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A Technique for the Functional Assessment of Nontidal Wetlands in the Coastal Plain of Virginia

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Introduction

Nontidal wetlands are known to perform a number of functions which benefit society. These functions include flood storage, surface and groundwater quality protection, fish and wildlife habitat, erosion control, primary productivity, and a recreational and educational resource for the public. The Commonwealth of Virginia has recognized the value of nontidal wetlands and has extended some protection to these resources in the coastal plain of Virginia via the Chesapeake Bay Preservation Act and resulting local zoning ordinances. Additional legislation for protection of nontidal wetlands may be considered in the future. Prudent and effective management of nontidal wetlands requires a knowledge of what resources exist and how they function. However, few studies of nontidal wetlands in the coastal plain of Virginia have been undertaken in the past.

The Virginia Institute of Marine Science (VIMS) is conducting a two-part study of nontidal wetlands in Virginia's coastal plain. First, we are attempting to describe the nontidal wetland resources of the coastal plain of Virginia in terms of characteristic vegetation assemblages. In conjunction with the vegetation study, we will attempt to describe the functioning of the wetlands studied. Our premise is that not all wetlands perform all functions at all times or perform functions equally well. We will investigate the relationships between wetland functions, wetland type, and location of the wetland within the landscape.

The purpose of this document is to describe the technique which has been derived to assess the functions of nontidal wetlands in the coastal plain of Virginia. At the present time, the technique is in the preliminary stages of development. It was field tested and revised during the spring and summer of 1991. It will now be used to analyze the functions of nontidal wetlands surveyed. This analysis is expected to result in elucidation of research needs and in further refinement of the technique.

The reader or user of this functional assessment technique should be aware of several caveats in its use:

1) One of our goals was to develop a rapid assessment method. Because of this goal, the technique chosen is necessarily simplistic. More in-depth studies may be required to achieve a more complete understanding of how the wetlands function.

2) We have attempted to reduce subjectivity in the method in order to achieve consistency between field personnel; however, some subjectivity was unavoidable in attempting to achieve the rapid assessment goal.

3) The technique has been developed for nontidal wetlands in the coastal plain of Virginia, and is not necessarily applicable to tidal wetlands, wetlands in other physiographic regions, or wetlands outside of Virginia.

4) Because this technique is in the preliminary development stage, we caution against its use in making management, policy, or regulatory decisions.

Future versions of this technique may address additional functions not included here (e.g., groundwater relationships, export of primary productivity from wetlands).

Comprehensive functional assessment techniques reviewed

Through the years, many techniques have been advanced to evaluate wetlands for their various functions and values. In deciding how we would assess the functions of Virginia's nontidal coastal plain wetlands, we surveyed literature on functional assessment techniques to determine if techniques existed which would be applicable to the present study. Limitations for the present study include the need for a very rapid assessment technique; data must be easily collected from existing sources or brief site visits. Our field season for the present study is limited to spring through fall of 1991, and we would like to visit as many nontidal wetland sites as possible during this brief time. Our goal is to develop a rapid assessment technique which, based on wetland and watershed characteristics, allows ranking of each wetland as having a High, Moderate, or Low probability of opportunity and effectiveness at performing each function.

The comprehensive assessment techniques reviewed are introduced below. These techniques are referred to in the following sections in which each function is addressed, and our chosen method for assessing each function described. Techniques for assessing single functions (e.g., flood storage, wildlife habitat) are reviewed in the sections addressing those functions. Literature review will be ongoing throughout the course of the study.

US Army Corps of Engineers Institute for Water Resources (IWR method) (Reppert et al., 1979)

The IWR method is one of the earliest attempts at comprehensive wetland evaluation. It was generated primarily for use by US Army Corps of Engineers personnel in evaluation of projects for its regulatory and civil works functions. The IWR method addresses the following functions and values: food chain production, general and specialized habitat for land and aquatic species, aquatic study areas/sanctuaries/ refuges, hydrologic support function, shoreline protection, storm and flood water storage, natural groundwater recharge, water purification, commercial fisheries, renewable resources and agriculture, recreation, aesthetics, and other special values.

The method is primarily a general framework for analyzing wetland functions and values, rather than providing specific evaluation criteria. However, it does incorporate some specific evaluation criteria (e.g., flood storage function). Where specific criteria are given, the technical basis for the criteria is generally not discussed. The approach of the IWR method is similar to that of subsequent wetland evaluation techniques and will be used in part in the present study as well.

US Army Corps of Engineers Wetlands Evaluation Technique (WET) (Adamus et al., 1987)

Using both available data and data collected during site visits, WET is used to evaluate individual wetlands for each of the following functions and values: groundwater recharge and discharge, floodflow alteration, sediment stabilization, sediment/toxicant retention, nutrient removal/ transformation, production export, aquatic diversity/abundance, wildlife diversity/abundance, and recreation and uniqueness/heritage. The technique evaluates these functions and values in terms of social significance, the opportunity that the wetland has to perform the function, and the effectiveness of the wetland at performing the function. The procedure for using WET involves answering a long series of questions about the wetland, then using a key to interpret these answers. Computer software for the interpretation step is also available. The result is a qualitative rating (high, moderate, or low) of the probability of the wetland's opportunity, effectiveness, and social significance for each function.

WET is an outgrowth of a Federal Highway Administration technique for evaluating wetlands for highway projects (Adamus and Stockwell, 1983). WET was designed for conducting initial rapid assessments of a particular wetland's functions and values. WET can also be used to assess changes with time in a wetland's functions and values (e.g., predicting the impact of a proposed project involving wetland alteration, or assessing changes which have occurred in the past) if adequate data are available or can be confidently estimated on future or past conditions.

Wetlands Evaluation Technique for Bottomland Hardwoods (WET-BLH) (Adamus et al., 1990)

WET-BLH is a modification of WET which applies to bottomland hardwoods (BLH) in the southeastern United States (i.e., from southern Virginia south to Florida, west to Texas, and north along the Mississippi River to southern Indiana and Illinois). As in WET, WET-BLH evaluates functions in terms of effectiveness, opportunity, and social significance. The functions evaluated by WET-BLH differ somewhat from those evaluated by WET. Groundwater recharge is not evaluated because BLH generally do not perform this function, and because recharge is difficult to predict using rapid assessment methods. Fish and wildlife functions are evaluated in three categories: finfish habitat, crayfish habitat, and wildlife habitat.

WET-BLH is somewhat more "user-friendly" than WET for a number of reasons. Each function is assessed individually, so evaluation of a subset of the functions is more easily accomplished than with WET. Questions to be answered about the wetlands characteristics are integrated with the interpretation keys, making the completion of the procedure potentially more rapid and informative, and seemingly less cumbersome. The scientific rationale and literature references for the functional assessment are included immediately after the assessment; the rationale for WET is included in separate volumes, one of which is not currently available.

As with WET, WET-BLH was designed for assessment of the functions of a particular wetland, but may also be used for: comparison of two or more wetlands, prioritization of wetlands for acquisition or research or advanced identification, identification of possible permit conditions, determination of project impacts on wetlands functions, and comparison of created or restored wetlands with reference or pre-existing wetlands.

Method for the evaluation of inland wetlands in Connecticut (Connecticut method) (Ammann et al., 1986; 1991)

The Connecticut method was developed as a rapid assessment method for use by public officials involved in wetland management who do not necessarily have backgrounds as wetland scientists or engineers. The method is therefore more simplified, rapid, and easier to use than WET. However, the technical rationales for many of the rating criteria are not included in the manual.

The Connecticut method addresses the following functions and values: flood control, ecological integrity, wildlife habitat, finfish habitat, nutrient retention and sediment trapping, educational potential, visual/esthetic quality, agricultural potential, forestry potential, water-based recreation, groundwater use potential, shoreline anchoring and dissipation of erosive forces, and noteworthiness. For each of these functions, a numerical scoring system allows comparison of the relative values of wetlands within a watershed. The 1991 revision involves some changes in the assessment of functions (e.g., the flood control function) and some changes in format. It also adds a function: archeological potential.

Zacherle technique (Zacherle, 1984)

Zacherle devised a method to quantify tidal marsh functions and to assess cumulative impacts of altering tidal marshes. He addressed the five marsh functions which are recognized in Virginia's Wetlands Guidelines (VIMS & VMRC, 1983): production and detritus availability, waterfowl and wildlife utilization, erosion protection, flood protection, and water quality. Zacherle identified criteria which determine a marsh's ability to perform each function and weighted the criteria by assigning quality points which are then added to produce a marsh's total value for each function. Marshes can then be compared, or the values can be used as a baseline from which to assess future impacts. Since the method is geared toward tidal situations, it will not be extensively incorporated in the present study.

<u>Methods chosen for the present study:</u>

The methods chosen for assessment of wetland functions in the present study have been derived from the comprehensive methods discussed above and single function methods discussed within the following sections. Portions of the WET-BLH and Connecticut methods were incorporated most extensively. Because of its simpler and more applicable regional approach, WET-BLH is emphasized over WET in the following discussion.

The following **functions** will be addressed by the present study:

Flood storage and flood flow modification
Nutrient retention and transformation
Sediment retention
Toxicant retention
Sediment stabilization
Wildlife habitat
Aquatic habitat
Public use

For each function, we address the **factors** which determine a wetland's ability to perform that function. Quantitative and qualitative assessment of the wetland results in a qualitative rating of High, Moderate, or Low for each factor. The relative importance of each factor is reflected in the combination of the factor ratings to produce an overall ranking of the wetland (again, High, Moderate, or Low) for each function. The sources of the methods and criteria, and the rationales for their selection, are included or referenced where appropriate.

Understanding of the groundwater component of a wetland's hydrology generally requires long term onsite monitoring of the wetland (Carter, 1986). Because of the need in the present study for a more rapid assessment method, we have chosen not to attempt to evaluate the groundwater recharge/discharge functions.

Delineation of the study area:

The wetland chosen as the study area should incorporate the entire contiguous wetland of similar topography and vegetation structure.

Function: Flood storage and storm flow modification

This function addresses the storage of water in the wetland and/or the reduction of water velocity by the wetland so that downstream movement of water is impeded (Adamus et al., 1990). Many wetlands store flood water and later release it. In doing so, the magnitude of flooding downstream from the wetlands may be reduced.

There are many factors and characteristics which determine the extent and existence of flood storage and flood flow modification by a wetland. Characteristics which enhance a wetland's **opportunity** to store floodwater and modify flood peaks are primarily watershed characteristics which increase the quantity and velocity of water entering the wetland:

- watersheds receiving frequent, intense rainstorms
- large watershed area
- steep slopes in watershed
- smooth land cover
- soils or land cover of slow or low permeability
- lack of upstream storage for flood water (e.g., channelized streams; no ponds or wetlands upstream of the wetland of interest)

A wetland's **effectiveness** at flood storage and flow modification depends on its capacity relative to the volume of inflow and its ability to hold water and reduce flow velocity. Characteristics which enhance a wetland's effectiveness in flood storage and flow modification:

- wetlands large relative to watershed
- wetlands not permanently flooded
- outlet from wetland constricted
- channel sinuosity within wetland is great
- wetland vegetation density is great (# stems/acre)
- stems of wetland plants are rigid

Methods for assessing the flood storage/flood flow modification function of wetlands range from a simplistic ratio of the area of the wetland to the area of the wetland's watershed (Reppert et al., 1979; Ammann et al., 1991) to complex computer simulation modeling of flood flows through wetlands (Kittelson, 1988; Ogawa and Male, 1986). An alternative approach is used by the WET methods (Adamus et al., 1987, 1990), which identify characteristics of wetlands and their watersheds which enhance or detract from the wetland's opportunity and ability to perform the function, and use these characteristics to produce a probability rating (High, Moderate, Low) for the wetland's opportunity and effectiveness at performing the function.

For the present study, a modification of the method of Simon et al. (1987) will be used as part of the evaluation of the flood storage and storm flow modification function of wetlands. This method is attractive because it provides a quantitative, volumetric measure of the flood storage capacity, rather than simply a qualitative High/Moderate/Low rating of the function as with the WET methods. Although the modeling methods (e.g., Kittelson, 1988; Ogawa and Male, 1986) would provide a more complete picture of the flood control function, those methods were determined to be inappropriate for the current level of effort. The Simon method strikes a balance between the complex modeling methods and the more simplistic area ratio methods used by Connecticut (Ammann et al., 1986, 1991) and Reppert et al. (1979).

The Simon method (Simon et al., 1987) involves calculation of the volume of runoff from the watershed, based on a 2 year, 24 hour rainfall, and the land use characteristics and soil hydrologic group classification of the watershed soils. This runoff volume is then compared to the holding capacity of the wetland, which is calculated by multiplying wetland area by wetland flood storage depth. Simon et al. (1987) contend that any wetlands which have the capacity to store more than 25% of the runoff delivered from the watershed "perform a significant flood storage function."

The U.S. Department of Agriculture Soil Conservation Service (SCS) has not completed soil surveys for several of the counties in which our study was conducted. In the soil surveys that were available, some soils were not classified with respect to soil hydrologic group. Due to this lack of information, this portion of the Simon method was eliminated, and runoff calculations were based only on rainfall and land use.

The Simon method does not consider the effects on runoff conveyance of wetlands in the watershed other than the wetland of interest. The modification of the Simon method used in this study divides a wetland's watershed into two sub-watersheds: the **upstream sub-watershed** which discharges to the wetland of interest through other wetlands, and the **primary sub-watershed** which discharges directly into the wetland of interest. Runoff volume from each sub-watershed is calculated separately. Factors were generated by the SCS for adjusting discharge volume where runoff is conveyed through wetlands prior to reaching the design point in peak discharge calculations (USDA-SCS, 1986). These adjustment factors are based on the ratio of wetland to upland in the watershed, and are applied in this study to the runoff volume from the upstream sub-watershed.

The following procedure is the modification of the Simon method used for the present study:

Step 1. Delineate the following areas:

a. the wetland of interest (this should include the entire contiguous area studied which is similar in terms of vegetation structure and density)

b. the entire watershed of the wetland of interest (i.e., all uplands and wetlands which drain into the wetland of interest)

c. other wetlands occurring in this watershed (=**upstream wetlands**)

d. the portion of the watershed which discharges directly to the wetland of interest, without passing through other wetlands first (=**primary sub-watershed**)

The **upstream sub-watershed** is that portion of the watershed, including wetlands, which discharges runoff to the wetland of interest through other wetlands (the upstream wetlands). The entire watershed of the wetland of interest = upstream sub-watershed + primary sub-watershed.

Step 2. Determine acreages of the wetland of interest, the primary sub-watershed, the upstream wetlands, and the upstream sub-watershed.

Area measurements will generally be made from USGS topographic maps with area dot grids or from digitizing these areas on a computerized geographic information system (GIS). For use in evaluation of other functions, calculate the following sub-watershed area weighting factors:

upstream sub-watershed area weighting factor

$$= \frac{\text{area of upstream sub–watershed}}{(\text{area of upstream sub–watershed} + \text{area of primary sub–watershed})}$$

primary sub-watershed area weighting factor

$$= \frac{\text{area of primary sub–watershed}}{(\text{area of upstream sub–watershed} + \text{area of primary sub–watershed})}$$

Step 3. Classify land use in the sub-watersheds. Land use will be determined using aerial photographs and field surveys. Proportions of land area within each land use will be assessed in 5% increments. Determine composite runoff curve numbers (RCN) for each of the two sub-watersheds using land use proportions and the following:

composite RCN= 55F + 70R + 81A + 92C + 80L

where:

F = proportion of sub-watershed in Forested or "natural" condition
R = proportion of sub-watershed in Residential land (houses/acre)
A = proportion of sub-watershed in Agricultural land (pasture and crops)
C = proportion of sub-watershed in Commercial/industrial/urban land
L = proportion of sub-watershed in Lakes or permanently flooded wetlands

(RCN's for each land use type were modified from Simon et al. (1987) and Kittelson (1988).)

Step 4. Find average runoff for each of the sub-watersheds, using:

If composite RCN $\geq$35, then average runoff= $$\frac{(3.5 - 0.2 \times \left(\frac{1000}{\text{RCN}} - 10\right))^2}{3.5 + 0.8 \times \left(\frac{1000}{\text{RCN}} - 10\right)}$$

If composite RCN <35, then average runoff = 0.001 inches.

This assumes a 2 year, 24 hour rainfall of 3.5 inches for the study area (Virginia Division of Soil and Water Conservation, 1980).

Step 5. Multiply the average runoff from the upstream sub-watershed by the appropriate adjustment factor (USDA-SCS, 1986) to obtain adjusted average runoff:

% of upstream sub-watershed that is comprised of wetlands:	adjustment factor:
0.2	0.94
0.5	0.88
1.0	0.83
2.0	0.78
2.5	0.73
3.3	0.69
5.0	0.65
6.7	0.62
10.0	0.58
20.0	0.53
25.0	0.50

Step 6. Multiply average runoff (inches) for each sub-watershed by the area of the sub-watershed (acres) to get subtotal runoff figures (acre-inches). (For the upstream sub-watershed, use the adjusted average runoff calculated in Step 5.)

Step 7. Sum the two subtotal runoffs to get total runoff (acre-inches).

Step 8. Elevation range (inches) within wetland x 0.5 = wetland flood storage depth (inches). The elevation range is the difference in elevation between the open water/wetland boundary and the wetland/upland boundary. Where possible, we will use a hand-held level and stadia rod to determine the elevation change to the nearest tenth of a foot.

Step 9. Wetland acreage (acres) x storage depth (inches) = wetland storage (acre-inches).

Step 10. Wetland storage / total runoff = proportion of flood water stored in wetland.

The Simon method is strictly volumetric, and does not consider factors (such as watershed slope) affecting the delivery of water to the wetland. Also, this method does not consider potential damage downstream from the wetland. The Simon method, as modified, provides a measure of both the opportunity a wetland has to perform the flood storage function (i.e., runoff volume) and the wetland's effectiveness at flood storage (i.e., flood storage volume). Two additional factors will be assessed in evaluating this function. The average watershed slope will be estimated either from soil surveys or from USGS topographic maps. This provides an additional measure of the opportunity a wetland has to perform the flood storage function. Finally, a qualitative assessment of the wetland's ability to retain/detain storm water will provide an additional measure of the wetland's effectiveness at this function. A summary of factors to be assessed in determining the flood storage and flood flow modification function and the hydrologic portion of other functions follows.

Factor 1: Proportion of 2 year, 24 hour storm volume stored in wetland (modification of Simon et al., 1987).

High: >25%
Low: ≤25%

(Simon et al. (1987) suggest the 25% threshold. Further refinement of ranking of this quantitative measure will occur following data collection.)

Factor 2: Watershed slope (%, obtained from USDA-SCS soil surveys or from USGS topo maps) (Ammann et al., 1986, 1991).

High: >8%
Moderate: 3-8%
Low: <3%

(The 3% and 8% thresholds are suggested by Ammann et al. (1986; 1991).)

Factor 3: Retention/detention of storm water within wetland (in part, Adamus et al., 1990).

High: detention time likely to be great due to significant constriction at outlet, very sinuous channels within the wetland, ponding within the wetland, high vegetation density within the wetland (stems/acre), and/or the wetland plants have rigid stems

Moderate: detention time likely to be intermediate

Low: detention time likely to be short due to lack of constriction at the wetland outlet, channelized flow through the wetland, low vegetation density within the wetland, and/or lack of vegetation with rigid stems.

In order to lessen the subjectivity of ranking this factor, priority will be given to the physical characteristics affecting retention/detention (i.e., outlet constriction, channel sinuosity, and ponding), and secondarily to the vegetation characteristics. Generally, we will consider forested wetlands to be of low stem density, scrub-shrub and non-persistent emergent wetlands to be of moderate density, and persistent emergent wetlands to be of high stem density. Actual field assessment may alter these guidelines. Woody species and some emergents will be considered to have rigid stems; other emergents will be considered to have non-rigid stems.

Overall ranking of flood storage and storm flow modification function:

A wetland will be rated as having a HIGH probability of performing the flood storage/flood flow modification function if either Factor 1 or Factor 3 is HIGH. A wetland will be rated as having a LOW probability of performing this function if Factor 3 and at least one of the other factors is rated LOW. All other wetlands will be rated MODERATE.

Function: Nutrient retention and transformation

This function addresses retention and transformation of inorganic phosphorus and nitrate imported into the wetland from the adjacent upland or from adjacent flooding water bodies (e.g., streams or rivers), coupled with the net annual export of organic phosphorus and nitrogen from the wetland to the adjacent bodies of water (Adamus et al., 1990). Nutrients may be retained physically (by being buried in the sediments) or biochemically (through denitrification and incorporation into plant material).

Retention of inorganic nutrients by wetlands may help alleviate eutrophication of water bodies. Incorporation of nutrients into plant material and subsequent export of plant material provides the nutrients in a form usable by aquatic food webs. Wetlands may also stabilize the timing of delivery of nutrients to the aquatic system.

A wetland's **opportunity** to perform the nutrient retention/transformation function is enhanced if there is a nearby source of nutrients (e.g., fertilizer from residential areas and cropland, waste from humans or livestock) and if the hydrologic characteristics of the watershed provide for delivery of these nutrients to the wetland. The watershed characteristics which enhance the opportunity of the wetland to perform the flood storage/flood flow modification function (such as steep slopes, low permeability, frequent and intense rainstorms) will also enhance delivery of nutrients to the wetland.

A wetland's **effectiveness** at retaining and transforming nutrients depends in part on detention time; sedimentation and nutrient transformation are more likely to occur in wetlands with longer flood duration. Organic matter in the soil lowers dissolved oxygen and allows denitrification. However, anoxic sediments may also allow release of phosphorus. Extractable aluminum in the soil has the ability to adsorb phosphorus.

Ammann et al. (1986; 1991) considered nutrient retention and sediment trapping together. Eight factors were equally weighted: watershed slope, nutrient sources, sediment sources, land use, watershed:wetland area ratio, wetland type bordering watercourse, water impoundment within wetland, flood storage in inches of runoff.

WET-BLH (Adamus et al., 1990) rates wetlands as HIGH for nutrient removal and transformation opportunity if nutrient sources exist and delivery is rated highly. Nutrient removal and transformation effectiveness is HIGH if the wetland is large relative to its watershed and is not permanently flooded, or if soils are of a type that are particularly effective at adsorbing phosphorus or removing nitrogen.

The present study will rate the nutrient retention and transformation function based on several factors: the existence of nutrient sources, the delivery of nutrients to the wetland (based on watershed slope and average runoff), and the retention of water by the wetland (based on flood storage capacity and physical and vegetation characteristics of the wetland).

Factor 1: Potential sources of excess nutrients (Ammann et al., 1986; 1991).

Low:	watershed predominantly (>75%) forested or other natural condition.
Moderate:	some cropland or pastureland; few dairies or other livestock operations; few septic systems; urban watershed; (non-point sources covering 25-50% of watershed).
High:	large areas of active cropland or pastureland; many dairies or other livestock operations; sewage treatment plant outfall(s); numerous septic systems; (non-point sources covering >50% of watershed).

Factor 2: Proportion of land with nutrient source (i.e., not forested or otherwise natural) whose runoff is not "treated" by other wetlands/storage areas in the watershed prior to reaching the wetland of interest:

High:	>75%
Moderate:	25-75%
Low:	<25%

(i.e., the more runoff that's "treated" by other wetlands, the less important the wetland of interest is for this function. Thresholds of 25 and 75% are arbitrary, and may be changed with additional research.)

Delivery of water to the wetland:

Factor 3: Average runoff in 2 year, 24 hour storm (inches). (Use adjusted average runoff for upstream sub-watershed obtained in Step 5 of flood control function calculations, and average runoff for primary watershed obtained in Step 4, and weight these by sub-watershed area weighting factors calculated in Step 2.)

High:	>2 inches
Moderate:	1-2 inches
Low:	<1 inch

(Thresholds based on "worst case" average runoff of approximately 3 inches calculated for an entirely commercial watershed with rainfall of 3.5 inches, using flood control function calculations.)

Factor 4: Average slope of watershed (same as Factor 2 in flood storage function).

High:	>8%
Moderate:	3-8%
Low:	<3%

Detention of water by the wetland:

Factor 5: Proportion of 2 year, 24 hour storm volume stored in wetland (same as Factor 1 inflood storage function).

High: >25%
Low: $\leq$25%

Factor 6: Retention/detention ranking (same as Factor 3 in flood storage function).

High:	detention time likely to be great due to significant constriction at outlet, very sinuous channels within the wetland, ponding within the wetland, high vegetation density within the wetland (stems/acre), and/or the wetland plants have rigid stems
Moderate:	detention time likely to be intermediate
Low:	detention time likely to be short due to lack of constriction at the wetland outlet, channelized flow through the wetland, low vegetation density within the wetland, and/or lack of vegetation with rigid stems.

Overall ranking of nutrient retention and transformation function:

A wetland will be rated as having a HIGH probability of performing the nutrient retention/transformation function if it is ranked HIGH or MODERATE for potential nutrient sources (Factor 1) and it is ranked HIGH or MODERATE for the proportion of land with nutrient sources whose runoff is not "treated" by other wetlands (Factor 2), and it is ranked HIGH for at least three of the other four factors. A wetland will be rated LOW if nutrient sources rank LOW and it ranks LOW for at least three of the other four factors. All other wetlands will be rated MODERATE.

Function: Sediment and toxicant trapping

This function addresses the retention of inorganic sediments and adsorbed toxicants delivered to the wetland from adjacent uplands or adjacent open water (Adamus et al., 1990).

As with nutrient removal and transformation, a wetland's **opportunity** to trap sediments and toxicants depends on the existence of a source of these materials on the upland adjacent to the wetland, and on the delivery of the materials to the wetland by hydrologic processes. Sources of sediments include active cropland, construction sites, eroding road banks and ditches, and stormwater outfalls. Sources of toxicants include pesticides from cropland and residential areas, industrial and sewage outfalls, landfills, heavily travelled roads, and irrigation return water (Adamus et al., 1990).

A wetland's **effectiveness** at trapping sediments and toxicants depends in part on the amount of time that flooding waters carrying these materials are detained by the wetland. Detention/retention time was addressed previously in the flood storage section.

WET-BLH ranks wetlands as HIGH for the combined sediment/toxicant retention function if sources of either exist in the watershed and if delivery to the wetland was ranked HIGH. WET-BLH ranks wetlands as MODERATE if sources exist, but delivery to the wetland is not HIGH. A LOW rating is given if sources do not exist.

Our approach will be similar to that of WET-BLH, except that we will treat the functions separately.

Factor 1: Potential sources of sediments (Ammann et al., 1986; 1991).

Low: watershed predominantly (75%) forested or otherwise undeveloped

Moderate: (non-point sources covering 25-50% of watershed)

- some active cropland
- few construction sites
- few other similar disturbed sites
- few stormwater outfalls

High: large areas of: (non-point sources covering 50% of watershed)

- active cropland
- construction sites
- eroding road banks, ditches, etc.
- many stormwater outfalls

Factor 2: Potential sources of toxicants (Adamus et al., 1990).

- pesticides
- industrial or sewage outfalls
- mines
- landfills/dumps
- severe oil runoff
- heavily travelled highways
- irrigation return water

Low:	watershed predominantly (75%) forested or otherwise undeveloped.
Moderate:	a few of these sources exist in the watershed, but they are located far from the wetland
High:	many of these sources exist in the watershed; or few exist, but they are located close to the wetland.

Factor 3: Proportion of land with sediment source whose runoff is <u>not</u> "treated" by other wetlands/storage areas in the watershed prior to reaching the wetland of interest:

High:	>75%
Moderate:	25-75%
Low:	<25%

(i.e., the more runoff that's "treated" by other wetlands, the less important the wetland of interest is for this function. Thresholds of 25 and 75% are arbitrary, and may be changed with additional research.)

Factor 4: Proportion of land with toxicant source whose runoff is <u>not</u> "treated" by other wetlands/storage areas in the watershed prior to reaching the wetland of interest:

High:	>75%
Moderate:	25-75%
Low:	<25%

(i.e., the more runoff that's "treated" by other wetlands, the less important the wetland of interest is for this function. Thresholds of 25 and 75% are arbitrary, and may be changed with additional research.)

Delivery of sediments/toxicants to wetland.

Factor 5: Average runoff (obtained during calculation of Factor 1 in flood storage function) (Simon et al., 1987).

High:	>2 inches
Moderate:	1-2 inches
Low:	<1 inch

Factor 6: Watershed slope (same as Factor 2 in flood storage function) (Ammann et al., 1986; 1991).

High:	>8%
Moderate:	3-8%
Low:	<3%

Detention of water by the wetland:

Factor 7: Proportion of 2 year, 24 hour storm volume stored in wetland (same as Factor 1 in flood storage function) (Simon et al., 1987).

High:	>25%
Low:	≤25%

Factor 8: Retention/detention ranking (same as Factor 3 in flood storage function) (Adamus et al., 1990, in part).

High:	detention time likely to be great due to significant constriction at outlet, very sinuous channels within the wetland, ponding within the wetland, high vegetation density within the wetland (stems/acre), and/or the wetland plants have rigid stems
Moderate:	detention time likely to be intermediate
Low:	detention time likely to be short due to lack of constriction at the wetland outlet, channelized flow through the wetland, low vegetation density within the wetland, and/or lack of vegetation with rigid stems.

Overall ranking of sediment/toxicant trapping functions:

A wetland will be rated as having a HIGH probability of performing the sediment trapping function if the sources are rated MODERATE or HIGH, if they are not "treated" by other wetlands, and if the delivery and retention factors are ranked highly. A wetland will be rated LOW for this function if sediment sources are minimal, and delivery and retention factors are ranked LOW. All other wetlands will be rated MODERATE.

Similarly, a wetland will be rated as having a HIGH probability of performing the toxicant retention function if the sources are ranked MODERATE or HIGH, if they are not "treated" by other wetlands, and if delivery and retention factors are ranked highly. A wetland will be rated LOW for this function if toxicant sources are minimal, and delivery and retention factors are ranked LOW. All other wetlands will be rated MODERATE.

Function: Sediment stabilization

This function addresses the wetland's ability to stabilize sediments within the wetland and to act as a buffer between the upland and erosive energy from adjacent open water. Wetlands act to protect upland property and to prevent degradation of water quality.

A wetland's **opportunity** to stabilize wetland sediments depends on the existence and magnitude of erosive forces impacting the wetland. Erosive forces may include wind- or boat-generated waves, migration of adjacent streams, and flooding of the wetland from watershed runoff or overbank flow from adjacent streams. Conditions which enhance the opportunity that a wetland has to dissipate erosive forces include (Adamus et al., 1990):

- high wave energy due to boat wakes or large fetch
- highly erodible soils in the wetland (Table 9 from WET-BLH)
- human disturbance within the wetland
- migration of adjacent streams
- flooding of the wetland
- impoundment of streams above the wetland.

A wetland's **effectiveness** at stabilizing sediment is enhanced by:

- dense vegetation
- wetland plants with rigid stems
- wide zone of vegetation (measured perpendicular to the shoreline).

Ammann et al., (1986; 1991) evaluate shoreline anchoring with three factors: evidence that the wetland is experiencing erosion from the adjacent waterway (i.e., eroding banks), the width of the wetland, and the vegetation density of the wetland. WET-BLH (Adamus et al., 1990) ranks a wetland's opportunity for stabilizing sediments as HIGH if the wetland contains erodible soils or experiences erosive conditions or channel instability. WET-BLH ranks the effectiveness of a wetland at stabilizing sediment as HIGH if its vegetation density is high, and plant stems are rigid.

The factors which the present study will consider are:

Sediment stabilization opportunity:

Factor 1: Erodibility of soils within the wetland (Adamus et al., 1990).

High: Soil erodibility coefficient >0.40 on scale of 0 to 0.50 (K in Universal Soil Loss Equation, available in USDA-SCS soil surveys)

Low: $K \leq 0.40$

(K threshold suggested by Adamus et al. (1990).)

Factor 2: Erosive conditions (Adamus et al., 1990).

High: any of the following exist:
- boat wakes
- large fetch (1 mile)
- regular disturbance of wetland soils
- migration of adjacent stream
- indication of erosion at open water/wetland boundary

Low: none of the erosive conditions listed exist.

Factor 3: Flooding.

High: evidence of flooding exists
- visual observation of flooding
- water marks
- lack of leaf litter
- drift/wrack lines
- water-borne sediment deposits
- water-stained leaves
- surface scoured areas
- floating-leaved plants

Low: no evidence of flooding exists

Sediment stabilization effectiveness:

Factor 4: Wetland roughness (Adamus et al., 1990) (same as vegetation portion of retention/detention evaluation—Factor 3 in flood storage function; actual density data collected during the study will further define these rankings).

High: wetland vegetation density high; vegetated with rigid-stemmed plants

Moderate: density moderate; stems moderately rigid

Low: density low; stems not rigid

Our approach to wetland ranking for this function will be similar to that of WET-BLH. Opportunity and effectiveness of sediment stabilization will be assessed separately, and these assessments will be combined to produce an overall ranking for the function. A wetland will be ranked as having a HIGH probability of having the **opportunity** to stabilize sediments if it either has erodible soils (Factor 1 = HIGH) or experiences erosive conditions (Factor 2 = HIGH). A wetland will be ranked as MODERATE if it lacks erosive conditions and erodible soils, but experiences flooding at least once every three years (Factor 3 = HIGH). Otherwise, a LOW ranking will be given. Wetland surface roughness (factor 4) is the only factor used to assess the wetland's probability of being **effective** at stabilizing sediments. Overall, a wetland will be ranked HIGH for the sediment stabilization function if both the opportunity and effectiveness are ranked HIGH. A LOW rating will be given if either opportunity or effectiveness is rated LOW. All other combinations will be rated MODERATE.

Function: Wildlife habitat

This function addresses the provision of food, cover, breeding sites and other critical habitat for vertebrate wildlife populations (Adamus et al., 1990). Assessment of the wildlife habitat function of a wetland presents a difficult problem in part because of the diversity of wildlife species (and their varied habitat needs) which may potentially use wetlands. Wetland characteristics which enhance use of a wetland by one species may prevent its use by another species. The diversity of wetland types anticipated to occur in the coastal plain of Virginia confounds the attempt to adopt or create a generic assessment technique.

Existing methods of evaluating wetlands as wildlife habitats recognize the fact that species require food, cover, water, and breeding sites in order to exist. Wetland characteristics which may enhance use of the wetland by wildlife species include:

- wetland surrounded by forested land or natural open land
- wetland connected to other habitats by vegetated corridors
- high diversity of vegetation within wetland, both in species and strata (although some species rely on monotypic stands)
- wetland acreage; generally, bigger = better, but some species rely on wetlands which are small
- critical features such as hardwood mast trees, snags which provide nesting and roosting cavities, trees with fleshy fruits, etc.
- wetlands located on permanent open water, although some species rely on ephemeral wetlands

Methods reviewed for assessing the wildlife habitat function presented a variety of approaches and goals. In the US Fish & Wildlife Service's Habitat Evaluation Procedure (HEP) (USFWS, 1980), the user chooses a species or group of species, and determines, based on knowledge of specific habitat requirements, the suitability of a wetland as habitat for those species. The wetlands rated highest for wildlife habitat are those with the greatest suitability for the species chosen.

Other approaches are more generic, using more general habitat features to rank wetlands as wildlife habitats. Golet's (1976) method ranks wetlands on 10 criteria which are weighted as to their importance to wildlife habitat in the northeastern U.S.. Golet ranks highest those wetlands which provide maximum wetland wildlife productivity and diversity. Golet's criteria, grouped by weighting from most important to less important, are:

- wetland class richness (classes include deep marsh, shallow marsh, open water, shrub swamp, and others)
- dominant class (seasonally flooded and deep marsh most valuable, and meadow least valuable)
- size (bigger = better)

- subclass richness (subclasses for shallow marsh include robust, narrow-leaved, broad-leaved, and floating-leaved)
- site type (bottomlands located beside open water considered more valuable than isolated wetlands)

- surrounding habitat types (the greater the percentage of land in forestland, agricultural or open land, or salt marsh, the better)

- cover type (most valuable is 26-75% of wetland covered by emergents, shrubs, trees occurring in dense patches or diffuse open stands)
- vegetative interspersion (the more interspersed the plant species and strata, the better)

- wetland juxtaposition (hydrological connection to other wetlands or open water makes wetland more valuable)

- water chemistry (total alkalinity >69 ppm, pH>7.5, most valuable)

In the WET-BLH technique (Adamus et al., 1990), regional biodiversity is emphasized by evaluation of the regional uniqueness of specific habitat features (such as mast trees, snags, etc.). The Connecticut methods (Ammann et al., 1986, 1991) assess the overall suitability of the habitat for a broad range of species by qualitative ranking of several characteristics (e.g., wildlife access to other wetlands, wetland size, and upland land use) which are weighted equally.

Both the Golet (1976) and Ammann et al. (1986; 1991) methods include wetland size and the existence of permanent open water as factors in assessing the wildlife habitat function, with the assumption that the bigger the wetland the better, and the more connected it is hydrologically with other wetlands, or the larger its area of permanent open water, the better. However, research has shown (e.g., Moler and Franz, 1987) that many species of amphibians in the southeastern U.S. are dependent on small, isolated, ephemeral wetlands as breeding sites, and that these sites are also important feeding and nesting sites for wading birds and shorebirds.

Our method therefore assumes that all wetlands (whether large or small, whether isolated or connected to permanent open water) function as wildlife habitats, and that their value as habitat is degraded with human disturbance of the wetland and its watershed. Our method also adopts the emphasis of WET-BLH (Adamus et al., 1990) on regional biodiversity as an important factor in ranking wetlands for the wildlife habitat function.

Factor 1: Surrounding land use (Golet, 1976).

Percent of land surrounding wetland (within 300 ft.) that is either forested or otherwise in natural vegetation:

High:	>90%
Moderate:	50-90%
Low:	<50%

(Threshold percentages are suggested by Golet (1976). The 300 ft. zone is a compromise and more easily assessed in the field than Ammann et al.'s (1986; 1991) 500 ft. zone.)

Factor 2: Wildlife access to other wetlands over land (Ammann et al., 1986, 1991).

High:	wetland is contiguous to other wetlands, or is connected by a corridor that is wooded or in natural vegetation
Moderate:	access partially blocked by roads, urban areas, etc.
Low:	wetland is surrounded by roads or development

Factor 3: Disturbance within wetland.

Probability that wetland with given level of disturbance serves as important habitat:

High:	wetland pristine or nearly so, with little or no sign of disturbance
Moderate:	(intermediate)
Low:	wetland highly disturbed; many paths, much filling or other disturbance

Factor 4: Potential sources of toxic inputs to wetlands (Adamus et al., 1990, in part) (inverse of Factor 2, sediment/toxicant trapping function).

Probability that wetland with given level of potential toxic inputs serves as important habitat:

High:	potential toxic inputs do not exist or are minimal.
Moderate:	few toxic inputs exist and they are located far from the wetland.
Low:	many toxic inputs exist; or few exist but they are located close to the wetland.

Factor 5: Regional biodiversity (in part, Adamus et al., 1990) (This rating will be based on NWI map classifications and on information from the state's Department of Game and Inland Fisheries and Heritage Program).

High:	wetland is the only one of its type (vegetation association or hydroperiod) within a radius of 2 km, or is known habitat of rare, threatened, or endangered plant or animal species.
Moderate:	wetland is one of only a few of its type within 2 km.
Low:	wetland is not the only one of its type within 2 km.

Factor 6: Special habitat features (modified from Adamus et al., 1987):

- standing snags with cavities
- trees with diameter 10"
- plants bearing fleshy fruits (e.g., cherry, persimmon)
- mast-bearing hardwoods (e.g., oak, beech, hickory)
- cone-bearing trees or shrubs
- tilled land with waste grains
- exposed bars (e.g., unconsolidated gravel, mud flat)

There will be no ranking of Factor 6, and this information will not (at this time) be used in evaluating the wildlife habitat function.

Overall assessment of wildlife habitat function (not including Factor 6):

Probability of wetland serving as wildlife habitat:

High:	if regional biodiversity (Factor 5) HIGH, or if most factors HIGH.
Moderate:	if regional biodiversity MODERATE and most factors not HIGH, or if most factors MODERATE.
Low:	if most factors LOW.

Function: Aquatic habitat

This function addresses the provision of food, cover, breeding sites, and other critical habitat requirements for fish populations (Adamus et al., 1990).

There are many factors which affect a wetland's suitability as habitat for fish. Characteristics which may affect a wetland's value to fish include:

- access of the wetland to fish (i.e., depth and permanence of surface water)
- water quality (e.g., temperature, dissolved oxygen, pH, turbidity, toxic inputs)
- existence of cover (e.g., rocks, branches, logs, undercut banks, submerged vegetation)
- food availability
- availability of spawning substrate (e.g., low growing vegetation, gravel bottom)
- disturbance of channel (e.g., channelization, artificial deepening or widening, realignment)

Methods for assessing the aquatic habitat function of wetlands include the Connecticut method (Ammann et al., 1986; 1991), which addresses the watercourses associated with the wetland rather than the wetland itself, and the WET methods (Adamus et al., 1987; 1990), which address the habitat utility of the adjacent waterway as well as the wetland itself. HEP (USFWS, 1980) includes HSI models for fish and invertebrates as well as other wildlife species.

Ammann et al. (1986; 1991) address finfish habitat for watercourses associated with wetlands. For wetlands associated with streams and rivers, the highest ranking is given to streams and rivers with the following characteristics:

- natural channel, either slow moving or with pools and riffles
- most or all of streambed shaded
- on a high order stream
- accessible to anadromous fish
- stream width >100′
- water quality (based on State standards)
- dominant watershed land use forested, wetland, or abandoned farmland
- >70% cover in water area (e.g., submerged logs, undercut banks)
- spawning areas exist (i.e., flooded vegetation or gravel bottom)

For wetlands associated with lakes and ponds, the highest ranking is given to wetlands on lakes and ponds with the following characteristics:

- area of pond and emergent vegetation 100 acres
- maximum depth >20′
- secchi depth >13′
- rooted submerged or emergent vegetation 15-50% of pond or lake
- water quality high (based on State standards)
- accessible to anadromous fish

WET (Adamus et al., 1987) addresses each of the following fish and invertebrate species groups separately: warmwater fish, coldwater fish, coldwater riverine fish, and northern lake fish, and saltwater fish and invertebrates.

WET-BLH (Adamus et al., 1990) addresses fish habitat and crayfish habitat separately. WET-BLH ranks a wetland as having a LOW probability of having the opportunity to provide fish habitat if it's not accessible to fish. A HIGH ranking is given to wetlands which are accessible and have suitable low flow habitat. A MODERATE rating is given to wetlands which are accessible, but do not have suitable low flow habitat. WET-BLH ranks a wetland as having a LOW probability of effectiveness of fish habitat if water quality stresses exist (i.e., sources of toxic inputs, low dissolved oxygen conditions) and if aquatic insect densities do not indicate that such stress is absent. A HIGH ranking is given to wetlands without water quality stress and with preferred habitat structure or flooding regimes; a MODERATE rating is given to wetland without water quality stress, but without habitat.

For the present study, our approach will be similar to that of WET-BLH:

Factor 1: Permanent water.

High: wetland located on watercourse that is permanently flooded to at least 4"

Low: water is not permanent, or is <4"

(Four inch threshold is the consensus of fishery biologists at a USEPA workshop (Hall et al., 1987).)

Factor 2: Accessibility of wetland to fish (Adamus et al., 1990, in part).

High: wetland is seasonally to permanently flooded

Low: wetland is flooded less often than seasonally

Factor 3: Water quality (Adamus et al., 1990).

Water quality stresses:

- pesticides
- industrial or sewage outfalls
- mines
- landfills/dumps
- severe oil runoff
- heavily travelled highways
- irrigation return water
- consistently low dissolved oxygen (<4.0 mg/l or <60% saturation)
- high temperature due to lack of shade or thermal effluents

Low: Water quality stresses are significantly present to the extent that use of the watercourse associated with the wetland by fish is severely restricted.

Moderate: Sources of water quality stresses may exist in the watershed or watercourse, but are not known to severely impact use of the wetland or watercourse by fish.

High: none of the water quality stresses listed above occur.

Factor 4: Channel as habitat (Adamus et al., 1990).

High: channel is natural

Moderate: channel has been modified, but is now recovering some natural features

Low: channel has been modified (e.g., channelization, artificial deepening or widening, realignment)

Factor 5: Cover (Adamus et al., 1990).

High: cover exists in at least 5% of surface or submerged area within 3 feet of surface in parts of channel with permanent flow

Low: cover <5%

(Cover values interpreted by Adamus et al. (1990) from Harmon et al. (1986) and Wallace and Benke (1984).)

Overall assessment of aquatic habitat function:

A wetland will be ranked HIGH for aquatic habitat if all factors are rated HIGH or MODERATE. A LOW rating will be given to any wetland rated LOW for any of the first three factors (i.e., not on permanent water, not accessible to fish, and having water quality stress). All other wetlands will be rated MODERATE for this function.

Function: Public use of the wetland

The functions addressed previously are all associated with some human-oriented values, but do not address directly the use of the wetland by humans. Although other methods address economic uses of wetlands (e.g., forestry and agricultural potential functions, Ammann et al., 1986), we will address the public use of a wetland only as a function of public access to the wetland.

Factor 1: Public access to the wetland.

Low:	not accessible to the public; privately owned & not near public roads; not on publicly accessible waterways
Moderate:	on a public roadway or publicly accessible waterway, but without parking facilities or water access facilities
High:	parking facilities available, or water access facilities available (e.g., park land); boardwalks available

Other Factors

The following factors will not be used to evaluate specific functions of wetlands. They may be used as independent variables to analyze and describe data collected.

Factor 1: Disturbance in surrounding landscape.

Low:	surrounding landscape all or mostly "natural"; little disturbance
Moderate:	(intermediate)
High:	surrounding landscape highly disturbed

Factor 2: Disturbance within wetland.

Low:	wetland pristine or nearly so, with little or no sign of disturbance
Moderate:	(intermediate)
High:	wetland highly disturbed; many paths, much filling or other disturbance

Factor 3: Landscape position (check all that apply). (These classifications were taken, in part, from a USEPA/USFWS wetland evaluation form used by the federal agencies in testing the 1991 revisions to the federal manual for identifying and delineating wetlands.)

_______Floodplain.
_______Headwaters.
_______Isolated.
_______Depressional.
_______Sloping.
_______Lakeside (i.e., lacustrine).
_______Streamside (perennial stream).
_______Streamside (intermittent stream).

_______Wetland is adjacent to a tidal wetland.
_______Wetland is bordered by upland.
_______Wetland is surrounded by other wetlands or open water, and is not directly bordered by upland.

Factor 4: Stream order. For wetlands associated with streams, determine the order of the stream. (Use the USGS topographic maps. A stream's headwaters are considered first order streams. When two first order streams join, they become second order streams, and remain so until joined by another stream of equal or higher order. A second order stream joined by a third order stream becomes a third order stream. Two second order streams join to become a third order stream.)

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Appendix A

Data sheets (long form) and Interpretation Keys

Appendix A

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Flood storage and flood flow modification

Calculation of Factor 1:

Step 1. Delineate the wetland of interest, its entire watershed, and other wetlands within that watershed, using USGS topo maps. Sub-divide these areas as follows:

Wetland of interest = entire contiguous area studied which is similar in vegetation structure and density.

Primary sub-watershed = that portion of the wetland of interest's watershed which discharges directly into the wetland of interest without passing through other wetlands first.

Upstream sub-watershed = that portion of the wetland of interest's watershed which discharges to the wetland of interest through other wetlands (this includes the upstream wetlands).

Upstream wetlands = wetlands in the upstream sub-watershed.

Step 2. Determine acreages:

Wetland of interest ________ acres **(X1)**
Primary sub-watershed ________ acres **(X2)**
Upstream sub-watershed (including upstream wetlands) ________ acres **(X3)**
Upstream wetlands ________ acres **(X4)**

Calculate (for use in assessment of water quality functions):

upstream sub-watershed area weighting factor

$$= \frac{X3}{(X2 + X3)} =$$ ________________________ **(X5)**

primary sub-watershed area weighting factor

$$= \frac{X2}{(X2 + X3)} =$$ ________________________ **(X6)**

Step 3. Determine the elevation range within the wetland of interest. The elevation range is the difference in elevation between the open water/wetland boundary and the wetland/upland boundary.

Elevation range = ___________ inches **(X7)**

Step 4. Classify land use in each sub-watershed.

Proportion of sub-watershed in each land use (Range of values = 0 to 1. Estimate to the nearest 0.05. The sum of each column = 1.0):

Sub-watershed Primary	Sub-watershed Upstream	Land use
Fp=	**Fu=**	Forested/"natural"
Ap=	**Au=**	Agricultural (pasture & crop land)
Rp=	**Ru=**	Residential (< 4 houses/acre)
Cp=	**Cu=**	Commercial/Industrial/Urban land
Lp= 0	**Lu=**	Lakes or permanently flooded wetlands
1.0	1.0	= Sum

Determine composite runoff curve numbers (RCN) for each sub-watershed, using land proportions and the following equations:

upstream sub-watershed composite RCN

$$= (55 \times Fu) + (81 \times Au) + (70 \times Ru) + (92 \times Cu) + (80 \times Lu)$$

$$= (55 \times \_\_\_\_) + (81 \times \_\_\_\_) + (70 \times \_\_\_\_) + (92 \times \_\_\_\_) + (80 \times \_\_\_\_) = \_\_\_\_\_\_ \quad \textbf{(X8)}$$

primary sub-watershed composite RCN

$$= (55 \times Fp) + (81 \times Ap) + (70 \times Rp) + (92 \times Cp) + (80 \times Lp)$$

$$= (55 \times \_\_\_\_) + (81 \times \_\_\_\_) + (70 \times \_\_\_\_) + (92 \times \_\_\_\_) + (80 \times \_\_\_\_) = \_\_\_\_\_\_ \quad \textbf{(X9)}$$

Step 5. Find average runoff for each of the sub-watersheds:

If composite RCN ≥ 35, then average runoff= $\dfrac{\left(3.5 - 0.2 \times \left(\dfrac{1000}{RCN} - 10\right)\right)^2}{3.5 + 0.8 \times \left(\dfrac{1000}{RCN} - 10\right)}$

If composite RCN < 35, then average runoff = 0.001 inches.

This assumes a 2 year, 24 hour rainfall of 3.5 inches for the study area (Virginia Division of Soil and Water Conservation, 1980).

upstream sub-watershed average runoff =

$$\frac{\left(3.5 - 0.2 \times \left(\frac{1000}{X8} - 10\right)\right)^2}{3.5 + 0.8 \times \left(\frac{1000}{X8} - 10\right)} = \_\_\_\_\_\_\_\_\_\_\_\_ \quad \textbf{(X10)}$$

primary sub-watershed average runoff =

$$\frac{\left(3.5 - 0.2 \times \left(\frac{1000}{X9} - 10\right)\right)^2}{3.5 + 0.8 \times \left(\frac{1000}{X9} - 10\right)} = \_\_\_\_\_\_\_\_\_\_\_\_ \quad \textbf{(X11)}$$

Step 6. Multiply the average runoff from the upstream sub-watershed (X10) by the appropriate adjustment factor (USDA-SCS, 1986) to obtain adjusted average runoff:

% of upstream sub-watershed that is comprised of wetlands:	adjustment factor:
0.2	0.94
0.5	0.88
1.0	0.83
2.0	0.78
2.5	0.73
3.3	0.69
5.0	0.65
6.7	0.62
10.0	0.58
20.0	0.53
25.0	0.50

adjusted average runoff for upstream sub-watershed

= X10 x adjustment factor = ____________________ inches **(X12)**

Step 7. Multiply average runoff (inches) for each sub-watershed by the area of the sub-watershed (acres) to get subtotal runoff figures (acre-inches).

primary sub-watershed total runoff = X11 x X2 = ________ acre-inches **(X13)**
upstream sub-watershed total runoff = X12 x X3 = ________ acre-inches **(X14)**

Step 8. Sum the two subtotal runoffs to get total runoff (acre-inches).

total runoff = X13 + X14 = ______________ acre-inches **(X15)**

Step 9. Determine flood storage depth in the wetland of interest (assumed to be half the elevation range within the wetland).

wetland flood storage depth = X7 x 0.5 = ____________________ inches (**X16**)

Step 10. Determine wetland storage capacity.

Wetland acreage (acres) x storage depth (inches) = wetland storage (acre-inches).

X1 x X16 = ______________________________ acre-inches (**X17**)

Step 11. Determine proportion of flood water stored in wetland.

$$\frac{\text{Wetland storage}}{\text{total runoff}} = \text{proportion of flood water stored in wetland}$$

$$\frac{X17}{X15} = \underline{\qquad\qquad\qquad\qquad} \text{ (range of values = 0 to 1)}$$

Factor 1 calculation worksheet—flood storage and flood flow modification

Step 1. Delineation.

Step 2. Wetland of interest = ______ acres **(X1)**
Primary sub-watershed = ______ acres **(X2)**
Upstream sub-watershed (including upstream wetlands) = ______ **(X3)**
Upstream wetlands = ______ **(X4)**

$$\frac{X3}{(X2 + X3)} = \_\_\_\_\_\_\_\_\_\_\_\_ \textbf{(X5)} \qquad \frac{X2}{(X2 + X3)} = \_\_\_\_\_\_\_\_\_\_\_\_ \textbf{(X6)}$$

Step 3. Elevation range = ______________ inches **(X7)**

Step 4.
upstream sub-watershed composite RCN
= (55 x Fu) + (81 x Au) + (70 x Ru) + (92 x Cu) + (80 x Lu)
= (55 x ____)+(81 x ____)+(70 x ____)+(92 x ____)+(80 x ____) = ______ **(X8)**

primary sub-watershed composite RCN
= (55 x Fp) + (81 x Ap) + (70 x Rp) + (92 x Cp) + (80 x Lp)
= (55 x ____)+(81 x ____)+(70 x ____)+(92 x ____)+(80 x ____) = ______ **(X9)**

Step 5.
upstream sub-watershed average runoff =

$$\frac{\left(3.5 - 0.2 \times \left(\frac{1000}{X8} - 10\right)\right)^2}{3.5 + 0.8 \times \left(\frac{1000}{X8} - 10\right)} = \_\_\_\_\_\_\_\_\_\_\_\_ \textbf{(X10)}$$

primary sub-watershed average runoff =

$$\frac{\left(3.5 - 0.2 \times \left(\frac{1000}{X9} - 10\right)\right)^2}{3.5 + 0.8 \times \left(\frac{1000}{X9} - 10\right)} = \_\_\_\_\_\_\_\_\_\_\_\_ \textbf{(X11)}$$

Step 6. X10 x adjustment factor = ________________________ inches **(X12)**

Step 7. X11 x X2 = ____________________ acre-inches **(X13)**

X12 x X3 = ____________________ acre-inches **(X14)**

Step 8. X13 + X14 = ____________________ acre-inches **(X15)**

Step 9. X7 x 0.5 = ____________________ inches **(X16)**

Step 10. X1 x X16 = ______________________________ acre-inches (**X17**)

Step 11. $\frac{X17}{X15}$ = ______________________________ (range of values = 0 to 1)

Flood storage and flood flow modification

Factor ratings

Factor 1: Proportion of 2 year, 24 hour storm volume stored in wetland

___High: >25%
___Low: ≤25%

Factor 2: Watershed slope

___High: >8%
___Moderate: 3-8%
___Low: <3%

Factor 3: Retention/detention of storm water within wetland (priority: physical characteristics; secondary: vegetation characteristics

___High: detention time likely to be great due to significant constriction at outlet, very sinuous channels within the wetland, ponding within wetland, high vegetation density within the wetland (stems/acre), and/or the wetland plants have rigid stems

___Moderate: detention time likely to be intermediate

___Low: detention time likely to be short due to lack of constriction at the wetland outlet, channelized flow through the wetland, low vegetation density within the wetland, and/or lack of vegetation with rigid stems.

Interpretation Key

1. Are either Factor 1 or Factor 3 HIGH?

Y—HIGH
N—go to 2.

2. Is Factor 3 MODERATE?

Y—MODERATE
N—go to 3

3. Are at least 2 of the 3 Factors MODERATE or HIGH?

Y—MODERATE
N—LOW

Nutrient retention and transformation

Data Collection/Factor Ratings

Factor 1: Potential sources of excess nutrients.

___Low:	watershed predominantly (>75%) forested or other natural condition.
___Moderate:	some cropland or pastureland; few dairies or other livestock operations; few septic systems; urban watershed; (nonpoint sources 25-50% of watershed area).
___High:	large areas of active cropland or pastureland; many dairies or other livestock operations; sewage treatment plant outfall(s); numerous septic systems (nonpoint sources >50% of watershed area).

Factor 2: Proportion of land with nutrient source (i.e., not forested or otherwise natural) whose runoff is <u>not</u> "treated" by other wetlands/storage areas in the watershed prior to reaching the wetland of interest:

___ High: >75%
___ Moderate: 25-75%
___ Low: <25%

Factor 3: Average runoff in 2 year, 24 hour storm. This is a composite of the average runoffs for the two sub-watersheds, weighted by sub-watershed areas (see Flood storage function worksheet p. A-5).

average runoff = (X12 x X5) + (X11 x X6) = ____________________ inches

___High: >2 inches
___Moderate: 1-2 inches
___Low: <1 inch

Factor 4: Average slope of watershed (see Flood Storage function, Factor 2).

___High: >8%
___Moderate: 3-8%
___Low: <3%

Factor 5: Proportion of 2 year, 24 hour storm volume stored in wetland (see Flood Storage function, Factor 1).

___High: >25%
___Low: ≤25%

Factor 6: Retention/detention ranking (Flood Storage function, Factor 3).

___High:	detention time likely to be great due to significant constriction at outlet, very sinuous channels within the wetland, ponding within the wetland, high vegetation density within the wetland (stems/acre), and/or the wetland plants have rigid stems
___Moderate:	detention time likely to be intermediate
___Low:	detention time likely to be short due to lack of constriction at the wetland outlet, channelized flow through the wetland, low vegetation density within the wetland, and/or lack of vegetation with rigid stems.

Interpretation Key

1. Is Factor 1 HIGH or MODERATE?

   Y—go to 2.
   N—go to 4.

2. Is Factor 2 LOW?

   Y—go to 4
   N—go to 3

3. Are at least 3 of the other 4 factors rated HIGH?

   Y—HIGH
   N—MODERATE

4. Are at least 3 of the other 4 factors LOW?

   Y—LOW
   N—MODERATE

Sediment and toxicant trapping

Data Collection/Factor Ratings

Factor 1: Potential sources of sediments.

___Low: watershed predominantly (>75%) forested or otherwise undeveloped

___Moderate: (nonpoint sources 25-50% of watershed)
- ___some active cropland
- ___few construction sites
- ___few other similar disturbed sites
- ___few stormwater outfalls

___High: large areas of: (nonpoint sources >50%)
- ___active cropland
- ___construction sites
- ___eroding road banks, ditches, etc.
- ___many stormwater outfalls

Factor 2: Potential sources of toxicants.

- ___pesticides
- ___industrial or sewage outfalls
- ___mines
- ___landfills/dumps
- ___severe oil runoff
- ___heavily travelled highways
- ___irrigation return water

___Low: watershed predominantly (>75%) forested or otherwise undeveloped.

___Moderate: a few of these sources exist in the watershed, but they are located far from the wetland

___High: many of the sources exist in the watershed; or few exist, but they are located close to the wetland.

Factor 3: Proportion of land with sediment source whose runoff is <u>not</u> "treated" by other wetlands/storage areas in the watershed prior to reaching the wetland of interest:

___ High: >75%
___ Moderate: 25-75%
___ Low: <25%

Factor 4: Proportion of land with toxicant source whose runoff is not "treated" by other wetlands/storage areas in the watershed prior to reaching the wetland of interest:

___ High: >75%
___ Moderate: 25-75%
___ Low: <25%

Factor 5: Average runoff (same as Factor 3, Nutrient retention/transformation function).

___High: >2 inches
___Moderate: 1-2 inches
___Low: <1 inch

Factor 6: Watershed slope (same as Factor 2, flood storage function).

___High: >8%
___Moderate: 3-8%
___Low: <3%

Factor 7: Proportion of 2 year, 24 hour storm volume stored in wetland (same as Factor 1, flood storage function).

___High: >25%
___Low: ≤25%

Factor 8: Retention/detention ranking (same as Factor 3, flood storage function).

___High: detention time likely to be great due to significant constriction at outlet, very sinuous channels within the wetland, ponding within the wetland, high vegetation density within the wetland (stems/acre), and/or the wetland plants have rigid stems

___Moderate: detention time likely to be intermediate

___Low: detention time likely to be short due to lack of constriction at the wetland outlet, channelized flow through the wetland, low vegetation density within the wetland, and/or lack of vegetation with rigid stems.

Interpretation Key

A. Sediment Trapping

1. Is Factor 1 HIGH or MODERATE?

Y—go to 2
N—go to 4

2. Is Factor 3 LOW?

Y—go to 4
N—go to 3

3. Are at least 3 of Factors 5 through 8 HIGH?

Y—HIGH
N—MODERATE

4. Are at least 3 of Factors 5 through 8 LOW?

Y—LOW
N—MODERATE

B. Toxicant Trapping

1. Is Factor 2 HIGH or MODERATE?

Y—go to 2
N—go to 4

2. Is Factor 4 LOW?

Y—go to 4
N—go to 3

3. Are at least 3 of Factors 5 through 8 HIGH?

Y—HIGH
N—MODERATE

4. Are at least 3 of Factors 5 through 8 LOW?

Y—LOW
N—MODERATE

Sediment Stabilization

Data Collection/Factor Ratings

Factor 1: Soil erodibility coefficient (K) (from USDA-SCS soil surveys; if more than one soil type exists in a wetland, use a composite K based on acreage).

___High: K>0.40
___Low: K≤0.40

Factor 2: Erosive conditions.

___High: any of the following exist:
___boat wakes
___large fetch (1 mile)
___regular disturbance of wetland soils
___migration of adjacent stream
___indication of erosion at open water/wetland boundary

___Low: none of the erosive conditions listed exist.

Factor 3: Flooding.

___High: evidence of flooding exists
___visual observation of flooding
___water marks
___lack of leaf litter
___drift/wrack lines
___water-borne sediment deposits
___water-stained leaves
___surface scoured areas
___floating-leaved plants

___Low: no evidence of flooding exists

Factor 4: Wetland roughness (same as vegetation portion of retention/detention factor—Factor 3, flood storage function).

___High: wetland vegetation density high; vegetated with rigid-stemmed plants

___Moderate: density moderate; stems moderately rigid

___Low: density low; stems not rigid

Interpretation Key

1. Are either Factor 1 or Factor 2 HIGH?

    Y—go to 3
    N—go to 2

2. Is Factor 3 HIGH?

    Y—go to 4
    N—LOW

3. Is Factor 4 HIGH?

    Y—HIGH
    N—go to 4

4. Is Factor 4 LOW?

    Y—LOW
    N—MODERATE

Wildlife Habitat

Data Collection/Factor Ratings

Factor 1: Surrounding land use.

Percent of land surrounding wetland (within 300 ft.) that is either forested or otherwise in natural vegetation:

___High:	>90%
___Moderate:	50-90%
___Low:	<50%

Factor 2: Wildlife access to other wetlands over land.

___High:	wetland is contiguous to other wetlands, or is connected by a corridor that is wooded or in natural vegetation
___Moderate:	access partially blocked by roads, urban areas, etc.
___Low:	wetland is surrounded by roads or development

Factor 3: Disturbance within wetland.

Probability that wetland with given level of disturbance serves as important habitat:

___High:	wetland pristine or nearly so, with little or no sign of disturbance
___Moderate:	(intermediate)
___Low:	wetland highly disturbed; many paths, much filling or other disturbance

Factor 4: Potential sources of toxic inputs to wetlands (inverse of Factor 2, sediment/toxicant trapping function).

Probability that wetland with given level of potential toxic inputs serves as important habitat:

___High:	potential toxic inputs do not exist or are minimal.
___Moderate:	few toxic inputs exist and they are located far from the wetland.
___Low:	many toxic inputs exist; or few exist but they are located close to the wetland.

Factor 5: Regional biodiversity (based on NWI map classifications and on information from the State's Dept. of Game and Inland Fisheries and Heritage Program).

___High: wetland is the only one of its type (vegetation association or hydroperiod) within a radius of 2 km, or is known habitat of rare, threatened, or endangered plant or animal species.

___Moderate: wetland is one of only a few of its type within 2 km.

___Low: wetland is not the only one of its type within 2 km.

Factor 6: Special habitat features:

___standing snags with cavities
___trees with diameter >10"
___plants bearing fleshy fruits (e.g., cherry, persimmon)
___mast-bearing hardwoods (e.g., oak, beech, hickory)
___cone-bearing trees or shrubs
___tilled land with waste grains
___exposed bars (e.g., unconsolidated gravel, mud flat)

Interpretation Key

1. Is Factor 5 HIGH?

   Y—HIGH
   N—go to 2

2. Are at least 3 of the 5 factors (not including Factor 6) HIGH?

   Y—HIGH
   N—go to 3

3. Is Factor 5 MODERATE?

   Y—MODERATE
   N—go to 4

4. Are at least 3 of the 5 factors (not including Factor 6) LOW?

   Y—LOW
   N—MODERATE

Aquatic Habitat

Data Collection/Factor Ranking

Factor 1: Permanent water.

___High: wetland located on watercourse that is permanently flooded to at least 4"

___Low: water is not permanent, or is <4"

Factor 2: Accessibility of wetland to fish.

___High: wetland is seasonally to permanently flooded

___Low: wetland is flooded less often than seasonally

Factor 3: Water quality.

Water quality stresses (check any which exist):
___pesticides
___industrial or sewage outfalls
___mines
___landfills/dumps
___severe oil runoff
___heavily travelled highways
___irrigation return water
___consistently low dissolved oxygen (mg/l or <% saturation)
___high temperature due to lack of shade or thermal effluents

___Low: Water quality stresses are significantly present to the extent that use of the watercourse associated with the wetland by fish is severely restricted.

___Moderate: Sources of water quality stresses may exist in the watershed or watercourse, but are not known to severely impact use of the wetland or watercourse by fish.

___High: none of the water quality stresses listed above occur.

Factor 4: Channel as habitat.

___High: channel is natural

___Moderate: channel has been modified, but is now recovering some natural features

___Low: channel has been modified (e.g., channelization, artificial deepening or widening, realignment)

Factor 5: Cover.

___High: cover exists in at least 5% of surface or submerged area within 3 feet of surface in parts of channel with permanent flow

___Low: cover <5%

Interpretation Key

1. Are all 5 factors HIGH or MODERATE?

Y—HIGH
N—go to 2

2. Are any of Factors 1 through 3 LOW?

Y—LOW
N—MODERATE

Public Use of the Wetland

Data Collection/Factor Ranking

Factor 1: Public access to the wetland.

___Low:	not accessible to the public; privately owned & not near public roads; not on publicly accessible waterways
___Moderate:	on a public roadway or publicly accessible waterway, but without parking facilities or water access facilities
___High:	parking facilities available, or water access facilities available (e.g., park land); boardwalks available

Other Factors

Factor 1: Disturbance in surrounding landscape.

___Low: surrounding landscape all or mostly "natural"; little disturbance

___Moderate: (intermediate)

___High: surrounding landscape highly disturbed

Factor 2: Disturbance within wetland.

___Low: wetland pristine or nearly so, with little or no sign of disturbance

___Moderate: (intermediate)

___High: wetland highly disturbed; many paths, much filling or other disturbance

Factor 3: Landscape position (check all that apply).

___ Floodplain.
___ Headwaters.
___ Isolated.
___ Depressional.
___ Sloping.
___ Lakeside (i.e., lacustrine).
___ Streamside (perennial stream).
___ Streamside (intermittent stream).

___ Wetland is adjacent to a tidal wetland.
___ Wetland is bordered by upland.
___ Wetland is surrounded by other wetlands or open water, and is not directly bordered by upland.

Factor 4: Stream order. For wetlands associated with streams, determine the order of the stream. (Use the USGS topographic maps. A stream's headwaters are considered first order streams. When two first order streams join, they become second order streams, and remain so until joined by another stream of equal or higher order. A second order stream joined by a third order stream becomes a third order stream. Two second order streams join to become a third order stream.)

Stream order __________

Appendix B

Field Data Sheet
(short form)

Field Data Sheet

(some questions may also require office work)
Page (in Appendix A)

A5 Elevation range ________________ (convert to inches)(X7)
A7 F3 __H __M __L (retention/detention)
A8 F1 __L __M __H (nutrient sources)
F2 __H __M __L (nutrient land proportion)
A10 F1 __L (sediment sources)
__M __some active cropland
__few construction sites
__few other similar disturbed sites
__few stormwater outfalls
__H large areas of:
__active cropland
__construction sites
__eroding road banks, ditches, etc.
__many stormwater outfalls
A10 F2 toxicant sources:
__pesticides __industrial or sewage outfalls
__mines __landfills/dumps __severe oil runoff
__heavily travelled highways __irrigation return water
__L __M __H
F3 __H __M __L (sediment land proportion)
F4 __H __M __L (toxicant land proportion)
A13 F2 erosive conditions:
__H __boat wakes __large fetch
__regular disturbance of wetland soils
__migration of adjacent stream
__indication of erosion at open water/wetland boundary
__L
A13 F3 __H __L __obs. flood. __water marks __lack litter
__drift/wrack lines __sed. depos. __water-stained leaves
__surf. scour __floating-leaved plants
A13 F4 __H __M __L (wetland roughness)
A15 F1 __H __M __L (wildlife habitat—surrounding land use)
A15 F2 __H __M __L (wildlife access to other wetlands)
A15 F3 __H __M __L (wetland disturbance—probability that wetland is habitat)
A16 __standing snags with cavities
__trees w/diameter 10"
__plants bearing fleshy fruits (e.g., cherry, persimmon)
__mast-bearing hardwoods (e.g., oak, beech, hickory)
__cone-bearing trees or shrubs
__tilled land w/waste grains
__exposed bars (e.g., unconsolidated gravel, mud flat)

A17 F1 __H __L (permanent water)
A17 F2 __H __L (fish access)
A17 F3 __pesticides __industrial or sewage outfalls __mines
__landfills/dumps __severe oil runoff
__heavily travelled highways __irrig. return water
__low DO __high temp. due to lack of shade or thermal effluents
__L __M __H __not applicable
A17 F4 __H __M __L __no channel (channel as habitat)
A18 F5 __H __L __no channel (cover)
A19 F1 __L __M __H (public access)
A20 F1 __L __M __H (landscape disturbance)
A20 F2 __L __M __H (wetland disturbance)

Landscape position (check all that apply):
___ floodplain ___ headwaters ___ isolated ___depressional ___sloping
___ lakeside ___streamside (perennial) ___streamside (intermittent)

Wetland is: ___adjacent to a tidal wetland ___ bordered by upland
___ surrounded by other wetlands or open water, and not directly bordered by upland

Appendix C

Office Data Sheet
(short form)

Office Data Sheet

Page (in Appendix A)

A1 Acreages:
Wetland of interest ___________ acres (**X1**)
Primary sub-watershed _________ acres (**X2**)
Upstream sub-watershed (including upstream wetlands) _______ acres (**X3**)
Upstream wetlands __________ acres (**X4**)

A2 (Step 4) Land use classification:

Proportion of sub-watershed in each land use (Range of values = 0 to 1. Estimate to the nearest 0.05. The sum of each column = 1.0):

Sub-watershed Primary	Sub-watershed Upstream	Land use
Fp=	**Fu**=	Forested/"natural"
Ap=	**Au**=	Agricultural (pasture & crop land)
Rp=	**Ru**=	Residential (< 4 houses/acre)
Cp=	**Cu**=	Commercial/Industrial/Urban land
Lp= 0	**Lu**=	Lakes or permanently flooded wetlands
1.0	1.0	= Sum

A7 F2 ___ >8 ___ 3-8 ___ <3 (watershed slope, %)

A13 F1 ___ >0.40 ___ ≤0.40 (wetland soil erodibility coefficient)

A16 F5 ___ H ___ M ___ L (regional biodiversity)

A20 F4 stream order _______

Appendix D

Summary Sheet

VIMS Nontidal Wetlands Functional Assessment Method—Summary Sheet

Flood storage and flood flow alteration

Factor 1: H L
Factor 2: H M L   Overall: H M L
Factor 3: H M L

Nutrient retention and transformation

Factor 1: H M L
Factor 2: H M L
Factor 3: H M L   Overall: H M L
Factor 4: H M L
Factor 5: H L
Factor 6: H M L

Sediment/toxicant retention

Factor 1: H M L
Factor 2: H M L   Overall:
Factor 3: H M L   Sediment trapping: H M L
Factor 4: H M L   Toxicant trapping: H M L
Factor 5: H M L
Factor 6: H M L
Factor 7: H L
Factor 8: H M L

Sediment stabilization

Factor 1: H L
Factor 2: H L
Factor 3: H L   Overall: H M L
Factor 4: H M L

Wildlife habitat

Factor 1: H M L
Factor 2: H M L
Factor 3: H M L   Overall: H M L
Factor 4: H M L
Factor 5: H M L

Aquatic habitat

Factor 1: H L
Factor 2: H L
Factor 3: H M L   Overall: H M L
Factor 4: H M L
Factor 5: H L

Public use

Factor 1: H M L

Other factors

Factor 1: H M L
Factor 2: H M L