Testing a Wetlands Mitigation Rapid Assessment Tool at Mitigation and Reference Wetlands within a New Jersey Watershed

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EXECUTIVE SUMMARY

The New Jersey Department of Environmental Protection (NJDEP) has embarked on a number of projects in order to develop a better understanding of wetland resources in the state. This project and a companion study, Development of Wetland Quality and Functional Assessment Tools and Demonstration (Hatfield et al. 2004), address approaches to assessing wetland function. The specific purpose of this study was to assist NJDEP in the evaluation of a rapid wetland assessment method that was developed to evaluate the probability that mitigated wetlands will perform wetland functions. In this study, we specifically evaluated a wetlands assessment methodology known as Wetland Mitigation Quality Assessment (WMQA). WMQA was developed through a prior DEP research study (Balzano et al. 2002) to evaluate the relative probability that a constructed wetland will eventually function similarly to natural wetlands. To build upon the prior research, specific goals of this study were to evaluate how WMQA performed when applied to a range of wetland types including mitigated and natural wetlands, evaluate consistency among different evaluators in the application of the methodology, and to assess sensitivity of the method to seasonal conditions.

WMQA was applied to a total of 24 different wetlands. Ten of the wetlands were mitigation wetlands that ranged in size from 0.1 to over 50.0 acres and varied in age from less than one year to over 9 years since creation. We also applied WMQA to fourteen natural wetlands, seven of which were forested and seven of which were emergent wetlands. To test for consistency among different evaluators applying the methodology, three separate teams independently evaluated each of the 24 wetlands using WMQA. The seasonal sensitivity of WMQA was tested by applying the methodology at mitigation and emergent wetlands early in the growing season as well as late in the growing season.

Mitigation wetlands generally scored lower than the emergent and forested wetlands while the emergent and forested wetlands were more similar in WMQA scores. Landscape setting and wildlife were the two variables that consistently scored lower for the mitigation sites compared to the natural wetlands. Some components of WMQA were less appropriate for evaluating conditions found in the natural wetlands and reflect the intent of the method to be used to assess mitigation wetlands. There was a significant difference among evaluator scores with one team consistently scoring wetlands higher than the other two across all wetland types. There was also a significant seasonal difference with the spring WMQA scores generally lower than the fall scores. This was particularly evident for the emergent wetlands and less so for the mitigation wetlands. The weightings that are used in calculating the final WMQA Index score did not markedly change average WMQA scores or individual wetland scores. There was no apparent influence of a learning curve as wetland evaluators became more familiar with the method. Wetland age or size also did not have a direct effect on the WMQA scores for the wetlands sampled.

Generally WMQA was found to be sufficiently sensitive to qualitatively assess potential wetland function for mitigation wetlands. The wide range of WMQA scores for mitigation sites reflect the diversity of conditions often associated with created wetlands. The methodology also demonstrated the expected pattern that natural wetlands have greater potential wetland function than created wetlands. Even though some of the individual variables that are used to determine a WMQA score were not particularly appropriate for the natural wetland conditions, the overall WMQA scores still showed the higher potential functioning for the natural wetlands. If the method were to be applied in a broader perspective across a wide range of wetland types, most of the variables would still be appropriate indicators of wetland function. The soils variable that used indicators for conditions typical of constructed wetlands would likely require some modification to reflect conditions specific to natural wetland function.

There were statistically significant differences in WMQA scores between seasons and among teams. However, in the context of a qualitative assessment procedure and management implications it is perhaps more important to consider what really reflects a significant difference operationally versus statistically. More experience with WMQA in a range of different conditions and wetland types will help distinguish what and when changes or differences in WMQA scores are relevant. The experience will also help in the development of guidelines and recommendations that will facilitate the interpretation of variation in WMQA scores. Comparing and contrasting the performance of WMQA with other wetland functional assessment techniques will provide a better basis for evaluating how well the method does in the context of other methods that were designed to evaluate natural wetlands (Hatfield et al. 2004).

Recommendations and Conclusions

WMQA provides a relatively easy and rapid way to evaluate wetland function and with some modification it could be used to evaluate natural as well as created wetlands. The merit to this would be a common baseline tool to evaluate wetlands rather than different methods for different wetland types or situations. As with all qualitative assessment approaches, WMQA only provides a general sense of whether a wetland, natural or created, will eventually evolve toward natural wetland function. As such, caution must be exercised when interpreting the assessment output. This does not substitute or negate the need for scientific information to improve our understanding of both natural and created wetland function.

The method showed sensitivity to seasonality, wetland type, and evaluator consistency in applying the method. The sensitivity to wetland type is a plus since it demonstrates the expected, that natural wetlands perform better than created wetlands. Though variables were not altered in this study, the authors clearly state that variables may be added or deleted depending on the circumstances encountered. Caution is warranted here that thorough documentation accompany any changes and there be an awareness that changing the method may detract from the ability to compare across different wetlands.

The method's sensitivity to seasonality has to be carefully considered. Either all wetlands need to be consistently evaluated during just one season of the year or wetlands need to be evaluated several times during the year to capture the variability attributable to seasonality versus longer-term trajectories of functional change.

Evaluator consistency can be explicitly addressed with training and repeatability assessment among different evaluators. For evaluators who frequently apply the method a consistency test once or twice a year would be warranted. However, for evaluators who infrequently use the method, they should train seasonally to ensure that they are not influenced by seasonal or inter-annual variability.

Further study is warranted to evaluate what constitutes a real difference in WMQA scores versus inherent variability. A change in total wetland score of 0.1 to 0.2 likely reflects noise in the process (though this range may be even greater). When the changes or differences in WMQA scores are greater than 0.2 further investigation as to why the scores are different is warranted.

Understanding why a wetland has a particular score is important from a number of perspectives including resource management, assessment of restoration potential, or evaluation of temporal trends in wetland function. Each of the six variables that are used to derive a single WMQA score providess important information and insights to wetland function. The importance of paying attention to these variables individually cannot be overstated.

Weightings did not exert a strong influence on overall WMQA index scores nor did the weightings change the relative rankings of the wetlands. The weightings added an unnecessary complication that could potentially introduce error into the computational portion of deriving the WMQA index.

CHAPTER 1. INTRODUCTION AND PROBLEM STATEMENT

The National Environmental Performance Partnership System (NEPPS), established in 1995 by the U.S. Environmental Protection Agency and the Environmental Council of States (ECOS), emphasizes the use of self-assessments and environmental indicators to evaluate the progress of state agencies in meeting their environmental goals (NJDEP 1996). As a participant in NEPPS, the New Jersey Department of Environmental Protection (NJDEP) has established the following goals with respect to wetlands: 1) to improve the quality and functioning of freshwater wetlands, 2) to implement effective techniques for the further enhancement of wetlands, 3) to achieve a net increase in wetland acreage by 2005, and 4) to implement more effective techniques for wetland creation (Balzano et al. 2002). Under the guidance of the New Jersey Freshwater Wetlands Protection Act, which regulates all proposed freshwater wetland activities, NJDEP is responsible for the management of land development in order to minimize wetland disturbance and loss.

Wetland mitigation is one approach used to compensate for wetland impacts or losses that occur due to activities that are permitted by NJDEP. Mitigation options include wetland creation, restoration, enhancement, and in some cases, preservation. The goal of mitigation is to replace the function and value of a wetland that has been lost or impacted. As such, it is important to evaluate the status of wetlands that are constructed through the mitigation process and the potential for these created wetlands to perform wetland functions.

In 1999-2000, NJDEP, in conjunction with Amy S. Greene Environmental Consultants, Inc. (AGECI), embarked on a project to evaluate the status of freshwater wetland mitigation in the state of New Jersey (Balzano et al. 2002). The project evaluated NJDEP's performance in attaining NEPPS goals by developing standards for monitoring the performance of freshwater wetland mitigation in New Jersey. Three indicators were used to determine the status of mitigation wetlands: 1) wetland area achieved, 2) concurrence with site plan specifications, and 3) wetland mitigation quality assessment. The mitigation quality assessment employed the Freshwater Wetland Mitigation Quality Assessment Procedure (WMQA), a rapid assessment methodology developed by AGECI in concert with NJDEP (Balzano et al. 2002). It is the third component of the above-referenced study, the WMQA, that is the focus of this research.

The Freshwater Wetland Mitigation Quality Assessment Procedure (WMQA) evaluates the probability that a mitigation or constructed freshwater wetland will develop into a naturally functioning wetland system. It is a qualitative methodology based on the concept that wetlands with a higher index score have a greater potential to function as natural wetlands. WMQA does not provide a direct quantitative measure of wetland function nor is it intended to assign a measure of absolute wetland quality. WMQA is intended to serve as an interim assessment tool to provide consistency and guidance to NJDEP's evaluation of the current status of New Jersey wetland mitigation efforts. It is not intended for use in regulatory evaluations nor to replace the criteria used to determine mitigation success. It is also not a substitution for applied research or training.

Wetland assessment methods, such as WMQA, have been developed to provide a rapid evaluation of wetland functioning by environmental managers. In general, assessment methods are designed to be straightforward, uncomplicated, and easy to apply within a relatively short timeframe. As a result, rather than using long-term, quantitative studies that monitor wetlands over more than one field season, the evaluator's "best professional judgment" is heavily relied on to determine wetland functioning. The assessment methodology also relies on readily observable field indicators that can be consistently and easily identified. An important element of the assessment methods is that they can be consistently applied by multiple users and across a wide range of wetland community types and field conditions in order to provide repeatability and confidence in scoring. Assessment methods can lend structure, repeatability, and consistency of documentation to field observations made by the evaluator.

The purpose of this study was to evaluate the WMQA methodology with respect to wetland type, observer variability, and seasonality. WMQA was applied in both natural and mitigation wetlands. The application of WMQA to both wetland types provided an indication of the relative functioning of mitigation wetlands compared to that of natural wetlands. Using the method on natural wetlands also provided an independent assessment of the relative utility of WMQA to evaluate natural wetlands. Applying

WMQA in multiple seasons and with multiple users provided an indication of the consistency and repeatability of the method.

In addition to augmenting the Balzano et al. (2002) report and testing the utility of the WMQA approach, this report also has links with two additional research projects that NJDEP has developed in concert with Rutgers University. NJDEP and Rutgers are collaborating on a study that is examining a number of different wetland functional assessment methodologies. The goal of this study was to provide a comprehensive knowledge base of functional assessment techniques as it moves forward in the development of indicators of wetland status, quality, and function that are appropriate for use by the state. NJDEP and Rutgers are also collaborating on the development of a wetlands hydrogeomorphic model (HGM) for low-gradient riverine wetlands. A portion of the reference wetland sites used in the development of the HGM model was also used as the natural forested wetlands for this study. Taken together, these studies will provide additional basis for how New Jersey may best assess its wetlands in terms of quality and function.

CHAPTER 2. DESIGN AND METHODS

The WMQA methodology was applied to a total of twenty-four (24) wetlands. Ten sites were mitigation/constructed wetlands, seven sites were natural forested wetlands, and seven sites were natural emergent wetlands. All of the sites were located in close proximity to New Jersey's Upper Passaic, Whippany-Rockaway Watershed, referred to by NJDEP as Watershed Management Area 6 (WMA 6).

Site Selection:

Mitigation Wetlands:

WMQA was applied to ten mitigation wetlands located in or in close proximity to WMA 6 (Figure 1). This geographic restriction on location of mitigation wetlands was imposed to facilitate comparison between the mitigation sites and existing natural wetlands that were being studied as reference wetlands in a related NJDEP-Rutgers University study cited above. Based upon a field reconnaissance conducted from their prior work (Balzano et al. 2002), the mitigation sites were recommended by AGECI from

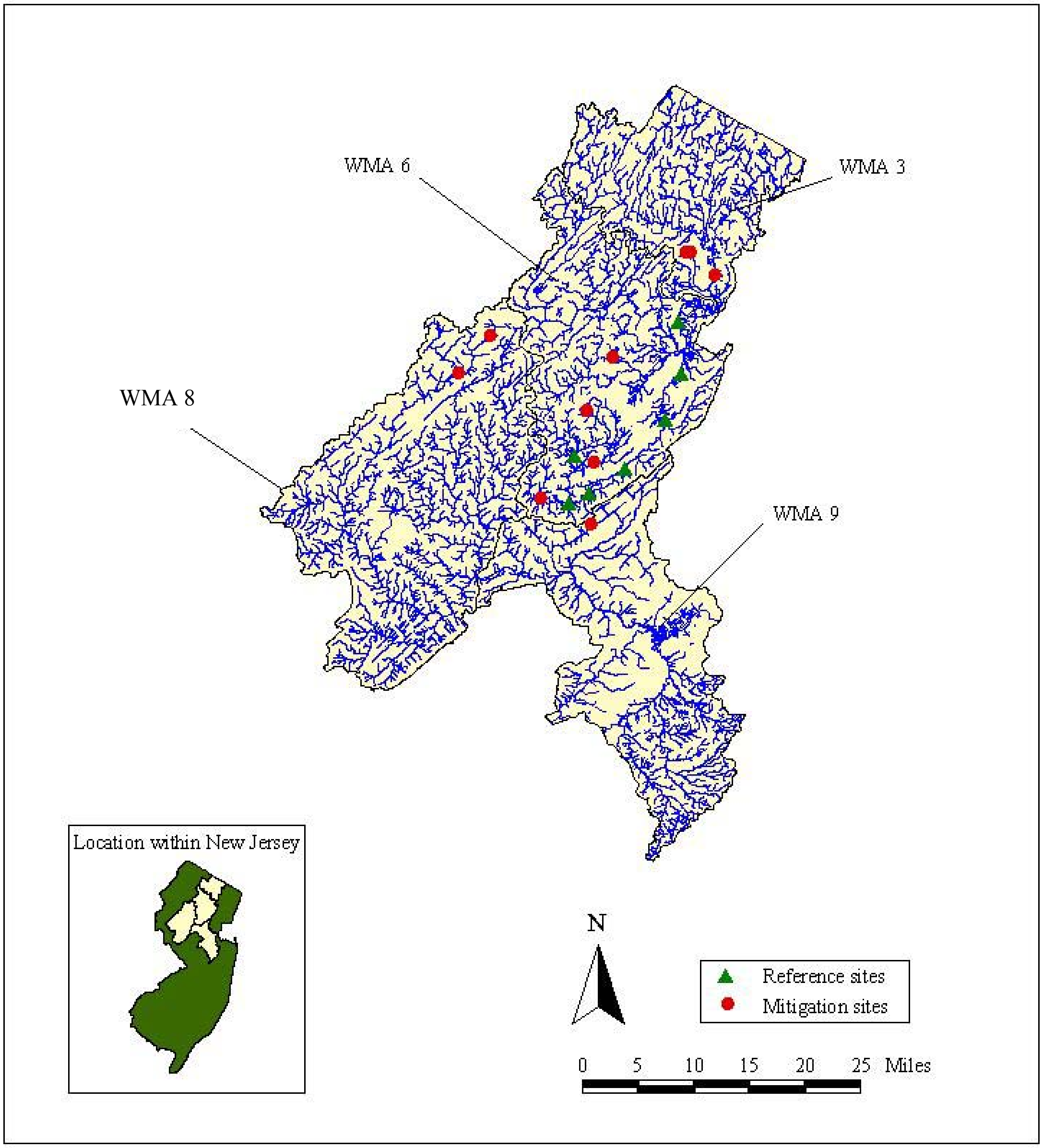

Figure 1. Location of reference and mitigation wetland sites. The sites spanned four NJDEP Watershed Management Areas (WMA 8, WMA 6, WMA 9, and WMA 3).

the database of mitigation sites they had already evaluated. In addition to the geographic restriction, AGECI also selected mitigation sites that were somewhat comparable to the natural wetlands used in this study (A. Ertman, personal communication). Mitigation wetland sites ranged from simple circular wetlands surrounded by a highway or in close proximity to commercial land use to more complex, heterogeneous wetlands surrounded by woodlands and with less extensive human impacts (site information is included as Appendix A). Ann Ertman of AGECI accompanied Rutgers on a preliminary site visit to each mitigation wetland to show where the wetland boundaries were that AGECI had identified and used in their study.

Natural Wetlands:

To assess WMQA's performance on natural wetland systems, the method was applied to seven forested riverine wetlands located along the Passaic River within WMA 6 (Figure 1). The sites were selected from wetlands currently used as reference sites for the development of the regional low-gradient riverine Hydrogeomorphic Method (HGM) model (Hatfield et al. 2002). The reference sites are considered to represent the most intact and natural riverine wetlands within WMA 6 (Appendix A).

In addition to the forested wetlands, seven natural emergent wetlands were also added to the original study for applying WMQA. While it was felt that WMQA evaluates the potential for a mitigated wetland to function as a natural wetland and hence wetland type should not matter, the mitigated sites were currently more similar to emergent wetlands. The mitigation wetlands were more comparable to the emergent wetlands in area, vegetation type, and hydrologic regime and the majority of the mitigation wetlands examined are more likely to continue to resemble emergent wetlands over time. It was felt that to better examine how WMQA evaluates wetland function it was necessary to add the emergent wetlands to the study. The emergent wetlands were within or in close proximity to the forested reference site (Appendix A).

The forested wetlands are generally part of a larger wetland complex. The boundaries of the entire wetland complex that contained the reference wetlands were used in this study. Boundaries of the wetland complexes and the emergent wetlands were determined using National Wetland Inventory (NWI) maps, except in the case of the Great Swamp National Wildlife Refuge site. The NWI maps were digitally superimposed onto USGS topographic maps so that the boundaries of the wetland could be identified and printed out. The Great Swamp National Wildlife Refuge consists of a large wetland complex and for the purposes of this study, the area evaluated was identified as a hydrologically distinct 24-acre wetland within the larger wetland complex.

<u>WMQA Methodology:</u>

WMQA provides a relative measure of the success of wetland mitigation by evaluating the relative probability that a constructed freshwater wetland will develop to function like a natural wetland system over time. The method is based upon the Wetland Rapid Assessment Procedure (WRAP), a rating index developed by the South Florida Water Management District (SFWMD) to assist the regulatory evaluation of mitigation sites. WRAP has been used extensively by the SFWMD and has been demonstrated to be a repeatable way to assess wetlands in a timeframe suitable for regulatory use (Miller and Gunsalus, 1997).

WMQA uses numerical rankings of six wetland variables. These wetland variables represent wetland function: hydrology, soils, vegetation composition/diversity (overstory and ground layer), wildlife suitability, site characteristics, and landscape characteristics (adjacent buffer, contiguity, land use) (Table 1). Each of the six variables is rated from 0 to 3 in increments of 0.5 based upon multiple indicators for each variable (Figure 2A and Appendix 2). A score of 3 represents a high probability of a variable achieving close to natural functioning over time while a score of 0 indicates a severely impacted or non-existent variable with a low probability of ever achieving natural wetland functioning.

It is important to note that the indicators are intended to provide general guidance for reviewers. All field indicators do not fit all mitigation sites and in some cases reviewers might base their rating on an indicator that is observed at a given mitigation site but not listed in the WMQA. Therefore, reviewers should assign a value for each variable based on the "best fit". Not all field indicators need to be met in order for a site to obtain a given score. It is important that the reviewers document the indicators they use to assign each score, especially any not listed in the protocol.

Hydrology wetland hydrology undesirable plant colonization plant stress plant mortality surface inundation water flow channelization redoximorphic features hydric soils	**Wildlife Suitability** cover adjacent resources human impediments nest/breeding activity
Soils topsoil erosion soil compaction debris	**Site Characteristics** maintenance edge:area ratio heterogeneity location size
Vegetation Composition/Diversity Overstory Layer plant cover invasive plants natural recruitment plant growth insects and herbivory plant stress diversity Ground Cover plant cover invasive plants natural recruitment plant growth insects and herbivory plant stress diversity	**Landscape Characters** Adjacent Buffer width invasive species wildlife suitability cover slope Contiguity contiguity Land Use land use

Table 1. WMQA wetland variables and field indicators for each variable.

A. Calculation of unweighted WMQA scores:

Variables (range 0-3)
- Hydrology
- Soils
- Vegetation Composition/Diversity
  - = (Overstory + Ground Cover)/2
- Wildlife Suitability
- Site Characteristics
- Landscape Characteristics
  - = (Adjacent Buffer + Contiguity + Land Use)/3

$$\textbf{WMQA score} = \frac{\text{sum of variable scores (V)}}{\text{sum of maximum possible variable scores }(V_{max})} = \frac{\Sigma V}{\Sigma V_{max}}$$

B. Calculation of weighted WMQA scores:

Wetland Variable	Weighting Factor
Hydrology	4.8
Soils	3.6
Vegetation Composition/Diversity	3.7
Wildlife Suitability	2.1
Site Characteristics	3.0
Landscape Characteristics	3.6

Variable x Weighting factor = Weighted Value

$$\textbf{WMQA weighted scores} = \frac{\text{sum of weighted values }(V_w)}{\text{sum of weighting factors}}$$

C. WMQA Index Calculation:

WMQA Index Score (0-1) = WMQA/3

Figure 2. Calculation of WMQA scores (from Balzano et al. 2002).

In the development of the WMQA, each of the six variables was assigned a weighting factor to reflect its relative importance to the overall score for a wetland (Figure 2B). Variables with higher weightings were determined to be more essential for a wetland to achieve natural wetland functioning than variables with a lower weighting factor (Balzano et al. 2002). These weightings were established by NJDEP and AGECI and reflect input from a panel of wetland experts from local government and academic institutions.

To calculate the overall weighted WMQA score for a wetland, each of the six variable scores was multiplied by its weighting factor and the weighted scores for the six variables were added together. This total was then divided by the maximum possible value to determine the final index score, which was expressed as a number between 0 and 1 (Figure 2). At the time this project commenced, the final draft of the WMQA method had not been released and an interim draft of the method from April 2000 was used for all fieldwork and analysis. However, the draft April 2000 WMQA method was the method implemented by AGECI (Balzano et al. 2002) and was determined to be the final method.

<u>Sampling Design:</u>

To assess how easy it was to interpret and implement WMQA, the Rutgers study team acquired WMQA documentation from AGECI. However, AGECI did not provide instruction or advise on how to implement the method. All participants who were involved in implementing WMQA had some previous wetland experience and everyone was trained in a one-day training session by the lead technician, J. Mokos.

To test consistency in application of the WMQA method, at each wetland the method was independently applied by three separate teams of two people each. A team leader who had specific training in wetland vegetation, soils, and hydrology was assigned to each team. The three team leaders were the same throughout the duration of the project while the second team member varied when scheduling conflicts preventing keeping team membership the same. The team leaders were also the same leaders in a related project with NJDEP and Rutgers, Development of Wetland Quality and Function Assessment Tools and Demonstration in WMAs 6 and 19 (Hatfield et al. 2004).

WMQA was applied to all twenty-four wetland sites (seven forested sites, seven emergent sites and ten mitigation sites) from September to October 2000. The method was applied to forested and emergent wetlands first, followed by the mitigation wetlands. To evaluate if WMQA gave consistent results regardless of time of year, a second application of WMQA was done in the field in May 2001 for the emergent wetlands and the mitigation wetlands. The September/October 2000 application was considered late growing season and May 2001 was considered early growing season. WMQA was not applied to the forested sites in the May sampling due to budgetary constraints imposed by the addition of the emergent wetlands to the sampling design. Since only two of the wetland types could be compared to test for seasonal differences, the emergent wetlands were chosen since the natural emergent reference wetlands were more comparable to the mitigation wetlands in terms of vegetation, soil, and hydrology.

Application of WMQA:

Office Preparation:

Implementing WMQA required collecting information from existing materials that could be assessed in the office and information gathered during a field visit to the site. The office portion included filling out data sheets including the project name, site name, evaluators, and date. The wetland type was identified from NWI maps for existing natural wetlands. Site characteristic and landscape characteristic variables were evaluated using aerial photographs, NWI maps, and 1:24,000 USGS topographic maps of the sites. The boundaries of the evaluation site were inspected and adjacent open space and/or natural areas were identified using the aerial photographs and NWI maps. A preliminary assessment of the dominant land use within one-quarter mile of the wetland boundary was performed using land use/land cover maps (NJDEP 2000) and aerial photographs. These areas were then re-evaluated while in the field to confirm the results of the preliminary office assessments. The three teams worked independently to complete the office evaluation. Since the composition of the teams were not necessarily the same between seasons, the WMQA method was implemented in its entirety each time it was used, including office preparation and field implementation.

Field Assessment:

Independently, each team walked at least 50% (in most cases 100%) of the perimeter of each wetland site to evaluate the wetland's hydrology, soils, vegetation composition and diversity, and wildlife suitability. In cases where 100% of the perimeter was not walked, the remainder was visually inspected. For the mitigation wetland sites, the wetland boundary and the wetland area that were used in the implementation of WMQA was that area identified by AGECI in the preliminary site visit and is representative of wetland area achieved in Balzano et al., 2002.

Site information including soil cores was recorded independently by each team at each site. The scores for each variable were determined using the list of indicators for each variable (Table 1, Appendix B) and the overall WMQA score for the wetland was calculated by each team according to the methodology (Figure 2).

Data Analysis:

To summarize the data, WMQA means and standard errors were calculated for the three wetland types (forested, emergent, and mitigation). Mean values of WMQA scores were calculated for each team, for all three wetland types sampled in the fall, and for the mitigated and emergent sites sampled in the spring. Means and standard errors were also calculated for each of the six variables that comprise the WMQA index score. To test for differences among wetland types, between seasons, and among different observers a Mixed Model Analysis of Variance was used (SAS 8.02). WMQA scores were arc-sine transformed to meet assumptions of normality and wetland type. Team and season were considered fixed effects and each wetland within a wetland type a random effect. We also tested if there was an interaction between wetland type and season and between wetland type and team. Significance values ($p=0.05$) were adjusted using the Tukey-Kramer adjustment to account for multiple comparisons. In addition, to further examine the influence of observer variability, for the mitigated wetlands we also examined how the average WMQA scores changed for mitigation wetlands when the scores from AGECI were included for the ten mitigation wetlands along with the three teams. We also examined whether there was a tendency for the team scores to change through time as they gained more experience with the method. To do this, we examined the variance structure of the team WMQA scores. In addition, we tested whether there was an influence of wetland size on WMQA scores for each of the three wetland types and an influence of wetland age, or time since construction, for mitigated wetlands. We examined each of the six variables that comprise the WMQA index score to determine which of the variables might account for differences in WMQA scores by wetland type. Finally, we examined the influence of the different weightings assigned to each of the six variables with respect to the overall WMQA wetland index score as well as the individual variables.

CHAPTER 3. QUALITY ASSURANCE

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 project director was responsible for coordinating field efforts, interfacing with AGECI, training personnel, maintaining the database, and overseeing data validation and quality control.

The project director and lead technician coordinated with the NJDEP project manager and AGECI staff to identify mitigation sites for use in the study design and to transfer the draft methodology to Rutgers University. The project director also coordinated with the NJDEP staff when emergent wetlands were added to the scope of study.

All evaluated wetland sites were selected so that they would be within relatively close proximity to each other. Since the forested reference sites were already being used in another study, they served to define the focal study area for the mitigation and emergent wetlands that were selected and evaluated. All wetlands were chosen without regard to wetland size and the mitigation sites were chosen without regard to age since construction.

All participants in the study were field trained during a one-day training session 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 three separate teams.

Each of the three teams applied the WMQA methodology 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 during the same timeframe, 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 sheets were rechecked in the lab.

To test for seasonal sensitivity of the WMQA method, data was collected in May at the beginning of the growing season to represent spring conditions and in August and early September to represent mid- to late-growing season conditions. The three team leaders were the same for both sampling seasons.

Data collection followed all sampling protocols outlined in the WMQA documentation and followed standard procedures. Data entry was done by the lead technician and validated independently by one of the other team leaders. The project director and lead technician monitored data analysis and synthesis.

CHAPTER 4. STUDY RESULTS

Results are reported using data collected during the late growing season except for the comparison between seasons. To compare WMQA results during different seasons, results are reported for both the late- and early-growing season field evaluations for emergent and mitigation wetlands. Results are also reported on unweighted wetland scores except for when the influence of weighting is considered. Results are stated as the mean ± standard error.

Wetland Area:

Wetland area differed among the three sampled wetland types (Table 2). Forested wetland sites are large wetland complexes and thus were larger on average with a mean acreage of 264.67 ± 171.74 (mean ±standard error). The maximum forested wetland area was 1285.93 acres at Horseneck Bridge and the minimum area was 22.41 acres at Great Swamp National Wildlife Refuge. The mean for wetland area was similar between natural emergent and mitigation wetlands, with average acreages of 5.58 ± 1.82 and 5.71 ± 5.09 respectively. However, the majority of the mitigation wetlands (nine out of ten) were less than two acres in size with just one large mitigation wetland of 50 acres. For emergent wetlands, the maximum wetland size was 12.65 acres followed by two wetlands

	Site Name	Wetland Type	Area (acres)
Natural Forested Wetland	Great Swamp	forest	22.41
	Dead River	forest	95.82
	South Main	forest	48.02
	Roosevelt	forest	146.50
	EOWA	forest	197.03
	Sommers Park	forest	57.00
	Horseneck Bridge	forest	1285.93
	Mean ± se		264.67 ± 171.74

	Site Name	Wetland Type	Area (acres)
Natural Emergent Wetlands	Great Swamp	scrub-shrub/emergent	12.65
	Dead River	emergent	9.16
	South Main	scrub-shrub/emergent	1.96
	Roosevelt	scrub-shrub/emergent	0.82
	EOWA	emergent	9.86
	Sommers Park	scrub-shrub/emergent	2.92
	Horseneck Bridge	scrub-shrub/emergent	1.70
	Mean ± se		5.58 ± 1.82

	Site Name	Mitigation Type	Area (acres)
Mitigation Wetlands	104	scrub-shrub	0.19
	77	scrub-shrub/emergent	0.32
	78a	forest	0.22
	78b	emergent	0.37
	127	forest/submerged open water	0.87
	73	forested	0.93
	130	forest/emergent	0.91
	89-C	emergent	51.51
	93	forest	0.67
	68	forest/scrub-shrub/emergent	1.88
	Mean ± se		5.03 ± 4.02

Table 2. The three general types of wetlands (forested, emergent, and mitigation wetlands) where WMQA was applied. Wetland type indicates what was specified in the design plan for mitigation wetlands and the NWI designation for natural wetlands.

Wetland acreage for mitigation sites reflects acreage achieved rather than that proposed in the mitigation plan.
that were more than nine acres in size. The smallest emergent wetland was 0.82 acres in size.

Comparisons Among Wetland Types:

With a maximum possible WMQA score of 1.0, the average WMQA score was 0.79 ± 0.02 in natural forested sites, 0.83 ± 0.02 in natural emergent sites, and 0.69 ± 0.03 in mitigation wetlands (Figure 3). Scores were higher on average in the natural wetlands than in the mitigation sites, with emergent wetlands exhibiting the highest scores overall. Mitigation wetlands had the greatest range in WMQA scores with the highest score of 0.93 and the lowest of 0.35. In contrast, the range for emergent wetlands scores was 0.97 to 0.73 while for the forested wetlands, the highest WMQA score was 0.95 and the lowest was 0.66. The WMQA scores were significantly different in the overall Mixed Model that tested for effects of wetland type ($F_{2,21}$=4.07, p>F=0.032). WMQA scores for emergent wetlands were significantly different from mitigation sites (p=0.025) while they were not different from forested wetland scores (p=0.434). However, WMQA scores were not significantly different between forested wetlands and mitigation wetlands (p=0.138).

Comparison Among Variables:

The final WMA score for a wetland is based on how six different variables are evaluated in the field and office. The six variables included hydrology, soils, vegetation, wildlife, site characteristics, and landscape characteristics. These variables were examined individually to determine if any were particularly sensitive to wetland type, season, or observer bias.

The forested and emergent wetlands generally scored higher than the mitigated wetlands for each of the six variables (Figure 4). With 3.0 being the highest possible score for each variable, emergent wetlands scored higher for hydrology, soils, wildlife, and landscape variables while forested wetlands had the highest score for vegetation and site variables. The hydrology variable had the highest score for the forested and

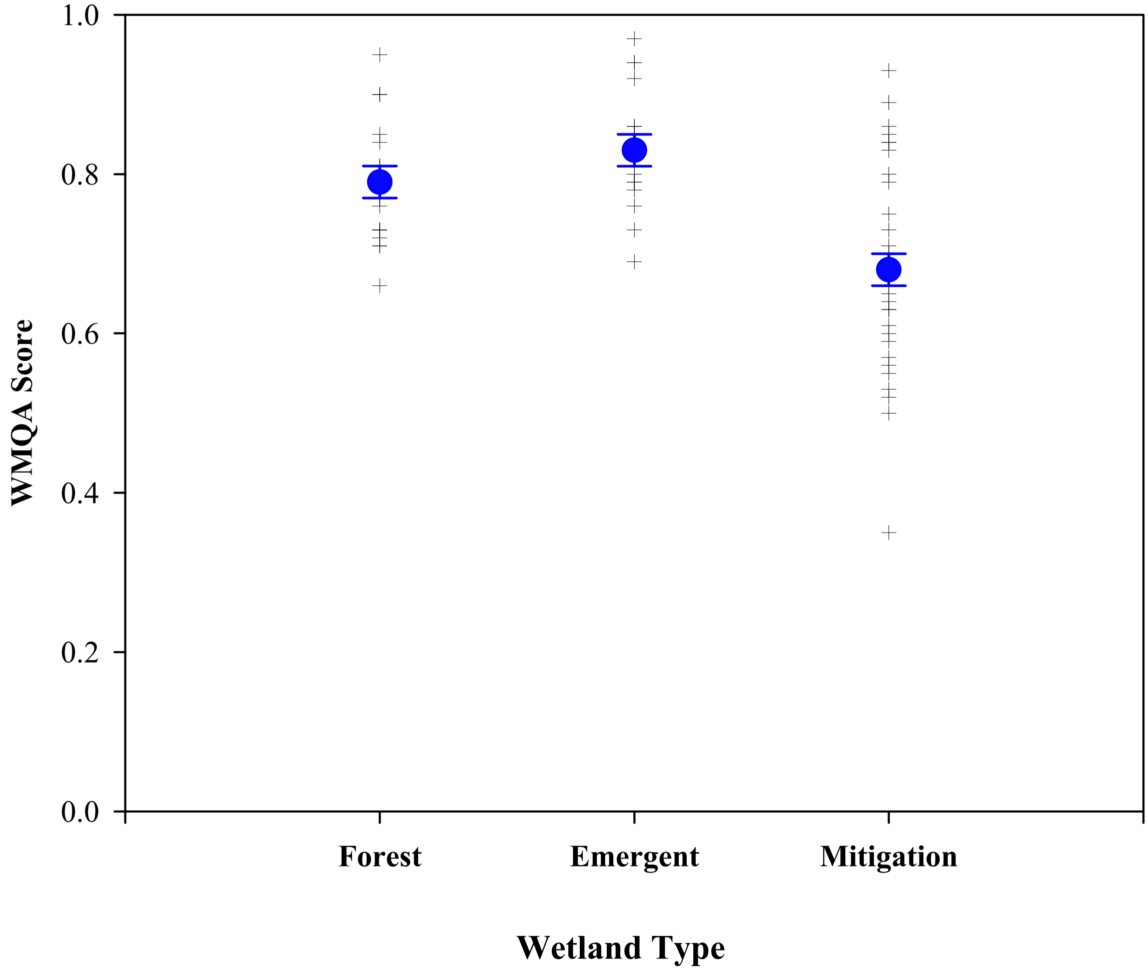

Figure 3. Comparison of overall and average unweighted WMQA scores for forested, emergent, and mitigation wetlands. Plus sign (+) indicates the individual WMQA scores for each team at each wetland. Circles (●) are the average WMQA scores for each wetland type and error bars indicate the standard error of the mean of each wetland type. WMQA scores can range from 0.0 to a maximum of 1.0. For forested and emergent wetlands, n=21 and for mitigated wetlands n=30.

emergent wetlands, 2.88 ± 0.05 and 2.67 ± 0.08, respectively. In contrast, the soil variable was the highest-scoring variable for the mitigated wetlands. In fact, the soils

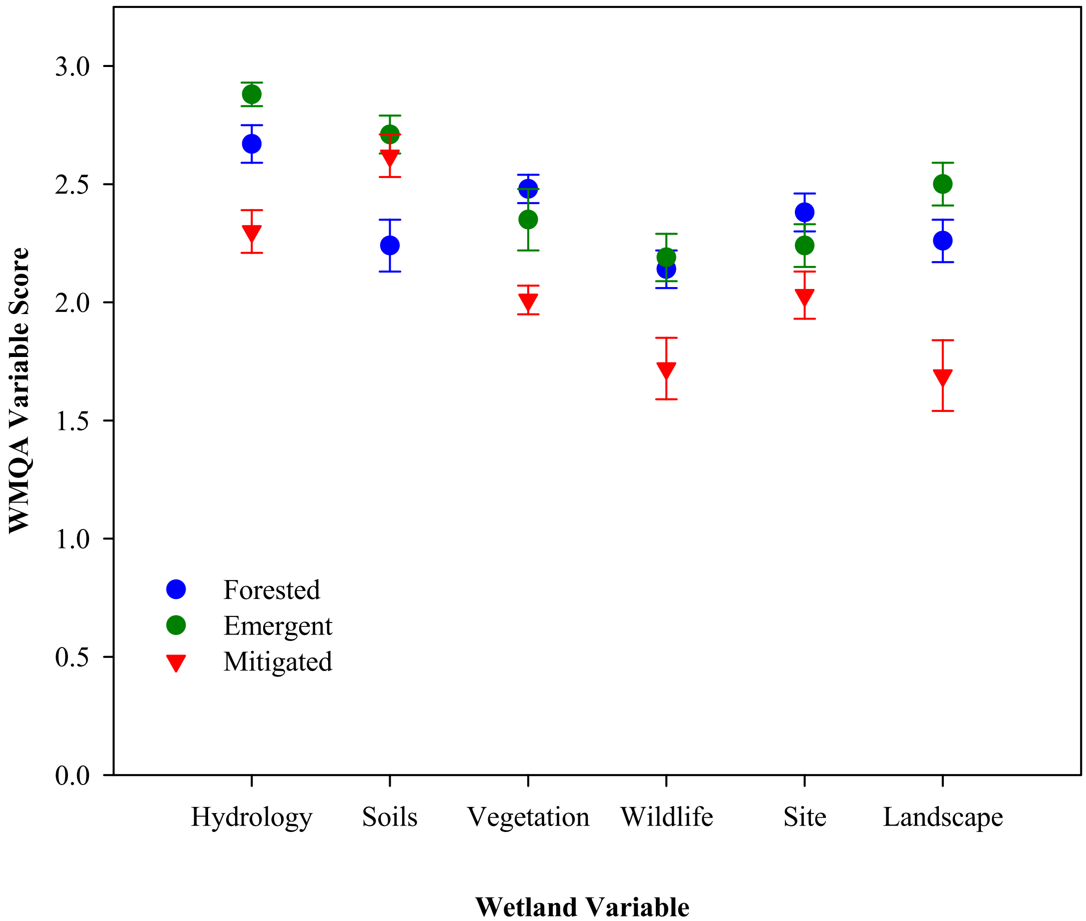

Figure 4: Comparison of unweighted WMQA variables for the three wetland types. Symbols represent the average variable score for each variable and error bars indicate the standard error of the mean of each variable. Variables are scored on a range between 0.0 as a minimum to a maximum score of 3.0. For forested and emergent wetlands, n=21 and for mitigated wetlands, n=30.

variable was the only variable where a natural wetland type, namely forested wetlands (2.24 ± 0.11), scored lower than the mitigation wetlands. The lowest scoring variable for the natural wetlands was the wildlife variable with 2.14 ± 0.08 for forested and 2.19 ± 0.10 for emergent. Both wildlife and landscape variables scored relatively lower for the mitigation sites with the landscape variable having the lowest score (1.69 ± 0.15) as well as the greatest variation in scores.

Comparison Between Weightings:

Weightings were assigned to each of the six wetland variables to reflect the relative importance of each variable to the overall score for a wetland (Figure 2). Variables with higher weightings were considered to be more essential for a mitigation wetland to achieve natural wetland functions than variables with a lower weighting factor (Balzano et al. 2002). For example, hydrology was considered to be the most critical variable to wetland function and it received the highest weighting factor (4.8) while wildlife suitability (2.1) was given the lowest weighting factor.

We compared the weighted vs. unweighted overall WMQA scores for the three wetland types to better understand the influence of the weightings (Figure 5). The weighting factors had a slight positive, but non-significant, effect on the overall average WMQA score with an average increase of 0.02 for the three wetland types. The average forested reference score increased from 0.79 ± 0.02 to 0.80 ± 0.02; mean emergent reference score increased from 0.83 ± 0.02 to 0.85 ± 0.02; and average mitigation wetland score increased from 0.68 ± 0.02 to 0.70 ± 0.02. The maximum change in wetland score due to weightings for any particular wetland was 0.02 (Table 3). Weighting the overall WMQA scores also did not change the relative rank order of the wetlands for each of the three wetland types.

Comparison Between Seasons:

Mean overall WMQA scores were higher in the fall than in the spring for both emergent and mitigation wetlands (Figure 6). Average overall WMQA scores in emergent reference sites decreased from 0.83 to 0.77 from fall to spring while for the mitigation wetlands, mean WMQA score decreased slightly from 0.68 to 0.66. The

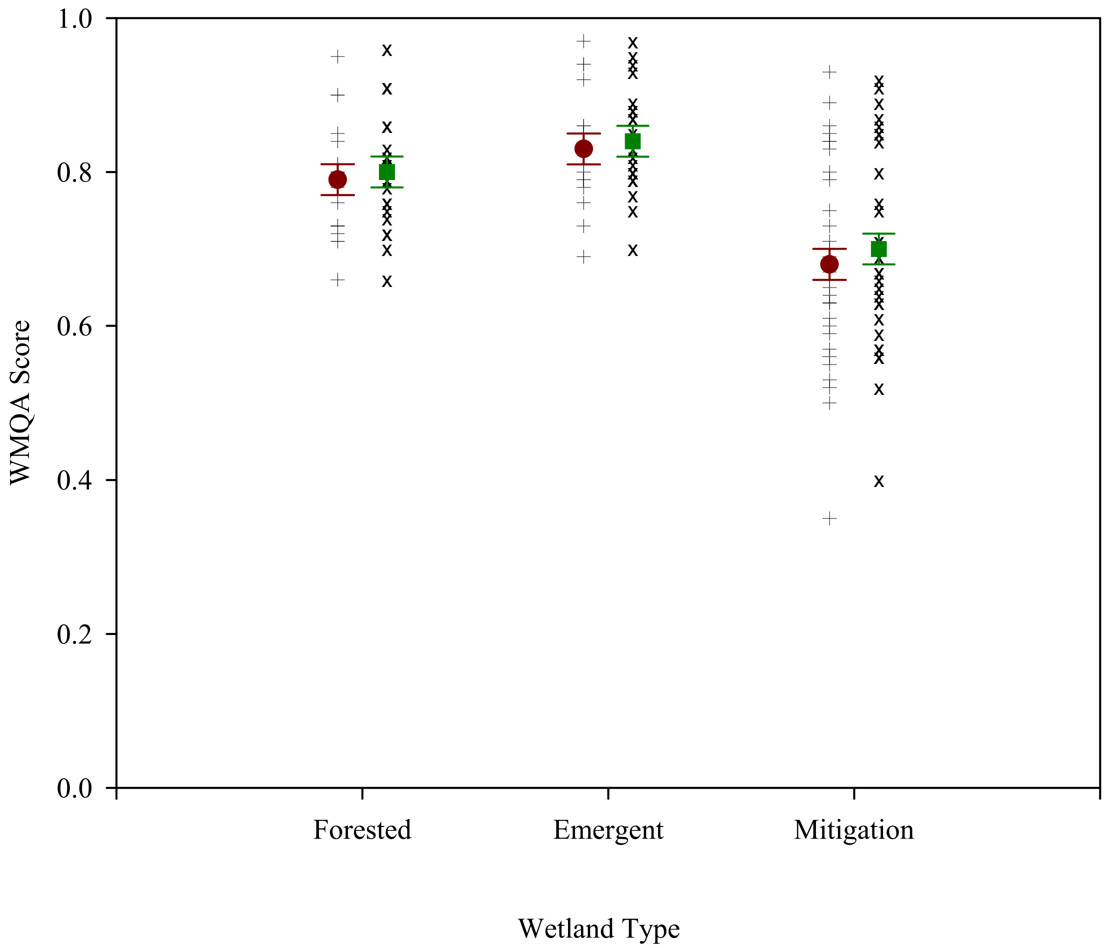

Figure 5. Comparison of weighted and unweighted overall WMQA scores for the three wetland types. Plus signs (+) indicate unweighted WMQA scores and (x) indicates weighted scores for each team at each wetland. Circles (●) are the mean of unweighted WMQA scores and squares (■) are the mean of weighted scores for each wetland type and error bars indicate the standard error of the mean of each wetland type. Forested and emergent wetlands, n=21, and mitigation sites, n=30.

	Unweighted Wetland Score	Weighted Wetland Score
Forested:		
Great Swamp	0.92	0.93
Dead River	0.80	0.82
South Main	0.79	0.80
Roosevelt	0.76	0.77
EOWA	0.75	0.76
Sommers Park	0.72	0.73
Horseneck Bridge	0.76	0.78
Average	**0.786**	**0.799**
Emergent:		
Great Swamp	0.94	0.95
Dead River	0.74	0.75
South Main	0.79	0.80
Roosevelt	0.82	0.84
EOWA	0.88	0.90
Sommers Park	0.79	0.81
Horseneck Bridge	0.85	0.87
Average	**0.830**	**0.846**
Mitigated:		
78-A	0.61	0.64
78-B	0.59	0.62
104	0.58	0.61
130	0.76	0.81
127	0.64	0.65
77	0.87	0.87
93	0.66	0.65
73	0.46	0.50
68	0.83	0.85
89-C	0.81	0.82
Average	**0.687**	**0.702**

Table 3. Comparison of individual wetland scores for weighted and unweighted values.

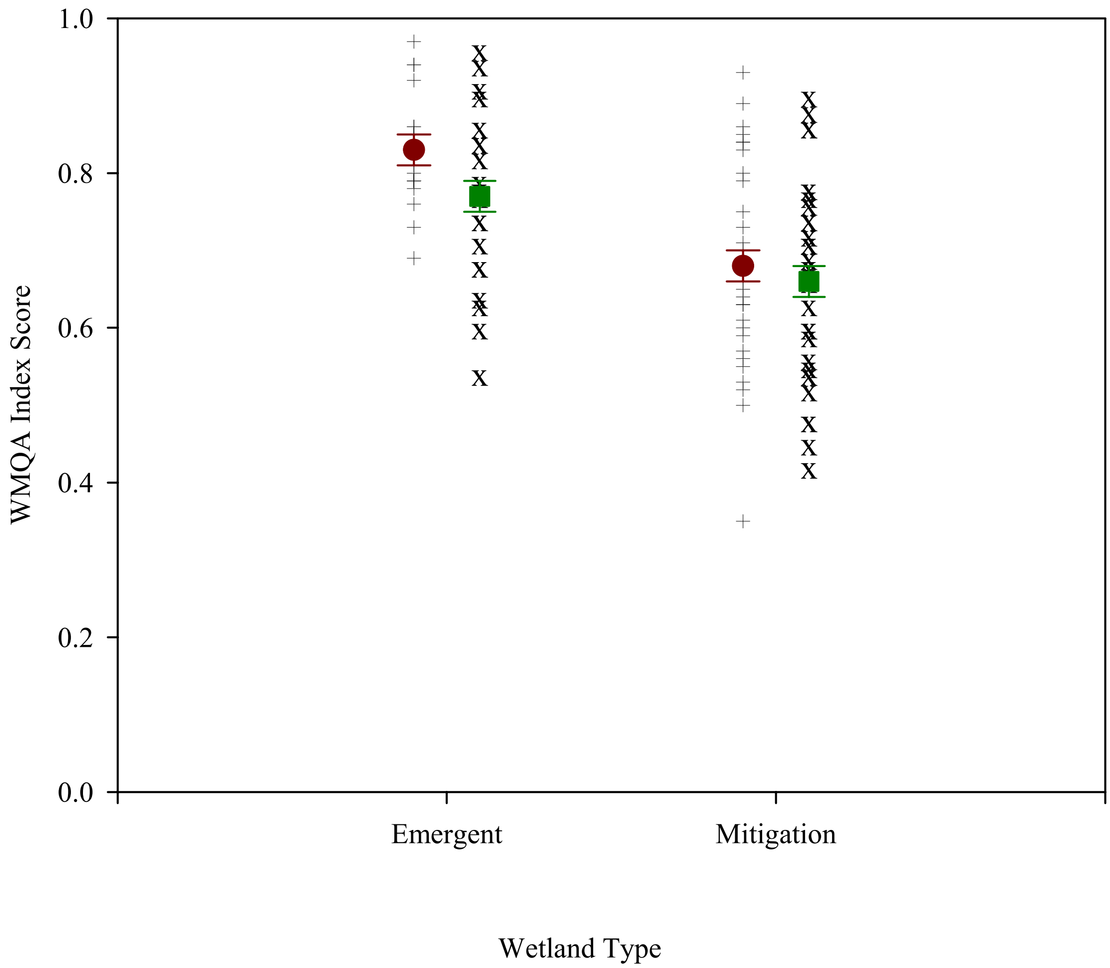

Figure 6. Comparison of unweighted overall and average WMQA scores for emergent and mitigation wetlands in early- and late-growing seasons. Plus sign (+) indicates late growing season (fall) WMQA scores and (x) indicates early growing season (spring) scores for each team at each wetland. Circles (●) are the mean late growing season WMQA scores and squares (■) are the mean early growing season scores for each wetland type. Error bars indicate the standard error of the mean score for each season.

seasonal differences were significant ($F_{1,83}$= 8.36, p>F=0.005) as were the wetland types ($F_{1,15}$=5.44, p>F=0.03) and the fall emergent wetland scores were different from the spring emergent scores (p=0.04) while seasonal scores were not different for the mitigated wetlands.

We also examined the response of each of the six variables to seasonality (Figures 7 and 8). The fall variable scores tended to be higher for the emergent wetlands with only site and landscape variables being similar between seasons. For the mitigation wetlands, only the hydrology and soils variables were higher in the fall than the spring and the remaining four variables were relatively close across seasons. Hydrology had the largest difference between seasons for both wetland types with a lower spring value than fall value. The landscape variable was the only variable that had a higher spring score compared to the fall and only for the mitigation wetlands.

Comparison Among Raters:

The teams gave significantly different scores to the different wetland types ($F_{2,42}$=10.81, p>F=0.002) (Figure 9). Teams 1 and 3 were more similar in their scoring (p=0.75) while Team 2 was consistently different from both Teams 1 and 3 (P<0.002). The second team tended to give the highest scores on average for all three wetland types: forested (0.84 ± 0.03), emergent (0.84 ± 0.04), and mitigation (0.73 ± 0.04). The first and third teams were more similar in their scoring of the different wetland types with respective scores of 0.77 (± 0.02) and 0.75 (± 0.03) at forested sites, 0.82 (± 0.02) and 0.83 (± 0.03) at emergent sites, and 0.68 (± 0.04) and 0.64 (± 0.05) at mitigation sites. All three teams had the similar average scores at the emergent wetlands. As part of the Balzano et al. 2002 study, AGECI had also evaluated the same ten mitigation sites as those used in this study using WMQA. The WMQA scores assigned to the mitigation wetlands by AGECI were lower (0.55 ± 0.05) than the individual Rutgers team scores and also lower than the average of the Rutgers team scores (0.68 ± 0.02) (Figure 8).

Other Considerations:

We also looked at the sensitivity of the WMQA score to other factors including wetland size and mitigation wetland age. Size did not appear to influence the wetland

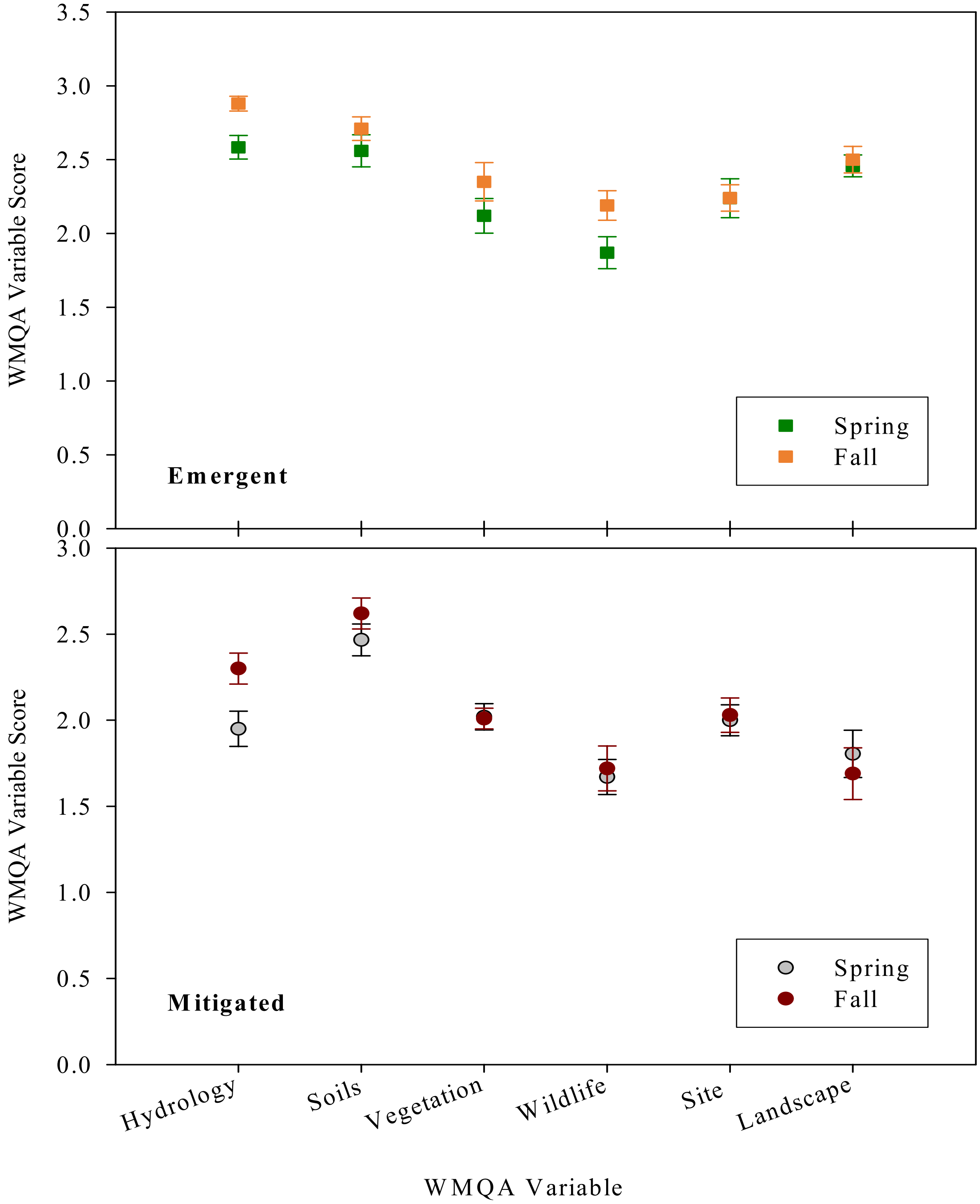

Figure 7: Comparison between unweighted WMQA index scores between early (spring) and late growing seasons (fall) for emergent and mitigated wetlands.

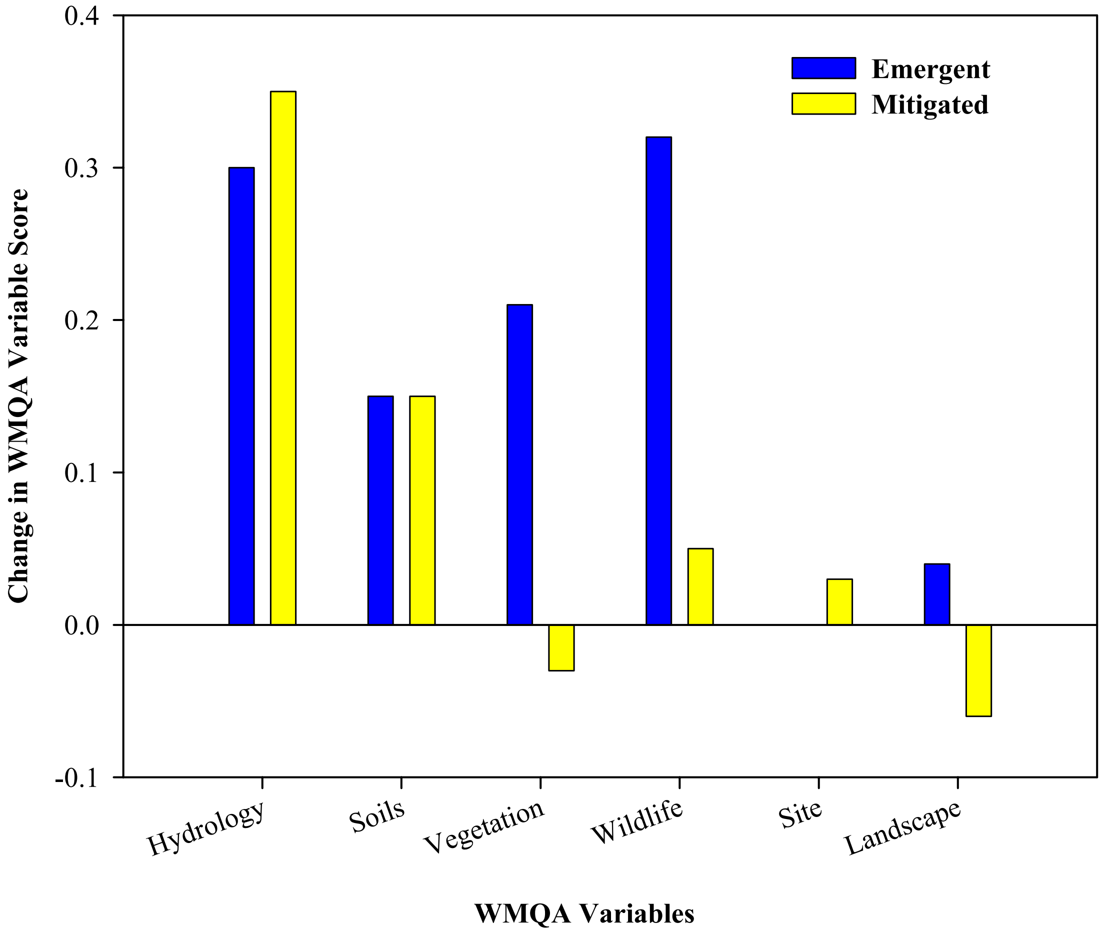

Figure 8. Changes in WMQA variable scores between early growing season and late growing season for emergent and mitigation wetlands. Values greater than 0.0 indicate that late growing season variable score was higher than the early growing season variable score. Values less than 0.0 indicate variable scores that were higher in the early growing season versus late in the growing season.

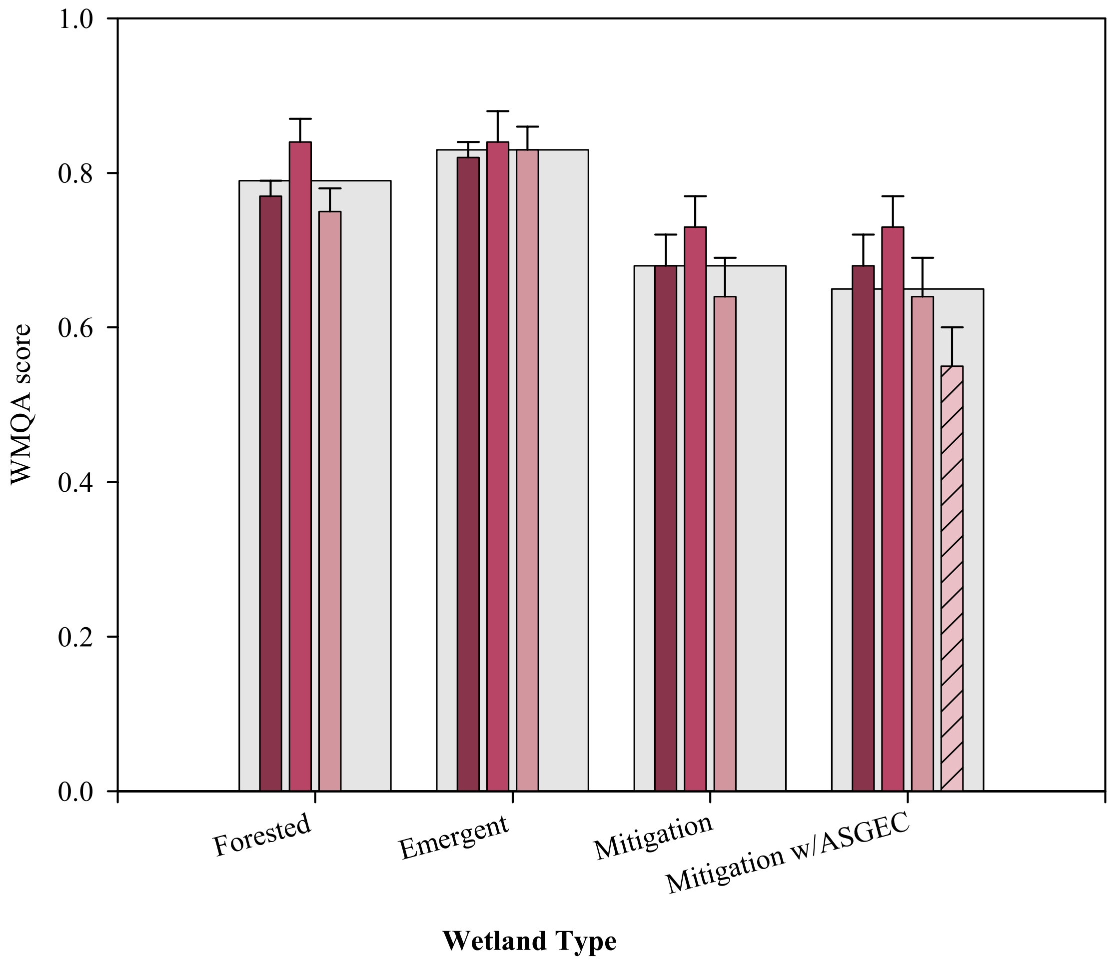

Figure 9. Comparison of unweighted group scores to overall WQA scores for each wetland type. The gray bars ( ) indicate the mean WMQA score for each wetland type while colored bars ( ) indicate mean WMQA scores for each team at each wetland type. Error bars are the standard error of the mean of each team's scores for each wetland type. WMQA scores can range from 0.0 to 1.0. Forested and emergent sites n=7; mitigation sites n=10).

scores (r^2<0.16) for the three wetland types. In addition, the age of the mitigated wetland did not seem to influence the WMQA score (r^2=0.05). Both of these findings agreed with the findings of Balzano et al. (2002) who found no correlation between WMQA score and wetland size and age for mitigation wetlands. Finally we also examined whether there appeared to be a 'learning curve' with the three Rutgers teams. A decrease in variability within and among teams over time could potentially indicate that the teams were becoming more consistent with time. However, the variability had no trend with respect to differences among team ratings through time (i.e., teams did not become more similar in their scores for individual wetlands over time) or within or among wetland types.

CHAPTER 5. DISCUSSION

The purpose of rapid wetland assessment techniques is to estimate wetland functioning in an efficient and accurate manner. The WMQA is a rapid assessment technique that was specifically developed to evaluate the potential functioning of mitigation wetlands. However, using this technique to assess functioning for both mitigation wetlands and natural wetlands enabled us to examine how robust the method was across wetland types. Applying the same methodology to the wetland types also provided some indication of the relative function of mitigation wetlands compared to natural wetlands. The methodology is designed to evaluate potential function and hence account for the successional trajectories inherent in created wetlands. Generally, the relatively high WMQA scores for natural wetlands indicate that the assessment method successfully recognizes wetland function; indeed, the relatively high scores indicate that some of the natural wetlands are functioning near their maximum according to this method.

The majority of the mitigation sites scored lower than the natural sites, a result similar to what has been found in other studies (Campbell et al. 2002, Mushet et al.2002, Stolt et al. 2001, and Magee et al. 1999). The intent of the WMQA methodology is to evaluate the potential for mitigated wetlands to develop and improve wetland function over time, thus the expectation is not that the mitigated wetland currently functions at the same standard as a natural functioning wetland. With WMQA providing a measure of potential functioning, low scores reflect the inability of a wetland to evolve to approximate normal wetland function. Consequently, many of the mitigated wetlands do not have the ability to assume normal wetland function as evaluated by this method. However, it is also important to note that several mitigation wetlands had WMQA scores in the same range as the natural wetlands thus implying that these individual mitigation sites do have the potential to function as well as the natural wetlands.

It is interesting to note that many of the forested and emergent natural wetlands did not actually score perfect scores of 1.0 even though most were considered reference wetlands. The study area, as well as the state of New Jersey, has experienced significant changes in land use in this century and development pressures continue to increase (Lathrop 2000). The reference wetlands were selected to reflect the most natural conditions that exist in an urbanizing environment. Less than perfect scores for the natural wetlands may reflect the influence of the changing landscape or it could simply reflect the fact that wetlands, even natural wetlands, do not perform all functions equally.

There was a wider range of wetland scores for the mitigated wetlands compared to the forested and emergent wetlands (Figure 3). The greater range may reflect differences in mitigation goals, in wetland design and creation, and/or in successional trajectories. For example, some of the mitigated wetlands evaluated were designed to become forested wetlands, others shrub-scrub, and some emergent. The functional potential of different mitigation wetland types, wetland age, and sensitivity of WMQA to different mitigation designs are all possible explanations for the wide spread of WMQA scores for the mitigated sites. However, the wide range of scores more likely reflects greater variability in mitigation success (as measured by wetland function), as has been seen in other studies (Brown and Veneman 2001, National Research Council 2001, Race and Fonesca 1996). Potential reasons for limited mitigation success are wide ranging: lack of consideration of wetland functioning in the design and creation process (Mitsch and Wilson 1996), improper consideration of landscape context that limited potential functioning (Whigham 1999, Bedford 1996), and lack of follow-through on mitigation plans (Balzano et al. 2002).

When a wetland functional assessment methodology such as WMQA provides an overall score for wetland function, the score alone makes it difficult to evaluate or assess where the underlying problems are for low-scoring wetlands. Generally, closer examination of the individual factors, or in the case of WMQA the six variables, provides greater insight into why the wetlands received a particular score. This is particularly informative for understanding why mitigated wetlands had generally lower scores. Of the six variables assessed in the WMQA, the landscape variable for mitigated wetlands was the lowest-scoring variable of all variables and all wetland types. An average landscape variable score of 1.7 out of 3.0 clearly demonstrates that landscape context for the mitigation sites may be the greatest impediment to continued evolution of functioning for many of the mitigation wetlands. The mitigation sites had more variability in their surrounding landscapes and were generally located within more disturbed, fragmented landscapes than the natural sites. The mitigated wetlands were frequently isolated wetlands along roadsides within a more urbanized, fragmented landscape categorized by higher intensity land use than that in the natural wetlands (Appendix A-3 vs A-1 and A-2 wetlands). While the statement generally holds true for most of the mitigation wetlands, at least two of the mitigated wetlands scored higher than the average landscape score for emergent wetlands, the highest scoring wetland type for this variable. Both mitigation sites 68 and 77 were a part of or were adjacent to open space areas. Both sites had higher contiguity scores and fewer invasive species than the other mitigation sites. When these factors were combined with the relative sizes of these two wetlands, the landscape scores were relatively higher than other mitigation sites. In contrast to the general setting for mitigation wetlands, forested and emergent natural wetlands are within larger wetlands complexes along the Passaic River and while the larger landscape of the Passaic River region tends to be fragmented, the local area in proximity to the reference wetlands remains somewhat intact. Specifically, reference wetlands exhibited greater contiguity to other wetlands, larger and more intact wetland-upland buffers, and less intense land use within the surrounding watershed.

The low scores for the wildlife variable further indicate higher incidences of anthropogenically derived disturbance around the mitigated wetlands. For wildlife, proximity and accessibility to habitat resources outside the wetland are inherent of the landscape setting. The typically small size of the mitigated wetlands (Table 2) also reflects the highly fragmented landscape associated with these wetlands which precludes habitat value for area-sensitive wildlife species. The wildlife variable was also the lowest-scoring variable for both the emergent and forested natural wetlands. While proximity and contiguity to habitat resources were not necessarily a problem for these sites, there still remains an overarching element of habitat fragmentation and presence of human impediments at the larger landscape scale that ultimately limits the value of these wetlands for wildlife utilization. This is further emphasized for the forested wetlands where the landscape variable had the widest range of WMQA scores.

Since the WMQA was designed to assess mitigation wetlands, it could potentially be more responsive in its assessment of mitigation wetlands than its evaluation of natural functioning wetlands. For example, several indicators are designed specifically for mitigation wetlands and hence may be less appropriate for assessing natural wetlands. Such is the case for indicators used in the soils variable. The indicators include the amount of topsoil present, the degree of erosion, and the extent of soil compaction in the wetland. Each of these indicators reflects to some degree the suitability of the site design and thus may be less meaningful for natural wetland assessment. For example, the soils variable was the highest average variable score for the mitigated sites indicating that soil stability was generally good and indeed approached the soil stability found in the emergent wetlands. However, forested wetlands had the lowest average score for the soils variable, almost 0.5 points lower than the average for mitigated wetlands. The forested reference sites are riverine forested wetlands with overbank flooding as the primary hydrologic source. As such, soil erosion and lack of organic matter accumulation is an intrinsic process in these wetlands as floodwaters scour the wetland's surface (Hatfield et al. 2002). Consequently, the forested wetlands with soil erosion as an intrinsic characteristic received lower WMQA scores for the soils variable. Conversely, in the context and intent of the WMQA methodology for evaluating mitigation wetlands, soil erosion and instability reflects inadequate design or construction techniques during wetland creation or lack of appropriate hydrology. As with any assessment methodology that is used outside of its intended purposes, the user must be mindful of whether it is an appropriate methodology for the conditions of interest, whether it can be readily modified to adequately measure the conditions, and how sensitive the method is to the modifications.

WMQA was found to be sensitive to seasonal differences with spring scores generally lower than fall scores for both emergent and mitigated wetlands. Emergent wetlands exhibited the greatest seasonal difference in scores (Figure 6). Our initial expectation was that the greatest variability would be found in the vegetation variable since the spring survey was done early in the growing season. Plants were coming out of winter dormancy and not fully leafed out which could potentially influence the evaluation of some elements of the vegetation variables in WMQA. While we did see this expected response primarily in the emergent wetlands, more importantly the greatest difference between seasons was in the hydrology variable for both the emergent and mitigated wetlands (Figure 7 and 8). Closer examination of the different indicators for the hydrology variable score provided some indication of why this variable score was different between seasons. For example, at Sommers Park, the emergent wetland that had the greatest seasonal difference, plant stress was not evident in the fall but was moderate in the spring. Evidence of flow channelization was also more evident in the spring when the site was very dry compared to the fall when it was partially inundated. Seasonal variation in moisture conditions and inundation likely accounted for the spring plant stress and better ability to see evidence of channelization that was not apparent in the fall when it was inundated. However, in contrast to Sommers Park, where two components seemed to explain most of the shift in seasonal differences in the hydrology variable, for other emergent wetlands that also exhibited seasonal differences there was no consistent pattern of change. Instead the changes were usually typified by a one-level downward change (i.e., from negligible to minimal, Appendix B) in several components. Lack of a strong pattern amongst the different components and rather a general overall decrease could suggest a general sensitivity of all of the components to seasonal variability.

In contrast, for the mitigation sites the pattern was somewhat more consistent especially for individual mitigation wetlands that had notable shifts in hydrology variable scores from the fall to the spring. Soil properties indicative of wetland conditions changed the most in their scores from the fall to the spring. Evidence of redoximorphic features shifted from being readily distinct or present in the fall to minimal or absent in the spring and this observation was consistent with all teams. Features indicative of hydric soils were also evaluated differently in the fall versus the spring with a consistent ranking of one or two levels lower in the spring evaluation. Shifts in how the soils variable was evaluated for the mitigation sites between seasons suggest that properties indicative of hydric wetland soils are dynamic, shifting between seasons. Indications of wetland soils are inherently problematic with mitigated wetlands (Bishel-Machung et al. 1996, Mitsch and Wilson 1996). The combination of bringing in off-site topsoil for wetland construction and the time lag for persistent indicators of hydric soils could potentially account for the seasonal differences. It is important to note that the seasonal pattern in soils was not necessarily associated with wetland age since the three mitigation wetlands where the soils variable changed the most spanned a range from 0 years to 9.5 years since creation.

Other factors of the hydrology variable that showed a consistent seasonal shift for mitigation wetlands included hydrology and inundation. In nearly all instances, wetland hydrology was not perceived to be as good in the spring as it was in the fall. This is further supported by lower rankings for surface inundation in the spring versus the fall. The mitigation wetlands exhibit a seasonal shift in hydrology, similar to that seen in the other wetland types including the reference emergent wetlands within the region. Since WMQA appears to be somewhat sensitive to seasonal variation, some caution may be warranted when applying WMQA in different seasons particularly since the hydrology variable receives the highest weighting (4.8) in WMQA.

The other variable that showed a seasonal shift was the wildlife variable for the emergent wetlands. The majority of the changes with season for this variable occurred in how nesting activity and cover were evaluated. Both components were consistently lower in the spring and reflect the effect of doing the evaluation before nesting starts and nesting potential can be hard to evaluate. Cover is also reduced since vegetation is just starting to leaf out. The fact that there was not a marked change in the wildlife component for the mitigation site may be associated with lack of seasonal sensitivity of this wetland type to the wildlife variable but it is more likely that the lack of response reflects the general lack of wildlife habitat availability irrespective of season.

The overall WMQA scores were not necessarily consistent across the three Rutgers teams. Several of the wetland WMQA index scores varied by as much as 0.18 points (out of a possible of 1.0) between teams. While two of the teams were generally similar in how they scored each wetland within and across wetland types, the third team's scores were consistently higher (Figure 9). All three teams had wetland experience and no one team tended to have more experience than the other two. In addition, it was not apparent that the high-scoring team tended to score one particular variable or several variables consistently higher than the other variables. However, the overall scores for the three Rutgers teams were generally more consistent with each other than they were to the WMQA scores that AGECI assigned to the mitigation wetlands. AGECI scores were all lower than the Rutgers teams' scores with the largest difference between WMQA scores being 0.43 when AGECI scores were included. There was intentional lack of coordination with AGECI in terms of training or information transfer for the WMQA method since one goal was to independently test the method. However, Rutgers teams were all trained at the same time by the same person, which likely contributed to their scores being more similar, and in fact suggests that training may be important to reduce variability among different evaluators. While consistency in wetland scores can be attributed to training, the reason for the persistently higher scores assigned by the Rutgers teams compared to AGECI are more difficult to determine. No one variable was scored lower by AGECI, ruling out the possibility of one particularly sensitive variable. Rather each of the six variables was scored between 0.35 to 0.5 points higher by Rutgers compared to AGECI. Other possible reasons for differences in WMQA scores between Rutgers and AGECI could be level of experience with assessing mitigation wetlands and/or experience with method development and implementation. The mitigation sites we evaluated were a subset of a much larger suite of mitigation wetlands that were being assessed by AGECI (Balzano et al. 2002). Consequently, AGECI assessed a wider repertoire of mitigated wetland conditions and also had a greater experience base that may have accounted for the difference in mitigation wetlands scores between AGECI and Rutgers. There may also be some influence in how wetlands are perceived when they are not independently evaluated for permit concurrence and functional assessment.

We found little difference when weightings were used to calculate the final index versus when the raw WMQA scores were used. The most any individual wetland WMQA score changed was by 0.02 points when weightings were applied (Table 3). This pattern was observed across all wetland types and teams suggesting that for this study the weightings did not add additional information to the functional assessment of wetlands. The wetland variables are interconnected to the point that applying the weightings is somewhat redundant. For example, indication of colonization by transitional/upland plants, hydrophyte stress, and hydrophyte mortality result in low vegetation scores but these factors are also indicators of impaired wetland hydrology, which reflects the relationship between hydrology and vegetation. The results from the overall WMQA scores support this interconnection among the wetland variables. Therefore, we found no persuasive reason for weighting the variables to reflect greater emphasis for particular functions.

CHAPTER 6. CONCLUSIONS

In general, we found that the WMQA method, as a qualitative assessment method, was capable of assessing potential functioning of mitigation wetlands. In a general context, the wide range of scores for the mitigation wetlands indicates that the method did not tend to overinflate the functional value of mitigated wetlands with some mitigation site scores approximating natural wetland function and others seriously lacking the potential or ability to perform wetland function. WMQA was also sufficiently sensitive to capture the lack of appropriate landscape setting, which not infrequently constrains the design process for wetland mitigation (National Research Council 2001, Bedford 1996). The low wildlife functional value mitigated wetlands provided is a reflection of the general lack of appropriate landscape setting and small size of the majority of the mitigation wetlands.

The WMQA methodology was also sufficiently sensitive to demonstrate the expected pattern of higher potential functioning of natural wetlands compared to mitigated wetlands. The range in WMQA scores reflects the changing landscape in which the reference sites are embedded. Since WMQA was designed specifically to address concerns related to mitigation wetland function some of the individual variables in the methodology are not necessarily appropriate for natural wetlands. These variables would need to be revised to reflect natural conditions if the method were to be used to further assess natural wetlands. However, we would not recommend deleting any of the variables as they provide valuable information on wetland function that could be useful from a resource management perspective.

The difference in seasonal and team scores emphasizes a number of important points with respect to WMQA and functional assessments in general. Field conditions will vary from season to season and it is extremely challenging if not impossible to have readily observable field indicators that are sensitive enough to qualitatively evaluate differences in wetland function and yet robust enough to incorporate seasonal variation. The seasonal variation in hydrology for both the mitigation and emergent, as evaluated by WMQA, illustrates that wetland function varies and was judged qualitatively to be less optimal in the spring than the fall. Quantitative approaches would likely reveal similar variability but perhaps not similar functional conclusions. While the seasonal pattern may be perceived as a weakness of WMQA, in fact it may be more indicative of how sensitive the methodology is to variation in wetland function, which in itself could provide useful management information. For instance, knowing the seasonal variability in hydrologic function could be helpful in understanding why some created wetlands are more successful than others. However, particular attention should be paid to the potential for seasonal variation with the hydrology and soils variables when evaluating mitigation wetlands with this method. This study suggests that the seasonally dynamic nature of the hydric soil properties of mitigated wetlands will influence how these wetlands are evaluated and the score the hydrology variable will receive. This seasonal influence will be further exacerbated by the fact that the hydrology variable has the largest weighting when calculating the final WMQA wetland score.

While there was a statistically significant seasonal difference in WMQA scores, in the context of a qualitative assessment procedure and management implications, it is perhaps more important to consider what really reflects a significant difference operationally versus statistically. On average, the WMQA scores for emergent wetlands decreased a total of 0.07 points between fall and spring while mitigation wetlands changed 0.02 points. This difference is statistically significant but the difference also reflects the variability inherent even in natural wetland systems. The fact that WMQA is sensitive to these seasonal differences actually facilitates a better understanding of the natural variability of the system and thus provides a context for when systems fluctuate widely.

The observed differences in season and team bring to the forefront management decisions and guidelines that should be established prior to implementing an assessment methodology such as WMQA on any sort of a broad basis. This is particularly important when comparing the functional potential of different wetlands or comparing the functional potential of the same wetland through time. What determines an ecologically or functionally significant difference in WMQA scores? Does a difference of 0.1 in WMQA scores have real significance in the context of a qualitative method such as WMQA? Differences in WMQA scores in the range of 0.1 to 0.2 likely reflect variation between seasons and/or observers and not necessarily a trend in actual wetland function. When the changes or differences in WMQA scores are greater than 0.2 then further investigation as to why the scores are different is warranted.

When a functional assessment methodology such as WMQA provides a single score for wetland function, important information could be missed. Two wetlands could easily have the same WMQA score but for quite different reasons. Understanding why a wetland has a particular score is important from a number of perspectives including resource management, assessing restoration potential, or evaluating temporal trends in wetland function. Each of the six variables that are used to derive a single WMQA score provides important information and insights to wetland function. The importance of paying attention to these variables individually cannot be overstated. Wetlands, even natural wetlands, do not perform all functions equally. Understanding what functions are lacking or have low potential for a wetland certainly provides important information for potential restoration strategies. However, particularly in the case of created wetlands, some functions may be targeted specifically in the design and creation of the mitigation wetland with the recognition that other functions are not possible or even desirable. Low WMQA scores for these wetlands could mask the success in achieving the desired goals while attention to the individual variables would provide a better indication of whether the wetland had the potential to achieve the desired function.

Performance of the WMQA:

The major informational variables and indicators needed to evaluate mitigation wetland functioning are addressed and the criteria for rating each of the six variables are appropriate (Hatfield et al. 2002b). Furthermore, we did not identify any additional variables or indicators that should be included in the method. WMQA appears relatively objective for a qualitative rapid assessment method. The method is straightforward and relatively easy to apply in the field.

The individual WMQA variables were weighted to emphasize variables considered more essential for a wetland to function. However, for this study the weightings did not exert a strong influence on overall WMQA index scores nor did the weightings change the relative rankings of the wetlands. The weightings added an unnecessary complication that could potentially introduce error into the computational portion of deriving the WMQA index.

Recommendations for WMQA Clarification:

Clarification of the guidelines for implementing the WMQA methodology will improve application of the method and potentially reduce variability among raters. Consistent training of field evaluators is recommended with regularly scheduled refresher courses. Procedures for validation and cross-validation as part of the training process would also reduce variability among evaluators. The weighting scheme added unnecessary complications to the method and did not improve the information content in the WMQA scores.

In general, we found the WMQA methodology was straightforward and easy to implement. However, there are several recommendations that would make the methodology less ambiguous and potentially more repeatable. These recommendations include:

- **INSTRUCTIONS.** Increasing detail in the instructions for the WMQA method may help to reduce variability among raters. For example, more detailed instructions on how to determine the potential for a young wetland to develop redoximorphic features in the soil would help alleviate problems in evaluating potential wetland functioning from current conditions at the site.

- **ROLE of PLAN.** It is unclear whether to evaluate a wetland according to current conditions or to the design plan. A wetland that was designed as a forested wetland but experienced high mortality of woody species currently behaves as an herbaceous wetland with little potential to develop into a forested wetland. It is not defined whether to evaluate this wetland as a forested wetland, according to the design plan, or as an herbaceous wetland, according to the current conditions.
- **LANGUAGE.** There are a few instances where language is ambiguous in the method and clarification is needed, mainly between the indicators for the hydrology and the vegetation variables.
- Plant stress is an indicator for both hydrology and for vegetation; however, this term has different meanings for each variable. For hydrology, plant stress is due to improper hydrology and is indicated by wilting, dieback, or lack of recruitment. For vegetation, plant stress indicates vegetative health through signs of abnormal growth patterns, chlorosis, or other abnormalities due to improper nutrition. Separate terms should be used for the plant stress indicator in each variable to reduce uncertainty in applying the method. Changing the term of plant stress to plant health in the vegetation component would help alleviate this confusion.
- Undesirable plant colonization, another indicator for the hydrology variable, indicates colonization by transitional or upland plants. This indicator may be confused with invasive plant colonization, an indicator for the vegetation variable, as they are similar in terminology. Undesirable plant colonization could be changed to transitional/upland plant succession to reduce ambiguity.

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