Development of Wetland Quality and Function Assessment Tools and Demonstration

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Prepared by Colleen A. Hatfield, Jennifer T. Mokos,
and Jean Marie Hartman
Rutgers University, New Brunswick, NJ 08901-8524

In conjunction with Marjorie Kaplan, Project Manager
New Jersey Department of Environmental Protection

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EXECUTIVE SUMMARY

The specific goal of this study was to enhance the state's ability to identify indicators for wetland value and function. To this end, the study focused on a suite of rapid assessment tools designed to evaluate wetland quality and function that could be readily implemented in the field. While previous studies have compared different assessment methods (Bartoldus 1999, 2000), few studies have been conducted that include an extensive literature review and the application of the most appropriate methods to wetlands in two different regions. Applying the different methods to the same wetlands allows for an accurate evaluation of the relative performance of each method. Applying the methods in two different regions provides insight to the robustness of the methods under different physical settings.

This project is integrally linked to other wetland-related projects under the direction of NJDEP. NJDEP and Rutgers University collaborated in studying the feasibility of developing a hydrogeomorphic model (HGM) for low-gradient riverine wetlands (Hatfield et al. 2002). In addition, NJDEP recently completed a study that evaluated the status of wetland mitigation in New Jersey (Balzano et al. 2002). As part of that project, a wetland functional assessment methodology known as Wetland Mitigation Quality Assessment (WMQA) was developed for constructed wetlands. WMQA was tested on constructed wetlands and natural wetlands (Hatfield et al. 2004), and is included in the suite of wetland assessment methodologies that were evaluated in this project.

Methods

An extensive literature search was conducted to identify existing methods or methods currently in development for assessing wetland function. The results from the literature search were entered into a database. Information entered into the database included authorship, intent, references and existing status of each method. The literature search concentrated on a range of information sources including primary literature, government documents and meeting abstracts.

A review of the database was conducted and twenty wetland assessment methodologies were initially selected based on their applicability to New Jersey. From the twenty methods, a final set of eight was selected for further study based on completeness of the methods, accessibility of information, and extent of documentation. Three teams of two evaluators each were formed and trained in the eight methods. All teams had some level of wetland expertise and all team leaders had advanced training and experience in wetland ecology. The eight methods were applied by each team at seven different forested riverine wetland sites in one watershed area (Watershed Management Area 6 – WMA 6). The forested wetlands were also part of the reference set for the 2002 HGM model study previously mentioned. To examine regional sensitivity of the different methods, five of the eight methods were applied at three forested riverine wetlands in a second watershed (WMA 19). Lack of financial resources limited the number of wetlands and methods that could be examined in the second watershed. Based on preliminary data analysis and ease of application in the field, we selected the five most effective methods to use in the second watershed.

Results

The eight methods tested included Descriptive Approach, Wetland Evaluation Technique (WET), Wisconsin Rapid Assessment Method (WI RAM), Technique for the

Functional Assessment of Nontidal Wetlands in the Coastal Plain of Virginia (referred to as VIMS), Guidance for Rating the Values of Wetlands in North Carolina (NC Guidance), Maryland Department of Environmental Protection Method for the Assessment of Wetland Function (MDE), Wetland Rapid Assessment Procedure (WRAP) and Freshwater Mitigation Quality Assessment Procedure (WMQA). These methods spanned a range of scoring approaches and goals (Table 1). The Descriptive Approach evaluates the occurrence of a wetland function while WET, VIMS and WMQA evaluate through different techniques the probability that a wetland function can occur. WI RAM and NC Guidance are designed to evaluate wetland value while MDE evaluates relative wetland value. Finally, WRAP evaluates the extent to which a wetland function is performed.

Three different types of rating systems are represented by the eight methods. The Descriptive Approach uses a presence/absence system, while WI RAM, VIMS, and WET use qualitative rating systems with either three or four categories available: low, medium/moderate, high, and exceptional (only WI RAM uses exceptional). These four rating systems do not supply an overall score for the wetland being evaluated. The remaining four methods (MDE, NC Guidance, WRAP, and WMQA) use quantitative rating systems where each function is scored and an overall score for the wetland is calculated based on the function scores. Due to the different intents and evaluation procedures, direct comparisons of the methods are not appropriate. Rather, the criteria we used for evaluating the different methods included whether the methods detected a river gradient because the seven wetlands are situated upstream to downstream. The wetland set also reflects a moderate disturbance gradient (Hatfield et al. 2002) and we evaluated the methods based on their ability to detect that gradient as well. We also evaluated how each method's individual functions responded across the seven wetlands. We compared repeatability between teams, and ease and efficiency of method implementation. We drew on our previous experience in the HGM study to further assess how the different methods evaluated the seven wetlands.

Not surprisingly, there was a wide range of variability with respect to how the different methods scored similar functions as well as how the functions reflected the river or disturbance gradient. For example, most of the wetland functions evaluated in the Descriptive Approach were assessed as present but perhaps due to its binary Yes/No approach, neither a river gradient nor disturbance gradient was detected across the seven wetlands. WET was comprised of three separate parts; WET Opportunity generally scored the wetland functions the highest of all methods across all wetlands, while there was no trend for WET Social or WET Effectiveness. WI RAM generally had lower scores for individual functions than any of the other methods, but showed no river gradient. VIMS showed a

Table 1. The eight methods implemented in this study.

Method	Goal	Weight	Area	Functional Measure	Overall Wetland Measure
Descriptive Approach	Indicators that function or value occurs	----	-----	Occurrence Yes/No (Principal Function)	----
WET	Probability that function or value will occur	----	----	High/Medium/Low	----
WIRAM	Measure of wetland functional value	----	----	Low, Medium, High, Exceptional, Not Applicable	----
VIMS	Probability that a function will occur	----	----	High, Medium, Low	----
NC Guidance	Rating of a wetland value	Yes	----	Functional Score: 0-5	Wetland Rating: 0-100
MDE	Wetland functional capacity relative to maximum capacity	--	Yes	Functional Capacity Index (FCI) for each function (0-1.0); FCI x area =Functional Capacity Units (FCU)	Total Functional Capacity (Sum of FCUs)
WRAP	Extent a wetland performs a specific function		Yes	Variable Score: 0-3	WRAP Score: 0-1.0
WMQA	Probability that a wetland will achieve function over time	If desired	----	Variable Score: 0-3	WMQA Score: 0-1.0
HGM	Relative functional capacity to reference conditions	----	Yes	Functional Capacity Index (FCI): 0-1.0	----

The table provides information as to the motivation and intent of the method, whether weights are incorporated into the formulation for assessing wetland functional status, whether wetland size is a consideration and the scoring method used.

distinct break between the upstream wetlands and the three wetlands located farthest downstream. NC Guidance emphasized the importance of the social functional value of wetlands with a general increase in overall wetland functional value in the downstream direction, which also reflects an increasing urbanization gradient. MDE incorporates size into determining overall wetland function, which led to a very wide gap between wetland scores simply due to size. Differences in area measurement by the three teams also contributed to score differences. WRAP was the best at showing the river gradient with scores generally decreasing in the downstream direction. WMQA also showed a similar trend along the river gradient, but this method tended to consistently score functions and overall wetland scores higher than WRAP.

We also compared the individual functions in each method to similar functions in the HGM model that was developed to measure relative functional capacity of these wetlands. The HGM also was designed to reflect the disturbance gradient. To a lesser extent, the HGM functions also reflected the river gradient. Generally, there were differing degrees of agreement between the eight methods evaluated and HGM with respect to individual functions or wetlands. In some instances, scores were comparable between similar functions in HGM and specific methods but the pattern did not persist across all functions. HGM also occasionally scored particular wetlands similar to one of the methods but the similarity did not persist across all wetlands.

When the methods were applied to the second watershed (WMA 19), each method generally scored the three wetlands as high as the more pristine wetlands we studied in WMA 6 for many of the individual functions. Comparable responses for functions such as sediment stabilization in the two watersheds indicated that methods were sensitive to wetland type because these wetlands are tightly coupled with the adjacent river and are subject to seasonal inundation and scouring. There is no indication of the river gradient in WMA 19, but with only three sites one would not necessarily expect to see it.

With respect to inconsistencies, each method had at least one or two functions, and sometimes more, where teams had noticeably different scores. Variables related to habitat and sediment functions tended to be the most inconsistent across all methods. For the method level, WET and WMQA had the greatest differences in team scores. For methods that used a numeric approach for each function as well as an overall wetland score, the differences between teams at the individual function level did not translate into differences in the overall score with the exception of WMQA. This suggests that function scores are somewhat insensitive to the individual components making up that score. Descriptive Approach, VIMS and WRAP had the least amount of variability between the different teams.

Ease of implementation is reflected in both how well the method is documented and how easy it is to obtain the supplemental information necessary to apply the method. In terms of support materials, the Descriptive Approach and WET were data and information intensive. This could potentially lead to concerns regarding availability of all the necessary information. Other methods, such as WRAP and WMQA, required only a few data sources that are generally more readily available. However, most methods called for land use/land cover maps, which are now widely available. Caution is warranted when using existing land use/land cover maps particularly in states such as

New Jersey where land cover is rapidly changing and even a dataset that is five years old may not accurately reflect what is encountered on the ground.

Adequate method documentation and explanations were important in terms of ensuring that the methods were being properly implemented and the teams were working within the confines and assumptions of a particular method. Adequate documentation helped determine when and where modification was necessary in order to use the methods in a different setting. Good documentation also resulted in increased user confidence by the teams. Methods like NC Guidance and WRAP were particularly well documented, while methods like WI RAM and Descriptive Approach were lacking in complete or adequate explanations. Thoroughness of documentation may also reflect a bias that is inherent between numeric and ranking approaches. Numeric approaches must lead the evaluator through a series of algorithms to arrive at an individual function score as well as an overall wetland score. This recipe type approach may intrinsically result in better documentation.

In terms of efficiency, most methods could be implemented in a day or less. WET was the exception to this rule, requiring over a day and sometimes two full days to apply the methodology to a single wetlands. WMQA was the quickest to implement. Generally, the most time consuming portion of each method was the walk of the wetland perimeter. Depending on the wetland size, this could consume a considerable amount of time to adequately assess the entire wetland. Training was also relatively efficient for all of the methods again with the exception of WET that required two days of training.

Recommendations and Conclusions

When evaluating the different wetland functional assessment methodologies, it is imperative that the goals, need and intent of the user are clearly defined. Different methods have been developed for different reasons and no one method will likely accommodate all situations. It is only through a careful definition of user requirements and how this relates to the intent of the different functions can one begin to select the most appropriate approach. This inherently makes it difficult, if not impossible, to compare all wetlands in all situations and for all purposes. However, there are some clear patterns from studies such as this that allow resource and regulatory managers to make more informed decisions.

Three different types of rating systems are represented by the eight methods employed in this study. The presence/absence rating system in the Descriptive Approach allows for a good deal of flexibility in the evaluation because the assessment can be tailored to the particular conditions at each wetland site. However, a large degree of 'best professional judgment' is required for this type of method, which could contribute to inconsistent application of the method. An interdisciplinary team of experts can mitigate this variability. The method does not necessarily provide information about the degree to which a wetland performs individual functions, thus making temporal trends or comparisons between different wetlands more difficult.

Three methods (WI RAM, VIMS, and WET) employ qualitative rating systems with multiple categories, though the ratings do not reflect quantitative evidence. These methods do not provide an overall wetland score. Therefore, if one wants to identify how a wetland is functioning, it is necessary to examine the individual functions or suite of functions to assess wetland functioning. Best professional judgment is important for all three of these methods, but it is inherently more relied on in WI RAM than the other two. WET and VIMS employ interpretive keys, while WI RAM relies entirely on best professional judgment. This means there is greater flexibility in WI RAM, allowing the evaluator to tailor the ratings to individual site conditions; however, as such, it is important that evaluators have ample experience to make an accurate determination of function. WET and VIMS are less adaptable, but given the more comprehensive instructions, they can be applied by evaluators possessing a greater range of expertise. The lack of an overall wetland score makes it difficult to compare multiple sites. WI RAM and VIMS were designed to examine sites on an individual basis. WET, however, specifically states that it may be used to compare wetlands to each other, though this may prove tedious with no overall wetland score.

The quantitative rating systems (NC Guidance, MDE, WRAP, and WMQA) produce an overall numerical score for each wetland making it is easier to directly compare different wetlands of the same type. However, scores are still based on a limited amount of information and are not absolute. In addition, two wetlands could have the same overall wetland score, but for quite different reasons that can only be discerned by examining the individual functions. It can be difficult to determine when scores actually differ significantly from each other or simply reflect natural variability, which is a consideration for all methods irrespective of their approach.

In all four numeric methods, the overall wetland score is determined quantitatively from the scores for each wetland function. Different methods require differing degrees of professional judgment in determining the score for each function. MDE and NC Guidance use flowcharts to assign a numerical score based on the presence of indicators for each function, while WRAP and WMQA allow for a greater degree of best professional judgment in the determination of a score for each function. The latter two methods have more flexibility than flowcharts and can be adjusted more easily to fit different types of wetlands or to better reflect what is occurring at unusual sites.

Careful and complete documentation is essential to ensure proper interpretation and implementation of the methods. Moreover, careful documentation should also include limitations and assumptions inherent in the model and when the method is not appropriate. We feel strongly that this point cannot be overstated considering the variety of circumstances that may be encountered in the field as well as the wide range of individuals with different experience levels who might be implementing the method. Both WI RAM and the Descriptive Approach were lacking in adequate documentation to guide implementation.

All of the methods rely on best professional judgment. This is the point that is most important for efficient and timely wetland functional assessment but is also the one most open to criticism due to their subjective nature. Training for a particular method will cut down on variability between different evaluators, which has been shown with WRAP (Miller and Gunsalus 1997). However, we also feel that a one-time training is likely not sufficient and evaluators should be repeatedly tested in a variety of situations and wetland types to increase the consistency between evaluators. The downside of this is that it is time consuming and costly and with the flux of evaluators in the regulatory and consulting environment, this will not be an easy hurdle to pass. However, adopting strategies similar to the wetland delineation certification process would provide the framework and protocol for ensuring consistency in functional assessments.

All of the methods are somewhat flexible and encourage the evaluators to make necessary modifications or to consider other factors when appropriate. However, guidance on how modifications might be made or what other factors are important to consider again reverts back to best professional judgement. While this strategy increases the flexibility and utility of the different assessment methodologies, it also increases the chances for differences between evaluators and/or wetland evaluations. Just as documentation is critical in method development, thorough documentation is essential in each instance when modifications or adjustments are made by individual evaluators and for individual wetlands.

We found that certain functions tended to be more variable between the different teams, methods and wetlands. These functions, particularly those related to habitat, frequently occur in wetland functional assessment methods. Due to the frequency with which these functions occur, and the ubiquity of the variability in the methods we tested, there is a pressing need to better understand the source of this variability. The differences may be due to a general lack of adequate detailed documentation in the methodology that results in greater reliance on interpretation rather than clearly defined indicators. However, it is also quite possible that these particular functions are more prone to errors in interpretation or natural variability in field indicators. Further study would be necessary to disentangle the causes of persistent differences.

The comparison between the two geographic locations showed some potentially interesting patterns in that the three wetlands in WMA 19 scored similarly to the more pristine wetlands in WMA 6 for many of the functional assessment methods. However, with only three sites it is difficult to determine whether these wetlands were indeed relatively undisturbed or if the methods were sensitive to geographic changes. Evaluating additional riverine wetland sites that encompass a greater range of variability in WMA 19 would help resolve this question.

While none of these methods were developed specifically for the riverine wetland type or for the region, only limited modification was deemed necessary to apply them. However, a larger suite of wetlands would be necessary to rigorously test the individual methods, and this is a factor we did not include in our assessment of efficiency and ease of implementation. Our analysis of these factors only included consideration of the need for minor modifications and the effort required to implement the different methods. A more accurate analysis of efficiency and implementation should include the complete process from method development to testing, calibration and implementation. This is of particular concern with methodologies that are wetland type or location specific such as the HGM. For states like New Jersey that are physiographically, hydrologically and anthropogenically complex, to develop or modify the HGM guidelines to accommodate this complexity would require considerable and lengthy resource commitments. Even for existing methods such as those studied here, analysis of efficiency and ease of implementation should also include the process of testing, modification, calibration and implementation if it is to be adopted over a wide geographic area or for different wetland types.

Three of the methodologies are currently in use within the regulatory framework (Descriptive Approach, WI RAM, WRAP) and WMQA is in review. In many instances, the other methods have been replaced by the HGM approach. HGM is the most rigorous in terms of method development and implementation and is also most widely used.

However, adopting the HGM approach within the State will require an extensive resource and time commitment due to the physical and anthropogenic complexities of the State. In the interim, a better understanding of wetland function from a variety of perspectives, such as that provided in this study, will help move the State forward in their effort to evaluate wetland quality.

Efforts such as this need to be coordinated and integrated with efforts directed toward evaluating wetland quality and water quality. There is a general lack of information that relates wetland function to wetland quality. For example, wetland function does not necessarily equate to wetland quality. A degraded wetland may be considered to have relatively high function. Evidence of this occurred during the implementation of NC Guidance, which based wetland function on the wetlands functional benefit to society. The wetlands that received the highest overall scores were those in closer proximity to urbanization reflecting their functional contribution to society. In contrast, the more pristine, less disturbed wetlands received the lowest overall functional score as they offered relatively less benefit to society.

There are a number of programs in New Jersey that document the status of natural resources in the state. The Endangered and Nongame Species Program Landscape Project and vernal pool project, the Heritage Program and the Ambient Biomonitoring Network (AMNET) biological monitoring program are such examples. To varying degrees, the different assessment methods utilized the existing natural resource information particularly in collecting information to help in the field assessment. However, the methods could be modified to better utilize this information. For example, only the Descriptive Approach evaluated the presence of endangered species and most indicators of wildlife habitat or floral diversity were field determined. Incorporating these various types of information into the assessment would better link functional assessment within the broader context of the natural resources of the area and facilitate establishing priorities for preservation and restoration.

Additional studies that compare different functional assessment methods are needed to understand if the findings in this study translate to similar results in other wetland types and in other regions. Expanding this study approach to different wetland types would elucidate similarities as well as differences between functioning of different wetland types. It would also help decipher the robustness and sensitivities of the different methods to different circumstances. The information and data from this study contributes to the growing body of knowledge of functional assessment and the goal of identifying indicators of wetland quality. A total of eight functional assessment methodologies have been considered here and contrasted with another functional assessment methodology, HGM. The assessment methods encompass a range of intents, purposes and scoring methodologies. There is no basis, nor was it the intent of this study, to consider one method superior over the others. Rather, the goal was to expand our understanding of the assumptions, limitations and strengths of the different methods. Applying these methods to a set of reference wetlands that represented a range of conditions further provided an essential basis for evaluating method performance. Identifying additional reference wetlands within the State that spans wetland types and physical conditions would greatly improve the State's ability to assess wetland quality and function.

CHAPTER 1. INTRODUCTION AND PROBLEM STATEMENT

Resource managers, planners, and regulators have grappled with how to evaluate wetland function for the last 20 or so years. While it is generally recognized that wetlands provide valuable economic, sociological, and ecological functioning, the actual process of evaluating wetland function has proven to be complex and problematic. Scientific understanding provides the basis and guidance for assessing wetland functions, but in many instances our scientific knowledge and understanding of specific wetland functions is not fully known, and in other instances, evaluation of wetland function requires that extensive spatial and temporal data be collected. The ability to accurately assess wetland function is further complicated by the fact that wetlands vary in type, in time, and in space, which directly influences their functional ability.

Scientists recognize the need to better understand wetland functioning and active research is ongoing. However, those who are involved with wetland protection, restoration, or mitigation generally do not have the time or resources to devote to quantitative studies that evaluate wetland functioning. Indeed, for states charged with regulatory protection of wetlands, the sheer number of wetlands that are under their jurisdiction, not to mention the variety of circumstances and wetland types, make quantitative assessment of wetland function unfeasible. The solution has been the development of rapid assessment methods that qualitatively assess wetland function. To the extent possible, these methods generally incorporate the scientific understanding of wetland function within a qualitative context. The development and use of these methods reflect the collective recognition by the scientific, planning, management, and regulatory community of the need to evaluate wetland function relatively quickly. These qualitative methods are generally intended to evaluate a suite of wetland functions for a wetland in less than a day.

Currently, there are numerous rapid assessment methods in existence or in development that are designed for or applicable to wetlands. Just the sheer number of methods (over 100 evaluated in this study) reflects the fact that there is no one method that will achieve all of the goals that may be desired for wetland functional assessment. Methods have been developed that are specific for a region, a wetland type, or a specific purpose, and, while some can be modified to meet different conditions, no one method will likely satisfy the diversity of assessment situations. The one general theme that is common across all methods, however, is that each assessment method strives to provide a tool for comparing the structure and function of natural and/or impacted wetlands. To varying degrees, these methods incorporate geological, hydrological, and biological information. The methods frequently differ in how these characteristics are prioritized and measured, and these differences usually reflect the region where the method was developed as well as the purpose of development. In the end, however, the motivation remains the same – the necessity of understanding and evaluating wetland function in order for resource managers to establish priorities for both protection and restoration strategies.

Operationally, from the State's perspective, to conduct a rapid assessment of wetland function, it would be more efficient to utilize existing methods and modify them when appropriate. However, with all of the methods available, it can be difficult to determine which method is appropriate. Bartoldus (2000) developed guidelines to aid in selecting appropriate wetland assessment procedures, but what is apparent from the guidelines is that a number of different rapid assessment techniques may be necessary to cover the diversity of wetlands and situations that are encountered. The situation is further complicated by the fact that rapid assessment methods do not necessarily evaluate the same wetland functions, the methods may emphasize different functions, or they may even measure functions differently. For example, some methods may evaluate wetland potential to perform a particular function, while other methods may evaluate capacity, and still others may simply measure occurrence of wetland function. These differences make it inherently difficult to evaluate different assessment techniques, thus hampering resource managers in the evaluation of their wetland resource base.

The goal of this study was to enhance the State's ability to identify indicators for wetland value and function by assessing a suite of existing methods and tools designed to evaluate wetland quality and function. There have been a few studies that have compared different assessment methods (Bartoldus 1999, 2000), even fewer studies have been conducted that include an extensive literature review of existing wetland methods accompanied by a comparison of how selected wetland assessment methods perform when applied to the same set of wetlands. Examination and comparison of the different methods in this manner augments the State's knowledge base as it moves forward in its efforts to develop appropriate indicators of wetland status, quality, and function. Certainly, this study cannot resolve all of the challenges that the State confronts when evaluating wetland function, but it will facilitate movement in that direction.

NJDEP has initiated a number of projects directed toward evaluating wetland quality and functions. This project contributes to that effort and builds toward developing a more integrated understanding of wetland resources. The other projects that work in this project builds upon includes a NJDEP and Rutgers University collaboration in the development of a hydrogeomorphic model (HGM) for low-gradient riverine wetlands (Hatfield et al. 2002). NJDEP also recently completed a study that evaluated the status of wetland mitigation in New Jersey (Balzano et al. 2002). As part of that project, a wetland functional assessment methodology, wetland mitigation quality assessment (WMQA), was developed for constructed wetlands. This methodology was tested on constructed wetlands and natural wetlands (Hatfield et al. 2004), and the methodology is also included in the suite of wetland assessment methodologies that were evaluated in this project.

CHAPTER 2. DESIGN AND METHODS

In brief, this project included an extensive literature review of existing wetland assessment methods. From this review, a set of 20 methods were selected for more thorough review from which eight were selected and applied to a suite of palustrine forested riverine wetlands in a watershed management area (NJDEP WMA) in central New Jersey. Based on the results from this initial application of methods, a subset of five methods was chosen and also field tested in a second watershed management area in southern New Jersey, which was physiographically distinct from the first watershed management area. All wetlands evaluated were of the same wetland classification, palustrine forested riverine wetlands, with a strong hydrologic connection to the adjacent watercourse. Comparison of methods between watersheds provided a better understanding of the methods' performance in different geographic settings.

Analysis of the field data and summary information collected with the different methods provided the basis for evaluating the different wetland assessment methods. Criteria for interpretation included information on the efficiency, accuracy, applicability, and training requirements for each tool that was field tested. Where appropriate, recommendations for improvements or modifications are made, particularly where categories or indices require adjustments to make them applicable in this region. Close examination of different methodologies can ultimately facilitate NJDEP's efforts to develop indicators to evaluate wetland quality and function that are appropriate for the State of New Jersey. The information gathered in this study can be useful in informing decision-making on policy, wetland regulation, and land management and protection issues.

A. Assessment Method Review and Selection

An extensive literature search was conducted to identify and compile a list of existing and newly developed wetland assessment methods. The search focused on scientific literature, government documents and publishers, as well as critical commentary in professional society newsletters and conference proceedings/ presentations. New wetland methods are continually being developed, but for this study only methods that were available as of Fall 2000 were included in the literature search. A database was created as a result of this search, including all of the methods that were pertinent for wetland assessment. The database included over 300 records. Each record in the database included the reference source, the wetland assessment goals, wetland types where the method was applicable, the region where the method had been developed and/or tested, current status of the method (proposed, tested, etc.), and where the method was being implemented. Additional information was also included that was specific to each record.

Critical review of the 300 plus records resulted in identification of approximately 100 different wetland assessment methodologies (Appendix A). The sources for the methodologies were national in geographic extent and addressed a range of wetland types from estuarine to depressional wetlands. From the 100 different methodologies, methods were selected that were considered complete (vs. draft form), were being or had been implemented, included documentation, and could potentially work for evaluating forested riverine wetlands. This resulted in approximately 20 methods being selected for further evaluation (Appendix B). The subset of 20 included a full range of approaches, from general functional assessment methodologies that evaluated a wide range of wetland functions to function-specific assessment methods, such as those that focused only on wildlife habitat. All available instructions and documentation were gathered for each of the 20 methods for further evaluation.

Thorough review of the 20 methods further narrowed the list to those methods that met the goals of the project and were appropriate for the area. A total of 8 methods were ultimately selected to use in the study based on consideration of completeness of method documentation, usefulness, comparability, and efficiency of application of the different methods. An additional criterion in the selection of the subset of 8 methods was that the method could be implemented by people who had experience in evaluating wetlands and wetland functions but did not necessarily have specialized experience or expertise. Examples of methods that were eliminated due to this consideration included the Habitat Evaluation Procedure (HEP), which required specialized knowledge and training on model development for organisms found in the wetlands, as well as the New England Fresh Water Invertebrate Biomonitoring Protocol (NEFWIBP; Hicks 1997) and the Wetland Index of Biotic Integrity (WIBI), both of which required aquatic insect taxonomic expertise.

In addition to selecting methods according to the above criteria, we also tried to select methods that spanned a range of intentions and scoring methods. For example, we chose methods that emphasized social value of the wetland as well as methods that emphasized ecological functioning. We chose methods that determined functioning that used a simple Yes/No response, produced a categorical ranking, or assigned a quantitative value to a function. Some methods gave an overall wetland score, while others did not. We included assessment methods that emphasized wetland potential to function, along with methods that emphasized wetland value. While this approach of selecting methods that have different purposes and measuring systems makes direct comparison between methods inherently difficult and problematic, we felt it was important to incorporate the breadth of available approaches to better understand how assessment of wetland functioning can vary. This type of approach will help reveal strengths and weaknesses of different assessment methods, as well as advantages and drawbacks of assessing particular wetland functions. This approach will contribute to the existing information base that will better inform the State in its efforts to identify indicators for wetland function.

The eight methods that we evaluated in detail included:

- Wetland Functions and Values: A Descriptive Approach (US ACOE 1995)
- Wetland Evaluation Technique (WET – Adamus et al. 1987)
- Wisconsin Rapid Assessment Methodology (WI RAM – Wisconsin DNR 1992)
- Technique for the Functional Assessment of Nontidal Wetlands in the Coastal Plain of Virginia (VIMS – Bradshaw 1991)
- Guidance for Rating the Values of Wetlands in North Carolina (NC Guidance – North Carolina DENR 1995)
- Maryland Department of the Environment Method for the Assessment of Wetland Function (MDE – Fugro East, Inc 1995)
- Wetland Rapid Assessment Procedure (WRAP – Miller and Gunsalus 1999)
- Freshwater Mitigation Quality Assessment Procedure (WMQA – Balzano et al. 2002)

B. Assessment Method Descriptions

The eight methods that were selected for implementation are briefly outlined below. The methods have different ways in which they evaluate and score individual functions. For example, the first method is the Descriptive Approach, which assesses wetland function with Yes/No responses. This is followed with methods that assess function with categorical rankings (e.g., High, Medium, Low). Assessment methods that assign a number to wetland functions follow these. This approach for presenting the methods is arbitrary, and we could have just as easily arranged these alphabetically or by value assessment versus potential functioning assessment.

Wetland Functions and Values: A Descriptive Approach

The Descriptive Approach was developed by the Army Corps of Engineers (ACOE) to identify the *presence of wetland functions and values* while reviewing projects for Section 404 permits to evaluate wetland impact and determine mitigation requirements (Table 2A). Developed in 1993 and published in 1995, it was a supplement to the Highway Methodology Workbook developed by the ACOE Regulatory Division. The method evaluates the presence of 13 functions: groundwater recharge/discharge, flood flow alteration, fish and shellfish habitat, sediment/toxicant retention, nutrient removal, production export, sediment/shoreline stabilization, wildlife habitat, recreation, educational scientific value, uniqueness/heritage, visual quality/aesthetics, and endangered species habitat (Table 3A).

With the Descriptive Approach, the presence or absence of a series of indicators is used to evaluate each individual function. A wetland evaluator fills out an evaluation form (Appendix C), indicating the presence or absence of a function with a simple yes or no. The rationale behind this decision is documented by listing all indicators that influenced the decision (indicators are numbered in the manual to allow for quick documentation). Additional indicators may also be employed according to the evaluator's best professional judgment. Principle functions are identified; these are considered the most important functions for the wetland and are thus named to set them apart from less important functions, since most sites will perform most functions to some degree.

As outlined above, the Descriptive Approach relies on best professional judgment and consensus of a team of evaluators to determine whether or not each function is present and which are the principal functions of the site. There is neither an individual rating of each function nor an overall score given to the wetland (US Army Corps of Engineers 1995). In fact, this method explicitly states that qualitative descriptions of wetland function are preferred over methods that provide or imply quantitative scores for wetland functioning. The rationale behind this stance is that often the information used to derive the rating is not provided, and it is difficult to deconstruct ratings to see what components or indicators led to a particular rating. Furthermore, the authors of this method argue that numerical ratings imply the use of quantitative information, which may not have been used. They warn against using weightings and against ranking of dissimilar functions.

The Descriptive Approach was updated in September of 1999. This updated version is largely the same as the original with minor changes in the text and changes in the list of indicators to increase consistency and eliminate duplication (Ruth Ladd, pers. comm., April 29, 2002). The New England District of the Army Corps of Engineers prefers the Descriptive Approach to other methods and uses it in its Section 404 permitting process for a wide variety of project types. It is usually employed by consultants and included in the application process for permits for ACOE review. There is a graphic approach in this method that can be used to display the relative spatial relationships of different wetlands and their individual functions. However, this approach was not implemented in this study.

Table 2A. Wetland assessment methods used in this study and that evaluate wetlands by Yes/No responses or Rankings

Method	**Authorship**	**Applicable**	**Purpose**	**Expertise Needed**	**Date**	**Current Status** (2002)
Descriptive Approach	New England Army Corps of Engineers	Tidal and non-tidal wetlands	Identify presence of wetland functions and values while reviewing projects for Section 404 permits	Interdisciplinary team of wetland professionals	1999	Used for local planning purposes; identify priority wetlands for restoration and preservation
WET	Army Corps of Engineers	Tidal and non-tidal wetlands	Identify qualitative probability of wetland function. Compare different wetlands; select priorities for wetland acquisition or research, identify permitting options, evaluate project impacts, or compare created or restored wetlands with reference wetlands for mitigation purposes	Environmental degree or several years relevant experience	1987	Some use by Highway Administrations to assess project impacts and mitigation requirements. No revisions or updates are expected
WIRAM	Wisconsin Department of Natural Resources and Minnesota Department of Natural Resources	Non-tidal wetlands in Wisconsin	Evaluate and provide a measure of wetland function in making routine Section 404 permit application decisions	Professionals w/ experience and training in wetland science	1992	Method used in 80-90% of all Wisconsin DNR wetland permitting cases (~800/yr). The long method is used about 20% of the time. Modified method used in Minnesota
VIMS	Virginia Institute of Marine Science	Nontidal wetlands in the coastal plain of Virginia	Evaluate the relative probability that a function will occur within the wetland – often done in conjunction with vegetation studies	Professionals with environmental science education	1991	Replaced by HGM and landscape based assessments (remote sensing)

Table 2B. Wetland assessment methods examined in this study that use numerical formulations to assess wetland function

Method	**Authorship**	**Applicable**	**Purpose**	**Expertise Needed**	**Date**	**Current Status** (2002)
NC Guidance	North Carolina Department of Environment and Natural Resources	Not applicable to salt and brackish wetlands or to stream channels	Evaluate the ability and opportunity of freshwater wetland sites to exhibit wetland functions. 401 Water Quality Certification, for acquisition, restoration, & mitigation banks)	Professionals with environmental science education	1995	Version 4 used for 401 Water Quality Evaluations
MDE	Maryland county planners	Non-tidal palustrine vegetated wetlands	Planning purposes; assess mitigation and/or compensation plans; wetlands from different classes can be compared	Knowledgeable people including planners and resource managers	1997	Occasionally used for prioritizing wetlands for preservation or restoration
WRAP	South Florida Water Management District	Non-tidal	Evaluate the success of Environmental Resource Permit (ERP) process in preserving, enhancing, or mitigating Florida's freshwater wetlands	Professionals with wetland training and experience with the State wetlands including flora and fauna	1999	Used by Florida Department of Environmental Protection, the South Florida Water Management District and the ACOE. Modified versions used in Mississippi, Alabama, Colorado and Arizona
WMQA	New Jersey Department of Environmental Protection	Mitigation or created wetlands	Provide a relative measure of wetland mitigation quality in the State of New Jersey	Professionals with wetland training and experience	2001	Developed by NJDEP to evaluate relative ability of mitigated wetlands to function as natural wetland over time

Table 3A. Wetland functions evaluated by Wetland Values and Assessment Methods.

	Groundwater			Water Quality Protection		Sediment/Shoreline				
Wetland Method	Groundwater Recharge	Groundwater Discharge	Flood Flow Attenuation	Sediment/ Toxicant Retention	Nutrient Removal/ Transformation	Sediment Stabilization	Shoreline Protection	Production Export	Floral Diversity	Fish and Shellfish Habitat
Descriptive Approach	x	x	x	x	x	x	x	x		x
WIRAM	x	x	x	x	x		x		x	x
VIMS			x	x	x	x				x
WET	x	x	x	x	x	x		x		x
MDE		x	x	x	x	x				x
NC Guidance			x	x	x		x			x

			Public use/Aesthetics/Recreation/Education				
Wetland Method	Wildlife Habitat	Endangered Species Habitat	Public use	Recreation	Educational/ Scientific Value	Uniqueness/ Heritage	Visual Quality/ Aesthetics
Descriptive Approach	x	x		x	x	x	x
WIRAM	x			x	x		x
VIMS	x		x				
WET	x			x		x	
MDE	x						
NC Guidance	x			x	x		

Table 3B. Wetland functions evaluated by Wetland Indicator Methods.

							Landscape Characteristics			
Wetland Method	Hydrology	Soils	Wildlife Utilization	Ground Cover	Canopy/ Overstory	Site Characters	Habitat Support/ Buffer	Contiguity	Water Quality Input (land use)	Water Quality Pre-treatment
WRAP	x		x	x	x		x		x	x
WMQA	x	x	x	x	x	x	x	x	x	

Wetland Evaluation Technique (WET)

The Wetland Evaluation Technique (WET) is a revision by the Army Corps of Engineers of the Federal Highway Administration's "Federal Highway Method." It was primarily designed to conduct an initial, rapid assessment of wetland functions. WET authors (Adamus et al. 1987) indicate that WET could be used for a variety of purposes, including to compare different wetlands to each other, select priorities for wetland acquisition or research, identify permitting options, evaluate project impacts, or compare created or restored wetlands with reference wetlands for mitigation purposes (Table 2A). Eleven functions are evaluated: ground water recharge, ground water discharge, flood flow alteration, sediment stabilization, sediment/toxicant retention, nutrient removal/transformation, production export, wildlife habitat, fish and shellfish habitat, uniqueness/heritage, and recreation (Table 3A).

WET is designed to assess the qualitative probability that a wetland function will occur. Functions are assessed in three different ways: social significance (the wetland's value to society, such as recreational opportunities and heritage properties of the wetland), effectiveness (the wetland's capability to perform the function), and opportunity (the wetland's opportunity to perform a function to its level of capability). WET uses a large number of predictors to assign the *qualitative probability of wetland function*. The wetland is characterized in terms of yes/no answers to questions that correlate with the physical, chemical, and biological characteristics of the wetland and its landscape. Responses to these questions are analyzed in a series of interpretation keys that assign probability ratings of high, moderate, or low to each function (Adamus et al. 1987, Appendix C). There is no overall rating assigned to each wetland, since it is inappropriate to "synthesize the probability ratings of the different functions and values into an overall probability rating for the wetland" (Adamus et al. 1987). It is also not advised that the ratings be converted into a number and be multiplied by wetland acreage.

WET has different levels of assessment depending on the level of detail necessary to evaluate wetland function. Level 1 assessment can be conducted in the office, while Levels 2 and 3 require field visits and provide more detailed and refined analysis of wetland function. For our study, Level 1 was done for all three elements (social significance, effectiveness, and opportunity). Level 2 assessment was done for effectiveness and opportunity assessments. The Level 2 for social significance, Level 3 for effectiveness and opportunity, and the Habitat Suitability assessments were not performed because they required detailed monitoring data and may have taken several weeks to complete.

Dating back to October 1987, this method has been superseded in many circles by shorter, simpler methods. As a widely applicable method, its usage is not fully known. WET has been used primarily by consultants. The method was also used recently in the Houston, Texas area to establish functional trading units as part of a mitigation bank (Paul Adamus, pers. comm., April 26, 2002). Paul Adamus, of Adamus Resource Assessment, Inc., has no plans to update the method; he finds reference-based, regionally specific methods to be far superior (pers. comm., April 26, 2002).

Rapid Assessment Methodology for Evaluating Wetland Functional Values (WI RAM)

WI RAM is a functional assessment methodology developed by the Wisconsin Department of Natural Resources (DNR) for non-tidal wetlands in Wisconsin (Table 2A). The method was developed jointly with the Minnesota Department of Natural Resources, which also continues to use a slightly modified version of the method (Scott Hausman, pers. comm., April 25, 2002). Its primary purpose is to evaluate and *provide a measure of wetland function* in making routine Section 404 permit application decisions (Bartoldus 1999). Eight functions are addressed: floral diversity, wildlife habitat, flood/stormwater attenuation, water quality protection, shoreline protection, groundwater, fishery habitat, and aesthetics/recreation/education (Table 3A). There is a short version that can be completed in the office and a long version that requires a site visit.

From a list of yes/no questions for each function (affirmative answers indicate the presence of indicators important for the function), the evaluator uses best professional judgment to assign a functional rating of Low, Medium, High, Exceptional, or N/A (Wisconsin Department of Natural Resources 1992, Appendix C). There is no overall rating assigned to the wetland.

No major changes have been made to the method since 1992. An amphibian supplement was completed but never made publicly available. The version employed in this study is the long version, which is used in roughly 20% of the cases in which the Wisconsin DNR employs the method. One of the two versions is used in 80-90% of all Wisconsin DNR wetland permitting cases, of which there are about 800 per year (Scott Hausman, pers. comm., April 25, 2002). Some consultants also use the method and submit results with permit applications for their clients.

Technique for the Functional Assessment of Nontidal Wetlands in the Coastal Plain of Virginia (VIMS)

The VIMS method was developed by the Virginia Institute of Marine Science to assess the functions of non-tidal wetlands in the coastal plain of Virginia (Table 2A). The method, based on the Wetland Evaluation Technique (WET), is primarily used to evaluate the relationships among vegetation structure, function, and landscape position. The method evaluates *the relative probability that a function will occur within the wetland.* Eight wetland functions are addressed: flood storage and flood flow modification, nutrient retention and transformation, sediment retention, toxicant retention, sediment stabilization, wildlife habitat, aquatic habitat, and public use (Table 3A).

Through field evaluation, indicators important to each of the functions are assigned a rating of High, Moderate, or Low. These results are then used to follow a dichotomous key, provided with the methodology, to obtain an overall rating of High, Moderate, or Low for each function (Appendix C). The rating represents the relative probability that the wetland has the opportunity to perform and/or be effective at performing that function. Through ratings, the VIMS method avoids arbitrary decisions about which wetland is best based solely on slight differences in a quantitative ranking, but still provides some judgment as to the quality of a site so that sites may be compared. The rating neither represents the value of the wetland for that function nor indicates that the wetland actually performs the function (Bradshaw 1991). Rather, wetlands are rated in terms of relative probability that the site has the opportunity to perform and/or is effective at performing each wetland function. There is no overall rating assigned to the wetland, rather a rating for each function is assigned.

Printed in December 1991, this research tool was intended for internal use and was to be refined as needed. The VIMS method was used by the Virginia Institute of Marine Science and sporadically by some consulting firms in Virginia for a time. However, it has been phased out and is being replaced by a hydrogeomorphic (HGM) model and by landscape-based assessments that rely primarily on remote sensing data (Carl Hershner, pers. comm., April 23, 2002).

Guidance for Rating the Values of Wetlands in North Carolina (NC Guidance)

NC Guidance is a rating system developed and released in 1995 by the North Carolina Department of Environment and Natural Resources to evaluate *the ability and opportunity of freshwater wetland sites to exhibit wetland functions* (Table 2B). It is not applicable to salt and brackish wetlands or to stream channels. NC Guidance is used as a tool for making 401 Water Quality Certification decisions in assessing wetland impact and thus in defining mitigation options. It is also used for evaluating wetland acquisition, restoration, and mitigation banks. NC Guidance assesses the following six functions: water storage, bank/shoreline stabilization, pollutant removal, wildlife habitat, aquatic life value, and recreation/education (Table 3A).

The NC Guidance method involves the use of flowcharts, which employ readily observable indicators for each wetland function (Appendix C). In moving through the flowchart, numerical scores are assigned to each function based on criteria provided in the flowchart. The numeric scores are multiplied by a weighting factor to get a weighted rating.

Function	Weight
Water Storage	4
Bank/Shoreline stabilization	4
Pollutant removal	5
Wildlife habitat	2
Aquatic life value	4
Recreation/Education	1

The weighted scores for all six functions are then added to obtain an overall rating for the wetland.

An important distinction for this method in comparison to others is that it evaluates only *wetland values* (*wetland functions that have positive effects for people and society*). Consequently, it is possible that the most pristine and undisturbed wetlands do not have the highest score if they do not provide a positive influence on society. Indeed, wetlands in proximity to human disturbance may be more valuable from this perspective and thus receive a higher rating than more pristine wetlands in a less disturbed landscape. For example, using this assessment method, the water quality protection value of a wetland increases when it is adjacent to a disturbed, developed area because it has more opportunity for pollutant removal than an undisturbed wetland in an undeveloped watershed (North Carolina Department of Environment and Natural Resources 1995).

Published in January 1995, the version used in this study was the fourth version of the method, which at the time of our study was considered by North Carolina Division of Environmental Management (NCDEM) to be more scientifically valid and to provide more consistent evaluations than previous versions. The fourth version is used by NCDEM for permitting purposes whenever an evaluation method is used. In 2001, the NCDEM processed about 1600 projects (John Dorney, pers. comm., April 26, 2002). The NCDEM has developed a newer version of the method that, as of spring 2002, has not yet been widely field tested and is neither publicly available nor in use (John Dorney, pers. comm. April 23, 2002). The major changes to the newer method reflect changes in North Carolina regulations and include dropping the weightings for each function, dropping the recreation/education function, and adding a function examining stream flow maintenance. This fifth version may not see usage; in spring 2002 the NCDEM was about to begin work on a statewide assessment method, for which NC Guidance and other methods currently in use in the state (such as a GIS-based method used by the Division of Coastal Management to monitor cumulative impacts and a hydrogeomorphic approach) are likely to be considered.

Maryland Department of the Environment Method for the Assessment of Wetland Function (MDE)

The MDE method was designed to rapidly assess wetland functions to determine the *relative functioning of wetlands compared to the maximum possible functional capacity*, as well as to allow comparison of wetlands to each other. The method was published in 1995, and a memo with additional information was published in March 1997. The method was developed primarily for use by Maryland county planners for broad-area planning purposes, and is applicable to non-tidal palustrine vegetated wetlands (Table 2B). While the method can be used to evaluate individual wetlands, it is more appropriate for assessing wetlands at a watershed scale (Fugro East Inc. 1995). The following wetland functions are assessed: groundwater discharge, flood flow attenuation, modification of water quality (includes sediment/toxicant retention and nutrient removal/transformation), sediment stabilization, aquatic diversity/abundance, and wildlife diversity/abundance (Table 3A).

This method includes both a desktop model and a field method model. The desktop model, designated for landscape-level use, does not require a site visit and utilizes GIS data and available published data for the assessment. The field method, which we implemented, requires a site visit to assess the current ground conditions of the wetland. The evaluator completes a checklist of indicators for each function. Each indicator contains a range of conditions from least to greatest wetland functioning (Appendix C). This information is then used in a flowchart for each function. A numerical score is assigned that corresponds to the degree of functioning for each indicator of a particular function. The sum of these indicator scores divided by the maximum possible score determines the Function Capacity Index (FCI) for each wetland function. MDE assumes that wetlands with a larger area have a greater opportunity to perform wetland functions. Therefore, the functional capacity index (FCI) score for each wetland function is multiplied by the wetland's area to determine the functional capacity units (FCU). The individual FCUs can be summed to represent Total Functional Capacity for the wetland relative to the maximum functional capacity. The wetland's FCU score can then be used to rank and compare different wetlands or to determine long-term trends in functions over time.

The MDE method is not widely used. The Maryland Department of the Environment assisted Maryland's Montgomery County in adapting the method for use in its local planning and will probably adapt some portions of the method for its own use in an upcoming project to identify priority wetlands for preservation and restoration (Denise Clearwater, pers. comm., April 24, 2002). If MDE is used in the permitting process, the field method should be used rather than the desktop model, due to the variability in the accuracy of the existing data sources (Fugro East, Inc. 1995).

Wetland Rapid Assessment Procedure (WRAP)

WRAP was developed by the South Florida Water Management District (SFWMD) to evaluate the success of their Environmental Resource Permit (ERP) process in preserving, enhancing, or mitigating Florida's freshwater wetlands (Table 2B). WRAP has been used by

SFWMD and ACOE in permit actions and for reviewing mitigation bank status. The method is a rating index that provides a numerical ranking for individual ecological and anthropogenic variables that is used to evaluate wetland condition. The method provides a measure of *the degree to which a wetland provides specific wetland functions.* The method can be used to evaluate a wide range of wetland systems (e.g., emergent marshes, wet prairies, hardwood swamps, and wet pine flatwoods), but should not be used to compare wetlands of different types. This method has been statistically tested, and the procedure was found to be repeatable and to have consistency between evaluator scores. Also, the functions that are evaluated are not strongly correlated with each other (Miller and Gunsalus 1999).

WRAP assesses six wetland functions ('variable' is the method terminology): wildlife utilization, wetland overstory/shrub canopy, wetland vegetative ground cover, adjacent upland/wetland buffer, field indicators of wetland hydrology, and water quality input and treatment systems (Table 3B). During the evaluation, each function is given a rating of 0-3, which correlates to the percent of functional value exhibited by the wetland (Appendix C). A score of 3 is considered to have 100% functional value, a score of 2 represents 67% functioning, a score of 1 represents 33% functioning or a loss of 67% of wetland function, and a score of 0 indicates a severely impacted system with negligible functioning. The evaluator may assign scores in increments of 0.5 where appropriate. An overall wetland rating is calculated by adding the scores for each function and dividing the sum by the maximum possible score. The result is an index whose value ranges between 0 and 1 and which correlates to the percent of functioning of the wetland. This index can be used to rank and compare wetlands, as long as they are of the same type (Miller and Gunsalus 1999). The rating index employed by the method can be combined with professional judgment to create a consistent and accurate evaluation of wetlands and provide a picture of how sites change over time.

WRAP was originally published in September of 1997 and has subsequently been updated. We used the August 1999 version, which was the 16th version of the method, with all versions spanning a five-year development period. There have been no further updates and none are presently planned (Boyd Gunsalus, pers. comm., April 23, 2002). The method is used throughout the State of Florida in the Army Corps of Engineers (ACOE) permitting process. The Florida Department of Environmental Protection and the South Florida Water Management District use it for permitting. The use of this method has also spread beyond Florida; it is now used for permitting in Alabama and Mississippi. In addition, consulting firms in Tucson, AZ, and Colorado have adopted the method by writing new community profiles to accompany it (Boyd Gunsalus, pers. comm., April 23, 2002). Florida has been working on a statewide assessment technique, but, as of spring 2002, had encountered technical snags that have prevented completion thus far.

Freshwater Wetland Mitigation Quality Assessment Procedure (WMQA)

WMQA evaluates the relative probability that a constructed freshwater wetland will develop to approximate functioning of natural wetland systems over time. It was developed under the direction of the New Jersey Department of Environmental Protection to provide a relative indication of the status of mitigated wetlands in the State of New Jersey (Table 2B). WMQA is intended to be used as an informatory tool, not a regulatory tool, as more research is needed to determine what indicators are the best predictors of mitigation quality (Balzano et al. 2002) and how best to tie those measures to mitigation goals. WMQA is based on the Wetland Rapid Assessment Procedure (WRAP) and is similar in its application. Six wetland functions are assessed: hydrology, soils, vegetation composition/diversity (overstory and ground layer), wildlife suitability, site characteristics, and landscape characteristics (adjacent buffer, contiguity, and land use) (Table 3B).

When this method is used, a wetland delineation should be performed to determine the wetland boundaries, since WMQA is only applicable within jurisdictional boundaries. For each function, a list of field indicators is provided, and the evaluator determines which condition best describes the field indicator (Appendix C). The collective condition of each of the field indicators is used to assign a relative score for each wetland function ranging from 0 to 3 in increments of 0.5. A score of 3 represents a high probability that that particular function will achieve natural functioning over time, while a score of 0 indicates a severely impacted or non-existent function with a low probability of natural wetland functioning. Each function score is multiplied by a weighting factor. The function scores are added and divided by the maximum possible score to provide an index that ranges from 0 to 1 (Balzano et al. 2001). The method provides a chart that gives a categorical ranking based on index scores.

Relative Rank	Corresponding Index Score	Potential to Provide Desirable Wetland Functions and Values
A	$0.75 \leq x \leq 1.00$	High
B	$0.50 \leq x < 0.75$	Moderate
C	$0.25 \leq x < 0.50$	Low
D	$0.00 \leq x < 0.25$	Poor

A team of two wetland scientists should collaborate to assign WMQA ratings. WMQA avoids producing a quantitative evaluation to prevent use as a substitute for direct quantitative measurement of wetland functions or use as a measure of absolute quality of a mitigation site. Additional indicators may be considered along with those discussed in the manual, and the evaluator may assign greater weight to indicators that are more important at given sites when determining the score for a function.

While this particular method was developed for the purpose of evaluating quality and function in created wetlands, it was also of interest to determine how this method performed in evaluating natural wetlands (Hatfield et al. 2004). Including the method in this study allowed us to compare the method's results with those of other functional assessment methods applied at natural wetlands.

C. Procedures for Methods Implementation

1. Wetland Description

All of the wetlands examined in this report are palustrine forested wetlands (PF01, Cowardin et al. 1979). They are also low-gradient, riverine wetlands with seasonal flooding. The wetlands are strongly connected to adjacent rivers, and overbank events are tightly coupled with river flow. We evaluated wetlands in two watershed management areas (NJDEP WMAs) to assess how a subset of the functional methods performed in different physiographic regions.

The majority of the wetland sites and all eight assessment methods were used within an area designated as Watershed Management Area 6 (WMA 6 – NJDEP). WMA 6, also considered the Upper Passaic Watershed Management Area, is located in the Passaic

Watershed Region (Region 1) of New Jersey and consists of the watersheds for the Rockaway River, Whippany River, and Upper Passaic River (Figure 1). Seven riverine wetland sites used in this study are located along the Upper Passaic River. The Upper Passaic River is roughly 50 miles long and drains the southern portion of WMA 6, most of which is located within Morris County, New Jersey. Located within the area once occupied by Glacial Lake Passaic, the overall watershed gradient is low, and the watershed contains many large floodplains and swamp/marsh complexes. The headwaters of the Upper Passaic River either are not impaired or are only moderately impaired as based on biological assessments, but some of the other waters in the watershed display various forms of pollution (NJDEP 1996). Surface water sources in WMA 6 currently meet drinking water standards, though many are threatened by eutrophication. Groundwater sources are generally good (NJDEP 1996). Roughly 45% of the land in WMA 6 consists of built land (NJDEP 1996). The remaining open lands are facing great development pressures despite frequent flooding in the area (NJDEP 2002).

The wetland sites in Watershed Management Area 6 (WMA 6) were selected because they were relatively intact wetlands in areas that are accessible, and most are in preserved areas. These particular wetlands are also part of the reference standards for the HGM study for riverine wetlands (Hatfield et al. 2002). In many instances, the wetlands are parts of larger wetland complexes along the Passaic River or one of its tributaries; the Great Swamp site is located on Great Brook, and the Dead River site can be found along Dead River. The sites all occur in a generally urbanizing area, and all sites have varying degrees of anthropogenic disturbances. These wetlands vary in size from the maximum wetland area of 1285.9 acres at Horseneck Bridge to the minimum area of 22.4 acres at Great Swamp National Wildlife Refuge (Table 4). South Main and Roosevelt are part of the Passaic River County Park, while Horseneck Bridge is a part of the Great Piece Meadows Preserve.

The borders of each wetland, except for the Great Swamp National Wildlife Refuge site, were initially determined from the National Wetland Inventory (NWI) maps and topographic maps. These borders were verified in the field. Great Swamp was the exception to this approach since it is a very large wetland complex, and implementation of the assessment methods at the scale of the entire wetland complex would have been difficult. For Great Swamp, a smaller portion of the wetland was identified for the study using hydrologically distinct wetland boundaries (e.g., roads and river).

The second watershed is located in the southwestern part of the state (Figure 2) and is designated Watershed Management Area 19 (WMA 19) by NJDEP. WMA 19 encompasses the Rancocas Creek system, as well as a few smaller watersheds, and is located in the Lower Delaware Watershed (Figure 2). A total of three low-gradient riverine wetlands (PF01) were evaluated in this watershed, all of which are along the North Branch of the Rancocas Creek in Burlington County. WMA 19 is less developed than WMA 6, with 44% of the watershed covered by forest, 5% by wetlands, and 3% by open water as of 1995 (NJDEP 2000).

Figure 1. Location of the seven riverine wetland sites in WMA 6

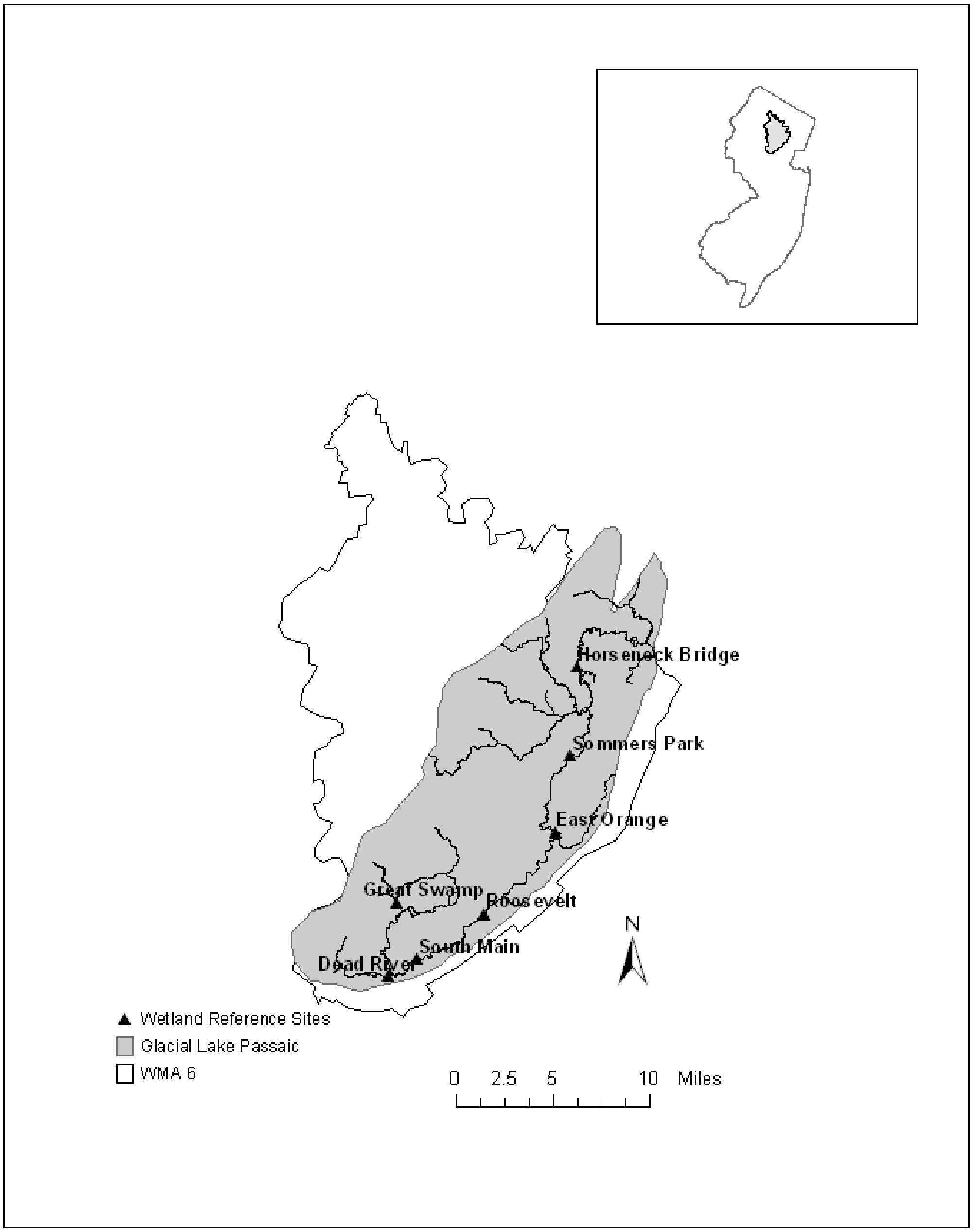


Table 4: The size of wetlands in Watershed Management Area 6 assessed in this study

Wetland Name	Area (acres)	Disturbance Ranking
Great Swamp	22.4	1
Dead River	95.8	2
South Main	48.0	2
Roosevelt	146.5	3
East Orange	197.0	4
Sommers Park	57.0	2
Horseneck Bridge	1285.9	3

Sites are listed according to their position along the Passaic River with Great Swamp the most upstream site and Horseneck Bridge the most downstream site. Disturbance Ranking reflects the relative disturbance rank for each of the wetlands. 1=least disturbed while 4=most disturbed (Hatfield et al. 2002)

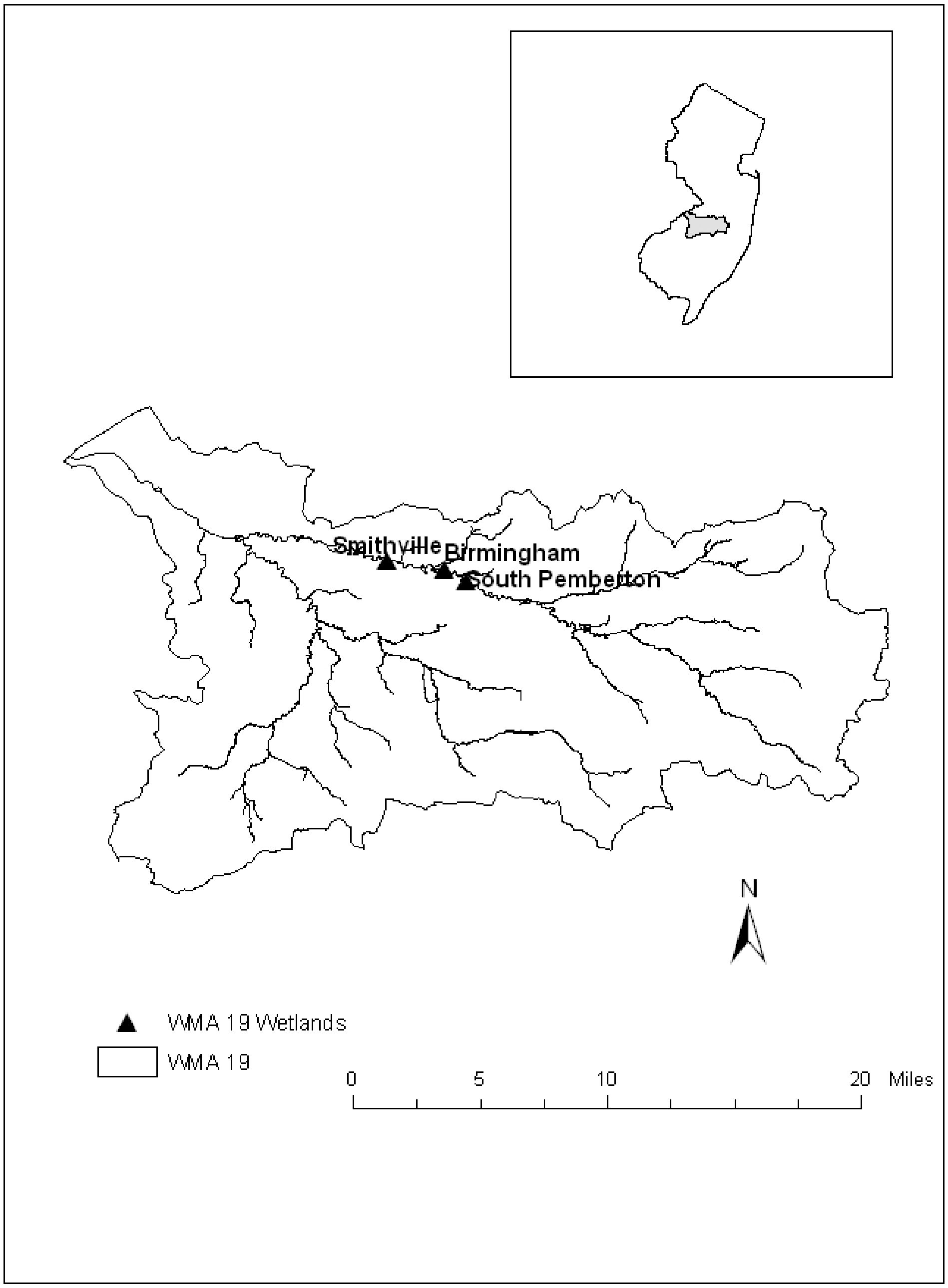
Another 17% of the area is used for agricultural purposes, while 30% is built land. Sections of the North Branch Rancocas Creek, both upstream (Mount Holly) and downstream (Pemberton) of the sites examined in this report, have impaired water quality (NJPIRG 2001).

The sites in WMA 19 were selected based on wetland type, watershed position, and wetland quality. Riverine palustrine forested wetlands were identified using NWI maps and USGS topographic maps. An on-site inspection of several wetlands in the area was used to further restrict sites for selection. Three wetlands on the North Branch of the Rancocas Creek were identified as suitable based on their size, stream order (comparable to that of sites in WMA6), and easily definable boundaries (Table 5).

Table 5: The size of three wetlands in Watershed Management Area 19 assessed in this study.

Wetland Name	Area (acres)
South Pemberton	15.0
Birmingham	31.0
Smithville	19.4

Figure 2. Location of WMA 19 wetland sites.



2. Terminology guide

In a study such as this, the terminology and definitions vary among methods. What one method may call an indicator may be referred to as a factor in another method. To avoid confusion, all wetland functions, values, or variables are referred to as functions, and all indicators, factors, considerations, or qualifiers are referred to as indicators in the body of this report. To provide guidance on how the different methods use the terminology, an explanation is provided below for terms and how they are actually used by each method.

Our use	Methods' terminology
Functions	Wetland Function Wetland Value Wetland Variable
Indicators	Indicators Factors Qualifiers Considerations

How we arrived at our classification terminology:

Descriptive Approach examines eight "functions" and five "values." "Functions" are those self-sustaining operations the wetland performs that have a physical or ecological impact on the area. "Values" refer to the usefulness of the site to humans beyond that of physical or ecological functioning. The method provides lists of "considerations/qualifiers" or "rationale factors." These qualifiers are used to indicate the rationale for decisions about whether or not a function is occurring at a site.

WET refers to both functions and values. It defines functions as the physical, chemical, and biological characteristics of the wetland and values as any characteristics that are beneficial to society. The method does not explicitly list indicators.

WI RAM frequently refers to functions as "functional values." The method does not explicitly list or refer to indicators, but rather presents lists of questions for evaluating each function.

VIMS refers to all functions as functions, but refers to what we categorize as indicators as "factors."

NC Guidance calls all its functions "values," by which it means functions that have some value to human society, whether the function is part of regular wetland ecosystem processes (e.g., water storage) or whether the wetland is simply useful to humans in some way (e.g., recreation/education). The method does not state or list indicators explicitly.

MDE employs six functions gleaned from The State of Maryland Nontidal Wetlands Protection Act of 1989. The method does not state or list indicators explicitly. However, the method differentiates among and defines functions, values, and indicators. Indicators are ecosystem characteristics, which, when combined, can be used to develop functional models. From these functional models, wetland functions can be derived. When considered on a landscape scale, these functions then can contribute to societal values.

WRAP primarily focuses on "variables" and indicators to assess wetland function. The variables approximate wetland function, but the variables themselves are more reflective of specific wetland characteristics that contribute to wetland functions, rather than of the functions themselves. Indicators are called indicators.

WMQA, like WRAP, primarily focuses on "variables" that approximate wetland function, so it does not evaluate wetland function per se. This reflects a greater focus on the wetland characteristics that contribute to wetland functions, rather than on the functions themselves. Indicators are called indicators.

3. Implementation

From June 2000 to September 2000, seven wetland functional assessment methodologies were applied at seven riverine wetlands in the Upper Passaic Watershed (WMA 6) in northeastern New Jersey. Three teams consisting of two people each applied the methods at each wetland site. Both team members had some wetland experience, and at least one team member had advanced experience and training in wetland vegetation, soils, and hydrology. All three teams were trained in each method prior to implementation in the field. Training time varied from one-half day to two days, depending on the method. While using the same team members for all assessment methods may have resulted in a tendency for teams to develop a perception of wetland function that influenced their scoring across the different scoring methods, variability among wetlands and functional methods followed no consistent pattern, suggesting that a 'team memory' did not predictably change method scoring.

Because of logistical considerations and the distance between wetland sites, one to three methods were implemented at a site during a visit. However, each method was done individually and in its entirety before additional methods were implemented. Three methods, WRAP, WI RAM, and MDE, were implemented on the same day at a site. VIMS, NC Guidance, and the Descriptive Approach were also on the same day at a site. WMQA took half a day per site, and two wetland sites were done per day. Implementing multiple methods on the same day could have influenced the variability between some method pairs due to lack of independence, but as previously mentioned there was no consistent pattern in the variation by wetland, date, or method.

In June 2001 the eighth assessment method, WET, was applied at the seven wetlands in WMA 6. Team leaders were consistent between years, and all team members were trained in the method during June 2001 by the project coordinator. Timewise, this method took one full day to apply at each site.

One person, who oversaw the entire project, organized data and information necessary to implement each method. Implementation of each method was divided into two portions, an office portion and a field portion. The office portion included examining available data, including NWI, topographic, and land use maps for each of the wetland sites (Table 6). The office portion of each method was completed for each site in the morning for the methods to be applied that day. The field portion of each method was then completed at each site in the afternoon.

In July 2001, five of the eight assessment methods were applied to three riverine wetlands in the Rancocas Creek Watershed (WMA 19). The five methods were selected based on their applicability to WMA 19 wetlands and their performance in WMA 6. Contractually, only two methods were to be applied in WMA 19, but no two methods were particularly more appropriate for across-watershed comparisons; consequently we included the five methods that were suitable. The methods that were applied included: WI RAM, VIMS, NC Guidance, MDE, and WRAP. The methods were performed in a fashion similar to that used for WMA 6, with an office portion and a field portion, as well as overlap in personnel.

4. Data Synthesis

Specifics for how we synthesized the data for each method are included with results for each method. Generally, for methods that were categorical we converted the ratings to numbers with low numbers reflecting low ratings and high numbers reflecting high ratings. For binary data such as the Descriptive Approach we converted the ratings into ±1.0 for data synthesis. For methods that assigned an overall score for the wetland or individual functions, no numeric adjustment was made. In all instances irrespective of the scoring type, for each method we evaluated all of the individual functions or indicators across all wetlands and this forms the primary basis for evaluating the different methods.

Since the methods have different approaches to assessing wetland function, it is not appropriate in most instances to directly compare the different methods. However, we could qualitatively compare each method's functional evaluations in the context of the river gradient, which also reflects an increasing urbanization gradient in the downstream direction for WMA 6. As previously mentioned, the wetlands also served as part of the reference set for the development of an HGM for low-gradient riverine wetlands. The reference wetland set was selected to reflect a disturbance gradient. To establish the gradient and identify the reference wetlands in the HGM model development, a combination of factors were used including disturbances within as well as adjacent to the site and disturbances within the wetland's subwatershed (Table 4, Hatfield et al. 2002). Consequently, there were two gradients, a river gradient and a disturbance gradient, that provided some basis for comparing how the different methods performed.

As another means of comparison, we also used the HGM functional capacity indices (FCIs, Hatfield et al. 2002) in the evaluation of the other wetland assessment methods. While we included the HGM indices, it does not necessarily mean that HGM is the standard by which to compare the other methods, rather it allows us to draw on our experience base with the HGM project and the development of the functional capacity indices for assessing wetland function. Since HGM was not directly part of this study, we did not have three teams independently apply the HGM model, thus there is just one functional capacity index score for each wetland function. In sum, for WMA6 we had three approaches for comparing the different functional assessment methods: the river gradient, the disturbance gradient, and the HGM FCIs.

Table 6. Materials required to complete the office and field portions of each of the eight methods.

Method	Materials Needed	
	Office	Field
Descriptive Approach	- USGS topographic maps - National Wetland Inventory (NWI) maps - Soils Conservation Service (SCS) soil surveys - Land use/land cover maps - Aerial photographs - Natural Heritage maps - Archaeological and historic site maps - Stocked Waters of New Jersey (1996) - NJ State Water Quality Inventory Report (1996) - Public drinking supply well maps - Sole-source aquifer maps - Biological monitoring data (NJDEP) - Surface water quality monitoring data (NJDEP)	Data Sheets
MDE	- USGS topographic maps * - National Wetland Inventory (NWI) maps * - Soils Conservation Service (SCS) soil surveys * - Land use/land cover maps * - Aerial photographs * - Natural Heritage maps * - 100-year floodplain maps *	- Data Sheets - pH meter * - Conductivity meter *
NC Guidance	- USGS topographic maps * - National Wetland Inventory (NWI) maps * - Soils Conservation Service (SCS) soil surveys * - Land use/land cover maps - Aerial photographs	- Data Sheets
VIMS	- USGS topographic maps * - National Wetland Inventory (NWI) maps - Soils Conservation Service (SCS) soil surveys * - Land use/land cover maps	- Data Sheets - Stadia rod * - Clinometer

	- Aerial photographs	
WET	- USGS topographic maps * - National Wetland Inventory (NWI) maps * - Soils Conservation Service (SCS) soil surveys * - Land use/land cover maps * - Aerial photographs * - Natural Heritage maps - HUC 14 watershed boundary maps - USGS Flood Hazard maps * - NJ State Water Quality Inventory Report (1996) - Public drinking supply well maps - Sole-source aquifer maps - Nonpoint source pollution data* - Sewage outfall data - Stream gauge data * - Biological monitoring data (NJDEP) - Surface water quality monitoring data (NJDEP)	- Data Sheets - USGS topographic maps * - SCS soil surveys * - Stream gauge data * - pH meter - Meter stick
WI RAM	- USGS topographic maps - National Wetland Inventory (NWI) maps - Soils Conservation Service (SCS) soil surveys - Land use/land cover maps - Aerial photographs - Natural Heritage maps	- Data Sheets - Soil auger - Munsell soil color chart Note: no materials were suggested in the documentation for WI RAM
WRAP	- USGS topographic maps * - National Wetland Inventory (NWI) maps * - Land use/land cover maps * - Aerial photographs *	- Data Sheets
WMQA	- USGS topographic maps * - National Wetland Inventory (NWI) maps * - Land use/land cover maps * - Aerial photographs *	- Data Sheets - Soil auger

* Materials suggested by methodology documentation and other items provided in method documentation.

For the different methods in WMA 19, we compared if any revealed a sensitivity to river gradient. Water quality impairments in both the upstream and downstream directions (NJPIRG 2001) also provided some context in which to test method sensitivity to these factors, in contrast to WMA6 wetlands where there was no recorded impairment.

To examine how similarly the teams assessed the wetlands within each of the methods, we took two different approaches depending on the scoring method for each wetland. For those methods that used categorical ratings, we constructed a matrix of team scores and assigned ranks to reflect the degree of agreement. For example, when all team scores agreed on a rating for a particular function, irrespective of what the ranking was, we rated the function as high agreement. For those with three categories (high, medium, low), complete agreement was assigned a 3. For those methods that had four categories (exceptional, high, medium, low), complete agreement was assigned a 4. Functions in which two teams agreed and the third did not, but where the scores varied only by one level (i.e.,H-H-M), agreement was assigned as 2. When agreement was the same for two teams but the third score varied by two levels (i.e.,H-H-L), agreement was assigned a 1. When none of the three teams agreed, an agreement rating of 0 was assigned. The agreement rating for each function was summed across all seven wetlands and divided by the maximum score possible to derive a percentage of agreement among the teams for a particular function. This procedure was done for all of the functions within a method for the Descriptive Approach, WET, VIMS, and WI RAM.

For the numeric methods that assigned a composite wetland score between 0 and 1.0 or 100 (MDE, NC Guidance, WRAP, and WMQA), we compared the different teams' scores for the wetland using the Kruskal-Wallis statistic since team scores were not normally distributed. Since MDE and NC Guidance also assign numeric values to the individual variables, we used the Kruskal-Wallis statistic to test for differences in team scores for the individual variables. For WRAP and WMQA, we used the agreement rating procedure described previously to evaluate team scores for the individual functions (due to the prevalence of ties with these two later methods).

We also evaluated training requirements for each method, how easy it was to obtain the materials necessary to do each method, how much time was needed to conduct each method, how well documented each method was, and how easy it was to follow each method's instructions.

D. Quality Assurance Program

All aspects of the work were under the direction of a project director, who was responsible for establishing and monitoring the design, implementation and analysis of the project. A lead field technician, who worked under the direction of the project director, was responsible for coordinating field efforts, training personnel, maintaining the database, and overseeing data validation and quality control. All data was entered and independently verified for both the database of wetland method types and the field data.

All participants in the study were field trained together during a one- to two-day training session per wetland method, and the training was consistently led by the lead technician. All participants had some previous experience with wetlands, and two participants in addition to the lead technician had extensive wetland experience. Those with advanced wetland experience served as team leaders for the three separate teams.

Each of the three teams applied each of the methods to each wetland independently. While there was overlap in when the teams were completing the office portion of the methodology, and the teams evaluated the sites within the same time frame, explicit attention was paid to limiting interactions among the teams that might bias application of the method. Procedures were in place to ensure completion of all data sheets while in the field, and data sheets were rechecked in the lab on the same day.

Data collection followed all sampling protocols outlined in each of the assessment methods and followed standard procedures. Data entry was done by the lead technician and validated independently. Data analysis and synthesis of the study were coordinated and conducted by the project director and lead technician.

CHAPTER 3. RESULTS

Results are presented for each of the two watersheds. Within each watershed results are organized by each of the wetland assessment methods. For methods that do not provide an overall wetland score, results are provided for the individual functions. For wetlands that assign a single wetland score, both the wetland score and the scores for the individual functions are included. The results are organized along the river gradient from upstream to downstream for each of the methods. For WMA 6, Great Swamp is the most upstream site, followed by Dead River, South Main, Roosevelt, East Orange, Sommers Park and finally Horseneck Bridge as the most downstream wetland.

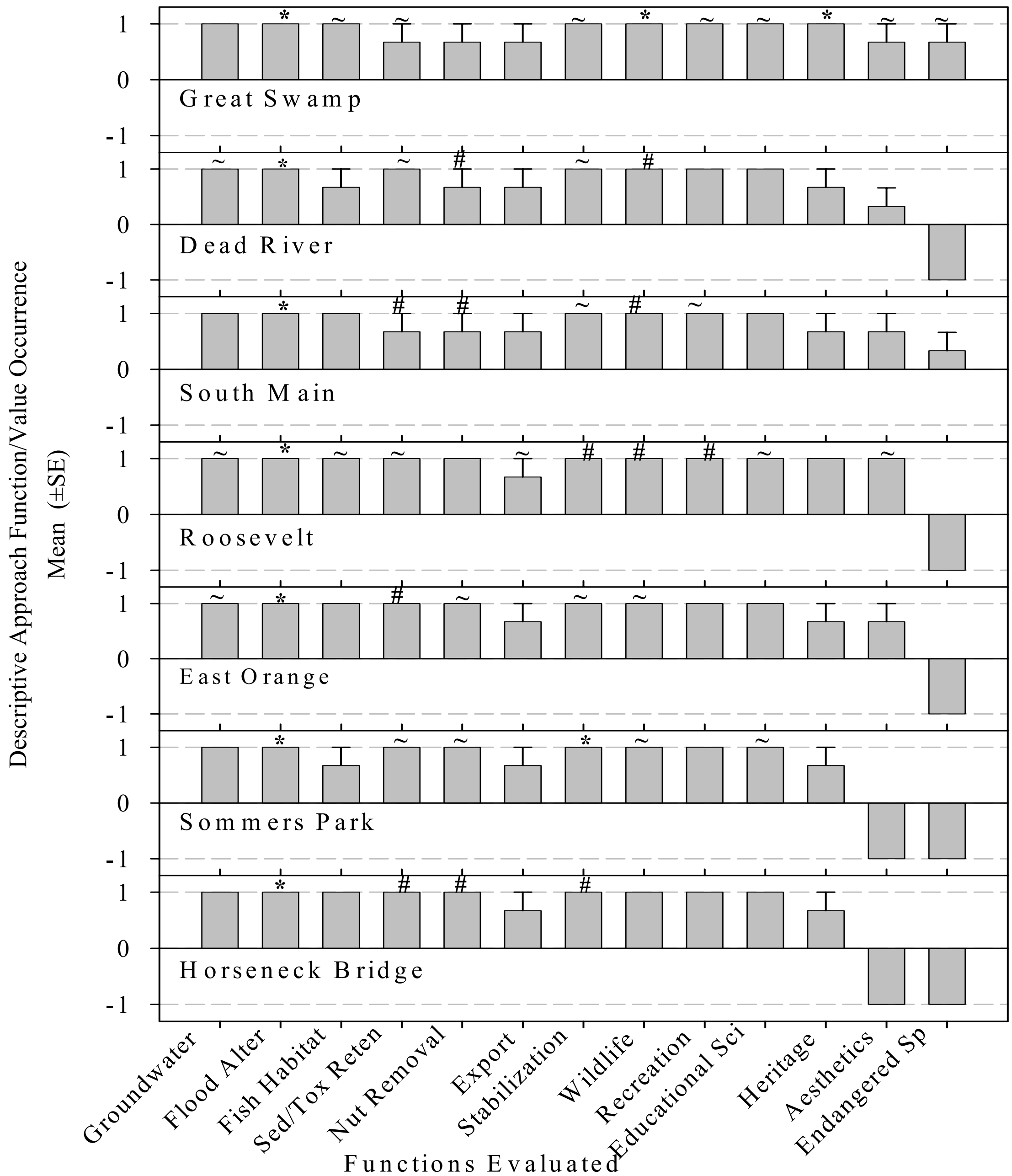
A. Watershed Management 6 (WMA 6)

Descriptive Approach

The Descriptive Approach uses a suite of indicators to evaluate whether a wetland function occurs within the wetland. The function is considered to be present (Yes) or absent (No), and it is noted whether a function is a primary function for the wetland. Most of the thirteen functions evaluated occurred to some degree in all of the wetlands in WMA 6 (Figure 3). Endangered species was the only function that was absent in the majority of the wetlands, and visual quality and aesthetics were absent from the two most downstream wetlands.

Flood alteration was considered to be a principle function for all of the wetlands by all of the teams (Figure 3). Sediment/toxicant retention and sediment stabilization were also considered important functions by at least two teams (Figure 3). However, more frequently, only one of the three teams considered a function to be a principle function (~).

Figure 3. Descriptive Approach scores for the seven riverine wetlands in WMA 6.



Yes/No responses were recorded as numeric values (Yes = +1, No = -1) for graphic purposes. Mean and standard errors were calculated for the different team responses for the Yes/No answers based on ±1 values. Bars represent average and standard errors of three teams ratings of each wetland. * - Functions that were considered principle functions by all three teams; # - Two teams agreed on a principle function; ~ - One team selected the function as principle. More than one function can be considered a principle function for a particular wetland. On the x-axis, Groundwater = groundwater recharge/discharge, Flood Alter = Flood Alteration, Fish Habitat = Fish and Shellfish Habitat, Sed/Tox Reten = Sediment/Toxicant Retention, Nut Removal = Nutrient Removal, Export = Production Export, Stabilization = Sediment/Shoreline Stabilization, Wildlife = Wildlife Habitat, Recreation = Recreation, Educational Sci = Educational Scientific Value, Heritage = Uniqueness/ Heritage, Aesthetics = Visual Quality/Aesthetics, and Endangered Sp = Endangered Species Habitat.

Wetlands did not necessarily score higher based on location on the river gradient with Horseneck Bridge, the most downstream wetland, having as many or more functions present as Great Swamp and Dead River, the two most upstream sites. Function also did not necessarily reflect disturbance since the most disturbed sites, East Orange, Roosevelt and Horseneck Bridge, had as many or more functions present as the less disturbed sites.

There was complete consensus for six of the thirteen functions between the different teams. These included groundwater recharge/discharge, flood alteration, sediment/shoreline stabilization, wildlife habitat, recreation, and education and scientific value. For any of the functions that did not score ± 1 in Figure 3, at least one of the teams did not agree with the other teams. For example, for Great Swamp there were five functions in which at least one team considered the function was not present while all three teams agreed that the remaining eight functions were present. This lack of consensus varied to some degree from one wetland to the next and was most prevalent in the upper portion of the river gradient. When the teams started with the method, they started with the most upstream wetlands and experience may account for a greater tendency for agreement in the downstream sites as evaluators became more familiar with the methodology. However, there was a consistent discrepancy with the Production Export function, which may suggest ambiguity in how the indicators are interpreted. Furthermore, the Heritage function lacked consensus in five out of seven times which spanned the entire river gradient. Finally, the lack of consensus on which functions were principle reflects the general lack of guidance in determining this component of the method.

Wetland Evaluation Technique (WET)

For this method, each wetland was evaluated for three different aspects of wetland function: social significance, effectiveness, and opportunity. Each aspect was considered based on the qualitative probability that a wetland function will occur within the wetland. Individual functions were rated low, moderate, or high probabilities (or in some instances uncertain). We assigned numeric values to each of these categories for graphing purposes and for assessing the variability among the different teams. A value of 1 was assigned to a low rating and 3 to a high rating. If there was uncertainty about a function in a particular wetland, it was left blank for that wetland when it was to be converted to a numeric value. The mean and standard error of the assigned ratings among teams was determined.

<u>WET Social Significance:</u>

For the social aspect of wetland function, none of the wetlands in WMA 6 had a consistently low rating for all functions (Figure 4a). In fact, the majority of the ratings were moderate or higher for all functions and all wetlands. Horseneck Bridge, the most downstream site, tended to have higher ratings across the different functions, with 8 of the 10 functions rated at moderate to high. For Great Swamp, the most upstream site, six of the ten functions approximated a high probability of providing that function; however, Great Swamp also had a relatively low probability of sediment stabilization. South Main and Roosevelt wetlands displayed the greatest variability among functions, having a number of both high and low scores each. South Main was rated as having low probability of altering floodwaters and supporting aquatic habitat diversity, while Roosevelt had a low probability of altering floodwaters and stabilizing sediment.

Recreation tended to score low for all of the wetlands. With the exception of some unmaintained passive hiking trails, none of the wetlands have exceptional recreational resources or provide a major public access to the river. In contrast, heritage scored the maximum for all of the wetlands. Other functions that consistently scored high across all wetlands were recharge, sediment/toxicant retention, nutrient removal and transformation, and wildlife. Other functions tended to vary by wetland. The more variable functions across the different wetlands include flood alteration, aquatic habitat, and sediment stabilization.

In terms of gradients, the sediment stabilization function tended to increase in the downstream direction, while aquatic habitat diversity was rated highest at the two ends of the river gradient (Great Swamp and Horseneck Bridge). None of the functions appeared to reflect the disturbance gradient.

For functions that overlap with or were somewhat similar to functional capacity indices (FCIs) from the HGM model, we included the FCI scores for these wetlands (Figure 5). Though HGM evaluates functions based on relative functional capacity, and WET evaluates the probability of a function occurring in the wetland, if a function receives a relatively high FCI score then it is reasonable to assume that that function should also have a high probability of occurring. In general, HGM tended to score the individual functions higher for the different wetlands, though there are exceptions. The wildlife function consistently scored lower in the HGM than in WET Social Significance for all of the wetlands. HGM suggests a downstream decrease in nutrient transformation that reflects both the river and disturbance gradients but this trend does not show up in WET Social Significance. The retention function was probably the most consistently evaluated by both methods, with HGM rating it only slightly higher or the same as WET. The function that consistently displayed the largest difference was flood flow alteration; HGM generally tended to score it considerably higher for all of the wetlands compared to WET Social Significance. The functions that were most variable in the scores for HGM and WET included nutrient transformation and groundwater recharge.

All of the teams agreed on the WET Social Significance heritage rating (i.e.,no variability) and also tended to agree on nutrient transformation (Figure 4a). Groundwater discharge had the greatest difference among the teams, perhaps suggesting ambiguity in how the function was interpreted. Sommers Park and Roosevelt exhibited consistent differences among team scores across the different functions with teams agreeing only on one of the ten functions.

<u>WET Effectiveness:</u>

For WET Effectiveness, again the majority of the wetlands scored moderate or higher for most of the wetland functions (Figure 4b). South Main tended to have the greatest variability, with only three functions rated as high (transformation, breeding, and wintering), groundwater discharge rated as low and recharge uncertain. Great Swamp was rated high for all but the four wildlife habitat components (breeding, migration, wintering, and aquatic) and export. Four of these five functions were rated moderate. Only migration and recharge were considered to have a relatively low functional probability for this wetland. Roosevelt tended to score the lowest for the functions with three of the functions (groundwater recharge, groundwater discharge, and production export) receiving low scores and only two (nutrient transformation and winter wildlife habitat) of the eleven functions receiving high scores.

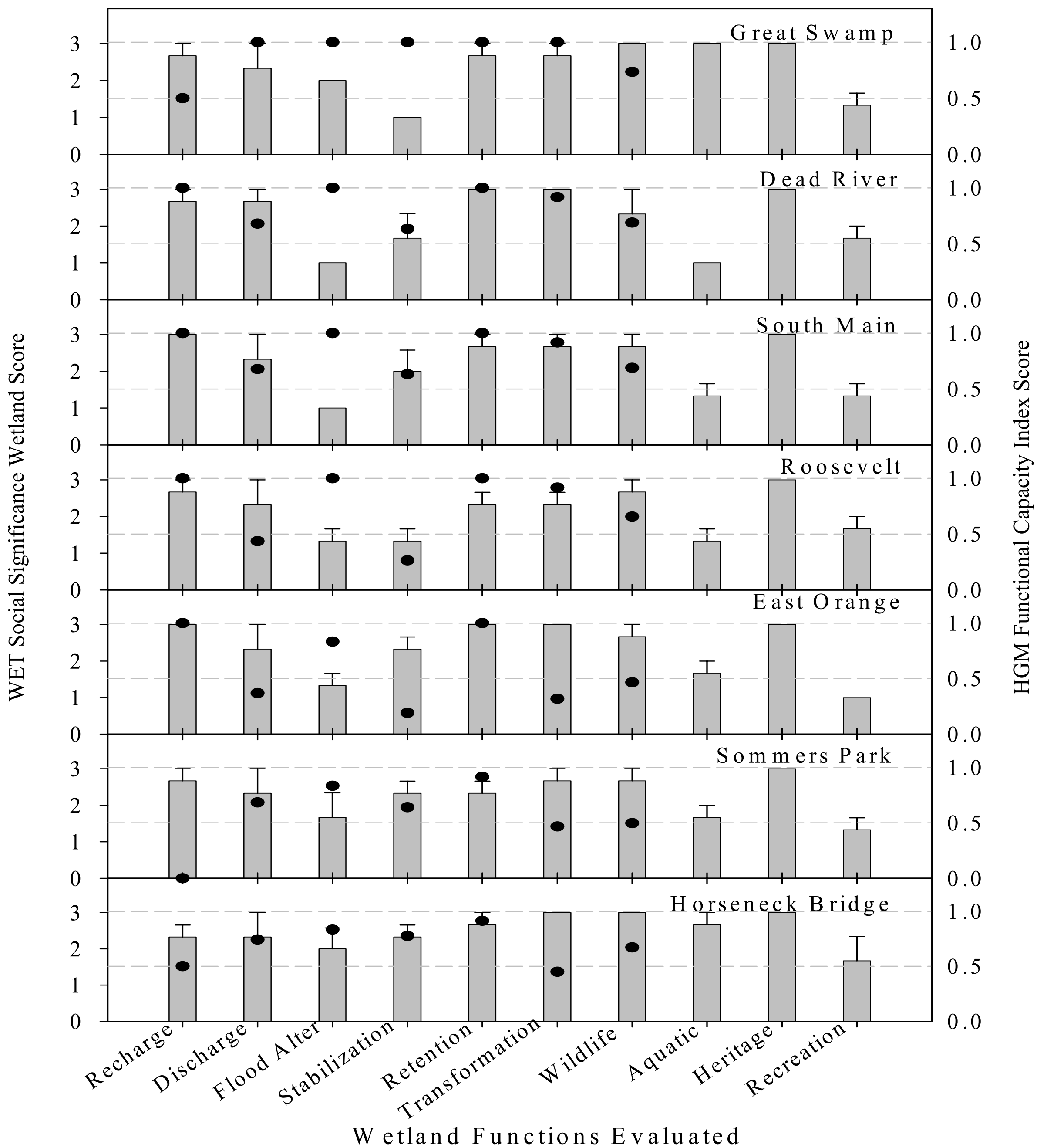
Groundwater recharge was consistently difficult to determine using the effectiveness criteria. There was sufficient indication of recharge for only three of the wetlands using the WET criteria. Groundwater discharge was the most variable function across the wetlands scoring moderately high at Great Swamp and low at South Main and Roosevelt. Transformation was considered high for all wetlands except Horseneck Bridge, where it received a moderate. Sediment/toxicant retention was high for all wetlands except two midstream sites, South Main and Roosevelt where it was rated as moderate. Unlike WET Social Significance, where flood alteration received low scores, flood alteration generally scored moderately high to high across the seven wetlands.

With the exception of Great Swamp, groundwater discharge increased in the downstream direction with Dead River, Sommers Park, and Roosevelt all receiving low scores. Conversely, aquatic habitat and to a lesser extent winter habitat decreased in the downstream direction. Otherwise, there was no apparent trend of function varying with downriver gradient for any of the functions, individually or collectively. In addition, wetland functioning did not appear to follow the disturbance gradient.

As with WET Social Significance, HGM FCI scores tended to be higher or equal to WET Effectiveness ratings for many functions (Figure 4b). Both HGM and WET Effectiveness were quite close in function assessment for Great Swamp and were somewhat close in five of the seven wetlands for flood flow alteration and retention. It was possible to determine groundwater recharge in HGM but more difficult with WET Effectiveness. HGM showed a downriver gradient in nutrient transformation, while WET Effectiveness consistently scored this function as high for all wetlands. Production export was consistently higher in HGM than with WET Effectiveness. Nutrient removal/transformation and sediment stabilization varied the most between the two methods.

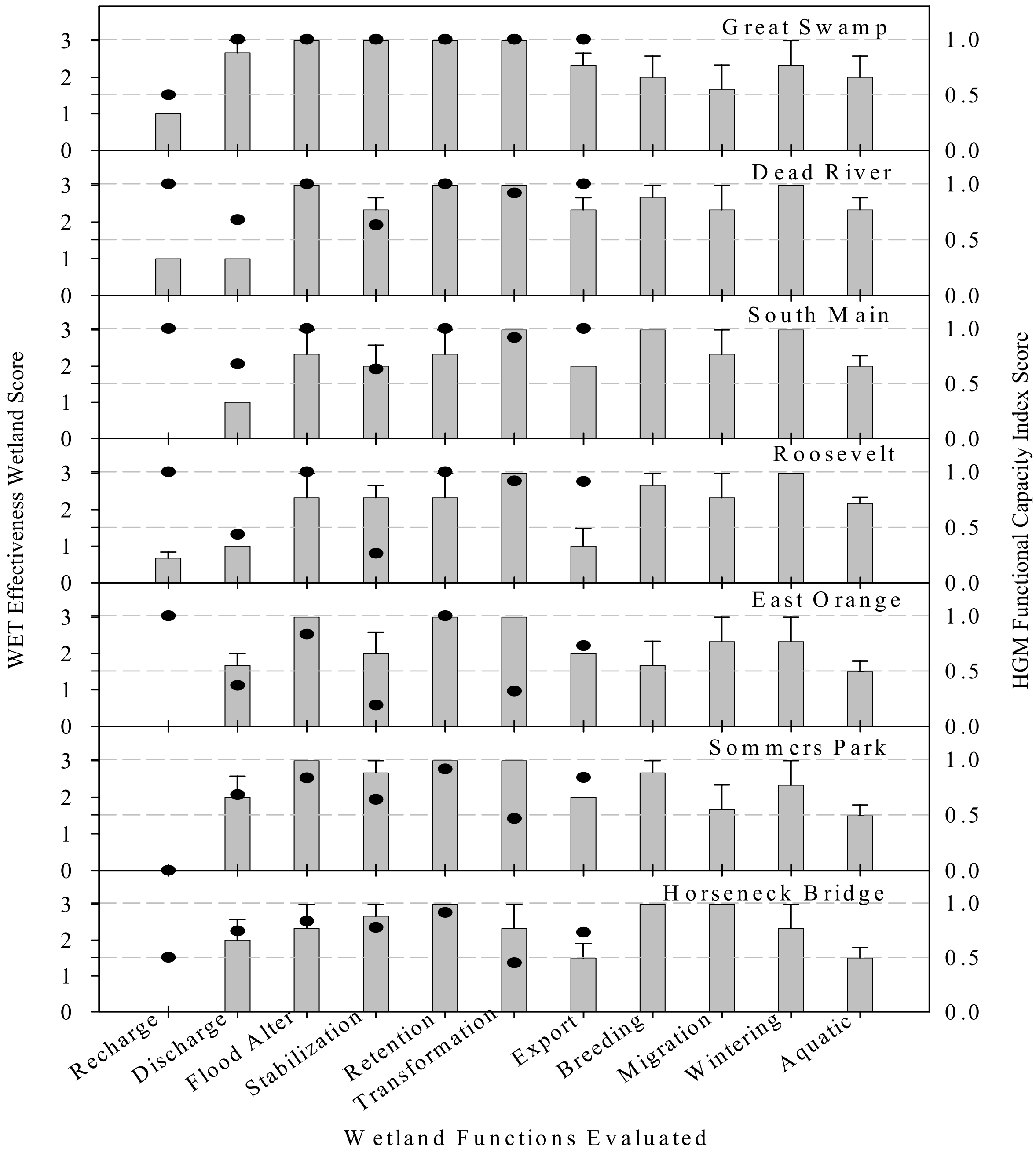
The habitat components, breeding, migration and wintering, had the highest variability among the different teams. This reflects the difficulty in determining some of the indicators for these functions with only one site visit. Sediment stabilization was also somewhat variable. Teams agreed in their assessment of nutrient transformation for the most part and there tended to be consensus for flood flow alteration. However, in general, team scores varied among functions and wetlands for Wet Effectiveness.

Figure 4a. WET Social Significance scores for the seven riverine wetlands.



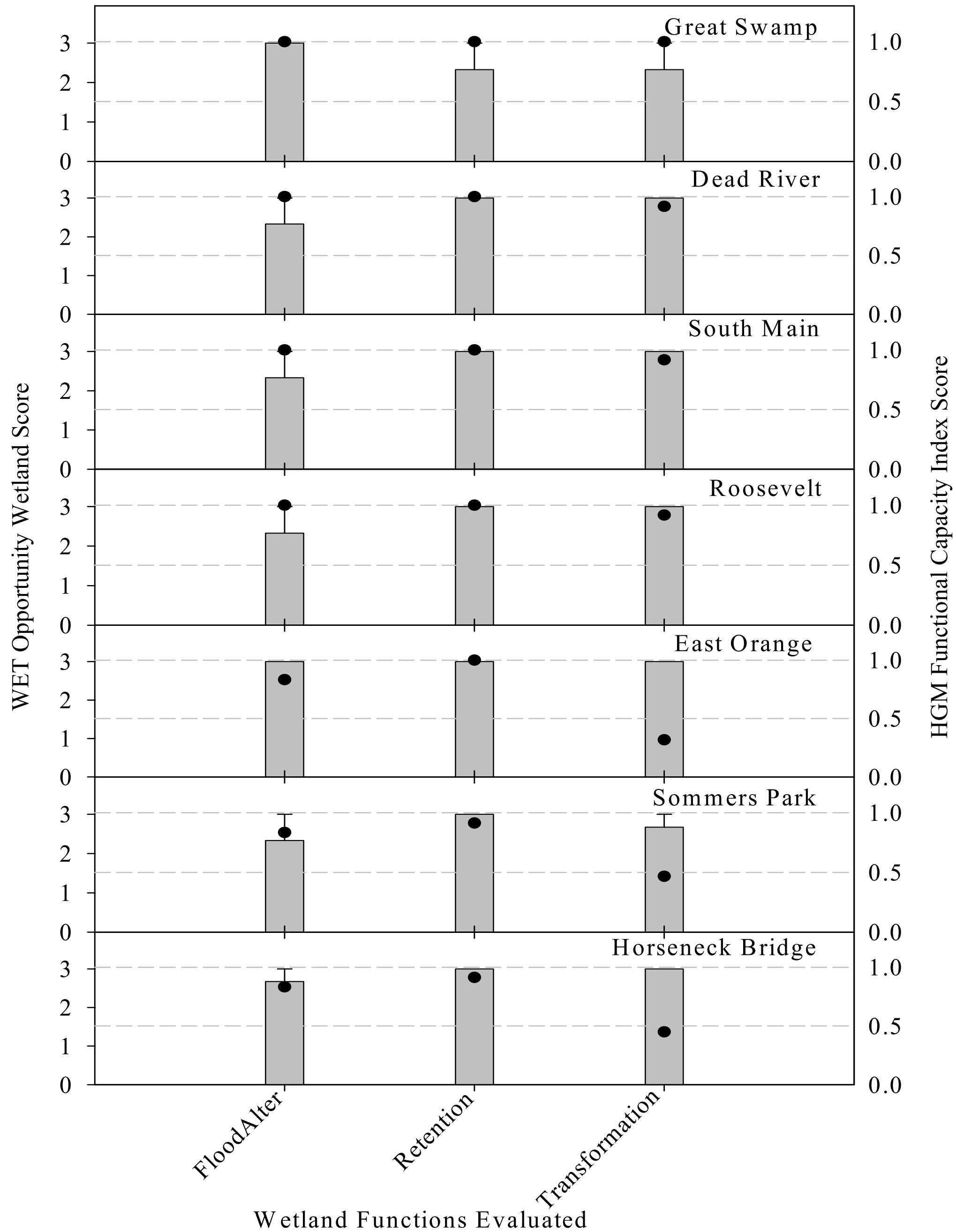
Bars represent average and standard errors of three teams' ratings of each wetland. Ratings were low (1), moderate (2), or high (3) for the relative probability that a particular function will occur in the wetland. Dots (●) represent the HGM functional capacity index values for wetland functions that are evaluated in both WET and HGM. The range for HGM FCIs is 0.0-1.0 (represented on the right y-axis). On the x-axis, Recharge = Groundwater Recharge, Discharge = Groundwater Discharge, Flood Alter = Floodflow Alteration, Stabilization = Sediment Stabilization, Retention = Sediment/ Toxicant Retention, Transformation = Nutrient Removal/Transformation, Wildlife = Wildlife Diversity/Abundance, Aquatic = Aquatic Diversity/Abundance, Heritage = Uniqueness/Heritage, and Recreation = Recreation.

Figure 4b. WET Effectiveness scores for the seven riverine wetlands.
Bars represent average and standard errors of three teams' ratings of each wetland. Ratings were low (1),



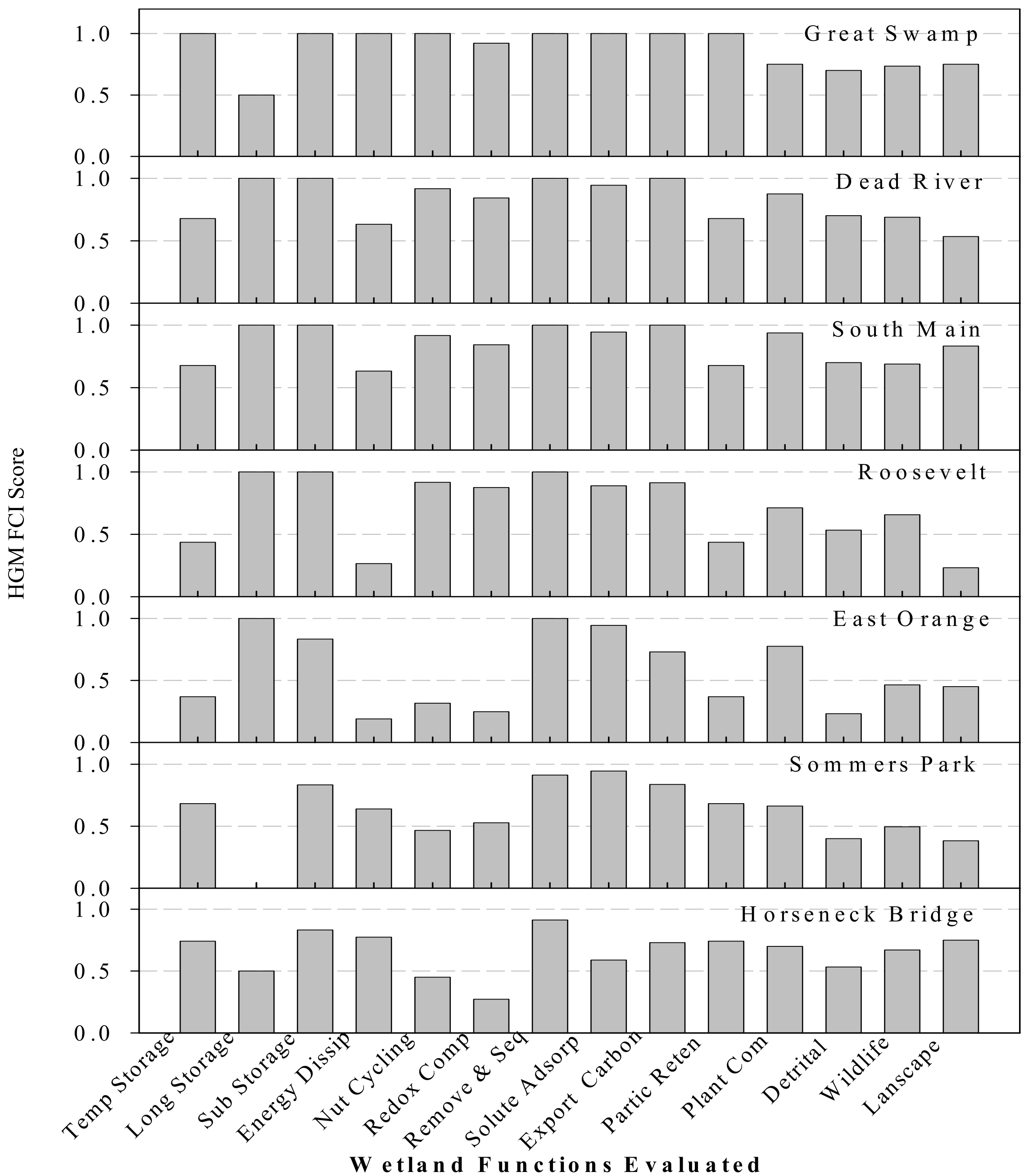
moderate (2), or high (3) for the relative probability that a particular function will occur in the wetland. Dots (●) represent the HGM functional capacity index values for wetland functions that are evaluated in both WET and HGM. The range (represented on the right y-axis) for HGM FCIs is 0.0-1.0. On the x-axis, Recharge = Groundwater Recharge, Discharge = Groundwater Discharge, Flood Alter = Floodflow Alteration, Stabilization = Sediment Stabilization, Retention = Sediment/ Toxicant Retention, Transformation=Nutrient Removal/Transformation, Export = Production Export, wildlife is represented by three components: Breeding, Migration, and Wintering Habitat, and Aquatic = Aquatic Diversity/Abundance. While HGM does include a wildlife FCI, HGM does not break it down into component parts, so it is not included in this comparison.

Figure 4c. WET Opportunity scores for the seven riverine wetlands.



Bars represent average and standard errors of three teams' ratings of each wetland. Ratings were low (1), moderate (2), or high (3) for the relative probability that a particular function will occur in the wetland. Dots (●) represent the HGM functional capacity index values for wetland functions that are evaluated in both WET and HGM. The range (represented on the right y-axis) for HGM FCIs is 0.0-1.0. On the x-axis, Flood Alter = Floodflow Alteration, Retention = Sediment/Toxicant Retention, and Transformation = Nutrient Removal/Transformation.

Figure 5. HGM scores that rate functional capacity indices (FCIs) for the seven wetlands.



The maximum wetland score for an FCI = 1.0. Bars represent the scores that were determined for each wetland for an HGM model for riverine floodplain wetlands (Hatfield et al. 2002). Temp Storage = Temporary Surface Storage; Long Storage = Long Term Surface Storage, Sub Storage = Subsurface Storage, Energy Dissip = Energy Dissipation, Nut Cycling = Nutrient Cycling, Redox Comp = Cycling of Redox-Sensitive Compounds, Remove&Seq = Remove and Sequester Elements & Compounds, Solute Adsorp = Solute Adsorption Capacity, Export Carbon = Export Organic Carbon, Partic Reten = Particulate Retention Capacity, Plant Comm = Maintain Characteristic Plant Community, Detrital = Maintain Characteristic Detrital Biomass, Wildlife = Provide Wildlife Habitat, and Landscape = Landscape-scale Biodiversity.

WET Functional Opportunity:

Finally, for Functional Opportunity, each of the seven sites consistently rated moderate or higher for the three functions. East Orange was the only site considered to have high scores for all three functions (Figure 4c). Great Swamp received high functioning only for flood alteration while the remainder of the sites scored high in two of the three functions.

Retention and transformation scored high for all of the wetlands except Great Swamp, while floodflow alteration ranged between moderate and high. There was no detectible response to either the river or disturbance gradient across the three functions. HGM scores were close (retention) or a bit higher for most of the wetlands. The exception was transformation, where again we see the downstream decrease in HGM scores versus the consistently high ratings for WET.

Teams agreed on wetland function for nutrient transformation and sediment retention for all of the wetlands except Great Swamp, where one of the teams ranked these functions as moderate and the other two ranked them as high. Flood alteration was the most variable from team to team.

Rapid Assessment Methodology for Evaluating Wetland Functional Values (WI RAM)

WI RAM assigns functional ratings using indicators of wetland function. The categorical ratings of wetland functional were converted to numeric values for graphical purposes and for comparisons among the different team scores. Scores of Low were represented as 1, Medium as 2, High as 3, and Exceptional as 4. Averages and standard errors of team scores were calculated. The majority of the wetlands were scored as having between medium and high value for most of the functions, but no single wetland consistently scored high across all wetland functions (Figure 6). Great Swamp was most variable with exceptional value for wildlife habitat and aesthetics/education but a relatively lower value for fisheries habitat and groundwater recharge/discharge. South Main consistently scored the highest across the functions with five of the functions scoring moderate or higher. Conversely, East Orange, Sommers Park, and Horseneck Bridge tended to have moderate or lower functioning across the eight wetland functions.

Scores for individual functions varied widely. With the exception of Great Swamp, flood attenuation generally scored high. The fisheries habitat functional value was consistently low across all seven wetland types. This is somewhat a function of the wetland type in that, while the wetlands are inundated for part of the year, inundation does not generally coincide with fish spawning or times when nursery habitat is critical. The method was sufficiently sensitive to detect the lack of fisheries habitat. In addition, the somewhat low score for groundwater function value is a reflection of the strong link between the wetland and the adjacent river, as well as a relatively impervious soil layer that retards groundwater recharge. Shoreline protection also consistently scored low across the different wetlands.

Individual functional values tended to decrease in the downstream direction with Great Swamp, Dead River, South Main, and Roosevelt, all having the majority of the function scores higher than medium. In contrast, for East Orange, Sommers Park, and Horseneck Bridge, 50 percent or fewer of the functions scored above medium (with Horseneck Bridge having only two functions that scored higher than medium).

Two of the functions seemed to reflect the river gradient but in opposite directions. Floodwater attenuation increased in the downstream, while aesthetics, recreation, and education decreased in the downstream direction. Floodwater attenuation is somewhat linked to wetland size, and there is a tendency for wetland size to increase in the downstream direction (Table 4). In contrast, the decrease in functional value for aesthetics, recreation, and education may reflect the urbanization gradient as well as the river gradient, since the extent of urbanization increases in the downstream direction. In addition, the aesthetics, recreation, and education function somewhat reflected the disturbance gradient with East Orange and Horseneck Bridge, the more disturbed sites, having lower scores. The exception to this is Roosevelt, which was considered to be relatively disturbed and yet this function received a high score from all three teams.

When compared to HGM FCI values, there is no general consensus between HGM and WI RAM within wetlands or across functions though there was closer agreement with the two most downstream wetlands, Sommers Park and Horseneck Bridge, as well as South Main. The FCI values for groundwater and water quality were close to or higher than the WI RAM scores across all of the wetlands, whereas the wildlife score is generally lower. Though variable in direction of difference in WI RAM, floral diversity most closely approximates the same score for the two methods, while flood attenuation and shoreline protection was the most variable.

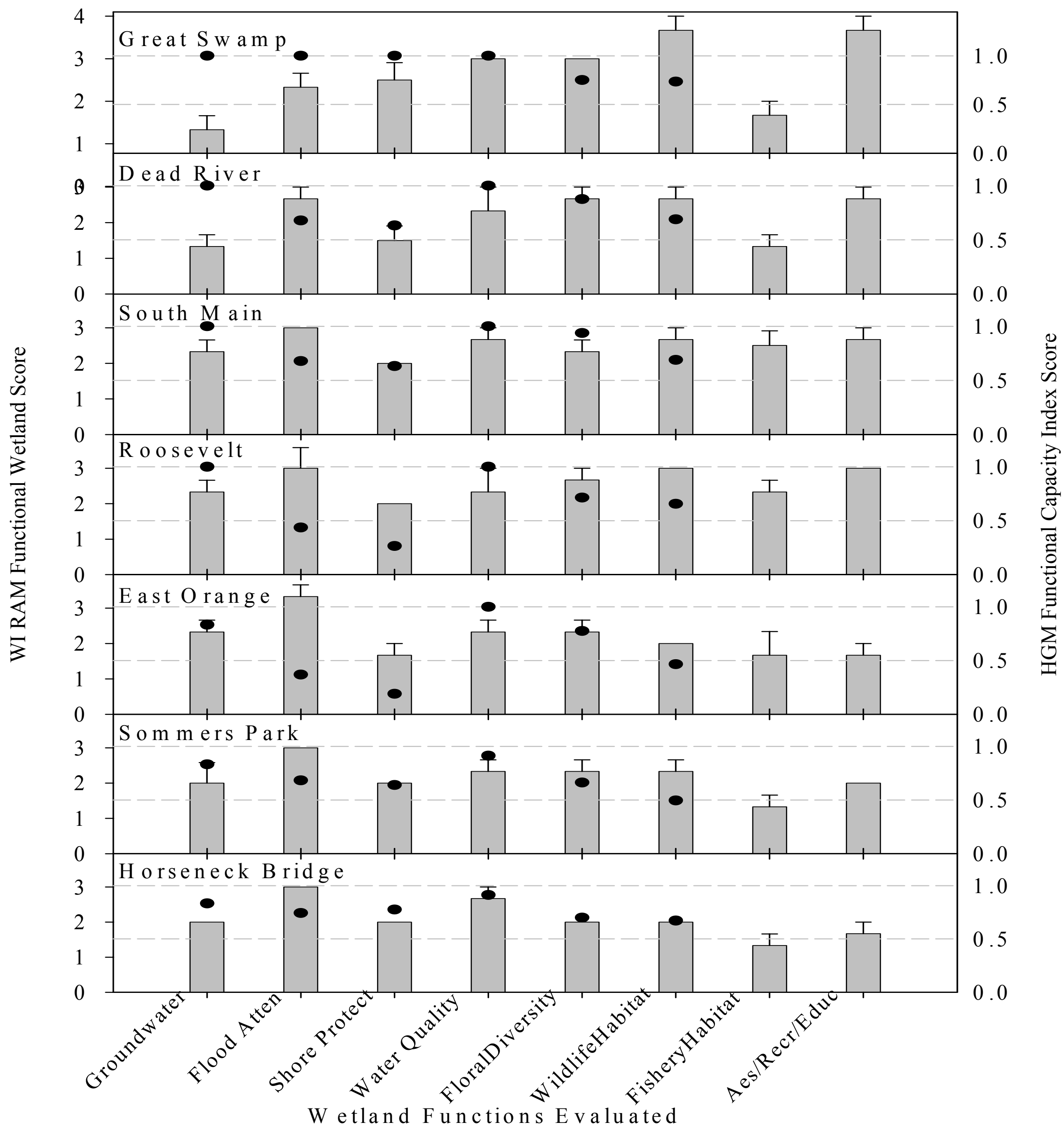
The three teams did not consistently agree or disagree on any one function or for any one wetland, though there was generally greater variability in team scores for fishery habitat. Dead River tended to be the most variable in that it was the only wetland where the three teams differed in their scores for all of the functions. This is in contrast to the remainder of the wetlands where one or more functions were scored consistently across teams.

VIMS

VIMS ranks the probability that different functions will occur in the wetland with high, moderate, or low probabilities. The method evaluates seven functions. We also included two of the "Other factors" in our assessment - landscape disturbance and disturbance within the wetland - and assigned them probabilities similar to the other functions. For these factors, however, if the disturbance was considered high, we assigned it a value of 1, and low disturbance was assigned a 3. While there were additional factors included in the "Other factors" category, they were not conducive to assigning a relative probability and were excluded in this analysis. To compare the categorical rankings graphically and among teams, scores were converted to 1 for low, 2 for moderate, and 3 for high probability. The scores for the three teams were averaged for each site and variability among team scores was determined.

Many of the functions assessed were considered to have moderate or lower probability of occurring. There was also a trend for lower probabilities in the downstream direction (Figure 7). In fact, the three most downstream wetlands were rated markedly lower in wetland functioning than the upstream sites. The exception was Great Swamp, which had moderate or higher probability of a function occurring in six out of nine functions. Great Swamp had the highest probability for wetland function for flood alteration, wildlife and aquatic habitat, and low landscape disturbance, but the wetland was also considered to have a low probability for nutrient transformation. The most downstream wetland, Horseneck Bridge, tended to have the lowest probabilities of wetland function, with only flood storage and flow alteration scoring a high probability.

Figure 6. WI RAM scores for the seven riverine wetlands in WMA 6.



Bars represent average and standard errors of three teams' ratings of each wetland. Ratings were low (1), moderate (2), high (3), or exceptional (4) as a measure of the wetland functional value. Dots (●) represent the HGM functional capacity index values for wetland functions that are similar between WI RAM and HGM. The range (represented on the right y-axis) for HGM FCIs is 0.0-1.0. On the x-axis, Groundwater = Groundwater Recharge/Discharge, Flood Atten = Flood and Stormwater Storage/Attenuation, Shore Protect = Shoreline Protection, Water Quality = Water Quality Protection, FloralDiversity = Floral Diversity, WildlifeHabitat = Wildlife Habitat, FisheryHabitat = Fishery Habitat, and Aes/Recr/Educ = Aesthetics/Recreation/Education.

Flood storage and alteration had a high probability across all wetlands, followed by sediment stabilization. Disturbance in the landscape and wetland increased downstream, reflecting the increasing urbanization. The probability of wildlife and aquatic habitat occurring also decreased downstream, while sediment stabilization tended to remain consistent in the moderate range along the river gradient. None of the functions closely followed the disturbance gradient. While landscape disturbance and wildlife habitat had low scores for the most disturbed site, East Orange, these two functions were comparable or lower for Sommers Park, which was considered a moderately disturbed site.

Only four functions were in common between the HGM and VIMS, but there was no consistent pattern in scores for these functions between the methods. In some instances, HGM scored higher or equal to the ratings with VIMS (i.e., Great Swamp), but in other instances, VIMS ratings were higher (East Orange). VIMS nutrient transformation scored similarly across all wetlands save Great Swamp, while there was a distinct upstream to downstream trend with HGM where the score became lower as one moved downstream. Sediment stabilization was the least variable between the two methods. Though VIMS assigned a higher probability for sediment stabilization versus HGM, the relative difference between the two methods was smaller for this function than for the other functions. Sommers Park and Horseneck Bridge were most consistent in how the two methods evaluated them.

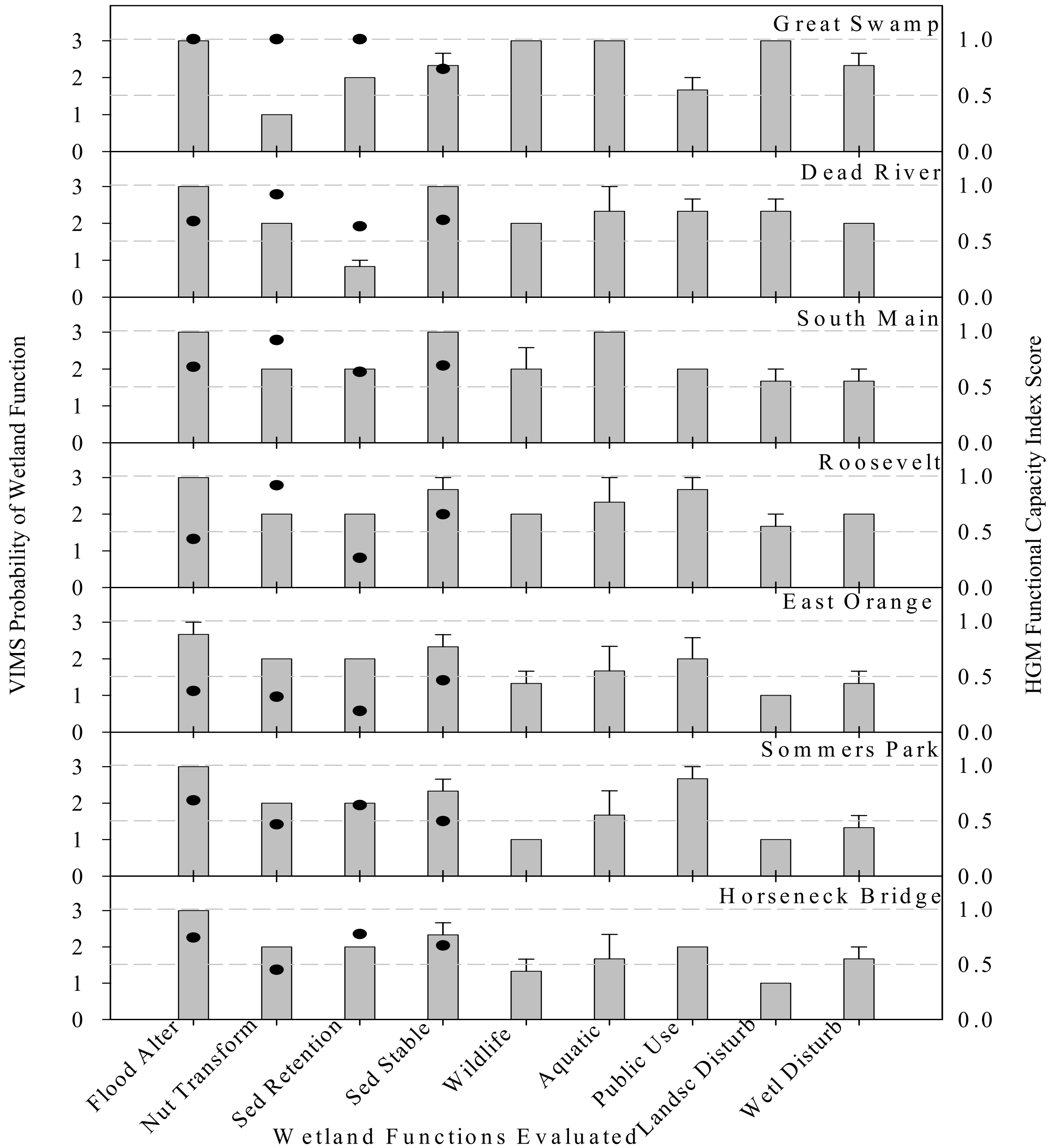
Teams tended to assign the same probabilities to flood alteration, nutrient transformation, and sediment retention, while disagreeing most widely on aquatic habitat. Public use of the wetland was probably more variable because the rating was determined by only one indicator, allowing differences in judgment to have a larger effect on the overall rating.

Guidance for Rating the Values of Wetlands in North Carolina (NC Guidance)

The NC Guidance method evaluates wetland value, which is somewhat different than the other methods that evaluate capacity or probability of wetland functioning. With NC Guidance, value is based on wetland functions that have positive effects for people and society. Individual functions (scored between 0-5) are multiplied by a predefined weighting factor to obtain the overall wetland score, ranging between 0 and 100. Consequently, with this method, the wetland receives an overall score.

The scores for the seven wetlands in WMA 6 tended to increase in the downstream direction and the lower five wetlands rated higher than 85 for wetland value (Figure 8). The highest scoring wetland was Horseneck Bridge (91.6 ± 0.9 out of a possible 100), the most downstream wetland, while the lowest scoring wetland was Great Swamp (60.8 ± 1.9), the most upstream wetland. As the Passaic River flows downstream from the Great Swamp, development increases within the watershed and water quality decreases, due to increased septic seepage, urban surface and road runoff, stormwater outfalls, and road and building construction (NJDEP 1996). The increase in scores along this gradient of increasing urbanization demonstrates the method's sensitivity to wetland functions that exert a more direct impact in close proximity to populated areas. This is the only method we examined that consistently showed this pattern.

Figure 7. VIMS scores for the seven riverine wetlands in WMA 6.



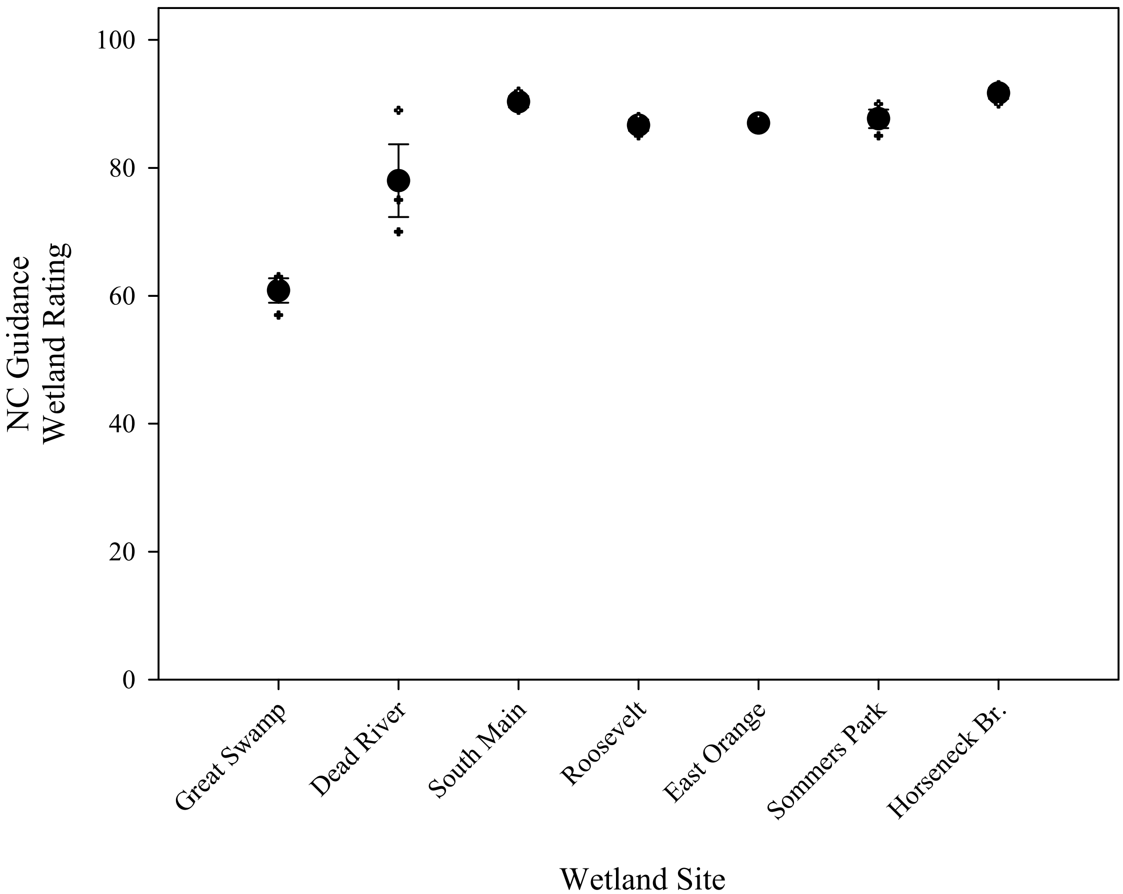
Bars represent average and standard errors of three teams' ratings for each wetland. Ratings were low (1), moderate (2), or high (3) as a measure of the probability that wetland functional will occur. Dots (●) represent the HGM functional capacity index (FCI) values for wetland functions that are similar between VIMS and HGM. The range (represented on the right y-axis) for HGM FCIs is 0.0-1.0. On the x-axis, Flood Alter = Flood Storage and Flood Flow Alteration, Nut Transform = Nutrient Retention and Transformation, Sed Retention = Sediment/Toxicant Retention, Sed Stable = Sediment Stabilization, Wildlife = Wildlife Habitat, Aquatic = Aquatic Habitat, Public Use = Public Use, Landsc Disturb = Landscape Disturbance, and Wet Disturb = Wetland Disturbance.

We also examined the individual functions to see how their scores changed with the wetland being examined (Figure 9). Note, we did not include the weightings with this analysis, thus the maximum value any function could be assigned was 6 on a scale of 0 to 6. As evident with the total wetland score, Great Swamp had lower individual scores for all functions compared to the other wetlands while South Main tended to have higher scores across the different functions. Pollutant removal was high for all of the wetlands except Great Swamp while bank stability increased in the downstream direction. Recreation/education was consistently low for all of the wetlands, a result similar to the social component of WET.

As with many of the other methods, HGM scores tended to differ from the NC Guidance scores. South Main, Sommers Park, and Horseneck Bridge had somewhat similar ratings for the four analogous functions. In contrast, Great Swamp scored markedly lower for NC Guidance wetland value than for HGM functional capacity while the remaining wetlands were quite variable in how the two methods scored the different functions.

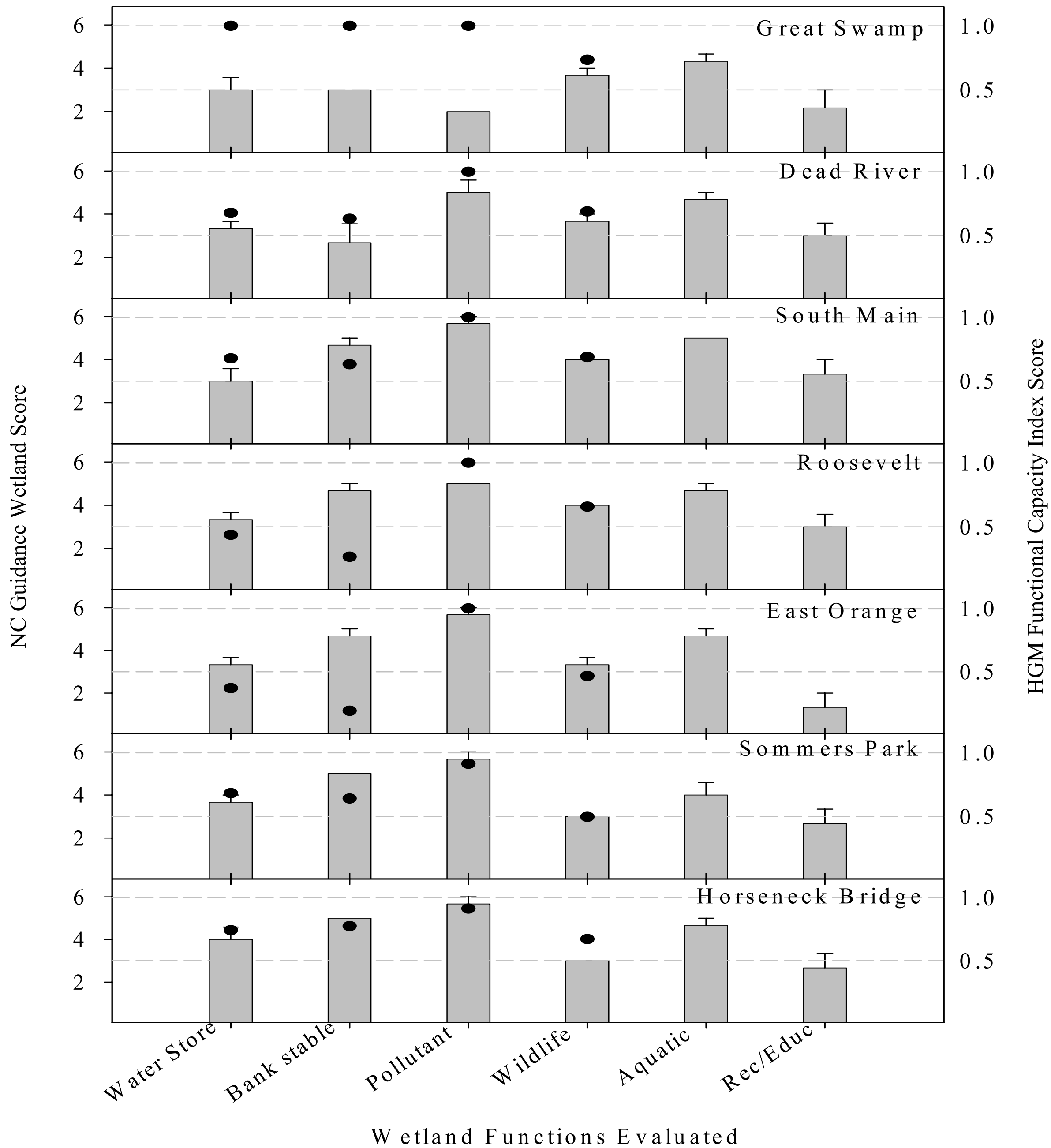
Teams generally scored all of the wetlands similarly, with Dead River being the most variable (Figure 8). There was no one function that explained this variability but rather slight differences in how the teams rated each of the functions that ultimately led to this difference (Figure 9). Recreation and education was the variable that teams tended to rate differently most often.

Figure 8. NC Guidance scores that rate functional value for the seven wetlands in WMA 6.



Dots (●) represent the mean score and standard error among the different teams. Crosshatches (+) represent the individual scores each team assigned to a particular wetland. A maximum score of 100 is determined by evaluating six wetland functions, applying a specific weight to each function and summing the scores to provide an overall wetland score for wetland functional value.

Figure 9. NC Guidance scores for the individual functions that are assessed.



In the actual methodology, these functions are multiplied by a specific weight and the weighted functions are summed for a maximum of 100. Here, the maximum score for each function is 6 with a range of 0-6. Bars represent average and standard errors of three team ratings for each wetland. Dots (●) represent the HGM functional capacity index (FCI) values for wetland functions that are similar between NC Guidance and HGM. The range (represented on the right y-axis) for HGM FCIs is 0.0-1.0. On the x-axis, Water Store = Water Storage, Bank Stable = Bank/Shoreline Stabilization, Pollutant = Pollutant Removal, Wildlife = Wildlife Habitat, Aquatic = Aquatic Life Value, and Rec/Educ = Recreation/Education.

MDE

With MDE, indicators for wetland functions are assigned values using a flowchart. The values are summed and divided by the maximum possible score to obtain the functional capacity index (FCI). The FCI is multiplied by the wetland area to obtain Functional Capacity Units for each wetland (Appendix C). MDE is the only method that explicitly incorporates wetland area into the calculation for determining a functional capacity, with the rationale that larger wetlands have greater functional capacity.

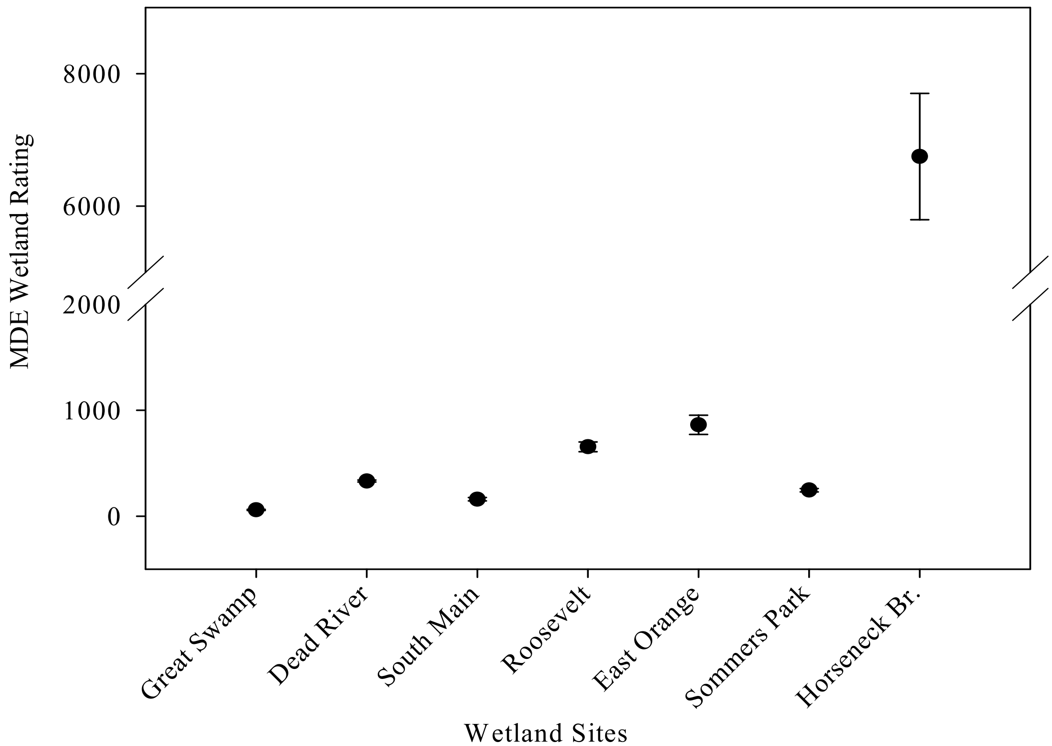
In MDE, with the range in wetland sizes we studied (Table 4, Figure 10b), not surprisingly we had a wide range of scores for the different wetlands (Figure 10a). Horseneck Bridge most notably had a much higher score than the other wetlands primarily due to its size. To compare wetland functions without scores being influenced by wetland size, we removed the area effect and just looked at the FCI values for each of the wetlands (Figure 11). We calculated the proportion of each function that a wetland fulfills (range 0-1.0) and totaled the proportions across the six different wetland functions for a maximum of 6.0 (for a perfectly functioning wetland). Without the area multiplier, WMA 6 sites showed neither an upstream to downstream trend. East Orange, the second largest site and the fifth site from upstream to downstream, received the highest score (3.94 out of 6.0), while Horseneck Bridge, the largest site and furthest downstream, received a middle score (3.67). The two smallest sites, Great Swamp and South Main (the first and third sites from upstream to downstream), still scored lower and tied for the lowest score (3.45 ±0.26 and 3.45±0.23, respectively). Overall, however, wetland scores were similar in that all scores were within the range of 3.4 to 3.94.

Including area in the determination of wetland function also has implications for the consistency in method application. For example, variability among the team scores was most notable for Horseneck Bridge. There was a difference of 0.78 points (out of a maximum of 6.0) between the high and low teams for this wetland. However, when even this small difference is multiplied by wetland acreage, the difference becomes amplified (Figure 10a). A second factor that can potentially contribute to the high variability between different evaluators is that in the instance of Horseneck Bridge each of the teams individually calculated wetland acreage and teams came up with slightly different numbers (Figure 10b).

Without area, the similarity in scores for wetland functional capacity is further reflected in the similarity in scores for the individual functions at each site (Figure 12). Most of the functions were in the mid-range (0.5 or higher), and no function or wetland received a perfect score. No individual function consistently scored lower than the others, and there was no evidence of either a stream or disturbance gradient response across wetlands or within functions. The lowest score was for aquatic diversity (0.31) at South Main, and the highest (0.82) was for flood attenuation at Dead River. Differences among the teams were quite low for most of the functions and within each wetland.

There were four HGM functions that could be compared to the MDE functions, including wildlife diversity, water quality, flood attenuation, and sedimentation stability (Figure 12). Although scores for wildlife diversity closely matched across all wetland sites between the two methods, scores for the other three functions were quite different. The HGM water quality FCI was consistently higher than MDE's score for water quality and the relative magnitude of the difference was consistent across the different wetlands. However,

Figure 10. A: MDE scores that rate functional capacity for the seven wetlands in WMA 6



The maximum wetland score is the FCI*wetland acreage. Dots (●) represent the mean and standard error is represented with bars. Crosshatches (+) represent the individual scores each team assigned to a particular wetland.

B: Acreages for each of the wetlands arranged in an upstream to downriver gradient.

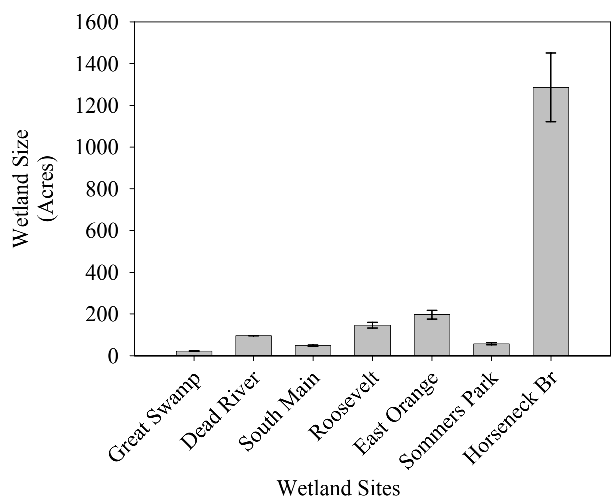
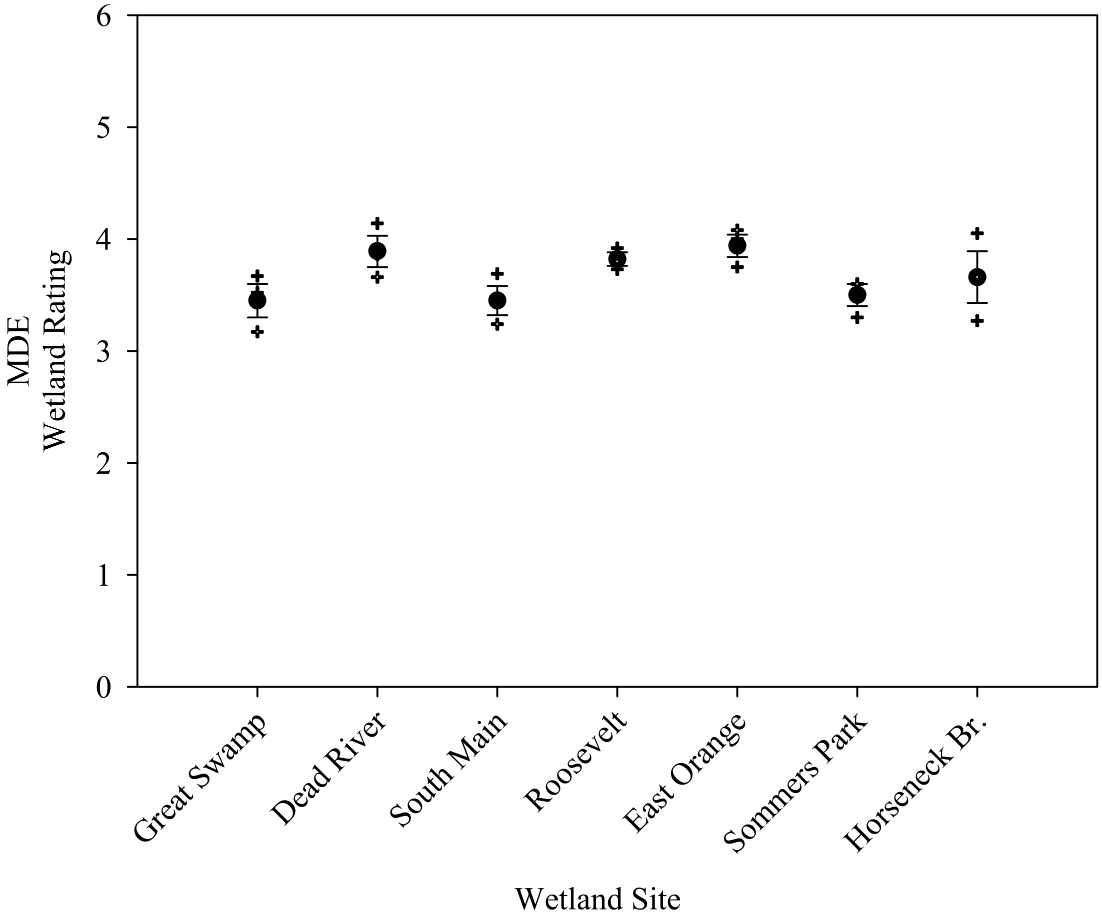


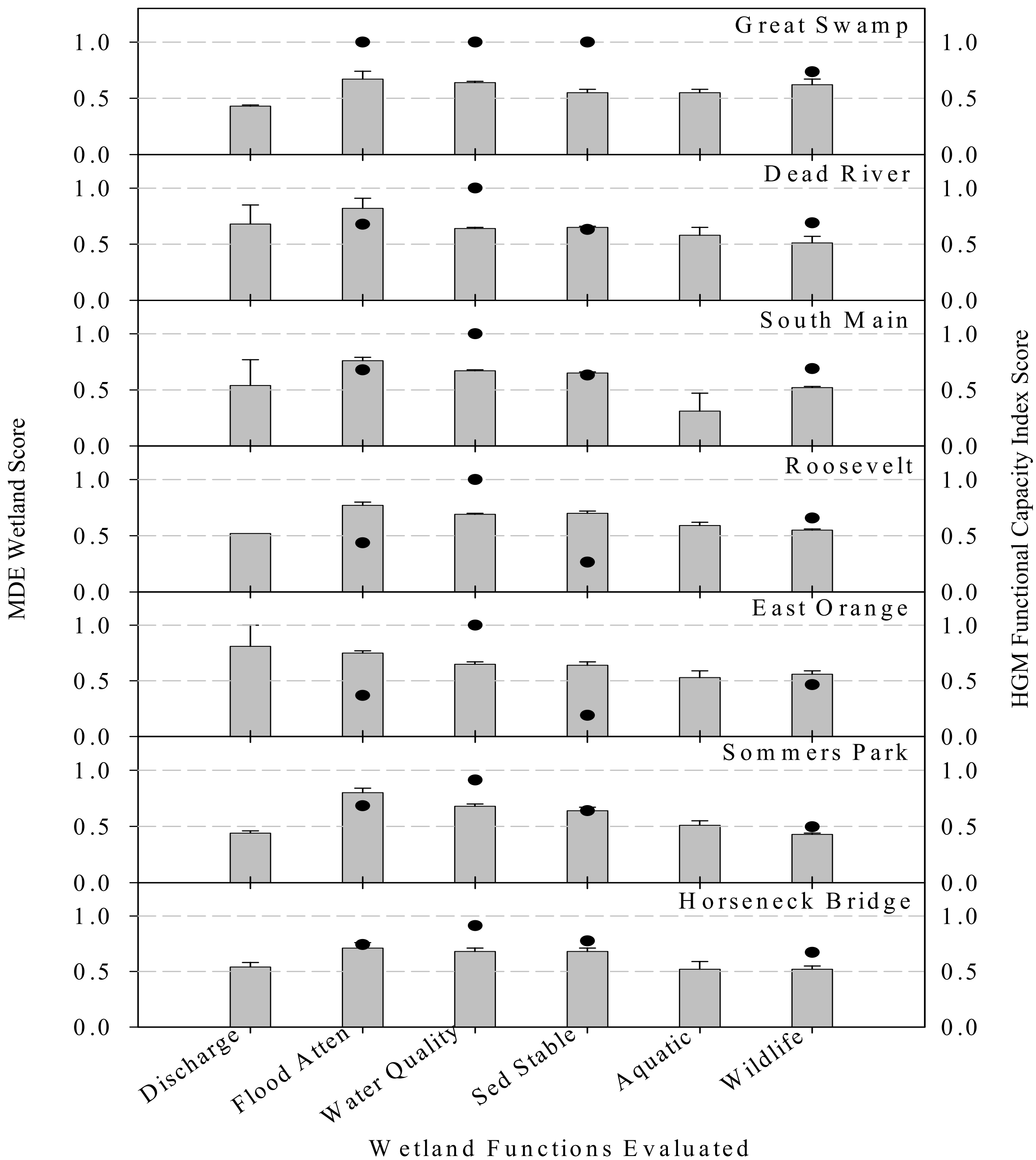
Figure 11. MDE scores for functional capacity indices (FCI) for the seven wetlands and where the effect of area has been removed.



A maximum score is 6.0 for each wetland. Dots (●) represent the mean and standard error among the different teams for each of the FCIs. Crosshatches (+) represent the individual scores each team assigned to a particular wetland.

Figure 12. MDE scores for the individual functions that are assessed.

The maximum score for each function is 1.0 out of a range of 0-1.0. Bars represent average and standard errors of three team ratings for each wetland. Dots (●) represent the HGM functional capacity index (FCI) values for wetland functions that are similar between MDE and HGM. The range (represented on the right y-axis) for



HGM FCIs is 0.0-1.0. For the x-axis, Discharge = Ground Water Discharge, Flood Attenuation = Flood Flow Attenuation, Water Quality = Water Quality, Sed Stable = Sedimentation Stabilization, Aquatic = Aquatic Diversity, and Wildlife = Wildlife Diversity.

the remaining two functions, flood attenuation and sedimentation stability, varied in no predictable pattern. The exception was that for HGM, both functions tended to decrease in the downstream direction until the last two wetlands, where the FCIs both increased; for MDE, the functional capacity was similar across the entire river gradient.

WRAP and WMQA

We combine the discussion of results for WRAP and WMQA since these two methods specifically rely on indicator variables as evidence for wetland function. WMQA was also a modification of WRAP (Balzano et al. 2002). A major distinction between the two methods is that WRAP evaluates the degree to which a wetland performs a particular function, while WMQA, which was developed to evaluate created wetland function, assesses the probability that a wetland function will develop over time. Both methods use a similar scoring procedure and give the wetland an overall score. The similarities in scoring approaches and common lineage allow us to compare how these methods assessed the same wetlands.

<u>WRAP:</u>

For WRAP, wetland scores generally decreased from upstream to downstream sites, with Great Swamp scoring the highest (0.79 ± 0.03) and Sommers Park, toward the downstream end of the river gradient, scoring the lowest (0.53 ± 0.01) (Figure 13). Roosevelt was the one exception to the general downstream decrease in wetland scores, scoring only slightly lower than Great Swamp (0.75 ± 0.04).

For the individual variables that comprise the overall wetland score, upstream wetlands tended to score 2 or higher (out of 3.0 possible), while downstream wetlands scored between 1.0 and 2.0 (Figure 14). Three of the variables, wildlife, habitat buffer, and water quality treatment, tended to decrease in the downstream direction, while the other variables did not vary with the river gradient; however, the pattern was sufficiently strong that the overall wetland scores declined downstream.

In terms of gradients, wetlands lower on the river gradient scored lower than wetlands located higher on the river gradient. The wetland scores also reflected the disturbance gradient for the three most upstream wetlands, with Great Swamp the least disturbed receiving the highest wetland score, followed by Dead River and South Main. However, the remaining four wetlands did not follow the disturbance gradient. Roosevelt, one of the more disturbed sites scored relatively high while East Orange, the most disturbed site, scored marginally higher overall than the two most downstream sites, which were less disturbed. Consequently, WRAP only moderately reflected the wetland disturbance gradient.

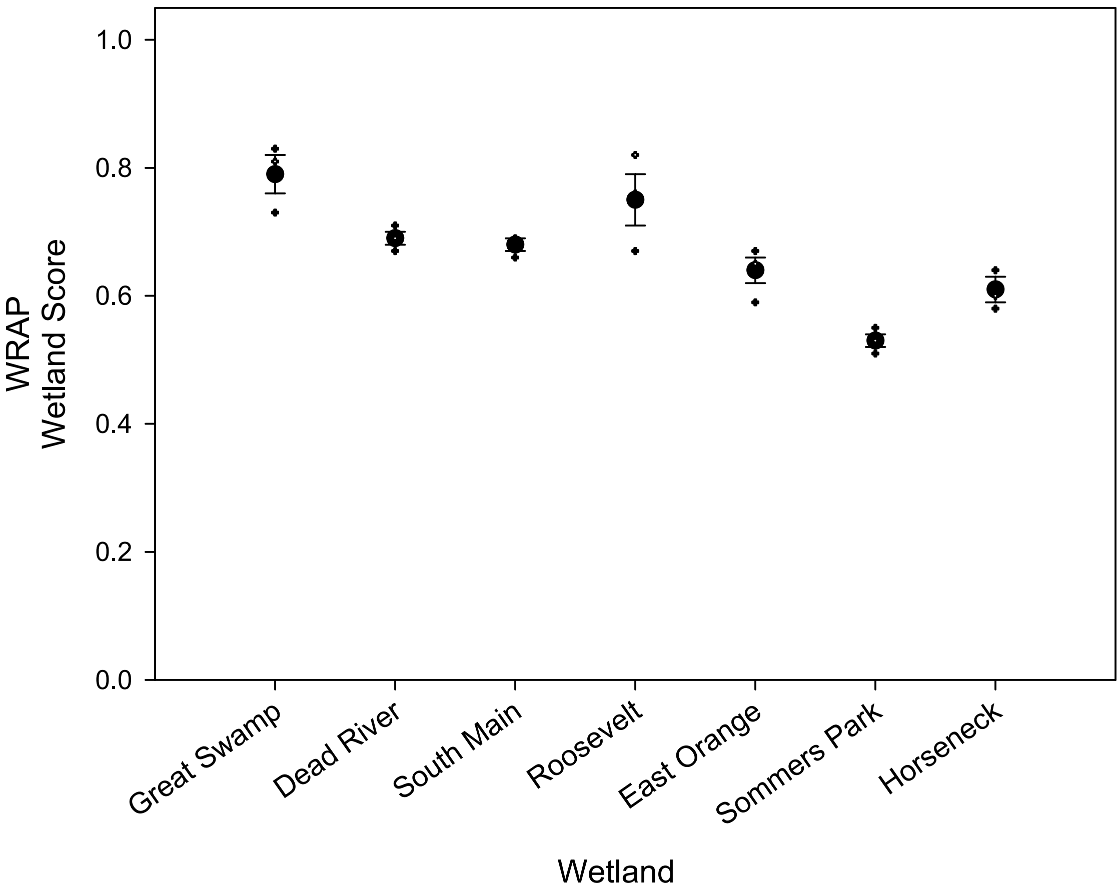
Overall the teams tended to assess the wetlands similarly (Figure 13) with Roosevelt having the greatest difference among the different assessors. However, the standard error for Roosevelt was ± 0.04, which translates into a relatively small difference among teams. Similarly, the variability is relatively small among teams for the individual functions (Figure 14). Vegetation canopy and habitat buffer tended to vary for all wetlands, but the differences were relatively small. Otherwise, team differences did not concentrate on one function or wetland and were generally low.

<u>WMQA:</u>

With WMQA all of the wetlands generally scored moderately high (Figure 15). Great Swamp, the highest scored wetland, received a score of 0.89 out of a possible of 1.0 and the lowest scoring wetland, Sommers Park, scored 0.71. Similar to WRAP, WMQA scores generally decreased in the downstream direction. The overall range in wetland scores was somewhat narrow with a difference of less than 0.2 separating the highest scoring wetland (Great Swamp) from the lowest scoring wetland (Sommers Park). All of the individual variables in WMQA scored 2 or higher for all of the wetlands assessed in WMA 6 (Figure 16). Hydrology, soils, and landscape variables decreased downstream while the other variables were similar across wetlands.

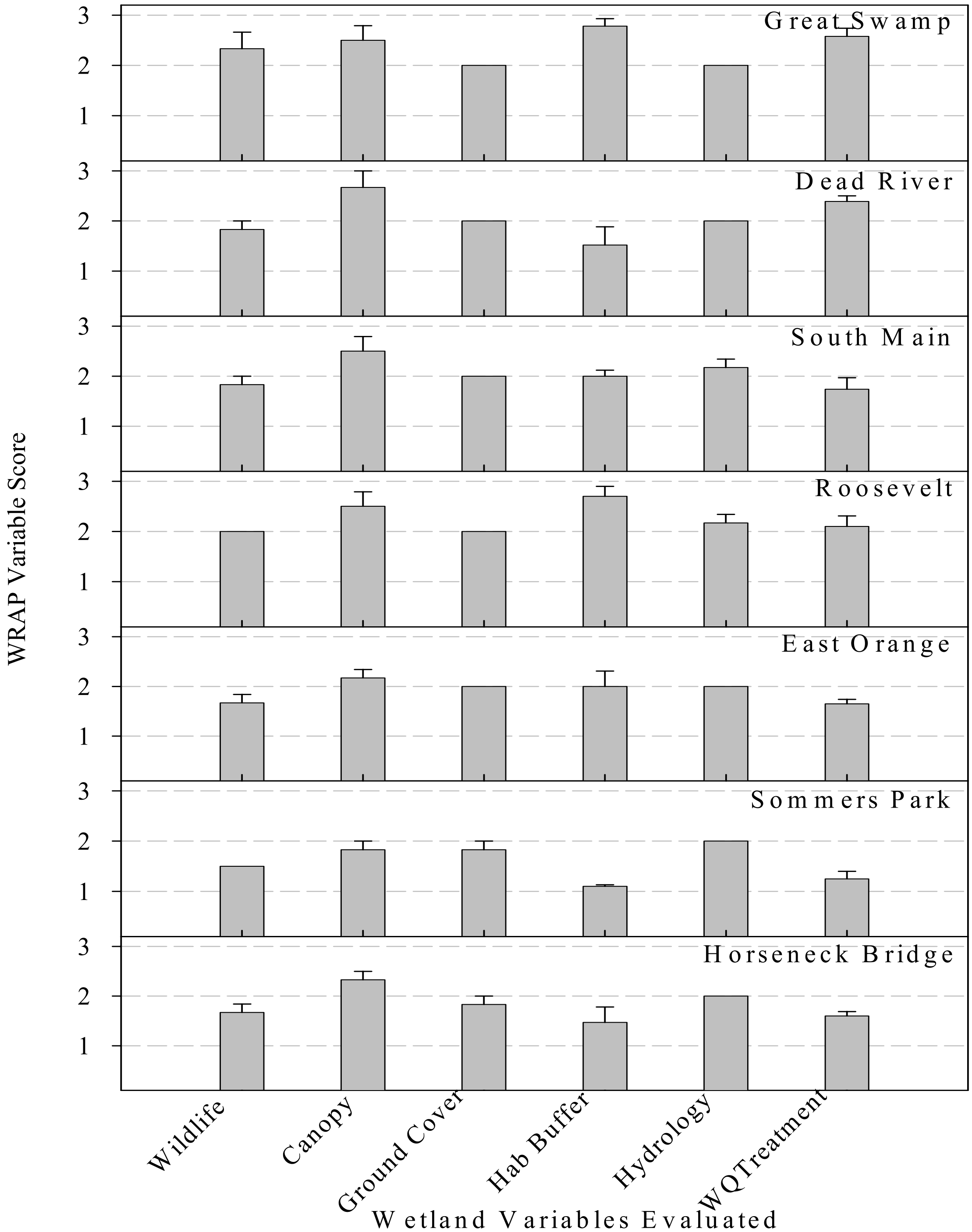
WMQA scores were consistently higher than WRAP scores for all sites, and the general decrease in assessed values in the downstream direction was not as marked as it was with WRAP (WMQA range 72 to 89%, WRAP range 53 to 79% - Figure 17). WMQA includes several functions that are not in WRAP. For example, a soils variable and site and landscape characteristics are specific to WMQA, while WRAP includes a water quality pretreatment variable that is not in WMQA. To determine if these variables explained the differences in wetland scores, we removed each of these from their respective assessment methods and recomputed the wetland score. Overall wetland values changed slightly, but the relative difference between the methods did not change, suggesting that it is how the individual variables are specifically evaluated and assigned numbers that led to the difference. This is further reinforced by the generally higher scores for the individual variables in WMQA versus WRAP (Figures 14 and 16). For example, hydrology is consistently rated higher in WMQA than in WRAP. The difference in scores likely reflects the basic differences in the intent and goals for the two methods. WMQA is intended to assess whether conditions are present to sustain the continued development and evolution of a created wetland. In contrast, WRAP assesses the current conditions of the wetland and hence is intended to reflect the current functioning of the wetland rather than its potential functioning.

Figure 13. WRAP wetland scores for assessing the extent that a wetland performs specific functions.



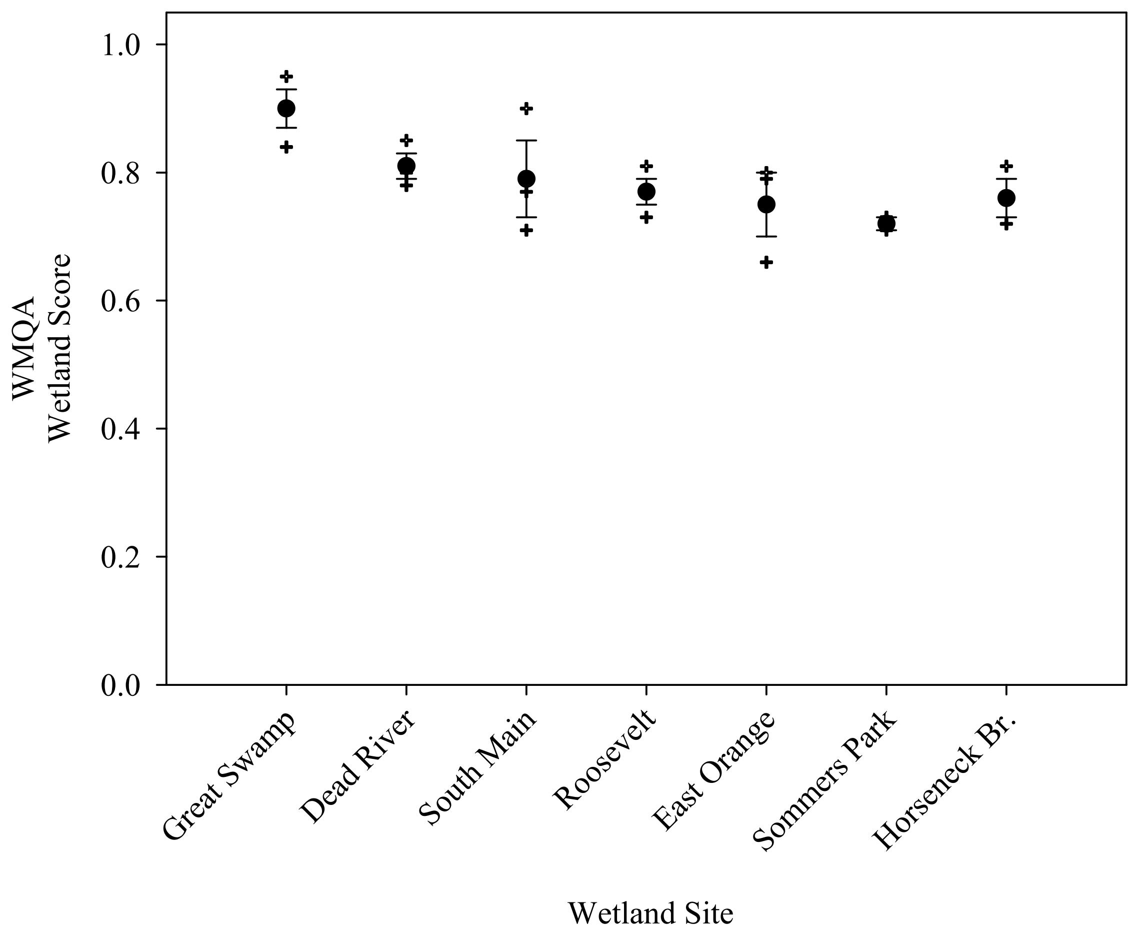
The wetland score ranges from 0.0 to 1.0. Dots (●) represent the mean wetland score and standard error among the different teams. Crosshatches (+) represent the individual scores each team assigned to a particular wetland.

Figure 14. WRAP scores for the individual variables that are assessed.



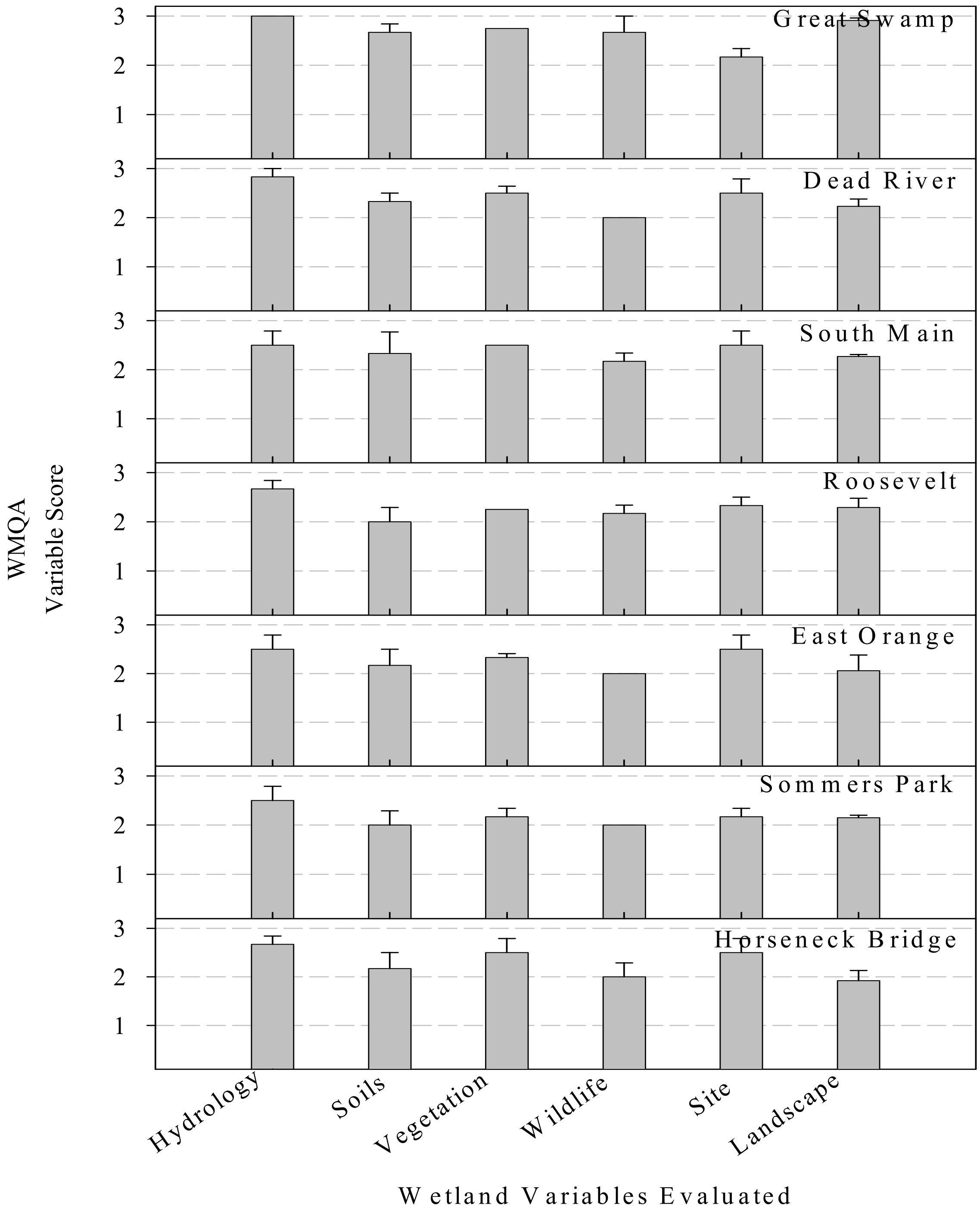
The maximum score for each function is 3 out of a range of 0-3. Bars represent average and standard errors of three team ratings for each wetland. On the x-axis, Wildlife = Wildlife Utilization, Canopy = Wetland Canopy Cover, Ground Cover = Wetland Ground Cover, Hab Buffer = Habitat Support/Buffer, Hydrology = Field Hydrology, and WQ Treatment = Water Quality Input/Treatment.

Figure 15. WMQA wetland scores for assessing the probability that a wetland will achieve function over time.



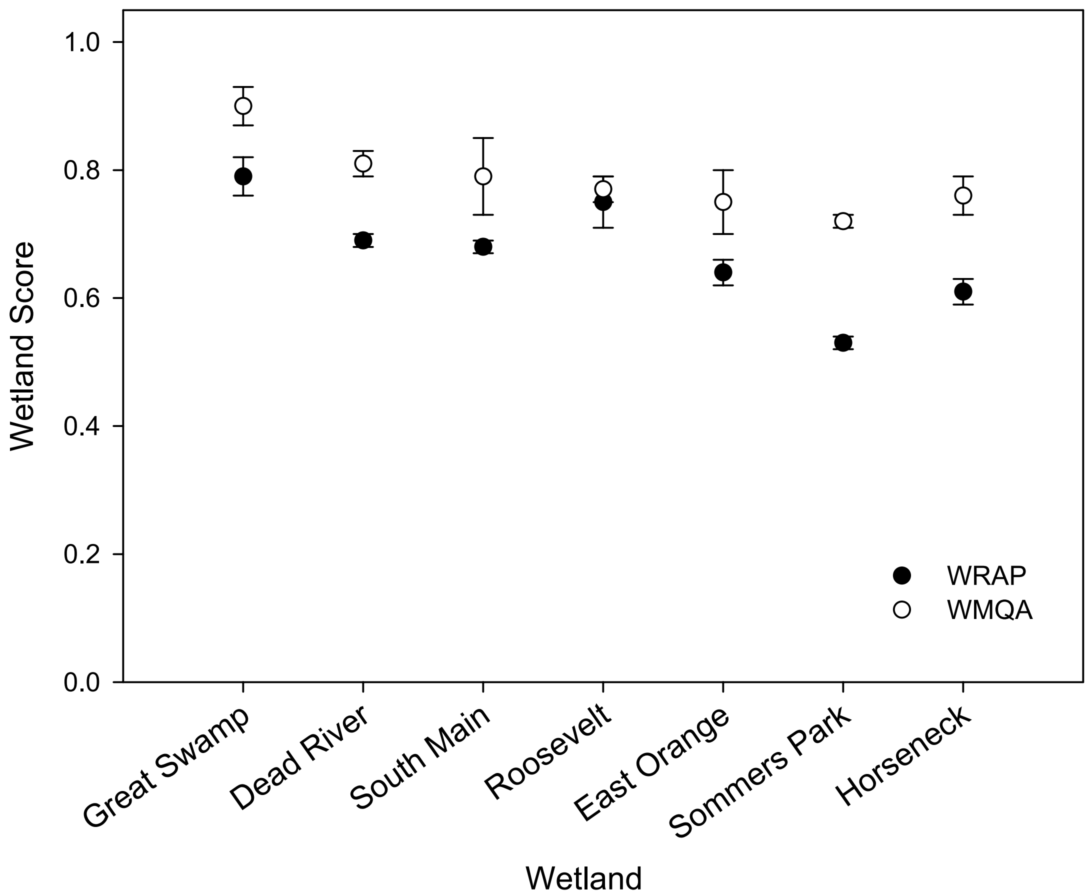
The maximum wetland score is 1.0 (range 0.0 to 1.0). Dots (●) represent the mean wetland score and standard error among the different teams. Crosshatches (+) represent the individual scores each team assigned to a particular wetland.

Figure 16. WMQA scores for the individual variables that are assessed.



The maximum score for each function is 3 (range 0.0-3.0). Bars represent average and standard errors of three team ratings for each wetland. On the x-axis, Hydrology = Hydrology, Soils = Soils, Vegetation = Vegetation Composition and Diversity, Wildlife = Wildlife Suitability, Site = Site Characteristics, and Landscape = Landscape Characteristics.

Figure 17. Comparison between WRAP and WMQA scores for the same wetlands.



Dots (●) represent the mean wetland score and standard error among the different teams for WRAP and open circles (O) represent the mean wetland score and standard error for WMQA.

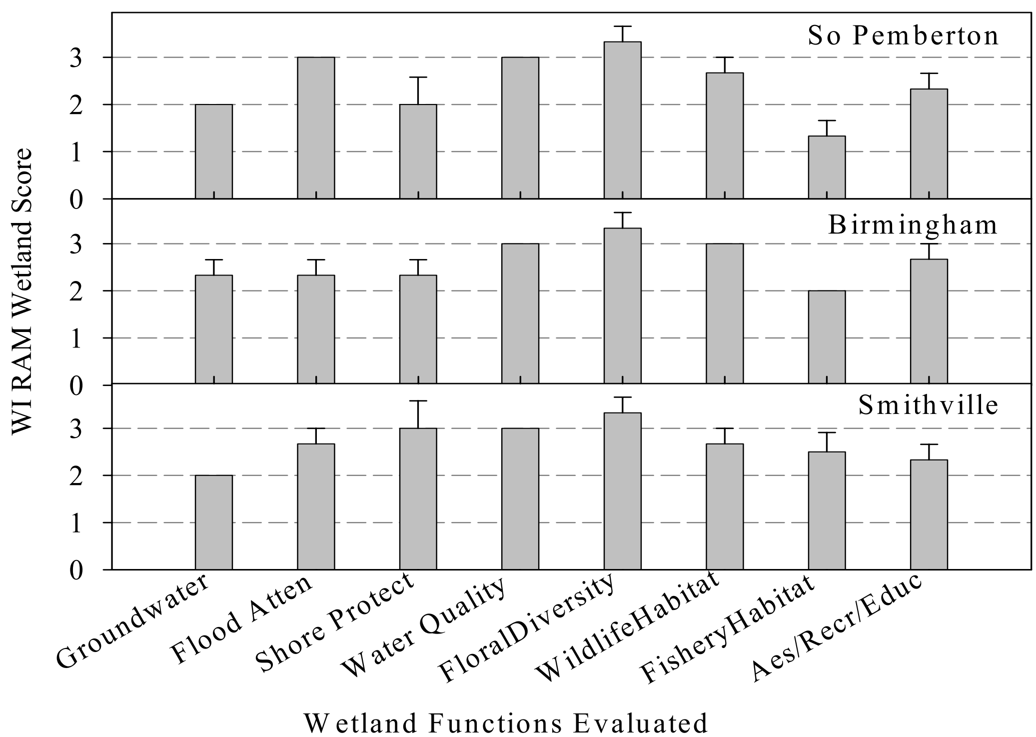
B. Watershed Management Area 19 (WMA 19)

The five methods, WI RAM, VIMS, NC Guidance, MDE, and WRAP, completed for WMA 19 are presented in a similar fashion as those for WMA 6. The wetlands are ordered in the upstream to downstream direction with South Pemberton being the most upstream site, followed by Birmingham and finally Smithville.

WI RAM

With WI RAM, which assigns categorical values to indicators of wetland function, all wetland functions were evaluated as moderate or higher for all three wetlands with the exception of fisheries habitat in South Pemberton (Figure 20). Smithville generally scored higher than the two upstream wetlands. South Pemberton was the most variable across the different wetland functions assessed. Floral diversity and water quality consistently scored

Figure 18. WI RAM scores for three riverine wetlands in WMA 19.



Bars represent average and standard errors of the three teams' ratings of each wetland. Ratings were low (1), moderate (2), high (3), or exceptional (4) as a measure of the wetland functional value. On the x-axis, Groundwater = Groundwater Recharge/Discharge, Flood Atten = Flood and Stormwater Storage/Attenuation, Shore Protect = Shoreline Protection, Water Quality = Water Quality Protection, FloralDiversity = Floral Diversity, WildlifeHabitat = Wildlife Habitat, FisheryHabitat = Fishery Habitat, and Aes/Recr/Educ = Aesthetics/Recreation/Education.

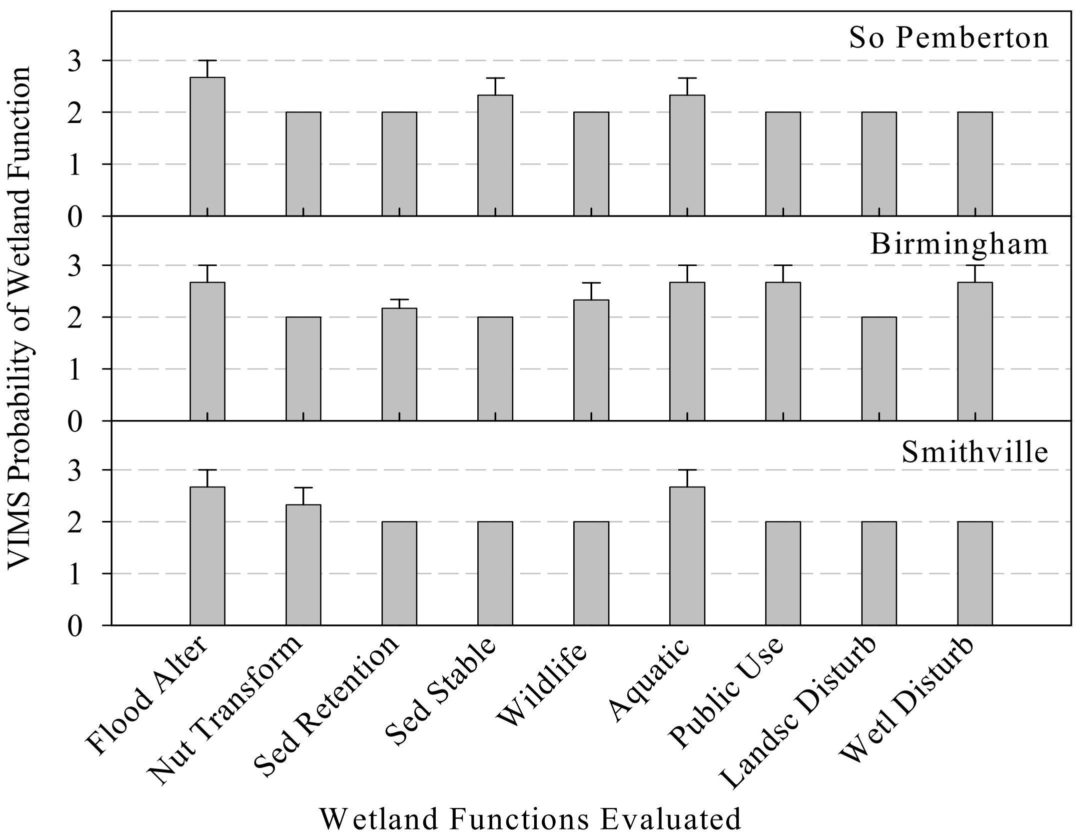
high across all three wetlands with floral diversity rated as high to exceptional. Fishery habitat and groundwater recharge were rated moderate or lower. Fisheries habitat and shoreline protection increased in the downstream direction while the remaining functions showed no trend with the underlying river gradient.

Teams were by and large consistent in their scores, particularly for water quality protection and groundwater recharge followed by wildlife habitat. The shoreline protection function was the most variable between the different teams with lack of agreement in ratings between the three teams in two out of the three wetlands assessed.

VIMS

VIMS, which categorically assesses the probability that a wetland function will occur, rated the wetlands in WMA19 as predominantly having moderate probability of wetland functioning (Figure 19). The Birmingham wetland had the greatest range in probability scores for the different assessed functions with three variables rated as moderate probability (2.0) and four variables rated as 2.67 out of 3.0. There was no trend for wetlands to reflect the river gradient with functioning increasing or decreasing in a particular direction. Flood alteration and aquatic habitat were consistently rated higher than the other functions across

Figure 19. VIMS scores for the riverine wetlands in WMA 19



Bars represent average and standard errors of three teams' ratings for each wetland. Ratings are low (1), moderate (2), or high (3) as a measure of the probability that wetland function will occur. On the x-axis, Flood Alter = Flood Storage and Flood Flow Alteration, Nut Transform = Nutrient Retention and Transformation, Sed Retention = Sediment/Toxicant Retention, Sed Stable = Sediment Stabilization, Wildlife = Wildlife Habitat, Aquatic = Aquatic Habitat, Public Use = Public Use, Landsc Disturb = Landscape Disturbance, and Wetl Disturb = Wetland Disturbance.

all three wetlands. These two functions also had the greatest variability in team scores across all three wetlands but the prevailing pattern was that two teams agreed on a rating while the third team varied by one step. However, for a number of functions all teams agreed on the same score within a wetland and some across wetlands. For example, for South Pemberton and Smithville six of the nine functions were rated the same by each of the three teams.

NC Guidance

All three wetlands in WMA19 averaged 85 or higher for wetland value using the NC Guidance criteria. South Pemberton had the greatest range of values between the different teams ranging from wetland values of 77 to 98 (Figure 20A). Birmingham followed with team scores ranging from 78 to 96 while there was very close consensus for Smithville's wetland value.

For the six individual wetland functions evaluated in this method, 6.0 was the maximum value any one function could be assigned. Smithville had the greatest range in function values with recreation and education value scoring less than half of the potential value while pollutant removal value was rated close to the maximum value of 6.0 (Figure 20B). All of the assessed functions for South Pemberton were rated at 4.0 or higher with the exception of recreation and education value. In fact, the education and recreation value was consistently low across all three wetlands. Water storage value decreased in the downstream direction from South Pemberton to Smithville while pollutant removal increased slightly in the downstream direction.

Differences in team ratings for individual functions were not specific to a particular function. There was greater agreement for Smithville functional values, which is reflected, in the narrow range of overall wetland scores (Figure 20A). There were greater differences between team ratings for pollutant removal, aquatic habitat and recreation/education value for South Pemberton while there was greater variability in team ratings for water storage and bank stability for Birmingham.

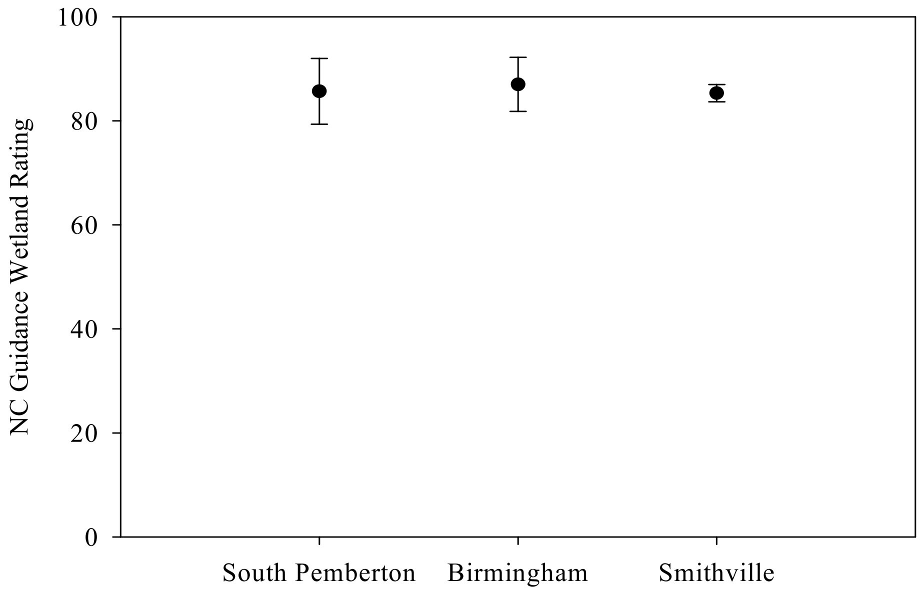
MDE

For MDE, which assesses the relative functioning of wetlands, Birmingham wetland was rated as having the higher functioning of the three wetlands in WMA19 (Figure 21A). The higher score for Birmingham is directly due to its size and it being larger than the other two wetlands (31 acres vs. 15 and 19 acres for South Pemberton and Smithville respectively). When area is factored out of the assessment methodology, all three wetlands score similarly (Figure 21B). All three wetlands were rated in the range of 4.0 out of 6.0. Team scores were slightly more variable for Birmingham but the standard error of ±0.21 would not influence the general interpretation of wetland relative functioning.

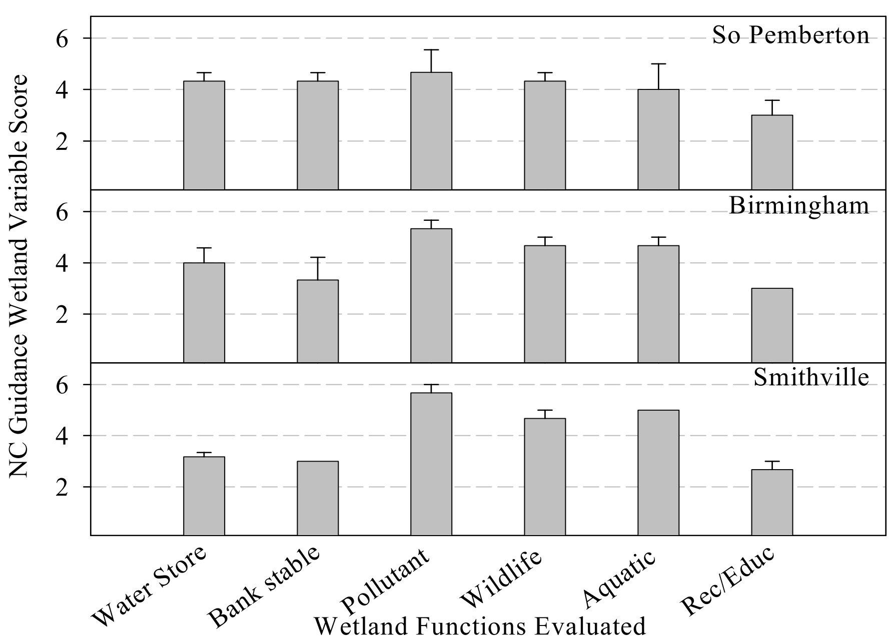
For the individual indicators assessed in the methodology, all indicators scored between 0.5 and 0.75 out of a total of 1.0 (Figure 22). Habitat indicators including aquatic and wildlife habitat generally scored lower than other wetland indicators for all three wetlands and wildlife was consistently the lowest scoring indicator. None of the indicators reflected the river gradient. Teams were relatively consistent in how they scored the different indicators. The discharge indicator exhibited the greatest variability between teams across all three wetlands whereas water quality had the least.

A

Figure 20. NC Guidance scores for riverine wetlands in WMA 19.

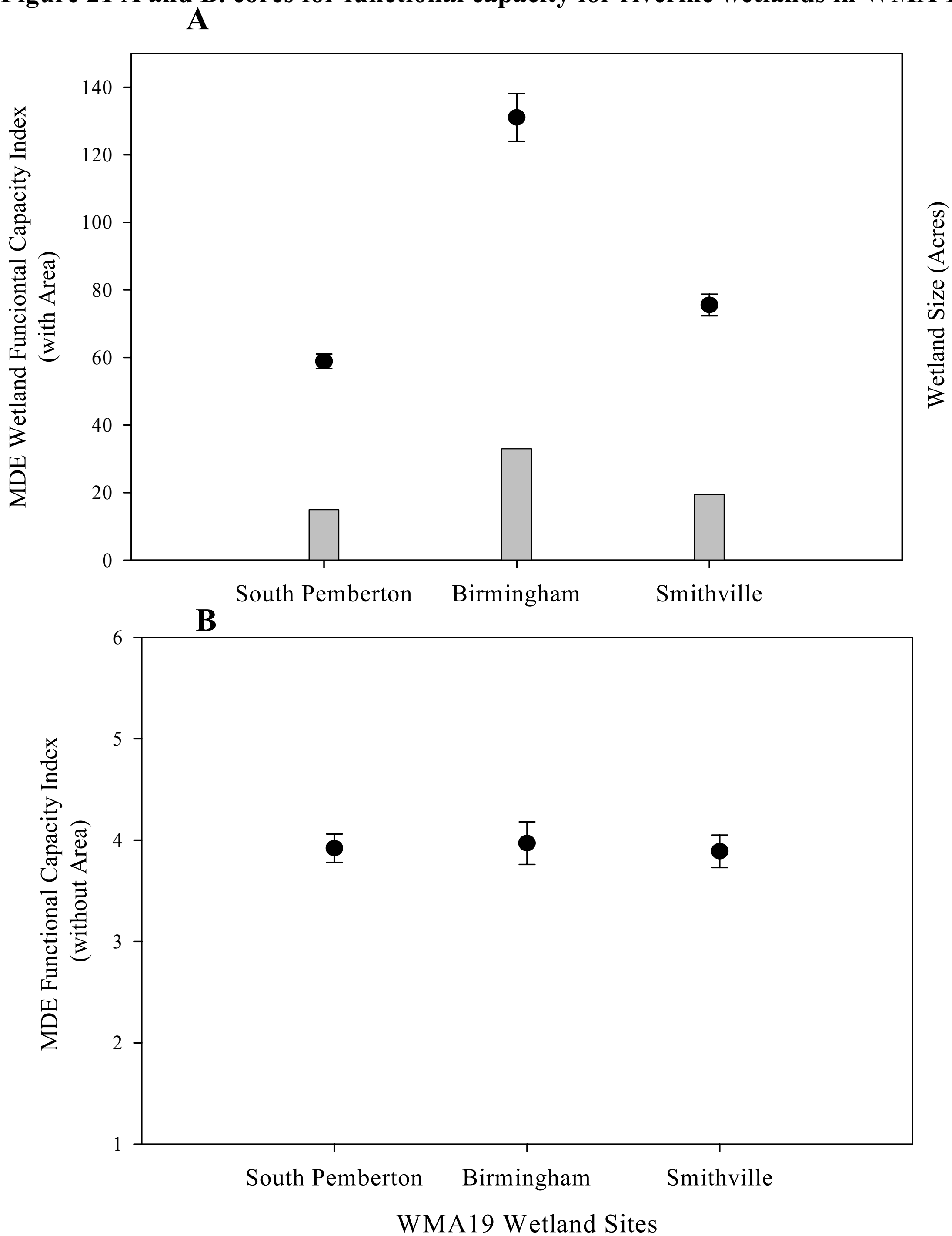


B



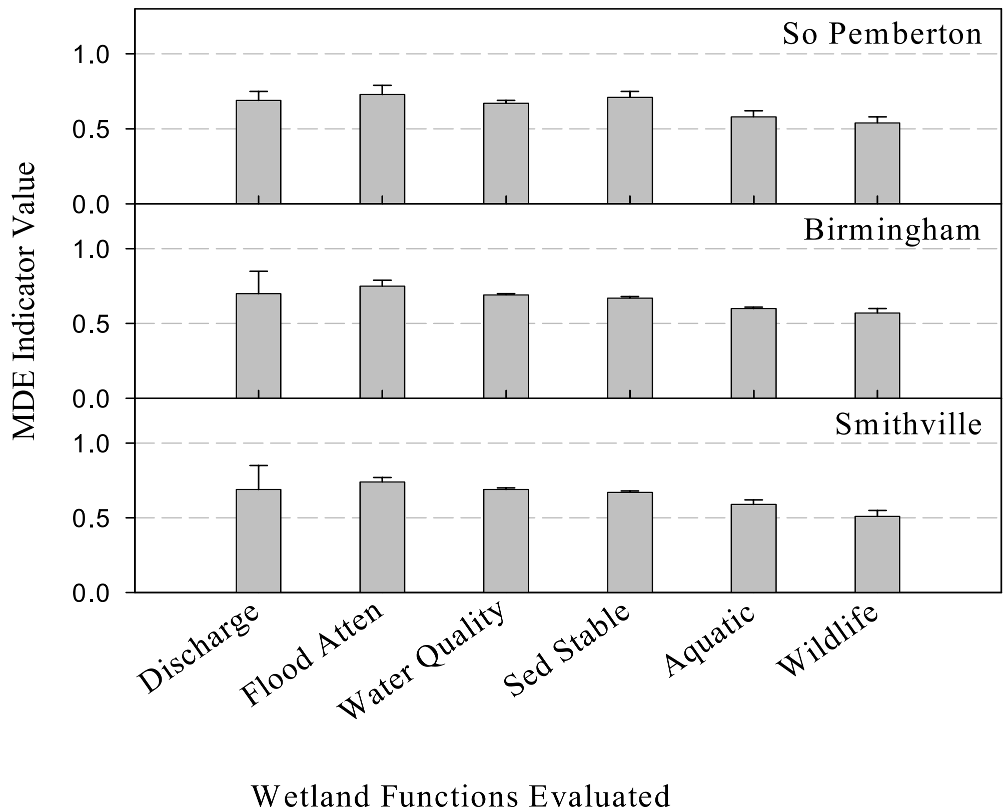
A. Ratings of functional value for each wetland. Dots (•) represent the mean score and standard error among the different teams. A maximum score of 100 is determined by evaluating six wetland functions (B), applying a specific weight to each function and summing the scores to provide an overall wetland score for wetland functional value. **B. NC Guidance scores for the individual functions.** The maximum score for each function is 6. Bars represent the average and standard errors of three team ratings for each wetland. On the x-axis, Water Store = Water Storage, Bank Stable = Bank/Shoreline Stabilization, Pollutant = Pollutant Removal, Wildlife = Wildlife Habitat, Aquatic = Aquatic Life Value, and Rec/Educ = Recreation/Education.

Figure 21 A and B. cores for functional capacity for riverine wetlands in WMA 19.



A. MDE scores that include area. The score is determined by multiplying the wetland area by the wetland FCI (calculated in MDE). Dots (•) represent the mean and standard error of the teams' wetland scores. Bars represent the acreage for each wetland. **B. MDE scores for functional capacity when area is not included in the calculations but rather the score reflects just the wetland FCI.** Dots (•) represent the mean and standard error for the three teams for the FCI scores.

Figure 22. MDE scores for the individual functions.



Bars represent the average and standard errors of three team ratings for each wetland. Maximum score is 1.0. For the x-axis, Discharge = Groundwater Discharge, Flood Atten = Flood Flow Attenuation, Water Quality = Water Quality, Sed Stable = Sedimentation Stabilization, Aquatic = Aquatic Diversity, and Wildlife = Wildlife Diversity.

WRAP

For WMA 19, WRAP scores ranged from 0.71 out of a maximum of 1.0 for Smithville to 0.86 for Birmingham with no trend for overall scores to vary with the river gradient (Figure 23A). For the individual variables, with the exception of water quality treatment and habitat buffer for the Smithville wetland, all variables scored 2.0 or higher out of a maximum possible of 3.0 (Figure 23B). Birmingham had the greatest range in variable scores with the lowest variable average of 2.2 for ground cover and 3.0 for canopy. Smithville scores were lower for the majority of the variables compared to the other two wetlands and is reflected in the somewhat lower overall wetland score. Hydrology tended to decrease in the downstream direction while the other variables showed no pattern to the underlying river gradient. Ground cover tended to score lower for all three wetlands compared to the other variables assessed while the specific variable that scored the highest varied between the different wetlands.

South Pemberton was the most variable in terms of overall wetland scores assigned by the teams (Figure 23A) though the range of variability was relatively small with a standard error of ±0.05. The South Pemberton score was more variable due to greater differences in team scores for the wildlife variable and the hydrology variable (standard errors ±0.50 and 0.33 respectively). However, these two variables were not consistently more variable across the three wetlands.

Team Variability:

When we examined the variability among the different teams in their assessments of the wetland functions, there was no consistent pattern among teams, such as one team consistently scoring differently from the other teams. For the Descriptive Approach, the similarity in team scores was relatively high and, in fact, was one of the highest with an average agreement of almost 87 percent across all functions, with a range of 100 percent agreement for six of the thirteen functions across the seven wetlands and a low of 50 percent agreement on production export (Table 7). However, interpretation of the agreement has to be tempered with the fact that there were only two choices, yes or no. Thus, the range of possible differences among the teams was constrained.

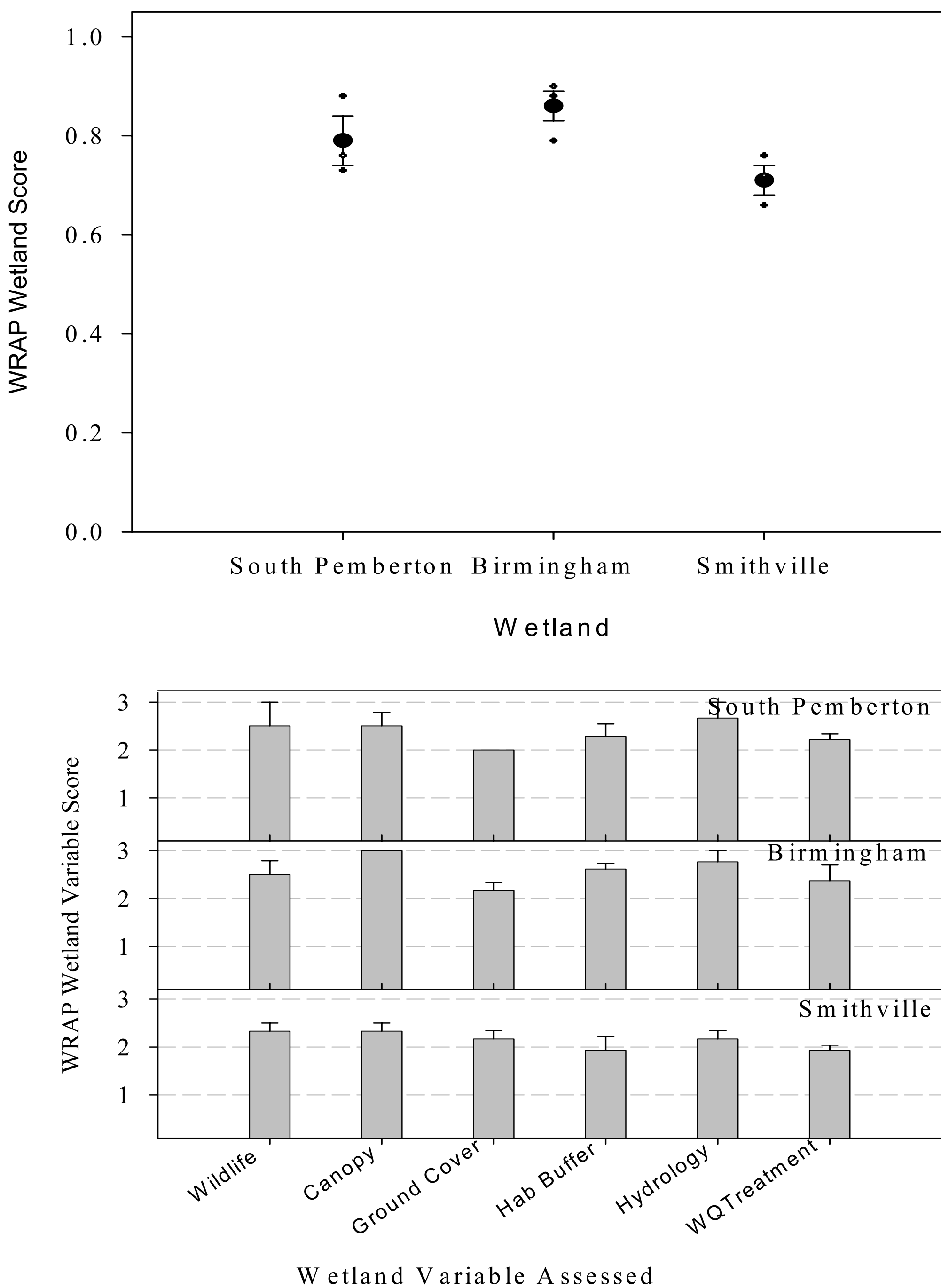
Table 7. Similarity in three team scores for the thirteen functions that are evaluated in the Descriptive Approach.

Descriptive Approach Function	Similarity in Team Scores
Groundwater Recharge/Discharge	100.0
Floodflow Alteration	100.0
Fish and Shellfish Habitat	85.7
Sediment/Toxicant Retention	85.7
Nutrient Removal	78.6
Production Export	50.0
Sediment/Shoreline Stabilization	100.0
Wildlife Habitat	100.0
Recreation	100.0
Educational Scientific Value	100.0
Uniqueness/Heritage	71.4
Visual Quality/Aesthetics	71.4
Endangered Species Habitat	85.7
Average	**86.8**

100 = complete consensus while 0 = no consensus among teams.

WET was the most variable method we examined with functions under the Effectiveness component showing the greatest difference in responses among the different teams across all functions (Average 64.9 agreement, Table 8). The functions evaluated under the Social component showed the greatest range of variability with a low of 38 percent agreement for groundwater discharge but a complete consensus across teams and wetlands for the uniqueness and heritage functioning.

Figure 23. WRAP scores for assessing extent of wetland function for WMA 19 wetlands.



A. Wetland scores for each wetland (out of a total of 1.0). Dots (•) represent the mean and standard error for wetland scores assigned by the different teams. Crosshatches (+) represent the individual team scores. **B. WRAP scores for the individual variables.** Maximum score is 3.0 and bars represent the average and standard error of team ratings. On the x-axis, Wildlife = Wildlife Utilization, Canopy = Wetland Canopy Cover, Ground Cover = Wetland Ground Cover, Hab Buffer = Habitat Support/Buffer, Hydrology = Field Hydrology, and WQ Treatment = Water Quality Input/Treatment.

Table 8. Similarity in team scores for each of the functions evaluated in the three WET components: Social, Effectiveness and Opportunity.

WET Social Functions	Similarity in Team Scores
Ground Water Recharge	76.2
Ground Water Discharge	38.1
Floodflow Alteration	66.7
Sediment Stabilization	57.1
Sediment/Toxicant Retention	76.2
Nutrient Removal/Transformation	81.0
Wildlife Diversity/Abundance	71.4
Aquatic Diversity/Abundance	76.2
Uniqueness Heritage	100.0
Recreation	66.7
Average	**71.0**
WET Effectiveness Functions	**Similarity in Team Scores**
Ground Water Recharge	76.2
Ground Water Discharge	61.9
Floodflow Alteration	71.4
Sediment Stabilization	52.4
Sediment/Toxicant Retention	81.0
Nutrient Removal/Transformation	90.5
Production Export	57.1
Breeding	61.9
Migration	42.9
Wintering	61.9
Aquatic Diversity/Abundance	57.1
Average	**65.7**
WET Opportunity Function	**Similarity in Team Scores**
Floodflow Alteration	57.1
Sediment/Toxicant Retention	90.5
Nutrient Removal/Transformation	85.7
Average	**77.8**

100 = complete consensus among teams and 0 = complete lack of consensus.

Teams tended to agree almost three-quarters of the time across functions and wetlands with WI RAM in WMA 6 (Table 9). Teams were most variable in their responses to the fish habitat function, while responses varied least for wildlife habitat. In contrast, there was greater inconsistency in how teams rated the different functions in WMA 19. In particular, teams tended to have different ratings for fishery habitat and shoreline protection in WMA 19. These two functions also had low similarities in scores in WMA 6. There was also greater inconsistency in ratings for flora diversity and aesthetics in WMA 19, which interestingly had some of the more similar scores in WMA 6.

Table 9. Similarity in team scores for functions assessed in WI RAM.

WI RAM Function	Similarity in Team Scores	
	WMA 6	WMA 19
Groundwater	67.86	83.33
Flood/Stormwater Attenuation	75.00	66.67
Shoreline Protection	67.86	16.67
Water Quality Protection	75.00	100.00
Floral Diversity	82.14	50.00
Wildlife Habitat	85.71	66.67
Fishery Habitat	57.14	25.00
Aesthetics/Recreation/Education	82.14	50.00
Average	**74.11**	**57.29**

100 = complete consensus and 0 = lack of consensus.

There was general agreement among teams in the VIMS method with an average of 76 percent agreement among teams across wetlands and functions in WMA 6 and even higher similarities between scores in WMA 19 with an 87 percent average agreement (Table 10a). There was complete consensus for sediment and toxicant retention function in both watersheds as well as with the nutrient retention and transformation function in WMA 6. There was considerable variability in how the teams evaluated the aquatic habitat function in WMA 6, which contributed to lower agreement in this watershed versus WMA 19. Flood storage and flow alteration had the greatest discrepancy between teams in WMA 6 but was one of the lower agreed upon functions in WMA 19.

With VIMS the teams rated a number of factors that are associated with each of the functions. We applied the agreement rating to the individual factors within a function in addition to the functions (Table 10b). Two things are interesting when comparing the similarity in factors with the similarity in the function scores that are derived from the factors. For the sediment and toxicant retention function, there are eight factors that are

Table 10a. Similarity in team scores for the main functions evaluated in VIMS.

VIMS Function	Function Similarity	
	WMA 6	WMA 19
Flood storage and flood flow alteration	95.2	66.7
Nutrient retention and transformation	100.0	88.9
Sediment/toxicant retention	100.0	100.0
Sediment stabilization	76.2	88.9
Wildlife habitat	76.2	88.9
Aquatic habitat	52.4	88.9
Public use	66.7	66.7
Other factors	85.2	88.9

VIMS Function	VIMS Factor #	Factor Similarity			
		WMA 6	Average	WMA 19	Average
Flood storage and flood flow alteration	1	81.0		33.3	
	2	71.4		66.7	
	3	66.7	**73.02**	66.7	**55.56**
Nutrient retention and transformation	1	57.1		66.7	
	2	81.0		66.7	
	3	81.0		33.3	
	4	71.4		66.7	
	5	81.0		33.3	
	6	71.4	**73.02**	66.7	**55.56**
Sediment/toxicant retention	1	66.7		77.8	
	2	61.9		66.7	
	3	85.7		66.7	
	4	81.0		66.7	
	5	76.2		33.3	
	6	71.4		66.7	
	7	95.2		33.3	
	8	66.7	**75.60**	66.7	**59.72**
Sediment stabilization	1	90.5		100.0	
	2	42.9		77.8	
	3	100.0		100.0	
	4	76.2	**77.38**	77.8	**88.89**
Wildlife habitat	1	85.7		55.6	
	2	66.7		77.8	
	3	76.2		88.9	
	4	71.4		66.7	
	5	81.0	**76.19**	100.0	**77.78**
Aquatic habitat	1	81.0		100.0	
	2	100.0		100.0	
	3	76.2		88.9	
	4	71.4		100.0	
	5	76.2	**80.95**	33.3	**84.44**

Table 10b. Similarity in team scores for each wetland function factor for VIMS for WMA 6 and WMA 9.

VIMS includes a number of different factors that are evaluated for each wetland function. 100 = complete consensus and 0 = no consensus.

evaluated. Agreement among teams ranged from 62 percent to 95 percent for WMA 6 but there was complete consensus in the overall nutrient retention and transformation functional score (Table 10a) irrespective of the variability with the individual factors. This trend is even more apparent for sediment/toxicant retention where there was considerable variability in team scores for the individual factors (particularly for WMA19) as observed in Table 10b, but complete consensus in the overall functional score (Table 10a).

We can contrast the complete consensus in retention functions, however, with aquatic habitat in WMA 6 where the individual factors had relatively high agreement (range from 71 to 100 percent), yet the overall agreement on aquatic habitat functioning was very low. This comparison between the individual factors and the overall wetland function score illustrates how even with a detailed key and instructions, best professional judgment can still impose variability on how the methods are interpreted.

For the numeric methods, statistical tests were only done for WMA 6 due to the small sample size in WMA 19. There was no significant difference among teams in the overall wetland score for MDE (p=0.34) and NC Guidance (p=0.44), even though there were several significant differences among teams for the individual functions that comprise the overall wetland score (Tables 11 and 12). For example, with MDE (Table 11), teams were significantly different in how they evaluated the FCIs (area removed) of flood attenuation (p=0.01) and aquatic habitat (p=0.047), but they were similar in how they evaluated groundwater, sediment stabilization, and wildlife habitat. There was evidence of a team bias with this method in that the same two teams consistently differed in scores for each of the functions that were significantly different.

Table 11. Kruskal Wallace test for significant differences between teams for wetland scores or individual function scores with MDE in WMA 6

Wetland or Function	Adjusted H	Degrees of Freedom	p-value
Overall Wetland	2.18	2	0.34
Groundwater Discharge	1.30	2	0.52
Flood Attenuation	9.22	2	0.01*
Water Quality	5.07	2	0.08
Sediment Stabilization	0.73	2	0.69
Aquatic Habitat	6.10	2	0.05*
Wildlife Habitat	2.07	2	0.36

(*indicates significance at 0.05)

In NC Guidance, function scores are multiplied by a weight to obtain the total wetland score. We evaluated the ratings for individual functions without the weights and found that although there was no overall difference among teams for the final wetland score, the individual functions were somewhat more variable (Table 12). For example, in instances where the adjusted H was relatively large (>4.0) though the overall model was not significant for differences between team scores, at least two teams varied significantly in their ratings. A case in point is water storage, where though the model was not significant (p=0.11) two of the teams were significantly different (p=0.004). Similar situations were observed with pollutant removal and recreation. Aquatic life value was significantly different between all teams (p=0.004). Unlike what was seen with MDE where two of the three teams consistently were different, the differences with NC Guidance varied between team and function.

For WRAP, the teams were not significantly different in their overall wetland scores (Adjusted H=0.32, p=0.85) but there were considerable differences among teams in rating habitat and water quality treatment (Table 13). However, teams tended to agree almost 80 percent of the time across functions and wetlands with habitat support and buffer and water quality input and treatment tending to lower the overall average agreement.

Table 12. Kruskal Wallis test for significant differences between teams for wetland scores or individual function scores with NC Guidance in WMA 6.

Wetland or Function	Adjusted H	Degrees of Freedom	p-value
Overall Wetland Score	1.63	2	0.44
Water Storage	4.47	2	0.11
Bank Stability	2.54	2	0.28
Pollutant Removal	5.38	2	0.07
Wildlife Habitat	0.36	2	0.83
Aquatic Life Value	10.94	2	0.004*
Recreation Education	8.61	2	0.13

(*indicates significance at 0.05)

Table 13. Similarity in team scores for the functions evaluated in WRAP.

WRAP Function	Similarity in Team Scores
Wildlife Utilization	85.7
Wetland Canopy	73.8
Wetland Ground Cover	95.2
Habitat Support/Buffer	59.5
Field Hydrology	92.9
WQ Input & Treatment	59.5
Average	**77.8**

100 = complete agreement among teams and 0 = no agreement among teams.

For WMQA, the teams were significantly different in how they scored the different wetlands (Adjusted H=6.15, p=0.05) and the variability was in how the teams scored soils, site characteristics, and landscape characteristics (Table 14).

Table 14. Similarity in teams scores for functions evaluated in WMQA

WMQA Function	Similarity in Team Scores
Hydrology	71.4
Soils	61.9
Vegetation Composition/Diversity	81.0
Wildlife Suitability	83.3
Site Characteristics	64.3
Landscape Characteristics	66.7
Average	**71.4**

100 = complete consensus and 0 = lack of consensus among teams.

Time Requirements:

All methods required at least one-half to one full day of training with the exception of WET, which took two days to train the teams in the specifics of the method. We did not keep an accurate record of the time required to gather all of the materials necessary to implement each method. However, this could be a considerable time commitment for some of the methods, such as the Descriptive Approach or WET, where rather detailed information is necessary.

We kept track of time requirements for completing the office portion of the method separately from the field portion (Table 15). The times reflect the time it took to actually complete each portion of the assessment method including looking at the materials in the office and answering the appropriate questions, or the time it took to collect the information necessary to complete the field portions of each method. WET required the most time, both in the office and in the field, while WMQA required the least. With the exception of WET, most of the office portion of the assessments was done in well under an hour.

The field portion was considerably longer for all methods, requiring between two and four hours to complete. The majority of this time was devoted to walking the wetland perimeter and becoming familiar with the site. Due to its sheer size, Horseneck Bridge (1285.9 acres) took the teams the longest time to complete the field assessment (Table 15). However, the field time requirements did not necessarily scale with wetland size. For example, it took almost as long on average to do the assessments for Sommers Park as it did to do them at East Orange, which is almost three times larger. In addition to size, other factors such as total perimeter length of the wetland and accessibility to the entire wetland perimeter influenced the assessment time requirement.

Table 15. Approximate time to complete the office and field portions of each wetland assessment method.

	Office time	Field time	Total time
Wetland Method	Hour:min	Hour:min	Hour:min
Descriptive Approach	:25	2:30	2:50
WET	3:00	4:00	7:00
WI RAM	:40	3:05	3:45
VIMS	:30	3:00	3:30
NC Guidance	:20	2:40	3:00
MDE	:20	3:08	3:28
WRAP	:40	2:43	3:23
WMQA	:05	2:15	2:20

Combined, office time and field time give an indication of how much time is required to implement the entire method. These times reflect averages across the different teams and across the different wetlands. However, it is important to again keep in mind that these times do not reflect the time required to collect the necessary supporting information to complete the individual methods. In addition, availability of accurate and up-to-date information could significantly influence some methods such as WET and Descriptive Approach and lack of up-to-date land use/land cover data could hamper correct completion of the office portion of most of the methods.

Ease of Implementation:

Teams consistently found that documentation was one of the most important elements in interpreting and implementing the different methods. The more thorough the method was described and the more complete the instructions, the more confident the teams were in their ability to interpret and apply the method in the spirit intended by the authors. Good documentation also provided an important basis when considering the possibility of modifying or adjusting the existing methodology.

We examined wetland method documentation in two different ways. First we examined how thoroughly the method was documented with respect to definitions, rationale, and justification (Table 16). This is important as it identifies the constraints, considerations, and circumstances appropriate for applying the method. While this information may not be needed for internal use by the agencies or authors who developed them, it is helpful for those who may wish to use or adapt the method for use in regions or wetland types different from those in which the method was developed.

Six of the eight methods included some description of how the method was developed and included references to relevant sources or other information that was used during method development (Table 16). Our documentation of the Descriptive Approach and WI RAM did not include this information, while VIMS and MDE included above-average descriptions of the reasoning behind the development of their methodologies. The other four methods provided adequate descriptions of their development. Five of the methods made some reference about what sort of expertise is required for evaluators implementing the method.

We also considered how easy the methods were to implement (Table 17). We considered the operational implementation of the methods, including descriptions and instructions in how to apply the methods, starting from the identification of wetland boundaries to drawing the final conclusions for wetland function. We rationalized that implementation is important when considering whether a method is appropriate for certain circumstances, but ease of implementation also facilitates efficiency in applying the method and boosts users' confidence in their ability to interpret and move through the method correctly.

Interestingly, the teams found the numeric assessment methods easier to implement than the categorical methods (Table 16), though they may have taken as long or longer to implement. This preference between method rating types may reflect variations in authorship and the intended audience, but it also likely reflects the complexity that is inherent in implementing the numeric methods and thus greater attention to detail. Each of the numeric methods requires calculating either function scores and/or an overall wetland score, and calculations inherently require more detailed documentation than methods that categorically rate the functions. However, well-documented categorical methods like VIMS that also guide the evaluator through a series of keys to arrive at a rating help reduce discrepancies among raters.

Table 16. Extent of documentation for each of the wetland functional assessment methods

	Purpose	Development/literature references	Expertise required	Instructions	Function descriptions	Indicators descriptions	Scoring/ rating guidelines	Glossary
Descriptive Approach	x		x	x	x	-		
WET	x	x	x	x	x	x	x	x
WIRAM				-				
VIMS	+	+		x	+	+	x	
NC Guidance	x	x		x	x	x	x	x
MDE	x	+	x	x	++	++	x	
WMQA	x	x	x	x	x	x	x	
WRAP	x	x	x	x	x	x	x	x

++ = excellent; + = above average; x = good/average; - = below average; blank = not present

Table 17. Ease of implementation for each of the different wetland assessment methods.

Wetland Method	Ease of preparation	Office	Field	Method organization	Data sheets
Descriptive Approach	-	-	+	+	-
WET	-	-	+	+	+
WI RAM	-	-	+	+	+
VIMS	+	+	-	+	-
NC Guidance	+	+	+	+	+
MDE	+	+	+	+	-
WRAP	+	+	+	+	+
WMQA	+	+	+	+	+

Legend

- poor/difficult
+ good/easy

Ease of Preparation:
- time intensive to gather materials, not readily apparent which references are required
+ materials easy to gather and necessary references are easy to determine

Office:
- time intensive in office, not readily apparent which questions are to be done in office
+ relatively rapid evaluation of office component; easy to distinguish what is to be completed in the office and what is to be done in the field

Field:
- some variables are difficult to collect or are not appropriate
+ variables are relatively easy to determine and are applicable in the field

Method Organization:
- method poorly organized and difficult to follow
+ method is relatively well organized and easy to follow

Data Sheets:
- data sheets lack organization, difficult to follow steps and determine final results. Some data sheets are missing
+ sheets are clear and all sheets necessary for completing the method is included

Table 18. Comparison of how the different assessment methods evaluated the different wetlands.

Wetland	HGM	Descriptive Approach	WET Social	WET Effect	WET Opp	WIRAM	VIMS	NC Guidance	MDE	WRAP	WMQA
Great Swamp	1	5	3	2	7	3	1	7	5	1	1
Dead River	3	7	5	1	4	4	2	5	2	3	2
South Main	2	6	6	6	4	2	4	1	6	4	3
Roosevelt	4	1	7	3	4	1	3	4	4	2	4
East Orange	7	3	2	7	1	5	7	3	1	5	6
Sommers Park	6	4	4	5	6	6	5	6	3	7	7
Horseneck Br.	5	2	1	4	2	7	6	2	7	6	5

The wetlands are listed from upstream to downstream. These wetlands are part of a reference set with Great Swamp representing the most intact, relatively pristine wetland and East Orange representing the most degraded wetland. HGM serves as the context for comparing how the other eight methods ordered the wetlands based on the proportion of functions that were assessed as higher than the mid range of possible scores.

CHAPTER 4. DISCUSSION

As mentioned in the beginning of this report, government bodies that are charged with the protection of wetlands require tools that allow them to assess the functional status of wetlands efficiently and in a timely manner. Such assessments assist in wetland preservation, conservation and restoration. The complexity and diversity of wetland types, and conditions, present resource managers with a great challenge in developing and implementing such tools. One of the first steps, however is to clearly identify the purpose, goals and need for the functional assessment. If the primary goal is to compare different wetlands in a variety of settings and across wetland types, some functional assessment approaches will be more appropriate than others. If, on the other hand, the goal is to study temporal trends within a wetland such as pre and post impact events or restoration efforts, different methods may be more appropriate. In circumstances where the goal is to evaluate wetland status in the context of existing impairment or restoration potential yet other methods are appropriate. This diversity of goals and intents is most certainly reflected in the existing range of methods as well as the on-going introduction of new methods. No one method will work across the range of goals, wetland types or circumstances. Yet, studies such as this provide a context to better understand the strengths and weaknesses of different assessment approaches (Appendix D).

In this study we evaluated eight different wetland assessment methods in terms of repeatability, ease of implementation, and efficiency. We were able to conduct this evaluation by applying the different methods to the same set of wetlands, all of which were floodplain forested riverine wetlands. In addition, we also had three teams that were consistent throughout the duration of the study and they applied each method to the wetlands. This allowed us to examine repeatability between evaluators in the application of the method results. Training and support material requirements along with extent and clarity of documentation allowed us to assess how easy it was to implement the different methods. Time requirements to implement the methods were related to efficiency.

While we could attempt to control for differences in wetland types and assessors, we could not control for differences inherent in the different methods. The methods in this report were developed for a wide range of purposes (Table 1). Some were developed for examining individual wetlands for permitting purposes, while others were developed for use in scientific studies or for planning. Some were designed to evaluate wetlands on a site-by-site basis, while others are geared to take a watershed approach. With the range of scoring methods, assessment of different functions and indicators, and different goals and purposes, we are somewhat limited in the types of direct comparisons between methods that are possible or appropriate. However, we can look at trends that emerged to better understand the implications associated with the different methods.

The riverine wetlands in WMA 6 were part of the reference set for an HGM feasibility study (Hatfield et al. 2002). The reference set represents a range of conditions spanning from relatively undisturbed to more disturbed, less pristine conditions (Smith et al. 2001b). In general, the reference wetlands followed this paradigm from more to less pristine in the downstream direction. Ideally, a functional assessment method should be sensitive to this gradient. To systematically examine this sensitivity to disturbance across the different methods, we used the relative order in which the HGM assessed the different wetlands as a framework for examining the sensitivity of the eight methods. For example, in HGM, Great Swamp had the highest functional value followed by South Main and then Dead River (Figure 5, Table 18). Roosevelt followed Dead River and the three most downstream wetlands were ranked in reverse order with the river gradient. East Orange was considered the least pristine. To compare this ranking with the results from each of the eight methods, we simply counted the proportion of individual functions that scored higher than the mid-range of possible scores for each wetland. For example, with VIMS, we counted the number of individual functions that scored higher than 2.0 for each wetland. Using this count, we then ordered the seven wetlands from high to low. We then compared the order of wetlands with HGM against the order arrived at using other wetland methods (Table 18).

WMQA most closely followed the HGM wetland order with just one positional shift for two upstream wetlands and two downstream wetlands (i.e., Dead River swapped places with South Main and East Orange swapped positions with Sommers Park in WMQA compared to HGM, Table 18). VIMS also rated Great Swamp with higher functioning and considered the three lower wetlands as lower functioning, but the order differed. None of the other methods identified the two ends of the gradient, except for NC Guidance, which considered the lower wetlands to have higher functional value than the upper wetlands. This reverse gradient reflects NC Guidance's emphasis on social values and the importance of functions that are relatively high when the site is in close proximity to urban centers.

In a few instances, a particular HGM function coincided with a similar function in one of the methods. For example, the retention function in WET and HGM was scored similarly across all wetlands (Figures 4 and 5). There were also instances where individual functional values were similar between HGM and an assessment method within a wetland (i.e., for Great Swamp and Horseneck Bridge, Water Quality in WI RAM – Figure 6) but the agreement was confined to individual wetlands and individual functions and did not persist across all wetlands or all functions.

With the different scoring methods, it is not possible to directly compare the differences in team scores across all of the methods. However, we did compare how similarly the different teams rated a particular function within a method across all wetlands. In nearly all methods, there were at least one or two functions that exhibited considerable differences in how the teams rated them. For example, in WET Social Functions, there was only a 38 percent consensus in team score for ground water discharge. In fact, it was not uncommon for functions related to habitat and sediment stabilization to exhibit the greatest differences between team scores within a particular method. This is the case for WET Social (Sediment Stabilization), WET Effectiveness (Sediment Stabilization, Wildlife and Aquatic Habitat), WI RAM (Shoreline Protection, Fishery Habitat), VIMS (Aquatic Habitat), NC Guidance (Aquatic Habitat), MDE (Aquatic Habitat), WRAP (Habitat Support/Buffer), and WMQA (Soils).

There was also quite a range in how similar team scores were when differences in teams' scores were averaged across the different functions within a method (Tables 7 through 14). The range extended from a low of 65% for WET Effectiveness to a high of 87% for the Descriptive Approach. It is important to note, however, that the Descriptive Approach is a binary (yes/no) method, which functionally reduces variability between the team responses. Collectively, WET had the greatest discrepancies among team scores, followed by WMQA and WI RAM. Within the numeric methods, where we could statistically test for differences between teams, three of the four methods were relatively robust to differences in team scoring of individual functions even in instances where there was quite a difference in similarity scores for the individual functions (i.e., in WRAP with less than a 60% similarity in team scores for Water Quality). This suggests that the process of translating the scores for individual functions to the overall wetland score reduced the variability among teams. WMQA was the only numeric method that showed a significant difference among teams for overall wetland scores and the source for the differences could be traced to three of the six assessed functions.

The lack of consistency in team ratings can stem from several sources that will require specific attention. This is particularly the case with those functions that tended to vary across all methods. For these particular functions, there is either a need for better documentation, more detailed study of the adequacy and temporal variability of the field indicators, and/or the need to modify the more variable functions.

In WMA 19, all three wetlands were rated moderate or higher by all five methods. WI RAM, NC Guidance and WRAP tended to score the wetlands higher than VIMS or MDE. In instances where there was any discernable difference between the wetlands, Birmingham, the middle wetland in the river gradient, tended to score slightly higher. As with the fisheries or aquatic habitat function in WMA 6, the methods uniformly scored this function lower in WMA 19 as well, indicating that riverine wetlands, at least in the settings we examined, are not conducive to supporting high functioning fish habitat. The river/urban gradient in WMA 6 provided a useful context for qualitatively comparing the different functions. Without a discernable gradient in WMA 19 it is difficult to evaluate the relative performance of the different methods in a different physiographic setting. However, across the different methods the WMA 19 wetlands generally had functional scores similar to the more pristine wetlands in WMA 6. In some instances, the WMA 19 wetlands had higher scores than the WMA 6 wetlands. It is also possible that some wetland functions exhibited a wetland-type response. For example, sediment stabilization tended to score similarly in both WMAs reflecting the intermediate to low sediment stability inherent in these riverine wetlands that experience seasonal inundation and scouring.

Assessment of Scoring Type

Three different types of rating systems are represented by the eight methods employed in this study. The Descriptive Approach uses a presence/absence system, while WI RAM, VIMS, and WET use qualitative rating systems with either three or four ratings available: low, medium/moderate, high, and exceptional (only WI RAM uses exceptional). These rating systems do not supply an overall score for the wetland being evaluated. The remaining four methods (MDE, NC Guidance, WRAP, and WMQA) use quantitative rating systems where each function is scored and an overall score for the wetland is calculated based on function scores.

The presence/absence rating system (based on our experience with the Descriptive Approach alone) has both advantages and disadvantages. The system allows for a good deal of flexibility in the evaluation since the assessment can be tailored to the particular conditions at each wetland site. The information collected (presence/absence) may be appropriate for many assessments due to its qualitative nature and does not imply a judgment based on quantitative data as has been argued for qualitative (L/M/H) ratings

(US ACOE 1995). However, a large degree of best professional judgment is required for this type of method which could contribute to inconsistent application of the method. The solution recommended by the method authors is that this method be applied by an interdisciplinary team of experts. This recommendation inherently increases resource costs (time*number of experts) to implement the method. If the goal of wetland assessment is to evaluate existing status of the wetland this method would help accomplish this goal. However, the method does not necessarily inform on the degree of functioning for individual functions so examining temporal trends or comparing different wetlands is more difficult with this method.

The qualitative methods that employ qualitative rating systems with multiple rating levels (WI RAM, VIMS, and WET) also have both advantages and disadvantages. Qualitative ratings can imply more quantitative scientific evidence to support functioning than is actually present. For these methods there is no overall wetland score, and it is necessary to examine the individual functions or suite of functions to assess overall wetland functioning. Best professional judgment is important for all three of these methods but it is inherently more relied on in WI RAM versus the other two. WET and VIMS employ interpretive keys based on the answers to indicator questions that lead the evaluator to a rating for each function. WI RAM provides no guidelines for the determination of an overall function rating, instead relying entirely on best professional judgment. This means there is greater flexibility in WI RAM, allowing the evaluator to tailor the ratings to individual site conditions; however, as such, it is important that evaluators have ample experience to make an accurate determination of functioning. The fact that WI RAM, with a 74 percent agreement among the different evaluators (Table 9), did not have the lowest agreement among evaluators suggests that this approach may be reasonable if greater flexibility is important, though training and cross-checking would be critical to ensure repeatability and consistency among evaluators. WET and VIMS are less adaptable, but given the more comprehensive instructions, they can be applied by evaluators possessing a greater range of expertise. VIMS was one of the more consistent methods with an average of 83 percent agreement among the evaluators for the different functions. This is in contrast to WET, which had explicitly detailed instructions and yet was one of the lower scoring methods for evaluator consistency. Lastly, the lack of an overall wetland score makes it difficult to compare large numbers of sites. For WI RAM and VIMS, which were designed to examine sites on an individual basis, this may not have proven problematic to the methods' authors. WET, however, specifically states that it may be used to compare wetlands to each other, though this may prove tedious with no overall wetland score. VIMS was designed to examine trends among wetlands on a function-by-function basis and to characterize individual wetlands, so it was not intended to provide comparisons across a wide number of wetlands.

The quantitative rating systems (employed by NC Guidance, MDE, WRAP, and WMQA) have different advantages and disadvantages relative to the qualitative methods. Since these methods produce an overall numerical score for each wetland, it is easier to directly compare different wetlands, at least those of the same wetland type. This comparison may be useful information; however, it is important that evaluators keep in mind that scores are still based on a limited amount of information and are not absolute. It is also important to recognize that two wetlands could have the same overall wetland score but for quite different reasons which can only be discerned by examining the individual functions. Additionally, it can be difficult to determine when scores actually differ significantly from each other or simply reflect natural variability. For example, does a wetland have to score 0.25 higher or lower to be different from another wetland or to denote a temporal change in wetland functioning? Indeed, this is a question that plagues all functional assessment methods, what denotes a significant change? In all four numeric methods, the overall wetland score is determined quantitatively from the scores for each wetland function. Different methods require differing degrees of professional judgment in determining the score for each function. MDE and NC Guidance use flowcharts to assign a numerical score based on the presence of indicators for each function, while WRAP and WMQA allow for a greater degree of best professional judgment in the determination of a score for each function. With these latter two methods, evaluators subjectively determine the score for each function using a list of criteria for each score as a guideline; these criteria are more flexible than flowcharts and can be adjusted more easily to fit different types of wetlands or to better reflect what is occurring at unusual sites. Three of the four numeric methods were repeatable among the different evaluators (WMQA had greater variability) for overall wetland scores, though there were significant differences for some of the individual variables. This suggests that the overall scores are robust and not especially sensitive to the details. Whether that is a good characteristic would have to be determined and would depend on a range of circumstances.

All eight of the methods we looked at evaluated wetland functioning. This is in contrast to biological assessments that are evaluated through Indices of Biological Integrity (IBI - Karr and Chu 1997). Functional and biological assessments convey different types of information about a wetland; they also fit differently into the regulatory framework. Function generally focuses on the services that a wetland provides to the environment, such as floodwater storage, sediment retention, water quality improvement, etc. Biological assessments are more directly linked to water quality and are used to determine the condition of the wetland plant and animal communities. However, a wetland that has high functional value may be low quality from an IBI perspective. For example, wetlands in an urban setting may provide high functional value to the surrounding landscape but be quite degraded from a quality perspective. Functional assessments are used in evaluating impacts related to dredge and fill permits under Section 404 of the Clean Water Act. The assessments are frequently used to estimate the degree or extent to which a function may change when a wetland is altered. The IBIs are used to evaluate a wetland with respect to water quality standards under Section 305b and Section 401 of the Clean Water Act. Therefore, legislatively, there is a precedence to evaluate both wetland function and condition. Assessing the condition and function of wetlands go hand in hand but, as logical as this might seem, our traditional approaches have been to look at these aspects of wetlands separately.

The methods we assessed have been in place for some time. Some are still in use or under review (Descriptive Approach, WI RAM, NC Guidance, WRAP, and WMQA) while others have been replaced by different approaches. Many states are moving toward the development of the hydrogeomorphic method (HGM – Smith 2001 a,b) for wetland functional assessment. As the name implies, this approach emphasizes the hydrologic connections and interactions in the framework of the geological setting. As such, this approach emphasizes the importance of defining the appropriate wetland type, since it will directly influence the functions that are likely for a particular wetland type. This approach also works within the framework of reference wetlands that ideally span the gradient from pristine to degraded wetland conditions within each wetland type.

Wetlands that are assessed with the HGM are compared to the reference wetlands to determine wetland functionality. The challenge with HGM is that it requires extensive upfront model development for each regional subclass (Smith et al. 1995). It requires the identification of a reference domain, sampling and establishment of reference wetlands and reference standards, and development of models for different wetland functions based on the reference system. More and more regional guidebooks are becoming available for different wetland subclasses, and while these guidebooks are useful, models developed for different regions may not be easily transferable to other regions (Cole et al. 2002). For states as geologically and hydrologically complex as New Jersey, implementation of the HGM approach would require considerable dedication of resources to develop HGM models for each of the State's seven wetland subclasses with modification for the five regional subclasses within the State. This is further confounded by the pervasive human imprint on the New Jersey landscape, which has to be incorporated into how reference systems are developed (Ehrenfeld 2000, Hatfield et al. 2002). Consequently, even existing guidebooks (Brinson et al. 1995) for the wetland subclasses require considerable modification to be functional.

Training and ease of implementation varied by method. However, better documentation generally led to greater confidence in appropriate application of the method. The extensive training and time to implement WET did not result in greater consistency across teams and also did not tend to reflect the river gradient as other methods did. Both WET and the Descriptive Approach require a somewhat extensive list of materials to answer some of the questions. If this material is not consistently available, this might influence the results but could lead to greater loss of information or variability in interpretation of the methods. In all instances, the teams felt the site visit was vital to their implementing the methods properly versus trying to arrive at a wetland functioning through a desktop approach.

CHAPTER 5. RECOMMENDATIONS AND CONCLUSIONS

When evaluating the different wetland functional assessment methodologies, it is imperative that the goals, needs and intent of the user are clearly defined. Different methods have been developed with different goals in mind and no one method will likely accommodate all situations. Clearly identifying the user requirements will help elucidate which methods are appropriate in different circumstances, with the expectation that several may be necessary. Awareness and careful consideration of the strengths as well as the limitations of the different qualitative assessment approaches will provide the basis for a more informed decision. However, even with a full awareness of the merits of qualitative assessment methods, at best they provide a general context for wetland functional assessment and are no substitute for quantitative data.

In this study, we examined the eight methods that spanned a range of scoring approaches and goals (Table 1). The Descriptive Approach evaluates the occurrence of a wetland function while WET, VIMS and WMQA evaluate through different techniques the probability that a wetland function can occur. WI RAM and NC Guidance are designed to evaluate wetland value while MDE evaluates relative wetland value. WRAP evaluates the extent that a wetland function is performed. It is only through a careful definition of user requirements and how this relates to the intent of the different functions can one begin to select the most appropriate approach. This inherently makes it difficult, if not impossible, to compare all wetlands in all situations and for all purposes. Differences in method intents, evaluation procedures and scoring emphasizes the necessity to have goals and purposes clearly identified before extensive resources are allocated to any one particular strategy. However, there are some clear patterns from studies such as this that allow resource and regulatory managers to make more informed decisions.

Methods that are not easy to implement, and are not efficient or repeatable are likely not worth the investment of further investigation. Such is the case with WET which was time intensive and relatively inconsistent in wetland scores between the different teams. Careful and complete documentation is essential to ensure proper interpretation and implementation of the methods. Moreover, careful documentation should also include limitations and assumptions inherent in the model and situations for which the method is not appropriate. We feel strongly that this point cannot be overstated considering the variety of circumstances that may be encountered in the field as well as the wide range of individuals with different experience levels who might have the opportunity to use the method. Both WI RAM and the Descriptive Approach were lacking in adequate documentation to guide implementation. If these methods are to be explored further, concerted effort should be devoted to interacting with those who are currently using the methods.

All of the methods rely on best professional judgment. This is the point that is most important for efficient and timely wetland functional assessment, but is also the one most open to criticism due to it's subjective nature. Training for a particular method will cut down on variability between different evaluators as has been shown with WRAP (Miller and Gunsalus 1997). However, we also feel that a one-time training is likely not sufficient and the evaluators should be repeatedly tested in a variety of situations and wetland types to increase consistency. The downside of this is that it is time consuming and costly and with the flux of evaluators in the regulatory and consulting environment, this will not be an easy hurdle to pass.

We found that certain functions tended to be more variable between the different teams, methods and wetlands. These functions, particularly those related to habitat, frequently occur in wetland functional assessment methods. Due to the frequency with which these functions are used, and the ubiquity of the variability in the methods we tested, there is a pressing need to better understand the source of variability. Differences may be due to a general lack of adequate detailed documentation in the methodology that results in greater reliance on interpretation rather than clearly defined indicators. However, it is also quite possible that these particular functions are more prone to errors in interpretation or natural variability of field indicators. Habitat is difficult to evaluate on a one-time visit. Habitat can vary seasonally and interannually; therefore, an evaluator visiting in the spring might score habitat function differently than if that same evaluator visited the site in midsummer or during a dry year or wet year. Furthermore, habitat functions that rely on evidence or sightings of wildlife use are problematic due to seasonal and/or diurnal wildlife behavior as well as the disturbance created by the presence of evaluators.

The comparison between two geographic locations showed some interesting patterns. The three wetlands in WMA 19 scored similarly to the more pristine wetlands in WMA 6 for many of the functional assessment methods. However, with only three sites it is difficult to determine whether these wetlands were indeed relatively undisturbed or if the methods were geographic sensitive. Evaluating additional riverine wetland sites that reflect a greater range of conditions in WMA 19 would help resolve this question.

Although none of these methods were developed specifically for the riverine wetland type or for the region, only limited modification was deemed necessary to apply them to the wetlands we evaluated. A larger suite of wetlands would be necessary to rigorously test the individual methods, evaluate necessary modifications, and assess calibration and implementation requirements.

Additional studies that compare different functional assessment methods are needed to understand if the findings in this study translate into similar results for other wetland types and other regions. The information and data from this study contributes to the growing body of knowledge regarding functional assessment and identifying indicators of wetland quality. A total of eight functional assessment methodologies, and to a lesser extent HGM, have been considered here. They encompass a range of intents, purposes and scoring methodologies. There is no basis, nor was it the intent of this study, to consider one method superior over the others. Rather our goal was to better understand the assumptions, limitations and strengths of the different methods.

Four of the methodologies are currently in use within the regulatory framework (Descriptive Approach, WI RAM, WRAP, and HGM) and WMQA is in review. HGM is the most rigorous in terms of method development and implementation and is also most widely used. However, adopting the HGM approach within the State will require an extensive resource and time commitment due to the physical and anthropogenic complexities of the State. In the interim, a better understanding of wetland function from a variety of perspectives will help move the State forward in their effort to evaluate wetland quality.

Studies that examine the way in which different wetland assessment methods evaluate the same wetland set are uncommon. By including a range of approaches, we have attempted to provide a sense of the complexities and challenges that are inherent in the assessment of wetland function. No one method was better than the others, but some performed stronger than others on a number of fronts. However, this is a limited study and further testing on additional wetlands would help determine the robustness of the results found in this study. Selecting the method that best meets the goals and needs of the user is fundamental to making the right choice. Understanding the challenges of methods that rely on best professional judgment and putting in place strategies to help standardize assessment results will lead to greater confidence and repeatability in the application of the functional assessment. The scientific understanding of wetlands continues to guide wetland assessment but resource managers are hampered in their ability to quantitatively study wetland function. While studies such as this cannot bridge that gap, it will hopefully provide a greater understanding of qualitative assessment techniques and facilitate the State in their efforts to manage their wetland resources.

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APPENDICES

Appendix A: Wetland Assessment Database

Appendix B: Additional Wetland Functional Assessments Critically Reviewed

Appendix C: Sample Method Instruction and Data Sheets for the Functional Assessment Methods Implemented in WMA6

Appendix D: Operational Strengths and Weaknesses of the Functional Assessment Methods Implemented in WMA 6