18:99-104.

Pardo, C.P. 1980. What Is Forestry's Contribution to Non-point Source Pollution? pp. 31-41 in *U.S. Forestry and Water Quality: What Course in the 80's? Proceedings of the Water Pollution Control Federation Seminar*. Richmond, VA.

Pate, P.P., Jr. and R. Jones. 1981. Effects of Upland Drainage on Estuarine Nursery Areas of Pamlico Sound, North Carolina. *Proceedings of the Symposium on Freshwater Inflow to Estuaries*. SanAntonio, TX. 1981.

Patience, N. and V. Klemas. 1993. *Wetland Functional Health Assessment Using Remote Sensing and Other Techniques: Literature Search*. NOAA Technical Memorandum NMFS-SEFSC-319. National Marine Fisheries Service, Southeast Fisheries Science Center, Beaufort Laboratory, Beaufort, NC.

Phillips, J.D. 1989a. Non-point Source Pollution Control Effectiveness of Riparian Forests Along a Coastal Plain River. *Journal of Hydrology* 110:221-237.

Phillips, J.D. 1989b. Non-point Source Pollution Risk Assessment in a Watershed Context. *Environmental Management* 13:493-502.

Phillips, J.D. 1991. Upstream Pollution Sources and Coastal Water Quality Protection in North Carolina. *Coastal Management* 19:439-449.

Porter, B.W. 1981. The Wetland Edge as a Community and its Value to Wildlife. In B. Richardson, (ed.). *Selected Proceedings of the Midwest Conference on Wetland Values and Management*. Freshwater Society.

Reddy, K.R. and W.H. Patrick, Jr. 1976. Effect of Frequent Changes in Aerobic and Anaerobic Conditions in Redox Potential and Nitrogen Loss in a Flooded Soil. *Soil Biol. Biochem.* 8:491-495.

Richardson, C.I. 1985. Mechanisms Controlling Phosphorous Retention Capacity in Freshwater Wetlands. *Science* 228:1424-1427.

Robinson, W.L. and E.G. Bolen. 1984. *Wildlife Ecologoy and Management*. Macmillan Publishing Co., New York.

Roth, R.R. 1976. Spatial Heterogeneity and Bird Species Diversity. *Ecology* 57:773-782.

Schueler, T.R. 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urbans BMPs*. Metropolitan Washington Council of Governments. Washington, DC.

Shepard, J.P. 1994. Effects of Forest Management on Surface Water Quality in Wetland Forests. *Wetlands* 14(1):18-26.

Siegel, D.I. 1988. Evaluating Cumulative Effects of Disturbance on the Hydrologic Function of Bogs, Fens, and Mires. *Environmental Management* 12(5):621-626.

Stewart, B.A., D.A. Woolhiser, W.H. Wischmeier, J.H. Caro, and M.H. Frere. 1976. *Control of Water Pollution from Cropland: An Overview*. EPA 600/2-75-025b, US EPA and USDA. Agricultural Research Service. Washington, DC.

Street, M.W. and J.D. McClees. 1981. North Carolina's Coastal Fishing Industry and the Influence of Coastal Alterations. pp. 238-251 in C.J. Richardson (ed.) *Pocosin Wetlands*. Hutchinson Ross Publishing. Stroudsburg, PA.

Sutter, L. 1999. DCM Wetland Mapping in Coastal North Carolina. Draft. North Carolina Division of Coastal Management, Department of Environment and Natural Resources.

REFERENCES CITED

Swift, B.L., J.S, Larson, and R.M. DeGraff. 1984. Relationship of Breeding Bird Density and Diversity to Habitat Variables on Forested Wetlands. *Wilson Bulletin* 96:48-59.

Taylor, J.R., M.A. Cardamone, and W.J. Mitsch. 1990. Bottomland Hardwood Forests: Their Functions and Values. *Ecological Processes and Cumulative Impacts: Illustrated by Bottomland Hardwood ecosystems*. J.G. Gosselink, L.C. Lee, and T.A. Muir, editors. Lewis Publishers, Chelsea, MI.

Taylor, T.J. and J.S. Barclay. 1985. Renovation of a Plains State Stream - Physical Problem Solving. pp. 62-66 in R.R. Johnson et al. (eds.) *Riparian Ecosystems and Their Management*. General Technical Report RM-120. USDA Forest Service. Fort Collins, CO.

Thomas, D.M. and M.A. Benson. 1970. *Generalization of Streamflow Characteristics from Drainage Basin Characteristics*. Water Supply Paper 1975. US Geological Survey. Washington, DC.

Tiner, R.W., Jr. 1984. *Wetlands of the United States: Current Status and Recent Trends*. US Fish and Wildlife Service. Washington, DC.

Tramer, E.J. and D.E. Suhrweir. 1975. Farm Woodlots as Biogeographic Islands: Regulation of Tree Species Richness. *Bulletin of the Ecological Society of America* 56:53.

US Army Corps of Engineers. 1990. *HEC-1 Flood Hydrograph Package*. CPD-1A Version 4.0. Hydrologic Engineering Center. Davis, CA.

US EPA, 1993. *Guidance Specifying Management Measures for Sources of Non-point Pollution in Coastal Waters*. EPA-840-B-92-002. Assessment and Watershed Protection Division. Washington, DC.

USFWS. 1990. *Wetlands: Meeting the President's Challenge*. 1990 Wetlands Action Plan. US Fish and Wildlife Service. Washington, DC.

Verry, E.S. and D.H. Boelter. 1979. Peatland Hydrology. pp. 389-402 in P.E. Greeson, J.R. Clark, and J.E. Clark (eds.) *Wetland Functions and Values: The State of Our Understanding*. American Water Resources Association. Minneapolis, MN.

Wayne, C.J. 1976. The Effect of Sea and Marsh Grass on Wave Energy. *Coastal Res*. 4:6-8.

Weller, M.W. 1988. Issues and Approaches in Assessing Cumulative Impacts on Waterbird Habitat in Wetlands. *Environmental Management* 12:695-701.

Weller, M.W. and C.S. Spatcher. 1965. *Role of Habitat in the Distribution and Abundance of Marsh Birds*. Iowa Agriculture and Home Economics Experiment Station Special Report No. 43.

Whigham, D.F., C. Chitterling, and B. Palmer. 1988. Impacts of Freshwater Wetlands on Water Quality: A Landscape Perspective. *Environmental Management* 12(5):663-671.

Wilcove, D.S. 1985. Nest Predation in Forest Tracts and the Decline of Migratory Songbirds. *Ecology* 66:1211-1214.

Willard, D.E. 1977. The Feeding Ecology and Behavior of Five Species of Herons in Southeastern New Jersey. *Condor* 79:462-470.

Williams, J.D. and C.K. Dodd, Jr. 1978. Importance of Wetlands to Endangered and Threatened Species. pp. 565-575 in P.E. Greeson, J.R. Clark and J.E. Clark (eds.) *Wetland Functions and Values: The State of Our Understanding*. American Water Resources Association. Minneapolis, MN.

Winter, T.C. 1988. A Conceptual Framework for Assessing Cumulative Impacts on the Hydrology of Non-tidal Wetlands. *Environmental Management* 12(5):605-620.

Wolman, M.G. and A.P. Schick. 1967. Effects of Construction on Fluvial Sediment, Urban and Suburban Areas of Maryland. *Water Resources Research* 3:451-464.

REFERENCES CITED

Yarbro, L.A., E.J. Kuenzler, P.J. Mulholland, and R.P. Sniffen. 1984. Effects of Stream Channelization on Exports of Nitrogen and Phosphorus from North Carolina Coastal Plain watersheds. *Environmental Management* 8:151-160.

Young, R.A., C.A. Onstad, D.D. Bosch, and W.P. Anderson. 1989. AGNPS: A Non-point Source Pollution Model for Evaluating Agricultural Watersheds. *Journal of S*

Appendix A: Wetland Type Definitions

Salt/Brackish Marsh (w-type = 1)

Any salt marsh or other brackish marsh subject to regular or occasional flooding by tides, including wind tides (whether or not the tide waters reach the marshland areas through natural or artificial watercourses), provided this shall not include hurricane or tropical storm waters. Coastal wetland plant species include: *Spartina alterniflora, Juncus roemerianus, Salicornia spp., Distichlis spicata, Limonium spp., Scirpus spp., Cladium jamaicense, Typha spp., Spartina patens and Spartina cynosuroides.*

Estuarine shrub scrub (w-type = 3)

Any shrub/scrub dominated community subject to occasional flooding by tides, including wind tides (whether or not the tide waters reach the marshland areas through natural or artificial watercourses). Typical species include *Myrica spp,* and *Juniperus virginiana*.

Estuarine Forested (w-type = 15)

A forested wetland community subject to occasional flooding by tides, including wind tides (whether or not the tide waters reach the marshland areas through natural or artificial watercourses). Examples include pine dominated communities with *Juncus spp.* understories or fringe swamp communities such as those which occur along the Albemarle and Pamlico sounds.

Maritime Forest (w-type = 16)

A wetland forested community characterized by its stunted growth because of the stresses imposed by its vicinity to salt spray from the ocean. Typical vegetation includes *Quercus virginiana, Acer rubrum,* and *Nyssa biflora*.

Freshwater Marsh (w-type = 2)

Herbaceous areas which are flooded for extended periods during the growing season. Included in this are marshes within lacustrine systems, some managed impoundments, some Carolina Bays, and nontidal other non-tidal marshes (i.e. marshes which do not fall into the Salt/Brackish Marsh category). Typical communities include species of sedges, millets, rushes and grasses not specified in the coastal wetland regulations. Also included is *Arundinaria gigantea, Sagittaria spp., Pontederia spp., Peltandra spp., Polygonum spp.,* and *Typha spp.*

Pocosin (w-type = 4)

Palustrine scrub/shrub communities (i.e. non-Estuarine Scrub/Shrub) dominated by evergreen shrubs, often mixed with *Pinus serotina* or *Pinus taeda*. Typically occur on saturated, acid, nutrient poor, sandy or peaty soils; usually removed from large streams and subject to periodic burning.

Bottomland Hardwood or Riverine Swamp Forests (w-type = 6)

Riverine forested or occasionally scrub-shrub communities usually occurring in floodplains, that are semi-permanently to seasonally flooded. In bottomland hardwood systems, typical species include *Quercus laurifolia, Quercus nigra, Quercus michauxii, Quercus lyrata, Liquidambar styraciflua, Fraxinus pennsylvanica, Populus spp., Salix spp., Betula nigra,* and occasionally *Pinus spp,* In swamp forest systems, typical species include *Taxodium spp., Nyssa spp., Fraxinus pennsylvanica,* and *Acer rubrum.*

Depressional Swamp Forest (w-type = 7)

Very poor;y drained non-riverine forested or scrub/shrub communities which are semi-permanently flooded or including temporarily flooded. Typical species include *Taxodium spp., Nyssa spp., Fraxinus pennsylvanica, Acer rubrum* and *Carya aquatica*.

Headwater Swamps (w-type = 17)

Wooded, riverine systems along first order streams. These include hardwood dominated communities with moist soil most of the year. Channels receive their water from overland flow and rarely overflow their own banks.

Hardwood Flat (w-type = 9)

Poorly drained interstream flats not associated with rivers or estuaries. Seasonally saturated by high water table or poor drainage. Species vary greatly but often include *Liquidambar styraciflua* and *Acer rubrum.*

Appendix A: Wetland Type Definitions (cont)

Pine Flats (w-type = 10)

Palustrine, seasonally saturated pine communities on hydric soils that may become quite dry for part of the year, generally on flat or nearly flat areas that are not associated with a river or stream system. Usually dominated by *Pinus taeda*. This category does not include managed pine systems.

Managed Pinelands (w-type = 11)

Seasonally saturated, managed pine forests (usually *Pinus taeda*) occurring on hydric soils. This wetland category may also contain non-managed pine forests occurring on hydric soils. Generally these are areas that were not shown on National Wetland Inventory maps. These areas may or may not be jurisdictional wetlands.

Human Impacted Wetlands (w-type 40)

Areas of human impact have physically disturbed the wetland, but the area is still a wetland. Impoundments and some cutovers are included in this category, as well as other disturbed areas such as power lines.

Drained Wetlands (w-type = 21 - 37)

Any wetland system described above that is, or has been, partially drained/ditched according to the US Fish & Wildlife National Wetland Inventory maps.

Cleared Wetlands (w-type 41 - 57)

Areas of hydric soils for which satellite imagery indicates a lack of vegetation in *both* 1988 *and* 1994. These areas are likely to no longer be wetlands.

Cutover Wetlands (w-type 61-77)

Areas for which satellite imagery indicates a lack of vegetation in 1994. These areas are likely to be still be wetlands, however, but they have been recently cut over. Vegetation in these areas may be revegetating naturally or may be in use for silvicultural activities.

<u>Wetland Modifiers Explanation:</u>

Drained: add 20 to w-type (e.g., drained hardwood flat = 29)
Cleared: add 40 to w-type (e.g., cleared pocosin = 44)
Cutover: add 60 to w-type (e.g., cutover pine flat = 70)
Note that these modifiers are not applicable to Managed Pine and Human Impacted wetland types.

Appendix B: Functional Assessment Field Sampling and Data Analysis

INTRODUCTION

The coastal plain of North Carolina contains a diverse collection of wetland types. These different wetland types perform various natural functions that are beneficial to the surrounding landscape. The role of North Carolina's wetlands as a sanctuary to wildlife has long been recognized (Wilson, 1962). Wetlands and their critical roles in protecting water quality (Leopold, 1974; DEM, 1992), preventing floods, erosion (Carter et al., 1978), and maintaining fish populations (Larson, 1981) have become increasingly evident.

The North Carolina Division of Coastal Management (NC DCM) developed a Geographic Information System (GIS) wetland functional assessment procedure for the North Carolina coastal plain. The primary objective of the procedure was to assess the relative function of wetlands by small watershed unit. The method was developed as part of the Carteret County Advance Identification (ADID) of Wetlands Project. NC DCM developed a method to identify field indicators of functions that would support statements in the GIS-based assessment with field-based data. The first wetlands that were mapped were drawn from the sample pool of functionally assessed wetlands. Generalities made from the field data will be incorporated into the GIS-based assessment procedure.

Initially, the field method divided wetlands into broad hydrogeomorphic (HGM) classes based on their position in the landscape: riverine and flats/depressional. The tidally-influenced marshes associated with estuarine waters were not included in the functional assessment procedure because of their protection under the North Carolina Coastal Area Management Act (CAMA). The field method provided information on functions that further supported water quality, hydrology, and habitat functions.

The methods developed in the Carteret County ADID provided reasonable delineations for 11 wetland types and 15 function indicators (Table 1). The entire dataset was divided by their HGM class (flats/depressional or riverine). For the flats/depressional dataset the hydrology function contained two indicators, surface water storage (SURF) and subsurface water storage (SUBSURF). The riverine dataset's hydrologic function consisted of SURF and SUBSURF as well as ground water modification (GW MOD) and velocity reduction (VEL RED).

The water quality function for the flats/depressional dataset contained the following indicators: nutrient transformations and processing (NUTRAN), removal of elements and compounds in precipitation and dryfall (PPT), storage of organic matter in soils (SOM), soil organic carbon to maintain spodosols (SPOD), and organic carbon export (OCEXP). The riverine dataset consisted of the same functions NUTRAN and OCEXP as the flats dataset as well as removal of dissolved and particulate material (REMOVMAT), and retention of woody structure (WOOD).

Both the riverine and the flats/depressional datasets contained the same four habitat indicator functions in the study. Study sites were examined for the presence of a characteristic plant community (PLANT), characteristic detrital biomass maintenance (DETRIT), vertical habitat structure maintenance (VERT), and maintenance of food web support (FOOD). For a summary of flats and riverine indicator functions, see Tables 2 and 3.

NC DCM examined 12 primary wetland types found in the coastal plain of North Carolina: freshwater marsh (FW MAR), estuarine shrub-scrub (EST SS), pocosin (POCOSN), bottomland hardwood (BLH), swamp (SWAMP), hardwood flat (HDWDFLT), pine flat (PINE FLT), pine plantation (PLANTN), maritime forest (MAR FOR), estuarine forest (EST FOR), and headwater (HDWTR). Appendix A contains definitions and major species of each wetland type. Using scores derived from each major function and overall totals, we attempted to group wetland types by various statistical methods into three separate functional value classes. These functional value classes were referred to as High, Medium, and Low.

METHODS

Wetland types were analyzed on the basis of their mean scores derived from hydrogeomorphic indicators observed in the field. The scoring system developed assigned points to each functional indicator. Two primary statistical techniques were utilized in an attempt to group wetland types according to their functional values. Cluster Analysis was used to separate the wetland types into major groups. The Multi-Response Permutation Procedure was utilized to test whether a significant difference between the groups exists. NC DCM also employed conventional statistical methods to examine our data. The parametric method, Analysis of Variance (ANOVA) and the non-parametric method Wilcoxon Rank Sum were used on each wetland type in the respective datasets. The wetland types/groups were compared to major functions (hydrology, water quality, habitat) by multiple comparison techniques (Dunn's method and SAS General Linear Model/Ryan-Einot-Gabriel-Welsch, GLM-REGW) where applicable.

Cluster Analysis

The cluster analysis statistical technique is from the PC-ORD System (McCune, 1991). PC-ORD software provides programs for multivariate analysis that are compatible on MS/PC-DOS microcomputers (McCune, 1991). Cluster analysis is a technique which sorts sample units (in our case, wetland types) into groups or clusters based on their overall resemblance to one another (Ludwig and Reynolds, 1988). The cluster models which presented in this report are displayed in a hierarchical structure called a dendrogram.

There are numerous methods by which PC-ORD can group clusters. For a review on Cluster Analysis and the different methods of grouping clusters, consult Gauch (1982) or Ludwig and Reynolds (1988). Ward's Method, or "minimum variance clustering," is quite popular among community ecologists since it operates on the underlying principle that at each stage of clustering the variance within clusters is minimized with respect to the variance between clusters (Ludwig and Reynolds, 1988). We found that measuring Euclidean distance by Ward's Method resulted in the lowest percent chaining. Chaining refers to the sequential addition of small groups to one or a few large groups in the cluster analysis (McCune, 1991). Dendrograms that have a high percent chaining are usually undesirable as they are not helpful in defining subgroups (McCune, 1991). Therefore, we used high percent chaining as the primary basis for eliminating poor clustering models.

Multi-Response Permutation Procedures

Multi-Response Permutation Procedures (MRPP) are non-parametric techniques for testing the hypothesis that no difference exists between two or more groups of entities (McCune, 1991). The MRPP is a technique similar in purpose to the t-test and one-way analysis of variance F test; however, the applicability of the MRPP does not require assumptions of normality or homogeneity (Zimmerman, 1985). A complete review on the MRPP technique can be found in Biondini (1985) and Zimmerman (1985).

MRPP employs various methods for weighting and distance measures to determine the necessary test statistics. We used the n/sum(n) method (where n is the number of items in a given group) for the weighting of groups, and the Euclidean distance method for the basic distance measure. The test statistic derived is the difference between the observed and expected deltas divided by the square root of the variance in delta (McCune, 1991). To explain the separation of the groups, the observed delta is compared to the expected delta (McCune, 1991). A probability value expresses the likelihood of getting a delta as extreme or more so than the observed delta (McCune, 1991). This probability value is the primary statistic used in our MRPP analysis.

The conventional statistics (ANOVA, Wilcoxon, Kruskal-Wallis), and the SAS procedure GLM-REGW, were performed on PC-SAS by the North Carolina State Center for Health & Environmental Statistics. Dunn's procedure was utilized for multiple comparisons between wetland types because of its ability to examine data with different sample sizes and data which were not normally distributed.

RESULTS

The field data were subjected to Cluster Analysis (CA) and Multi-Response Permutation Procedures (MRPP). Analyses were performed on all pertinent wetland types versus all indicator functions and then broken down into indicator function clustering and MRPP analysis as it would pertain to the three primary wetland functions: hydrology, water quality, and habitat. For example, the flats dataset clustering of 10 wetland types against the hydrologic function utilizes 2 indicator functions: SURF and SUBSURF (Table 2). Because the MRPP cannot be completed when a cluster group consists of a single wetland type, groups occasionally had to be combined. This combination is noted when appropriate.

The Flats/Depressional Dataset

The flats dataset contains 10 wetland types and 11 indicator functions (Table 2). The indicator functions were grouped within the three major functions as shown in Table 2. A cluster analysis was run on all indicator functions and each major wetland function. In all, four separate cluster analyses were performed on the flats data. A summary of the clustering data can be reviewed in Table 4.

Four separate analyses of MRPP were also performed on the corresponding cluster groupings (for each major function and all indicator functions together). The primary test statistic which we considered was the p-value of a smaller or equal delta. All other information such as group Euclidean average distance or observed and expected deltas were listed in the respective figures. A summary of the MRPP groups for the flats dataset may be viewed in Table 5.

The cluster analysis performed with the flats wetland type versus all the indicator functions yielded three primary clusters with a 10.00 percent chaining (Figure 1). Consult Table 4 for the group clusters of "All Indicator" functions seen in the flats dataset. The MRPP analysis showed a p-value of .17%, rejecting the null hypothesis (Figure 2). Therefore, there was a statistically significant difference exhibited between each of the groups.

Appendix B (cont.)

The cluster analysis of the wetland types versus the hydrologic functions gave three primary clusters with a percent chaining of 45.00 (Figure 1). Refer to Table 4 for group clusters in the hydrology function exhibited in the flats dataset. The MRPP analysis was pooled into two groups (cluster groups A and B relate to MRPP group 1 while group C correlated to group 2) (Table 6). The MRPP gave a p-value of .47% which suggests that the groups are statistically different from one another (Figure 2).

The water quality function produced four clusters with a percent chaining of 10.00 (Figure 3). Consult Table 4 for group clusters of the water quality function in the flats dataset. The wetland type HDWTR was grouped with Group 1 in the MRPP. The MRPP analysis showed a significant difference between the groups with a p-value of .32% (Figure 4).

Cluster analysis of the habitat function exhibited three primary groups with a percent chaining of 20.00 (Figure 3). Refer to Table 4 for group clusters of the habitat function in the flats dataset. The MRPP analysis again showed that there were significant differences between the groups with a p-value of .11% (Figure 4).

Analysis of Variance tests were run on the flat wetland types with respect to each major function (hydrology, water quality, and habitat). In each major function, a highly significant difference ($p > .0001$) among the wetland types was demonstrated. To examine differences among different groups of wetland types, a multiple comparison method (SAS-GLM-REGW) was employed. However, in order to perform this test, the data must be normally distributed. In the flats dataset, only the data associated with the water quality function was normally distributed. The SAS-REGW test yielded three primary groups: Group 1 (POCOSIN, SWAMP, and HDWTR), Group 2 (HDWDFLT, FW MARSH, MAR FOR, PINE FLT, and EST SS), and Group 3 (EST FOR, PLANTN).

For the hydrology and habitat major functions of the flats dataset a SAS-REGW could not be performed (not normally distributed); however, Wilcoxon Rank Sum test and the multiple comparative analog Dunn's Procedure were utilized. Both the hydrology and habitat functions exhibited significant Wilcoxon Rank Sum p-values ($p > .0001$). The Dunn's Procedure for the hydrology function yielded four pairs of wetland types significantly different from one another (EST SS-SWAMP, PINE FLT-SWAMP, PLANTN-SWAMP, and POCOSIN-SWAMP). For the habitat function, Dunn's Procedure gave eight pairs of wetland types significantly different from one another: EST FOR-FW MAR, FW MAR-HDWTR, FW MAR-HDWDFLT, FW MAR-SWAMP, HDWTR-PLANTN, PINEFLT-SWAMP, PLANTN-SWAMP, and POCOSIN-SWAMP.

The Riverine Dataset

The riverine dataset was comprised of 8 wetland types and 12 indicator functions (Table 3). The indicator functions were grouped within each major function as shown in Table 3. A cluster analysis was run on all the data in the riverine dataset and by each major function. A summary of the cluster groups for the riverine dataset is shown in Table 5. MRPP analyses were run on each riverine major function and the overall function. A summary of the MRPP groups can be viewed in Table 7.

The cluster analysis of the riverine wetland types versus all the indicator functions showed four clusters with a percent chaining of 27.27 (Figure 5). The MRPP yielded a significant p-value of .38% (Figure 6). For the MRPP analysis, the wetland type EST SS was added to Group 1 and PLANTN was added to Group 2 (Table 7).

Riverine wetland types clustered versus the hydrology functions yielded four groups with a 45.45% chaining (Figure 5). The MRPP for the hydrology function was not able to reject the null hypothesis with a p-value of 33.7% (Figure 6). Therefore, the groups were not significantly different.

The water quality function produced a dendrogram with 36.36% chaining and four clusters (Figure 7). The MRPP analysis for the riverine water quality function gave a statistically significant p-value of 1.1% (Figure 8). The wetland type EST SS, which clustered as a single entity, was added to Group 2 of the MRPP (Table 7).

Riverine data clustered versus the habitat function yielded a 27.27% chaining with four primary groups (Figure 7). The MRPP analysis of the riverine habitat function yielded a significant p-value of .38% (Figure 8). The wetland types EST SS and PLANTN clustered as single entities; therefore, they were added to the MRPP groups 1 and 2, respectively.

Analysis of Variance (ANOVA) tests were run on the primary three riverine wetland types (BLH, HDWTR, and SWAMP) with respect to each major function. Hydrology, water quality, and habitat all yielded p-values that were not statistically significant. The data in each major function were not normally distributed, therefore the SAS-REGW procedure would not apply; however, Wilcoxon Rank Sum tests were performed to detect any differences among wetland types. Hydrology was the only major function to yield a significant p-value in the Wilcoxon test ($p > 0.0420$). The Dunn's Procedure for the riverine hydrology function showed one pair of wetland types significantly different from each other: BLH-SWAMP.

DISCUSSION

In the analyses of the data we have attempted to group wetland types in terms of their functional value as determined by hydrogeomorphic indicators. Initially, we examined the entire dataset for overall trends in the data. We quickly realized that the data represented two separate datasets: those samples associated with the flats/depressional sites and those with the riverine sites. The samples were then sorted according to their respective hydrogeomorphic class with the resulting statistical analyses focused separately on the flats and the riverine datasets. The basis for the statistical analyses of all the data was the mean indicator scores derived from field indicators related to each major function (hydrology, water quality, and habitat) and to the overall function. We have shown through various statistical methods how different wetland types may group together with respect to each major function. From these groups we developed a wetland valuation rating (High, Medium, and Low) for each major function and the overall dataset. The High, Medium, and Low groups that we proposed were based on trends observed in the statistical data and support from the literature.

The Flats/Depressional Dataset

Each MRPP analysis that was run on the flats dataset produced statistically significant differences among the cluster groups. We accepted a significance level of 5% and in every case the p-value reflected significance well below that figure. This confirmed that the cluster analyses were separating out groups and that these groups were statistically different from the others.

An interesting and useful cluster analysis performed on the flats dataset was that of the wetland types versus all the functions. In that particular dendrogram (Figure 1), three primary groups are found. A potential High, Medium, and Low grouping can be formulated from the analysis. Group A consisted of the SWAMP and HDWTR wetland types and could from the higher mean indicator scores (Table 8) be classified as the High functional value wetlands. Group B consisted of MAR FOR, HDWDFLT, EST FOR, and EST SS wetland types and could be classified as the Medium functional value class. The Low functional value class would be comprised of the POCOSIN, PLANTN, PINE FLT, and FW MAR wetland types (Table 8).

The flats wetland types versus the hydrology function also exhibited a potentially useful dendrogram (Figure 1). Group A consisted only of the SWAMP wetland type and again, could be thought of as in the High grouping. Group B, the Medium functional value grouping, consisted of POCOSIN, HDWDFLT, MAR FOR, HDWTR, FW MAR, EST SS, and EST FOR. The Low rating could be attributed to the wetland types found in Group C: PLANTN, and PINE FLT. The Dunn's Procedure supported the wetland type SWAMP as significantly different than many of the other wetland types in the flats dataset (EST SS, PINE FLT, PLANTN, and POCOSIN).

Considering the two largest clusters of the flats versus water quality function dendrogram (Figure 2), one could divide the wetland types into High and Medium/Low groups. The High group would contain the SWAMP, POCOSN, and HDWTR wetland types while the Medium/Low group would contain the remainder of the wetland types for the flats dataset. The SAS-REGW procedure also confirmed this grouping with the SWAMP/POCOSIN/HDWTR as the High value group for water quality function and the PLANTN and EST FOR wetland types representing the Lower value wetlands. The remainder of the wetland types make up the Medium value wetland group.

The habitat function yielded three groups, which may be classified in the three-tier grouping. The High value group consisted of Group A (SWAMP, HDWDFLT, EST FOR, EST SS, MAR FOR, and HDWTR) wetland types. The Medium tier was composed of Group B (POCOSIN and PINE FLT) wetland types. The Low value group consisted of Group C (PLANTN, ALTERED, and FW MAR) wetland types. Group A had the highest mean indicator scores in the habitat function with Group B and Group C having the medium and low scores, respectively (Table 8). The Dunn's Procedure supported many of the above findings with the wetland types SWAMP and FW MAR significantly different from a number of the wetland types (POCOSIN, PLANTN, PINE FLT, FW MAR) and (EST FOR, HDWTR, HDWDFLT, SWAMP), respectively.

Therefore, based on patterns and trends exhibited by the cluster analyses and further evidence from the MRPP, and supported by the SAS-REGW and Dunn's Procedures, we propose an overall general grouping of wetland types into High, Medium, and Low functional value categories for the flats/depressional dataset.

The High functional value group would include the SWAMP, HDWTR, and the FW MAR wetland types. The SWAMP and HDWTR wetland types often clustered together; however, the FW MAR wetland type often clustered with the Low group (Table 4). The indicator scoring system employed favored forested wetlands, therefore, a wetland type such as FW MAR, with an appreciable amount of open water scored lower and tended to cluster with the lower functional value wetlands. NC DCM included the FW MAR wetland type in the High functional value class for two reasons: (1) the relative scarcity of this wetland type in the coastal plain of North Carolina (Wilson 1962, DEHNR 1991), and (2) examples from the literature supporting its high functional value in relation to hydrology, water quality, and habitat (DEHNR 1991, Mitsch and Gosselink 1986).

The Medium functional value group would contain the following wetland types: HDWDFLT, EST SS, EST FOR, POCOSIN, and MAR FOR. The Low functional value group would consist of the PLANTN and PINE FLT wetland types.

A MRPP analysis was performed on the proposed groupings stated above (excluding FW MAR from the High group). The p-value of .43% showed a statistically significant difference between the groups (Figure 9). The mean indicator scores for each group correlated directly with the High, Medium, and Low classes (Table 8). To further substantiate the SWAMP and HDWTR wetland types as "Highly" functionally valuable wetlands, the following discussion in the riverine dataset section provides examples from the literature to support the inclusion of SWAMP and HDWTR (of both flat and riverine origin) as functionally high value wetlands.

The Riverine Dataset

The riverine dataset was essentially composed of three wetland types: BLH, SWAMP, and HDWTR. Of the 84 sample sites in the riverine dataset, the three aforementioned wetland types comprised 94% of the dataset. The other five wetland types were single samples (Table 3). The flats dataset, with a more equitable distribution of wetland types, provided more potential for a preliminary division into the High, Medium, and Low functional classes. Not unexpectedly, these three riverine wetland types (BLH, SWAMP, and HDWTR) often clustered together, usually with the other wetland types clustering as single entries. Moreover, the riverine dataset showed a consistently higher percentage chaining than the flats/depressional dataset due to the five single wetland type entries. Of the four cluster analyses that were run on the riverine dataset, the primary three (BLH, SWAMP, and HDWTR) clustered together in three occasions: hydrology (Figure 5), habitat (Figure 7), and the overall function (Figure 5).

Given the nature of the riverine dataset, Cluster Analysis was not able to divide the riverine wetland types into different functional value classes. However, Cluster Analysis did reveal that the primary three riverine wetland types (BLH, SWAMP, and HDWTR) represent their own data subset. Standard Analysis of Variance (ANOVA) showed that there was no significant difference between the BLH, SWAMP, and HDWTR wetland types with respect to each major function. The Wilcoxon Rank Sum tests also showed no difference in the three wetland types except for the major function hydrology in which Dunn's Procedure singled our BLH and SWAMP as being significantly different. However, the aforementioned technique was performed solely on the primary three riverine wetland types.

Therefore, NC DCM proposed that the BLH, SWAMP, and HDWTR wetland types make up the riverine High overall functional value group. The basis for this decision stems from their higher overall and major function (hydrology, water quality, and habitat) scores these wetland types exhibited in the data (Table 9). In this case, the BLH and HDWTR wetland types exhibited somewhat lower scores than the SWAMP wetland type (Table 9). Moreover, the MRPP method showed that the groups given by the cluster analysis were significantly different (with the exception of the hydrology function) from one another, therefore, the scores were significantly higher (Table 9).

To further support our data, we have included a few examples from the literature which support the wetland types BLH, SWAMP, and HDWTR (both riverine and flats) as "High" functional value wetlands with respect to each major function and to the overall function (all indicators).

The hydrologic function of the assessment procedure focuses on surface water runoff, floodwater storage, and shoreline stabilization. Surface water runoff is greatly affected by a wetland's size and position in the watershed. Novitzki (1978) showed that 50% of the reduction in flood peaks can result from the first 5% of wetland area in the watershed. Wetlands located in headwaters generally desynchronize tributary and main channel peaks, while lakes and wetlands with restricted outlets hold back floodwaters and attenuate flood peaks (Carter et al., 1978). Vegetative cover also is an integral facet of wetland flood water storage. Vegetation attenuates floodwaters by creating frictional drag in proportion to stem density (Marble, 1992). Adamus et al. 1983, listed from most to least effective the vegetative forms that perform the above function: forested (coniferous), forested (deciduous), shrub-scrub, emergent persistent, emergent non-persistent, and aquatic bed (rooted vascular). Vegetative cover of a wetland also is important in its ability to stabilize a shoreline or a streambank. Kite (1980) showed that vegetation effective for long-term streambank protection exhibits water-tolerant characteristics and penetrating, branching roots. Therefore, a forested wetland located along an intermittent or permanent stream such as a swamp forest or bottomland hardwood, would have the opportunity and ability to demonstrate its function within the respective watershed.

The riverine water quality functions of the assessment procedure focus on non-point source and floodwater cleansing characteristics in determining functional value for a respective wetland. Wetlands located in urban, agricultural, or disturbed watersheds have an increased ability to receive sediments and pollutants. Moreover, the position of a wetland in the landscape is a very important characteristic determining the opportunity of a wetland to receive and retain sediment and nutrients. Headwater riparian wetlands are most critical in terms of ensuring water quality since small streams comprise most of the total stream length within a watershed (Leopold, 1974). In addition, Novitzki (1978b) found that approximately 80% of the sediment entering a wetland was retained in the headwaters.

Sediments, associated nutrients, and toxicants, when transported into a wetland, may be removed by chemical breakdown, burial, and/or assimilated into plant tissue (DEM, 1992). The extent of removal is primarily determined by vegetative cover, duration of flooding, and soil type. Reppert (1979) found that the density of woody vegetation should be greater than 80% for a wetland to effectively trap sediments. Reppert suggests that a wetland with vegetative cover between 50% and 80% can retain moderate amounts of sediment, and an open canopy of 20% to 50% retains only a small proportion of the incoming sediment. Yarbro (1984) showed that phosphorus was efficiently retained in riverine wetlands during flooding conditions. The results showed that when less than 50% of the floodplain was inundated, between 10% and 17% of the incoming total phosphorus was retained. Alternatively, inundation above 50% yielded between 47% and 69% retention of phosphorus. In addition, Jordan (1986) compared four wetlands, two that flooded frequently and two which rarely flooded. The results showed that the forested and herbaceous wetlands that flooded on a frequent basis accumulated significantly larger amounts of sediment than the two wetland areas that rarely flooded. Marble (1992) stated that those wetlands with alluvial, alfisol, ferric, clay or other fine soils will be most effective at phosphorus retention. Therefore, wetlands that are forested, frequently inundated, and contain a suitable soil type for pollutant (toxicants and/or nutrients) removal perform high functional values for the respective watershed.

The habitat function for the assessment procedure considers threatened and endangered species and significant natural areas in addition to habitat characteristics affecting terrestrial and aquatic wildlife. If the wetland contains flora or fauna which appear on the North Carolina's threatened and endangered species list (from the NC Natural Heritage Program) then the wetland functional value rating is High. Because of the transient nature of terrestrial wildlife and the relatively short period of time on site, assessing a functional value for wildlife habitat is often difficult. However, research has shown that the presence of water, vegetative diversity, and surrounding land use (in the watershed) contribute to wildlife abundance and diversity. For example, Brinson (1981) determined that the most heavily used wildlife areas in North Carolina were located in a zone within 600 feet of a stream or open water. In addition, Golet (1978) has shown that more wildlife species occur in wetlands that are hydrologically connected to other wetlands. Forested wetlands with well developed herbaceous, shrub, sapling, and tree layers provide an important habitat for wildlife diversity. Many researchers have found a positive correlation between horizontal and vertical vegetative diversity and wildlife diversity (Bradshaw, 1991; Ammann, 1991; Adamus et al., 1987; Harris et al., 1983; and Odum et al., 1979). In summary, a wetland that rates a High functional value for wildlife habitat would probably show diverse vegetative structure, and be located near a body of open water or along a stream.

Factors that are important to aquatic life in wetlands include the presence of permanent water, frequent flooding, pH, vegetation diversity, and surrounding land use (DEM 1992). The highest value wetlands for aquatic life are permanently flooded or intermittently exposed over at least 10% of their area (Marble 1992). Larson et al. (1981) showed that southeastern bottomland hardwood forests are used by nearly all fishes of the adjoining river as feeding, spawning, and/or nursery areas. Wetlands with well interspersed patches of vegetation or diffuse open stands of vegetation provide the best aquatic habitat (Marble 1992). Generally, the most important wetlands in terms of habitat value contain a mixture of trees and shrubs, emergent plants, aquatic macrophytes, and some open water (DEM 1992).

CONCLUSION

Historically, the objective of the ADID was to determine which wetlands in Carteret County, were of ecologically high value and thus should be protected from dredge and fill. The ultimate goal for this study and others to follow would be to produce wetland maps with functional value indicated and for use by local governments for decision making and long range planning. We visited more than 350 sample sites primarily in Carteret County, and the data retrieved from these sites has enabled us to develop a functional assessment procedure for different wetland types. Initially, the dataset was divided by HGM class, then analyzed primarily by cluster analysis and multi-response permutation procedures.

The flats dataset showed trends in the clustering results which grouped the wetland types SWAMP and HDWTR together. These wetland types had significantly higher mean indicator scores. Consequently, NC DCM classified these wetland types as flats representative of the High functional value wetlands (Table 8). NC DCM also included FW MAR in the High functional group although it usually clustered with the wetland types representative of the Low functional group (PINE FLT and PLANTN). Because of the discrepancies of our scoring system to non-forested wetlands, the relative scarcity of freshwater marshes in the North Carolina coastal plain and the known beneficial functions these wetlands provide, NC DCM decided to include this wetland type in the High functional value class. Alternatively, those wetland types whose mean scores were consistently lower and clustered together were the PINE FLT and PLANTN wetland types. The wetland types of the flats dataset which often clustered together and showed moderate mean indicator scores included: MAR FOR, EST FOR, EST SS, POCOSN, AND HDWDFLT (Table 8).

The riverine dataset showed three primary wetland types, BLH, SWAMP, and HDWTR, which clustered together in all cases but one (water quality). These wetland types also had higher mean indicator scores than the other wetland types in the riverine dataset (Table 9). The groupings displayed in Table 9 are based on the riverine MRPP groups.

One could make a case for not including the five other riverine wetland types (PINE FLT, EST SS, PLANTN, EST FOR, and HDWD FLT) in the statistical analyses since they appeared only as single entries in the dataset, and in fact, this was done with more conventional statistical techniques, with negative results. However, NC DCM felt these wetland types, when included, did exhibit differences from the primary three riverine wetland types (BLH, SWAMP, and HDWTR) which then enabled NC DCM to distinguish the latter group as Higher in functional value. While the BLH, SWAMP, and HDWTR wetland types make up nearly 95% of the riverine dataset, we felt differences shown in mean indicator scores and clustering along with substantial support from the literature warrant the classification of the above 3 wetland types as functionally High value wetlands.

The above recommendations and observations for both the flats/depressional and riverine datasets are geared toward an overall wetland rating through examination of all functions collectively. NC DCM feels that an overall rating for the proposed wetland maps would be the most beneficial for the local and regional planners. Each wetland type could be evaluated and given a rating with respect to each major function (hydrology, water quality, habitat), and in many cases wetland types would differ in functional capabilities with respect to each major function. For this information NC DCM would refer to the cluster summaries of the flats/depressional and riverine datasets.

Appendix B (cont.)

FIGURE 1

FLATS DATA vs ALL INDICATOR FUNCTIONS

```
Percent chaining =  10.00
                       L O G   o f   D I S T A N C E
      -1.119            .040           1.200           2.360           3.519
        |-------+-------+-------+-------+-------+-------+-------+-------+
SWAMP   -----------------------------------|
                                           |-----------A----|
HDWTR   -----------------------------------|                |
                                                            |
MARFOR  ------------|                                       |---------|
                    |---------|                             |         |
HDWDFL  |           |         |                             |         |
        |-----------|         |-------------------------B---|         |
ESTFOR  |                     |                                       |
                              |                                       |
ESTSS   ----------------------|                                       |
                                                                      |
POCOSN  -----------------------------------------------|              |
                                                       |              |
PLANTN  -----------------------------|                 |---C----------|
                                     |-----------|     |
PINEFL  -----------------------------|           |-----|
                                                 |
FWMAR   -----------------------------------------|
```

FLATS DATA vs HYDROLOGY FUNCTION

```
 Percent chaining =  45.00
                      L O G   o f   D I S T A N C E
      -6.685          -4.769          -2.854           -.939            .976
        |-------+-------+-------+-------+-------+-------+-------+------+
SWAMP   ----------------------------------------------------A---------|
                                                                      |
POCOSN  ---------------------|                                        |
                             |---|                                    |
HDWDFL  ---------------------|   |                                    |
                                 |-------|                            |
HDWTR   |                        |       |                            |
        |------------------------|       |----|                       |
FWMAR   |                                |    |                       |
                                         |    |                       |
MARFOR  ---------------------------------|    |------------B----|     |
                                              |                 |     |
ESTSS   ------------|                         |                 |     |
                    |-------------------------|                 |-----|
ESTFOR  ------------|                                           |
                                                                |
PLANTN  --------------------------------------------|           |
                                                    |-----C-----|
PINEFL  --------------------------------------------|
```

FIGURE 2
MULTI-RESPONSE PERMUTATION PROCEDURES (MRPP)

FLATS vs ALL INDICATOR FUNCTIONS

```
INPUT HAS   10  WETLAND
THERE WERE  11  FUNCTIO
WEIGHTING OPTION:  C(I) = n(I)/sum(n(I))

DISTANCE MEASURE = Euclidean

GROUP NUMBER  1 OF SIZE   2 HAS AN AVERAGE DISTANCE =       1.8320208
GROUP NUMBER  2 OF SIZE   4 HAS AN AVERAGE DISTANCE =       2.1452494
GROUP NUMBER  3 OF SIZE   4 HAS AN AVERAGE DISTANCE =       1.0824680
THE TEST STATISTIC IS =      -3.9489068
THE OBSERVED DELTA IS =       1.6574911
THE EXPECTED DELTA IS =       2.5205177
THE VARIANCE OF DELTA =       .47763328E-01
THE SKEWNESS OF DELTA =      -.80530833

 PROBABILITY OF A SMALLER OR EQUAL DELTA =     .00170269
```

FLATS vs HYDROLOGY

```
INPUT HAS   10  WETLAND
THERE WERE   2  FUNCTIO
WEIGHTING OPTION:  C(I) = n(I)/sum(n(I))

DISTANCE MEASURE = Euclidean

GROUP NUMBER  1 OF SIZE   8 HAS AN AVERAGE DISTANCE =       .42669679
GROUP NUMBER  2 OF SIZE   2 HAS AN AVERAGE DISTANCE =       .52009598
THE TEST STATISTIC IS =      -4.5671409
THE OBSERVED DELTA IS =       .44537663
THE EXPECTED DELTA IS =       .60609777
THE VARIANCE OF DELTA =       .12383893E-02
THE SKEWNESS OF DELTA =      -2.2842500

 PROBABILITY OF A SMALLER OR EQUAL DELTA =     .00471710
```

Appendix B (cont.)

FIGURE 3

FLATS DATA vs WATER QUALITY FUNCTION

```
CLUSTER ANALYSIS,   EUCLIDEAN DISTANCE  WARD'S METHOD     Percent chaining =  10.00

                    L O G   o f   D I S T A N C E
      -2.507          -1.361           -.216            .929           2.074
        |-------+-------+-------+-------+-------+-------+-------+-------+
SWAMP   ----------------------------|
                                    |-----------------A----|
POCOSN  ----------------------------|                      |-----------|
                                                           |           |
HDWTR   ----------------------------------------------B----|           |
                                                                       |
PLANTN  ----------|                                                    |
                  |-------------------------|                          |
ESTFOR  ----------|                         |                          |
                                            |------C---|               |
PINEFL  --------------------|               |          |               |
                            |---------------|          |               |
MARFOR  |                   |                          |               |
        |-------------------|                          |---------------|
HDWDFL  |                                              |
                                                       |
FWMAR   ------------------------------------------|    |
                                                  |-D--|
ESTSS   ------------------------------------------|
```

FLATS DATA vs HABITAT FUNCTION

```
CLUSTER ANALYSIS,   EUCLIDEAN DISTANCE  WARD'S METHOD     Percent chaining =  20.00
                   L O G   o f   D I S T A N C E
      -3.058          -1.508            .042           1.592           3.142
        |-------+-------+-------+-------+-------+-------+-------+-------+
SWAMP   -----------------|
                         |--------|
HDWDFL  -------|         |        |
               |---------|        |-----|
ESTFOR  -------|                  |     |
                                  |     |----------|
ESTSS   --------------------------|     |          |
                                        |          |------A------------|
MARFOR  --------------------------------|          |                   |
                                                   |                   |
HDWTR   -------------------------------------------|                   |
                                                                       |
POCOSN  |                                                              |
        |------------------------------------------B------|            |
PINEFL  |                                                 |            |
                                                          |------------|
PLANTN  ------------------------------------|             |
                                            |------C------|
FWMAR   ------------------------------------|
```

FIGURE 4

MULTI-RESPONSE PERMUTATION PROCEDURES (MRPP)

FLATS DATA vs WATER QUALITY FUNCTION

```
 INPUT HAS   10  WETLAND
THERE WERE   5  FUNCTIO
WEIGHTING OPTION:  C(I) = n(I)/sum(n(I))

DISTANCE MEASURE = Euclidean

GROUP NUMBER  1 OF SIZE   3 HAS AN AVERAGE DISTANCE =       1.0432764
GROUP NUMBER  2 OF SIZE   5 HAS AN AVERAGE DISTANCE =       .65312513
GROUP NUMBER  3 OF SIZE   2 HAS AN AVERAGE DISTANCE =       1.1060742

THE TEST STATISTIC IS =      -3.5193961
THE OBSERVED DELTA IS =       .86076030
THE EXPECTED DELTA IS =       1.2377404
THE VARIANCE OF DELTA =       .11473620E-01
THE SKEWNESS OF DELTA =      -.75876056

 PROBABILITY OF A SMALLER OR EQUAL DELTA =     .00328094
```

FLATS DATA vs HABITAT FUNCTION

```
 INPUT HAS   10  WETLAND
THERE WERE   4  FUNCTIO
WEIGHTING OPTION:  C(I) = n(I)/sum(n(I))

DISTANCE MEASURE = Euclidean

GROUP NUMBER  1 OF SIZE   6 HAS AN AVERAGE DISTANCE =       .97239887
GROUP NUMBER  2 OF SIZE   2 HAS AN AVERAGE DISTANCE =       .30659426
GROUP NUMBER  3 OF SIZE   2 HAS AN AVERAGE DISTANCE =       1.1099998
THE TEST STATISTIC IS =      -4.1097749
THE OBSERVED DELTA IS =       .86675814
THE EXPECTED DELTA IS =       1.9302940
THE VARIANCE OF DELTA =       .66968136E-01
THE SKEWNESS OF DELTA =      -.77009040

 PROBABILITY OF A SMALLER OR EQUAL DELTA =     .00117972
```

FIGURE 5

RIVERINE DATA vs ALL INDICATOR FUNCTIONS

```
Percent chaining =  27.27

                    L O G   o f   D I S T A N C E
      -.447            .719           1.886           3.053           4.220
        |-------+-------+-------+-------+-------+-------+-------+-------+
BLH     --------------|
                      |-------|
SWAMP   |             |       |
        |-------------|       |---------A------|
HDWTR   |                     |                |
                              |                |-----------------------|
PINEFL  ----------------------|                |                       |
                                               |                       |
ESTSS   --------------------------------B------|                       |
                                                                       |
PLANTN  ----------------------------------------C------|               |
                                                       |---------------|
HDWDFL  ---------------------------------|             |
                                         |------D------|
ESTFOR  ---------------------------------|
```

RIVERINE DATA vs HYDROLOGY FUNCTION

```
Percent chaining =  45.45

                    L O G   o f   D I S T A N C E
      -1.124           -.259            .605          1.469           2.333
        |-------+-------+-------+-------+-------+-------+-------+-------+
BLH     --------------|
                      |------------------A-------|
SWAMP   |             |                          |
        |-------------|                          |
HDWTR   |                                        |---------|
                                                 |         |
PINEFL  -------------------------|               |         |
                                 |-------B-------|         |-----------|
ESTFOR  -------------------------|                         |           |
                                                           |           |
PLANTN  ---------------------------------|                 |           |
                                         |--------C--------|           |
ESTSS   ---------------------------------|                             |
                                                                       |
HDWDFL  ------------------------------------------D--------------------|
```

FIGURE 6

MULTI-RESPONSE PERMUTATION PROCEDURES (MRPP)

RIVERINE DATA vs ALL INDICATOR FUNCTIONS

```
INPUT HAS    8  WETLAND
 THERE WERE  12  FUNCTIO
 WEIGHTING OPTION:  C(I) = n(I)/sum(n(I))

 DISTANCE MEASURE = Euclidean

 GROUP NUMBER  1 OF SIZE   5 HAS AN AVERAGE DISTANCE =       1.9224570

 GROUP NUMBER  2 OF SIZE   3 HAS AN AVERAGE DISTANCE =       3.6860060
 THE TEST STATISTIC IS =      -4.3453310
 THE OBSERVED DELTA IS =       2.5837878
 THE EXPECTED DELTA IS =       4.0305237
 THE VARIANCE OF DELTA =       .11084926
 THE SKEWNESS OF DELTA =      -1.7464730

  PROBABILITY OF A SMALLER OR EQUAL DELTA =     .00384555
```

RIVERINE DATA vs HYDROLOGY FUNCTION

```
INPUT HAS    8  WETLAND
 THERE WERE   4  FUNCTIO
 WEIGHTING OPTION:  C(I) = n(I)/sum(n(I))

 DISTANCE MEASURE = Euclidean

 GROUP NUMBER  1 OF SIZE   3 HAS AN AVERAGE DISTANCE =       .85879566
 GROUP NUMBER  2 OF SIZE   3 HAS AN AVERAGE DISTANCE =       2.5133439
 GROUP NUMBER  3 OF SIZE   2 HAS AN AVERAGE DISTANCE =       1.1357817
  THE TEST STATISTIC IS =      -.36402852
 THE OBSERVED DELTA IS =       1.5484978
 THE EXPECTED DELTA IS =       1.5901126
 THE VARIANCE OF DELTA =       .13068501E-01
 THE SKEWNESS OF DELTA =      -.39088442

  PROBABILITY OF A SMALLER OR EQUAL DELTA =     .33703575
```

FIGURE 7

RIVERINE DATA vs WATER QUALITY FUNCTION

Percent chaining = 36.36

```
                     L O G   o f   D I S T A N C E
      -2.843          -1.784           -.724            .335          1.395
        |-------+-------+-------+-------+-------+-------+-------+-------+
BLH     |
        |----------------------------------A------|
HDWTR   |                                         |
                                                  |----------|
SWAMP   -----------------|                        |          |
                         |----------|             |          |
ESTFOR  -----------------|          |------B------|          |---------|
                                    |                        |         |
PINEFL  ----------------------------|                        |         |
                                                             |         |
ESTSS   --------------------------------------------C--------|         |
                                                                       |
PLANTN  -----------------------------------|                           |
                                           |--------------D------------|
HDWDFL  -----------------------------------|
```

RIVERINE DATA vs HABITAT FUNCTION

Percent chaining = 27.27

```
                    L O G   o f   D I S T A N C E
      -2.063           -.552            .959           2.471          3.982
        |-------+-------+-------+-------+-------+-------+-------+-------+
BLH     ------------------------|
                                |
SWAMP   |                       |------A-------|
        |-------------|         |              |
HDWTR   |             |---------|              |
                      |                        |-----------------------|
PINEFL  --------------|                        |                       |
                                               |                       |
ESTSS   -------------------------------B-------|                       |
                                                                       |
PLANTN  --------------------------------------C------|                 |
                                                     |-----------------|
HDWDFL  --------------------------------|            |
                                        |-----D------|
ESTFOR  --------------------------------|
```

FIGURE 8

MULTI-RESPONSE PERMUTATION PROCEDURES (MRPP)
RIVERINE DATA vs WATER QUALITY FUNCTION

```
INPUT HAS    8  WETLAND
    THERE WERE   4  FUNCTIO
    WEIGHTING OPTION:  C(I) = n(I)/sum(n(I))

    DISTANCE MEASURE = Euclidean

    GROUP NUMBER  1 OF SIZE   2 HAS AN AVERAGE DISTANCE =       .34132098

    GROUP NUMBER  2 OF SIZE   4 HAS AN AVERAGE DISTANCE =       .93795927

    GROUP NUMBER  3 OF SIZE   2 HAS AN AVERAGE DISTANCE =       .69462213

    THE TEST STATISTIC IS =      -2.7977403
    THE OBSERVED DELTA IS =       .72796541
    THE EXPECTED DELTA IS =       .99550933
    THE VARIANCE OF DELTA =       .91448247E-02
    THE SKEWNESS OF DELTA =      -.71037093

     PROBABILITY OF A SMALLER OR EQUAL DELTA =     .01057138
```

RIVERINE DATA vs HABITAT FUNCTION

```
INPUT HAS    8  WETLAND
    THERE WERE   4  FUNCTIO
    WEIGHTING OPTION:  C(I) = n(I)/sum(n(I))

    DISTANCE MEASURE = Euclidean

    GROUP NUMBER  1 OF SIZE   5 HAS AN AVERAGE DISTANCE =       1.3455621

    GROUP NUMBER  2 OF SIZE   3 HAS AN AVERAGE DISTANCE =       2.2937802

    THE TEST STATISTIC IS =      -4.3764696
    THE OBSERVED DELTA IS =       1.7011439
    THE EXPECTED DELTA IS =       3.4245902
    THE VARIANCE OF DELTA =       .15507711
    THE SKEWNESS OF DELTA =      -1.7829369

     PROBABILITY OF A SMALLER OR EQUAL DELTA =     .00384718
```

FIGURE 9

MULTI-RESPONSE PERMUTATION PROCEDURES (MRPP)

FLATS vs ALL INDICATOR FUNCTIONS (-FW MARSH)

```
INPUT HAS    9  WETLAND
  THERE WERE  11  FUNCTIO
  WEIGHTING OPTION:

  C(I) = n(I)/sum(n(I))

  DISTANCE MEASURE = Euclidean

  GROUP NUMBER  1 OF SIZE   2 HAS AN AVERAGE DISTANCE =       1.8320208

  GROUP NUMBER  2 OF SIZE   5 HAS AN AVERAGE DISTANCE =       1.5745250

  GROUP NUMBER  3 OF SIZE   2 HAS AN AVERAGE DISTANCE =       1.5055564

  THE TEST STATISTIC IS =      -3.2287706
  THE OBSERVED DELTA IS =       1.6164200
  THE EXPECTED DELTA IS =       2.2551987
  THE VARIANCE OF DELTA =       .39140512E-01
  THE SKEWNESS OF DELTA =      -.62947674

   PROBABILITY OF A SMALLER OR EQUAL DELTA =     .00439497
```

Appendix B (cont.)

TABLE 1

OVERALL DATASET

WETLAND TYPES	INDICATOR FUNCTIONS
1. FW MAR (Freshwater Marsh)	1. SURF (Surface water)
2. HDWTR (Headwater)	2. SUBSURF (Subsurface water)
3. EST SS (Estuarine Shrub-scrub)	3. VEL RED (Velocity Reduction)
4. POCOSN (Pocosin)	4. GW MOD (Groundwater modification)
5. BLH (Bottomland Hardwood)	5. NUTRAN (Nutrient Transformations)
6. SWAMP (Swamp)	6. PPT (Removal of elements)
7. HDWDFLT (Hardwood Flat)	7. OCEXP (Organic Carbon export)
8. PINE FLT (Pine Flat)	8. SOM (Soil organic matter)
9. PLANTN (Pine Plantation)	9. SPOD (Spodosols)
10. MAR FOR (Maritime Forest)	10. WOOD (Woody retention)
11. EST FOR (Estuarine Forest)	11. REMAT (Removal of dissolved)
	12. PLANT (Plant community)
	13. VERT (Vertical habitat)
	14. DETRIT (Detritus)
	15. FOOD (Foodweb support)

Appendix B (cont.)

TABLE 2

FLATS/DEPRESSIONAL DATASET

WETLAND TYPES

1. FW MAR (Freshwater Marsh)
2. EST FOR (Estuarine Forest)
3. EST SS (Estuarine Shrub-scrub)
4. POCOSN (Pocosin)
5. HDWTR (Headwater)
6. SWAMP (Swamp)
7. HDWDFLT (Hardwood Flat)
8. PINE FLT (Pine Flat)
9. PLANTN (Pine Plantation)
10. MAR FOR (Maritime Forest)

INDICATOR FUNCTIONS

HYDROLOGY

1. SURF (Surface water)
2. SUBSURF (Subsurface water)

WATER QUALITY

3. NUTRAN (Nutrient Transformations)
4. PPT (Removal of elements)
5. OCEXP (Organic Carbon export)
6. SOM (Soil organic matter)
7. SPOD (Spodosols)

HABITAT

8. PLANT (Plant community)
9. VERT (Vertical habitat)
10. DETRIT (Detritus)
11. FOOD (Foodweb support)

Appendix B (cont.)

TABLE 3

RIVERINE DATASET

WETLAND TYPES	INDICATOR FUNCTIONS
	HYDROLOGY
1. BLH (Bottomland Hardwood)	1. SURF (Surface water)
2. SWAMP (Swamp)	2. SUBSURF (Subsurface water)
3. HDWTR (Headwater)	3. VEL RED (Velocity Reduction)
4. EST FOR (Estuarine Forest)	4. GW MOD (Groundwater modification)
5. EST SS (Estuarine Shrub-scrub)	WATER QUALITY
6. PLANTN (Pine Plantation)	5. NUTRAN (Nutrient transformations)
7. HDWDFLT (Hardwood Flat)	6. OCEXP (Organic Carbon Export)
8. PINE FLT (Pine Flat)	7. WOOD (Woody retention)
	8. REMAT (Removal of dissolved)
	HABITAT
	9. PLANT (Plant community)
	10. VERT (Vertical habitat)
	11. DETRIT (Detritus)
	12. FOOD (Foodweb support)

Appendix B (cont.)

TABLE 4

FLATS/DEPRESSIONAL DATASET

CLUSTERING SUMMARY

	ALL	HYDROLOGY	WATER QUALITY	HABITAT
GROUP A	SWAMP HDWTR	SWAMP	SWAMP POCOSN	SWAMP HDWD FLT EST FOR EST SS MAR FOR HDWTR
GROUP B	MAR FOR HDWDFLT EST FOR EST SS	MAR FOR HDWD FLT HDWTR POCOSN FW MAR EST SS EST FOR	HDWTR	POCOSN PINE FLT
GROUP C	POCOSN PLANTN PINE FLT FW MAR	PLANTN PINE FLT	PINE FLT PLANTN EST FOR MAR FOR HDWD FLT	PLANTN FW MAR
GROUP D	N/A	N/A	FW MAR EST SS	N/A

Appendix B (cont.)

TABLE 5

RIVERINE DATASET

CLUSTERING SUMMARY

	ALL	HYDROLOGY	WATER QUALITY	HABITAT
GROUP A	BLH SWAMP HDWTR PINE FLT	BLH SWAMP HDWTR	BLH HDWTR	BLH SWAMP HDWTR PINE FLT
GROUP B	EST SS	PINE FLT EST FOR	SWAMP EST FOR PINE FLT	EST SS
GROUP C	PLANTN	PLANTN EST SS	EST SS	PLANTN
GROUP D	HDWDFLT EST FOR	HDWD FLT	PLANTN HDWD FLT	EST FOR HDWD FLT

Appendix B (cont.)

TABLE 6

FLATS/DEPRESSIONAL DATASET

MRPP GROUP SUMMARY

	ALL	HYDROLOGY	WATER QUALITY	HABITAT
GROUP 1	SWAMP HDWTR	SWAMP POCOSN HDWDFLT HDWTR FW MAR MAR FOR EST SS EST FOR	SWAMP POCOSN HDWTR	SWAMP HDWDFLT EST FOR EST SS MAR FOR HDWTR
GROUP 2	MAR FOR HDWDFLT EST FOR EST SS	PLANTN PINEFLT	PLANTN EST FOR PINEFLT MAR FOR HDWDFLT	POCOSN PINEFLT
GROUP 3	POCOSN PLANTN PINEFLT FW MAR	N/A	FW MAR EST SS	PLANTN FW MAR

Appendix B (cont.)

TABLE 7

RIVERINE DATA

MRPP GROUP SUMMARY

	ALL	HYDROLOGY	WATER QUALITY	HABITAT
GROUP 1	BLH SWAMP HDWTR PINE FLT EST SS	BLH SWAMP HDWTR	BLH HDWTR	BLH SWAMP HDWTR PINE FLT EST SS
GROUP 2	PLANTN HDWDFLT EST FOR	PLANTN EST SS HDWDFLT	SWAMP EST FOR PINE FLT EST SS	PLANTN HDWDFLT EST FOR
GROUP 3	N/A	PINE FLT EST FOR	PLANTN HDWDFLT	N/A

Appendix B (cont.)

TABLE 8

FLATS/DEPRESSIONAL DATASET

FUNCTIONAL VALUE SUMMARY
(with Mean indicator scores shown)

	ALL	HYDROLOGY	WATER QUALITY	HABITAT
HIGH VALUE	Swamp Hdwtr X=10.35	Swamp X=7.67	Swamp Pocosin Hdwtr X=10.71	Swamp Hdwd flt Est for Est ss Mar for Hdwtr X=12.21
MEDIUM VALUE	Mar for Hdwd flt Est for Est ss X=8.60	Mar for Hdwd flt Hdwtr Pososn Fw mar Est ss Est for X=6.32	Fw mar Est ss X=8.06	Pocosn Pine flt X=9.41
LOW VALUE	Pocosn Plantn Pine flt Fw mar X=7.47	Plantn Pine flt X=5.63	Pine flt Hdwd flt Mar for Est for Plantn X=7.70	Plantn Fw mar X=6.46

Appendix B (cont.)

TABLE 9

RIVERINE DATA

FUNCTIONAL VALUE SUMMARY
(with Mean indicator scores)

	ALL	HYDROLOGY	WATER QUALITY	HABITAT
HIGH VALUE	Blh Swamp Hdwtr Pine flt Est ss X=10.22	Blh Swamp Hdwtr X=9.75	Swamp Est for Pine flt Est ss X=10.05	Blh Swamp Hdwtr Pine flt Est ss X=11.46
MEDIUM VALUE	Plantn Hdwdflt Est for X=8.13	Plantn Est ss Hdwdflt Pine flt Est for X=8.68	Blh Hdwtr X=9.63	Plantn Hdwdflt Est for X=6.35
LOW VALUE			Plantn Hdwdflt X=9.03	

Appendix B (cont.)

REFERENCES (for appendices)

Adamus, Paul R., L.T. Stockwell. 1983. A Method for Wetland Functional Assessment: Volume I. Critical Review and Evaluation Concepts. Federal Highway Administration Rep. No. FHWA A-IP-82-23.

Ammann, Alan P., Amanda Lindley Stone. 1991. Method for the Comparative Evaluation of Nontidal Wetlands in New Hampshire. New Hampshire Department of Environmental Services. Concord, New Hampshire. NHDES-WRD-1991-3.

Biondini, M. E., C. D. Bonham, and E. F. Redente. 1985. Secondary successional patterns in a sagebrush (Artemisia tridentata) community as they relate to soil disturbance and soil biological activity. Vegetatio 60: 2536.

Bradshaw, Julie G. 1991. A Technique for the Functional Assessment of Nontidal Wetlands in the Coastal Plain of Virginia. Virginia Institute of Marine Science. Special Report N. 315.

Brinson, Mark M., B. L. Swift, R. C. Plantico [and others]. 1981. Riparian ecosystems: their ecology and status. U. S. Department of the Interior, Fish and Wildlife Service, FWS/OBS-81/17.

Carter, Virginia, M. S. Bedinger, Richard P. Novitzki, W. O. Wilen. 1978. Water Resources and Wetlands. In: Greeson, Phillip E., John R. Clark (eds.). Wetland Functions and Values: The State of Our Understanding. American Water Resources Association. Lake Buena Vista, Florida.

DEM 1992. Indicators of Freshwater Wetland Function and Value for Protection and Management. North Carolina Department of Environment, Health, and Natural Resources. Division of Enviromental Management, Water Quality Section.

Gauch, H. G. 1982. Multivariate analysis in community ecology. Cambridge University Press, New York.

Golet, Frank C. 1978. Rating the Wildlife Value of Northeastern Fresh Water Wetlands. In: Greeson, Phillip E., John R. Clark, Judith E. Clark (eds.) Wetland Functions and Values: The State of Our Understanding. American Water Resources Association. Minneapolis, Minnesota.

Harris, H. J., Mark S. Milligan, Gary A. Fewless. 1983. Diversity: Quantification and Ecological Evaluation in Freshwater Marshes. Biological Conservation 27. pp.99-110.

Jordan, T. E., D. L. Correll, W.T. Peterjohn, D. E. Weller. 1986. Nutrient flux in a landscape: The Rhode River watershed and receiving waters. In: Correll, D. L. (ed.) Watershed research perspectives. Smithsonian Institution Press, Washington, D. C.

Kite, D. J. 1980. Water Courses - open drains or sylvan streams? In: Trees at Risk. Tree Council Annu. Conf. (in association with World Wildlife Fund) March 1980, London.

Larson, J.S., M. S. Bedinger, C. F. Bryan (and others). 1981. Transition from wetlands to uplands in southeastern bottomland hardwood forests. pp.225-273. In: Clark, J.R. and J. Benforado (eds.) Wetlands of bottomland hardwood forests. Elsevier Scientific Publishing Co. New York.

Leopold, L. B. 1974. Water: A Primer. W. H. Freeman and Co., San Francisco, CA.

Ludwig, John A., James F. Reynolds. 1988. Statistical ecology: a primer on methods and computing. John Wiley and Sons, New York.

Marble, Anne D. 1992. A Guide to Wetland Functional Design. Lewis Publishers, Inc. Missouri.

Appendix B (cont.)

McCune, Bruce. 1991. Multivariate Analysis on the PC-ORD System. Department of General Science, Oregon State University, Corvallis, Oregon. 503-737-4151.

Novitzki, Richard P. 1978. Hydrologic Characteristics of Wisconsin's Wetlands and their Influence on Floods, Stream Flow, and Sediment. In: Greeson, Phillip E., John R. Clark, Judith E. Clark (eds.). Wetland Functions and Values: The State of Our Understanding. American Water Resources Association. Lake Buena Vista, Florida.

Novitzki, R. P. 1978. Hydrology of the Nevin Wetland Near Madison, Wisconsin. US Geological Survey, Water Resources Investigations.

Odum, William E., Michael L. Dunn, Thomas J. Smith III. 1979. Habitat Value of Tidal Fresh Water Wetlands. In: Greeson, Phillip E., John R. Clark, Judith E. Clark (eds.). Wetland Functions and Values: The State of Our Understanding. American Water Resources Association. Minneapolis, Minnesota.

Reppert, Richard T., Wayne Sigleo, Eugene Stakiv, Larry Messman, Caldwell Meyers. 1979. Wetland Values: Concepts and Methods for Wetlands Evaluation. U. S. Army Corps of Engineers. Institute for Water Resources. IWR Research Report 79-r1.

Wilson, Kenneth A. 1962. North Carolina Wetlands, Their Distribution and Management. North Carolina Wildlife Resources Commission. Raleigh, North Carolina.

Yarbro, L. A., E. J. Kuenzler, P. J. Mulholland, R. P. Sniffen. 1984. Effects of stream channelization on exports of nitrogen and phosphorus from North Carolina coastal plain watersheds. Environmental Management Vol. 8, pp. 151-160.

Zimmerman, G. M., H. Goetz, and P. W. Mielke, Jr. 1985. Use of an improved statistical method for group comparisons to study effects of prairie fire. Ecology 66: 606-611.