Watershed-based Wetland Characterization for Delaware's Nanticoke River Watershed: A Preliminary Assessment Report

U.S. Fish and Wildlife Service
National Wetlands Inventory
Northeast Region
Hadley, MA 01035

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by

R.W. Tiner, H.C. Bergquist, J.Q. Swords, and B.J. McClain

U.S. Fish and Wildlife Service
Northeast Region
National Wetlands Inventory Program
300 Westgate Center Drive
Hadley, MA 01035

Prepared for the
Delaware Department of Natural Resources and Environmental Control
Division of Soil and Water Conservation
89 Kings Highway
Dover, DE 19901

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Table of Contents

Thematic Maps in separate folder on the CD

Introduction

Today there is great interest in managing wetland resources from a watershed standpoint or landscape perspective. Wetland managers need information on a variety of topics including the location and type of existing wetlands, wetland functions, potential wetland restoration sites, and the overall condition of natural habitat in the watershed. The U.S. Fish and Wildlife Service's National Wetlands Inventory Program has developed products that expand the use of its conventional maps and digital products to aid in resource management. The Delaware Department of Natural Resources and Environmental Control (DNREC) is attempting to reduce nonpoint source pollution impacts in the Nanticoke watershed and wanted the above information for the Delaware portion of the Nanticoke River watershed. This information would be used to help improve water quality and management and conservation of fish and wildlife habitat in wetlands, streams, riparian areas, and uplands in Delaware. Similar work has recently been completed for the Maryland portion of the watershed (Tiner et al. 2000). In the future, both efforts may be combined into a single report.

The DNREC, through its Division of Soil and Water Conservation, provided funding to the Service to produce watershed-wide information on wetlands, streams, riparian areas, and uplands. The following products were scheduled for production: 1) a wetland characterization report for the Delaware portion of the Nanticoke River watershed, 2) a set of GIS-produced maps showing wetlands and highlighting wetlands of potential significance for performing various functions, 3) edited and updated digital databases, 4) updated NWI maps for 11 quads, and 5) a summary of the remotely-sensed natural habitat (ecological) integrity indices for the Nanticoke River watershed and its subbasins.

The report is organized into the following sections: *Study Area, Methods, General Scope and Limitations of the Study, Appropriate Use of this Report, Rationale for Preliminary Functional Assessments, Results, Conclusions, Acknowledgments*, and *References*. Two appendices provide keys to hydrogeomorphic wetland classification and the functional assessment findings for subbasins. Thematic maps are contained in a separate folder on the CD version of this report.

Study Area

The study area is the Delaware portion of the Nanticoke River watershed. This roughly 490-square mile drainage area occurs in western Delaware along its border with Maryland. It represents about 25 percent of the state of Delaware. This watershed contains the six subbasins: Broad Creek, Deep Creek, Gravelly Branch, Gum Branch, Marshyhope Creek, and the Nanticoke River. The watershed encompasses parts of Sussex, Kent, and New Castle Counties. It appears on the following 14 quads: Seaford West, Sharptown, Hebron, Hickman, Greenwood, Ellendale, Seaford East, Georgetown, Laurel, Trap Pond, Delmar, Pittsville, Burrsville, and Harrington.

Methods

The purpose of the project was to produce new information to assist Delaware wetland managers in wetland planning and evaluation at the watershed level (see section on *Appropriate Use of this Report*). The foundation of this project was construction of a fairly comprehensive, geospatial wetland database. The existing wetland digital data for Delaware included the National Wetlands Inventory (NWI) data (based on 1:24,000 maps derived from mostly early 1980s-1:58K color infrared photography), the State's wetland data (based on digital orthophoto quarter-quads produced from spring 1992-1:40K color infrared photographs), and the State's land use and land cover data (mid-1990s data). The NWI data were used as the foundation since they are part of a national database and match up well with other national digital data, especially hydrology data from the U.S. Geological Survey. The State data were used as collateral data to improve the delineation of wetlands in the NWI database. Updated NWI data and land use/land cover data were derived through interpreting spring 1998-1:40K black and white photography.

The NWI database was also expanded to include hydrogeomorphic-type attributes for all mapped wetlands and waterbodies, an inventory of ditches, an inventory of potential wetland restoration sites, and geospatial data on land use and land cover in both watersheds. The information contained within the database was then used to produce summary statistics, thematic maps, and a wetland characterization report for the watersheds. The characterization included: 1) a summary of the extent and distribution of wetland types (by NWI type and hydrogeomorphic type), 2) a preliminary assessment of wetland functions for each watershed, 3) an inventory of potential wetland restoration sites, 4) a description of the condition of wetland and waterbody buffers, 5) an overall assessment of natural habitat for the watershed, and 6) an assessment of the extent of ditching. The following discussion describes procedures used to produce this information. The report summarizes the study findings for each watershed. These results should be considered preliminary as they have not been subject to agency or field review.

Improved Baseline NWI Data

The first step in the project was updating the NWI maps and digital database, since these data would be used for the analysis of wetland functions. The existing NWI dataset was both dated (derived from early 1980s photography) and conservative (e.g., many flatwoods were not mapped). We updated the NWI digital data using a digital transfer scope. This equipment allowed integration of existing digital wetland and hydric soil data and editing of the digital data through photointerpretation of spring 1998-1:40K black-and-white aerial photography. Digital data used to assist in updating were: 1) Delaware wetlands produced by the State from 1992 photography, and 2) hydric soil data from the U.S.D.A. Natural Resources Conservation Service's (NRCS) soil surveys for Kent and Sussex Counties. Utilizing hydric soils digital data to help expand the mapping of flatwood wetlands may have led to some errors of commission (i.e., inclusion of upland forests in flatwood polygons), since these are among the most difficult wetlands to photointerpret (Tiner 1999). These wetlands tended to be classified as a seasonally saturated forested wetland of some kind (broad-leaved deciduous, needle-leaved evergreen, or mixed; NWI codes such as PFO1B, PFO4B, PFO1/4B, and PFO4/1B). For the original NWI mapping, most of the mapped wet flatwoods were labelled as temporarily flooded, since ponding was observed in a few places. Since the 1980s, more work has been done in the Coastal Plain and the hydrology of wet flatwoods has been determined to be best described as “seasonally saturated.” This is because high water tables are typical in winter and early spring, with little standing water present. Locally these wetlands are often called “winter wet woods.” The classifications of these flatwoods were revised to reflect a seasonally saturated condition (i.e., applied the “B” or “saturated” water regime modifier). The NRCS data for hydric soils and Delaware wetland data were mainly used as collateral sources to aid in flatwood wetland identification and the former also for assisting in classification of floodplain wetlands.

Expanded NWI Data

Once a more complete inventory of wetlands was created, the NWI database was further expanded by adding hydrogeomorphic-type information to each mapped wetland. Landscape position, landform, water flow path, and other descriptors were applied to all wetlands in the NWI digital database by merging NWI data with on-line U.S. Geological Survey topographic maps and consulting aerial photography where necessary (see Tiner 2000; Appendix of this report for keys to these descriptors).

Landscape position defines the relationship between a wetland and an adjacent waterbody, if present. Four landscape positions are relevant to the study watersheds: 1) lotic (along freshwater rivers and streams), 2) lentic (in lakes, reservoirs, and their basins), 3) terrene (isolated, headwater, or fragments of former isolated or headwater wetlands that are now connected to downslope wetlands via drainage ditches), and 4) estuarine (in estuaries). Lotic wetlands are further separated by river and stream gradients as high (e.g., shallow mountain streams on steep slopes - not present in the study areas), middle (e.g., streams with moderate slopes - not present in the study areas), low (e.g., mainstem rivers with considerable floodplain development as in the Nanticoke watershed), and tidal (i.e., under the influence of the tides). "Rivers" are separated from "streams" solely on the basis of channel width: watercourses mapped as linear (one-line) features on an NWI map and a U.S. Geological Survey topographic map were designated as streams, whereas two-lined channels (polygonal features) on these maps were classified as rivers. Total river-stream length was determined by running a centerline through all river polygons and adding this mileage to the miles of linear streams.

Landform is the physical form of a wetland or the predominant land mass on which it occurs (e.g., floodplain or interfluve). Six types are recognized in the study areas: basin, interfluve, flat, floodplain, fringe, and island (see Table 1 for definitions). The Johnston soil was the only soil series in the watershed that was associated with floodplain wetlands.

Additional modifiers were assigned to indicate water flow paths associated with wetlands: bidirectional, throughflow, inflow, outflow, or isolated. Bidirectional flow is two-way flow either related to tidal influence or water level fluctuations in isolated lakes and impoundments. Throughflow wetlands have either a watercourse or another type of wetland above and below it, so water flows through the subject wetland. All lotic wetlands are throughflow types. Inflow wetlands are sinks where no outlets exist, yet water is entering via a stream or river or an upslope wetland. Outflow wetlands have water leaving them and moving downstream via a watercourse or a slope wetland. Isolated wetlands are essentially closed depressions or flats where water comes from surface water runoff and/or ground water discharge.

Other descriptors applied to mapped wetlands include headwater, drainage-divide, and fragmented. Headwater wetlands are sources of streams or wetlands along first order (perennial) streams. They include wetlands connected to first order streams by ditches. The latter wetlands were also labeled with a ditched modifier. Many such wetlands are remnants of once larger interfluve wetlands that drained directly into streams. Drainage-divide wetlands are wetlands that occur in more than one watershed or subbasin, straddling the defined watershed boundary line between a watershed or subbasin and a neighboring one. We identified pieces of wetlands separated by major highways (federal and state roads) as fragmented wetlands. This is a first step in addressing the issue of fragmentation which is quite complex and beyond the scope of our work. For example, we did not apply the descriptor to wetlands that were simply reduced in size due to land use practices. The listing of fragmented wetlands is extremely conservative.

For open water habitats such as the ocean, estuaries, lakes, and ponds, we also applied additional descriptors following Tiner (2000). For the study watersheds, such classification was mainly relevant for ponds.

Preliminary Assessment of Wetland Functions

After improving and enhancing the NWI digital database, several analyses were performed to produce a preliminary assessment of wetland functions for the watershed. Nine wetland functions were evaluated: 1) surface water detention, 2) streamflow maintenance, 3) nutrient transformation, 4) sediment and other particulate retention, 5) shoreline stabilization, 6) fish and shellfish habitat, 7) waterfowl and waterbird habitat, 8) other wildlife habitat, and 9) biodiversity. The rationale for correlating wetland characteristics with wetland functions is described in a later section of this report. After running the analyses, a series of maps for watershed were generated to highlight wetland types that may perform these functions at high or other significant levels. Statistics and topical maps for the study area were generated by ArcView software.

Table 1. Definitions and examples of landform types (Tiner 2000).

Landform Type	**General Definition**	**Examples**
Basin*	a depressional (concave) landform	lakefill bogs; wetlands in the saddle between two hills; wetlands in closed or open depressions, including narrow stream valleys
Slope	a landform extending uphill (on a slope)	seepage wetlands on hillside; wetlands along drainageways or mountain streams on slopes
Flat*	a relatively level landform, often on broad level landscapes	wetlands on flat areas with high seasonal ground-water levels; wetlands on terraces along rivers/streams; wetlands on hillside benches; wetlands at toes of slopes
Floodplain	a broad, generally flat landform occurring on a landscape shaped by fluvial or riverine processes	wetlands on alluvium; bottomland swamps
Interfluve	a broad level to imperceptibly depressional poorly drained landform occurring between two drainage systems (on interstream divides)	flatwood wetlands on coastal or glaciolacustrine plains
Fringe	a landform occurring along a flowing or standing waterbody (lake, river, stream) and typically subject to permanent, semipermanent flooding or frequent tidal flooding; including wetlands within stream or river channels and estuarine wetlands with unrestricted tidal flow	buttonbush swamps; aquatic beds; semipermanently flooded marshes; salt and brackish marshes
Island	a landform completely surrounded by water (including deltas)	deltaic and insular wetlands; floating bog islands

*May be applied as sub-landforms within the Interfluve and Floodplain landforms.

Wetland Restoration Site Inventory

Wetland restoration efforts have been accelerating over the past decade throughout the country. Much of the work done to date has been on an ad hoc basis without knowledge of a broader universe of potential sites. In many areas of the country, site selection for wetland restoration has simply been driven by opportunities and not by a holistic view of watersheds and wetland resources. Recently, the State of Massachusetts initiated a watershed-based restoration process, where potential wetland restoration sites are identified throughout an entire watershed, then matched with locations of various "watershed-deficits" (e.g., flooding problems, areas of degraded water quality, and lack of connectivity between significant fish and wildlife habitats) in an effort to promote wetland restoration where the greatest public good can be gained. Such work provides agencies, organizations, and others interested in wetland restoration with a wide selection of potential sites. The Delaware Department of Natural Resources and Environmental Control is interested in this process, so we identified potential wetland restoration sites for the subject watershed.

An inventory of potential wetland restoration sites was performed by examining aerial photos, hydric soil information, and existing wetland data (e.g., for farmed wetlands, wetlands experiencing possible hydrologic restrictions, plus diked, ditched, and excavated vegetated wetlands). Two major types of wetland restoration sites were identified: Type 1 sites - former vegetated wetlands that appear suitable for restoration, and Type 2 sites - existing vegetated wetlands whose functions appear to be significantly impaired by ditching, excavation, and impoundment. Type 1 restoration sites included former wetlands that were filled and that did not have buildings or other facilities constructed on them, farmed wetlands, and vegetated wetlands that were converted to deepwater habitats such as impounded lakes. Farmed wetlands may technically be considered Type 2 candidates, but since their condition is impaired to the point that they only minimally meet the definition of wetland in the subject areas, they were considered Type 1 sites. Type 2 restoration sites are mostly existing vegetated wetlands that are impounded, excavated, partly drained (ditched), and potentially tidally restricted, but also include shallow ponds constructed on hydric soils. For ditched wetlands, no attempt was made to evaluate the scope and effect of ditching as this requires field-based assessment. One, however, might consider the degree of ditching as observed on the map showing the extent of ditching as a way of assessing the relative impact of ditching on various wetlands.

Ditch Inventory

To determine the extent of ditches in the watershed, we began with the digital hydrology coverage from the U.S. Geological Survey 1:24K map series (digital line graphs - DLGs). This coverage was reviewed to help separate "natural streams" from "ditches" and formed the foundation for the "ditch" data layer. To create an up-to-date "ditch" coverage, photointerpretation of 1998 aerial photography[1] was performed using a digital transfer scope.

[1]For the Nanticoke watershed, initial mapping of ditches was accomplished by photointerpreting 1989 photos since the 1998 photos were not available until later in the project.

Ditches were separated from channelized and natural streams. Data presented include number of ditch miles and the density of ditches per study watershed.

Water Resource Buffer Analysis

A 100m-wide (328 feet) stream buffer has been reported to be important for neotropical migrant bird species in the Mid-Atlantic region (Keller et al. 1993) and streamside vegetation providing canopy coverage over streams is important for lowering stream temperatures and moderating daily fluctuations that is vital to providing suitable habitat for certain fish species (e.g., trout). Review of the literature on buffers suggests wider buffers, such as 500m (1,640 feet) or more, for certain species of wildlife (e.g., Kilgo et al. 1998 for southern bottomland hardwood stream corridors). Semlitsch and Jensen (2001) emphasize that "wetland buffers" should be better described as "core habitat" for semiaquatic species and they urge that such areas be protected and managed as vital habitats. They found that 95 percent of the breeding population of mole salamanders lived in the adjacent forest within 164m (538 feet) of their vernal pool wetland. An interesting article by Finlay and Houlahan (1996) indicates that land use practices around wetlands may be as important to wildlife as the size of the wetland itself. They reported that removing 20 percent of the forest within 1000m (3,281 feet) of a wetland may have the same effect on species as destroying 50 percent of the wetland. For literature reviews of wetland and stream buffers, see Castelle et al. (1994) and Desbonnet et al. (1994).

The condition of these buffers is also significant for locating possible sources of water quality degradation. Wooded corridors should provide the best protection, while developed corridors (e.g., urban or agriculture) should contribute to substantial water quality and aquatic habitat deterioration. Since wetland and waterbody buffers are important features that relate to the quality of these aquatic habitats, we performed an analysis of the condition of these buffers. This information was also used in evaluating the overall ecological condition or the condition of natural habitats for each watershed.

A 100m-wide buffer was selected for analysis. The buffer was positioned around various water resource features, i.e., wetlands, lakes, ponds, streams, and ditches. To evaluate the condition of the buffer, we created a land use/land cover data layer by combining existing digital data with new photointerpretation. The state's existing digital data on land use/land cover was used as the foundation. These data were updated by interpreting 1998 aerial photography (1:40,000 black and white) using a digital transfer scope. We used the Anderson et al. (1976) land use/land cover classification system and classified upland habitats to level two in this system. The following categories were among those identified: developed land (e.g., residential, commercial, industrial, transportation/communication, utilities, other, institutional/government, and recreational), agricultural land (cropland, pasture, orchards, nurseries, horticulture, feedlots, and holding areas), forests (deciduous, evergreen, mixed, and clear-cut), wetlands (from NWI data), and transitional

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These data were updated with the 1998 photos to create a 1998-era database for ditches.

land (moving toward some type of development or agricultural use, but future status unknown). Data layers were constructed for the entire "land" area of each watershed so that information could also be used for assessing their overall ecological condition. Buffer analysis is one of the key landscape variables used to judge this condition. Data on buffers were reported for various water resource features: perennial nontidal rivers and streams, wetlands, ponds and lakes (impoundments), and a few combinations of perennial rivers and streams, intermittent streams, and ditches.

Overall Ecological Condition of the Watershed

There are many ways to assess land use/cover changes and habitat disturbances. The health and ecological condition of a watershed may be assessed by considering such features as the integrity of the lotic wetlands and riparian forests (upland forests along streams), the percent of land uses that may adversely affect water quality in the watershed (% urban, % agriculture, % mining, etc.), the actual water quality, the percent of forest in the watershed, and the number of dams on streams, for example. Recent work on assessing the condition of watersheds has been done in the Pacific Northwest to address concerns for salmon (Wissmar et al. 1994; Naiman et al. 1992). A Wisconsin study by Wang et al. (1997) found that instream habitat quality declined when agricultural land use in a watershed exceeded 50 percent, while when only 10-20 percent of the watershed was urbanized, severe degradation occurred.

To assess the overall ecological condition of watersheds, the Northeast Region of the U.S. Fish and Wildlife Service has developed a set of largely remotely-sensed "natural habitat integrity" indices (formerly referred to as "ecological integrity indices"). The variables for these indices are derived through air photointerpretation and/or satellite image processing coupled with knowledge of the historical extent of wetlands and open waterbodies. They are coarse-filter variables for assessing the overall condition of watersheds. They are intended to augment, not supplant, other more rigorous, fine-filter approaches for describing the ecological condition of watersheds (e.g., indices of biological integrity for macroinvertebrates and fish and the extent and distribution of invasive species) and for examining relationships between human impacts and the natural world. The natural habitat integrity indices can be used to develop "habitat condition profiles" for individual watersheds of varying scales (i.e., subbasins to major watersheds). Indices can be used for comparative analysis of subbasins within watersheds and to compare one watershed with another. They may also serve as one set of statistics for reporting on the "state-of-the-environment" by government agencies and environmental organizations or for evaluating the historic trends in the extent of natural habitats.

The indices are rapid-assessment types that allow for frequent updating (e.g., every 5-10 years). They may be used to assess and monitor the amount of "natural habitat" compared to the amount of disturbed aquatic habitat (e.g., channelized streams, partly drained wetlands, and impounded wetlands) or developed habitat (e.g., cropland, grazed meadows, mined lands, suburban development, and urbanized land). The index variables include features important to natural resource managers attempting to lessen the impact of human development on the environment. The indices may also be compared with other environmental quality metrics such as indices of biological integrity for fish and/or macroinvertebrates or water quality parameters. If significant correlations can be found, they may aid in projecting a "carrying capacity" or threshold for development for individual subbasins. This would require further classification of the developed land category into various agricultural types and urban/suburban types which is easily accomplished.

Prior to initiating this project, a total of nine indices were developed for nontidal areas. We split one of them into two indices for a new total of ten indices. All of them, in one way or another, represent habitat condition in a watershed. Six indices address natural habitat extent (i.e., the amount of natural habitat occurring in the watershed and along wetlands and waterbodies): natural cover, river-stream corridor integrity, vegetated wetland buffer integrity, pond and lake buffer integrity, wetland extent, and standing waterbody extent. Use of terms like "natural habitat" and "natural vegetation" have stirred much debate, yet despite this, we feel that they are useful for discussing the effects of human activities on the environment. For purposes of this study, "natural habitats" are defined as areas where significant human activity is limited to nature observation, hunting, fishing, or timber harvest, and where vegetation is allowed to grow for many years without annual introduction of chemicals or annual harvesting of vegetation or fruits and berries for commercial purposes. Natural habitats may be managed, yet are not intensively managed or subjected to heavy human traffic. They are places where wetland and terrestrial wildlife find food, shelter, and water. In other words, they are essentially plant communities represented by "natural" vegetation such as forests, meadows, and shrub thickets. They are not developed sites (e.g., impervious surfaces, lawns, turf, cropland, pastures, or mowed hayfields). Managed forests are included as natural habitat, whereas orchards and vineyards are not. "Natural habitat" therefore includes habitats ranging from pristine woodlands and wetlands to wetlands now colonized by invasive species (e.g., Phragmites australis or Lythrum salicaria) or commercial forests planted with loblolly pine. Natural vegetation does not imply that substantial groundcover must be present, but simply that the communities reflect the vegetation that is capable of growth and reproduction in accordance with site characteristics (e.g., sand dunes and beaches).

Three indices emphasize human-induced alterations to streams and wetlands. These "stream and wetland disturbance indices" address dammed stream flowage, channelized stream flowage, and wetland disturbance. The nine specific indices may be combined into a single, composite index called "remotely-sensed natural habitat integrity index" for the watershed. All indices have a maximum value of 1.0 and a minimum value of zero. For the habitat extent indices, the higher the value, the more habitat available. For the disturbance indices, the higher the value, the more disturbance. For the remotely-sensed natural habitat integrity index, all indices are weighted, with the disturbance indices subtracted from the habitat extent indices to yield an overall "natural habitat integrity" score for the watershed.

Data for these indices came from the improved NWI digital database and a newly created land use/land cover database for the two watersheds. The data were derived primarily through aerial photointerpretation with review of existing information. The indices do not include certain qualitative information on the condition of the existing habitats (habitat quality) as reflected by the presence, absence, or abundance of invasive species or by fragmentation of forests, for example. It may be possible to add such data in the future, especially for the latter. Another consideration would be establishment of minimum size thresholds to determine what constitutes a viable “natural habitat” for analysis (e.g., 0.04 hectare/0.1 acre patch of forest or 0.4 hectare/1 acre minimum?). Other indices may also need to be developed to aid in water quality assessments (e.g., index of ditching density for agricultural and silvicultural lands). The nine indices are summarized below.

Habitat Extent Indices

These indices have been developed to provide some perspective on the amount of natural vegetation that occurs in a watershed. The following areas are emphasized: the entire watershed, stream and river corridors, vegetated wetlands and their buffers, and pond and lake buffers. The extent of standing waterbodies is also included to provide information on the amount of aquatic habitat in the watershed. Each index is briefly described below.

The Natural Cover Index (I_{NC}) is derived from a simple percentage of the subbasin that is wooded (e.g., upland forests or shrub thickets and forested or scrub-shrub wetlands) and “natural” open land (e.g., emergent wetlands or “old fields;” but not cropland, hayfields, lawns, turf, or pastures). These areas are lands supporting “natural vegetation” and they exclude open water of ponds, rivers, lakes, streams, and coastal bays.

> $\mathbf{I_{NC} = A_{NV}/A_W}$, where A_{NV} (area in natural vegetation) equals the area of the watershed’s land surface in “natural” vegetation and A_W is the area of "watershed" excluding open water.

The River-Stream Corridor Integrity Index (I_{RSCI}) is derived by considering the condition of the stream corridors around perennial rivers and **streams**[2]:

> $\mathbf{I_{RSCI} = A_{VC}/A_{TC}}$, where A_{VC} (vegetated river-stream corridor area) is the area of the river-stream corridor that is colonized by “natural vegetation” and A_{TC} (total river-stream corridor area) is the total area of the river-stream corridor.

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[2]Including streams designated as seasonally flooded/saturated intermittent streams (i.e., R4SBEx) which flow for long periods during the year, but not year-round. Such streams were identified on the source data (U.S.Geological Survey DLGs) as perennial, but based on our field experiences and those of Amy Jacobs (DNREC) it was agreed that these streams are not perennial.

The width of the river-stream corridor may be varied to suit project goals, but for this project, a 200-meter (656 feet) corridor (100m on each side of the river or stream) was evaluated. To compute total river-stream length, the centerlines of river polygons are used to derive river length and this was added to stream length (from linear data). Also note that these corridors include impounded sections of rivers and streams, so that a continuous river or stream corridor is evaluated. The centerlines of these polygons were used to determine stream length. For this watershed, the index was applied to nontidal rivers for assessing the composite natural habitat integrity index. When the entire Nanticoke River watershed is evaluated in the future, the index should include tidal portions of the river as well.

The Wetland Buffer Integrity Index (I_{WB}) is a measure of the condition of wetland buffers within a specified distance (e.g., 100m) of mapped vegetated wetlands for the entire watershed:

> $\mathbf{I_{WB} = A_{VB}/A_{TB}}$, where A_{VB} (area of vegetated buffer) is the area of the buffer zone that is in natural vegetation cover and A_{TB} is the total area of the buffer zone.

This buffer is drawn around existing vegetated wetlands. While the buffer zone may include open water, the buffer index will focus on land areas that may support free-standing vegetation. Note that for the analysis of the Maryland portion of the Nanticoke River watershed, the wetland buffers were included with the pond and lake buffers in an index called Wetland and Waterbody Buffer Index (I_{WWB}). Buffer width can be varied according to regional needs and conditions. For the Nanticoke River watershed analysis, a 100m buffer was examined.

The Pond and Lake Buffer Integrity Index (I_{PLB}) addresses the status of buffers of a specified width around these standing waterbodies (excluding in-stream impoundments that are included in the river-stream corridor integrity index):

> $\mathbf{I_{PLB} = A_{VB}/A_{TB}}$, where A_{VB} (area of vegetated buffer) is the area of the buffer zone that is in natural vegetation cover and A_{TB} is the total area of the buffer zone.

See comments under the wetland buffer integrity index above. Ponds are shallow waterbodies mapped as palustrine unconsolidated bottoms and unconsolidated shores by NWI. Vegetated ponds are mapped as a vegetated wetland type and their buffers are not included in this analysis, but instead are evaluated as wetland buffers. For the Nanticoke River watershed analysis, a 100m buffer was examined.

The Wetland Extent Index (I_{WE}) compares the current extent of vegetated wetlands (excluding nonvegetated, open-water wetlands) to the estimated historic extent.

> $\mathbf{I_{WE} = A_{CW}/A_{HW}}$, where A_{CW} is the current area of vegetated wetland in the watershed and A_{HW} is the historic vegetated wetland area in the watershed.

The I_{WE} is an approximation of the extent of the original wetland acreage remaining in the watershed. Farmed wetlands are included where cultivation is during droughts only, since they are likely to support "natural vegetation" during normal and wet years. Where farmed wetlands are cultivated more or less annually such as in much of the Northeast region, they are not included in the area of vegetated wetland, since they lack "natural vegetation" in most years and only minimally function as wetland. For the Nanticoke watershed, hydric soils data are available for the Kent and Sussex Counties portion of the watershed and were used to calculate the wetland extent index for the watershed.

The Standing Waterbody Extent Index (I_{SWE}) addresses the current extent of standing fresh waterbodies (e.g., lakes, reservoirs, and open-water wetlands - ponds) in a watershed relative to the historic area of such features.

> $\mathbf{I_{SWE} = A_{CSW}/A_{HSW}}$, where A_{CSW} is the current standing waterbody area and A_{HSW} is the historic standing waterbody area in the watershed.

Since the Nanticoke watershed has experienced a net gain in ponds and impoundments over time, the I_{SWE} value is 1.0+ which indicates a gain in this aquatic resource with no specific calculations necessary. A value of 1.0 was used for determining the composite natural habitat integrity index for the watershed.

Stream and Wetland Disturbance Indices

A set of three indices have been developed to address alterations to streams and wetlands. For these indices, a value of 1.0 is assigned when all of the streams or existing wetlands have been modified.

The Dammed Stream Flowage Index (I_{DSF}) highlights the direct impact of damming on rivers and streams in a watershed.

> $\mathbf{I_{DSF} = L_{DS}/L_{TS}}$, where L_{DS} is the length of perennial streams impounded by dams (combined pool length) and L_{TS} is the total length of perennial streams in the watershed (including the length of in-stream pools).

Note that the total stream length used for this index will be greater than that used in the channelized stream length index, since the latter emphasizes existing streams and excludes the length of dammed segments. *See footnote 2.* Also note that this index was not applied to the full length of the Nanticoke River, but only to linear streams. In the future, this index should be expanded to include the entire river-stream length (i.e., the Dammed River-Stream Flowage Index).

The Channelized Stream Length Index (I_{CSL}) is a measure of the extent of channelization of streams within a watershed.

$I_{CSL} = L_{CS}/L_{TS}$, where L_{CS} is the channelized stream length and L_{TS} is the total stream length for the watershed.

Since this index addresses channelization of existing streams, it focuses on the linear streams. The index will usually emphasize perennial streams as it does for the Nanticoke River study, but could include intermittent streams, if desirable. *See footnote 2.* The total stream length does not include the length of: 1) artificial ditches excavated in farmfields and forests, 2) dammed sections of streams, and 3) polygonal portions of rivers.

The Wetland Disturbance Index (I_{WD}) focuses on alterations within existing wetlands. As such, it is a measure of the extent of existing wetlands that are diked/impounded, ditched, excavated, or farmed:

$I_{WD} = A_{DW}/A_{TW}$, where A_{DW} is the area of disturbed or altered wetlands and A_{TW} is the total wetland area in the watershed.

Wetlands are represented by both vegetated and nonvegetated (e.g., shallow ponds) types and also include natural and created wetlands. Since the focus of our analysis is on "natural habitat," diked or excavated wetlands (or portions thereof) are viewed as an adverse action. We recognize, however, that many such wetlands may serve as valuable wildlife habitats (e.g., waterfowl impoundments), yet they remain classified as disturbed wetlands.

Composite Habitat Index for the Watershed

The Composite Natural Habitat Integrity Index (I_{CNHI}) is a combination of the preceding indices. It seeks to express the overall condition of a watershed in terms of its potential ecological integrity or the relative intactness of "natural" plant communities and waterbodies, without reference to specific qualitative differences among these communities and waters. Variations of I_{CNHI} may be derived by considering buffer zones of different widths around wetlands and other aquatic habitats (e.g., $I_{CNHI\ 100}$ or $I_{CNHI\ 200}$) and by applying different weights to individual indices or by separating or aggregating various indices (e.g., stream corridor integrity index, river corridor integrity index, or river-stream corridor integrity index).

For the analysis of Delaware's Nanticoke River watershed, the following formula was used to determine this composite index:

$$I_{CNHI\ 100} = (0.5 \times I_{NC}) + (0.125 \times I_{RSCI200}) + (0.125 \times I_{WB100}) + (0.05 \times I_{PLB100}) + (0.1 \times I_{WE}), + (0.1 \times I_{SWE}) - (0.1 \times I_{DSF}) - (0.1 \times I_{CSL}) - (0.1 \times I_{WD})$$

where the condition of the 100m buffer is used throughout. (Note: With this size buffer, the river/stream corridor width becomes 200m.)

While the weighting of the indices may be debatable, the results of this analysis are comparable among subbasins. The same weighting scheme must be used whenever comparisons of this index are made between watersheds or major portions of watersheds, such as the Maryland portion of the Nanticoke to the Delaware portion of the Nanticoke watershed.[3]

Data for Natural Habitat Integrity Indices

The data used to compile these indices come from a few sources. Primary data sources included the enhanced NWI digital data layer, U.S.D.A. Natural Resources Conservation Service's soil data, the State's land use/land cover data for the Nanticoke watershed. and the U.S. Geological Survey digital line graphs (DLGs). We updated the original NWI data to the year 1998 through photointerpretation using a digital transfer scope. Spring 1998-1:40,000 black and white photography was used for updating. This update focused on major areas of land use change and, therefore, does not represent a comprehensive revision. We emphasized changes between "natural" habitat, agriculture, and developed land. We added coding for larger levees along channelized streams, but did not recode all levees. Many levees had been classified as agricultural land by the State. Stream data based on 1:24,000 topographic maps were expanded to include a more complete assessment of ditches and channelized stream segments. We also changed the classification of many headwater stream segments draining interfluve wetlands from perennial to intermittent (seasonally flooded/saturated = "E") since such streams do not flow year-round (confirmed by Amy Jacobs, Delaware Department of Natural Resources and Environmental Control)

General Scope and Limitations of the Study

Wetland Inventory and Digital Database

The wetlands inventory and digital database are an update of the original NWI database and serve as the foundation for a preliminary watershed characterization. One must, however, recognize the limitations of any wetland mapping effort derived mainly through photointerpretation techniques (see Tiner 1997, 1999 for details). For example, use of spring aerial photography for wetland mapping precludes identification of freshwater aquatic beds. Such areas are included within areas mapped as open water (e.g, lacustrine and palustrine unconsolidated bottom) because vegetation is not developed so they appear as water on the aerial photographs. Also drier-end wetlands such as seasonally saturated and temporarily flooded wetlands are often difficult to separate from nonwetlands through photointerpretation.

Although not a prime purpose of the study, we identified some wetlands that were subjected to fragmentation. Our approach was an extremely conservative one, focusing on wetlands separated by major roads. We recognize that many small wetlands are actually the remaining fragments (remnants) of once large wetlands and may also be considered fragments. However, for this

[3] For the Maryland portion of the Nanticoke watershed, an earlier version of the formula was used, so results are not equivalent, although they should be similar. Additional analysis is required to make more valid comparisons.

report, we applied the fragmented descriptor ("fg") only to wetlands that were divided into two or more units by major roads which likely disrupted the hydrology and created an increased risk for wildlife crossing. Moreover, the fragmented descriptor was only applied to pieces of wetlands separated by major roads, hence the results are extremely conservative. Fragmentation in this context, therefore, did not address the issue from the broad landscape perspective. To do so requires analysis beyond the scope of our study. For readers with an interest in fragmentation, the overall pattern of habitat fragmentation can be seen by looking at Map 22, while the pattern of wetland fragmentation may be observed on one of the wetland maps prepared for this study (i.e., Maps 1-4).

Preliminary Assessment of Wetland Functions

At the outset, it is important to emphasize that this functional assessment is a preliminary one based on wetland characteristics interpreted through remote sensing and using the best professional judgment of the senior author and an ad hoc group of wetland specialists assembled by the DNREC.[4] Wetlands believed to be providing potentially high or other significant levels of performance for a particular function were highlighted. As the focus of this report is on wetlands, an assessment of deepwater habitats (e.g., lakes, rivers, and estuaries) for providing the listed functions was not done (e.g., it is rather obvious that such areas provide significant functions like fish habitat). Also, no attempt was made to produce a more qualitative ranking for each function or for each wetland based on multiple functions as this would require more input from others and more data, well beyond the scope of this study. For a technical review of wetland functions, see Mitsch and Gosselink (2000) and for a broad overview, see Tiner (1985; 1998).

Functional assessment of wetlands can involve many parameters. Typically such assessments have been done in the field on a case-by-case basis, considering observed features relative to those required to perform certain functions or by actual measurement of performance. The present study does not seek to replace the need for such evaluations as they are the ultimate assessment of the functions for individual wetlands. Yet, for a watershed analysis, basin-wide

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[4]On June 14, 2001, DNREC held a workshop to review draft protocols prepared by the U.S. Fish and Wildlife Service for this project based on previous wetland assessment studies including one for the Maryland portion of the Nanticoke watershed. Fourteen participants included representatives from DNREC, Delaware Natural Heritage Program, Maryland Department of Natural Resources, Maryland Department of the Environment, Smithsonian Environmental Research Center, and U.S. Geological Survey (see *Acknowledgments*).

field-based assessments are not practical or cost-effective or even possible given access considerations. For watershed planning purposes, a more generalized assessment is worthwhile for targeting wetlands that may provide certain functions, especially for those functions dependent on landscape position and vegetation life form. Subsequently, these results can be field-verified when it comes to actually evaluating particular wetlands for acquisition purposes, e.g., for conservation of biodiversity or for preserving flood storage capacity. Current aerial photography may also be examined to aid in further evaluations (e.g., condition of wetland/stream buffers or adjacent land use) that can supplement our preliminary assessment.

This study employs a watershed assessment approach that may be called "Watershed-based Preliminary Assessment of Wetland Functions" (W-PAWF). W-PAWF applies general knowledge about wetlands and their functions to develop a watershed overview that highlights possible wetlands of significance in terms of performance of various functions. To accomplish this objective, the relationships between wetlands and various functions must be simplified into a set of practical criteria or observable characteristics. Such assessments could also be further expanded to consider the condition of the associated waterbody and the neighboring upland or to evaluate the opportunity a wetland has to perform a particular function or service to society, for example.

W-PAWF usually does not account for the opportunity that a wetland has to provide a function resulting from a certain land-use practice upstream or the presence of certain structures or land-uses downstream. For example, two wetlands of equal size and like vegetation may be in the right landscape position to retain sediments. One, however, may be downstream of a land-clearing operation that has generated considerable suspended sediments in the water column, while the other is downstream from an undisturbed forest. The former should be actively performing sediment trapping in a major way, while the latter is not. Yet if land-clearing takes place in the latter area, the second wetland will likely trap sediments as well as the first wetland. The entire analysis typically tends to ignore opportunity since such opportunity may occurred in the past or may occur in the future and the wetland is awaiting a call to perform this service at higher levels than presently. An exception would be for a wetland type that would not normally be considered significant for a particular function (e.g., sediment retention), but due to current land use of adjacent areas now receives substantial sediment input and thereby performs the function at a significant level.

W-PAWF also does not consider the condition of the adjacent upland (e.g., level of disturbance) or the actual water quality of the associated waterbody which may be regarded as important metrics for assessing the health of individual wetlands (not part of this study). Collection and analysis of these data were done as another part of this study but were not incorporated into the preliminary functional assessment.

We further emphasize that the preliminary assessment does not obviate the need for more detailed assessments of the various functions. This assessment should be viewed as a starting point for more rigorous assessments, as it attempts to cull out wetlands that may likely provide significant functions based on generally accepted principles and the source information used for this analysis. This type of assessment is most useful for regional or watershed planning purposes. For site-specific evaluations, additional work will be required, especially field verification and collection of site-specific data for potential functions (e.g., following the HGM assessment approach as described by Brinson 1993a and other onsite evaluation procedures). This is particularly true for assessments of fish and wildlife habitats and biodiversity. Other sources of data may exist to help refine some of the findings of this report. Additional modeling could be done, for example, to identify habitats of likely significance to individual species of animals (based on their specific life history requirements).

Wetland Restoration Site Inventory

The results of this inventory were derived from air photointerpretation with review of hydric soils data and updated wetland and land use/cover geospatial data. Time did not permit for field checking, so results should be considered conservative. Areas identified as potential Type 1 restoration sites had visible evidence of restoration potential (e.g., wet depressions in cropland and fill sites without buildings).

Type 2 sites could be expanded to include wetlands where the adjacent land use may produce significant adverse impacts on the quality of the wetland, but this was not an objective of our project. Many, if not most, wetlands in the watershed could be highlighted as having potentially significant adverse impacts from adjacent land use practices as many wetlands are surrounded by cropland. Many of these wetlands, however, were identified as being adversely impacted by ditching. In addition, by examining the wetland buffer map, one can extract information on land use practices contiguous with a wetland which could be used to ascertain potentially negative impacts from external sources.

Rather than piecemeal restoration of small isolated wetlands, wetland restoration of large wetland blocks (e.g., restoring huge flatwood interfluves) appears more beneficial to a goal of restoring wetland ecosystems. To accomplish this, hydric soil information should be consulted. These data will reveal significantly larger areas of hydric soils, presumably former wetlands that are now cultivated where smaller presently isolated farmed wetlands, small impoundments, and/or vegetated wetlands could be linked together to form a larger vegetated wetland that can be connected to an existing wetland. Where hydric soil data are not available in digital form, this could be done by visual examination of soil survey maps or perhaps by simply drawing lines around the ditch network to predict the extent of former wetlands. This type of evaluation can be made by consulting the wetland restoration site map which can be used as a reference for identification large-scale restoration projects. Field work, however, is required to evaluate the true restoration potential of any site as there are often limitations and other issues (e.g., landowner support) that can only be determined during field inspection.

Ditch Inventory

Photointerpretation of aerial photographs was performed to identify ditches in this watershed. Although limited field work was performed for this project, such work did not focus on the ditches. Additional work should be done in the future to verify the accuracy and completeness of this inventory. Based on such work, some revision of the database may be required. In any event, the existing data present a good perspective on the extent of ditching throughout the watershed.

Appropriate Use of this Report

The report provides a basic characterization of wetlands in the Delaware portion of the Nanticoke watershed including a preliminary assessment of wetland functions. Keeping in mind the limitations mentioned above, the results are a first-cut or initial screening of the watershed's wetlands to designate wetlands that may have a significant potential to perform different functions. The targeted wetlands have been predicted to perform a given function at a significant level presumably important to the watershed's ability to provide that function. "Significance" is a relative term and is used in this analysis to identify wetlands that are likely to perform a given function at a level above that of wetlands not designated. Review of these preliminary findings and consideration of additional information not available to us may identify the need to modify some of the criteria used to identify wetlands of potential significance for certain functions.

While the results are useful for gaining an overall perspective of the watershed's wetlands and their relative importance in performing certain functions, the report does not identify differences among wetlands of similar type and function. The latter information is often critical for making decisions about wetland acquisition and designating certain wetlands as more important for preservation versus others with the same categorization. Additional information may be gained through consulting with agencies having specific expertise in a subject area and by conducting field investigations to verify the preliminary assessments. When it comes to actually acquiring wetlands for preservation, other factors must be considered. Such factors may include: 1) the condition of the surrounding area, 2) the ownership of the surrounding area and the wetland itself, 3) site-specific assessment of wetland characteristics and functions, 4) more detailed comparison with similar wetlands based on field data, and 5) advice from other agencies (federal, state, and local) with special expertise on priority resources (e.g., for wildlife habitat, contact appropriate federal and state biologists). The latter agencies may have site-specific information or field-based assessment methods that can aid in further narrowing the choices to help insure that the best wetlands are acquired for the desired purpose.

The report is a watershed-based wetland characterization for the Nanticoke watershed. The report does not make comparisons with other watersheds, although comparisons between subbasins within this watershed were made from the “natural habitat integrity” standpoint. Be advised that there may be characteristics (e.g., water quality and habitat concerns) that actually make acquisition, restoration, or preservation of certain wetlands in one of these subbasins, a higher priority than protection of similar wetlands in the other subbasins. This was beyond the scope of the present study.

The report is useful for natural resource planning as an initial screening for considering prioritization of wetlands (for acquisition, restoration, or strengthened protection), as an educational tool (e.g., helping better our understanding of wetland functions and the relationships between wetland characteristics and performance of individual functions), and for characterizing the differences among wetlands (both form and function). It can also serve as benchmark for documenting future trends in wetlands, river-stream corridors, and other natural features.

Rationale for Preliminary Functional Assessments

Nine functions were evaluated: 1) surface water detention, 2) streamflow maintenance, 3) nutrient transformation, 4) sediment and other particulate retention, 5) shoreline stabilization, 6) fish and shellfish habitat, 7) waterfowl and waterbird habitat, 8) other wildlife habitat, and 9) biodiversity. The criteria used for identifying these functions using the digital wetland database are discussed below. The criteria were developed by the senior author of the report and reviewed and modified for the subject watersheds based on comments from an ad hoc group of wetland specialists working on Delaware's Nanticoke River watershed.

In developing a protocol for designating wetlands of potential significance, wetland size was generally disregarded from the criteria, with few exceptions (i.e., other wildlife habitat and biodiversity functions). This approach was followed because it was felt that the State and others using the digital database and charged with setting priorities should make the decision on appropriate size criteria as a means of limiting the number of priority wetlands, if necessary. Our study was intended to present a more expansive characterization of wetlands and their likely functions and not to develop a rapid assessment method for ranking wetlands for acquisition, protection, or other purposes. The criteria for identifying different levels of potential significance can be modified in the future based on review of this report's findings and field evaluation. Note that palustrine farmed wetlands have not been identified as being significant for any function. They were viewed as severely degraded wetlands that perform various functions at minimal levels. Consequently, they represented sites where substantial gains in wetland functions may be achieved through restoration projects.

Surface Water Detention

This function is important for reducing downstream flooding and lowering flood heights, both of which aid in minimizing property damage and personal injury from such events. In a landmark study on the relationships between wetlands and flooding at the watershed scale, Novitzki (1979) found that watersheds with 40 percent coverage by lakes and wetlands had significantly reduced flood flows -- lowered by as much as 80 percent -- compared to similar watersheds with no or few lakes and wetlands in Wisconsin. Floodplain wetlands, other lotic wetlands (basin and flat types), estuarine fringe wetlands along coastal rivers, and estuarine island wetlands in these rivers provide this function at significant levels. Wetlands dominated by trees and/or dense stands of shrubs (with higher frictional resistance) could be deemed to provide a higher level of this function as such vegetation may further aid in flood desynchronization versus similar wetlands with emergent cover. Trees and dense shrubs produce high roughness which helps dissipate energy and lower velocity of flood waters. Yet, this requirement was not applied to the data set as emergent wetlands along waterways are also likely to provide significant flood storage. Floodplain width could also be an important factor in evaluating the significance of performance of this function by individual wetlands (e.g., for acquisition or strengthened protection). There is no quantitative information for establishing a significance threshold based on size, so floodplain width was not used as a selection factor in this study.
For this analysis, the following correlations were used:

High - Estuarine Fringe, Estuarine Island, Lotic Floodplain, Lotic Basin, Lotic Fringe, Lentic Basin wetlands, and Throughflow Ponds (=in-stream)

Moderate - Terrene wetlands that are not ditched (no size criterion; excluding Slope wetlands) amd Lotic Flat wetlands

Some - Other Ponds and Terrene ditched wetlands (excluding Slope wetlands)

Streamflow Maintenance

Many wetlands are sources of groundwater discharge and some may be in a position to sustain streamflow in the watershed. Such wetlands are critically important for supporting aquatic life in streams. Terrene headwater wetlands (by definition, the sources of streams) perform these functions at notable levels. Lotic wetlands along first order streams may also be important for streamflow maintenance, so they were also designated as headwater wetlands. Groundwater discharging into streamside wetlands may contribute substantial quantities of water for sustaining baseflows. Floodplain wetlands are known to store water in the form of bank storage, later releasing this water to maintain baseflows. This also aids in reducing flood peaks and improving water quality (Whiting 1998). Among several key factors affecting bank storage are porosity and permeability of the bank material, the width of the floodplain, and the hydraulic gradient (steepness of the water table). The wider the floodplain, the more bank storage given the same soils. Gravel floodplains drain in days, sandy floodplains in a few weeks to a few years, silty floodplains in years, and clayey floodplains in decades. In good water years, wide sandy floodplains may help maintain baseflows.

For this analysis, the following correlations were used:

High - Terrene and Lotic headwater wetlands that are not ditched, Lentic headwater wetlands, and Outflow Ponds and Lakes (classified as PUB... on NWI), and other headwater Ponds

Moderate - Lotic Floodplain wetlands, Throughflow Ponds and Lakes (classified as PUB... on NWI), and Lentic former floodplain wetlands

Some - Terrene and Lotic ditched headwater wetlands

Nutrient Transformation

All wetlands recycle nutrients, but those having a fluctuating water table are best able to recycle nitrogen and other nutrients. Vegetation slows the flow of water which causes deposition of mineral and organic particles and nutrients (nitrogen and phosphorus) bound to them, whereas hydric soils are the places where chemical transformations occur (Carter 1996). Microbial action in the soil is the driving force behind chemical transformations in wetlands. Microbes need a food source -- organic matter -- to survive, so wetlands with high amounts of organic matter should have an abundance of microflora to perform the nutrient cycling function. Wetlands are so effective at filtering and transforming nutrients that artificial wetlands are constructed for water quality renovation (Hammer 1992). Natural wetlands performing this function help improve local water quality of streams and other watercourses.

Numerous studies have demonstrated the importance of wetlands in denitrification. Simmons et al. (1992) found high nitrate removal (greater than 80%) from groundwater during both the growing season and dormant season in Rhode Island streamside (lotic) wetlands. Groundwater temperatures throughout the dormant season were between 6.5 and 8.0 degrees C, so microbial activity was not limited by temperature. Even the nearby upland, especially transitional areas with somewhat poorly drained soils, experienced an increase in nitrogen removal during the dormant season. This was attributed to a seasonal rise in the water table that exposed the upper portion of the groundwater to more organic matter (nearer the ground surface), thereby supporting microbial activity and denitrification. Riparian forests dominated by wetlands have a greater proportion of groundwater (with nitrate) moving within the biologically active zone of the soil that makes nitrate susceptible to uptake by plants and microbes (Nelson et al. 1995). Riparian forests on well-drained soils are much less effective at removing nitrate. In a Rhode Island study, Nelson et al. (1995) found that November had the highest nitrate removal rate due to the highest water tables in the poorly drained soils, while June experienced the lowest removal rate when the deepest water table levels occurred. Similar results can be expected to occur in the Nanticoke River watershed. For bottomland hardwood wetlands, DeLaune et al. (1996) reported decreases in nitrate from 59-82 percent after 40 days of flooding wetland soil cores taken from the Cache River floodplain in Arkansas. Moreover, they surmised that denitrification in these soils appeared to be carbon-limited: increased denitrification took place in soils with greater amounts of organic matter in the surface layer.

Nitrogen fixation is accomplished in wetlands by microbial-driven reduction processes that convert nitrate to nitrogen gas. Nitrogen removal rates for freshwater wetlands are very high (averaging from 20-80 grams/square meter) (Bowden 1987). The following information comes from a review paper on this topic by Buresh et al. (1980). Nitrogen fixation has been attributed to blue-green algae in the photic zone at the soil-water interface and to heterotrophic bacteria associated with plant roots. In working with rice, Matsuguchi (1979) believed that the significance of heterotrophic fixation in the soil layer beyond the roots has been underrated and presented data showing that such zones were the most important sites for nitrogen fixation in a Japanese rice field. This conclusion was further supported by Wada et al. (1978). Higher fixation rates have been found in the rhizosphere of wetland plants than in dryland plants.

Phosphorus removal is largely done by plant uptake (Patrick, undated manuscript). Wetlands that accumulate peat have a great capacity for phosphorus removal. Wetland drainage can, therefore, change a wetland from a phosphorus sink to a phosphorus source. This is a significant cause of water quality degradation in many areas of the world including the United States, where wetlands are drained for agricultural production. Hydric soils with significant clay constituents fix phosphorus due to its interaction with clay and inorganic colloids. Reduced soils have more sorption sites than oxidized soils (Patrick and Khalid 1974), while the latter soils have stronger bonding energy and adsorb phosphorus more tightly.

From the water quality standpoint, wetlands associated with watercourses are probably the most noteworthy. Numerous studies have found that forested wetlands along rivers and streams ("riparian forested wetlands") are important for nutrient retention and sedimentation during floods (Whigham et al. 1988; Yarbro et al. 1984; Simpson et al. 1983; Peterjohn and Correll 1982). This function by forested riparian wetlands is especially important in agricultural areas. Brinson (1993b) suggests that riparian wetlands along low order streams may be more important than those along higher order streams.

Wetlands with seasonally flooded and wetter water regimes (including tidal regimes - seasonally flooded-tidal, irregularly flooded, and regularly flooded) were identified as having potential to recycle nutrients at high levels of performance. Estuarine vegetated fringe and island wetlands were similarly designated for like reasons. The soils of these wetlands should have substantial amounts of organic matter that would promote microbial activity.

Wetlands with a temporarily flooded water regime including those in tidal environments (temporarily flooded-tidal) were identified as having a moderate potential for performing this function. Terrene outflow wetlands surrounded by cropland (50% or more of their upland perimeter is in contact with cropland) were deemed to have some potential for nutrient transformation. Since farming often introduces agrochemicals and sediment into streams, wetlands between cropland and streams lie in landscape positions that favor recycling of nutrients derived from runoff.

For this analysis, the following correlations were used:

High - All vegetated wetlands and mixed unconsolidated bottom-vegetated wetlands with seasonally flooded (C), seasonally flooded/saturated (E), semipermanently flooded (F), seasonally flooded-tidal (R), irregularly flooded (P), and regularly flooded (N) water regimes (this includes Estuarine, Lotic, Terrene, and Lentic wetlands - mostly floodplain, basin, interfluve-basin, and fringe types)

Moderate - Lotic flat and floodplain-flat wetlands with temporarily flooded (A) and temporarily flooded-tidal (S) water regimes

Some - Terrene vegetated wetlands surrounded by >50% farmland

Retention of Sediments and Other Particulates

Many wetlands owe their existence to being located in areas of sediment deposition. This is especially true for floodplain wetlands. This function supports water quality maintenance by capturing sediments with bonded nutrients or heavy metals (as in and downstream of urban areas). Estuarine and floodplain wetlands plus lotic and lentic fringe and basin wetlands (including lotic ponds) are likely to trap and retain sediments and particulates at significant levels. Lotic flat wetlands are flooded only for brief periods and less frequently than the wetlands listed above due to their elevation. They were classified as having moderate potential for sediment retention. For this analysis, lotic flats that were seasonally saturated were also included in the moderate category, but further evaluation might justify changing their potential to some since they are not inundated. Terrene outflow wetlands surrounded by cropland may now perform this function at some level of potential significance due to erosion of tilled soils. Isolated ponds may be locally significant in retaining such materials, and were also designated as having possible some potential.

For this analysis, the following correlations were used:

High - Estuarine Fringe, Estuarine Island, Lentic Basin, Lentic Fringe, Lotic Floodplain, Lotic Basin, Lotic Fringe and Throughflow Pond (in-stream)

Moderate - Lotic Flat, Terrene Basin, Terrene Fringe-pond, and Terrene Interfluve Basin wetlands, Isolated Ponds, and Outflow Ponds

Some - Terrene Flat and Interfluve Flat wetlands surrounded by >50% cropland

Shoreline Stabilization

Vegetated wetlands along rivers and streams provide this function. Vegetation stabilizes the soil, thereby preventing erosion. Wetlands adjacent to inland waters serve as buffers to reduce erosion of uplands from flowing waters and thereby stabilize shorelines. For this analysis, the following correlations were used:

High - Estuarine vegetated wetlands, Lotic wetlands (vegetated including tidal types; except island wetlands), Lentic wetlands (vegetated, except island types), and Terrene Fringe-pond wetlands

Provision of Fish and Shellfish Habitat

The assessment of potential habitat for fish and shellfish was based on generalities that could be refined for particular species of interest by others at a later date. For tidal areas, the assessment emphasized palustrine and riverine tidal emergent wetlands, unconsolidated shores (tidal flats) and estuarine wetlands. For nontidal regions, palustrine aquatic beds[5] and semipermanently flooded wetlands ranked higher than seasonally flooded types due to the longer duration of surface water. Palustrine forested wetlands along streams (lotic stream wetlands) were deemed

[5]No palustrine aquatic beds were mapped, but these areas could be important fish habitat.

important for maintaining fish and shellfish habitat since their canopies help moderate water temperatures. Ponds and the shallow marsh-open water zone of impoundments were identified as wetlands having some potential for fish and shellfish habitat.

Other wetlands providing significant fish habitat may exist, but were not be identified due to the study methods. Such wetlands may be identified based on actual observations or culled out from site-specific fisheries information that may be available from the State. Also recall that this assessment is focused on wetlands, not deepwater habitats, hence the exclusion of the latter from this analysis, despite widespread recognition that rivers, streams, ponds, and impoundments are the primary residences of fish and shellfish. Moreover, all wetlands that are significant for the streamflow maintenance function could be considered vital to sustaining the watershed's ability to provide in-stream fish and shellfish habitat. While these wetlands may not be providing significant fish and shellfish habitat themselves, they support base flows essential to keeping water in streams for aquatic life.

For this analysis, the following correlations were used:

High - Estuarine Emergent, Estuarine Unconsolidated Shore, Palustrine Tidal Emergent (including mixtures with Scrub-Shrub and Forested), Riverine Tidal Unconsolidated Shore, Riverine Tidal Emergent, Palustrine Semipermanently Flooded, Palustrine Aquatic Bed, Palustrine Unconsolidated Bottom/vegetated wetland (Emergent, Scrub-Shrub, or Forested), Palustrine vegetated wetland with a Permanently Flooded water regime, and Ponds associated with Semipermanently Flooded vegetated wetlands

Moderate - Lotic Stream wetlands that are Palustrine Emergent (including mixtures with Scrub-Shrub or Forested wetlands that are seasonally flooded/saturated), and Throughflow Ponds

Some - Outflow Ponds and Isolated Ponds

Important for Stream Shading - Lotic Stream wetlands that are Palustrine Forested wetlands (includes mixes where forested wetland predominates; excluding those along intermittent streams)

Provision of Waterfowl and Waterbird Habitat

Wetlands considered to be important waterfowl and waterbird habitat were estuarine wetlands (vegetated or not), riverine emergent wetlands, estuarine and riverine unconsolidated shores[6]

[6]The only estuarine or riverine unconsolidated shore mapped was a temporarily flooded-tidal

(excluding temporary flooded-tidal), palustrine tidal and riverine tidal emergent wetlands (including emergent/shrub mixtures), semipermanently flooded wetlands, mixed open water-emergent wetlands (palustrine and lacustrine), and aquatic beds. For this analysis, palustrine tidal scrub-shrub/emergent wetlands and tidal forested/emergent wetlands were designated as having moderate significance for these birds, yet they should be evaluated to determine if their status should be upgraded to high potential. Ponds were considered to have some potential for providing waterfowl and waterbird habitat.[7]

Wetlands that may be significant to wood duck were identified, since wooded streams are particularly important for them. Seasonally flooded lotic wetlands that were forested or mixtures of trees and shrubs (excluding those along intermittent streams) were deemed as wetlands with significant potential for use by wood ducks. Wetlands listed as having high potential for waterfowl and waterbird habitat also include some types important to wood ducks (e.g., semipermanently flooded lotic shrub/emergent wetlands).

Seasonally flooded emergent wetlands (including mixtures with shrubs) were not designated as potentially significant for waterfowl and waterbirds. Field checking of these types may reveal that some are freshwater marshes that may provide significant habitat. If so, these types may be added to the wetlands of significance in the future. Other wetlands worthy of further consideration are forested wetlands bordering estuarine wetlands. They may be important for colonial nesting birds. If they provide such habitat in the Nanticoke watershed, then they should be added to the list.

For this analysis, the following correlations were used:

High - Estuarine Emergent, Estuarine Unconsolidated Shore, Riverine Tidal Emergent, Riverine Tidal Unconsolidated Shore (Regularly Flooded), Palustrine Semipermanently Flooded, Palustrine Aquatic Bed, Palustrine Tidal Emergent, Palustrine Tidal Emergent/Scrub-Shrub, Palustrine vegetated wetlands that are Permanently Flooded, and Ponds associated with Semipermanently Flooded

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riverine one.

[7]Ponds on wildlife management areas (e.g., refuges) should be considered to be of moderate significance due to their management. Since we did not have the location of such refuges in our digital database, these ponds could not be separated from the rest of the ponds. Hence, all ponds were designated as having some potential for this function.

vegetated wetlands

Moderate - Palustrine Tidal Scrub-Shrub/Emergent and Forested/Emergent

Some - Other Palustrine Unconsolidated Bottom

Significant for Wood Ducks - Lotic wetlands (excluding those along intermittent streams) that are Forested or Scrub-shrub wetlands or mixtures of these two types (including freshwater tidal and nontidal), and Lotic wetlands that are Forested/Emergent with a Seasonally Flooded/Saturated or wetter water regime (including Seasonally Flooded-Tidal) and Unconsolidated Bottom/Forested

Provision of Other Wildlife Habitat

The provision of other wildlife habitat by wetlands was evaluated in general terms. Species-specific habitat requirements were not considered. In developing an evaluation method for wildlife habitat in the glaciated Northeast, Golet (1972) designated several types as outstanding wildlife wetlands including: 1) wetlands with rare, restricted, endemic, or relict flora and/or fauna, 2) wetlands with unusually high visual quality and infrequent occurrence, 3) wetlands with flora and fauna at the limits of their range, 4) wetlands with several seral stages of hydrarch succession, and 5) wetlands used by great numbers of migratory waterfowl, shorebirds, marsh birds, and wading birds. Golet subscribed to the principle that in general, as wetland size increases so does wildlife value, so wetland size was important factor for determining wildlife habitat potential in his approach. Other important variables included dominant wetland class, site type (bottomland v. upland; associated with waterbody v. isolated), surrounding habitat type (e.g., natural vegetation v. developed land), degree of interspersion (water v. vegetation), wetland juxtaposition (proximity to other wetlands), and water chemistry.

For this project, wetlands important to waterfowl and waterbirds were identified in a separate assessment (see above). Emphasis for assessing "other wildlife" was placed on conditions that would likely provide significant habitat for other vertebrate wildlife (mainly herps, interior forest birds, and mammals). Opportunistic species that are highly adaptable to fragmented landscapes were not among the target organisms, since there seems to be more than ample habitat for these species now and in the future. Rather, animals whose populations may decline as wetland habitats become fragmented by development are of more concern. For example, breeding success of neotropical migrant birds in fragmented forests of Illinois was extremely low due to high predation rates and brood parasitism by brown-headed cowbirds (Robinson 1990). Newmark (1991) reported local extinctions of forest interior birds in Tanzania due to fragmentation of tropical forests. Fragmentation of wetlands is an important issue for wildlife managers to address. Some useful references on fragmentation relative to forest birds are Askins et al. (1987), Robbins et al. (1989), Freemark and Merriam (1986), and Freemark and Collins (1992). The latter study includes a list of area-sensitive or forest interior birds for the eastern United States. The work of Robbins et al. (1989) is particularly relevant to the study watersheds as they addressed area requirements of forest birds in the Mid-Atlantic states. They found that species such as the black-throated blue warbler, cerulean warbler, Canada warbler, and black-and-white warbler required very large tracts of forest for breeding. Table 2 lists some area-sensitive birds for the region. Ground-nesters, such as veery, black-and-white warbler, worm-eating warbler, ovenbird, waterthrushes, and Kentucky warbler, are particularly sensitive to predation which may be increased in fragmented landscapes. Robbins et al. (1989) suggest a minimum size of 7,410 acres to retain all species of the forest-breeding avifauna in the Mid-Atlantic region.

The analysis identified two wetland types as potentially highly significant for other wildlife: 1) large wetlands ($\geq$ 20 acres) regardless of vegetative cover but excluding pine plantations, and 2) smaller diverse wetlands (10-20 acres with multiple cover types). These two categories covered most wetlands along stream corridors that connect large wetland complexes. Other vegetated wetlands were designated as having some potential significance for providing wildlife habitat.

Given the general nature of this assessment of "other wildlife habitat," the State may want to refine this assessment in the future by having biologists designate "target species" that may be used to identify important wildlife habitats in the Nanticoke watershed. After doing this, they could identify criteria that may be used to identify potentially significant habitat for these species in the watershed. Dr. Hank Short (U.S. Fish and Wildlife Service, retired) compiled a matrix listing 332 species of wildlife and their likely occurrence in wetlands of various types in New England from ECOSEARCH models (Short et al. 1996) that he developed with Dr. Dick DeGraaf (U.S. Forest Service) and Dr. Jay Hestbeck (U.S. Fish and Wildlife Service).[8] DeGraaf and Rudis (1986) summarized habitat, natural history, and distribution of New England wildlife. Much of what is in the ECOSEARCH models comes from this source. These sources may be useful starting points for determining relationships between wildlife and wetlands and may be expanded to cover the Mid-Atlantic region.

For this analysis, the following correlations were used:

High - Large wetlands ($\geq$20 acres, excluding pine plantations) and small diverse wetlands (10-20 acres with 2 or more covertypes),

Some - Other vegetated wetlands

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[8]Copies of the matrix can be obtained by contacting R. Tiner (address on title page).

Table 2. List of some area-sensitive birds for forests of the Mid-Atlantic region. (Source: Robbins et al. 1989).

Species	Area (acres) at which probability of occurrence is reduced by 50%
<u>Neotropical Migrants</u>	
Acadian flycatcher	37
Blue-gray gnatcatcher	37
Veery	49
Northern parula	1,280
Black-throated blue warbler	2,500
Cerulean warbler	1,700
Black-and-white warbler	543
Worm-eating warbler	370
Ovenbird	15
Northern waterthrush	494
Louisiana waterthrush	865
Canada warbler	988
Summer tanager	99
Scarlet tanager	30
<u>Short-distance Migrants</u>	
Red-shouldered hawk	556
<u>Permanent Residents</u>	
Hairy woodpecker	17
Pileated woodpecker	408

Conservation of Biodiversity

In the context of this report, the term "biodiversity" is used to identify certain wetland types that appear to be scarce or relatively uncommon in the watershed, or individual wetlands that possess several different covertypes (i.e., diverse wetland complexes), or complexes of large wetlands. Schroeder (1996) noted that to conserve regional biodiversity, maintenance of large-area habitats for forest interior birds is essential. As noted above, Robbins et al. (1989) suggest a minimum forest size of 7,410 acres to retain all species of the forest-breeding avifauna in the Mid-Atlantic region.

For recognizing the conservation of biodiversity function, we attempted to highlight areas that may contribute to the preservation of an assemblage of wetlands that encompass the natural diversity of wetlands in the Nanticoke watershed. Forested areas 7,410 acres and larger that contained contiguous palustrine forested wetlands and upland forests were designated as important for maintaining regional biodiversity of avifauna based on recommendations by Robbins et al. (1989). We also identified a few other large wetlands in the watershed (e.g., possibly important for interior nesting birds and wide-ranging wildlife in general) and wetlands that were uncommon types (based on mapping classification and not on Natural Heritage Program data). All riverine tidal wetlands and oligohaline wetlands were identified as significant for this function because they are often colonized by a diverse assemblage of plants and are among the most diverse plant communities in the Mid-Atlantic region.

Use of Natural Heritage Program data and GAP data have been suggested, but these data were not provided for the Nanticoke watershed in digital form for our use. Consequently, there was no attempt to incorporate such data into our analysis. It is expected that Natural Heritage and GAP information will be utilized at a later date by the State for more detailed planning and evaluation. Consequently, the wetlands designated as potentially significant for biodiversity are simply a foundation to build upon. Local knowledge of significant wetlands will further refine the list of wetlands important for this function. For information on rare and endangered species, contact the Delaware Natural Heritage Program.

For this analysis, the following correlations were used:

> Wetlands with Atlantic white cedar or bald cypress, Estuarine oligohaline emergent wetlands, Riverine tidal emergent wetlands, Palustrine tidal emergent wetlands (including emergent and scrub-shrub mixtures), Palustrine emergent wetlands seasonally flooded and wetter that are not ditched, diked, or excavated (including mixtures with scrub-shrub), Palustrine tidal scrub-shrub wetlands, Semipermanently flooded Palustrine scrub-shrub wetlands, Semipermanently flooded Palustrine forested wetlands (including mixtures), Seasonally flooded and wetter Palustrine forested/emergent wetlands, Palustrine tidal deciduous/evergreen forested wetlands, Palustrine tidal mixed forested/scrub-shrub wetlands, Palustrine tidal evergreen forested wetlands, and Palustrine wetlands within any 7,410-acre tract of contiguous forestland (both wetland and upland forests)

Results

Wetland Classification and Inventory

Wetlands were classified according to the U.S. Fish and Wildlife Service's official wetland classification system (Cowardin et al. 1979) and by landscape position, landform, and water flow path descriptors following Tiner (2000). Summaries for the study area are given in Tables 3 and 4 and illustrated in Maps #1 through #4. The maps are presented on a compact disk which also contains a copy of this report. Table 3 summarizes covertypes through the subclass level of the Service's classification ("NWI types"), while Table 4 tabulates statistical data on wetlands by landscape position and landform ("HGM types"). Twenty-four percent of the watershed area (which includes the river itself) is occupied by wetlands. If the river and its tributaries are excluded from the watershed area, the percent of "land" represented by wetlands amounts to 25 percent.

Wetlands by NWI Types

According to the NWI, the Nanticoke watershed had 77,359 acres of wetlands, excluding linear features (Table 3; Map #1). Nearly all of the wetlands were palustrine types, with only 80 acres of estuarine wetlands and 34 acres of riverine wetlands. Seventy-nine percent of the wetlands was forested (including mixed forested/scrub-shrub types). Many of the existing palustrine scrub-shrub and scrub-shrub/emergent wetlands represent successional plant communities of cut-over forested wetlands in various stages of regrowth. Ninety-eight percent of the wetlands was nontidal (beyond tidal influence), while only two percent was tidal. About 71 percent of the watershed's wetlands was impacted by ditching, farming, impoundment, or excavation, with 65 percent alone being partly drained due to ditching and channelization. Four percent of the wetlands was farmed. Only 419 wetland acres were impounded, while 666 acres were excavated.

Most (82%) of the watershed's wetlands were seasonally saturated with high water tables in winter and early spring (Table 4). Ten percent was seasonally flooded types. Only 2 percent of the Nanticoke watershed's wetlands was tidal. (Note: Palustrine farmed wetlands were not included in the above statistics, since no water regime was attributed to them.)

The watershed also had 2,382 acres of deepwater habitats: 1,222 acres of tidal rivers, 138 acres of nontidal rivers, 328 acres of estuarine river, and 693 acres of impounded lakes. In addition, the watershed contained 532 miles of linear nontidal streams.

Table 3. Wetlands in the Nanticoke watershed classified by NWI wetland type to the class level (Cowardin et al. 1979). Other modifiers have been deleted from NWI types for this compilation.

NWI Wetland Type	**Acreage**
Estuarine Wetlands	
Emergent (Oligohaline)	79.9
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Subtotal	79.9
Palustrine Wetlands	
Emergent (Nontidal)	1,040.0
Emergent (Tidal)	87.5
Farmed	3,309.6
Scrub-Shrub/Emergent	4,210.9 (including 59.8 tidal)
Broad-leaved Deciduous Forested (Nontidal)	25,154.1 (including 267.7 cypress)
Broad-leaved Deciduous Forested (Tidal)	1,083.2
Needle-leaved Evergreen Forested	4,673.9 (including 12.6 tidal)
Mixed Forested (Nontidal)	17,622.6
Mixed Forested (Tidal)	182.5
Deciduous Forested/Emergent	320.0 (including 0.9 tidal)
Forested/Scrub-Shrub and Forested/Scrub-Shrub	12,343.1 (including 11.7 tidal; 25.5 cypress)
Deciduous Scrub-Shrub	1,496.5 (including 41.0 tidal)
Needle-leaved Evergreen Scrub-Shrub (Nontidal)	3,010.1
Scrub-Shrub (Nontidal)	2,047.9
Unconsolidated Bottom/Vegetated	40.4 (including 34.8 cypress)
Unconsolidated Bottom (Nontidal)	622.9 (including 7.9 uncon. shore)
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Subtotal	77,245.2
Riverine Wetlands	
Emergent (Tidal)	33.5
Unconsolidated Shore (Tidal)	0.3
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Subtotal	33.8
GRAND TOTAL (ALL WETLANDS)	77,358.9

Table 4. Distribution of Nanticoke wetlands according to water regime.

Water Regime	Percent of Watershed's Wetlands*
Temporarily Flooded	3.7
Saturated (Seasonally)	82.4
Seasonally Flooded	5.5
Seasonally Flooded/Saturated	4.9
Semipermanently Flooded	0.5
Permanently Flooded	0.7
Artificially Flooded	0.1
Regularly Flooded (tidal)	0.1
Irregularly Flooded (tidal)	0.1
Seasonally Flooded-Tidal	1.9
Temporarily Flooded-Tidal	0.1

*Excludes palustrine farmed wetlands.

Hydrogeomorphic-Type Wetlands[9]

A total of 3,947 wetlands (excluding ponds) was inventoried in the Nanticoke River watershed and classified by their hydrogeomorphic features (Table 5; Maps #2-#4). Nearly 83 percent of the individual wetlands (excluding ponds) occurred in terrene landscape positions (Map #2). These wetlands accounted for 85 percent of the watershed's wetland acreage. Lotic wetlands were second-ranked in extent, making up 14 percent of the acreage and 16 percent of the number. The remaining 1 percent of the acreage was comprised of estuarine wetlands (0.7% of the acreage) lying along estuarine waters and lentic wetlands (0.3% of the acreage) associated lake basins including large impoundments.

From the landform standpoint, interfluve wetlands accounted for 74 percent of the wetland acreage (excluding ponds) (Map #3). Floodplain wetlands were next in abundance representing 13 percent of the acreage, while flats and basins comprised 7 percent and 5 percent, respectively.

Outflow wetlands were the predominant water flow path type (Map #4). They totaled nearly 62,000 acres and represented 81 percent of the wetland acreage. Throughflow wetlands ranked next at 14 percent (10,532 acres), followed by isolated wetlands (3%; 2,678 acres) and bidirectional flow wetlands (2%; 1,597 acres). Ponds were nearly equally divided between outflow types (43%) and isolated types (39%), with the rest being throughflow types (18%).

Wetlands fragmented by major roads amounted to 4,411 acres. This represents about 6 percent of the wetland acreage. If fragmentation was considered from the landscape perspective, the figure would be much higher as many remnants of once larger wetland complexes (i.e., interfluves) are now surrounded by cropland. Also many minor roads cris-cross wetlands throughout the watershed.

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[9]**All wetlands, except palustrine unconsolidated bottoms and shores, were characterized by HGM-type descriptors. These exceptions were classified as pond or lake types and are not reflected in the summary statistics.**

Table 5. Wetlands (excluding ponds) in the Nanticoke watershed classified by landscape position, landform, and water flow path (Tiner 2000). See Appendix for definitions.

Landscape Position	**Landform**	**Water Flow**	**# of Wetlands**	**Acreage**
Estuarine			*11*	*513.7*
	Fringe*	Bidirectional	11	513.7
Lentic			*50*	*252.3*
	Basin	Bidirectional	3	5.8
		Throughflow	21	94.3
	Flat	Throughflow	9	23.7
	Fringe	Throughflow	14	123.5
	Island	Throughflow	3	5.0
Lotic River			*174*	*944.8*
	Floodplain	Bidirectional**	117	812.3
		Throughflow	6	28.0
	Fringe	Bidirectional**	50	104.2
	Island	Bidirectional**	1	0.3
Lotic Stream			*443*	*9,708.6*
Perennial			400	9,532.1
	Basin	Throughflow	25	66.5
	Flat	Throughflow	55	562.6
	Floodplain	Throughflow	298	8,745.5
	Fringe	Throughflow	22	157.5
Intermittent			4	15.6
	Basin	Throughflow	2	11.8
	Flat	Throughflow	2	3.8

Tidal				39		160.9
	Floodplain	Bidirectional		26		139.8
	Fringe	Bidirectional		13		21.1
Terrene			*3269*		*65,328.3*	
	Basin	Isolated	820		956.5	
		Outflow		682		2,629.9
		Throughflow		36		61.3
	Flat	Isolated	294		996.7	
		Outflow		289		3,321.4
		Throughflow		53		303.7
	Fringe	Outflow		1		0.9
	Interfluve	Isolated	56		724.6	
		Outflow		1010		55,988.7
		Throughflow		28		344.6

*Includes tidal freshwater wetlands contiguous with estuarine wetlands and along estuarine waters
**Freshwater tidal reach

Maps

Twenty-two maps were produced at 1:90,000 to profile the Nanticoke's wetlands and watershed. These maps have been distributed to the Delaware Department of Natural Resources and Environmental Control. They are also included in a separate folder on the CD containing this report. The report and accompanying maps may be put up on the NWI homepage (wetlands.fws.gov) under "reports and publications" in the near future.

A list of the 22 maps follows:

Map 1 - Wetlands and Deepwater Habitats Classified by NWI Types
Map 2 - Wetlands Classified by Landscape Position
Map 3 - Wetlands Classified by Landform
Map 4 - Wetlands Classified by Water Flow Path
Map 5 - Potential Wetlands of Significance for Surface Water Detention
Map 6 - Potential Wetlands of Significance for Streamflow Maintenance
Map 7 - Potential Wetlands of Significance for Nutrient Transformation
Map 8 - Potential Wetlands of Significance for Sediment and Other Particulate Retention
Map 9 - Potential Wetlands of Significance for Shoreline Stabilization
Map 10 - Potential Wetlands of Significance for Fish and Shellfish Habitat
Map 11 - Potential Wetlands of Significance for Waterfowl and Waterbird Habitat
Map 12 - Potential Wetlands of Significance for Other Wildlife Habitat
Map 13 - Potential Wetlands of Significance for Biodiversity
Map 14 - Potential Wetland Restoration Sites
Map 15 - Extent of Ditching
Map 16 - Condition of Perennial River and Stream Corridors (200m)
Map 17 - Condition of Wetland Buffers (100m)
Map 18 - Condition of Pond and Lake Buffers (100m)
Map 19 - Extent of Natural Vegetation in the Watershed
Map 20 - Condition of Streams (Channelized or Dammed vs. Natural)
Map 21 - Condition of Vegetated Wetlands (Partly Drained/Excavated/Impounded vs. Not Altered)
Map 22 - Potential Sites for Restoring Wildlife Travel Corridors

The first four maps depict wetlands by the Service's classification system (NWI types) and by landscape position, landform, and water flow path. Maps 5-13 highlight wetlands that may perform each of the referenced functions at a significant level. Maps 14-22 address some other important natural resource features of the watershed.

Summary of Preliminary Functional Assessment Data

The rationale for preliminary assessment of wetlands for performing each of nine functions and designated wetland types of potential significance are given in the Methods section. Table 6 summarizes the results for each function for the watershed (see Maps 5-13), while the findings for each subbasin are given in Appendix B.

Nearly 96 percent of the wetland acreage was identified as potentially significant for surface water detention, while almost 91 percent was deemed as potentially significant for streamflow maintenance. The headwater position of this portion of the Nanticoke watershed led to most wetlands being designated as important for the latter function. For nutrient transformation, about 65 percent of the wetland acreage may have at least some potential, and a nearly equal amount (67%) was identified as potentially significant for sediment and other particulate retention. Approximately 15 percent of the wetland acreage may have potential for shoreline stabilization. About 14 percent of the wetlands was predicted to have at least some potential as habitat for or provide significant benefits to fish and shellfish. Please note that wetlands designated as significant for the streamflow maintenance should also be considered vital to sustaining the watershed's ability to provide in-stream fish habitat. Fifteen percent of the wetland acreage may have some potential for providing waterfowl and waterbird habitat, with most of the designated wetlands potentially benefitting wood duck. Almost 84 percent of the wetlands were identified as potentially important as habitat for other wildlife. Wetlands listed as potentially important for biodiversity represented about 39 percent of the wetland acreage. For this function, one large contiguous forest of 21,069 acres contained 12,777 acres of wetland (85% of which was forested or mixed forested/scrub-shrub types), while six large wetland complexes of the following sizes were identified: 1,342 acres, 1,554 acres, 1,545 acres, 986 acres, 1,428 acres, and 4,458 acres. These complexes plus the wetlands in the large contiguous forest accounted for 31 percent of the watershed's wetlands, while rare or uncommon wetland types comprised only 8 percent.

Readers should keep in mind that this assessment was based on remote sensing techniques and specific studies that may have been published on various functions were not reviewed. In particular, known sites important to maintaining biodiversity such as those on record with the Delaware Natural Heritage Program were not consulted. Consequently, the listing is conservative and represents a starting point, not an end point for an assessment of wetlands important for various functions. These sources could be reviewed by the State at a later date to add or delete wetlands from the list in their future planning and evaluation efforts.

Table 6. Preliminary functional assessment results for wetlands of the Nanticoke watershed.

Function	**Potential Significance**	**Acreage**	**% of Wetland Acreage**
Surface Water Detention	High Potential	10,803	14.0
	Moderate Potential	15,770	20.4
	Some Potential	47,328	61.2
Streamflow Maintenance	High Potential	15,772	20.4
	Moderate Potential	7,520	9.7
	Some Potential	46,915	60.6
Nutrient Transformation	High Potential	9,625	12.4
	Moderate Potential	2,020	2.6
	Some Potential	38,832	50.2
Retention of Sediments and Inorganic Particulates	High Potential	10,931	14.1
	Moderate Potential	2,681	3.5
	Some Potential	38,358	49.6
Shoreline Stabilization	High Potential	11,364	14.7
Fish/Shellfish Habitat	High Potential	666	0.9
	Moderate Potential	57	0.1
	Some Potential	513	0.7
	Shading Potential*	9,239	11.9
Waterfowl/Waterbird Habitat	High Potential	644	0.8
	Moderate Potential	55	0.1
	Some Potential	596	0.8
	Wood Duck Potential	10,279	13.3
Other Wildlife Habitat	High Potential	60,670	78.4
	Some Potential	3,945	5.1
Biodiversity	Wetlands with Atlantic White Cedar	120	0.2
	Wetlands with Bald Cypress	328	0.4
	Estuarine Oligohaline Wetlands	80	1.0
	Riverine Tidal Wetlands	34	-
	Uncommon Fresh Tidal Wetlands	212	2.7
	Uncommon Nontidal Wetlands	264	3.4
	Wetter Palustrine Emergent Wetlands	95	0.1
	Wetlands within 7,410+ acre Forest	12,777	16.5
	Large Wetland Complexes (six: 1327 a; 1554; 1545; 986; 1428; 4458 a)	11,297	14.6

Potential Wetland Restoration Sites

Due to the history of human activities in this watershed, there are many opportunities for wetland restoration. Over 55,000 acres of potential wetland restoration sites were identified (Map 14). A total of 4,178 acres of Type 1 wetland restoration sites were identified in the Nanticoke watershed and 50,909 acres of Type 2 sites (Table 7). Two-thirds of the watershed's wetlands were designated as Type 2 sites (degraded wetlands whose functions may be improved by various types of restoration). Farmed wetlands (constituting 4 percent of the watershed's wetlands) were identified as potential Type 1 restoration sites, since their current wetland functions are minimal due to severe modification. They represented 79 percent of the Type 1 restoration acreage.

The extent of ditching in this watershed is significant (see following subsection). As a result, almost 99 percent of the Type 2 potential restoration sites consisted of partly drained (ditched) wetlands. The effect of drainage on these wetlands must be evaluated in the field on a case-by-case basis. Some of these wetlands may have minimal adverse effects, while many others may be seriously impacted by the drainage ditches. For example, ditched wetlands with a seasonally flooded/saturated water regime (e.g., PFO1Ed) may be less adversely impacted than those classified with a temporarily flooded water regime (e.g., PFO1Ad). The extent of ditching has been highlighted for potential restoration sites on the wetland restoration site map (Map 14) to provide some visual perspective on the magnitude of ditching in the affected wetlands.

Some of the impounded wetlands listed under Type 2 sites may include both former vegetated wetlands and uplands, whereas some of the impoundments designated as potential Type 1 restoration sites include former stream or river channels. Field investigations or an examination of historical aerial photographs are required to sort out the differences. Nonetheless, most of the latter types occupied landscape positions (i.e., adjacent to floodplains) where they could be restored to provide floodplain wetland functions, if desirable.

Narrow man-made levees along channelized streams also represent potential Type 1 wetland restoration sites, but were not included in the above statistics. Construction of many of these levees involved depositing spoil material produced from stream channelization projects onto wetlands. Complete removal of this fill would produce some gains in wetland acreage and restore wetland hydrology to some degree. At a minimum, the hydrology of the affected wetlands could be improved by creating openings in the levees in a sufficient number of places to reconnect these landward wetlands with their adjacent streams. Clearly, this would improve the surface water detention function of these wetlands.

Table 7. Acreage and number of potential wetland restoration sites in the Nanticoke watershed.

Potential Type 1 Restorations	**No. of Sites***	**Acreage**
Effectively drained or filled former wetlands (now dryland)**	57	84.5
Farmed wetlands	1,397	3,309.6
Impoundments (former vegetated wetlands)***	10	653.3
Excavated former vegetated wetlands	7	130.5
Total	1,471	4,177.9

Potential Type 2 Restorations	**No. of Sites***	**Acreage**
Impounded Wetlands and Ponds (formerly vegetated wetlands)	98	418.7
Ditched Palustrine Wetlands	2,886	50,155.7
Excavated Wetlands	371	334.2
Total	3,355	50,908.6

*Sites relate to mapped polygons; one large wetland complex therefore may contain a number of sites.
**Does not include narrow man-made levees along channelized streams.
***Includes undetermined acreage of former riverbed or streambed.

Extent of Ditching

A total of 1,128 miles of ditches was inventoried by this project. This figure amounts to 2.3 miles of ditches per square mile of land area. Map 15 shows the extent of ditching in the Nanticoke watershed. Also note that besides the ditches, the watershed had 438 miles of channelized nontidal rivers and streams, representing 80 percent of the total nontidal perennial river and stream length in the watershed. The channelized stream segments can be interpreted as opportunities for stream restoration. Priorities for such restoration might start with channelized perennial and seasonally flooded/saturated intermittent streams.

Water Resource Buffer Analysis

Buffers were established around several water resource features to evaluate the condition of lands immediately surrounding wetlands and waterbodies. The buffer excludes open water areas. . Maps 16 through 18 show the condition of the 100m buffer around the following features: 1) perennial rivers and streams (nontidal), 2) vegetated wetlands, and 3) ponds and lakes, respectively. While the 100m buffer often includes some open water, our analysis focused on the "land" portion of the buffer since this is the zone that may be vegetated or developed. Approximately 59 percent of 100m buffer around perennial rivers and streams[10] still possessed natural vegetation intact, while 80 percent of the "developed" buffer consisted agricultural land. Only 36 percent of the 100m buffer around vegetated wetland remains vegetated, while slightly more (39%) of the buffer around ponds and lakes is vegetated.

Analyses were performed for buffers around various combinations of waterbodies, with the following results: 1) perennial nontidal and tidal rivers and streams: 59 percent vegetated, 2) perennial and intermittent nontidal rivers and streams and ditches: 41 percent vegetated, 3) perennial and intermittent rivers and streams, tidal rivers, and ditches: 42 percent vegetated, and 4) perennial streams only (including intermittents with prolonged flows: R4SBEx, and excluding impounded stream segments): 59 percent.

Readers should note that buffer areas mapped as agricultural land may represent opportunities to restore natural vegetation along streams, wetlands, and other waterbodies. Such areas should

[10]Perennial streams include streams designated as seasonally flooded/saturated intermittent streams (i.e., R4SBEx) which flow for long periods during the year, but not year-round. Such streams were identified on the source data (U.S.Geological Survey DLGs) as perennial, but based on our field experiences and those of Amy Jacobs (DNREC), they were determined to be intermittent.

typically be cropland that may be readily revegetated with native woody species to restore effectiveness of natural buffers.

Natural Habitat Integrity Indices

These indices were calculated for the entire Delaware portion of the watershed and for each corresponding subbasin. Note stream corridor and various buffer analyses focus on the "land" portion of the buffer (i.e., the area that may contain self-supporting vegetation) and excludes any open water areas in that zone.

Values for the Entire Watershed

The values for the nine indices for the Delaware portion of the Nanticoke River watershed are calculated and presented below.

Natural Cover Index = 128,028 acres of natural vegetation/312,779 acres of land in watershed = **0.41**

River-Stream Corridor Integrity Index for Perennials Only (100m buffer = 200m corridor) = 28,092 acres of natural vegetation in buffer/47,302 acres of buffer = **0.59**

Vegetated Wetland Buffer Index (100m) = 28,779 acres of natural vegetation in upland buffer/79,380 acres of upland buffer = **0.36**

Pond and Lake Buffer Index (100m) = 2,460 acres of natural vegetation in upland buffer/6,289 acres of upland buffer = **0.39**

Wetland Extent Index = 59,529 acres of wetlands/143,945 acres of hydric soil map units = **0.41** (Note: Estimated from hydric soil data available for 85 percent of the watershed)

Standing Waterbody Extent Index = **1.0** due to impoundment and pond construction

Dammed Stream Flowage Index = 17.6 miles dammed/574.3 miles of perennial nontidal rivers and streams = **0.03**

Channelized Stream Length Index = 437.8 miles of channelized streams/556.7 miles of perennial nontidal rivers and streams = **0.79**

Wetland Disturbance Index = 54,550 acres of altered wetlands/77,362 acres of wetlands = **0.71**

Composite Natural Habitat Integrity Index = $\mathbf{I_{CNHI\ 100} = (0.5 \times I_{NC}) + (0.125 \times I_{RSCI200}) + (0.125 \times I_{WB100}) + (0.05 \times I_{PLB100}) + (0.1 \times I_{WE}), + (0.1 \times I_{SWE}) - (0.1 \times I_{DSF}) - (0.1 \times I_{CSL}) - (0.1 \times I_{WD})}$ = (0.5 x 0.41) + (0.125 x 0.59) + (0.125 x 0.36) + (0.05 x 0.39) + (0.1 x 0.41) + (0.1 x 1.0) - (0.1 x 0.03) - (0.1 x 0.79) - (0.1 x 0.71) = 0.485 - 0.153 = **0.33**

The above indices provide evidence of a severely stressed system. A pristine watershed has an index value of 1.0 for natural habitat integrity. The value of 0.33 for the Nanticoke watershed indicates significant human modification. While stream corridors seem to be in somewhat reasonable shape regarding natural vegetation (59% of the 200m corridor is in natural vegetation), nearly two-thirds of the vegetated wetland buffer and 61 percent of the pond and lake buffers have been developed. Overall, the Nanticoke watershed has lost 59 percent of both its natural habitat and its original wetlands, while 79 percent of its streams have been channelized, and 71 percent of its current wetlands are altered by ditches, diking, excavation, or farming. Forty-one percent of the land in the watershed is covered with "natural vegetation," 50 percent is in agriculture, and 9 percent is developed. If the response of this watershed to farming and development is similar to that of Wisconsin watersheds studied by Wang et al. (1997), we can expect significant degradation of water quality, since they found that watersheds with more than half of their acreage in agriculture experienced significant declines in instream habitat quality versus watersheds with less agriculture and more forest.

Summaries for Each Subbasin

A summary of vital statistics for each subbasin are presented in Tables 8 through 15, with results of the preliminary assessment of wetland functions for each subbasin presented in Appendix B. Wetland characteristics are outlined in Table 8. Land use and land cover features are presented in Table 9. The condition of various stream buffers is presented in Table 10, while the condition of the 100m buffer around lakes and ponds, and around wetlands are given in Tables 11 and 12, respectively. Alterations of streams and the extent of ditching is tabulated in Table 13. Wetland alterations are outlined in Table 14. Remotely-sensed natural habitat integrity indices are summarized in Table 15. Application of the natural habitat integrity indices to individual subbasins within the watershed could aid in targeting areas for preservation and restoration. From the indices for the entire watershed, we have seen that this watershed is extremely impacted by human activities, mainly agriculture. Gravelly Branch, with composite index value of 0.51, appears to be in noticeably better condition than the other subbasins. All other subbasins have composite index scores less than 0.40. Marshyhope Creek and Nanticoke River subbasins appear to be in the worst condition, with composite index values of less than 0.30.

Table 8. Wetland acreage for each subbasin of the Nanticoke watershed by NWI type. Coding: E2EM = Estuarine Emergent; PEM/SS-M = Palustrine Mixed Emergent and Scrub-Shrub; PEM = Palustrine Emergent; Pf = Palustrine Farmed; PFO-M = Palustrine Mixed Forested; PFO/EM-M = Palustrine Mixed Forested/Emergent; PFO/SS-M = Palustrine Mixed Forested/Scrub-Shrub; PFO-D = Palustrine Deciduous Forested; PFO-E = Palustrine Evergreen Forested; PSS-M = Palustrine Mixed Scrub-Shrub; PSS-D = Palustrine Deciduous Scrub-Shrub; PSS-E = Palustrine Evergreen Scrub-Shrub; PUB/V = Palustrine Unconsolidated Bottom Mixed with Vegetated Wetland; PUB = Palustrine Unconsolidated Bottom (includes Unconsolidated Shore); R1EM = Riverine Tidal Emergent Wetland

Wetland Type	**Broad Creek**	**Deep Creek**	**Gravelly Branch**	**Gum Branch**	**Marshyhope Creek**	**Nanticoke River**
E2EM	33.1	-	-	-	-	47.0
PEM/SS-M	1062.1	421.6	710.1	335.1	822.6	862.6
PEM	187.8	154.8	167.1	3.7	318.6	294.8
Pf	701.2	538.0	172.6	38.8	950.9	908.1
PFO/SS-M	3,917.7	1,228.7	933.3	1,875.3	4,034.6	2,862.0
PFO/EM-M	105.3	-	-	7.3	201.1	6.4
PFO-M	1,409.2	3,363.3	3,326.1	1,400.8	2,725.6	3,071.7
PFO-D	4,584.3	3,455.8	1,641.5	1,085.9	9,316.5	6,153.1
PFO-E	1,141.8	1,270.8	1,133.2	105.1	548.1	474.9
PSS-M	749.1	357.6	502.6	182.5	153.1	103.1
PSS-D	534.8	175.6	71.4	137.7	320.5	256.5
PSS-E	952.9	787.7	440.1	272.3	363.6	193.5
PUB/V	41.3	-	-	-	-	-
PUB	218.9	106.3	15.4	30.6	36.7	215.0
R1EM	1.8	7.3	-	-	-	24.4
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Total	15,641.3	11,867.5	9,113.4	5,475.1	19,791.9	15,473.1

Table 9. Summary statistics for land use and landcover in subbasins of the Nanticoke watershed.

	Acreage of Land Use/Cover Type (percent of total subbasin)			
Subbasin	**Developed**	**Agriculture**	**"Natural Vegetation"***	**Water**
Broad Creek	6,920 (9%)	38,261 (51%)	29,650 (39%)	976 (1%)
Deep Creek	3,753 (9%)	15,655 (39%)	20,815 (51%)	364 (1%)
Gravelly Branch	1,499 (6%)	7,544 (31%)	15,321 (63%)	142 (<1%)
Gum Branch	1,042 (5%)	9,277 (48%)	8,967 (46%)	45 (<1%)
Marshyhope Creek	2,513 (4%)	33,988 (54%)	25,743 (41%)	124 (<1%)
Nanticoke River	11,480 (12%)	52,820 (57%)	27,533 (30%)	1394 (1%)

*Includes pine plantations and other commercial forests

Table 10. Condition of the 100m buffer along streams in each subbasin for four cases: 1) perennial rivers and streams only (excluding tidal reach), 2) perennials and tidal, 3) perennials, intermittents, and ditches, 4) perennials including tidal, plus intermittents and ditches, and 5) perennial streams only (linears including R4SBEx). Buffer data addresses the "land" portion of the buffer and does not include open water areas.

	Percent of Buffer in "Natural Vegetation"				
Subbasin	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Broad Creek	58%	59%	42%	43%	59%
Deep Creek	65%	64%	48%	48%	65%
Gravelly Branch	80%	80%	61%	61%	81%
Gum Branch	73%	73%	49%	49%	73%
Marshyhope Creek	54%	54%	37%	37%	54%
Nanticoke River	51%	53%	32%	34%	50%

Table 11. Condition of the 100m buffer along lakes and ponds for each subbasin.

Subbasin	**Percent of Buffer in "Natural Vegetation"**
Broad Creek	42%
Deep Creek	41%
Gravelly Branch	57%
Gum Branch	44%
Marshyhope Creek	37%
Nanticoke River	34%

Table 12. Condition of the 100m buffer around vegetated wetlands for each subbasin.

Subbasin	Percent of Buffer in “Natural Vegetation”
Broad Creek	40%
Deep Creek	41%
Gravelly Branch	49%
Gum Branch	46%
Marshyhope Creek	28%
Nanticoke River	31%

Table 13. Disturbance values for streams and extent of ditching in each subbasin of the Nanticoke River watershed. Note that totals do not always add up due to computer round-off procedures.

Subbasin	Miles of Channelized Stream (% of total)*	Miles of Flowing Perennial Streams*	Miles of Dammed Stream (% of total)**	Miles of Perennial Streams**	Miles of Ditches
Broad Creek	77.3 (59%)	131.1	8.0 (6%)	138.7	251.8
Deep Creek	70.1 (87%)	80.2	3.1 (4%)	82.3	143.9
Gravelly Branch	37.2 (89%)	41.9	3.3 (7%)	45.0	77.0
Gum Branch	35.0 (96%)	36.3	-	36.3	55.2
Marshyhope Creek	110.3 (94%)	117.4	-	117.4	326.8
Nanticoke River	107.6 (75%)	143.1	3.1 (2%)	146.2	272.9

*Excludes tidal reach, impounded segments, and intermittent streams
**Excludes tidal reach and intermittent streams

Table 14. Extent of altered wetlands in each subbasin.

Subbasin	Ditched Acres	Farmed Acres	Impounded Acres	Excavated Acres	Total Acres (% of wetlands)
Broad Creek	8,695	701	199	239	9,834 (63%)
Deep Creek	7,909	538	117	103	8,667 (73%)
Gravelly Branch	4,827	173	61	25	5,086 (56%)
Gum Branch	4,353	39	7	28	4,427 (81%)
Marshyhope Creek	16,168	951	1	38	17,158 (87%)
Nanticoke River	8,203	908	34	232	9,377 (61%)

Table 15. Remotely-sensed natural habitat indices for each subbasin in the Delaware portion of the Nanticoke River watershed. (Note: The River-Stream Corridor Index includes the tidal reach.)

	Remotely-sensed Natural Habitat Indices									
Subbasin	I_{NC}	$I_{RSCI200}$	I_{WB100}	I_{PLB100}	I_{WE}	I_{SWE}	I_{DSF}	I_{CSL}	I_{WD}	$I_{CNHI100}$
Broad Creek	0.40	0.59	0.40	0.42	0.45	1.0	0.06	0.59	0.63	0.36
Deep Creek	0.52	0.64	0.41	0.41	0.43	1.0	0.04	0.87	0.73	0.39
Gravelly Branch	0.63	0.80	0.49	0.57	0.52	1.0	0.07	0.89	0.56	0.51
Gum Branch	0.46	0.73	0.46	0.44	0.35	1.0	0.00	0.96	0.81	0.34
Marshyhope Creek	0.41	0.54	0.28	0.37	0.38*	1.0	0.00	0.94	0.87	0.28
Nanticoke River	0.30	0.53	0.31	0.34	0.36*	1.0	0.02	0.75	0.61	0.27

*Calculations based on part of subbasin where digital soils data were available (37% of Marshyhope Creek subbasin and 92% of the Nanticoke River subbasin).

Wildlife Travel Corridors

Many wetlands and other natural habitats in the Nanticoke River watershed have become fragmented by human actions. In particular, agricultural conversion of wetlands and neighboring forests and channelization projects have divided many of these habitats into smaller parcels, thereby reducing the connectivity among natural habitats. As one aid to help guide wildlife habitat improvement in the watershed, a map showing some possible places for restoring connectivity was compiled. Map 22 shows potential sites for restoring connectivity among wildlife habitats through reforestation of 200m swaths. The designated lands should be open land (mostly cropland) that are suitable for reforestation (with landowner permission).

Please note that other groups have spent a great deal of time working on "Delmarva Conservation Corridors" and that individuals interested in wildlife travel corridors and habitat fragmentation should contact the U.S. Fish and Wildlife Service's Delaware Bay Estuary Project Office for information on these corridors (302-653-9152).

Conclusions

The findings of this report should be considered preliminary. Field checking should be conducted to validate the interpretations. The report should, however, serve as a guide to wetlands in the Nanticoke watershed and to their functions. It is a starting point for resource planning rather than an endpoint. The characterization serves as one tool to aid in wetland conservation and watershed management. It should be used with other tools derived from field observations and other site-specific data.

In the final analysis, a few issues arose that warrant further consideration by the State's ad hoc committee for the Nanticoke. These issues are mostly related to the criteria used for identifying wetlands of potential significance for some functions. For streamflow maintenance, should ditched portions of headwater wetlands be given the same rating as nonditched portions? In our assessment, the former were identified as having some potential for this function, while the latter were designated as having high potential. Should all floodplain wetlands be designated as having potential for streamflow maintenance or should this potential only be attributed to floodplain wetlands along low order streams and not to those along mainstem rivers? For nutrient transformation, based on field investigations, is there a reliable positive correlation between seasonally flooded and wetter water regimes and amount of organic matter in the soil? Also, what is the role of seasonally saturated wetlands ("B" water regime; flatwoods) in nutrient cycling? Presently, only those flatwoods with more than 50 percent of their borders in cropland were deemed of some significance for nutrient cycling. For shoreline stabilization, pond-fringe wetlands were included as having high potential for shoreline stabilization. Should they be given a lower rating? Field checking of seasonally flooded and seasonally flooded/saturated emergent wetlands should be done to determine if they are marshes or wet meadows. If the former, they will likely have higher potential as both fish and shellfish habitat and waterfowl habitat than they were given in this report. Palustrine tidal scrub-shrub/emergent wetlands and tidal forested/emergent wetlands were designated as having moderate significance for waterfowl and waterbirds, should their status be upgraded to high potential? All vegetated wetlands were identified as having at least some potential as habitat for other wildlife. Is the committee still comfortable with this?

In regard to fragmentation, for this study, we focused on major road crossings and did not treat small isolated pieces of once larger wetlands that have been chopped up by development as fragmented. Would it be better to apply this modifier ("fg") to all potentially fragmented wetlands? While a four-lane highway (interstate) clearly represents a fragmenting structure, does a two-lane paved road produce similar consequences? And if so, what about unpaved roads? Another question arose in applying the fragmentation descriptor to wetland polygons - should this descriptor be applied to: 1) the entire wetland (main wetland body and the fragmented section), or 2) only to the fragmented piece(s)? Many large wetlands only had a small portion that was fragmented.

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Photointerpretation of wetlands, potential wetland restoration sites, and land use/cover for this project was performed by John Swords. Gary Doucett mapped the extent of ditches. Wetland classification of HGM-types following Tiner (2000) was performed by Herb Bergquist who also processed much of the geospatial data. Bobbi Jo McClain produced the thematic maps and assisted in data tabulation. Ralph Tiner developed the correlations between wetland characteristics and wetland functions used to produce the preliminary assessment of wetland functions, analyzed the data, and prepared the project report. Susan Essig reviewed the final manuscript for clarity and content.

Amy Jacobs (DNREC) and the wetland group she assembled for reviewed the draft protocols for correlating wetland characteristics with wetland functions and provided recommendations to modify the selection criteria. Participants included David Bleil, Katheleen Freeman, Cathy Wazniak, Mitch Keiler, and Bill Jenkins (Maryland Department of Natural Resource); Julie LaBranche (Maryland Department of the Environment); Marcia Snyder, Dennis Whigham, and Don Weller (Smithsonian Environmental Research Center); Matt Perry and Jon Willow (U.S. Geological Survey); Mark Biddle (DNREC); and Peter Bowman (Delaware Natural Heritage Program). Mark also provided land use and land cover information from the state's digital database. Peggy Emslie (formerly with DNREC) helped initiate this project by identifying the value of this type of analysis for watershed planning and management.

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APPENDICES

APPENDIX A. Keys to Waterbody Type and Hydrogeomorphic-type Wetland Descriptors for U.S. Waters and Wetlands (Operational Draft) (Tiner 2000)

Keys to Waterbody Type and Hydrogeomorphic-type Wetland Descriptors for U.S. Waters and Wetlands (Operational Draft)

U.S. Fish and Wildlife Service
National Wetlands Inventory Project
Northeast Region
300 Westgate Center Drive
Hadley, MA 01035

September 2000

Keys to Waterbody Type and Hydrogeomorphic-type Wetland Descriptors for U.S. Waters and Wetlands (Operational Draft)

Ralph Tiner, Regional Wetland Coordinator

U.S. Fish and Wildlife Service
National Wetlands Inventory Project
Northeast Region
300 Westgate Center Drive
Hadley, MA 01035

September 2000

Introduction

The U.S. Fish and Wildlife Service's official wetland and deepwater habitat classification emphasizes a host of characteristics associated with these habitats including vegetation, soils, hydrology, salinity, and certain impacts (e.g., beaver, partly drained, and impounded) (Cowardin et al. 1979). These are important characteristics for describing wetlands and for assessing fish and wildlife habitat, but are not adequate for addressing abiotic features important for evaluating other wetland functions (e.g., chemical characteristics of the water, habitat maintenance, and water storage and transport) (Brinson 1993). Moreover, the classification of deepwater habitats is quite limited mainly to general aquatic ecosystem (marine, estuarine, lacustrine, and riverine) and bottom substrate type, with a few subsystems noted for riverine deepwater habitats. There is need for more indepth classifications for both wetlands and waterbodies.

For example, Dr.Mark Brinson created a hydrogeomorphic (HGM) classification system to fill this void (Brinson 1993). The HGM system is actually more of "a generic approach to classification and not a specific one to be used in practice" (p. 2). It is a way of looking at wetlands in a geographic region for assessing ecosystem functions. Current studies are underway in several regions to develop HGM profiles for certain types of wetlands.

To aid in use of HGM data when available and to better describe wetlands from the abiotic standpoint, a set of keys have been developed (Tiner 1997). These keys attempt to bridge the gap between the Service's classification and the HGM system by providing descriptors for landscape position and landform. While more specific than the basic HGM types, the new descriptors can be easily correlated with these types to make use of HGM data when they become available. The landscape position and landform descriptors can be added to existing National Wetlands Inventory maps and digital data or to other wetland maps. These descriptors can also be used to describe wetlands for reports of various kinds including wetland permit reviews, wetland trend reports, and other reports requiring more comprehensive descriptions of individual wetlands. This information can be used to prepare a characterization of the functions performed by similar wetland types. These characterizations may be used to predict the likely functions of individual wetlands or to estimate the capacity of an entire suite of wetlands to perform certain functions in a watershed, for example. These characterizations would be derived from our current knowledge of wetland functions for specific types and be refined in the future, as needed, based on the applicable HGM profiles. Based on experiences over the past 3 years, some revisions to the keys in Tiner 1997 have been made and are included in this document.

For deepwater habitats, additional information is also useful. For example, identification of the extent of dammed rivers and streams in the United States is a valuable statistic, yet according to the Service's classification dammed rivers are classified as Lacustrine deepwater habitats with no provision for separating dammed rivers from natural lakes and large impoundments (e.g., reservoirs). The description of estuarine deepwater habitats is also limited following Cowardin et al. 1979. Information on different types of estuaries

would be useful.

Two sets of keys have been developed to enhance the current classification of wetlands and waterbodies. The added features are considered descriptors for application to the existing system or can be used independently to describe a wetland or deepwater habitat.

The first set of keys is for describing wetlands by landscape position, landform, water flow path and other modifiers. It is an update of an earlier set of keys published in 1997 as "Keys to Landscape Position and Landform Descriptors for U.S. Wetlands (Operational Draft)" (Tiner 1997). Application of these operational keys has revealed the need for minor adjustments and additional modifiers. Pilot studies applying these keys also underscored the need to better describe associated waterbodies. This led to the development of the second set of keys focusing on deepwater habitats and other waterbodies (e.g., ponds). The keys provided are still considered operational draft as they have mainly been used in the Northeastern U.S. and need to be applied to arid, semiarid, and arctic regions for further testing. A glossary of technical terms is provided at the end of this publication.

Wetland Keys

Three keys are provided to identify wetland landscape position and landform for individual wetlands: Key A for classifying the former and Keys B and C for the latter (for inland wetlands and coastal wetlands, respectively). Users should first identify the landscape position associated with the subject wetland following Key A. Afterwards, using Key B for inland wetlands and Key C for salt and brackish wetlands, users will determine the associated landform. The landform keys include provisions for identifying specific regional wetland types such as Carolina bays, pocosins, flatwoods, cypress domes, prairie potholes, playas, woodland vernal pools, West Coast vernal pools, interdunal swales, and salt flats. Various modifiers may also be applied to better describe wetlands, such as inflow, throughflow and outflow types, pond types, headwater areas, and other features of interest.

Key A: Key to Wetland Landscape Position

This key characterizes wetlands based on their location in or along a waterbody, in a drainageway, or in isolation.

1. Wetland is located in or along a lake, estuary, ocean, stream, or river and any associated floodplain..2
1. Wetland occurs on a slope, flat, or in a depression (including ponds, potholes, and playas) lacking a stream, but may be ditched*...................................Terrene (*go to Key B for landform*)

***Stream may originate from a terrene wetland, but if a stream enters and exits the**

wetland even if flow is nonchannelized within, the wetland is <u>lotic</u> and not terrene because the wetland is part of the hydrologic (downstream) flow of the stream system.

[<u>Note</u>: *Modifiers* may include H<u>eadwater</u> (for first-order streams, possibly second-order streams also; including large wetlands in upper portion of watershed believed to be significant groundwater discharge sites) and for terrene wetlands whose outflow goes directly to an estuary or the ocean: <u>Estuarine Outflow</u> or <u>Marine Outflow</u>, respectively.]

2. Wetland is located in or along a salt or brackish waterbody (ocean or estuary).........................3
2. Wetland is located in or along a fresh waterbody..4

3. Wetland is located along shores of the ocean.......................Marine (*go to Key C for landform*)
3. Wetland is located in or along an estuary (salt or brackish waters)............................Estuarine (*go to Key C for landform*) (<u>Note</u>: If area was formerly connected to estuary but now is completely cut-off from tidal flow, consider as one of inland landforms - Terrene, Lentic, or Lotic, depending on current site characteristics. Such areas should be designated with a modifier to identify such wetlands as "former estuarine wetland.")

4. Wetland is located in or along a lake or reservoir (standing waters).........Lentic (*go to Key B for landform*)

[<u>Note</u>: Lentic wetlands consist of all wetlands in a lake basin, including those bordering streams that empty into the lake. The upstream limit of lentic wetlands is defined by the upstream influence of the lake which is usually approximated by the limits of the basin within which the lake occurs. These streamside lentic wetlands are designated as "<u>Throughflow</u>", thereby emphasizing the stream flow through these wetlands. Other lentic wetlands are typically classified as "<u>Bidirectional Flow</u>" since waters rise and fall with lake levels during the year.]

4. Wetland is located in or along a river or stream (flowing waters).....................................Lotic (*specify whether wetland is associated with a River or Stream - see following note, then go to couplet "a" below; also see note under first couplet #4 re: streamside wetlands in lake basins*)

[<u>Note</u>: A <u>River</u> is a broad channel mapped as a polygon (2-lined watercourse) on a U.S.G.S. topographic map, while a narrower channel mapped as a linear feature is a <u>Stream</u>. Artificial drainageways--ditches--are considered part of the Lotic classification. *Modifiers* may be applied: <u>Perennial</u> (flowing water year-round),

Intermittent (seasonal flow only), Headwater (first order streams, possibly second order streams also; including large wetlands in upper portion of watershed believed to be significant groundwater discharge sites), and Channelization (excavated and/or stream course modified). See Waterbody Key for classification of rivers, streams, canals, and ditches.]

a. Flow of water is bidirectional due to tidal influence (freshwater tidal areas)...........Tidal Gradient (*go to Key B for landform*)
a. Flow is unidirectional; no tidal influence..b

b. Water flow is generally rapid due to steep gradient; typically little or no floodplain development; watercourse is generally shallow with rock, cobbles, or gravel bottoms; first and second order "streams"; part of Cowardin's Upper Perennial and Intermittent subsystems..High Gradient (*go to Key B for landform*)
b. Watercourse characteristics are not so; "stream" order greater than 2..........................c

c. Water flow is generally slow; typically with extensive floodplain; water course shallow or deep with mud or sand bottoms; typically fifth and higher order "streams", but includes lower order streams in nearly level landscapes such as the Great Lakes Plain (former glacial lakebed) and the Coastal Plain (the latter streams may lack significant floodplain development) and ditches; Cowardin's Lower Perennial subsystem.............Low Gradient (*go to Key B for landform*)
c. Water flow is fast to moderate; with little to some floodplain; usually third and fourth order "streams"; part of Cowardin's Upper Perennial subsystem.............................Middle Gradient (*go to Key B for landform*)

Key B: Key to Inland Landforms

1. Wetland occurs on a noticeable slope (e.g., greater than a 2 percent slope)........Slope Wetland

a. Wetland created by paludification processes (where in areas of low evapotranspiration and high rainfall, peat moss moves uphill creating wetlands on hillslopes) which cause wetland to develop upslope of primary water source...................Paludified Slope Wetland
a. Wetland not formed by paludification processes..b

b. No surface water inflow from a stream or other waterbody, or no suspected significant surface or ground water inflow from nonslope wetland or other waterbody at a higher elevation and no outflow to a stream or no suspected

significant surface or ground water flow to a wetland or waterbody at a lower elevation.............<u>Isolated Slope Wetland</u>

b. Wetland not hydrologically isolated...c

c. Surface water inflow from a stream or other waterbody, <u>or</u> suspected significant surface or ground water inflow from a nonslope wetland or other waterbody at a higher elevation <u>and</u> no observable or known significant outflow of surface or ground water to a stream or a nonslope wetland or waterbody at a lower elevation.......<u>Inflow Slope Wetland</u>

c. Wetland not an inflow wetland, but either throughflow or outflow..............................d

d. No surface water inflow from a stream or other waterbody, <u>or</u> no suspected significant surface or ground water inflow from a wetland or other waterbody at a higher elevation, <u>and</u> water is discharged from this wetland to a stream or other waterbody, <u>or</u> there is significant outflow of surface or ground water to a wetland or other waterbody at a lower elevation...<u>Outflow Slope Wetland</u>

d. Surface water inflow from a stream or other waterbody, <u>or</u> suspected significant surface or ground water inflow from a nonslope wetland or other waterbody at a higher elevation <u>and</u> water passes through the subject wetland to a stream, another wetland, or other waterbody at a lower elevation....................................<u>Throughflow Slope Wetland</u>

[*Modifiers* can be applied to Slope Wetlands to designate the type of inflow or outflow as <u>Channelized Inflow or Outflow</u> (intermittent or perennial, stream or river), <u>Nonchannelized Inflow or Outflow</u> (wetland lacking stream, but connected by observable surface seepage flow), or <u>Nonchannelized-Subsurface Inflow or Outflow</u> (suspected subsurface flow from or to a neighboring wetland upslope or downslope, respectively).]

1. Wetland does not occur on a distinct slope..2

2. Wetland forms an island...Island Wetland

a. Island formed in a delta at the mouth of a river or stream...............<u>Delta Island Wetland</u>

a. Island not formed in a delta..b

b. Island surrounded by a river or stream...<u>River Island Wetland</u> or <u>Stream Island Wetland</u>

b. Island formed in a lake or pond................<u>Lake Island Wetland</u> or <u>Pond Island Wetland</u>

[<u>Note</u>: Vegetation class and subclass from Cowardin et al. 1979 should be applied to characterize the vegetation of these wetland islands; vegetation is assumed to be rooted unless designated by a *modifier* (<u>Floating Mat</u>) to indicate a floating island.]

2. Wetland does not form an island...3

3. Wetland occurs within the banks of a river or stream or along the shores of a pond, lake, or island, or behind a barrier beach or island, <u>and</u> is typically permanently inundated, semipermanently flooded, or otherwise flooded for most of the growing season, or permanently saturated due to this location...Fringe Wetland

a. Wetland forms along the shores of an upland island within a lake, pond, river, or stream...b

a. Wetland does not form along the shores of an island...c

b. Wetland forms along an upland island in a river or stream................<u>River Island Fringe Wetland</u> or <u>Stream Island Fringe Wetland</u>

b. Wetland forms along an upland island in a lake or pond....................<u>Lake Island Fringe Wetland</u> or <u>Pond Island Fringe Wetland</u>

c. Wetland forms in or along a river or stream..............................<u>River Fringe Wetland</u> or <u>Stream Fringe Wetland</u>

c. Wetland forms in or along a pond or lake...d

d. Wetland forms along a pond shore..<u>Pond Fringe Wetland</u>

d. Wetland forms along a lake..e

e. Wetland forms behind a barrier island or beach along a lake...........<u>Barrier Island Fringe Wetland</u> or <u>Barrier Beach Fringe Wetland</u>

e. Wetland forms along a lake shore...<u>Lake Fringe Wetland</u>

[<u>Note</u>: Vegetation is assumed to be rooted unless designated by a *modifier* to indicate a floating mat (<u>Floating Mat</u>).]

3. Wetland does not exist along these

shores...4

4. Wetland occurs on an active or inactive (former) floodplain (alluvial processes dominate currently or did so in the past, historically)..Floodplain Wetland* (could specify the river system, if desirable). Sub-landforms are listed below.

a. Wetland occurs on the active floodplain, not separated from the river by dikes or artificial levees..b
a. Wetland is now isolated from typical floodplain processes, separated by dikes, artificial levees, or road/railroad embankments (former or historic floodplain)...................c

b. Wetland forms in a depressional feature on a floodplain..........<u>Floodplain Basin Wetland</u> or <u>Floodplain Oxbow Wetland</u> (a special type of depression)
b. Wetland forms on a broad nearly level terrace...........................<u>Floodplain Flat Wetland</u>

c. Wetland is a depressional feature on an isolated floodplain........<u>Former Floodplain Basin Wetland</u> or <u>Former Floodplain Oxbow Wetland</u> (a special type of depression)
c. Wetland forms on a broad nearly level terrace................<u>Former Floodplain Flat Wetland</u>

***[<u>Note</u>: Questionable floodplain areas may be verified by consulting soil surveys and locating the presence of alluvial soils, e.g., Fluvaquents or Fluvents, or soils with Fluvaquentic subgroups. Water flow path for "former floodplain wetlands" may be designated, e.g., Inflow, Outflow, or Isolated.]**

[*Modifiers*: <u>Partly Drained</u>. <u>Confluence wetland</u> - wetland at the intersection of two or more streams. <u>River-mouth</u> or <u>stream-mouth wetland</u> - wetland at point where a river and stream empties into a lake. <u>Meander scar wetland</u> - floodplain basin wetland, the remnant of a former river meander.]

4. Wetland does not occur on a floodplain...5

5. Wetland occurs on an interstream divide (interfluve)..................................Interfluve Wetland or specify *regional types* of interfluve wetlands, for example: Carolina Bay Interfluve Wetland, Pocosin Interfluve Wetland, and Flatwood Interfluve Wetland (Southeast). Sub-landforms are listed below.

a. Wetland forms in a depressional feature.................................. <u>Interfluve Basin Wetland</u>
a. Wetland forms on a broad nearly level terrace ....<u>Interfluve Flat Wetland</u>

[*Modifiers*: Partly Drained. Should designate Water Flow Path: most will be outflow, but other types: throughflow, inflow, and isolated, see couplet #6 below.]

5. Wetland does not occur on an interfluve...6

6. Wetland exists in a distinct depression..Basin Wetland or specify *regional types* of basin wetlands, for example: Carolina Bay Basin Wetland and Pocosin Basin Wetland (Atlantic Coastal Plain), Cypress Dome Basin Wetland (Florida), Prairie Pothole Basin Wetland (Upper Midwest), "Salt Flat" Basin Wetland (arid West), Playa Basin Wetland (Southwest), West Coast Vernal Pool Basin Wetland (California and Pacific Northwest), Interdunal Basin Wetland (sand dunes), Woodland Vernal Pool Basin Wetland (forests throughout the country), Polygonal Basin Wetland (Alaska), Sinkhole Basin Wetland (karst/limestone regions), or Pond Wetland Basin (throughout country).

a. No surface water inflow from stream or other waterbody, or no suspected significant surface or ground water inflow from a wetland or other waterbody at a higher elevation <u>and</u> no outflow to stream or no suspected significant surface or ground water flow to a wetland or waterbody at a lower elevation ....<u>Isolated Basin Wetland</u>

a. Wetland not hydrologically isolated...b

b. Surface water inflow from a stream or other waterbody, or suspected significant surface or ground water inflow from a wetland or other waterbody at a higher elevation <u>and</u> no observable or known significant outflow of surface or ground water to a stream or a wetland or waterbody at a lower elevation.....................................<u>Inflow Basin Wetland</u>

b. Wetland not an inflow wetland...c

c. Surface water inflow from a stream or other waterbody, <u>or</u> suspected significant surface or ground water inflow from a wetland or other waterbody at a higher elevation <u>and</u> water passes through the subject wetland to a stream, another wetland, or other waterbody at a lower elevation; this includes wetlands along lakes (lentic basin wetlands) which have a stream flowing through them.............................<u>Throughflow Basin Wetland</u>

(<u>Note</u>: If wetland is a lentic basin wetland, the directional flow of throughflow should be designated as lake inflow or lake outflow.)

c. Wetland not subjected to throughflow...d

d. No surface water inflow from a stream or other waterbody, <u>or</u> no suspected significant surface or ground water inflow from a wetland or other waterbody at a higher elevation, <u>and</u> water is discharged from this wetland to a stream or other waterbody, <u>or</u> there is significant outflow of surface or ground water to a wetland or other waterbody at a lower elevation...<u>Outflow Basin Wetland</u>

d. Along a lake and subjected to fluctuating water levels (including water tables) principally due to changes in lake levels................<u>Bidirectional Flow Lentic Basin Wetland</u>

[<u>Note</u>: *Modifiers* may be applied to indicate artificially created basins due to beaver activity or human actions or artificially drained basins: <u>Beaver</u> (beaver-created), <u>Human-caused</u> (created for various purposes or unintentionally formed due to human activities; may want to specify purpose), and <u>Partly drained</u> (drainage ditches observed). Other *modifiers* may be applied to designate the type of inflow or outflow as <u>Channelized</u> (intermittent or perennial, stream or river), <u>Nonchannelized-wetland</u> (contiguous wetland lacking stream), or <u>Nonchannelized-subsurface flow</u> (suspected subsurface flow to neighboring wetland), or to identify a headwater basin (<u>Headwater</u>) or a drainage divide wetland that discharges into two or more watershed (<u>Drainage divide</u>), or to denote a spring-fed wetland (<u>Spring-fed</u>), a wetland bordering a pond (<u>Pond border</u>) and a wetland bordering an upland island in a pond (<u>Pond island border</u>). For ponds, may also want to add modifiers that identify the nature of the area surrounding the pond, e.g., farm, residential, commercial, industrial, coal mine, forest, and others - see "Waterbody Keys". For lotic basin wetlands, consider additional modifiers such as <u>confluence wetland</u> - wetland at the intersection of two or more streams; <u>river-mouth</u> or <u>stream-mouth wetland</u> - wetland at point where a river and a stream empties into a lake.]

6. Wetland exists in a relatively level area...Flat Wetland or specify *regional types* of flat wetlands, for example: Salt Flat Wetland (in the Great Basin).

a. Wetland created by paludification processes (where in areas of low evapotranspiration and high rainfall, peat moss moves uphill creating wetlands on hillslopes and broad upland flats) which cause wetland to develop upslope of primary water source....<u>Paludified Flat Wetland</u>

a. Wetland not formed by paludification processes..b

b. No surface water inflow from stream or other waterbody, <u>or</u> no suspected significant surface or ground water inflow from a wetland or other waterbody at a higher elevation <u>and</u> no outflow to stream or no suspected significant surface or ground water flow to a wetland or waterbody at a lower

elevation..<u>Isolated Flat Wetland</u>

b. Wetland not hydrologically isolated...c

c. Surface water inflow from a stream or other waterbody, <u>or</u> suspected significant surface or ground water inflow from a wetland or other waterbody at a higher elevation <u>and</u> water passes through the subject wetland to a stream, another wetland, or other waterbody at a lower elevation; this includes wetlands along lakes (lentic flat wetlands) which have a stream flowing through them................................<u>Throughflow Flat Wetland</u>
(<u>Note</u>: If wetland is a lentic flat wetland, the directional flow of throughflow should be designated as lake inflow or lake outflow.)

c. Wetland not subjected to throughflow...d

d. No surface water inflow from a stream or other waterbody, <u>or</u> no suspected significant surface or ground water inflow from a wetland or other waterbody at a higher elevation, <u>and</u> water is discharged from this wetland to a stream or other waterbody, <u>or</u> there is significant outflow of surface or ground water to a wetland or other waterbody at a lower elevation...<u>Outflow Flat Wetland</u>

d. Along a lake and subjected to fluctuating water levels (including water tables) principally due to changes in lake levels.................<u>Bidirectional Flow Lentic Flat Wetland</u>

[<u>Note</u>: If desirable a *modifier* for drained flats can be applied: <u>Partly drained</u>. Other *modifiers* can be applied to designate the type of inflow or outflow as <u>Channelized</u> (intermittent or perennial, stream or river), <u>Nonchannelized-wetland</u> (contiguous wetland lacking stream), or <u>Nonchannelized-subsurface flow</u> (suspected subsurface flow to neighboring wetland). For lotic flat wetlands, consider additional modifiers such as <u>confluence wetland</u> - wetland at the intersection of two or more streams; <u>river-mouth</u> or <u>stream-mouth wetland</u> - wetland at point where a river and a stream empties into a lake.]

Key C: Key to Coastal Landforms

1. Wetland forms an island...Island Wetland

a. Occurs in a delta...<u>Delta Island Wetland</u>

a. Occurs elsewhere either in a river or an

embayment...b

b. Occurs in a river...<u>River Island Wetland</u>

b. Occurs in a coastal embayment..<u>Bay Island Wetland</u>

1. Wetland does not form an island, but occurs elsewhere..2

2. Wetland occurs along the shore...Fringe Wetland

a. Occurs behind a barrier island or barrier beach spit...........<u>Barrier Island Fringe Wetland</u> or <u>Barrier Beach Fringe Wetland</u> [*Modifier* for overwash areas....<u>Overwash</u>]

a. Occurs elsewhere...b

b. Occurs along a coastal embayment or along an island in a bay..........<u>Bay Fringe Wetland</u> or <u>Bay Island Fringe Wetland</u> or <u>Coastal Pond Fringe Wetland</u> (a special type of embayment, typically with periodic connection to the ocean unless artificially connected by a bulkheaded inlet) or <u>Coastal Pond Island Fringe Wetland</u>

b. Occurs elsewhere...c

c. Occurs along a coastal river or along an island in a river...............<u>River Fringe Wetland</u> or <u>River Island Fringe Wetland</u>

c. Occurs elsewhere..d

d. Occurs along an oceanic island..<u>Ocean Island Fringe Wetland</u>

d. Occurs along the shores of exposed rocky mainland...............<u>Headland Fringe Wetland</u>

2. Wetland occurs in an artificial impoundment or behind a road or railroad embankment where tidal flow is at least somewhat restricted..Basin Wetland

[*Modifiers* may be applied to designate created basins: <u>Human-induced</u> (managed fish and wildlife areas; salt hay; tidally restricted-road, tidally restricted-railroad, other road crossing (no significant tidal restriction suspected), other railroad crossing (no significant tidal restriction suspected), and other situations to be determined.]

Waterbody Keys

These keys are designed to expand the classification of waterbodies beyond the system and subsystem levels in the Service's wetland classification system (Cowardin et al. 1979). Users are advised first to classify the waterbody in one of the five ecosystems: 1) marine (open ocean and associated coastline), 2) estuarine (mixing zone of fresh and ocean-derived salt water), 3) lacustrine (lakes, reservoirs, large impoundments, and dammed rivers), 4) riverine (undammed rivers and tributaries), and 5) palustrine (e.g., nontidal ponds) and then apply the waterbody type descriptors below.

Five sets of keys are given. Key A helps describe the major waterbody type. Key B identifies different stream gradients for rivers and streams. It is similar to the subsystems of Cowardin's Riverine system, but includes provisions for dammed rivers to be identified as well as a middle gradient reach similar to that of Brinson's hydrogeomorphic classification system. The third key, Key C, addresses lake types, while Keys D and E further define ocean and estuary types, respectively. Key F is a key to water flow paths of ponds, lakes, and reservoirs. Keys G and H are for coastal waterbodies: the former is for describing tidal ranges and the latter is for describing general circulation patterns in estuaries. The coastal terminology applies concepts of coastal hydrogeomorphology.

Key A. Key to Major Waterbody Type

1. Waterbody is predominantly flowing water, either unidirectional or tidal.................................2

2. Flow is unidirectional and waterbody is a river, stream, or similar channel............................3

3. Waterbody is a polygonal feature on a U.S. Geological Survey map or a National Wetlands Inventory Map (1:24,000/1:25,000)..River

3. Waterbody is a linear feature on such maps..Stream

<u>**Go to River/Stream Gradient Key and for other modifiers (Key B)**</u>**.**

2. Flow is tidal (bidirectional) at least seasonally; waterbody is an ocean, embayment, river, stream, or lake...4

4.Waterbody is freshwater..5

5. Waterbody is a polygonal feature on a U.S. Geological Survey map or a National Wetlands Inventory Map (1:24,000/1:25,000)....................................River*

5. Waterbody is a linear feature on such maps...Stream

*** Note: In rare cases, lakes may be tidal (if so, waterbody is classified as a Tidal Lake).**

Go to River/Stream Gradient Key and for other modifiers (Key B).

4.Waterbody is salt or brackish...6

7. Part of a major ocean or its associated embayment (Marine system of Cowardin et al. 1979) ....Ocean
Go to Ocean Key (Key D).

7. Part of an estuary where fresh water mixes with salt water (Estuarine system of Cowardin et al. 1979)..Estuary

Go to Estuary Key (Key E).

1. Waterbody is predominantly standing water or essentially so; not subjected to tides*..............8

*** Note: In rare cases, fresh waterbodies may be tidal (if so, waterbody is classified as a Tidal Lake or Tidal Pond using criteria below to separate lakes from ponds).**

8. Waterbody is permanently flooded and deep (>than 6.6 ft at low water)......................Lake

Go to Lake Key (Key C).

8. Waterbody is shallow (< 6.6 ft at low water)..9

9. Waterbody is small (< 20 acres)..Pond

Separate natural from artificial ponds, then add other modifiers like the following. Some ***examples*** **of modifiers for ponds: beaver, alligator, marsh, swamp, vernal, Prairie Pothole, Sandhill, sinkhole/karst, Grady, interdunal, farm-cropland, farm-livestock, golf, industrial, sewage/wastewater treatment, stormwater, aquaculture-catfish, aquaculture-shrimp, aquaculture-crayfish, cranberry, irrigation, aesthetic-business, acid-mine, arctic polygonal, kettle, woodland, borrow pit, Carolina bay, tundra, coastal plain, and in-stream.**
(Note: Wetlands associated with ponds are typically either Terrene basin wetlands, such as a Cypress dome or cypress-gum pond, or Terrene pond fringe wetlands, such as semipermanently flooded wetlands along margins of pond.)

9. Waterbody is large (≥20

acres)..Lake

Go to Lake Key (Key C).

Key B. River/Stream Gradient and Other Modifiers Key

1. Water flow is under tidal influence...Tidal Gradient

Type of tidal river or stream: 1) natural river, 2) natural stream, 3) channelized river, 4) channelized stream, 5) canal (artificial polygonal lotic feature), 6) ditch (artificial linear lotic feature), 7) restored river segment (part of river where restoration was performed), and 8) restored stream segment (part of stream where restoration was performed).

1. Water flow is not under tidal influence (nontidal)...2

2. Water flow is dammed, yet still free-flowing at least seasonally ....Dammed Gradient

Type of dammed river: 1) lock and dammed (canalized river, a series of locks and dams are present to aid navigation), 2) run-of-river dammed (low dam allowing flow during high water periods; often used for low-head hydropower generation), and 3) other dammed (unspecified, but not major western hydropower dam as such waterbodies are considered lakes, e.g., Lake Mead and Lake Powell).

2. Water flow is unrestricted...3

3. Water flow is perennial (year-round); perennial rivers and streams..................................4

4. Water flow is generally rapid due to steep gradient; typically little or no floodplain development; watercourse is generally shallow with rock, cobbles, or gravel bottoms; first and second order "streams"; part of Cowardin's Upper Perennial subsystem.......................... ....High Gradient*

4. Water flow is not so; some to much floodplain development.....................................5

5. Water flow is generally slow; typically with extensive floodplain; water course shallow or deep with mud or sand bottoms; typically fifth and higher order "streams", but includes lower order streams in nearly level landscapes such as the Great Lakes Plain (former glacial lakebed) and the Coastal Plain (the latter streams may lack significant floodplain development); Cowardin's Lower Perennial subsystem ....Low

Gradient*

5. Water flow is fast to moderate; with little to some floodplain; usually third and fourth order "streams"; part of Cowardin's Upper Perennial subsystem ....Middle Gradient*

3. Water flow is seasonal or aperiodic (intermittent); Cowardin's Intermittent subsystem..Intermittent Gradient*

*<u>Type of river or stream</u>: 1) <u>natural river- single thread</u> (one channel), 2) <u>natural river - multiple thread (braided)</u> (multiple, wide, shallow channels), 3) <u>natural river-multiple thread (anastomosed)</u> (multiple, deep narrow channels), 4) <u>natural stream-single thread</u>, 5) <u>channelized river</u> (dredged/excavated), 6) <u>channelized stream</u>, 7) <u>canal</u> (artificial polygonal lotic feature), 8) <u>ditch</u> (artificial linear lotic feature), 9) <u>restored river segment</u> (part of river where restoration was performed), and 10) <u>restored stream segment</u> (part of stream where restoration was performed). Other possible descriptors: 1) <u>for perennial rivers and streams</u> can distinguish <u>riffles</u> (shallow, rippling water areas), <u>pools</u> (deeper, quiet water areas), and <u>waterfalls</u> (cascades), 2) <u>deep rivers</u> ($\geq$6.6 ft at low water) from <u>shallow rivers</u> (<6.6 ft at low water), 3) nontidal river or stream segment emptying into an estuary, ocean, or lake (<u>estuary-discharge</u>, <u>ocean-discharge</u>, or <u>lake-discharge</u>), 4) classification by stream order (1^{st}, 2^{nd}, 3^{rd}, etc), and 5) channels patterns (<u>straight</u>, <u>slight meandering</u>, <u>moderate meandering</u>, and <u>high meandering</u>).

Key C. Key to Lakes.

1. Waterbody is permanently flooded and deep (>than 6.6 ft at low water)..................................2

2. Waterbody is not dammed or impounded..Natural Lake

<u>Modifiers for main body, semi-enclosed embayment, and seiche-influenced</u>; also <u>river-fed</u> and <u>stream-fed</u> descriptors.

2. Waterbody is dammed or impounded...3

3. Dammed river valley...Dammed Valley Lake

3. Dammed natural lake...Dammed Lake

<u>Modifiers for main body, semi-enclosed embayment, water-level controlled lake, reservoir (public water supply), high-dam impoundment, other impoundment, and seiche-influenced</u>; also <u>river-fed</u> and <u>stream-fed</u> descriptors.

1.Waterbody is shallow (< 6.6 ft at low

water)...4
4. Waterbody is essentially permanently flooded...Shallow Lake*
4. Waterbody is not permanent, goes dry in most years..5
5. Waterbody is seasonally flooded in most years.....................................Seasonal Lake*
5. Waterbody is flooded intermittently...Intermittent Lake*

***Can use additional modifiers listed under Pond (see Key A) and others (e.g., crater, lava flow, aeolian, fjord, oxbow, other floodplain, glacial, alkali, and manmade), as appropriate; also <u>river-fed</u> and <u>stream-fed</u> descriptors. Wetlands associated with these types of lakes are typically considered Terrene basin and flat wetlands.**

Key D. Ocean Key.

1. Waterbody is completely open, not protected by any feature.................................Open Ocean
1. Waterbody is somewhat protected...2
2. Associated with coral reef or island 3
3. Open but protected by coral reef .... Reef-protected Waters
3. Protected by a coral island.. Atoll Lagoon
2. Not associated with coral reef or island..4
4. Deep embayment cut by glaciers, with an underwater sill at front end, restricting circulation; associated with rocky headlands...Fjord
4. Other semi-protected embayment.....................Semi-protected Oceanic Embayment

Key E. Estuary Key.

1. Estuary is surrounded by rocky headlands and shores...2
2. Deep embayment cut by glaciers, with an underwater sill at front end, restricting circulation...Fjord Estuary
2. Not so, either open or semi-enclosed..................................Rocky Headland Bay Estuary*

*** <u>Modifiers: Open or Semi-enclosed</u>**

1. Estuary not surrounded by rocky headlands and shores..3

3. Estuary is a drowned river valley ....Drowned River Valley Estuary*

***Modifiers: Open Bay, River Channel, Semi-enclosed Bay**

3. Estuary is not a drowned river valley...4

4. Waterbody is behind and protected by barrier islands or barrier beaches.......................5

5. Waterbody is behind a barrier island ....Barrier Island Back Bay Estuary

5. Waterbody is behind a barrier beach..6

6. Waterbody is completely protected by beaches and intermittently connected to salt water except where artificially kept open...7

7. Water is brackish to fresh ....Coastal Pond Estuary

7. Water is hypersaline..Hypersaline Lagoon Estuary

6. Waterbody is protected by beaches, but has free exchange of tidal water due to natural forces..Barrier Beach Back Bay Estuary

4. Waterbody is not behind barrier islands or beaches, but is an open or semi-enclosed embayment...8

8. Waterbody is protected by islands.............................Island Protected Bay Estuary

8. Waterbody is not protected by islands...................................Shoreline Bay Estuary

Modifier: Tidal Inlet (includes any ebb- or flood- deltas that are completed submerged) and Shoals (shallow water areas).

Key F. Key to Water Flow Paths for Ponds, Lakes, and Reservoirs

1. Water flow is mainly out of the pond, lake or reservoir via a river, stream, or ditch....Outflow*

1. Water flow is not so...2

2. Water flow comes in from river, stream, or ditch, goes through and out of the lake or reservoir via a river, stream, or ditch...Throughflow*

2. Water flow is not throughflow...3
3. Water flow enters via a river, stream, or ditch, but does not exit pond, lake or reservoir; waterbody serves as a sink for water...Inflow*
3. No apparent channelized inflow, source of water either by precipitation or by underground sources ....Isolated

*Modifier: Ditch (for inflow, outflow, and throughflow via a ditch network).

Key G. Key to Tidal Range Types

1. Tide range is greater than 4m (approx. >12 feet) ....Macrotidal
1. Tidal range is less than 4m 2
2. Tidal range is 2-4m (approx. 6-12 feet) ....Mesotidal
2. Tidal range is less than 2m (approx. < 6 feet) ....Microtidal

Key H. Key to Estuarine Hydrologic Circulation Types

1. Estuary is river-dominated with distinct salt wedge moves seasonally up and down the river; fresh water at surface with most saline waters at bottom; low energy system with silt and clay bottoms ......Salt-wedge Estuary
1. Estuary is not river-dominated 2
2. Estuarine water is well-mixed, no significant salinity stratification, salinity more or less the same from top to bottom of water column; high-energy system with sand bottom ....Homogeneous Estuary
2. Estuarine water is partially mixed, salinities different from top to bottom, but not strongly stratified; low energy system ....Partially Mixed Estuary

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Glossary

***Barrier Beach* -- a coastal peninsular landform extending from the mainland into the ocean or large embayment or large lake (e.g., Great Lakes), typically providing protection to waters on the backside and allowing the establishment of salt marshes; similar to the barrier island, except connected to the mainland**

***Barrier Island* -- a coastal insular landform, an island typically between the ocean (or possibly the Great Lakes) and the mainland; its presence usually promotes the formation of salt marshes on the backside**

***Basin* -- a depressional (concave) landform; various types are further defined by the absence of a stream (isolated), by the presence of a stream and its position relative to a wetland (throughflow, outflow, inflow), or by its occurrence on a floodplain (floodplain basins include ox-bows and sloughs, for example)**

***Bay* -- a coastal embayment of variable size and shape that is always opens to the sea through an inlet or other features**

***Carolina Bay* -- a wetland formed in a semicircular or egg-shaped basin with a northwest to southeast orientation, found along the Atlantic Coastal Plain from southern New Jersey to Florida, and perhaps most common in Horry County, South Carolina**

***Channelization* -- the act or result of excavating a stream or river channel to increase downstream flow of water or to increase depth for navigational purposes**

***Channelized* -- water flow through a conspicuous drainageway, a stream or a river**

***Cypress Dome* -- a wetland dominated by bald cypress growing in a basin that may be formed by the collapse of underlying limestone, forest canopy takes on a domed appearance with tallest trees in center and becoming progressively shorter as move toward margins of basin**

***Delta* -- a typically lobed-shaped or fan-shaped landform formed by sedimentation processes at the mouth of a river carrying heavy sediment loads**

***Ditch* – a linear, often shallow, artificial channel created by excavation with intent to improve drainage of or to irrigate adjacent lands**

***Drained, Partly* -- condition where a wetland has been ditched or tiled to lower the ground water table, but the area is still wet long enough and often enough to fall within the range of conditions associated with wetland hydrology**

***Estuarine* -- the landscape of estuaries (salt and brackish tidal waterbodies, such as bays**

and coastal rivers) including associated wetlands, typically occurring in sheltered or protected areas, not exposed to oceanic currents

Flat **-- a relatively level landform; may be a component of a floodplain or the landform of an interfluve**

Flatwood **-- forest of pines, hardwoods or mixed stands growing on interfluves on the Gulf-Atlantic Coastal Plain, typically with imperfectly drained soils; some flatwoods are wetlands, while others are dryland**

Floodplain **-- a broad, generally flat landform occurring in a landscape shaped by fluvial or riverine processes; for purposes of this classification limited to the broad plain associated with large river systems subject to periodic flooding (once every 100 years) and typically having alluvial soils; further subdivided into several subcategories: flat (broad, nearly level to gently sloping areas) and basin (depressional features such as ox-bows and sloughs)**

Fringe **-- a wetland occurring along a flowing or standing waterbody, i.e., a lake, river, stream, estuary, or ocean; note that ponds are excluded**

Ground Water **-- water below ground, held in the soil or underground aquifers**

Headland **-- the seaward edge of the major continental land mass (North America), commonly called the mainland; not an island**

High Gradient **-- the fast-flowing segment of a drainage system, typically with no floodplain development; equivalent to the Upper Perennial and Intermittent Subsystems of the Riverine System in Cowardin et al. 1979**

Inflow **-- water enters; an inflow wetland is one that receives surface water from a stream or other waterbody or from significant surface or ground water from a wetland or waterbody at a higher elevation and has no significant discharge**

Interdunal **-- occurring between sand dunes, as in interdunal swale wetlands found in dunefields behind ocean and estuarine beaches and in sand plains like the Nebraska Sandhills**

Interfluve **-- a broad level to imperceptibly depressional poorly drained landform occurring between two drainage systems, most typical of the Coastal Plain**

Island **-- a landform completely surrounded by water and not a delta; some islands are entirely wetland, while others are uplands with or without a fringe wetland**

Karst **-- a limestone region characterized by sinkholes and underground caverns**

Lentic **-- the landscape position associated with large, deep standing waterbodies (such as lakes and reservoirs) and contiguous wetlands formed in the lake basin (excludes seasonal and shallow lakes which are included in the *Terrene* landscape position).**

Lotic **-- the landscape position associated with flowing water systems (such as rivers, creeks, perennial streams, intermittent streams, and similar waterbodies) and contiguous wetlands**

Low Gradient **-- the slow-flowing segment of a drainage system, typically with considerable floodplain development; equivalent to the Lower Perennial Subsystem of the Riverine System in Cowardin et al. 1979 plus contiguous wetlands**

Marine **-- the landscape position (or seascape) associated with the ocean's shoreline**

Middle Gradient **-- the segment of a drainage system with characteristic intermediate between the high and low gradient reaches, typically with limited floodplain development; equivalent to areas mapped as Riverine Unknown (R5) in the Northeast Region plus contiguous wetlands**

Nonchannelized **-- water exits through seepage, not through a river or stream channel or ditch**

Outflow **-- water exits; an outflow wetland has water leaving via a stream or seepage to a wetland or waterbody at a lower elevation, it lacks an inflow source**

Oxbow **-- a former mainstem river bend now partly or completely cut off from mainstem**

Paludified **-- subjected to paludification, the process by which peat moss engulfs terrains of varying elevations due to an excess of water, typically associated with cold, humid climates of northern areas (boreal/arctic regions and fog-shrouded coasts)**

Playa **-- a type of basin wetland in the Southwest characterized by drastic fluctuations in water levels over the normal wet-dry cycle**

Pocosin **-- a shrub and/or forested wetland forming on organic soils in interstream divides (interfluves) on the Atlantic Coast Plain from Virginia to Florida, mostly in North Carolina**

Pond **-- a natural or human-made shallow open waterbody that may be subjected to periodic drawdowns**

Prairie Pothole **-- a glacially formed basin wetland found in the Upper Midwest especially in the Dakotas, western Minnesota, and Iowa.**

Reservoir **-- a large, deep waterbody formed by a dike or dam created for a water supply for drinking water or agricultural purposes or for flood control, or similar purposes.**

Salt Pond **-- a coastal embayment of variable size and shape that is periodically and temporarily cut off from the sea by natural accretion processes; some may be kept permanently open by jetties and periodic maintenance dredging**
Salt Flat **-- a broad expanse of alkaline wetlands associated with arid regions, especially the Great Basin in the western United States**

Sinkhole **-- a depression formed by the collapse of underlying limestone deposits; may be wetland or nonwetland depending on drainage characteristics**

Slope **-- a wetland occurring on a slope; various types include those along a sloping stream (fringe), those (paludified) formed by paludification -- the process of bogging or swamping of uplands by peat moss in northern climes (humid and cold), and those not designated as one of the above and typically called seeps**

Stream **– a natural drainageway that contains flowing water at least seasonally; different stream types:** ***perennial*** **where water flows continously in all years except drought or extremely dry years; <u>intermittent</u> where water flows only seasonally in most years; <u>channelized</u> where stream bed has been excavated or dredged**

Subsurface Flow **-- water leaves via ground water**

Surface Water **-- water occurring above the ground as in flooded or ponded conditions**

Terrene **-- wetlands surrounded or nearly so by uplands and lacking a channelized outlet stream; a stream may enter or exit this type of wetland but it does not flow through it as a channel; includes a variety of wetlands and natural and human-made ponds**

Throughflow **-- water entering and exiting, passing through; a throughflow wetland receives significant surface or ground water which passes through the wetland and is discharged to a stream, wetland or other waterbody at a lower elevation**

Tidal Gradient **-- the segment of a drainage basin that is subjected to tidal influence; essentially the freshwater tidal reach of coastal rivers; equivalent to the Tidal Subsystem of the Riverine System in Cowardin et al. 1979 plus contiguous wetlands**

Vernal Pool **-- a temporarily flooded basin; woodland vernal pools are found in humid temperature regions dominated by trees, these pools are surrounded by upland forests, are usually flooded from winter through mid-summer, and serve as critical breeding grounds for salamanders and woodland frogs; West Coast vernal pools occur in California, Oregon, and Washington on clayey soils, they are important habitats for many rare plants and animals**

APPENDIX B. Preliminary Functional Assessment Findings for Each Subbasin

Results for Broad Creek

Function	Potential Significance	Acreage	% of Wetland Acreage
Surface Water Detention	High Potential	2,915	18.6
	Moderate Potential	3,514	22.5
	Some Potential	8,422	53.8
Streamflow Maintenance	High Potential	4,194	26.8
	Moderate Potential	1,447	9.3
	Some Potential	8,354	53.4
Nutrient Transformation	High Potential	2,807	17.9
	Moderate Potential	326	2.1
	Some Potential	4,899	31.3
Retention of Sediments and Inorganic Particulates	High Potential	2,999	19.2
	Moderate Potential	580	3.7
	Some Potential	4,899	31.3
Shoreline Stabilization	High Potential	3,159	20.2
Fish/Shellfish Habitat	High Potential	328	2.1
	Moderate Potential	40	0.3
	Some Potential	167	1.1
	Shading Potential*	2,503	16.0
Waterfowl/Waterbird Habitat	High Potential	315	2.0
	Moderate Potential	-	-
	Some Potential	208	1.3
	Wood Duck Potential	2,889	18.5
Other Wildlife Habitat	High Potential	10,950	70.0
	Some Potential	1,162	7.4
Biodiversity	Atlantic White Cedar	86	0.5
	Bald Cypress	328	2.1
	Estuarine Oligohaline Wetlands	33	0.3
	Riverine Tidal Wetlands	2	-
	Uncommon Fresh Tidal Wetlands	41	0.3
	Uncommon Nontidal Wetlands	53	0.3
	Seasonally Flooded or wetter Palustrine Wetlands	36	0.3
	Large Wetland Complexes (1 partial)	1,241	7.9

<u>Results for Deep Creek</u>

Function	Potential Significance	Acreage	% of Wetland Acreage
Surface Water Detention	High Potential	1,529	12.9
	Moderate Potential	2,456	20.7
	Some Potential	7,320	61.7
Streamflow Maintenance	High Potential	2,427	20.4
	Moderate Potential	1,277	10.8
	Some Potential	7,242	61.0
Nutrient Transformation	High Potential	1,120	9.4
	Moderate Potential	285	2.4
	Some Potential	4,207	35.4
Retention of Sediments and Inorganic Particulates	High Potential	1,544	13.0
	Moderate Potential	311	2.6
	Some Potential	3,896	32.8
Shoreline Stabilization	High Potential	1,580	13.3
Fish/Shellfish Habitat	High Potential	49	0.4
	Moderate Potential	6	-
	Some Potential	94	0.8
	Shading Potential*	1,443	12.2
Waterfowl/Waterbird Habitat	High Potential	29	0.2
	Moderate Potential	11	0.1
	Some Potential	106	0.9
	Wood Duck Potential	1,484	12.5
Other Wildlife Habitat	High Potential	8,375	70.6
	Some Potential	440	3.7
Biodiversity	Riverine Tidal Wetlands	7	-
	Uncommon Fresh Tidal Wetlands	21	0.2
	Uncommon Nontidal Wetlands	11	0.1
	Seasonally Flooded or wetter Palustrine Wetlands	7	-
	Wetlands within 7,410+ acre Forest	4,463	28.5
	Large Wetland Complexes **(1 partial)**	**47**	**0.4**

Results for Gravelly Branch

Function	Potential Significance	Acreage	% of Wetland Acreage
Surface Water Detention	High Potential	693	7.6
	Moderate Potential	3,651	40.1
	Some Potential	4,565	50.1
Streamflow Maintenance	High Potential	3,550	39.0
	Moderate Potential	664	7.3
	Some Potential	4,540	49.8
Nutrient Transformation	High Potential	1,145	12.6
	Moderate Potential	40	0.4
	Some Potential	1,327	14.6
Retention of Sediments and Inorganic Particulates	High Potential	720	7.9
	Moderate Potential	524	5.8
	Some Potential	1,310	14.4
Shoreline Stabilization	High Potential	727	8.0
Fish/Shellfish Habitat	High Potential	47	0.5
	Moderate Potential	2	-
	Some Potential	10	0.1
	Shading Potential*	650	7.1
Waterfowl/Waterbird Habitat	High Potential	47	0.5
	Moderate Potential	-	-
	Some Potential	12	0.1
	Wood Duck Potential	660	7.2
Other Wildlife Habitat	High Potential	7,755	85.1
	Some Potential	241	2.6
Biodiversity	Uncommon Nontidal Wetlands	8	-
	Seasonally Flooded or wetter Palustrine Wetlands	6	-
	Wetlands within 7,410+ acre Forest	7,148	78.4
	Large Wetland Complexes (**1 partial**)	**244**	**2.7**

Results for Gum Branch

Function	Potential Significance	Acreage	% of Wetland Acreage
Surface Water Detention	High Potential	382	7.0
	Moderate Potential	957	17.5
	Some Potential	4,097	74.8
Streamflow Maintenance	High Potential	860	15.7
	Moderate Potential	347	6.3
	Some Potential	4,079	74.5
Nutrient Transformation	High Potential	202	3.7
	Moderate Potential	95	1.7
	Some Potential	3,926	71.7
Retention of Sediments and Inorganic Particulates	High Potential	382	7.0
	Moderate Potential	123	2.2
	Some Potential	3,926	71.7
Shoreline Stabilization	High Potential	423	7.7
Fish/Shellfish Habitat	High Potential	7	0.1
	Moderate Potential	-	-
	Some Potential	27	0.5
	Shading Potential*	415	7.6
Waterfowl/Waterbird Habitat	High Potential	7	0.1
	Moderate Potential	-	-
	Some Potential	27	0.5
	Wood Duck Potential	420	7.6
Other Wildlife Habitat	High Potential	4,787	87.4
	Some Potential	145	2.6
Biodiversity	Uncommon Nontidal Wetlands	5	-
	Seasonally Flooded or wetter Palustrine Wetlands	1	-
	Wetlands within 7,410+ acre Forest	1,166	21.3
	Large Wetland Complexes **(2 partial)**	**1,582**	**28.9**

Results for Marshyhope Creek

Function	**Potential Significance**	**Acreage**	**% of Wetland Acreage**
Surface Water Detention	High Potential	1,167	5.9
	Moderate Potential	2,223	11.2
	Some Potential	15,451	78.1
Streamflow Maintenance	High Potential	2,161	10.9
	Moderate Potential	1,067	5.4
	Some Potential	15,466	78.1
Nutrient Transformation	High Potential	1,102	5.6
	Moderate Potential	340	1.7
	Some Potential	16,233	82.0
Retention of Sediments and Inorganic Particulates	High Potential	1,167	8.2
	Moderate Potential	592	3.0
	Some Potential	16,232	82.0
Shoreline Stabilization	High Potential	1,282	6.5
Fish/Shellfish Habitat	High Potential	6	-
	Moderate Potential	1	-
	Some Potential	34	0.2
	Shading Potential*	1,242	6.2
Waterfowl/Waterbird Habitat	High Potential	81	0.4
	Moderate Potential	-	-
	Some Potential	36	0.2
	Wood Duck Potential	1,231	6.2
Other Wildlife Habitat	High Potential	16,623	84.0
	Some Potential	663	3.3
Biodiversity	Uncommon Nontidal Wetlands	175	0.9
	Seasonally Flooded or wetter Palustrine Wetlands	7	-
	Large Wetland Complexes **(4: 1327 a; 1554; 1545; 986)**	**5,412**	**27.3**

Results for Nanticoke River

Function	Potential Significance	Acreage	% of Wetland Acreage
Surface Water Detention	High Potential	4,118	26.6
	Moderate Potential	2,968	19.2
	Some Potential	7,472	48.3
Streamflow Maintenance	High Potential	2,579	16.7
	Moderate Potential	2,720	17.6
	Some Potential	7,233	46.7
Nutrient Transformation	High Potential	3,249	21.0
	Moderate Potential	935	6.0
	Some Potential	8,241	53.3
Retention of Sediments and Inorganic Particulates	High Potential	4,119	26.6
	Moderate Potential	550	3.6
	Some Potential	8,095	52.3
Shoreline Stabilization	High Potential	4,193	27.1
Fish/Shellfish Habitat	High Potential	229	1.5
	Moderate Potential	9	-
	Some Potential	180	1.2
	Shading Potential*	2,986	19.3
Waterfowl/Waterbird Habitat	High Potential	165	1.1
	Moderate Potential	44	0.3
	Some Potential	207	1.3
	Wood Duck Potential	3,595	23.2
Other Wildlife Habitat	High Potential	12,180	78.7
	Some Potential	1,293	8.4
Biodiversity	Atlantic White Cedar	33	0.2
	Estuarine Oligohaline Wetlands	47	0.3
	Riverine Tidal Wetlands	24	0.2
	Uncommon Fresh Tidal Wetlands	160	1.0
	Uncommon Nontidal Wetlands	2	-
	Seasonally Flooded or wetter Palustrine Wetlands	38	0.2
	Large Wetland Complexes (2 partials)	2,771	17.9