ENVIRONMENTAL REVIEWS AND CASE STUDIES

The North Carolina Wetland Assessment Method (NC WAM): Development of a Rapid Wetland Assessment Method and Use for Compensatory Mitigation

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The North Carolina Wetland Assessment Method (NC WAM) was developed from 2003 to 2007 by a team of federal and state agencies to rapidly assess the level of wetland function. NC WAM is a field method which is science-based, reproducible, rapid, and observational in nature used to determine the level of wetland function relative to reference for each of 16 North Carolina general wetland types. Three major functions (Hydrology, Water Quality, and Habitat) were recognized along with 10 sub-functions. Sub-functions and functions are evaluated using 22 field metrics on a field assessment form. Data are entered into a computer program to generate High, Medium, and Low ratings for each sub-function, function, and the overall assessment area based on an iterative Boolean logic process using 71 unique combinations. The method was field tested across the state at more than 280 sites of varying wetland quality. Examples are presented for the use of NC WAM for compensatory mitigation notably to calculate functional uplift from wetland enhancement. Calibration and verification analyses to date show that the results of the method are significantly correlated with long-term wetland monitoring data and NC WAM has been verified for one wetland type (headwater forest) using these data.

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Background

Wetland Functional Assessment

Many methods to assess wetland function have been developed and utilized across the United States in the past decades (Bartoldus, 1999) including in North Carolina [Sutter et al., 1999; NC Division of Environmental Management (NCDEM), 1995], Ohio (Ohio EPA, 2001), California (San Francisco Estuary Institute, 2008), Oregon (Oregon Department of State Lands, 2012), and Washington state (Hruby, 2004). The US Environmental Protection Agency (USEPA, 2006) suggests three levels of wetland functional assessment: Level 1, which is a GIS-based assessment; Level 2, which is a rapid, field-based assessment; and Level 3, which is an intensive site assessment. In North Carolina, the previously developed methods can be characterized as Level 1 (Sutter et al., 1999) and Level 2 (NCDEM, 1995) assessments. In addition, the NC Division of Water Quality (NCDWQ)(now the NC Division of Water Resources) has begun Level 3 assessments (Baker and Savage, 2008; Baker et al., 2013; Savage and Baker, 2010). Level 2 assessments appear to be of two general types—the first (such as Ohio: Ohio EPA, 2001 or Washington State: Hruby, 2004), which are strictly observationally based and the second (such as California: San Francisco Estuary Institute, 2008), which include the collection of field data. Although both are described as rapid assessments, the observationally based methods take significantly less time than the methods that require data collection. As described below, the team developing NC WAM decided to develop an observationally based method to reflect its main end

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use (regulatory permit review and compliance) and the time realistically available for evaluation by these regulatory agencies in NC. As an indication of the importance of rapid wetland assessment methods, the National Wetland Condition Assessment conducted by the USEPA and states during 2011 developed and tested a US Rapid Assessment Method as part of a nationwide effort to assess the quality of the nation's wetlands (USEPA, 2011).

In order to improve the process of developing wetland rapid assessment methods, Fennessy et al. (2007) suggested several critical elements as follows: (a) measure wetland condition, (b) be truly rapid, (c) include a site visit, (d) be verifiable, (e) consider all three universal features of wetlands (hydrology, soils, and vegetation), (f) consider regionalization based on hydrogeologic settings, (g) define assessment area, (h) assess different wetland types, (i) address issues associated with scoring, and (j) consider highly valuable wetlands or features. These concepts provide a valuable, comprehensive construct within which to develop and test all wetland rapid assessment methods. In addition, Sutula et al. (2006) outlined a six-step process for the development of RAMs as follows: (a) organize RAM development by selecting applications and geographic scope, (b) conduct a literature review, (c) develop metrics for the method, (d) verify the method to distinguish between wetlands with varying condition, (e) calibrate and verify the method, and (f) implement through outreach and training. All of the 10 elements from Fennessy et al. (2007) and the six elements from Sutula, et al. (2006) were addressed in the development of NC WAM although not necessarily in the order outlined by those authors.

Purpose and Overview of NC WAM

NC WAM was developed by an interagency team of federal and state agency staff—the N.C. Wetland Functional Assessment Team (WFAT). The process for developing this method is outlined in Dorney et al. (2014) and the pertinent parts of that process are outlined below. The purpose of NC WAM is to provide the public and private sectors in North Carolina with a field method that is science-based, reproducible, rapid, and observational in nature in order to determine the level of function for a wetland relative to reference (when appropriate) for each general wetland type within North Carolina. The method is focused on providing useful information for the Corps and state wetland permitting procedures. The overall conceptual model of NC WAM was determined by the Interagency Leadership Team, which was staffed by policy-level administrators of several state and federal agencies involved in the wetland permitting process. Their mandate to the WFAT was to develop a field-based, rapid assessment method using the three main functions of Hydrology, Water Quality, and Habitat that would coincide with ongoing watershed planning efforts and rapid stream functional assessments. Four crucial, initial decisions were made by the WFAT. First, NC WAM was designed to be reference-based to compare the present level of function for a particular wetland to an appropriate standard. Second, comparisons are only made within wetland type rather than between wetland types as a natural consequence of the reference-based decision. This approach allows each wetland to be located on a conceptual functional continuum, ranging from relatively undisturbed, reference examples of the specific wetland type (functional rating of "High") to heavily disturbed examples of the same wetland type (functional rating of "Low"). The WFAT decided that any comparison between wetland types would have to be a decision by regulatory agencies during permitting. Third, due to the broad-based approach of the wetland assessment method, the WFAT decided that ratings would be qualitative (High, Medium, and Low) rather than quantitative. The WFAT agreed that assigning a specific value along a numerical continuum would greatly exaggerate the accuracy with which current knowledge and this method can realistically be applied. Fourth, NC WAM is designed to take no more than 15 minutes for a trained assessor to evaluate a wetland after the wetland boundary has been delineated using the Corps of Engineers wetland delineation manual and its Regional Supplements (Environmental Laboratory 1987).This decision was made by the WFAT based on the amount of time realistically available to conduct wetland functional assessments for most permitting actions. The authors of NC WAM intended that it will be the standard method used in North Carolina for wetland assessment for Section 404/401 permitting for the (US) Federal Clean Water Act and Isolated Wetland permitting by all federal and state agencies. To date, the use of the 16 wetland types is required for all 404 Permits and results of NC WAM evaluations are commonly included in Individual 404 Permit applications.

NC WAM defines 16 general wetland types in North Carolina and yields an overall functional rating relative to reference (if available) for each wetland type. Functions are considered to vary among these wetland types, but are relatively consistent within each wetland type within the same ecoregion (Griffith et al., 2002). Functional ratings depend on indicators of the level of function based on field observations rather than actual measurements of function. Functional ratings are generated based on 22 questions (metrics) concerning wetland field indicators on the NC

WAM Field Assessment Form. To complete the Field Assessment Form, the trained assessor selects the appropriate answer(s), or descriptor(s), for each metric. The selected descriptors are then converted by a computer program (the Rating Calculator) into a functional rating for each metric. Metric descriptors are combined to provide sub-function ratings using a weighting strategy following Boolean logic that reflects the relative importance of the metric to wetland sub-functions. Likewise, sub-function ratings are combined to generate function ratings and wetland function ratings are combined to yield an overall wetland rating.

Development of NC WAM

NC WAM was developed as part of a collaborative effort by representatives of the US Army Corps of Engineers (USACE), US Department of Transportation Federal Highway Administration (USFHWA), USEPA, US Fish and Wildlife Service (USFWS), NC Division of Coastal Management (NCDCM), NC Department of Transportation (NCDOT), NCDWQ, NC Ecosystem Enhancement Program (NCEEP), NC Natural Heritage Program (NCNHP), and the NC Wildlife Resources Commission (NCWRC). Between 2003 and 2007, the WFAT met 27 times in the office and spent 33 days in the field examining wetlands across the state of North Carolina visiting a total of 280 wetland sites for about 700 person-days spent developing and testing the method before its completion in April 2008. All decisions were made by consensus of WFAT members. Since then, the NC WAM User Manual (NC WFAT, 2010) has been refined several times and a four-day training course has been developed and conducted to train students in the proper use of the method.

General Approach

Metrics

The WFAT recognized that direct measurement of wetland function is impractical within time limitations imposed on this (or any) rapid field assessment method. Therefore, NC WAM uses indicators of wetland condition relative to a reference wetland (if appropriate) as a surrogate for wetland function. In effect, observed wetland condition is used to infer wetland function. These indicators are general measures (metrics) of the level of function for the wetland. A condition metric examines inherent wetland characteristics that affect its ability to perform a given function.

Reference wetlands

NC WAM defines a reference wetland as a typical, representative, or common example of that particular wetland type without, or removed in time from, substantial human disturbance as suggested by Sutula et al. (2006). For the purposes of NC WAM, the term "reference wetland" includes a range of biotic and abiotic characteristics within each recognized wetland type and is synonymous with "relatively undisturbed."

NC WAM considers reference wetlands to be available for all 16 general wetland types with the exception of Pine Flat, Non-Tidal Freshwater Marsh, and some sub-types of Basin Wetland. In order to properly utilize NC WAM, assessors must be familiar with the geomorphology, hydrologic regime, water quality characteristics, typical vegetation structure and composition, and wildlife attributes for a range of reference examples of each general wetland type. Since some of the general wetland types are heterogeneous for certain characteristics, it may be necessary to choose a site-specific reference—one that matches the site under evaluation more precisely than merely belonging to the same general wetland type.

Some wetland types do not have a usable reference. Pine Flat, Non-Tidal Freshwater Marsh, and some sub-types of Basin Wetland are largely successional in North Carolina and therefore a natural reference is not present. For instance, Basin Wetlands without reference include freshwater marshes along the fringes of dug ponds. For wetlands without reference, the presence or absence of stressors and the intensity of those stressors is a crucial factor in the rating.

Although not a true general wetland type, wetlands that are "intensively managed" include any wetland that has been severely altered or unintentionally created by humans and is maintained in a severely altered state. Intensively managed wetlands have degraded wetland functions, but the sites remain jurisdictional wetlands. These areas may include, but are not limited to, farmed wetlands and mowed wetlands within utility-line corridors. In general, altered wetlands tend to be classified as a disturbed version of the original type rather than as a new wetland type.

Wetland Functions and Sub-functions

NC WAM considers chemical, physical, and biological functions for each general wetland type and assesses the general performance of each function relative to that wetland type. Scientific literature, other wetland functional assessment methods, and best professional judgment formed the basis for generation of a list of wetland functions, sub-functions, and field indicators for this field-based method. The primary reference for wetland functional assessments was Bartoldus (1999).

Three primary wetland functions were identified for NC WAM: Hydrology, Water Quality, and Habitat. Each of these primary functions was sub-divided into sub-functions. The Hydrology function is divided into (a) surface storage and retention, and (b) sub-surface storage and retention. The Water Quality function is divided into (a) particulate change, (b) soluble change, (c) pathogen change, (d) physical change, and (e) pollution change. The first four Water Quality sub-functions are considered for riparian wetlands, and the fifth Water Quality sub-function (pollution change) is a combination of components of the first four and is considered for non-riparian wetlands. The Habitat function is divided into (a) physical structure, (b) landscape patch structure, and (c) vegetation composition.

Disturbances and Stressors

The term "disturbance" in NC WAM refers to both natural and anthropogenic activities that may result in alteration of one or more wetland functions. Natural disturbances include, but are not limited to storm and fire damage, salt-water intrusion when inappropriate for that wetland type, beaver impoundment, stream migration, and sedimentation. The term "stressor" refers to a typically anthropogenic activity that affects one or more wetland functions by altering the wetland from reference. The response of a wetland to a stressor depends on wetland type, size, and severity of the stressor. The presence of stressors is anticipated to always degrade the level of function for the wetland

Wetland Types

NC WAM recognizes 16 general wetland types for North Carolina. The purpose of specifying general wetland types is to (a) provide a unified list of wetland types for North Carolina, (b) account for the inherent differences in function for each wetland type, and (c) account for permitting of impacts by wetland type or groupings of wetland types. These 16 general wetland types are (a) Salt/Brackish Marsh, (b) Estuarine Woody Wetland, (c) Tidal Freshwater Marsh, (d) Riverine Swamp Forest, (e) Seep, (f) Hardwood Flat, (g) Non-Riverine Swamp Forest, (h) Pocosin, (i) Pine Savanna, (j) Pine Flat, (k) Basin Wetland, (l) Bog, (m) Non-Tidal Freshwater Marsh, (n) Floodplain Pool, (o) Headwater Forest, and (p) Bottomland Hardwood Forest. Each description in the User Manual contains a discussion of where the wetland type can be found in the state; observations about its typical hydrology, soil, and vegetation; whether reference wetlands are available; what other wetland types tend to grade into the wetland type; and which other wetland classification schemes incorporate the type. In addition, the User Manual contains multiple color photographs of representative examples of each wetland type to assist the evaluator in the critical selection of the proper wetland type. General wetland types are a consolidation of wetland types previously defined by the NCNHP in Schafale and Weakley (1990) with 59 types. It should be noted that since the general wetland types in NC WAM are a consolidation of types defined by these sources, definitions may overlap. A crosswalk of the NC WAM types with other wetland classification schemes is provided in the User Manual.

Dichotomous key

The initial step in the field application of NC WAM is to identify wetland types found at the site. To this end, NC WAM uses a Dichotomous Key. If the assessor believes that a wetland can reasonably fit into more than one wetland type, the assessor may rate the wetland as each potential wetland type. If there is evidence suggesting that the wetland is a type other than the keyed type, the assessor should document this evidence and then classify the wetland accordingly.

Wetland Assessment Metrics

As noted above, NC WAM assesses the level of wetland condition as an alternative to direct assessment of wetland function. The method of determining the level of function of a specific wetland is to answer a series of questions (metrics) concerning (a) the observed level of function for the wetland, and (b) the opportunity for modification of wetland functions due to disturbances in the watershed draining to the wetland. A list of metrics specific to each general wetland type was generated by the WFAT. Metrics corresponding to wetland types with a reference standard are designed to assess the departure of a wetland from the reference standard. All metrics for each of the 16 wetland types were field tested and revised at multiple test sites representing various levels of disturbance. Following initial field testing, state and federal agency personnel participated in beta-testing exercises focused on the applicability of metrics for all general wetland types. Beta testing included an abbreviated classroom explanation of the method, field

Table 1. List of Field Metrics Used in NC WAM

1. Ground Surface Condition/Vegetation Condition – assessment area condition metric
2. Surface and Sub-Surface Storage Capacity and Duration – assessment area condition metric
3. Water Storage/Surface Relief – assessment area/wetland type condition metric
4. Soil Texture/Structure – assessment area condition metric
5. Discharge into Wetland – assessment area opportunity metric
6. Land Use – opportunity metric
7. Wetland Acting as Vegetated Buffer – assessment area/wetland complex condition metric
8. Wetland Width at the Assessment Area – wetland type/wetland complex condition metric
9. Inundation Duration – assessment area condition metric
10. Indicators of Deposition – assessment area condition metric
11. Wetland Size – wetland type/wetland complex condition metric
12. Wetland Intactness – wetland type condition metric
13. Connectivity to Other Natural Areas – landscape condition metric
14. Edge Effect – wetland type condition metric
15. Vegetative Composition – assessment area condition metric
16. Vegetative Diversity – assessment area condition
17. Vegetative Structure – assessment area/wetland type condition metric
18. Snags – wetland type condition metric
19. Diameter Class Distribution – wetland type condition metric
20. Large Woody Debris – wetland type condition metric
21. Vegetation/Open Water Dispersion – wetland type/open water condition metric
22. Hydrologic Connectivity – assessment area condition metric

exercises, and a provision for comments. Following beta testing, metrics for each of the wetland types were finalized.

Field Assessment Form

The User Manual contains detailed explanations of all 22 metrics used in NC WAM (Table 1). Each of these metrics has a series of check boxes with various multiple-choice questions intended to evaluate that metric and its deviation from reference or the effect of a variety of stressors (see Table 2 for an example). The comprehensive metric list for all general wetland types originally included 63 individual metrics. In order to generate a single, relatively concise field metric evaluation form, the original 63 metrics were separated into their component parts, reorganized, and condensed into the 22 "condensed" metrics on the Field Assessment Form.

Table 2. Example of Metric from Field Assessment Form

9. Inundation Duration – assessment area condition metric

Answer for assessment area dominant landform.

■ **A** Evidence of short-duration inundation (<7 consecutive days)

■ **B** Evidence of saturation, without evidence of inundation

■ **C** Evidence of long-duration inundation or very long-duration inundation (7 to 30 consecutive days or more)

Completion of a wetland functional assessment is typically a six-step process: (a) becoming familiar with regional features through off-site research (mostly map analysis); (b) conducting an on-site investigation to determine separate general wetland types; (c) determining the boundaries of one or more assessment areas within the proposed project or study area; (d) conducting a rapid, on-site evaluation of each assessment area; (e) conducting an in-office map/GIS evaluation if needed; and (f) using the Rating Calculator to generate assessment ratings.

NC WAM Rating Calculator and Boolean Logic

A critical tool needed for data analysis to generate wetland functional ratings in NC WAM is the Rating Calculator. The Rating Calculator utilizes a Boolean logic chain of reasoning to convert metric evaluation results into ratings. The Boolean logic process was developed by the WFAT following extensive discussions regarding possible interactions between and among various metrics and sub-functions. These results were evaluated at numerous field sites by the WFAT. The Boolean logic was written into a computer program (Rating Calculator) that generates ratings for wetland metrics, sub-functions, functions, and the overall wetland. The Rating Calculator is an Excel macro with 71 unique Boolean logic combinations across the 16 general wetland types.

The Boolean process proceeds by using selected metric descriptors to sequentially generate ratings for sub-functions, functions, and overall function. Each level of function subsumes the next, effectively serving as building blocks for the levels that follow (Figure 1). For instance, of the four levels of functional assessment, the metric level has the narrowest purview. By themselves, metrics pertain to very specific aspects of the wetland (see Table 2 for an example). Collectively, metrics are organized into sub-functions. The combination of the descriptors of all metrics within a particular sub-function produces a sub-function rating that offers a broader account of wetland function. Ratings generated for all sub-functions corresponding to a

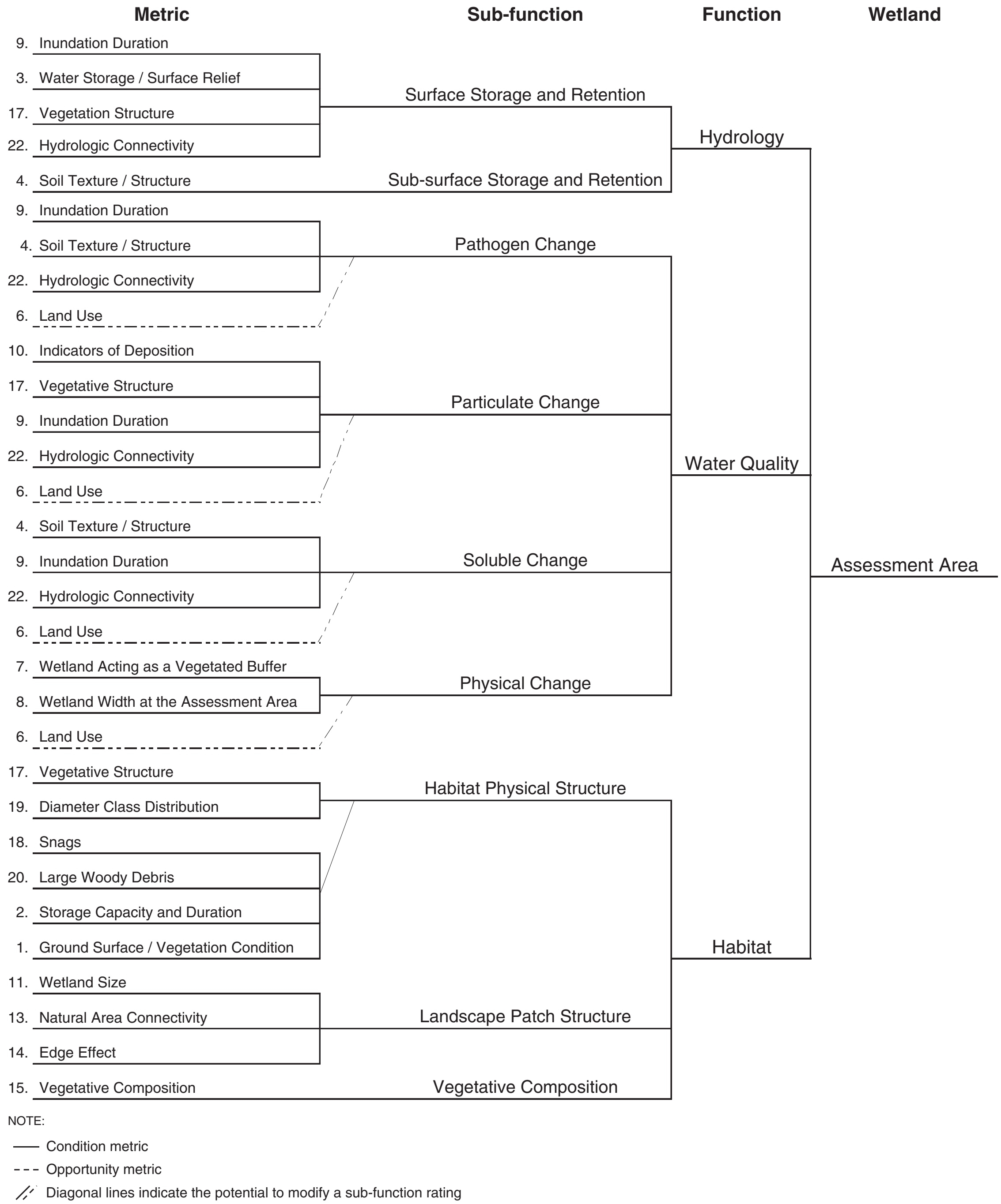

Figure 1. Bottomland Hardwood Forest Metric-Function Diagram

particular wetland function (such as the Hydrology function) are combined to produce a function rating for Hydrology, Water Quality, or Habitat. Ultimately, individual wetland function ratings are combined to produce an Overall wetland rating. This overall wetland rating is the most comprehensive of the four levels of function—an aggregate of all functional levels considered in NC WAM. The assessor completes the form within the Rating Calculator by selecting proper boxes and option buttons. The program generates functional ratings from the completed form.

The use of NC WAM results in an overall rating for each assessed wetland, ratings for each of the three

Table 3. Random Forest Importance Score by NC WAM Overall and Function and indicator type for selected index

Indicator Type	Overall NC WAM	Hydrology	Habitat	Water Quality
Vegetation Index				
Annual: Perennial	11.96	14.45	10.40	4.71
Mean Coefficient of Conservatism	13.10	13.59	11.01	
Fern Percent Cover	10.81	7.28	8.69	
FQAI Cover Metric	6.98	4.31	11.09	
FQAI Species Count Metric	8.36	4.66	10.61	4.71
Percent Cover Exotic Grass Species		5.58		
Moss Percent Cover	4.19	3.54		
Percent Sensitive (C > 7)	3.90	5.65		
Percent Tolerant (C < 2	4.84	3.53	11.58	
Pole Timber Density		4.10		
Wetland Shrub Percent Cover		4.92	6.43	
Macroinvertabrate Index				
Evenness	4.63	5.37		
Percent Microcrustacea	5.52	6.54	7.96	
Percent Coleoptera				
Percent Crustacea				4.71
Percent Decapoda				4.71
Percent Predator		4.39	3.86	
Amphibian Index				
Species Richness			8.99	4.71

specific functions and up to ten sub-functions, as well as documentation of field conditions that contribute to the ratings. The product resulting from completion of NC WAM includes, but is not limited to, a completed Field Assessment Form (with assessor notes), a completed Wetland Rating Sheet, a site map, site photographs, and additional notes if appropriate.

Validation of the Method

NCWAM was validated using independent measures of wetland condition calculated from intensive wetland monitoring data. Headwater forest wetlands were selected for this validation exercise based on availability of appropriate Level 3 data. Additional validation of NCWAM will occur in the future when level 3 data are available for other wetland types. For Headwater Forests, a total of 33 sites have been studied intensively with long-term monitoring data (Level 3 studies) for up to six years across the Piedmont and Coastal Plain of North Carolina (Baker and Savage, 2008). The monitoring consisted of groundwater well levels, surface water chemistry, soil descriptions, amphibian and aquatic macroinvertebrate diversity, presence and abundance, vegetation analysis, and quality of the surrounding buffer. To this end, the association between NCWAM overall score and NCWAM functions (water quality, hydrology, and habitat) and independent measures of wetland conditions. Indices of Biotic Integrity (IBIs) was evaluated for three biotic areas: amphibians (6 indices), macroinvertebrates (36 indices), and plants (29 indices). Different types of biological attributes were calculated for each taxa group such as species richness, percent tolerant species, and percent sensitive species. A Land Development Index (LDI) value was calculated for each site's watershed and 300m and 50m buffer following Brown and Vivas (2003). Water quality indices were developed for 19 water quality parameters including ammonia, calcium, copper, dissolved organic carbon (DOC), dissolved oxygen (percent and mg/L), fecal coliform, lead, magnesium, nitrite + nitrate ($NO2 + NO3$), phosphorous, specific conductivity, total Kjeldahl (TKN), total organic carbon (TOC), total suspended solids (TSS), turbidity, and water temperature, zinc, and pH. Soil averages were calculated for pH, copper, lead, calcium, manganese, and zinc among other parameters. The Ohio Rapid Assessment Method v. 5.0 (Mack, 2001) was used to calculate a disturbance score for each of the wetland sites.

A random forest classification was first performed to identify the best predictors among all the indices for each of the three main NCWAM functions and the NCWAM Overall Score (Table 3) (Liaw and Wiener, 2002). Annual: Perennial was the only variable deemed important in the

Table 4. Discriminant analysis and correct classification of NCWAM scores. Metrics selected using Random Forest.

	Only Amphibians		Macroinvertebrates		Vegetation		Abiotic		
	Correct/total	%	Correct/total	%	Correct/total	%	Correct/total	%	All measures
Overall_NCWAM Score	16/28	57.1	20/30	66.7	22/30	73.3	15/32	46.9	89.42
Hydrology	12/30	40	19/28	67.9	29/33	87.9	23/32	71.9	85.61
Water Quality	22/33	66.7	25/30	83.3	25/33	75.8	16/33	48.5	91.67
habitat	23/33	69.7	24/28	85.7	28/33	84.8	19/33	57.6	95.45

Overall and for each of the three functions. Mean coefficient of conservation, Fern Percent Cover, FQAI Cover metric, percent Tolerant ($C < 2$) and Percent Microcrustacea were found important for Overall NCWAM as well as the hydrology and habitat functions.

Using the best predictors identified by the random forest analysis, discriminant analysis was then used to classify the wetlands in Low, Medium, and High categories using Amphibian, Macroinvertebrates, and Vegetation Metrics, as well as the Abiotic variables (LDI index and soil variables) (Table 4). The agreement between the classification provided by the intensive data and NCWAM overall and main functions was calculated. Using all measures, NC WAM correctly classified the Overall wetland condition 89.43% of the times; the habitat condition was correctly predicted 95.45%, followed by Water Quality and Hydrology (91.67% and 85.61%, respectively). In summary, we concluded that the Overall NC WAM score as well as the scores for the three main functions (Hydrology, Water Quality, and Habitat) are significantly related to and predicted by the long term Level 3 monitoring data, thereby calibrating NC WAM for the Headwater Forest wetland type.

Further investigations of the association between NC WAM and the raw intensive measures will be done by modeling the probability of classifying a wetland in Low, Medium, and High. The approach for these calibration efforts will be to determine how well the results of long-term monitoring efforts correlate with NC WAM ratings and if needed, determine how to modify NC WAM ratings (probably through adjustments in the Boolean logic) to result in NC WAM ratings that correlate as closely as possible with these long-term monitoring results. The WFAT will then have to reconvene to review these results and recommendations before any changes are made to the method since only the agencies that developed and approved the method have the authority to make changes to the method. Since the two wetland types with long term monitoring data (Headwater Forest and Basin Wetlands) may represent other wetland types, the WFAT will have to decide if it is appropriate to make changes in the method for other wetland types based on the results from these two types.

Use of NC WAM to Evaulate Compensatory Mitigation

Mitigation Success

NC WAM can be used to evaluate the success of compensatory mitigation by mitigation providers and wetland regulators as a supplement to traditional wetland mitigation success measures. Burton (2008) examined twelve older (constructed between 1993 and 2002) wetland restoration sites (total of 881 hectares) constructed on prior-converted farm land in the North Carolina Coastal Plain. A total of 37 separate NC WAM evaluations were conducted, since some mitigation sites had multiple assessment areas due to multiple wetland types or varying wetland condition on the sites. Overall, 76% of the sites were evaluated High for Hydrology, 68% as High for Water Quality and 14% as High for Habitat. Overall 65% of the sites rated as High. The most common pattern of functions was High for Hydrology, High for Water Quality and Low (or Medium) for Habitat (21 of the 37 evaluations). The general pattern of Low for the Habitat rating (57% of evaluations) was expected since these sites were all planted on prior-converted farmland and most of the woody stems classified as saplings rather than trees. It is expected that as these sites mature, the Habitat rating will increase. Four sites were rated Low Overall and these ratings were due to beaver-related flooding, stream channelization, man-made berms or soil compaction that resulted in reduced wetland function. In summary, NC WAM provided valuable information especially for sites with problematic mitigation success and can serve as a valuable source of information as a supplement to traditional measures of mitigation success such as hydrological monitoring, vegetation growth, and presence of hydric soils.

Functional Uplift from Mitigation

Use of NC WAM to calculate the level of functional uplift from wetland enhancement has been explored. Functional uplift is defined as the determination of the level of increase of wetland function from activities conducted on existing, non-fully functional wetlands. Wetland enhancement is defined as "the manipulation of the physical, chemical, or biological characteristics of an aquatic resource to heighten, intensify, or improve a specific aquatic resource function(s)" without a gain in wetland area (USACE and USEPA, 2008). This rule requires regulatory documentation of uplift from compensatory mitigation and no-net loss of acreage and function. The method to use to document that uplift is left up to the individual Corps Districts. One way of documenting that uplift and simultaneously encouraging wetland enhancement is outlined below.

In order to determine functional uplift from enhancement, a NC WAM evaluation is conducted on the wetland in its present state and then a NC WAM evaluation is completed on the site based on the projected outcome after the proposed enhancement activity. Since determination of mitigation ratios is inherently a numerical process, the NC WAM results needed to be converted to a numerical ranking system. The following equation is used to calculate the level of functional uplift:

$$\text{Functional uplift} = \frac{\text{EnhAcres}(\text{MitQual}_{\text{post}} - \text{EnhQual}_{\text{pre}})}{\text{EnhTypeRatio}}$$

Where

- EnhAcres = Enhancement acreage
- $\text{MitQual}_{\text{post}}$ = Mitigation quality post-enhancement
- $\text{MitQual}_{\text{pre}}$ = Mitigation quality pre-enhancement
- EnhTypeRatio = Enhancement Type Ratio (equals 2:1)
- NC WAM rating of Low = 0.5, of Medium = 1 and of High = 2 for Post and Pre Mitigation Quality

The NCDWQ 401 Certification rules [15A NCAC 2H.0506 (h) (6)] require 1:1 restoration or creation in order to achieve no net loss of wetlands although the rules also allow the Director to waive that portion of the rule if the "public good would be better served by other types of mitigation." In addition, the joint mitigation rule of the USACE and USEPA (2008, p. 19594) defines no net loss for wetland acreage and function (emphasis added). This equation and use of NC WAM provide a consistent mechanism to calculate the degree of functional uplift from wetland enhancement that could then be used to calculate functional replacement for unavoidable impacts to address these regulatory requirements. Therefore, this method provides a means to calculate functional uplift from wetland enhancement which otherwise would receive little to no mitigation credit. The analysis outlined above and described below utilizes the overall wetland score but could easily be calculated using any or all of the three functional scores. In the examples below, the regulatory agencies determined that use of overall score was appropriate in these instances.

Bonnerton Hardwood Flat mitigation site

As a condition of the 401 Water Quality Certification issued by the NC Division of Water Quality to PCS Phosphate on January 15, 2009 (NCDWQ, 2009), a wetland mitigation effort will be conducted on the site by restoring natural flow to the relict stream channel, adjacent Headwater Forest and adjacent Hardwood Flat through filling of the ditch and redirecting it to flow via its natural pattern into or adjacent to these wetlands. A NC WAM evaluation was completed for the Hardwood Flat before and after mitigation. The existing level of function for these wetlands was rated as Medium mainly as a result of the hydraulic alteration. The future level of function for this wetland was projected to be High if the ditch was filled and flow redirected into the relict stream channel. Using the above equation, the site yielded 0.69 hectares of restoration-equivalents from the 1.3 hectare Hardwood Flat wetland. This amount of mitigation credit was explicitly acknowledged in the 401 Water Quality Certification issued by the NCDWQ (Condition number 8: Porter Creek Enhancement; NCDWQ Quality, 2009) and incorporated by reference by the USACE in their 404 Permit for the project. In addition, the possibility of functional uplift from the headwater forest wetland as well as stream restoration credit is provided in the 401 Water Quality Certification if PCS Phosphate provides additional monitoring that documents that uplift.

Meadow Branch Mitigation site

This site involves a 18.1 hectare parcel acquired by the NCEEP in southeastern North Carolina in the floodplain of SaddleTree Swamp. The stream has been dredged in the past and will continue to be dredged as a result of upstream flooding concerns in the City of Lumberton. The site has a 1.2 to 1.8 meter high spoil berm, which is located parallel to the stream and created from regular dredging of the stream channel along the entire length of the property. The opposite side of the stream does not have a berm and experiences regular overbank flooding. This site contains Riverine Swamp Forest (3.2 hectares) and Bottomland Hardwood Forest (14.5 hectares) that have had their hydrology modified by removal of regular overbank flooding as a result of the berm. In addition, there is a

Table 5. Restoration opportunities Saddle Tree Swamp mitigation site using functional uplift calculated using NC WAM.

Mitigation Type and Location	Hectares	Functional Uplift – hectare equivalents
Enhance bottomland hardwood forest from Low to Medium	10.5 hectares	2.6 hectare-equivalents
Enhance riverine swamp forest from Low to High	3.2	2.4
Preserve bottomland hardwood forest	4.05	0
Restore bottomland hardwood forest by removing logging road	0.33	0.33

small logging road that could be removed from the upper part of the site to yield 0.33 hectares of wetland restoration credit.

NC WAM forms completed for the site's wetlands showed that both the Bottomland Hardwood Forest and Riverine Swamp Forest were presently rated Low overall quality mainly due to the effect of the berm on overbank flooding. NC WAM forms were then completed to project wetland quality if the berm were breached at regular intervals sufficient to restore normal overbank flooding (Table 5). These results showed that the Bottomland Hardwood Forest could be improved from a present rating of Low to Medium overall quality and the Riverine Swamp Forest could be raised from the present level of function from Low to High overall quality. This difference reflects the fact that the Riverine Swamp Forests are closer to the stream channel than the Bottomland Hardwood Forests and are therefore more likely to show benefit from more frequent overbank flooding after the berm is breached. Originally, the site had 0.33 hectares of wetland restoration equivalents but using this functional uplift process, the site yielded 5.33 hectares of restoration equivalents. Monitoring would probably consist of comparing the restored hydrology on the site to the existing hydrology on the other side of the stream which is not affected by the berm to document restoration of overbank flooding.

Comparison to other rapid assessment methods

Comprehensive reviews of rapid assessment methods have been prepared by Bartoldus (1999), Sutula et al. (2006), and Fennessy et al. (2007). In comparison to the methods described in Bartoldus (1999), NC WAM's use of a dichotomous key for wetland types, use of Boolean logic to organize the evaluation process, availability of evaluation results at various levels (overall, function, and sub-function), and development and use of the computer calculator are steps forward in the development of rapid assessment methods which may be valuable tools for developers of methods elsewhere. Eventual adoption of rapid assessment methods to portable electronic media (such as tablets and cell phones) will increase the practicality and portability of these methods thereby enhancing their practical uses. Overall, NC WAM has proven to be a useful and practical tool for use in wetland regulatory programs, wetland mitigation and watershed assessment in North Carolina. Additional testing and refinement of the method in the coming years should serve to increase its value in wetland assessment.

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