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An analysis of wetland patterns and functions at the watershed and sub-watershed scales, with *policy applications

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AN ANALYSIS OF WETLAND PATTERNS AND FUNCTIONS AT THE WATERSHED AND SUB-WATERSHED SCALES, WITH POLICY APPLICATIONS

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APPROVAL SHEET

This dissertation is submitted in partial fulfillment of

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ABSTRACT

This dissertation addresses the need to define *potential* impacts of recent and proposed changes in federal wetland regulation in a quantifiable manner. Consideration was made not only of total wetland acreage and wetland types that could sustain losses, but also to categorize the effect such losses would have in terms of wetland functions, at the watershed scale. This work took a Geographic Information Systems (GIS) approach, and included employing a best-professional judgment model for scoring habitat, water quality and flood attenuation functions to determine potential cumulative impacts; a water quality study which related wetland and watershed variables to nutrient and sediment loads; and an amphibian metapopulation model to determine the effects of loss of landscape connectivity resulting from wetland management decisions. The study area encompassed several watersheds in Southern Virginia, USA.

Results from best professional judgment model show that despite a decrease over the years in *acreage* receiving reduced regulatory protection, the *functional caliber* of wetlands afforded the least protection is actually higher with each new implementation of regulatory criteria. These results, and the results of similar models, updated as more information and data sets become available, should be a valuable tool for both regulators and managers at local, as well as regional and federal levels.

The water quality model reduced 41 wetland and watershed variables to 5 principal components, which were then used in regression equations to relate the variables to nutrient and sediment loads. Although differing variables played roles in different water quality components, the overriding factor affecting improved water quality related to the proportion of vegetated area found within a 100 meters of stream courses, with negative water quality related to the proportion of developed to vegetated areas within the 100 meter buffer.

Results from the amphibian habitat model highlight the importance of the pattern of wetlands across the landscape. Removal of wetlands smaller than 0.5 acres had a greater influence on occupancy rates in all wetlands, presumably due to their position providing between wetland connectivity.

Policy and management decisions should be altered to consider each of these conclusions if functional conservation is to be achieved.

AN ANALYSIS OF WETLAND PATTERNS AND FUNCTIONS AT THE WATERSHED AND SUB-WATERSHED SCALES, WITH POLICY APPLICATIONS

Chapter 1. Introduction

It is estimated that the contiguous United States contained more than 200 million acres of wetlands in the early 1700's. By the mid 1970's, only 46% of those wetlands remained (, Dahl 1990, Dahl 2000, Feierabend and Zelazny 1987, Tiner 1984). It is only since the 1970's that federal laws have been geared towards protection, rather than conversion of wetlands, as we have begun to recognize the valuable functions wetlands perform, such as improvement of water quality by storage or alteration of contaminants, and flood and erosion protection for downstream areas by detention of flood waters. Wetlands also provide critical habitat for many species, including an estimated 190 species of amphibians, 270 species of birds and 5,000 species of plants (Feierabend and Zelazny 1987). Approximately half of the federally listed threatened or endangered animal species are wetland dependent (Niering 1988), and over 95% of commercially harvested fish and shellfish spend at least a portion of their life cycle in wetlands (Feierabend and Zelazny 1987).

Many pieces of legislation at both the federal and state levels contain components that aid in the goal of protecting wetland resources. The most prominent of these is the national Clean Water Act, enacted in 1972, with Section 404 requiring the Army Corps of Engineers to oversee a permitting process for the dredging and filling of wetlands. Additional laws provide incentives for wetland protection and restoration, as well as acquisition or permanent easements by federal and state agencies. Implementing wetland policy has fallen to a variety of regulatory agencies, including the Environmental Protection Agency (EPA), the Army Corps of Engineers (the Corps), the U.S. Fish and Wildlife Service (USFWS), the Natural Resources Conservation Service (NRCS), state agencies and local governments.

Managing wetlands is a difficult task, demanding that a balance be found between protecting a valuable public resource and protecting the rights of private property owners. The maneuvering between these seemingly diametrically opposed forces occurs from the beginning of the law making process, down through interpretation of policies, programs, and delineation manuals, and even to individual permit or easement decisions. Confounding this process are: wetlands themselves, which defy easy categorization and determination of their functions; and the changing emphasis society puts on how it values those functions. Because of these conflicts, wetland protection is still evolving, and federal agencies continue to adapt their programs and guidelines, both in response to internal pressures as well as lawsuits brought against them. Intensifying the debate is the fact that the Clean Water Act is overdue for reauthorization, having expired September 30, 1990, leading to efforts to amend, and in some instances, completely rewrite this pivotal law.

"No net loss" policies have been announced by both the 1989 -1993 Bush and the Clinton administrations regarding wetland protection, and although the current Bush administration has yet to declare a wetland policy, concern over the exact definition and interpretations of "no net loss" continue. Both USFWS and the Department of Agriculture have conducted separate surveys of wetland loss, and have concluded that the yearly loss of wetlands has decreased from nearly 500,000 acres per year from 1954 to 1974, down to less than 100,000 acres per year since the mid 1980's. While this is an improvement, many would argue that failure to meet the national "no net loss" policy alone is cause for action. Moreover, the issue of how different policies affect type and location of wetlands lost, and cumulative impacts that occur from such losses, are cause for concern. For example, most legislative and regulatory actions have the effect of targeting small wetlands for the majority of losses incurred. This fact has lead to numerous papers considering the value of these small wetlands (e.g., Gucinski 1978; Semlitsch and Bodie 1998)

Jurisdictional and scientific definitions of wetlands are not necessarily congruent. Jurisdictional delineations deal with the letter of the law as written, and interpretation through regulation and administrative programs. These actions seek to balance scientific understanding, with economic and social pressures in determining whether and how a wetland is to be protected. My rationale for this work is to consider that there may be limits to which the natural system can be compromised for the latter two considerations without disproportionately endangering the fundamental qualities for which we value wetlands in the first place. To that end, my work will address three wetland functions considered of value to society: 1) primary productivity and habitat; 2) water quality modification; and 3) flood storage and attenuation. I will be looking at patterns of wetlands and land use within watersheds to assess the potential effects of cumulative impacts of regulatory decisions on the functions wetlands perform.

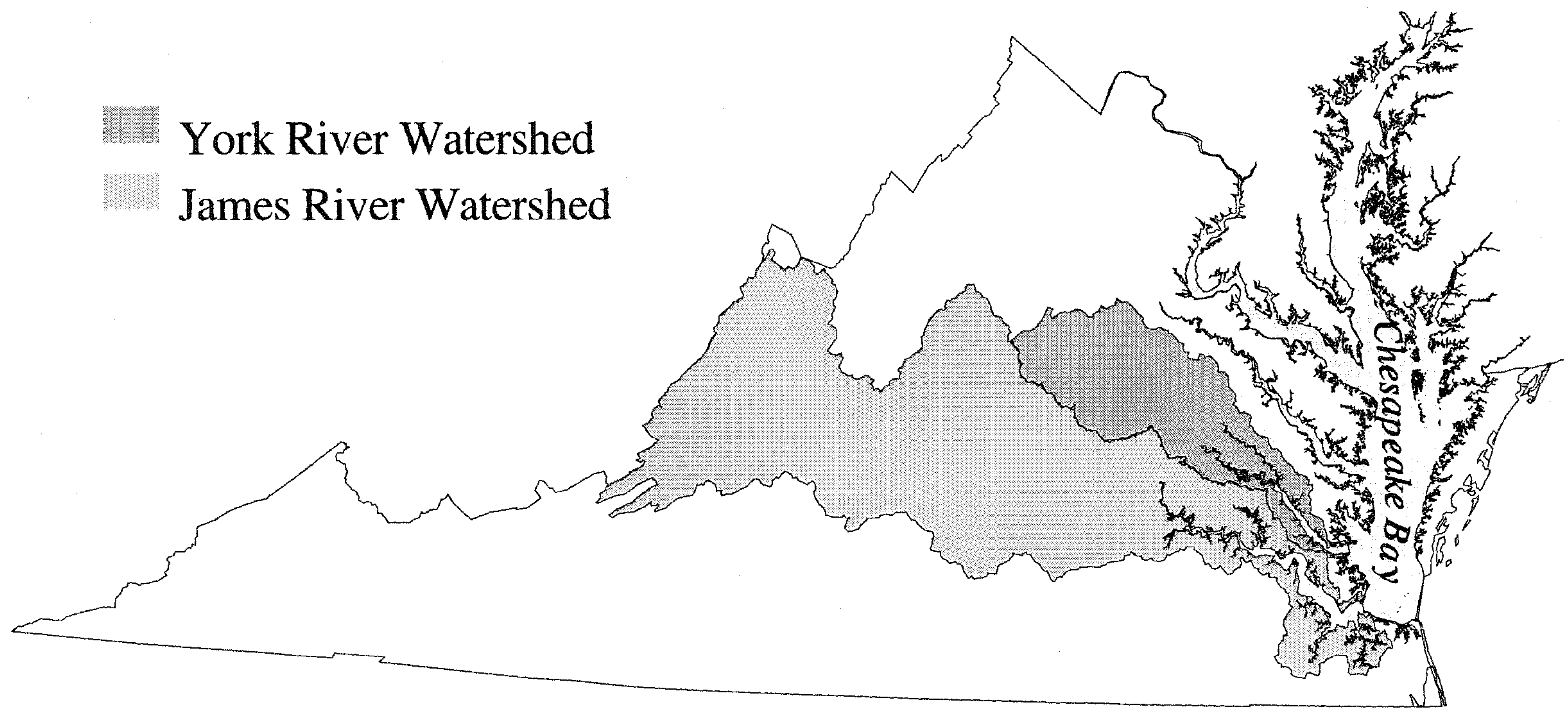
The scope of my dissertation relates to federal wetland legislation, however my study sites are constrained to watersheds in the southeastern area of Virginia. I specifically address potential policy ramifications within the York and James River Watersheds, tributaries of the Chesapeake Bay (Figure 1).

Primary Productivity and Habitat

Many wetland types are among the most productive ecosystems in the world. Freshwater wetlands have a net primary productivity equal to that of tropical rain forests at approximately 2000 $g/m^2/year$. Salt marshes can be even higher, at about 2375$g/m^2/year$ (Tiner 1984). This biomass, and the detritus formed as the plants die and decay, provides food for a number of animals in both the aquatic and terrestrial environments.

Theories of biodiversity point to preservation of large, pristine tracts of land as the ideal to maintain high levels of species diversity (Diamond 1975, MacArthur and Wilson 1967). However, the degree of fragmentation of natural habitats caused by human development has forced scientists and resource managers to consider the role of smaller reserves. Many argue against the arbitrary determination that a tract is "too small" past a certain size to be worthy of preservation (e.g., Jenkins 1989, Gucinski 1978, Shafer 1995). While a tract may be too small to satisfy "minimum dynamic area" for some species, it may be

Watershed locations in the Commonwealth of Virginia



Fiure 1-1

sufficient for the long-term survival of others (Shafer 1995). What may be an isolated fragment of habitat for some species, may provide an important aspect of landscape heterogeneity for more wide-ranging species (Harris 1988). The Nature Conservancy has preserved habitat fragments as small as a half acre which still support the same floral assemblage as they did 80 years ago (Jenkins 1989). Wetland tracts as small as 0.1 acres may, depending on type and location, have significant value in terms of productivity, detritus availability, and habitat (Silberhorn et al. 1974). Many small tracts, including those with low species diversity, can harbor rare species or be one of the last remaining examples of a particular habitat type (Shafer 1995). In James City County, Virginia, Skiffe's Creek and Graylin Woods both provide sites where very rare species of plants exist in wetland habitats as small as 5 and 7 acres (Clark 1993). Such fragments can be cores for habitat restoration, or provide individuals that may introduced to other suitable habitats, or cultivated to increase population levels.

An important additional consideration is that wetlands may be complete even at small sizes: that is, they are not necessarily fragments of larger wetlands that have been lost or isolated by development. Weakley and Schafale (1994) point out that most of the wetlands found in the Southern Blue Ridge are small (<10 ha), and many are too small to be recognized or mapped on NWI maps with a scale of 1:24,000. Yet these wetlands have great species and community diversity and provide habitat for many rare as well as common plants and animals. In the southeastern U.S., small isolated wetlands are critical breeding sites for many species of amphibians and can be important nesting and feeding sites for waders and shorebirds (Moler and Franz 1987 In: Bradshaw 1991). Canvasbacks (*Aythya valisineria*), whose populations on their wintering ground in Chesapeake Bay are one-fifth what they were 40 years ago, actually prefer to nest in small, semi-permanent wetlands, in stands of cattail, bulrush or whitetop grass (Haramis 1991). Another Chesapeake Bay inhabitant, the wood duck (*Aix sponsa*), depends upon bottomland hardwood forests, shrub swamps, and flooded shrub fringes of forests along small water courses for breeding (Haramis 1991).

Loss of wetlands not only has an effect on total wetland habitat available, it changes the ecosystem dynamics across the landscape in which they are found. Theories of metapopulation dynamics (Levins 1970, Hanski and Gilpin 1991) may be applied to populations of animals or plants that are isolated in patches of habitat. These patches are, in effect, islands of habitat surrounded by areas that are inhospitable either due to human development or unsuitable habitat type. The theory argues that while local populations may go extinct, the presence of multiple sources, on other "islands", can serve to rescue, or recolonize the area. It may be argued that since wetlands are often isolated from one another, the species that make use of these areas are already dispersing some distance between habitats, exhibiting the migration facet of the metapopulation theory. This ability for individuals or propagules to move between multiple tracts can protect a population against demographic accidents, genetic erosion, localized environmental change, natural catastrophes and human disturbance (Shafer 1995). While each species will probably have a different maximum dispersal distance (Pickett and Thompson 1978), the elimination of small wetlands in the landscape may destroy critical "stepping stones" for this dispersal to occur, limiting the ability of species to move between wetlands. Some areas, such as riparian forests, may act as habitat for some species, and provide a corridor linking habitats for others (Simberloff and Cox 1987; Pearson 1994). Gibbs (1993) created a simplified spatial model to simulate the loss of all <10 acre palustrine scrub/shrub and palustrine emergent wetlands in a 600 km^2 area of Maine to determine the effects such a loss would have on the metapopulation dynamics of salamanders and newts, frogs, turtles, small birds, and small mammals. He observed elevated extinction risks for turtles, small birds, and small mammals, suggesting that "the presence of small wetlands may be critical for the persistence of certain wetland taxa, particularly those with low population growth rates and low densities."

While most natural scientists and resource managers would agree with the concept that to be truly preserved, species and habitat must be saved in replicate, current understanding points to the need to consider interaction dynamics between wetlands and other nearby non-wetland habitat as well. Many wetland plant and animal populations depend on aspects of habitats in the surrounding landscapes; without these complementary habitats, the populations could collapse (Pearson 1994, Semlitsch 1998). The presence of wetlands as ecotones in a landscape can also affect the plant and animal distributions and diversity in surrounding areas (Risser 1995, Trettin et al. 1994). Management of the entire drainage basin, including the protection of buffer zones around wetlands, is necessary to increase the viability of species in wetlands (Harris 1988, Holland 1993, Semlitsch 1998, Shafer 1995). Improved water quality that can result from these buffer zones may be as important for wildlife as maintenance of habitat diversity.

Water Quality

Wetlands can serve biogeochemical functions by removing or altering organic and inorganic nutrients and contaminants from the water that flows through them. Depending on type and location, wetlands may play an important role in the global cycles of nitrogen, phosphorus, sulfur, methane, and carbon dioxide (Mitsch and Gosselink 2000). These materials may be taken out of the water by accumulation in plants and microorganisms, burial in the sediment, and denitrification. Inorganic nutrients may be transformed by wetland organisms into organic forms usable elsewhere in the aquatic food web. The sedimentation of organic material in the wetland may provide long-term detention for some nutrients and toxins (Hemond and Benoit 1988). Wetland vegetation can reduce turbidity, improving water quality by helping to bind sediment with their roots, and reducing current velocity and dampening waves through friction (Tiner 1984). Wetland plants are also capable of assimilating some metals and chemical compounds, can trap suspended sediments, and aid in flocculation of suspended particulates (Hemond and Benoit 1988). Silberhorn et al. (1974) found that any marsh that is at least 2 feet in average width can have significant value in filtering sediment.

Flood Storage/Flood Flow Alteration

Wetlands that are flooded by overbank transport naturally provide for temporary floodwater storage. While this process is essential to the wetland, from a human point of view, this storage protects downstream property from more severe flooding and erosion that comes with increased water flows. Water from wetlands is released slowly, protecting downstream areas from the potentially damaging effects of flood peaks from tributaries reaching the main river at the same time (Tiner 1984). Isolated and non-riparian wetlands also hold rainwater and runoff, contributing to flood control. Hydrographic modification is directly related to the total amount of wetlands within a watershed or the amount in headwater reaches (NRC 1995). However, this relationship may not be strictly linear, and successive losses in wetland area may cause exponential rise in flood peaks (Gosselink and Lee 1989, Johnston 1994)

The need for this protection is clear: an estimated 134 million acres of the conterminous U.S. experience flooding each year. Almost 100 million of those acres are agricultural land, many of which were former wetlands (Feierabend and Zelazny 1987). The further loss of wetlands may only be expected to exacerbate the problem. An example of the value of this function is the Charles River

Natural Valley Storage Project, completed in 1984, which preserved a complex of wetlands near Boston, Massachusetts, for the purpose of flood control. It is estimated that the project, with a total cost of $8.3 million, saves an average of 2.1 million dollars in flood damage each year (Feierabend and Zelazny 1987).

Current Federal Wetland Legislation

Previously, there were laws on the books that encouraged destruction of wetlands, including provisions in the federal tax code, public works legislation, and farm programs. These included the Swamp Land Act of 1850 (43U.S.C.§§981 et seq.), which granted states control of the formerly federally owned wetlands within their boundaries, for the purpose of "reclaiming" the wetlands through drainage and levee construction (Mitsch and Gosselink 2000). Federal laws now serve either to protect and conserve wetlands, or at the very least not support their destruction. Below is a synopsis of the main federal legislation affecting wetlands, as well as comments on the benefits and shortfalls, including controversy about their scope and efficacy. Most of this legislation has been in place for 2 decades or more. The only major wetland legislation to be enacted in recent years deals with agricultural wetlands, in the 1996 and 2002 Farm Bills.

Clean Water Act (CWA) (33 U.S.C. 1251-1387) (formerly titled the Federal Water Pollution Control Act)– First passed into law in 1972, Section 404 of the CWA is the central regulatory program for the nation's wetland protection. The Act lists as one of its main objectives "to protect, restore and maintain the chemical, physical and biological integrity of the waters of the United States". Although the main text of the CWA never actually uses the word "wetlands", they are written into the definition of "waters of the United States", which includes:

1. all waters which are presently used, have been used in the past, or may be used in the future for interstate or foreign commerce;
2. all interstate waters, including interstate wetlands;
3. all other waters, such as intrastate lakes, rivers, streams, mudflats, sand flats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds, which through their use, degradation or destruction could affect interstate or foreign commerce;
4. the territorial seas;
5. tributaries of those waters described above; and
6. wetlands adjacent to those waters above.

In addition, federal jurisdiction has been upheld in court for some wetlands with less apparent connection to navigable waters or interstate commerce, including artificially created wetlands, seasonal wetlands, and isolated wetlands.

These regulated wetlands are defined according to the wetland delineation manual issued by the Army Corps of Engineers in 1987. The manual was prepared jointly by the Corps, EPA, FWS, and the National Marine Fisheries Service (NMFS). This manual provides consistency among agencies with responsibility of field determination of wetlands. A slightly different manual was prepared with the Corps by the Natural Resources Conservation Service for use on agricultural wetlands.

Section 404 of the Clean Water Act requires landowners or developers to obtain a permit from the Army Corps of Engineers if they are intending to dispose of any dredge or fill material in any water of the United States. The definition of "discharge of any dredged material" includes:

1. The addition of dredged material to specified discharge site located in the waters of the United States;
2. The runoff or overflow from a contained land or water disposal area; and
3. any addition, including any redeposit, of dredged material, including excavated material, into waters of the United States which is incidental to any activity, including mechanized land clearing, ditching, channelization, or other excavation.

The definition of "discharge of fill material" includes:

1. placement of fill that is necessary for the construction of any structure in a water of the United States;
2. the building of any structure or impoundment requiring rock, sand, dirt, or other material for its construction;
3. site-development fills for recreational, industrial, commercial, residential and other uses:
4. causeways and road fills;

5. dams and dikes;
6. property protection and/or reclamation devices such as riprap, groins, seawalls, breakwaters, and revetments; and
7. beach nourishment.

While the U.S. Army Corps of Engineers, in conjunction with the Environmental Protection Agency, is the primary administrator of Section 404 permits, other federal agencies are also involved in wetland management. These include the Departments of Agriculture and Interior.

Permits granted to applicants fall under the heading of either individual permits or general permits. Those activities classified by the U.S. government to be of minimal impact to wetlands have been granted a blanket authorization by the Army Corps of Engineers under general permits. All other permits are considered on an individual basis, based on two primary factors:

1. Compliance with regulations established by EPA pursuant to CWA Section 404 (b)(1) (known as the "Section 404(b)(1) guidelines") to assess the proposed project's impact on environmental quality; and
2. whether the project is in the public interest.

Section 404 was last significantly amended by Congress in 1977. However, there have been lawsuits in recent years that have altered the Corps regulations issued under CWA authority.

North Carolina Wildlife Federation et al. v. Tulloch- the Corps and EPA had issued regulations in 1993 that extended regulatory purview to cover "fallback" of materials occurring from certain landclearing and excavation activities in wetlands. In 1997 a U.S. District Court for the District of Colombia ruled that incidental fallback is not pollution under the CWA and that the Corps had overstepped their jurisdiction. In January of 2001 the Clinton administration issued a regulation to close the loophole of "The Tulloch Rule", which was estimated to have resulted in the conversion of 20,000 acres of wetlands (Zinn and Copeland 2002). After reviewing the rule, the current Bush administration agreed to allow the regulation to take affect, unmodified. Two industry groups have brought lawsuits against the regulation.

U.S. v. Wilson- In 1997 the U.S. 4th District Court of Appeals found in favor of a Maryland developer, ruling that the Corps had exceeding its CWA authority in claiming jurisdiction over isolated wetlands on the basis of migratory bird utilization. This ruling affects only the states in the 4th district, namely Virginia, West Virginia, Maryland and the Carolinas. The Corps in these states can still exert authority over isolated wetlands, but only in cases where there is a substantial connection between the wetland and interstate commerce.

Solid Waste Agency of Northern Cook County (SWANCC) v. U.S. Army Corps of Engineers - In January of 2001, the U.S. Supreme court ruling that the Corps had exceeded its authority in regulation of isolated wetlands on the basis that several excavation trenches in Illinois had evolved into wetlands which serve as habitat for migrating waterfowl. The policy implications of this ruling were to define isolated wetlands as outside the reading of “navigable waters” in the CWA. Legislation to amend the CWA to include such waters has been introduced (S. 2780, H.R. 5194)

Nationwide Permits

Nationwide permits allow the Corps to minimize effort involved in permitting procedures by allowing certain categories of activities to take place on minimal amounts of acreage without an individual permit. These permits are authorized for 5 years and must be regularly renewed by the Corps. These permits have undergone several changes within the last 6 years, including decreases in the acreage limits allowed to proceed under the general permits. One of the most controversial of the general permits, nationwide permit 26 (NWP 26) previously allowed for activities which occurred on a particular subset of wetlands, and has since been replaced with a series of activity-based permits more in keeping with the congressional intent for general permits to be applied on the basis of activity type, rather than wetland type (Copeland 2002a). These permits are considered in more detail below, and in Chapter 2.

The Corps received an average of 74,500 Section 404 permit requests each year from FY96 to FY99. Of those, more than 84% were issued under a general permit. In FY99, 21,556 acres of wetlands were permitted to be impacted. More than double that amount of acreage was required under those permits to be created, enhanced, or preserved as mitigation for those losses (Copeland 2002b)

Section 401 of the Clean Water Act is designed to ensure all applicable state water quality standards are met by projects that receive federal Section 404 permits. Permit applicants are reviewed to assess whether materials to be discharged into a wetland meet effluent limitations, water quality standards and any other applicable provisions of state law. This provision gives states considerable authority over the federal permitting process. If the criteria established by the state for dredge and fill disposal are not met, the federal permit should be denied, and any conditions imposed on a permit by the state must be met as part of the federal permit (Gilchrist 1995).

Concern has been raised by wetland protection advocates that the CWA does not do an adequate job protecting wetlands from the many activities that threaten them. Since its jurisdiction is limited to the discharge of dredge and fill material, it is not able to protect these resources from activities that flood, drain, or otherwise reduce or destroy wetland functions. In addition, when Section 404 was amended in 1977, exemptions were provided for some major activities. Among those no longer requiring a permit are ongoing ranching, farming and forestry activities, these actions were put under the purview of the Department of Agriculture and are regulated separately (see Federal Farm Bill, below). There is also questions as to the appropriateness of excluding wetlands from protection because of their small size or lack of connection to a major tributary water system: this exemption encompasses approximately 20% of all wetlands in the U.S.

While there is controversy over the provisions of the Act among both those who seek to protect wetlands and those who wish to encourage development, there is also debate over whether or not it is the best vehicle and approach to wetland protection. Although the objectives of the CWA are broad, there are many who feel that a law based principally on water quality is not the appropriate vehicle to protect wetlands and the multiple functions they perform, such as flood control and wildlife habitat (Copeland 2002b).

Rivers and Harbors Act of 1899 This act codified the Army Corps of Engineers authority over maintaining the navigability of the nation's waterways. This legislation also includes jurisdiction over some wetlands because the regulatory definition of navigable waters for this act extends to those waters subject to the ebb and flow of tide and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce. An important phrase in this Act has important consequences for wetlands management, providing that a 'determination of navigability, once made, applies laterally over the entire surface of the water body, and is not extinguishable by later actions or events which impede or destroy navigable capacity".

Judicial review of this legislation expanded the Corps permit authority to extend to projects that would damage the ecological status of waters. This authority was codified by congress under the Clean Water Act in the 1970's (NRC 1995).

Section 10 in the Rivers and Harbors Act specifically prohibits activities that would alter or obstruct any navigable water of the U.S. Regulated activity includes those that would alter the course, location, condition, or capacity of a navigable water. Permit reviews under Section 10 are usually performed in conjunction with the CWA Section 404 permit reviews (Gilchrist 1995).

Coastal Zone Management Act – 1972. The purpose of this act was to provide for each coastal state to develop its own comprehensive Coastal Zone Management Plan. These plans are reviewed and approved by the U.S. Department of Commerce, with the entire program administered by the National Oceanic and Atmospheric Administration. Due to "federal consistency" requirements, approval under the state's individual plan must be met before a federal permit is issued for activities in the coastal zone. Although this review procedure is similar to the Section 401 certification under the CWA, it is a distinctly separate process and in fact, may be conducted by different state agencies (Gilchrist 1995).

Food, Agriculture, Conservation and Trade Act (Federal Farm Bill) In response to concerns from the agricultural community over clean water act wetland issues, a separate vehicle for wetland protection was created within the 1985 Food Security Act (P.L. 98-198, 99 Stat. 1504) (NRC 1995). The provision known as "Swampbuster" addresses the conversion of wetlands into cropland, and makes farmers who drain wetlands ineligible for federal farm program benefits, including U.S. Department of Agriculture (USDA) price and income supports, crop insurance, farm storage facility loans, disaster assistance, Farmers Home Administration loads and Commodity Credit Corporation storage payments. Swampbuster applies to the person who converts the wetland, and includes all of that individual's crops, not merely those grown on the converted land. Beginning in 1990, this bill also included authorization of the Wetland Reserve Program (see non-permit programs, below) as well as other conservation programs that can impact wetland protection efforts, such as the Conservation Reserve Program and the Environmental Quality Incentives Program (EQIP).

Historically, controversies arose over differences between the USDA and Corps definitions and delineations of wetlands. This law clarifies the role of the USDA's Soil Conservation Service (now the National Resource Conservation Service, or NRCS) as the lead federal agency for delineating wetlands on agricultural land (Zinn 2002).

Related legislation:

National Environmental Policy Act of 1969 (NEPA). Requires all federal agencies to evaluate the environmental impacts of activities they undertake, or permits they approve. Under this law, agencies are required to fully disclose activities and potential impacts prior to permit issuance, and require consideration of alternatives or mitigation options to minimize or avoid negative environmental impacts. In some cases, the impact review for permitting under Section 404 of the CWA proceeds to a formal environmental impact review process (Gilchrist 1995).

Endangered Species Act (ESA). Because wetlands provide habitat to many endangered or threatened species, the ESA can come into play in a permit application. This act requires federal agencies to consult with the Fish and Wildlife Service and the National Marine Fisheries Service to determine, prior to permit issuance, that the proposed activities will not adversely affect species protected under the ESA, or degrade or destroy their habitat.

The Fish and Wildlife Act of 1956, the Migratory Marine Game-Fish Act, and the Fish and Wildlife Coordination Act. These statutes provide protection for the quality of the aquatic environment as it relates to the conservation, improvement and enjoyment of fish and wildlife resources. They require federal agencies to consult with the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service, as well as with the appropriate state agencies managing fish and wildlife resources in the affected area, prior to authorizing any activity which would modify any body of water (Gilchrist 1995).

Section 7(a) of the Wild and Scenic Rivers Act. Prohibits the issuance of federal permits for any water resource project construction which would have a direct and adverse affect on the values of any designated Wild and Scenic River. Created in 1968, this Act subscribes to the values of wild and scenic rivers as those which "with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values"(16 U.S.C. 1271-1287).

Non Permit Wetland Protection Programs:

There are several federal programs aimed at protecting our nation's wetland resources that do not involve the permitting process. These include programs to encourage scientific study and education on wetland topics, easements on privately owned lands, as well as those that act to preserve wetlands by outright acquisition of land.

National Estuarine Research Reserve System (NERRS) This program, administered by the National Oceanic and Atmospheric Administration, provides management for selected pristine estuarine areas , intended to preserve these areas for education and research. NERRS now includes a series of 25 reserves across the nation.

National Estuary Program (NEP) A program within the Environmental Protection Agency, NEP was established by Congress in 1987 as part of the Clean Water Act (section 320) with the aim of improving the quality of estuaries of national importance. There are currently 28 estuaries with comprehensive conservation and management plans under NEP, aimed at attaining and maintaining water quality for human consumption, fishery and wildlife habitat and for recreational activities.

Wetland Reserve Program (WRP) This program, which was created as part of the Farm Bill, allows farmers to place easements on wetlands they own in return for compensation, based on the resulting reduction in land value. As of March, 1998, the program contained nearly 590,000 acres, with nearly 40% of the wetlands located in Louisiana, Mississippi, and Arkansas. Most of the land (88%) was enrolled under permanent easement, as all WRP lands were prior to the 1996 farm bill. Beginning with the FY98 appropriation, this program became an entitlement, with enrollment capped at 975,000 acres. Ten percent of the land currently enrolled is in 30 year easements, and an additional 2% are enrolled in 10-year restoration agreements. With the most recent Farm bill authorization, in 2002, an annual enrollment goal of 250,000 acres through 2007 is authorized, with a maximum enrollment ceiling of 2,275,000 acres (Zinn 2002).

Coastal Wetlands Planning, Protection and Restoration Act (P.L. 101-646). Administered by the USFWS, this program funds competitive grants to states for activities to protect and acquire coastal wetlands. In FY98, more than $10 million dollars was disbursed to restore more than 13,000 acres in 13 states, although the majority of the sites are in Louisiana.

Ramsar Convention (Convention on Wetlands of International Importance). One hundred and eight nations have signed onto this agreement to slow the rate of wetland loss. Over 900 sites have been designated worldwide, with 15 sites in the U.S. However, nomination is voluntary and there is no real enforcement mechanism for subsequent failure to manage sites appropriately.

North American Wetlands Conservation Act. Under this law, federal matching grants are awarded for wetland conservation projects which help to implement the North American Waterfowl Management plan. Project sites are in Canada and Mexico, as well as throughout the United States. Reauthorized in the 105th Congress through the year 2003, it authorizes the spending of up to 30 million dollars per year.

During each congressional session since 1991, more than 75 bills have been introduced with contained wetland provisions. Contentious wetland provisions in the Clean Water Act reauthorization during the 103rd session prevented that bill from passing, although an “anti-environmental, pro-landowners rights” reauthorization, H.R. 961, passed in the House during the 104th. However, it was not passed in the Senate, and thus did not become law. The only major pieces of wetland legislation to be passed since 1990 are the Federal Agricultural Improvement and Reform Act of 1996 and the Farm Security and Rural Investment Act of 2002(P.L.104-127, P.L. 107-171), better known as the 1996 and 2002 Farm Acts.

Federal Wetlands Policy

The sum of these laws, however, does not total to a comprehensive wetlands policy. The first Bush administration announced a "no net loss" policy, and Clinton vowed to carry through on that theme, announcing his own policy on August 24, 1993. Clinton's policies included (1) using the best available science to define and delineate wetlands (2) improving the regulatory program and encouraging non-regulatory options, and (3) expanding partnerships in wetland protection

<u>Clean Water Action Plan</u>

In February of 1998, President Clinton announced the latest in policy initiatives for clean water, entitled the Clean Water Action Plan: Restoring and Protecting America's Waters. Protecting and restoring wetlands is listed as a key feature of natural resource stewardship included in the plan. The goal was set to attain "a net increase of 100,000 acres of wetlands per year by 2005." Since the government's own assessment of wetland loss is at the rate of 100,000 acres per year, the program will require a gross gain in wetland coverage of 200,000 acres per year. This would augment the goal of continuing to reduce the rate of wetland losses through currently existing programs, and by improving federal programs to that end. Programs that are expected to contribute to this gain are the USDA's Wetland Reserve and Conservation Reserve programs, the Army Corps of Engineers Environmental Restoration Programs, the Department of Interior's Partners for Fish and Wildlife program and the North American Wetlands Conservation Act. The agricultural programs are expected to yield a gain of 125,000 to 150,000 acres per year by 2005, while the other federal programs are expected to contribute an increase of 40,000 to 60,000 acres by 2005. Non-federal programs are expected to provide approximately 35,000 acres per year to round out the numbers, increasing incentives to landowners to restore wetlands.

Another interesting feature of the Clean Water Action Plan is a new Corps program, Challenge 21 (Section 212, P.L. 106-53, WRDA 99). This proposes to create a community–based watershed approach toward restoring riverine ecosystems and mitigating flood hazards. Through the use of increased fiscal and policy incentives, the program would aim to promote greater use of non-traditional, non-structural flood hazard mitigation. Such strategies include easements, land acquisition, and construction of setback levees. By avoiding the building of traditional flood management structures, riverine ecosystems would be better protected and natural areas such as wetlands would be restored and sustained. A report to congress is meant to be delivered in 2003. Unfortunately, this program has yet to be appropriated any funding.

The current Bush administration has not formally announced any policy regarding wetlands. Despite previous "no net loss" policies, wetlands continue to be lost at the rate of 58,500 acres per year over the last 10 years. These losses are due primarily to four main sources: urban development, which accounts for 30% of the losses, agricultural conversion (26%), silviculture (23%) and 21% to rural development (Dahl 2000).

Specific alternatives considered

Despite the fact that the Clean Water Act has yet to be reauthorized, the passage of H.R. 961 in the 104th Congress, and changes made by the U.S. Army Corps of Engineers to wetlands regulations and the federal farm bill has kept the wetland debate rolling, with hearings on wetland issues taking place in both the House and Senate in the 105^{th}, 106^{th} and 107^{th} Congresses.

Of the approximately 75 bills per year which are introduced in the House and Senate regarding wetland issues, one stands out as the only one in the past decade as both substantial and having passed in the House: H.R. 961. There have been changes regarding federal wetland regulation during that time, most notably the changes to nationwide permit 26 and the subsequent replacement permits. Table 1-1 summarizes the specific criteria under each legislative scenario that will be assessed in this dissertation.

Table 1-1. Legislative alternatives and specific criteria considered in this dissertation

Legislative scenario	timeline	Specifics addressed
H.R. 961	Passed house in 104th congress, never enacted	• Less than 10 contiguous acres *or* • Isolated from surface hydrology *or* • Less than 21 days of inundation – *c* denoting conservative assessment, *i* an inclusive assessment
NWP26–10	Prior to 1996	• Isolated or headwater *and* • Less than 10 acres affected
NWP26-3	1996-2000	• Isolated or headwater *and* • Less than 3 acres affected
NWP 39	2000-present	• Loss of non-tidal wetlands associated with residential, commercial or institutional development *and* • Less than ½ acre affected *a* – assessed for those areas zoned residential, commercial, commercial/industrial and mixed use zones *b* – assessed for those areas zoned agricultural/rural residential/forestry

H.R. 961

This legislation, which was introduced by the House Transportation Committee Chairman Bud Shuster (R-PA), passed the U.S. House of

Representatives by a 240/185 vote, despite strong objections by the environmental community as well as the Administration. In addition to requiring compensation for any federal agency action under Section 404 which would lessen the fair market value of the land by 20% or more, the legislation set up a tiered approach to wetland protection that many environmentalists feared would open the door to widespread wetland destruction. This tiered system would classify wetlands into class A,B, or C, with Class A receiving the most protection, Class B limited protection and Class C none at all. A Class A wetland is defined as a "wetland that is of critical significance to the long-term aquatic system of which the wetland is a part". In order to qualify as an A, the wetland (with the exception of prairie pothole features, playa lakes and vernal pools) must consist of or be a portion of 10 or more contiguous wetland acres, have a defined surface outlet for relief of water flow, and there must "exist a scarcity of functioning wetland within the watershed or aquatic system such that an activity in waters of the United States carried out in the wetland would seriously jeopardize the availability of critical wetland functions".

In addition, to meet the "Criteria for delineation of wetlands", in the case of a non-tidal wetland, water must be "on or above the surface of the ground for at least 21 consecutive days during the growing season in a year of normal rainfall".

While this legislation has not been reintroduced, it still serves as a valuable gauge as the only Clean Water Act reauthorization language to pass the House in the last 10 years, and will most likely be revisited in future reauthorization considerations.

Nationwide Permit 26

This permit pertained to discharges in headwaters or isolated waters, that is, to non-tidal waters that have a flow rate of less than 5 cubic feet per second, or are not part of or adjacent to surface hydrology. This permit was the most controversial of the Nationwide Permits, as environmentalists were concerned that it singles out certain types of wetlands for unmonitored losses, with potentially large negative cumulative impacts. Concern had been raised that this permit is actually illegal, as it violates the CWA's requirement that nationwide permits cover activities that are "similar in nature". Developers and property rights advocates, on the other hand, favored this permit for its simplification of the construction permitting process.

Prior to 1996, this permit authorized activities affecting up to 10 acres of waters, with a pre-construction notice (PCN) required to be sent to the Corps if the activity would affect 1 to 10 acres.

In 1996, the Corps issued a new ruling that capped the permit at 3 acres, with a PCN required for an area of 1/3 to 3 acres being affected. This measure was designed to expire 2 years later, with NWP26 to be replaced by a series of activity specific nationwide permits. Controversies over the proposed new permits delayed the changeover, and this version of the NWP 26 remained in effect until June of 2000

Legislation was introduced in the 105th Congress by Rep. Mark Neumann (R-WI) to try to codify this permit at the higher pre-1996 levels, and in the 106^{th}, H.R. 2605, the FY2000 Energy and Water Development Appropriations bill included a provision to delay implementation of the new permits even further, until Congress received a report on the impacts of the proposed changes on the Corps workload and compliance costs.

Nationwide Permit 39. This permit was issued in 2000 as part of the new activity-based permits which replaced NWP 26. It applies to residential, commercial and institutional developments and allows for up to 1/2 acre of loss in non-tidal waters, or 300 linear feet of streambed. It also requires that compensatory mitigation be carried out to address loss of aquatic resource functions and values.

Federal definitions of Wetlands

There are currently three different definitions of wetlands that are in use by federal agencies. The USACE definition as defined by the Clean Water Act, relies primarily on hydrology for determination of wetland status, and uses hydrophytic vegetation as a proxy for wetland hydrologic conditions being present. The Natural Resources Conservation Service uses the definition provided in the Food Security Act, which relies on the presence of hydric soils as the determinant for wetland definition, and categorically states a policy of not including Alaskan permafrost wetlands which have a "high potential for agricultural development". Both of these two definitions have their basis in legislation. The third definition was created by the Fish and Wildlife Service, through a process of professional meetings and review. It provides the basis for national assessment and mapping through the National Wetland Inventory.

None of these definitions is considered to be complete from a scientific viewpoint (NRC, 1995). The USACE definition does not take into consideration that wetlands can be supported on non-soil substrates, nor that they do not necessarily need vascular plants to be providing valuable ecological functions. It also does not provide guidance for consideration that wetlands are ecosystems that occur as integrated systems of soil, hydrology, and adapted organisms. The FSA definition has similar flaws, but in addition fails to recognize the importance of hydrology as a defining characteristic of wetlands. While the FWS definition includes non-hydric substrates and considers the wetland as an ecological system, it defines a wetland as being a transitional area between aquatic systems and uplands. While this is true in many cases, it does not encompass all of the conditions under which a wetland may exist.

Tasked with reviewing current wetland definition and regulation by Congress in 1993, the National Research Council instated a Committee on Wetland Characterization that developed the following reference definition of a wetland:

> *A wetland is an ecosystem that depends on constant or recurrent, shallow inundation or saturation at or near the surface of the substrate. The minimum essential characteristics of a wetland are recurrent, sustained inundation or saturation at or near the surface and the presence of physical, chemical and biological features reflective of the recurrent sustained inundation or saturation. Common diagnostic features of wetlands are hydrologic soils and hydrophytic vegetation. These features will be present except where specific physicochemical, biotic, or anthropogenic factors have removed them or prevented their development.*

Importantly, the NRC points out that a wetland must be considered under the ecosystem concept: that to try to manage them without consideration of the interplay of chemical, biological and physical factors in the environment is inappropriate, and likely will be ineffective (NRC 1995).

Cumulative Impacts

Concern has been raised that the current site-by-site approach to wetland permitting allows for the piecemeal destruction of the wetland system across the watershed, and does not consider potential cumulative effects that the loss may have at the watershed scale. What may appear as a relatively minor impact to an individual area may have far more devastating effects when combined with the effects of other impacts occurring at different times and places, an effect which William Odum (1982) characterized as “the tyranny of small decisions”. Cumulative effects occur at scales larger than that of the immediate sites of impact, and often are not explainable by simply adding the effects of each individual impact (Hemond and Benoit 1988). It is important to consider that the concept of cumulative impacts includes both effects that may occur both within the same type of impact, or across different types of actions. For example, the cumulative impact of habitat loss with diminished water quality will have a far greater impact on aquatic organisms than either of those conditions alone. Additionally, the effect of one type of action may have effects that are not linear. For example, there may be increased, even exponential loss of population size with incremental habitat area lost. There may even be instances in which the habitat is either so diminished in extent or connectivity that despite some habitat remaining, certain populations may become extinct.

In 1978 the U.S. Council on Environmental Quality introduced the concept of cumulative impacts as part of their recommendations for the implementation of the National Environmental Policy Act (NEPA: 40 C.F.R. Sect. 1508.7). It defined cumulative effects as

> The impact on the environment which results from the incremental impact of the action when added to other past, present, and future actions regardless of what agency (Federal or non-federal) or person undertakes such other actions.

In 1980, the EPA included cumulative impact assessment in it's guidelines for Section 404 implementation (45 FR 85344Sec. 230.11(g)):

> g) *Determination of cumulative effects on the aquatic ecosystem.*
>
> (1) Cumulative impacts are the changes in an aquatic ecosystem that are attributable to the collective effect of a number of individual discharges of dredged or fill material. Although the impact of a particular discharge may constitute a minor change in itself, the cumulative effect of numerous such piecemeal changes can result in a major impairment of the water resources and interfere with the productivity and water quality of existing aquatic ecosystems.
>
> (2) Cumulative effects attributable to the discharge of dredged or fill material in waters of the United States should be predicted to the extent reasonable and practical. The permitting authority shall collect information and solicit information from other sources about the cumulative impacts on the aquatic ecosystem. This information shall be documented and considered during the decision-making process concerning the evaluation of individual permit applications, the issuance of a General permit, and monitoring and enforcement of existing permits.

Similarly, the U.S. Army Corps of Engineers included cumulative impacts in their Section 404 guidelines, issued in 1984 (33CFR Sec. 320.4(b)(3)):

> (3) Although a particular alteration of a wetland may constitute a minor change, the cumulative effect of numerous piecemeal changes can result in a major impairment of wetland resources. Thus, the particular wetland site for which an application is made will be evaluated with the recognition that it may be part of a complete and interrelated wetland area. In addition, the district engineer may undertake, where appropriate, reviews of particular wetland areas in consultation with the Regional Director of the U. S. Fish and Wildlife Service, the Regional Director of the National Marine Fisheries Service of the National Oceanic and Atmospheric Administration, the Regional Administrator of the Environmental Protection Agency, the local representative of the Soil Conservation Service of the Department of Agriculture, and the head of the appropriate state agency to assess the cumulative effect of activities in such areas.

As Preston and Bedford stated in their 1988 paper on cumulative impacts "Ideas can have strong intuitive appeal, yet not affect decision making because they lack any explicit operational formulation". Despite numerous advances in the science of assessing cumulative impacts (e.g., Croonquist and Brooks 1991, Gosselink and Lee 1989, Hemond and Benoit 1988, Johnston 1994, Lee and

Gosselink 1988), in the decades following these guidelines, there remains no single universally accepted approach to assessing cumulative impacts, nor even any general principles accepted by all scientists and managers (Hirsch, 1988; CEQ 1997). Current wetland policy does not incorporate assessment of cumulative impacts in a consistent manner into permit review. Ideally cumulative impact analyses should be used to drive watershed wide planning and evaluation. Application of cumulative effects into planning strategies have been applied primarily to issues of wetland restoration and mitigation projects (e.g., Bedford 1999). Few papers have addressed the issue of a method to assess cumulative impacts in terms of area planning. Exceptions include: Abruzzese and Leibowitz's Synoptic Approach (1997), which allows for relative comparison of functional losses between watersheds, based on minimal data input; and more promisingly, the work done on the North Carolina Coastal Region Evaluation of Wetland Significance (NCCREWS), which as it's name implies is limited to coastal wetlands (Sutter et al. 1996), and most recently the work of Sutter and Cowen (2003) on the Spatial Wetland Assessment for Management and Planning (SWAMP) which builds on the NCCREWS model. These cumulative impact assessments will be discussed further in the conclusion.

Scale

Assessing cumulative impacts requires consideration of the time as well as the distance over which impacts can reasonably be detected. Our ability to assess the time portion of scale is limited by the history of monitoring of the criteria we wish to assess. Ideally the length of monitoring should be sufficient to separate the effects of natural variations or stochastic events from trends that may occur due to altered resource use.

For spatial scales, the area should be sufficient to consider connections that may occur between individual units of a given resource across the landscape as well as interactions that may occur due to the resource's location within the landscape. For example, the wetlands may provide important sources of plants and animals to each other to buffer population declines due to stochastic events: in this case, wetland proximity to others of the same type at distances appropriate to organism dispersal are important. The wetland location in reference to other features of the landscape is important in assessing resources that make use of or will be affected by nearby features, such as nesting and foraging areas in the case of habitat, or nutrient sources in the case of water quality function.

Based on the simple fact that water quality is determined by inputs and interactions within a system's hydrologic features, the obvious scale of study for that function is at the watershed and sub-watershed levels, and there is evidence that for wetland-related organisms, the appropriate scale for habitat as well (Holland 1993).

Objectives of Dissertation

My objective in writing this dissertation is two-fold; (1) to look at how wetland science has or has not been able to influence the legislative arena to create laws which will lead to sound management of our nation's wetland resources; and (2) to explore whether or not the cumulative effects of wetland loss on water quality and habitat can be assessed to provide guidance for wetland management. The questions which I will try to answer are:

1. How well is current legislation and the resultant management doing at conserving and maintaining wetlands, not only in terms of acreage, but also their overall functions and values?

2. Are the proposed changes in wetland legislation an improvement over the situation?

3. Can a method be created for addressing cumulative impacts of wetland loss across the landscape?

Since the advent of concern over loss of beneficial wetland functions, in the 1970's, numerous methodologies have been created to try to measure these functions and their benefits. The reasons for doing so have been many and diverse, from regulatory, planning, management and educational viewpoints. Some widely used approaches include the U.S. Fish and Wildlife's Habitat Evaluation Procedure (HEP, USFWS1980), and the more rapid Wetland Evaluation Procedure (WET) (Adamus et al. 1987). Although many assessment techniques have since been spawned to cover a variety of functions and address regional and local differences, most of them assess individual wetlands, and most require information collected in the field to complete the assessment (Bartoldus, 1999)

This dissertation aims to take a Geographic Information System (GIS) approach that is appropriate to considering larger regions for the purpose of assessing potential cumulative impacts of legislative and regulatory decisions, at a scale at which those effects are likely to occur. Chapter 2 will address a model created to employ what is now known about the relationship between wetland and landscape pattern and function to assess the potential cumulative impacts of wetlands lost under various management scenarios. Chapter 3 will focus on water quality, and attempt to further identify wetland and landscape patterns which mitigate nitrogen, phosphorus and suspended sediment loads within watersheds. Chapter 4 will address habitat function as it relates to metapopulations of amphibians, to further define the effects of cumulative wetland loss. Finally, Chapter 5 will provide a summation of the results gleaned from these studies, and suggest practical methods to enhance the minimization of cumulative impacts in wetland management.

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Chapter 2. GIS -Based Assessment Protocol for Proposed Wetland Legislation and Regulation

Introduction

Despite continuing policies of "no net loss", wetlands continue to be lost in the conterminous United States at a rate of 58,500 acres per year (Dahl 2000). Although this represents an 80% reduction in loss rates from the previous decade, continued losses as well as the disproportionate affects on different wetland types are cause for concern. Within the last decade, 4.6% of freshwater emergent wetlands as well as 2.4% of forested wetlands have been lost, while estuarine wetland loss was less than 0.3% (Dahl 2000). This is due in part to stronger regulations placed at both federal and state levels for protecting tidal wetlands, as well as differing development pressures across the landscape. Within the timeframe of the Dahl study, there have been several proposed and actual changes in federal wetlands regulation, including a House approved complete rewrite of Section 404, the main federal regulatory statute, in the Clean Water Act, and several changes in Nationwide Permits under the U. S. Army Corps of Engineers.

There is often a considerable time lag between the implementation of new legislation and regulations, and analyses that gauge the impacts of these changes. Very little has been done to assess the *potential* impacts of these changes in a quantifiable manner in terms of total wetland acreage and wetland types that could sustain losses, and even less to try to categorize the effects such losses would have in terms of wetland function. This study assesses the potential effects of H.R. 961, Nationwide Permit 26 (NWP26) and the new replacement permits on the wetlands in a watershed located in southeastern Virginia, U.S.A. It uses the criteria presented for wetland permitting requirements under each of the scenarios to quantify the area and type of wetlands with the potential to be affected. It then applies a modified version of a protocol developed by the Chesapeake Bay Program Wetlands Workgroup (1998) to determine the probability that the wetlands affected will be important in performing a specific wetland function; namely, habitat, water quality, and flood attenuation. All mapped wetlands in the watershed were scored for these three functions. Overall scores were then compared to the scores of those wetlands potentially lost under each scenario. Due to the greater percentage of palustrine wetlands nationwide than in Virginia, and the desire to make this study more indicative of potential nationwide effects, palustrine wetlands were also analyzed separately.

Study site. The area chosen for this study was the York River Watershed, which includes the York, Mataponi and Pamunkey Rivers, and their tributaries (Figure 2-1). The upper reaches of the watershed extend approximately 200 kilometers inland to Albemarle county. The lower reaches of the watershed end where the York River meets the southwestern end of Chesapeake Bay. In all, the

York River Watershed location in the Commonwealth of Virginia

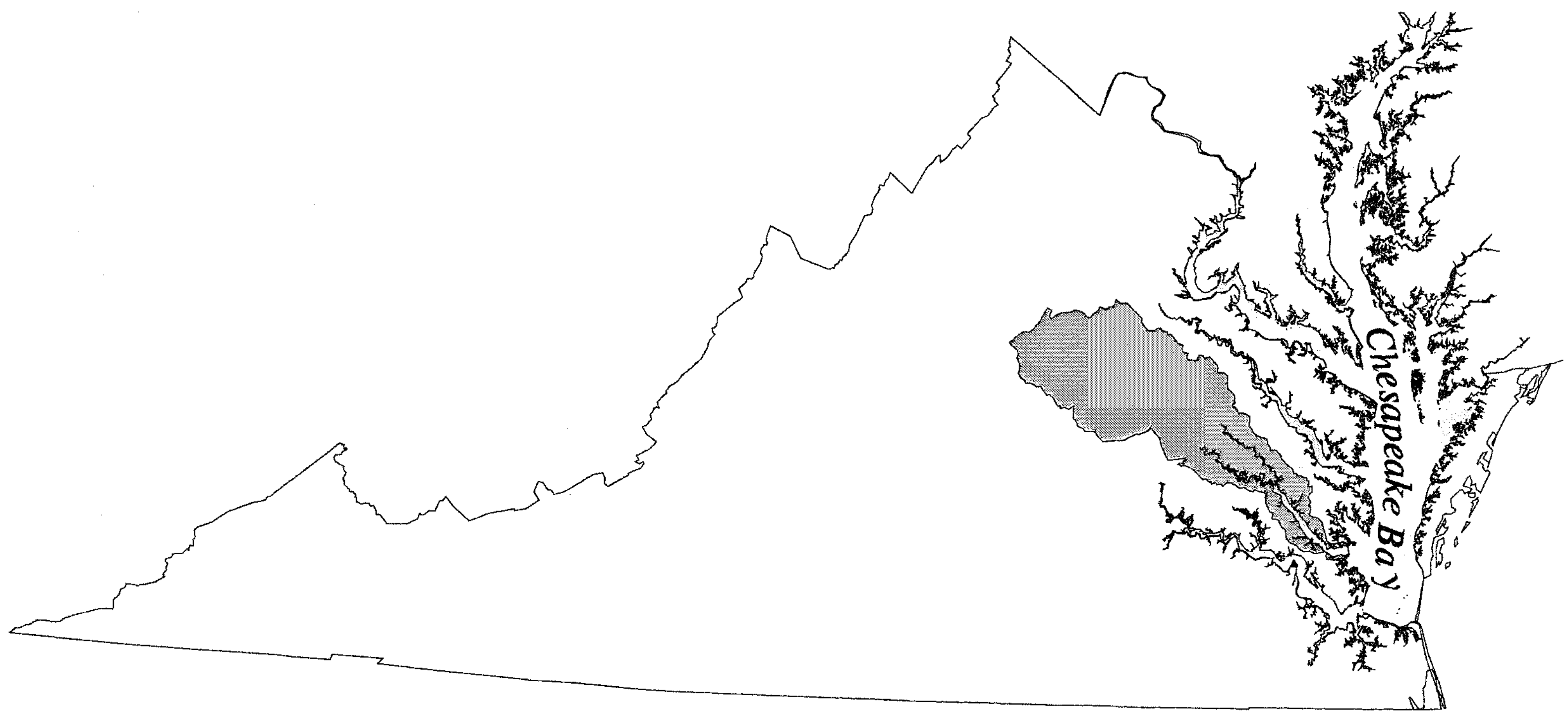

Figure 2-1

watershed covers approximately 1,711,000 acres. The watershed has a land-use composition of 69%forested, 24%agricultural and 7% urban land.

According to the 1996 digitized National Wetland Inventory (NWI) maps, there are over 22,000 individual wetlands in the York River Watershed, comprising a total of 46,849 hectares (>117,000 acres). Of these, the most predominant type is Palustrine Forested, and the least abundant are the Lacustrine wetlands (Figure 2-2). These percentages are similar to national figures, where Palustrine Forested wetlands account for half of the nation's vegetated wetlands. Due to its coastal location, however, the York River incorporates a higher percentage of estuarine vs. palustrine vegetated wetlands than the national figures, which are at 6% and 94%, respectively (Dahl 2000).

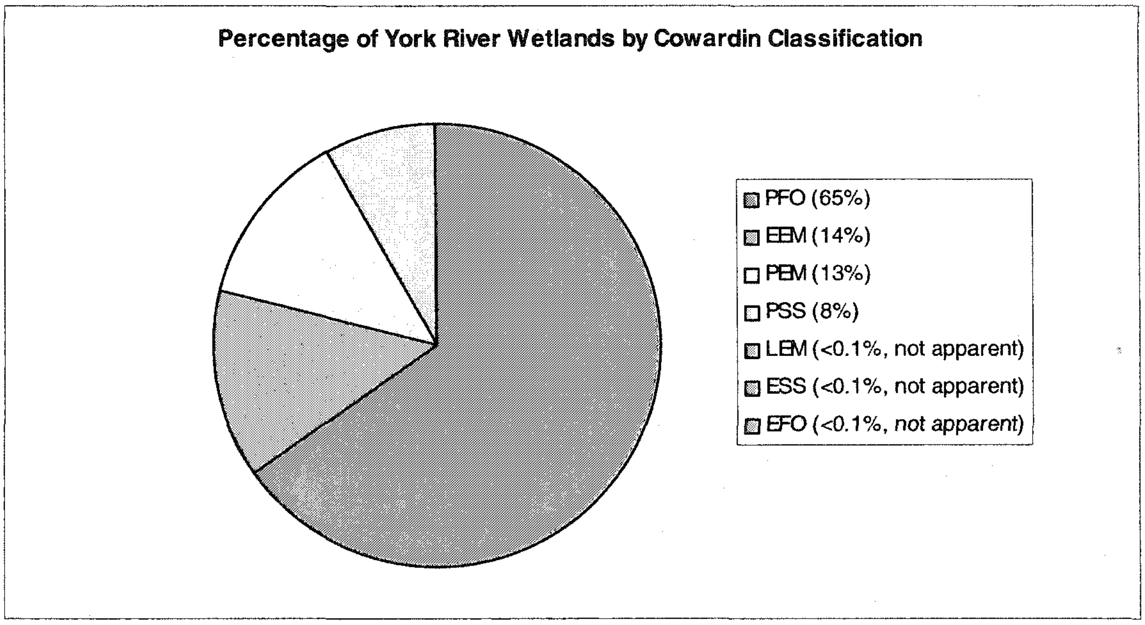

Figure 2-2. Percentage of York River Wetlands by Cowardin (et al, 1979)Classification: E: estuarine, L: lacustrine, P: palustrine, EM:emergent, SS: scrub shrub, and FO:forested.

In assessing the impacts of the legislative and management scenarios, the following hypotheses were considered:

Ho: The scenarios examined do not affect wetlands disproportionately by type (Cowardin classification) or functional ability.

Ha1: The scenarios examined affect wetland disproportionately by type and functional ability.

Ha2: The scenarios examined affect wetlands disproportionately by functional ability but not by type.

Ha3: The scenarios examined affect wetlands disproportionately by type but not by functional ability.

Methods:

A. Number and type of wetlands affected.

The wetland coverages used throughout this study were the most recent versions the U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI), based on photographs taken at a 1:40,000 scale and mapped at a scale of 1:24,000. (Figure 2-3). For the purposes of habitat identification, the NWI includes deep water as well as unvegetated wetland classifications. In keeping with the current need for proof of wetland vegetation for an area to be classified as a jurisdictional wetland, only those wetlands coded as emergent, forested, or scrub/shrub were used in this study.

HR961 – The three criteria by which wetlands would be excluded from current levels of protection were 1) that they be less than 10 contiguous acres; 2) isolated from surface hydrology; or 3) having less than 21 days of continuous inundation

Using ARC/INFO commands, these determinations were made in the following ways:

1) All contiguous wetland areas less than 10 acres (40468. 6 m^2) were compiled from the watershed coverage.
2) Isolated areas were defined in the legislation as those wetlands that did not "have a defined surface for relief of water flow". For this, wetlands in the watershed were examined in conjunction with the U.S. Census Tiger data map of the hydrology in the watershed. In Arcedit, all wetland areas intersecting with a river, creek, or other potential surface outlet were deleted.
3) To determine those wetlands most likely to be excluded by the 21day inundation rule, wetlands in the watershed were organized according to the NWI classification water regime modifiers. It was assumed that for non-tidal wetlands, virtually all of those with a regime of A, B, or C (that is, temporarily flooded, saturated, or seasonally flooded) would fail the 21 day inundation test, and wetlands with a water regime classified D or E (seasonally flooded-well drained and seasonally flooded-saturated) were considered to potentially be excluded as well(J. Perry and P. Mason,

pers. comm.). Since they are not permanently flooded, there is a chance that at the time of site review they will not meet the 21 day inundation criteria. This problem is exacerbated by the fact that the permit applicant may request that the review take place during the dry season. The legislation would also exclude seasonal tidal wetlands, however no wetlands of this type are found within the York River Basin.

These coverages were then combined with the first two to create a conservative (using the A, B, and C modifiers-HR961c) and an inclusive (using A-E modifiers-HR961i) assessment of those wetlands that would receive reduced or no protection under this act.

NWP26 - Since both versions of Nationwide Permit 26 (3 and 10 acre limits) only apply to isolated and headwater wetlands, isolated wetlands were determined according to the procedure for step 2 above. Headwater wetlands were then determined as those that intersected first order streams according to EPA's Reach File 3 (RF3) Strahler classification (Figure 2-4). Analysis of the effects of this legislation consists of determining loss of maximum acreage from larger wetland parcels as well as including all wetlands that are smaller in total extent than the acreage limits. This was done twice, to determine potential losses under the 3 acre (12140.6m^2) and 10 acre (40468.6m^2) versions.

NWP39 - Of the replacement permits for NWP26, the residential/commercial/ institutional permit, which allows for up to 0.5 acres (2023.4 m^2) of non-tidal wetlands to be filled without an individual permit, was assessed using watershed areas zoned or planned for such potential uses (Figure 2-5). This zoning coverage was made by combining digitized county zoning maps within the watershed and standardizing the zoning classifications. While most of the zoning maps contained clear delineations of classes that met the requirements of the replacement permit, some of the county classifications proved problematic. The agricultural/rural residential/forestry class poses difficulty in trying to assess the amount of acreage potentially affected, as these lands might fall under the replacement permit if the land is actually used for a residential dwelling, but it would not even fall under Section 404 Corps jurisdiction if it is to be used for agricultural purposes. For this reason, and since it comprises such a large proportion of the watershed, this zoning classification was addressed separately. This resulted in two replacement permit coverages: one which includes all non-tidal wetlands in residential, commercial, commercial/industrial and mixed use zones (NWP 39a); and the other which is strictly made up of the non-tidal wetlands within the agricultural/rural residential/forestry zones (NWP 39b). From these coverages, both non-tidal wetlands below the 0.5 acre limit, and 0.5 acre portions of those above the limit were assessed.

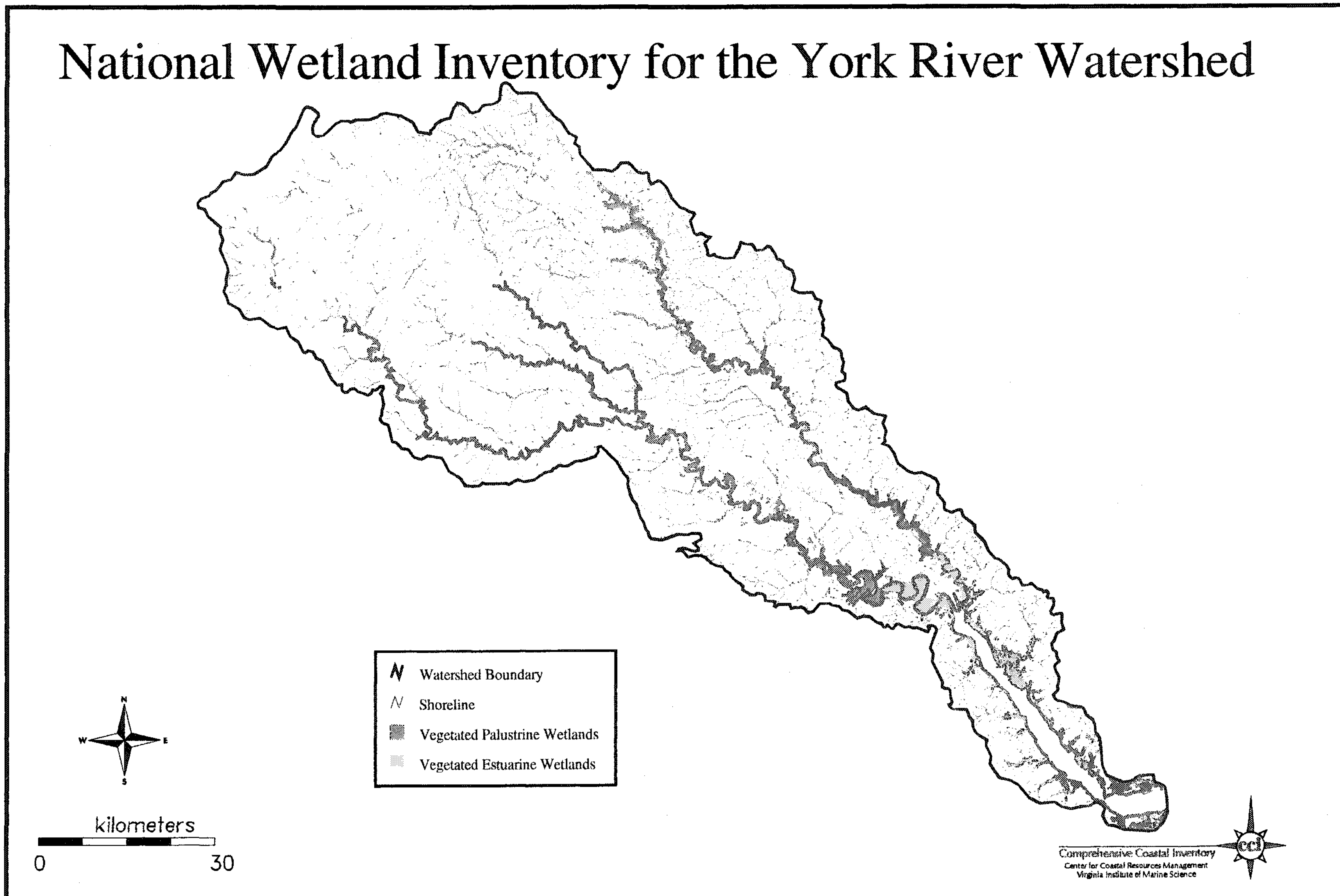
National Wetland Inventory for the York River Watershed
Watershed Boundary
Shoreline
Vegetated Palustrine Wetlands
Vegetated Estuarine Wetlands
N
W
E
S
kilometers
0
30
Comprehensive Coastal Inventory
Center for Coastal Resources Management
Virginia Institute of Marine Science
cci

Figure 2-3

B. Assessment of water quality, flood mitigation, and habitat loss under proposed changes

The impacts of wetlands lost on water quality, flood mitigation, habitat, bank stabilization and sediment control functions were assessed using a modification of the protocol developed under the Chesapeake Bay Program Wetlands Initiative (CBPWW 1998). This protocol ranks wetlands ability to perform a given function on the basis of National Wetland Inventory (NWI) wetland type (Cowardin et al 1979), then further modifies the ranking for opportunity to perform a given function, based on prevalence of surrounding land use type and existence of external influences such as roads or point source discharges within a given distance from the wetland. This protocol was carried out using a series of Arc Macro Language (AML) scripts so that the procedure for rating all of the watershed's wetlands could be run continually on a unix platform with minimal human input after the initial coverages and procedure were set (Appendix A). In order to reduce computational time, the wetland coverage for the watershed was divided between the coastal and piedmont areas, with care taken to not bisect any wetlands, and run on two separate computers. The completed coverages were then recombined for the final tallies.

The first step was to rate the probability that a wetland was performing a given function based on type (Table 2-1). Wetlands that have combination classifications (e.g. palustrine forested/scrub shrub (PFO/SS)) were scored using the first type listed, as it represents the predominant wetland type.

Table 2-1. Probability that a given type of wetland is performing a selected function (3= high, 2 = medium, 1 = low) (after CBPWW, 1998)

Wetland	Habitat	Water Quality	Flood Protection
EEM	3	2	1
ESS	3	2	2
EFO	3	2	2
PEM	3	3	2
PSS	3	3	3
PFO	3	3	3
LEM	3	3	2
REM	3	3	1

Adjustments were then made by either raising or lowering the score depending on the influence surrounding land use has on a wetlands ability to perform a given function. This influence was calculated by multiplying the percent of a given land use within a 3 meter buffer (so designated to reflect the adjacent landuse) by either +0.5(positive effect), -0.5 (negative effect) or 0 (neutral). The factors for habitat, water quality and flood protection are given below (Tables 2-2, 2-3, and 2-4). The coverage used for determining land use was the 1996 Environmental Protection Agency Region III Multi-resolution land characteristics (MRLC) data set. The MRLC was created from Landsat photos translated into raster digital data with a 30 x 30 meter pixel size, and was converted into a polygon coverage for these analyses (Figure 2-6).

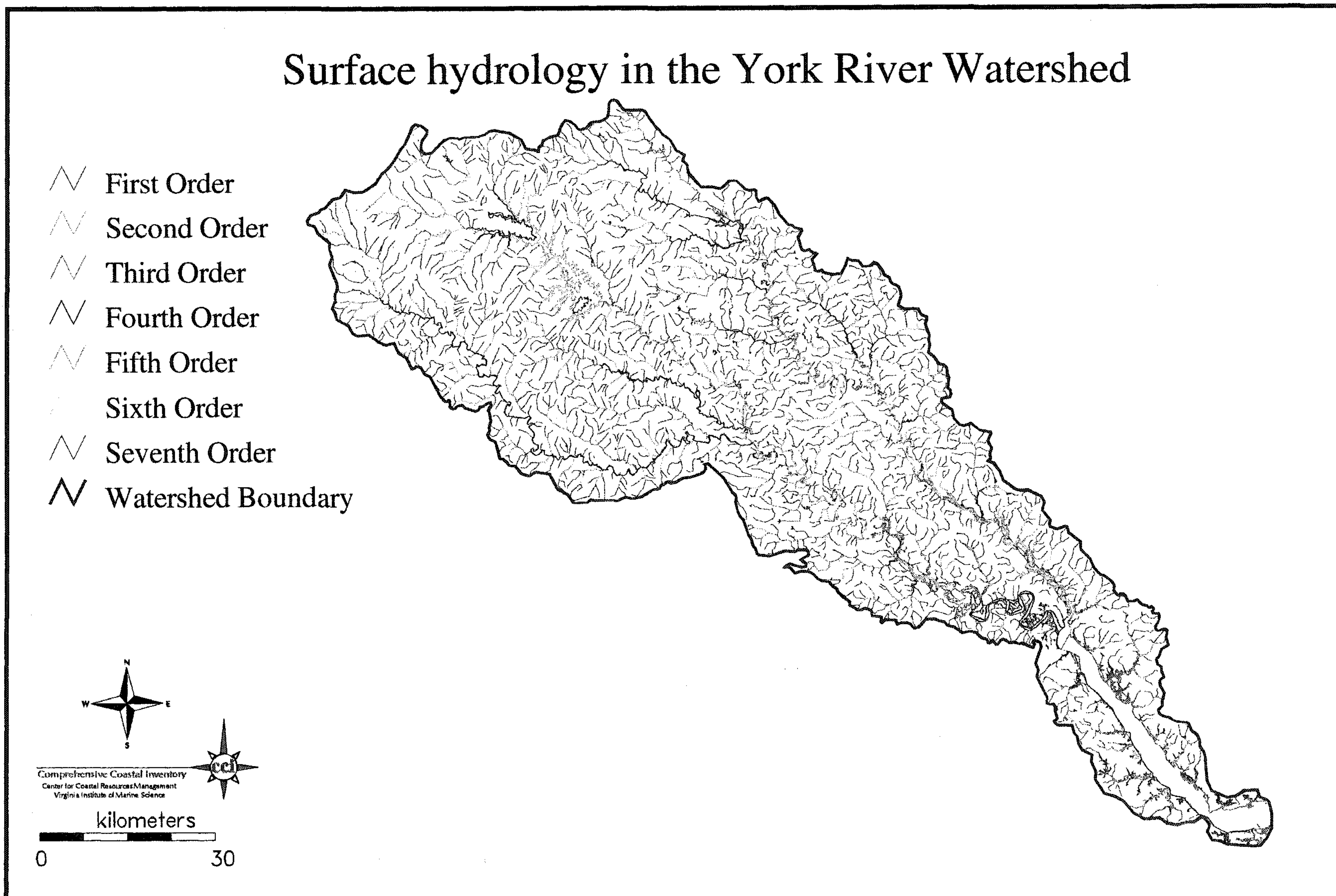
Surface hydrology in the York River Watershed
First Order
Second Order
Third Order
Fourth Order
Fifth Order
Sixth Order
Seventh Order
Watershed Boundary
N
W
E
S
Comprehensive Coastal Inventory
Center for Coastal Resources Management
Virginia Institute of Marine Science
kilometers
0
30

Figure 2-4

Table 2-2. Probability that performance of a habitat function by a given type of wetland adjacent to a given type of land use is particularly important : factors multiplied by percent of each land use type within a 3 meter buffer of a given wetland. (after CBPWW, 1998)

Wetland	Lo Dev	Hi Dev	Grass	Crop	Forest	Wetland	Beach	Barren
EEM	-0.5	-0.5	0	0	0.5	0.5	0	0
ESS	-0.5	-0.5	0	0	0.5	0.5	0	0
EFO	-0.5	-0.5	0	0	0.5	0.5	0	0
PEM	-0.5	-0.5	0	0	0.5	0.5	0	0
PSS	-0.5	-0.5	0	0	0.5	0.5	0	0
PFO	-0.5	-0.5	0	0	0.5	0.5	0	0
LEM	-0.5	-0.5	0	0	0.5	0.5	0	0
REM	-0.5	-0.5	0	-0.5	0.5	0.5	0	0

Table 2-3. Probability that performance of a water quality function by a given type of wetland adjacent to a given type of land use is particularly important : factors multiplied by percent of each land use type within a 3 meter buffer of a given wetland. (after CBPWW 1998)

Wetland	Lo Dev	Hi Dev	Grass	Crop	Forest	Wetland	Beach	Barren
EEM	0.5	0.5	0.5	0.5	0	0	0	0.5
ESS	0.5	0.5	0.5	0.5	0	0	0	0.5
EFO	0.5	0.5	0.5	0.5	0	0	0	0.5
PEM	0.5	0.5	0.5	0.5	0	0	0	0.5
PSS	0.5	0.5	0.5	0.5	0	0	0	0.5
PFO	0.5	0.5	0.5	0.5	0	0	0	0.5
LEM	0.5	0.5	0.5	0.5	0	0	0	0.5
REM	0.5	0.5	0.5	0.5	0	0	0	0.5

Table 2-4. Probability that performance of a flood protection function by a given type of wetland adjacent to a given type of land use is particularly important : factors multiplied by percent of each land use type within a 3 meter buffer of a given wetland. (after CBPWWI, 1998)

Wetland	Lo Dev	Hi Dev	Grass	Crop	Forest	Wetland	Beach	Barren
EEM	0.5	0.5	0	0	0	0	0	0
ESS	0.5	0.5	0	0	0	0	0	0
EFO	0.5	0.5	0	0	0	0	0	0
PEM	0.5	0.5	0	0	0	0	0	0
PSS	0.5	0.5	0	0	0	0	0	0
PFO	0.5	0.5	0	0	0	0	0	0
LEM	0.5	0.5	0	0	0	0	0	0
REM	0.5	0.5	0	0	0	0	0	0

The final step in the evaluation process relates to the proximity of other features, with scores again adjusted either up or down by 0.5 if the feature was present. The features considered and the ranks assigned are as follows.

- ***Aquatic reef points within 1 km buffer*** - increase habitat and water quality by 0.5 The source for this data is the Chesapeake Bay Program's mapping of reef restoration sites, which includes both oyster and fish reef activities. At the time of this study, only one such reef in the study area was mapped, at the mouth of the York (Figure 2-7).
- ***Road within 33m buffer*** - decrease habitat by 0.5, increase water quality and flood mitigation by 0.5. The source for the road coverage was the 1992 U.S. Census Bureau's Tiger data (Figure 2-8).
- ***Point source discharge within 33m buffer*** - decrease habitat by 0.5, increase water quality and flood mitigation by 0.5. Point source discharge information, including latitude and longitude readings for each site was obtained from the Virginia Department of Environmental Quality. These data were converted into a GIS point coverage using ARCVIEW (Figure 2-9).
- ***Headwater stream within 0.5km*** - increase water quality and flood protection by 0.5. The hydrology coverage used was a version of the Environmental Protections Agency's Reach file version 3 (RF3), coded for internal use with stream order according to the Strahler method (see Gordon et al, 1992). Headwater streams were considered to be those with a stream order of 1 (Figure 2-4).

- ***Wetland falling within riparian forest buffer*** - increase water quality and flood protection by 0.5. The riparian buffer coverage was created in a two-step process. First, the USGS 1:100,000 digital line graph hydrology coverages were buffered by 33 meters on each side. The MRLC land use data was then used to identify all forested areas within this buffer area, to create the final riparian buffer map (Figure 2-10).
- ***Submerged aquatic vegetation within 1 km buffer*** - increase habitat quality and water quality by 0.5. The source for this data was the VIMS SAV program. SAV bed maps were combined for the years 1971 through 1998 to provide the greatest realistic area of existing or potential SAV beds (Figure 2-7). Mapping was done at a 1:24,000 scale.
- ***Wetlands with rare, threatened or endangered species either in the wetlands themselves or within a 33 meter buffer*** - increase habitat by 0.5. This data was provided by the Virginia Department of Conservation and Recreation's Division of Natural Heritage (DCR) from its Biological and Conservation Data System (BCD) in a decimal degree point coverage (Figure 2-11).

The total scores for all wetlands within a watershed were compared against the ranks of wetlands lost under the different legislative/regulatory scenarios. Consideration was given to the fact that initial scores for different wetland types, coupled with differing proportions in the York river watershed of estuarine and palustrine wetlands compared to that of the nation might limit the applicability of

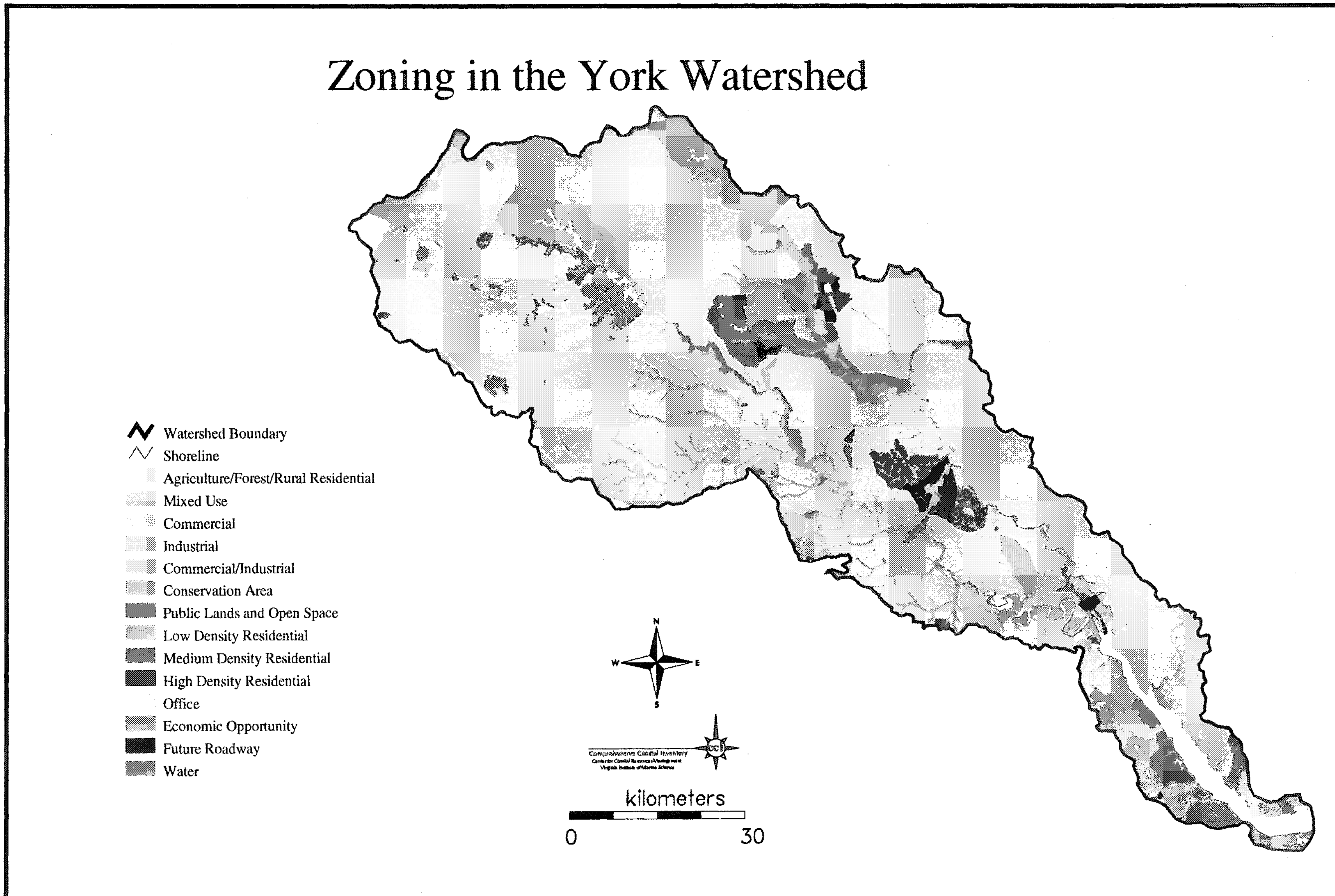
Zoning in the York Watershed
Watershed Boundary
Shoreline
Agriculture/Forest/Rural Residential
Mixed Use
Commercial
Industrial
Commercial/Industrial
Conservation Area
Public Lands and Open Space
Low Density Residential
Medium Density Residential
High Density Residential
Office
Economic Opportunity
Future Roadway
Water
N
W
E
S
kilometers
0
30

Figure 2-5

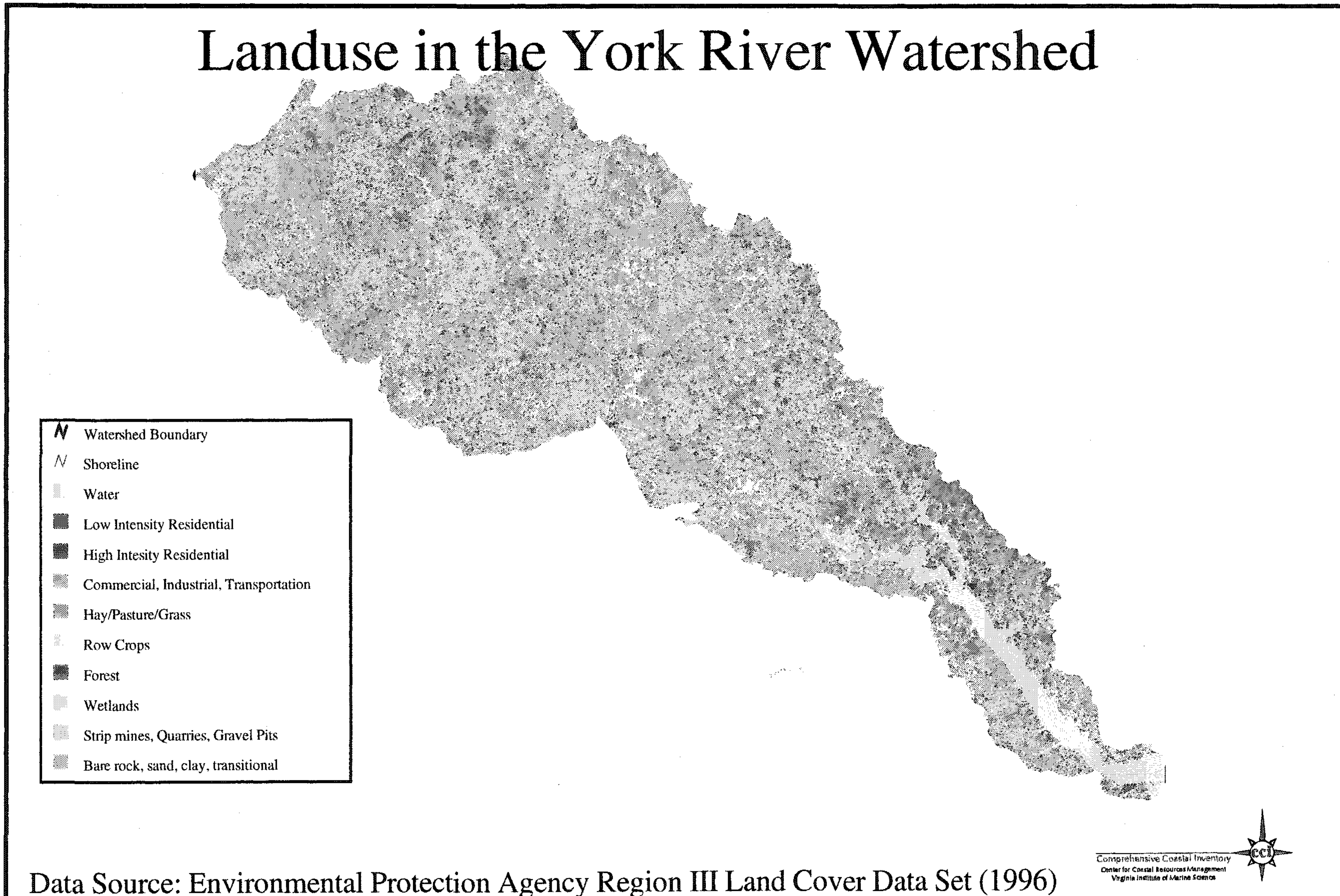
Landuse in the York River Watershed
Watershed Boundary
Shoreline
Water
Low Intensity Residential
High Intesity Residential
Commercial, Industrial, Transportation
Hay/Pasture/Grass
Row Crops
Forest
Wetlands
Strip mines, Quarries, Gravel Pits
Bare rock, sand, clay, transitional
Comprehensive Coastal Inventory
Center for Coastal Resources Management
Virginia Institute of Marine Science
cci
Data Source: Environmental Protection Agency Region III Land Cover Data Set (1996)

Figure 2-6

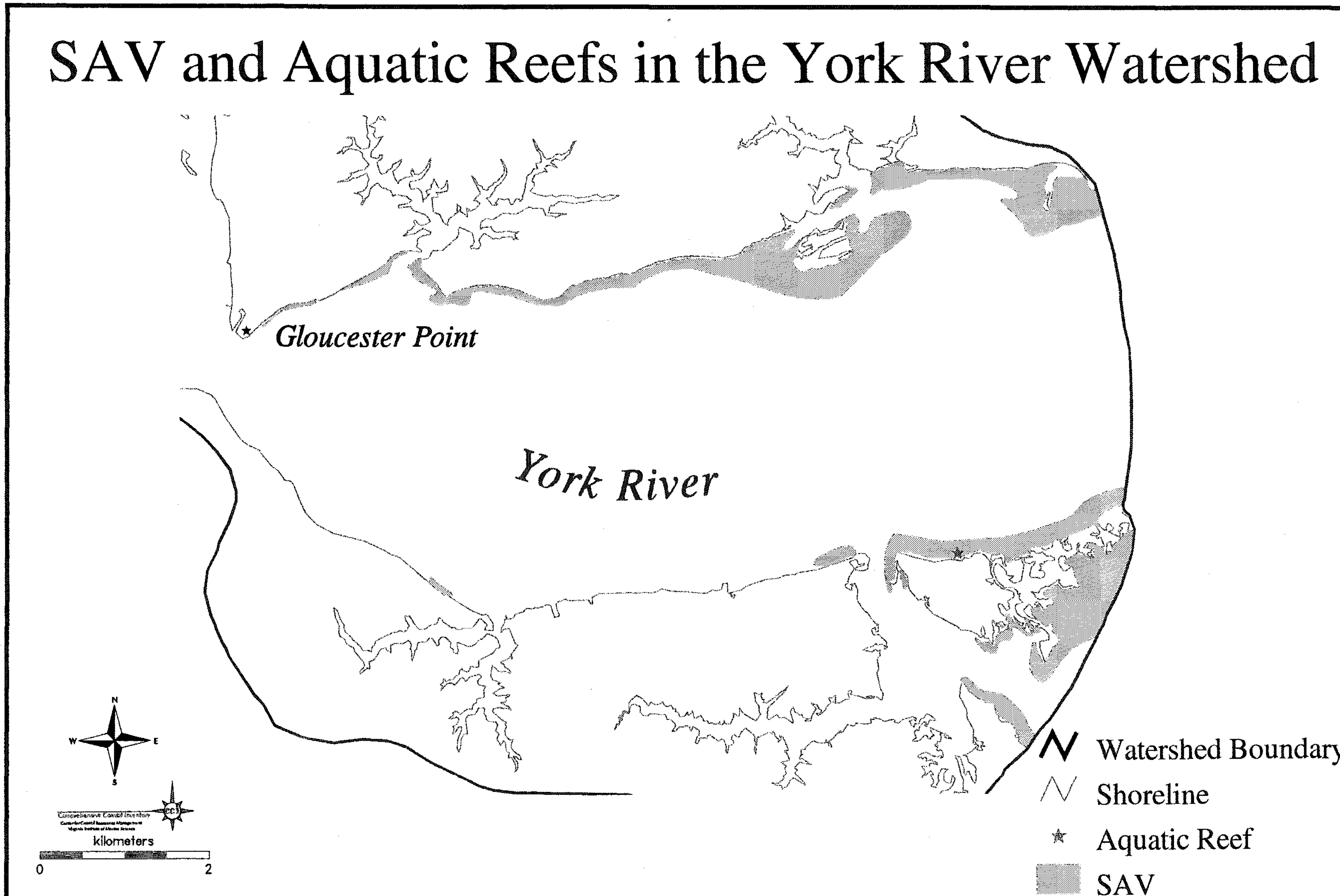
SAV and Aquatic Reefs in the York River Watershed
Gloucester Point
York River
N
W
E
S
kilometers
0
2
Watershed Boundary
Shoreline
Aquatic Reef
SAV

Figure 2-7

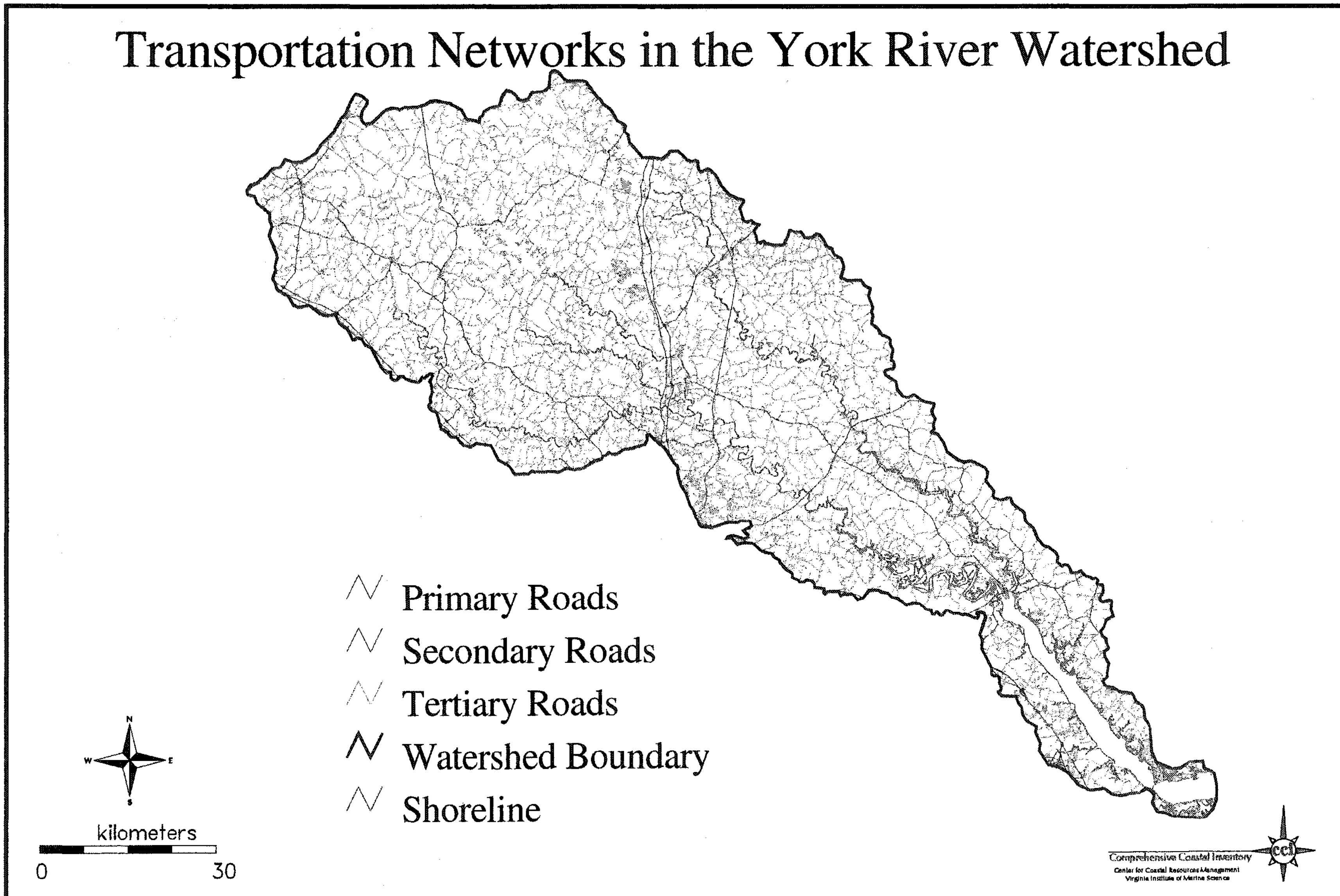
Transportation Networks in the York River Watershed
Primary Roads
Secondary Roads
Tertiary Roads
Watershed Boundary
Shoreline
N
W
E
S
kilometers
0
30
Comprehensive Coastal Inventory
Center for Coastal Resources Management
Virginia Institute of Marine Science
cci

Figure 2-8

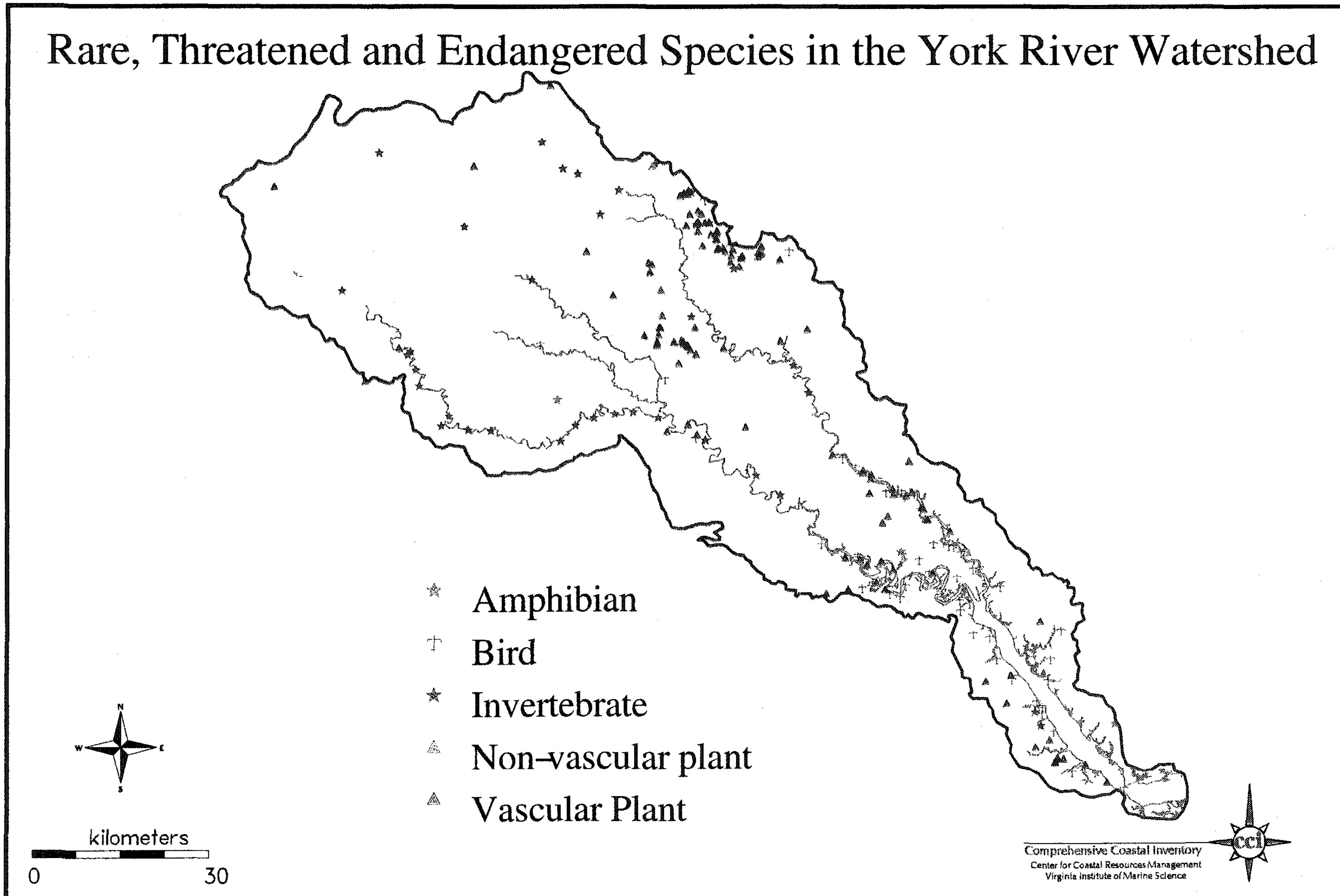
Rare, Threatened and Endangered Species in the York River Watershed
Amphibian
Bird
Invertebrate
Non-vascular plant
Vascular Plant
kilometers
0
30
Comprehensive Coastal Inventory
Center for Coastal Resources Management
Virginia Institute of Marine Science
cci

Figure 2-9

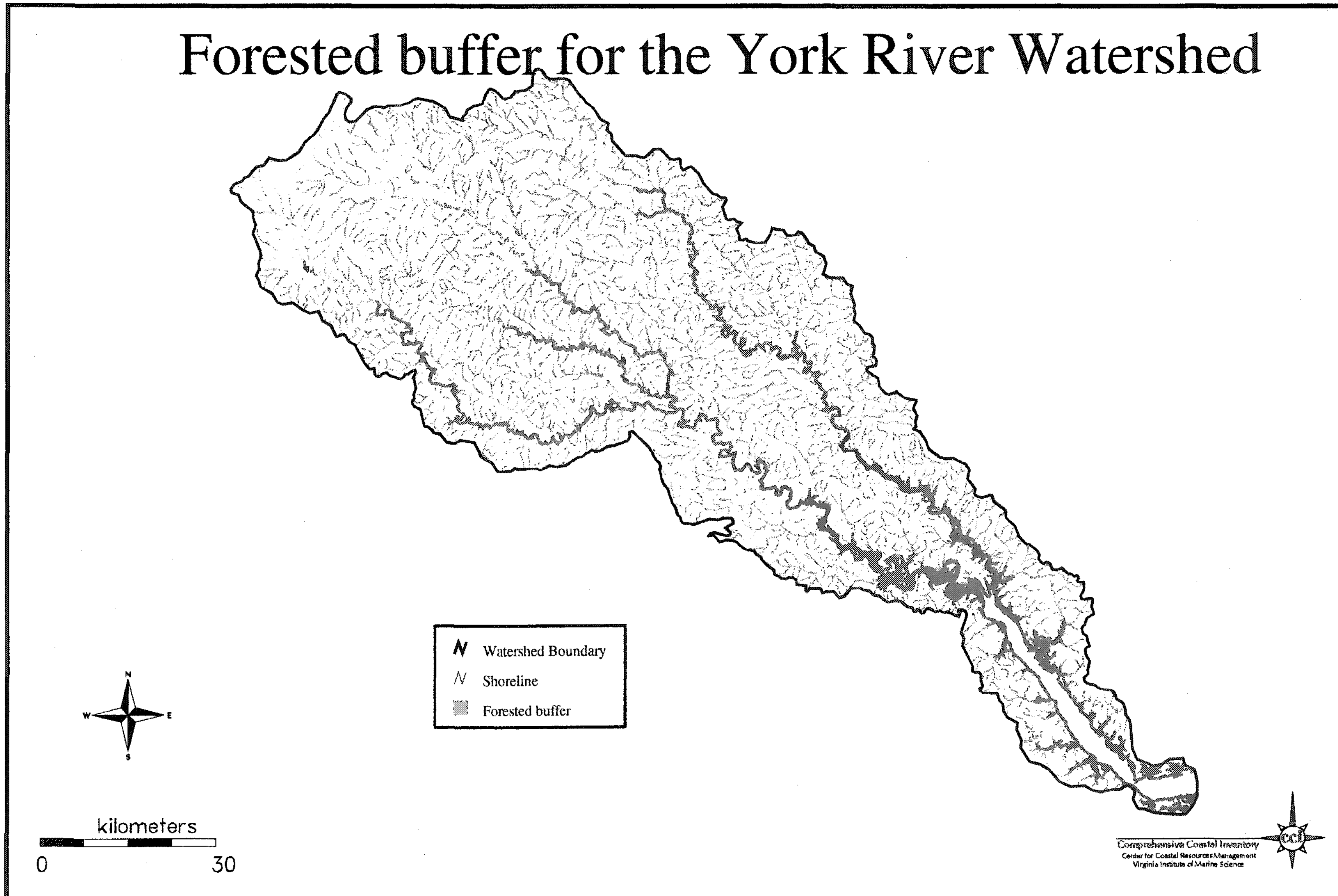
Forested buffer for the York River Watershed
Watershed Boundary
Shoreline
Forested buffer
N
W
E
S
kilometers
0
30
Comprehensive Coastal Inventory
Center for Coastal Resources Management
Virginia Institute of Marine Science
cci

Figure 2-10

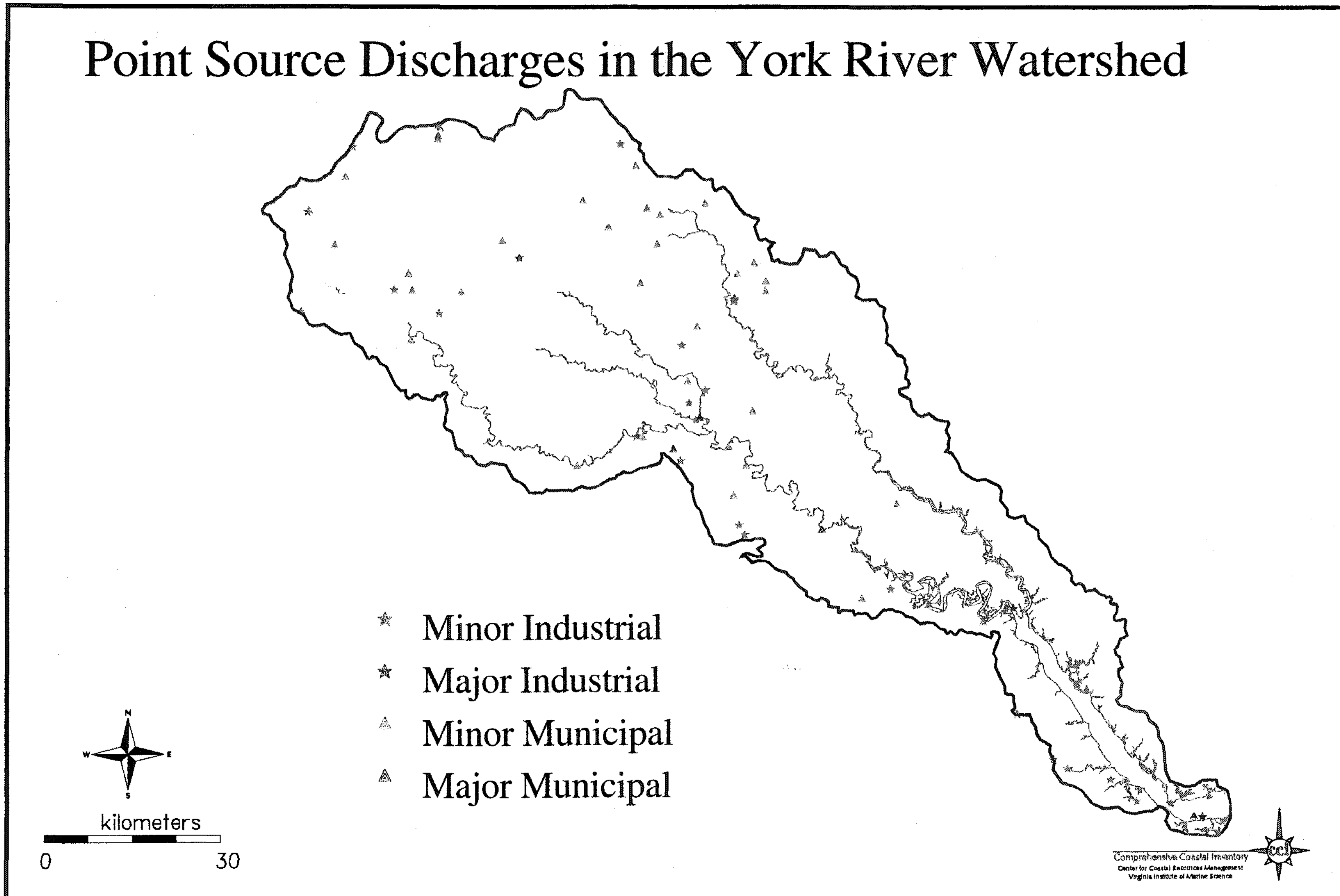
Point Source Discharges in the York River Watershed
Minor Industrial
Major Industrial
Minor Municipal
Major Municipal
N
W
E
S
kilometers
0
30
Comprehensive Coastal Inventory
Center for Coastal Resources Management
Virginia Institute of Marine Science

Figure 2-11

these results in predicting nationwide effects. Therefore, separate analyses were also run for just palustrine wetland results.

SigmaPlot was used for all graphing, and Minitab was used for all statistical analyses.

Results

The results, by wetland type, of the assessment for all York River Watershed wetlands are reported in Table 5, below. In each of the legislative scenarios, palustrine wetlands are far more impacted than the estuarine or lacustrine wetlands.

Table 2-5. Hectares of wetlands and percentage of wetland types potentially unprotected under the various scenarios in the York River Watershed.

	E2EM	E2FO	E2SS	L2EM	PEM	PFO	PSS	Total
Watershed	6380.86	12.38	20.09	17.90	6054.80	30490.25	3869.91	46846.09
HR961-conservative	330.89	1.08	3.27	0.80	3020.19	23731.49	2042.03	29129.75
%	**5.2**	**8.7**	**16.3**	**4.5**	**49.9**	**77.8**	**52.8**	**62.2**
HR961 – inclusive	330.89	1.08	3.27	0.80	3334.11	26132.89	2933.57	32736.60
%	**5.2**	**8.7**	**16.3**	**4.5**	**55.1**	**85.7**	**75.8**	**69.9**
NWP26 (3)	0	0	0	0	369.69	1172.16	177.79	1719.64
%	**0**	**0**	**0**	**0**	**6.1**	**3.8**	**4.6**	**3.7**
NWP26 (10)	0	0	0	0	427.05	1566.55	213.23	2206.83
%	**0**	**0**	**0**	**0**	**7.1**	**5.1**	**5.5**	**4.7**
NWP39a	0	0	0	0	79.90	268.90	47.40	396.20
%	**0**	**0**	**0**	**0**	**1.3**	**0.9**	**1.2**	**0.8**
NWP39b	0	0	0	0	643.51	1588.20	380.0	2612.1
%	**0**	**0**	**0**	**0**	**10.6**	**5.2**	**9.8**	**5.6**

Table 2-6 reports both the mean (directly calculated from scores for individual wetlands) and weighted mean (calculated based on the percentage of acreage at each score) for comparison. Comparing the two statistics allows for consideration of the distribution of scores by both the number of wetlands and acreage.

Table 2-6. Mean and weighted mean of scores for wetlands affected by each scenario

	habitat scores		**water quality scores**		**flood attenuation scores**	
	Mean	**Weighted mean**	**Mean**	**Weighted mean**	**Mean**	**Weighted mean**
Water	3.36	3.31	3.80	3.77	3.49	3.49
HR961c	3.35	3.30	3.81	4.02	3.51	3.89
HR961i	3.35	3.30	3.81	4.02	3.52	3.89
NWP26-3	3.32	3.28	3.93	3.64	3.63	3.36
NWP26-10	3.32	3.10	3.93	3.64	3.63	3.39
NWP39a	3.31	3.32	3.87	3.88	3.62	3.64
NWP39b	3.36	3.37	3.89	3.90	3.61	3.63

Habitat

Results of the Mann-Whitney U test for non-weighted habitat scores are presented in Table 2-7. They show that at an alpha level of 0.05, the wetlands potentially affected by a conservative estimate of HR961, as well as Nationwide Permit 26 (both at 3 and 10acre limits) and the conservative reading of NWP 39 (NWP39a) have scores significantly lower than those that would be expected if they affected wetlands equally across the range of scores. However, NWP39 considered for the areas zoned agricultural/rural residential/forested (NWP39b) scored significantly higher than the underlying watershed scores. Consideration of the weighted means (Table 2-6) and Figure 2-13, in which acreage affected is taken into account, only NWP26 at both the 3 and 10 acre levels have substantially lower scores overall, a difference which is highlighted in the correspondence analysis run for all of the scenarios (Figure 2-14)

Table 2-7. Mann – Whitney U test (two tailed) results for habitat scores. H relates the test group's standing to the watershed.

Comparison	p	p adjusted for ties	H
Watershed vs. HR961 – conservative	0.01216	0.0067	significantly lower
Watershed vs HR961 - inclusive	0.3735	0.3319	equal
Watershed vs. NWP26(3 and 10)	0.000	0.000	significantly lower
Watershed vs. NWP39a	0.000	0.000	significantly lower
Watershed vs. NWP39b	0.0005	0.0002	significantly higher

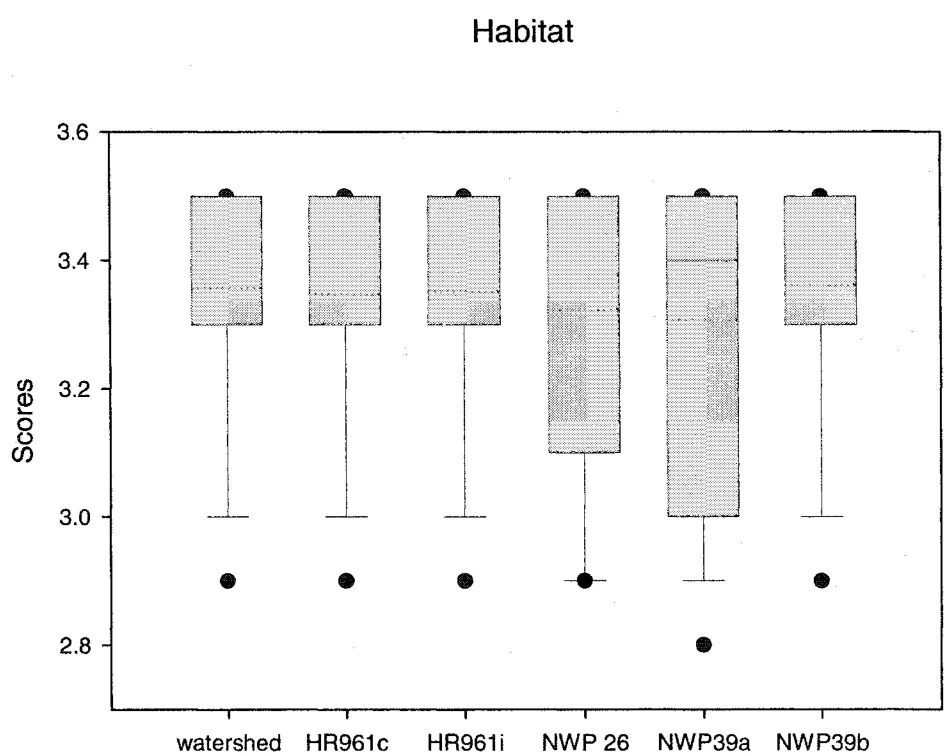

Figure 2-12. Box plot of habitat scores for each of the legislative scenarios, as well as the parent watershed. Whiskers show 10^{th} and 90^{th} percentiles, black dots show 5^{th} and 95^{th}. The mean is represented by a dotted line, median where distinct from the mean by a solid line

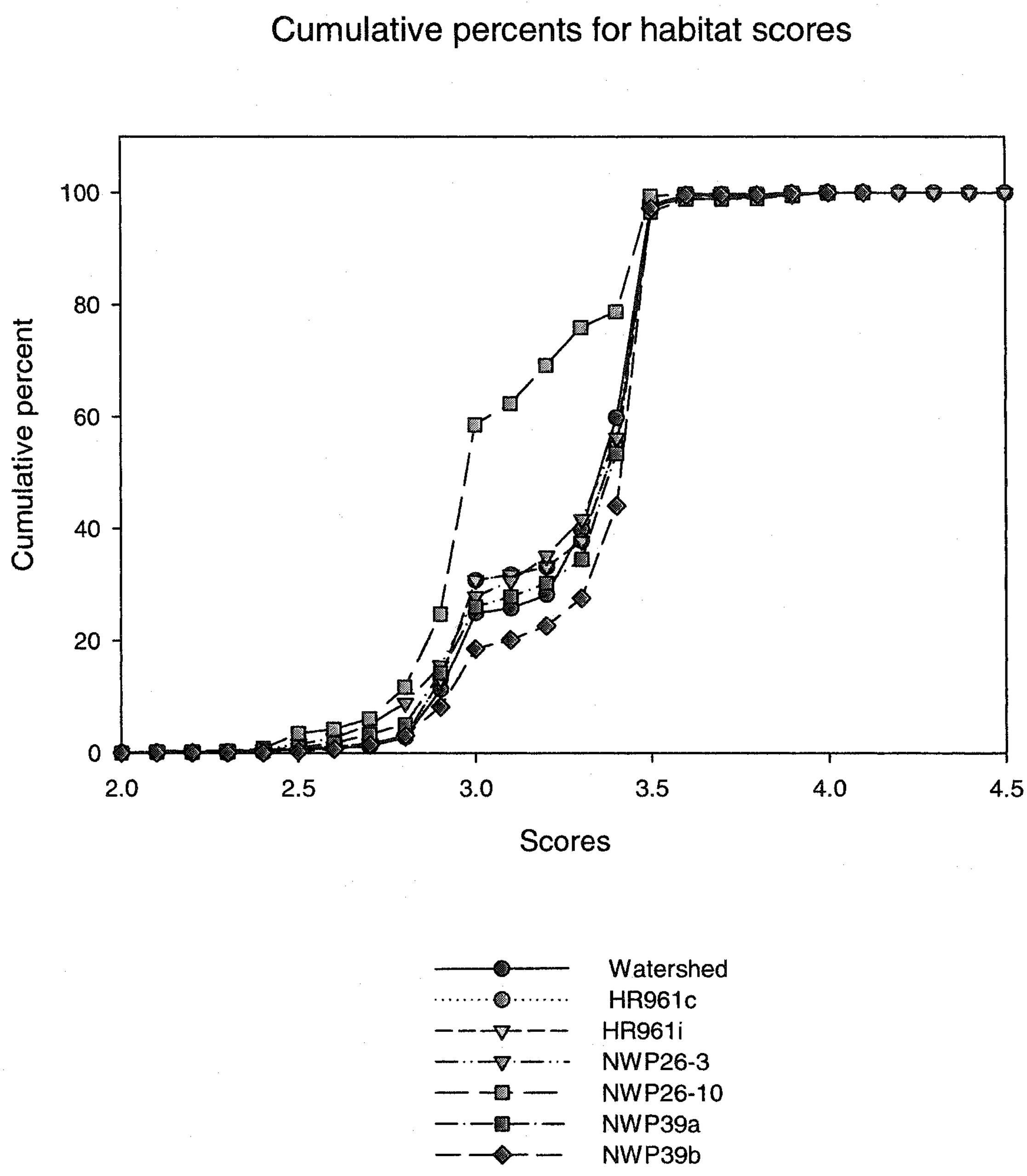

Figure 2-13 . Cumulative acreage percents at habitat scores for each scenario.

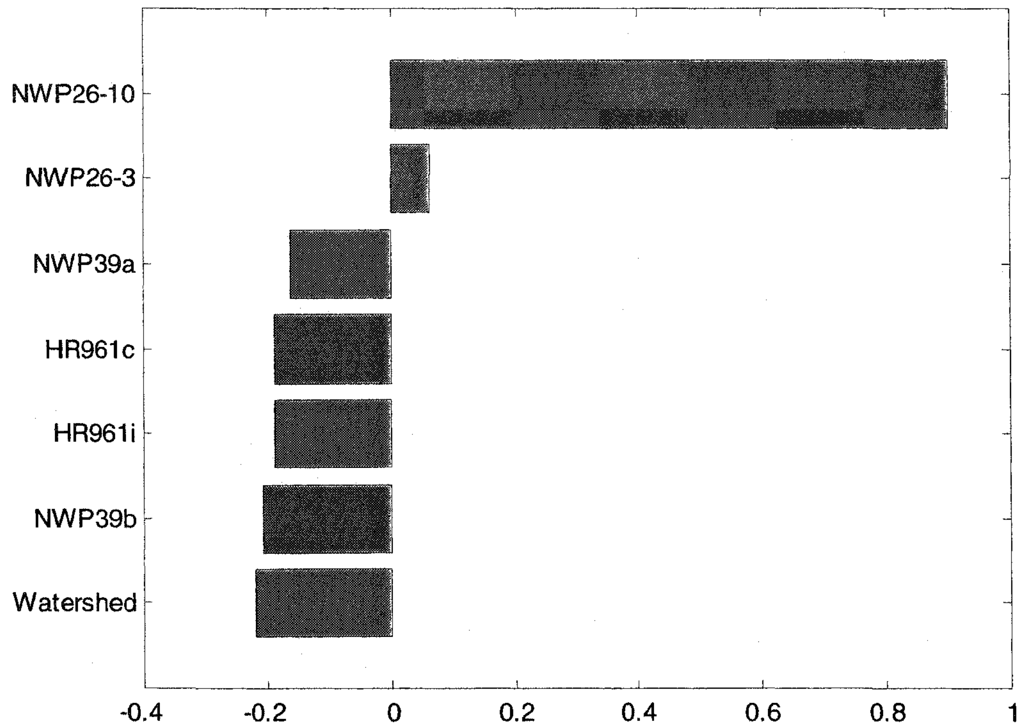

Figure 2-14. Correspondence analysis results for acreage percentage at habitat scores for each scenario.

Water Quality

Results of the Mann-Whitney U test for water quality scores are presented in Table 8. They show that the wetlands potentially affected by Nationwide Permit 26 as well as the replacement NWP39 have scores significantly higher than those that would be expected if they affected wetlands equally across the range of scores. Consideration of the weighted means (Table 2-6) and cumulative percentages at each score (Figure 2-16) suggest that when considered by acreage affected, both levels of NWP 26 affect more low scoring wetlands than any of the

other scenarios, including the parent population, while both readings of HR961 and NWP39a would affect the most high scoring wetlands. Consideration of the correspondence analysis results support these conclusions (Figure 2-17).

Table 2-8. Mann Whitney U test (two-tailed) results for water quality scores. H relates the test group's standing to the watershed.

Comparison	p	p adjusted for ties	H
Watershed vs. HR961 – conservative	0.1511	0.1282	equal
Watershed vs HR961 - inclusive	0.4764	0.4496	equal
Watershed vs. NWP26 (3 and 10)	0.000	0.000	significantly higher
Watershed vs. NWP39a	0.000	0.000	significantly higher
Watershed vs. NWP39b	0.000	0.000	significantly higher

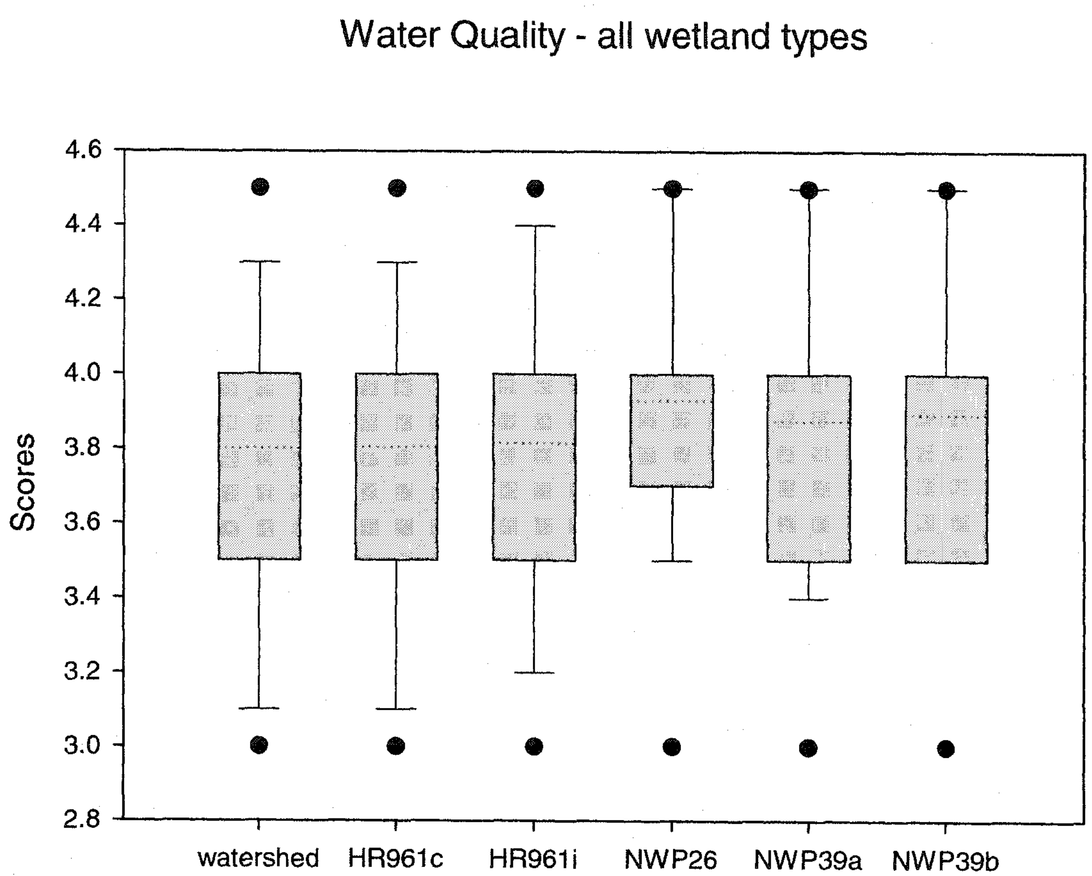

Figure 2-15. Box plot of water quality scores for each of the legislative scenarios, as well as the parent watershed. Whiskers show 10th and 90th percentiles, black dots show 5th and 95th. The mean is represented by a dotted line.

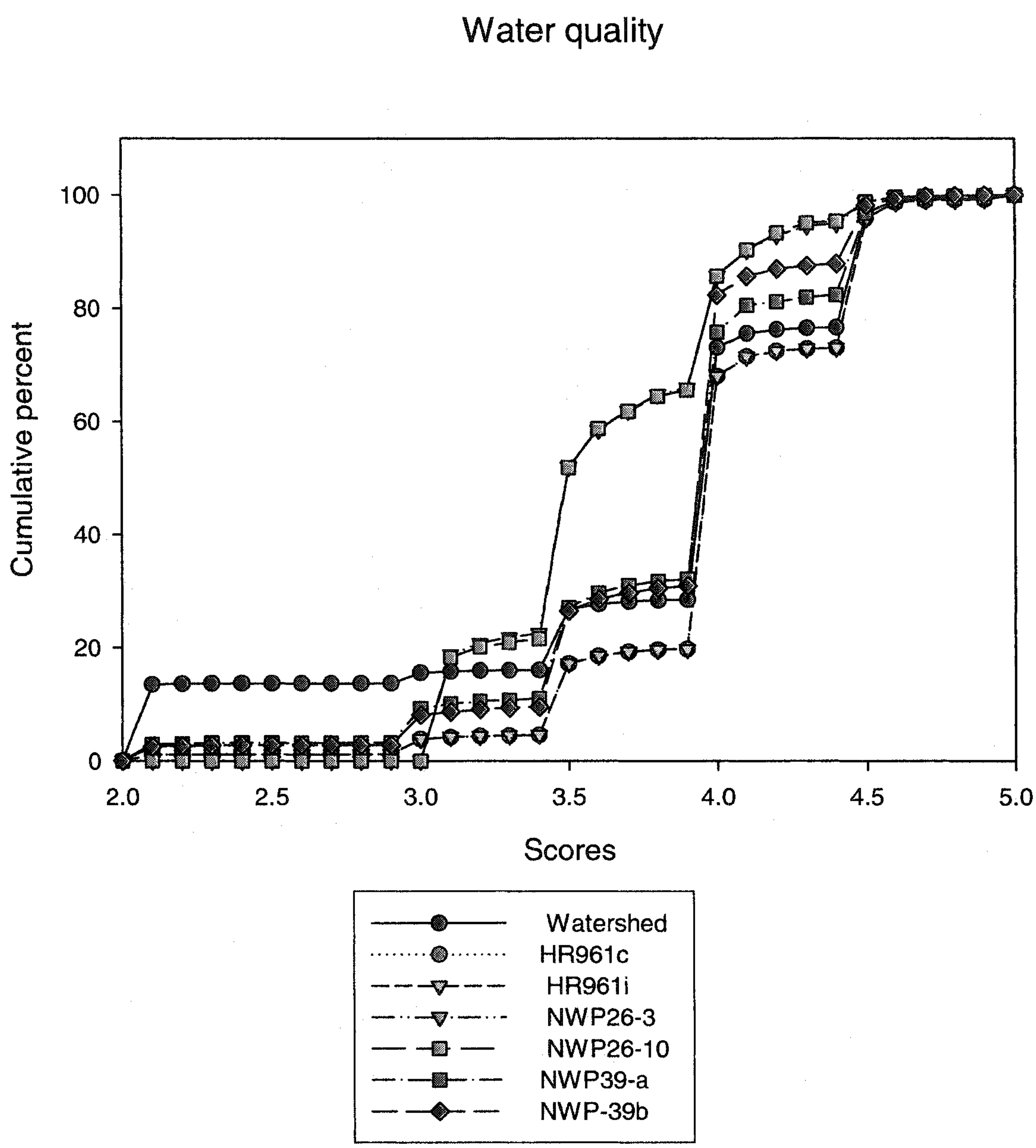

Figure 2-16. Cumulative acreage percents at water quality scores for each scenario

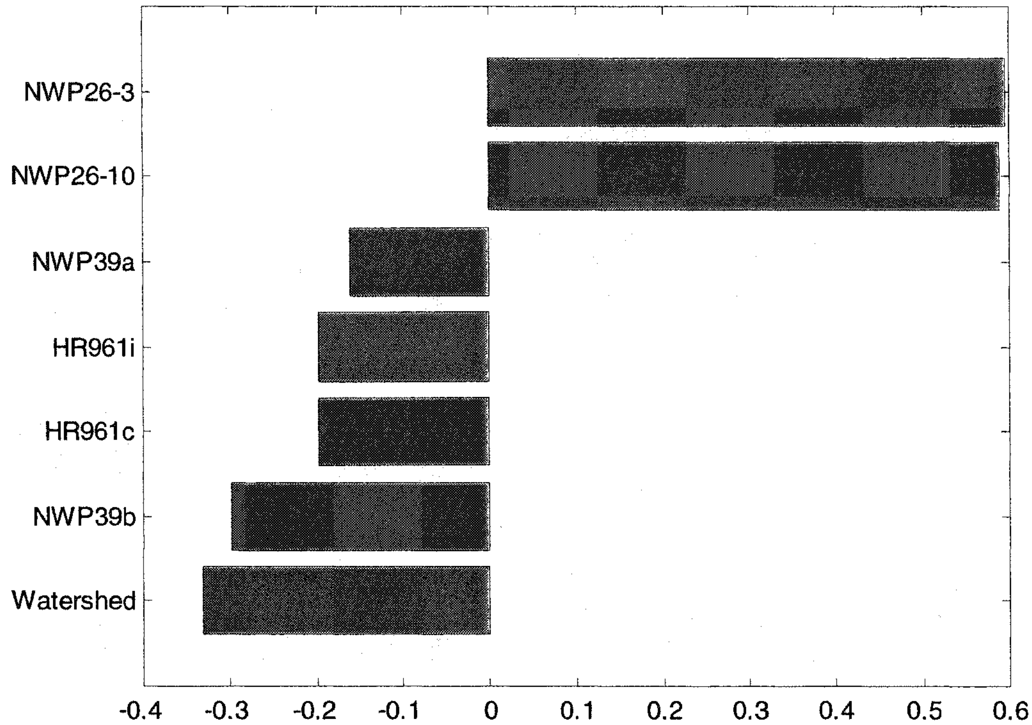

Figure 2-17. Correspondence analysis results for acreage percentage at habitat scores for each scenario.

Flood attenuation

Results of the Mann-Whitney U test for flood attenuation scores are presented in Table 2-9. They show that the wetlands potentially affected by the inclusive estimate of HR961, as well as Nationwide Permit 26 and the both zoning considerations for the residential replacement permit have scores significantly higher than those that would be expected if they affected wetlands equally across the range of scores. Looking at the weighted means (Table 2-6) and the cumulative percentages by acreage at each score (Figure 2-19), once again the results for both versions of NWP26 are moderated downward, with lower percentages scoring in the upper ranges. Both readings for HR961 and NWP39a would put at risk a higher caliber of wetlands in terms of flood attenuation by acreage across the watershed.

Table 2-9. Mann Whitney U test (two-tailed) results for flood attenuation scores. H relates the test group's standing to the watershed.

Comparison	*p*	*p* adjusted for ties	H
Watershed vs. HR961 – conservative	0.6190	0.6049	equal
Watershed vs. HR961 - inclusive	0.0065	0.0046	significantly higher
Watershed vs. NWP 26 (3 and 10)	0.0000	0.0000	significantly higher
Watershed vs. NWP39a	0.0000	0.0000	significantly higher
Watershed vs. NWP39b	0.0000	0.0000	significantly higher

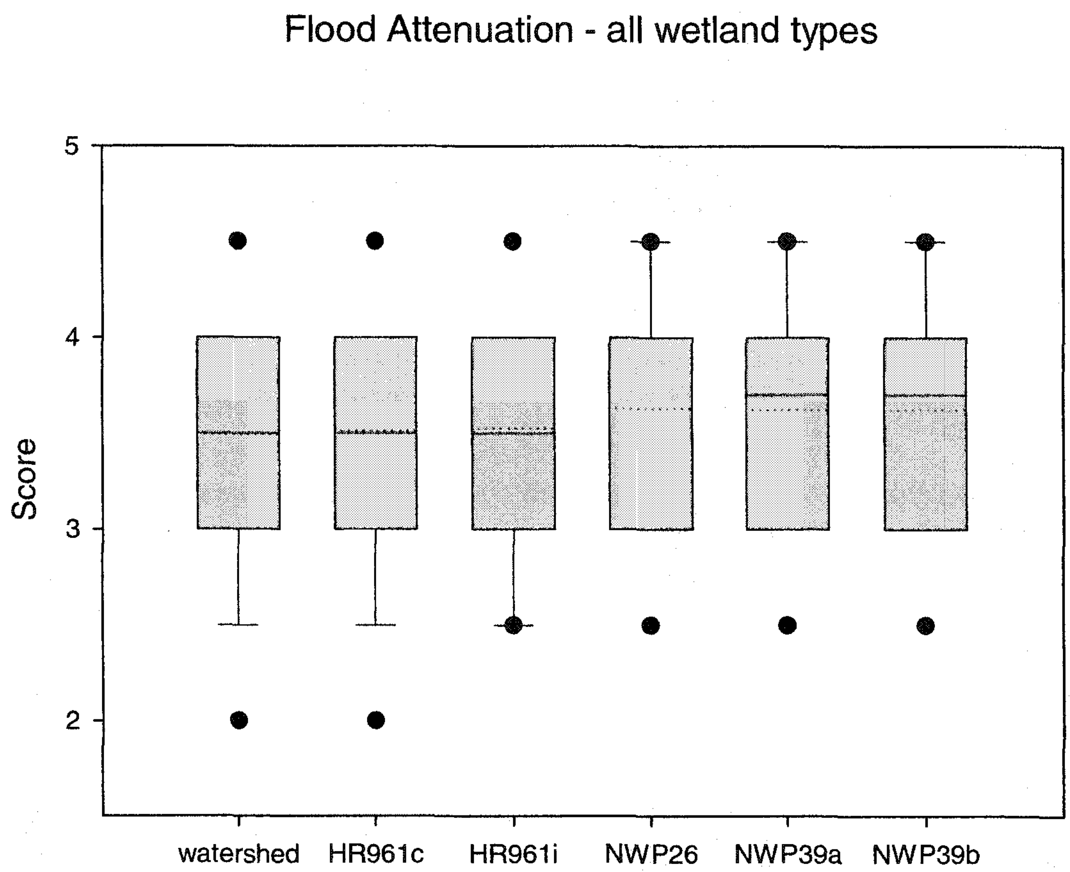

Figure 2-18. Box plot of flood attenuation scores for each of the legislative scenarios, as well as the parent watershed. Whiskers show 10th and 90th percentiles, black dots show 5th and 95th. The mean is represented by a dotted line, median where distinct from the mean by a solid line.

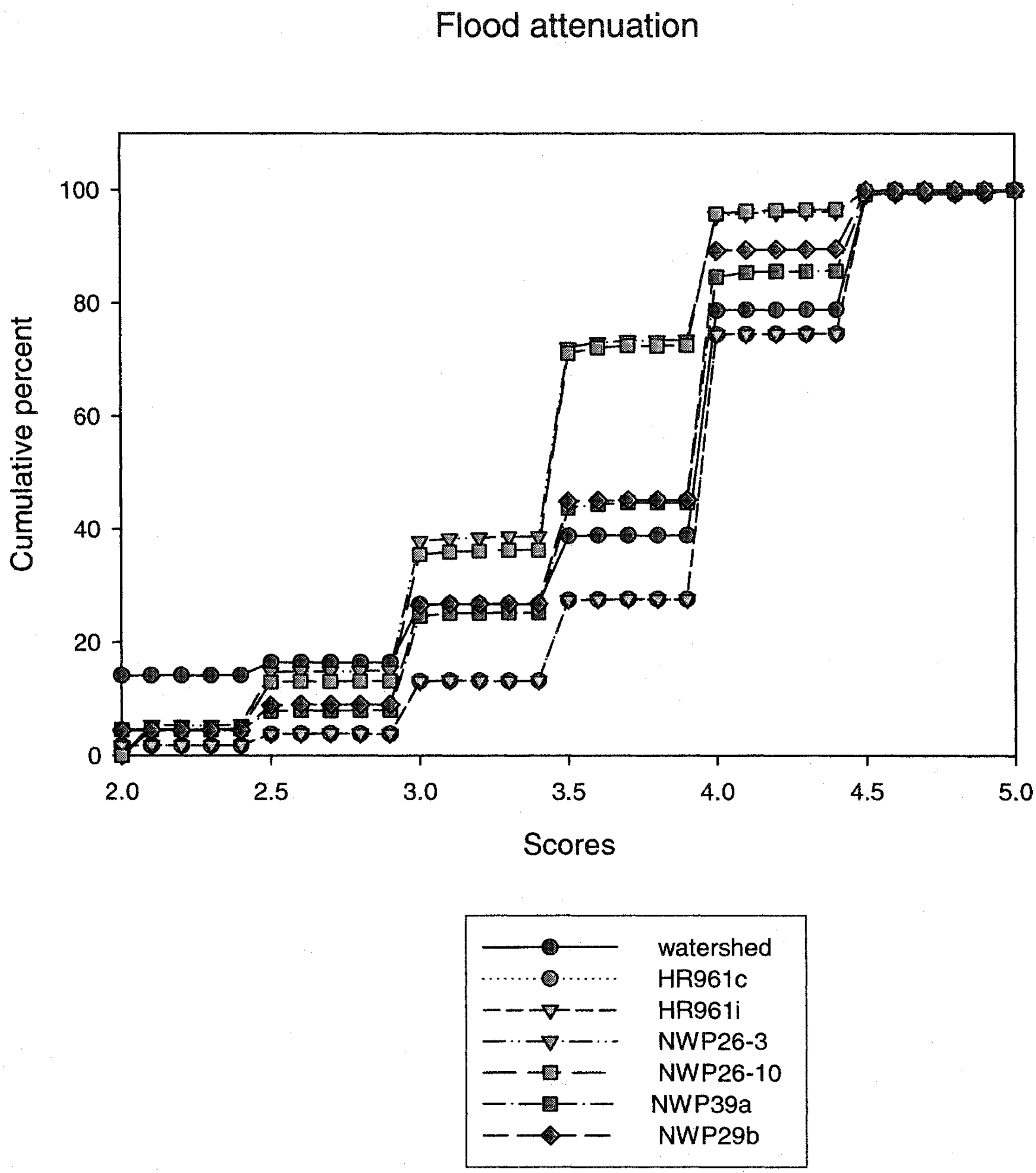

Figure 2-19. Cumulative acreage percents at flood attenuation scores for each scenario

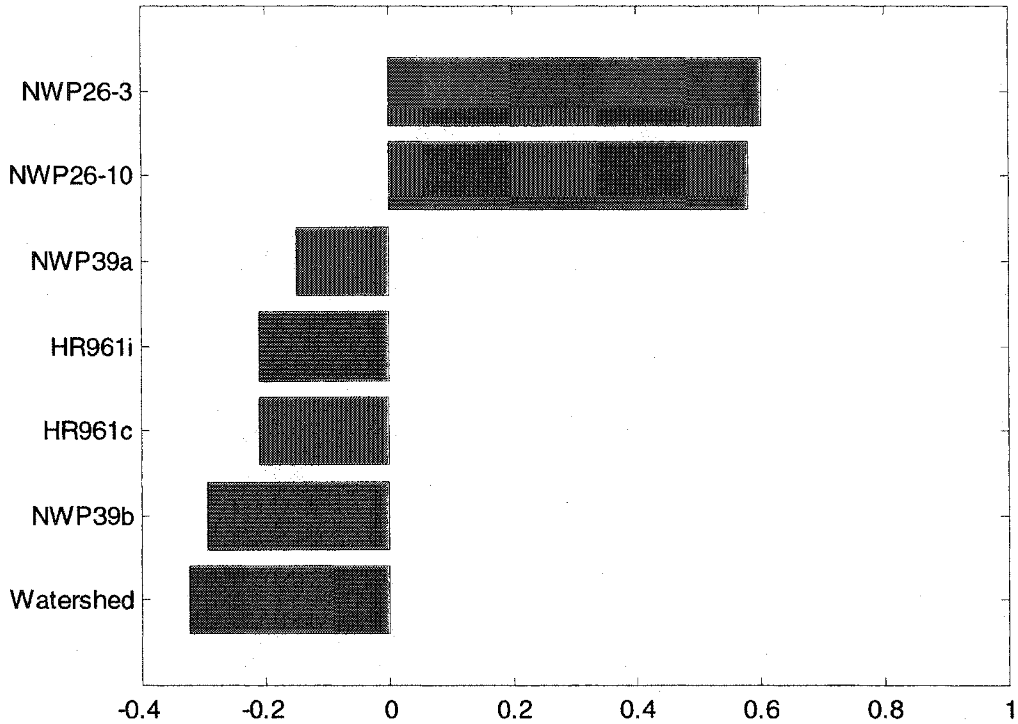

Figure 2-20. Correspondence analysis results for acreage percentage at flood attenuation scores for each scenario.

Palustrine Wetlands

Results for palustrine wetlands only as compared to watershed-wide comparisons differ only in the results for HR. 961, and only in the following two ways 1) results for the conservative reading of H.R.961 were found to be significantly lower for water quality (Table 2-11), and 2) results for the inclusive estimate of H.R. 961 were no longer significantly higher, but equal to the parent population in terms of flood attenuation potential (Table 2-12). These results are discussed in more detail in the individual scenario sections below.

Table 2-10. Mann Whitney U test (two-tailed) results for habitat scores – palustrine only. H relates the test group's standing to the watershed.

Comparison	*p*	*p* adjusted for ties	H
Watershed vs. HR961 – conservative	0.0109	0.0054	significantly lower
Watershed vs. HR961 - inclusive	0.2867	0.2433	equal
Watershed vs. NWP26 (3 and 10)	0.0000	0.0000	significantly lower
Watershed vs. NWP39a	0.0000	0.0000	significantly lower
Watershed vs. NWP39b	0.0395	0.0234	significantly higher

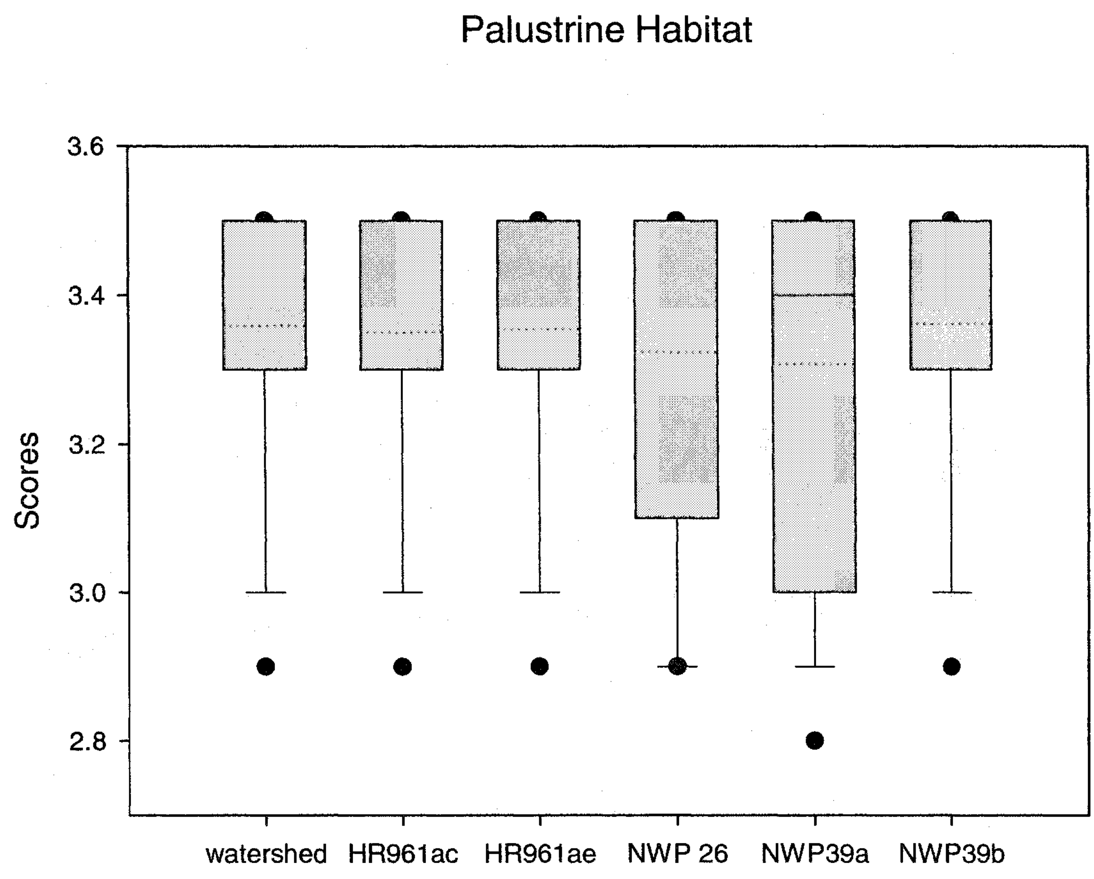

Figure 2-21. Box plot of habitat scores for each of the legislative scenarios, as well as the parent watershed, for palustrine wetlands only. Whiskers show 10th and 90th percentiles, black dots show 5th and 95th. The mean is represented by a dotted line, the median where distinct from the mean by a solid line.

Table 11. Mann Whitney U test (two-tailed) results for water quality scores – Palustrine only. H relates the test group's standing to the watershed.

Comparison	p	p adjusted for ties	H
Watershed vs. HR961 – conservative	0.0.0010	0.0005	significantly lower
Watershed vs HR961 - inclusive	0.1567	0.1303	equal
Watershed vs. NWP26 (3 and 10)	0.000	0.000	significantly higher
Watershed vs. NWP39a	0.1118	0.0896	equal
Watershed vs. NWP39b	0.000	0.000	significantly higher

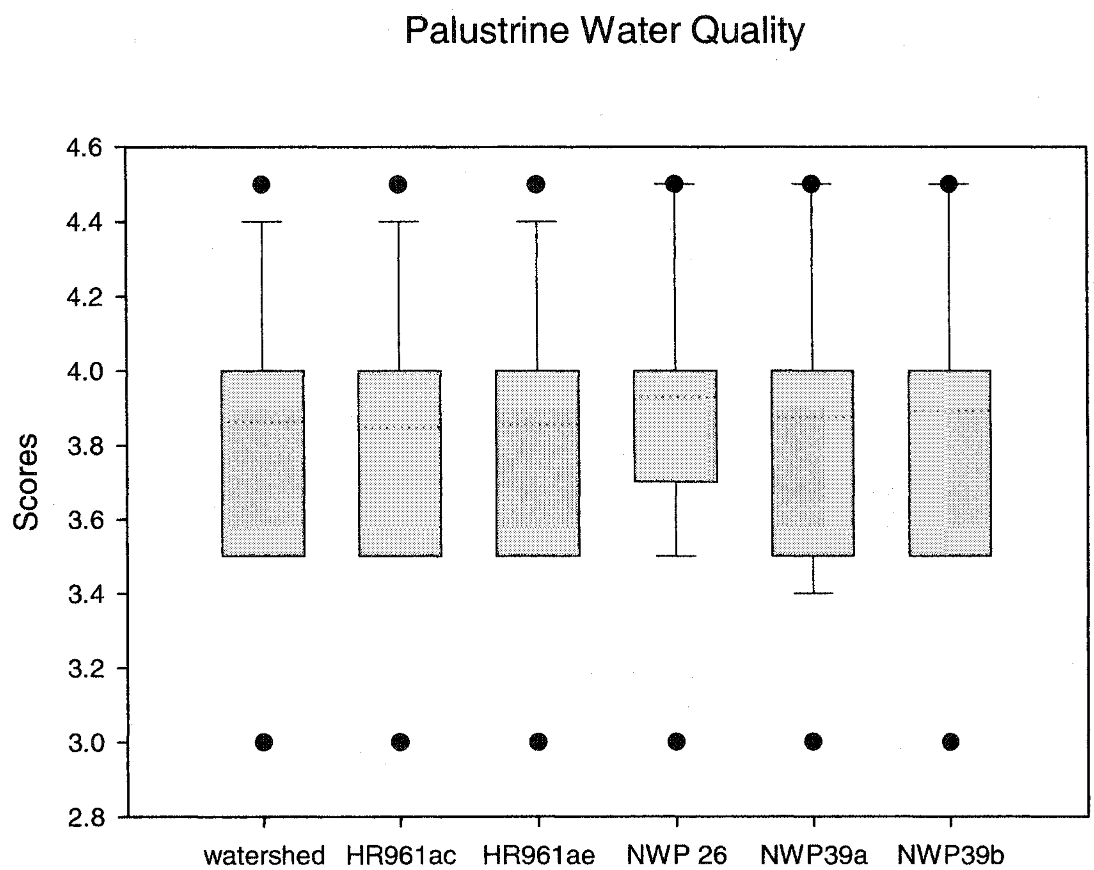

Figure 2-22. Box plot of water quality scores for each of the legislative scenarios, as well as the parent watershed, for palustrine wetlands only. Whiskers show 10th and 90th percentiles, black dots show 5th and 95th. The mean is represented by a dotted line.

Table 2-12. Mann Whitney U test (two-tailed) results for flood attenuation scores – palustrine only. H relates the test group's standing to the watershed.

Comparison	p	p adjusted for ties	H
Watershed vs. HR961 – conservative	0.2107	0.1911	equal
Watershed vs HR961 - inclusive	0.4881	0.4685	equal
Watershed vs. NWP26 (3 and 10)	0.0000	0.0000	significantly higher
Watershed vs. NWP39a	0.0005	0.0003	significantly higher
Watershed vs. NWP39b	0.0000	0.0000	significantly higher

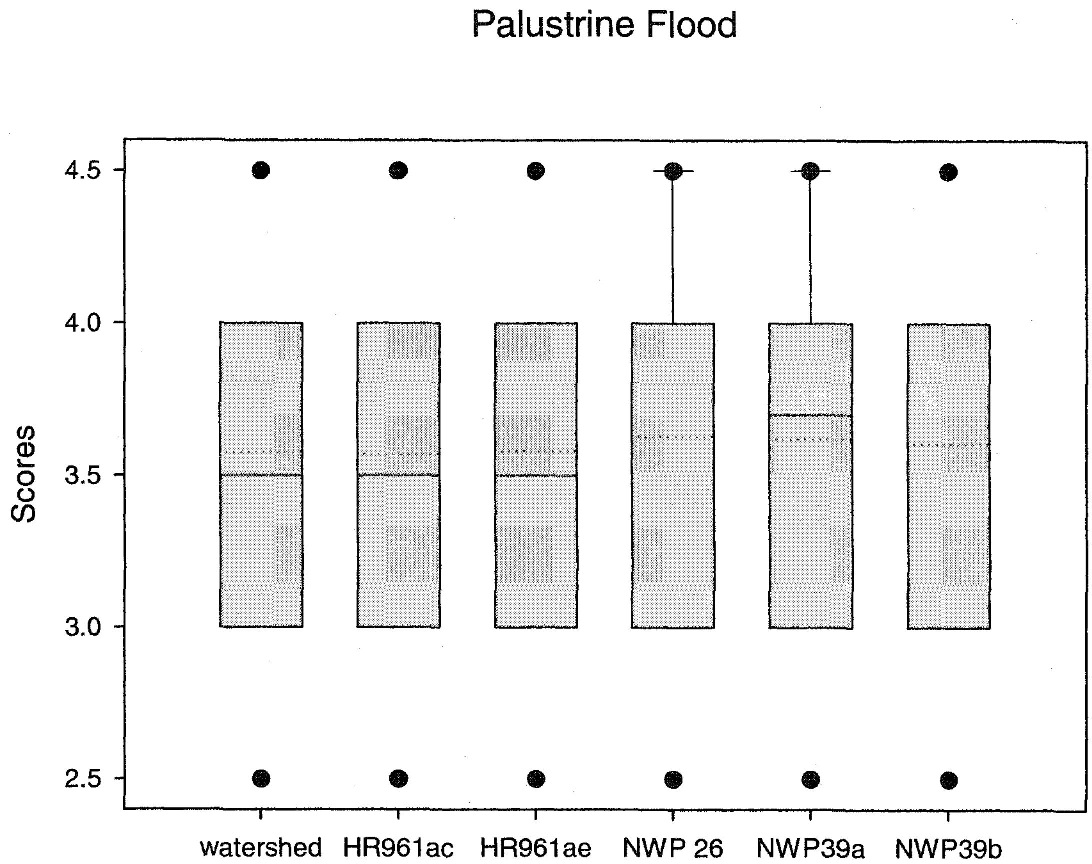

Figure 2-23. Box plot of flood scores for each of the legislative scenarios, as well as the parent watershed, for palustrine wetlands only. Whiskers show 10th and 90th percentiles, black dots show 5th and 95th. The mean is represented by a dotted line, the median where distinct from the mean by a solid line.

Results by scenario

Results of H.R. 961

The determination of *isolated* applies to 5.2% of all wetland acreage in the York River Watershed. Calculation of the "less than 21 days of inundation rule" would exclude 57% of all wetland acreage for those with hydrologic regimes of A, B, or C, and 66.6% if all regimes from A through E are included (Table 2-13).

Table 2-13. Percentages affected by each of the criteria considered for H.R.961.

	All wet-lands (%)	EEM (%)	EFO (%)	ESS (%)	Lacustrine (%)	PEM (%)	PFO (%)	PSS (%)
isolated	5.2	n/a	n/a	n/a	n/a	6.8	5.9	5.1
<10acres	12.8	5.2	8.7	16.3	4.5	20.6	12.3	17.5
<21 days (a,b,c)	57	n/a	n/a	n/a	n/a	39.4	75.1	43.4
<21 days (a-e)	66.6	n/a	n/a	n/a	n/a	47.6	84	71.7

The totals for these combined criteria (Table 2-5) would exclude between 62 and 70% of the wetland area in the watershed from current levels of protection. Although this legislation sought to capture those wetlands of less ecological importance for reduced protection, comparisons against the other wetlands in the watershed only resulted in one test where the wetlands scored lower than that of the parent population, for habitat, and only in the conservative estimation of the criteria (Table 2-7). For the inclusive estimate's habitat scores, as well as water quality scores for both estimates, there is no significant difference between the scores of the parent population and those that would receive reduced protection under this legislation (Table 2-8, Figure 2-14). For flood protection, the more inclusive reading of the criteria actually resulted in capturing wetlands that tended to score higher than would be expected if they had been drawn evenly from the underlying population. (Table 2-9, Figure 2-16). Moreover, consideration of the weighted scores (Table 6) and percentage at each score by acreage (Figures 2-13, 2-15, and 2-17) suggest that both the conservative and inclusive estimate would capture more high scoring wetland area compared with the parent population, for all of the three functions.

The effects for palustrine wetlands alone show scores significantly lower for both habitat and water quality for the conservative estimate. For the inclusive estimates all three functions score in ranges similar to that of the whole population (tables 2-10, 2-11, and 2-12). These results suggest that the effects for the nation would be to select not only the majority of the wetlands for exclusion from current levels of protection, but that the legislation would not have the intended effect of properly categorizing wetlands in terms of function and subsequent value.

Results of NWP26

Approximately 5.5% of wetlands in the watershed are isolated or headwater wetlands. Of that, full implementation of NWP26 would result in 67% of the acreage being permitted for dredge and fill activities under the three acre limit, and 86% of it permitted under the ten acre limit. While the test results for habitat scores show that the wetlands that would be affected are of relatively lower value (Table 2-7), test results for both water quality and flood attenuation functions are both significantly higher than those of the parent population (Table 8 and 9). These results hold for the palustrine only tests, suggesting that at either level these permits selected for some of the nation's highest functional levels of wetlands to receive reduced consideration for protection (Tables 2-10,2-11, and 2-12). Consideration of the scores by acreage moderate this view (Table 2-6). In the case of the 10 acre limit for habitat (Figure 2-13) and both the 3 and 10 acre limits for water quality and flood attenuation (Figures 2-15 and 2-17), affected wetlands may actually have lower functional potential than would be expected from the parent population.

Results of NWP39

NWP39a - Restrictive assessment (residential, commercial, industrial, mixed use). The total area of wetlands affected under this permit is less than a quarter of those affected by the NWP26 permit that it serves as partial replacement for – affecting 0.8% of total wetland acreage, as opposed to 3.7% affected by NWP26, the 3 acre limit or the 4.7% under the NWP26 10 acre limit (Table 2-5). However, it apparently does little to resolve the issues raised for NWP26, above. Namely, it still appears to select for losses of some of the wetlands with the highest potential in terms of performing water quality and flood attenuation functions. Consideration of scores by acreage also show this discrepancy, as well as showing higher percentages having elevated scores for habitat (Figures 2-13, 2-15 and 2-17). Results are similar for palustrine, with the exception that water quality falls out just below the rejection level for an alpha of 0.05, categorizing as equal to the parent population (Tables 2-10, 2-11 and 2-12).

NWP39b – Farm (agricultural/rural residential/forested). Inclusion of these wetlands under the replacement permit would jeopardize a further 5.6% of wetland acreage within the watershed (Table 5). Moreover, the functional potential scores rank significantly higher for this group on all three functions tested (Tables 2-7, 2-8 and 2-9) compared to the parent population. The weighted means (Table 6) and percentages at each score by acreage (Figures 2-13, 2-15 and 2-17) reinforce this conclusion. The results for palustrine only are comparable, with scores ranking significantly higher for habitat, water quality and flood attenuation functions (Tables 2-10, 2-11 and 2-12).

Discussion

In terms of acreage affected under the different scenarios, these results show that palustrine, and in particular palustrine emergent wetlands, are disproportionately selected for reduced levels of protection in each case. This coincides with numbers from the recent FWS survey that found the greatest percent loss over the last ten years to occur in this group (Dahl, 2000).

If you look at the scenarios in order from NWP26 – 10 acres, to NWP26 – 3 acres, to NWP39a, and consider that the dates in which these proposals were accepted or implemented as 1977, 1996, 2000, one can see the trend in reduction of acreage affected, from 2207, to 1720, to 400 hectares (under the conservative estimate), respectively. This is a positive step for wetland conservation, but not surprising, given that the limits for these general permits went from 10 acres, to three, to one half. What may be surprising, is that the change from 10 acres to 3 only reduced the area affected by 22%: this is due to the skewed size distribution of isolated and headwater wetlands, with the majority of them measuring less than 3 acres. What should be of concern, however, are the high quality wetlands, from a functional potential perspective, that are excluded in increasing proportions from the original permit, to the interim permit, to the current replacement permit.

It is reasonable to say that these results are unexpected. One of the substantial reasons for the Corps modifying the permit was to reduce the impacts on isolated and headwater wetland areas. In addition to the Corps receiving criticism from the environmental community over NWP26 improperly addressing the intent of the general permits, which were to cover activities which are similar in nature (and of minimal impact to the environment), much concern had been raised that these wetlands were, in fact, serving critical ecological functions within their watersheds. Many functions of wetlands are not affected by issues of isolation or adjacency (NRC 1995). Isolated wetlands are often important habitat for waterfowl (Haramis 1991) and amphibians (Semlitsch and Bodie 1998) and may serve as important groundwater recharge areas and thus affect water quality issues (Brinson 1988). Headwater wetlands are still connected to the surface water flows and can provide even greater impact on stream water quality than wetlands in higher order reaches (Peterjohn and Correl 1984, Whigham et al 1988, Brinson 1993).

The inclusion of areas zoned as agricultural/rural residential/forested would greatly increase the acreage under the jurisdiction of NWP 39. This acreage would also increase even further the percentage of high quality wetlands affected. While it is very likely that some of this area will be developed into homes that would therefore fall under the purview of NWP 39, negative impacts may in fact be greater under it's designation as agricultural or forested. These uses are not included under Section 404 of the Clean Water Act at all, and are only addressed by programs such as Swampbuster and the Wetlands Reserve Program that seek voluntary protection of wetlands by landowners.

Many critics of the current federal program have suggested that if wetlands provide functions to varying degrees, then their protection should take a tiered approach, with maximum protection given to those wetlands that are of the highest quality in terms of functional value, and eased permitting requirements for those that serve minimal functions. H.R. 961 attempted just such an approach. Implementation of this legislation would have had devastating results in terms of sheer numbers of wetland acreage affected. These results show that as much as 70% of the York River Watershed wetland area would receive reduced or no protection under this law. These findings are comparable to estimates made in the U.S. Army Corps of Engineers' (correspondence, 1995) test of the impacts of the legislation on Virginia's wetlands. That report estimated that 77% of all wetland area in Virginia would no longer be considered jurisdictional, with regulatory authority retained on only 12.5% of palustrine wetlands. It is important to recognize that the numbers cited in the present study provide a conservative assessment of the wetlands that would receive reduced, or no protection. Inclusion of those wetlands too small to be mapped, and those affected by other criteria of the legislation not assessed here, such as the requirement that a wetland be vegetated by greater than 50 percent dominant facultative or obligate wetland plants, would undoubtedly increase these numbers. The analyses conducted in this study also show that the wetlands chosen were *not* those least likely to perform important functions. Rather, they scored as if drawn at random from the population, or potentially higher in the case of flood attenuation.

Clearly, from a management perspective, the criteria used by H.R. 961 were not appropriate. Scientific evidence which contraindicated the criteria chosen had already been made available at the time the bill was written, in addition to the already mentioned inadvisability of singling out isolated wetlands for decreased protection. In terms of inundation, the decision to make delineation of non-tidal wetlands dependent upon 21 days of inundation during the growing season is not based on scientific understanding of the biological, physical, geological, and chemical bases for wetland functions. Wetland functions such as water quality improvement are based on the anaerobic activity of micro-organisms; activity which occurs when the soil is saturated to the root zone for at least 7 days, and the temperature is above 0° C, a condition which may occur year-round in many places (Perry et al 1991, Arenson 2003). Saturated wetlands may in fact be more efficient than flooded ones in improving the quality of the water that passes through them, as maximum exchange between the water and plant roots can occur, resulting in maximum retention of toxicants or nutrients (Hemond and Benoit 1988). Acreage limits are also questionable. Not only can small tracts serve critical wetland functions, it has been suggested that the shape of the wetland, particularly as it relates to length of wetland adjacent to streams or other habitat types, may be more important than overall size (Brinson 1993, Gucinski 1978).

Studies regarding variables that relate to wetland functional capacity are often difficult to translate into easily identifiable parameters that can be ranked in terms of importance. Yet societal and economic pressures continue to dictate that wetlands will be altered or destroyed, and that a permitting process is necessary to minimize negative environmental consequences. The methodology used in this paper has three major points to recommend it; 1) it was created using best professional judgment by wetland scientists with knowledge of both local conditions and the body of scientific literature relating to the subject, 2) it provides the basis for considering both capacity and opportunity of wetlands to perform a given function, including consideration of landscape setting and 3) it makes use of digital coverages that can be made available to all state and local government agencies with GIS capabilities and the desire to consider the complex of wetlands within their jurisdiction and the cumulative functions they perform. For these reasons it provides a legitimate framework for assessing both the individual and cumulative impacts that may result from management decisions.

It should not, however, be seen as a static tool. Updates to available coverages with current information at refined scales should be sought, and new understandings of wetland functions incorporated as they become available. The fundamental inputs should also be regularly re-evaluated. For example, although the Fish and Wildlife Service's National Wetland Inventory is the most readily available format for digitized wetland coverages, it has inherent limitations. In addition to "missing" smaller wetlands which were not mapped at the 1:24.000 scale, the Cowardin classifications used were created as a system of habitat identification, and may not be ideal for addressing issues of water quality, flood attenuation, sediment stabilization or other functions for which wetlands may be valued. Consideration of a mapping system which uses the HGM approach may prove a more valuable assessor of wetland function, and should be sought.

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Chapter 3. Water Quality Cumulative Impact Assessment

Introduction

Current legislation deals with wetland permitting on a case by case, or wetland by wetland basis, without considering the impact to the matrix of wetlands throughout a watershed. Loss of a wetland not only eliminates the functions that wetland had performed, it places greater burdens on the functional capacity of the remaining wetlands within a drainage system. In order to assess the cumulative impact of wetlands lost, it is necessary to categorize the cumulative *effect* of wetlands within the watershed mosaic on function (Johnston et al. 1990). This paper aims to better define the relationship wetland and landscape patterns have to water quality measures.

Wetlands can serve water quality functions by removing or altering organic and inorganic nutrients and contaminants from the water that flows through them. Depending on type and location, they may play an important role in the global cycles of nitrogen, phosphorus, sulfur, methane, and carbon dioxide (Mitsch and Gosselink 1986). These materials may be taken out of the water by accumulation in plants and microorganisms, burial in the sediment, and denitrification. Inorganic nutrients may be transformed by wetland organisms into organic forms usable in the aquatic food web. The sedimentation of organic material in the wetland may provide long-term detention for some nutrients and toxins (Hemond and Benoit 1988). Wetland vegetation can reduce turbidity, improving water quality by helping to bind sediment with their roots, and reducing current velocity and dampening waves through friction (Tiner 1984). Wetland plants are also capable of assimilating some metals and chemical compounds, can trap suspended sediments, and aid in flocculation of suspended particulates (Hemond and Benoit 1988). Silberhorn et al (1974) found that any marsh that is at least 2 feet in average width can have significant value in filtering sediment.

Filling or draining of a wetland changes it from an area of accretion to an area of erosion, allowing the nutrients and toxicants which had been sequestered over time in the sediment to rapidly re-enter the system (Brinson 1988). Alterations in surrounding land-use can also affect the water balance and the amount of pollutants entering a wetland (Pearson 1994), and should be considered in efforts to maintain water quality.

The Chesapeake Bay Program has identified increased nutrients and suspended solids as critical factors affecting the Bay ecosystem. These conditions have led to eutrophication and depressed oxygen levels, as well as shifts in the ecological balance, negatively affecting benthic organisms and leading to the loss of submerged aquatic vegetation.

Nutrients (Nitrogen and Phosphorus)

Nutrients may enter wetlands from both natural and anthropogenic sources, and are present in both soluble and particulate forms. The most common forms for dissolved nitrogen entering a wetland are as nitrate (NO_3), ammonium (NH_4^+), and insoluble organic compounds (Hemond and Benoit 1988). Some ammonium in wetlands is also the product of atmospheric nitrogen fixation by bacteria and algae associated with wetland soils, water and plants. Dissolved phosphorus primarily enters the wetland as phosphate (PO_4^-) or soluble organic phosphorus (Kelly and Harwell 1985).

Both nitrogen and phosphorus can be removed from water flowing through wetland in two ways. The first is through accumulation in plants and organisms that assimilate the nutrients. The second is through sedimentation, which may occur as the solutes sorb onto particulates. These two processes sequester the nutrients, removing them from the water but not entirely from the system. They may re-enter the aquatic system as plants decompose, or in the event that dredging or erosion resuspend the sediment. Flooding of the wetland may also lead sorbed and particulate nutrients to be flushed into adjacent waters. In a third process, denitrification, facultative anaerobic bacteria, present in anoxic soils, metabolize NO_3^- (used as the final electron acceptor in respiration) into N_2O or N_2, These are released to the atmosphere as gases, and thus removed from the immediate system.

Season can have an effect on the ability of wetlands to sequester nutrients. While plants may translocate nutrients to below-ground biomass for winter storage (Banko and Smart 1980), senescence of plants and leaching from the subsequent litter decomposition may lead to increased output from some wetlands (Polunin 1984, Peverly 1985). In addition, in temperate winter, wetlands will no longer have the plant biomass to absorb the same amount of nutrients from other sources. However, a great deal of the nutrients may be retained in the wetlands in those cases where vegetation is incorporated into the sediment (Delaune et al. 1986).

Suspended Solids

Suspended solids may be considered pollutants in and of themselves, or because of the chemicals which may be sorbed onto them. They may be composed of organics, which raise the biological oxygen demand (BOD) of the water, and increase the potential for hypoxia and anoxia in the aquatic system. High levels of suspended solids may also inhibit light penetration, which would decrease photosynthesis levels and oxygen production, or increase levels of siltation that may disturb organisms which utilize the benthos. Substances which may be associated with suspended solids include nutrients, heavy metals, radionuclides, and xenobiotic organic pollutants (Hemond and Benoit 1988).

Suspended solids enter wetlands through runoff from the watershed, decompostion of vegetation, and by inundation from adjacent waterways. Wetlands can serve to alter, assimilate, or sequester particulate matter as well as toxicants which may be associated with it. Wetland vegetation acts to slow water velocities, thus providing for additional retention time during which the pollutants may be broken down. Decreased water velocities will also act to increase sedimentation of the suspended solids.

The salt/freshwater interface created when runoff reaches estuarine or marine wetlands increases flocculation and subsequent sedimentation processes. Freshwater wetlands do not tend to induce flocculation, due to their low ionic concentrations, however microbial colonization of particles can render them "sticky" and cause them to aggregate. Plant exudates may also create a "fly-strip"-like surface on which fine particles will adhere (Lee et al. 1976, in Hemond and Benoit).

Kadlec and Kadlec (1978, in Hemond and Benoit) found that suspended solid fluxes in wetlands varied from 97% removal to a 250% increase, indicating that different wetlands may serve either as a source of a sink for suspended solids.

The use of wetlands in wastewater treatment is a testament to the fact that they are capable of assimilating greater than natural loads of certain nutrients and toxics and consequently provide improved water quality.

Nutrients and toxics can enter wetlands from either adjacent upland areas or flooding by adjacent bodies of water such as rivers or streams. Brinson (1993) calls the former riparian transport, and the latter overbank transport, with riparian transport responsible for most of the nutrient removal and sediment deposition that occurs in wetlands. Since riparian transport is more common the further upstream a wetland is located, wetlands in the upper drainage systems are believed to have the greatest impact on water quality, with even a 1 hectare loss in a lower order stream having a more detrimental effect than the same loss in a higher order stream (Whigham et al. 1988, Brinson 1993).

Water quality functions can also be considered in terms of wetland type. Palustrine wetlands are found to be major sinks for nitrogen, phosphorus and other potential water pollutants (Whigham et al. 1988, Brinson 1988). Phillips et al (1993) found that nitrate concentrations in both ground and surface water are inversely related to the extent of forested wetlands. Those wetlands in riparian areas are valued for the filtering of water from intensively managed landscapes that often exist along watercourses. Isolated wetlands (without an inlet or outlet for water flow) exist in extreme headwater positions with little catchment area or opportunity to interact with upland runoff. As such, they typically have low elemental concentrations and should be considered to sustain the production of good quality water and protected from development which could cause them to lose their nutrients to downstream areas (Brinson 1988). Saturated wetlands may in fact be more efficient at improving the quality of the water which passes through them, as maximum exchange between the water and plant roots can occur, resulting in maximum retention of toxicants or nutrients (Hemond and Benoit 1988). Finally, while fringe wetlands such as tidal marshes may not have great impact on water quality, their value as habitat for fish and wildlife call for management of upstream wetlands to protect them from inflows of pollutants that result from poor water quality (Brinson 1988).

As noted above, there are many factors that can affect a wetland's capacity for water quality functions. For the purposes of this study, I attempted to quantify the effects of wetland and watershed characteristics on total nitrogen, kjeldahl nitrogen, total phosphorus, and total suspended solids found at water quality monitoring sites. The wetland and watershed variables I explored are listed below, along with the a priori reasoning for why I believed they might be important factors. Part of the reasoning for conducting this study was to verify the importance, and the relative importance of these factors in water quality.

Percent of watershed by land use: agricultural, developed, wetland, non-wetland vegetated, barren. Surrounding land would logically be correlated with water quality, as providing either the source of contaminants or helping to sequester them prior to reaching the open water testing site. Factors such as impervious surfaces, outflows for storm water runoff, increased application of fertilizers and pesticides, and decreased vegetation, associated with developed and agricultural land, might be expected to reduce water quality. Both nitrogen and phosphorus concentrations were found to be as much as 9 times higher in-stream in watersheds which were at least 90% agricultural as opposed to those that were at least 90% forested (Omernik 1977). In Iowa, it was found that levels of nitrate in streams were inversely related to the percentage of the watershed composed of wetlands (Jones et al. 1976). Nitrogen concentrations were found to be significantly reduced in surface runoff flowing from agricultural fields through 19m of riparian forest (Peterjohn and Correll 1984). Comparisons of watershed landuse type were made with both wetlands, and all vegetated areas, to determine the roles wetlands as well as forested buffers play in nutrient and sediment removal.

Percent of watershed by wetland vegetative type: forested, scrub/shrub, or emergent. Wetlands are classified in the NWI coverages by these three vegetative types. Due to the yearly senescence of the herbaceous plants, wetlands characterized as emergent may provide nutrient uptake during the growing season but may constitute areas of nutrient export during the winter months.

A-E hydrologic class (% watershed). This distinction is included to discern if those wetlands with reduced hydro-periods may still be performing significant water quality functions. The signature A-E refers to the National Wetland Inventory hydrologic modifiers (Cowardin et al 1979), with A= temporarily flooded; B= saturated; C=seasonally flooded; D= seasonally flooded-well drained; and E=seasonally flooded-saturated. While the effect of an individual wetland may not be great, the sheer dominance of these types may make them important. In addition, those wetlands that are only saturated have greater interaction with the water which flows through them, and the fluctuation of the soil from dry to wet could cause additional reactions to occur which could alter the structure of nutrients and toxicants which enter there.

Other hydrology (those not A-E) classes (% watershed). These are the classes most likely to retain wetland status under a variety of management scenarios, due to evident long term flooding or saturation.

Wetland/upland fringe: developed, agricultural, vegetated. Quantifies land use in a 100m wide fringe surrounding wetlands. Relates land use that affects water quality to wetland potential for interception of water. Wetlands can act as sinks for nitrogen and phosphorus, often found in high concentrations in urban and agricultural runoff. Wetland/upland edges have been shown to have an important effect on chemical fluxes within the landscape (Whigham and Chitterling 1988).

Stream fringe by % land use: developed, wetland, agricultural, non-wetland vegetated Measured in terms of % of total fringe for both a 20m buffer and a 100 meter buffer.. Related to amount of runoff allowed to flow unimpeded (by vegetation) into stream. Vegetated riparian zones help sequester nutrients and toxicants before they can reach the waterway. Phosphorus and sediment accumulation is greatest in wetlands within 20 m of streams (Johnston et al. 1984).

Isolated wetlands. Isolated wetlands have historically received reduced protection under wetland legislation and management: percentage of isolated wetlands were included in this study to determine what specific link they may have to water quality.

Average soil surface permeability. Areas with greater permeability will have greater soil interaction with water, rather than over-ground runoff. However, it may also relate to the amount of wetlands naturally found in the area, as well-drained soils, in the absence of a high water table, may not be wetlands.

Average watershed slope. Related to flow rates and retention times. Longer retention times increase chances of interaction and alteration or sequestering of nutrients and toxics.

Anthropogenic inputs. Available data for point source phosphorus and nitrogen, phosphorus and nitrogen delivered to the landscape as agricultural fertilizers, and atmospheric nitrate deposition loads were used to evaluate the impact of estimated fluxes into the system from human inputs. These numbers were combined in the final regression testing to one variable for annual anthropogenic nitrogen, and one variable for anthropogenic phosphorus.

Alternative Hypotheses:

Ho There is no link between landscape use and configuration, and water quality

Ha There is a link, which is adjustable by conceivable human influence

Ho There is a link, but it is not adjustable by reasonable human influence

METHODS

Southern Virginia was chosen as the region of study due to the accessibility of GIS coverages for wetlands and landuse in that region available at the Virginia Institute of Marine Science.

Due to the limited availability of long-term water quality data sets, this procedure began from the point of obtaining sites within the area with appropriate data available, rather than having the opportunity to construct a more rigorous and random sampling design. Long term water quality data were extracted from EPA's STORET data base for the years 1989 through 1995, to reflect the timeframe during which the landsat photos from which the land use coverage was created. Six sites and their associated watersheds in southern Virginia (Figure 3-1) were chosen on the basis of the following:

1) They needed to have a minimum of 4 continuous years of sampling, with the sampling occurring at least once monthly.
2) Data needed to be collected at the site for suspended solids, total phosphorus, and kjeldahl nitrogen.
3) Data on daily flow rates needed to be accessible for the sites to compute annual loads.
4) Data were preferentially chosen that were collected by the same agency, to minimize sampling and testing differences. Each of the samples here was taken by the Virginia State Water Control Board, which has since been restructured into the Virginia Department of Environmental Quality.

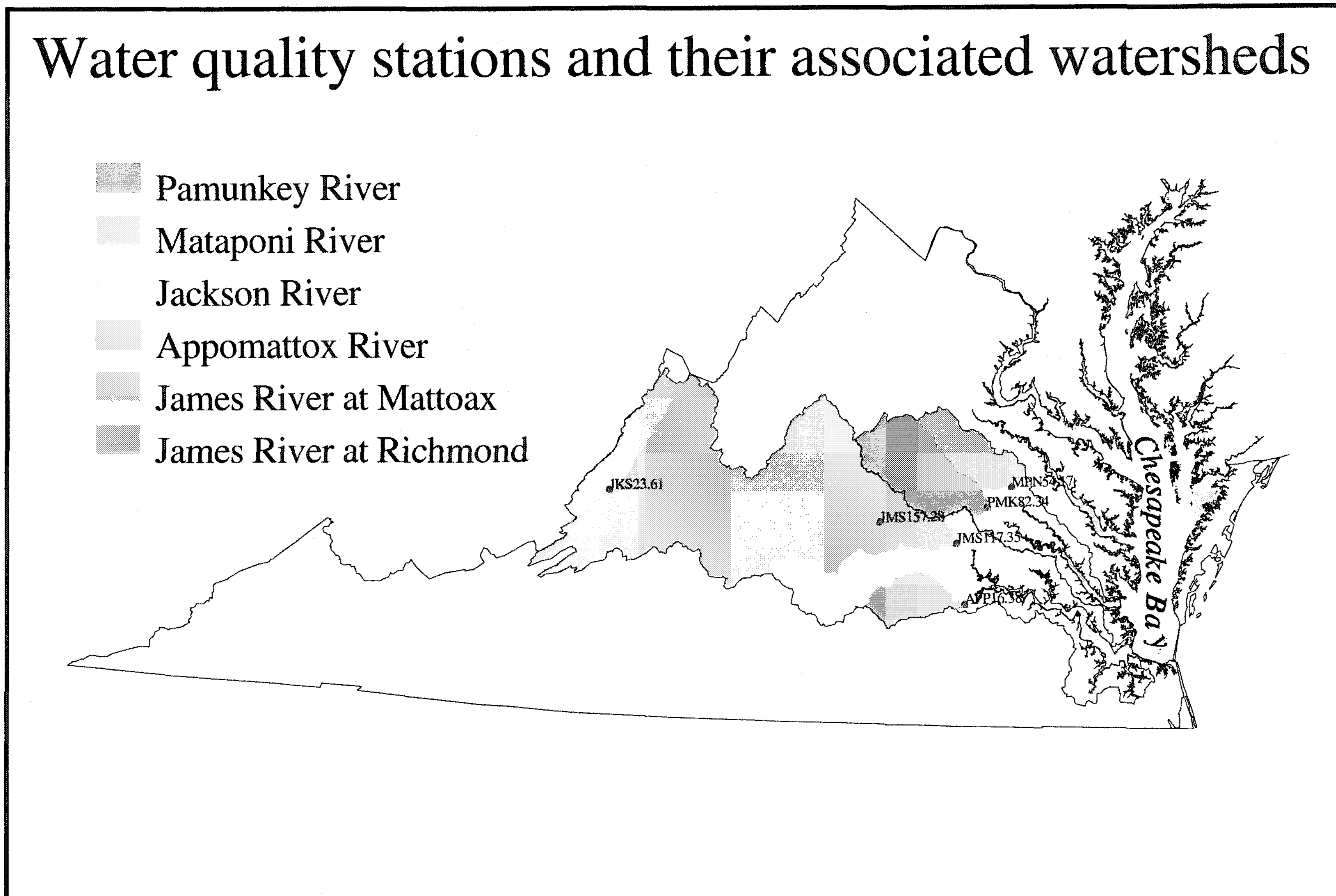
Water quality stations and their associated watersheds
Pamunkey River
Mataponi River
Jackson River
Appomattox River
James River at Mattoax
James River at Richmond
JKS23.61
JMS157.28
PMK82.34
JMS117.35
APP16.38
Chesapeake Bay

Figure 3-1

Average annual loads of each of the tested constituents were calculated in three steps: first, a regression equation was created based on the observed concentrations, time of the year and flow rate at the time of sample collection; second, a daily concentration data set was created based on daily stream flow rates at the site and the predictive regression equation, and finally, the loads were calculated based on mean concentrations and discharges for the time period covered by the sampling.

The regression model for determining concentrations has the following form:

$$\ln(C) = \beta_0 + \beta_1\left[\ln\left(\frac{Q}{\tilde{Q}}\right)\right] + \beta_2\left[\ln\left(\frac{Q}{\tilde{Q}}\right)\right]^2 + \beta_3\left[T - \tilde{T}\right] + \beta_4\left[T - \tilde{T}\right]^2 + \beta_5 \sin(2\pi T) + \beta_6 \cos(2\pi T) + \varepsilon$$

where

C	= the constituent concentration (in mg/L)
Q	= the instantaneous discharge (in ft^3/s)
T	= time (in years)
β	= coefficient of the regression model
ε	= model error and
$\tilde{Q}$ and $\tilde{T}$	= centering variables

The centering variables are defined by the following equation (defined here for $\tilde{T}$, a similar equation relates $\tilde{Q}$ to $\overline{Q}$).

$$\tilde{T} = \overline{T} + \frac{\sum_{i=1}^{N}(T_i - \overline{T})^3}{2\sum_{i=1}^{N}(T_i - \overline{T})^2}$$

Daily concentrations were then calculated based on daily stream flow values for the sites, obtained through USGS, and the regression equations derived for each of the constituents at each of the sites. Daily loads were then calculated using the following equation:

$$L_d = Q_d \times C_d \times K,$$

where for any day, d,

L_d = the daily mean load (in kg/d)

Q_d = the daily mean discharge for that interval (in ft^3/s)

C_d = th mean concentration (in mg/L)

K = 2.447, the correction factor for unit conversion

Annual loads were then calculated based on the total of all daily loads divided by the precise number of years represented in the data set. These methods for determining loads were obtained from the USGS Chesapeake Bay River Input Monitoring Program, based on the work of Cohn et al. (1992).

Data for total nitrogen were based on Kjeldahl nitrogen plus nitrate and nitrite. Nitrite and nitrate sampling were not done in this data set for the Appomattox and Mattaponi stations, so only 4 of the watersheds were used in all total nitrogen analyses.

Independent variables

Watersheds associated with the sampling sites were delineated using Digital Elevation Models (DEM) and Arc/Info Grid commands. Resultant watersheds were compared to USGS hydrologic units to ensure appropriate boundaries.

Wetland maps were then created from the most recent versions of the Fish and Wildlife Service's National Wetlands Inventory (NWI) for each watershed. The NWI is based on photographs taken at a 1:40,000 scale and mapped at a scale of 1:24,000. Wetlands were characterized by percentage of palustrine forested wetlands, and palustrine emergent and scrub/shrub in relation to proportion of forested. This method was carried through the process, where one percentage of a whole is calculated, then the remaining variables calculated in relation to that amount in order to retain independence of all variables. Percentage of wetland totals which were isolated, as well as wetlands by hydrologic regime of A-E vs. non-A-E were calculated.

Landuse maps were created for each watershed from the 1996 Environmental Protection Agency Region III Multi-resolution Land Characteristics (MRLC) data set. The MRLC was created from Landsat photos translated into raster digital data with a 30x30 meter pixel size, and converted into a polygon coverage for these analyses. NWI coverages were combined with MRLC coverages, so that consideration of wetlands within the land-use analyses would match the data used to characterize wetlands within each watershed. All remaining pixels coded for wetlands within the MRLC after combination with the NWI, were coded as "non-wetland vegetated". Land use was analyzed by watershed for both percentage of the watershed made up of wetlands, and percentage vegetated, combining both wetland and non-wetland forested areas. These were compared to area of developed, agricultural, and barren land use types.

Twenty meter and 100 meter buffers were created on each side of streams using the 2000 U.S. Census Bureau's Tiger data for hydrology. Corresponding percentages and comparisons were made for the land use in the buffers as had been done for the watersheds as a whole. Twenty meter buffers were created around all wetland polygons, and the same landuse variables measured for these buffers.

Soil permeability data was acquired from the USGS (http://md.usgs.gov/gis/chesbay/doc/perm.htm) for the Chesapeake Bay Watershed. The soil data were based on a grid coverage of the State Soil Geographic Data Base (STATSGO) which was attributed with a numeric value representing the permeability of the soil in inches per hour (in/hr). The coverage was clipped for each watershed in this study, and both the mean and the standard deviation considered in the principle components analysis.

Slope was calculated from Digital Elevation Model data for each of the watersheds. Using Arc/Info grid commands, a grid representing percentage of slope, ranging from 0 to 125 percent was created. Mean slope as well as standard deviation of slope were included for each watershed.

Atmospheric nitrogen inputs were calculated based on a map available through the Maryland USGS (http://md.usgs.gov/gis/chesbay/doc/atdep.htm). This map provided an interpolated coverage for the Chesapeake Bay region based National Atmospheric Deposition Program (NADP) for 188 point measurements within the United States of 1987 mean atmospheric wet-deposition estimates for nitrate. The floating point grid was converted to an integer grid, from which a polygon coverage was created. This was then clipped for each watershed, and the resulting estimate of annual atmospheric deposition calculated for the area.

Agricultural nitrogen and phosphorus data were obtained from a USGS coverage based on Chesapeake Bay Program (CBP) estimates (http://md.usgs.gov/gis/chesbay/doc/agloads.htm). The USGS coverage was based on acres of 1985 conventional-till, conservation-till, and hay land uses calculated by the CBP within the Chesapeake Bay watershed for each county and CBP watershed model segment (CBPWS) using Crop Tillage and county Agricultural Census data bases. Both data for manure and commercial fertilizer application rates were used, and loads for each watershed computed based on USGS estimated stream segment loads.

Load data for point sources of nitrogen and phosphorus were obtained through the USGS. Point coverages were made by USGS based on information from the Environmental Protection Agency's (EPA) Permit Compliance System (PCS) State National Pollutant Discharge Elimination System (NPDES) discharge monitoring reports, with modifications from the Virginia Department of Environmental Quality (Preston and Brakebill, 1999). Data for 1990, 1991, and 1992 were averaged to provide a mean annual discharge for the period of study.

A Principal Components Analysis (PCA) was conducted on the 41 watershed variables (table 3-6) to reduce them to a smaller explanatory set of independent, uncorrelated variables. These principal components and the combined totals for anthropogenic nutrient inputs were then used in a step-wise multiple regression analysis against the water quality parameters.

RESULTS

All regression coeffiecients with a p value of 0.1 or below were retained in the regression equation, and singular terms for which the squared term was found significant were retained as well in order to properly quantify the relationship to the term. Similarly, in instances where either the sine or the cosine were found significant, both terms were retained. Each of the coefficients for the regression terms that were found to be significant are presented in Table 3-1, below.

Table 3-1. Results for concentration regression models for total kjeldahl nitrogen (TKN), total nitrogen (TN), total suspended solids (TSS) and total phosphorus (TP)

	β	APP16.38	JKS23.62	JMS117.35	JMS157.28	MPN54.17	PMK82.34
TKN n=6	constant	-0.57346	-1.0118	-0.8687	-0.24546	-0.42301	-0.37683
	ln[Q/$\tilde{Q}$]	0.18788	-0.36869	0.8392	0.74944	0.23633	0.26671
	ln[Q/$\tilde{Q}$]^2			0.26691	0.14361		
	T-$\tilde{T}$		0.03059	0.03390		-0.03103	
	(T-$\tilde{T}$)^2		-0.019311	0.01593		0.01844	
	sin(2πT)	-0.15285	-0.02517	-0.07464	-0.20430	-0.26784	-0.31195
	cos(2πT)	-0.05706	0.10565	-0.15726	-0.14261	-0.27620	-0.167450
	sin(2πT)/4			**-0.06158	-0.11174	*0.10186	0.00303
	cos(2πT)/4			**-0.22453	0.10615	*0.12269	-0.21205
	R^2(adj) %	15.8	51.3	45.8	43.3	48.1	48.0
	p	0.000	0.000	0.000	0.000	0.000	0.000
	D-W stat	1.46	1.61	2.16	1.69	1.74	1.84
TN n=4	constant		-0.34978	-0.20099	-0.0937		-0.18581
	ln[Q/$\tilde{Q}$]		-0.15322	0.31240	0.25423		0.13559
	T-$\tilde{T}$		0.01944				0.02515
	(T-$\tilde{T}$)^2		-0.02357				-0.03456
	sin(2πT)		-0.01960	-0.17592	-0.12994		-0.15686
	cos(2πT)		0.11325	-0.06478	-0.07730		-0.09942
	R^2(adj) %		35.6	29.2	22.6		20.0
	p		0.000	0.000	0.001		0.009
	D-W stat		1.58	1.73	1.78		2.66
TSS n=6	constant	2.69979	2.4720	3.3091	5.3654	2.10870	3.6559
	ln[Q/$\tilde{Q}$]	0.64401	0.7049	1.5214	1.45327	0.1623	0.2462
	ln[Q/$\tilde{Q}$]^2	0.04806	0.1409	0.1950		-0.05820	-0.11948
	T-$\tilde{T}$		0.11566	0.09331	0.06531	0.074252	0.08413
	(T-$\tilde{T}$)^2		-0.02082		-0.02454	0.17377	-0.01832
	sin(2πT)	0.08407	-0.1218	-0.4042	-0.50873		-0.2385
	cos(2πT)	0.20849	0.15221	-0.2195	-0.22736		-0.17979
	R^2 (adj) %	75.9	23.1	59.9	79.1	31.5	55.5
	p	0.000	0.00	0.000	0.000	0.000	0.000
	D-W stat	1.56	2.24	1.77	1.62	1.23	1.52
TP n=6	constant	-2.6633	-1.9761	-0.0276	-1.2429	-2.67238	-2.21340
	ln[Q/$\tilde{Q}$]	0.34103	-0.4838	0.5897	0.9185	0.27673	0.22034
	ln[Q/$\tilde{Q}$]^2		0.1369	0.15949	0.17731	0.02611	
	T-$\tilde{T}$	-0.04270	-0.03613	-0.07129	-0.02870	-0.01151	
	(T-$\tilde{T}$)^2	0.05553	0.09388	0.02347	0.2870	0.16007	
	sin(2πT)	0.08901	0.2453		-0.28815	-0.28034	-0.21749
	cos(2πT)	0.11262	0.2016		0.00652	-0.17746	-0.16133
	sin(2πT)/4			-0.13662			
	cos(2πT)/4			-0.18629			
	R^2(adj) %	57.1	44.4	25.4	43.7	20.4	17.0
	p	0.000	0.000	0.000	0.000	0.000	0.000
	D-W stat	1.45	1.83	2.21	1.71	1.46	1.76

* β value is for cos/sin (2πT)/3
** β value is for cos/sin (2πT)/5

All of the regression equations were found to be highly significant ($p \leq 0.009$). R – squared values ranged from a low of 15.8% to a high of 79.1%. These results were in keeping with the results achieved in the upper Chesapeake by Cohn et al. (1992), who found that although the equations for concentration had relatively low R^2 values (between 10 and 50%) , they achieved R^2 values generally between 75 and 98% in using the regression equations to calculate actual loads.

In general, the regression equations for suspended solids appeared to explain more of the variation in concentration than those for the nutrient constituents, although this was reversed for the JKS23.62 site, which stretches along the Appalachians.

Loads for each of the water quality constituents are presented in tables 3-2 through 3-5.

Table 3-2. Calculated total nitrogen loads for each of the watersheds, in kg. Data on nitrate and nitrite were unavailable for the Appomattox and the Mataponi.

	Annual	**Spring**	**Summer**	**Fall**	**Winter**
APP16.38	n/a	n/a	n/a	n/a	n/a
JKS23.62	477682.9	187484.9	76978.17	71166.18	142053.6
JMS117.35	4736069	1960060	770681.8	701794.9	1303532
JMS157.28	5481403	2243698	950539.4	811353.6	1475812
MPN54.17	n/a	n/a	n/a	n/a	n/a
PMK82.34	624103.3	279745.4	97593.67	54758.32	192005.9

Table 3-3. Calculated total kjeldahl nitrogen loads for each of the watersheds, in kg.

	Annual	Spring	Summer	Fall	Winter
APP16.38	563478.5	241771.8	71461.86	52797.02	212711.2
JKS23.62	301531.7	105538.8	55773.41	53270.54	86949
JMS117.35	3473580	389072.4	538992.4	1811353	734161.6
JMS157.28	3195506	1371902	596960.4	481061.1	745582
MPN54.17	243300.9	112834.2	36511.75	21386.53	72568.44
PMK82.34	454554.8	185164.2	82655.41	50344.61	136390.7

Table 3-4. Calculated total phosphorus for each of the watersheds, in kg.

	Annual	Spring	Summer	Fall	Winter
APP16.38	81080.34	39800.21	6888.204	5286.378	31460.76
JKS23.62	301969.9	101673.2	53398.19	57190.36	89708.14
JMS117.35	1007894	463832.4	148566.4	127684.4	267810.3
JMS157.28	1252609	502517.8	204701.5	223251.7	322137.5
MPN54.17	32162.39	14438.33	4374.004	3399.25	9950.809
PMK82.34	94337.02	6395.274	23268.17	42366.28	22307.3

Table 3-5. Calculated total suspended solids loads for each of the watersheds, in kg.

	Annual	Spring	Summer	Fall	Winter
APP16.38	16929492	8724409	1032798	879076.6	6786659
JKS23.62	6501120	3117752	623739	602258.1	2157371
JMS117.35	5.11E+08	2.89E+08	85964864	50493320	85756490
JMS157.28	4.73E+08	2.14E+08	92598252	68008191	97868175
MPN54.17	4998880	2013675	554405.3	835721	1595079
PMK82.34	20489917	9289620	3086215	1619066	6495016

All six of the watersheds have a majority of landuse characterized by non-wetland vegetated areas. The second largest landuse group for each watershed was agricultural, and percentages of the watershed occupied by wetlands ranged from less than one percent in the region of the James River, to over 8% in the region of the Mattaponi (figure 3-2a-f, Table 3-6).

Figure 3-2. Characterization of watersheds by major land-use types.

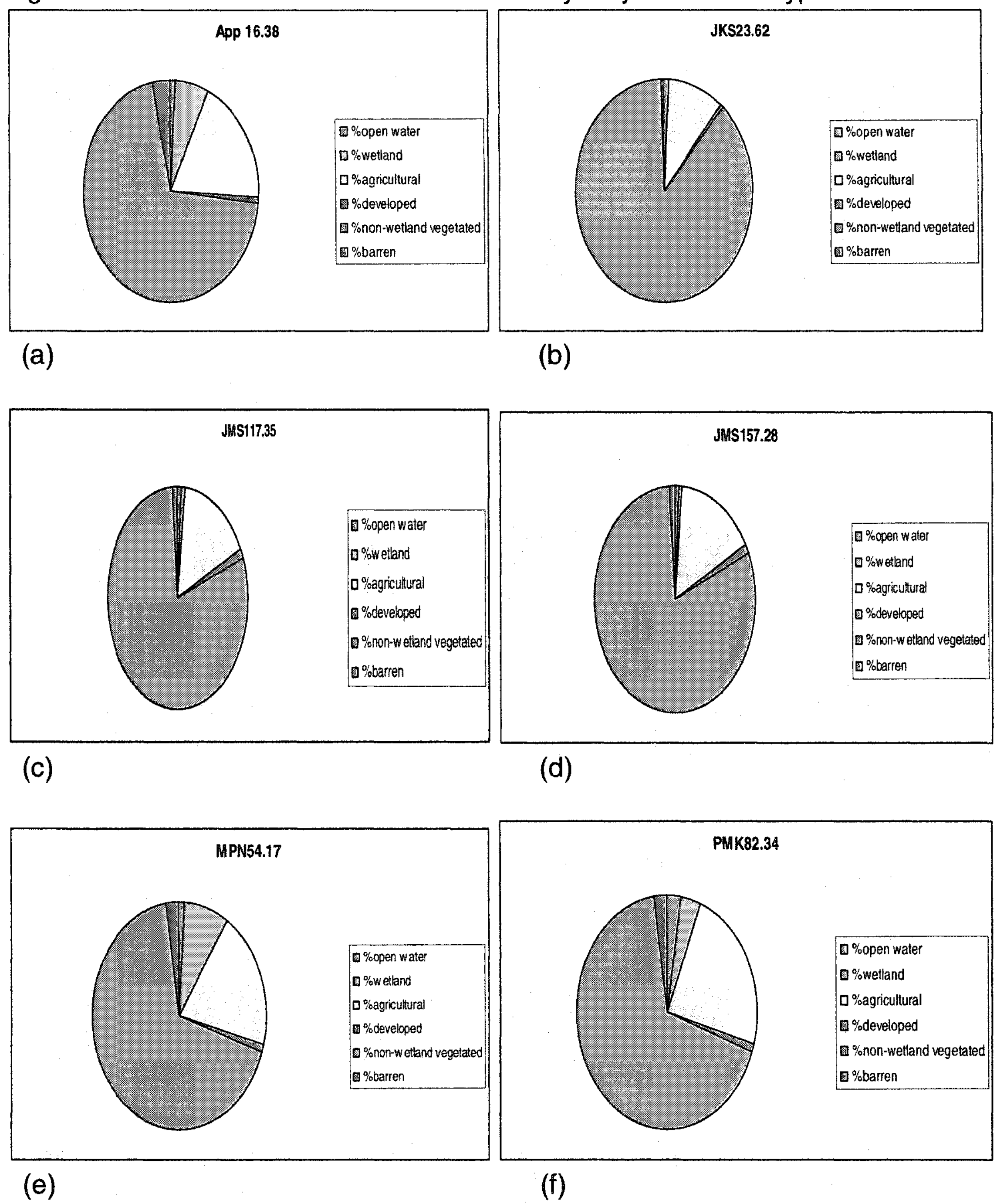

Table 3-6. Independent variables measured for each of the six watersheds. Variables are listed as they appear in the principal components analysis, / denotes ratio.

Character-izing:	*variable*	**APP16.38**	**JKS23.62**	**JMS117.35**	**JMS157.28**	**MPN54.17**	**PMK82.34**
Watershed	Area (km^2)	116.56	150.77	1728.00	1598.03	154.50	281.90
	shed-developed/wet	0.11	4.98	1.86	2.44	0.15	0.32
	shed-agriculture/wet	3.17	114.99	19.44	27.66	2.40	6.21
	shed - non-wetland veg/wet	11.92	1010.21	96.69	141.69	8.22	17.89
	shed-wetland%	5.98	0.088	0.83	0.057	8.30	3.85
	shed - barren/wet	0.53	3.20	1.34	1.84	0.27	0.56
	shed - veg%	77.23	89.12	81.18	81.71	76.58	72.72
	shed - dev/veg	0.0086	0.0049	0.019	0.017	0.017	0.017
	shed - ag/veg	0.25	0.11	0.20	0.19	0.26	0.33
	shed - barren/veg	0.041	0.003	0.014	0.013	0.030	0.030
	slope mean	2.561	14.976	9.277	9.79	2.932	3.238
	slope s.d.	1.716	8.226	7.841	7.914	1.939	2.121
	soil mean	1.476	5.04	2.956	3.086	3.903	1.826
	soil s.d.	0.974	1.746	1.924	1.935	2.157	1.306
Wetlands in watershed	PFO%	75.82	39.62	72.83	75.79	77.50	77.66
	PSS/PFO	0.15	0.22	0.14	0.11	0.15	0.10
	A-E/non A-E	10.09	23.50	15.47	59.42	9.35	10.17
	isolated wetlands%	6.110	40.556	12.023	14.097	5.437	5.201
Wetland buffers	wat/wetbuf	0.01	0.12	0.05	0.06	0.04	0.05
	veg%wetbuf	89.70	47.45	78.31	75.66	85.82	84.70
	dev/wetbuf	0.0035	0.0076	0.0067	0.0062	0.0060	0.0043
	wetag/wetbuf	0.084	0.98	0.21	0.25	0.096	0.12
	barren/wetbuf	0.016	0.002	0.0097	0.011	0.019	0.0097
100m stream buffers	buff-developed/wet	0.026	2.395	0.656	0.942	0.038	0.049
	buff - agriculture/wet	0.345	48.077	6.737	9.985	0.391	0.937
	buff - non-wetland veg/wet	2.865	225.907	29.427	43.773	2.321	4.026
	buff - wetland%	23.2	0.359	2.618	1.778	26.390	16.407
	buff - barren/wet	0.078	1.022	0.373	0.548	0.039	0.083
	buff - veg %	89.658	81.504	79.666	79.600	87.649	82.455
	buff - ag/veg	0.090	0.212	0.022	0.223	0.118	0.186
	buff - dev/veg	0.007	0.011	0.221	0.021	0.012	0.010
	buff - barren/veg	0.019	0.005	0.012	0.012	0.012	0.017
20m stream buffers	tbuff-developed/wet	0.040	0.753	0.150	0.192	0.031	0.048
	tbuff - agriculture/wet	0.141	17.831	2.160	2.991	0.335	0.421
	tbuff - non-wetland veg/wet	1.511	78.609	10.161	14.465	1.274	2.152
	tbuff - wetland%	36.894	1.014	7.381	5.332	37.640	27.348
	tbuff - barren/wet	0.018	0.447	0.076	0.007	0.016	0.035
	tbuff - veg %	92.657	80.706	82.381	82.460	85.609	86.204
	tbuff - ag/veg	0.0561	0.224	0.194	0.193	0.147	0.134
	tbuff - dev/veg	0.016	0.009	0.013	0.012	0.014	0.015
	tbuff - barren/veg	0.007	0.006	0.007	0.007	0.007	0.011

Table 3-7. Annual loads (in kg) of anthropogenic nutrient inputs for each of the six watersheds. Inputs were included as one combined total for each constituent in the regressions.

	APP16.38	JKS23.62	JMS117.35	JMS157.28	MPN54.17	PMK82.34
Atmospheric Nitrogen	312795	453977	4659043	4300000	426000	782000
Agricultural N	11619823	7083175	14464506	985347	14408296	29462589
Agricultural P	2479330	481168	6183519	6167823	1684614	4394220
Point source N	0	295326	1055693	1055693	2095	81288
Point source P	0	105470	452331	452331	843	31657
Total N	11932618	7832478	20179242	6341040	14836392	30325877
Total P	2479330	586638	6620154	6635851	1685457	4425876

Principal Components Analysis (PCA) yielded five principal components that accounted for 100% of the variance in the data (figure 3-3). Principal Component 1 (PC1)(Figure 3-4) is characterized primarily by wetland pattern across the watershed and within buffers. PC2 (Figure 3-5) relates to watershed area, the extent of vegetation and the relationship of developed area to vegetated area. PC3 (Figure 3-6) is related to soil permeability mean and standard deviation, as well as relationships between the ag and barren components compared to vegetative area. PC4 (Figure 3-7) describes the variability in developed and agricultural areas compared to vegetated areas in the 100 meter buffer, and PC5 (Figure 3-8) appears most closely linked to the proportion of hydrologic regimes of wetlands in the watershed.

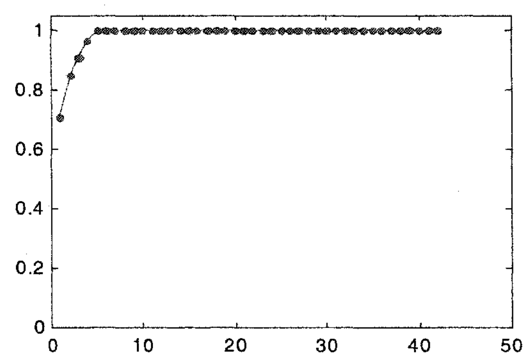

Figure 3-3. Principal components explanatory power. Principal components are on the x axis, cumulative ratio of whole data set explained by each component is on the y axis.

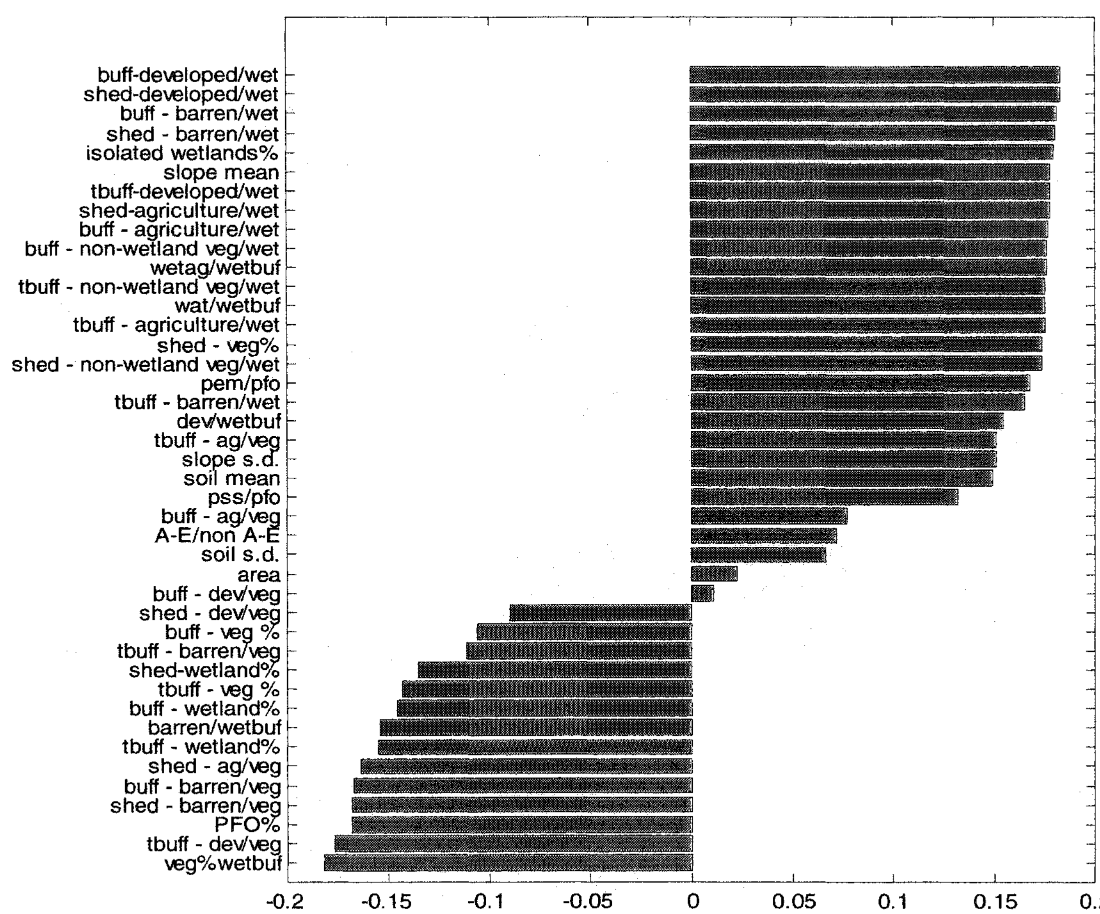

Figure 3-4. Loadings by variable for Principal Component 1 (PC1)

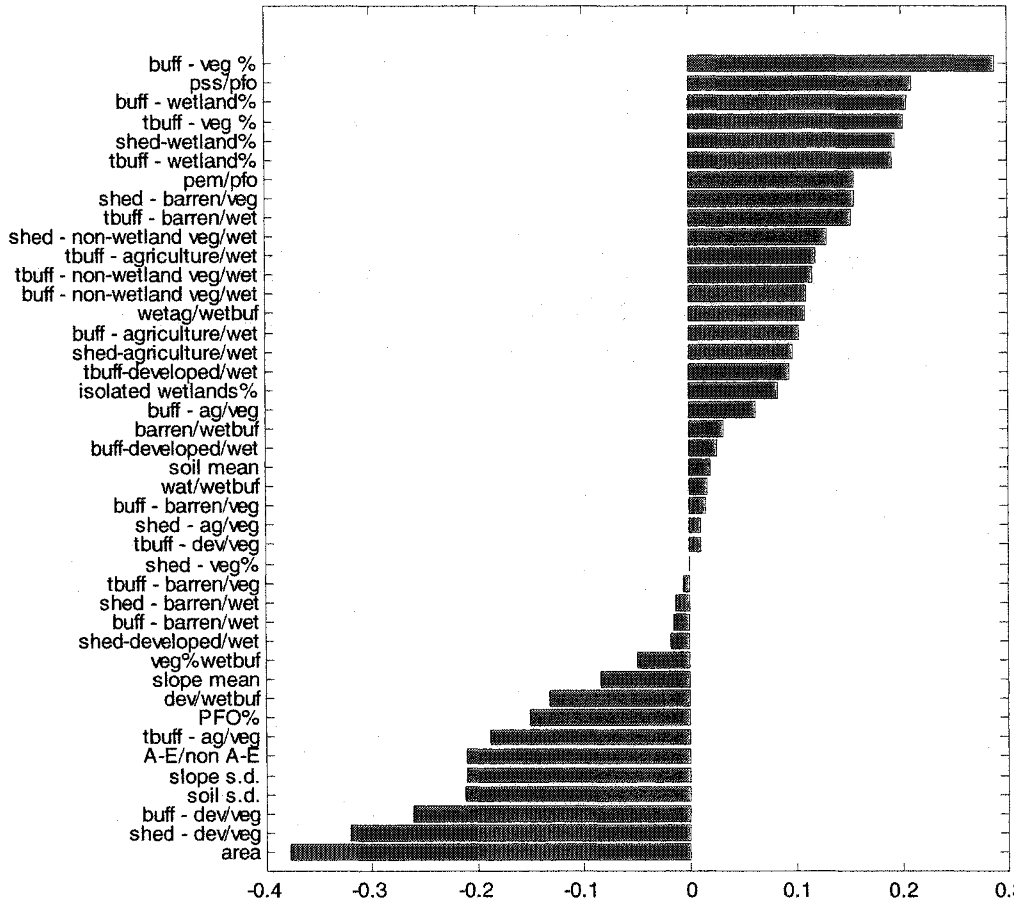

Figure 3-5. Loadings by variable for Principal Component 2 (PC2)

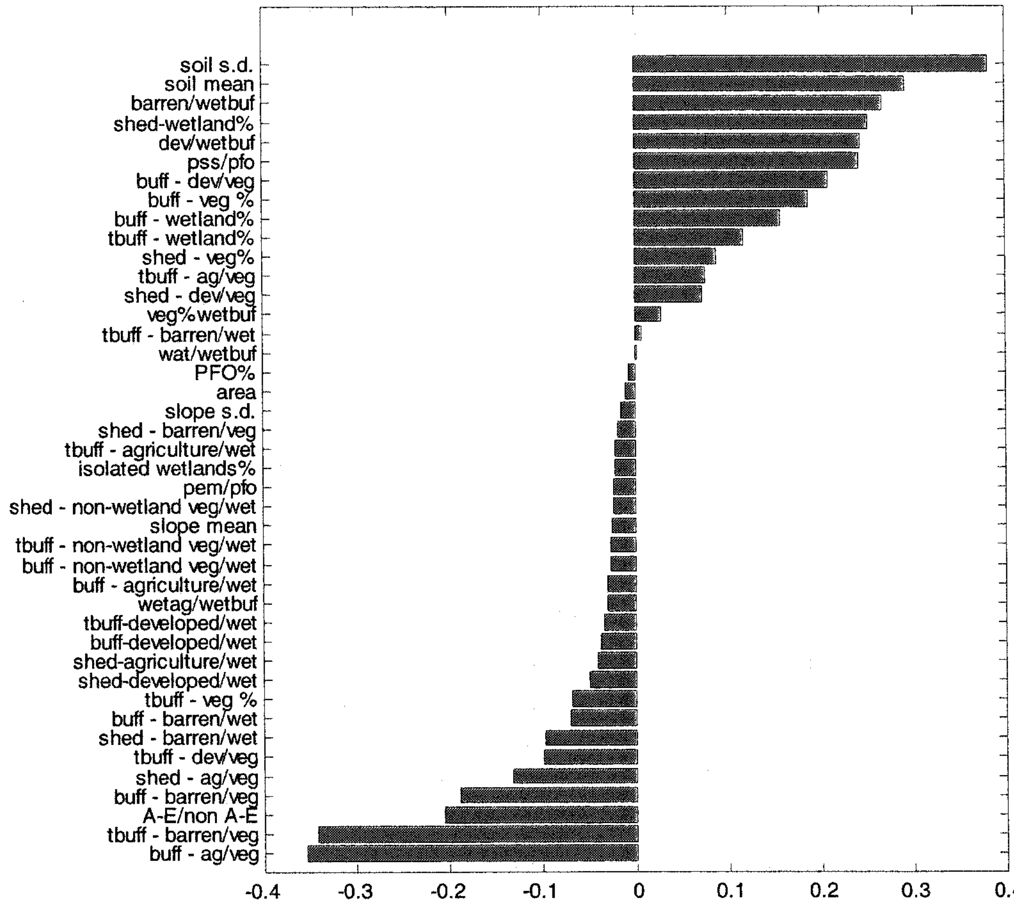

Figure 3-6. Loadings by variable for Principal Component 3 (PC3)

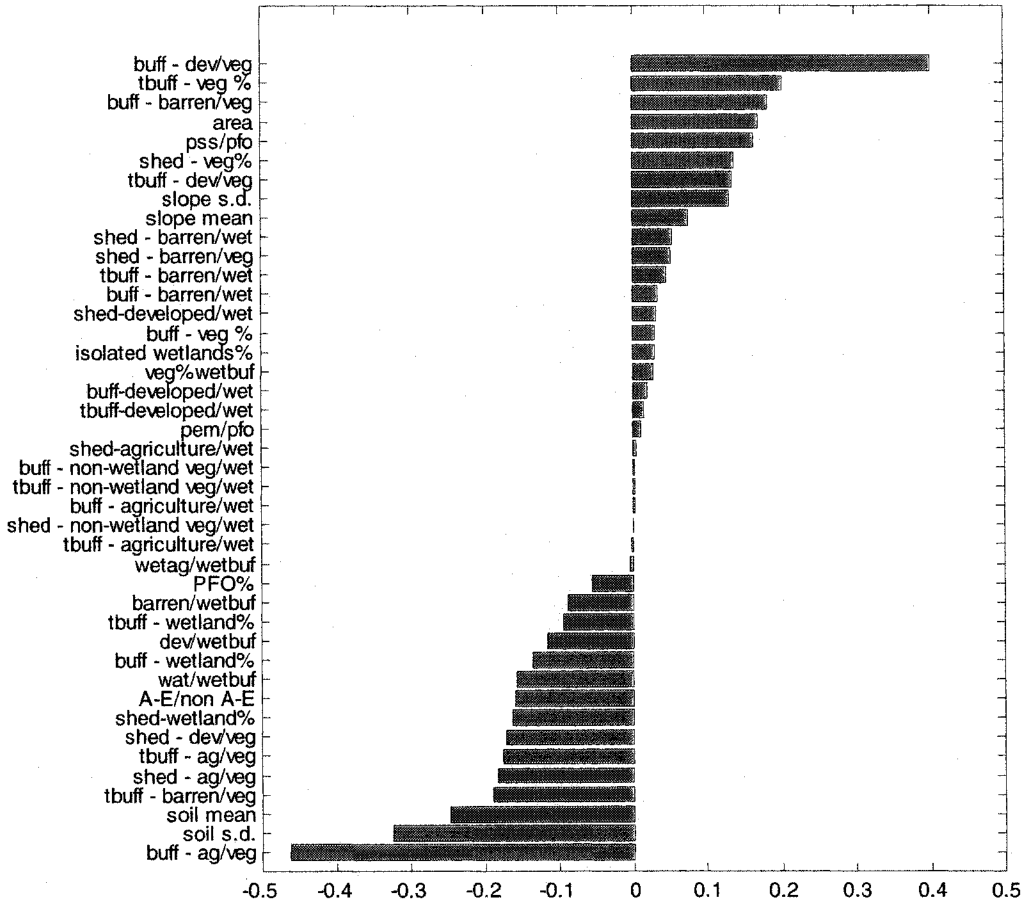

Figure 3-7. Loadings by variable for Principal Component 4 (PC4)

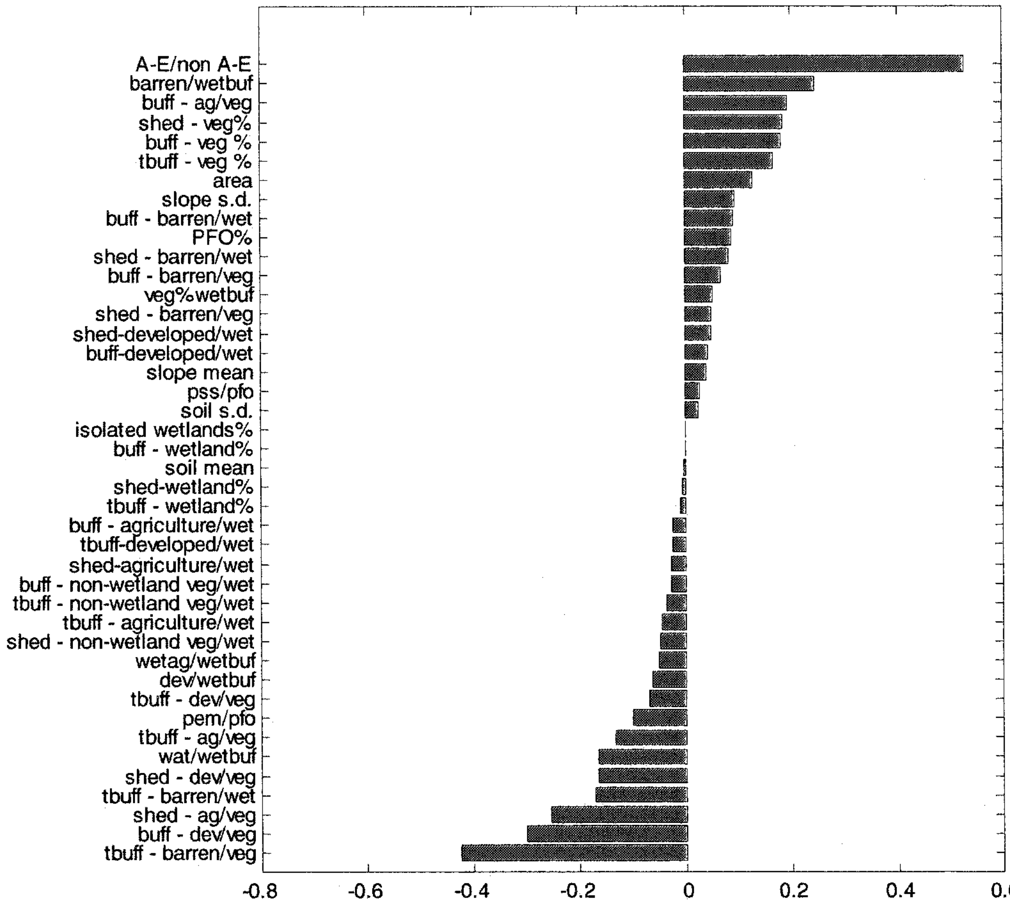

Figure 3-8. Loadings by variable for Principal Component 5 (PC5)

Stepwise multiple regressions were run for annual as well as seasonal loads. The results of the regression analyses show that PC2 is a significant and in many cases, *sole* contributing independent variable in each equation (Table 3-8). In general, negative coefficients imply improved water quality, and positive coefficients indicate a link to poorer water quality. The signs for each of the coefficients for principal components were then used to assess individual variable effects. For example, principal component two has a negative coefficient in all of the equations, meaning that PC2 is related to positive water quality. However, when one considers the loadings each of variables has, an increased percent of the 100 meter buffer which is vegetated is positively loaded on the components, and therefore might be said to have a positive effect (which one might intuit), but the extent of the watershed and the proportion of the 100 meter buffer which is developed, compared to vegetated is negatively loaded on the component: therefore one would conclude that those areas that have a relatively high developed to vegetated area would have decreased water quality. The inclusion of area as negatively related to water quality suggests that there is a "per unit area" increase in nutrient and suspended solids reaching waterways.

Principal Component 3 is negatively linked to total kjeldhal nitrogen (TKN) for the spring only. Since PC3 is related positively to soil porosity and deviation, and negatively to the ratio of agricultural to vegetated area, it may be showing that during the times of heaviest streamflow coupled with the timing of agricultural fertilizer application, the importance of soil retention time and vegetation available for excess nutrient uptake becomes critical for reducing nitrogen influxes to streams.

Principal Component 4 was positively linked to both TKN and total suspended solids (TSS). PC4 relates to proportions of the 100 meter stream buffer that either agricultural or developed compared to vegetated. In this case, it seems that agricultural fields are actually decreasing the flux into streams of TKN during the fall and winter and TSS during the spring, and that these effects are great enough to affect annual loads.

Principal Component 5 is positively related to TKN during the winter and spring, and TSS during the fall and winter. PC5 relates positively to the proportion of short-duration vs. long duration inundation of wetlands in the watershed, and negatively to the proportion of barren to vegetated areas within the 20 meter buffer. In terms of hydrologic regime, the results make sense as one might expect that decreased retention in wetlands leads to decreased removal of nitrogen and suspended solids prior to waters reaching streams. The higher loadings of the hydrologic regimes on the principal component may be the dominating factor here, as one would not expect that an increase of barren areas would lead to a decrease of nitrogen, much less sediment to the nearby waterways.

Anthropogenic inputs were significantly correlated to annual nitrogen loads. They are *negatively* correlated, implying that the higher the inputs, the more improved the water quality. Since it is hard to imagine how this might be the case, the results may be spurious. It is highly likely that anthropogenic inputs at the time of sampling may be decoupled from concurrent water quality measurements, due to aquifer retention times.

Table 3-8. Results of regression analyses for water quality variables. PC1 is omitted, as it was not found to be significant in any of the equations.

	Season	Adj. R^2 %	F	*p*	Regression coefficients					
					Constant	PC2	PC3	PC4	PC5	Anth. inputs
TKN N=6	Annual	98.8	141.22	0.007	1950059	-573205	-	334505		-0.037928
	Spring	95.2	34.11	0.029	401050	-130793	-99726	-	259677	N/A
	Summer	81.7	23.37	0.008	230393	-96424	-	-	-	N/A
	Fall	79.9	10.95	0.042	411702	-215659	-	270475	-	N/A
	Winter	97.7	70.65	0.014	331395	-113694	-	75825	75081	N/A
TN N=4	Annual	100	3939.55	0.011	3257992	-957308	-	-	-	-0.078809
	Spring	84.4	17.25	0.053	819521	-393976	-	-	-	N/A
	Summer	80.3	13.26	0.068	330984	-161747	-	-	-	N/A
	Fall	79.7	12.81	0.070	282753	-143702	-	-	-	N/A
	Winter	84.2	17.03	0.054	550839	-257403	-	-	-	N/A
TSS N=6	Annual	90.8	25.78	0.013	172141497	-91868932	-	48655430	-	N/A
	Spring	95.2	50.73	0.005	87730956	-47274148	-	32024778	-	N/A
	Summer	83.5	26.34	0.007	30643379	-16839159	-	-	-	N/A
	Fall	89.2	21.63	0.017	30643541	-16839204	-	-	9734573	N/A
	Winter	89.3	21.76	0.016	33443315	-16637839	-	-	11015612	N/A
TP N=6	Annual	70.2	12.76	0.023	461675	-184378	-	-	-	-
	Spring	71.8	13.72	0.021	188110	-80885	-	-	-	N/A
	Summer	68.4	11.83	0.026	73533	-28739	-	-	-	N/A
	Fall	61.4	8.97	0.040	76530	-28083	-	-	-	N/A
	Winter	66.9	11.09	0.029	123896	-46468	-	-	-	N/A

Discussion

The dominance of PC2, and the exclusion of PC1 in all of the regression equations shifts the focus of water quality improvement in this region to consideration of vegetation in the watershed as a whole, and specifically in the 100 meter buffer, rather than directly to wetland measures. These results are not too surprising given the dominance of vegetated areas in all of the watersheds studied, and the small proportion of vegetated area comprised of wetlands. The sample size of watersheds may not have been able to provide sufficient variability to separate out potential relationships between wetlands and water quality and the effects of vegetation in general. Legislatively, however, there is more protection given to wetland areas than specifically to forested areas. Lessons learned from this study would still be valid in informing wetland management.

Specifically, the importance of maintaining vegetative areas in the 100 meter buffers around streams is highlighted. Within the watersheds studied, the Chesapeake Bay Act and Regulations require that a vegetated buffer area at least 100-feet wide be located adjacent to all waterways and their contiguous wetlands. Although this study did not address the 100 foot buffer directly, the dominance of the100 meter buffer, rather than the 20 meter (approximately 60 feet) buffer in mediating water quality indicates that a wider buffer may be more appropriate to protecting water quality. Moreover, there may be relationships between other landuses within the watershed and the buffer area that can be used to determine optimal buffer size. For instance, the relationships between developed and vegetated areas, as represented in PC2, may play a more important role than the proportion of agriculture to vegetated areas. Caution should be taken though, to consider that there may be proportions at which these relationships change, e.g., in the case of agricultural rather than vegetatively dominated watersheds.

Soil permeability was also found to be linked to nitrogen levels, these results agree with the findings of Preston and Brakebill (1999) for the Chesapeake Bay. They consider that soil permeability may shunt the course of nitrogen compounds into groundwater pathways that increase detention times and potential for losses through denitrification.

In conclusion, while this study was able to provide general support for the concept of conserving wetlands and other vegetated areas to mediate water quality, additional studies with larger sample sizes would be of great benefit in further defining relationships that might be used in wetland and landscape management efforts to improve water quality.

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Chapter 4. Amphibian Habitat Cumulative Impact Assessment

Introduction

Since the late 1970's there has been increasing concern over worldwide declines in amphibian populations (Phillips 1990, Blaustein and Wake 1990, Wake 1991). Hypotheses for the declines have included such potential factors as UV radiation increases due to depletion of the ozone layer, the greenhouse effect, acid rain, water pollution and drought, and it is most likely due to a combination of factors. Loss of habitat, however, stands out as a significant overriding factor affecting many species today, and most likely sets the stage for increased impacts from other negative influences (Barinaga 1990, Blaustein and Wake 1990). Amidst concerns of habitat fragmentation as a hazard for many populations, amphibians exhibit the characteristic of using habitat types that are naturally discontinuous in the landscape. Fragmentation within this context involves the loss of habitat patches, which may affect populations not only by loss of habitat area, but also by potentially isolating the remaining patches by altering the proximity of patches to each other. The spatial structure of amphibian habitats, with their dependence on both discrete habitat types within the landscape and the dispersal of individuals between habitat sites, demonstrates the characteristic metapopulation distribution (Hanski and Gilpin 1991, Hecnar and M'Closkey 1996). Species exhibiting metapopulation dynamics are susceptible to population declines from habitat isolation, due to the decreased likelihood of local sub-populations being "rescued" from extinction by immigration from neighboring populations. Amphibians, due to physiological constraints, site fidelity and limited dispersal ability, are particularly susceptible to fragmentation (Blaustein, et al. 1994). Species richness of amphibians has been negatively correlated with wetland isolation and road density of the intervening landscape (Lehtinen et al.1999). Semlitsch and Bodie (1998) have noted the potential effects of NWP 26 related loss of small wetlands on amphibian metapopulations, based solely on dispersal distances. Their results demonstrated that loss of small wetlands may decrease the chance of local population rescue and result in loss of diversity in the regional amphibian fauna.

Amphibians have been chosen as indicator species for ecosystem health, as they are abundant, integral components of many different ecosystem types, and often function as local top predators (Wake 1991). This fact, coupled with their dependence on wetlands and the connectivity of population dynamics between habitat patches lend themselves to use in modeling the effects of wetland habitat loss across the landscape.

For this model, amphibian species found in the coastal region of southeastern Virginia were used to estimate the potential effects of wetland loss by size class, as size is often a primary determinant in wetland regulation. The decision was made to model wetland habitat that was connected through terrestrial, rather than aquatic dispersal to simplify movement dynamics. Mole salamanders, of the genus *Ambystoma,* typically make use of seasonal to semi-permanent wetlands for breeding, while relying on nearby upland habitat throughout the remainder of the year. The wetlands used for breeding are typically isolated from watercourses that would introduce the pressure of fish predation (Sexton and Bizer 1978). Ambysomids found in southeastern Virginia include the eastern tiger salamander (*Ambystoma tigrinum tigrinum*) and Mabee's salamander (*Ambystoma mabeei*). Both of these species are on Virginia's threatened and endangered list. Threats to these species include both terrestrial and aquatic habitat loss, acid precipitation causing declines in pH, genetic pollution from introduced Midwestern waterdogs sold as fishing bait, and predation from fish stocked in breeding ponds. (Mitchell et al. 1999)

This paper reports the results of applying a spatially explicit landscape and metapopulation model to assess the effects of wetland habitat loss on *Ambystoma* populations. Geographic Information System (GIS) maps and general ambystomid life history parameters were used to define simulations created by the Program to Assist in Tracking Critical Habitat (PATCH), put out by EPA's National Health and Environmental Effects Research Laboratory Western Ecology Division

Ambystomids have more limited dispersal capabilities than most amphibians, and the results should therefore provide a conservative estimate of the importance of differing size classes of seasonally inundated palustrine wetlands in the persistence of the amphibian metapopulations that make use of them for breeding habitat

Study site

The general study area is the southwestern shore of the Chesapeake Bay. The two sites chosen for study coincide with known county occurrences for *Ambystoma mabeeii* and *Ambstoma tigrinum tigrinum,* and were further defined to areas isolated by local waterways (figure 4-1) The northern site contains 480 potential breeding wetlands, accounting for 1476 hectares of habitat, while the southern site has 1241 hectares dispersed amongst 980 individual wetlands.

Methods

Parameterizing of the PATCH model:

PATCH is a females only model, requiring that the species have territories associated with each individual. Since amphibians are not territorial, "territories" were assigned by using carrying capacity numbers to estimate the areal extent

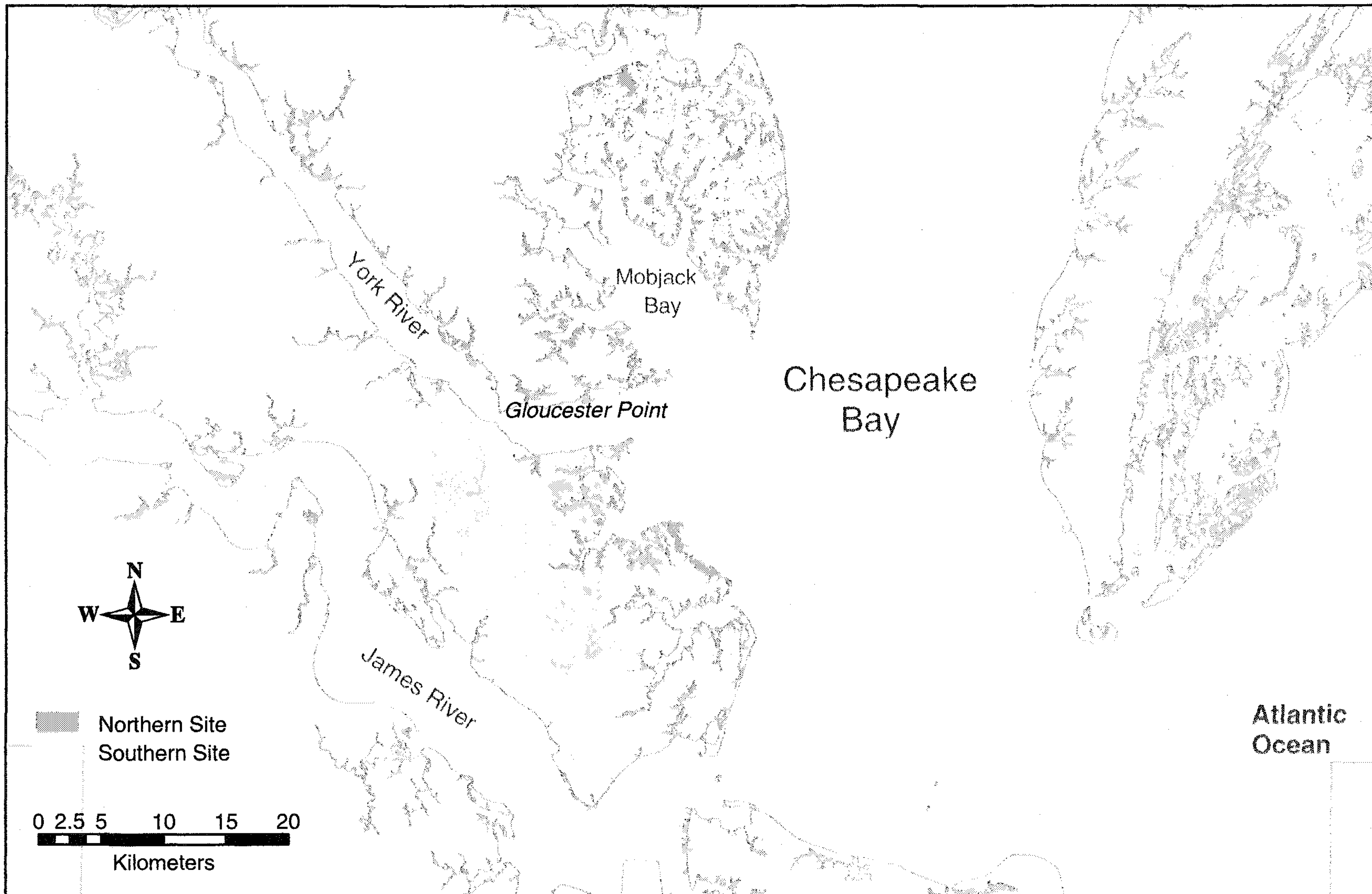


Figure 4-1 Ambystoma Wetland Habitat Sites

required to support a single breeding individual. PATCH allows you to set minimum and maximum territory sizes, where the minimum is the territory size in optimal breeding habitat, and the maximum is reached in marginal habitat. In this study, optimal territory was set at 60 m^2, with a maximum territory size of 400m^2 , based on the work of Graham et al (1999)

In addition to supplying the required maps, PATCH requires that habitat affinities, movement behavior, and vital rates matrices be provided for the model.

Habitat affinities:

Palustrine forested wetlands with non-tidal hydrologic regimes of C (denoting "seasonal", see Cowardin et al., 1979) or greater were considered to be potential breeding territory for Ambystoma species. Digitized coverages of National Wetlands Inventory maps were selected for these particular wetland types.

Land use was characterized for a 100-meter buffer around each of the wetlands. Land use data was obtained from the EPA's National Land Cover Data (NLCD). The area in terms of percent of the buffer made up of each land use was weighted according to the following:

Water – 1.0

Forest – 1.0

Low density residential – 0.5

Pasture/hay – 0.5

High density residential – 0.0

Row crops - 0.2

Barren - 0.1

Industrial – 0.o

The resultant scores were then used to characterize the wetlands in terms of habitat quality, on a scale of 1 to 10, with 1 being the worst habitat, and 10 completely optimal (Figures 4-2 and 4-3).

Water as part of the wetland buffer was considered to be an optimal habitat, as it provides the habitat necessary for breeding, egg laying and larval stages.

Forested buffer area was also considered to contribute to provide optimal habitat both specifically for habitat, but also for it's capacity to filter toxins and nutrients prior to interacting with the wetland environment, and in modifying aquatic temperatures (Knutson et al, 1999).

Low density residential is defined within the landuse cover as being 30 to 80% vegetated. This factor is moderated by the possibility that the vegetation may include intensively managed lawn areas, with the potential to add harmful pesticide and nutrient loads to the breeding wetland (Knutson et al 1999).

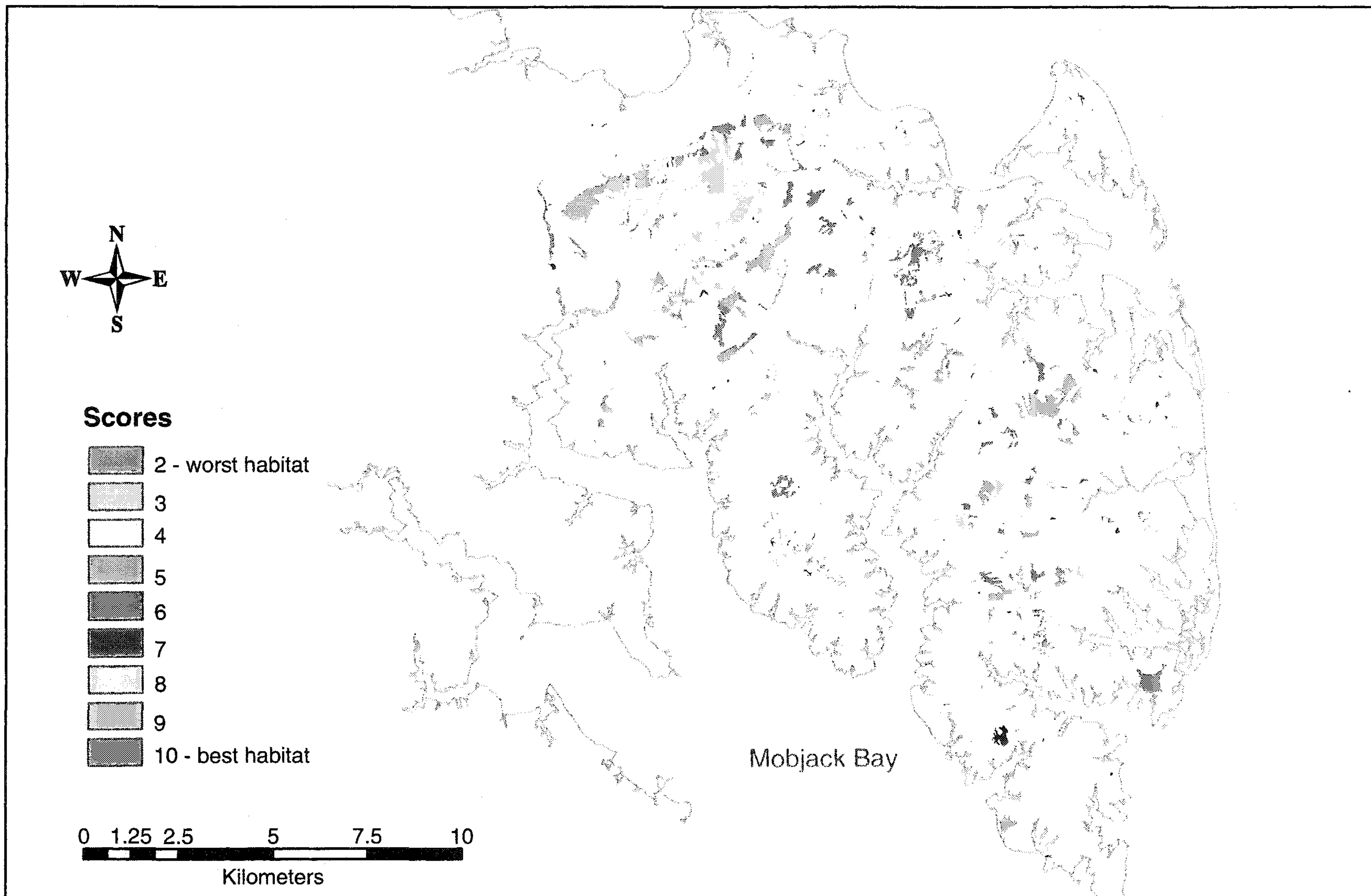


Figure 4-2. Surrounding Landuse-based Weights of All Ambystoma Wetland Habitat in Northern Site

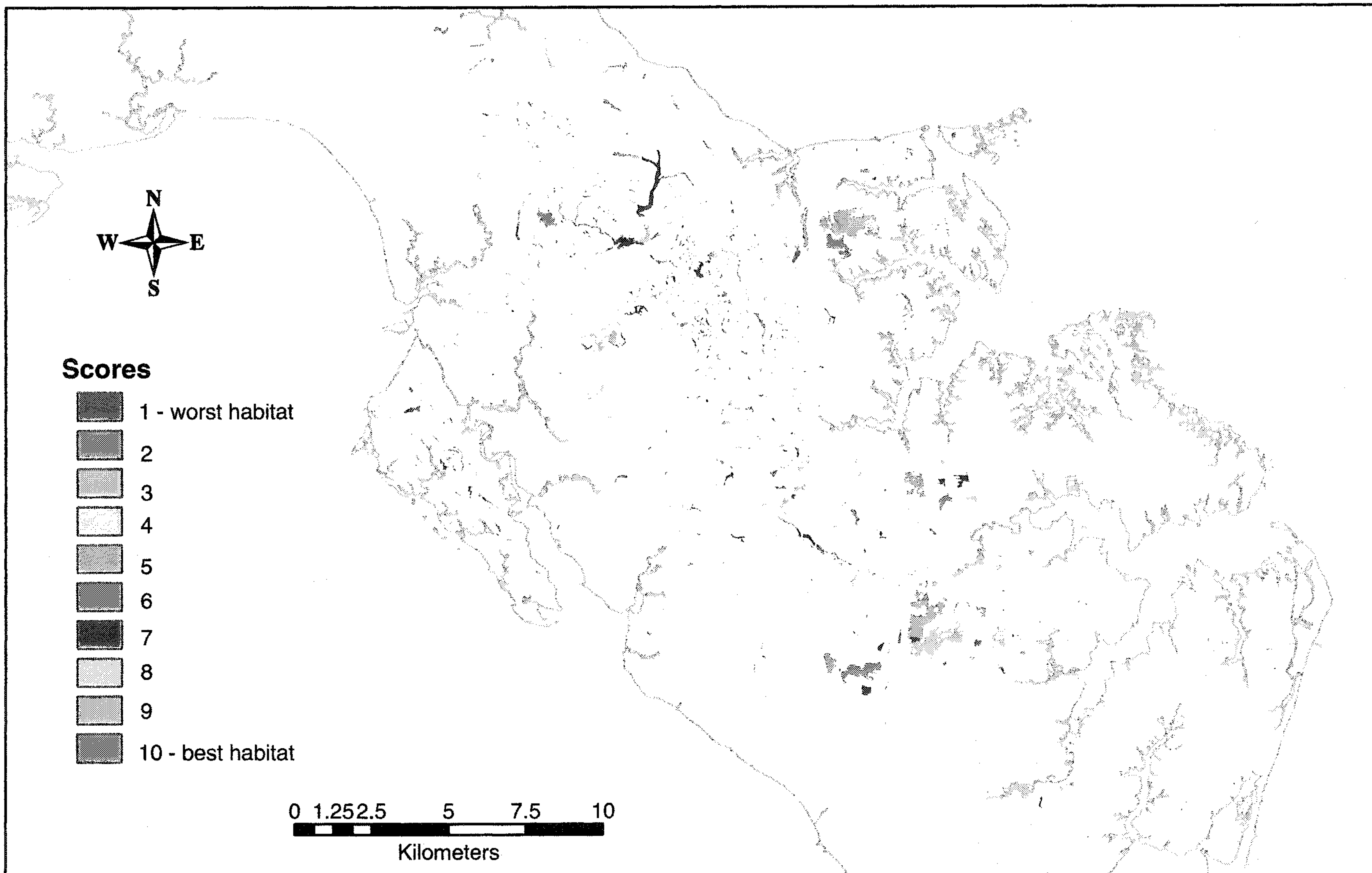


Figure 4-3. Surrounding Landuse-based Weights of All Ambystoma Wetland Habitat in Southern Site.

High density residential refers to urban-type housing developments, where the vegetation component is less than 20% of the cover, and "constructed materials" accounting for 80 to 100% of the cover. Lehtinen et al. (1999) found that amphibian species richness was negatively correlated with proportion of urban land-use, and caution that urbanization may not only decrease habitat and increase toxin fluxes into nearby wetlands, but may limit reproductive success in the surrounding watershed due to extreme water level fluctuations.

Agricultural land uses were divided in two separate agricultural classes, due to the differing nature of farm management involved.

Pasture/hay areas in general are not intensively managed in terms of nutrient or pesticide application, and they provide considerable cover for migrating or foraging amphibians.

Row crops are far less likely to provide suitable habitat. Amphibian populations may be decreased in agricultural settings due to the effects of fertilizers and pesticides (Howe et al. 1998, Freemark et al. 1995 and Hanson et al. 1994), decreased vegetative cover, and burrow disturbance or hindrance caused by the soil compaction that results from the use of large farm equipment. Tilled fields are most likely inhospitable for many amphibian species (Bonin et al. 1997, in Knutson 1999).

Barren –includes areas characterized by bare rock, gravel, sand, or other non-vegetated substrate, and include strip mines, quarries, gravel pits and other exposed earth areas that would be inhospitable to amphibians.

Industrial – includes roads, highways and all developed areas not classified as high intensity residential. These areas would most likely be devoid of amphibians, and may in fact cause increased mortality for surrounding populations.

Movement behavior:

The PATCH model specifies that young of the year move to seek territories, and older individuals without territories move to find breeding habitat. Additionally, site fidelity must be specified to say whether individuals are likely to leave their territories in search of new and/or better breeding areas, combined with information on the habitat affinity rating of the current site.

Amphibians are believed to be non-random in choosing migratory directions. Members of the Ambstoma genus have been shown to not only have high breeding site fidelity from year to year, but individuals have been seen to actually reenter a breeding pond from the same direction and in the same location each time (Dodd and Cade 1998).

Movement in the model was therefore directed to the nearest available breeding site as if they had complete knowledge of the landscape.

Movement occurs twice per year: once as the young of the year disperse in the fall away from their natal sites, and in the spring to drive movement of adults to breeding habitat just prior to breeding. The limitations of the model specifies that very juvenile must disperse from their natal site.

It has been suggested that dispersal of amphibian species can range from less than 100m to 1500m or more (Lehtinen et al. 1999). Estimates for average dispersal distances of Ambystomids vary greatly in the literature. One summary of available information suggests a range as high as 625 meters (Semlitsch 1998). Graham et al. (1999) calculated that the likelihood of an ambystomid salamander (*macrodactylum*, in this case) to disperse a given distance from a breeding pond remains steady from the pond edge to 250 meters out, then decreases linearly from 250 meters to a value of 0 at 750 meters away In a radio tracking study of *Ambystoma tigrinum melanostrictum* (Richardson et al. 1999), none of the tagged animals traveled more than 150m from the pond where they were captured. For the purposes of this study, dispersal limits were placed at a maximum distance of 660m from the wetland.

Vital rates matrix:

Survival rates and fecundity were handled in PATCH in the form of a Lefkovitch (stage structured) projection matrix (reference Caswell 2001). The PATCH model includes a post-breeding census; therefore the first entry of the matrix is always 0 as the first age or stage class will not yet be of breeding age.

Because PATCH is an individual based, spatially explicit model, survival and reproduction are calculated based not only by the input matrix, but also by modeling the influence of less-than optimal habitat on the matrix parameters. In the absence of evidence suggesting a more complex relationship, these influences were scaled linearly, with matrix inputs considered to reflect conditions in optimal habitat.

Although data exist for number of eggs per female for all *Ambystoma* species (e.g., Martof et al. 1980), evidence of stage specific mortality rates were not available. Similarly, information is lacking in the literature (see, for example, Halley et al. 1996) to estimate an intrinsic rate of increase with which to frame demographic variables. We do know that ambystomids live lifespans on the order of 10-15 years, and take several years to reach sexual maturity. Variables were therefore set by conducting sensitivity analysis under beginning conditions (i.e., the full complement of wetlands), which would allow for a gradually increasing population.

The stage-structured population and relevant matrix terms are shown in figure 4-4.

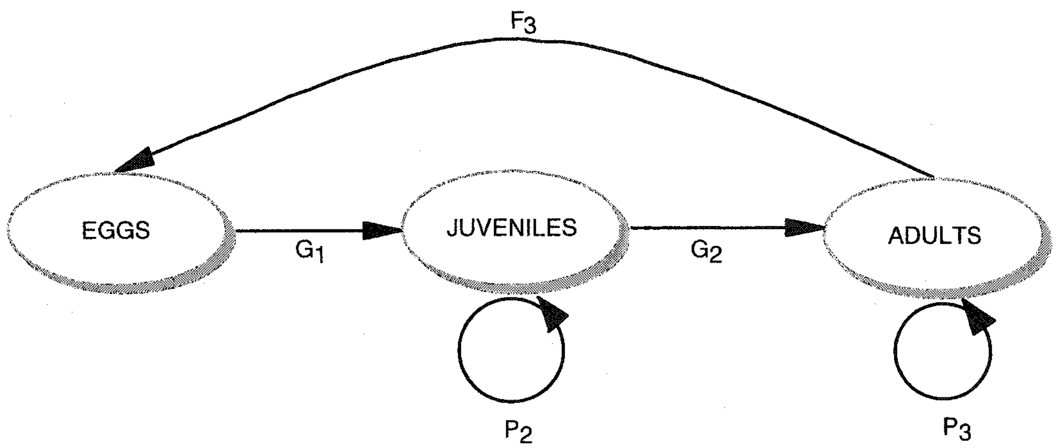


Figure 4-4. Diagram of life stages and demographic links.

Translating these terms into matrix format gives us:

$$X_{Ambystoma} = \begin{matrix} P_1 & F_2 & F_3 \\ G_1 & P_2 & 0 \\ 0 & G_2 & P_3 \end{matrix}$$

where:

X is the vital rates matrix

P is the probability that an individual will survive the year and remain in its current stage

G is the probability that an individual will survive the year and mature to the next stage

and

F is the fecundity, in terms of females per female per year

Since all eggs mature to the juvenile stage in the first year, and juveniles do not produce any offspring, the matrix becomes:

$$X_{Ambystoma} = \begin{matrix} 0 & 0 & F_3 \\ G_1 & P_2 & 0 \\ 0 & G_2 & P_3 \end{matrix}$$

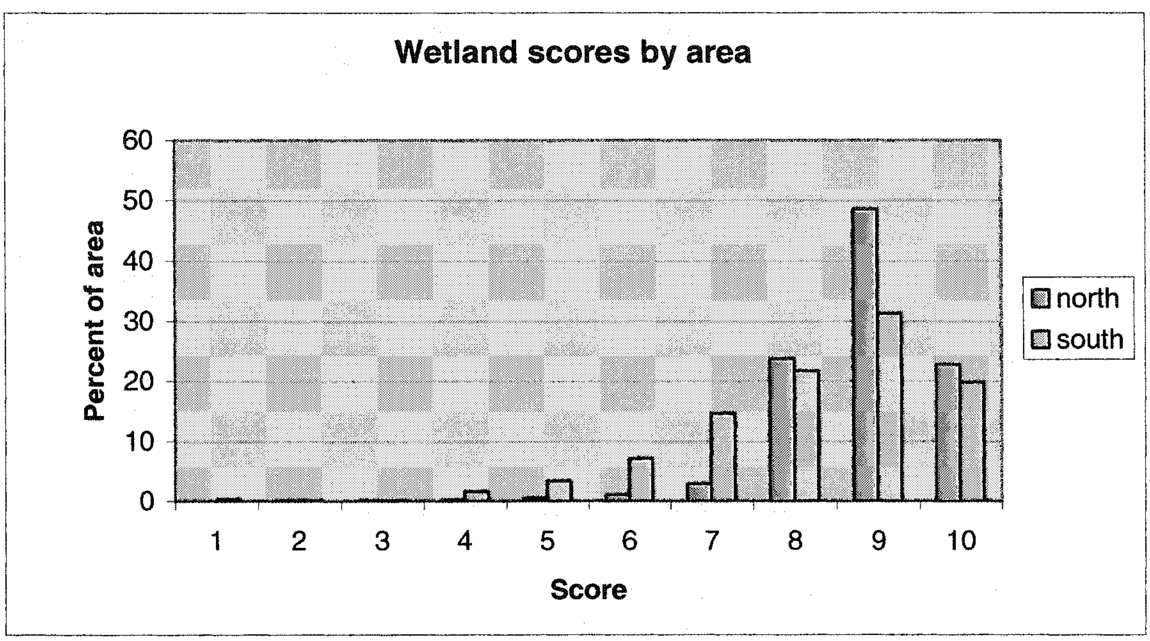
The estimates arrived at to simplify the population dynamics to a steady and moderate increase, given an initial population of 200 adult females dispersed into optimal habitats are:

$$X_{Ambystoma} = \begin{matrix} 0 & 0 & 40 \\ 0.1 & 0.3 & 0 \\ 0 & 0.1 & 0.5 \end{matrix}$$

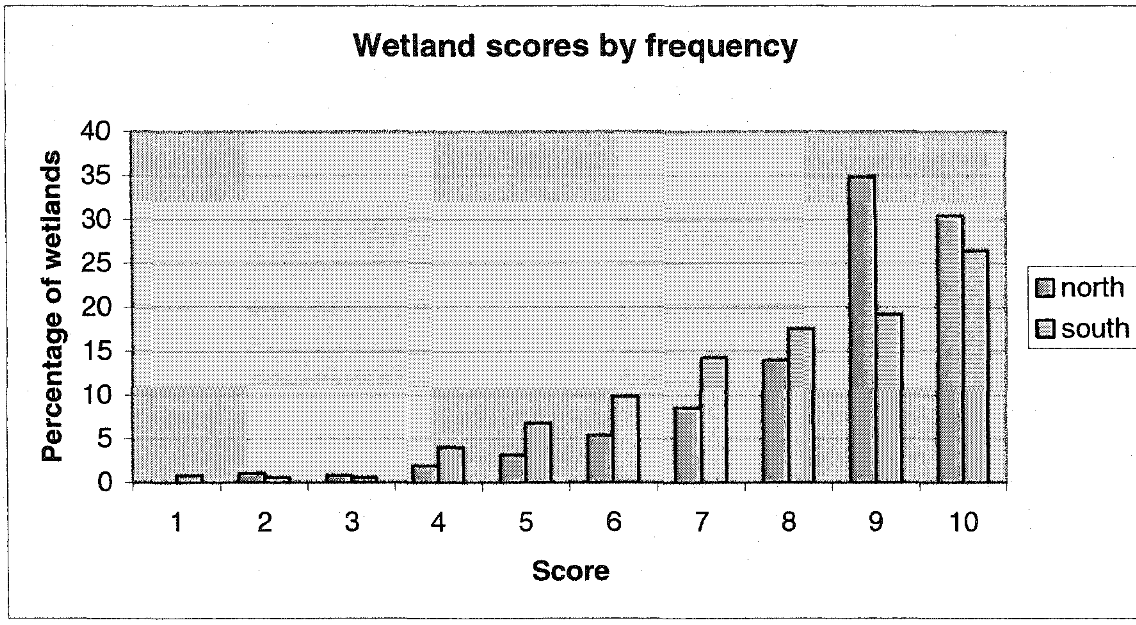
Habitat affinities, movement behavior, and the vital rates matrix were kept constant for each run as a control measure. For the base wetland complement, the model was run for 100 replicates of 50 years each. For assessing the effects of the wetland loss scenarios, the model was run for 20 years, allowing the population to equilibrate. In the 21st year of the simulation, habitat maps were exchanged from the base map to the “scenario” map reflecting wetland loss, and the simulation allowed to run for an additional 30 years to complete the 50 year time series. Each of these simulations was also run for 100 replicates for each of the scenarios.

Results

Habitat scores for both sites were generally high, reflecting the large amount of forested land in both areas. Scoring of the wetland habitat resulted in relatively higher scores by *frequency* than if one considers the same data by *area* (figure 4-5). This suggests that at least some of the larger wetlands scored lower than their smaller counterparts



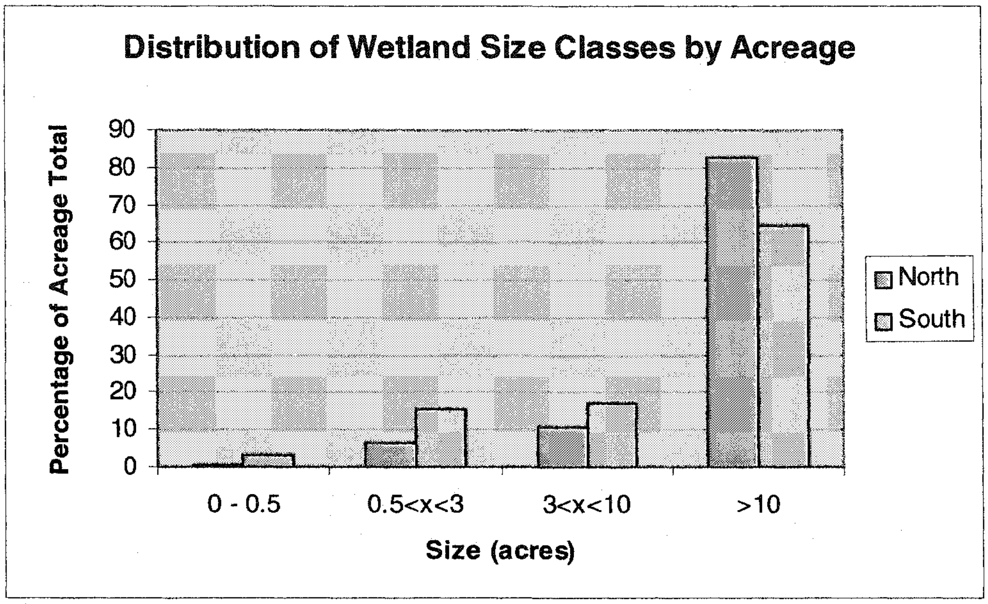
(a)



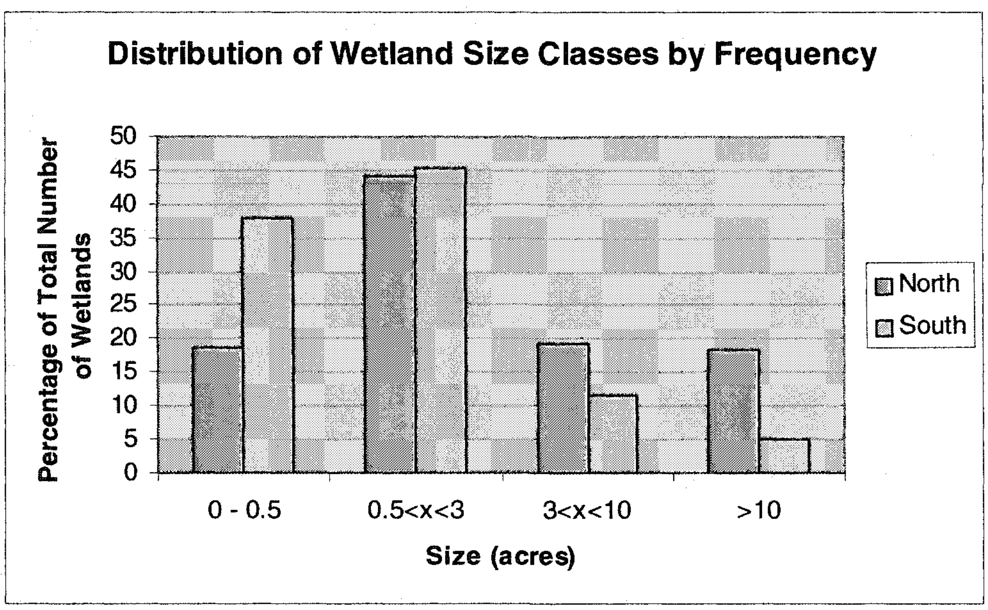
(b)

Figure 4-5. Results of habitat scoring for all study wetlands by surrounding landuse in a 100 meter buffer by (a) area and (b) frequency

Complete loss of the complement of wetlands in lower size classes, particularly in the less than 0.5 acre category, does not substantially reduce the overall *acreage* of potential habitat available, but it greatly affects the *abundance* of wetlands found throughout the landscape (figure 4-6)



(a)



(b)

Figure 4-6. Distribution of tested size classes of wetlands, by (a) overall acreage and (b) frequency of occurrence.

The only loss scenario showing a significant change in population size was the effect of losing all less than 10 contiguous acre wetlands, and only for the northern site (Table 4-1).

Table 4-1. T-test results of population size at 50 years

		Mean (±S.E.)	P (0.05)
North	All wetlands	611 (± 33)	-
	Greater than ½ acre	592 (± 31)	0.68
	Greater than 3 acres	568 (± 34)	0.37
	Greater than 10 acres	391 (± 25)	0.00
South	All wetlands	697 (± 35)	-
	Greater than ½ acre	696 (± 39)	0.99
	Greater than 3 acres	736 (± 37)	0.45
	Greater than 10 acres	733 (± 62)	0.61

However, patterns of *occupancy* were greatly shifted through the scenarios, and relative abundance, or frequency of wetlands proved more influential on occupancy rates than acreage. Loss of those wetlands totaling less than 3 contiguous acres had the greatest impact on occupancy rates, shifting a greater proportion of the wetlands remaining to less frequent occupancy (figures 4-7 and 4-9). Correspondence analyses confirm the substantially increased impact of the loss of the less-than-three-acre size class wetlands on occupancy rates for both sites (figures 4-8 and 4-10).

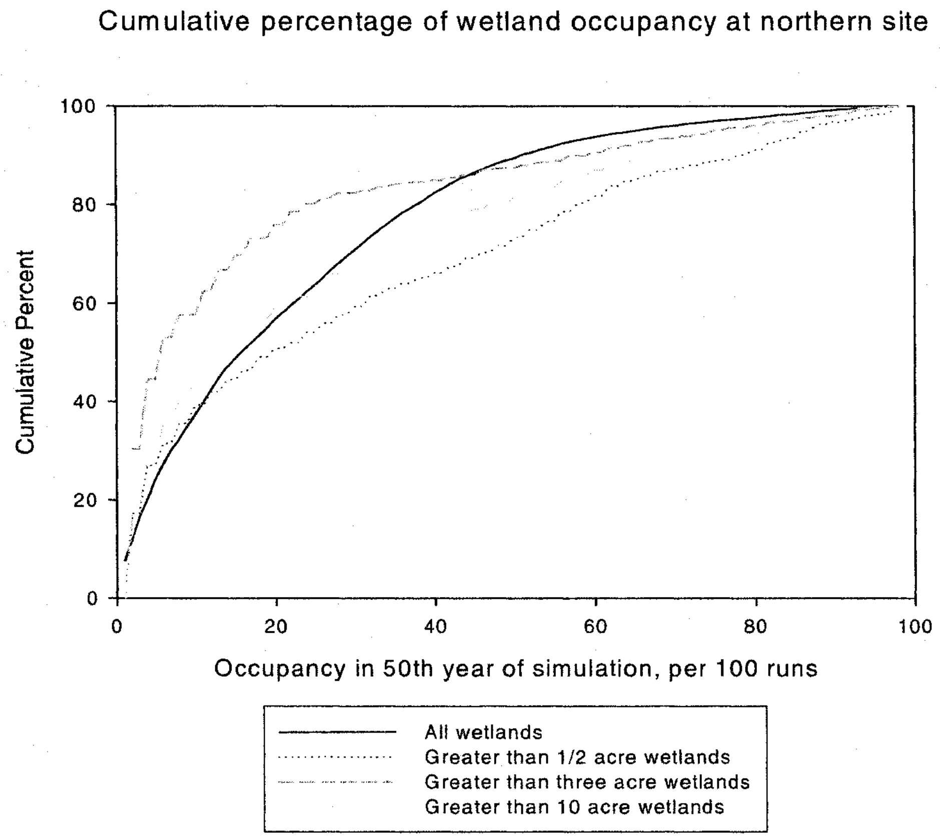


Figure 4-7. The effects of wetland loss scenarios on occupancy rates for the northern site.

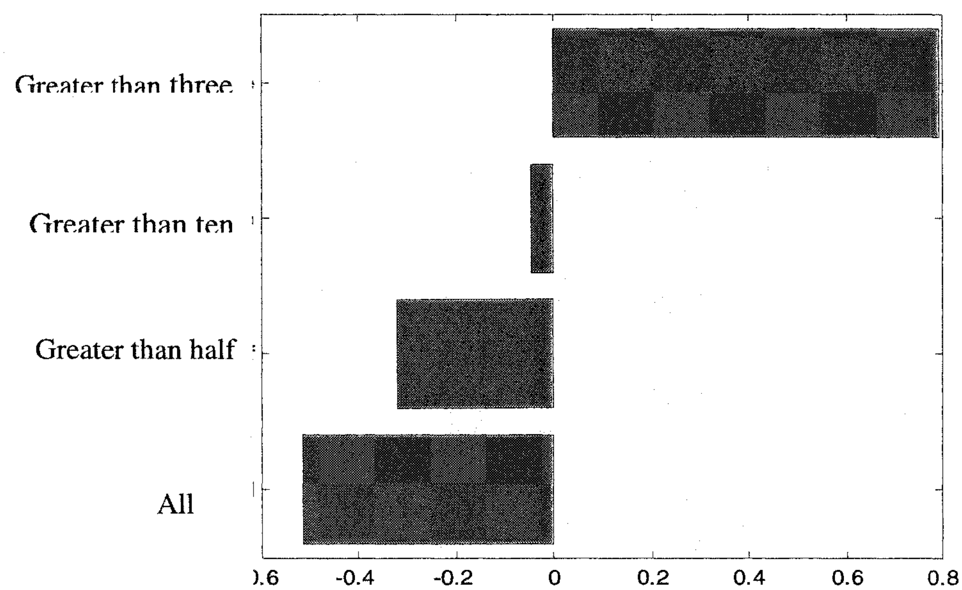


Figure 4-8. Correspondence analysis of occupancy rate curves for the northern site.

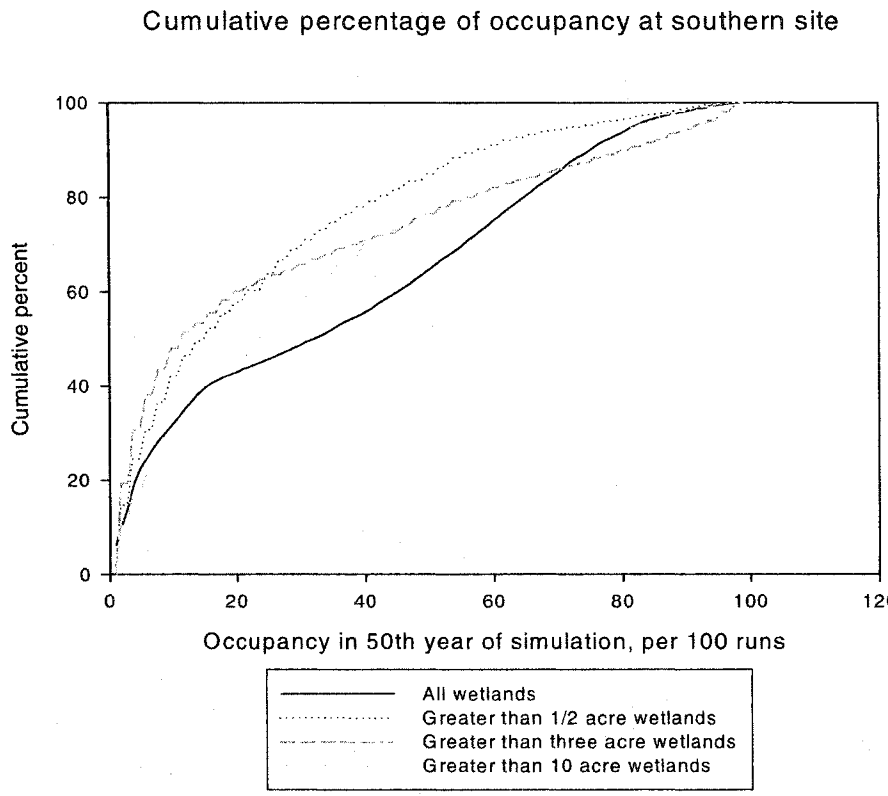


Figure 4-9. The effects of wetland loss scenarios on occupancy rates for the southern site.

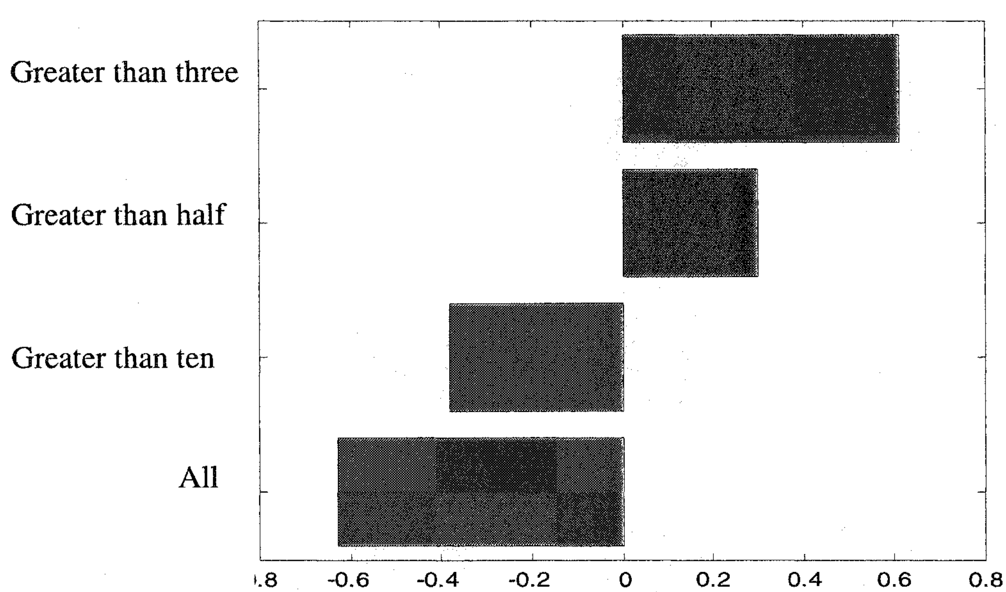


Figure 4-10. Correspondence analysis of occupancy rater curves for the southern site.

Consideration of the mapped distribution of the sites occupied overall, however, shows the greatest magnitude of change in the number of sites occupied at the 0.5 acre loss level, resulting in a mere quarter to a third of the occupancy retained (figures 4-11 through 4-18). Note that the loss of these small wetlands themselves is difficult to impossible to detect at this scale. However, the effect of their loss on occupancy of nearby sites is evident.

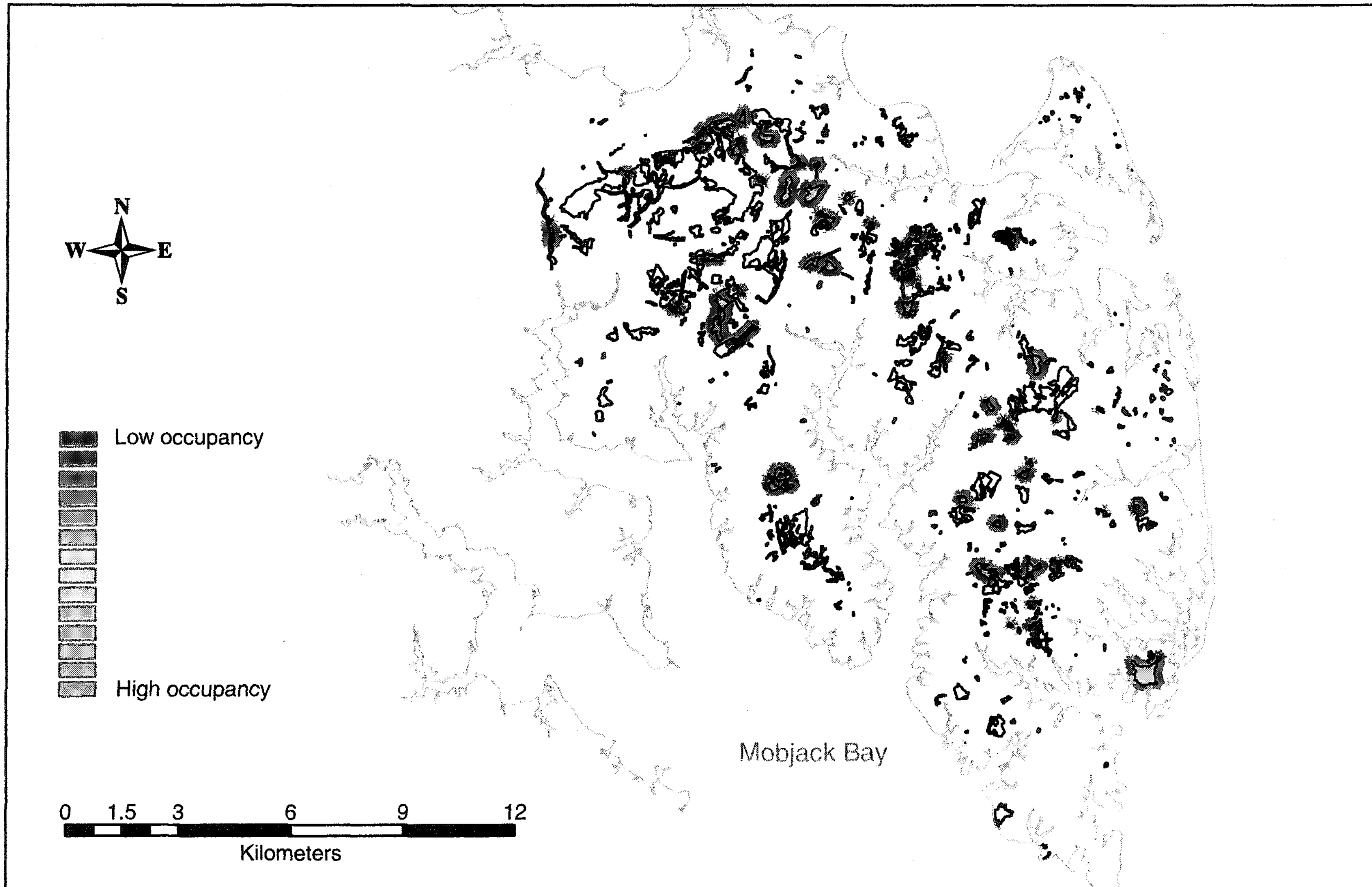


Figure 4-11. Occupancy Rates of All NWI Wetlands in Northern Site.

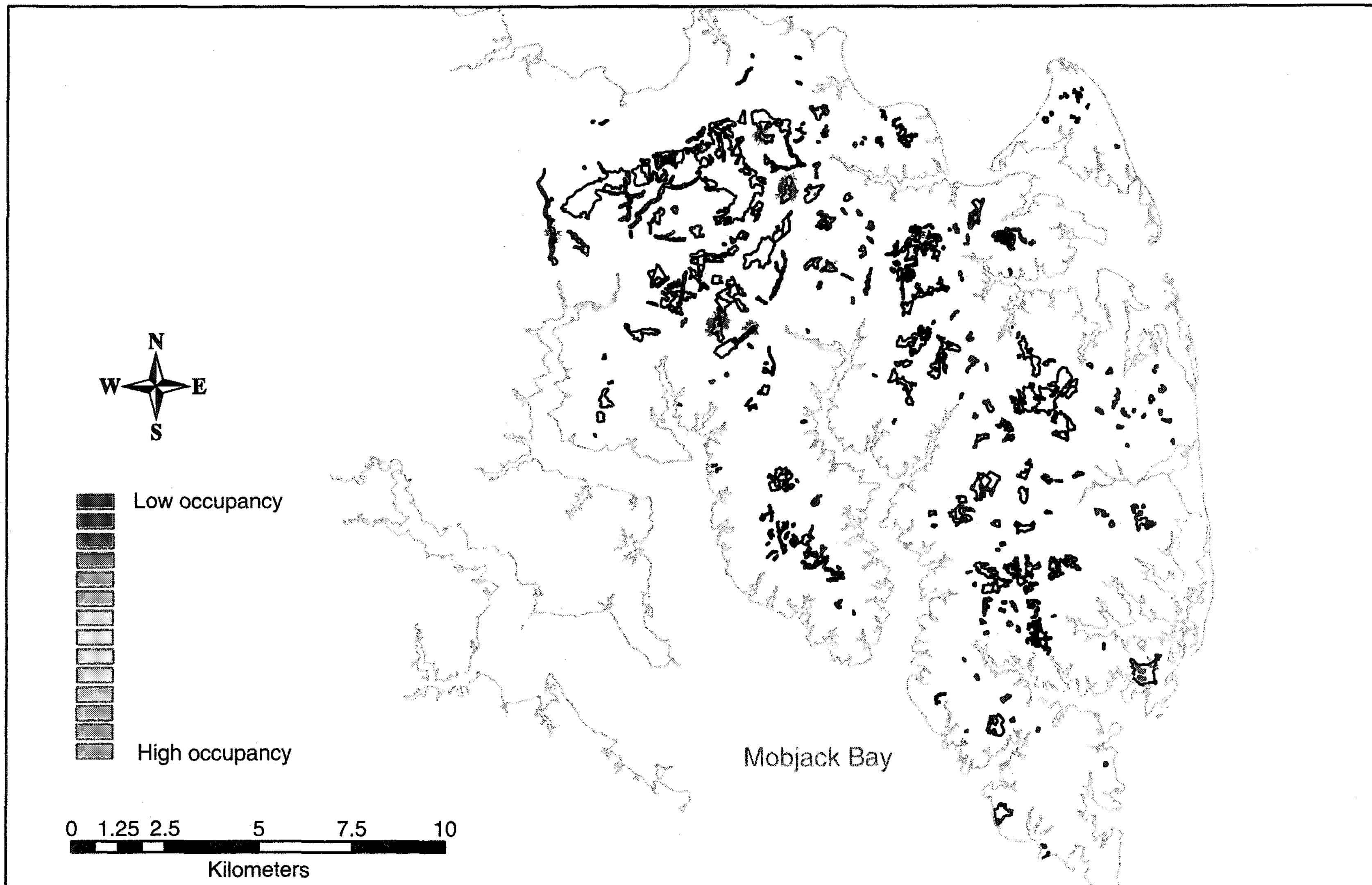


Figure 4-12. Occupancy Rates of All Greater-than-1/2-acre NWI Wetlands in Northern Site.

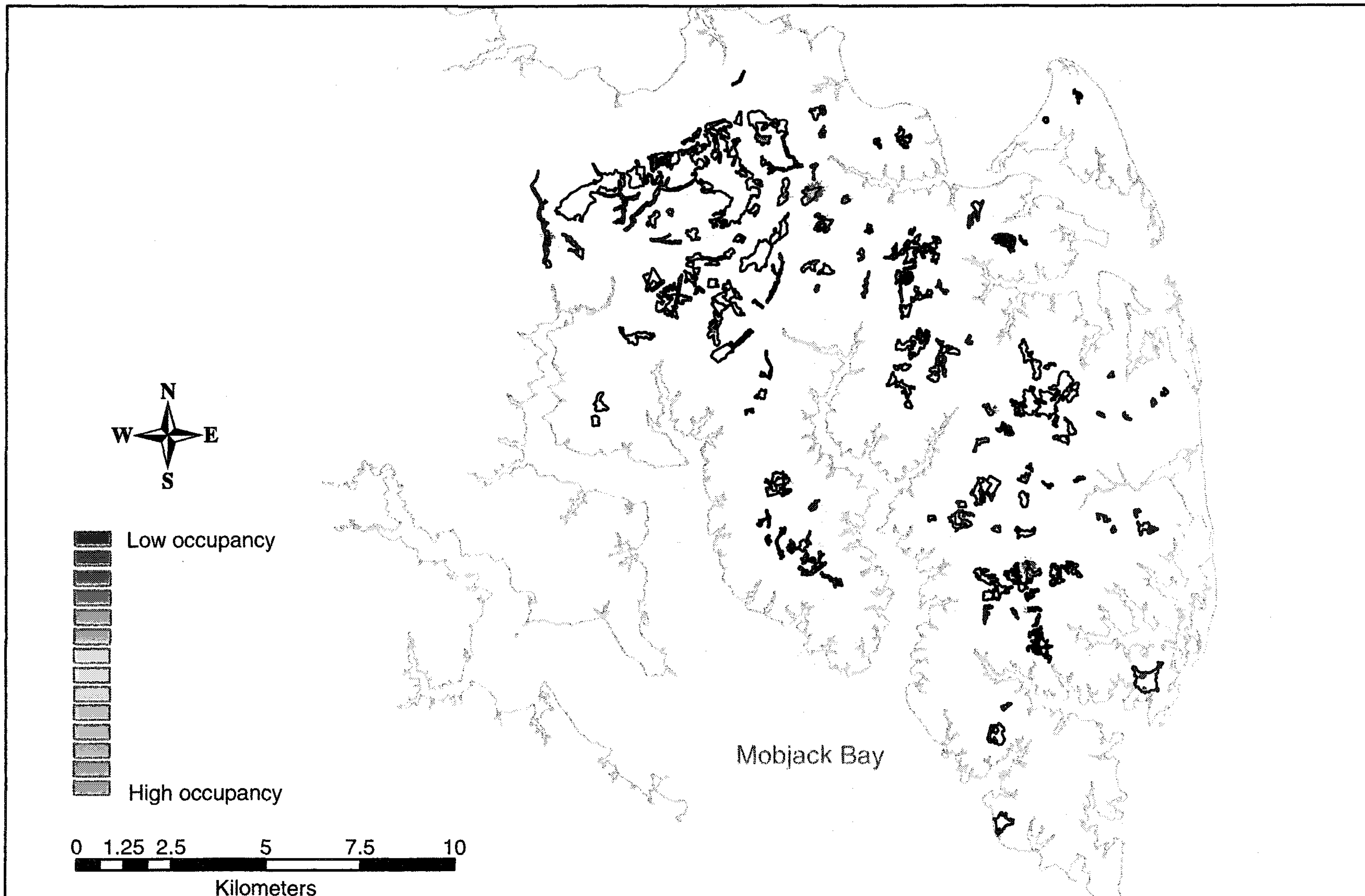


Figure 4-13. Occupancy Rates of All Greater-than-3-acre NWI Wetlands in Northern Site.

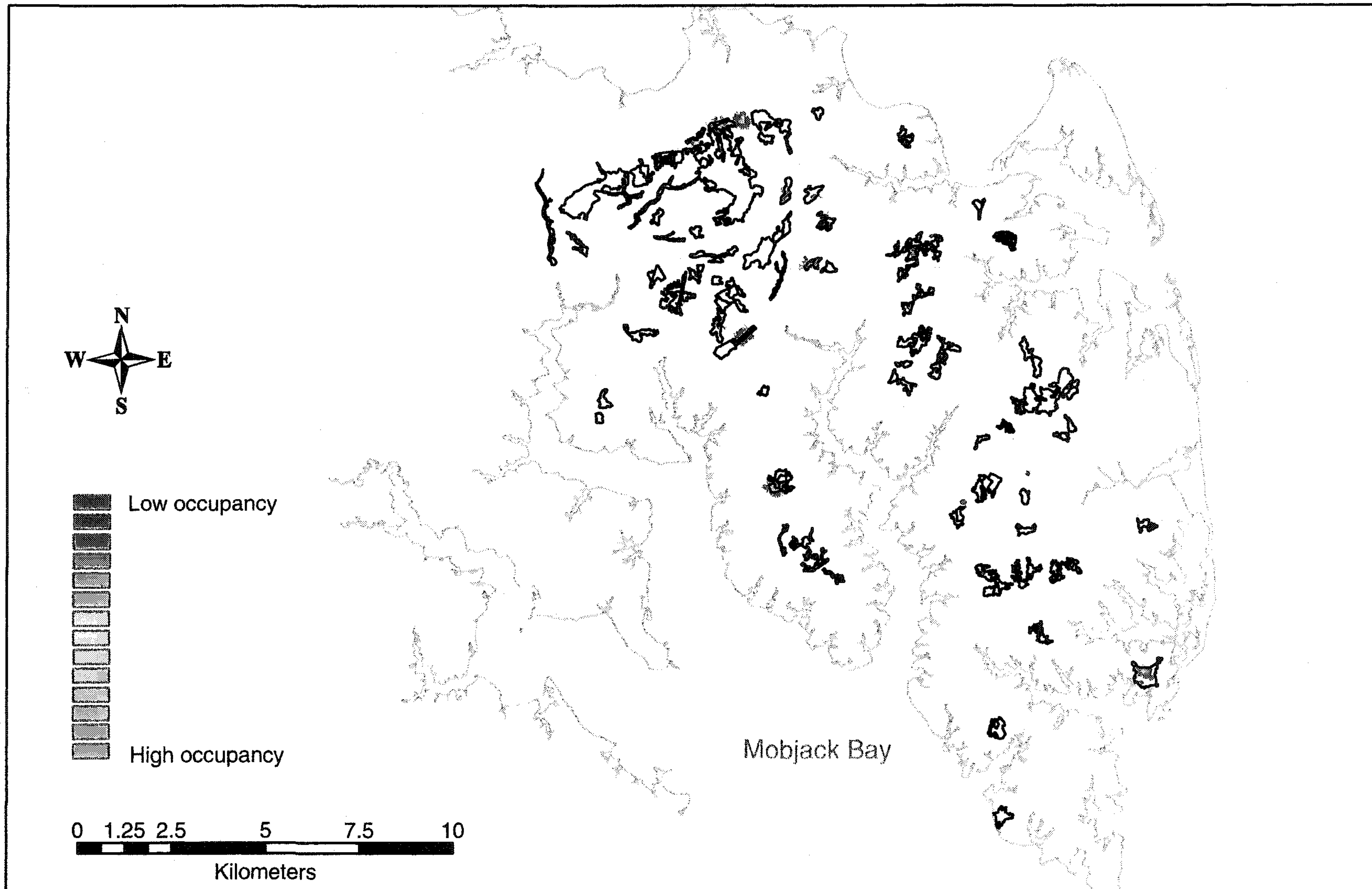


Figure 4-14. Occupancy Rates of All Greater-than-10 acre NWI Wetlands in Northern Site.

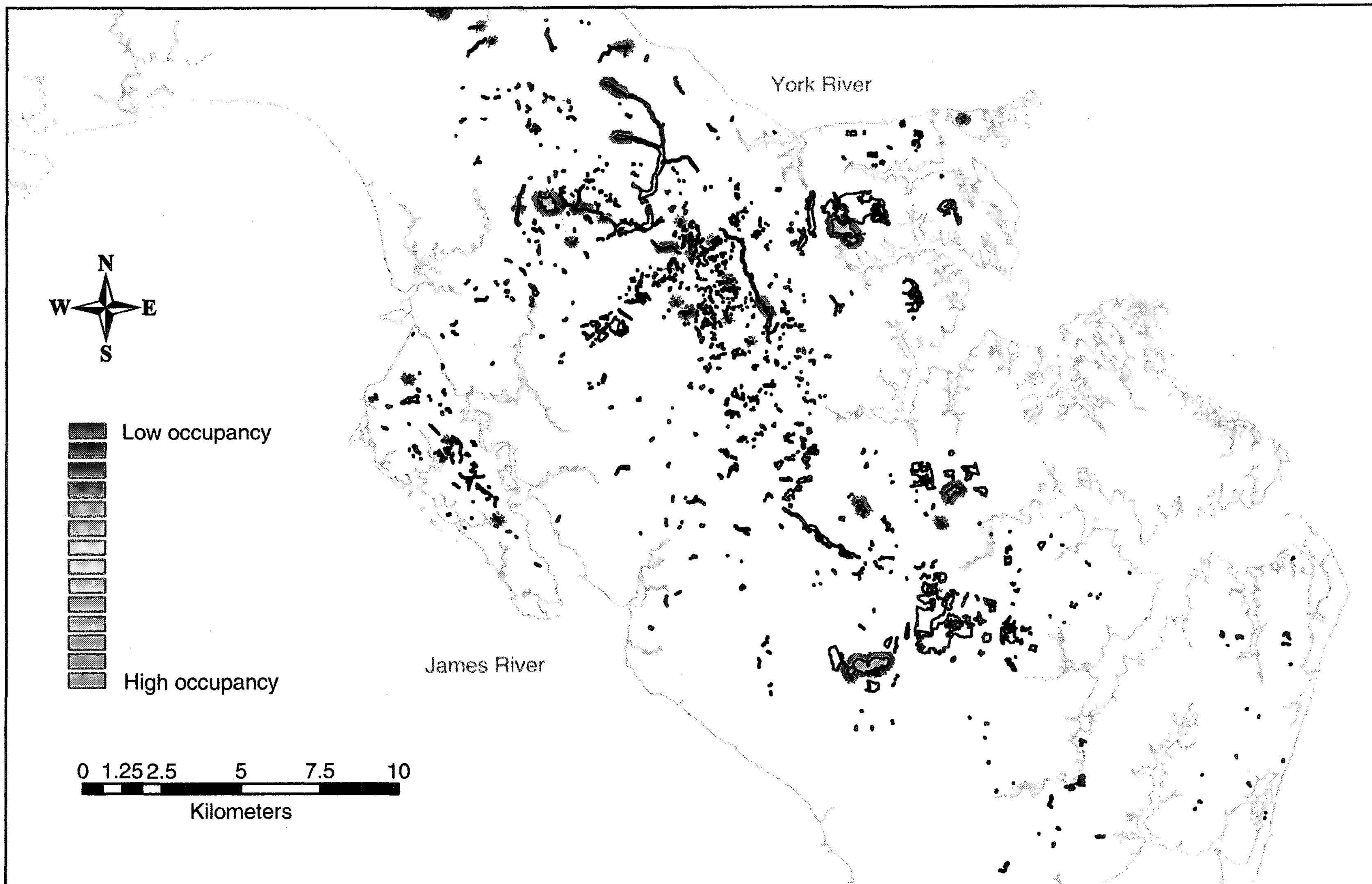


Figure 4-15. Occupancy Rates of All NWI Wetlands in Southern Site.

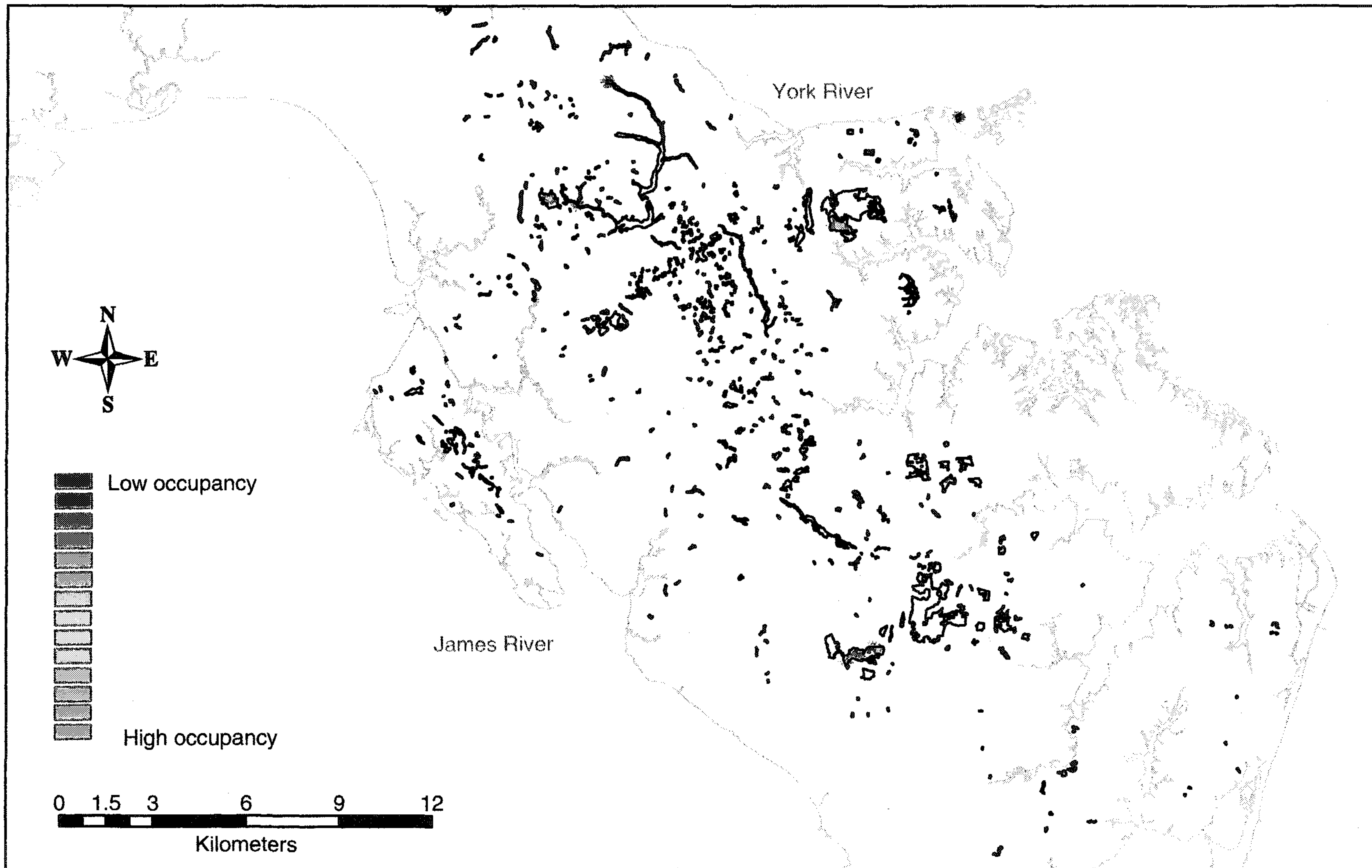


Figure 4-16. Occupancy Rates of All Greater-than-1/2-acre NWI Wetlands in Southern Site.

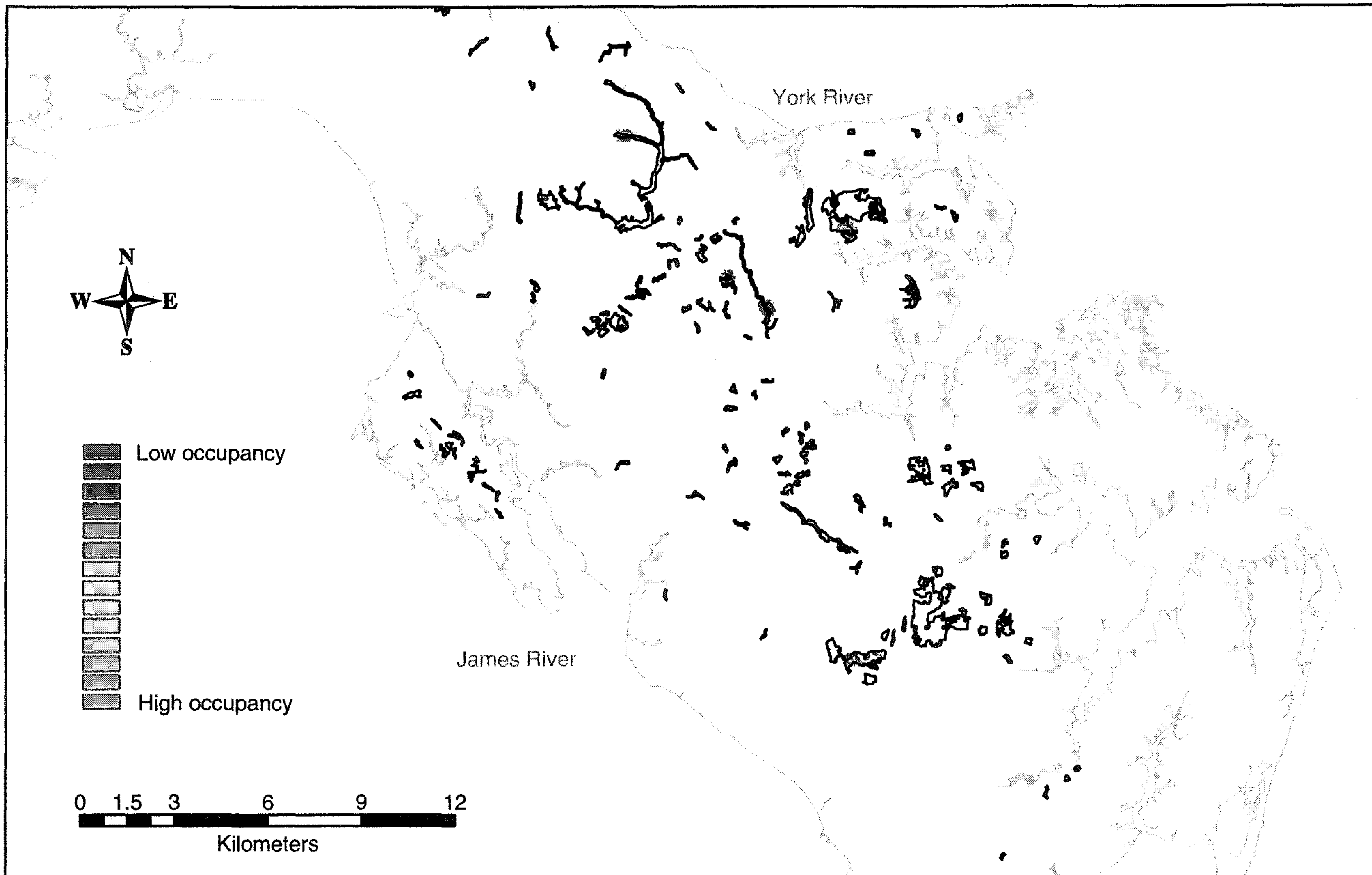


Figure 4-17. Occupancy Rates of All Greater-than-3-acre NWI Wetlands in Southern Site.

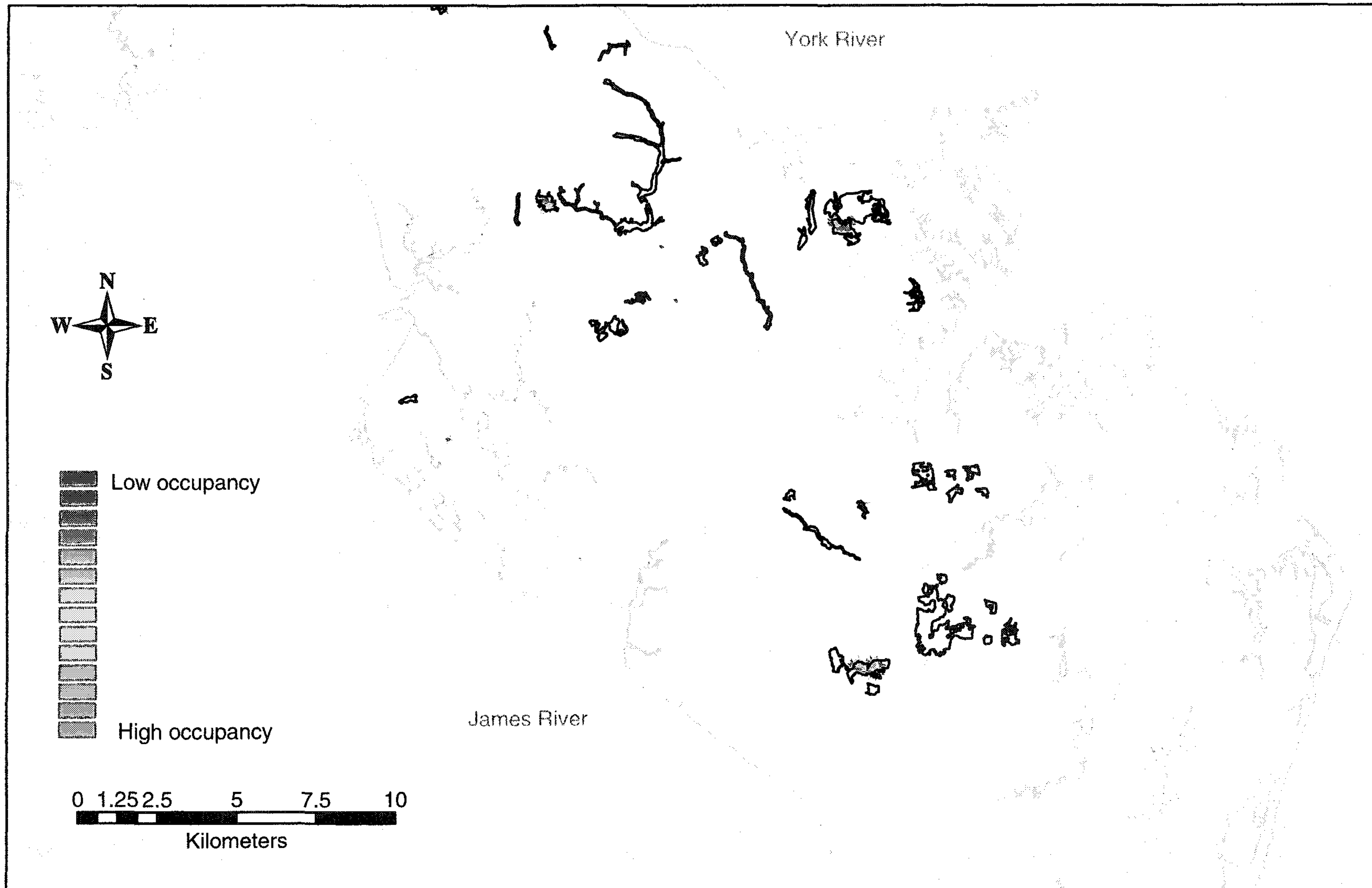


Figure 4-18. Occupancy Rates of All Greater-than-10-acre NWI Wetlands in Southern Site.

Discussion

These results suggest that the effects of loss of small wetlands, which in themselves do not necessarily support substantial populations, can be very detrimental to the survivorship of populations in nearby, larger wetlands. The dynamics seem to go beyond a static source/sink determination of wetland value to a population. Rather, they may indicate a sort of "leap-frog" effect (if you'll excuse the amphibian pun) where small areas of breeding habitat, while not adding significantly to the overall population size, provide the conduit for immigration, at generational timescales, to larger areas of habitat. These smaller wetlands would then be critical to providing rescue effects to areas influenced by stochastic environmental events, and to preclude genetic isolation within the larger sites.

Distributions of amphibians are naturally discontinuous across the landscape. The distribution patterns currently evident are indicative of both a life history which makes use of discrete sites for breeding, and historical changes in the environment, such as the Pleistocene glaciation and extensive deforestation by Europeans (Mitchell and Reay, 1999). Amphibians may be particularly susceptible, however, to negative effects of anthropogenic habitat fragmentation. Lands converted from forests for human use are characteristically dry, open areas that limit migration more strictly than simple distance calculations, as most amphibians are constrained to remaining near moist refugia (Gibbs, 1998).

A distinction needs to be drawn between the natural heterogeneity of the landscape, to which amphibians have adapted their life cycle, and fragmentation of the landscape, which results from human impact (Opdam et al. 1993). Roads prove to be one of the greatest barriers to amphibian movement between refugia. Gibbs (1998) found that roads provided significant hindrance to amphibian movements, in fact he suggests that amphibians may cross substantial areas of open land to reach breeding ponds, provided there are no roads in their pathway. Lehtinen et al (1999) similarly found species richness negatively associated with not only habitat isolation, but also to the density of roads that occurred in the intervening landscape. This model does not specifically address roads as a source of mortality associated with migration. Instead, it assumes the impact is incorporated in effects associated with the immediately surrounding landuse.

This model has many limitations. It is dependent on the spatial resolution and accuracy of both wetland and landuse maps, it estimates both appropriate habitat and the rate of population increase; it even estimates the size and initial location of breeding populations. Wetland areas too small to be mapped may be important breeding sites, as ambstomids have been found to breed in ponds as small as $9m^2$ (Graham et al 1999). Munger et al. (1997) found that NWI maps were unable to completely predict presence or absence of frogs at specific sites, although they endorsed the use of NWI's for amphibian habitat prediction over large areas where complete site visits were not feasible.

The model does not take into account environmental stochasticity or density dependent effects. There is no accounting for the decreased probability of successful mating (Allee effect) at depressed population sizes, nor is there consideration of cannibalistic tendencies which some of species exhibit at higher densities (e.g., *Ambystoma tigrinum*: Ziemba and Collins 1999)

In short, these results must be seen as preliminary in addressing *Ambystoma* management. Much work needs to be done to improve the model: most pressingly needed are data to appropriately model the vital rates, the intrinsic rate of increase, and to address the completeness and appropriateness of the NWI maps in representing the spatial structure of amphibian habitat at the landscape level.

However, the model is appropriate for pointing out potentially important roles small wetlands play as linkages across the landscape. Semlitsch and Bodie responded to the changes in NWP26 in the late 1990's by considering the increase in distances between wetlands with the removal of small wetlands, using 1.2 ha (3 acres) and 4 ha (10 acres) as their study groups. They found that removal of the smaller size wetlands increased the distance between palustrine wetlands by 41.3% (195m) and a 136.1% increase (641 m) for loss of all less than 10-acre wetlands.

The replacement of NWP26 with general permits capped at ½ acre is an improvement in the protection of overall acreage of habitat. Although not directly measured, one might also expect a decrease in the gap distance from what Semlitsch and Bodie found at the former permitting levels. However, the results of this study suggest that loss of these small wetlands might none-the-less be extremely deleterious to preserving the metapopulation dynamics of local wetland species.

These findings point to the inadvisability of using size as an appropriate delimiter of importance of wetlands within the landscape. Although far less easy to define, if we are to manage wetlands for the preservation of habitat and biodiversity, a far more complex system of criteria needs to be employed when choosing which wetlands might be lost with minimal effects to the system. These criteria must, at a minimum, consider wetlands as a complex in conjunction with each other and the surrounding upland habitat (see also Lehtinen et al. 1999, Gibbs 1998). In a review of the pertinent literature, Semlitsh (1998) has concluded that a buffer zone of 164.3 meters surrounding wetland breeding habitat should encompass the necessary habitat for 95% of a site's population for most amphibian species. However, considerations for metapopulations need to take into account not only terrestrial habitat adjacent to breeding ponds, but distance to nearby breeding habitat, migration routes, and directionality of migration (Stenhouse 1985, Dodd and Cade 1998). Modeling of local systems through the use of Geographic Information Systems and ground-truthing, while initially labor intensive, might be geared towards indicator species or species of special concern, and care taken in the permitting process to preserve these necessary linkages.

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Chapter 5 Conclusions

The objective of this dissertation, as discussed in the introduction, was two-fold; (1) to look at how wetland science has or has not been able to influence the legislative arena to create laws which will lead to sound management of our nation's wetland resources; and (2) to explore whether or not the cumulative effects of wetland loss on water quality and habitat can be assessed to provide guidance for wetland management.

Specifically, the questions which I tried to answer were:

1. How well is current legislation and the resultant management doing at conserving and maintaining wetlands, not only in terms of acreage, but also their overall functions and values?

2. Are the proposed changes in wetland legislation an improvement over the situation?

3. Can a method be created for addressing cumulative impacts of wetland loss across the landscape?

My primary conclusion, based on all three studies, is that while the progression of regulation over the last decade has been an improvement in overall acreage of wetlands protected, it is not an improvement at protecting function. In fact, it has been just the reverse: wetlands afforded the least protection constitute a disproportionate number of the most important wetlands.

Dahl (2000) has already concluded that current wetland protection efforts are still resulting in losses on the scale of 58,500 acres per year. It is unreasonable to expect that "no net loss" will ever be translated into complete cessation of all activities that alter or destroy wetlands. In fact, such an approach could not be scientifically defended. Few, if any wetland scientists would argue that all wetlands perform functions to the level that their importance outweighs human development needs (NRC 1995).

What I suggest, however, is that the current criteria, and in particular, size, are inappropriate measures to quantify level of functional importance. Rather, a method must, and can be created to assess functional importance at a cumulative landscape scale, as accurately as possible. It is the results of this type of assessment that should be used to drive the regulation of wetlands.

I have taken three separate approaches to address the potential effects of wetland regulation in conserving the functions for which society values wetlands. My first approach was to apply best professional judgment on the criteria that lead to both capacity and opportunity for wetlands to perform a given function – I will call this the scoring model. My next approach was to attempt to better define the relationship between wetland and landscape parameters in determining in-stream water quality through a regression model. Finally, I attempted to use a structured metapopulation model (*sensu* Verboom et al. 1993) to define the potential effect of habitat loss to amphibians.

The scoring model has the benefit of being applicable to the evaluation of an entire watershed of wetlands without needing to conduct extensive site visits and individual assessments. One of its key drawbacks, however, involves the flip side of one of its great assets. The numerical nature of the scoring, while allowing comparisons to be drawn between wetlands, may have the unfortunate consequence of appearing to be empirical measures. It is critical to point out that this is not the case; the final scores are very dependent upon the assumption of weights assigned to each particular feature. Numbers provide a convenient way to "add" the potential impacts of type, position, and surrounding landuse features into an accessible form for comparison. It must always be made clear, however, that when these scores are being compared or used for impact assessment, that they are relative, not absolute.

The water quality regression model makes use of currently existing data sets to respond to questions of landscape effect on nutrient and sediment inputs. Because the data was not originally collected for this purpose, a more rigorous sampling design was not possible. Arguments may be made that 3 of the 6 sub-watersheds are nested, the water quality sampling points being downstream from each other, and thus are not truly independent. A broader selection of sites would also have been able to more adequately address the importance of these variables under conditions where forests were not the predominant landuse, for example. While not being robust enough to support the development of specific mathematical relationships, the available data do allow general conclusions regarding the relationship of landuse and water quality.

The structured metapopulation model, similarly, makes use of known data in trying to answer new questions. The limitations discussed on the parameters specifically known about ambystomid populations do not undercut the importance of the findings regarding key linkages that small wetlands may provide to habitat connectivity.

The generality of these findings is a strength for applying these assessments to broad questions. Models cannot simultaneously be accurate to the specific conditions and generally applicable: either they are robust at drawing general conclusions, but not predicting specific outcomes, or they speak to a very well defined set of circumstances only (Verboon et al.1993).

While separate, these three approaches are best viewed with the scoring model as the primary backbone in creating a technique for assessing the loss of function, at landscape scales, associated with wetland regulation and permitting decisions. The second and third approaches can be seen as examples of research that attempt to further define cumulative effects of wetland and landscape pattern for use in such a scoring model. For example, results of the water quality regression model suggest that at least in landscapes dominated by forest, the configuration of vegetated land, including wetlands, is most critical within 100 meters of waterways. Such an assessment would be easy to apply to the scoring model, with an appropriate increase in the water quality score for such wetlands. In terms of habitat, determination of critical core areas, in addition to definition of distance to nearest potential habitat could be added to the model to better quantify habitat scores.

Results of both the water quality and habitat studies reconfirm what we know from the literature: that wetland function cannot be properly assessed without considering position in the landscape in relation to the hydrology, other land uses, and other wetlands. Much of the wetland research regarding patterns and processes is geared towards mitigation (e.g., Bedford, 1999). Questions of appropriate hydrology, placement, interconnectedness and scale are all considered within this context to determine the appropriate placement of created wetlands. Ideally just such cumulative impact analyses should be used to drive watershed wide planning and evaluation. I propose that these same parameters be used to define areas of “unacceptable” loss, for management purposes.

Few studies have addressed the issue of a method to assess cumulative impacts in terms of area planning. The exceptions include: Abruzzese and Leibowitz's Synoptic Approach (1997), which allows for relative comparison of functional losses between watersheds, based on minimal data input; and more promisingly, the work done on the North Carolina Coastal Region Evaluation of Wetland Significance (NCCREWS). NCCREWS, as it's name implies is limited to coastal wetlands (Sutter et al. 1999). More recently the work of Sutter and Cowen (2003) on the Spatial Wetland Assessment for Management and Planning (SWAMP), builds on the NCCREWS model. SWAMP has many advantages to recommend it: not only is it built on the HGM classification (Brinson, 1993) of wetlands, which more appropriately addresses a variety of functions than the NWI Cowardin (et al, 1979), it also has a user-friendly arc-view interface which can be easily queried to determine the results of management decisions.

It has been the aim of my dissertation to apply and evaluate practical techniques for assessing the cumulative impact of potential wetland losses. The benefit of these analyses for policy making purposes appears to lie in defining what negative effects may occur due to wetland loss on a watershed. The assessments do not attempt to define allowable losses in the absence of evidence of negative impact. This type of potential negative impact assessment has precedence in the policy arena, from economic policies to social welfare modeling.

" (M)odels do provide an interesting and powerful form of 'advice'. It is not remotely close to the 'correct answer' envisioned by Simon (1960) and others, wherein the technological wonders of management science would give decision-makers answers to the questions of what they should do. Rather, it is advice on what not to do. The best models point out just how bad the results of a truly problematic policy might be, and this proves to be exceedingly valuable in the policy-making process." King and Kramer, 1993.

This and similar models will therefore most appropriately be used for determining, *a priori*, the potential effects of widescale management decisions and regulations, and in conjunction with site visits to determine potential landscape scale cumulative impacts of individual permitting decisions.

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APPENDIX

STEP1

```
/* Step1.aml - Calculates initial wetland score for Step 1 of protocol
/* for the Chesapeake Bay Program Wetlands Initiative.

&severity &error &ignore
&s cov [response 'Enter NWI coverage name for Step 1 of protocol']

/* add attributes to wetland coverage. For step 1: WSHAB (habitat quality),
/* WSSEDI (sediment control), WSFLOOD (flood control and for step 2 : ASHAB
(adjusted
/* score for habitat), ASSEDI (adjusted score for sediment control),
/* ASWATER (adjusted score for water quality), ASFLOOD (adjusted score for
/* flood control, ASBANK (adjusted score for bank stabilization).

additem %cov%.pat %cov%.pat WSHAB   2 4 I
additem %cov%.pat %cov%.pat WSWATER 2 4 I
additem %cov%.pat %cov%.pat WSFLOOD 2 4 I
additem %cov%.pat %cov%.pat ASHAB   4 5 N 1
additem %cov%.pat %cov%.pat ASWATER 4 5 N 1
additem %cov%.pat %cov%.pat ASFLOOD 4 5 N 1


/* Calculate initial scores.

arcedit
  edit %cov% poly
  select nwi_class cn 'PE'
  calc wshab = 3
  calc wswater = 3
  calc wsflood = 2
  select nwi_class cn 'E2F'
  calc wshab = 3
  calc wswater = 2
  calc wsflood = 2
  select nwi_class cn 'E2S'
  calc wshab = 3
```

```
  calc wswater = 2
  calc wsflood = 2
  select nwi_class cn 'E2E'
  calc wshab = 3
  calc wswater = 2
  calc wsflood = 1
  select nwi_class cn 'PS'
  calc wshab = 3
  calc wswater = 3
  calc wsflood = 3
  select nwi_class cn 'PF'
  calc wshab = 3
  calc wswater = 3
  calc wsflood = 3
  select nwi_class cn 'L2E'
  calc wshab = 3
  calc wswater = 3
  calc wsflood = 2
  select nwi_class cn 'R1E'
  calc wshab = 3
  calc wswater = 3
  calc wsflood = 1
  select nwi_class cn 'R2E'
  calc wshab = 3
  calc wswater = 3
  calc wsflood = 1
  select nwi_class cn 'R3E'
  calc wshab = 3
  calc wswater = 3
  calc wsflood = 1
  select nwi_class cn 'R4E'
  calc wshab = 3
  calc wswater = 3
  calc wsflood = 1

save
q

&return
```

STEP 2

```
/* step2.aml - determines adjustment factors for adjacent land use
/* influence. This aml looks at the entire periphery of the wetland polygon,
/* and calculates a score based upon all the landuse types.

&sv cover [response 'Enter coverage name from Step 1 (nwi coverage).']
&sv name [response 'Enter first 3 letters of watershed name (YK1)']
&sv landuse [response 'Enter MRLC land use coverage name']

/* make list file of id numbers.
tables
sel %cover%.pat
&severity &error &ignore
nselect
aselect %cover%-id > 0 and nwi_class cn 'E2EM'
aselect %cover%-id > 0 and nwi_class cn 'E2SS'
aselect %cover%-id > 0 and nwi_class cn 'E2FO'
aselect %cover%-id > 0 and nwi_class cn 'PEM'
aselect %cover%-id > 0 and nwi_class cn 'PSS'
aselect %cover%-id > 0 and nwi_class cn 'PFO'
aselect %cover%-id > 0 and nwi_class cn 'L2EM'
aselect %cover%-id > 0 and nwi_class cn 'R1EM'
aselect %cover%-id > 0 and nwi_class cn 'R2EM'
aselect %cover%-id > 0 and nwi_class cn 'R3EM'
aselect %cover%-id > 0 and nwi_class cn 'R4EM'
&severity &error &fail
unload list%cover%.out %cover%-id
q

/* make coverage of selected wetlands.
ae
edit %cover% poly
&severity &error &ignore
select %cover%-id > 0 and nwi_class cn 'E2SS'
aselect %cover%-id > 0 and nwi_class cn 'E2EM'
aselect %cover%-id > 0 and nwi_class cn 'E2FO'
aselect %cover%-id > 0 and nwi_class cn 'PEM'
aselect %cover%-id > 0 and nwi_class cn 'PSS'
aselect %cover%-id > 0 and nwi_class cn 'PFO'
aselect %cover%-id > 0 and nwi_class cn 'L2EM'
aselect %cover%-id > 0 and nwi_class cn 'R1EM'
```

```
aselect %cover%-id > 0 and nwi_class cn 'R2EM'
aselect %cover%-id > 0 and nwi_class cn 'R3EM'
aselect %cover%-id > 0 and nwi_class cn 'R4EM'
&severity &error &fail
put %name%nwi
q

build %name%nwi poly

&if not [iteminfo %cover%.pat -info agrid-code -exists] &then
 additem %cover%.pat %cover%.pat agrid-code 4 8 b # wsflood
&if not [iteminfo %cover%.pat -info alu_class -exists] &then
 additem %cover%.pat %cover%.pat alu_class 50 50 c # agrid-code


&sv fileerr = [open list%cover%.out openerr -read]

/* Check for errors in opening file.
&if %openerr% <> 0 &then
   &return &warning Error opening file.

/* Read from file
&sv record = [read %fileerr% readerr]
&if %readerr% <> 0 &then
   &return &warning Could not read file.

&sv poly = [TRIM %record% ]
&setvar poly [subst %poly% , '']


&do &until %readerr% = 102

&severity &error &ignore

  &if [exists p[substr %cover% 1 3]%poly% -cover] &then
    kill p[substr %cover% 1 3]%poly% all
  &if [exists pb[substr %cover% 1 3]%poly% -cover] &then
    kill pb[substr %cover% 1 3]%poly% all
  &if [exists pb2[substr %cover% 1 3]%poly% -cover] &then
    kill pb2[substr %cover% 1 3]%poly% all

/* open an arcedit session, select a polygon from the big coverage and create
/* a new coverage. Buffer the single polygon with a 3m buffer, union the buffer
/* with the original polygon, and then select the outside portion of the buffer.
/* Intersect the 3m buffer with landuse and then create a new coverage
/* containing only the landuse within the buffer strip.
```

```
/* select the polygon and make a separate coverage.
arcedit
 edit %name%nwi poly
  sel %name%nwi-id = %poly%
  put p[substr %cover% 1 3]%poly%
q

build p[substr %cover% 1 3]%poly% line
build p[substr %cover% 1 3]%poly% poly

/* create a 3 meter buffer and prefix it pb.
buffer p[substr %cover% 1 3]%poly% pb[substr %cover% 1 3]%poly% # # 3 .1
line
/*build pb[substr %cover% 1 3]%poly%

/* union buffer with with wetland polygon. prefix pu
union pb[substr %cover% 1 3]%poly% p[substr %cover% 1 3]%poly% pu[substr
%cover% 1 3]%poly% .01
/*build pu[substr %cover% 1 3]%poly%

/* select the outer 3 meters of buffer and create new coverage with prefix b.
arcedit
 edit pu[substr %cover% 1 3]%poly% poly
  sel nwi_class = ' '
  put b[substr %cover% 1 3]%poly%
/*q

apc arc build b[substr %cover% 1 3]%poly%
/* instead of intersecting with large landuse coverage, select landuse
/* polygons that passthrough the buffer and put into a new coverage. Then
/* intersect.
 mape b[substr %cover% 1 3]%poly%
 ec %landuse%
 ef poly
/* new section to avoid passthru error!)
/*sel select = 'y'
/*calc select = ' '
apc reselect %landuse% poly overlap b[substr %cover% 1 3]%poly% poly
apc calc %landuse% poly select = 'y'
apc clearsel %landuse% poly
sel select = 'y'
 put lu%name%%poly%
 apc arc build lu%name%%poly%

/* intersect 3 meter outside buffer with landuse - prefix bi.
```

```
apc arc intersect b[substr %cover% 1 3]%poly% lu%name%%poly% bi[substr
%cover% 1 3]%poly% poly .01
/*apc arc build bi[substr %cover% 1 3]%poly%


/* select only date that is inside the buffer and prefix new cover with bi2.
/*arcedit
  edit bi[substr %cover% 1 3]%poly% poly
    sel inside = 100
    put bi2[substr %cover% 1 3]%poly%
/*q

 apc arc build bi2[substr %cover% 1 3]%poly%

/* Determine the frequency of landuse types within the buffer strip (bi2).
apc arc frequency bi2[substr %cover% 1 3]%poly%.pat bi2f[substr %cover% 1
3]%poly%.dat
    grid-code
    lu_class
    end
    area
    end

/* Find the total area of the buffer strip. Get nwi_class variable from single
/* polygon coverage.
/*arcedit
 edit bi2f[substr %cover% 1 3]%poly%.dat info
    select grid-code ne 0
    statistics # # init
      sum area
    end
    &sv sumarea [SHOW STATISTIC 1 1]
q n

additem bi2f[substr %cover% 1 3]%poly%.dat bi2f[substr %cover% 1
3]%poly%.dat totalarea 8 10 f 3
additem bi2f[substr %cover% 1 3]%poly%.dat bi2f[substr %cover% 1
3]%poly%.dat percent 8 8 f 2
additem bi2f[substr %cover% 1 3]%poly%.dat bi2f[substr %cover% 1
3]%poly%.dat nwi_class  20 20 c

tables
 select p[substr %cover% 1 3]%poly%.pat
   &sv classitem [show record 2 item nwi_class]
/* calculate the percent of landuse types.
 sel bi2f[substr %cover% 1 3]%poly%.dat
```

```
 calc totalarea = %sumarea%
 calc percent = area / totalarea
 move [quote %classitem%] to nwi_class
q

/* add  AS function items to frequency table
additem bi2f[substr %cover% 1 3]%poly%.dat bi2f[substr %cover% 1
3]%poly%.dat ASHAB   4 5 n 1
additem bi2f[substr %cover% 1 3]%poly%.dat bi2f[substr %cover% 1
3]%poly%.dat ASWATER 4 5 n 1
additem bi2f[substr %cover% 1 3]%poly%.dat bi2f[substr %cover% 1
3]%poly%.dat ASFLOOD 4 5 n 1

/* run stepcalc.aml to calculate values for the functions
/* in the frequency table.
&r stepcalc %cover% %poly%

arcedit
 edit bi2f[substr %cover% 1 3]%poly%.dat info
  select grid-code ne 0
   statistics # # init
     sum ashab
     end
&sv sashab [show statistic 1 1]
   statistics # # init
     sum aswater
     end
&sv saswater [show statistic 1 1]
   statistics # # init
     sum asflood
     end
&sv sasflood [show statistic 1 1]
q

/* Calculate the final function values. Call stepcalc2.aml
&r stepcalc2 %cover% %poly% %sashab% %saswater% %sasflood%

   &if [delete bi2f[substr %cover% 1 3]%poly%.dat -info] = 0 &then
      &type pf[substr %cover% 1 3].dat deleted successfully
 &else &type unable to delete file


&if [exists p[substr %cover% 1 3]%poly% -cover] &then
  kill p[substr %cover% 1 3]%poly% all
&if [exists pb[substr %cover% 1 3]%poly% -cover] &then
  kill pb[substr %cover% 1 3]%poly% all
```

```
&if [exists pu[substr %cover% 1 3]%poly% -cover] &then
 kill pu[substr %cover% 1 3]%poly% all
&if [exists b[substr %cover% 1 3]%poly% -cover] &then
 kill b[substr %cover% 1 3]%poly% all
&if [exists bi[substr %cover% 1 3]%poly% -cover] &then
 kill bi[substr %cover% 1 3]%poly% all
&if [exists bi2[substr %cover% 1 3]%poly% -cover] &then
 kill bi2[substr %cover% 1 3]%poly% all
&if [exists lu%name%%poly% -cover] &then
 kill lu%name%%poly% all

/* Get next record.
 &sv record = [read %fileerr% readerr]
 &sv poly = [TRIM %record% ]
 &setvar poly [subst %poly% , '']
 &type %poly%
&end


rm list%cover%.out

/*&echo &off
&type Step2amod.aml is complete! Now go to step 3.
&return
```

STEPCALC

```
/* stepcalc.aml - calculateS the function values by finding the landuse
/* type value and multiplying the percent of area by the value for each landuse
/* type.

&args cover poly
&severity &error &ignore

tables
  select bi2f[substr %cover% 1 3]%poly%.dat
  &sv class [show record 2 item nwi_class]
  &if %class% cn 'E1EM' &then
    &do
      reselect grid-code = 2
 calc ashab = -.5 * percent
 calc aswater = .5 * percent
 calc asflood = .5 * percent
    aselect
    reselect grid-code = 3
  calc ashab = -.5 * percent
```

```
calc aswater = .5 * percent
calc asflood = .5 * percent
  aselect
  reselect grid-code = 4
calc ashab = 0 * percent
calc aswater = .5 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 5
  aselect  grid-code = 6
calc ashab = 0 * percent
calc aswater = .5 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 7
  aselect  grid-code = 8
  aselect  grid-code = 9
calc ashab = .5 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 10
  aselect grid-code = 11
calc ashab = .5 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 14
calc ashab = 0 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 12
  aselect grid-code = 13
  aselect grid-code = 15
calc ashab = 0 * percent
calc aswater = .5 * percent
calc asflood = 0 * percent
  &end

&if %class% cn 'E2EM' &then
  &do
    reselect grid-code = 2
calc ashab = -.5 * percent
calc aswater = .5 * percent
calc asflood = .5 * percent
```

```
    aselect
    reselect grid-code = 3
  calc ashab = -.5 * percent
  calc aswater = .5 * percent
  calc asflood = .5 * percent
    aselect
    reselect grid-code = 4
  calc ashab = 0 * percent
  calc aswater = .5 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 5
    aselect  grid-code = 6
  calc ashab = 0 * percent
  calc aswater = .5 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 7
    aselect  grid-code = 8
    aselect  grid-code = 9
  calc ashab = .5 * percent
  calc aswater = 0 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 10
    aselect grid-code = 11
  calc ashab = .5 * percent
  calc aswater = 0 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 14
  calc ashab = 0 * percent
  calc aswater = 0 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 12
    aselect grid-code = 13
    aselect grid-code = 15
  calc ashab = 0 * percent
  calc aswater = .5 * percent
  calc asflood = 0 * percent
   &end

&if %class% cn 'E1SS' &then
   &do
    reselect grid-code = 2
```

```
calc ashab = -.5 * percent
calc aswater = .5 * percent
calc asflood = .5 * percent
  aselect
  reselect grid-code = 3
calc ashab = -.5 * percent
calc aswater = .5 * percent
calc asflood = .5 * percent
  aselect
  reselect grid-code = 4
calc ashab = 0 * percent
calc aswater = .5 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 5
  aselect  grid-code = 6
calc ashab = 0 * percent
calc aswater = .5 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 7
  aselect  grid-code = 8
  aselect  grid-code = 9
calc ashab = .5 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 10
  aselect  grid-code = 11
calc ashab = .5 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 14
calc ashab = 0 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 12
  aselect  grid-code = 13
  aselect  grid-code = 15
calc ashab = 0 * percent
calc aswater = .5 * percent
calc asflood = 0 * percent
 &end
```

```
&if %class% cn 'E2SS' &then
  &do
   reselect grid-code = 2
 calc ashab = -.5 * percent
 calc aswater = .5 * percent
 calc asflood = .5 * percent
   aselect
   reselect grid-code = 3
 calc ashab = -.5 * percent
 calc aswater = .5 * percent
 calc asflood = .5 * percent
   aselect
   reselect grid-code = 4
 calc ashab = 0 * percent
 calc aswater = .5 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 5
   aselect  grid-code = 6
 calc ashab = 0 * percent
 calc aswater = .5 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 7
   aselect  grid-code = 8
   aselect  grid-code = 9
 calc ashab = .5 * percent
 calc aswater = 0 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 10
   aselect  grid-code = 11
 calc ashab = .5 * percent
 calc aswater = 0 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 14
 calc ashab = 0 * percent
 calc aswater = 0 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 12
   aselect  grid-code = 13
   aselect  grid-code = 15
 calc ashab = 0 * percent
 calc aswater = .5 * percent
```

```
calc asflood = 0 * percent
  &end


&if %class% cn 'E1FO' &then
  &do
   reselect grid-code = 2
 calc ashab = -.5 * percent
 calc aswater = .5 * percent
 calc asflood = .5 * percent
   aselect
   reselect grid-code = 3
 calc ashab = -.5 * percent
 calc aswater = .5 * percent
 calc asflood = .5 * percent
   aselect
   reselect grid-code = 4
 calc ashab = 0 * percent
 calc aswater = .5 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 5
   aselect  grid-code = 6
 calc ashab = 0 * percent
 calc aswater = .5 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 7
   aselect  grid-code = 8
   aselect  grid-code = 9
 calc ashab = .5 * percent
 calc aswater = 0 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 10
   aselect  grid-code = 11
 calc ashab = .5 * percent
 calc aswater = 0 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 14
 calc ashab = 0 * percent
 calc aswater = 0 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 12
```

```
    aselect  grid-code = 13
    aselect  grid-code = 15
  calc ashab = 0 * percent
  calc aswater = .5 * percent
  calc asflood = 0 * percent
   &end

&if %class% cn 'E2FO' &then
   &do
    reselect grid-code = 2
  calc ashab = -.5 * percent
  calc aswater = .5 * percent
  calc asflood = .5 * percent
    aselect
    reselect grid-code = 3
  calc ashab = -.5 * percent
  calc aswater = .5 * percent
  calc asflood = .5 * percent
    aselect
    reselect grid-code = 4
  calc ashab = 0 * percent
  calc aswater = .5 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 5
    aselect  grid-code = 6
  calc ashab = 0 * percent
  calc aswater = .5 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 7
    aselect  grid-code = 8
    aselect  grid-code = 9
  calc ashab = .5 * percent
  calc aswater = 0 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 10
    aselect  grid-code = 11
  calc ashab = .5 * percent
  calc aswater = 0 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 14
  calc ashab = 0 * percent
  calc aswater = 0 * percent
```

```
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 12
    aselect  grid-code = 13
    aselect  grid-code = 15
  calc ashab = 0 * percent
  calc aswater = .5 * percent
  calc asflood = 0 * percent
   &end

&if %class% cn 'PEM' &then
   &do
    reselect grid-code = 2
  calc ashab = -.5 * percent
  calc aswater = .5 * percent
  calc asflood = .5 * percent
    aselect
    reselect grid-code = 3
  calc ashab = -.5 * percent
  calc aswater = .5 * percent
  calc asflood = .5 * percent
    aselect
    reselect grid-code = 4
  calc ashab = 0 * percent
  calc aswater = .5 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 5
    aselect  grid-code = 6
  calc ashab = 0 * percent
  calc aswater = .5 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 7
    aselect  grid-code = 8
    aselect  grid-code = 9
  calc ashab = .5 * percent
  calc aswater = 0 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 10
    aselect  grid-code = 11
  calc ashab = .5 * percent
  calc aswater = 0 * percent
  calc asflood = 0 * percent
    aselect
```

```
  reselect grid-code = 14
calc ashab = 0 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 12
  aselect  grid-code = 13
  aselect  grid-code = 15
calc ashab = 0 * percent
calc aswater = .5 * percent
calc asflood = 0 * percent
 &end

&if %class% cn 'PSS' &then
 &do
  reselect grid-code = 2
calc ashab = -.5 * percent
calc aswater = .5 * percent
calc asflood = .5 * percent
  aselect
  reselect grid-code = 3
calc ashab = -.5 * percent
calc aswater = .5 * percent
calc asflood = .5 * percent
  aselect
  reselect grid-code = 4
calc ashab = 0 * percent
calc aswater = .5 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 5
  aselect  grid-code = 6
calc ashab = 0 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 7
  aselect  grid-code = 8
  aselect  grid-code = 9
calc ashab = .5 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 10
  aselect  grid-code = 11
calc ashab = .5 * percent
```

```
 calc aswater = 0 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 14
 calc ashab = 0 * percent
 calc aswater = 0 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 12
   aselect  grid-code = 13
   aselect  grid-code = 15
 calc ashab = 0 * percent
 calc aswater = .5 * percent
 calc asflood = 0 * percent
  &end

&if %class% cn 'PFO' &then
  &do
   reselect grid-code = 2
 calc ashab = -.5 * percent
 calc aswater = .5 * percent
 calc asflood = .5 * percent
   aselect
   reselect grid-code = 3
 calc ashab = -.5 * percent
 calc aswater = .5 * percent
 calc asflood = .5 * percent
   aselect
   reselect grid-code = 4
 calc ashab = 0 * percent
 calc aswater = .5 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 5
   aselect  grid-code = 6
 calc ashab = 0 * percent
 calc aswater = .5 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 7
   aselect  grid-code = 8
   aselect  grid-code = 9
 calc ashab = .5 * percent
 calc aswater = 0 * percent
 calc asflood = 0 * percent
   aselect
```

```
   reselect grid-code = 10
   aselect  grid-code = 11
 calc ashab = .5 * percent
 calc aswater = 0 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 14
 calc ashab = 0 * percent
 calc aswater = 0 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 12
   aselect  grid-code = 13
   aselect  grid-code = 15
 calc ashab = 0 * percent
 calc aswater = .5 * percent
 calc asflood = 0 * percent
  &end

&if %class% cn 'L1EM' &then
  &do
   reselect grid-code = 2
 calc ashab = -.5 * percent
 calc aswater = .5 * percent
 calc asflood = .5 * percent
   aselect
   reselect grid-code = 3
 calc ashab = -.5 * percent
 calc aswater = .5 * percent
 calc asflood = .5 * percent
   aselect
   reselect grid-code = 4
 calc ashab = 0 * percent
 calc aswater = .5 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 5
   aselect  grid-code = 6
 calc ashab = 0 * percent
 calc aswater = .5 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 7
   aselect  grid-code = 8
   aselect  grid-code = 9
 calc ashab = .5 * percent
```

```
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 10
  aselect  grid-code = 11
calc ashab = .5 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 14
calc ashab = 0 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 12
  aselect  grid-code = 13
  aselect  grid-code = 15
calc ashab = 0 * percent
calc aswater = .5 * percent
calc asflood = 0 * percent
 &end

&if %class% cn 'L2EM' &then
  &do
   reselect grid-code = 2
 calc ashab = -.5 * percent
 calc aswater = .5 * percent
 calc asflood = .5 * percent
   aselect
   reselect grid-code = 3
 calc ashab = -.5 * percent
 calc aswater = .5 * percent
 calc asflood = .5 * percent
   aselect
   reselect grid-code = 4
 calc ashab = 0 * percent
 calc aswater = .5 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 5
   aselect  grid-code = 6
 calc ashab = 0 * percent
 calc aswater = .5 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 7
```

```
  aselect  grid-code = 8
  aselect  grid-code = 9
calc ashab = .5 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 10
  aselect  grid-code = 11
calc ashab = .5 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 14
calc ashab = 0 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 12
  aselect  grid-code = 13
  aselect  grid-code = 15
calc ashab = 0 * percent
calc aswater = .5 * percent
calc asflood = 0 * percent
 &end

&if %class% cn 'R1EM' &then
 &do
  reselect grid-code = 2
calc ashab = -.5 * percent
calc aswater = .5 * percent
calc asflood = .5 * percent
  aselect
  reselect grid-code = 3
calc ashab = -.5 * percent
calc aswater = .5 * percent
calc asflood = .5 * percent
  aselect
  reselect grid-code = 4
calc ashab = 0 * percent
calc aswater = .5 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 5
  aselect  grid-code = 6
calc ashab = -.5 * percent
calc aswater = .5 * percent
```

```
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 7
    aselect  grid-code = 8
    aselect  grid-code = 9
  calc ashab = .5 * percent
  calc aswater = 0 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 10
    aselect  grid-code = 11
  calc ashab = .5 * percent
  calc aswater = 0 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 14
  calc ashab = 0 * percent
  calc aswater = 0 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 12
    aselect grid-code = 13
    aselect grid-code = 15
  calc ashab = 0 * percent
  calc aswater = .5 * percent
  calc asflood = 0 * percent
   &end
&if %class% cn 'R2EM' &then
   &do
    reselect grid-code = 2
  calc ashab = -.5 * percent
  calc aswater = .5 * percent
  calc asflood = .5 * percent
    aselect
    reselect grid-code = 3
  calc ashab = -.5 * percent
  calc aswater = .5 * percent
  calc asflood = .5 * percent
    aselect
    reselect grid-code = 4
  calc ashab = 0 * percent
  calc aswater = .5 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 5
    aselect  grid-code = 6
```

```
 calc ashab = -.5 * percent
 calc aswater = .5 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 7
   aselect  grid-code = 8
   aselect  grid-code = 9
 calc ashab = .5 * percent
 calc aswater = 0 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 10
   aselect  grid-code = 11
 calc ashab = .5 * percent
 calc aswater = 0 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 14
 calc ashab = 0 * percent
 calc aswater = 0 * percent
 calc asflood = 0 * percent
   aselect
   reselect grid-code = 12
   aselect grid-code = 13
   aselect grid-code = 15
 calc ashab = 0 * percent
 calc aswater = .5 * percent
 calc asflood = 0 * percent
  &end
&if %class% cn 'R3EM' &then
  &do
   reselect grid-code = 2
 calc ashab = -.5 * percent
 calc aswater = .5 * percent
 calc asflood = .5 * percent
   aselect
   reselect grid-code = 3
 calc ashab = -.5 * percent
 calc aswater = .5 * percent
 calc asflood = .5 * percent
   aselect
   reselect grid-code = 4
 calc ashab = 0 * percent
 calc aswater = .5 * percent
 calc asflood = 0 * percent
   aselect
```

```
    reselect grid-code = 5
    aselect  grid-code = 6
  calc ashab = -.5 * percent
  calc aswater = .5 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 7
    aselect  grid-code = 8
    aselect  grid-code = 9
  calc ashab = .5 * percent
  calc aswater = 0 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 10
    aselect  grid-code = 11
  calc ashab = .5 * percent
  calc aswater = 0 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 14
  calc ashab = 0 * percent
  calc aswater = 0 * percent
  calc asflood = 0 * percent
    aselect
    reselect grid-code = 12
    aselect grid-code = 13
    aselect grid-code = 15
  calc ashab = 0 * percent
  calc aswater = .5 * percent
  calc asflood = 0 * percent
   &end
&if %class% cn 'R4EM' &then
   &do
    reselect grid-code = 2
  calc ashab = -.5 * percent
  calc aswater = .5 * percent
  calc asflood = .5 * percent
    aselect
    reselect grid-code = 3
  calc ashab = -.5 * percent
  calc aswater = .5 * percent
  calc asflood = .5 * percent
    aselect
    reselect grid-code = 4
  calc ashab = 0 * percent
  calc aswater = .5 * percent
```

```
calc asflood = 0 * percent
  aselect
  reselect grid-code = 5
  aselect  grid-code = 6
calc ashab = -.5 * percent
calc aswater = .5 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 7
  aselect  grid-code = 8
  aselect  grid-code = 9
calc ashab = .5 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 10
  aselect  grid-code = 11
calc ashab = .5 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 14
calc ashab = 0 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 12
  aselect grid-code = 13
  aselect grid-code = 15
calc ashab = 0 * percent
calc aswater = .5 * percent
calc asflood = 0 * percent
 &end

&if %class% cn 'R5EM' &then
 &do
  reselect grid-code = 2
calc ashab = -.5 * percent
calc aswater = .5 * percent
calc asflood = .5 * percent
  aselect
  reselect grid-code = 3
calc ashab = -.5 * percent
calc aswater = .5 * percent
calc asflood = .5 * percent
  aselect
```

```
  reselect grid-code = 4
calc ashab = 0 * percent
calc aswater = .5 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 5
  aselect  grid-code = 6
calc ashab = -.5 * percent
calc aswater = .5 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 7
  aselect  grid-code = 8
  aselect  grid-code = 9
calc ashab = .5 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 10
  aselect  grid-code = 11
calc ashab = .5 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 14
calc ashab = 0 * percent
calc aswater = 0 * percent
calc asflood = 0 * percent
  aselect
  reselect grid-code = 12
  aselect grid-code = 13
  aselect grid-code = 15
calc ashab = 0 * percent
calc aswater = .5 * percent
calc asflood = 0 * percent
 &end

q
&return
```

STEPCALC2

```
/* stepcalc2.aml - calculate the final function values by adding the original score
/*to the summed final correction value.

&args cover poly sashab saswater sasflood sasbank sassedi
```

```
&severity &error &ignore

ae
 ec %cover%
 ef poly
 sel %cover%-id = %poly%
  &sv recd [show select 1]
  &sv class [show polygon %recd% item attribute]

  &if %class% cn 'E1EM' &then
    &do
 calc ashab = %sashab% + 3
 calc aswater = %saswater% + 2
 calc asflood = %sasflood% + 1
    &end

 &if %class% cn 'E2EM' &then
    &do
 calc ashab = %sashab% + 3
 calc aswater = %saswater% + 2
 calc asflood = %sasflood% + 1
    &end


&if %class% cn 'E1SS' &then
   &do
 calc ashab = %sashab% + 3
 calc aswater = %saswater% + 2
 calc asflood = %sasflood% + 2
   &end

&if %class% cn 'E2SS' &then
   &do
 calc ashab = %sashab% + 3
 calc aswater = %saswater% + 2
 calc asflood = %sasflood% + 2
   &end

&if %class% cn 'E1FO' &then
   &do
 calc ashab = %sashab% + 3
 calc aswater = %saswater% + 2
 calc asflood = %sasflood% + 2
   &end

&if %class% cn 'E2FO' &then
```

```
  &do
 calc ashab = %sashab% + 3
 calc aswater = %saswater% + 2
 calc asflood = %sasflood% + 2
  &end

&if %class% cn 'PEM' &then
  &do
 calc ashab = %sashab% + 3
 calc aswater = %saswater% + 3
 calc asflood = %sasflood% + 2
  &end

&if %class% cn 'PSS' &then
  &do
 calc ashab = %sashab% + 3
 calc aswater = %saswater% + 3
 calc asflood = %sasflood% + 3
  &end

&if %class% cn 'PFO' &then
  &do
 calc ashab = %sashab% + 3
 calc aswater = %saswater% + 3
 calc asflood = %sasflood% + 3
  &end

&if %class% cn 'L1EM' &then
  &do
 calc ashab = %sashab% + 3
 calc aswater = %saswater% + 3
 calc asflood = %sasflood% + 2
  &end

&if %class% cn 'L2EM' &then
  &do
 calc ashab = %sashab% + 3
 calc aswater = %saswater% + 3
 calc asflood = %sasflood% + 2
  &end

&if %class% cn 'R1EM' &then
  &do
 calc ashab = %sashab% + 3
 calc aswater = %saswater% + 3
 calc asflood = %sasflood% + 1
```

```
  &end

&if %class% cn 'R2EM' &then
  &do
 calc ashab = %sashab% + 3
 calc aswater = %saswater% + 3
 calc asflood = %sasflood% + 1
  &end

&if %class% cn 'R3EM' &then
  &do
 calc ashab = %sashab% + 3
 calc aswater = %saswater% + 3
 calc asflood = %sasflood% + 1
  &end

&if %class% cn 'R4EM' &then
  &do
 calc ashab = %sashab% + 3
 calc aswater = %saswater% + 3
 calc asflood = %sasflood% + 1
  &end

&if %class% cn 'R5EM' &then
  &do
 calc ashab = %sashab% + 3
 calc aswater = %saswater% + 3
 calc asflood = %sasflood% + 1
  &end

save
q

&return
```

STEP 3

```
/* Step3.aml - determines adjustment factors for Chesapeake Bay "external
/* influence" coverages.

/*&args cover
&echo &on
&sv cover [response 'What is cover name (chicknwinew)']
&sv name [response 'Enter first 3 letters of watershed name(chi :chickahominy)']

/* adds items to coverage in preparation for Step 3 analysis: EXHAB (external
```

```
/* influence for habitat quality), EXWATER (external influence for water
/* quality), EXFLOOD (external influence for flood protection),
/* Also adds indentifying attributes for external influences:
/* ovlreef (the wetland area is within 1 km of aquatic reef points),
/* ovlhwtr (wetland area is within.5 km of stream, head-water sections),
/* ovlroad (wetland is within 33m of a roadway),
/* ovlpts (wetland is within 33m of a point source discharge),
/* ovlfrst (wetland area is within the Riparian Forest coverage area),
/* ovlsavt (wetland is within 1km of submerged aquatic veg tier 1 coverage pts),
/* ovlrte (wetland area and/or 33m buffer contain rte species).

&if not [iteminfo %cover%.pat -info ovlreef -exists] &then
 additem %cover%.pat %cover%.pat ovlreef 1 1 C # ASFLOOD
&if not [iteminfo %cover%.pat -info ovlhwtr -exists] &then
 additem %cover%.pat %cover%.pat ovlhwtr 1 1 C # ovlreef
&if not [iteminfo %cover%.pat -info ovlroad -exists] &then
 additem %cover%.pat %cover%.pat ovlroad 1 1 C # ovlhwtr
&if not [iteminfo %cover%.pat -info ovlfrst -exists] &then
 additem %cover%.pat %cover%.pat ovlfrst 1 1 C # ovlroad
&if not [iteminfo %cover%.pat -info ovlsavt -exists] &then
 additem %cover%.pat %cover%.pat ovlsavt 1 1 C # ovlfrst
&if not [iteminfo %cover%.pat -info ovlrte -exists] &then
 additem %cover%.pat %cover%.pat ovlrte 1 1 C # ovlsavt
&if not [iteminfo %cover%.pat -info ovlpts -exists] &then
 additem %cover%.pat %cover%.pat ovlpts 1 1 C # ovlrte

&if not [iteminfo %cover%.pat -info EXHAB -exists] &then
 additem %cover%.pat %cover%.pat EXHAB   4 5 N 1 ovlpts
&if not [iteminfo %cover%.pat -info EXWATER -exists] &then
 additem %cover%.pat %cover%.pat EXWATER 4 5 N 1 EXHAB
&if not [iteminfo %cover%.pat -info EXFLOOD -exists] &then
 additem %cover%.pat %cover%.pat EXFLOOD 4 5 N 1 EXWATER

arcedit
 &if [exists z%name%mdr.dat -info] &then
  kill z%name%mdr.dat info y
 &if [exists z%name%rte.dat -info] &then
  kill z%name%rte.dat info y
 &if [exists z%name%hwtr.dat -info] &then
  kill z%name%hwtr.dat info y
 &if [exists z%name%road.dat -info] &then
  kill z%name%road.dat info y
 &if [exists z%name%frst.dat -info] &then
  kill z%name%frst.dat info y
 &if [exists z%name%savt.dat -info] &then
  kill z%name%savt.dat info y
```

```
 &if [exists z%name%pts.dat -info] &then
   kill z%name%pts.dat info y

 edit %cover% poly
 select all
 calc ovlreef = ''
 calc ovlpts = ''
 calc ovlrte = ''
 calc ovlhwtr = ''
 calc ovlroad = ''
 calc ovlfrst = ''
 calc ovlsavt = ''
 save
q

/* Create buffers

&if not [exists %name%rtebuf -cover] &then
  buffer %name%rte %name%rtebuf # # 33 .01 point round full
&if not [exists %name%hwtrbuf -cover] &then
  buffer %name%hwtr %name%hwtrbuf # # 500 .01 line round full
&if not [exists %name%roadbuf -cover] &then
  buffer %name%roads %name%roadbuf # # 33 .01 line round full
&if not [exists %name%ptsbuf -cover] &then
  buffer %name%pts %name%ptsbuf # # 33 .01 point round full
/* tier is SAV
&if [exists %name%tier -cover] &then
 &do
&if not [exists %name%tierbuf -cover] &then
  buffer %name%tier %name%tierbuf # # 1000 .01 line round full
 &end
&if [exists mdreef -cover] &then
 &do
&if not [exists mdreefbuf -cover] &then
  buffer mdreef mdreefbuf # # 1000 .01 point round full
 &end

/*The remainder of the code takes each buffer and identities it with the
/* main nwi coverage. Only those nwi polys that intersect a buffer are
/* selected and their -ids are placed into a textfile. The stp6lp.aml
/* subroutine takes the list, reselects all the -ids in the main coverage
/* and calcs the appropriate items to 'y' thereby indicating that the
/* particular nwi poly is impacted by a particular external influence.

/* Reefs
```

```
&if [exists z%name%mdr -cover] &then
  kill z%name%mdr all

&if [exists mdreefbuf -cover] &then
 &do

identity %cover% mdreefbuf z%name%mdr poly .01 join

frequency z%name%mdr.pat z%name%mdr.dat
%cover%-id
inside
end
end

arcedit
edit z%name%mdr.dat info
  select inside <> 100 or %cover%-id = 0
  delete
save
q

tables
sel z%name%mdr.dat
unload list%cover% %cover%-id
q

kill z%name%mdr all

&r step3sub %cover% %name% mdr ovlreef
 &end

/*rare, threatened, endangered

&if [exists z%name%rte -cover] &then
  kill z%name%rte all
identity %cover% %name%rtebuf z%name%rte poly .01 join

frequency z%name%rte.pat z%name%rte.dat
%cover%-id
inside
end
end

arcedit
edit z%name%rte.dat info
  select inside <> 100 or %cover%-id = 0
```

```
  delete
save
q

tables
sel z%name%rte.dat
unload list%cover% %cover%-id
q

kill z%name%rte all

&r step3sub %cover% %name% rte ovlrte

/* point source discharges

&if [exists z%name%pts -cover] &then
  kill z%name%pts all
identity %cover% %name%ptsbuf z%name%pts poly .01 join

frequency z%name%pts.pat z%name%pts.dat
%cover%-id
inside
end
end

arcedit
edit z%name%pts.dat info
  select inside <> 100 or %cover%-id = 0
  delete
save
q

tables
sel z%name%pts.dat
unload list%cover% %cover%-id
q

kill z%name%pts all

&r step3sub %cover% %name% pts ovlpts

/* Headwater streams

&if [exists z%name%hwtr -cover] &then
  kill z%name%hwtr all
identity %cover% %name%hwtrbuf z%name%hwtr poly .01 join
```

```
frequency z%name%hwtr.pat z%name%hwtr.dat
%cover%-id
inside
 end
end

arcedit
edit z%name%hwtr.dat info
  select inside <> 100 or %cover%-id = 0
  delete
save
q

tables
sel z%name%hwtr.dat
unload list%cover% %cover%-id
q

kill z%name%hwtr all

&r step3sub %cover% %name% hwtr ovlhwtr

/* Roads

&if [exists z%name%road -cover] &then
  kill z%name%road all
identity %cover% %name%roadbuf z%name%road poly .01 join

frequency z%name%road.pat z%name%road.dat
%cover%-id
inside
end
end

arcedit
edit z%name%road.dat info
  select inside <> 100 or %cover%-id = 0
  delete
save
q

tables
sel z%name%road.dat
unload list%cover% %cover%-id
q
```

```
kill z%name%road all

&r step3sub %cover% %name% road ovlroad

/* Riparian forest

&if [exists z%name%frst -cover] &then
  kill z%name%frst all
identity %cover% %name%fstbuf z%name%frst poly .01 join

frequency z%name%frst.pat z%name%frst.dat
%cover%-id
dissolve
end
end

arcedit
edit z%name%frst.dat info
  select dissolve = 0  or %cover%-id = 0
  delete
save
q

tables
sel z%name%frst.dat
unload list%cover% %cover%-id
q

kill z%name%frst all

&r step3sub %cover% %name% frst ovlfrst

/* SAV - submerged aquatic vegetation

&if [exists z%name%savt -cover] &then
  kill z%name%savt all
&if [exists %name%tierbuf -cover] &then
 &do
identity %cover% %name%tierbuf z%name%savt poly .01 join

frequency z%name%savt.pat z%name%savt.dat
%cover%-id
inside
end
end
```

```
arcedit
edit z%name%savt.dat info
  select inside <> 100 or %cover%-id = 0
  delete
save
q

tables
sel z%name%savt.dat
unload list%cover% %cover%-id
q

kill z%name%savt all

&r step3sub %cover% %name% savt ovlsavt
 &end

&return
```

STEP 3sub

```
/* step3sub.aml - this is a sub macro that is called by Step3.aml.
/* Chesapeake Bay Program Wetlands Initiative protocol.
/*
&args cover name sub column
&if [exists list%cover% -file] &then
&do
&sv fileerr = [open list%cover% openerr -read]
&sv record = [read %fileerr% readerr]
&sv poly = [TRIM %record% ]

/*selects the coverage and ensures no records are currently selected.
arcedit
  &if %readerr% = 0 &then
    &do
      edit %cover% poly
      select all
      nselect
      &do &until %readerr% > 0
&setvar poly [subst %poly% , '']
/* adds a record to selected set based upon the -id in the listcover file
/* and calcs the variable to equal y (yes).. The ids from the listcover
/* file are from wetland polys that intersect the buffer in question.
 aselect %cover%-ID = %poly%
        &sv record = [read %fileerr% readerr]
        &sv poly = [TRIM %record% ]
```

```
    &end
    calc %column% = 'Y'
    save
   &end
/*  &if [exists %name%%sub%.dat -info] &then
/*    kill %name%%sub%.dat info y
  &if [exists %cover%%sub%.dat -info] &then
   kill %cover%%sub%.dat info y
q
rm list%cover%
&end
&return
```

STEP4

```
/* step4.aml - Calculates adjustment factors for the external influences.

&sv cover [response 'Enter coverage name']
/*&args cover
&severity &error &ignore
&echo &on

arcedit
  edit %cover% poly
  select nwi_class cn 'EEM'
  aselect nwi_class cn 'ESS'
  aselect nwi_class  cn 'EFO'
  aselect nwi_class cn 'PEM'
  aselect nwi_class cn 'PSS'
  aselect nwi_class cn 'PFO'
  aselect nwi_class cn  'LEM'
  aselect nwi_class cn 'REM'
  calc exhab = ashab
  calc exwater = aswater
  calc exflood = asflood

  nselect
  calc ovlreef = ''
  calc ovlpts = ''
  calc ovlrte = ''
  calc ovlhwtr = ''
  calc ovlroad = ''
  calc ovlfrst = ''
  calc ovlsavt = ''

  select nwi_class cn  'EEM' and ovlreef = 'Y'
  aselect nwi_class cn 'ESS' and ovlreef = 'Y'
```

```
  aselect nwi_class cn 'EFO' and ovlreef = 'Y'
  aselect nwi_class cn 'PEM' and ovlreef = 'Y'
  aselect nwi_class cn 'PSS' and ovlreef = 'Y'
  aselect nwi_class cn 'PFO' and ovlreef = 'Y'
  aselect nwi_class cn 'LEM' and ovlreef = 'Y'
  aselect nwi_class cn 'REM' and ovlreef = 'Y'
  calc exhab = exhab + 0.5
  calc exwater = exwater + 0.5


select nwi_class cn  'EEM' and ovlrte = 'Y'
  aselect nwi_class cn 'ESS' and ovlrte = 'Y'
  aselect nwi_class cn 'EFO' and ovlrte = 'Y'
  aselect nwi_class cn 'PEM' and ovlrte = 'Y'
  aselect nwi_class cn 'PSS' and ovlrte = 'Y'
  aselect nwi_class cn 'PFO' and ovlrte = 'Y'
  aselect nwi_class cn 'LEM' and ovlrte = 'Y'
  aselect nwi_class cn 'REM' and ovlrte = 'Y'
  calc exhab = exhab + 0.5


select nwi_class cn  'EEM' and ovlpts = 'Y'
  aselect nwi_class cn 'ESS' and ovlpts = 'Y'
  aselect nwi_class cn 'EFO' and ovlpts = 'Y'
  aselect nwi_class cn 'PEM' and ovlpts = 'Y'
  aselect nwi_class cn 'PSS' and ovlpts = 'Y'
  aselect nwi_class cn 'PFO' and ovlpts = 'Y'
  aselect nwi_class cn 'LEM' and ovlpts = 'Y'
  aselect nwi_class cn 'REM' and ovlpts = 'Y'
  calc exhab = exhab - 0.5
  calc exwater = exwater + 0.5
  calc exflood = exflood + 0.5

select nwi_class cn  'EEM' and ovlhwtr  = 'Y'
  aselect nwi_class cn 'ESS' and ovlhwtr = 'Y'
  aselect nwi_class cn 'EFO' and ovlhwtr = 'Y'
  aselect nwi_class cn 'PEM' and ovlhwtr = 'Y'
  aselect nwi_class cn 'PSS' and ovlhwtr = 'Y'
  aselect nwi_class cn 'PFO' and ovlhwtr = 'Y'
  aselect nwi_class cn 'LEM' and ovlhwtr = 'Y'
  aselect nwi_class cn 'REM' and ovlhwtr = 'Y'
  calc exwater = exwater + 0.5
  calc exflood = exflood + 0.5

select nwi_class cn  'EEM' and ovlroad = 'Y'
  aselect nwi_class cn 'ESS' and ovlroad = 'Y'
```

```
  aselect nwi_class cn 'EFO' and ovlroad = 'Y'
  aselect nwi_class cn 'PEM' and ovlroad = 'Y'
  aselect nwi_class cn 'PSS' and ovlroad = 'Y'
  aselect nwi_class cn 'PFO' and ovlroad = 'Y'
  aselect nwi_class cn 'LEM' and ovlroad = 'Y'
  aselect nwi_class cn 'REM' and ovlroad = 'Y'
  calc exhab = exhab - 0.5
  calc exwater = exwater + 0.5
  calc exflood = exflood + 0.5

select nwi_class cn  'EEM' and ovlfrst = 'Y'
  aselect nwi_class cn 'ESS' and ovlfrst = 'Y'
  aselect nwi_class cn 'EFO' and ovlfrst = 'Y'
  aselect nwi_class cn 'PEM' and ovlfrst = 'Y'
  aselect nwi_class cn 'PSS' and ovlfrst = 'Y'
  aselect nwi_class cn 'PFO' and ovlfrst = 'Y'
  aselect nwi_class cn 'LEM' and ovlfrst = 'Y'
  aselect nwi_class cn 'REM' and ovlfrst = 'Y'
  calc exwater = exwater + 0.5
  calc exflood = exflood + 0.5

select nwi_class cn  'EEM' and ovlsav = 'Y'
  aselect nwi_class cn 'ESS' and ovlsav = 'Y'
  aselect nwi_class cn 'EFO' and ovlsav = 'Y'
  aselect nwi_class cn 'PEM' and ovlsav = 'Y'
  aselect nwi_class cn 'PSS' and ovlsav = 'Y'
  aselect nwi_class cn 'PFO' and ovlsav = 'Y'
  aselect nwi_class cn 'LEM' and ovlsav = 'Y'
  aselect nwi_class cn 'REM' and ovlsav = 'Y'
  calc exhab = exhab + 0.5
  calc exwater = exwater + 0.5

save
q
&type Step4.aml is complete.
&return
```

VITA

JENNIFER NEWTON BISSONNETTE

Born in Providence, Rhode Island, 22 October 1967. Graduated from Smithfield High School in 1985. Earned a B.S. in Biology from Eckerd College, St. Petersburg, Florida, in 1992. Entered doctoral program in College of William and Mary, School of Marine Science in 1994. Took a leave of absence, from 1997 through 1998 to participate in a Knauss Marine Policy Fellowship, on Capitol Hill, working in the Office of Congressman Sam Farr (D-CA). Returned to doctoral studies in the summer of 1999.