State of Ohio
Environmental Protection Agency

Wetlands Unit
Division of Surface Water

A Functional Assessment of Mitigation Wetlands in Ohio: Comparisons with natural systems.

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Executive Summary

The goal of the Clean Water Act, to restore and maintain the chemical, physical and biological integrity of the nation's surface waters, includes wetlands. With respect to wetlands, one means of implementing this goal is to regulate the discharge of dredged or fill materials under Sections 404 and 401 of the Clean Water Act. Under Sections 404 and 401, wetland impacts first must be avoided if possible, then minimized and finally compensatory mitigation (i.e., restoring or creating a wetland to replace the one destroyed) must take place for any wetland fills that are permitted.

The objective of this study was to assess how well compensatory mitigation is working in Ohio through a comparison of mitigation and natural (or reference) wetlands. All mitigation projects included in the study were permitted through the Clean Water Act Sections 404/401 program. Quantitative measures were taken to assess plant community composition, wetland size and basin morphometry, and soil characteristics. Qualitative measures were taken on buffer area characteristics. Identical measurements were taken on a population of reference wetlands for comparison. In all, 14 mitigation wetlands and seven reference wetlands were assessed.

The major findings of this study include:

• There was not a single case were a wetland impact had occurred and a corresponding mitigation project had not been done. There were several cases where mitigation projects had not been constructed because the wetland impact had not occurred either. In other words, wetland fills are being compensated for.

• This data shows an average replacement ratio of wetland acres established on the ground of 1.26: 1. This can be viewed in several ways. One is that the mitigation projects are not meeting their stated goal of a 1.5:1 mitigation ratio, falling on average 0.24:1 acre short. Conversely, there has been an acreage surplus of 0.26 acres for every acre of wetland impact. From this perspective Ohio is achieving a net gain of wetland acreage in the Section 401 program. The size of the discrepancy in the required mitigation acreage compared to the actual mitigation acreage is

primarily the result of a single mitigation project, a very large project in the Ohio EPA regulatory program that has not been judged to be successful to date (Wilson and Mitsch 1996). If this project is treated as an outlier, the average mitigation ratio in the field is 1.43:1 (67.9 acres of wetland mitigation for 47.6 acres of impacts). Although the 1.5:1 mitigation ratio was not met in all projects, the remaining acreage that has not developed into jurisdictional wetland has helped contribute to the creation of upland buffers surrounding the wetlands.

- Findings show a decrease in native plant species diversity associated with wetland mitigation projects (significant at < 0.01) in the early stages of development.

- No significant differences were found in the Floristic Quality Assessment Index (FQAI) values between mitigation and reference sites. The relatively wide range in condition of the reference wetlands contributed to this finding, as did the fact that many of the mitigation projects had surprisingly diverse plant assemblages.

- The results of the draft Buffalo Corps of Engineers Wetland Evaluation Methodology (BWEM) indicate that the mitigation wetlands are not functionally equivalent to the reference sites (in spite of the range of quality in the reference wetlands, i.e., the reference wetlands were not considered to be 'least impacted' sites that would be expected to perform most highly). From a functional perspective, mitigation projects are not yet measuring up to natural sites with respect to flood water retention, water quality improvement and habitat provision as measured by the BWEM. Continued monitoring should be done to track the development of wetland functions at mitigation sites as the projects age.

An evaluation of mitigation project success can be approached in three ways:

- from an acreage perspective, mitigation in Ohio can be viewed as a success because there has been a net gain in wetland acreage, i.e., the no net loss goal is being met;

- using the BWEM to assess wetland functions, the mitigation projects cannot be judged

to be fully successful. On average, they were outperformed for each of the three functions analyzed in the BWEM by the reference sites. It is unclear at this point how much of the difference may be due to the young age of the mitigation projects. Time will show if the mitigation wetlands continue to improve functionally. The loss of wetland functional ability in the short term speaks to the temporal loss of wetland functions that occurs due to mitigation. If the mitigation wetlands improve functionally over time, there has still been a temporary loss of wetland functional ability from the landscape.

• an assessment of floral diversity indicates that there is no significant difference in total species richness between the two groups, although the percent of total species that are native was significantly higher in the natural wetlands. This indicates that, at least in the short term, there is a loss of native plant species diversity occurring through the mitigation process. The loss of native plant diversity has implications, as yet unmeasured, for native faunal diversity.

Introduction

The principle goal of the Clean Water Act is to restore and maintain the chemical, physical and biological integrity of the nation's surface waters, including wetlands. One means of implementing this goal is by regulating the discharge of dredged or fill materials to wetlands under Section 404 of the Clean Water Act. Prior to a section 404 permit being issued by the U.S. Army Corps of Engineers, the state where the project is located must issue a Section 401 certification stating that the discharge will not violate its water quality standards. As in other states, Ohio uses the 401 program to protect the water quality of wetlands and other surface waters. Under Sections 404 and 401, wetland impacts first must be avoided if possible, then minimized and finally compensatory mitigation (i.e., restoring or creating a wetland to replace the one destroyed) must take place for any wetland fills that are permitted. Mitigation is seen as a way to reconcile the need for economic development and environmental protection (Roberts 1993). It is also a means to meet the federal policy of "no-net loss" of wetlands.

Several studies have reported that wetland mitigation projects have had limited success in replacing the functions of lost wetlands (Race and Fonseca 1996, Roberts 1993, Brown 1991, Erwin 1991, Gwin and Kentula 1990). Problems that may contribute to this phenomenon include: mitigation wetlands are not constructed as permitted; wetland shorelines are too regular and too steep (Gwin and Kentula 1990); soils are not appropriate for wetland establishment; and applicants either failing to construct wetlands at all, or the wetland size did not meet permit conditions resulting in a net loss of wetland acreage. Excavation to nutrient-poor subsoils and a lack of adequate hydrology also have been cited as reasons for mitigation failure (Gwin and Kentula 1990, McCoy and Kulp 1992). Other studies have reported on the overall status of wetland restoration and creation. In a comprehensive assessment, Kusler and Kentula (1990) report that information on the restoration and creation of inland freshwater wetlands is particularly lacking. Most studies that have been done are site-specific and have not used

reference sites for comparison.

At question is whether wetland mitigation projects provide the wetland area and functions of the original wetlands. Mitigation ratios, which determine the amount of wetland that must be reestablished to compensate for wetland losses, are set depending on the perceived value of the impact site, the difficulty of replacement and the time lag that might occur between impact and compensation. Nationally, mitigation ratios usually range between 1:1 and 4:1 (Zedler 1996).

Zedler (1996) has described successful mitigation as "providing a habitat that is functionally equivalent to the one that will be lost." To date, there have been no agreed upon performance standards for mitigation projects that allow an assessment of project success. Typically, the approach is to reproduce structural characteristics (e.g. plant density or community composition) with the assumption that functional attributes will follow (Simenstead and Thom 1996). Particularly problematic is the issue of reestablishing and maintaining appropriate hydrology. This requires a landscape-scale approach to identify the wetland's hydrological context (Bedford 1996). Brinson (1993) and Brinson and Rheinhardt (1996) have called for long-term studies of reference wetlands to set performance standards for mitigation projects. These reference wetlands would be chosen based on their high level of ecological functioning, and could be used to set goals for use in regulatory programs. Another problem in ensuring success is the short time horizon for post-wetland construction monitoring. Mitsch and Wilson (1996) have suggested a 15 - 20 year monitoring period for freshwater marshes and even longer periods for forested or peat accumulating wetlands.

The objective of this study was to assess how well compensatory mitigation is working in Ohio through a comparison of mitigation and natural (or reference) wetlands. This information will ultimately be used to help guide the development of ecologically based mitigation performance goals (not part of this report). All mitigation projects included in the study were permitted through the Clean Water Act Section 404/401 program. Quantitative measures were taken to assess plant community structure, wetland size and basin morphometry, and soil characteristics.

Qualitative measures were taken on buffer area characteristics and observations were noted of any wildlife species. Identical measurements were taken on a population of reference wetlands for comparison. In all, 14 mitigation wetlands and seven reference wetlands were visited during the summer and early fall of 1995. Only those mitigation projects which were, at minimum, in their second growing season at that time were included in the analysis. Reference wetlands were selected in the same Cowardin class (Cowardin et al. 1979) and hydrologic unit (as defined by USGS, 1988) as one or more of the mitigation wetlands.

Materials and Methods

1. Site Selection

A. Mitigation wetlands

Mitigation wetlands included in the study were selected based upon the type of permit that was issued and the age of the mitigation project. All wetland assessments took place between July and early October 1995. The mitigation projects included were permitted under Clean Water Act Section 401 water quality certifications and the majority were projects that received individual 401 permits (i.e., those projects affecting wetlands adjacent to other water bodies or with impacts of 5 acres or more). Each wetland mitigation project certified under the Ohio Section 401 program undergoes a site review in the third year, during which the progress of the project is assessed and recommendations for corrective actions are made, if necessary. To reduce variability in site conditions that might result from the early establishment of the wetlands, particularly differences due to the establishment of the plant communities, only those projects in their second growing season or older were included. The oldest site sampled for this study was in its fifth growing season.

Five projects were eliminated from this study because either the mitigation project had not been constructed or construction was just beginning (i.e., the project was in its first growing season). Unlike other studies which have reported wetland impacts without a mitigation project being undertaken, in this case, whenever a mitigation project had not been completed, the wetland impact had not occurred. Several applicants had renewed their permits with the view that their project may go forward, but the projects at the time of this study had not caused any impacts to wetlands.

Four mitigation wetlands were assessed that are not included in the data analyses presented below. One mitigation project included a series of nearly 20 small wetlands which were restored

or created within an 18 hole golf course. The difficulties of sampling many small wetlands in conjunction with the fact that they were actively "gardened" (i.e., planted, weeded, etc.) to improve their aesthetics resulted in a site that was not representative of more "natural" mitigation projects. A second project was eliminated because the data set associated with this site was incomplete. One project was not considered because it was discovered during our field visit that the site was in its first growing season, and a fourth project was excluded because it was a mitigation bank. The bank was much larger than many of the other mitigation projects, and because it serves to mitigate for many wetland fills and receives a differing level of scrutiny, it was not considered to be representative of the wider population of mitigation sites.

Table 1 provides summarizes information on the 10 mitigation wetlands included in the full analysis, including the year the project was constructed, location, whether or not the site was planted (either with seed or plant stock), hydrological information on the size of the drainage area supporting the wetland (where available), and whether or not the project could be considered a restoration, creation, or enhancement project. The latter data is based on the soils at the site. If hydric soils were present, the mitigation wetland was considered a restoration project. In many cases, the mitigation project was constructed on non-hydric soils with hydric inclusions. Because the location of the inclusions are not mapped, these projects were considered to have both creation and restoration components. Several projects were constructed adjacent to existing wetlands with the intent of improving (generally through hydrological modification) the existing wetland. In these cases the project was deemed to include an enhancement component. All the information shown on Table 1 came from Ohio EPA project files. Table 1 also shows the location of the natural wetland sites used as reference wetlands (see below).

B. Reference wetlands

The selection of natural wetlands to use as reference sites was based on several factors. All the mitigation projects were classified as palustrine emergent wetlands under the Cowardin classification system (Cowardin et al. 1979), although several were designed and planted to

Table 1. a) Mitigation wetlands site information summary, and b) reference site location information.

a)

Mitigation Project Site Name	Year Constructed	Site Planted (yes/no)	Drainage Area (acres)	Restoration* or Creation Project	Enhancement Included (yes/no)	Project Location County	USGS Watershed HUC number†
Aurora	1993	Yes	n/a	C/R	Yes	Portage	04110003
Borror	1992 (Feb)	Yes	340	C/R	No	Union	00506001
City of Cambridge	1992	Yes	n/a	C	No	Guernsey	00504001
Gavin	1993 (Nov)	Yes	3775	C	No	Gallia	05030202
JMB	1994	Yes	108	C/R	No	Franklin	05060001
Pizzuti	1993	Yes	n/a	C/R	No	Delaware	05060001
R and F Coal	1993	Yes	55.5	C/R	No	Belmont	05030106
Rittman	1993	No	9	C/R	No	Wayne	05040001
Ross Labs	1992	Yes	642	R	No	Franklin	05060001
Walmart	1991	Yes	n/a	R	Yes	Jackson	05090101

* based on the presence of hydric soils; many sites contained a mixture of hydric and non-hydric soils.
† Hydrologic Unit Codes, USGS 1988.

b)

Reference Site Name	Project Location County	USGS Watershed HUC number†
Audubon	Portage	04110003
Belmont	Belmont	05030106
Cooper Hollow	Jackson	05090101
Pickerington ponds	Fairfield	05030204
Riley	Champagne	05060001
Salt Fork	Guernsey	05040005
Stages Pond	Pickaway	05060001

develop into forested systems (at these sites, saplings became established to varying degrees but the sites will not be considered forested for some time). In order to make direct comparisons, reference sites were also palustrine systems dominated by emergent vegetation. In many cases the natural wetlands contained a mosaic of community types that included wooded and shrub scrub areas. Within a given wetland, when forested or shrub-scrub communities were distinct from herbaceous communities they were not included in this analysis (i.e., only the emergent portion was included). In addition , the large size of some of the reference sites (in many cases 25 acres or larger) made the selection of a portion of the site necessary for the assessment. The reference sites were chosen to be of the same size as the mitigation sites, i.e., ranging between about one and 15 acres. It should be noted that there was no attempt to choose only high quality sites. Wetlands were selected randomly without regard to quality to ensure that the reference sites reflected the range of quality present in the Ohio landscape. It is assumed that these reference sites more accurately reflect the range of quality of the impacted wetlands which, although they were not assessed, were not all of the highest quality.

The watershed where the mitigation wetland was located was also a factor in selecting reference sites. Ohio EPA has adopted the USGS hydrologic units (known by hydrologic unit code, HUC) as the watershed scale for use in wetland planning and permitting. These were defined by the USGS (1988) for use in water resource planning purposes. The mitigation wetlands included in this study occurred in seven of the 44 hydrologic units located in Ohio and reference sites were chosen in five of these watersheds.

Natural wetland sites that were included in the study are as follows:

- Audubon Nature Preserve, in Aurora, (Portage County), owned by the Audubon Society. A portion of a relatively large wetland complex was used for the assessment.
- A wetland located in Belmont County, adjacent to strip mined lands in the Muskingum Watershed Conservancy District.
- A wetland located in the Ohio Department of Natural Resources (ODNR) Cooper

Hollow Wildlife Area, Jackson County.

• A portion of the wetlands located at the ODNR Pickerington Ponds State Nature Preserve located in Franklin and Fairfield Counties.

• A wetland located in Champaign County between State Route 4 and the Conrail railroad tracks approximately 5 miles southwest of Mechanicsburg, and known as the Riley wetland.

• A wetland located in the ODNR Salt Fork Wildlife Area in Guernsey County, near Salt Fork Lake.

• A wetland in the ODNR Stages Pond State Nature Preserve in Pickaway County.

2. Field Methods

A rapid assessment approach was used in this study. The field protocols were designed so a small team of people could collect as much information on a site in one field day, therefore data collection at each site took approximately one day using a team of four people. Some larger sites required a second field visit. Preparation for the field visit included a write up of information from the project file (for mitigation sites only) which entailed approximately a half day's work. Approximately one day also was spent after the visit to process field samples (i.e. to identify plant voucher specimens). A series of seven data collection forms were developed to ensure consistent and complete data collection. Many of these were based on data forms in Magee et al. (1993). Each form addresses a different aspect of the wetland ecosystem:

Form 1: Project file information

Form 2: General information on site (including map sketch)

Form 3: Mapping (surveying) data

Form 4: Vegetation data

From 5: Photographic log

Form 6: Soils data

Form 7: Wildlife observations.

General information was collected on each wetland to describe the extent of vegetation cover and characteristics of any buffer areas (Form 2). Buffer areas were defined as the 100 m of land surrounding the wetland boundary (Magee et al. 1993). Land use within the buffer was recorded, as was an estimate of its suitability for wildlife habitat. The latter was an estimate based on best professional judgement. Areas that may not have been suitable as habitat (i.e., for nesting or grazing) were included if they could be used as a corridor to other habitat areas.

In addition to investigating the above mentioned aspects of wetland ecosystems, an additional objective of this study was to field test a method designed to assess wetland functions and perform a wetland functional analysis. The U.S. Army Corps of Engineers, Buffalo District, has developed a draft functional assessment method for use in its 404 program. The method provides a score for each of the following: the water retention ability of the wetland, the water quality improvement function, and its habitat value. Since the northern third of Ohio lies in the Buffalo District, this method was designed for use in Ohio, as well as other states in the Buffalo District. The draft method applies to depressional wetlands only; a variant may be developed for riparian wetlands. The seven field data forms listed above were designed to incorporate all of the information needed to complete the Buffalo Wetland Evaluation Methodology (BWEM). Following field data collection, each site was scored using the Buffalo method.

A. Wetland Area

In order to assess the actual wetland area that had been created or restored at the mitigation sites, a wetland boundary determination was made in the field, using the changes in plant communities and any indicators of hydrology. Where needed, soil cores were taken to confirm the wetland edge. A full delineation procedure was not conducted at each site, however, because many of the mitigation wetlands were excavated, a relatively distinct boundary existed at the "top" of the basin. Prior to measurement of the wetland area, the site was scouted and the boundary marked.

Through the course of this project, several methods were used to estimate the actual area of jurisdictional wetland that had been created at the mitigation sites. Initially, sizes were to be estimated by using conventional surveying techniques (i.e., transit and stadia rod). This proved very time consuming and, at larger sites would have necessitated more than one day being spent to assess wetland size. For this reason, a Global Positioning System (GPS) unit was used to determine the area of several of the large sites.

Once the wetland boundary had been determined, a ten-channel, Magellan ProMark X GPS receiver was used to log the coordinates of the boundary. Data was collected at one second intervals. Data were downloaded from the field receiver for post processing using the Magellan 3.0 release software. All data sets were corrected using a stationary file from the Ohio State University base station in Columbus. The corrected data was averaged into point coordinates. This data was imported into the ArcInfo Geographic Information System to create an Arc/Info coverage of the wetland area. The area measurement tool in ARCTOOLS was used to calculate total acres.

For the largest site included in the study, the JMB mitigation project, and on the recommendation of the firm that designed the site, a size estimate was made using an aerial photograph. Small wetland areas within the site made the use of the GPS impractical for mapping. To calculate wetland size the photo was overlaid with grid paper and the area determined using the "counting-squares" method. Boundaries were determined by a thorough examination of the site (on several occasions), then identifying those same boundaries on the photo.

B. Morphometry

A baseline was established at the wetland sites that lay along the long axis of the wetland or perpendicular to any obvious environmental gradients (Magee et al. 1993). Several transects were located perpendicular to the baseline at evenly spaced intervals along the baseline. Wetland size dictated the number of transects established. At least one transect was also established parallel to the baseline.

The transit was positioned to enable the operator to see as much of the wetland and the transects as possible. A benchmark was established at each site to serve as a reference elevation (normally a natural, unmovable feature). A reading was taken on the benchmark at the beginning of each transect and if the transit was moved (turning). One crew member carried the stadia rod to different positions along the transects, holding the stadia rod while the person operating the transit recorded the data and indicated the general location of sampling points on the site sketch. More frequent measures were taken at the wetland edges where slopes were often more pronounced. The size of the wetland (length of the transect) was used to determine the number of sampling points. Water depths were also taken at several points in each wetland. However, since the sampling time ranged from June through early October, the period of time when many depressional wetlands become shallower or even dry out completely, these data were not included in the analysis.

The data collected was used to calculate bank slopes, draw bottom profiles, and calculate an index of microtopography. The latter was estimated by using the standard deviation about the mean of the bottom elevation.

C. Vegetation

Two to four transects were established in each wetland running perpendicular to the baseline described above. These transects were strategically placed to sample a representative cross section of the vegetation types present. Plants were sampled using a circular quadrate frame with an area of 0.6 square meters at uniformly spaced intervals along the transect. The interval distance was determined in the field as a function of wetland size. A minimum of 30 quadrats were sampled in each wetland and any species that were noted along the distance of the transect (whether they fell within a quadrat or not) were recorded. Only cases where the quadrat contained vegetation (i.e., not open water) were counted towards the total sample.

The plant community composition was surveyed in each quadrat. All species occurring in each

plot were identified and recorded, and percent cover was estimated visually for each species. If the identity of any species was in doubt, or where field personnel disagreed as to the identity of a species, a voucher specimen was collected and returned to the office for subsequent identification and/or confirmation at the Ohio State University Herbarium. Within each quadrat, coverage was estimated using the following increments:

For Cover of:	Used Increments of:
1% to 5%	1%
> 5% to 30%	5%
> 30%	10%

In addition, water depth (if present), and the percent of any open water or bare soil in the quadrat also were recorded. Vegetation was classified according to Reed (1988).

D. The Floristic Quality Assessment Index

The Floristic Quality Assessment Index (FQAI; Andreas and Lichvar 1995) was calculated for each wetland area included in this study. The Floristic Quality Assessment Index is a vegetative community index tailored specifically to Ohio flora by Barbara K. Andreas, Ph.D., and based on the method developed by Wilhelm and Ladd (1988). The FQAI is designed to assess the degree of nativeness of an area based on the presence of ecologically conservative species. It is thought to reflect the degree of human-caused disturbance to an area by accounting for the presence of cosmopolitan, native species, as well as non-native taxa. This index has potential as a measure of ecosystem condition because it assigns a repeatable and quantitative value to the vegetation community.

A total species list was compiled for each site. Each species on the list was assigned a rating of between 0 and 10 according to Andreas and Lichvar (1995). A rating of 0 is given to opportunistic native invaders and nonnative species. Ratings of 1 - 10 are assigned as follows:

<u>Values of 1-3:</u> applied to taxa that are widespread and do not indicate a particular community;

<u>Values of 4-6</u>: applied to species that are typical of a successional phase of some native community;

<u>Values of 7-8</u>: taxa that are typical of stable or "near climax" conditions;

<u>Values of 9-10</u>: taxa that exhibit high degrees of fidelity to a narrow set of ecological parameters.

The total species list from each wetland was used to calculate the FQAI value for each site as follows:

$$I \frac{R}{N}\sqrt{N} \quad \text{or} \quad I \frac{R}{\sqrt{N}}$$

Where I = the FQAI score

R = Sum of coefficient of conservatism (C of C)

N = Total number of native species.

As it is written (Andreas and Lichvar 1995), the FQAI is calculated by summing the coefficients of conservatism (for which non-native species score a zero) and dividing by the total number of native species. Thus, non-natives are 'invisible' in both the numerator and the divisor of this equation. A justification for leaving non-native species out of the equation is that the role of non-native species in a given community is difficult to assess, therefore they have been excluded (Wilhelm and Ladd 1988). In order to test whether the number of non-native species in a community makes a significant difference in how that community scores, an equation for a modified FQAI (modFQAI) value was developed. The modified version of the FQAI was

calculated by including the number of non-native species in the total species count, such that:

$$modI \frac{R}{N'}\sqrt{N'} \quad \text{or} \quad modI \frac{R}{\sqrt{N'}}$$

Where modI = modified FQAI score

R = Sum of coefficient of conservatism (C of C)

N' = Total number of native plus non-native species.

E. Soils

Five soil samples were taken per wetland. Samples were distributed throughout the wetland with care taken to sample in the major vegetation zones, and zones of open water, saturation and temporarily or intermittently flooded areas, if present. Within each zone the sample point was randomly selected. A 1.9 cm diameter soil probe was used to collect samples to a depth of 25 cm (10 inches). If more than one horizon was present in the sample color determinations were made for both. Data on matrix color, mottle color, abundance and size, and other indicators of wetland hydrology such as the presence of oxidized root channels and any hydrogen sulfide smell, an indicator of anaerobic conditions typical of wetland soils, also were collected.

F. Wetland Watersheds

Data on the drainage area supporting the wetlands were gathered from mitigation project reports, where available. If this information was not provided and where possible, U.S. Geological Survey quadrangle maps (1:24,000) were used to calculate the drainage areas directly.

Results and Discussion

1. General Site Characteristics

General information collected on each wetland to describe the extent of vegetation cover and characteristics of any buffer areas is shown in Table 2. Open water in the mitigation sites ranged from 0 - 95 percent and in the references sites from 10 - 50 percent. The Pizzuti mitigation site, which had 95 percent open water, fits a conventional view of mitigation projects, namely a pond with a fringe of vegetation. One of the most notable differences between the mitigation and reference sites is the extent of open water. Open water dominated the mitigation wetlands, averaging nearly 50 percent. Reference wetlands by comparison averaged 25 percent and the maximum extent of open water at any of the sites was only 50 percent. An unpaired t-test showed that this difference is statistically significant ($t = 2.103$; $p = 0.05$). Corresponding to the lower amount of open water was a higher cover of emergent vegetation in the reference wetlands (58 versus 33 percent). The mix of shrubs and trees was similar in the two groups, although obviously any trees were much less mature in the mitigation sites.

Buffer characteristics were similar in the two groups, both in terms of land use and the percent of the buffer around the wetland that could be used by wildlife species. To determine the wildlife utilization potential of the buffer area, an estimate was made of the percent of the buffer zone that could be utilized by wildlife as habitat or a reasonably safe access corridor. Vegetated buffers were predominant, accounting for 76 percent of land use around mitigation sites and 65 percent around reference sites. Human land use was defined to include agricultural areas, industrial-commercial zones, housing and roadways. In both groups, approximately one quarter of the buffer area was dominated by human landuse. Buffers containing roads were the most common reason for inclusion in the human landuse category. Generally, all wetlands in this study had buffers of high enough quality to benefit wildlife and protect the wetland. At some of the mitigation sites, the buffer areas were a result of a portion of the site not developing into wetland

Table 2. Proportion of open water and plant cover, and buffer characteristics in the mitigation and reference wetlands.

Mitigation Site Name	% Open Water	% Vegetated			Buffer Characteristics			% Buffer usable by Wildlife
		emergent	shrubs	trees	% human landuse	% adjacent water	% vegetation*	
Aurora	10	100	0	0	10	5	85	90
Borror	45	40	5	10	0	0	100	100
Cambridge	85	8	0	2	30	0	70	70
Gavin	50	39	3	3	35	0	65	100
JMB	50	10	30	60	20	0	80	20
Pizzuti	95	5	0	0	30	0	70	100
R and F Coal	85	15	0	0	0	0	100	100
Rittman	0	5	80	15	60	0	40	100
Ross Labs	60	25	5	10	10	5	85	100
Walmart	15	80	2	1	20	10	70	100
MEAN	**49.5**	**33**	**13**	**10**	**22**	**2**	**76**	**88**

Reference Site Name	% Open Water	% Vegetated			Buffer Characteristics			% Buffer usable by Wildlife
		emergent	shrubs	trees	% human landuse	% adjacent water	% vegetation*	
Audubon	50	38	10	2	0	0	100	100
Belmont	10	69	20	1	60	0	40	70
Cooper Hollow	20	60	15	5	20	20	60	100
Pickerington ponds	25**	65	5	5	10	20	70	100
Riley	25	67	3	5	90	0	10	60
Salt Fork	20	50	25	5	0	0	100	100
Stages Pond	20†	55	15	10	0	25	75	100
MEAN	**25**	**58**	**13**	**5**	**26**	**9**	**65**	**90**

* includes herbaceous vegetation, shrubs and trees

** includes a 5% mudflat area

† includes a 10% mudflat area

(see below).

The only significant difference in the buffer characteristics between the two groups was the amount of open water adjacent to the wetland ($p = 0.08$), i.e., if the wetland had a direct surface linkage to an adjacent water body. Nearly 10 percent of the reference site buffer areas had such surface water links. The higher degree of hydrologic connectivity has implications for the hydrological and biodiversity functions of mitigation versus natural (reference) wetlands, and may increase, for example, their potential for water quality improvement.

2. Wetland Area

The current regulatory requirements for wetland replacement in the mitigation process in Ohio is 1.5 acres of created or restored for every acre of wetland fill. This is in keeping with the "no net loss" policy for wetlands, both at the state and federal level. Table 3 shows the results of the areal measurements that were made at each mitigation site and a comparison with the permit requirements. Data on two projects (Kemper and Rostan) are included in this table which are not included in other sections of this report. Since data on their respective sizes was collected, it was included to maximize the amount of data available for this discussion.

The total number of wetland acres authorized for impacts and thereby lost through the permitting of these 11 projects was 84.9 acres. Mitigation requirements as written into the Section 401/404 permits was 141.3 acres; full compliance with mitigation acreage requirements would have resulted in an average mitigation ratio of 1.6:1. The total area determined to be wetland in the field at the mitigation sites was 107.5 acres. The deviation from actual mitigation requirements was therefore a shortfall of 24 percent. In nearly all cases the land parcel was sized to support a wetland large enough to meet permit specifications but the wetland boundaries did not approach the parcel boundaries. In some cases there was a large discrepancy between the land area available for the mitigation project and the actual proportion of the project site that met wetland

Table 3. Comparison of wetland size: required acreage versus wetland area estimates from field visits. Negative values indicate a decrease in acreage. Mitigation ratios were generally 1.5:1 unless special conditions applied.

Site Name*	Actual wetland impacts	Mitigation requirement	Field size estimate acres	Net change in wetland acres	Net mitigation acres: required - actual	Methodology**
Aurora†	1.0	1.5	2.8	1.8	1.3	GPS
Borror	5.8	8.6	9.5	3.7	0.9	GPS
City of Cambridge	3.2	4.8	5.2	2.0	0.4	GPS
JMB	37.3	70.0	39.6	2.3	-30.4	Aerial Photo
Kemper	1.6	2.5	2.0	0.4	-0.4	GPS
Pizzuti	6.9	10.4	10.4	3.5	0.0	S
R and F Coal	0.5	0.7	1.3	0.8	0.6	S
Rittman	0.9	1.4	2.8	1.9	1.5	GPS
Ross Labs†	8.9	13.4	13.8	4.9	0.5	S
Rostan	6.8	10.2	6.1	-0.7	-4.1	S
Walmart	12.0	18.0	14.0	2.0	-4.0	S
Total	**84.9**	**141.3**	**107.5**	**22.7**	**-33.8**	

Deviation from mitigation requirements: -24%
Deviation from mitigation requirements w/out JMB: -2%
Net change in actual wetland acreage: 27%

† much of the acreage in this project was wetland enhancement
* Data not available for Gavin project.
** Methods include S = conventional surveying techniques, GPS = use of a Global Positioning System, Aerial Photo = estimate from an aerial photo.

criteria (according to the 1987 Federal Manual). In looking at these projects as a whole, the average mitigation rate was 1.26:1; the intent for wetland acreage mitigation has not been realized.

It should be noted that the statistics on mitigation wetland size shown in Table 3 are skewed by the JMB wetland site. In the Ohio Section 401 program this is considered a very large wetland impact (37.3 acres) with a mitigation requirement of 70 acres. Problems establishing hydrology at the site have hindered wetland establishment. This is reflected by the fact that approximately 30 acres of the site was not meeting the criteria for jurisdictional wetlands. The size of this project gives it a disproportionate influence on the data presented in Table 3. If this project is not included the mitigation shortfall is reduced to two percent, i.e., there are only three acres missing from the 141.3 acres that were required to be reestablished to meet the 1.5:1 ratio. When this outlier is removed, the data reflects that wetland mitigation projects are generally meeting their acreage targets.

A comparison of the number of wetland acres actually lost to the number of acres reestablished in the mitigation process (including the JMB project) shows that there was a net increase in actual wetland area of 22.7 acres, for a total increase of 27 percent (Table 3). Thus the State of Ohio, as indicated by these projects, has achieved a no net loss of wetlands, and has even accomplished a net gain in total wetland acres, through the Section 401 program.

3. Morphometry

Bank slopes and bottom topography were calculated using the elevation data collected along transects in each wetland. These are essential measures of basin morphometry that have a strong influence on long-term vegetation community structure and productivity (Keddy 1991, Brown 1991). Morphometry has implications for a wetland's functional ability, for example, steeper slopes and less microtopographical relief may lead to shorter retention times and diminish the

ability of the wetland to remove nutrients, sediments, and other compounds (Kadlec and Knight 1996). These conditions may also lead to a less diverse plant community which in turn may limit faunal diversity.

Average bank slopes were significantly steeper in mitigation wetlands than in reference wetlands (Figure 1). Values in mitigation wetlands ranged from 246:1 to 0.35:1 (horizontal : vertical, see Table 4). The most gentle slope was found at the Rittman site where existing natural topography was used to establish the wetland (i.e., there was no excavation). Here a berm was placed at one edge of the property and water was allowed to accumulate behind the berm, taking advantage of the gentle elevation gradient found at the site. The very shallow slope found along one side of the Cambridge wetland (62:1) was located where a long, shallow mudflat area had been created. Interestingly, banks around the remainder of this wetland were among the steepest recorded. The steepest slope was found within the JMB site where a pond was created as part of the mitigation project. Bank slopes of the pond were extremely steep, precluding essentially all emergent plant growth. Although data are not available, the boundaries of the JMB site, where the natural topography constituted the edge, had very gentle slopes. By comparison, slopes in the reference wetlands ranged from 241:1 to 16:1 (Table 5). Several of the natural wetlands had been impacted by human activities which affected their banks. For example, the Riley site was hemmed in by an elevated railroad bed and an elevated roadway, each of which created a very steep slope along a portion of the wetland perimeter.

Roughness was calculated as the variance of the ground surface elevation around the mean, providing a measure of microtopographic relief in each wetland basin (Brown 1991). Roughness varied in the mitigation wetlands from a low of 0.35 to a high of 2.25, and in the reference wetlands from 0.35 to 0.87. Contrary to expectation, average roughness was significantly higher in the mitigation wetlands (means were 1.4 and 0.6 for mitigation and reference sites respectively; $p = 0.01$). Other studies have cited the lack to topographic relief as one weakness in the design of mitigation wetlands (need some cites). Brown (1991) found a similar range in roughness values for a series of wetlands in Florida, with values ranging from 0.07 to 0.90. This study also

Figure 1. Box plot showing means, standard deviations and ranges for bank slope data at mitigation and reference wetlands. Means are significatnly different at $p < 0.01$.

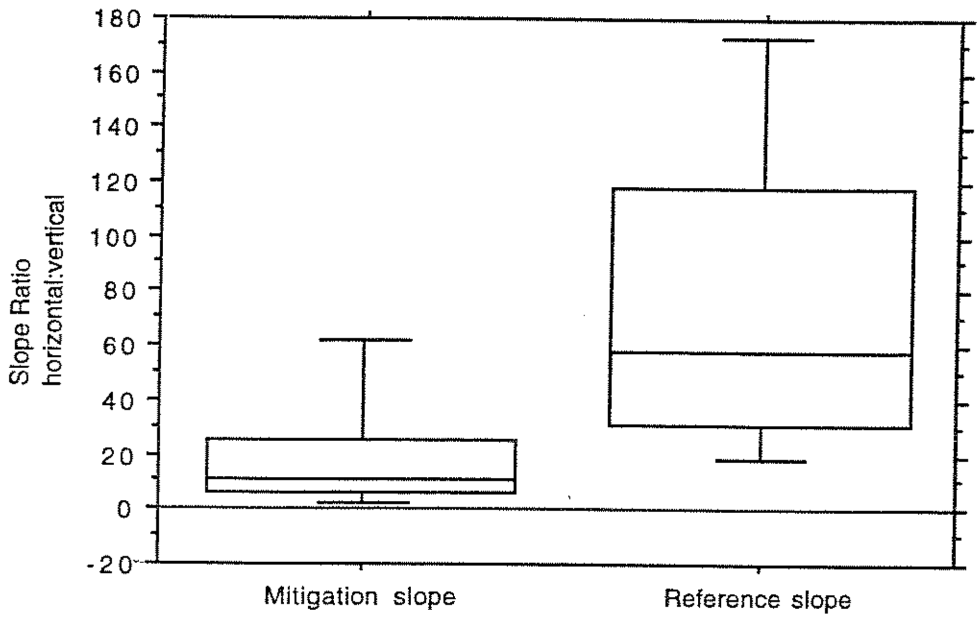


Table 4. Bank slopes of mitigation wetlands. In each wetland, slopes were measured at several positions around the wetland circumference.

Site Name	Slope (horizontal:vertical)
Aurora	
bank slope 1	6.9: 1
bank slope 2	6.4: 1
bank slope 3	33.2: 1
Borror	
bank slope 1	29: 1
bank slope 2	25.5: 1
Cambridge	
bank slope 1	6.9: 1
bank slope 2	1.5: 1
bank slope 3	4.6: 1
bank slope 4	62.3: 1*
Gavin	
bank slope 1	14.7: 1
bank slope 2	24.8: 1
JMB (pond's edge)	
bank slope 1	0.35: 1
Pizzuti	
bank slope 1	10.5: 1
bank slope 2	12.4: 1
bank slope 3	6.6: 1
bank slope 4	2.5: 1
bank slope 5	13.3: 1
Pizzuti	
bank slope 1	10.5: 1
bank slope 2	12.4: 1
bank slope 3	6.6: 1
bank slope 4	2.5: 1
bank slope 5	13.3: 1
R and F Coal	
bank slope 1	2.9: 1
bank slope 2	10.5: 1
bank slope 3	17.8: 1
Rittman	
bank slope 1	10.9: 1
bank slope 2	246: 1
Ross Labs	
bank slope 1	5.9: 1
bank slope 2	121:1
Walmart	na

Table 5. Bank slopes of reference wetlands. In each wetland, slopes were measured at several positions around the wetland circumference.

Site Name	Slope (horizontal:vertical)	Site Name	Slope (horizontal:vertical)
Audubon		**Riley**	
bank slope 1	49.7: 1	bank slope 1	103.9: 1
bank slope 2	162: 1	bank slope 2	22.5: 1
bank slope 3	17.6: 1	bank slope 3	33: 1
		bank slope 4	241.3: 1
Belmont			
bank slope 1	201: 1		
		Salt Fork	
Cooper Hollow		bank slope 1	16.: 1
bank slope 1	50.8: 1	bank slope 2	24.3: 1
bank slope 2	111.6: 1		
bank slope 3	175.8: 1	**Stages Pond**	
		bank slope 1	58.7: 1
Pickerington ponds		bank slope 2	109.3: 1
bank slope 1	137: 1		
bank slope 2	36.7: 1		
bank slope 3	63: 1		

documented higher mean microtopographical roughness in mitigation wetlands, although the difference in this data was not significant. Relatively abrupt bottom contours as a result of excavation activities at the mitigation sites may be one cause. In addition, many of the natural wetlands occurred in very gently sloping depressions and did not contain hummock-forming vegetation species which would lead to more microtopographical relief.

4. Vegetation

The flora of the mitigation and reference sites was compared to evaluate how natural wetland communities might differ from those in newly established mitigation wetlands. Characteristics of the wetland plant communities are shown in Table 6, including the results of the FQAI analyses. FQAI values in the mitigation wetlands ranged from 12.6 to 26.3. The lowest score was found at the R and F Coal site, a small mitigation project that had been constructed on strip-mined lands. The high score was for the Ross Labs wetland, which was comprised of two discrete wetland areas (separated by a road) in its 3rd growing season at the time of this study. FQAI values at the reference sites ranged from 17.0 to 25.5. The Belmont county site, also on mined lands and a control for the R and F Coal mitigation site, received the lowest score in the reference wetland group. This site did show evidence of human disturbance and mine drainage inflow. An unpaired t-test revealed that the mean FQAI values were not significantly different between the two groups.

The modified FQAI (modFQAI) scores were consistently lower than the unmodified scores, and interestingly, mean scores were significantly lower for mitigation wetlands as compared to the reference wetlands ($p < 0.10$). Differences in the modFQAI values reflect the fact that the proportion of native species were significantly higher in the reference sites, averaging 87.9 percent as compared to 73.9 percent in the mitigation wetlands ($p < 0.01$). The mean difference in the percent of the community made up of native species between mitigation and reference sites was 14.0 percent (Table 6). This represents a significant loss of native plant diversity as a result of the

Table 6. Summay of floristic data for mitigation and reference wetlands, including the Floristic Quality Assessment Index (FQAI), the modified FQAI, and the percent of plant species with an indicator status of OBL, FACW or FAC (see text for details).

Site Name	FQAI value	modFQAI	Percent Native Species	Total Number Species	% hydrophytes (OBL to FAC spp)
Mitigation Wetlands					
Aurora	22.8	19.4	73	81	65.4
Borror	23.2	21.4	86	67	76.1
City of Cambridge	16.4	13.3	67	43	69.8
Gavin	20.7	17.7	76	57	71.1
JMB	16.1	13.7	75	41	75.0
Pizzuti	20.0	16.8	73	61	60.3
R and F Coal	12.6	9.4	65	39	70.5
Rittman	13.8	12.8	78	36	69.4
Ross Labs	26.3	23.2	79	72	63.3
Walmart	23.3	18.5	67	71	66.7
Mean	***19.5***	***16.6***	***73.9***	***56.8***	***68.8***
		**	*		*
Reference Wetlands					
Audubon	25.5	23.6	90	50	87.5
Belmont	17.0	15.0	91	27	91.3
Cooper Hollow	24.2	22.8	92	65	77.8
Pickerington ponds	21.2	19.6	87	54	75.0
Riley	18.6	16.5	79	38	78.9
Salt Fork	22.9	21.4	89	54	81.1
Stages Pond	21.5	19.5	87	47	82.2
Mean	***21.6***	***19.8***	***87.9***	***47.9***	***82.0***

* means significantly different at $p < 0.01$

** means significantly different at $p < 0.10$

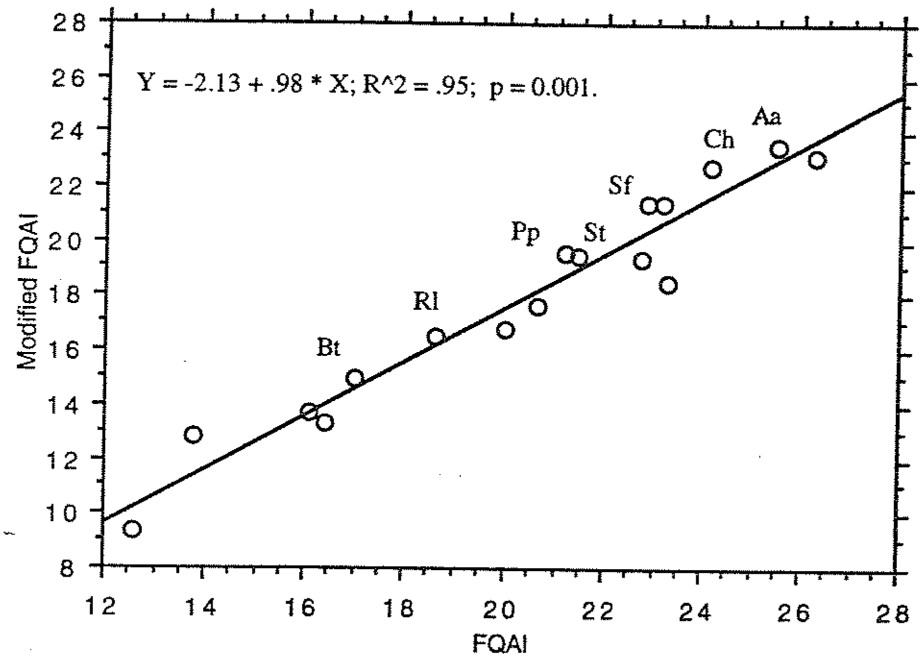
replacement of natural wetlands with mitigation projects. It is interesting to note that total species numbers did not differ significantly between the two groups, therefore traditional diversity indices might not reveal any differences in the macrophyte communities (cf. Brown 1991). The fact that there was no difference in species richness indicates that native species are being displaced by non-native ones. This loss of native species in mitigation projects should be a concern in efforts to maintain native biodiversity.

As expected, a least-squares regression analysis showed that there is a significant relationship between the FQAI and the modFQAI (Figure 2). However, there is a slight bias in the data; all points representing the reference sites are located above the regression line. This is a function of the higher proportion of native species at the reference sites; the difference that this created in the modFQAI values was enough to lead to a significant difference in the mitigation and reference site means.

One trend that is often expected in wetland mitigation or restoration projects is that species diversity will increase with the age of the project (Kentula et al. 1992). A least squares regression analysis revealed no relationship in this data between the age of the project and species richness at the site. Given that the data here were collected over a very short age range (projects were 2 to 5 years old), it is not surprising that such a trend was not apparent.

The proportion of hydrophytic vascular plant species in each wetland also was calculated (Table 6). Hydrophytes are defined here as those species with an indicator status of obligate wetland, facultative wetland or facultative (after Reed 1988). The percent hydrophytes in the mitigation wetlands ranged from 60.3 percent to 76.1 percent, with a mean of 68.8 percent. Natural wetlands ranged from 75.0 percent to 91.3 percent, with a significantly higher mean of 82.0 percent ($p < 0.01$). Overall, natural wetlands had more wetland species in their plant communities. USEPA has developed an evaluation procedure for mitigation projects based, in part, on the percent of the site dominated by hydrophytes in which greater than 85 percent is considered an effective project, 75 - 84 percent is partially effective, and less than 74 percent is

Figure 2. Regression model showing relationship between the FQAI scores and the modified FQAI scores. Abbreviations shown are for the reference wetlands as shown below. All other points represent mitigation wetlands.



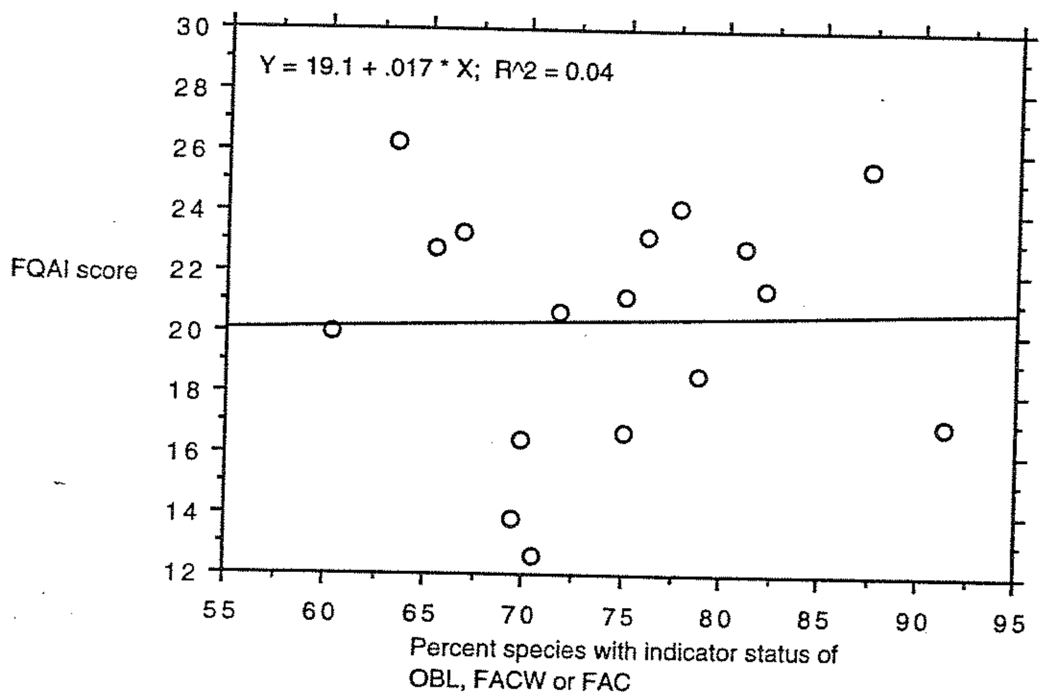
Site abbreviations are as follows: Bt, Belmont; Rl, Riley; Pp, Pickerington Ponds; St, Stages Pond; Sf, Salt Fork; Ch, Cooper Hollow; Aa, Audubon.

considered a project failure (Kline 1991, as cited in McCoy and Kulp 1992). In this procedure dominant species are estimated by percent cover. If we apply this criteria using the proportion of the *total* species in the community that are hydrophytes (a more complete data set than called for in the original analysis), two of the seven reference sites would be considered fully effective, and all seven would be meet at least partial success criteria. By comparison none of the mitigation wetlands would meet the criteria to be fully effective, and only two projects (20 percent of the total number of sites) would be considered partially effective. A full 80 percent of the mitigation sites would be considered failures by this criteria.

A comparison was made of the proportion of hydrophytes as a function of the FQAI score at each site to determine if a higher proportion of species adapted to wet conditions was found in "higher quality" communities as defined by the FQAI. No relationship was found (Figure 3), indicating that the wetland indicator status (Reed 1986) does not reflect the same information about the plant community as the FQAI. The FQAI value is designed to be sensitive to the specialized habitat requirements that some plants exhibit, as well as the presence of non-native species. These habitat requirements go beyond the probability that a species is found in waterlogged environments. For example, *Typha latifolia* has a coefficient of conservatism of two, yet is an obligate wetland species. The score of two indicates that this species is relatively widespread and can grow in a wide variety of wetland types, i.e., it is not restricted to a particular type of wetland.

In total, there were a total of 269 species of plants recorded at the 10 mitigation wetlands and 166 species found in the seven reference wetlands (for a complete inventory of species see the appendix). The number of species found at mitigation projects is surprisingly high. Interestingly, the mean total species richness was not significantly different in the two groups, so the high total number of species recorded at the mitigation projects may be due in part to the higher number of mitigation projects included in this study (10 versus seven reference sites). In addition, the total number of species recorded at the reference wetlands does not represent their total species richness because in many cases only a portion of the reference wetland was included in the

Figure 3. Regression model showing relationship between the FQAI scores and the percent hydrophytes in the plant community (defined as those with an indicator status of OBL, FACW or FAC). The model is not significant.



assessment so not all species at the site were surveyed. There is no literature available on the flora of mitigation wetlands with which to compare the results of this study.

5. Soils

Data on the soils in the mitigation and reference wetlands are shown in Table 7. Detailed data on each soil sample is presented in the Appendix. Data is presented for the percent of samples taken at each site with matrix colors typical of hydric soils and the percent samples with mottles. Other indicators of hydric soils and wetland hydrology such as the occurrence of gleyed soils, the presence of root channels or the smell of hydrogen sulfide, also were recorded.

Matrix colors tended to be brighter for soils in the mitigation sites. Most soil samples in both the mitigation and reference sites showed colors typical of mineral hydric soils, namely a matrix chroma of 2 or less where the soils are mottled. In the mitigation wetlands 68 percent of the soil cores had matrix chromas of 2 or less while in the reference wetlands 80 percent had low chroma values. The upper soil horizon was much more developed in the reference wetlands as evidenced by the fact that the upper horizon was deeper than 10 inches (the length of the soil probe) at each point where a sample was taken in each reference site (this data can be found in the appendix). Contrary to other studies which found mitigation wetland soils rarely had mottles (e.g., Confer and Niering 1992), the soils at these mitigation sites nearly all displayed some degree of mottling. The fact that many of these projects were restoration efforts where there were some hydric soils present may explain the extent of the soil development.

Gley colors were observed rarely in both sets of samples. The development of gleyed soils is limited to sites where soils are semi-permanently or permanently flooded and iron present in the soil is chemically reduced (Mitsch and Gosselink 1993). This process occurs over long time periods and is not common in Ohio soils, and would not be expected in mitigation soils.

Table 7. Soils data for mitigation and reference wetlands. Five samples were taken at each site and each was subdivided into two samples if two soil horizons were present. When samples were subdivided, if either subsample displayed the characteristic, the whole sample was counted as possessing it.

Mitigation Site Name	% samples with colors typical of hydric soils*	% samples with mottles	% samples with gley colors	% samples with root channels	% samples with H2S odor
Aurora	100	100	0	20	20
Borror	100	100	0	60	0
Cambridge	20	100	0	0	0
Gavin	60	100	0	0	0
JMB	20	60	0	0	0
Pizzuti	75	75	0	0	0
R and F Coal	40	60	0	20	0
Rittman	100	100	0	0	20
Ross Labs	100	100	0	0	20
Walmart	60	100	10	80	20
MEAN	**68**	**90**	**1**	**18**	**8**

Reference Site Name	% samples with colors typical of hydric soils	% samples with mottles	% samples with gley colors	% samples with root channels	% samples with H2S odor
Audubon	80	60	0	0	0
Belmont	60	80	0	0	0
Cooper Hollow	100	100	0	40	0
Pickerington ponds	100	100	40	60	0
Riley	100	60	0	80	0
Salt Fork	40	40	0	0	0
Stages Pond	80	60	20	60	0
MEAN	**80**	**71**	**9**	**34**	**0**

* as defined in the 1987 Wetland Delineation manual, chromas of 2 or less in mottled soils as measured immediately below the A horizon or at 10", whichever is shallower. If samples were sundivided into different horizons, the color of the lower horizon was used.

One of the questions concerning mitigation projects is the development of hydric soil characteristics occur over time. The relationship of mitigation project age to the presence of indicators of hydric soils was investigated using a least-squares regression analysis. No relationship was found between the percent of samples that had mottles and project age. However, a significant relationship was found between the percent of samples that had root channels and age (Figure 4), demonstrating that this indicator of hydric soils is developing with time and is progressing at the mitigation wetlands.

6. Wetland Functional Assessment

One of the key questions in the wetland mitigation process is to what extent does the replacement wetland provide the hydrological and biological functions of the impacted wetland. The Buffalo Wetland Evaluation Methodology (BWEM) was designed to evaluate three broad functions in depressional wetlands including water retention, water quality improvement, and a habitat component designed to evaluate both vegetation and wildlife habitat. The method was devised in part for use in the Buffalo District Corps of Engineers Section 404 program for assessment of both natural and mitigation wetlands, although it has not been widely implemented (Kathy Ryan, pers. comm.).

While there are no data on the wetlands that were impacted for comparison in this study, the mitigation sites were compared with the natural wetlands to investigate the functional equivalency of the mitigation projects. Portions of the data collected above were used to complete the Buffalo Wetland Evaluation Methodology for each wetland site. In this method, between seven and 10 pieces of data are used for the evaluation of each function. Each element is scored with a value between one and three. The score for each element in each wetland and the final scores for each wetland are shown in Table 8. The score for each function is meant to stand alone, the method is not designed so that the three scores are added for a single composite score. The maximum possible score for each function is 21 for water retention, 24 for water quality improvement and

Figure 4. Regression model for the percentage of soil samples with observable root channels as a function of project age (years).

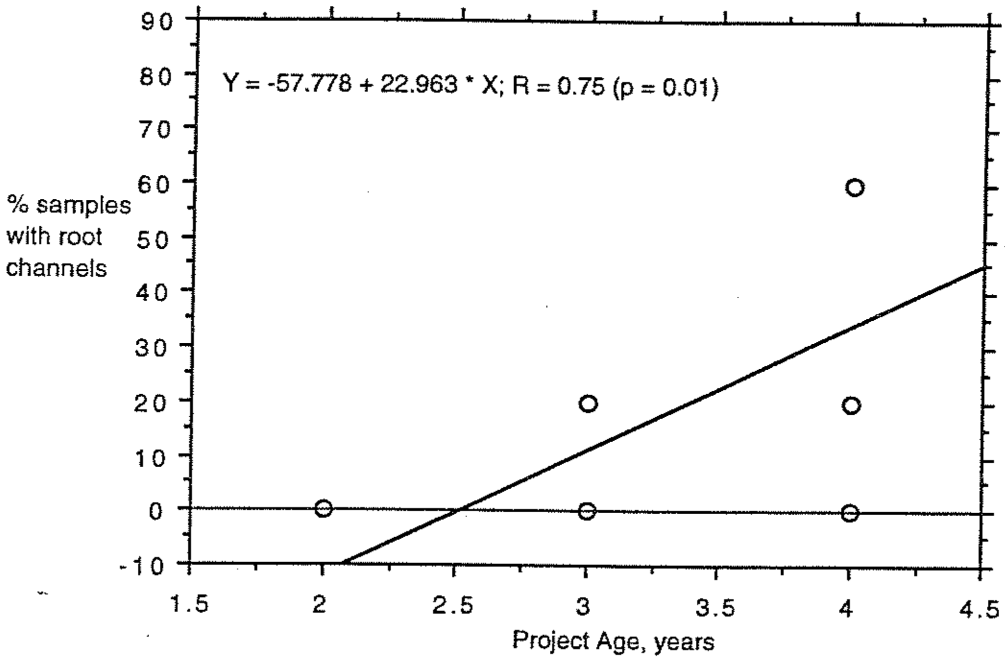


Table 8. Results of the Buffalo Wetland Evaluation Method (BWEM) for the assessment of three wetland functions for a) mitigation wetlands, and b) reference wetlands. Summary scores for each wetland are shown at the bottom of each column and the means for each function for mitigation and reference wetlands are shown at the far right.

A) Mitigation Wetlands

BWEM Components	Aurora	Borror	City of Camb.	Gavin	JMB	Pizzuti
Water Retention Component						
a. Size of Wetland	2	3	3	3	3	3
b. Size of Watershed	1	2	2	1	3	2
c. Average depth of basin	1	3	3	3	1	3
d. Restrictive nature of outlet	1	1	2	2	2	3
e. Slope of buffer (bank w/in 50')	2	2	1	2	2	2
f. % soils that are v. poorly drained	1	2	2	3	2	3
g. Perimeter to area ratio	2	2	2	2	2	2
Total for Component	**10**	**15**	**15**	**16**	**15**	**18**
Water Quality Improvement Component						
a. Size of Wetland	2	3	3	3	3	3
b. Size of Watershed	1	2	2	1	3	2
c. Average depth of basin	1	2	2	2	1	2
d. Restrictive nature of outlet	1	1	2	2	2	3
e. Slope of buffer (bank w/in 50')	2	2	1	2	2	2
i. Avg. % cover in the WEA	2	2	1	1	2	1
j. % perennial herbaceous spp.	2	2	2	2	2	1
k. Depth of A or O soil horizon	2	2	1	1	1	1
Total for Component	**13**	**16**	**14**	**14**	**16**	**15**
Habitat Component (vegetation and wildlife)						
a. Size of Wetland	2	3	3	3	3	3
h. # plant communities	2	2	2	2	2	2
l. Avg. # veg. strata	1	2	1	1	1	1
m. Number of plant species	3	3	2	3	2	3
n. Avg. dominant species	2	1	1	1	2	1
o. FQAI score	2	2	1	2	1	1
p. % open water	3	2	1	2	3	1
q. Inflow water quality	3	3	2	2	3	3
g. Perimeter to area ratio	3	2	3	2	2	2
r. % Buffer useable by wildlife	3	3	3	3	2	3
Total for Component	**24**	**23**	**19**	**21**	**21**	**20**

A (cont.)) Mitigation Wetlands

BWEM Components	R & F Coal	Ritttman	Ross	Walmart
Water Retention Component				
a. Size of Wl	2	2	3	3
b. % of Wsd that is Wl	2	3	2	2
c. Average depth of basin	3	1	2	2
d. Restrictive nature of outlet	1	2	1	2
e. Slope of buffer (w/in 50')	1	2	2	2
f. % soils that are v. poorly drained	1	3	3	2
g. Perimeter to area ratio	2	2	2	2
Total for Component	**12**	**15**	**15**	**15**
Water Quality Improvement Component				
a. Size of Wl	2	2	3	3
b. Size of Wsd	2	3	2	2
c. Average depth of basin	2	1	2	1
d. Restrictive nature of outlet	1	2	1	2
e. Slope of buffer (w/in 50')	1	2	2	2
i. Avg. % cover in the WEA	1	2	2	1
j. % perennial herbaceous spp.	2	3	2	2
k. Depth of A or O soil horizon	1	2	3	2
Total for Component	**12**	**17**	**17**	**15**
Habitat Component (vegetation and wildlife)				
a. Size of Wl	2	2	3	3
h. # plant communities	2	1	2	2
l. Avg. # veg. strata	1	2	1	1
m. Number of plant species	2	2	3	3
n. Avg. dominant species	1	1	1	2
o. FQAI score	1	1	2	2
p. % open water	1	2	2	3
q. Inflow water quality	1	3	2	1
g. Perimeter to area ratio	2	3	2	2
r. % Buffer useable by wildlife	3	3	3	3
Total for Component	**16**	**20**	**21**	**22**

Average for all sites	*St. dev. for all sites*
14.6	*2.17*
14.9	*1.66*
20.7	*2.21*

B) Reference Wetlands

BWEM Components	Audubon	Belmont	Cooper Hollow	P- Ponds	Riley	Salt Fork
Water Retention Component						
a. Size of Wetland (whole area)	3	3	3	3	3	3
b. Size of Watershed	2	1	2	2	2	2
c. Average depth of basin	2	2	2	2	2	2
d. Restrictive nature of outlet	3	2	3	3	3	2
e. Slope of buffer (bank w/in 50')	3	3	3	3	2	3
f. % soils that are v. poorly drained	1	3	2	2	3	2
g. Perimeter to area ratio	2	2	2	2	2	2
Total for Component	**16**	**16**	**17**	**17**	**17**	**16**
Water Quality Improvement Component						
a. Size of Wetland	3	3	3	3	3	3
b. Size of Watershed	2	1	2	2	1	2
c. Average depth of basin	2	2	2	2	2	2
d. Restrictive nature of outlet	3	2	3	3	3	2
e. Slope of buffer (bank w/in 50')	3	3	3	3	2	3
i. Avg. % cover in the WEA	3	2	2	2	3	2
j. % perennial herbaceous spp.	2	3	2	3	2	3
k. Depth of A or O soil horizon	3	3	3	3	3	3
Total for Component	**21**	**19**	**20**	**21**	**19**	**20**
Habitat Component (vegetation and wildlife)						
a. Size of Wetland	3	3	3	3	3	3
h. # plant communities	3	2	3	3	2	3
l. Avg. # veg. strata	3	2	1	3	1	2
m. Number of plant species	3	1	3	3	2	3
n. Avg. dominant species	1	1	1	1	1	2
o. FQAI score	2	1	2	2	1	2
p. % open water	2	3	3	3	3	3
q. Inflow water quality	3	2	3	3	2	3
g. Perimeter to area ratio	2	2	2	2	2	2
r. % Buffer useable by wildlife	3	3	3	3	3	3
Total for Component	**25**	**20**	**24**	**26**	**20**	**26**

B (cont.)) Reference Wetlands

BWEM Components	Stages Pond
Water Retention Component	
a. Size of Wetland (whole area)	3
b. Size of Watershed	2
c. Average depth of basin	2
d. Restrictive nature of outlet	2
e. Slope of buffer (bank w/in 50')	3
f. % soils that are v. poorly drained	3
g. Perimeter to area ratio	2
Total for Component	**17**
Water Quality Improvement Component	
a. Size of Wetland	3
b. Size of Watershed	2
c. Average depth of basin	2
d. Restrictive nature of outlet	3
e. Slope of buffer (bank w/in 50')	3
i. Avg. % cover in the WEA	2
j. % perennial herbaceous spp.	3
k. Depth of A or O soil horizon	3
Total for Component	**21**
Habitat Component (vegetation and wildlife)	
a. Size of Wetland	3
h. # plant communities	3
l. Avg. # veg. strata	1
m. Number of plant species	2
n. Avg. dominant species	1
o. FQAI score	2
p. % open water	3
q. Inflow water quality	3
g. Perimeter to area ratio	2
r. % Buffer useable by wildlife	3
Total for Component	**23**

Average for all sites	*St. dev. for all sites*
16.5	*0.55*
20.0	*0.89*
23.5	*2.81*

30 for the habitat component.

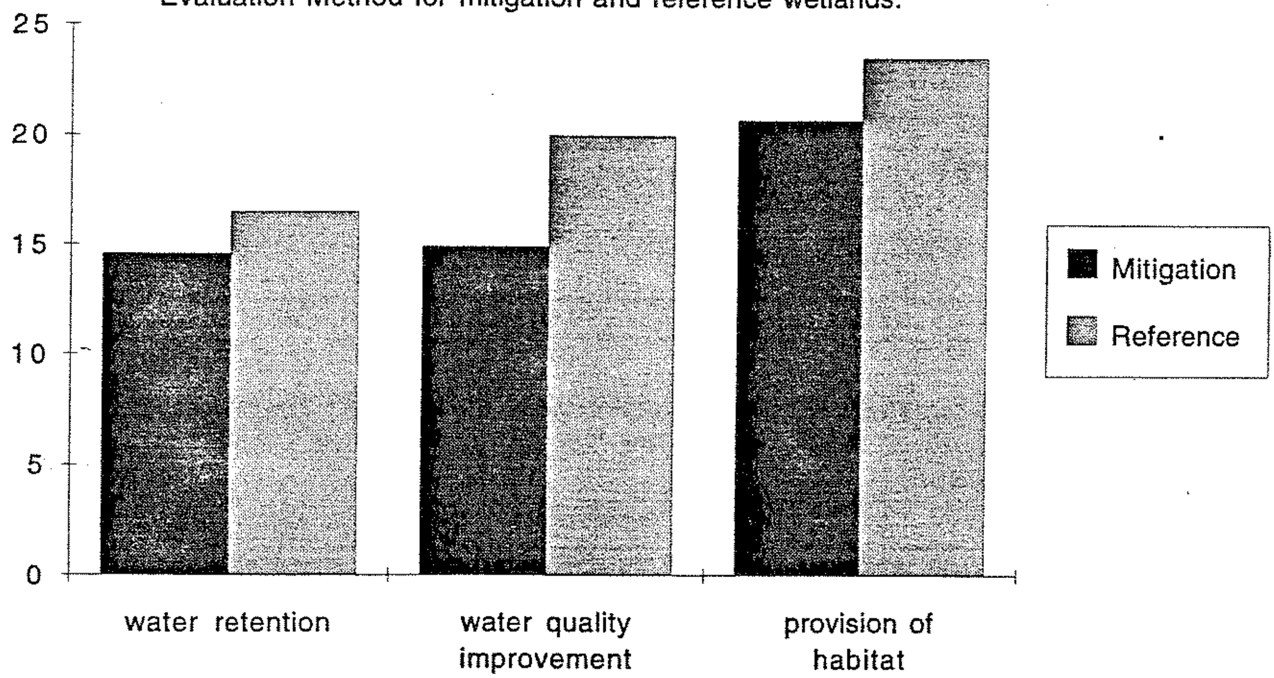
Scores were significantly higher for each of the three functions in the reference wetlands (Figure 5). Mean scores for the reference wetlands, with the exception of the habitat component, had very low standard deviations indicating that they received consistently high scores, with an average of 16.5 ± 0.5 for water retention, 20 ± 0.9 for water quality improvement, and 23.5 ± 2.8 for habitat. One of the stated goals of the mitigation process is to ensure that the functions and values that wetlands provide are maintained. The results of this analysis using the BWEM indicate that mitigation wetlands are not functionally equivalent to natural wetlands in the early stages of their development. The young age of the mitigation projects is one factor that might lead to the lower scores. As these ecosystems mature they may show an increase in their functional capacity. Their development should be monitored.

Several factors led to the differences between the mitigation and reference wetlands. The natural wetlands tended to be larger. All reference wetlands scored maximum points (three) for the question on size, and this piece of data contributes to the score of each function. Buffer slopes tended to be more shallow in natural wetlands (a factor in water retention and water quality functions), and the depth of the upper soil horizon was consistently deeper at the natural sites.

The use of size to indicate wetland quality is controversial, although it is often included as an element of wetland functional assessment. Size can be an important factor for some functions such as flood water retention and habitat for many types of species. Other attributes, such as amphibian habitat, are much less size dependent and may even be more favorable in small sites. Because size is a factor in some wetland functions, it will undoubtedly continue to be used as a surrogate measure until better tools are developed.

Although the BWEM is intended to serve as a rapid wetland assessment technique, many of the data elements it requires are not easily obtained, therefore, the time needed to complete this method can be substantial. For example, one of the data requirements for the habitat component

Figure 5. Means for each function assessed in the Buffalo Wetland Evaluation Method for mitigation and reference wetlands.



is the FQAI score. A thorough, systematic survey of the wetland flora by a well-trained field botanist is required to obtain this score. Determining the size of the watershed supporting the wetland also was found to be a time consuming task, as was determining the perimeter to area ratio. Direct measurement of the wetland perimeter is sometimes an arduous task depending on the type of vegetation and the size and configuration of the wetland in question. There is currently no remote means accurate enough to use in collecting this information.

Summary and Conclusions

Making a judgement about whether a mitigation project is an ecological success continues to be controversial because there is no standard criteria that define success. The evaluation of success is further hampered by the fact that the replacement of wetland functions cannot be evaluated directly because there is rarely an evaluation of the functions that were lost when the original wetland was filled (Zedler and Weller 1990). Most wetland projects do not have specified goals by which they can be judged. This is true for mitigation wetlands in Ohio where functional assessments have not been routinely performed for wetlands that are impacted through Section 401/404 activities. In spite of these limitations, and the fact that there is not consistent data available on the condition of the impacted wetlands, the data collected in this study and the use of a set of reference sites does allow many conclusions to be drawn on the quality of mitigation projects.

A summary of the findings of this study includes:

• We did not discover a single case were a wetland impact had occurred and a corresponding mitigation project had not been done. In cases where mitigation projects had not begun, the wetland impact had not occurred either. In other words, wetland fills are being compensated for.

• This data shows an average replacement ratio of wetland acres established on the ground of 1.26: 1. This can be viewed in two ways. One is that the mitigation projects are not meeting their stated goal of a 1.5:1 mitigation ratio, falling on average 0.24:1 acre short. The size of this discrepancy is primarily the result of the JMB mitigation project, a very large project that has not been judged to be successful to date (Wilson and Mitsch 1996). If this project is treated as an outlier, the average mitigation ratio in the field is 1.43:1 (67.9 acres of wetland mitigation for 47.6 acres of impacts).

On the other hand, even when the JMB project is included in the calculations, there is an acreage surplus of 0.26 acres for every acre of wetland impacted. From this perspective Ohio is achieving a net gain of wetland acreage in the Section 401 program. Although the 1.5:1 mitigation ratio was not met in all projects, the remaining acreage that has not developed into jurisdictional wetland has helped contribute to the creation of an upland buffer surrounding the wetland.

• Findings show a decrease in native plant species diversity associated with wetland mitigation projects (significant at < 0.01) in the early stages of development. The fact that there was no difference in species richness indicates that native species are being displaced by non-native ones. This has implications for regional diversity and should be monitored over longer time periods to determine whether native species diversity will increase as projects age.

• No significant differences were found in the FQAI values between mitigation and reference sites. The relatively wide range in condition of the reference wetlands contributed to this finding, as did the fact that many of the mitigation projects had surprisingly diverse plant assemblages.

• The Buffalo Wetland Evaluation Methodology (BWEM) indicate that these mitigation wetlands are not functionally equivalent to the reference sites (in spite of the range of quality in the reference wetlands, i.e., they were not least impacted wetlands that would be expected to perform most highly). From a functional perspective, mitigation projects are not yet measuring up to natural sites with respect to flood water retention, water quality improvement and habitat provision as measured by the BWEM. Longer-term monitoring should be done to track the development of wetland functions at the mitigation sites as the projects age.

In sum, an evaluation of mitigation project success can be approached in three ways:

- from an acreage perspective, mitigation in Ohio can be viewed as a success because there has been a net gain in wetland acreage, i.e., the no net loss goal is being met;

- using an assessment of wetland functions, the mitigation projects can not be judged yet

as a success. They were outperformed for each of the three functions analyzed in the BWEM by the reference sites. It is unclear at this point how much of the difference may be due to the young age of the mitigation projects. Time will show if the mitigation wetlands continue to improve functionally. The loss of wetland functional ability in the short term speaks to the temporal loss of wetland functions that occurs due to mitigation. If the mitigation wetlands improve functionally over time, there has still been a temporary loss of wetland functional ability from the landscape.

• from an assessment of floral diversity there is no significant difference in total species richness between the two groups, although the percent of total species that are native was significantly higher in the natural wetlands. This indicates that, at least in the short term, there is a loss of native plant species diversity occurring through the mitigation process. The loss of native plant diversity has implications, as yet unmeasured, for native faunal diversity. This finding is cause for concern and the patterns of plant succession should be tracked over a longer time period to determine whether this loss of native diversity is ameliorated with time.

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Appendix A: Floristic Data

Master species list for the Aurora Mitigation Wetland

Key:*=alien taxon; **=may include both native and nonnative populations

E = Endangered; nl = no listing

Species Name	FQAI Value	Indicator Status
Achillea millefolium	0 *	FACU
Agrimonia parviflora	2	FAC
Agrostis alba (aka A. gigantea)	0	FACW
Alisma subcordatum	2	OBL
Alopecurus aequalis	2	OBL
Ambrosia artemisiiflia	0	UPL
Anthoxanthum odoratum	0 *	UPL
Arctium minus	0 *	FACU
Arctium sp.		
Aster novae-angliae	3	FACW
Aster pilosus	1	UPL
Bidens coronata	3	OBL
Bidens frondosa	2	FACW
Carex granularis	3	FACW+
Carex grayii	5	FACW+
Carex crinita	2	OBL
Carex squarrosa	5	FACW
Carex tribuloides	4	FACW+
Carex vulpinoidea	3	OBL
Carya ovata	6	FACU-
Cephanlanthus occidentalis	7	OBL
Ceratophyllum demersum	5	OBL
Chrysanthemum leucanthemum	0	UPL
Cinna arundinacea	4	FACW+
Cirsium arvense	0 *	FACU
Cirsium vulgare	0 *	OBL
Cornus racemosa	2	FAC
Cyperus strigosus	2	FACW
Daucus carota	0 *	UPL
Dipsacus sylvestris	0	UPL
Echinocloa crusgalli	0 *	FACU
Eleocharis obtusa	2	OBL
Elodea canadensis	2	OBL
Elymus virginicus	3	FACW-
Epilobium coloratum	2	OBL
Eupatorium perfoliatum	3	FACW+
Eupatorium serotinum	3	FAC-
Euthamia graminifolia	2	FAC
Fragaria virginiana	2	FACU
Geranium masculatum	4	FACU
Glyceria septentrionalis	5	OBL
Hypericum perforatum	0 *	UPL
Ilex verticillata	7	FACW+
Impatiens capensis	2	FACW

Juncus effusis	1	FACW+
Juncus tenuis	1	FAC-
Lactuca serriola	0 *	FAC-
Leersia oryzoides	1	OBL
Lemna minor	4	OBL
Lobelia cardinalis	7	FACW+
Ludwigia palustris	4	OBL
Lycopus virginicus	4	OBL
Lysimachia nummularia	0 *	OBL
Mentha spicata	0 *	FACW+
Myosotis scorpioides	0 *	OBL
Oxalis corniculata	0 *	FACU
Phalaris arundinacea	0	FACW+
Pilea pumila	4	FACW
Plantago major	0 *	FACU
Panicum sp		
Polygonum arifolium	4	OBL
Polygonum sagittatum	3	OBL
Potamogeton pectinatus	3	OBL
Potentilla simplex	1	FACU-
Prunella vulgaris	0 **	FACU+
Quercus rubra	7	FACU-
Rosa multiflora	0 *	FACU
Rumex acetosella	0 *	UPL
Salix nigra	3	FACW+
Scirpus atrovirens	2	OBL
Scirpus cyperinus	1	FACW+
Sida spinosa	0 *	UPL
Sisyrhinchium angustifolium	4	FACW+
Solidago canadensis	1	FACU
Solidago juncea	2	
Solidago rugosa	3	FAC
Sonchus arvensis	0 *	UPL
Sparganium eurycarpum	4	OBL
Spirodela polyrhiza	5	OBL
Typha latifolia	2	OBL
Verbascum blattaria	0 *	UPL
Verbena urticifolia	4	FACU
Vibernum lentago	0 *	FAC

Sum of FQAI values	175
# of native species	59
Total number of species	81
FQAI Score	**22.8**
Modified FQAI (r/sq rt of total spp.#)	**19.4**

Note: % total species which are native 73%

Master species list for the Borror Mitigation Wetland
Key:*= alien taxon;**=may include both native and nonnative populations
E = Endangered; nl = no listing

Species Name	FQAI Value	Indicator Status
Alisma subcordatum	2	OBL
Apocynum cannabinum	3	FACU
Asclepias incarnata	5	OBL
Aster novae-angliae	3	FACW-
Aster pilosus	1	UPL
Betula nigra	6	FACW
Bidens frondosa	2	FACW
Carex frankii	5	OBL
Carex tribuloides	4	FACW+
Carex vulpinoidea	3	OBL
Cephalanthus occidentalis	7	OBL
Cirsium muticum	8	OBL
Cornus amomum	2	FACW
Cyperus strigosus	2	FACW
Datura stramonium	0 *	UPL
Daucus corota	0 *	UPL
Dipsacus sylvestris	0	UPL
Echinochloa crusgalli	0 *	FACU
Eleocharis acicularis	3	OBL
Eleocharis obtusa	2	OBL
Erigeron annuus	1	FACU
Eupatorium perfoliatum	3	FACW+
Euthamia graminifolia	2	FAC
Fragaria virginiana	2	FACU
Fraxinus pennylvanica	6	FACW
Geum laciniatum	2	FAC+
Impatiens capensis	2	FACW
Juncus effusus	1	FACW+
Leersia oryzoides	1	OBL
Lemna minor	4	OBL
Lobelia cardinalis	7	FACW+
Lobelia siphilitica	4	FACW+
Ludwigia palustris	4	OBL
Lycopus americanus	3	OBL
Lycopus virginicus	4	OBL
Najas minor	0 *	OBL
Panicum capillare	1	FAC-
Penthorum sedoides	3	OBL
Phalaris arundinacea	0	FACW+
Polygonum amphibium	5	OBL
Polygonum caespitosum	0 *	FACU-
Polygonum hydropiper	3	OBL
Polygonum pensylvanicum	1	FACW
Populus deltoides	5	FAC

Potamogetan foliosis	4	OBL
Potamogetan nodosus	3	OBL
Prunella vulgare	0 **	FACU+
Quercus palustris	4	FACW
Rosa multiflora	0 *	FACU
Rumex crispus	0 *	OBL
Sagittaria latifolia	2	OBL
Salix exigua	1	OBL
Scirpus americanus	5	OBL
Scirpus atrovirens	2	OBL
Scirpus cyperinus	1	FACW+
Scirpus validus	6	OBL
Euthamia graminifolia	2	UPL
Scutellaria lateriflora	3	
Solidago sp.		
Sparganium eurycarpum	4	OBL
Teucrium canadense	3	FACW-
Trifolium pratense	0 *	FACU-
Typha angustifolia	0	OBL
Typha latifolia	2	OBL
Ulmus rubra	2	FACW-
Wolffia columbiana	6	OBL
Vernonia altissima/gigantea	3	UPL

Sum of FQAI values	175
# of native species (needs correction)	57
Total number of species	67
FQAI Score	**23.2**
Modified FQAI (r/sq rt of total spp.#)	**21.4**

Note: % total species which are native 86%

Master species list for the City of Cambridge Mitigation Wetland

Key:*=alien taxon; **=may include both native and nonnative populations

E = Endangered; nl = no lising

Species Name	**FQAI Value**	**Indicator Status**
Acer rubrum	2	FAC
Alisma subcordata	2	OBL
Amianthium canadense	nl	UPL
Asclepias incarnata	5	OBL
Ascyrum hypericoides	nl	FACU
Aster pilosus	1	FAC
Carex frankii	5	OBL
Cirsium arvense	0 *	FACU
Daucus carota	0 *	UPL
Echinocloa crusgalli	0 *	FACU
Eleocharis acicularis	3	OBL
Eleocharis obtusa	2	OBL
Eupatorium perfoliatum	3	FACW+
Fraxinus pennsylvanica	6	FACW
Hypericum perforatum	0 *	UPL
Juncus effusus	1	FACW+
Juncus interior	1	FACU
Juncus tenuis	1	FAC-
Lemna minor	4	OBL
Lindernia dubia	4	OBL
Lotus corniculatus	0 *	FACU-
Ludwigia palustris	4	OBL
Lycopus virginicus	4	OBL
Myriophyllum spicatum	0 *	OBL
Najas minor	0 *	OBL
Panicum sp.		
Polygonum pensylvanicum	1	FACW
Polygonum persicaria	0 *	FACW
Populus deltoides	5	FAC
Potamogetan nodosus	3	OBL
Potamogeton crispus	0 *	OBL
Potamogeton foliosus	4	OBL
Quercus bicolor	7	FACW+
Salix exigua	1	OBL
Satureja vulgaris	3	UPL
Scirpus atrovirens	2	OBL
Scirpus cyperinus	1	FACW+
Solanum carolinense	0 *	UPL
Solidago graminifolia	nl	UPL
Typha angustifolia	0	OBL
Ulmus sp.		
Vallisneria americana	8	OBL
Verbena hastata	4	FACW+

Sum of FQAI values	87
# of native species	28
Total number of species	43
FQAI Score	**16.4**
Modified FQAI (r/sq rt of total spp.#)	**13.3**

Note: % total species which are native 67%

Master species list for the Gavin Mitigation Wetland

Key: *=alien taxon; **=may include both native and nonnative populations

E = Endangered; nl = no listing

Species Name	FQAI Value	Indicator Status	
Alisma plantago aquatica	2	OBL	1
Allium canadense	3	FACU	1
Arrhenatherum elatius	0 *	FACU	1
Asclepias incarnata	5	OBL	1
Boehmeria cylindrica	4	FACW+	1
Carex comosa	2	OBL	1
Carex frankii	5	OBL	1
Carex tribuloides	4	FACW+	1
Carex vulpinoidea	3	OBL	1
Catalpa speciosa	0 *	FAC	1
Cyperus strigosis			1
Cornus amomum	2	FACW	1
Daucus carota	0 *	UPL	1
Dipsacus sylvestris	0 *	NI	1
Dracocephalum parviflorum	0 *	FACU-	1
Eleocharis obtusa	2	OBL	1
Eupatorium perfoliatum	3	FACW+	1
Eupatorium purpureum	7	UPL	1
Galium tinctorium	6	OBL	1
Impatiens capensis	2	FACW	1
Juncus articulatus	4	OBL	1
Juncus dudleyi	4	FACU	1
Juncus effusus	1	FACW+	1
Juncus interior	1	FACU	1
Juncus macer	nl		1
Juncus tenuis	1	FAC-	1
Leersia oryzoides	1	OBL	1
Lemna minor	4	OBL	1
Ludwigia alternifolia	5	FACW+	1
Ludwigia palustris	4	OBL	1
Lycopus virginicus	4	OBL	1
Lysimachia nummularia	0 *	OBL	1
Lythrum sp.			
Mimulus ringens	5	OBL	1
Onoclea sensibilis	3	FACW	1
Oxalis corniculata	0 *	FACU	1
Panicum boscii	5	UPL	1
Panicum dichotomum	3	UPL	1
Phalaris arundinacea	0	FACW+	1
Polygonum punctatum	0 *	FACW	1
Polygonum sagittatum	3	OBL	1
Polygonum sp.			1
Populus deltoides	5	FAC	1
Potamogetan diversifolius	6	OBL	1

Potamogetan nodosus	3	OBL	1
Panicum clandestinum	3	FAC+	1
Rubus occidentalis	1	UPL	1
Rumex crispus	0 *	FACU	1
Salix exigua	1	OBL	1
Salix nigra	3	FACW+	1
Scirpus atrovirens	2	OBL	1
Scirpus validus	6	OBL	1
Solidago sp.			
Sparganium eurycarpum	4	OBL	1
Trifolium pratense	0 *	UPL	1
Typha angustifolia	0	OBL	1
Typha latifolia	2	OBL	1

Sum of FQAI values	134
# of native species	42
Total number of species	57
FQAI Score	**20.7**
Modified FQAI (r/sq rt of total spp. #)	**17.7**

Note: % total species which are native 76%

Master species list for the JMB Mitigation Wetland
Key: * = alien taxon; ** = may include both native and nonnative populations
E = Endangered; nl = no listing

Species Name	FQAI Value	Indicator Status
Acer negundo	3	FAC+
Alisma subcordata	2	OBL
Carex lupulina	3	OBL
Ceratophyllum demersum	5	OBL
Cirsium vulgare	0 *	FACU-
Echinochloa crusgali	0 *	FACU
Eleocharis obtusa	2	OBL
Elodea canadensis	2	OBL
Festuca arundinacea	0 *	FACU
Geum laciniatum	2	FAC+
Impatiens capensis	2	FACW
Juncus interior	1	FACU
Juncus tenuis	1	FAC-
Lemna minor	4	OBL
Lycopus americanus	3	OBL
Lysimachia nummularia	0 *	OBL
Melilotus officinalis	0 *	FACU-
Najas minor	0 *	OBL
Mentha spp.		
Oxalis stricta	0	UPL
Phalaris arundinacea	0	FACW+
Plantanus occidentalis	7	FACW-
Poa pratensis	0 *	FACU
Polygonum persicaria	0 *	FACW
Polygonum amphibium	5	OBL
Pontederia cordata	7	OBL
Populus deltoides	5	FAC
Potamogetan nodosus	3	OBL
Potamogetan pectinatus	3	OBL
Quercus bicolor	7	FACW+
Quercus palustris	4	FACW
Ranunculus aboritivus	4	FACW-
Rorippa palustris	1	OBL
Rumex crispus	0 *	FACU
Sagittaria latifolia	2	OBL
Scirpus validus	6	OBL
Soladago canadensis	1	FACU
Sorghum halapense	0 *	FACU
Typha angustifolia	0	OBL
Typha latifolia	2	OBL
Valerianella umbilicata	3	FAC
Veronica peregrina	1	FACU-

Sum of FQAI values	88
# of native species	30
Total number of species	41
Final FQAI Score	**16.1**
Modified FQAI (r/sq rt of total spp. #)	**13.7**

Note: % total species which are native 75%

Master species list for the Pizzuti Mitigation Wetland

Key: * = alien taxon; ** = may include both native and nonnative populations

E = Endangered; nl = no listing

Species Name	FQAI Value	Indicator Status
Achillea millefolia	0 *	FACU
Agrimonia parviflora	2	FAC
Agrostis perennans	4	FACU
Alisma subcordatum	2	OBL
Ambrosia artemisiifolia	0	FACU
Apocynum cannabinum	3	FACU
Aristida grass (bird of P)		
Asclepias incarnata	5	OBL
Bidens frondosa	2	FACW
Carex frankii	5	OBL
Ceratophyllum demersum	5	OBL
Cirsium vulgare	0 *	FACU-
Convolvulus arvensis	0 *	UPL
Cyperus squarrosus	3	UPL
Cyperus strigosus	2	FACW
Daucus carota	0 *	UPL
Dianthera americana	nl	UPL
Dipsacus sylvestris	0 *	NI
Echinocloa crusgalli	0 *	FACU
Eleocharis obtusa	2	OBL
Elodea canadensis	2	OBL
Erigeron annuus	1	FACU
Eupatorium perfoliatum	3	FACW+
Euthamia graminifolia	2	FAC
Hypericum perforatum	0 *	UPL
Juncus effusus	1	FACW+
Juncus tenuis	1	FAC-
Leersia oryzoides	1	OBL
Ludwigia palustris	4	OBL
Lycopus americanus	3	OBL
Mimulus ringens	5	OBL
Nuphar advena	5	OBL
Oxalis corniculata	0 *	FACU
Panicum lanuginosum	2	UPL
Panicum virgatum	4	FAC
Penthorum sedoides	3	OBL
Physostegia virginiana	6 **	FAC+
Plantago lanceolata	0 *	UPL
Polygonum persicaria	0 *	FACW
Polygonum punctatum	6	OBL
Populus deltoides	5	FAC
Potamogetan foliosus	4	OBL
Potamogetan nodosus	3	OBL
Prunella vulgaris	0 **	FACU+

Pycanthemum tenuifolium	3	FACW
Rubus sp.		
Rudbeckia hirta	3	FACU-
Rumex crispex	0 *	FACU
Salix exigua	1	OBL
Scirpus atrovirens	2	OBL
Scirpus validus	6	OBL
Setaria viridis	0 *	UPL
Solanum carolinesnse	0 *	UPL
Solidago spp.		
Sporobolus neglectus	3	FACU-
Trifolium arvense	0 *	UPL
Typha angustifolia	0	OBL
Typha latifolia	2	OBL
Vallisneria americana	8	OBL
Verbena hastata	4	FACW+
Vernonia altissima	3	FAC

Sum of FQAI values	131
number of native species	43
Total number of species	61
FQAI Score	**20.0**
Modified FQAI (r/sq rt of total spp. #)	**16.8**
% total species which are native	73%

Master species list for the R & F Coal Mitigation Wetland
Key: * = alien taxon; ** = may include both native and nonnative populations
E = Endangered; nl = no listing

Species Name	FQAI Value	Indicator Status
Acer rubrum	2	FAC
Agrostis alba (aka A. gigantea)	0	FACW
Alisma subcordatum	2	OBL
Asclepias incarnata	5	OBL
Cardamine sp.		
Carex hystericina	4	OBL
Carex vulpinoidea	3	OBL
Chenopodium album	0 *	FACU+
Cirsium sp.		
Cyperus strigosus	2	FACW
Daucus carota	0 *	UPL
Digitaria sanguinalis	0 *	FACU-
Dipsacus sylvestris	0 *	UP
Echinocloa crusgalli	0	FACU
Eleocharis obtusa	2	OBL
Epilobium strictum	9 T	OBL
Equisetum sp.		
Eupatorium perfoliatum	3	FACW+
Helimthis sp.		
Iris pseudacorus	0 *	OBL
Juncus effusus	1	FACW+
Juncus torreyi	3	OBL
Juncus tenuis	1	FAC-
Leersia oryzoides	1	OBL
Melilotus alba	0 *	FACU-
Najas minor	0 *	OBL
Phleum praetense	0 *	FACU
Polygonum lapathifolium	1	FACW+
Polygonum persicaria	0 *	FACW
Populus deltoides	5	FAC
Potamogetan foliosus	4	OBL
Rumex crispus	0 *	FACU
Salix exigua	1	OBL
Scirpus atrovirens	2	OBL
Scirpus validus	6	OBL
Solidago sp.		
Trifolium arvense	0 *	UPL
Typha angustifolia	0	OBL
Typha latifolia	2	OBL

Sum of FQAI values	59
number of native species	22
Total number of species	39
FQAI Score	**12.6**
Modified FQAI (r/sq rt of total spp. #)	**9.4**
% total species which are native	65%

Master species list for the Rittman Mitigation Wetland
Key: * = alien taxon; ** = may include both native and nonnative populations
E = Endangered; nl = no listing

Species Name	FQAI Value		Indicator Status
Agrostis alba (aka A. gigantea)	0		FACW
Asclepias incarnata	5		OBL
Ascyrum hypericoides	nl		FACU
Betula nigra	6		FACW
Boehmeria cylindrica	4		FACW+
Carex frankii	5		OBL
Carex tribuloides	4		FACW+
Carex vulpinoidea	3		OBL
Chrysanthemum leucanthemum	0	*	UPL
Cirsium arvense	0	*	FACU
Cirsium vulgare	0	*	FACU-
Convolvulus arvensis	0	*	UPL
Cornus amomum	2		FACW
Cornus stolonifera	4		FACW+
Daucus carota	0	*	UPL
Erigeron annuus	1		FACU
Eupatorium perfoliatum	3		FACW+
Euthamia graminifolia	2		FAC
Fraxinus pennsylvanica	6		FACW
Geum laciniatum	2		FAC+
Juncus effusus	1		FACW+
Leersia oryzoides	1		OBL
Ludwigia palustris	4		OBL
Lycopus americanus	3		OBL
Lycopus virginicus	4		OBL
Oxalis corniculata	0	*	UPL
Phalaris arundinacea	0		FACW+
Phleum praetense	0	*	FACU
Phytolacca americana	2		FACU+
Prunella vulgaris	0	**	FACU+
Prunus serotina	3		FACU
Rubus occidentalis	1		UPL
Rumex crispus	0	*	FACU
Salix exigua	1		OBL
Solidago gigantea	2		FACW
Toxicodendron radicans	1		FAC
Trifolium pratense	0	*	FACU-
Vernonia altissima	3		UPL
Viburnum dentatum	2		FAC
Viburnum recognitum	2		FACW-

Sum of FQAI values (r)	77
number of native species	31
Total number of species	36
FQAI Score	**13.8**
Modified FQAI (r/sq rt of total spp. #)	**12.8**
% total species which are native	78%

Master species list for the Ross Mitigation Wetland

Key: * = alien taxon; ** = may include both native and nonnative populations

E = Endangered; nl = no listing

Species Name	FQAI Value	Indicator Status
Acer rubrum	2	FAC
Acer saccharinum	3	FACW
Agrostis perennans	4	FACU
Alisma subcordata	2	OBL
Ambrosia artemisiifolia	0	FACU
Asclepias incarnata	5	OBL
Aster simplex (aka A. lanceolatus)	2	
Betula nigra	6	FACW
Bidens coronata	3	OBL
Bidens frondosa	2	FACW
Calamagrostis canandensis	4	FACW+
Carex frankii	5	OBL
Carex vulpinoidia	3	OBL
Celtis occidentalis	6	FACU
Ceratophyllum demersum	5	OBL
Convolvulus sepium	nl	UPL
Cyperus strigosus	2	FACW
Datura stramonium	0 *	UPL
Daucus carota	0 *	UP
Dipsacus sylvestris	0 *	NI
Echinacea purpurea	8	UPL
Echinocloa walteri	7	FACW+
Eleocharis obtusa	2	OBL
Elymus canadensis	3	FACU+
Elymus virginicus	3	
Eupatorium perfoliatum	3	FACW+
Fragaria virginiana	2	FACU
Fraxinus pennsylvanica	6	FACW
Galium palustre	9 E	OBL
Geum laciniatum	2	FAC+
Helianthus sp.		
Hydrocotyle americana	8	OBL
Impatiens capensis	2	FACW
Juncus effusus	1	FACW+
Juncus tenuis	1	FAC-
Leersia oryzoides	1	OBL
Lemna minor	4	OBL
Liquidambar styraciflua	7	FAC
Lotus corniculatus	0 *	FACU-
Ludwigia palustris	4	OBL
Lycopus virginicus	4	OBL
Oenothera biennis	2	FACU-
Oxalis stricta	0	UPL
Penstemon digitalis	3	FAC

Phalaris arundinacea		0	FACW+
Phleum pratense		0 *	FACU
Pilea pumila		4	FACW
Polygonum hydropiper		3	OBL
Polygonum persicaria		0 *	FACW
Populus deltoides		5	FAC
Potamogetan nodosus		3	OBL
Potentilla norvegica		1	FACU-
Prunella vulgaris		0 **	FACU+
Pycnanthemum tenuifolium		3	FACW
Quercus palustris		4	FACW
Robinia pseudoacacia		0 **	FACU-
Rorippa sylvestris		0	UPL
Rudbeckia laciniata		5	FACW
Rudbeckia hirta		3	FACU-
Rumex crispus		0 *	FACU
Samolus parviflorus		5	OBL
Scirpus fluviatilis		5	OBL
Scirpus validus		6	OBL
Solidago canadensis		1	FACU
Solidago gigantea		2	FACW
Taraxacum officinale		0 *	FACU-
Trifolium arvense		0 *	UPL
Trifolium pratense		0 *	FACU-
Typha latifolia		2	OBL
Verbena hastata		4	FACW+
Vernonia altissima (aka V. gigantea)		3	UPL
Viburnum dentatum		2	FAC
Viburnum trilobum	nl		FACW

Sum of FQAI values (r)	197
number of native species	56
Total number of species	72
FQAI Score	**26.3**
Modified FQAI (r/sq rt of total spp. #)	**23.2**
% total species which are native	79%

Master species list for the Walmart Mitigation Wetland

Key: * = alien taxon; ** = may include both native and nonnative populations

E = Endangered; nl = no listing

Species Name	FQAI Value	Indicator Status
Acer platanoides	0 *	UPL
Acer rubrum	2	FAC
Achillea millefolium	0 *	FACU
Agrostis stolonifera	nl	UPL
Alisma plantago-aquatica	2	OBL
Alliaria officinalis	0	
Allium cernuum	5	UPL
Althaea offinialis	0 *	FACW+
Asclepias incarnata	5	OBL
Aster spp.		
Betula nigra	6	FACW
Bidens connata	2	FACW+
Carex comosa	2	OBL
Carex frankii	5	OBL
Carex vulpinoidea	3	OBL
Chrysanthemum leucanthemum	0 *	UPL
Convolvulus arvensis	0 *	UPL
Cornus amomum	2	FACW
Cyperus strigosus	2	FACW
Daucus carota	0 *	UPL
Dianthus armeria	0 *	UPL
Eleocharis obtusa	2	OBL
Eupatorium hyssopifolium	nl	UPL
Eupatorium perfoliatum	3	FACW+
Fraxinus pennsylvanica	6	FACW
Galium aparine	2	FACU
Hibiscus mocheutos	8	OBL
Impatiens capensis	2	FACW
Juncus effusus	1	FA CW+
Juncus interior	1	FACU
Juncus tenuis	1	FAC-
Leersia oryzoides	1	OBL
Lemna minor	4	OBL
Lonicera canadensis	8	FACU
Ludwigia palustris	4	OBL
Lycopus virginicus	4	OBL
Lysimachia ciliata	4	FACW
Lythrum alatum	7	FACW+
Mimulus ringens	5	OBL
Najas minor	0 *	OBL
Nasturtium officinale	0 *	OBL
Oxalis dillenii	0	
Penthorum sedoides	3	OBL
Phalaris arundinacea	0	FACW+

Phleum pratense		0 *	FACU
Pilea pumila		4	FACW
Plantago lanceolata		0 *	UPL
Plantanus occidentalis		7	UPL
Polygonum persicaria		0 *	FACW
Populus deltoides		5	FAC
Quercus bicolor		7	FACW+
Quercus macrocarpa		6	FAC-
Quercus palustris		4	FACW
Ranunculus pensylvanicus		3	OBL
Rorippa sessiliflora	nl		OBL
Rubus occidentalis		1	UPL
Rumex crispus		0 *	FACU
Sagittaria latifolia		2	OBL
Salix exigua		1	OBL
Salix nigra		3	FACW+
Scirpus atrovirens		2	OBL
Scirpus cyperinus		1	FACW+
Scirpus fluviatilis		5	OBL
Solidago spp.			
Taraxacum officinale		0 *	FACU-
Trifolium arvense		0 *	UPL
Trifolium palustris	nl		UPL
Typha angustifolia		0	OBL
Typha latifolia		2	OBL
Veronica peregrina		1	FACU-
Xanthium strumarium		0 *	FAC

Sum of FQAI values (r)	156
# of native species	45
Total number of species	71
Final FQAI Score	**23.3**
Modified FQAI (r/sq rt of total spp. #)	**18.5**
% total species which are native	6[illegible]%

Master species list for the Audubon/Aurora Reference Wetland

Key: * = alien taxon; ** = may include both native and nonnative populatic

E = Endangered; nl = no listing

Species Name	FQAI Value	Indicator Status
Acer saccharum	6	FACU-
Anthoxanthus odoratum	0 *	FACU
Apocynum medium	3	UPL
Asclepias incarnata	5	OBL
Betula nigra	6	FACW
Bidens frondosa	2	FACW
Carex comosa	2	OBL
Carex frankii	5	OBL
Carex lupulina	3	OBL
Carex tribuloides	4	FACW+
Carex vulpinoidea	3	OBL
Ceratophyllum demersum	5	OBL
Cirsuim sp.		
Cornus amomum	2	FACW
Cornus racemosa	2	FAC
Cornus stolonifera	4	FACW+
Cyperus strigosis	2	FACW
Daucus carota	0 *	UPL
Dipsacus syvestris	0 *	NI
Eleocharis obtusa	2	OBL
Eupatorium perfoliatum	3	FACW+
Fragaria virginiana	2	FACU
Galium boreale	8	FACU
Impatiens capensis	2	FACW
Juncus effusus	1	FACW+
Leerzia oryzoides	1	OBL
Lemna minor	4	OBL
Lemna trisulca	6	OBL
Ludwigia palustris	4	OBL
Lycopus americanus	3	OBL
Myriophyllum spicatum	0 *	OBL
Polygonum amphibium	5	OBL
Polygonum hydropiperoides	5	OBL
Polygonum pennsylvanicum	1	FACW
Polygonum persicaria	0 *	FACW
Polugonum punctatum	6	OBL
Polygonum sagittatum	3	OBL
Populus deltoides	5	FAC
Ranunculus flabellaris	6	OBL
Scirpus cyperinus	1	FACW+
Scirpus validus	6	OBL
Sium suave	5	OBL
Solidago sp.		
Sparganium eurycarpum	4	OBL

Spirea alba	3	FACW+
Spirodela polyrhiza	5	OBL
Typha latifolia	2	OBL
Utricularia vulgaris	7	OBL
Vernonia altissima/gigantia	3	FAC
Vitus riparia	4	FACW
Wolffia columbiana	6	OBL

Sum of FQAI values	167
# of native species	43
Total number of species	50
Final FQAI Score	**25.5**
Modified FQAI (r/sq rt of total spp	23.6
% total species which are native	90%

Master species list for the Belmont County Reference Wetland

Key: * = alien taxon; ** = may include both native and nonnative populations

E = Endangered; nl = no listing

Species Name	FQAI Value	Indicator Status
Acer rubrum	2	FAC
Asclepias incarnata	5	OBL
Boehmeria cylindricia	4	FACW+
Carex lupulina	3	OBL
Carex tribuloides	4	FACW+
Cornus amomum	2	FACW
Crataegus sp.		
Dianthera americana	8	OBL
Echinocystis lobata	3	FAC
Epilobium sp.		
Eupatorium perfoliatum	3	FACW+
Galium sp.		
Hibiscus palustris	8	
Leersia oryzoides	1	OBL
Mentha spicata	0 *	FACW+
Najas flexilis	8	OBL
Nuphar advena	5	UPL
Phalaris arundinacea	0	OBL
Polygonum amphibium	5	FACW+
Polygonum hydropiper	3	OBL
Salix eriocephala	1	FACW
Scirpus validus	6	OBL
Solanum dulcanaria	0 *	FAC-
Solidago sp.		
Sparganium eurycarpum	4	OBL
Typha latifolia	2	OBL
Ulmus americana	1	FACW-

Sum of FQAI values	78
# of native species	21
Total number of species	27
Final FQAI Score	17.0
Modified FQAI (r/sq rt of total spp. #)	15.0
Note: % native species	91%

Master species list for the Cooper Hollow Reference Wetland

Key: * = alien taxon; ** = may include both native and nonnative populations

E = Endangered; nl = no listing

Species Name	FQAI Value	Indicator Status
Acer rubrum	2	FAC
Agrimonia parviflora	2	FAC
Agrostis scabra	3	FAC
Alisma subcordatum	2	OBL
Alnus sp.		
Asclepias incarnata	5	OBL
Aster novae-angliae	3	FACW
Aster pilosus	1	UPL
Aster simplex	2	OBL
Betula nigra	6	FACW
Bidens coronata	3	OBL
Bidens frondosa	2	FACW
Boehmeria cylindrica	4	FACW+
Callitriche palustris	10 T	UPL
Carex lurida	3	OBL
Carex squarrosa	5	FACW
Carex tribuloides	4	FACW+
Carex vulpinoidea	3	OBL
Cephalanthus occidentalis	7	OBL
Cornus amomum	2	FACW
Cyperus strigosis	2	FACW
Echinocloa crusgalli	0 *	FACU
Eleocharis acicularis	3	OBL
Eleocharis obtusa	2	OBL
Elodea canadensis	2	OBL
Erogrostis spectabilis?	2	UPL
Eupatorium perfoliatum	3	FACW+
Eupatorium purpureum	7	UPL
Euthamia graminifolia	2	FAC
Euthamia graminifolia	2	FAC
Fraxinus pennsylvanica	6	FACW
Galium palustre	9 E	OBL
Hypericum virginicum	3	UPL
Impatiens capensis	2	FACW
Juncus effusis	1	FACW+
Leersia oryzoides	1	OBL
Ludwigia alternifolia	5	FACW+
Ludwigia palustris	4	OBL
Lysimachia nummularia	0 *	OBL
Mimulus ringens	5	OBL
Onoclea sensibilis	3	FACW

Oxalis stricta	0	UPL
Panicum clandestinum	3	FAC+
Panicum sp.		
Penthorum sedoides	3	OBL
Phalaris arundinacea	0	FACW+
Polygonum hydropiper	3	OBL
Polygonum sagittatum	3	OBL
Pycnanthemum tenuifolium	3	FACW
Rosa multiflora	0 *	FACU
Rubus allegheniensis	1	FACU-
Rumex crispus	0 *	FACU
Sagittaria latifolia	2	OBL
Salix exigua	1	OBL
Salix nigra	3	FACW+
Scirpus atrovirens	2	OBL
Scirpus cyperinus	1	FACW+
Scutellaria lateriflora	3	FACW+
Solidago canadensis	1	FACU
Solidago nemoralis	3	UPL
Solidago ohioensis	10	OBL
Sorghum halepense	0 *	FACU
Sparganium eurycarpum	4	OBL
Typha latifolia	2	OBL
Vernonia altissima/gigantia	3	UPL

Sum of FQAI values	184
# of native species	58
Total number of species	65
FQAI Score	**24.2**
Modified FQAI (r/sq rt of total spp.#)	**22.8**

Note: % total species which are native 92%

Master species list for the Pickerington Ponds Reference Wetland

Key: * = alien taxon; ** = may include both native and nonnative populations

E = Endangered; nl = no listing

Species Name	FQAI Value	Indicator Status
Agrimonia parviflora	2	FAC
Ambrosia artemisiifolia	0	FACU
Apocynum medium	3	UPL
Asclepias incarnata	5	OBL
Boehmeria cylindrica	4	FACW+
Cirsium arvense	0 *	FACU
Convovulus arvensis	0 *	UPL
Cornus amomum	2	FACW
Cornus rugosa	7	
Cyperus odoratus	5	FACW
Cyperus strigosis	2	FACW
Daucus carota	0 *	NI
Dipsacus sylvestris	0 *	UPL
Echinochloa crusgalli	0 *	FACU
Eleocharis obtusa	2	OBL
Eleocharis palustris	4	OBL
Eragrostis hypoides	4	OBL
Eupatorium perfoliatum	3	FACW+
Eupatorium rugosum	4	NI
Euthamia graminIfolia	2	FAC
Hypericum mutilum	5	FACW
Impatiens capensis	2	FACW
Leerzia oryzoides	1	OBL
Lemna minor	4	OBL
Lindernia dubia	4	OBL
Ludwigia palustris	4	OBL
Lycopus americanus	3	OBL
Mimulus ringens	5	OBL
Myriophyllum spicatum	0 *	OBL
Oenothera biennis	2	FACU-
Phalaris arundinacea	0	FACW+
Phytolacca americana	2	FACU+
Polygonum amphibium	5	OBL
Polygonum foliosus	4	UPL
Polygonum hydropiper	3	OBL
Polygonum lapathifolium	1	FACW+
Polygonum pensylvanicum	1	FACW
Polygonum persicaria	0 *	FACW
Polygonum punctatum	6	OBL
Polygonum sagittatum	3	OBL
Potamogetan nodosus	3	OBL
Pycnanthemum tenuifolium	3	FACW
Rhus typhina	2	UPL
Rubus spp.		

Rubus hispidus ?	5	FACW
Salix exigua	1	OBL
Salix nigra	3	FACW+
Scirpus atrovirens	2	OBL
Scirpus validus	6	OBL
Sonchus arvensis	0 *	FAC
Typha latifolia	2	OBL
Verbena hastata	4	FACW+
Verbena urticifolia	4	FACU
Vernonia altissima/gigantia	3	UPL
Viburnum dentatum	2	FAC
Vitus riparia	4	FACW

Sum of FQAI values	144
# of native species	46
Total number of species	54
FQAI Score	**21.2**
Modified FQAI (r/sq rt of total spp.#)	**19.6**

Note: % total species which are native 87%

Master species list for the Riley Reference Wetland
Key: * = alien taxon; ** = may include both native and nonnative populations
E = Endangered; nl = no listing

Species Name		FQAI Value	Indicator Status
Acer rubrum		2	FAC
Acer saccharinum		3	FACW
Alisma plantago aquatica		2	OBL
Ambrosia artemisiifolia		0 *	FACU
Apocynum medium		3	UPL
Asclepias incarnata		5	OBL
Betula nigra		6	FACW
Bidens frondosa		2	FACW
Cirsium muticum		8	OBL
Convolvulus arvensis		0 *	UPL
Dipsacus sylvestris		0 *	NI
Echinocloa crusgalli		0 *	FACU
Fraxinus pennsylvanica		6	FACW
Impatiens capensis		2	FACW
Leersia oryzoides		1	OBL
Lemna minor		4	OBL
Lemna trisulca		6	OBL
Najas minor		0 *	OBL
Oenothera biennis		2	FACU-
Phalaris arundinacea		0	FACW+
Polygonum amphibium		5	OBL
Polygonum hydropiper		3	OBL
Polygonum lapathifolium		1	FACW+
Polygonum pensylvanicum		1	FACW
Populus deltoides		5	FAC
Potamogetan filiformis	nl		OBL
Potamogetan foliosis		4	OBL
Potamogetan nodosus		3	OBL
Potamogetan pectinatus		3	OBL
Rumex crispus		0 *	FACU
Salix exigua		1	OBL
Scirpus validus		6	OBL
Setaria viridis		0 *	UPL
Sparganium eurycarpum		4	OBL
Typha angustifolia		0	OBL
Typha latifolia		2	OBL
Vallisneria americana		8	OBL
Vitis riparia		4	FACW

Sum of FQAI values	102
# of native species	30
Total number of species	38
FQAI Score	**18.6**
Modified FQAI (r/sq rt of total spp.#)	**16.5**

Note: % total species which are native 79%

Master species list for the Salt Fork Wildlife Area Reference Wetland
Key: * = alien taxon; ** = may include both native and nonnative populations
E = Endangered; nl = no listing

Species Name	FQAI Value	Indicator Status
Acer rubrum	2	FAC
Agrimonia parviflora	2	FAC
Alisma subcordatum	2	OBL
Azolla caroliniana	0 *	OBL
Bidens cernua	3	OBL
Bidens connata	2	FACW+
Bidens frondosa	2	FACW
Boehmeria cylindrica	4	FACW+
Cephalanthus occidentalis	7	OBL
Cornus stolonifera	4	FACW+
Cyperus odoratus	5	FACW
Cyperus strigosus	2	FACW
Echinocloa crusgalli	0 *	FACU
Eleocharis obtusa	2	OBL
Eleocharis palustris	4	OBL
Eragrostis hypoides	4	OBL
Galium tinctorium	6	OBL
Galium palustre	9	OBL
Fraxinus pennsylvanica	6	FACW
Helianthus angustifolius	nl	
Impatiens capensis	2	FACW
Juglans nigra	5	FACU
Juncus effusis	1	FACW+
Leersia oryzoides	1	OBL
Lemna minor	4	OBL
Lindernia dubia	4	OBL
Lysimachia nummularia	0 *	OBL
Mentha arvensis	2	UPL
Myriophyllum spicatum	0 *	
Nuphar advena	5	UPL
Onoclea sensibilis	3	FACW
Phalaris arundiancea	0	FACW+
Polygonum erectum	1	UPL
Polygonum pennsylvanicum	1	FACW
Polygonum persicaria	0 *	FACW
Polygonum punctatum	6	OBL
Polygonum saggittatum	3	OBL
Rosa multiflora	0 *	FACU
Rotala ramosior	5	OBL
Rumex verticillatus	5	OBL
Sagittaria latifolia	5	OBL
Salix exigua	1	OBL
Salix nigra	3	FACW+
Scutellaria lateriflora	3	

Scirpus cyperinus	1	FACW+
Scirpus validus	6	OBL
Solidago sp.		
Sparganium eurycarpum	4	OBL
Spirodela polyrhiza	5	OBL
Toxicodendron radicans	1	FAC
Typha latifolia	2	OBL
Veronica americana	3	OBL
Vernonia altissima/gigantea	3	UPL
Wolffia columbiana	6	OBL

Sum of FQAI values	157
# of native species	47
Total number of species	54
FQAI Score	**22.9**
Modified FQAI (r/sq rt of total spp.#)	**21.4**

Note: % total species which are native 89%

Master species list for the Stage's Pond Reference Wetland
Key: * = alien taxon; ** = may include both native and nonnative populations
E = Endangered; nl = no listing

Species Name	FQAI Value		Indicator Status
Acer rubrum		2	FAC
Alnus rugosa		6	FACW+
Althaea officinalis		0 *	FACW+
Ambrosia altissima		0	UPL
Apocynum medium		3	FACU
Asclepsis incarnata		5	OBL
Aster pilosus		1	UPL
Betula nigra		6	FACW
Carex frankii		5	OBL
Carex vulpinoidia		3	OBL
Chichorium intybus	nl		UPL
Cirsium muticum		8	OBL
Convulvus sepium	nl		NL
Cornus amomum		2	FACW
Cornus racemosa		2	FAC
Cyperus strigosis		2	FACW
Daucas carota		0 *	UPL
Euthamia graminifolia		2	FAC
Geum laciniatum		2	FAC+
Hibiscus moscheutos		8	OBL
Lamium aplexicaule		0 *	UPL
Lemna minor		4	OBL
Lobelia siphilitica		4	FACW+
Lycopus americanus		3	OBL
Mentha arvensis		2	FACW
Mimulus ringens		5	OBL
Panicum sp			
Phalaris arundiancea		0	FACW+
Phleum pratense		0 *	FACU
Pilea pumila		4	FACW
Polygonum amphibium		5	OBL
Polygonum pensylvanicum		1	FACW
Polygonum persicaria		0 *	FACW
Populus deltoides		5	FAC
Rosa multiflora		0 *	FACU
Sagittaria latifolia		2	OBL
Salix exigua		1	OBL
Salix nigra		3	FACW+
Scirpus fluviatilis		5	OBL
Scirpus validus		6	OBL
Scutellaria laterifolia		3	FACW+
Setaria viridis		0 *	UPL
Sium suave		5	OBL
Solidago sp.			
Sparganium eurycarpum		4	OBL
Spirodela polyrhiza		5	OBL
Toxicodendron radicans		1	FAC
Typha latifolia		2	OBL
Vernonia altissima		3	FAC
Vitis riparia		4	FACW

Sum of FQAI values	134
# of native species	39
Total number of species	47
FQAI Score	**21.5**
Modified FQAI (r/sq rt of total spp.#)	**19.5**

Note: % total species which are native 87%

Appendix B: Soil Data

Soils data for mitigation and reference wetlands. Five samples were taken at each site and each was subdivided into two samples if two soil horizons were present.

Mitigation Wetlands

Site ID	**Core length** inches*	**Matrix Color** --- Munsell color rating ---	**Mottle Color**	**Mottle Abundance** (few, common, many)	**Mottle size** (small, large)	**Gleyed** (yes, no)	**Root channels** (yes, no)	**H2S smell** (yes, no)	**Water depth** inches
Aurora1a	0--2	10YR 4/1	10YR 6/8	few	large	no	no	no	4
Aurora1b	2--10	10YR 6/1	10YR 6/8	many	large	no	no	no	
Aurora2a	0 -- 10	10YR 5/1	5YR 5/8	many	large	no	no	no	0**
Aurora2b	n/a								
Aurora3a	0 -- 10	5YR 6/1	7.5YR 6/8	many	large	no	no	no	0
Aurora3b	n/a								
Aurora4a	0--1	10YR 5/1	5YR 5/8	many	large	no	yes	no	0
Aurora4b	1 --10	10YR 6/1	10YR 5/8	many	large	no	no	no	
Aurora5a	0--10	10YR 5/1	10YR 5/8	common	small	no	no	yes	5
Aurora5b	n/a								
Borror1a	0 -- 2.5	10YR 5/2	7.5YR 6/8	common	small	no	yes	no	0
Borror1b	2.5--10	7.5YR 5/2	7.5YR 5/8	many	large	no	no	no	
Borror2a	0 --10	10YR 5/1	10YR 6/8	many	large	no	no	no	saturated
Borror2b	n/a								
Borror3a	0--5	10YR 5/1	10YR 5/8	few	small	no	no	no	0
Borror3b	5--10	10YR 6/1	10YR 6/8	many	n/a	no	no	no	
Borror4a	0--10	10YR 5/1	10YR 6/8	many	small	no	yes	no	0
Borror4b	n/a								
Borror5a	0--10	10YR 5/1	10YR 7/8	few	small	no	yes	no	-1
Borror5b	n/a								

* Length of probe equals 10 inches

** soil surface dry, depth to groundwater not recorded

Site ID	Core length inches*	Matrix Color --- Munsell color rating ---	Mottle Color	Mottle Abundance (few, common, many)	Mottle size (small, large)	Gleyed (yes, no)	Root channels (yes, no)	H2S smell (yes, no)	Water depth inches
Cambridge1a	0--10	7.5YR 4/4	7.5YR 6/8	common	small	no	no	no	1
Cambridge1b	n/a								
Cambridge2a	0--4.5	10YR 6/4	7.5YR 5/6	many	large	no	no	no	8
Cambridge2b	4.5--10	10YR 5/3	7.5YR 4/4	few	small	no	no	no	
Cambridge3a	0--5	10YR 5/1	10YR 7/6	common	small	no	no	no	15
Cambridge3b	5--10	7.5YR 5/3	7.5YR 5/8	many	large	no	no	no	
Cambridge4a	0--3.5	2.5Y 4/2	10YR 5/8	few	small	no	no	no	20
Cambridge4b	3/5--10	10YR 4/2	10YR 5/6	few	small	no	no	no	
Cambridge5a	0--10	7.5YR 4/6	7.5YR 3/2	few	small	no	no	no	2
Cambridge5b	n/a								
Gavin1a	0--10	10YR 3/2	5YR 4/6	common	small	no	no	no	saturated
Gavin1b	n/a								
Gavin2a	0-10	10YR 5/3	10YR 5/8	many	large	no	no	no	2
Gavin2b	n/a								
Gavin3a	0--10	10YR 6/2	5YR 5/6	many	large	no	no	no	18
Gavin3b	n/a								
Gavin4a	0--10	5YR 4/4	10YR 4/6	many	large	no	no	no	saturated
Gavin4b	n/a								
Gavin5a	0--10	10YR 4/2	10YR 5/6	few	small	no	no	no	1
Gavin5b	n/a								
JMB1a	0--2.5	10YR 4/1	none	n/a	n/a	no	no	no	18
JMB1b	2.5--10	10YR 3/2	10YR 10/6*	few	small	no	no	no	
JMB2a	0--10	10YR 3/2	none	n/a	n/a	no	no	no	12
JMB2b	n/a								
JMB3a	0--4	10YR 3/1	2.5YR 4/6	new	small	no	no	no	18
JMB3b	4--10	10YR 5/6	7.5YR 6/8	many	large	no	no	no	
JMB4a	0--1.5	10YR 3/1	10YR 5/6	few	small	no	no	no	15
JMB4b	1.5 --10	10YR 5/4	10YR 4/6	many	large	no	no	no	
JMB5a	0--10	10YR 4/3	none	n/a	n/a	no	no	no	dry
JMB5b	n/a								

Site ID	Core length inches*	Matrix Color --- Munsell color rating ---	Mottle Color	Mottle Abundance (few, common, many)	Mottle size (small, large)	Gleyed (yes, no)	Root channels (yes, no)	H2S smell (yes, no)	Water depth inches
Pizzuti1a	0 -- 1	10YR 3/1	none	n/a	n/a	no	no	no	1
Pizzuti1b	1--10	10YR 5/2	10YR 6/8	many	large	no	no	no	
Pizzuti2a	0--10	2.5YR 4/2	none	n/a	n/a	no	no	no	saturation
Pizzuti2b	n/a								
Pizzuti3a	0 -- 10	10YR 4/2	10YR 5/8	common	small	no	no	no	6
Pizzuti3b	n/a								
Pizzuti4a	0 -- 10	10YR 6/1	10YR 6/8	many	large	no	no	no	24
Pizzuti4b	n/a								
R&F1a	0--10	2.5Y 5/2	5YR 5/4	few	large	no	yes	no	saturated
R&F1b	n/a								
R&F2a	0--10	7.5YR 6/1	10YR 7/6	few	large	no	no	no	1
R&F2b	n/a								
R&F3a	0--10	2.5Y 6/3	none	n/a	n/a	no	no	no	12
R&F3b	n/a								
R&F4a	0--10	2.5Y 6/3	7.5YR 6/8	few	large	no	no	no	saturated
R&F4b	n/a								
R&F5a	0--2	10YR 3/3	none	n/a	n/a	no	no	no	1
R&F5b	n/a - rocks/coal								
Rittman1a	0--10	10YR 4/2	5YR 4/6	few	small	no	no	no	0
Rittman1b	n/a								
Rittman2a	0--10	10YR 4/2	7.5YR 5/8	common	small	no	no	no	0
Rittman2b	n/a								
Rittman3a	0--6	10YR 4/1	10YR 5/8	few	small	no	no	yes	0
Rittman3b	6--10	10YR 6/2	10YR 6/8	many	small	no	no	no	
Rittman4a	0-3	10YR 4/1	10YR 5/8	few	small	no	no	no	saturated
Rittman4b	3--10	10YR 5/1	10YR 5/8	many	small	no	no	no	
Rittman5a	0--4	10YR 4/1	10YR 5/6	few	small	no	no	no	saturated
Rittman5b	4--10	10YR 5/2	10YR 5/6	few	small	no	no	no	

Site ID	Core length inches*	Matrix Color	Mottle Color	Mottle Abundance (few, common, many)	Mottle size (small, large)	Gleyed (yes, no)	Root channels (yes, no)	H2S smell (yes, no)	Water depth inches
		--- Munsell color rating ---							
Ross1a	0--4.5	10YR 3/1	10YR 5/8	few	small	no	no	no	6
Ross1b	4.5--10	2.5Y 2.5/1	7.5YR 5/8	few	small	no	no	no	
Ross2a	0--5	10YR 4/1	none	n/a	n/a	no	no	no	8
Ross2b	5--10	10YR 4/1	10YR 6/6	few	small	no	no	no	
Ross3a	0--4.5	10YR 3/1	10YR 5/8	few	small	no	no	no	6
Ross3b	4.5--10	2.5YR 2.5/1	7.5YR 5/8	few	small	no	no	no	
Ross4a	0--5	10YR 4/1	none	n/a	n/a	no	no	yes	8
Ross4b	5--10	10YR 4/1	10YR 6/6	few	small	no	no	no	
Walmart1a	0-10	2.5Y 5/2	-	common	large	no	yes	no	< -10
Walmart1b	n/a								
Walmart2a	0--10	2.5Y 5/3	7.5YR 5/6	many	large	no	yes	no	2
Walmart2b	n/a								
Walmart3a	0--10	10YR 5/2	7.5YR 4/6	common	small	no	yes	no	n/a
Walmart3b	n/a								
Walmart4a	0--1	10YR 3/1	none	n/a	n/a	no	no	no	saturated
Walmart4b	1--10	10YR 5/3	2.5YR 4/8	few	small	no	yes	no	
Walmart5a	0--3	N 2.5	5YR 4/6	common	large	yes	no	yes	3
Walmart5b	3--10	10YR 6/1	7.5YR 4/6	many	large	no	no	yes	

Reference Wetlands

Site ID	Core length inches	Matrix Color	Mottle Color	Mottle Abundance (few, common, many)	Mottle size (small, large)	Gleyed (yes, no)	Root channels (yes, no)	H2S smell (yes, no)	Water depth inches
		Munsell color rating							
Audubon1a	0 --10	2.5YR 4/2	7.5YR 5/8	few	small	no	no	no	saturated
Audubon1b	n/a								
Audubon2a	0--10	7.5YR 2/1	none			no	no	no	20
Audubon2b	n/a								
Audubon3a	0--10	10YR 3/2	none			no	no	no	30
Audubon3b	n/a								
Audubon4a	0--10	10YR 5/1	10YR 5/8	many	large	no	no	no	2
Audubon4b	n/a								
Audubon5a	0--10	10YR 5/1	10YR 6/8	few	large	no	no	no	saturated
Audubon5b	n/a								
Belmont1a	0 --10	2.5Y 3/2	10YR 5/8	common	small	no	no	no	12
Belmont1b	n/a								
Belmont2a	0 -- 10	10YR 3/3	7.5YR 5/8	few	small	no	no	no	saturation
Belmont2b	n/a								
Belmont3a	0--10	2.5YR 3/2	10YR 5/8	few	small	no	no	no	saturation
Belmont3b	n/a								
Belmont4a	0 --10	10YR 3/3	10YR 5/8	few	small	no	no	no	saturation
Belmont4b	n/a								
Belmont5a	0--10	10YR 3/1	none			no	no	no	8
Belmont5b	n/a								
Cooper1a	0--10	2.5Y 5/2	7.5YR 5/8	few	small	no	no	no	15
Cooper1b	n/a								
Cooper2a	0--10	10YR 5/2	7.5YR 5/8	common	small	no	yes	no	dry
Cooper2b	n/a								
Cooper3a	0--10	10YR 4/2	7.5YR 5/8	few	small	no	no	no	saturated
Cooper3b	n/a								
Cooper4a	0--10	10YR 6/2	7.5YR 5/8	common	large	no	yes	no	7
Cooper4b	n/a								
Cooper5a	0--10	10YR 6/1	7.5YR 5/8	common	small	no	no	no	12
Cooper5b	n/a								

Site ID	Core length	Matrix Color	Mottle Color	Mottle Abundance	Mottle size	Gleyed	Root channels	H2S smell	Water depth
	inches*	--- Munsell color rating ---		(few, common, many)	(small, large)	(yes, no)	(yes, no)	(yes, no)	inches
Pponds1a	0--10	2.5YR 3/1	10YR 4/6	common	large		yes	no	saturated
Pponds1b	n/a					no			
Pponds2a	0--10	2.5YR 2.5/1	7.5YR 4/6	many	large	no	yes	no	saturated
Pponds2b	n/a								
Pponds3a	0--10	5YR 2.5/1	5YR 4/6	few	small	no	no	no	saturated
Pponds3b	n/a								
Pponds4a	0-10	N 2.5	5YR 5/6	few	small	yes	yes	no	saturated
Pponds4b	n/a								
Pponds5a	0--10	N 2.5	10YR 5/8	few	large	yes	no	no	1
Pponds5b	n/a								
Riley1a	0--10	10YR 3/2	5YR 5/8	few	small	no	yes	no	saturation
Riley1b	n/a								
Riley2a	0--10	10YR 2/1	none	n/a	n/a	no	yes	no	saturation
Riley2b	n/a								
Riley3a	0--10	10YR 3/1	none	n/a	n/a	no	no	no	3
Riley3b	n/a								
Riley4a	0--10	10YR 3/2	5YR 5/8	common	small	no	yes	no	13
Riley4b	n/a								
Riley5a	0--10	10YR 3/1	5YR 5/8	many	small	no	yes	no	19
Riley5b	n/a								
SaltFork1a	0--10	10YR 8/2	10YR 6/4; 10YR 6/6	few	large	no	no	no	saturation
SaltFork1b	n/a								
SaltFork2a	0--10	10YR 2/4	7.5YR 5/8	common	large	no	no	no	sarturated
SaltFork2b	n/a								
SaltFork3a	0--10	7.5YR 4/3	none	n/a	n/a	no	no	no	saturated
SaltFork3b	n/a								
SaltFork4a	0--10	10YR 4/2	none	n/a	n/a	no	no	no	saturated
SaltFork4b	n/a								
SaltFork5a	0--10	10YR 4/1	none	n/a	n/a	no	no	no	5
SaltFork5b	n/a								

Site ID	Core length inches*	Matrix Color --- Munsell color rating ---	Mottle Color	Mottle Abundance (few, common, many)	Mottle size (small, large)	Gleyed (yes, no)	Root channels (yes, no)	H2S smell (yes, no)	Water depth inches
Stages1a	0--10	10YR 2/1	10YR 5/6	common	small	no	yes	no	< -10
Stages1b	n/a								
Stages2a	0--10	N 2.5	none	n/a	n/a	yes	no	no	-2
Stages2b	n/a								
Stages3a	0--10	10YR 2/2	none	n/a	n/a	no	no	no	< -10
Stages3b	n/a								
Stages4a	0--10	10YR 3/1	10YR 5/4	many	small	no	yes	no	< -10
Stages4b	n/a								
Stages5a	0--10	10YR 2/2	10YR 5/6	few	small	no	yes	no	< -10
Stages5b	n/a								