## Horwood Critique Article

# Toward No Net Loss: A Methodology for Identifying Potential Wetland Mitigation Sites Using a GIS

**Cynthia R. Brown and Floyd O. Stayner**

***Abstract:*** *This paper describes a decision-support methodology developed by the South Carolina Water Resources Commission for the selection of potential wetland mitigation sites, utilizing a GIS and 1:24,000 scale information sources to automate the mitigation site-evaluation process. The described methodology combines the capabilities of GIS technology with current scientific theory and narrows the choices for mitigation site selection based on landscape-scale indicators of wetland functions such as size, shape, contiguity and hydrologic position. This systematic approach thoroughly inventories the wetlands occurring within a watershed and identifies large complexes of potential mitigation sites. It offers obvious advantages over current piecemeal approaches to mitigation site selection which often contradict the goal of "no net loss" of wetland function due to the selection of sites which are fragmented or unconnected and not defensible in the long run. By explicitly stating ecological assumptions that should be considered when selecting sites for wetland mitigation, the proposed methodology can help streamline the decision-making process through an initial identification of potential mitigation sites requiring further site-specific evaluation by wetland specialists. As described in the paper, the model should be applied for advanced planning in establishing mitigation banks and for more specific analysis of proposed mitigation plans considering the long-term value of wetland functions actually enhanced by mitigation activities. It should be expanded and tested with better data as such information resources become available. It can provide needed guidance to our data collection and classification agenda. This model provides a foundation for working towards the goal of no net loss of wetland functions as we attempt to balance inevitable land use modifications with the watershed-level goals established by the Clean Water Act and related legislation.*

Permitted land use, development pressures, and illegal fill activity continue to threaten the viability of our nation's wetlands. Although regulatory safeguards have been established to avoid or minimize the impacts resulting from such activities, compensatory mitigation is sometimes required to replace the ecological loss resulting from wetland destruction or fragmentation. In this study, potential mitigation sites on the South Carolina Coastal Plain are identified using a GIS and 1:24,000 scale information sources.

When designing strategies for mitigation, it is often assumed that area-for-area replacement of the same type of wetland (i.e., "in-kind"), at the same location as the filled wetland (i.e., "on-site"), will assure that any lost ecological function is offset. However, in-kind mitigation projects are often not available on-site. As a result, mitigation is pursued on-site/out-of-kind, off-site/in-kind or finally off-site/out-of-kind. Also, 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. Too often, the ability of a replacement wetland to mimic the ecological function of the filled wetland is 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**

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## Horwood Critique Article

In 1985, URISA established the Horwood Critique Prize in memory of Dr. Edgar Horwood of the University of Washington, who founded URISA in 1966. The objective of the prize is to challenge information systems professionals to more critically interpret developments in the field. The prize is given annually to the author(s) of a paper published in the previous annual *URISA Proceedings* representing the best critical analysis of an urban, federal, regional or local system design, implementation or application; technology policy or issue; or contextual environment.

Papers are judged on their candor, critical insights, and conclusions and methods employed in the critique. All papers appearing in the Proceedings are judged in the competition. In this issue of the *URISA Journal*, we are featuring the 1995 Horwood winner, "Toward No Net Loss: A Methodology for Identifying Potential Wetland Mitigation Sites Using a GIS," by Cynthia R. Brown and Floyd O. Stayner. In keeping with the critical intent of these papers, we welcome your comments.

**overall ecological integrity of the entire watershed.** In many instances, off-site wetlands located within the same watershed best meet these 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 provides an initial screening tool for identifying 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. While wetlands are responsible for providing a broad spectrum of ecological and social benefits, those considered in this study include a site's potential to contribute to wildlife habitat (based on contiguity, fragmentation, size, and extent of interior habitat) and water quality and floodwater storage (based on geomorphological setting, stream order and stream proximity). In addition, known locations of endangered/threatened/rare species habitat and significant natural areas, as well as cultural resources, are considered. 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 subbasin in South Carolina is used as a case study for the application of this model.

## Data Development

The data used in this study 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. Table 1 describes available data coverages used in this study.

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 Natural Resource and Conservation Service's (NRCS) 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 classification are simplified to four categories of community types:

- savannahs/wet meadows/freshwater marsh;
- wet flatwoods/pine savannahs;
- bottomland hardwoods/wooded swamp/deciduous shrub swamp; and
- bayforest/evergreen shrub bog.

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 cat-

TABLE 1. Data Used In Analyses

| Coverage | Source | 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 | Natural Resource and 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 |

egories are also simplified to several community types for use in this study and include urban, agricultural cropland/pastureland, mixed forest, pine plantation, and other upland.

The soils data are derived from standard NRCS 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 to include only those with 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 edge-matching and attribute correction where possible. One problem with the DLG data that could not be corrected was the currency problems inherent with 1:24,000 quad maps that are the source for DLG data. These maps range in date from 1960 to 1989 in the study area. Funding and source material were not available to update any of the older 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 study area with relatively undisturbed, high-quality natural communities.

Other data themes 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. These data were obtained from the agencies responsible for the particular permitting activities.

## Model Components

When identifying sites suitable for mitigation, a wide spectrum of factors must be considered. These include the potential for successful mitigation posed by physical characteristics and the potential public or natural resource benefits provided by mitigation. Logistical considerations, such as availability for acquisition and number of landowners, are also valid considerations but 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). The sequence of analytical steps used to address the model components is as follows:

- Identify wetlands (by community type and watershed) that are physically amenable to mitigation; then
- Evaluate the opportunity potential of these sites to provide public benefits through either improved wildlife habitat, water-quality enhancement or floodwater storage; and finally
- 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.

## *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 (Table 2).

Mitigation efforts in the Southeast sometimes involve restoration of marginal agriculture lands to bottomland hardwood 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. 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 by first identifying hydric soils, as defined for each county by the SCS. These 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. All such areas are termed prior converted (PC) wetlands in this study.

In order to identify sites suitable for enhancement, 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 likely represent abandoned gravel pits, large ditches or the occasional sewage treatment pond. Impounded areas are often wetlands associated with dams or stock ponds. Drained areas exist where the water level has been lowered but where hydrophytes have survived. It should be noted that wetland vegetation may remain intact 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 have mitigation potential (personal communication, Charlie Storrs, U.S. Fish and Wildlife Service).

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 wetlands that are crucial in providing habitat, maintaining water quality and sustaining proper hydrologic function. Ecologically, these sites are extremely important. It can be argued that preservation of these viable areas is a desirable component of a mitigation plan, as they provide some current level of ecological function. These areas can also increase the likelihood of successful mitigation of nearby

**TABLE 2. Definition of Mitigation Classes**

| 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 |

degraded sites due to intact hydrology and the presence of a seed source. This methodology requires that connected mitigation sites be identified according to the status and position of currently existing, functional wetlands. It is necessary to identify these unmodified wetlands in order to perform proximal analyses.

## *Opportunity Analyses: determining the benefits*

Opportunity analyses are performed in order to evaluate the potential that an identified potential 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*

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 loss and fragmentation are perhaps 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 with adequate interior habitat. Fragmentation results in a landscape well-suited for edge species such as deer. Thus, mitigation strategies should consider habitat needs for those species less adaptable to human-induced perturbations on the landscape and should place priority on large intact sites with a large proportion of interior habitat. Also, since many species utilize a range of habitats during their life cycle or seasonally, it is important that upland/wetland complexes be identified. The criteria used to identify mitigation sites in this analysis prioritize mitigation sites based on their contiguity with upland habitats, their degree of fragmentation, the presence of interior habitat and total habitat area.

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 impact 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.

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 multi-lane 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.

Edge habitat is common 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.* 1991). 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.

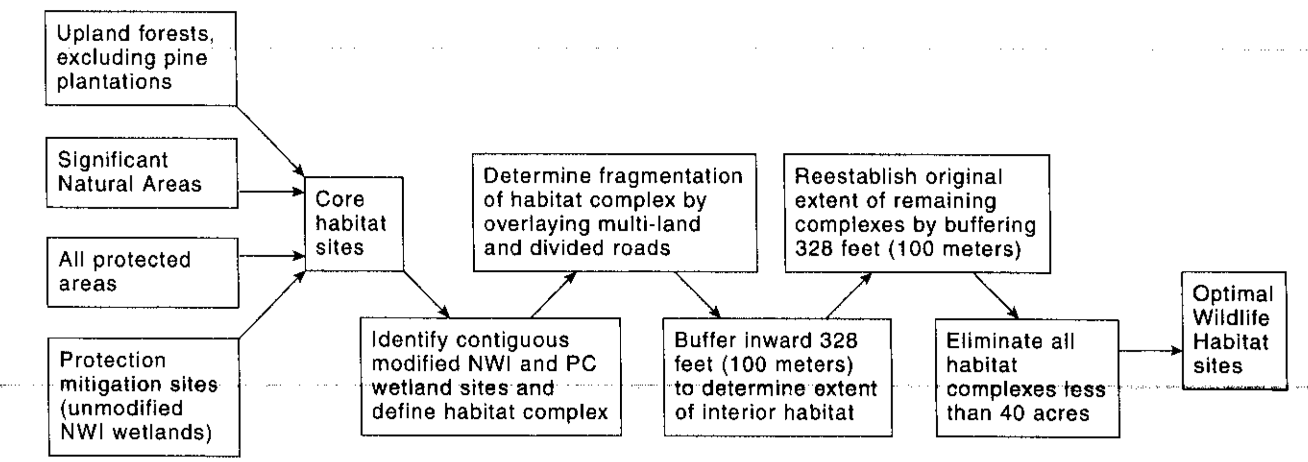
Finally, only habitat complexes of at least 40 acres in size are considered for the rest of the habitat analysis (Adamus 1987). Also considered are all enhancement and restoration sites that are not part of a habitat complex but that are at least 40 acres in size. Figure 1 provides a summary of steps used in the wildlife habitat analyses.

### *Water Quality and Floodwater Storage*

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. However, it is recognized that watershed-level characteristics do influence a site's potential to serve these functions.

Wetland location within a watershed is an important determinant of its contribution to water quality. Brinson (1988) contended that 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 to store floodflow. Because of this, and because of their abundance in the study area, these wetland sites are given sole consideration in the water quality and floodwater storage analyses. A wetland's position along a drainage network also influences its opportunity to contribute to water quality and store floodflow (Kuenzler 1989; Brinson 1988; Whigham *et al.* 1988). 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

FIGURE 1. **Steps in Wildlife Habitat Analyses.**




nutrients and sediments resulting from these land uses settle out and are recycled. 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). 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. In higher order wetlands, overbank flow dominates. 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.

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 wetlands falling within the resulting polygon are identified. These areas, because of their adjacency, are considered primary wetlands for hydrology and water-quality function. Each is assigned a wetland order according to 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 wetland 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 sequence of steps taken in these analyses is presented in Figure 2.

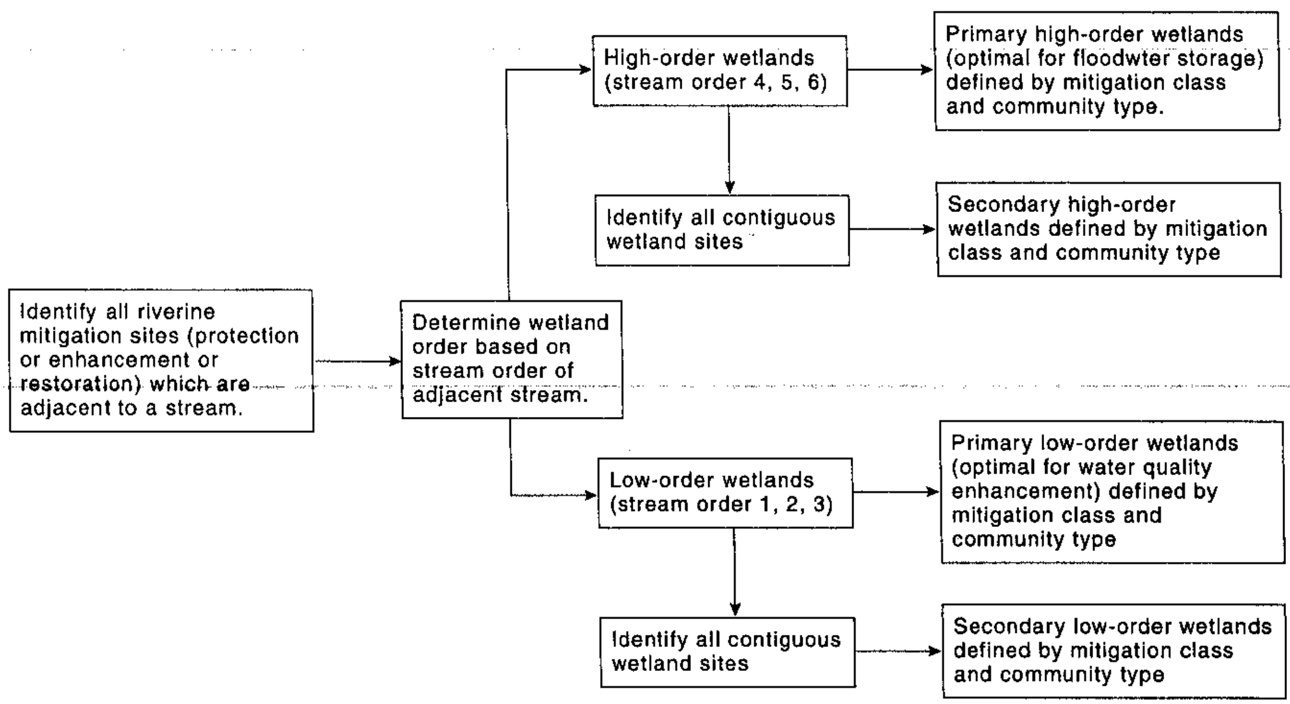
### *Unique Opportunities/Barriers and Potential Threats—locating endangered species, cultural resources, and potential contaminant sources*

Endangered species habitat and cultural resource sites (archaelogic/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 been done primarily in areas where development has occurred. 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 are fairly remote and are least likely to have thorough pre-established rare/endangered species habitat and cultural inventories. 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 study area was performed in 1992 in order to identify natural areas of significance. The result of that

FIGURE 2. Steps in Water Quality/Floodflow Storage Analyses.




inventory indicate that natural habitat acreage—especially upland habitat—has dramatically decreased in the study area. In fact, for the most part, river corridors serve as the last refuge for natural plant communities. 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. Figure 3 provides a complete overview of the summary of steps used in identifying potential mitigation sites.

## Results

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 than those delineated by NWI were not identified. Field verification revealed 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. This is partially attributable to the rather conservative selection of hydric soils used 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 subbasin. 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 field verification of study results also indicate that although the model was successful in identifying enhancement sites—many of which 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

**FIGURE 3. Summary of Steps for Identifying Potential Mitigation Sites.**

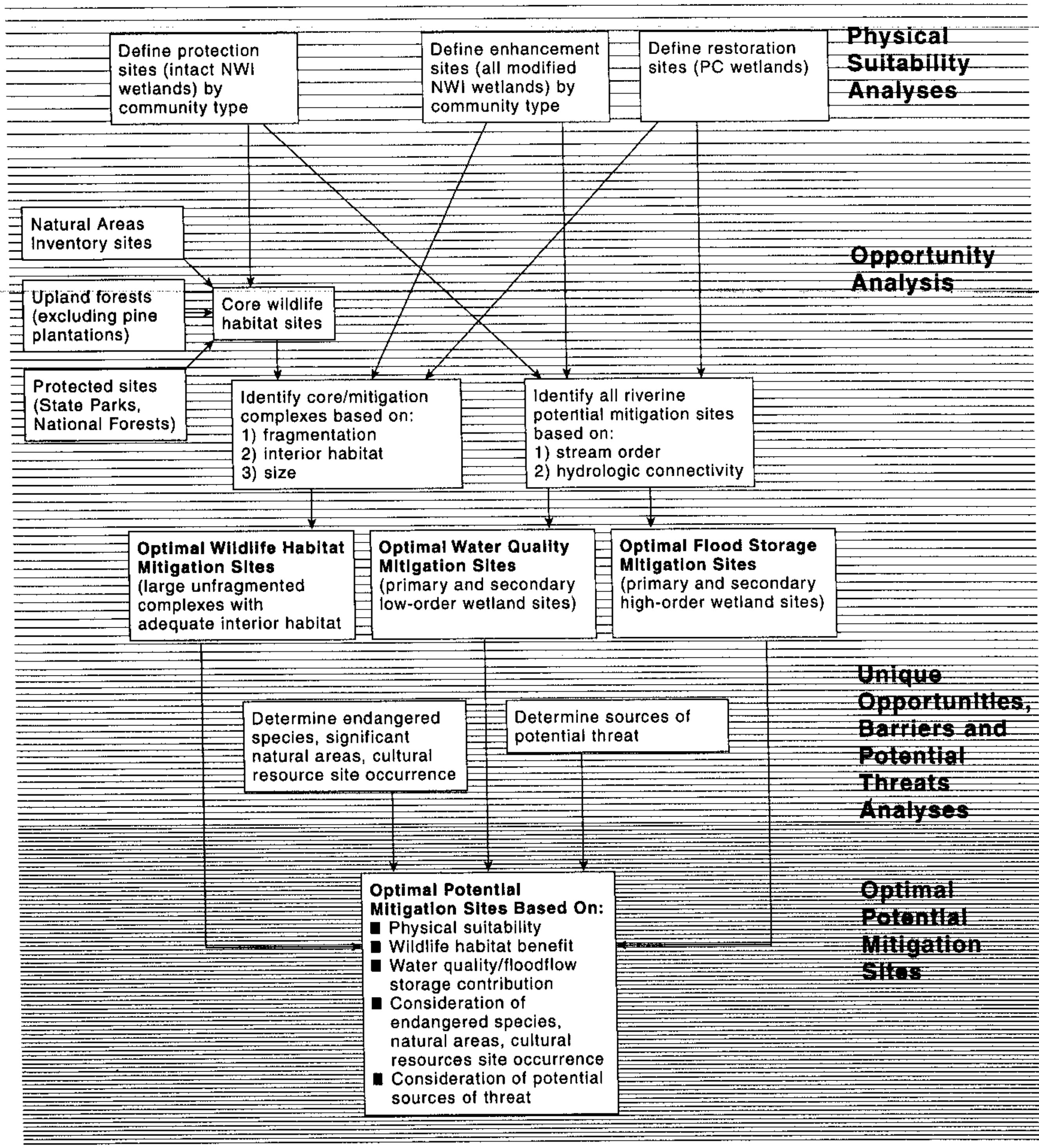
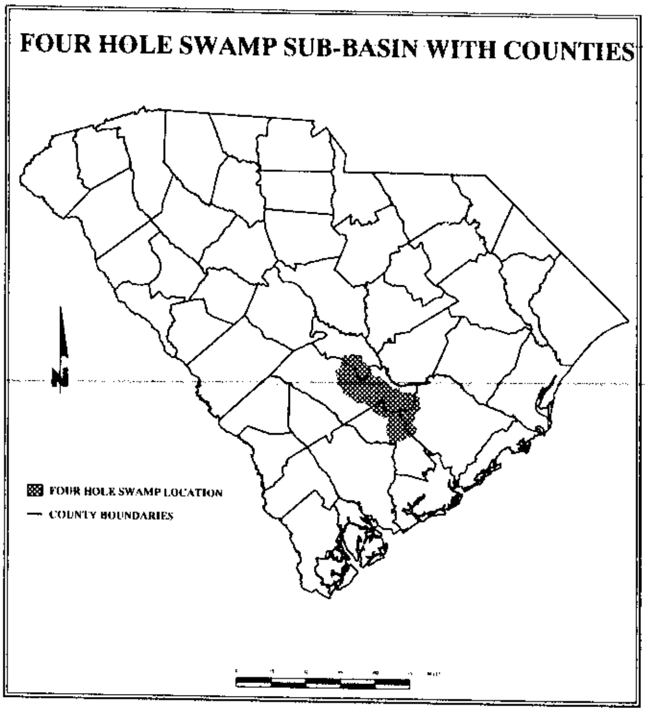


FIGURE 4. The Four Hole Swamp Study Area.




to the fact that a large number of sites identified as protection sites in the NWI data 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 NWI 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 of the drainage system, 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.

## Conclusions

This model provides a basis for identifying potential wetland mitigation sites according to 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.
- Optimal wildlife habitat on the basis of existence of interior habitat.
- 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.
- Unique opportunities to provide habitat for rare, threatened, or endangered species and communities.

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. Indicated sites might be more thoroughly assessed by descriptive methods of functional evaluation such as the Habitat Evaluation Procedures or the Wetlands Evaluation Technique to better determine opportunity potential. This methodology is especially effective in identifying large complexes of mitigation sites, rather than isolated fragmented areas. Thus, it can be a useful tool for identifying potential sites for mitigation banks.

Because this methodology is a decision-support tool, the resulting information can better direct mitigation decisions made by those in the regulatory arena. It considers landscape level indicators of function and places priority on large, 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 sites which, upon mitigation, could contribute to the overall ecological function of the watershed.

## Acknowledgements

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