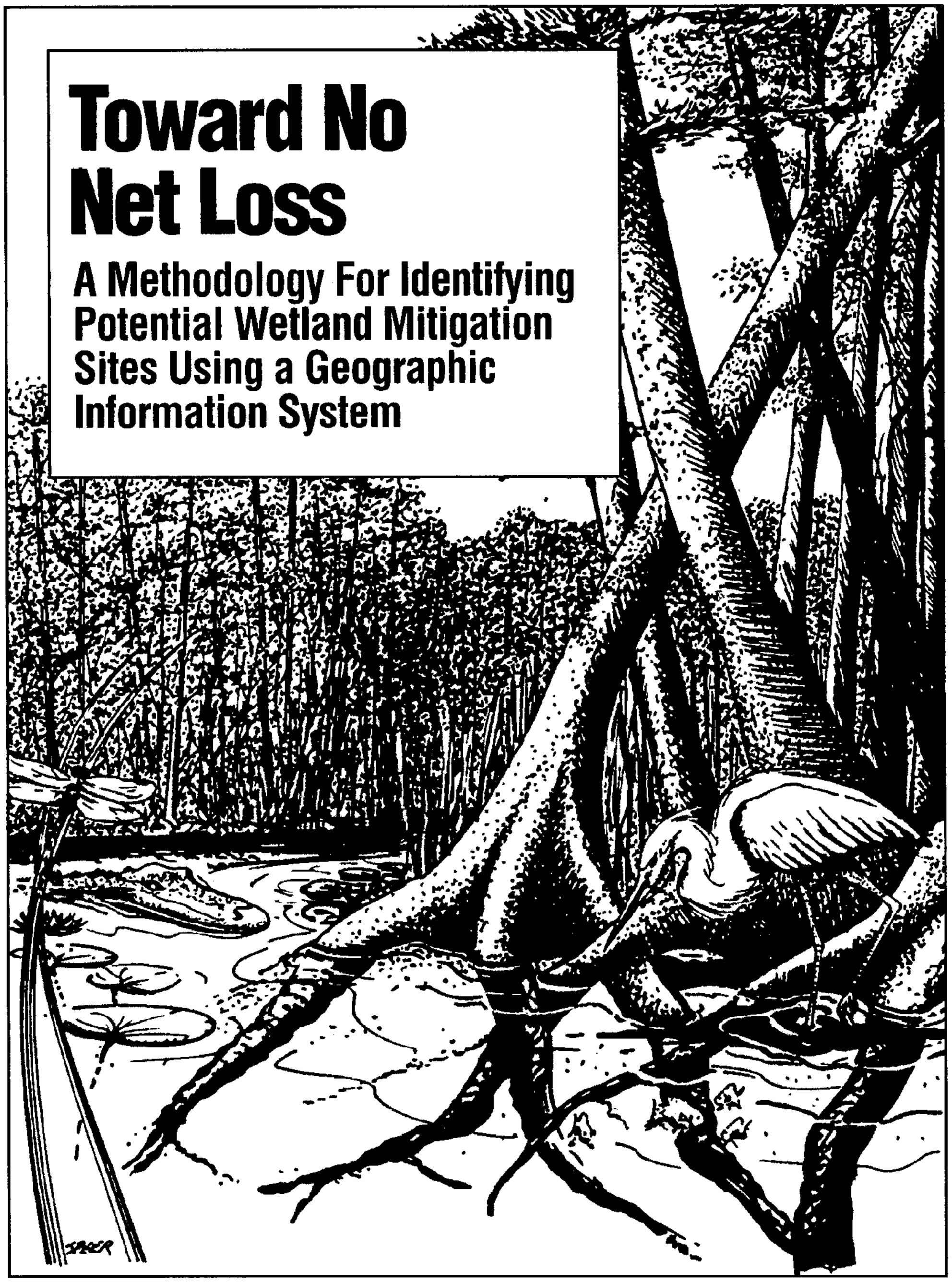
Toward No Net Loss

A Methodology For Identifying Potential Wetland Mitigation Sites Using a Geographic Information System



South Carolina Water Resources Commission Report No. 178

USEPA Report No. EPA904-R-94-001

Toward No Net Loss

A Methodology For Identifying Potential Wetland Mitigation Sites Using a Geographic Information System

SCWRC Report No. 178, November 1993

USEPA Report No. EPA904-R-94-001

Cynthia R. Brown
Project Manager

Floyd O. Stayner
GIS Analyst

Christopher L. Page
Field Biologist

Cynthia A. Aulbach-Smith
Consulting Botanist

South Carolina Water Resources Commission
1201 Main Street, Suite 1100
Columbia, S.C. 29201
(803) 737-0067

A limited number of this publication is available for distribution. When this supply is depleted contact the National Technical Information Service (NTIS) at (703) 487-4650.

Acknowledgements

This study was prepared with funding from the United States Environmental Protection Agency Region IV office of Wetlands Planning under Cooperative Agreement #CD994081-92-1. It does not necessarily reflect the views of this agency and no official endorsement should be inferred.

Several individuals and agencies contributed information and advice important to the development of this study. Their help is greatly appreciated. The U.S. Fish and Wildlife Service, the South Carolina Wildlife and Marine Resources Department, and the South Carolina Department of Health and Environmental Control all provided valuable input in the development of model criteria. Dr. James Gosselink provided extensive review of this project. Danny Johnson of South Carolina Water Resources Commission, Charlie Storrs of the National Wetlands Inventory, and Dennis De Francesco of the Soil Conservation Service offered considerable technical expertise. Hugh Archer of the South Carolina Water Resources Commission and Barbara Postles provided guidance, advice, and support. Roy Newcome of Water Resources Commission provided technical editing of the final document.

Contents

Introduction 1
- The issues 1
- Value of information 2

Model Development 5
- Criteria and data evaluation 5
- Model components 8
  - Physical suitability analyses 8
    - Restoration sites 8
    - Enhancement sites 8
    - Protection sites 9
  - Opportunity analyses 9
    - Wildlife habitat 9
      - Justification 9
      - Criteria 10
    - Water quality and floodwater storage 11
      - Justification 11
      - Criteria 12
  - Unique opportunities/barriers and potential threats 12

Model Application 15
- Study area 15
- Automating criteria 20
  - Data preparation 20
  - GIS analyses 20
    - Initial site selection 20
    - Wildlife habitat opportunity analysis 22
    - Water quality/floodwater storage analysis 28
    - Composite overlay 32
    - Unique opportunities/potential threats 32
  - Model complications/improvements 32
- Field-truthing 39
  - Verification of source data 39
  - Other observations 42

Conclusions 43

References 45

Appendix I - Generalized NWI wetlands used in analyses 49

Appendix II - Generalized land use data used in analyses 50

Appendix III - Hydric soils list by county used in analyses 50

Figures

Figure 1. Flowchart of steps in wildlife habitat analyses 11
Figure 2. Flowchart of steps in water quality and floodwater storage analyses. 12
Figure 3. Flowchart of steps for identifying optimal mitigation sites. 14
Figure 4. Map showing location of Four Hole Swamp sub-basin 16
Figure 5. Map showing counties in Four Hole Swamp sub-basin 17
Figure 6. Map showing land resource areas in Four Hole Swamp sub-basin 18
Figure 7. Map of land use/land cover in Four Hole Swamp sub-basin 19
Figure 8. Map of potential mitigation sites by mitigation class 21
Figure 9. Map of core habitat sites 23
Figure 10. Map of core habitat sites and adjacent degraded sites 24
Figure 11. Map showing results of edge elimination analysis 25
Figure 12. Map of habitat sites 40 acres or greater 26
Figure 13. Map of all potential wildlife habitat sites 27
Figure 14. Map of potential mitigation sites and stream network 29
Figure 15. Map of high-order hydrology sites 30
Figure 16. Map of low-order hydrology sites 31
Figure 17. Map of potential hydrology sites 31
Figure 18. Map of all opportunity analyses sites 34
Figure 19. Map of final selected potential mitigation sites 35
Figure 20. Map of unique opportunity sites 36
Figure 21. Map of potential threat sites 37
Figure 22. Map of hydrologic regime for potential mitigation sites 38
Figure 23. Map of isolated field check site 40
Figure 24. Map of riverine field check site 41

Table

Table 1. Available data coverages. 7

Definition of terms

Core habitat sites — all protection NWI sites, protected areas, significant natural area, and/or intact upland forest (excluding pine plantations)

Core habitat complex — the complex formed by core habitat sites and contiguous restoration and enhancement sites

Enhancement sites — any NWI wetland that is modified (i.e., ditched, drained, impounded, or excavated)

In-kind mitigation — a project in which the replacement site has the same species composition as the filled wetland site

Mitigation — wetland protection, enhancement, or restoration activities required to compensate for wetland losses permitted under Section 404 of the Clean Water Act

Mitigation banking — a system in which the creation, enhancement, restoration, or preservation of wetlands is recognized by a regulatory agency as generating compensation credits allowing the future development of other wetland sites*

Mititgation class — type of mitigation (protection, enhancement, or restoration)

Off-site mitigation — for this study, mitigation which occurs in a different watershed or project site location

On-site mitigation — for this study, mitigation which occurs in the same watershed or project site location

Opportunity — the public, cultural, or natural resource benefit a mitigation site could potentially provide

Out-of-kind mitigation — a project in which the replacement site has a different species composition than the filled wetland site

Physical suitability — potential for successful mitigation based on soil, hydrology, and vegetation characteristics of a site

Protected area — public land, including state parks, national wildlife refuges, national forests, etc.

Protection sites — any NWI wetland that is not modified (i.e., ditched, drained, impounded, or excavated)

Restoration sites — agriculture fields with hydric soils (prior converted wetlands)

Significant natural area — a high-quality, relatively undisturbed natural community or complex of communities as identified by the Natural Areas Inventory.

Threat — sources of pollution that pose a potential threat to successful mitigation. These include nutrient sources, sediment sources, and toxic sources. It is recognized that, in fact, a wetland might be restored or enhanced to ameliorate the consequences of these potential threats.

Wetland order — the order assigned to a candidate mitigation site on the basis of the stream order of an associated stream

* From Environmental Law Institute

Introduction

The Issues

Permitted land use, development pressures, and illegal fill activity continue to threaten the viability of our Nation's wetlands. Regulatory safeguards have been established to avoid or minimize the impacts resulting from such activities, but when these "sequencing" steps cannot be taken compensatory mitigation is sometimes required to replace the ecological loss resulting from wetland destruction or fragmentation.[1] This project proposes a methodology to systematically locate suitable mitigation sites on the South Carolina Coastal Plain that could potentially contribute to the state's wetland resource. It utilizes a currently available Geographic Information System (GIS) and 1:24,000-scale information sources to automate the mitigation site evaluation process. The validity of this methodology is a function of the currentness, scale, and accuracy of available data and the selection criteria used. It can be generalized or focused on the basis of different scale data appropriate to the geographic coverage of the investigation.

When designing strategies for mitigation, it is often assumed that area-for-area replacement of the same type of wetland, on-site, will assure that any lost ecological function is offset. However, in-kind mitigation projects are often not available on-site; thus, mitigation is pursued on-site/out-of-kind, off-site/in-kind and finally off-site/out-of-kind. Unfortunately, many projects, both on-site and off-site, are fragmented or unconnected and not defensible in the long run. Thus, conventional approaches to mitigation have the potential to counter the desired goal of "no net loss" of wetland acreage. Furthermore, the ability of a replacement wetland to mimic the ecological function of the filled wetland is often questionable. The goal of "no net loss" of wetland function can also be contradicted.

To adequately address the issue of functional replacement, the potential mitigation site must first be considered as an integrated component of the landscape, hydrologically linked to all other land uses/land covers within the watershed (Lee and Gosselink, 1988). Thus, sound mitigation strategies require identifying sites that have not only a high physical potential for successful mitigation (i.e., appropriate soils, hydrology, and vegetation), but that also contribute to the overall ecological integrity of the entire watershed. In many instances, off-site/within watershed wetlands best meet these

[1] U.S. EPA has adopted the goal of the National Wetlands Policy Forum to achieve no overall net loss of the Nation's remaining wetland base, as defined by acreage and function; and to restore and create wetlands, where feasible, to increase the quality and quantity of the Nation's wetlands resource base. Section 404 permits are evaluated under guidelines that prohibit wetland loss unless all appropriate and practical steps have been taken to minimize and otherwise mitigate impacts on the aquatic ecosystem. A February 1990 MOA between EPA and the Corps of Engineers clarified that mitigation should occur according to the following "sequencing" steps: 1)avoidance of impacts through evaluation of practicable alternatives, 2)minimization; and 3)compensation for unavoidable impacts through restoration or creation.

criteria. In identifying these potential mitigation sites, it is necessary to recognize similar characteristics between the filled and replacement wetland sites.

Our understanding of how wetland characteristics relate to wetland function has greatly increased in the last several years. Certain large-scale, physical characteristics of wetlands, including the size, shape, and position of a wetland site on the landscape, generally support wetland function (Brinson, 1988; Preston and Bedford, 1988; O'Neil et al., 1991; Whigham et al., 1988; Kuenzler, 1989; Taylor et al., 1990; Harris and Gosselink, 1990). GIS is a tool that can be used by regulators and managers to help identify and evaluate these landscape-scale characteristics. The GIS methodology proposed in this study broadly identifies complexes of wetlands within a hydrologic unit that are physically amenable to restoration, enhancement, or protection. Sites determined to be physically suitable for wetland mitigation are segregated into community type and further evaluated to determine their potential to provide "opportunity", or social/ecological benefits, and to assess threats that may influence the utility of the site. The opportunities considered in this study include a site's potential to contribute to 1) wildlife habitat on the basis of fragmentation, size, and extent of interior habitat; and 2) water quality and floodwater storage on the basis of hydrologic connectivity and position on the landscape. Other opportunity analyses require consideration of known locations of endangered/threatened/rare species habitat and significant natural areas, as well as cultural resources. Threats are identified in this study as potential toxic, nutrient, or sediment sources and include mines, hazardous waste sites, and industrial and domestic waste landfills. The Four Hole Swamp sub-basin in South Carolina is then used as a case study for application of this model.

Wetland mitigation sites identified by this methodology can be reported by community type, size, watershed location, and potential opportunity contribution. This information can help managers and regulators identify complexes of in-kind mitigation areas within the same watershed as the filled wetland and, with information provided by the opportunity analyses, make an initial judgment about a site's potential to replace lost wetland functions. Potential mitigation sites indicated by this methodology might be more thoroughly assessed by descriptive methods of functional evaluation such as the Habitat Evaluation Procedures (HEP) or the Wetlands Evaluation Technique (WET)[2] to better determine opportunity potential. Thus, this model can be used as an initial screening tool for directing mitigation decisions and can augment the best professional judgment of natural resource managers and regulators when choosing wetland mitigation sites.

[2]These methodologies, developed by the Fish and Wildlife Service and Corps of Engineers, respectively, are popular tools used for site-specific functional evaluations. HEP's objective is to determine habitat suitability (both wetlands and uplands) for a variety of species by examining habitat features for these species. WET can be employed to evaluate the variety of functions provided by wetlands.

Value of Information

Because this methodology is especially effective in identifying large complexes of mitigation sites of different classes — protection, enhancement, restoration — and of different community types, it can be a useful tool for identifying potential sites for mitigation banks. It is recognized that the potential drawbacks from mitigation banking are quite significant and argued by many environmentalists and regulatory agencies. Many who oppose mitigation banking often refer not only to ecological concerns but also to shortcomings that relate more to institutional factors. Conversely, the economic and ecological advantages of using established mitigation banks to offset the impacts of a particular development project, or for offering credits to compensate for future wetland impacts, can also be strongly argued. In spite of the complex issues surrounding mitigation banking, the concept appears to be gaining general acceptance as a viable alternative for mitigating the consequences of wetland loss and fragmentation. Indeed, recent directives from the Clinton administration endorse the use of mitigation banks as a means of offsetting wetland loss:

> *"While a number of technical and procedural questions regarding the establishment and long term management of mitigation banks remain, conceptually mitigation banking, with appropriate environment safeguards, offers numerous advantages. Banking provides for greater certainty of successful compensatory mitigation in the permit process by requiring mitigation to be established before permits are issued. Banks are often ecologically advantageous because they consolidate fragmented wetland mitigation projects into one large contiguous parcel that can more effectively replace the lost wetland functions within the watershed. Mitigation banks also provide a framework for financial resources, planning and technical expertise to be brought together in a fashion often not possible with smaller mitigation projects."*
>
> *(White House Office of Environmental Policy, 1993)*

This study is not intended to be a treatise on mitigation banking. It does, however, support the notion that ecological benefits can be derived from restoring, enhancing and/or protecting large wetland complexes, given that mitigation is opted for only after the appropriate sequencing steps have taken place.

Presently, no national policies or regulations exist to insure that ecological factors are incorporated into mitigation bank siting decisions. However, guidance documents produced by various federal and state regulatory agencies do exist that define, with varying degrees of specificity and prioritization, mitigation banking criteria (Environmental Law Institute, 1993). It can be reasonably anticipated that, given the recent administrative directives, these guidance documents will eventually gain specificity or be replaced with regulations on mitigation banking. In general, certain common recommendations addressing ecological considerations emerge from the documentation that exists. These include:

- soil type and water availability
- existing resource value, size, location
- presence of contaminants
- location in same watershed as impact areas
- location on former wetland site
- adjacency to high-value habitat protected from future development and compatibly managed
- habitat for rare or threatened species (Environmental Law Institute, 1993)

In this proposed methodology, all of the above considerations are incorporated to varying degrees in the identification of potential wetland mitigation sites. More complete, accurate, and current data can be used to provide a finer filter for the GIS application proposed. The degree to which any factor is included or excluded must be analyzed against available data sources.

Apart from the goal of replacing lost value resulting from wetland permitting activity, identifying mitigation complexes with this methodology can also contribute to strategically broader ecological goals. For example, information obtained from these analyses can be useful in achieving the protection objectives of other planning and conservation efforts such as Habitat Conservation Plans, Water Quality/ Watershed Management Strategies, North American Waterfowl Management Plans, State Comprehensive Outdoor Recreation Plans, and the Wetlands Reserve Program. In general, these federal and state sponsored wetland protection strategies are aimed at preserving the array of wetland functions through restoration, planning, or acquisition initiatives (World Wildlife Fund, 1992). Several existing cooperative efforts demonstrate the benefits to be gained from the integration of program objectives. The Nature Conservancy offices in North Carolina and Louisiana, for example, have both entered into Memoranda of Agreements with various state and federal regulatory and development agencies on separate initiatives that achieve the goal of endangered or threatened species protection while providing wetland banks from which mitigation credits can be credited and debited (personal communications; Merrill Lynch, North Carolina Nature Conservancy and David Pashley, Louisiana Nature Conservancy).

Finally, this methodology is not meant, nor does it have the capability, to replace established functional assessment methodologies. It is valuable for making initial identifications of potential mitigation sites on the basis of broad characteristics indicative of function. As assessment approaches such as the Hydrogeomorphic Classification System[3] are verified and improved upon, it is possible that a methodology such as the one suggested in this study could aid in the identification of functional values on the basis of hydrogeomorphic characteristics — characteristics that, given sufficiently detailed data, could be modeled in a geographic information system.

[3] The Hydrogeomorphic Classification System is a recently developed classification tool that relies on general hydrologic and geomorphic principles as indicators of abiotic function. A survey of these features results in a wetland profile which is intended to provide, with expert interpretation, information on the functions provided by a regionally representative wetland.

Model Development

Section 2

Criteria and Data Evaluation

In the first stage of model development, several state and federal regulatory and natural resource agencies were contacted and asked to list the qualities a site should possess (or not possess) to qualify as a potential mitigation site. A literature search was also undertaken to further identify qualities that increase the likelihood of a site to accomplish mitigation goals. The literature also revealed that no such GIS application has been employed elsewhere to identify potential mitigation sites. From the suggestions provided through agency comments and from the criteria gathered through the literature search, it became apparent that a wide spectrum of factors must be considered in identifying mitigation sites. In general, the factors relate to one or more of the following:

- The mitigation potential a site possesses on the basis of **physical characteristics.**
- The mitigation potential a site possesses (or lacks) on the basis of identifiable **threats**.
- The **opportunity** for public or natural resource benefit that a site, if mitigated, would provide.
- The political or legal **logistics** that mitigation of a particular site would present.

Example of Mitigation Criteria From Regulatory and Natural Resource Agencies

Hydric Soils
Appropriate Soils
Potential wildlife corridors
Detailed spatial relationships
Identifiable level of previous impact
Site must have been a wetland in the past
Location within same watershed as impacts
Presence of endangered or sensitive species or communities
In close proximity to similar or already managed wetland habitat
Potential for water quality improvements through control of point and nonpoint discharges
Hydrologic connection with existing, functional wetland or other predictable water source
Preferred wetland vegetation already growing in the area in small quantities or can be planted with a reasonable likelihood of success after restoration of the hydrology

In order to determine data availability and suitability, and thus what criteria were realistic to consider, the data were inventoried. These data were developed by the South Carolina Water Resources Commission (SCWRC) as part of the Natural Resources Decision Support System (NRDSS) project that began in 1988 (Hale et al., 1991). One of the objectives of the project was to develop a GIS to provide products and services to support natural resource management decisions.

Each data layer used in this study adheres to accepted national data classification systems and mapping standards as established by various Federal programs. These include the U.S. Geological Survey's (USGS) National Mapping Division's Digital Line Graph (DLG) program, U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI) program, and the Soil Conservation Service's (SCS) county soils mapping program. All data are based on the 1:24,000 scale USGS topographic map series. The digital data are registered to common geographic registration coordinates, insuring comparability of various data layers in scientific analyses.

The layers of primary importance to this study are wetlands, land use, soils, roads, hydrography, and significant natural areas. The wetlands data are derived from 1:40,000 color infrared National Aerial Photography Program (NAPP) photography captured in 1989. Wetlands delineations are classified according to the Cowardin classification system developed by the NWI (Cowardin et al., 1979). For the purposes of this study, the wetland classifications are simplified to several categories of community types (Appendix I).

The land use data are photointerpreted in conjunction with the wetlands data. Land use is mapped for all upland areas, or those areas not classified as wetlands. These data are classified to Level II of the Anderson classification system (Anderson, 1976). The land use categories are also simplified to several community types for use in this study (Appendix II).

The soils data are derived from standard SCS county soils maps. A hydric attribute was added to label those soils that have hydric characteristics as defined for each county by SCS. The hydric soils category used in this study was reduced substantially (Appendix III) to include only those with little or no agricultural productivity potential as determined by state soil scientists .

The roads and hydrography are standard USGS 1:24,000-scale (DLG) products. Several attributes were added to the DLG data by SCWRC, including drainage order, which is pertinent to this study. All streams in the hydrography data layer were ordered by using the Strahler method of stream ordering (Strahler, 1952). The SCWRC employs several quality control procedures on the data to correct various problems with the original digital data. These procedures include edgematching and attribute correction where possible. One problem with the DLG data that could not be corrected was the datedness of some maps. The digital data are derived from existing topographic maps that, in the Edisto River Basin, range in date from 1960 to 1989. No attempt has been made to update any of the older digital data.

The significant natural areas data layer was developed as a result of the Natural Areas Inventory, a study sponsored by the National Oceanic and Atmospheric Administration and conducted by the South Carolina Water Resources Commission and The Nature Conservancy (White, 1993). In this study, natural areas of particular ecological significance were delineated by using NAPP photography and field verified by overflights and ground surveys. The final sites were then digitized by the SCWRC. The purpose of this systematic survey was to identify sites in the Edisto River basin with relatively undisturbed, high-quality natural communities.

Other data layers available for this study include domestic waste permits, industrial waste permits, hazardous waste sites, archaeology sites, historic sites, sensitive species and communities of concern sites, and mining and reclamation sites. All these data were obtained from the agencies responsible for the particular permitting activities. Table 1 lists the available data coverages that were considered appropriate for this study.

After considering the suggested criteria and evaluating the available data, three general model components suitable for GIS analysis were developed:

- physical suitability
- opportunity potential on the basis of watershed characteristics
- identified threats and unique opportunities

Logistical considerations, such as availability for acquisition and number of landowners, were beyond the scope of this study. However, these could be considered if more detailed spatial data themes covering these elements were available (e.g. parcel maps, real estate data). Also beyond the scope of this study was consideration of those criteria requiring site-specific data such as detailed soils information (rooting volume, fertility), site geology, and detailed elevation differences. It should be emphasized that this proposal establishes a practical methodology for identifying potential mitigation sites while recognizing reasonable expectations of spatial data themes and data scale availability. The findings are intended to serve as a rough filter for the initial identification of potential mitigation sites on the basis of general physical characteristics and position on the landscape. Thus, it directs mitigation efforts on the basis of landscape characteristics. It is recognized that site-specific data would be required to ultimately determine the potential for mitigation success at a given site. As supported by Preston and Bedford (1988), this analysis takes a qualitative, synoptic approach, considering "intrinsic and landscape-level wetland attributes." This approach reflects, in part, the methodology suggested by Leibowitz et al. (1992) in that it employs a "landscape

Table 1. Available data coverages

Coverage	Source	Spatial data type
Mining and reclamation	South Carolina Land Resources Conservation Commission	polygon
Hazardous wastes treatment, storage and disposal	South Carolina Department of Health and Environmental Control	point
All landfills	South Carolina Department of Health and Environmental Control	point
Archaeology	South Carolina Institute of Archaeology and Anthropology	polygon
National Register of Historic Places	South Carolina Department of Archives & History, U.S. Department of the Interior	polygon/point
Protected areas (government parks, forests, refuges)	U.S. Geological Survey topographic quadrangle maps	polygon
Sensitive species and communities of concern	South Carolina Wildlife and Marine Resources Department	point
Digital line graphs (separate coverages for roads, hydrography)	U.S. Geological Survey topographic quadrangle maps	line
Soils	Soil Conservation Service topographic quadrangle maps	polygon
Land use	1989 NAPP 1:40000 photography, 10-acre resolution, South Carolina Water Resources Commission	polygon
Wetlands	1989 NAPP 1:40000 photography, 1-acre resolution, National Wetlands Inventory, U.S. Fish and Wildlife Service	polygon
Natural Areas Inventory	1989 NAPP 1:40000 photography, South Carolina Water Resources Commission	polygon

approach" using existing data .

The sequence of analytical steps used to address the model components is as follows:

1) identify wetlands (by community type and watershed) that are physically amenable to mitigation; then

2) evaluate the opportunity potential of these sites to provide public benefits through either improved wildlife habitat, water quality enhancement or floodwater storage; and finally

3) further assess the opportunity a site provides (or potential limitations it poses) by identifying unique cultural or public benefits (e.g. endangered species, historic/archaeologic sites) and assess the threats (e.g. nearby mines, landfills) that may diminish a site's long term mitigation potential.

The exact procedures and rationale used to develop each of these model components are described in the following section.

Model Components

Physical Suitability Analysis — defining mitigation classes

In conducting the physical suitability analysis, three types of potential mitigation classes are identified: restoration and enhancement sites, which possess potential for wetland reestablishment and protection sites, which represent viable, functioning wetlands important to the ecological landscape.

Restoration Sites

The Environmental Protection Agency (EPA), in its 1993 draft mitigation banking guidance, defined wetland restoration as the, "process of returning a significantly disturbed or totally altered site to its previously existing functional wetland condition by some action of man (e.g., prior converted cropland or farmed wetlands reestablished as bottomland hardwood forested wetlands)." As mentioned previously, this model is intended to indicate potential mitigation sites on the Coastal Plain of South Carolina. Here, as in much of the Southeast Coastal Plain, acre upon acre of wetlands have been drained and converted to various land uses including silviculture, agriculture, and pastureland. Currently, mitigation efforts in the Southeast often involve restoration of marginal agriculture lands to wetlands (personal communication, Dr. Russell Lea, Hardwood Research Cooperative, North Carolina State University). These lands typically occur on the margins of flood plains where the hydrologic regime is unpredictable. Frequent flooding makes these areas effectively unproductive for agriculture; thus, farmers are often willing to allow their property to be restored to an original bottomland hardwood community, for example, and have future use restricted by perpetual conservation easements or other transfers of development rights.

In this study, potential restoration sites are identified according to the following progression. Hydric soils, as defined for each county by the SCS, include those soils for which the entire mapped area is identified as hydric. These areas are further analyzed to determine mitigation potential on the basis of soil productivity as derived from the SCS Land Capability Classes. Only those soils with low reported crop yields are given consideration in this study. State soil scientists have further reduced the list of potential soil types to those that have extremely limited or no agricultural productivity.

Next, agricultural areas are identified in the Anderson level II land use data layer and overlaid with the hydric soils data to find corresponding areas. The agricultural areas that are identified as hydric are assumed, in this methodology, to represent wetlands that have been converted to cropland. It is not possible with the available data to identify when these areas were actually converted to cropland or the degree of flooding; thus, all such wetlands — farmed, prior converted, converted — are termed prior converted (PC) wetlands in this study.[4]

DEFINING RESTORATION SITES

Segregate soils data according to hydric characteristic.

Determine mitigation potential on the basis of agricultural productivity of soil.

Identify agriculture areas in Anderson level II land use maps.

Overlay selected hydric soils with agriculture polygons.

Identify the hydric soils that correspond to agriculture areas.

These corresponding areas represent prior converted (PC) wetlands, or the potential restoration sites.

Enhancement Sites

The draft mitigation banking guidance document issued in 1993 by EPA defined wetland enhancement as "the improvement or addition of one or more functions to an existing wetland or other aquatic habitat (e.g., re-introduction of natural meanders to a channelized stream system, installation of water control structures, planting of desirable species, control of exotics, creation of marsh from open water habitat)."

In order to identify sites suitable for enhancement, the digital version of the 1989 NWI data are analyzed to identify areas that have been altered to some extent by dikes, impoundments, excavations, drains, or ditches. Only those areas that support hydrophytic vegetation (i.e., palustrine emergent, palustrine scrub shrub, palustrine forested) are included in this analysis. Interpretation of the alphanumeric NWI code can often lend insight into community type or land use at the time of image capture. For example, excavated areas, defined by Cowardin et al. (1979) as areas that "lie within a basin or channel excavated by man," likely represent abandoned gravel pits, large ditches, or the occasional sewage treatment pond. Impounded areas, defined as areas "created or modified by a barrier or dam which purposefully or unintentionally obstructs the outflow of water," likely represent wetlands associated with dams, stock ponds, or some other type of impoundment. Diked areas are defined by Cowardin as areas that are "created or modified by a man-made barrier or dike designed to obstruct the inflow of water." Partly drained areas exist where "the water level has been artificially lowered, but the area is still classified as wetland because soil moisture is sufficient to support hydro-

[4] These wetland classifications were developed by the Agriculture Department's Soil Conservation Service. Because this study is not concerned with regulatory distinctions, these classes are considered one and the same.

phytes. Drained areas are not considered wetlands if they can no longer support hydrophytes." It should be noted that wetland vegetation may remain for decades after drainage. Thus, even though hydrologically altered wetlands support hydrophytic vegetation, changes in hydroperiod imply changes in wetland function (Brinson, 1988). Although these systems are characterized as wetlands, restoring their hydrology could prevent the inevitable conversion to a system characteristic of drier soils. In general, it has been suggested that most ditched/partially drained sites likely represent silviculture areas or abandoned agriculture fields. In some instances, the surrounding flood plain of a channelized stream might also qualify (personal communication, Charlie Storrs, U.S. Fish and Wildlife Service). All modified areas are given consideration in this methodology if they support hydrophytic vegetation as mentioned.

It is recognized that some modified wetlands, as defined in this study, might actually qualify as restoration sites, owing to the loss of wetland function. Determining the degree of this loss would require a site investigation.

DEFINING ENHANCEMENT SITES

All NWI polygons that:

are ditched, drained, diked, impounded, or excavated AND

support emergent, scrub-shrub, or forested vegetation.

Protection Sites

Protection sights include all NWI wetlands that theoretically have not been modified as described above. For purposes of this analysis it is assumed that these wetlands are fully functional jurisdictional wetlands that are crucial in providing habitat, maintaining water quality, and sustaining proper hydrologic function. Ecologically, these sites are extremely important. While jurisdictional wetlands are protected through federal and state permit programs, some are in fact subject to management practices that, in some cases, pose a threat to the site's ecological integrity.[5] It can be assumed that preservation of these viable areas is a desirable component of a mitigation plan. Also, the proposed methodology requires that connected mitigation sites be identified according to the status and position of currently existing, functional wetlands. Thus, it is necessary to identify these unmodified wetlands in order to perform proximal analyses.

SUMMARY OF MITIGATION CLASSES

- **Restoration - agricultural fields with hydric, marginally productive or unproductive soils, which represent prior converted wetlands**
- **Enhancement - all modified NWI wetlands (ditched/partially drained, excavated, or diked/impounded)**
- **Protection - all NWI wetlands that have not been modified**

Opportunity Analyses — determining the benefits

Opportunity analyses are performed in order to evaluate the potential that an identified candidate mitigation site might have in providing public, natural, or cultural benefits on the basis of watershed characteristics. The opportunities, or benefits, considered for these analyses are wildlife habitat, water quality, and floodwater storage.

Wildlife Habitat

The following discussion provides a rationale, as supported by researched literature, for the choice of criteria used to evaluate the potential of candidate mitigation sites to provide wildlife habitat.

Justification — Many native species populations are in decline in South Carolina, as in other parts of the country. While population decline is attributable to a variety of causes, habitat encroachment is one of the most significant. Reduction in biological diversity and species quantity is directly related to the reduction in total area available for wildlife habitat. This is especially true for far-ranging species requiring extensive tracts of land. For example, data available for the Edisto River basin on the South Carolina Coastal Plain, suggest that high-level carnivores (and omnivores) including the eastern cougar, the black bear, and the red wolf have been extirpated from the region (Marshall, 1993). Landscape fragmentation is another factor contributing to population decline. The resulting subpopulations are isolated, leading to increased inbreeding and reduced fecundity. Also, several species utilize a range of habitats during their life cycle or seasonally. The elimination of any single habitat could have a negative impact on population size. The conversion of much of the natural forest cover in South Carolina to pine plantation is also likely to be responsible for species decline. Studies show that a change in forest structure from complex natural stands to a monoculture system dramatically affects species composition. (Langley and Shure, 1980; Harris et al., 1975; Noble and Hamilton, 1975).

Noss (1983) argues that habitat diversity, a measure of ecosystem integrity, can only be achieved through management strategies that are comprehensive in scope, considering isolated preserves in the context of a fragmented land-

[5] For example, important exceptions to the protection authority under §404(f) include 1)normal (ongoing) farming, silviculture, and ranching practices; 2)maintenance and emergency reconstruction of dikes, dams and similar structures; 3)construction or maintenance of farm ponds and irrigation ditches, and maintenance of drainage ditches; 4)construction of temporary sedimentation basins; and, 5)construction or maintenance of farm, forest, mining, and other temporary roads.

scape. As Harris (1985) points out, a collection of parts is very different from a functional system. He contends that isolated habitat islands, such as the isolated wetlands found on the Coastal Plain, could be transformed into an "integrated island archipelago system" if a passageway between patches was secured. It is feasible that these scattered isolated wetlands might be connected by the large stretches of contiguous streamside habitat, or riparian corridors, that exist in many areas of the Coastal Plain. Streamside buffers provide permanent habitat for a myriad of plant and less far-ranging animal species. Many mast-producing plant species occur in the riparian zone, thus providing a consistent food source in many streamside habitats. Also, because of adequate soil moisture and the aerobic conditions existing in many riparian ecosystems, decomposition is rapid in riparian zones and nutrients are readily available to both the terrestrial and aquatic food chains. As Forman and Godron (1981) noted, however, many species cannot survive the seasonal flooding or wet soils characteristic of lowlands and must have an associated well-drained upland area on which to seek refuge.

Oftentimes, the species that are better able to adjust to barriers posed by fragmentation and isolation are in less need of protection. As previously stated, populations of large, far-ranging species are declining in the region. Interestingly, there seems to be a healthy abundance of species more characteristic of edge/field habitat, such as deer (Marshall, 1993). As supported by Diamond (1976), Noss (1983), Forman and Godron (1981), and Saunders et al. (1991), mitigation strategies should consider habitat needs for those species less adaptable to human-induced perturbations on the landscape and thus should place priority on large intact sites with a large proportion of interior habitat and areas providing habitat connectivity.

Criteria — Many of the criteria used to identify mitigation sites in this analysis are based on properties espoused by Harris (1984) as important for wildlife habitat and include total habitat area, interior habitat extent, and the distribution of habitat patches in relation to one another and drainage patterns in the watershed.

Mitigation sites that are optimal for wildlife habitat are identified by first defining core habitat sites and then identifying contiguous enhancement and restoration sites. Core habitat sites are defined in this study as all unmodified wetland sites (protection sites), as well as all intact upland forests (excluding pine plantations), protected areas (i.e. wildlife refuges, state parks, national forests), and Significant Natural Areas as identified by the Natural Areas Inventory. The Natural Areas Inventory was a study sponsored by the National Oceanic and Atmospheric Administration and conducted by the South Carolina Water Resources Commission and The Nature Conservancy. The purpose of this systematic survey was to identify sites in the Edisto River basin — the larger drainage system of which Four Hole Swamp is a component — with relatively undisturbed, high-quality natural communities. Thus, Natural Areas Inventory data exist for the study area selected for model application. Such data do not exist for other basins in the South Carolina Coastal Plain.

Contiguous enhancement and restoration sites that, if mitigated, would extend the acreage of these core habitat sites are then identified. This association of core habitat sites and contiguous mitigation sites is termed "habitat complex." Identified habitat complexes as well as contiguous mitigation sites (without associated core habitat sites) are further analyzed to determine optimal wildlife habitat on the basis of three criteria: fragmentation, extent of interior habitat, and size.

All habitat complexes and potential mitigation sites are evaluated for fragmentation by considering the existence of paved roads. Large multilane or divided highways pose significant barriers to wildlife movement. These highways are overlaid on the selected habitat sites to further divide the sites and determine true habitat boundaries.

The existence of edge habitat is ubiquitous across the landscape; it can therefore be argued that habitat needs for edge species are already met by the existing landscape conditions. Thus, the habitat complexes meeting the above criteria are further analyzed to determine conditions supporting good interior habitat. In this analysis, the complex boundaries are reduced by 328 feet (100 meters) to determine interior habitat (Temple, 1986; from O'Neil et al., 1990). It is theorized that this distance effectively represents edge habitat. If any of the complex remains after reduction, it can be assumed that the complex provides some interior habitat function. The habitat sites remaining after reduction are expanded back to their original boundaries.

Finally, only habitat complexes of at least 40 acres in size are considered for the rest of the habitat analysis (Adamus, 1987). Also considered are all enhancement and restoration sites that are not part of a habitat complex but that are at least 40 acres in size.

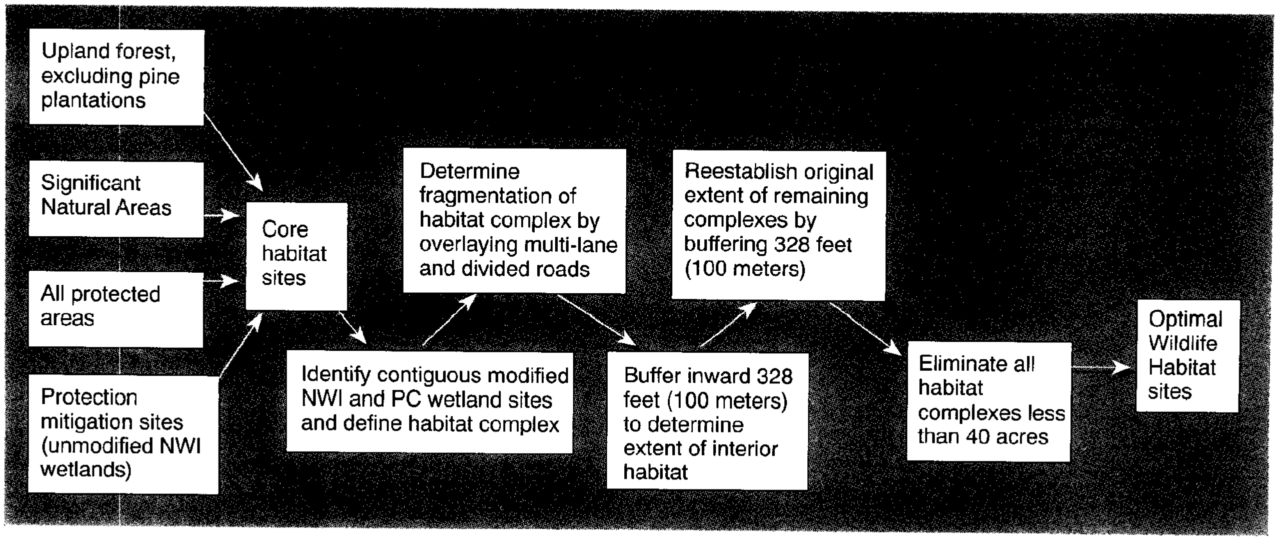


Figure 1. Steps in wildlife habitat analyses

Water Quality and Floodwater Storage

The following discussion provides a rationale, as supported by researched literature, for the choice of criteria used to evaluate the potential of candidate mitigation sites to provide water quality and floodwater storage function.

Justification — Because wetland systems are extremely variable in structural characteristics, it is difficult to identify unifying concepts that would allow a convenient breakdown of wetland types on the basis of water quality or hydrologic function. Hydrology, for example, is influenced by such site-specific characteristics as 1) site geometry, which determines storage capacity; 2) microtopographic relief or "roughness," which determines flow velocity and duration; 3) vegetation, which influences evaporation/transpiration and, therefore, flood duration; and 4) soil properties, such as permeability, which influence water routing (Gosselink et al., 1990). There are also site-specific characteristics, many of which are closely tied or identical to those above, that largely influence a site's ability to serve a water quality enhancement function. Such characteristics include slope, sinuosity, water velocity on tract, stem density, soil clay and organic matter content, and loading rates (Scott et al., 1990). As mentioned previously, it is not the intent of this model to definitively characterize the effectiveness of a site in performing a water quality or hydrologic function according to such site-specific characteristics. Rather, it is recognized that there also exist watershed level characteristics that influence a site's potential to serve these functions. The primary characteristics considered in this analysis are hydrologic and watershed position, as discussed below.

Wetland location within a watershed is an important determinant of its contribution to water quality. Brinson (1988) contended that the geomorphological setting of three wetland categories — basin, fringe and riverine — is the driving factor contributing to water quality impact because of differences in hydroperiod, hydrologic energy, and nutrients among the three. In general, basin or depressional wetlands receive runoff from a relatively small area since they are most often located in headwater areas. Soils in these areas are generally well suited to assimilate nutrients; however, because of their location it is often the case that little water actually flows through them, and opportunity for nutrient transformation is low compared to the other wetland types. Consequently, they might be considered more valuable as wildlife habitat than as nutrient assimilation zones. Riverine wetlands, because of their extensive association with upland systems and the nature of their soils, have both high capacity and opportunity to positively impact water quality and store floodflow. Because of this, and because of their abundance in the South Carolina Coastal Plain, these wetland sites are given sole consideration in the water quality and floodwater storage analyses. Fringe wetlands, or those occurring adjacent to large bodies of water or at the base of a drainage system (e.g., tidal marsh), are small compared to the large bodies of water that flush them. Fringe wetlands do not compose a major portion of the selected sub-basin and were not given independent treatment in this study. While the above described relationships generally hold across geographic regions, it is recognized that some exceptions may apply to a particular region. Thus, for application in other areas, the presence and function of isolated or fringe wetlands may demand a more thorough consideration of their contribution to water quality and floodflow storage.

Not only is watershed position an important determinant of a wetland's opportunity to contribute to water quality, but it can also be argued that its position along a drainage network dictates its opportunity to contribute to water quality (Kuenzler, 1989; Brinson, 1988; Whigham et al., 1988). Potential flood storage capabilities are also linked to this characteristic. Brinson (1988) distinguishes between two transport vectors for water and nutrients — riparian transport and overbank transport — with one mode of transport dominating over the other depending on stream order. Riparian transport, or overland water runoff, from agriculture, urban and silviculture areas first encounters wetlands associated with small order streams. It is here that a majority of the nutrients and sediments resulting from these land uses settle out and are recycled. Also, runoff is attenuated in these wetlands, helping to alleviate downstream flooding. Those wetlands immediately adjacent to a stream have an even greater opportunity to remove pollutants before they are introduced into the water column. Research supports the notion that, with some exceptions, the percentage of overland runoff that contacts wetland environments decreases as stream order increases. Thus, with some exceptions, low-order wetlands have a greater opportunity to enhance water quality than do higher order wetlands (Whigham et al., 1988; Kuenzler, 1989). These riparian areas are particularly important in an agricultural landscape such as the Four Hole Swamp sub-basin (from Whigham et al., 1988; Peterjohn and Correll, 1984).

In higher order wetlands the dominant transport vector is overbank flow. In general, these downstream wetland systems, especially if immediately adjacent to a stream, have greater opportunity to store excess streamflow during peak events (Taylor et al., 1990; Harris and Gosselink, 1990). It is also recognized that a pollutant removal function will subsequently result from water storage.

Criteria — In this analysis, all riverine wetland mitigation sites immediately adjacent to a stream, as delineated on the DLGs, are identified. To determine wetland adjacency, streams are buffered 98.4 feet (30 meters) on both sides, and sites falling within the resulting polygon are identified. These areas, because of their adjacency, are considered primary sites for hydrology and water quality function. Each is assigned a wetland order according the order of its associated stream. Lower order wetlands represent those that, theoretically, have the greatest potential impact on water quality while attenuating runoff. Higher order wetlands represent those that might have the greatest opportunity to store floodflow while effectively removing pollutants from floodwaters.

Hydrologic connectivity of all other riverine mitigation sites is then determined by identifying sites that are adjacent to the sites adjacent to a stream (as defined in above paragraph). All connected sites are classified according to their associated wetland and termed secondary wetlands. The steps involved in the water quality/hydrology opportunity analyses are summarized in Figure 2.

Unique Opportunities/Barriers and Potential Threats — locating endangered species, cultural resources, and potential contaminant sources

Endangered species habitat and cultural resource sites (archaeologic/historic sites) represent important public resources and benefit from some protection provided by state and federal programs. Sites containing these resources may or may not be optimal for mitigation. The impact, either negative or positive, of a mitigation project on these resources should be determined on a site-specific basis. These sites are identified and overlaid on the final composite, created by overlaying the results of the habitat and water quality/floodwater storage analyses.

In many instances, cultural and endangered species inventories have primarily been done in areas where development has occured. While occurrence information exists for those sites, geographically extensive spatial data coverages that are "complete" for these themes do not exist. It should be noted that this methodology will, in most cases, direct initial selections for priority mitigation sites to areas that

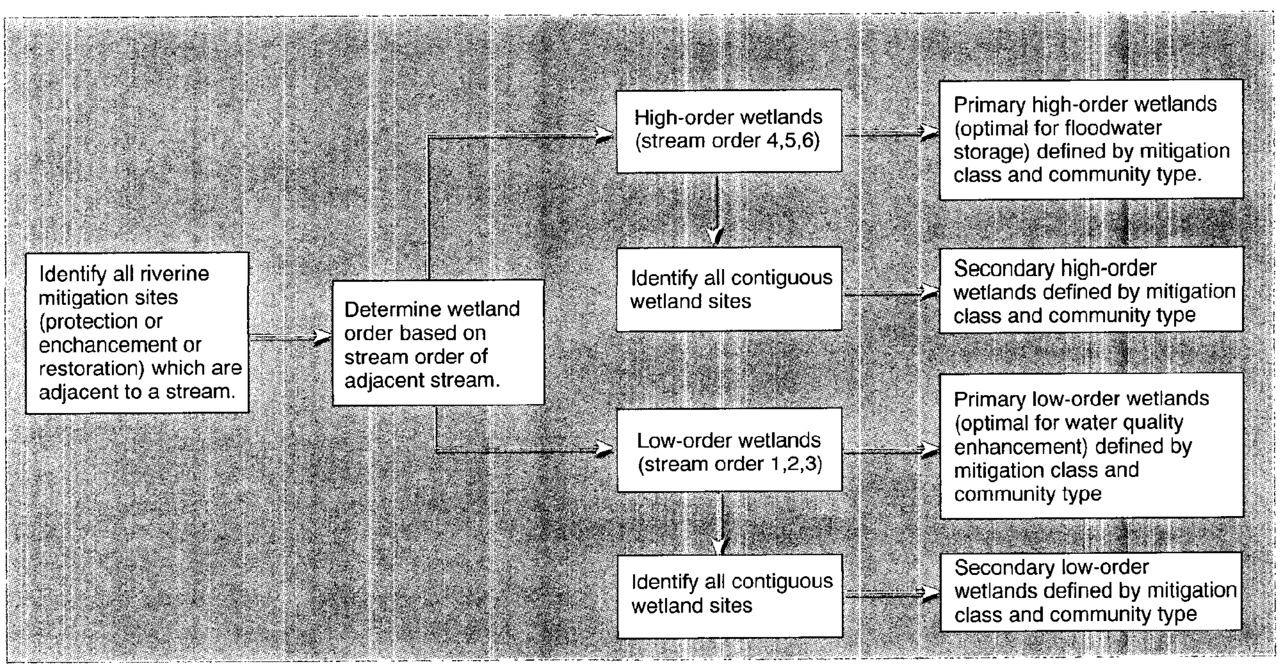


Figure 2. Steps in water quality and floodwater storage analyses

are fairly remote and are least likely to have thorough preestablished rare/endangered species habitat and cultural inventories. Thus, synoptic assessment of these impacts are deemed appropriate for this methodology only with subsequent site-specific inventory work.

As previously mentioned, a Natural Areas Inventory of the Edisto River basin was performed in 1992 in order to identify natural areas of significance. The results of that inventory indicate that natural habitat acreage — especially upland habitat — has dramatically decreased in the basin. In fact, for the most part, river corridors serve as the last refuge for natural plant communities. Thus, these identified communities as well as any upland significant natural areas are overlaid on the composite to graphically display priority wetland mitigation sites in relation to these features.

Finally, it is recognized that surrounding land uses and management practices may pose a threat to the continued viability of a mitigation site. Conversely, the negative impacts of these activities could be ameliorated by a restored or enhanced wetland. In this study, potential sources of threat are defined as nutrient, sediment, and toxicant sources and include domestic and industrial landfills, mines, and hazardous-waste sites. The proximity of these potential sources to mitigation sites is graphically represented on the final composite. Determining whether these sources would threaten the success of a mitigation project or, in fact, be mitigated by a restored wetland, would obviously have to be done on a site-by-site basis. The overlay does provide an information tool that can assist in the indicated field work but it cannot provide a substitute for the site-specific analysis. A summary schematic of the GIS analyses as discussed in the above section is presented in Figure 3.

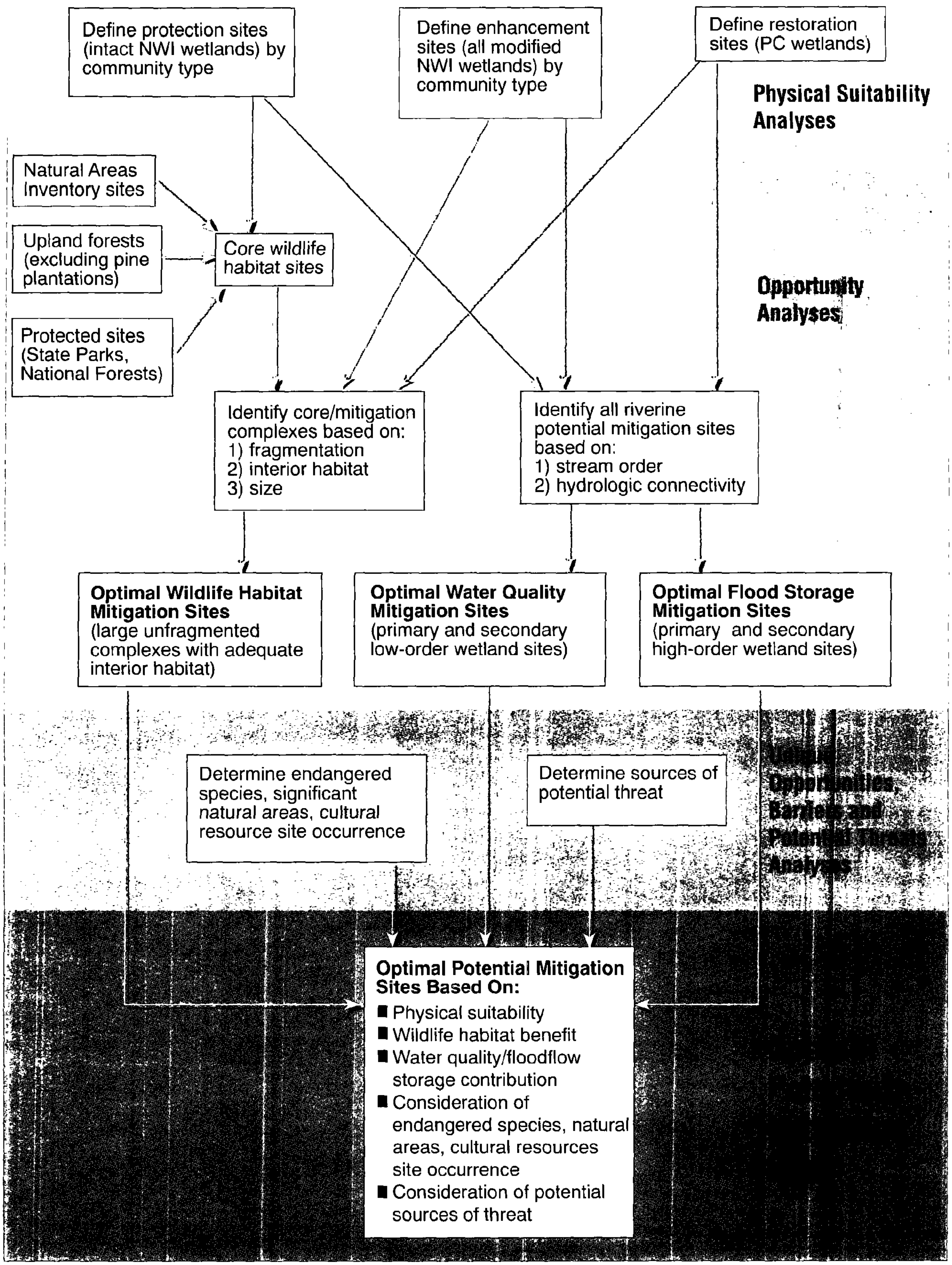


Figure 3. Summary of steps for identifying optimal sites

Model Application

Section 3

Study Area

The Four Hole Swamp sub-basin is one of four sub-basins in the Edisto River basin (Figure 4) in South Carolina and is the study area for this model application. In 1992, the South Carolina Water Resources Commission performed an ecological characterization of the Edisto River Basin. The purpose of the ecological characterization was to describe overall ecosystem health on the basis of land use/land cover trends, water quality trends, changes in hydrology, and biological indicators (Marshall, 1993). The following information about Four Hole Swamp sub-basin and the vicinity resulted from or was compiled during the characterization.

The Four Hole Swamp headwaters originate in the Coastal Plain in Calhoun and Orangeburg Counties and drain about 650 square miles from four counties—Orangeburg, Calhoun, Dorchester, and Berkeley (Figure 5). The Four Hole Swamp system spans approximately 50 miles before it discharges into the mainstem of the Edisto River.

The SCS has divided the state of South Carolina into six Land Resource Areas on the basis of soil conditions, climate, and land use (U.S. Department of Agriculture, 1978). These Land Resource Areas are defined primarily by soil characteristics that provide a basis for describing potential vegetation and land uses. The Four Hole Swamp sub-basin encompasses two of the six Land Resource Areas: the Atlantic Coast Flatwoods and the Southern Coastal Plain (Figure 6).

The Atlantic Coast Flatwoods, which composes the vast majority of the study area, is nearly level and is dissected by many broad, shallow valleys with meandering stream channels. Elevations range from about 25 to 125 feet with local relief of a few feet to about 20 feet. The soils are predominantly somewhat poorly to very poorly drained and formed in sandy to clayey Coastal Plain sediment. The Southern Coastal Plain is an area of gentle slopes. Local relief is in tens of feet. The soils are predominantly well or moderately well drained and formed in loamy or clayey Coastal Plain sediments.

There are distinct patterns of land use and land cover in the Four Hole Swamp sub-basin that correspond to the natural characteristics of the landscape (Figure 7). The fertile loamy and clayey soils of the Southern Coastal Plain area support some of the most productive agricultural land in South Carolina. The sandy and clayey soils of the Atlantic Coast Flatwoods also support some very large agricultural areas. As the watershed narrows at its base, however, the Flatwoods become dominated by forestland, primarily pine plantations. The riverine bottomlands or flood plains remain mostly forested, and they form a dendritic or branching pattern of forested wetland corridors throughout the sub-basin. Many of these wetlands are in a modified condition and have been ditched, drained, diked, or impounded. In many areas these wetlands have been totally altered, with the native vegetation converted to agriculture, pine plantations,

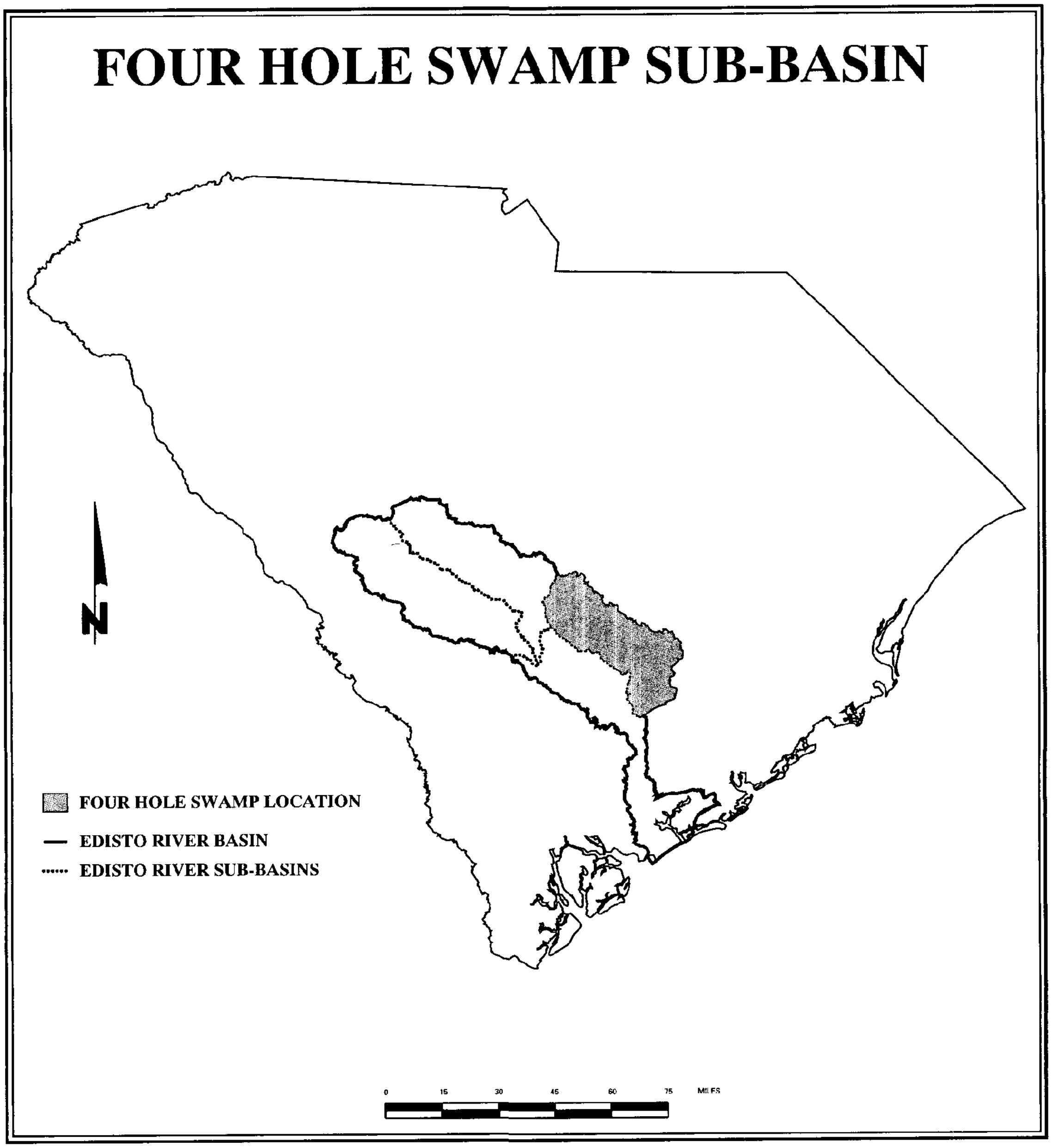


Figure 4. Location of Four Hole Swamp sub-basin

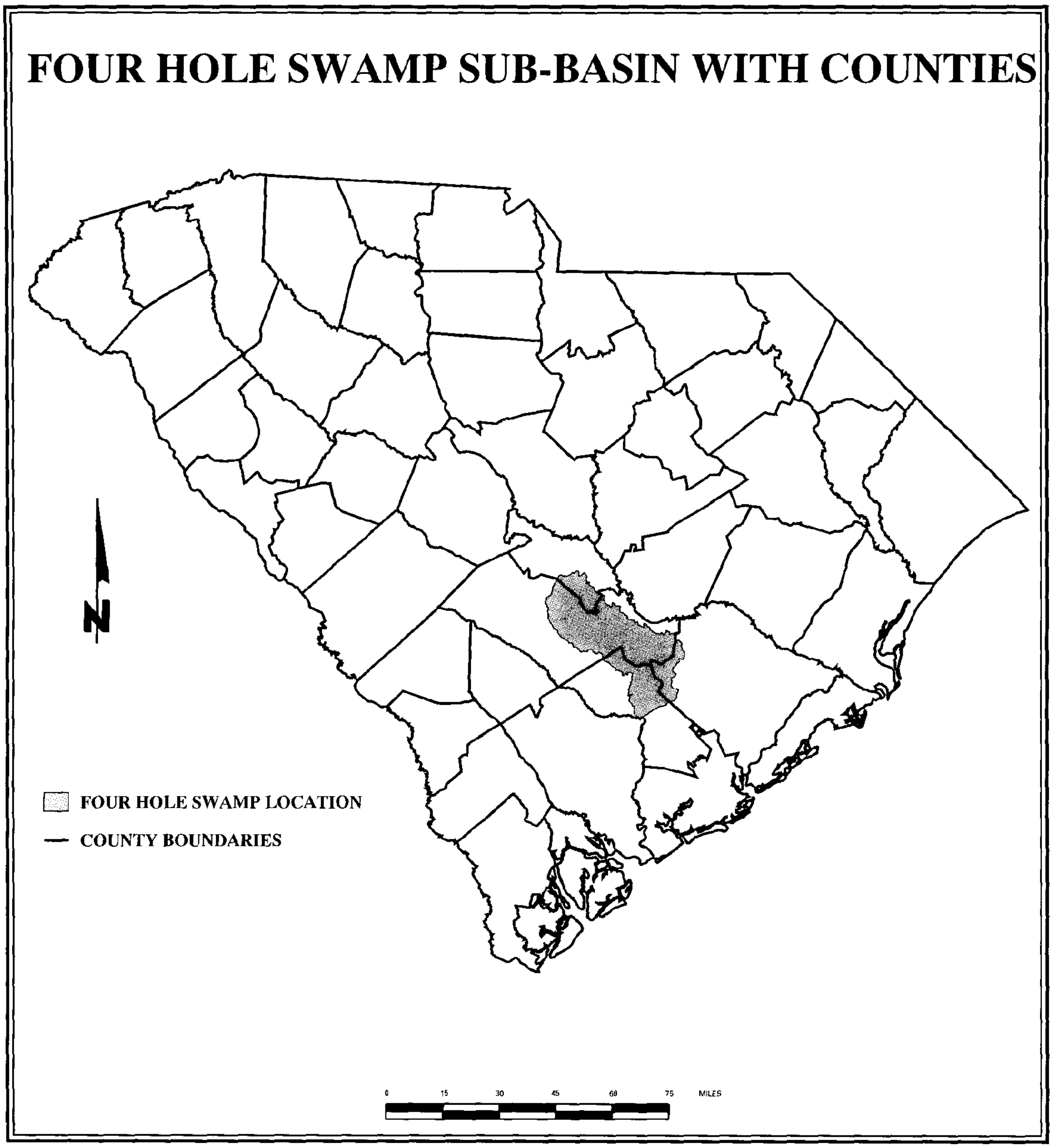


Figure 5. Counties in Four Hole Swamp sub-basin

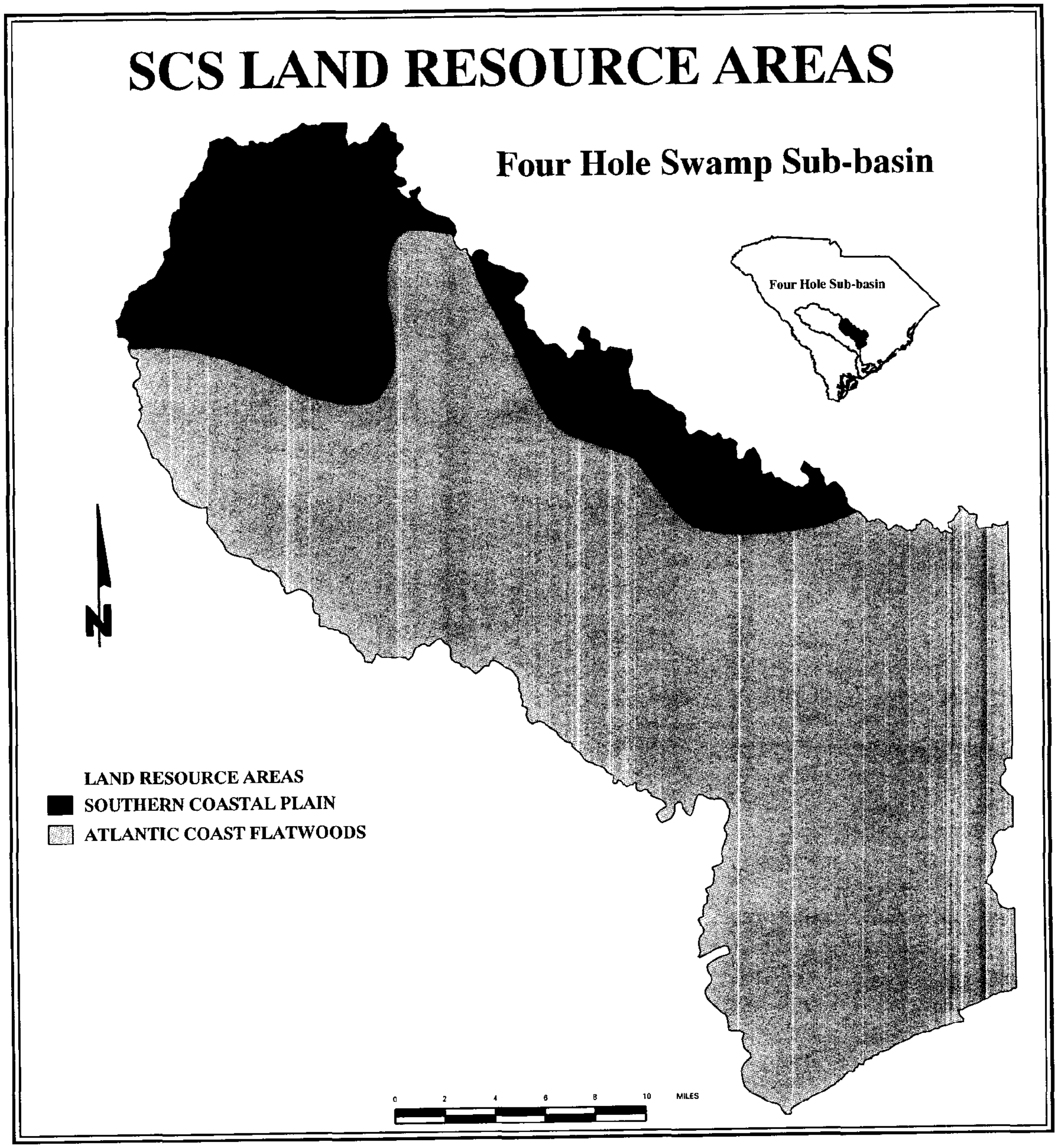


Figure 6. Land Resource Areas in Four Hole Swamp sub-basin

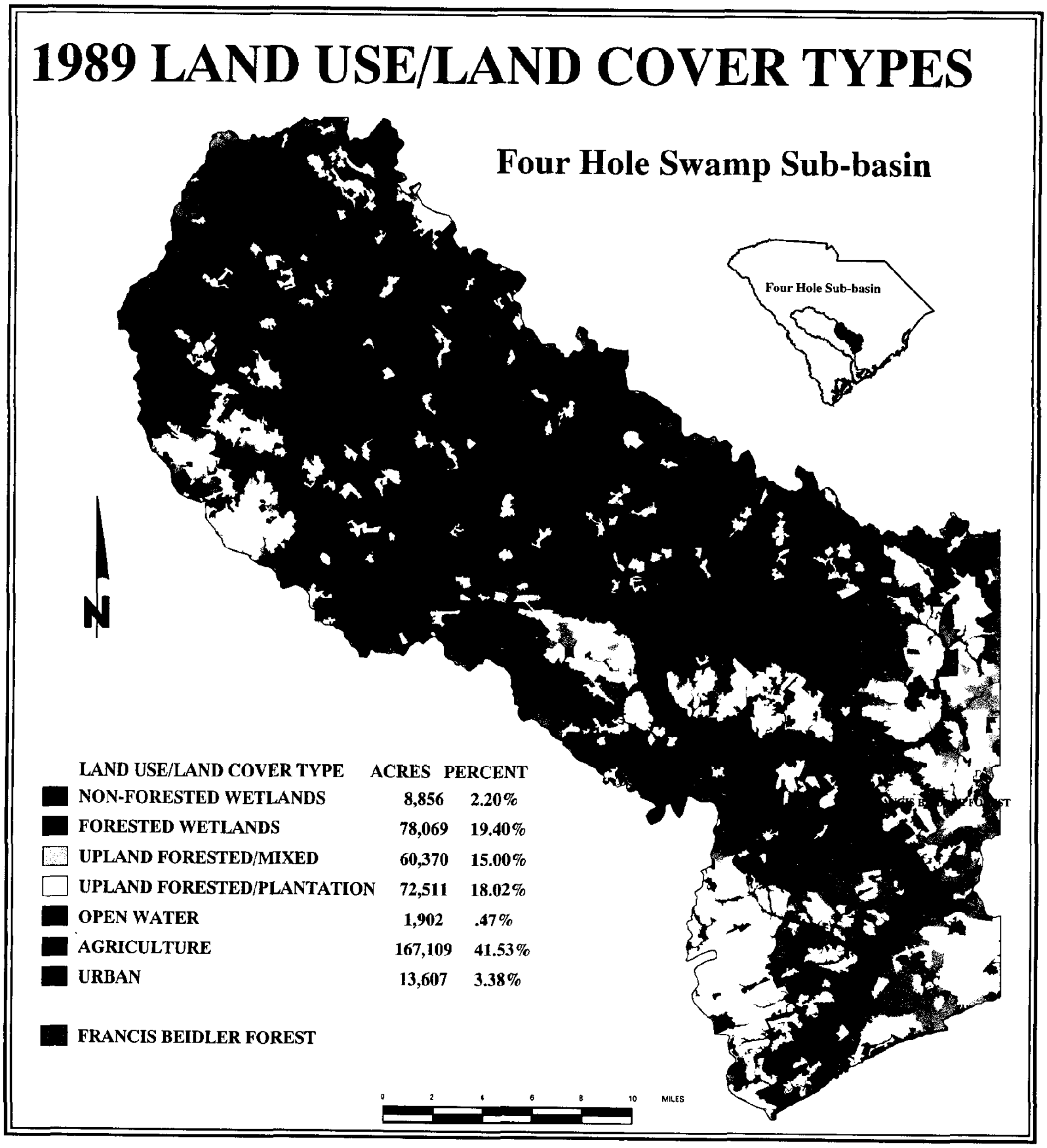


Figure 7. Land use/land cover in Four Hole Swamp sub-basin

and, adjacent to Orangeburg, urban land uses. The city of Orangeburg is the only large urban area within the sub-basin.

The only protected natural area in the Four Hole Swamp sub-basin is the Francis Beidler Forest, an 11,000-acre bottomland hardwood swamp. It contains the largest old-growth stand of tupelo and cypress in the country, as well as a large variety of birds, mammals, reptiles and amphibians, and many rare plants. The habitats of many plant and animal species in the sub-basin are threatened by hydrologic alterations and other manmade impacts. Several animal species that occur in the sub-basin, including the red-cockaded woodpecker, the bald eagle, and the wood stork, all of which have specific habitat needs, are listed as federally endangered or threatened. Numerous plants and animals listed as state threatened or endangered are also found in Four Hole Swamp.

Automating Criteria

Data Preparation

The SCWRC has been building a natural resources GIS for the last five years. The Commission's efforts have been funded primarily through the support of NOAA and the state of South Carolina. Additional support has been received from USGS, USFWS, SCS, and the National Park Service. ARC/INFO GIS is used to implement this model.[6] This GIS provides a full complement of various GIS functions, including raster-based processing.

The hardware used was an IBM RISC/6000 technology and includes a model 970 server and model 360 workstation. The server is equipped with 12 gigabytes(GB) of disc storage and 128 megabytes(MB) of memory (RAM). The workstation has 1 GB of disc storage and 64 MB of RAM. These systems are connected by Ethernet.

The original intent of implementing this model was to use the ARC module with data in a traditional vector format. It became apparent early on that this would not be possible because of the complexity of the data. The Four Hole Swamp sub-basin consists of portions of 17 quadrangles containing over 402,000 acres. These individual quadrangles were merged by dissolving their associated boundaries, and then clipped to the hydro-unit boundary, creating large individual datafiles for each data layer required by the study. This procedure created polygons that exceeded the maximum number of arcs per polygon (i.e. 10,000 arcs per polygon) permitted in ARC. The proximal analyses required by the model prevented the analyses being conducted on an individual quadrangle basis because it would introduce arbitrary polygon boundaries at the quadrangle boundaries.

[6] ARC/INFO is a proprietary software package developed and marketed by the Environmental Systems Resource Institute, Redlands, California.

The complexity issue required that the model be implemented by using the GRID module in ARC/INFO. As a consequence, all data layers were converted to a grid cell format using the POLYGRID command. It was decided that a 16.4-foot (5-meter) cell size should be used to insure that even very small candidate mitigation sites were not generalized. This did not eliminate the map complexities — data layers are 12,726 rows by 11,431 columns of grid cells — but permitted the data to be analyzed. The polygon identification numbers from ARC ("-ID" value) are used for the cell values. The use of these values serves two purposes: preserving the original polygon boundaries and providing a tie to associated INFO attributes. The preservation of polygon boundaries was necessary for later analyses where wetland polygons were used as surrogates for elevation data. No digital elevation model or hypsography data were available for the study area. Additionally, the polygon identification number permitted all original INFO data attributes to be used in subsequent GRID analyses. Attributes were added to grid cell data by using the JOINITEM command.

GIS Analyses

Initial Site Selection

The initial phase of applying this model to the Four Hole Swamp sub-basin required defining mitigation classes. The three mitigation classes — restoration, enhancement, and protection — and the rationale for their selection criteria are discussed in the previous section. Restoration sites were selected by overlaying the hydric soils data layer with the uplands data layer, using the CON function. The CON function provides data evaluation capabilities by using conditional statements that test the presence or absence of specified data values in individual grid cells. Each cell was evaluated and only those areas containing both a hydric soil and an agricultural land use were defined as potential restoration sites.

The protection and enhancement sites were selected from the NWI data on the basis of their classification codes. Cells having a NWI code lacking a modifier (i.e. ditched or drained (d), diked or impounded (h), or excavated (x)) were identified as protection sites. Conversely, those cells possessing one of these codes were identified as enhancement sites. Also, only those areas that apparently support hydrophytic vegetation, as indicated by the codes PEM, PSS, or PFO, were selected.

All restoration, enhancement, and protection sites were combined to create a data file representing all potential mitigation sites in the Four Hole Swamp sub-basin. The COMBINE function was used because all sites are independent and mutually exclusive. Finally, any potential mitigation site contained within a protected area was eliminated since, theoretically, these areas are already protected and not a viable mitigation alternative (Figure 8). The CON function is used to test for the existence of a protected area. In this study case, the only protected area in the Four Hole Swamp is the

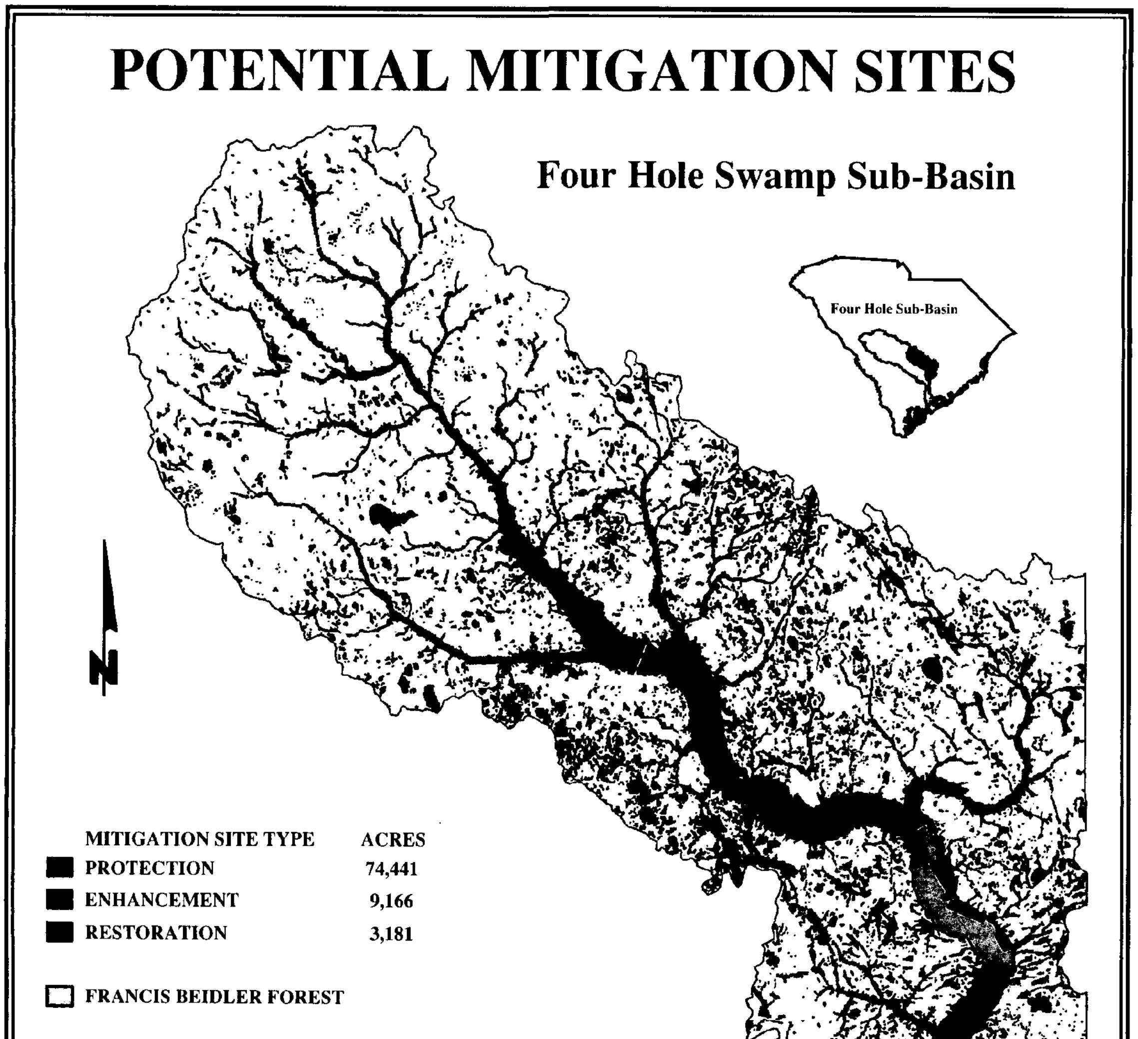


Figure 8. Potential mitigation sites by mitigation class

Francis Beidler Forest, which is a private preserve managed by the National Audubon Society. Figure 8 shows that the overwhelming majority of potential mitigation sites within the study area are protection sites. Four Hole Swamp has undergone much landscape alteration but still contains large areas of these quality wetlands. Several large enhancement sites, many of which appear as remnants of former Carolina Bays, exist and may provide significant mitigation opportunities. Few restoration sites exist in the study area. This scarcity does not seem problematic of the source data since these sites follow streams and are adjacent to "wetter" areas, as would be expected. Instead, the scarcity appears to be a function of the very restricted list of hydric soils used for the selection criteria. This will be discussed later.

One apparent problem resulting from a delineation error was the misclassification of what is clearly a road crossing the bottomland area. Although it should have been coded as transportation/utilities, this area was classified as agriculture in the Uplands data layer and thus was identified as a restoration site. It was not changed because doing so would invalidate the field verification of source data.

Wildlife Habitat Opportunity Analysis

The wildlife habitat opportunity analysis evaluated the potential mitigation sites with regard to their ability to serve a wildlife habitat function. The first step in this analysis was the assembling of core habitat sites. These core habitat sites comprised all the protection sites selected above, all upland forests (excluding pine plantation sites) from the uplands data layer, all protected areas (Francis Beidler Forest), and all significant natural areas (Figure 9). On the basis of the model definition, these sites represent prime wildlife habitat areas in the sub-basin.

The model defines multilane roads as significant barriers to wildlife movement. These multilane roads were selected from the DLG roads data layer (codes 203 and 307). Since these codes represent only divided highways, South Carolina county highway maps were used to update other multi-lane roads. The selected roads were buffered to a distance of 131 feet (40 meters or 8 cells) to represent the highway right-of-ways, using the EXPAND function. This function adds successive rows of cells to a feature until reaching the specified distance. All added cells are given values identical to the parent feature. No attempt was made to add new roads or to make a distinction between roads according to the number of lanes they might have. Therefore, all multilane roads were buffered the same distance. The buffered roads were overlaid with the original core habitat sites, using the CON function. All cells containing a core habitat site and a road were eliminated.

Adjacent restoration and enhancement sites (termed hereafter as "degraded sites") are added to the fragmented core habitat map to determine the amount of habitat each would add, upon mitigation, to the core habitat sites. The added sites were bisected with the same buffered roads used above (Figure 10).

In order to examine adjacency, the fragmented core habitat sites and the degraded mitigation sites are combined. The REGIONGROUP function in GRID, using the CROSS option, evaluates the connection of each cell in relation to its surrounding or neighbor cell. All connected cells are given a unique identifier. In this particular case the command syntax appears as follows:

```
newmap = REGIONGROUP (oldmap, #, EIGHT,
  CROSS, 0)
```

The above command specifies that each cell will be evaluated in relation to its eight neighbors but will not be connected to any neighbor cell with a value of 0. Surrounding cells with values other than 0 will be connected. Connecting these degraded and core habitat sites results in regions with unique cell values. These grouped regions, or habitat complexes, further define all potential wildlife habitat areas within the study area.

Subsequently, each complex boundary is buffered inward by a distance of 328 feet (100 meters or 20 cells) using the REDUCE function to eliminate all "edge" habitat (Figure 11). The REDUCE function simply eliminates successive rows until the distance specified is met or the feature is eliminated. Thus, the reduction along the boundary eliminated all habitat complexes 656 feet (200 meters) or less in width. A comparison of Figure 10 and Figure 11 demonstrates this. By definition, areas within 328 feet (100 meters) of a region boundary are "edge" habitat areas and not viewed as significant, since the fragmented nature of the study area provides an abundance of this particular habitat. The habitat complexes remaining represent areas containing adequate interior habitat for wildlife. The remaining regions were buffered outward to a distance of 328 feet (100 meters) — the original boundaries — using the EXPAND function.

The remaining habitat complexes were evaluated for size characteristics. The model defines only habitat complexes of 40 acres or greater as containing adequate space for wildlife habitat. Given this criteria, each habitat complex was evaluated and only those containing a minimum of 40 acres were selected using the CON function. The areas remaining after this procedure represent the optimal wildlife habitat complexes contained within the study area (Figure 12). Finally, the original potential wetland mitigation sites, defined by mitigation class, were overlaid with the optimal habitat complexes, using the CON function. Only those cells containing both an optimal habitat complex and a potential mitigation site were selected. These represent the potential mitigation sites meeting the wildlife opportunity analysis criteria.

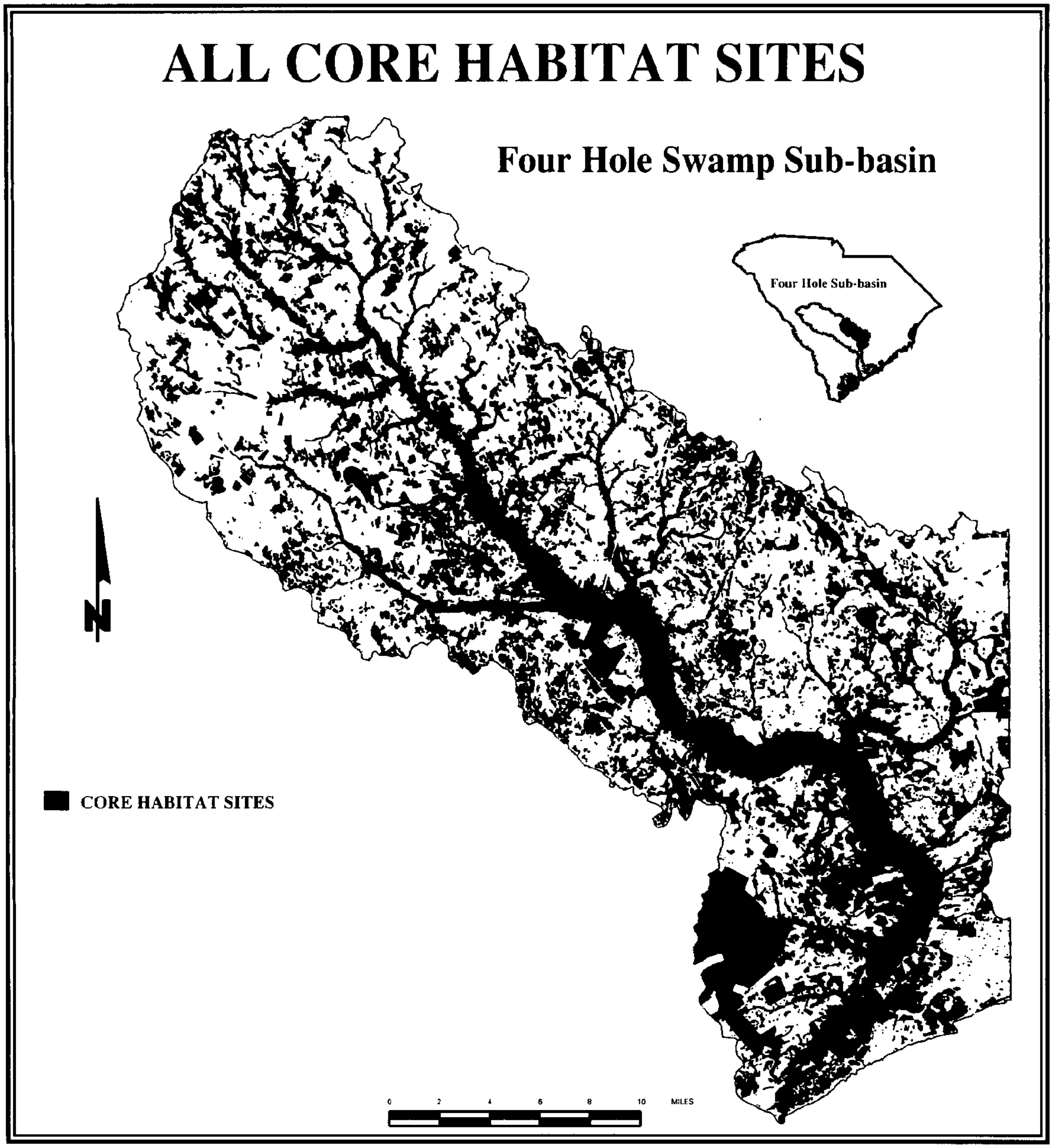


Figure 9. Core habitat sites

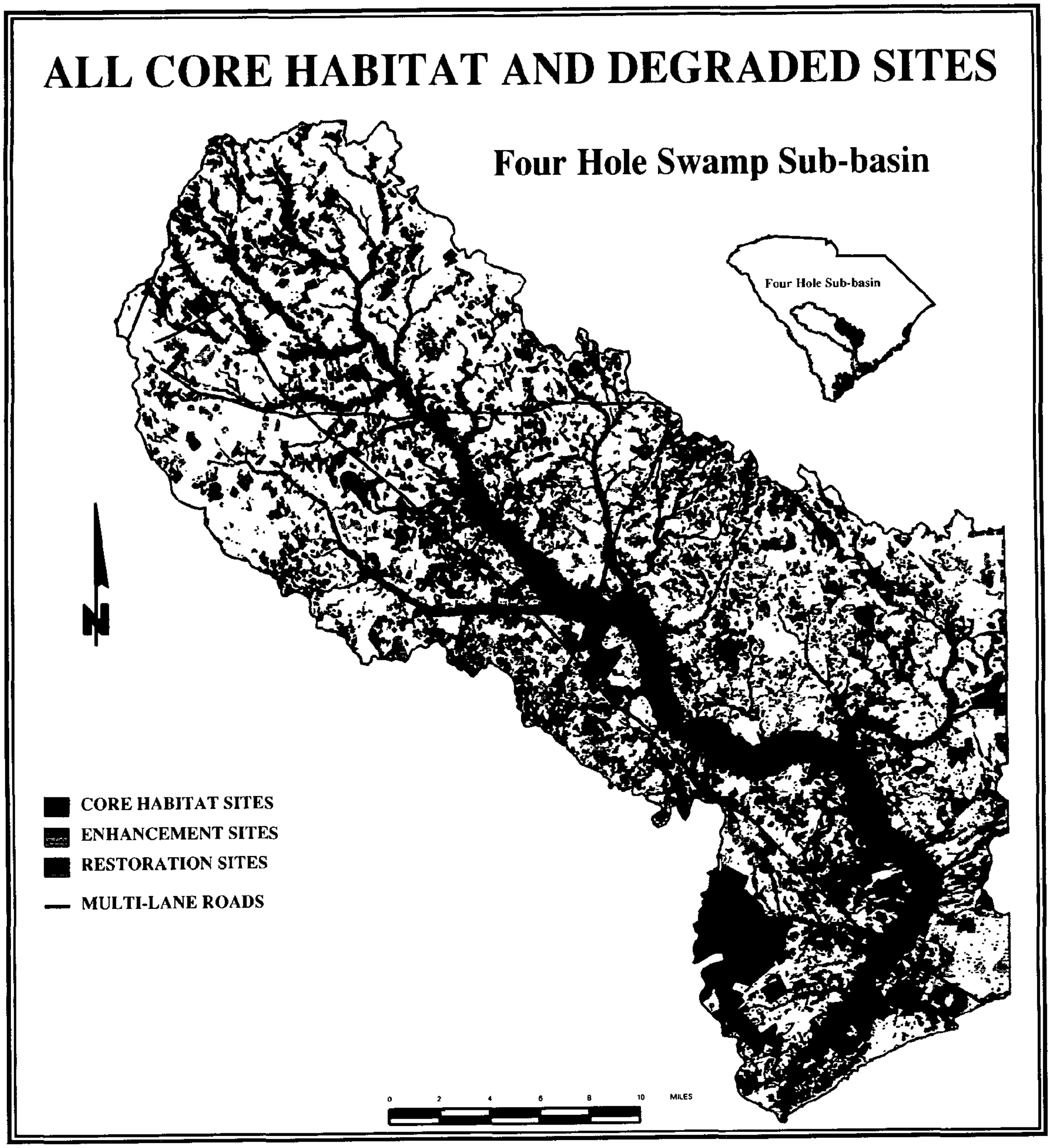


Figure 10. Core habitat sites and adjacent degraded sites

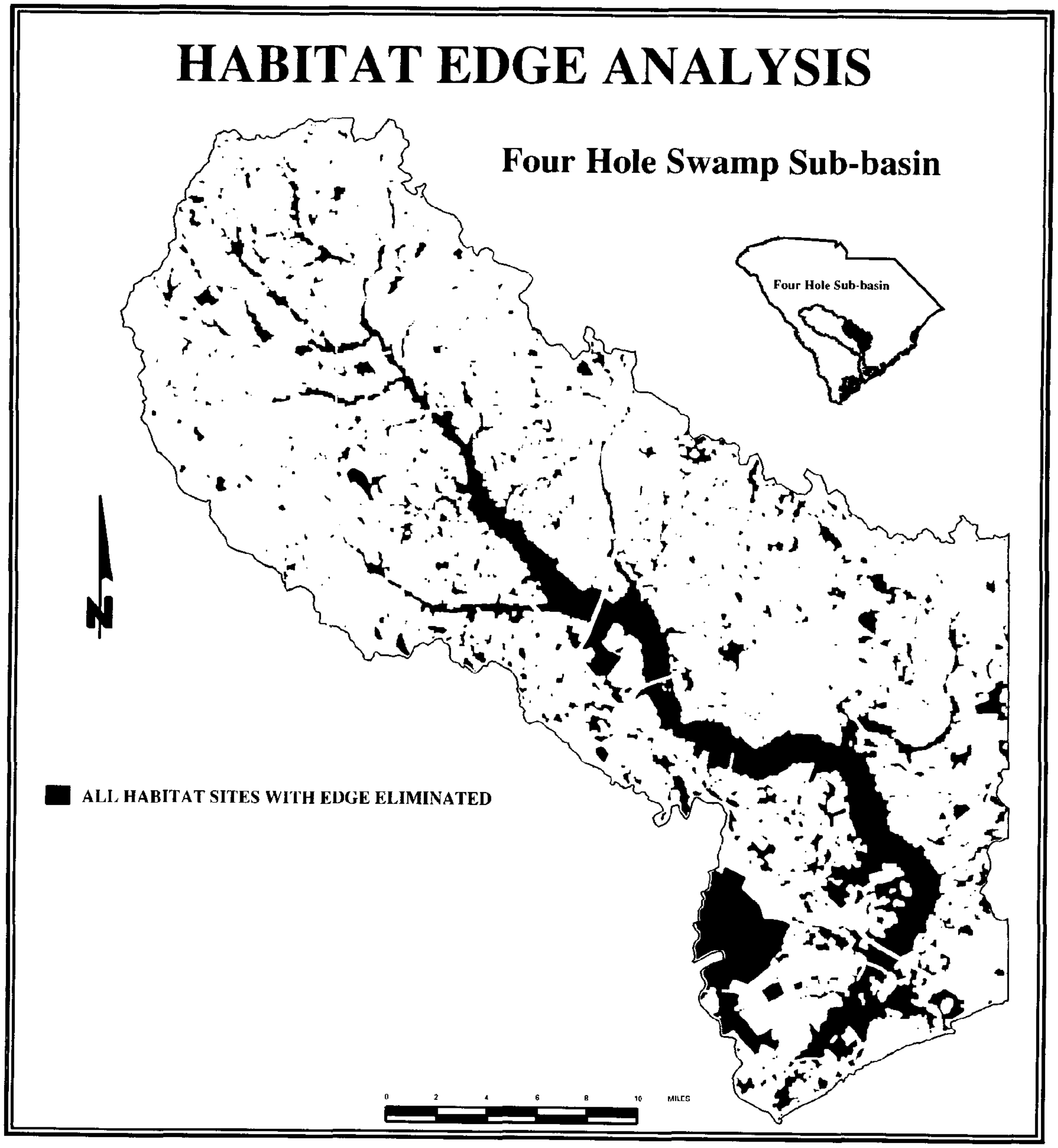


Figure 11. Results of edge elimination analysis

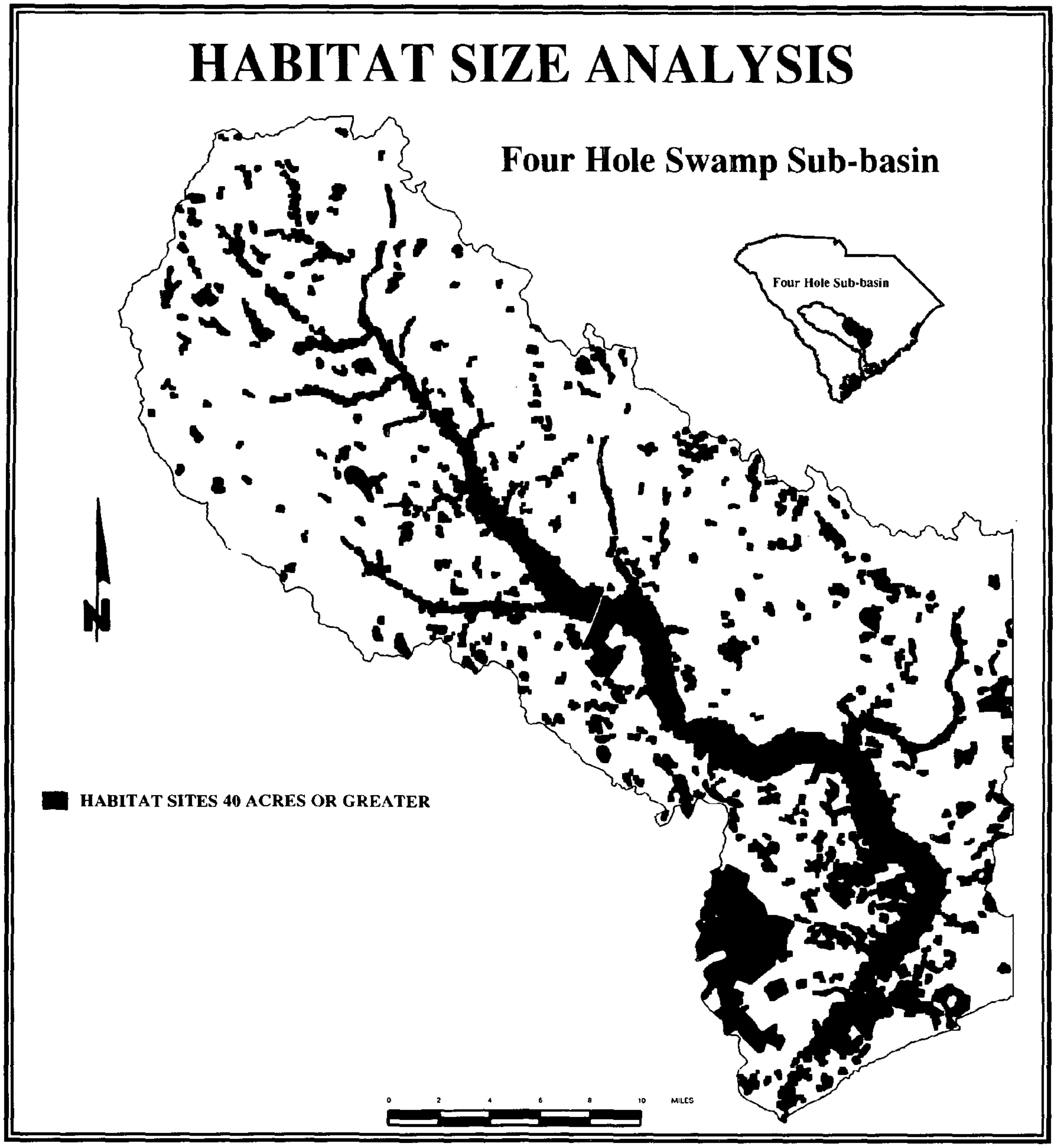


Figure 12. All habitat sites 40 acres or greater in size

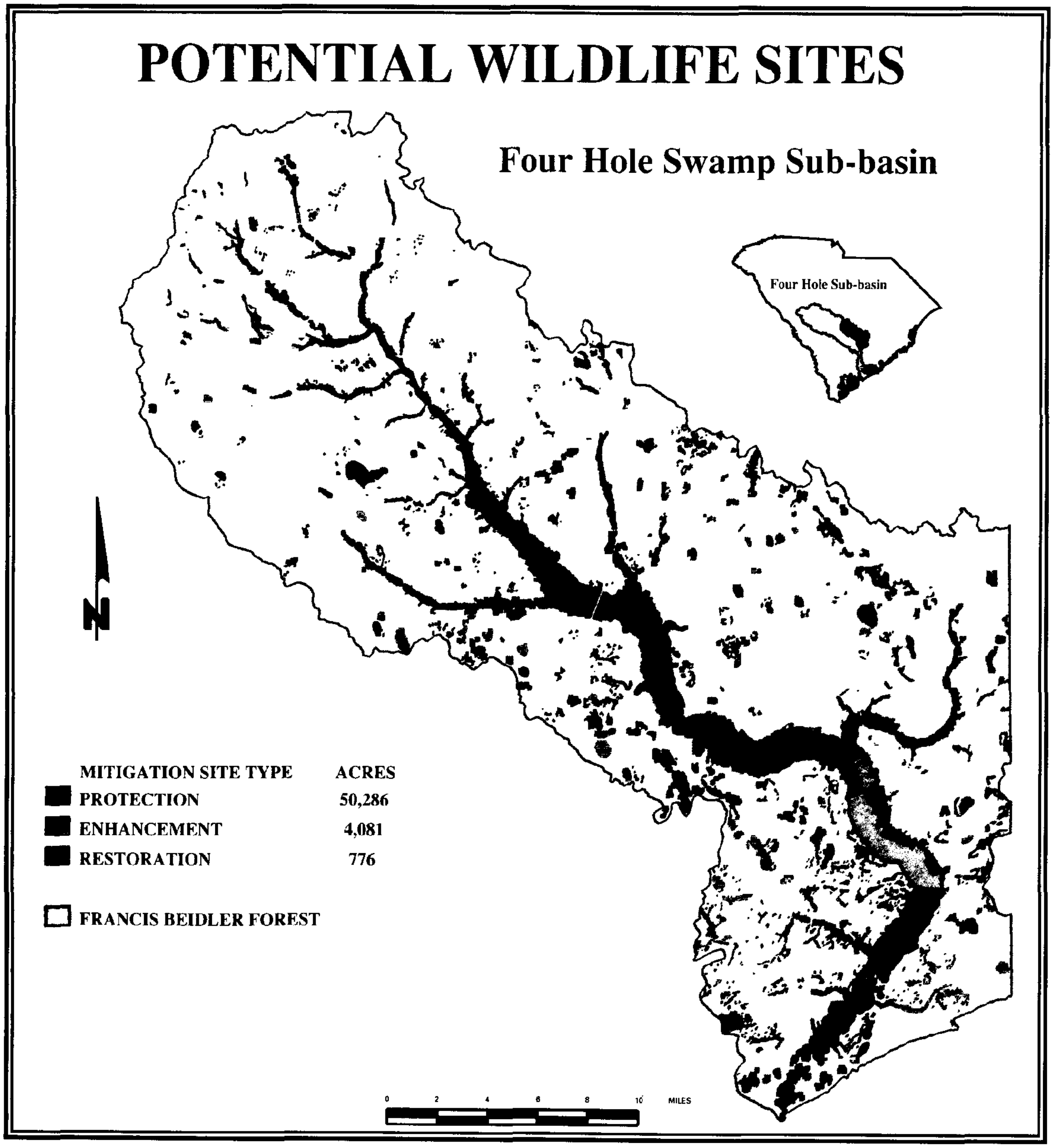


Figure 13. All potential wildlife habitat sites

Figure 13 depicts the potential mitigation sites that theoretically provide the greatest wildlife habitat benefit. Not surprisingly, a larger number of protection sites satisfy the wildlife opportunity criteria than do restoration or enhancement sites. While several large enhancement sites were identified as serving a wildlife habitat function, few of the restoration sites were considered optimal for wildlife habitat, owing to the restrictive size criteria.

Water Quality and Floodwater Storage Analyses

These analyses considered the potential flood storage capacity a potential mitigation site might possess and the ability of a site to contribute to stream water quality. Streams and their associated drainage order were obtained from the DLG hydrography data layer. High-order streams were defined as all 4th-, 5th-, and 6th-order streams, while low-order streams were defined as 1st-, 2nd-, and 3rd-order streams. All streams were selected and recoded to single values reflecting either a high or low order. Figure 14 represents all potential mitigation sites, and their stream network, plotted by their respective order. Because of the braided nature of portions of the Four Hole drainage system, some portions of the high-order stream network had to be added. In these areas on the mainstem, the stream network disappears from the digital data. A single stream was digitized to complete the drainage pattern.

Potential flood storage sites (high-order sites) were defined as any potential mitigation site adjacent to a high-order stream. Additionally, each site was defined as a primary and secondary site depending on its position on the landscape. In this study, wetland sites were used as a surrogate for elevation data. If elevation data had been available, the landscape topography could have been defined and used to assess hydrologic flow. No elevation data exist in a digital format for the study area; thus, this model assumes that any adjacent site receives overbank flow from its related stream or an adjacent wetland site. By definition, primary sites are those potential sites immediately adjacent to a high-order stream and assumed to be most effective in storing overbank flow. Secondary sites are adjacent to any primary site or adjacent to any secondary site that is adjacent to a primary site and assumed to be less important in floodflow storage.

All high-order streams were buffered to a distance of 32.8 feet (10 meters or 2 cells) using the EXPAND function. This width was an arbitrary value selected to represent the stream surface, since the hydrography data layer is represented by a single line in the data base. The assumption was that any potential mitigation site within 32.8 feet (10 meters) of a stream would receive overbank flow from the identified adjacent stream. This assumption requires each potential mitigation site within 32.8 feet (10 meters) of the stream to be retrieved with its associated polygon identification number ("-ID") used to code the cell value in the original grid conversion of the data. The ID permits the entire area, as defined by polygonal boundaries, to be retrieved for each potential mitigation site.

Initially, execution of the EUCDISTANCE function in GRID was attempted to retrieve these IDs; however, this required massive amounts of temporary storage. The function exhausted 800 MB of free space on the disk and required more to complete the task. As a result, an alternative method was devised. The buffered streams were overlaid with the potential mitigation sites. All selected cells were given the original polygon ID value. The FREQUENCY command in ARC was used to eliminate duplicate polygon IDs. An arbitrary value was assigned to each ID and joined to the existing VAT data files using the JOINITEM command in ARC. The arbitrary value permitted the retrieval of all cells that defined the polygonal area of each adjacent potential mitigation site.

Figure 15 illustrates one problem with the definition of primary high-order sites. While many adjacent sites were accurately classified as primary high-order by this methodology, the mainstem of Four Hole contains numerous areas or islands wholly contained within these primary high-order bottomland wetlands. These wetlands were not identified as primary high-order because they did not satisfy the distance criteria. Upon examination, most of these areas were found to be potential mitigation sites and defined as wetlands; however, GRID does not afford any easy means of selecting and recoding these areas in an automated fashion.

All other unselected potential mitigation sites were evaluated to determine if they were adjacent to a primary high-order site or to other secondary high-order sites that were adjacent to primary high-order sites. The adjacency of sites was evaluated by the REGIONGROUP function and according to the same method used in the wildlife opportunity analysis as described above. Additionally, the CON function was used to differentiate between primary and secondary sites.

Figure 15 shows all identified primary and secondary high-order sites. The methodology was very successful in selecting high-order sites — the bottomland areas were identified as providing important flood control functions. However, the inclusion of numerous secondary sites within the bottomland area was a departure from the expected outcome of this methodology. A judgment was made to treat all high-order potential sites identically regardless of their ranking (i.e. primary or secondary).

Water quality sites, termed low-order sites, were defined as any potential mitigation sites adjacent to low-order streams. All selected sites were segregated into primary and secondary sites, using methods and selection criteria described above. Figure 16 shows all primary and secondary low-order sites identified by this method.

The model did not function well in the identification of low-order sites. Again, for purposes of this study, low-order sites were defined as 1st-, 2nd- and 3rd-order sites and were assumed to represent headwater wetlands. As can be

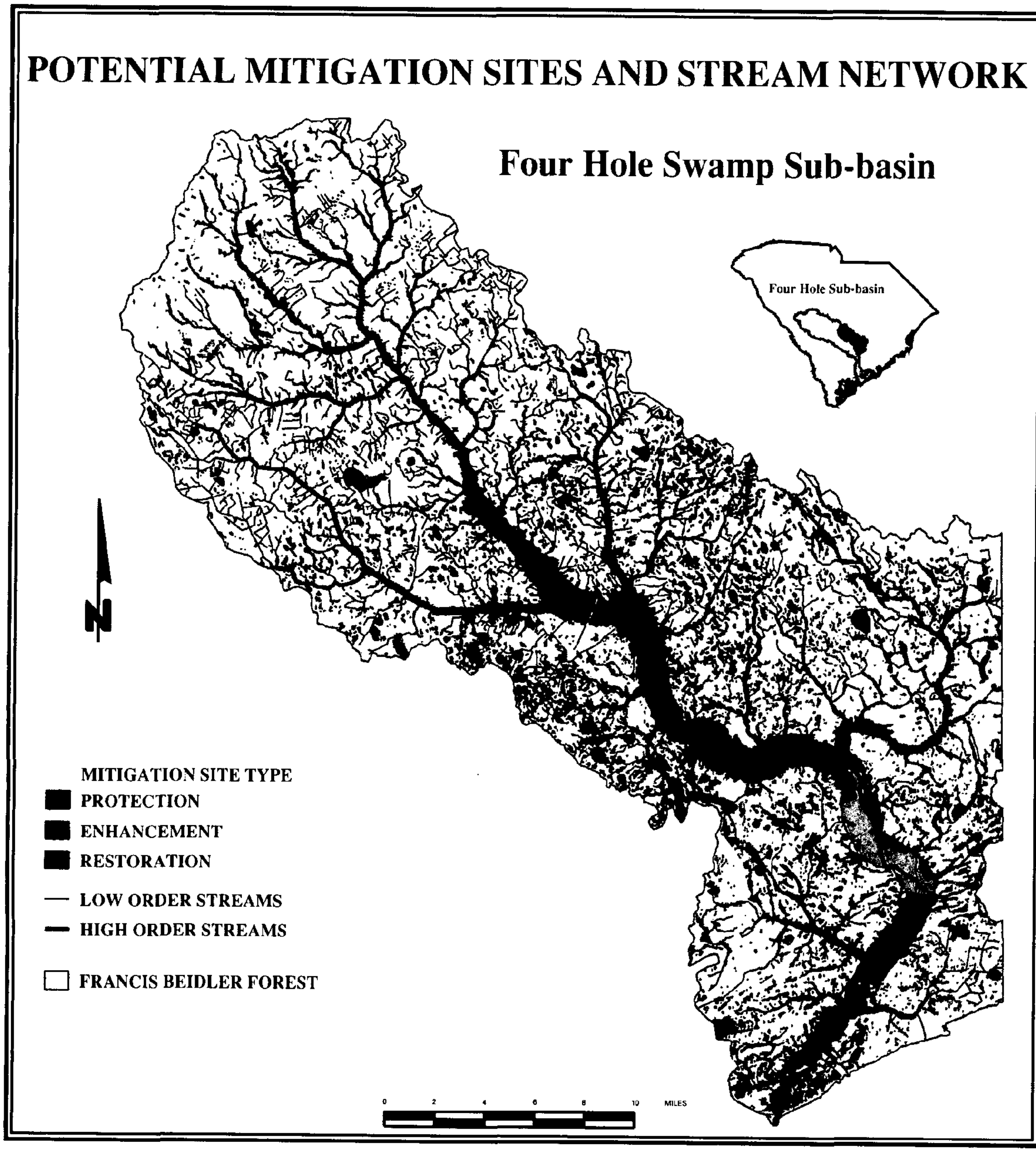


Figure 14. Potential mitigation sites and stream network

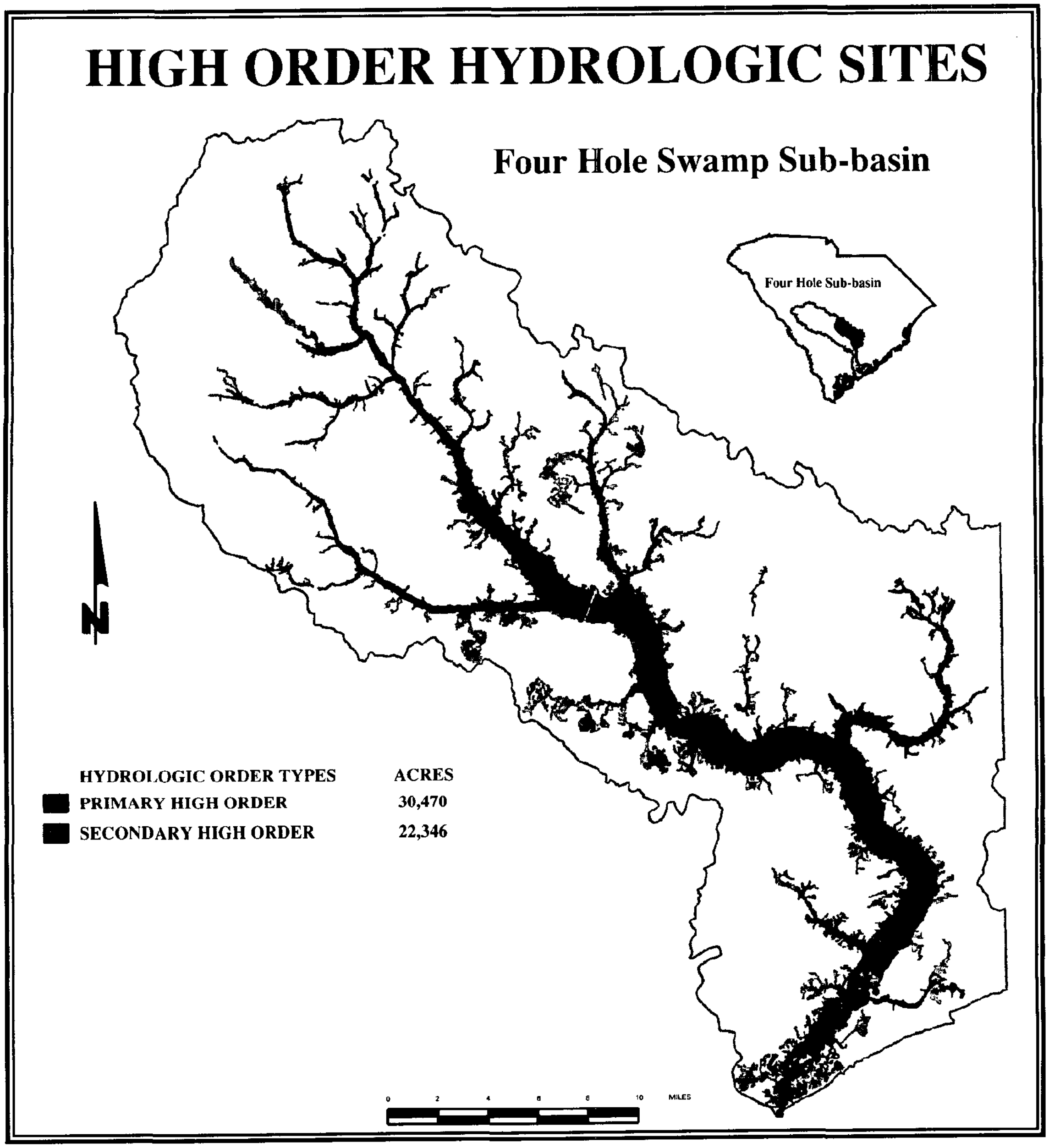


Figure 15. High-order potential wetland mitigation sites

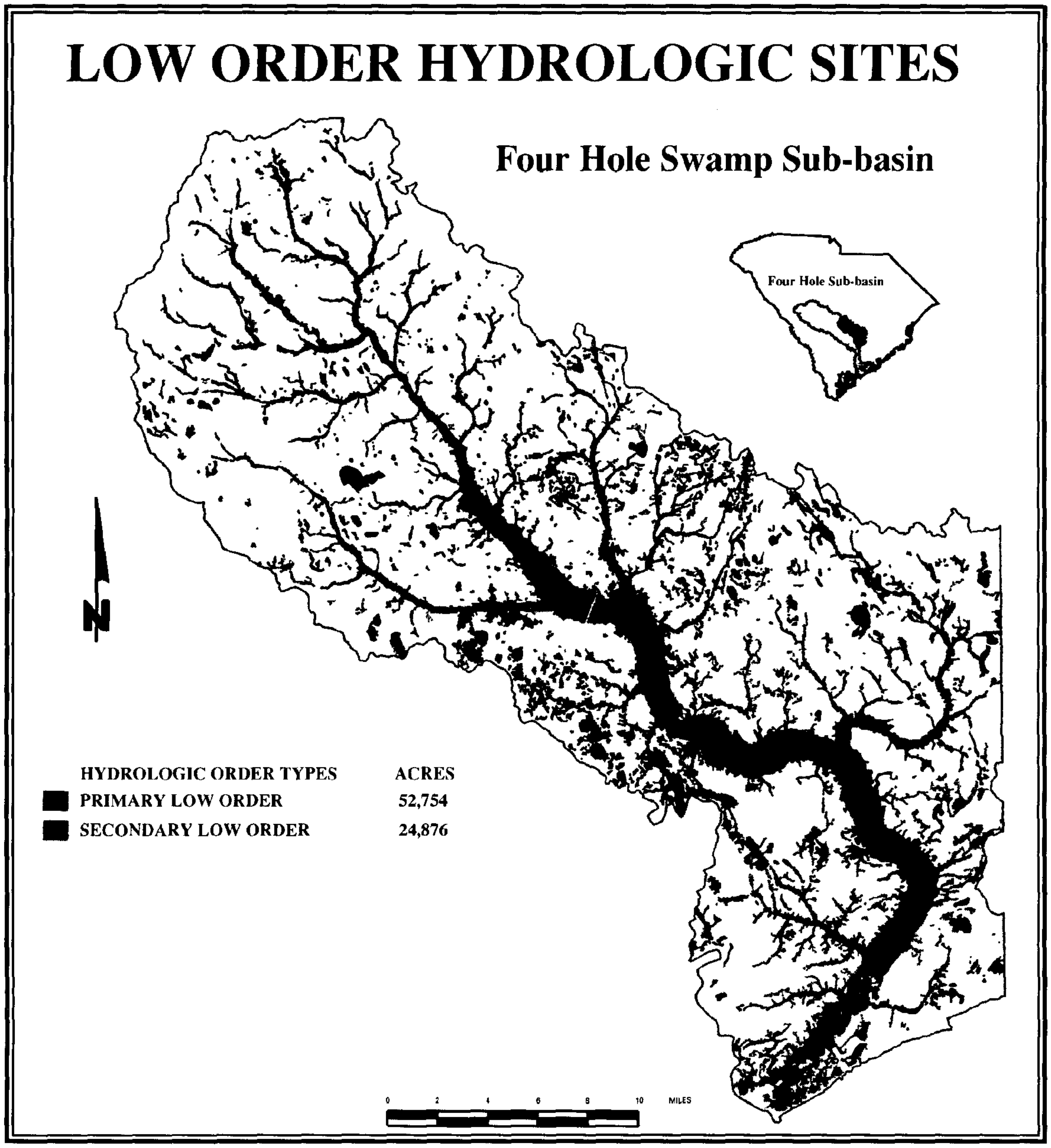


Figure 16. Low-order potential wetland mitigation sites

seen, however, it was often the case that many bottomland sites were assigned a low-order as a result of this methodology. Figure 14 reveals that this occurred because a large number of low-order streams flow directly into the mainstem areas of the study area.

Finally, all high- and low-order potential mitigation sites were combined to illustrate the relationship between the high-order sites and low-order sites. Figure 17 depicts the combined sites and illustrates those areas that serve single or dual hydrologic functions as defined by the model. The low-order stream assignment, described above, causes the majority of the wetlands in the study area to be identified as dual hydrologic function sites.

Composite Overlay

Figure 18 is a composite overlay of the opportunity analyses depicting all selected wildlife, and high- and low-order potential mitigation sites that meet any or all of the defined opportunity analyses criteria. Figure 18 illustrates the importance of the mainstem area in the Four Hole Swamp sub-basin. The area serves multiple opportunity functions in the sub-basin.

Figure 19 shows the same identified opportunity sites shown in Figure 18 broken out by mitigation class. A comparison of Figures 8 and 19 shows that the sites eliminated by this methodology are those very small isolated candidate sites that exist in the study area.

Unique Opportunity/Potential Threats Analysis

The potential mitigation sites identified in the overlay composite were evaluated with respect to the unique opportunities existing in the sub-basin. Unique opportunities were defined as the occurrence of sensitive species or communities of concern, archaeology sites, significant natural areas, or historic sites. These sites, in combination with the identified sites, present unique opportunities for mutual protection of important sub-basin resources. The identified unique sites are overlaid with the potential mitigation sites to determine the number and type of unique opportunities falling within each site (Figure 20). Each site is labelled with its related unique opportunities for future reference.

Lastly, identified mitigation sites are evaluated with respect to the potential threats existing in the sub-basin. Potential sources of threats were defined as hazardous-waste sites (including generating, disposal, treatment, or storage sites), mining sites, and industrial and domestic waste sites. Figure 21 shows the potential threats in the sub-basin in relation to the identified sites.

Model Complications/Improvements

The wildlife habitat analysis was quite successful in identifying potential mitigation sites that might serve as optimal habitat according to model definitions. The water quality/floodwater storage analyses were not as successful in distinguishing between primary and secondary sites or in further identifying low- and high-order sites.

Because elevation data were not available for the study area, it was decided that wetlands data would be used as a surrogate for characterizing the flood plain. An initial look at the wetlands data revealed that, especially on the mainstem, the only modifier that distinguished adjacent polygons was the modifier relating to hydrologic regime. In large part, wetland "system," "class," and "subclass" were coded identically for adjacent polygons. Thus, it was originally theorized that the hydrologic modifier incorporated into the NWI alphanumeric code (A,B,C,F,G, or H) might adequately describe hydrologic properties within the riparian system. For example, permanently flooded areas ("H") would have greater connection to a water body than intermittently exposed areas ("G") and so on. If this theory held true, sites adjacent to a stream as defined in the DLGs (i.e. primary sites) would be distinguished from areas farther from the stream (i.e. secondary sites) as denoted by different hydrologic modifiers (e.g., F vs. C) in the data base. Upon testing this theory in the procedures described above, it became apparent that, due to the complexity of the hydrologic system in Four Hole Swamp, these relationships do not necessarily hold true. Figure 22 shows the highly complex hydrologic nature of the wetland system especially as it occurs on the mainstem. The braided stream network pattern, which in some parts of the data base was digitized as a single line, further prevents a clear characterization of the riparian system according to this methodology.

The second problem encountered in this methodology was the identification of wetlands on the basis of stream order of the adjacent stream. As mentioned, many of the wetland areas associated with the mainstem of Four Hole Swamp were actually identified as having low-order wetland properties. While many of these wetlands serve the dual hydrology function identified in this study, it can be argued that, according to the assumptions and definitions provided by this model, these areas are critical for floodflow storage. A reevaluation of stream order definition could possibly contribute to a clearer distinction between the two wetland types. For example, had low-order streams been defined as only 1st- and 2nd-order, perhaps fewer low-order wetlands would have been identified on the mainstem.

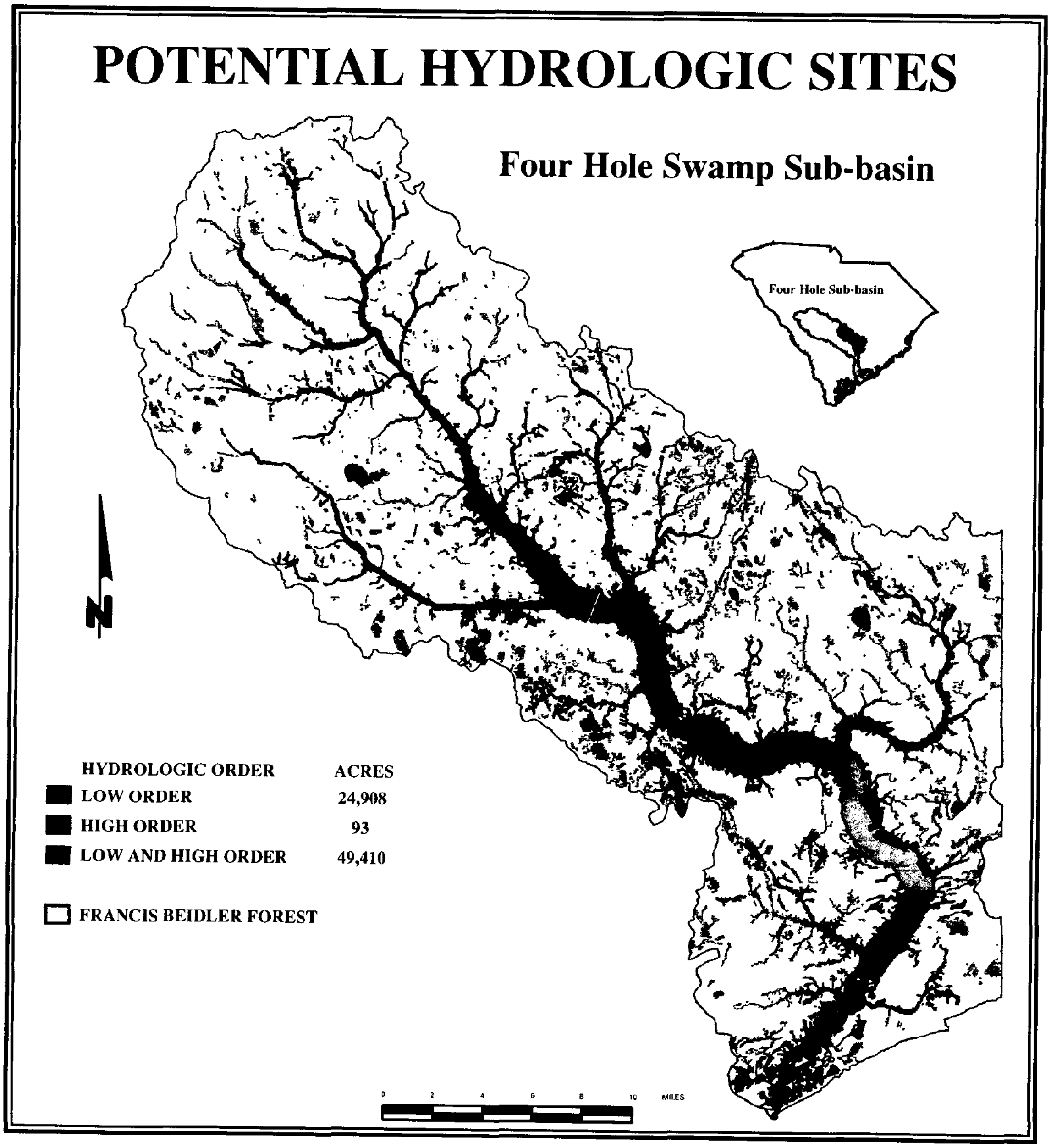


Figure 17. All potential wetland mitigation sites identified by water quality/floodwater storage analyses

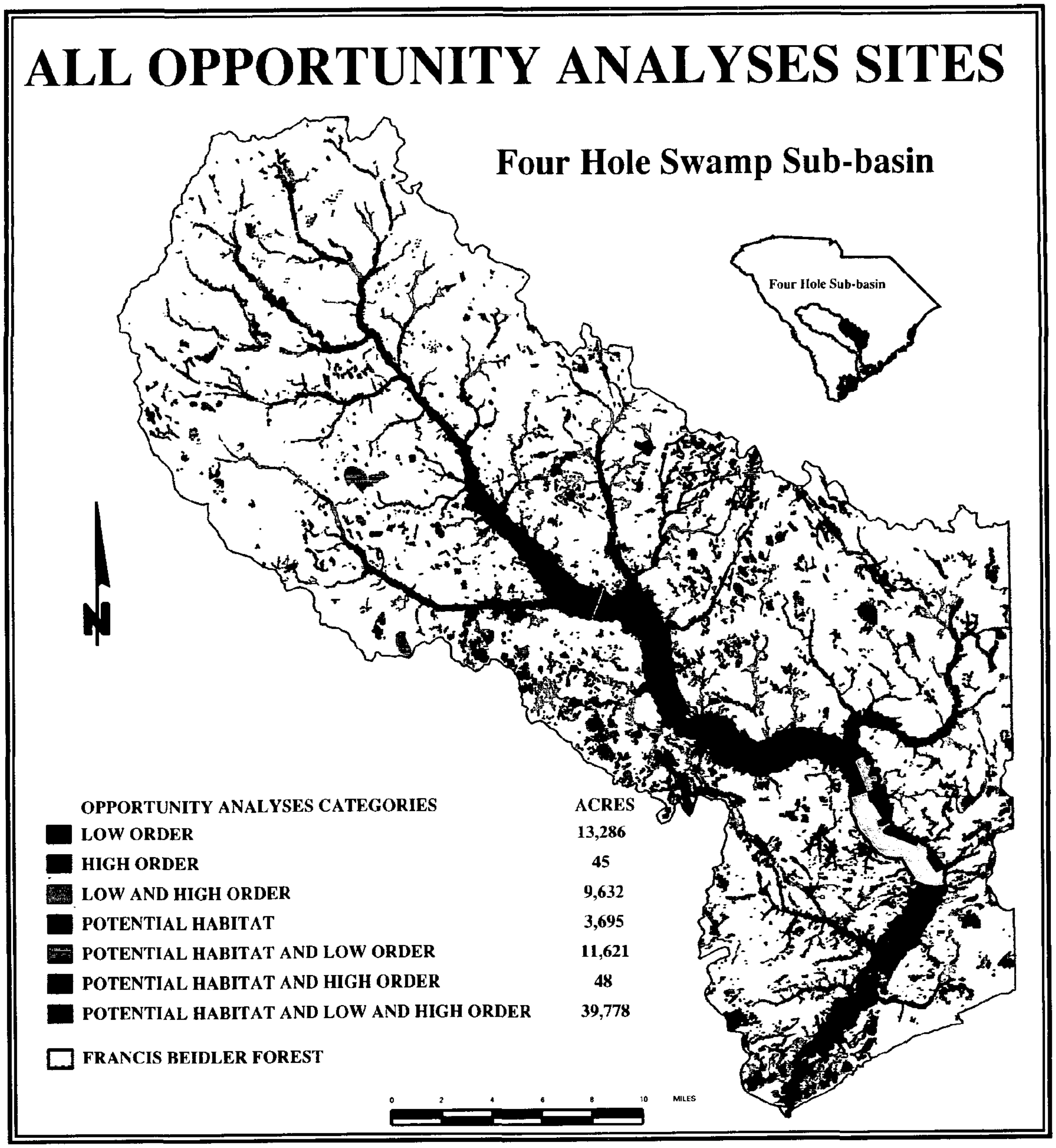


Figure 18. Composite overlay of potential wetland mitigation sites identified by all opportunity analyses

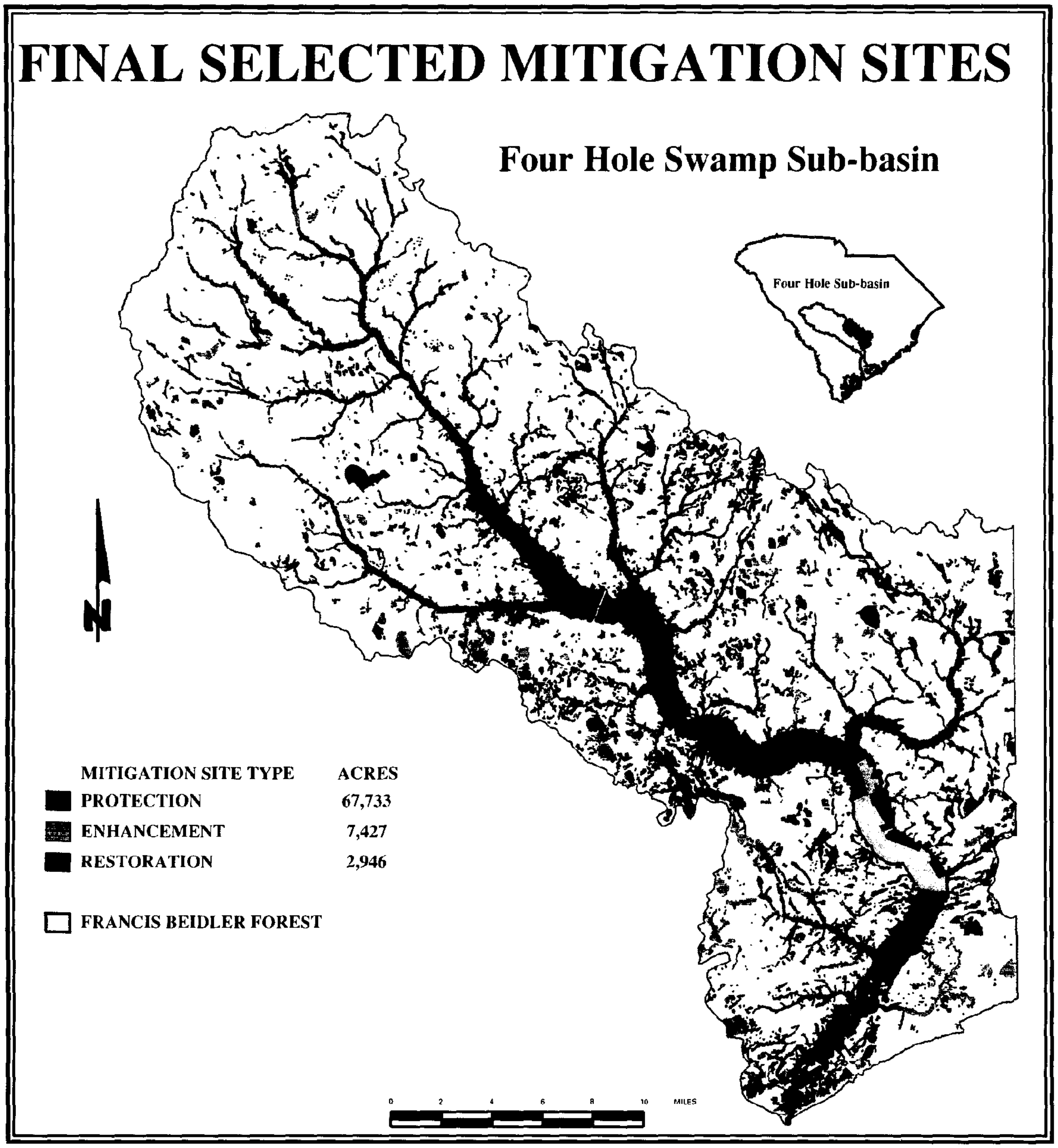


Figure 19. Final selected potential mitigation sites identified by mitigation class

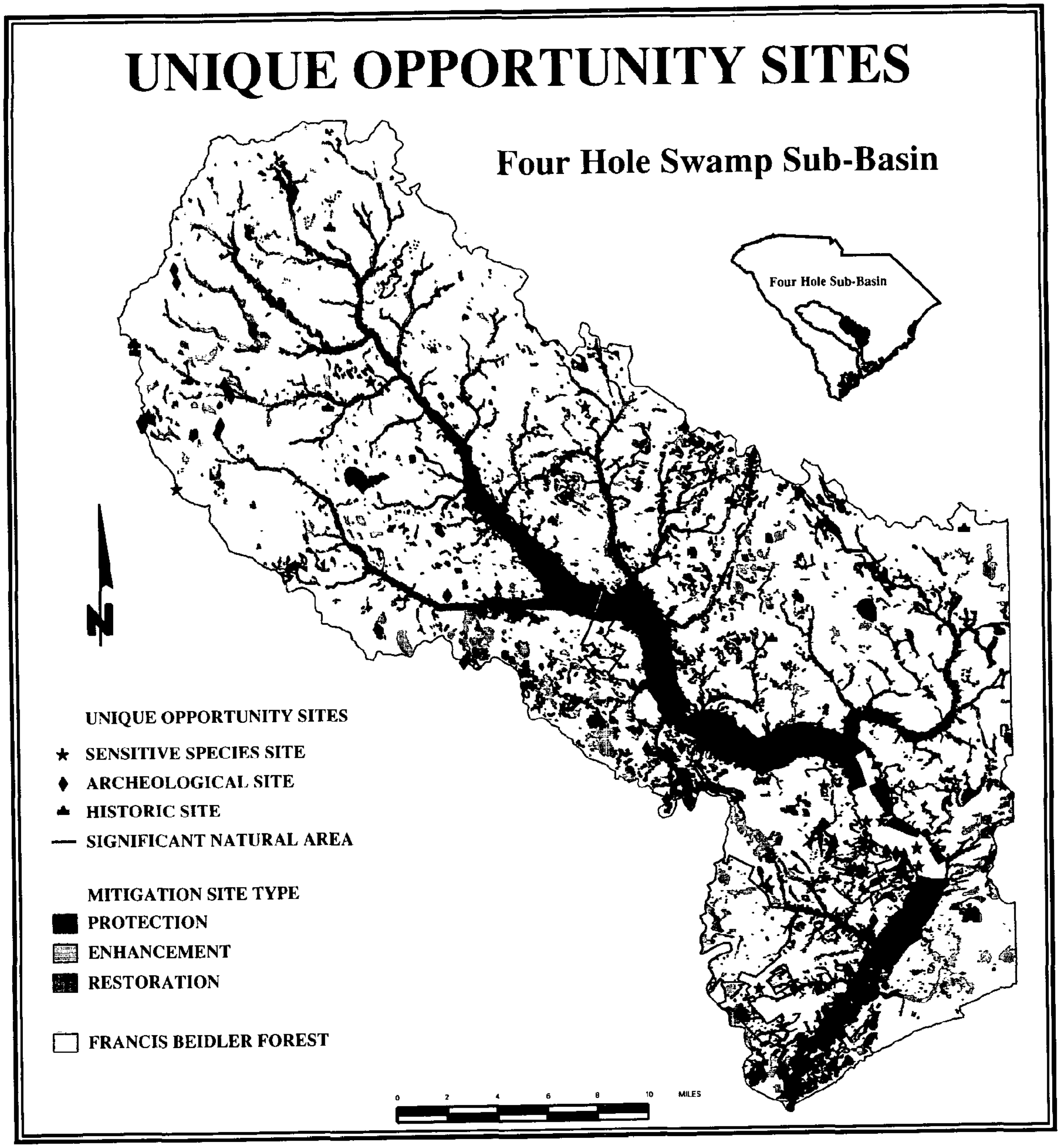


Figure 20. Unique opportunity occurrence

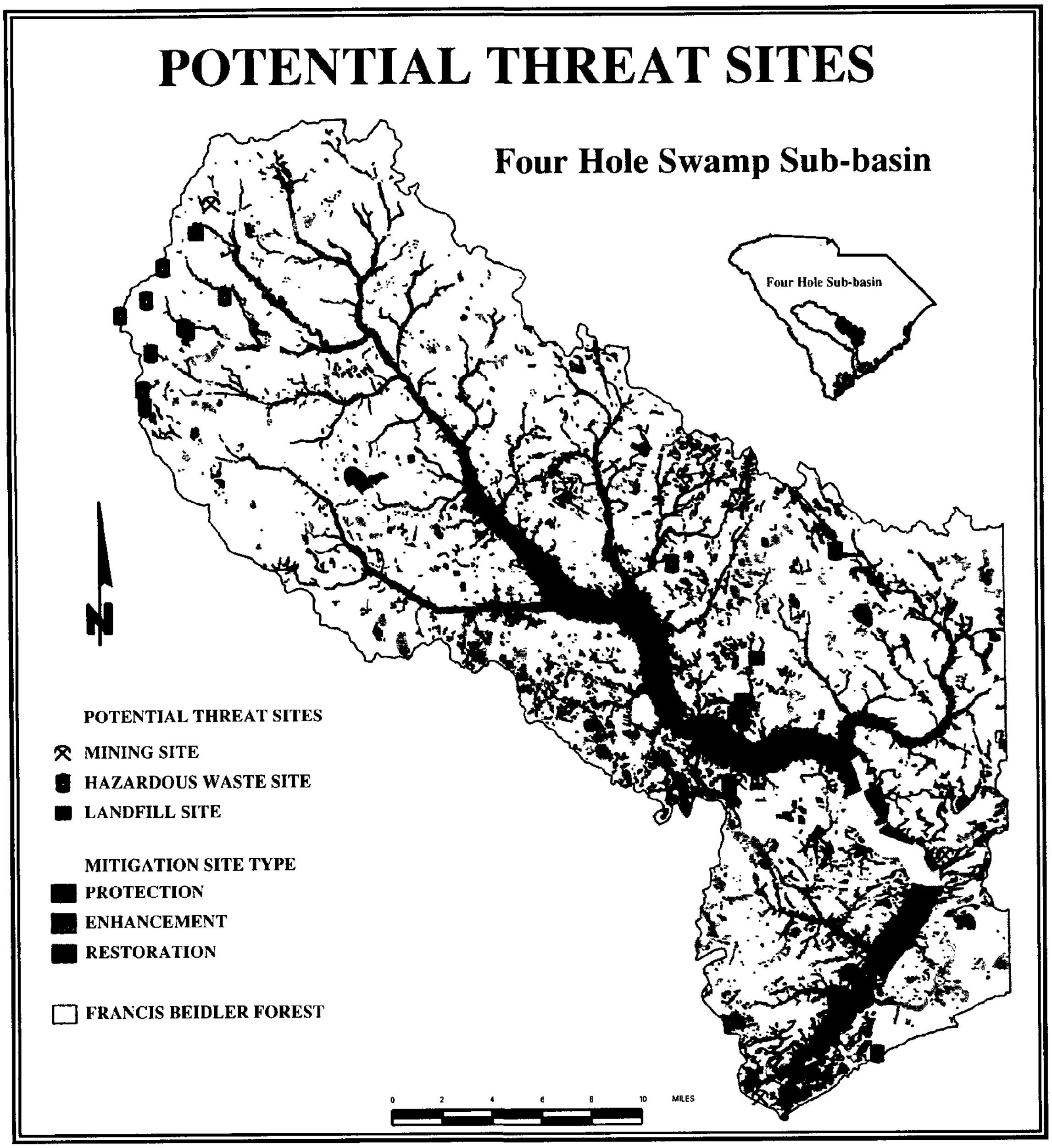


Figure 21. Potential threat occurrence

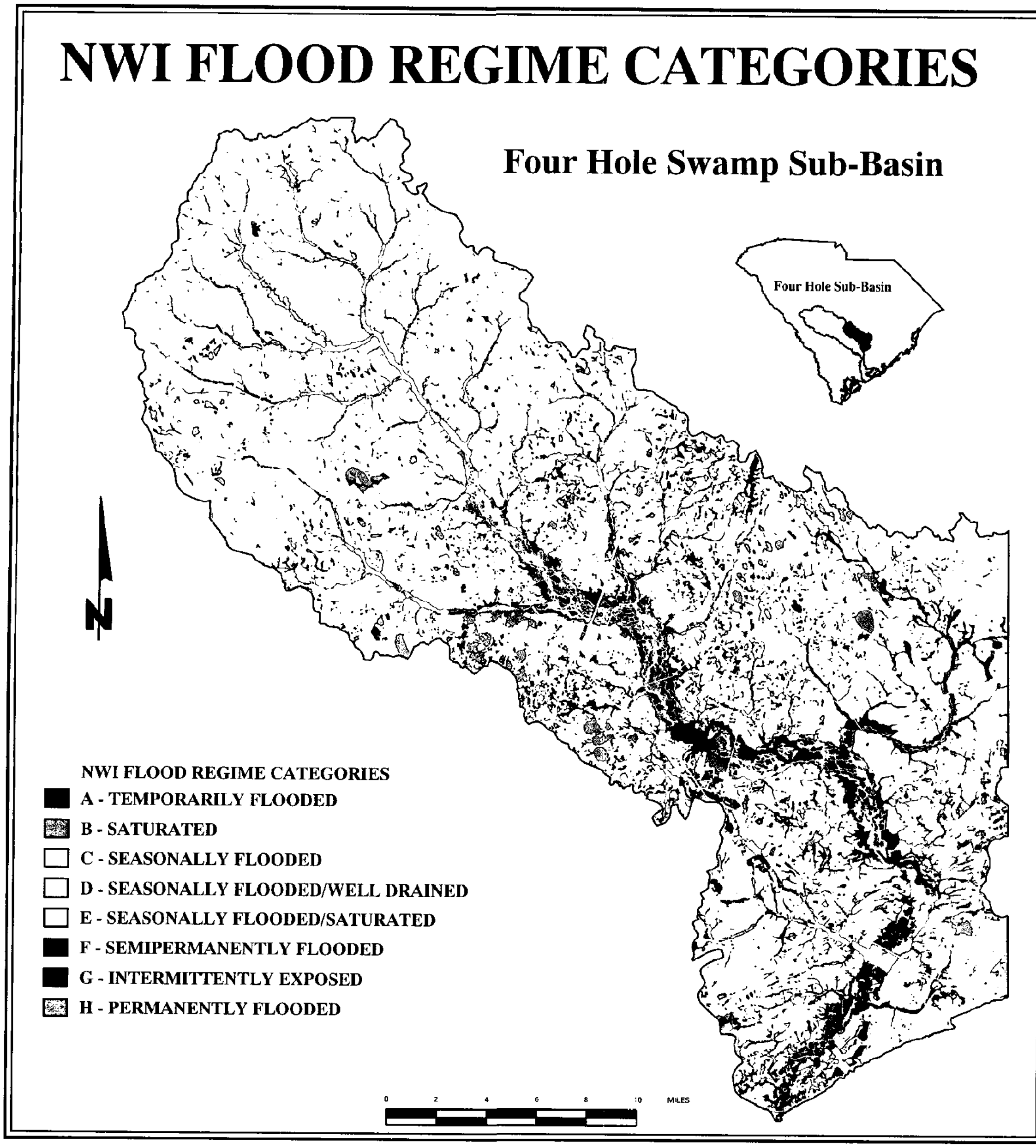


Figure 22. Hydrologic regime of potential mitigation sites in Four Hole Swamp

Field-Truthing

After identifying potential mitigation sites through the GIS analyses, a sample set was extracted for field sampling. The objective of the field visits was to generally validate the assumptions made for identifying the three mitigation classes as described earlier in this study. This was accomplished by 1) verifying the accuracy of the GIS-generated and source data regarding community type or land use, approximate size, presence of alteration (if indicated by the NWI modifiers); and 2) generally assessing the logic used in defining mitigation classes. It should be noted that because of resource constraints the rigorous sampling of species type, species composition, and soil types was not performed. Rather, qualitative assessments of these factors were made. In addition, a qualitative assessment of the site's wetland status was made. Such characteristics as wetland plant species and various soil properties indicative of "driving" hydrology were generally assessed to confirm that the site would likely qualify as jurisdictional or could be brought into jurisdictional status upon mitigation. Precise delineations, which would ultimately determine the status of selected polygons, were not within the purview of this study. It should be noted that the assumptions made to define the opportunity criteria outlined in this study were not verified in the field — i.e. site-specific field evaluations were not made to determine the ability of a wetland site to serve a wildlife habitat, water quality, or hydrology function. Rather, the rationale used to develop the criteria used for these analyses is supported by the literature, as described earlier in this study.

In sampling the sites for field verification, several factors were considered. It was desired that statistical rigor be used in site selection — that is, that a proportionate number of potential mitigation sites be randomly selected for each mitigation class (enhancement, restoration, and protection). However, because of limited resources and time, it was necessary that sites be relatively accessible. While it is recognized that the identification of sites on the basis of their accessibility, rather than a random sample, would result in a biased sampling of sites, the reality of resource constraints dictated that those sites most accessible be identified and field-truthed.

The final composite overlay of potential mitigation sites (defined by the three mitigation classes) was visually analyzed to identify clusters of sites, representative of the three mitigation classes, that might serve as potential field-truthing sites. Roads providing access to these field sites were identified by overlaying the primary and secondary road data layer. Quad maps were then cross referenced to identify roads, other than primary and secondary roads, that might yield access to the field sites. An attempt was made to locate both isolated (Figure 23) and riverine (Figure 24) clusters throughout the length of the basin.

Verification of Source Data

The results of the field work done as part of this study indicated that the thematic data used in applying this methodology are accurate with some exceptions. Acreages derived from the NWI data appeared to be, for the most part, accurate, although precise boundaries were not delineated in the field. Acreage figures derived during field verification were estimates.

General community types, with few exceptions, were also accurate; however, in several instances, especially in the headwater bottoms, large tracts have been recently clearcut. Thus, these areas obviously do not presently support the community types indicated in the NWI data derived from 1989 photography. The implication for mitigation in these instances is not clear. It could be argued that, depending on the hydric status of species pioneering the clearcut sites, these areas could potentially serve as enhancement sites, with the planting of bottomland species being indicated (personal communication, Kent Campbell, United Consulting Group, Ltd.).

Some exceptions to the NWI-based classification of palustrine emergent areas were noted. Many of these areas are actually young pine plantations and, in some cases, agricultural fields. It is thought that environmental conditions at the time of image capture might have contributed to the misinterpretation of these communities. South Carolina experienced above-average precipitation in 1989, the year during which the photography was taken. Also, the image was captured in early spring, a wet time of year. Thus, some areas interpreted as emergent wetlands were probably ponded agricultural fields or pine plantations. Finally, the immature status of the pine species at the time of image capture and the short stature of agriculture crops contributed to the misclassification of an emergent, persistent community type for these polygons.

For the most part, it was possible to locate restoration sites, or PC wetlands, on the ground; however, this mitigation class was more difficult to assess (i.e. to verify on the basis of the two factors defining this class - agricultural land use and a specific soil type) since detailed soil surveys were not made in the indicated areas.

Without exception, it was found that NWI polygons coded with a modifier indicative of ditching, impoundment, or excavation had, in fact, been modified accordingly. Unfortunately, the converse was not always true. It was sometimes the case that a site, although listed as a protection site because of the lack of a modifier in the NWI data base, had experienced some degree of ditching or was otherwise modified. This condition was especially apparent in the case of side ditching and, in some instances, where the main channel had been straightened or excavated to enhance

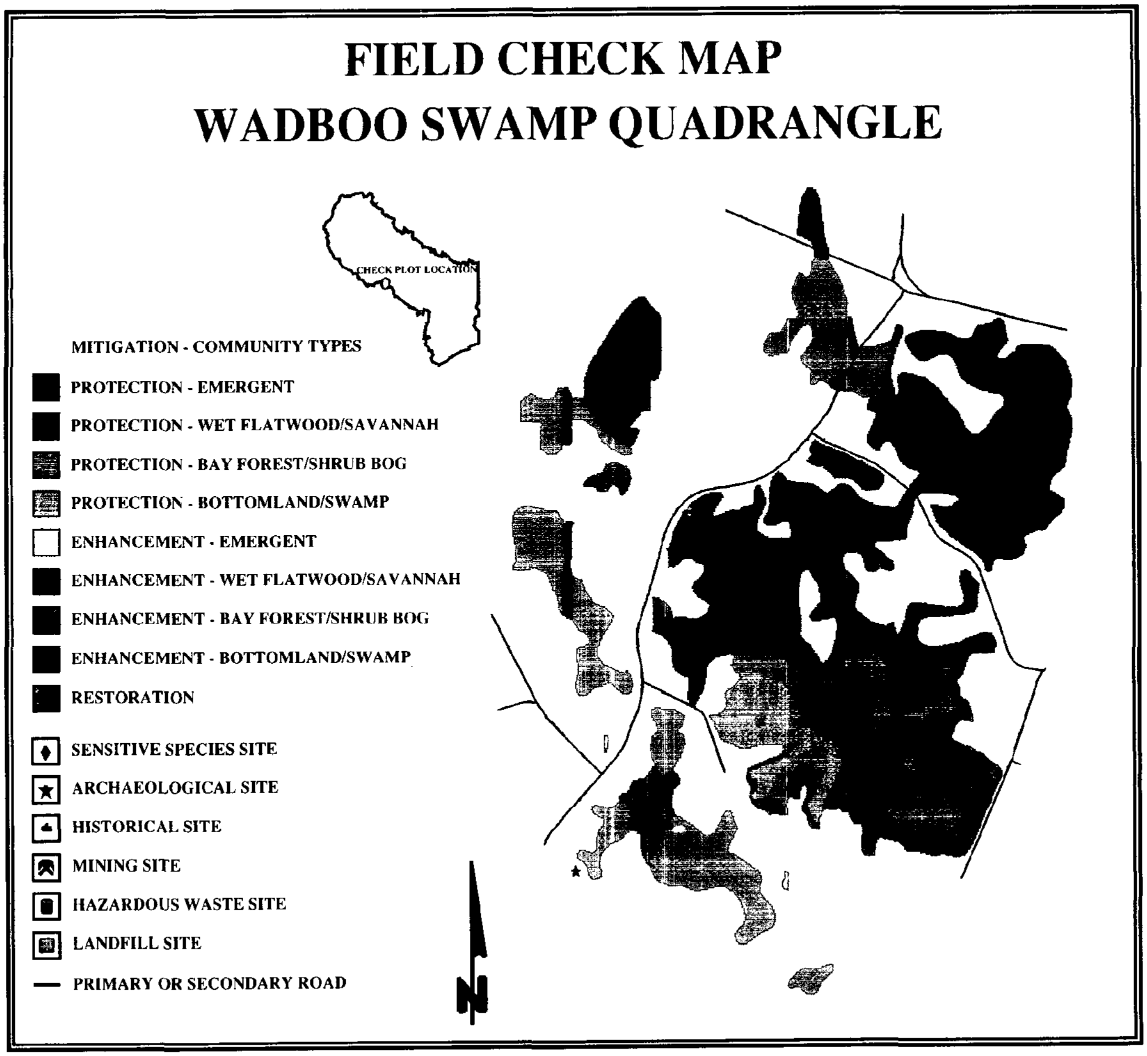


Figure 23. Isolated field check site

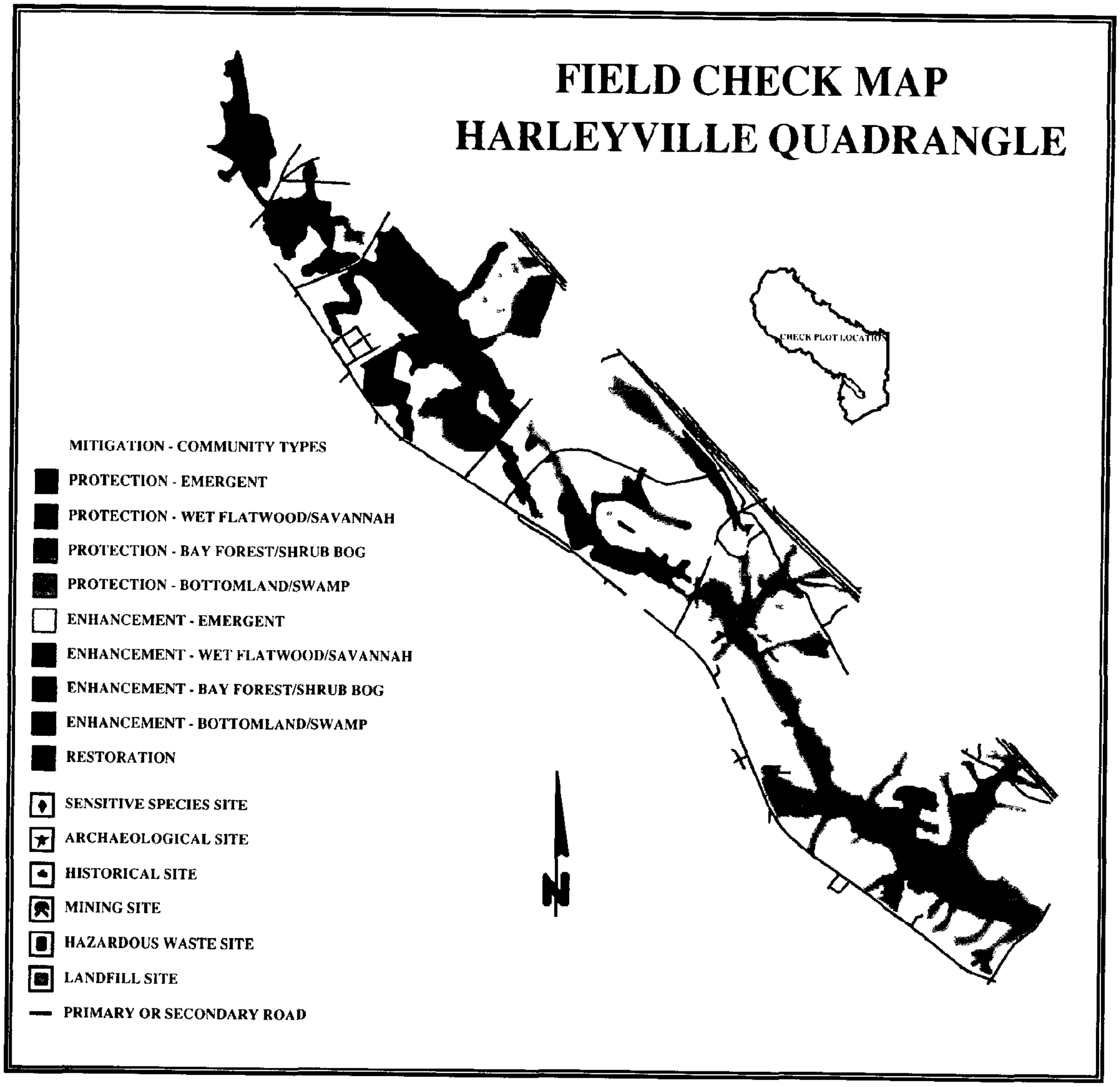


Figure 24. Riverine field check site

drainage of the surrounding landscape. On the basis of the noted exceptions between data and field checks, it can be reasonably inferred that the number of potential enhancement sites in the Four Hole sub-basin is greater than the number found through application of this methodology.

Other Observations

An effort was also made to generally assess the wetland status of the selected mitigation field sites. Although identified NWI polygons, both modified (enhancement sites) and unmodified (protection sites), generally supported a wetland community and were delineated as such during image interpretation, it was sometimes the case where "driving" hydrology did not appear to be present "on the ground" as indicated by non-hydric soil conditions or the invasion of plant species requiring more xeric habitat conditions. This "drying out" of certain areas, especially those areas indicated in the NWI data as temporarily flooded, could be attributed to one or a combination of several factors, as follows:

- The ditching and subsequent drainage of many modified wetland areas to the point where water tables are significantly lowered.
- The possibility that South Carolina is at the end of a 15-year drought cycle.
- Increased water withdrawals over the past decades.

If, in fact, ditching is responsible for the drying out of some wetland areas, it becomes obvious that hydrologic restoration might reverse the observed trend. While there has been some fear expressed by the farming community that such activity might reverse draining so that productive farmlands again become flooded, successful agricultural water table management has occurred in the Coastal Plain of North Carolina. In these circumstances, it has been possible for farmers to regulate water table levels to optimize water availability for crop growth. At the same time, the contributing watershed receives the ecological benefit of restored hydrology and, subsequently, wetland maintenance (personal communication, Bud Badr, SCWRC).

It was also observed in the field that PC wetlands, as defined and identified in this study, varied in their ability to support agricultural crops. Some appeared to be actively farmed, while others were fallow or planted in wildlife food plots. Again, this mitigation class was the most difficult to assess because detailed soil surveys were not made. It was noted, however, that in many cases these areas provided contiguity for fragmented riverine systems, especially in headwater areas. It was also observed that abandoned agricultural fields, not identified by this methodology, were a common feature of the landscape, occurring both in association with wetland systems and in upland areas. It became apparent that the criteria used in this methodology to locate potential wetland restoration sites were not adequate for identifying all prior converted wetlands or farmed wetlands that have since been abandoned. As mentioned previously, the soils used to define hydric agriculture fields were those identified by soil scientists as the least productive because of their extreme hydric condition. However, complex economic factors and environmental factors other than soil productivity are also responsible for the abandonment of farming operations. Thus, additional data and/or an amended methodology would be required for a thorough identification of all PC wetlands in this watershed.

Finally, the alphanumeric NWI code provides some subtle clues about specific land use activity that, if properly interpreted, might allow for the identification of polygons having a greater desirability for mitigation. For example, while many palustrine, unconsolidated bottom areas (coded as "PUB" in the NWI data base) were actually reservoirs lacking mitigation potential, sites exist that qualify as prime areas for mitigation, depending on the degree of soil disturbance and other physical factors. It has been suggested that some palustrine, unconsolidated bottom areas that have been excavated actually represent gravel pits, abandoned or otherwise, and possess potential for vegetation reestablishment (personal communication, Charlie Storrs, U.S. Fish and Wildlife Service). These areas were not identified by this methodology, since only sites currently supporting vegetation were selected. Other mitigation sites identified through this methodology, but that might be given more detailed attention during the physical suitability analyses, were vegetated areas that have been excavated. In many cases, these areas have been manipulated and then abandoned, as indicated by the establishment of vegetation. Again, depending on the composition of species pioneering these sites, they may or may not be desirable for mitigation.

Conclusions

Section 4

The methodology described in this report identifies potential wetland mitigation sites on the basis of physical factors (soils, hydrology, vegetation) and according to the following characteristics indicative of ecological function:

- Fragmentation.
- Contiguity with other wetland areas and, thus, inclusion in large complexes.
- Existence of interior habitat for wildlife.
- Juxtaposition to water bodies and thus the opportunity to provide floodflow storage and water quality improvement.
- The existence of potential threats to the ecological integrity of a site.
- Opportunities to provide habitat for rare, threatened, or endangered species and communities.

The value of considering these ecological factors in mitigation site selection, for banking or otherwise, cannot be overstated. Indeed, fragmentation continues to persist as a result of wetland fill activity. Thus, large complexes of wetland sites — areas vital to the ecological integrity of watersheds — are dwindling. Strategic reconstruction of indicated mitigation sites could restore or improve the ecological health of many watersheds across the country.

The physical suitability analyses were successful in thoroughly inventorying the landscape for potential protection and enhancement sites according to their respective definitions, although wetlands other that those delineated by NWI were not identified. It was noted in the field, however, that abandoned farmed wetlands and prior converted wetlands were common throughout the study area although not always selected by this methodology as potential restoration sites. It is felt that this is partially attributable to the rather conservative selection of hydric soils in the overlay operation. If the entire list of hydric soils had been used for each county rather than the few identified in this study as extremely hydric, it is probable that this methodology would have identified a greater number of the abandoned farmed wetland and prior converted sites existing in Four Hole Swamp sub-basin. However, the factors contributing to the wholesale abandonment of farming operations in the Coastal Plain and in other places are largely a function of complex economic conditions and only partially related to the physical characteristics of the soil. Data on farmland abandonment are available in hard copy from SCS. It is feasible that these data, in digital form or otherwise, could be used to supplement the results obtained from these GIS analyses in identifying PC wetlands.

Results from this study also indicate that although the model was successful in identifying enhancement sites —

many of which appear to have true mitigation potential as they are currently being effectively drained — there are actually a greater number of potential enhancement sites in the field than determined by this methodology. This is due to the fact that a large number of sites identified as protection sites have actually been modified in some way. While the data used for application of this methodology were fairly current, it is recognized that cross-referencing the final sites selected through this methodology with NAPP or other aerial photography, prior to field verification, would expedite the site selection process. Interpretation of current aerial photography can detect recent changes in land use or land cover as well as verify the alphanumeric code provided by the National Wetlands Inventory data.

Execution of the wildlife habitat component resulted in successful identification of potential mitigation sites that might serve as optimal habitat according to model definitions. Many of the restoration sites fell out of the model; however, large complexes of the three mitigation classes, all which possess adequate interior habitat, were found. Execution of the water quality/floodwater storage analyses was not completely successful in identifying distinct low- and high-order wetland sites. While high-order wetlands were consistently identified along the mainstem, low-order wetlands were identified in the headwaters as well as on the mainstem. A different characterization of wetland orders, would likely contribute to better definition of these areas. In addition, a clear delineation of primary and secondary sites was not always possible. This component of the methodology could not consider the complex hydrology existing in the Four Hole Swamp drainage system. Elevation data would be required to better characterize hydrologic conditions in the riparian system.

As would be expected, the results of the opportunity analyses indicate that the mainstem of Four Hole Swamp is an area that contributes greatly to the ecological integrity of the sub-basin. The mitigation and annexation of degraded wetland sites to intact and protected portions of this riparian system, could ensure the long-term ecological viability of Four Hole Swamp.

While the information resulting from this methodology can better direct mitigation decisions made by those in the regulatory arena, there is of course no substitute for the expertise contributed by knowledgeable specialists. This methodology is intended to be a decision *support* tool, not a decision system. It considers landscape level indicators of function and places priority on contiguous complexes of potential mitigation sites. By *explicitly stating* ecological assumptions that should be considered when selecting sites for wetland mitigation, it can help streamline the decision-making process through an initial identification of potential mitigation sites requiring further site-specific evaluation by wetland specialists.

References

Section 5

Adamus, Paul R. 1987. Wetland Evaluation Technique for Bottomland Hardwood Functions. EPA document.

Anderson, J.A., E.E. Hardy, J.T. Roach, and R.T. Witmer. 1976. *A land use and land cover classification system for use with remote sensor data.* U.S. Geological Survey Professional Paper 964.

Askins, R.A., M.J. Philbrick, and D.S. Sugeno. 1987. *Relationship between the regional abundance of forest and the composition of forest bird communities.* Biol. Conserv. 39: 129-152.

Brinson, M.M. 1988. *Strategies for assessing the cumulative effects of wetland alteration on water quality.* Environmental Management 12(5):655-662.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, FWS/OBS-79/31, Washington, D.C., 103 pp.

Diamond, J. M. 1976. *Island biogeography and conservation: strategy and limitations.* Science 193:1027-1029.

Environmental Law Institute. 1993. *Wetland Mitigation Banking.*

Environmental Protection Agency. 1993. *Draft Mitigation Banking Guidance*, Region IV, Atlanta, GA.

Forman, Richard T. T., and Michael Godron. 1981. *Patches and Structural Components for a Landscape Ecology.* Bioscience. (31)10:733-740.

Gosselink, J.G., B.A. Touchet, J. VanBeek, and D. B. Hamilton. 1990. *Bottomland Hardwood Forest Ecosystem Hydrology and the influence of Human Activities: the Report of the Hydrology Workgroup.* Pages 347 - 387 in J. G. Gosselink, L.C. Lee, T.A. Muir (editors). Ecological Processes and Cumulative Impacts Illustrated by Bottomland Hardwood Wetland Ecosystems. Lewis Publishers, Inc.

Hale, A.M., W.D. Marshall, and J.D. Scurry. 1991. *GIS Plus Policy Research: South Carolina's Natural Resources Decision Support System.* Geo Info Systems. (1)6:22-35.

Harris, L.D., L.D. White, J.E. Johnston and D.G. Milchunas. 1974. *Impact of Forest Plantations on North Florida Wildlife and Habitat.* Proceedings of the 28th Annual Southeastern Association of Game and Fish Commission 28:659-657.

Harris, L.D. 1984. *The fragmented forest: Island Biogeography Theory and the Preservation of Biotic Diversity.* University of Chicago Press, Chicago, 211 pp.

Harris, L.D. 1985. *Conservation corridors: a highway system for wildlife.* ENFO Report 85-5. Environmental Information Center of the Florida Conservation Foundation, Winter Park, Florida.

Harris, L.D. and James Gosselink. 1990. *Cumulative Impacts of Bottomland Hardwood Forest Conversion on Hydrology, Water Quality, and Terrestrial Wildlife.* Pages 259 - 322 in J. G. Gosselink, L.C. Lee, T.A. Muir (editors). Ecological Processes and Cumulative Impacts Illustrated by Bottomland Hardwood Wetland Ecosystems. Lewis Publishers, Inc.

Karr, J.R. and I.J. Schlosser. 1978. *Water resources and the land-water interface.* Science 201: 229-234.

Kuenzler, E.J. 1989. *Value of Forested Wetlands as Filters for Sediments and Nutrients.* Pages 85-96 in D.D. Hook and R. Lea (editors). Proceedings of the Symposium: Forested Wetlands of the Southern United States. U.S. Department of Agriculture, Forest Service. Gen. Tech. Rep. SE-50, Asheville, NC.

Langley, Albert K. Jr., and Donald J. Shure, 1980. *The Effects of Loblolly Pine Plantations on Small Mammal Populations.* American Midland Naturalist 103(1):59-65.

Lee, Lyndon C. and James G. Gosselink. 1988. *Cumulative Impacts on Wetlands: Linking Scientific Assessments and Regulatory Alternatives.* Environmental Management 12(5):591-602.

Leibowitz, S. G., B. Abbruzzese, P. R. Adamus, L. E. Hughes, J. T. Irish. 1992. *A Synoptic Approach to Cumulative Impact Assessment*, EPA/600/R-92/167, October 1992.

Lowrance, Richard, Ralph Leonard and Joseph Sheridan. *Managing riparian ecosystems to control nonpoint pollution.* Journal of Soil and Water Conservation. Feb.-Mar. 1985:87-91.

Marshall, W.D. 1993. Assessing Change in the Edisto River Basin: an Ecological Characterization. Report # 177. SCWRC.

Mitigation Site Type Classification: A Methodology to Classify Pre-Project Mitigation Sites and Develop Performance Standards for Construction and Restoration of Forested Wetlands. Results of an EPA-Sponsored Workshop, Falls Creek State Resort Park. Pikeville, TN, August 13-15, 1989.

Noble, Robert E., and Robert B. Hamilton. 1975. *Bird Populations in Even-Aged Loblolly Pine Forests of Southeastern Louisiana.* Proceedings of the 29th Annual Southeastern Association of Game and Fish Commission 29:441-450.

Noss, R.F. 1983. *A regional landscape approach to maintain diversity.* BioScience 33:700-706.

Nutter, W.L. and J.W. Gaskin. 1989. *Role of Streamside Management Zones in Controlling Discharges to Wetlands.* Pages 81-84 in D.D. Hook and R. Lea (editors) Proceedings of the symposium: Forested wetlands of the Southern United States. U.S. Department of Agriculture, Forest Service. Gen. Tech. Rep. SE-50, Asheville, N.C.

O'Neil, L.J., T. M. Pullen, Jr., R.L. Schroeder. 1991. *A Wildlife Community Habitat Evaluation Model for Bottomland Hardwood Forests in the Southeastern United States.* U.S. Fish and Wildlife Service Biological Report 91(X).

Peterjohn, W.T., and D.L. Correll. 1984. *Nutrient Dynamics in an Agricultural Watershed: Observations on the Role of a Riparian Forest.* Ecology 6(5):1466-1475.

Preston, Eric M. and Barbara L. Bedford. 1988. *Evaluating Cumulative Effects on Wetland Functions: A Conceptual Overview and Generic Framework.* Environmental Management 12(5):565-583.

Saunders, Denis A., Richard J. Hobbs, and Chris R. Margules. 1991. *Biological Consequences of Ecosystem Fragmentation: A Review.* Conservation Biology 5:18-32.

Scott, M.L., B.A. Kleiss, W.H. Patrich, and C.A. Segelquist. 1990. *The Effect of Development Activities on Water Quality Functions of Bottomland Hardwood ecosystems: the Report of the Water Quality Workgroup.* Pages 411 - 453 in J. G. Gosselink, L.C. Lee, T.A. Muir (editors). Ecological Processes and Cumulative Impacts Illustrated by Bottomland Hardwood Wetland Ecosystems. Lewis Publishers, Inc.

Strahler, A.N. *Hypsometric (area-altitude) analysis of erosional topography.* Geological Society of America, Bulletin 63: 1117 - 1142.

Taylor, J.R., M.A. Cardamone and W.J. Mitsch. 1990. *Bottomland Hardwood Forests: Their Functions and Values.* Pages 13 - 86 in J. G. Gosselink, L.C. Lee, T.A. Muir (editors). Ecological Processes and Cumulative Impacts Illustrated by Bottomland Hardwood Wetland Ecosystems. Lewis Publishers, Inc.

Temple, S.A. 1986. Predicting impacts of habitat fragmentation on forest birds: A comparison of two models. Pages 301 - 304 in J. Verner, M. L. Morrison, and C.J. Ralph, eds. Wildlife 2000: Modeling habitat relationships of terrestrial vertebrates. Univ. Wisconsin Press, Madison.

U. S. Department of Agriculture. 1978. General soil map of South Carolina. USDA Soil Conservation Service.

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.

White, J. and C. Aulbach-Smith. 1993. *Edisto River Basin Natural Area Inventory: Survey Standards and Guidelines.* Report for the Natural Resources Decision Support System prepared by The Nature Conservancy, Chapel Hill, North Carolina, and by the South Carolina Water Resources Commission, Columbia, South Carolina. May 1993 edition. 110 p.

White House Office of Environmental Policy. 1993. *Clinton Administration Proposal on Protection of U.S. Wetlands.*

World Wildlife Fund. 1992. *Statewide Wetlands Strategies. A Guide to Protecting and Managing the Resource.* Island Press, Washington, D.C., 268 pp.

Appendices

Appendix I

Generalized NWI Wetlands Used in Analyses*

Emergent (Savannahs, Wet Meadows, Freshwater Marsh)

PEM1A_	PEM1F_	PEM1N
PEM1B	PEM1H_	PEM1R_
PEM1C_	PEM1K_	PEM1T_
PEMA	PEM1Mh	PEMFx
PEMC	PEM1P	PEM/SS1T
		U/PEM1T

Wet Flatwoods and Pine Savannah

PFO4A_	PFO4/SS3A_	PSS4C
PFO4C	PFO4/SS3C_	PFOSS4A
PFO4R	PFO7A	PSS3A_
PFO4S	PFO7S	
PFO4/1A	PSS4A	

Bottomland Hardwoods, Wooded Swamps, Deciduous Shrub Swamps

PFO1A_	PFO1B	PSS1C_
PFO1S	PFO1C_	PSS1F_
PFO1/2A	PFO1F_	PSS1N
PFO1/3A	PFO1G_	PSS1R
PFO1/4A_	PFO1P	PSS1T
PFO1/4S	PFO1R_	PSS2KH
PFO1/SS3A_	PFO1T	PSS6C
PFO1/SS4A_	PFO1/2_	PSS6F_
PFO1/4C_	PFO1/3C	PSS6K_
PFO1/4R	PFO1/3R	PSS6M_
PFO1/SS4R	PFO1/SS3C	PSS6N
PFO4/1C	PFO1/SS3F	PSS6R_
PFO4/1R	PFO1/SS3R	PSS1/2F_
PFO/SS1C	PFO2	PSS1/2T
PSS1A_	PFO5_	PSS1/3C_
PSS1S	PFO6C_	PSS1/3F_
PSS1/3A_	PFO6F_	PSS1/3H
PSS1/3S	PFO6G_	PSS1/3R
PSS1/4A	PFO6N	PSS1/3T
PSS1/4C	PFO6/AB4Hh	PSS1/4T
PSS3/1A	PFO/EM1C	PSS1/7R
PSS6Ad	PFO/EM1F	PSSC
PSS6S	PFO/SS6Fh	PSS6/EMIF
PFO/SS6T	PSS/EM1C	

*John Hefner, Fish and Wildlife Service, National Wetlands Inventory

Bay Forests, Evergreen Shrub Bogs

PFO1/3B	PSS1B_
PFO1/4B	PSS3A
PFO1/SSB	PSS3B_
PFO3/SS1B	PSS3C_
PFO4B	PSS3R_
PFO4/1B	PSS3S
PFO4/3C	PSS7A_
PFO4/2C	PSS7B
PFO4/SS1B	PSS7C
PFO4/SS3B	PSS7F
PFO7B	PSS7R
PFO7C_	PSS1/3B
PFO7Kh	PSS1/4B
PFO7R_	PSS3/1A
PFO/SS3B	PSS3/1B
PSS3/1C	

Appendix II

Generalized Land Use Data Used in Analyses

Urban
U11
U12
U13
U14
U15
U16
U17

Agricultural Cropland/Pastureland
U21

Mixed Forest
U41
U42
U43

Pine Plantation
U42P

Other Upland
U22
U31
U32
U75
U76

Appendix III

Hydric Soils List by County Used for Analyses*

Berkeley
Meggett loam
Pamlico muck
Pickney loamy fine sand

Calhoun
Swamp

Dorchester
Elloree loamy fine sand
Grifton fine sandy loam
Mouzon fine sandy loam
Osier loamy fine sand
Rutlege loamy fine sand

Orangeburg
Bibb sandy loam
Elloree loamy sand
Johnston sandy loam
Mouzon fine sandy loam

*Dennis De Francesco, Soil Conservation Service

Toward No Net Loss

Total copies:	300
Total cost:	$4840.50
Cost per copy:	16.15
Date:	11-93

S.C. Water Resources Commission
Printed on recycled paper