Development of Methods to Assess and Monitor Small Wetlands Restored on Private Lands

Final Report to U.S. EPA – Region V
Wetland Program Grant # CD96509801-0

February 2006

Organization:
Ozaukee County Planning, Resources, & Land Management Department
121 West Main Street
Port Washington, WI 53074
(262) 238-8270

Author & Project Coordinator:
Jill A. Hapner, Biologist
GeoBotany Systems
10120 N. Foxkirk Circle
Mequon, Wisconsin 53097
(262) 242-7398

This report was prepared by the Ozaukee County Planning, Resources, & Land Management Department under Grant No. CD96509801-0 from the U.S. Environmental Protection Agency, Region 5. Points of view expressed in this report do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency. Mention of trade names and commercial products does not constitute endorsement of their use.

As a result of this work, separate manuscripts containing detailed information are currently under preparation.

Contact for Further Information

Jill A. Hapner, Biologist
GeoBotany Systems
10120 N. Foxkirk Circle
Mequon, Wisconsin 53097
(262) 242-7398
jahewitt@wi.rr.com

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY:

The purpose of this study was to determine to what extent wetlands restored on private lands in Ozaukee County, Wisconsin are providing the landscape functions that were the expressed purpose of their construction: increasing plant diversity and water quality, providing wildlife habitat and storm water storage, and reducing soil erosion. We measured these functions on individual sites and then extrapolated their cumulative effects to a County landscape scale. The resulting information, will allow the agencies to improve the efficiency of use of future County wetland restoration funds to achieve effective restorations. An assessment of the relative functions of the existing wetland restorations will enable adaptive decisions for improving the local County wetland restoration program. This assessment will contribute to establishing guidelines for maintaining existing and restoring future wetlands that will develop and provide a high degree of function, or ecosystem services.

During the past 20 years, federal, state, and local government agencies have constructed over 300 wetland restorations, covering more than 350 acres, on private land in Ozaukee County. Their efforts are continuing, with several additional wetlands appearing on the landscape each year through incentives such as those provided by the United States Department of Agriculture (USDA), United States Fish & Wildlife Service (USFWS), Wisconsin Department of Natural Resources (WDNR), and County Priority Watershed Programs. These programs encourage landowners to temporarily remove highly erodible land from agricultural use and restore natural plant communities. The projects were not intended to restore the pre-settlement (primarily forested) plant communities of the area. The general goals of this restoration program are to: increase wildlife habitat and plant diversity, reduce soil erosion, improve water quality by filtering pollutants and sediments, and provide storm water storage to reduce flooding.

Ozaukee County initially completed a Geographic Information System (GIS) inventory of these wetlands. GIS digital coverage includes: 5-ft. DEM, and 2-ft. Topographic Mapping; IKONOS 2001 MS Satellite Imagery; Southeastern Wisconsin Regional Planning Commission 2005, 2000, & 1995 Orthophotography and 1995 and 2000 Land Use; SSURGO Certified Soil Survey; WDNR Wetland Inventory and Sub-watershed Boundaries. As a result of this effort, many questions regarding this population of wetlands can now be easily answered, and the wetland sites have been added to the state wetland inventory.

While inventorying these wetlands is important, inventory alone does not constitute a comprehensive wetland restoration assessment and monitoring program. Much effort is needed beyond the initial inventory to examine how the wetlands currently function as components of the county landscape. It is also essential that we have a means to monitor changes in the functional status of these wetlands as well as the restoration of additional wetlands in the county. This project expanded on the GIS approach to inventorying wetlands, allowing us to evaluate the current ecologic functions and estimate the resulting impacts on the landscape utilizing a combination of landscape, rapid, and intensive site assessment levels.

For this project we collected field data on biological functions in 35 wetlands and combined that with historical and current data on 19 and 66 sites respectively, providing a large (40%) sample of the county wetland restoration population. Our sample allowed inter-comparison of sites ages 1-17 years as well as intra-comparison of several sites at 1-3 years and again at 12 years post construction. We assessed the physical functions of the sample sites using the modeling function of GIS software and digital data layers. The measurable differences between current and pre-restoration landscapes allowed us to assess change due to construction of the wetland sites. These data were statistically and spatially analyzed for differences in function related to restoration design and placement in the landscape.

In addition, a survey was developed and utilized to aid in the identification of the most common and immediate management concerns of the landowners. This information, along with the functional assessment results, was used to develop a county monitoring plan that can be utilized by all agencies participating in the restoration program.

2. INTRODUCTION:

Ozaukee is the county with the smallest land area in the State of Wisconsin, covering approximately 609 km^2. The County is located in southeastern Wisconsin, and has 45 km of Lake Michigan shoreline (Figure 1). Over the past 20 years, federal, state, and local government agencies have constructed 326 wetland restorations with grassland buffers, which cover more than 350 acres of private land in Ozaukee County (Figure 2). Their efforts are continuing, with several additional wetlands appearing on the landscape each year through incentives such as those provided by the United States Department of Agriculture (USDA), United States Fish & Wildlife Service (USFWS), Wisconsin Department of Natural Resources (WDNR), and County Priority Watershed Programs. These programs encourage landowners to temporarily remove highly erodible land from agricultural use and restore natural plant communities. Not intended to restore the pre-settlement (primarily forested) wetland communities of the area, the restoration program goals are to: increase wildlife habitat and plant diversity, reduce soil erosion, improve water quality by filtering pollutants and sediments, and provide storm water storage to reduce flooding.

In most of the region, data pertaining to wetlands voluntarily restored on private lands was vague, inconsistent, and primarily only available in hard-files. Few of these wetlands were included in state and national wetland inventories, although collectively they contribute substantially to the region's wetland acreage. Our recently created GIS inventory database allowed systematic investigation regarding the relative functional status of the sites. The new organizational structure also allows future monitoring, using newly acquired orthophotography, as contracts expire and ownership of the wetlands changes.

Prior to this project, these small wetland restorations lacked comprehensive functional assessment or any monitoring or protection. There were many reasons the wetlands were not monitored including: lack of agency field staff, private ownership, fragmented geographic locations, and potential transient existence resulting from 10–15 year renewable contracts. More than half of the restorations have expired contracts and are vulnerable to renewal of agriculture and grazing practices. Spot checks by resource managers and sporadic field studies by graduate students had revealed concerns for inadequate hydrology and invasion of exotic plant species in many sites, whereas other sites had developed and maintained diverse native plant communities with functional hydrologic regimes. Although the sites were constructed with the intent of temporarily providing 5 ecological functions, those functions had not been assessed on a landscape scale.

Bartoldus (1999) evaluated 40 available functional wetland assessment procedures and considered only two to be applicable in all 50 states. Furthermore, although most implement systematic models, many procedures are based on subjective, qualitative observations rather than objective or quantitative data (NRC 2001). Currently, there is no accepted, generalized functional assessment procedure that can be used as a universal screening tool, but rather, procedures have been developed for singular needs such as wetland mitigation banking (Stein et al. 2000), wetland structure (Smith et al. 1995), and human impact on natural sites (Lillie et al. 2002).

Because specific needs vary with each wetland ecosystem situation, there may be no ideal wetland assessment procedure (NRC 2001). Traditionally, wetland restorations are assessed by rating the functions under investigation and comparing restored sites to similar, near by, natural sites (Ehrenfeld 1983, Kentula et al. 1993, Yoder and Rankin 1995, Brinson and Rheinhardt 1996, White and Walker 1997, Brown 1999, Karr and Chu 1999, Rheinhardt et al. 1999, NRC 2001, USEPA 2002a, Seabloom and van der Valk 2003). However, because these wetlands are not constructed to replace original native wetland habitat, assessment of these sites is best done as a comparison *between* sites as well as chronologically *within* sites. The unique nature of the restoration goals and potentially temporary existence of the wetlands warranted the development and implementation of novel assessment and monitoring methods. These methods may also be used in future efforts to monitor wetland habitat restored through the CRP, Partners for Wildlife, and similar wetland restoration programs throughout the region.

Furthermore, evaluation of biological and physical functioning of these conservation wetlands should be capable of accounting for the changing landscape matrix (i.e. geographic area rapidly shifting from agricultural to exurban-residential). With this in mind, an objective procedure for present and continued assessment of the 2 biological (wildlife use, plant diversity) and 3 physical (soil stabilization, pollutant filtering, storm water storage) functions was developed and customized for this particular population of wetland conservation practices. This assessment procedure is sensitive to the effects of: time, landscape position, natural processes, and variation in function over a dynamic range (NRC 2001). The resulting science-based knowledge can be translated into restoration strategies to prioritize placement of varying sizes and types of wetlands in the landscape to achieve desired functions (Zedler 2003).

In an effort to develop an integrated approach to wetland assessment and monitoring, the United States Environmental Protection Agency (U.S. EPA 2003, draft.) has identified three levels of assessment:

Level 1, Landscape Assessment: Examines populations of wetlands across a landscape in the context of other landscape patterns. This level of assessment can be used to evaluate and assess landscape functions, develop and prioritize watershed needs, and track wetland gains and losses.
Level 2, Rapid Assessment: Measures condition and stressors affecting condition (e.g. failed hydrologic modifications, colonization of invasive species, sedimentation and eutrophication, harmful surrounding land practices).
Level 3, Intensive Site Assessment: Calibrates or validates methods and findings of Levels 1 and 2. Intensive site assessment can be used as a diagnostic tool and for developing performance standards.

This study expanded on prior research by using this integrated approach to examine biological and physical functions as they relate to wetland restoration site age, design, and placement within the Ozaukee County landscape. In addition, our analysis may be useful in identifying landscape subunits within the region where future wetland conservation practices would achieve the greatest functional capacity (McAllister et al. 2000, Zedler 2003).

3. PROJECT GOALS AND OBJECTIVES:

1) To determine the functional status of small wetland restorations in Ozaukee County, Wisconsin, in regard to plant diversity, wildlife use, erosion control, storm water storage, and water quality.

2) To analyze the effects of restoration age, design, and placement in the landscape on their ability to perform those five functions.

3) To develop a comprehensive wetland restoration assessment and monitoring program for small wetlands on private lands in Ozaukee County.

4) To evaluate landowner management concerns.

4. DETERMINING FUNCTIONAL STATUS OF WETLAND RESTORATIONS:

Wetland restorations are generally considered successful if as they mature they meet the intended functions of the restoration project. We used methods for examining the functions of wetland restorations in Ozaukee County that allow comparison of the sites before and after restoration of the wetland. We modeled the physical functions (reducing soil erosion, improving water quality, providing storm water storage) of 106 wetland restorations in a way that allowed a measure of the change in the watershed as the result of the wetland restoration project. Biological functions (plant diversity and wildlife use) were directly measured on 106 sites, chosen with a stratified-random selection process to have equal numbers of wetlands in 4 age groups (1-5, 6-9, 10-13, and 14-17 years post construction). The vegetation of some of these 106 sites was sampled more than once (in 1990-92 and 2002-2004) so there were a total of 120 samples of vegetation data utilized in our analysis. The surface water drainage basins were delineated for all 106 wetland sites and were utilized in the modeling process (Appendix A).

4.1 PLANT DIVERSITY

Plant diversity, or quality of the native wetland plant community, is likely to be the primary and most important biological function of wetland restorations because the structure of the remainder of the biotic communities is dependent on the primary producers. Detailed quantitative samples of the plant community were collected using uniform methods in all 120 sample sites in this study. Resource-intensive ground surveys have been the traditional means for large-scale classification and mapping of vegetation communities. For most wetland management purposes, vegetation needs to be classified at least to the species association level. However, current research is investigating the general use of combining Geographic Information Systems (GIS), remote sensing, and fieldwork to classify and map wetland vegetation (Bernthal and Willis 2004, Lachowski et al. 2000, Nagendra and Gadgil 1999, Rowlinson et al. 1999, Rutchy and Vilchek 1999, Spanglet et al. 1998, Mueller 1997, Wolter et al. 1995, Hinson et al. 1994, Miller 1994).

Until recently, only small-scale remotely sensed imagery was available and utilized to analyze vegetation on a regional scale. Over the past decade large-scale (1-foot pixel) black and white digital orthophotography has been widely available for most regions. In addition, Space Imaging launched the IKONOS satellite platform in 1999. IKONOS imagery is available in 4-meter resolution, in 3 color bands and 1 near-infrared band. The cost is approximately $11 per square kilometer, making it affordable for many wetland vegetation community-mapping applications, such as monocultures of non-native invasives. Baseline mapping of Cattail (*Typha* spp.) and reed canary grass (*Phalaris arundinacea*) monocultures can provide data to monitor change in wetland community structure over time. An increase in cattail and reed canary grass cover may indicate nutrient loading to the wetlands (U.S.EPA 2002c, Woo and Zedler 2002).

4.1.1 Methods

4.1.1.a Vegetation sampling

Following methods previously implemented by Reinartz and Warne (1993) and Hapner (2003), quantitative vegetation cover data was systematically recorded during the months of June and July 2004 in each of 35 field sample sites and added to existing and historical data to yield a sample of 120 sites. We established five transects parallel to the wetland basin slope and equally spaced around the perimeter (Figure 3). Five, 0.25-m^2 quadrats were equally spaced along each transect from the wetland/upland boundary (quadrat #1) to the maximum water depth at which emergent vegetation occurred (quadrat #5). Within each of the 25 quadrats, we recorded the cover of each plant species on the following modified Braun-Blanquet scale: 0 = absent, 1 = cover 0 to 5%, 2 = cover 6 to 25%, 3 = cover 26 to 50%, 4 = cover 51 to 75%, 5 = cover 76 to 100%. Quadrats containing unidentifiable (late flowering) plants were marked and re-sampled in September. Cover data was converted to the cover class midpoint (i.e., 2.5, 15, 38, 63, 88) for analysis. Tree and shrub seedlings were also identified to species and recorded in these 0.25-m^2 quadrats. We recorded shrub and tree cover on a 5 -meter line intercept centered on the quadrat and perpendicular to the transect. The aerial intercept of shrub and tree species with a diameter at breast-height (dbh) greater than or equal to 2.5 cm diameter was recorded to the nearest decimeter along this line, providing a direct estimate of cover. Percent cover of each tree and shrub species was calculated as the length of the line covered, divided by 5 meters.

Plant nomenclature followed Gleason and Cronquist (1991). Voucher specimens were collected for each plant species present in the study sites. Plants, which were unidentifiable in the field were collected and returned to the UW-Milwaukee Field Station plant laboratory for identification. Woody species were also classified by the life stage of the individual (i.e., herbaceous seedling or woody).

Five indices were calculated to summarize and assess the diversity and quality of the plant community of each study site (Appendix B): 1) a flora (complete species list) to estimate floristic richness using the number of species observed, 2) percent native species (number of native species divided by number of species observed), 3) number of native wetland plants present (native plants with wetland indicator status of obligate, facultative wetland, or facultative) (Reed 1997), 4) Wisconsin Floristic Quality Index (Bernthal 2003), and 5) Shannon-Wiener Diversity Index. The data were compared to the general vegetation cover prior to restoration (intra-site change over time) as well as between field sample sites (inter-site comparison).

4.1.1.b Remote Sensing of invasive species

Ground Data Collection:

Cattail and reed canary grass (RGC) monocultures were mapped in the field on printed 1-foot pixel resolution digital orthophotographs during the growing seasons over a three-year period (2002-2004). The aerial photographs were printed on a relative scale of 1cm = 0.5 m, and an absolute scale of 1:1,400. We used this information to digitize signature polygon training samples utilizing ArcGIS 8.3. The Cattail and RCG monoculture shapefiles were imported to ERDAS Imagine 8.4 GIS software.

Image Preprocessing and Selection:

The ATCOR extension was used initially to correct for any atmospheric distortions with respect to the single-date September 2001, full-county coverage, and September 2002 (Belgium and Grafton townships) IKONOS 4 - meter multispectral (0.45 – 0.85 µm) satellite imagery. The 4 spectral bands were combined into one image file utilizing the Stack function in ERDAS Imagine. The composite image was then georectified to the Ozaukee County 2000 1-ft black and white orthophotographs. Twenty ground control points collected from the orthophotographs, and the Polynomial Geometric model was used to rectify the images. To eliminate image pixels outside of the study areas, the Ozaukee County Wetland Restoration Inventory ArcGIS shapefile was utilized to provide a distinct area of interest (AOI) in which to run the classification.

The September 2001 full-county image was not utilized due to significant (>20%) cloud and shadow cover confounding spectral signatures within our small wetland targets. IKONOS multi-spectral imagery captured in September 2002 for the Township of Belgium was relatively free of clouds and associated shadows, and was therefore utilized in the classification. Thirty-three percent of the county wetland restoration sites are located within Belgium Township. Several classification trials were executed and fine-tuned according to the problems identified. For brevity, the final, most accurate methods and results will be reported, and specific difficulties will be examined in the Results and Discussion section below (4.1.2.b).

Spectral Signature Collection:

Spectral signatures were created by utilizing the monoculture polygon shapefiles associated with the ground mapping and the Imagine Region Grow AOI icon (Spectral Euclidean Distance = 2.00). Seventeen and twelve signature points were collected for cattail and RCG classes respectively. Additionally, twenty-four signatures were collected for open water using the IKONOS image as a guide. The 3 duplicate class signatures were then merged for each of three classes (Cattail, RCG, and Open Water) and saved as a merged signature file.

Supervised Classification:

Next, a nonparametric supervised classification was performed on the AOI image using the Parallelepiped Non-parametric Rule (Unclassified and Overlap Options were both set at “Unclassified” to map only cattail and RCG cover types) and the merged signature file. All other defaults were selected. The parallelepiped decision rule is based on a simple Boolean “and/or” logic and is widely used in remote sensing classification (Jenson 2005). The algorithm is not dependent on normal distribution of the spectral data and is fast and simple, since the data file values are compared to limits that remain constant for each band in the signatures (ERDAS 1999).

Post Classification Analysis:

Each output classification file was layered in the same viewer with the orthophotographs. Utility/Flicker was used to visually compare each classified image with the ground-referenced data. Visual inspection allowed classes in the Raster Attribute Editor table to be labeled to the ground-referenced corresponding vegetation cover types.

Accuracy assessments were calculated as percent accuracies and compared using estimates of the kappa statistic (KHAT) (Congalton and Green 1999). KHAT uses the entire error matrix, producing a measure of accuracy, which accounts for agreements expected by chance.

4.1.2 Results and Discussion

4.1.2.a Vegetation sampling

Two hundred sixty-eight plant species were recorded during vegetation sampling of 120 sites (Appendix C). Of those, 41 species are tree, shrub, or woody vine growth forms, 67 species (25%) are non-native or introduced, and 170 (63%) are classified as wetland species. Species richness (number of plant species) observed in each site ranged from 4 to 80; percent native species ranged from 23% to 86%; Wisconsin Floristic Quality Index ranged from 4.00 to 29.57; Shannon-Wiener Diversity Index ranged from 1.09 to 3.68 (Appendix B).

21 native plant species were introduced to 5 of the studied wetlands in 1991. Of these 21 seeded species, nineteen were recorded during my 2002 to 2004 study (Table 1). Seven of the 21 introduced native species (*Alisma subcordatum, Asclepias incarnata, Carex retrorsa, Cornus sericea, Eupatorium maculatum, Scirpus atrovirens,* and *S. validus*) occurred frequently in unseeded sites as well.

Prior to restoration efforts, these areas were typically rotated in monocultures of hay, corn, oats, and/or beans with a few common agricultural weedy species occurring along with the crop. With the exception of site # 46, all sites have increased richness, relative native species, WFQI, and diversity following wetland restoration/creation.

4.1.2.b Remote sensing of invasive species

Cattail, which colonizes in relative deep waters, was confused with open water during initial classification trials. IKONOS spectral signatures for open water was quite variable, and when a third signature merged these variations and distinguished them from cattail, the classification was much improved.

The wetlands of interest are quite small (most < 0.50 acres) and the initial boundaries were digitized using 1-ft resolution imagery. Executing an overlay of these files to a less resolute (4-meter) image introduced an AOI boundary error to the classification process.

Furthermore, cattail monocultures are found within the wetland boundaries more often than RCG monocultures, which tend to have more aerial cover on and outside the restoration boundary. With this in mind, more areas of cattail were mapped than were RCG. This was evident during the Accuracy Assessment with 23 of the 25 random points generated in the cattail class and only 2 of 25 points in the RCG class. Future classification trials could include buffering the wetland restoration shapefile to include more area, or re-digitizing the boundaries utilizing the less-resolute IKONOS imagery. An area column could then be added in the attribute table to record area of each class in hectares. Percent cover of cattail and reed canary grass could then be accurately calculated for each site. Percent area of each monoculture could be calculated using the corresponding histogram data of each classification output file and compared to ground-referenced vegetation map percentages.

An error matrix was calculated for the supervised classification. The maximum number of random points was generated by running Search Count repeatedly. This yielded 25 random points throughout the classified image, all located within the wetland restorations AOI. Reference values were entered for each random point and compared with their subsequent ERDAS Imagine-assigned class. The error matrix quantified how well the Imagine supervised classification of spectral values corresponds to the field data. Overall accuracy of the supervised classification was 80%. Users accuracy (probability of a map user finding the given class at that point on the ground) was 78.26%.

Training a computer system to recognize patterns in remotely sensed data by using ground-referenced data can provide an objective, statistical means for mapping vegetation assemblages. Sensor system and environmental constraints must be kept in mind, and ideally, ground referenced information is collected at the same time as the remote sensing data acquisition (Jenson 2005). This is especially true when the environmental conditions are dynamic due to an unsynchronized disturbance regime, such as exhibited in the Ozaukee County wetland restorations (i.e. muskrat consumption of cattail). Therefore, some of the disparity between field data (collected during summer 2002-2004), orthophotograph mapping (collected spring 2000), and image classification (collected fall 2002) can be explained by the different dates of data collection. Additionally, field mapping the cattail and RCG monocultures on the orthophotographs was difficult due to the mosaic nature of the vegetation with gradual blending from one type to another, making decisions on the boundaries challenging.

Future efforts to more accurately classify cattail and RCG monocultures could include using spatial enhancements such as Texture Analysis. According the ERDAS (1999), Texture Analysis works best with radar bands, but visual/near-infrared applications for vegetation mapping has been successful. Trees have colonized mature (>10 years) wetland restorations, and Texture Analysis may be used in combination with specifying a signature for woody cover.

Cattail and RCG monocultures can be identified easily with the naked eye on 1-ft pixel BW orthophotos. Future classification trials should include executing the methods utilized with the IKONOS imagery on the 1-band Orthophotography image as well.

4.2 WILDLIFE USE

4.2.1 Methods

General Wildlife:

Following methods previously implemented by Hapner (2003), qualitative wildlife data were recorded during the months of June and July in each of 35 field sample sites. Sightings and signs (i.e. vocalizations and physical evidence) of birds, mammals and anurans were recorded as "sight" and "sign" respectively in each of the field sample sites. These data were combined with existing data (Hapner 2003) yielding a sample of 101 sites (no wildlife data were recorded in historical sites). These data were utilized to assess wildlife use prior to and after the restoration by consulting with wildlife biologist Noel Cutright, Ph.D. and local expert herpetologist, Gary Casper, Ph.D.

Wildlife recorded as present in the sites were divided into two categories, those that are likely to have been present prior to the restoration project, and those that would not have been present with the previous land use. The number of wildlife species recorded during site visits, whose presence depends on the wetland and 20-foot upland buffer restoration, serves as an index of wildlife habitat use (Appendix B).

Avian:

Quantitative bird surveys were conducted in 11 sites, added to existing data collected during 2002 and 2003 field seasons (Hapner 2003), and compared to historical data collected in the same sites in 1994 (Leithoff 1997). This yielded information on the same sites at ages 2-6 and at ages 11-15. Thirty sites were surveyed in 1994, all of which we resurveyed between 2002 and 2004. Following the previous protocol, the sites were each visited twice within the first 2 weeks of June, 2004 between 0600 and 0900. The small size of the wetland with grassland buffer enabled sampling the entire site (up to a 100 meter diameter sample area) as one unit from one or two vantage points.

Following methods used by Leithoff (1997), binoculars were utilized prior to approaching the vantage point to identify and record species, which were likely to flush. In instances where flushing occurred, an effort was made to avoid duplication of counts within a wetland complex. Visual and auditory detection of birds during an 8-minute count at each vantage point was recorded by species. In an effort to elicit a response from secretive species such as the Sora (*Porzana carolina*), Virginia Rail (*Rallus lilicola*), King Rail (*Rallus elegans*), American Bittern (*Botaurus lentiginosus*) , and Least Bittern (*Ixobrychus exilis*) a taped recording of their calls was played for 6 minutes. Species observed just after or before the 8-minute count period were noted separately. Species observed flying over wetland sites were tallied as such, to distinguish from those on the site.

We reviewed avian habitat literature (Robbins, 1991) and conferred with local UW-Milwaukee expert ornithologists (Millicent Ficken, Ph.D., Noel Cutright, Ph.D., and

William Mueller, M.S.) to distinguish bird species, which are using the sites as a result of the wetland and grassland buffer restoration from those that may have also used the site during agricultural land use.

4.2.2 Results and Discussion

General Wildlife:

The number of wildlife species recorded during site visits whose presence is determined to rely on the wetland and grassland buffer restoration ranged from 1 to 11 (Appendix B). Deer, possum, skunk, and raccoon would have used the sites before the wetlands were restored, and are now joined by muskrat, beaver, and mink as a result of the wetland habitat restoration efforts. Wood and Green frogs were observed in several sites. All wetland conservation sites are within 1000 meters from another restored site or a natural wetland, providing potential contiguous habitat for seasonal migrating amphibian species.

Avian:

A total of 62 bird species were recorded during the 2002-2004 surveys (Table 2, Appendix D), of which 18 are considered wetland dependent. Thirty-five species recorded during the surveys are most likely utilizing the upland buffer surrounding the wetland basin, and 9 species most probably utilized the site prior to the restoration during active agricultural practices.

The total number of species that we recorded using the restorations in 2002-2004 was very similar to the 1994 census, however, our follow-up survey revealed a dramatic shift in old field and wetland habitat guilds (Tables 2 and 3). Sixty-three avian species were recorded in 1994 (Table 3), of which 39 are considered wetland dependent (more than twice the number of wetland-dependent species recorded a decade later). Only 16 species recorded during the 1994 survey were most likely utilizing the upland buffer surrounding the wetland basin, which is less than half the number of grassland-dependent species recorded in our follow-up survey. Similar to the 2002-2004 censuses, 8 species most probably utilized the site prior to the restoration during active agricultural practices in 1994.

This dramatic shift from dominance by wetland and water dependent birds to grassland dependent birds over a ten-year period is likely the result of two simultaneous changes to the wetland habitat. Over this ten year period the grassland that buffers the restoration has matured and developed additional vegetation complexity, providing suitable habitat for a greater variety of grassland birds. At the same time, cattail has colonized, and now densely occupies, much of what was formerly an open water zone in the wetlands. The mud flats that were present when the wetlands were young , and which also provide habitat for some shore birds, are now colonized by vegetation. As the result of these changes, habitat for some of the wetland dependent bird species has been lost as the vegetation in the wetlands succeeds.

4.3 STORM WATER STORAGE

Many authors have related the total storage capacity of lakes and wetlands within a watershed to the peak floods experienced (Novitzki 1979, Carter et al. 1979, USDOT 1983, Ogawa and Male 1986, Johnston et al. 1990, Johnston 1994, Potter 1994, Cedfeldt et al. 2000, NRC 2001). A minimum of 10-20% total area of wetlands and lakes in a particular watershed has been found to provide adequate storm water storage (Novitzki 1979, Johnston et al. 1990).

Unlike the biotic functions of wetlands which take time to develop, the ability of a newly constructed or restored wetland to provide the storm water storage function may be fully realized immediately after construction. The storm water storage function of a restored wetland may even decrease slowly over time as sediments accumulate and vegetation takes up an increasing volume of the storage space. The storm water storage function of the restored Ozaukee County wetlands is therefore based solely on the physical characteristics of the wetlands and their drainage basins, and the placement of those restorations in the landscape.

The ideal model to describe the storm water storage function of an individual wetland is a dynamic model that estimates in detail, 1) the runoff generated by the drainage basin from a range of storm events under a range of pre-storm soil moisture or saturation conditions and using the specific slopes and soil characteristics of that drainage basin, 2) the available storage capacity in the wetland at the time of the rainfall, based on the recent history of precipitation events and the ground water recharge and evapotranspiration characteristics of the wetland, and 3) the specific ability of the wetland to retain and detain stormwater based on the design and outflow characteristics of the wetland. In other words, the most realistic model for stormwater storage of an individual wetland will be a dynamic model that uses actual historical precipitation records to estimate the real delivery of stormwater to the wetland. We found that there was no available dynamic stormwater storage model appropriate for these wetland restorations, and available for use in this study. We are currently working with Dr. Kenneth Potter, School of Engineering, UW-Madison, to develop a dynamic model for these systems, but that model is not yet available, and is beyond the scope of the work for this grant project.

There is another useful approach to understanding the stormwater storage behavior of this population of wetland restorations in the landscape. The approach we used for this project treats the restorations as a large population of wetlands and examines the relative capacity of the individual wetland to retain stormwater based solely on the storage volume of the wetland relative to the area of the drainage basin which discharges to the wetland. What this level of analysis provides is an indication of the design "fit" between the size, or storage capacity, of the wetland and the area of its drainage basin. The population of wetlands restored in Ozaukee County includes everything from relatively large wetlands with very small drainage basins, to relatively small wetlands with large drainage basins. The former clearly have more capacity to perform the stormwater storage function than the opportunity to provide that function based on the loading of water delivered to them; while the latter will be overwhelmed by the runoff that reaches the wetland and will provide very little stormwater storage for the drainage basin. This analysis provides a way for the designers of these restorations to consider size and placement of the wetlands in their drainage basins to provide a reasonable "fit" between capacity and opportunity to detain surface water runoff.

We drew contour maps of the basin shape (essentially bathymetric contour maps) of a sub-sample of wetlands having a range of surface areas. These contour maps of the basins allow the calculation of the available storage capacity of the wetland at a variety of water levels (draw downs) below the outflow elevation of the wetland. Using these storage capacity volumes at a variety of draw downs, we then calculated the centimeters of runoff that the wetland could retain from the area of its drainage basin.

This index of the stormwater storage capacity of a wetland is therefore based solely on "fit" between the volume of the wetland and area of its drainage basin. As a way to compare the relative capacity of a population of wetlands, this method therefore implies several characteristics that are assumed to be uniform across all wetlands, including: 1) soil permeability, vegetation cover, and runoff characteristics of the watershed, 2) topography of the watershed, 3) relationship between the surface area of the wetland (measured) and the storage capacity (modeled) of the wetland, 4) groundwater discharge (leakiness), and rate of evapotranspiration of the wetland – available storage capacity, and 5) outflow characteristics of the wetland discharge. In other words this assumes that at the time of a hypothetical precipitation event all wetlands will be drawn down to the same stage, and the runoff volume of the watershed will be proportional only to its area.

For the purpose of understanding this large population of wetlands this very generalized modeling approach is appropriate for two reasons. It is rare that many of these wetlands have any surface water discharge except during spring snow-melt, so the capacity of the wetland to detain stormwater is not dependent on outflow design; the wetlands are retaining almost all the surface water that reaches them during the growing season. This method is clearly capable of identifying wetlands that are dramatically oversized or undersized for their drainage basins, which will allow the wetland designers to analyze how these restorations can be made to more efficiently provide the stormwater storage function.

4.3.1 Methods

Landscape Assessment:

A threshold of 10-20% wetland/lake area in a particular watershed has been generally recommended to provide adequate storm water storage (Novitzki 1979, Johnston et al. 1990). County sub-watershed boundaries were used to quantitatively determine the percent increase in potential storm water storage area in each sub-watershed as a result of the wetland restoration efforts. These methods serve as a landscape assessment of storm water storage benefits.

Additionally, we attempted to identify heavily developed sub-watersheds, which may depend on restored wetland basins during peak flow events (USDOT 1983). By utilizing the 4-meter IKONOS satellite imagery and the ISODATA algorithm in ERDAS Imagine Professional 8.4 software, an unsupervised classification was performed to calculate the percent of impermeable surface area (i.e. roads, buildings, parking lots) within each subwatershed.

Estimation of Stormwater retention – General Model:

In order to determine the relative capacity of the 106 individual wetland restorations in this study to retain stormwater we had to develop a relationship between wetland surface area (measured for each wetland from aerial photographs and recorded in the GIS database) and the storage volume of the wetland at a variety of stages of draw down (water surface elevations below the outflow elevation). We developed a storm water storage model, which enabled us to relatively rate the potential and capacity for each of wetland restoration to retain event-specific runoff.

Estimation of typical basin volume:

In order to develop a relationship between wetland surface area and typical basin volume, we selected 10 wetlands that spanned the representative range of sizes of the restored wetlands and that were both old and relatively young restorations (in case the typical design slopes had changed over time). We found the elevation of the surface water outflow point for each of these 10 wetlands. The elevation of the surface water outflow point is the maximum high water level that can be achieved in the wetland. Most of the wetlands are constructed with a simple berm, and water levels above this outflow elevation will cause discharge at the same rate as inflow. The total volume of the wetland below this elevation is the maximum water volume that the wetland can hold when it is “full”.

We obtained ground surface elevations on a sufficient number of transects across each wetland to allow us to draw an accurate contour map of the three-dimensional shape of the wetland basin. Elevations were recorded as relative to the elevation of the outflow point. Each transect began and ended at a point higher than the outflow elevation, and at least one transect was always placed to transect the deepest part of the basin.

- Aerial extent of wetlands:

The GIS inventory contained the boundaries of each wetland digitized on an aerial photograph. Field study indicated that the boundary of the digitized wetland area, based on the spectral signature of wetland vegetation and soils, was always smaller than (contained within) the boundary of the area that would be filled with water when water is at the outflow elevation, the high-water line. We determined that on average, the boundary of the high-water line was 6 ft (1.83 m) outside of the boundary of the wetland digitized on the aerial photograph. This distance between the wetland boundary and the high-water line varies from point to point depending on the slope at the wetland margin, but we found that most wetlands were constructed with relatively uniform slopes, and that 6 ft (1.83 m) is a reliable estimate of this distance.

In order to draw a contour map of each wetland basin, the digitized boundary of wetland vegetation was used to establish the aerial shape of the wetland, and the high-water line was estimated by using ArcGIS to establish, and calculate the area of, a 6 ft (1.83 m) buffer around the digitized wetland boundary. The digital shape of the boundary of the wetland vegetation was "scaled up" to the total surface area of the high-water level using this method. The area of the wetland vegetation, and the high-water surface area of each of the ten study wetlands were recorded.

- Volume of wetlands:

Contour maps of each of the ten wetland basins were drawn with a 15 cm contour interval using the elevation data collected on transects in the field. Each contour interval was digitized, and ArcGIS was used to calculate the *relative* area within the contour interval. The absolute area (in square meters) within each contour line was then calculated by multiplying the relative areas by the absolute high-water surface area of the wetland. The water "Stage" in the wetland is presented in centimeters of "draw down" below the high water, or outflow, elevation. The area of the 0.0 contour is therefore the same as the total area of the "High-water Basin".

Volume within each 15 cm stage increment was calculated by multiplying the average of the areas within the upper and lower contours that bound that "slice" of the three-dimensional shape, by the vertical thickness of that "slice" (in most cases 15 cm). This is an appropriate method for calculating the volume of what is essentially an irregular three-dimensional object that is a trapezoid on any cross section. The total basin volume (in cubic meters) is the sum of the volumes contained with all slices of the volume defined by the contour intervals (Table 4).

We found a very close linear relationship between the surface area of wetlands recorded in the GIS and the total volume or storage capacity of the wetland ($r^2 = 0.89$, Figure 4a). As would be expected, this linear relationship is even tighter between the storage capacity at a –15 or –30 cm draw down stage and the surface area of the wetland (Figure 4b). We found, therefore, that we could accurately estimate the storage capacity of all 106 wetlands at a variety of draw down stages by using the linear regression equations developed for the 10 measured wetlands. The total volume, and the storage capacities at –15, -30, -46, and -61cm draw down stages were estimated for all 106 wetlands using the linear regressions developed for these 10 wetlands.

Determining the surface watershed for each wetland basin:

We wanted to compare the relative storage capacity of the wetlands with the relative size of the drainage basin that delivers surface water to that wetland. We needed to determine the boundaries of surface water drainage basin, or watershed, of each restored wetland. We worked with Jeff Stone to develop computer programs that would delineate the watershed boundaries from the available 2-foot interval contour maps (Appendix A). The 2-foot contour maps were converted to a digital elevation model (DEM), and a program was written to determine the boundaries of the watersheds using the DEM. The watershed boundaries estimated by the computer programs were checked and edited manually using standard visual interpretation of 2-foot contour interval topographic maps and field data. The surface watershed areas utilized in our analysis are those estimated by delineating the surrounding upland area that slopes, or drains, to that particular wetland (i.e., if a series of small restored wetlands existed in the watershed, the drainage area was limited to the upland that drained to each particular wetland).

To examine the relationship between the storage capacity of an individual wetland and the size of its surface watershed, the storage capacity of each wetland was expressed as the number of centimeters of runoff from the entire watershed that could be stored in the wetland given various starting draw down stages (Figure 5, Appendix B)

4.3.2 Results and Discussion

<u>Landscape Assessment:</u>

GIS layers that provided areas of wetlands and lakes, and the boundaries of sub-watershed were used to determine the change in percentage of wetland and lake area in the watershed resulting from these wetland restorations. In Sucker Creek, Sheboygan River, and North Branch Milwaukee River sub-watersheds (Figure 2), the restorations have increased wetland area by 1.02, 1.05, and 1.09% respectively. Less than 1% increase in lake and wetland area was estimated in the remaining sub-watersheds in the county. This is due to the small size of the individual wetland restorations relative to the area of the sub-watersheds. Although the percentage increase in wetland area in the sub-watersheds appears to be small, an increase approaching 1% is a substantial increase in capacity when the threshold levels to provide adequate capacity are only 10 to 20% of the watershed area Novitzki (1979) and Johnston et al. (1990). This assessment was problematic for numerous reasons. Many county sub-watersheds include area outside the county boundaries, suggesting this type of assessment should be completed at the watershed scale rather than the individual county scale. Also, the Wisconsin Wetland Inventory does not include wetlands less than 2 acres in size, rendering the task of assessing existing wetland/pond/lake area incomplete.

As with the vegetation mapping, IKONOS multi-spectral imagery captured in September 2002 for the county township of Belgium was relatively free of clouds and associated shadows, and therefore utilized in the classification. The ERDAS Imagine ISODATA analysis was unsuccessful due to confounding spectral values, primarily such as those associated with vegetation. The date of IKONOS imagery collection (late September) is not as ideal as early spring imagery collection for this particular application. With this in mind, future attempts to map and quantify impervious surface should include leaf-off imagery and image enhancement analyses such as Normalized Differential Vegetation Index, Tasseled Cap Indices, Texture analysis, and Principal Components analysis to separate confounding spectral values such as vegetation from man-made land cover.

<u>Stormwater Runoff Retention:</u>

The total volume of the 10 wetlands studied varied from 82 m^3 to over 1,400 m^3 (Table 4). This largest wetland sampled, with a surface area of 0.36 ha, is substantially larger than the mean (0.22 ha), and places that particular wetland well within the upper quartile of the study wetlands, with only 17 wetlands having larger surface areas. The maximum depth of the 10 wetlands sub-sampled varied from 42.7 cm to 131 cm.

The surface water storage capacity of this population of wetlands has the distribution shown in Figure 5. It is rare that the vast majority of these wetlands are not at a draw down stage of at least –15 to –30 cm prior to a storm event for most of the growing season. At –15 cm draw down two-thirds of the wetlands have the capacity to retain more than 1 cm of runoff from their entire watershed area (Figure 5a); at a –30 cm draw down nearly half of the wetlands (52) will retain over 1 inch (2.5 cm) of runoff from their basins (Figure 5b).

We are currently in the process of the dynamic modeling of runoff from the watersheds that incorporates both actual precipitation data for the region and the factors of soil, slope, and cover specific to the watershed. However, even without this more detailed and realistic modeling, it is clear that it will take a major storm event to produce even an average of 1 cm of runoff from the entire watershed of these wetlands except during periods when the soils are either completely saturated or frozen. A reasonable goal for these wetland restorations may be that they retain at least 1 cm of runoff from their watersheds at a –15 cm draw down stage. With this goal in mind, the designers of these wetland projects could examine in detail those 34 wetlands (Figure 5a), which do not meet this goal, and determine in which cases either the location in the watershed or the size of the wetland could have been altered to better meet stormwater storage functional goals. This can provide a better understanding of design criteria for stormwater management.

4.4 EFFECTS OF LAND COVER CHANGE ON SOIL EROSION

It would be difficult to empirically measure the actual reduction in soil erosion associated with the construction of this population of wetlands. The goal of decreasing soil erosion with these wetland restorations must therefore be evaluated using models that estimate the loading to the wetlands, or the amount of soil erosion per hectare from land with different soil types, slopes, and covers. Prior to restoration of these wetlands, sediment in surface runoff from agricultural land was carried by drainage swales, ditches, and drain tiles to the nearest waterway. There was no wetland to provide detention or storage of sediments. Much of this sediment is now concentrated in the restored wetland basins. Additionally, the accompanying change in land cover (i.e. vegetation cover) within the surface drainage basin has affected the amount of sediments carried by surface flow, which can be estimated utilizing existing models.

After a thorough review of existing soil erosion models, we determined Water Erosion Prediction Project (WEPP, Flanagan et al 2001) and more specifically, the Geo-spatial interface for the WEPP model, GeoWEPP (University of Buffalo 2003), to be most suitable for our purposes. However, the current GeoWEPP version only functions under

ArcView 3.x. software, which was unavailable for this project. A GeoWEPP version for ArcGIS 8-9x is currently in the beta testing phase and will most likely be released in March 2006 (C. Renschler, personal communication, June 7, 2005). With this in mind, the decision was made to utilize the Spatial Analyst - Model Builder extension, which is readily available in ArcGIS to complete this particular project objective. The GeoWEPP model will be employed as planned as soon as it is available.

4.4.1 Methods

Utilizing ArcGIS and the Spatial Analyst extension, we created a model to calculate risk indices for soil erosion. Erosion risk modeling was performed within the individual surface drainage areas of 106 wetland restoration sites. Inputs to the model included slope (derived from the digital topography data), soil erosion potential, (Tolerable Soil Loss, or "T- values" assigned by USDA) and current and pre-restoration vegetation cover (derived from current field data, and historical aerial photos and farm plans). The inverse of the USDA T-values were used as inputs for this model to yield values of 1 (least subject to erosion) to 5 (high erosion potential). Vegetation cover prior to and following wetland restoration in each drainage basin was mapped, classified, and assigned values that reflect an ordinal scale of erosion potential as follows: forest = 1, old field/grassland = 3, residential = 6, agriculture = 9.

Within each drainage basin, the proportion of the total area occupied by each vegetation class was multiplied by the class value, and totaled to yield the vegetation cover input value, between 1 and 9, utilized in the model. We considered slope to be a more important factor in erosion than either vegetation or T-value, therefore slope values were weighted 50 percent while T-values and vegetation cover class were each weighted 25%. Pre-restoration and post-restoration soil erosion risk indices were used to calculate a percent reduction as a result of each wetland restoration.

4.4.2 Results and Discussion

Reductions in soil erosion risk ranged from 0 – 50% (Appendix B), with a mean percent reduction of 22.87% (std. dev. 9.87) (Figure 6). The reductions estimated by the present model are primarily a reflection of the change in vegetation cover in the surface drainage area of each wetland following restoration, as opposed to an indication of the capacity of the wetland itself to trap sediment. Only a small proportion of the studied wetlands continue to have agriculture as an active land use in 100% of their drainage basins. Most have converted to residential and old field/grassland.

Prior to wetland construction, any sediment in surface runoff from these drainage basins was carried by ditches and drain tiles to the nearest waterway with minimal detention or filtering. Much of this sediment is now concentrated in the restored wetland basins, since discharge from most of these wetlands basins is a relatively rare event during the growing season. Until the more sophisticated GeoWEPP model of soil erosion of these wetlands is completed, the relative ability of these wetlands to retain surface water runoff from their watersheds (Figure 5) is probably the best relative index of the actual ability of the wetland itself (as separated from land use changes in the watershed) to retain sediments and improve water quality. The ability of a wetland to serve a surface water sediment reduction function is related primarily to two factors, 1) the loading that the wetland receives (i.e. the opportunity to perform the function) and, 2) the detention time of water in the wetland (adequate time for the smaller sediment particles to settle from the water column). The final estimates that we obtain with GeoWEPP of the ability of this population of wetlands to remove sediments from water will undoubtedly be highly correlated with the stormwater detention and retention function of the wetlands.

4.5. EFFECTS OF LAND COVER CHANGE ON WATER QUALITY

We proposed to quantify rates of sediment and nutrient accumulation in a small subset of our study wetlands over the past 20 years by examining sediment cores collected from the wetlands. This effort to quantify rates of sediment and nutrient accumulation was dependent on choosing and duplicating four separate land use types (agriculture, grassland, residential, mixed) in 8 mature sites (> 13 years post construction). This proved impossible with our population of wetlands due to many older sites returning to agriculture as well as dynamic land use changes within the surface drainage basins since wetland construction. This portion of the study was therefore abandoned as not being feasible.

As with soil erosion, the goal of improving water quality would be difficult to directly measure with this particular population of wetlands. Most are perched isolated basins with no defined inlet or outlet, which makes measuring a change in water chemistry challenging. However, approximately 40% of the sites were designed by implementing ditch plugs, drainage tile blocks, and/or drainage tile breaks. Prior to the restoration, pollutants in surface runoff, such as pesticides and herbicides used during active agriculture practices, were most likely carried by the ditches and drain tiles to the nearest waterway with minimal detention or filtering. Much of this runoff is now concentrated in the restored wetland basins, which allows the current nutrient loading to be taken-up and utilized by the wetland vegetation and stored in sediment. As is the case with soil erosion, the accompanying change in land cover within each wetland surface drainage basin has also affected the amount of nutrients carried by surface flow, and can be quantified utilizing existing models.

4.5.1 Methods

Nutrient Loading Indices were calculated for 106 wetland sites by modifying methods developed by U.S. EPA (2002b). Former and current land use classes in each surface drainage basin (also delimited for soil erosion modeling) were digitized and assigned corresponding values of nutrient (nitrogen and phosphorus) loss rates (Table 5). Within each drainage basin, percent of each land cover class was multiplied by the average nutrient loss rate, and totaled to yield the vegetation cover input value utilized in the model. The percent reduction in nitrogen and phosphorus (Appendix B) was calculated as the loading associated with current land use subtracted from the loading of the previous land use, and that quantity divided by the loading of the original land use and multiplied by 100. In other words it was calculated in the standard way that one calculates a percent change. The positive numbers in Appendix B therefore reflect a percent reduction in nutrient loading.

4.5.2 Results and Discussion

Reductions in nitrogen and phosphorus loading were highly correlated (Figure 7). This correlation is due to the fact that both indices are based on the same land cover percentages multiplied by a different, but correlated, set of loss rates (Table 5). Annual phosphorus reduction ranged from 0.52 – 72.99%, with a mean percent change of 51.66 (std. dev. 21.99) (Figure 8, Appendix B). Annual nitrogen reduction ranged from 0.56 – 55.77%, with a mean percent change of 39.92 (std. dev. 16.55) (Figure 9, Appendix B). Land use remained virtually unchanged in the drainage basins of Sites # 52 and 53, which accounts for the low nutrient index values. Twenty-one wetland restorations (17%) continue to have 50% or more active agriculture practices within their drainage basins. Conversely, 55% of the sites no longer have agriculture use in the watershed due to the conservation practice. Twenty-four percent (n = 29) sites contain urban land cover, and two wetland watersheds contain mostly natural vegetation.

Land use in the drainage basins of about one-third of the studied wetlands changed from almost entirely agricultural before construction of the wetlands to mostly natural vegetation after the wetlands were restored. This change was associated with converting the land from active agriculture to Conservation Reserve Program (CRP) land about the same time that the wetlands were restored. This land conversion results in a 55% reduction in the nitrogen loss rate and a 73% reduction in phosphorus loss per hectare (Table 5). This dramatic conversion in land use, and the associated reductions in nitrogen and phosphorus loading to this population of wetlands, therefore causes the unusual looking distribution of reduction in nutrient loading indices in Figures 8 and 9.

5. ANALYZING THE EFFECTS OF RESTORATION DESIGN AND PLACEMENT IN THE LANDSCAPE ON FUNCTION

5.1 Methods

5.1.1 Ordination:

Cover data of the most common plant species recorded in each sample site were included in analysis to measure similarities between sites based on the vegetation data. Detrended correspondence analysis (DECORANA, Hill 1979) was used to ordinate the vegetation data from the original 120 sites and to group the sites by the similarity of their vegetation. DECORANA plots multidimensional species space into 2-dimensional space. The distance between two sites may be interpreted as a measure of similarity/dissimilarity based on their vegetation composition.

Ordinations were performed for the 120 sites using combined quadrat cover data (quadrats 1-5) as well as with data recorded in each quadrat, or hydrologic zone (Figure 3). This allowed grouping of the 120 sample sites by overall plant cover data as well as comparison of each concentric plant community zone described by individual quadrats placed along a hydrologic gradient.

5.1.2 Pearson Correlation Analysis:

We searched for and summarized patterns of variation within the GIS generated, modeled, and field collected data. We tested for significant effects of *independent* wetland variables recorded in the Ozaukee County Wetland Restoration Inventory such as: age, design (e.g. wetland size and seeding treatment) and landscape placement (e.g. project type, drainage basin area to wetland area ratio, surrounding land use, and distance to: woodland, wetland, active agriculture, and road) (Appendix E) on the *dependent* wetland site indices: vegetation composition (i.e., richness, percent native plants, number of native wetland plants, floristic quality, and diversity), wildlife habitat (i.e. number of wildlife species), soil erosion (i.e. soil erosion risk index), storm water storage (i.e. individual event storage potential), and water quality (i.e. nutrient loading indices) (Appendix B). We used step-wise regression analysis to examine correlations of these metric values, which ordered the values by strength of prediction.

We calculated the pairwise Pearson Correlation coefficients (Appendix F) of all summary statistics calculated and estimated for the 106 un-seeded, naturally colonized, wetlands in the study (SYSTAT 9, 1998). The pairwise correlation coefficients were calculated: 1) to determine which of the independent variables were highly correlated with one another and therefore were essentially measures of the same wetland characteristic (e.g. all of the measures of the ability of the wetlands to retain runoff); and 2) to find those significant and meaningful correlations that would reveal relationships between the independent variables and the variables related to wetland function (e.g. very strong and highly significant correlations between Number of Wildlife Species (Wild) and measure of native plant diversity and floristic quality) (Appendix F).

5.2 Results & Discussion

5.2.1 Ordination

Ordinations performed with the combined quadrat data resulted in confounding results. This is most like due to our intentional placement of sampling quadrats along a hydrologic gradient, which described 5 separate wetland plant communities established within separate hydrologic zones. Figure 10 shows mean percent cover of open area, woody vegetation and 4 plant species recorded for sampling quadrats 1 through 5. For example, Canada goldenrod (*Solidago canadensis*) had the highest mean cover in quadrat #1 (at the upland/wetland boundary) but was not recorded in quadrat #5 (open water/emergent vegetation). Conversely, water plantain (*Alisma subcordatum*) had highest mean cover recorded in quadrat #5 and rarely occurred in quadrats 1 and 2. The establishment of two non-native, invasive species, reed canary grass (*Phalaris arundinacea*) and cattail (*Typha* spp.), indicate specific hydrologic preferences. *Phalaris* reaches highest mean cover in quadrats 1 and 2, while *Typha* prefers to colonize in quadrats 4 and 5. The two species appear to find mutual conditions in the 3rd quadrat, along with woody vegetation, which establishes highest mean percent cover in that particular hydrologic zone. With this in mind, we classified the cover data by quadrats, and ran separate analyses for the 120 study sites to compare vegetation communities in the 5 hydrologic zones.

Ordination of quadrat #3 cover data from 120 sample sites using open area and 32 species with mean percent cover of 0.25 or more (Table 6) with DECORANA produced groupings related to age groups. The data were plotted showing wetland samples in species space (Figure 15) and species in sample space (Figure 16). When sample wetland sites were plotted by DECORANA, age classes 1 through 4 were identified as distinct clusters with some overlap of neighboring classes due to the one-year separation between age classes (e.g. vegetation composition in a five year old wetland may be very similar to a 6 year old wetland) as well as the presence of general species that may establish and persist in that particular hydrologic zone over the time period examined (e.g. reed canary grass and cattail). The use of DECORANA ordination of species in sample space (Figure 16) graphically illustrated which plant species cause the sample units in Figure 15 to plot in their perspective locations. Species plotted to the right on the first axis (e.g. quack grass, *Elytrigia repens*) had higher recorded cover in younger sites. Conversely, species plotted to the left on the first axis (e.g. adult tree species) were recorded only in the older wetland sites. Woody vegetation (dbh of 2.5 cm or greater) is recorded in the flora of 53 wetland restoration sites as follows: 17% of age group 1-5, 30% of age group 6-9, 50% of age group 10-13, and 80% of age group 14-17.

5.2.2 Pearson Correlation Analysis:

The significant correlations among the summary statistics (Appendix F) describing this population of 106 un-seeded, naturally colonized, wetlands fell into three classes:

1) Those sets of independent or dependent variables that are different measures of the same characteristic, or those variables that were used to calculate or estimate

another variable, and would therefore be expected to be highly correlated. These include:

a. Age and age class;
b. Wetland acreage and length of perimeter;
c. Richness, diversity, number of native species,
d. Percentage of native species, number of native wetland species, and Wisconsin Floristic Quality Index;
e. The four estimates of centimeters of runoff retained and a negative relation of these to the size of the drainage basin.
f. The percentage of agricultural land in the wetland's surface water drainage basin is highly correlated with the soil erosion and nutrient loading indices because the amount of agricultural land in the drainage basin was one of the variables used to model the loading indices.

2) A set of unexpected significant correlations that are unexplained, some of which may indicate artifacts of changes in the management of the wetland restoration program over time. These include:
   a. Significant correlations between wetland age and water depth, percentage of agricultural land in the drainage basin, and the soil erosion, nitrogen loading, and phosphorus loading indices.
   b. Negative correlations between distance to the nearest road and the ability of the wetland to retain stormwater runoff from the drainage basin.
   c. Negative correlations between distance to the nearest constructed wetland and distance to the nearest woodland and natural wetland, and the soil and nutrient loading indices.

3) Most of the remainder of the significant correlations in the matrix reveal important relationships between the age, design, and landscape placement of the wetlands and their plant and animal biotic characteristics. These include:
   a. Percentage of native plant species, mean coefficient of conservatism of the plants, Wisconsin Floristic Quality Index, the cover of woody plants (inverse of WdCov), and the cover of *Salix exigua* all increase significantly with age of the wetlands, while the percentage of open ground and the cover of quack grass, *Elytrigia repens*, decrease with age.
   b. Larger wetlands support a greater number of wildlife species (positive correlation between "Size" and "Wild").
   c. Wetlands with more permanent water (greater "Water Depth") have higher mean coefficients of conservatism and Wisconsin Floristic Quality Indices.
   d. Distance to the nearest active agricultural field is significantly positively correlated with all measures of native plant diversity and quality of the plant community ("Rich, H, Native, PNat, NNWS, and WFQI") and with the number of wildlife species, and is negatively correlated with the cover of reed canary grass, "RCG". In other words the farther the wetland is from and active agricultural field, the higher the quality of the wetland vegetation and wildlife function.

e. Distance to the nearest road is similarly correlated positively with measures of the quality of the plant community and the wildlife usage.
f. Distance to the nearest constructed wetland is positively correlated with the quality and diversity of the native wetland plant community.
g. The closer the wetland is to the nearest woodlot the higher the quality and diversity of the native wetland plant community (negative correlation with "Wood").
h. Woody plant cover in the wetland and the cover of *Salix exigua* are both significantly greater in wetlands with woodlots nearby, while the cover of quack grass (*Elytrigia repens*) is lower.
i. Distance to the nearest natural wetland has a very strong negative correlation with the proportion of native species in the restored wetland.
j. The proportion of the wetland's drainage basin occupied by agricultural land has strong negative correlations with all of the plant community diversity and quality indices measured. The less agricultural land in the basin the higher the quality of the wetland plant community.
k. There are positive correlations between soil erosion risk and nitrogen and phosphorus loading reductions, and the plant diversity and WFQI statistics.
l. The larger the drainage basin relative to the size of the wetland ("BWR") the greater the cover of reed canary grass in the wetland.
m. Plant species richness, number of native species, number of native wetland species, and the Wisconsin Floristic Quality Index all have very strong positive correlations with the number of wildlife species using the wetlands.
n. The percentage of open ground, "Open", is strongly negatively correlated with all measures of plant community diversity and quality. As the wetlands mature the amount of open ground decreases and the quality of the plant community increases.

6. DEVELOPING A COMPREHENSIVE WETLAND RESTORATION ASSESSMENT AND MONITORING PROGRAM:

Field data was collected on 35 randomly chosen sites and added to data previously collected on 85 sites (Reinartz and Warne 1993, Leithoff 1997, Hapner 2003) to currently yield information on 40% of the county wetland restorations. This information was used as site base-line data as well as ground reference to verify or correct remotely sensed information presently stored in the GIS. Baseline data also allowed us to assess current function as well as monitor change in the wetland functions over time.

By conferring with NRCS, USFWS, WDNR, and County restoration technical advisors, a practical monitoring program was developed. Utilizing the GIS database, sites lacking biological assessment will be systematically selected each year and the landowners contacted for permission to collect field data. Field methods and sample data sheet are provided in Appendix G. Resulting information will be added to the GIS database.

As new aerial photography is captured (approximately every 5 years), remotely sensed baseline wetland characteristics will be monitored and updated, and newly constructed sites will be digitized and added to the database. Landowner information will be updated automatically using the County's digital cadastral map and tax identification numbers. Also, the GIS database allows tracking of specific contracts, and as individual contracts expire, landowners will be contacted to discuss future wetland status.

7. EVALUATING LANDOWNER MANAGEMENT CONCERNS:

A survey was developed and distributed to 125 private landowners and 5 agencies identified by the GIS database (Appendix H). This survey identified common and immediate concerns of landowners, and resulted in prompt communication between many agency managers and owners (see pages H1-H4). The survey is also available on line at: http://www.co.ozaukee.wi.us/PlanningResourcesLandManagement/LAND OWNER SURVEY REPORT.pdf

8. SUMMARY & RECOMMENDATIONS:

Biological Functions:

Wetland restorations initially seeded with 21 species of native wetland plants developed high floristic quality, which was maintained more than a decade later (Figure 11). Sixteen of the 21planted species established and maintained populations (Table 1). Although seven of those species volunteered to colonize in unseeded sites as well, immediate establishment of those species may have pre-empted the establishment of invasive species such as reed canary grass (*Phalaris arundinacea*). In fact, mean cover of reed canary grass in 12-year old seeded sites is 48% less than in unseeded sites of the same age class. Given the conservation contract length (10-15 years), initial seeding could provide higher floristic quality over the potentially short time the wetland exists in the landscape.

Our data suggests that floristic quality in unseeded sites increases dramatically in the first 5 years following restoration/creation. The floristic composition then stabilizes, indicating that the vegetation community becomes “mature” (Figure 11). However, woody vegetation develops in most sites during the second decade, changing the structure and subsequently, the microclimate of the plant community (Figure 17). Increased shade from the woody canopy may cause a shift in sun and shade-tolerant plant composition. For example, mean percent cover of reed canary grass (*Phalaris arundinacea*) decreases in wetlands older than 10 years (Figure 18), coinciding with an increase in mean percent woody cover (Figure 17). As tree and shrub canopy develops over time, the climate of the herbaceous stratum may favor shade tolerant species associated with lowland woodlands of southeastern Wisconsin. In fact, species commonly found in local natural swamps and moist woods such as ostrich fern (*Matteuccia struthiopteris*), sensitive fern (*Onoclea sensibilis*), common woodreed (*Cinna arundinacea*), and water parsnip (*Sium suave*) were recorded in older (> 14 years) wetland restoration sites with relatively high woody cover. Although these wetlands were only intended to provide ecosystem services for 10 to 15 years, most sites remain in the landscape well beyond contract termination.

Figures 12 and 13 reveal inverse relationships between WFQI and distance to the nearest natural wetland and woodlot. Proximity of a native wetland seed source appears to be most influential during the initial five years following restoration. Perplexingly, few species are shared between the flora of upland woodlot and our study sites, and this particular relationship may be a consequence of unmapped ephemeral ponds located in the woodlots. Moreover, the proximity of a woodlot may indicate a greater percent of natural vegetation in the local surface drainage basin of the wetlands. This latter hypothesis is supported by Figure 14, which represents the inverse relationship between WFQI and the relative area of active agriculture in the local surface drainage basin.

The data shows positive relationships between size of the wetland and WFQI, and the number of wildlife species recorded during site visits whose presence is determined to rely on the wetland/upland buffer restoration practice (Appendix F, Figure 19). Floristic quality appears to have a significant affect on the number of wildlife species utilizing the wetland and surrounding grassland buffer, therefore, all the factors affecting WFQI listed in section 5.2.2 may also affect wildlife use (Appendix F).

The shift in avian habitat guilds from wetland-dependent species (ages 2-6) to grassland dependent species (ages 11-15) may be due to the tremendous change in relative area of open ground, vegetation, and open water in the wetlands and grassland buffers over time. Wetlands ages 1-5 have higher mean percent open ground in quadrats 1-4 and open water in quadrat 5 than do older sites. Over time, the grassland buffers mature and wetland vegetation establishes in former mudflat areas (Figure 20). As shown in Figure 21, many sites develop cattail (*Typha* spp.) monocultures, which opportunistically spread down slope due to the ephemeral hydroperiod of most wetland sites. This results in a decrease in open water area and increase in cattail cover over time. Figure 21 shows the "bird's eye-view" of representative restorations, suggesting that wetlands with relatively small open water areas may not attract many waterfowl species.

Avian use of the wetland and grassland buffer may facilitate dispersal of plant species, overcoming the distance separating the conservation sites (DeVlaming and Proctor 1968, Agami and Waisel 1986, Galatowitsch and van der Valk 1996, Lopez et a. 2002, Mueller and van der Valk 2002). Theoretically, wetlands with higher floristic quality and larger open water areas may attract more bird species, which in turn may serve as a vector for seed dispersal, further increasing floristic quality.

Future wetland restoration efforts where plant diversity and wildlife habitat are primary objectives should include introduction of native wetland plant species. This recommendation is especially important for restorations located more than 500 meters from a natural wetland or woodland. Also, active agriculture should not cover more than 50% of the drainage basin to allow development of floristic quality and less invasive plant monocultures. If providing habitat for waterfowl species dependent on large open water areas is of special concern, wetlands should be designed with a larger area that is at least 3-feet (1 meter) deep to provide an area for permanent water not conducive to cattail establishment and persistence.

Physical Functions:

Most of the more sophisticated and detailed modeling of stormwater detention, and water quality functions of the wetland restorations is still underway. We found that it was necessary to develop models for estimating the absolute detention and retention of storm water in the wetlands, because appropriate dynamic models do not exist for these systems. Similarly, models to estimate the absolute retention of sediments and nutrients from runoff in the wetlands have not been applied because availability of the most appropriate software has been delayed. However, the most critical analysis to enable improvement in the design of these wetlands is an understanding of the factors affecting their ability to retain and detain water relative to the size of their surface water drainage basins. We have made considerable progress in estimation of this relative function.

Working with Jeff Stone, we developed methods to convert the 2-foot contour interval shapefiles available as a GIS layer, to the 5-foot digital elevation model (DEM) for the sites, and then to a computerized estimation of boundaries of the surface watershed of each wetland. This delineation of the drainage basin boundaries was critical for much of the other physical function and landscape placement analysis conducted on the wetlands. The ability to delineate wetland watershed boundaries within the GIS is a major advance.

The storage capacity of the 106 wetlands studied indicates that at a –15 cm draw down stage they have an average capacity to store 1.85 cm of runoff from their drainage basins with a range of storage capacity from less than 0.1 cm to over 9 cm of runoff from the basin at the –15 cm stage (Appendix B, Figure 5a). An average ability to retain 1.85 cm of runoff from the entire drainage basin at only a –15 cm draw down below the seldom obtained "full" level, is an impressive amount of designed storage capacity for this population of wetlands as a whole.

There is, however, room for improvement in the design of individual wetland to perform a stormwater retention function. There are 34 wetlands in the study group with the capacity to retain less than 1.0 cm of runoff at a –15 cm draw down (Appendix B, Figure 5a). Most of these wetlands could probably have been constructed to be somewhat larger, or placed somewhat higher in their watersheds so that their water retention capacity more closely matched the size of the drainage basin. It is this set of wetlands that would be expected to exceed capacity and overflow frequently. They are therefore expected to be less effective at all the water quality functions, since the temporarily stored nutrients and sediments may regularly be flushed from the system during storm events.

There are also some examples of the opposite extreme of capacity not matching loading from the watershed. There are three wetlands that have the capacity to retain over 5 cm (2") of runoff from the entire watershed with only a –15 cm draw down starting condition (Appendix B, Figure5a). These wetlands may represent a more efficient use of resources if they were located lower in their watersheds. They may also have a tendency to dry out frequently if they are not groundwater supported, because the amount of surface water reaching the wetland is likely to be inadequate to maintain hydrology.

It will be useful for wetland designers to study these wetlands that are a less than optimal fit to the stormwater runoff loading from their watersheds (Appendix B). Using these wetlands as a study group for examples of how design can be improved with respect to the stormwater retention function will be very useful for developing improved design criteria. Analysis of these wetlands can help inform our future wetland restorations.

<u>Monitoring & Management:</u>

Most landowners plan to maintain their wetland restorations well beyond the contract period and many are considering restoring additional wetlands and/or establishing other conservation practices (Appendix H). Contingent on this decision is the availability of maintenance advice and support. We were rarely denied access to our randomly selected wetland sites; the large majority of landowners were eager to have their wetland(s) visited and assessed. Concerns recorded in the landowner survey (Appendix H) are representative of those voiced personally by the landowners during our site visits. Concerns voiced most often include invasive plant species and low/fluctuating water levels. Allen and Vandever (2003) reported similar results in their national survey of Conservation Reserve Program participants. The authors found that many landowners are willing to implement management to maintain floristic quality and wildlife habitat and seek advice and assistance to do so. Most issues can be addressed by sharing information with the landowners such as invasive plant species identification and management, as well as the different ecosystem services provided by wetlands that are seasonally verses permanently inundated. Addressing these common concerns promotes landowner appreciation for the unique characteristics of their wetland site(s), which in turn, encourages landowners to maintain the wetland in our county landscape.

Keeping in mind the lack of agency field staff relative to the number of wetlands restored on private lands, we developed a practical monitoring program, which can be implemented for Ozaukee County by one individual on a part-time, seasonal basis (Appendix G). Utilizing the GIS Wetland Restoration Inventory database and digital map layers, current landowner and land use information will be updated each year. Physical functions will be assessed utilizing the updated geodatabase and modifying our existing models as more sophisticated models become available. Thirty wetland sites will be systematically selected (each site will be visited approximately every ten years) and the landowner contacted to offer advice and field assessment. With landowner permission, field visits will allow collection of data to measure biological condition (Appendix G).

These “conservation” wetlands are a complex of newly created resource patches. Because they were not designed to achieve pre-settlement conditions, their biological and physical functions are often discounted. Alternatively, these potentially temporary wetlands can be viewed as ecological experiments from which we can evaluate ecological theory, thereby advancing the field of Restoration Ecology. Although this was not a goal of the agencies or landowners, there is much ecologists can learn from these experiments that may inform future conservation policy and practice. The methods developed in this project will allow long-term assessment and monitoring efforts in Ozaukee County as well as other counties where aggressive efforts have been made to restore small wetlands on private lands. Continued assessment and communication with landowners enables adaptive decision-making for improving wetland restoration programs such as establishing guidelines for maintaining existing and restoring future wetlands that will develop and provide a high degree of function, or ecosystem services.

9. REFERENCES:

Agami,Y and Waisel,Y. 1986. The Role of Mallard Ducks (*Anas platyrhynchos*) in Distribution and Germination of Seeds of the Submerged Hydrophyte *Najas marina* L. Oecologia 68:473-475.

Allen, A.W. and Vandever, M.W. 2003. A National Survey of Conservation Reserve Program (CRP) Participants on Environmental Effects, Wildlife Use, and Vegetation Management on Program Lands. Biological Science Report, USGS/BRD/BSR-2003-0001.

Bartoldus, C.C. 1999. A Comprehensive Review of Wetland Assessment Procedures: A Guide for Wetland Practitioners. St. Michaels, MD: Environmental Concern Inc.

Bernthal, T.W. 2003. Development of a Floristic Quality Assessment Methodology for Wisconsin. Wisconsin Department of Natural Resources, Bureau of Fisheries Management and Habitat protection, Madison, WI.

Bernthal, T.W. and Willis, K.G. 2004. Using Landsat 7 Imagery to Map Invasive Reed Canary Grass (*Phalaris arundinacea*): A Landscape Level Wetland Monitoring Methodology.

Brinson, M.M. and Rheinhardt, R.D. 1996. The Role of Reference Wetlands in Functional Assessment and Mitigation. Ecological Applications 6: 69-76.

Brown, S.C. 1999. Vegetation Similarity and Avifaunal Food Value of Restored and Natural Marshes in Northern New York. Restoration Ecology 7: 56-68.

Carter, V., Bedinger, M.S., Novitzki, R.P., and Wilen, W.O. 1979. Water Resources and Wetlands. In: Greeson, P.E., Clark, J.R. & Clark J.E. (Eds.) Wetland Function and Values: the State of Our Understanding. Proc. Nat. Symp. On Wetlands, Lake Buena Vista, FL. Amer. Water Resources Assoc., Minneapolis, MN.

Cedfeldt, P.T., Watzin, M.C, and Richardson, B.D. 2000. Using GIS to Identify Functionally Significant Wetlands in the Northeastern United States. Environmental Management 26 (1): 13-24.

Congalton, R.G. and Green, K. 1999. Assessing the Accuracy of Remotely Sensed Data: Principles and Practices. New York: Lewis.

DeVlaming, U. and Proctor, V.W. 1968. Dispersal of Aquatic Organisms: Viability of Seeds Recovered From the Droppings of Captive Killdeer and Mallard Ducks. American Journal of Botany 55:20-26.

Ehrenfeld, J.G. 1983. The Effects of Changes in Land-use on Swamps of the New Jersey Pine Barrens. Biological Conservation 25: 353-375.

ERDAS 1999. ERDAS Imagine Field Guide (5th ed.) Atlanta GA: ERDAS.

Galatowitsch, S.M. and van der Valk, A.G. 1996. Characteristics of Recently Restored Wetlands in the Prairie Pothole Region. Wetlands 19:733-755.

Gleason, H.A. and Cronquist, A. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. 2nd Ed. New York: New York Botanical Garden.

Hapner J.A. 2003. Factors influencing how small wetland restorations self-design and function as components of the Southeastern Wisconsin landscape. Unpublished data.

Hill, M.O. 1979. DECORANA – A FORTRAN Program for Detrended Correspondence Analysis and Reciprocal Averaging. Ithaca, NY. Ecology and Systematics, Cornell University.

Hinson, J.M., German, C.D. Pulich, W. Jr. 1994. Accuracy Assessment and Validation of Classified Satellite Imagery of Texas Coastal Wetlands. Mar. Technol. Soc. J. 28-2:4-9.

Jenson, J.R. 2005. Introductory Digital Image Processing. 3rd Ed. Prentice Hall: New Jersey.

Johnston, C.A. 1994. Cumulative Impacts to Wetlands. Wetlands 14 (1): 49-55.

Johnston, C.A., Dentenbeck, N.E., and Niemi, G.J. 1990. The Cumulative Effect of Wetlands on Stream Water Quality and Quantity: A Landscape Approach. Biogeochemistry 10 (2): 105-142.

Karr, J.R. and Chu, E.W. 1999. Biological Monitoring and Assessment: Using Multimetric Indexes Effectively. Island Press: Covelo, CA.

Kentula, A., Brooks, R., Gwin, S., Holland, C., Sherman, A., and Sifneos, J. 1993. An Approach to Improving Decision Making in Wetland Restoration and Creation. U.S. Environmental Protection Agency Publication.

Lachowski, H., Maus, P., and Roller, N. 2000. From Pixels to Decisions. Digital Remote Sensing Technologies for Public Land Managers. Journal of Forestry 98:13-15.

Leithoff, K. 1997. Wildlife Usage of Small Created and Restored Wetlands in Ozaukee County, Wisconsin. M.S. Thesis. University of Wisconsin-Milwaukee.

Lillie, R.A., Garrison, P. Dodson, S.I., Bautz, R.A., and LaLiberte, G. 2002. Refinement and Expansion of Wetland Biological Indices for Wisconsin. WDNR Final Report to USEPA – Region V, Madison, WI.

Lopez, R.D, Davis, C.B., and Fennessy, M.S. 2002. Ecological Relationships Between Landscape Change and Plant Guilds in Depressional Wetlands. Landscape Ecology 00: 1-14.

McAllister, L.S., Penistone, B.E., Leibowitz, S.G. Abbruzzese, B. and Hyman, J.B. 2000. A Synoptic Assessment for Prioritizing Wetland Restoration Efforts to Optimize Flood Attenuation. Wetlands 20 (1): 70-83.

Miller, R. 1994. Classifying Lower Colorado River Basin Lands Using Satellite Imagery. U.S. Dept. of the Interior, Bureau of Reclamation, Applied Sciences Branch, Denver, CO.

Mueller, E. 1997. Mapping Riparian Vegetation Along Rivers; Old Concepts and New Methods. Aquatic Botany 58-3-4:317-332.

Mueller, M. and van der Valk, A.G. 2002. The Potential Role of Ducks in Wetland Seed Dispersal. Wetlands 22 (1): 170-178.

Nagendra, H. and Gadgil, M. 1999. Satellite Imagery as a Tool for Monitoring Species Diversity: An Assessment. Journal of Applied Ecology 36:388-397.

National Research Council (NRC). 2001. Compensating for Wetland Losses Under the Clean Water Act. Washington, DC: National Academy Press.

Novitzki, R.P. 1979. Hydrologic Characteristics of Wisconsin's Wetlands and Their Influence on Floods, Stream Flow, and Sediment. In: Greeson, P.E., Clark, J.R. & Clark J.E. (Eds) Wetland Function and Values: the State of Our Understanding. Proc. Nat. Symp. On Wetlands, Lake Buena Vista, FL. Amer. Water Resources Assoc., Minneapolis, MN.

Ogawa, H. and Male, J.W. 1986. Simulating the Flood Mitigation Role of Wetlands. Journal of Water Resources Planning and Management 112:114-128.

Potter, K.W. 1994. Estimating Potential Reduction Flood Benefits of Restored Wetlands. Water Resources Update 97: 34-38.

Reed, P.B. 1997. Revision of the National List of Plant Species that occur in Wetlands. Washington, DC, U.S. Department of the Interior, U.S. Fish and Wildlife Service.

Reinartz, J.A., and Warne, E.L. 1993. Development of Vegetation in Small Created Wetlands in Southeastern Wisconsin. Wetlands: 13 (3): 155-164.

Rheinhardt, R.D., Rheinhardt, M.C., Brinson, M.M., and Faser, K.E. 1999. Application of Reference Data for Assessing and Restoring Headwater Ecosystems. Restoration Ecology 7: 241-251.

Robbins, S.D. 1991. Wisconsin Birdlife Population and Distribution: Past and Present. University of Wisconsin Press. Madison, WI.

Rowlinson, L.C., Summerton, M., and Ahmed, F. 1999. Comparison of Remote Sensing Data Sources and Techniques for Identifying and Classifying Alien Invasive Vegetation in Riparian Zones. Water S.A. 25-4:497-500.

Seabloom, E.W. and Van der Valk, A.G. 2003. Plant Diversity, Composition, and Invasion of Restored and Natural Prairie Pothole Wetlands: Implications for Restoration. Wetlands 23 (1): 1-12.

Smith, R.D., Ammann, A., Bartolus, C, and Brinson, M. 1995. An Approach for Assessing Wetland Functions Using Hydromorphic Classification, Reference Wetlands, and Functional Indices. Wetland Research Program Tech. Report WRP-DE-9. Vicksburg, MS: U.S. Army Corps of Engineers, Waterways Experiment Station. Available online: http://www.wes.army.mil/el/wetlands/wlpubs.html.

Spanglet, H.J., Ustin, S.L., and Rejmankovz, E. 1998. Spectral Reflectance Characteristics of California Subalpine Marsh Plant Communities. Wetlands 18-3:307-319.

Stein, E.D., Tabatabai, F., and Ambrose, R.F. 2000. Wetland Mitigation Banking: A Framework for Crediting and Debiting. Environmental Management 26: 233-250.

SYSTAT, 1998. SYSTAT Version 9 for Windows. SPSS, Inc

U.S. Department of Transportation (USDOT). 1983. A Method for Wetland Functional Assessment. Vol.1. Report No. FHWA-IP-82-23. National Technical Information Service. Springfield, VA.

U.S. EPA. 2002a. Methods for Evaluating Wetland Condition: Using Vegetation to Assess Environmental Conditions in Wetlands. Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA-822-R-02-020.

U.S. EPA. 2002b. Methods for Evaluating Wetland Condition: Land-Use Characterization for Nutrient and Sediment Risk Assessment. Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA-822-R-02-025.

U.S. EPA. 2002c. Methods for Evaluating Wetland Condition: Vegetation-Based Indicators of Wetland Nutrient Enrichment. Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA-822-R-02-025.

U.S. EPA. 2003. Elements of a Wetland Monitoring and Assessment Program. Draft.

White, P.S. and Walker, J.L. 1997. Approximating Nature's Variation: Selecting and Using Reference Information in Restoration Ecology. Restoration Ecology 5: 338-349.

Wolter, P.T., Mladenoff, D.J., Host, G.E., and Crow, T.R. 1995. Improved Forest Classification in the Northern Lake States Using Multi-Temporal Landsat Imagery. Photogrammetric Engineering & Remote Sensing. 16-9:1129-1143.

Woo, I. and Zedler, J.B. 2002. Can Nutrients Alone Shift a Sedge Meadow Towards Dominance by the Invasive Typha x Glauca? Wetlands 22 (3): 509-521.

Yoder, C.O. and Rankin, E.T. 1995. Biological Criteria Program Development and Implementation in Ohio. In: Davis, W.S., Simon, T.P. (Eds). Biological Assessment and Criteria, Tools for Water Resource Planning and Decision Making. CRC Press: Boca Raton, FL.

Zedler, J.B. 2003. Wetlands at your service: reducing impacts of agriculture at the watershed scale. Frontiers in Ecology and the Environment 1 (2): 65-72.

10. ACKNOWLEDGEMENTS:

We would like to thank the following individuals (listed alphabetically) for their contributions to this project:

- Damon Anderson, Ozaukee County Land Information Department
- Lori Artiomow, Ecological Renaissance
- Tom Bernthal, Wisconsin Department of Natural Resources
- Dr. Gary Casper, Milwaukee Public Museum
- Dr. Noel Cutright, WeEnergies
- Donalea Dinsmore, Wisconsin Department of Natural Resources
- Dr. Millicent Ficken, University of Wisconsin - Milwaukee
- Dr. Glen Fredlund, University of Wisconsin - Milwaukee
- Cathy Garra, U.S. Environmental Protection Agency - Region 5
- Steve Hovick, University of Wisconsin - Milwaukee
- Art Kitchen, United States Fish & Wildlife Service
- Dr. Val Klump, Great Lakes WATER Institute
- Rhonda Krueger, United States Fish & Wildlife Service
- Ivan (Ike) Kumrow, Wisconsin Department of Natural Resources
- Daniel Lynch, Natural Resources Conservation Service
- Peter Maier, University of Wisconsin - Milwaukee
- William Mueller, Wisconsin Society for Ornithology
- Travis Olson, Wisconsin Coastal Management Program
- Dr. Kenneth Potter, University of Wisconsin - Madison
- Dr. James Reinartz, University of Wisconsin – Milwaukee Field Station
- Armin Schwengel, Wisconsin Department of Natural Resources

- Missy Sparrow, Wisconsin Department of Natural Resources
- Robert Weihrouch, Natural Resources Conservation Service
- Dorothy Wormbly, U.S. Environmental Protection Agency - Region 5
- Dr. Joy Zedler, University of Wisconsin - Madison
- Ozaukee County wetland restoration landowners

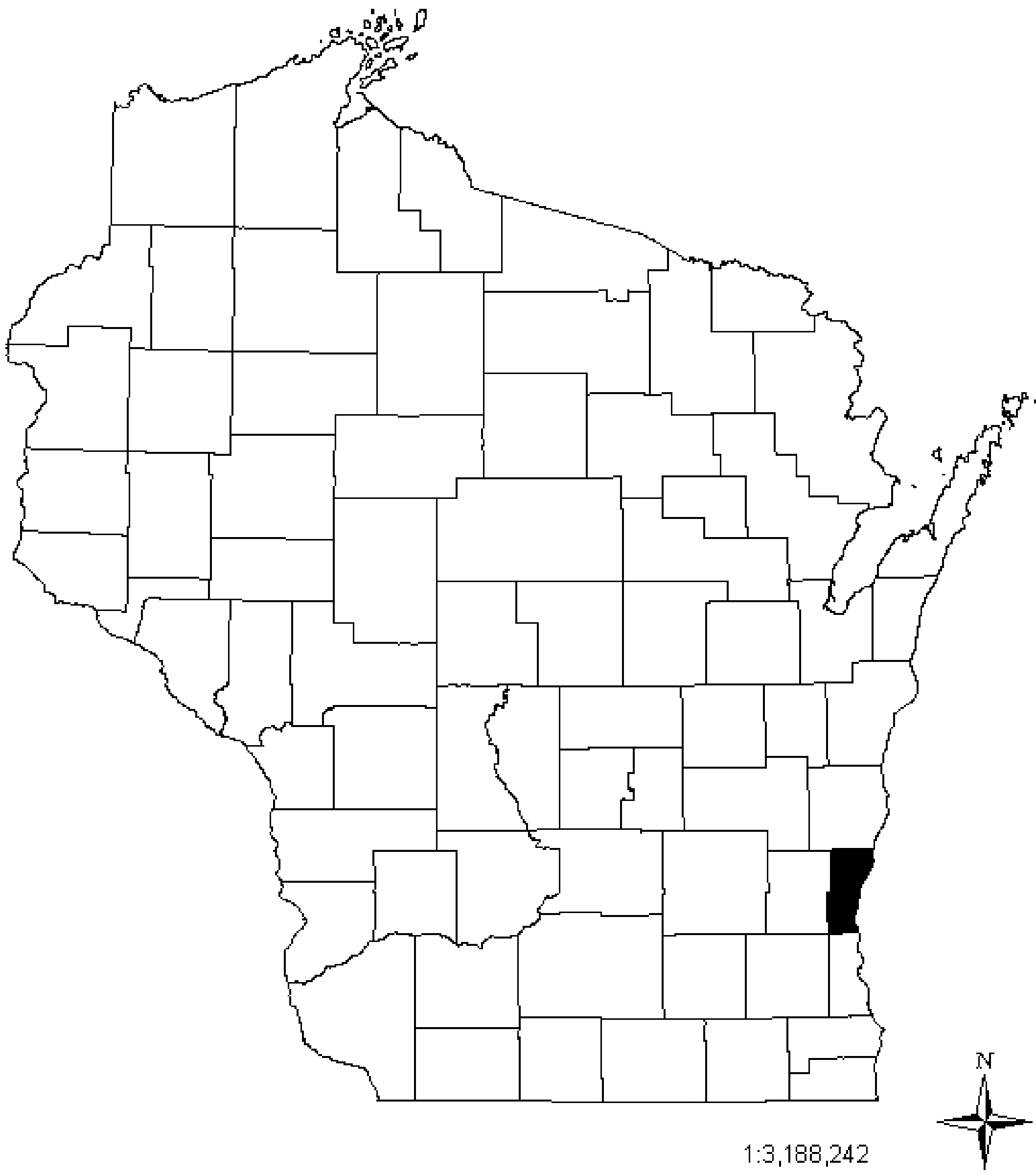


Figure 1. Location of Ozaukee County in southeastern Wisconsin.

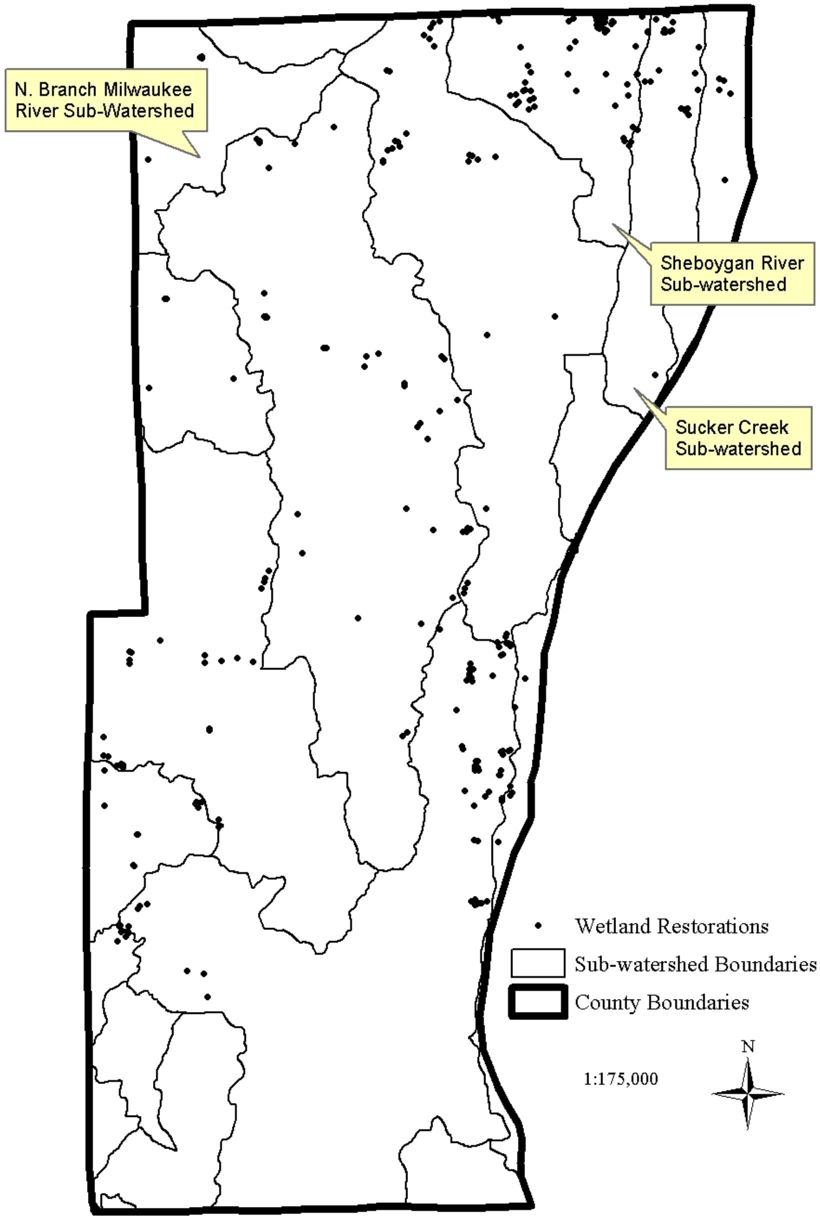


Figure 2. Location of wetland restorations within Ozaukee County sub-watersheds.

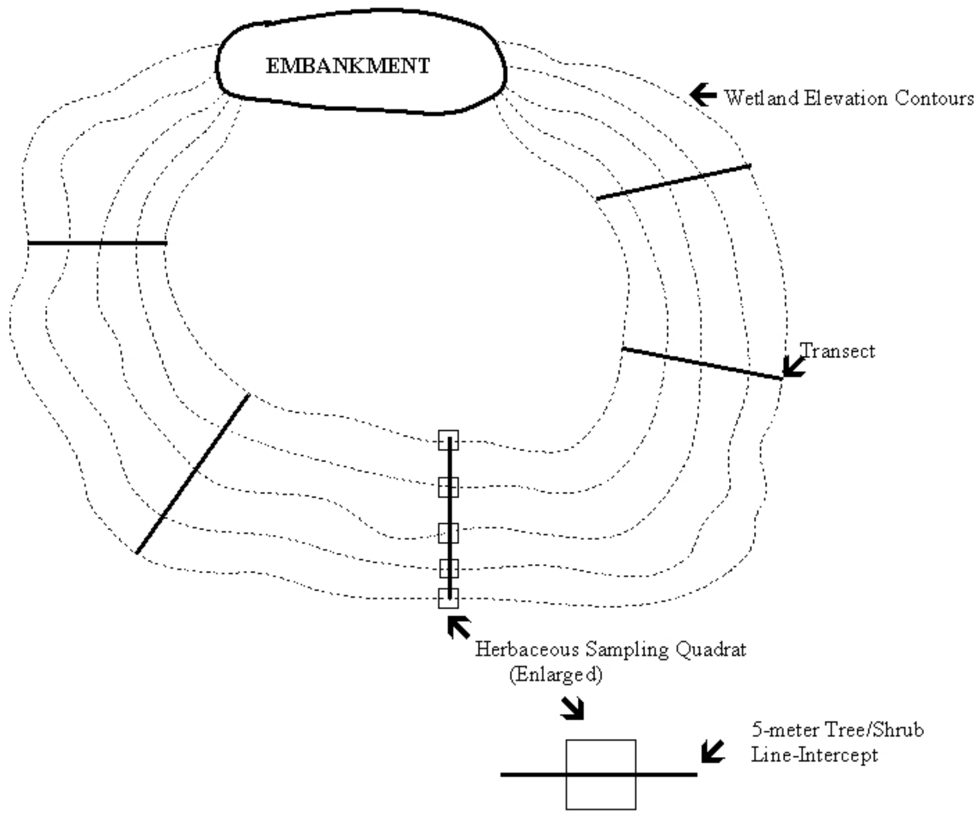


Figure 3. Aerial diagram of sampling scheme for wetland vegetation. Quadrats were placed along a hydrologic gradient, yielding 25 quadrats per wetland.

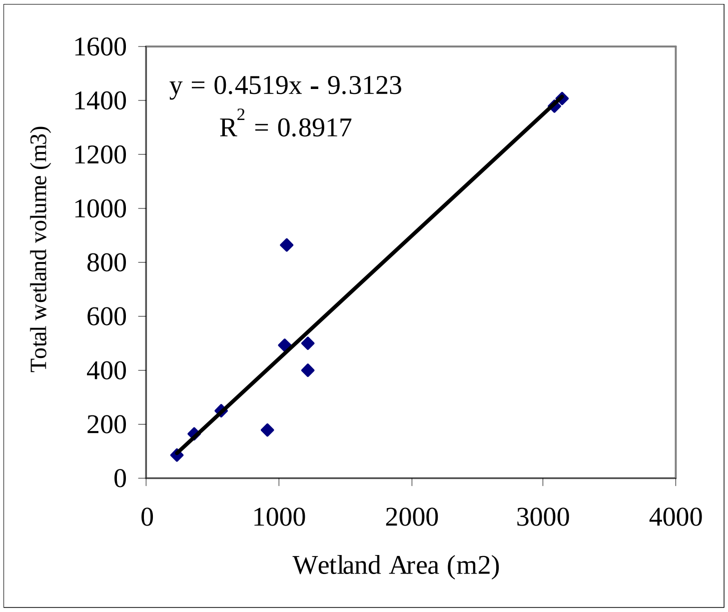


Figure 4a. Relationship between wetland area and total wetland volume.

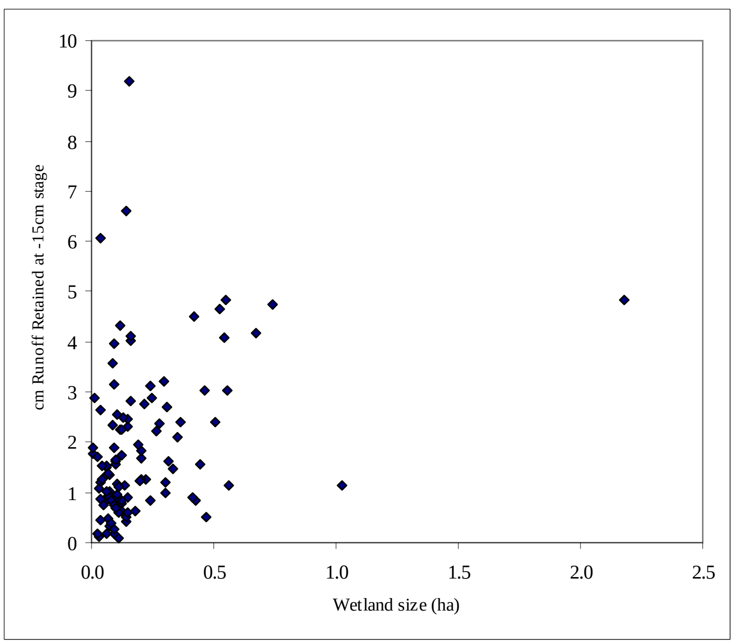


Figure 4b. Relationship between wetland area and storage capacity at –15 cm stage.

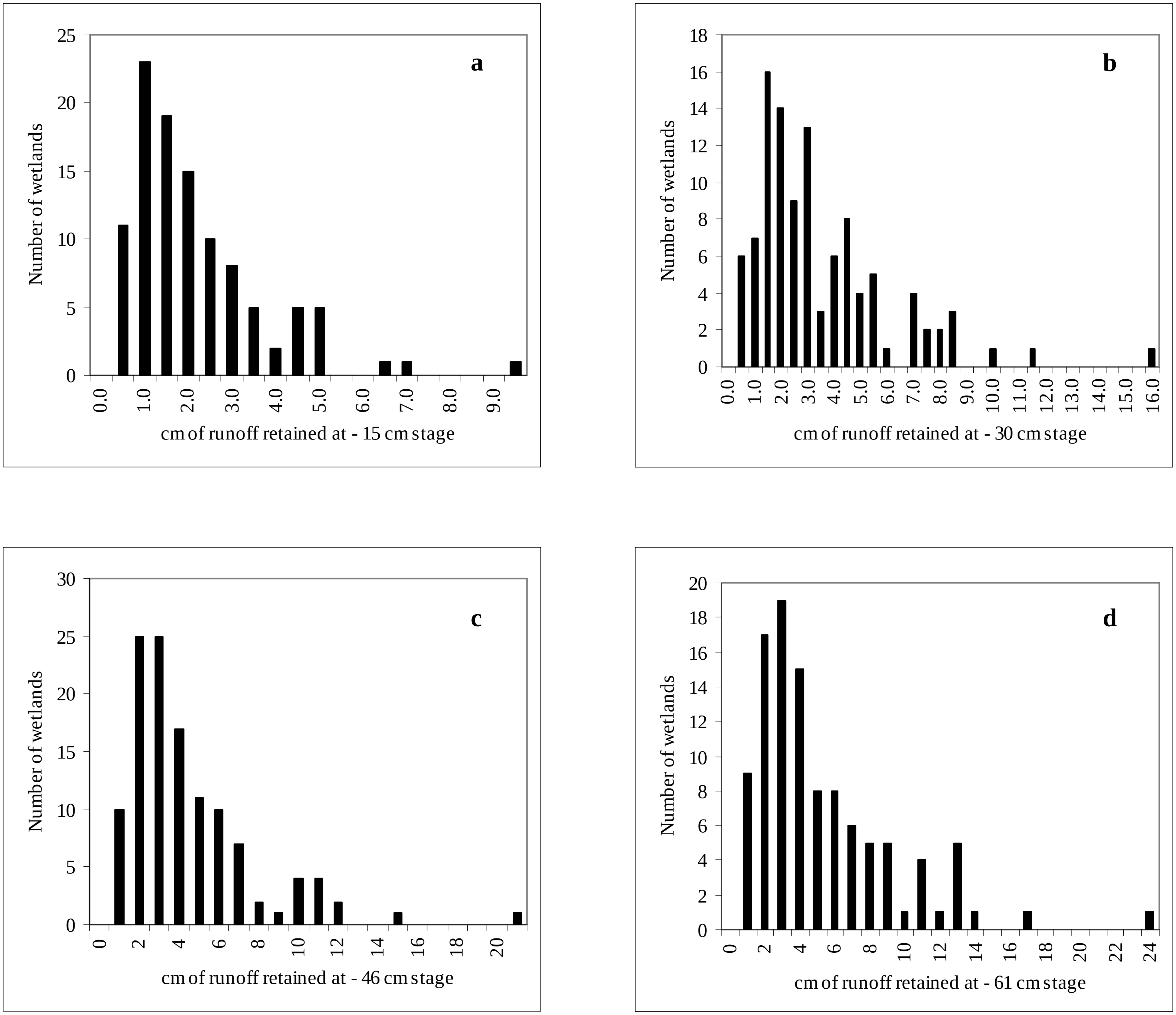


Figure 5. Number of wetlands and corresponding capacity for runoff retained at 15, 30, 46, and 61 cm draw down of total wetland volume.

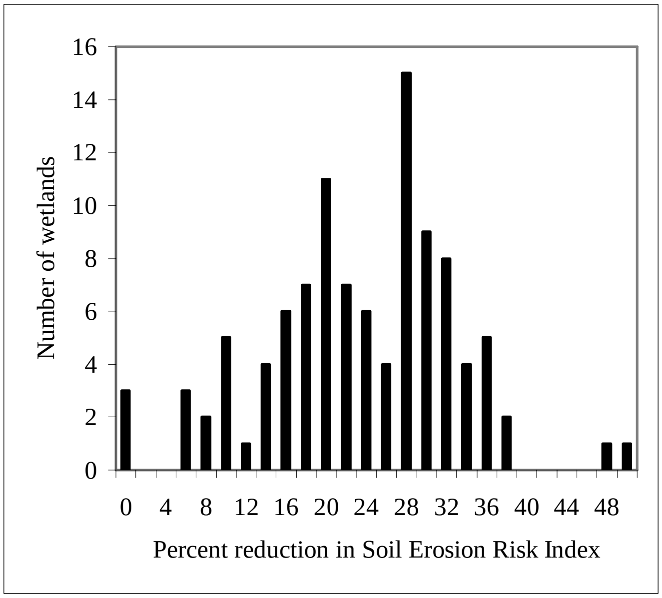


Figure 6. Frequency distribution of the number of wetland restorations providing different percentage reductions in the modeled Soil Erosion Risk Index. See text for methods of calculation of the index.

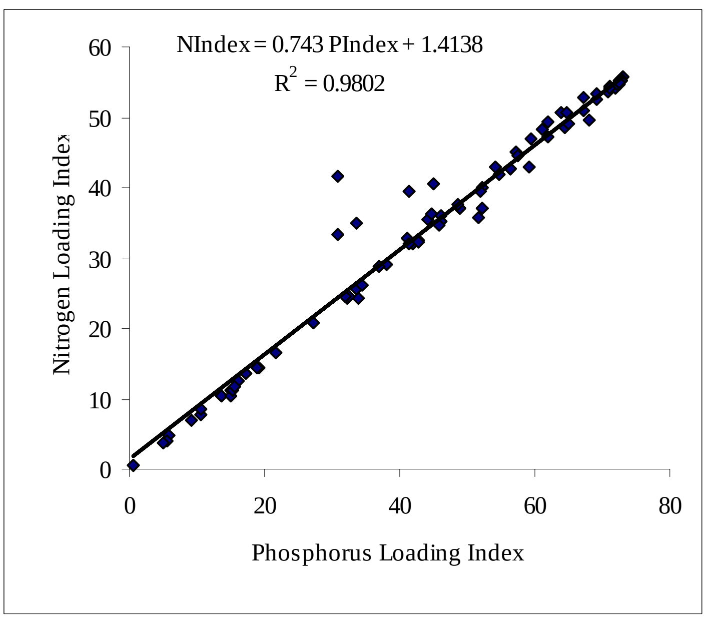


Figure 7. Relationship between phosphorus and nitrogen indices.

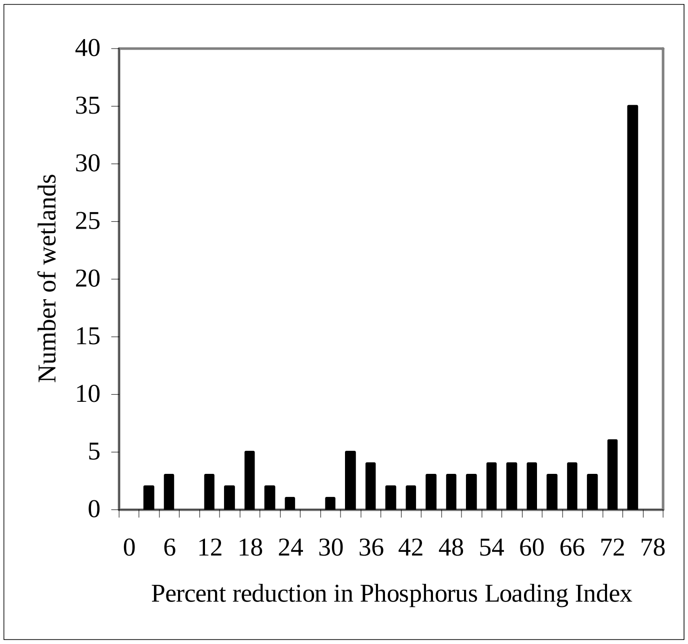


Figure 8. Frequency distribution of the number of wetland restorations providing different percentage reductions in the Phosphorus Loading Index. See text for calculation of the index.

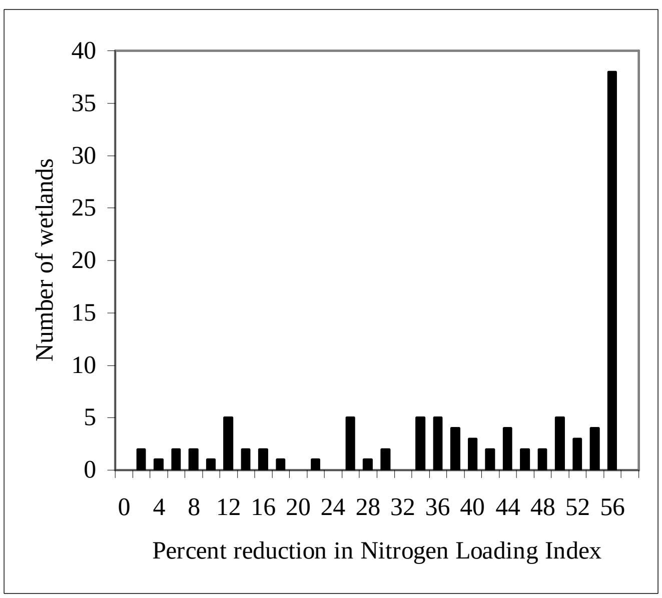


Figure 9. Frequency distribution of the number of wetland restorations providing different percentage reductions in the Nitrogen Loading Index. See text for calculation of the index.

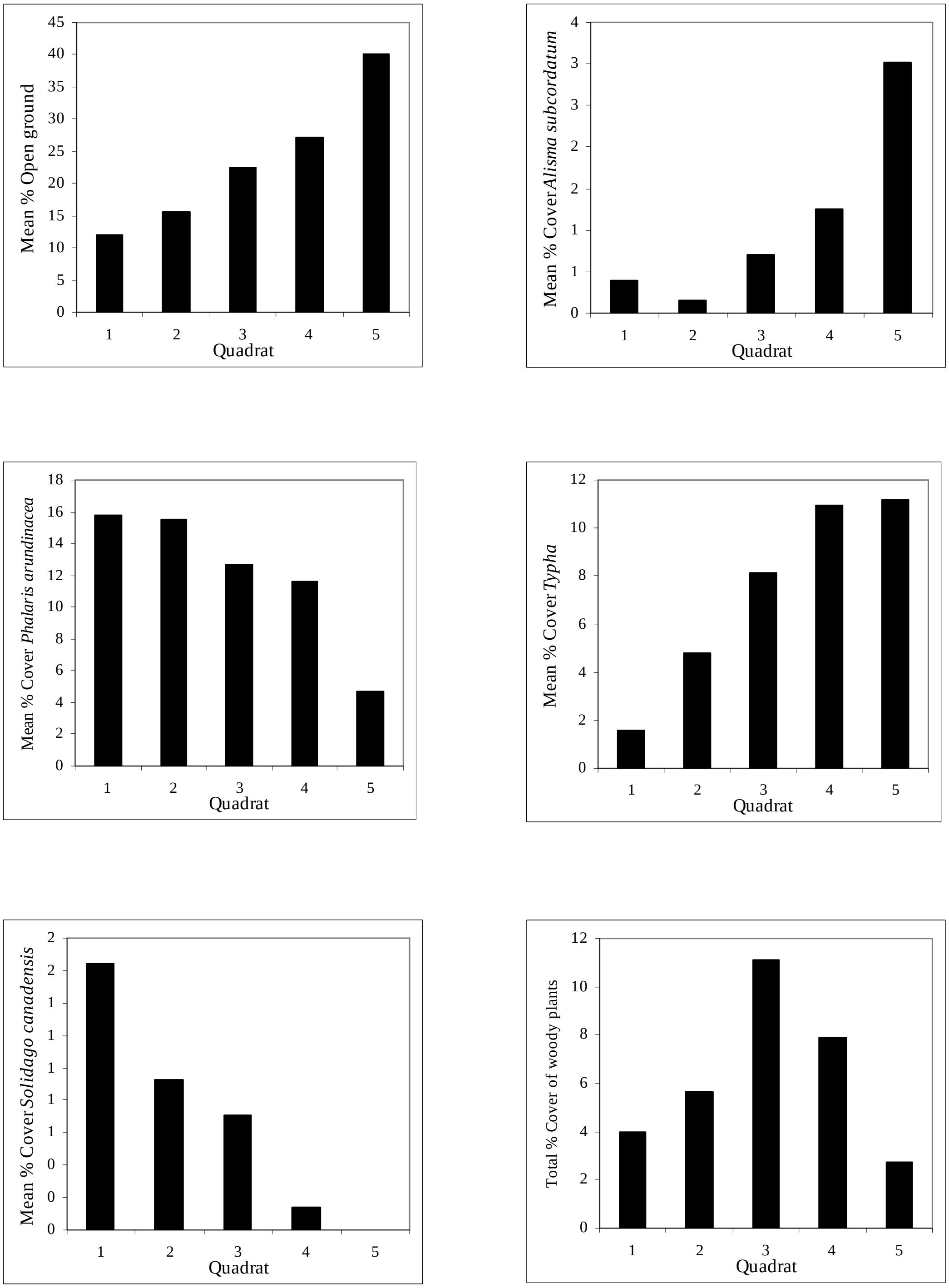


Figure 10. Mean percent cover of open ground, water plantain (*Alisma subcordatum*), reed canary grass (*Phalaris arundinacea*), cattail (*Typha* spp.), Canada goldenrod (*Solidago canadensis*), and woody vegetation (dbh of 2.5 cm or more) in sampling quadrats 1 through 5 of 120 wetland sites.

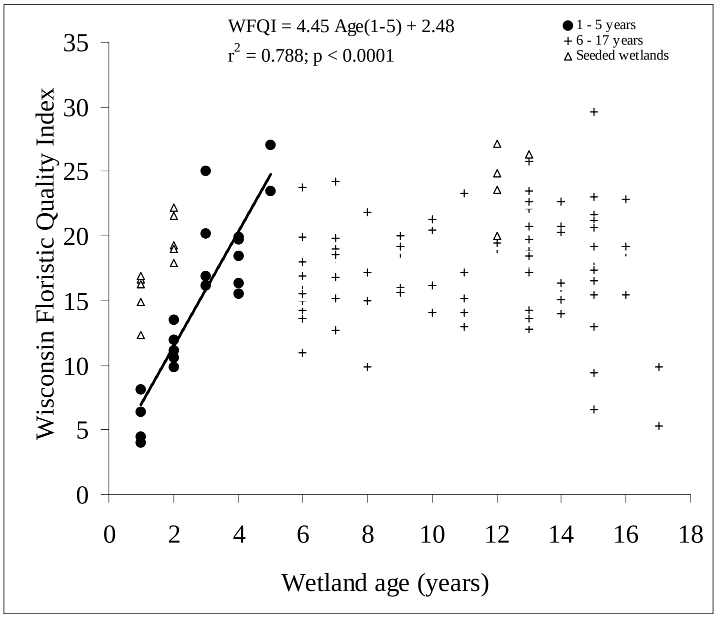


Figure 11. Relationship between wetland age (years since construction) and Wisconsin Floristic Quality Index. The regression of WFQI on age is shown for wetlands 1 to 5 years old (solid circles).

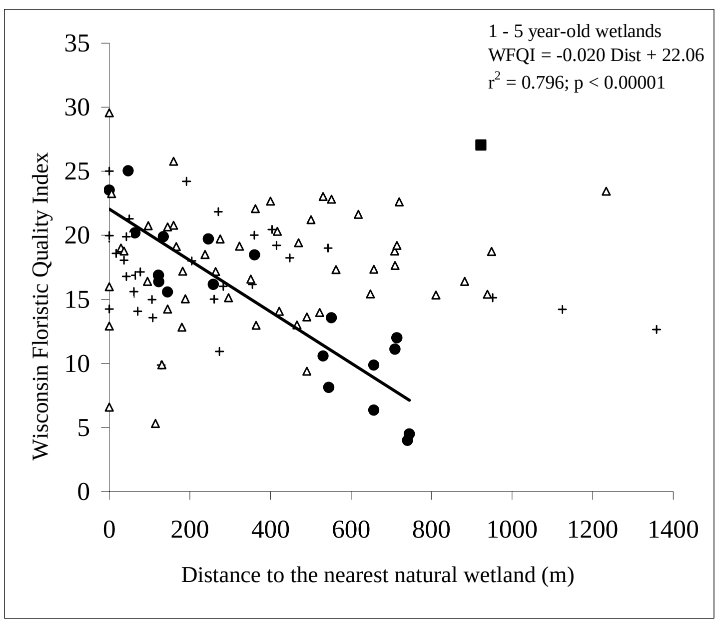


Figure 12. Relationship between distance to the nearest natural wetland and the Wisconsin Floristic Quality Index. The linear regression line and equation shown are for wetlands 1 to 5 years of age (filled circles). Wetlands 6 – 10 (plus signs) and 11 – 17 (triangles) years of age do not have a significant relationship between WFQI and the distance to woods. One, five year old wetland (solid square) was an outlier and was removed from the data before regression.

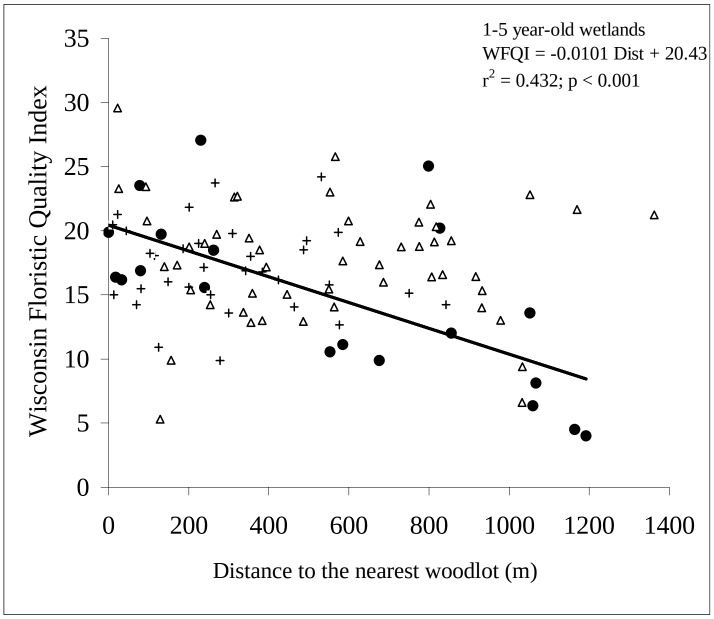


Figure 13. Relationship between distance to the nearest upland woodlot and the Wisconsin Floristic Quality Index (WFQI). The linear regression line and equation shown are for wetlands 1 to 5 years of age (circles). Wetlands 6 to 10 (plus signs) and 11 to 17 (triangles) years of age do not have a significant relationship between WFQI and distance to woodlots.

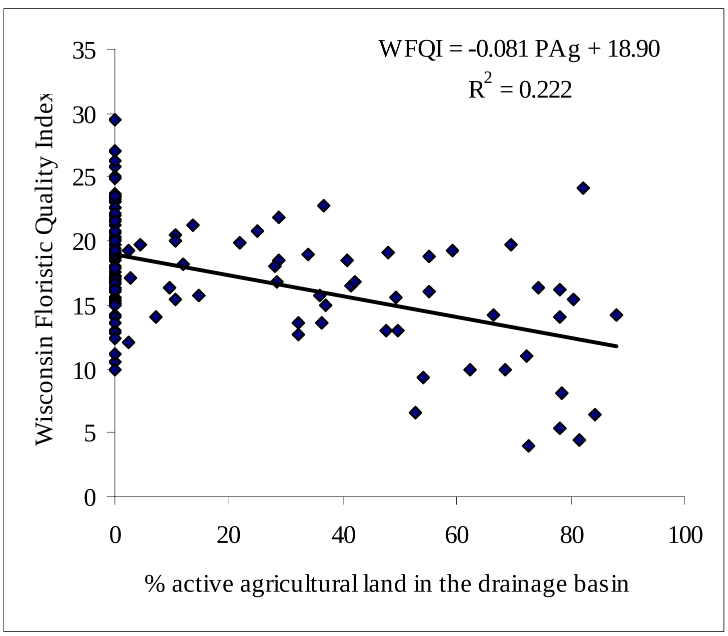


Figure 14. Relationship between percent active agricultural practice in the drainage basin and the Wisconsin Floristic Quality Index.

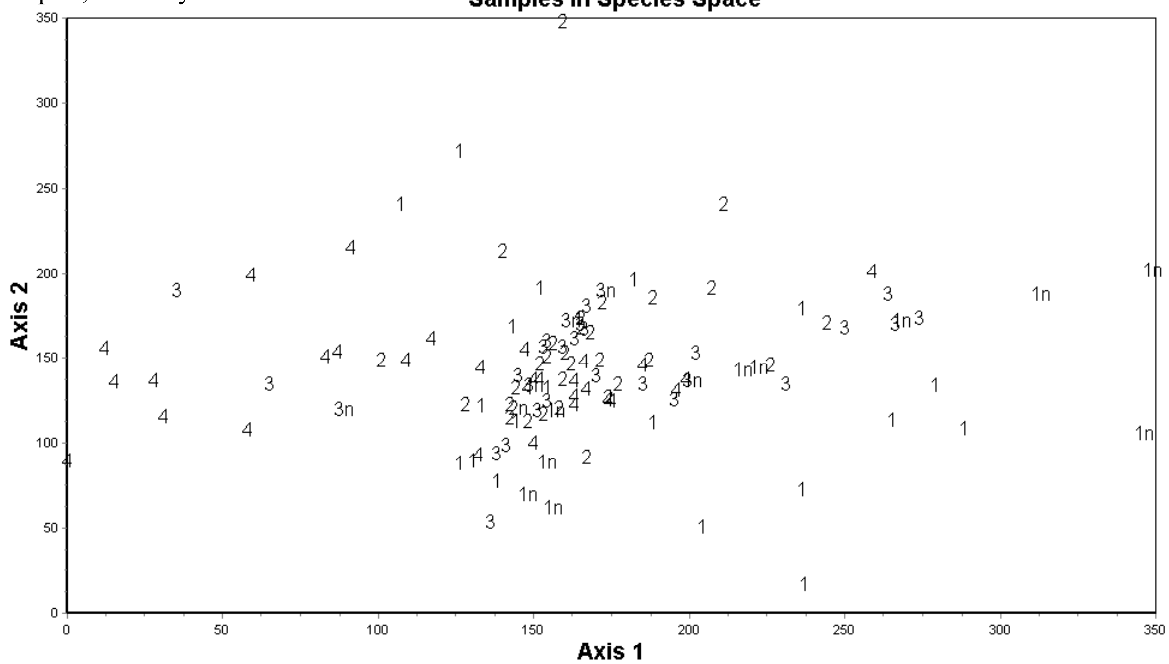


Figure 15. DECORANA ordination of sampling quadrat #3 data in 120 wetlands. The four age classes are indicated: 1 = ages 1-5 years, 2 = 6-9 years, 3 = 10-13 years, 4 = 14-17 years, (n = native planting).

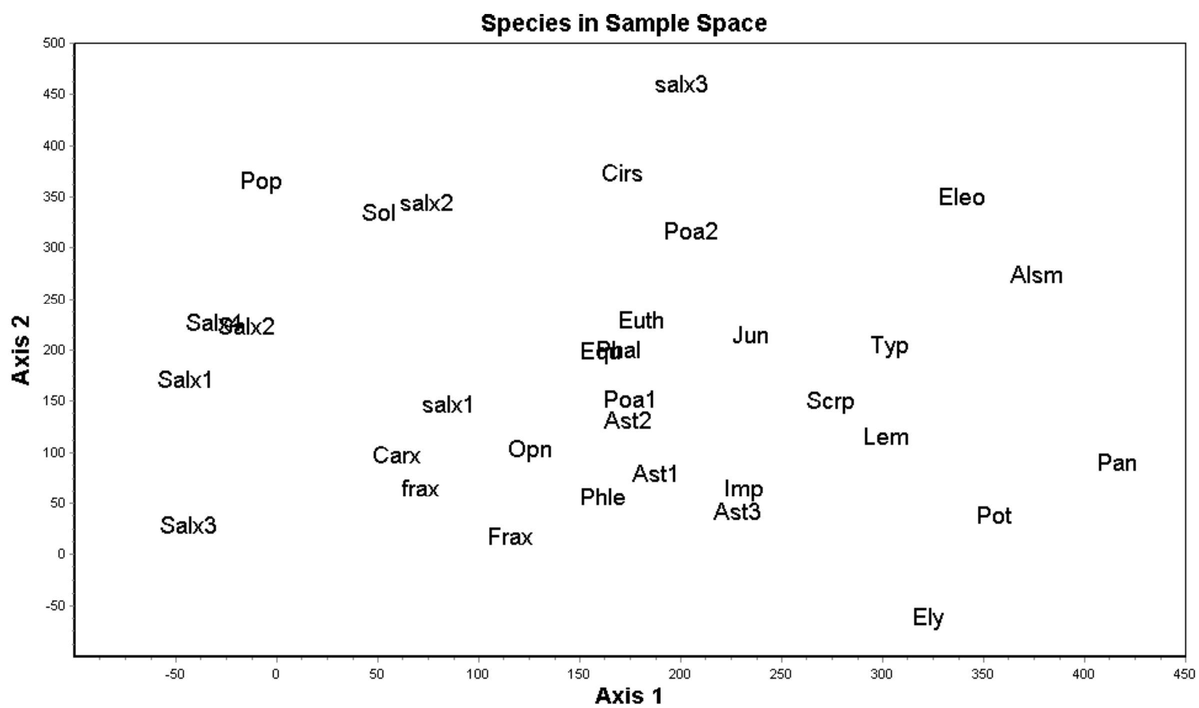


Figure 16. DECORANA ordination of 34 species with a mean percent cover of 0.25% or more in sampling quadrat #3. Codes identify species and are keyed in Table 6.

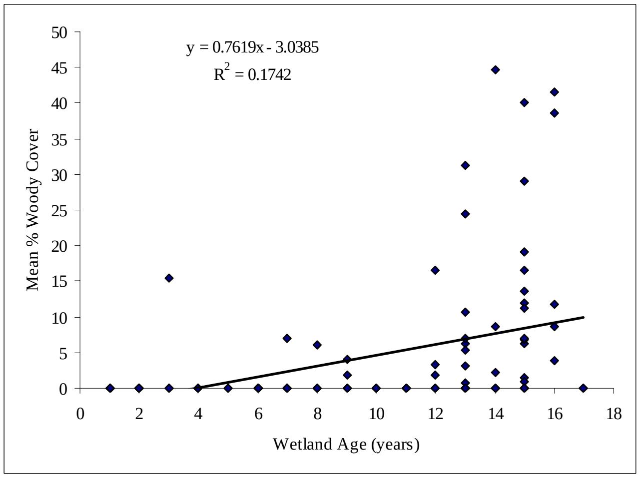


Figure 17. Relationship between wetland age and mean percent woody vegetation cover (dbh of 2.5 cm or more).

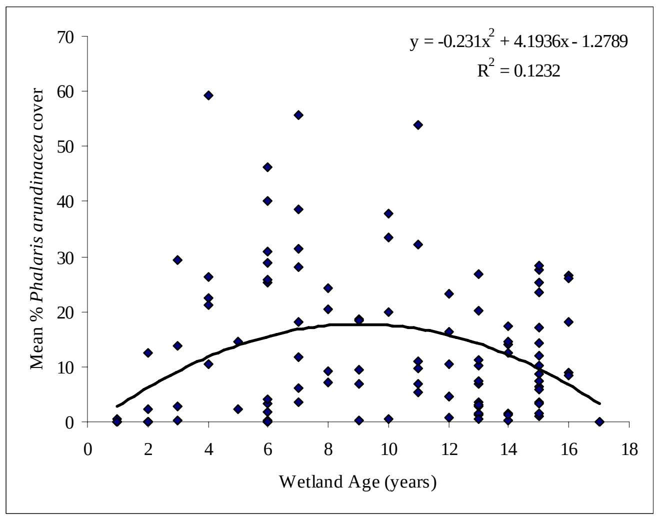


Figure 18. First order polynomial regression representing the relationship between wetland age and mean percent reed canary grass (*Phalaris arundinacea*) cover

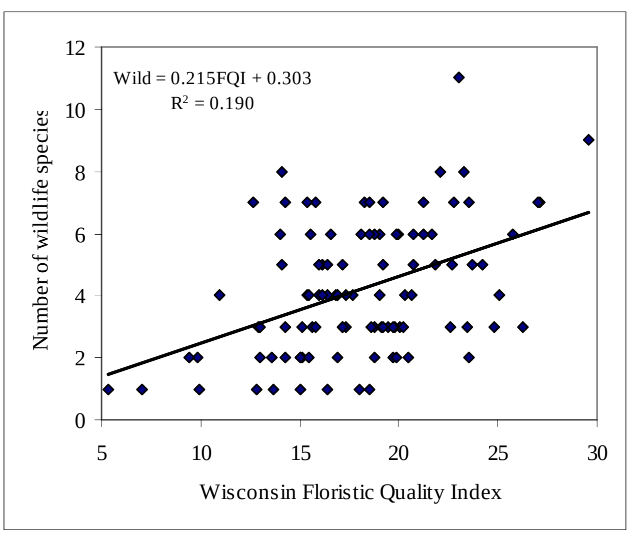


Figure 19. Relationship between Wisconsin Floristic Quality Index and number of wildlife species recorded during site visits whose presence is determined to rely on the wetland/upland buffer restoration practice.

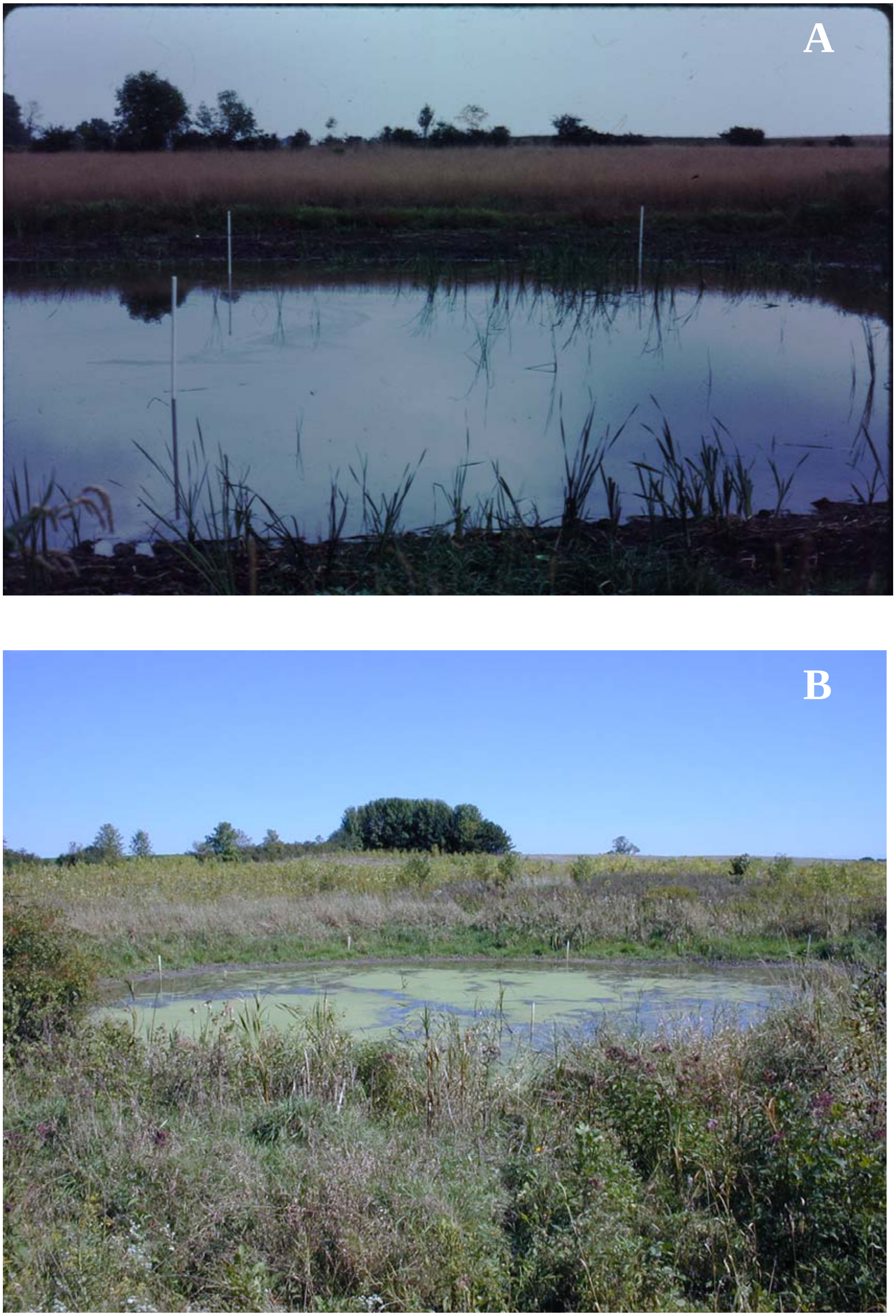


Figure 20. Wetland one year following restoration (A), and eleven years following restoration (B).

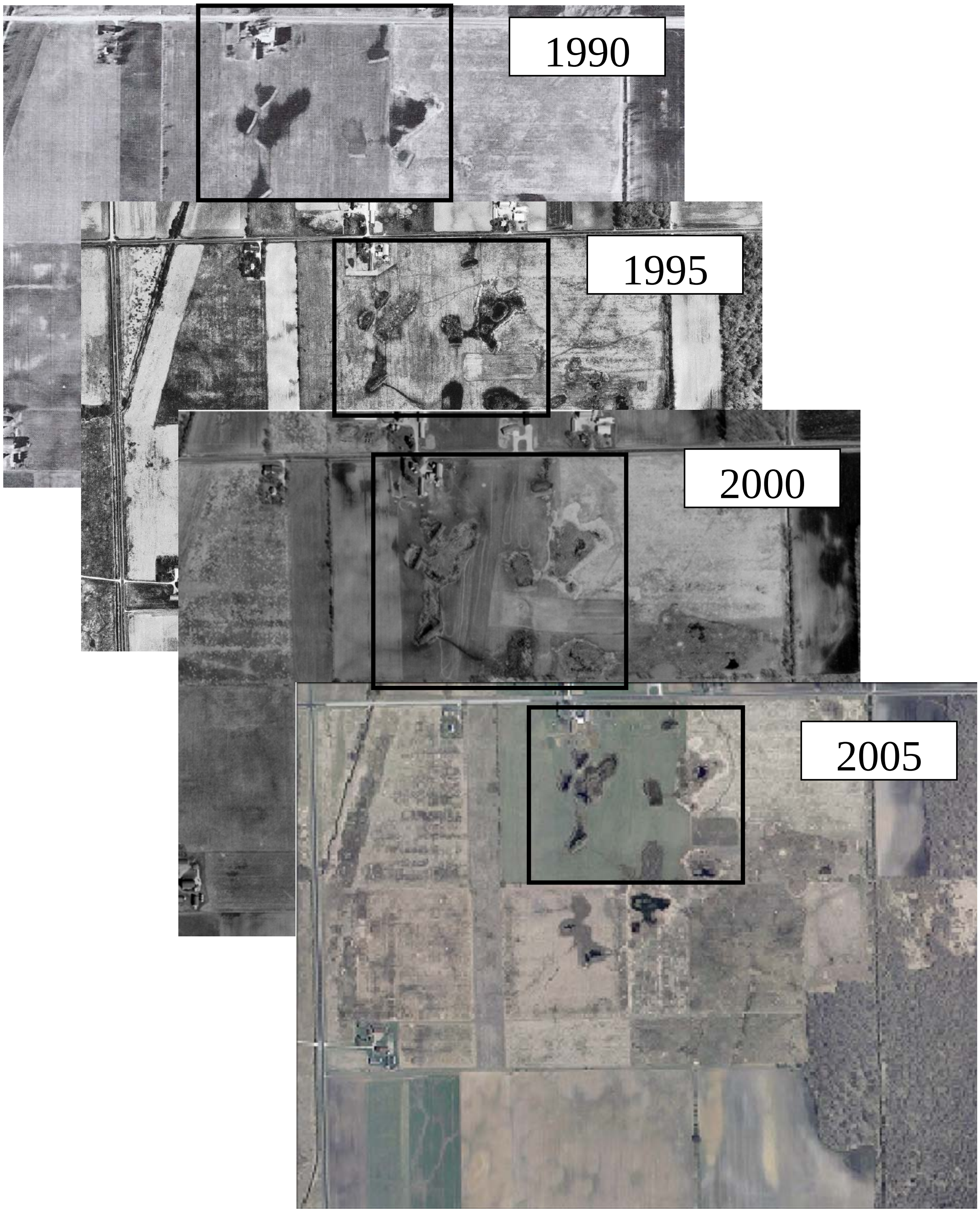


Figure 21. Aerial photography of wetlands restored in 1989. As the wetlands age, open water is often replaced with cattail (*Typha* spp.) monocultures.

Figure 22. Woody vegetation established in the third sampling quadrat of a 16 year old wetland restoration.

Table 1. Twenty-one plant species introduced to 5 wetlands in 1991: * observed only in 1991-1992, ** observed only during 2002-2004, + commonly observed in unseeded sites during 2002-2004, species listed in bold observed during both surveys, *Potentilla palustris* unobserved in both surveys.

Species	**Common Name**
***Alisma subcordatum* +**	Water plantain
***Asclepias incarnata* +**	Marsh milkweed
Carex aquatilis **	Sedge
C. bebbii	Sedge
C. comosa	Sedge
C. lacustris	Sedge
*C. lasiocarpa***	Sedge
***C. retrorsa* +**	Sedge
C. rostrata	Sedge
C. stipata	Sedge
***Cornus sericea* +**	Red-osier dogwood
***Eupatorium maculatum* +**	Joe-pye weed
Glyceria grandis	Mannagrass
Juncus nodosus	Rush
*Pontederia cordata**	Pickerel-weed
Potentilla palustris	Marsh-potentilla
Sagittaria latifolia	Arrowhead
***Scirpus atrovirens* +**	Dark green bulrush
***S. validus* +**	Softstem bulrush
Sparganium eurycarpum	Bur-reed

Table 2. Avian species observed while re-visiting the thirty 1994 wetland restoration survey sites in Ozaukee County during the 2002, 2003, and 2004 field seasons. Species are classified according to their primary habitat (Robbins, 1991).

Cultivated Land	**Old Field**	**Wetland**
American Robin	American Crow	American Coot
Barn Swallow	American Goldfinch	Belted Kingfisher
Cliff Swallow	American Kestrel	Blue-winged Teal
Common Grackle	Baltimore Oriole	Canada Goose
Eastern Kingbird	Black-capped Chickadee	Great Blue Heron
Eastern Meadowlark	Blue Jay	Green-backed Heron
Eastern Phoebe	Bobolink	Killdeer
European Starling	Brown-headed Cowbird	Mallard
Northern Oriole	Cedar Waxwing	Pied-billed Grebe
	Chimney Swift	Red-winged Blackbird
	Chipping Sparrow	Sandhill Crane
	Clay-colored Sparrow	Sedge Wren
	Common Yellowthroat	Sora Rail
	Downy Woodpecker	Spotted Sandpiper
	Eastern Bluebird	Virginia Rail
	Field Sparrow	Willow Flycatcher
	Gray Catbird	Wood Duck
	House Finch	Yellow Warbler
	House Wren	
	Mourning Dove	
	Northern Cardinal	
	Northern Flicker	
	Norther Harrier	
	Red-bellied Woodpecker	
	Red-tailed Hawk	
	Ruby-throated Hummingbird	
	Savannah Sparrow	
	Scarlet Tanager	
	Song Sparrow	
	Tree Swallow	
	Turkey Vulture	
	Upland Sandpiper	
	Warbling Vireo	
	White-breasted Nuthatch	
	Yellow-breasted Chat	

Table 3. Avian species identified during the 1994 censusing of 30 Ozaukee County wetland restorations (Leithoff 1997). Species are classified according to their primary habitat (Robbins 1991).

Cultivated Land	Old Field	Wetland
American Robin	American Crow	American Bittern
Barn Swallow	American Goldfinch	American Coot
Common Grackle	American Tree Sparrow	American Wigeon
Eastern Kingbird	Bobolink	Belted Kingfisher
Eastern Meadowlark	Brown-headed Cowbird	Blue-winged Teal
European Starling	Cedar Waxwing	Bonaparte's Gull
House Sparrow	Common Yellowthroat	Bufflehead
Northern Oriole	Field Sparrow	Canada Goose
	Gray Catbird	Common Snipe
	Mourning Dove	Gadwall
	Northern Cardinal	Great Blue Heron
	Northern Harrier	Greater Scaup
	Ring-necked Pheasant	Greater Yellowlegs
	Savannah Sparrow	Green-backed Heron
	Song Sparrow	Green-winged Teal
	Tree Swallow	Herring Gull
		Killdeer
		Least Sandpiper
		Lesser Scaup
		Lesser Yellowlegs
		Mallard
		Marsh Wren
		Northern Pintail
		Northern Rough-winged Swallow
		Northern Shoveler
		Pied-billed Grebe
		Redhead
		Red-winged Blackbird
		Ring-necked Duck
		Ruddy Duck
		Short-billed Dowitcher
		Solitary Sandpiper
		Sora
		Spotted Sandpiper
		Swamp Sparrow
		Virginia Rail
		White-throated Sparrow
		Willow Flycatcher
		Wood Duck

Table 4. Data measured and calculated to estimate the potential storage volume for 10 wetland basins.

Site #	Wetland (sq m)	High Water Basin (sq m)	Total Volume (cu m)	Volume -15 cm (cu m)	Volume -30 cm (cu m)	Volume -46 cm (cu m)	Volume -61 cm (cu m)	Wetland Watershed (sq m)	Wat/Wet Area
8	564	708	248	92	160	205	230	11626	20.60
11	1228	1489	501	187	311	395	450	10728	8.74
17	1216	1501	397	185	302	370	397	23726	19.51
58	1049	1296	491	174	306	402	464	18159	17.30
78	365	513	161	67	113	142	157	14220	38.98
82	923	1179	180	127	172	180	180	51599	55.88
92	3081	3535	1381	443	748	978	1146	16511	5.36
96	1060	1329	867	180	325	450	560	17226	16.25
97	231	352	82	43	68	81	82	26312	113.68
100	3144	3579	1411	457	786	1044	1238	28296	9.00

Table 5. Potential nutrient loss rates (kg/ha/yr) for different upland land-use classes.

		Nutrient Loss Rate	
Land Use		**Nitrogen**	**Phosphorus**
Natural vegetation (NV)	(100 % forest, wetland, and/or grassland)	0.44	0.0085
Mostly natural vegetation (MNV)	(>75 % NV)	0.45	0.0180
Agricultural (A)	(100 % active cropland)	0.98	0.0310
Mostly Urban (MU)	(>75 % developed)	0.79	0.0300

Source: Modified from U.S. EPA. 2002b.

Table 6. Mean percent cover of open area and 32 species included in DECORANA analysis of quadrat #3 vegetation zones in 120 wetland sites. Codes refer to those used in Figure 16.

Code	Species	Common Name	Mean % Cover
Opn	Open		22.48
Phal	*Phalaris arundinacea*	Reed canary grass (I)	12.67
Typ	*Typha* spp.	Cattail (I)	8.14
Salx1	*Salix exigua* (tree)	Sandbar willow	2.84
Salx2	*Salix petiolaris* (tree)	Meadow willow	2.33
Salx3	*Salix amygdaloides* (tree)	Peach-leaf willow	1.41
Ely	*Elytrigia repens*	Quackgrass (I)	1.03
Lem	*Lemna minor*	Duckweed	0.86
Poa1	*Poa palustris*	Fowl meadow grass	0.72
Sol	*Solidago canadensis*	Common goldenrod	0.71
Alsm	*Alisma subcordatum*	Water plantain	0.70
salx1	*Salix exigua* (sdlg)	Sandbar willow	0.69
Eleo	*Eleocharis palustris*	Spike rush	0.65
Pop	*Populus deltoides* (tree)	Cottonwood	0.60
salx2	*Salix petiolaris* (sdlg)	Meadow willow	0.58
Frax	*Fraxinus pennsylvanica* (tree)	Green ash	0.56
Salx4	*Salix bebbiana* (tree)	Beaked willow	0.52
Poa2	*Poa pratensis*	Kentucky bluegrass (I)	0.49
Equ	*Equisetum arvense*	Horsetail	0.47
Pot	*Potamogeton foliosus*	Leafy pondweed	0.47
Ast2	*Aster lanceolatus (simplex)*	Marsh aster	0.45
Ast1	*Aster firmus (lucidulus)*	Panicled aster	0.44
Scrp	*Scirpus validus*	Softstem bulrush	0.39
frax	*Fraxinus pennsylvanica* (sdlg)	Green ash	0.38
Euth	*Euthamia graminifolia*	Common flat-topped goldenrod	0.32
Phle	*Phleum pratense*	Timothy (I)	0.31
Pan	*Panicum capillare*	Witch grass	0.30
Jun	*Juncus tenuis (dudleyi & interior)*	Rush	0.29
Cirs	*Cirsium arvense*	Canada thistle (I)	0.29
Ast3	*Aster lateriflorus*	Calico aster	0.29
Imp	*Impatiens capensis*	Jewelweed	0.26
Carx	*Carex retrorsa*	Sedge	0.26
salx3	*Salix amygdaloides* (sdlg)	Peach-leaf willow	0.25

Appendix A. Deriving Drainage Basins for Small Wetlands
Document Created by: Jeff Stone[1] and Jill Hapner

This document contains a brief discussion of drainage basin analysis performed on Digital Elevation Model (DEM) files created by two different methods:

1. Contour to DEM using TOPOGRID function (a.k.a., TOPOGRID method).
2. Contour to TIN to DEM using CREATETIN function with hard line features (a.k.a., TIN method).

Generally there are 2 issues that generate different drainage basins:

1. Elevation models created by using the TOPOGRID method are different from elevation models created by the TIN method, which then creates different *Flow Direction Models* due to the different elevation models.
2. The WATERSHED function in Spatial Analyst (Raster Calculator), ArcGIS8.3 generates different drainage basins than the WATERSHED function in the ArcInfo GRID command-line module – see discussion in the *ArcInfo GRID vs. ArcGIS Spatial Analyst* section below.

General Discussion – TOPOGRID vs. CREATETIN

The **TOPOGRID** function creates surface models using an interpolation method similar to a thin plate spline technique. For a full discussion read the TOPOGRID help file in the ArcInfo Workstation ArcDoc help system. Basically, it's similar to taking a piece of flexible metal and fitting it through all the known contours lines to create a continuous elevation surface. Because of this "bending" or "fitting" process, areas between contour lines get pushed below or above their "true" elevation values. This creates a problem when trying to determine flow direction, since some areas might be modeled at lower relative elevations than the neighboring area, thus creating sinks where none should occur. This limits the area that should be included as part of a contributing drainage basin.

Figure 1 shows an example where the surface elevation was pushed below the surrounding contours, creating a low spot or sink, thus blocking downhill flow from reaching its true accumulation point or wetland. This can be seen better in a cross-section profile (**Figure 2b**) **–** 200 feet from the start point (Label A), there is a small dip in the surface that acts like a sink that blocks flow from getting to the wetland area.

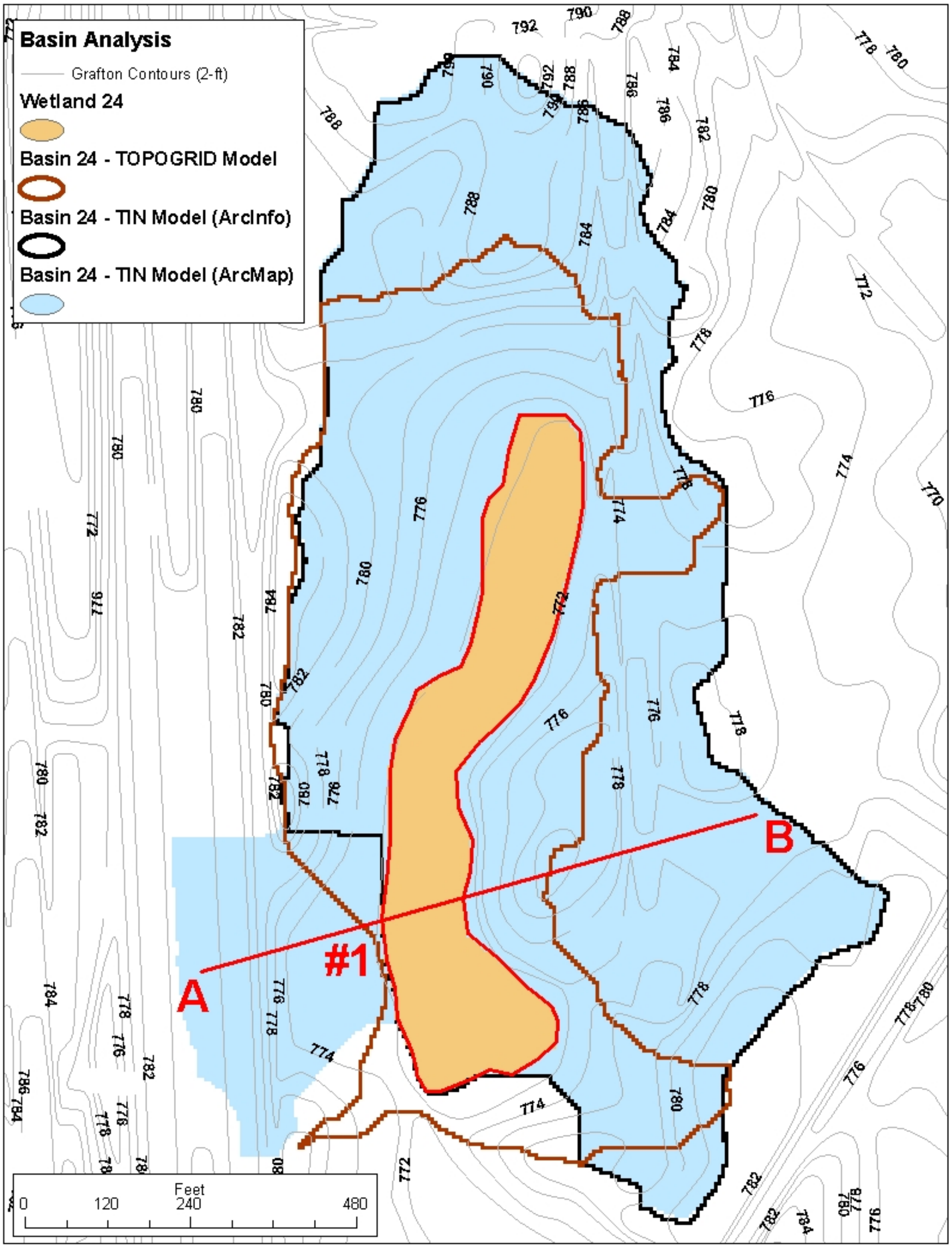

Basin Analysis
Grafton Contours (2-ft)
Wetland 24
Basin 24 - TOPOGRID Model
Basin 24 - TIN Model (ArcInfo)
Basin 24 - TIN Model (ArcMap)
A
B
#1
Feet
0
120
240
480

Figure 1

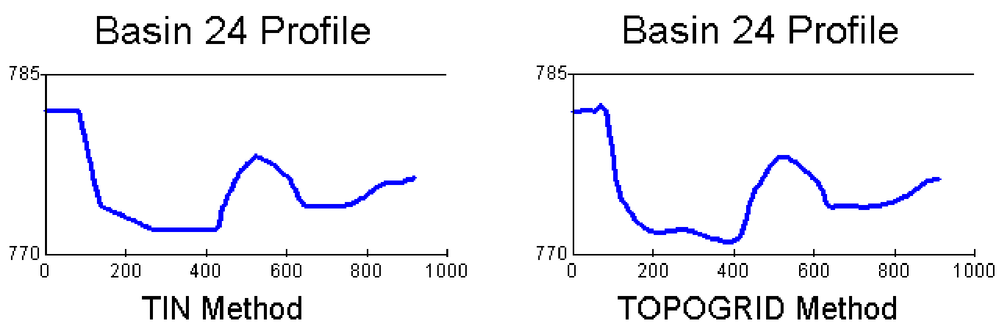


Figure 2

Overall, it seems that the elevation surface generated with the TIN method produces a better analysis environment for modeling drainage basins. This appears to be due to the removal of isolated low spots or sinks generated by the TOPOGRID method.

The **CREATETIN** command creates a surface model using triangular facets (triangles are assembled based on nearest-neighbor concepts). See the "What is a TIN?" or TIN "Description of" in the ArcInfo Workstation ArcDoc help system. The main point to note about elevation surfaces created with the TIN method is that flat areas in the original contour data are maintained in the elevation model. This situation could occur with any interpolation method, but seems more prominent when a TIN is created. This only presents a problem when trying to determine the drainage basin for a wetland that is situated within a large, flat area in the surface model. **Figure 3** shows a situation where the wetland is located in such an area. When trying to determine the contributing drainage area, the WATERSHED function determines that no adjoining raster cells contribute to the area since the area is flat. A possible solution would be to expand the search area until elevation changes are detected, and then use the expanded area to determine the drainage basin. This method is not known to be available in any raster analysis software – but could be done by manual methods in Spatial Analyst.

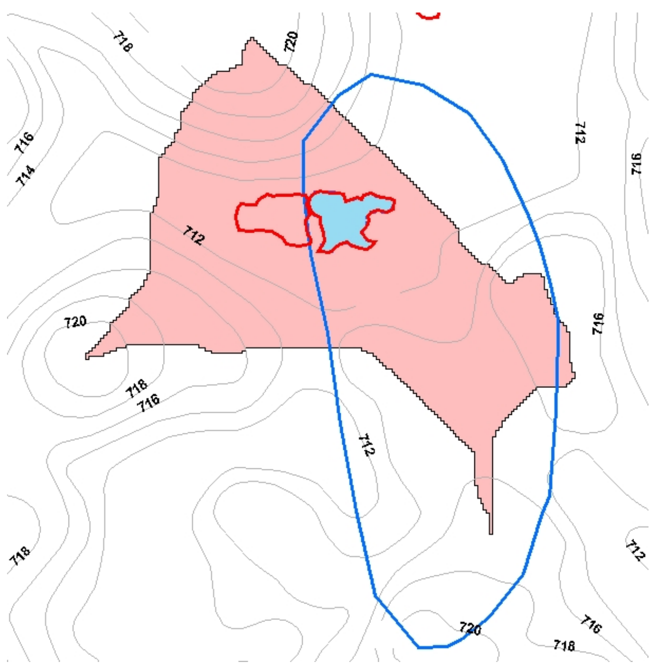
Figure 3

The wetland (Id #25) is outlined in red, with blue fill. The blue fill is actually the extent of the drainage basin created from the DEM created with the TIN method.

The rose colored area was created from the DEM created with the TOPOGRID method.

The blue outline was created from manual methods (Hapner).

Not much similarity between any of the methods.



ArcInfo GRID vs. ArcGIS Spatial Analyst

For some unknown reason, drainage basins created in the ArcInfo GRID (command-line) module are different from basins created with the Spatial Analyst (Raster Calculator) extension in ArcGIS8.3. **Figure 1** shows the difference between the two basins – both basins were derived from the elevation model (DEM) that was created using the CREATETIN function instead of the TOPOGRID function. The basin indicated with a black outline was created in ArcInfo GRID while the basin indicated with solid blue fill was created in ArcMap 8.3. This issue was tested on several different basins with some resulting in similar boundaries and others having different boundaries as shown in Figure 1. To understand the reasons for the different results, the underlying algorithms and parameters would need to be compared. Every attempt was made to keep the parameters and dataset (DEM) the same during this testing.

Accuracy of the computer-delineated drainage basins was field verified in Spring 2004. Six wetland restoration sites were randomly selected, and the local surface drainage basins were field-surveyed. Each field-measured delineation was compared to the computer-derived delineations for accuracy. Only one site did not agree with the computer-generated delineations. We then manually checked 105 sites, which were visited during field sampling using the digital 2-foot topography contours and found 66% to agree with one or both of the computer generated drainage basins. Neither computer method was more accurate than the other; reasons for inaccuracy include:

1) Large areas of flat terrain (as noted above)
2) Dike, ditch, and road construction following topography data collection
3) “Tiered” clusters of restored wetlands

The methods employed to automate delineation of local surface drainage basins have great potential. For the purposes of our project, the inaccurate basins (34%) were manually edited using digital topography data and field notes, and utilized in modeling physical wetland functions.

[1]Jeff Stone, GIS Specialist
Department of Forest Ecology
University of Wisconsin-Madison
Madison, WI
jdstone@students.wisc.edu

Appendix B. Functional indices for 120 Ozaukee County wetland restoration sites. Richness, number of plant species. % Native Species, native percent of flora. NatWet Species, number of native wetland species: FAC and wetter. WFQI, Wisconsin Floristic Quality Index. H, Shannon-Weaver Diversity Index. Wildlife, number of species whose presence was determined to be the result of the restoration. % Reduction of Water Quality Indices, the percent reduction in the indices of soil erosion, and nitrogen and phosphorus loading in the drainage basin as the result of implementing the restoration (see text for calculation of the indices). Storm Water Runoff Retained (expressed as cm from the surface drainage basin) At : 15, 30, 46, and 61 centimeters draw down in wetland water level. Seeded sites are in bold. NA indicates no data for historical sites. Physical function index means calculated without duplicate sites.

		Vegetation Functional Indices						**% Reduction of Water Quality Indices**			**Storm Water Runoff Retained (cm from drainage basin) At:**			
Site #	**Age Sampled**	**Richness**	**%Native Species**	**NatWet Species**	**WFQI**	**H**	**Wildlife**	**Soil Erosion**	**Nitrogen**	**Phosphorus**	**-15 cm stage**	**-30 cm stage**	**-46 cm stage**	**-61 cm stage**
1	6	25	52	11	15.79	1.80	7	30.00	47.10	61.97	1.02	1.69	2.14	2.41
2	6	55	49	23	14.23	2.42	2	0.00	7.01	9.04	1.69	2.87	3.75	4.38
3	8	39	64	20	15.00	1.88	2	16.67	32.80	41.22	2.32	3.92	5.09	5.90
4	9	47	68	24	16.01	3.16	4	26.09	55.28	72.69	2.82	4.76	6.18	7.18
5	10	45	60	24	16.16	2.39	5	35.29	55.03	72.54	4.01	6.77	8.80	10.22
6	7	44	59	24	18.25	2.56	7	20.00	45.05	57.30	2.40	4.11	5.43	6.43
7	10	30	73	19	14.07	1.09	8	15.79	11.79	15.69	0.34	0.56	0.71	0.80
8	**12**	**37**	**78**	**25**	**20.03**	**2.76**	**3**	**35.29**	**40.61**	**45.03**	**0.81**	**1.33**	**1.65**	**1.83**
9	**12**	**73**	**75**	**48**	**24.84**	**3.26**	**3**	**35.29**	**54.90**	**72.46**	**1.20**	**1.94**	**2.35**	**2.51**
10	11	13	85	11	12.93	1.66	3	16.67	24.32	33.82	1.77	2.57	2.44	1.74
11	**12**	**59**	**76**	**39**	**23.55**	**3.15**	**7**	**42.86**	**55.00**	**72.52**	**1.75**	**2.95**	**3.80**	**4.38**
12	**12**	**68**	**79**	**47**	**27.11**	**3.51**	**7**	**33.33**	**55.33**	**72.72**	**2.24**	**3.76**	**4.84**	**5.57**
13	13	68	72	30	26.30	3.42	3	26.09	55.27	72.68	3.17	5.30	6.75	7.69
14	11	36	69	23	17.20	2.19	3	25.00	50.66	63.80	0.89	1.51	1.95	2.26
15	6	33	52	10	10.93	2.54	4	19.23	14.42	19.30	4.33	7.28	9.37	10.78
16	6	23	70	14	14.24	1.61	7	9.09	3.79	4.87	0.08	0.13	0.16	0.19
17	6	57	65	31	18.07	3.45	6	26.09	54.98	72.51	0.79	1.32	1.70	1.96
18	11	52	77	34	23.27	2.86	8	31.58	55.17	72.62	2.33	3.89	4.94	5.60
19	13	49	67	29	18.78	2.59	3	15.79	24.32	32.35	4.66	7.96	10.52	12.46
20	8	23	61	10	9.88	1.80	2	6.67	7.77	10.42	1.20	2.04	2.68	3.15
21	9	43	74	28	18.60	2.50	3	20.00	41.61	30.89	1.62	2.72	3.47	3.97
22	9	34	74	21	15.60	2.23	3	46.15	55.77	72.99	6.07	9.84	11.86	12.67
23	13	30	77	17	17.31	2.46	3	31.58	54.25	72.06	4.10	6.93	9.00	10.46
24	13	23	70	13	14.24	1.89	3	31.58	55.36	72.74	1.70	2.72	3.17	3.26

		Vegetation Functional Indices						% Reduction of Water Quality Indices			Storm Water Runoff Retained (cm from drainage basin) At:			
Site #	Age Sampled	Richness	%Native Species	NatWet Species	WFQI	H	Wildlife	Soil Erosion	Nitrogen	Phosphorus	-15 cm stage	-30 cm stage	-46 cm stage	-61 cm stage
25	13	10	70	6	12.83	1.18	1	37.50	55.40	72.76	1.90	2.77	2.63	1.88
26	11	25	76	18	15.13	2.38	3	27.27	55.26	72.68	0.92	1.52	1.92	2.15
27	13	48	71	27	20.76	2.67	6	21.05	41.77	54.78	1.35	2.25	2.84	3.21
28	13	39	69	22	18.50	2.66	7	50.00	55.29	72.70	1.50	2.48	3.10	3.45
29	10	47	74	28	20.47	3.08	2	26.32	35.73	51.75	1.84	3.11	4.07	4.75
30	13	51	75	33	22.07	2.81	8	28.57	55.10	72.58	4.74	8.10	10.74	12.74
31	11	29	62	16	12.98	2.17	2	22.22	54.58	72.26	2.88	4.41	4.72	4.27
32	11	23	74	16	14.06	2.40	5	28.57	55.33	72.72	1.29	2.12	2.62	2.88
33	7	33	58	15	15.13	2.51	2	31.58	55.67	72.93	0.49	0.81	1.02	1.14
34	15	36	61	17	15.34	3.12	4	26.09	55.05	72.55	1.26	2.05	2.51	2.72
35	15	36	61	19	16.42	3.03	5	26.09	55.21	72.64	1.96	3.32	4.33	5.05
36	13	36	56	16	13.64	2.77	1	26.09	55.77	72.99	1.02	1.69	2.12	2.37
37	15	37	70	23	17.64	2.40	4	30.00	55.39	72.76	1.25	2.12	2.77	3.25
38	15	34	71	23	17.34	2.43	4	26.09	55.04	72.54	2.47	4.17	5.40	6.26
39	7	19	47	9	12.66	2.29	7	17.39	37.03	48.90	1.57	2.64	3.37	3.85
40	12	28	86	23	19.01	2.26	4	33.33	55.32	72.71	2.75	4.67	6.10	7.14
41	6	38	71	22	15.02	2.83	2	18.18	49.66	68.07	0.84	1.41	1.81	2.08
42	15	36	64	18	15.44	2.87	4	27.78	49.07	64.96	3.12	5.30	6.95	8.15
43	6	38	76	21	17.99	2.83	1	20.00	39.96	52.34	0.83	1.38	1.76	1.99
44	6	43	72	24	15.81	2.95	3	13.64	31.88	41.29	0.19	0.32	0.41	0.46
45	14	38	66	21	16.00	2.43	5	13.64	24.62	32.49	4.52	7.71	10.18	12.02
46	15	4	50	2	7.07	1.22	1	14.29	26.10	34.32	1.13	1.93	2.56	3.05
47	10	46	74	29	21.28	2.54	7	18.18	37.10	52.33	0.83	1.39	1.80	2.07
48	7	47	72	29	19.01	3.09	6	14.29	28.73	36.98	0.62	1.05	1.35	1.56
49	7	28	86	23	19.79	2.26	3	17.86	52.47	69.18	0.42	0.71	0.92	1.07
50	7	68	75	42	24.21	2.91	5	0.00	4.05	5.49	0.52	0.87	1.13	1.30
51	14	38	66	21	16.40	2.43	1	10.00	14.28	18.77	3.04	5.20	6.88	8.15
52	6	37	57	15	15.49	3.06	2	5.26	0.56	0.52	1.28	2.16	2.82	3.30
53	15	62	81	47	29.57	2.80	9	0.00	0.56	0.56	0.62	1.04	1.35	1.56
54	15	54	65	31	21.65	2.85	6	30.00	54.90	54.90	2.09	3.56	4.69	5.53
55	15	52	71	33	21.23	2.91	6	25.00	54.98	72.51	1.47	2.51	3.31	3.89

		Vegetation Functional Indices						% Reduction of Water Quality Indices			Storm Water Runoff Retained (cm from drainage basin) At:			
Site #	Age Sampled	Richness	%Native Species	NatWet Species	WFQI	H	Wildlife	Soil Erosion	Nitrogen	Phosphorus	-15 cm stage	-30 cm stage	-46 cm stage	-61 cm stage
56	16	39	64	23	15.40	2.50	7	28.57	48.48	64.34	6.62	11.16	14.46	16.76
57	16	40	73	27	18.75	2.41	6	35.29	54.94	72.48	1.54	2.55	3.19	3.57
58	13	43	67	27	17.18	2.83	5	28.57	49.37	61.83	0.89	1.49	1.92	2.20
59	17	12	50	5	5.32	1.86	1	13.33	10.27	14.87	1.40	2.31	2.90	3.25
60	17	16	50	8	9.90	2.11	1	12.50	20.72	27.31	1.14	1.94	2.57	3.04
61	15	67	70	39	23.03	3.29	11	33.33	54.36	71.18	1.50	2.56	3.40	4.03
62	15	46	70	27	19.12	3.01	3	27.27	55.17	72.62	3.21	5.46	7.18	8.45
63	14	50	70	31	20.77	2.82	5	31.58	54.99	72.51	0.64	1.09	1.42	1.65
64	16	37	59	21	18.76	2.90	2	27.27	54.62	72.29	0.61	1.03	1.33	1.53
65	14	27	70	17	13.99	2.45	6	31.58	50.85	67.20	1.23	2.08	2.71	3.17
66	16	50	74	32	19.22	2.89	5	26.09	54.01	70.98	2.39	4.07	5.37	6.34
67	16	59	76	42	22.81	3.19	7	19.05	34.71	45.80	0.84	1.43	1.88	2.20
68	14	38	82	29	20.32	2.95	4	35.29	54.63	72.29	0.76	1.27	1.62	1.85
69	14	47	77	33	22.68	2.72	5	31.58	54.81	72.40	0.19	0.32	0.39	0.44
70	15	36	75	23	16.58	2.49	6	22.22	32.48	42.71	4.84	8.26	10.93	12.95
71	13	47	79	37	25.79	2.92	6	33.33	54.95	72.49	1.18	1.98	2.54	2.91
72	14	24	71	15	15.05	2.47	1	19.05	42.97	54.07	0.70	1.17	1.50	1.71
73	13	47	64	28	22.62	3.20	3	29.41	52.74	67.17	2.50	4.21	5.44	6.29
74	15	44	68	24	19.17	3.05	7	13.04	24.43	31.89	0.50	0.86	1.14	1.35
75	12	41	66	25	19.43	2.90	3	31.58	54.94	72.48	2.26	3.80	4.90	5.65
76	13	61	67	36	23.44	3.27	3	25.00	46.84	59.55	2.23	3.79	4.98	5.84
77	15	9	56	5	9.39	1.74	2	21.43	25.71	33.64	4.16	7.12	9.43	11.19
78	13	44	77	31	19.71	2.65	2	22.73	53.32	69.10	0.46	0.75	0.90	0.95
79	15	14	57	8	13.01	1.94	3	17.65	29.09	38.17	1.07	1.72	2.04	2.15
80	15	54	72	33	20.67	3.43	4	35.29	54.78	72.38	2.63	4.28	5.19	5.59
81	9	46	72	31	19.99	2.84	6	25.00	44.49	57.44	0.12	0.19	0.22	0.23
82	8	43	70	26	17.14	2.53	3	23.81	50.57	64.73	0.28	0.47	0.60	0.68
83	7	38	74	28	18.52	2.67	1	17.39	32.32	42.75	0.76	1.25	1.54	1.68
84	6	30	77	21	16.88	2.16	2	21.05	32.01	42.06	1.13	1.91	2.47	2.86
85	6	18	67	11	13.58	1.60	2	21.05	36.99	48.93	1.65	2.76	3.54	4.05
86	6	43	81	34	23.72	2.23	5	20.69	54.92	72.47	0.86	1.40	1.69	1.81

		Vegetation Functional Indices						% Reduction of Water Quality Indices			Storm Water Runoff Retained (cm from drainage basin) At:			
Site #	Age Sampled	Richness	%Native Species	NatWet Species	WFQI	H	Wildlife	Soil Erosion	Nitrogen	Phosphorus	-15 cm stage	-30 cm stage	-46 cm stage	-61 cm stage
87	8	51	73	33	21.84	3.13	5	26.67	37.66	48.74	0.83	1.42	1.88	2.22
88	7	34	74	24	16.80	2.43	4	35.71	48.34	61.04	3.57	5.95	7.57	8.61
89	9	41	76	30	19.21	1.97	3	14.29	12.48	16.22	0.40	0.67	0.85	0.96
90	6	50	68	33	19.88	3.29	2	23.53	42.54	56.31	1.57	2.67	3.53	4.18
91	5	80	65	51	27.04	3.37	7	21.05	33.28	30.73	1.89	3.17	4.04	4.61
92	4	40	68	24	16.37	2.69	4	19.05	42.87	59.09	2.71	4.61	6.06	7.14
93	3	69	72	40	25.03	3.68	4	21.74	39.46	41.50	1.01	1.56	1.70	1.59
94	3	57	65	31	20.19	3.48	3	17.39	34.91	33.48	1.54	2.50	3.06	3.31
95	4	48	65	26	18.48	2.83	6	15.79	35.90	46.09	4.09	6.98	9.24	10.94
96	3	33	67	16	16.18	2.52	4	9.52	11.25	15.40	0.95	1.60	2.05	2.35
97	3	32	72	19	16.88	2.64	4	19.05	39.58	52.05	0.18	0.28	0.33	0.33
98	4	46	74	30	19.88	1.98	6	23.81	42.59	56.33	2.38	4.04	5.31	6.24
99	4	37	59	19	15.57	2.03	6	9.52	13.71	17.30	0.89	1.52	2.01	2.38
100	4	46	63	27	19.71	2.61	3	9.52	16.60	21.71	1.61	2.74	3.60	4.24
101	5	52	77	38	23.53	3.11	2	37.50	55.49	72.82	9.18	15.50	20.12	23.35
102	2	23	61	12	9.88	2.54	NA	26.09	55.04	72.54	2.47	4.17	5.40	6.26
103	2	23	57	11	11.11	2.61	NA	30.00	55.39	72.76	1.25	2.12	2.77	3.25
104	2	25	68	15	13.57	2.84	NA	19.05	34.71	45.80	0.84	1.43	1.88	2.20
105	2	23	61	13	12.01	2.75	NA	26.09	54.01	70.98	2.39	4.07	5.37	6.34
106	2	29	52	12	10.57	2.77	NA	33.33	54.36	71.18	1.50	2.56	3.40	4.03
107	1	11	27	3	4.00	2.19	NA	5.88	4.70	5.85	1.10	1.84	2.37	2.73
108	1	12	33	2	4.50	2.05	NA	11.76	10.50	13.54	2.56	4.30	5.52	6.33
109	1	13	23	3	6.36	2.18	NA	5.26	8.64	10.68	0.99	1.68	2.21	2.60
110	1	22	50	9	8.13	2.62	NA	7.14	11.16	15.10	2.88	4.89	6.41	7.52
111	**1**	**33**	**58**	**15**	**12.38**	**2.82**	**NA**	**26.09**	**54.66**	**72.31**	**1.79**	**3.04**	**3.99**	**4.69**
112	**2**	**28**	**75**	**19**	**17.87**	**2.58**	**NA**	**26.09**	**54.66**	**72.31**	**1.79**	**3.04**	**3.99**	**4.69**
113	**1**	**38**	**58**	**20**	**14.92**	**3.03**	**NA**	**35.29**	**54.90**	**72.46**	**1.20**	**1.94**	**2.35**	**2.51**
114	**2**	**41**	**76**	**29**	**21.55**	**3.33**	**NA**	**35.29**	**54.90**	**72.46**	**1.20**	**1.94**	**2.35**	**2.51**
115	**1**	**36**	**72**	**23**	**16.67**	**3.17**	**NA**	**42.86**	**55.00**	**72.52**	**1.75**	**2.95**	**3.80**	**4.38**
116	**2**	**30**	**83**	**24**	**22.20**	**2.75**	**NA**	**42.86**	**55.00**	**72.52**	**1.75**	**2.95**	**3.80**	**4.38**
117	**1**	**43**	**65**	**24**	**16.24**	**3.17**	**NA**	**35.29**	**40.61**	**45.03**	**0.81**	**1.33**	**1.65**	**1.83**

		Vegetation Functional Indices						% Reduction of Water Quality Indices			Storm Water Runoff Retained (cm from drainage basin) At:			
Site #	Age Sampled	Richness	%Native Species	NatWet Species	WFQI	H	Wildlife	Soil Erosion	Nitrogen	Phosphorus	-15 cm stage	-30 cm stage	-46 cm stage	-61 cm stage
118	2	36	78	27	19.26	3.00	NA	35.29	40.61	45.03	0.81	1.33	1.65	1.83
119	1	44	75	27	16.89	3.30	NA	33.33	55.33	72.72	2.24	3.76	4.84	5.57
120	2	40	75	27	19.01	3.26	NA	33.33	55.33	72.72	2.24	3.76	4.84	5.57
Mean	9.12	38.68	67.53	23.31	17.32	2.63	4.18	22.87	39.92	51.66	1.85	3.11	3.98	4.56

Appendix C. List of plant species observed in 120 wetland restorations in Ozaukee County, Wisconsin. W.I.S., Wetland Indicator Status; CC, Wisconsin Floristic Quality Index Coefficient of Conservatism; (I), Introduced.

Species	**Common name**	**W.I.S.**	**CC**	**Species #**
Acalypha rhomboidea	Rhombic copperleaf	FACU	0	274
Acer negundo	Box-elder	FACW-	0	2
Acer saccharinum	Silver maple	FACW	2	3
Acer saccharum	Sugar maple	FACU	5	4
Achillea millefolium	Common yarrow	FACU	1	41
Agalinis tenuifolia	Common agalinis	FACW	6	279
Agalinis purpurea	Purple false foxglove	FACW	7	265
Agrimonia gryposepala	Common agrimony	FACU+	2	43
Agrimonia rostellata	Woodland agrimony (I)	FACU		44
Agrostis gigantea	Redtop (I)			45
Alisma subcordatum	Water plantain	OBL	3	46
Alliaria petiolata	Garlic mustard (I)	FAC		47
Alnus incana	Speckled alder	OBL	4	324
Amaranthus arenicola	Sandhill amaranth (I)	FACU		48
Amaranthus blitoides	Amaranth (I)			325
Amaranthus rudis	Amaranth	FACW	0	49
Ambrosia artemisiifolia	Common ragweed	FACU	0	50
Ambrosia trifida	Giant ragweed	FAC+	0	51
Andropogon gerardii	Big bluestem	FAC-	4	42
Angelica atropurpurea	Common great angelica	OBL	6	255
Arctium minus	Common burdock (I)			53
Artemisia vulgaris	Mugwort (I)			54
Asclepias incarnata	Marsh milkweed	OBL	5	55
Asclepias syriaca	Milkweed		1	56
Aster ciliolatus	Northern heart-leaved aster		4	57
Aster ericoides	Heath aster	FACU-	4	58
Aster firmus (lucidulus)	Panicled aster	FACW+	6	59
Aster lanceolatus (simplex)	Marsh aster	FACW	4	60
Aster lateriflorus	Calico aster	FACW-	3	61
Aster novae-angliae	New England aster	FACW	3	62
Aster pilosus	Frost aster	FACU+	1	63
Aster prenanthoides	Zigzag aster	FAC		264
Barbarea vulgaris	Yellow rocket (I)	FAC		65
Bidens cernua	Bur-marigold	OBL	4	66
Bidens comosa	Strawstem beggar-ticks	OBL	5	67
Bidens connata	Purplestem beggar-ticks	OBL	6	68
Bidens discoidea	Few-bracted beggar-ticks	FACW	8	69
Bidens frondosa	Devil's beggar-ticks	FACW	1	70
Bromus inermis	Brome grass (I)			71
Calamagrostis canadensis	Bluejoint grass	OBL	5	72
Caltha palustris	Marsh-marigold	OBL	6	261
Cannabis sativa	Hemp	FAC		258
Capsella bursa-pastoris	Shepard's purse (I)	FAC-		73
Cardamine hirsuta	Hoary bitter-cress	FACW+	3	326
Cardamine rhomboidea	Spring-cress	OBL	6	322
Carex alopecoidea	Sedge	FACW+	5	281
Carex aquatilis	Sedge	OBL	7	74

Species	Common name	W.I.S.	CC	Species #
Carex bebbii	Sedge	OBL	4	75
Carex blanda	Sedge	FAC	3	76
Carex comosa	Sedge	OBL	5	77
Carex cristatella	Sedge	FACW-	4	78
Carex granularis	Sedge	FACW+	3	253
Carex hystericina	Sedge	OBL	3	275
Carex lacustris	Sedge	OBL	6	79
Carex lasiocarpa	Sedge	OBL	9	80
Carex retrorsa	Sedge	OBL	6	81
Carex rostrata	Sedge	OBL	10	82
Carex stipata	Sedge	OBL	2	83
Carex stricta	Sedge	OBL	7	84
Carex sp.	Sedge			85
Carex tribuloides	Sedge	FACW+	4	254
Carex vulpinoidea	Foxtail sedge	OBL	2	86
Cerastium arvense	Field chickweed	FACU-	4	87
Cerastium brachypetalum	Mouse-ear chickweed (I)			88
Cerastium vulgatum	Common chickweed (I)	FACU		276
Chelone glabra	Turtlehead	OBL	7	269
Chenopodium album	Lamb's quarters or pigweed (I)	FAC-		90
Chrysanthemum leucanthemum	Ox-eye daisy (I)			91
Chrysanthemum s.l.				250
Cichorium intybus	Chicory (I)			92
Cicuta bulbifera	Bulbiliferous water-hemlock	OBL	7	93
Cicuta maculata	Common water-hemlock	OBL	6	94
Cinna arundinaceae	Common woodreed	FACW	5	95
Cirsium altissimum	Tall thistle		6	96
Cirsium arvense	Canada thistle (I)	FACU		97
Cirsium vulgare	Bull thistle (I)	FACU-		98
Cladium mariscoides	Twig rush	OBL	10	99
Coreopsis lanceolata	Longstalk tickseed	FACU	8	100
Cornus amomum	Silky dogwood	FACW+		40
Cornus sericea	Red-osier dogwood	FACW	3	5
Crataegus sp.	Hawthorne (I)			7
Cyperus erythrorhizos	Redroot flatsedge	OBL	3	102
Dactylis glomerata	Orchard grass (I)	FACU		103
Daucus carota	Queen Anne's lace (I)			104
Echinacea purpurea	Purple coneflower (I)			105
Echinochloa crusgalli	Barnyard grass (I)	FACW		106
Echinochloa muricata	Barnyard grass	OBL	1	107
Echinocystis lobata	Wild cucumber	FACW-	2	108
Elaeagnus commutata	Silver-berry (I)			6
Eleocharis acicularis	Spike rush	OBL	5	109
Eleocharis obtusa	Spike rush	OBL	3	110
Eleocharis palustris	Spike rush	OBL	6	111
Elytrigia repens	Quackgrass (I)			112
Epilobium coloratum	Willow-herb	OBL	3	113
Epilobium leptophyllum	Willow-herb	OBL	8	114
Equisetum arvense	Horsetail	FAC	1	115
Equisetum hyemale	Scouring rush	FACW-	3	116

Species	Common name	W.I.S.	CC	Species #
Erigeron annuus	Daisy fleabane	FAC-	0	118
Erigeron strigosus	Prairie fleabane	FAC-	2	119
Erysimum cheiranthoides	Wormseed mustard (I)	FACU		120
Eupatorium maculatum	Joe-pye weed		4	121
Eupatorium perfoliatum	Boneset	FACW+	6	122
Euthamia graminifolia	Common flat-topped goldenrod	FAC	4	123
Euthamia gymnospermoides	Great Plains flat-topped goldenrod	FACW	6	124
Festuca elatior (arundinacea)	Tall or alta fescue (I)	FACU+		125
Festuca sp.	Fescue (I)			126
Filipendula rubra	Queen of the prairie (I)	FACW+		127
Fragaria virginiana	Wild strawberry	FAC-	1	128
Fraxinus americana	White ash	FACU	5	8
Fraxinus pennsylvanica	Green ash	FACW	2	9
Fraxinus nigra	Black ash	FACW+	8	10
Galium trifidum	Northern three-lobed bedstraw	OBL	10	129
Gentiana andrewsii	Prairie closed or bottle gentian	FACW	6	130
Gentianopsis crinita	Fringed gentian	FACW+	6	131
Geum aleppicum	Yellow avens	FAC+	3	132
Geum canadense	White avens	FAC	2	133
Glechoma hederacea	Gill-over-the-ground (I)	FACU		134
Glyceria grandis	Mannagrass	OBL	6	135
Glyceria striata	Fowl managrass	OBL	4	136
Helenium autumnale	Sneezeweed	FACW+	4	138
Helianthus giganteus	Giant sunflower	FACW	4	266
Hesperis matronalis	Dame's rocket (I)			139
Hypericum perforatum	Common St. John's-wort (I)			141
Ilex verticillata	Winterberry	FACW+	7	11
Impatiens capensis	Jewelweed	FACW	2	142
Iris virginica	Blueflag	OBL	5	143
Iva xanthifolia	Big marsh elder	FAC	0	144
Juncus effusus	Soft rush	OBL	4	146
Juncus nodosus	Rush	OBL	6	147
Juncus tenuis (dudleyi & interior)	Rush	FAC	4	148
Juncus torreyi	Torrey's rush	FACW	4	149
Larix laricina	Tamarack	FACW	8	12
Lemna minor	Duckweed	OBL	4	152
Lepidium campestre	Field-cress (I)			153
Leersia oryzoides	Rice cut grass	OBL	3	151
Linaria vulgaris	Butter - n - eggs			154
Lobelia siphilitica	Great blue lobelia	FACW+	5	270
Lonicera tatarica	Tartarian honeysuckle (I)	FACU		13
Lotus corniculatus	Bird's-foot trefoil (I)	FAC-		156
Ludwigia polycarpa	Top-pod water-primrose	OBL	6	157
Lycopus americanus	Water horehound	OBL	4	158
Lycopus virginicus	Virginia water-horehound	OBL	8	159
Lythrum salicaria	Purple loosestrife (I)	OBL		161
Malva neglecta	Common mallow (I)			162
Matteuccia struthiopteris	Ostrich fern	FACW	5	273
Medicago lupulina	Black medic (I)	FAC-		163
Medicago sativa	Alfalfa (I)			164

Species	Common name	W.I.S.	CC	Species #
Melilotus alba	White clover (I)	FACU		165
Melilotus officinalis	White sweet-clover (I)	FACU		166
Mentha arvensis	Mint	FACW	3	167
Mimulus ringens	Monkey-flower	OBL	6	168
Monarda fistulosa	Wild bergamot	FACU	3	169
Muhlenbergia sp.	Muhly			170
Oenothera biennis	Evening primrose	FACU	1	172
Onoclea sensibilis	Sensitive fern	FACW	5	256
Oxalis stricta	Common yellow wood-sorrel	FACU	0	173
Panicum capillare	Witch grass	FACU	1	174
Parthenocissus vitacea	Grape woodbine	FACU	4	14
Pedicularis lanceolata	Swamp lousewort	FACW+	8	267
Penthorum sedoides	Ditch stonecrop	OBL	3	176
Phalaris arundinacea	Reed canary grass (I)	FACW		177
Phleum pratense	Timothy (I)	FACU		178
Phragmites australis	Common reed	FACW+	1	179
Physocarpus opulifolius	Ninebark	FACW-	6	15
Pilea pumila	Clearweed	FACW	3	180
Pinus strobus	White pine	FAC	5	16
Plantago major	Common plantain (I)	FAC+		181
Poa palustris	Fowl meadow grass	FACW+	5	182
Poa pratensis	Kentucky bluegrass (I)	FAC-		183
Polygonum amphibium	Water smartweed	OBL	5	184
Polygonum aviculare	Common smartweed	FAC-		280
Polygonum careyi	Smartweed	FACW+	6	185
Polygonum caespitosum	Smartweed (I)	UPL		186
Polygonum convolvulus	Black bindweed (I)	FAC-		187
Polygonum hydropiper	Water-pepper (I)	OBL		188
Polygonum lapathifolium	Nodding smartweed	FACW+	2	189
Polygonum pensylvanicum	Pinkweed	FACW+	1	190
Polygonum persicaria	Lady's thumb (I)	FACW		191
Polygonum punctatum	Dotted smartweed	OBL	5	192
Populus deltoides	Cottonwood	FAC+	2	17
Populus tremuloides	Quaking aspen	FAC	2	18
Potamogeton foliosus	Leafy pondweed	OBL	6	194
Potamogeton natans	Pondweed	OBL	5	195
Potamogeton pectinatus	Sago pondweed	OBL	3	196
Potentilla norvegica	Strawberry weed	FAC	0	197
Potentilla recta	Sulphur five-fingers (I)			198
Potentilla simplex	Old-field five-fingers	FACU-	2	199
Prunella vulgaris	Self-heal	FAC	1	200
Prunus virginiana	Choke cherry	FAC-	3	328
Quercus bicolor	Swamp white oak	FACW+	7	331
Quercus rubra	Northern red oak	FACU	5	330
Ranunculus acris	Common or meadow buttercup (I)	FACW-		201
Ranunculus bulbosus	Bulbous buttercup (I)			202
Ranunculus flabellaris	Yellow water-crowfoot	OBL	8	203
Ranunculus longirostris	White water-crowfoot	OBL	8	204
Ranunculus sceleratus	Cursed crowfoot	OBL	3	205
Ratibida pinnata	Globular coneflower		4	206

Species	**Common name**	**W.I.S.**	**CC**	**Species #**
Rhamnus cathartica	Common buckthorn (I)	FACU		19
Rhamnus frangula	Glossy buckthorn (I)	FAC+		20
Ribes americanum	Wild black current	FACW	4	21
Rorippa palustris	Marsh cress	OBL	3	207
Rosa multiflora	Multiflora rose (I)	FACU		22
Rubus idaeus (strigosus)	Red raspberry	FACW-	3	23
Rubus pubescens	Dwarf raspberry	FACW+	7	209
Rudbeckia hirta	Black-eyed Susan	FACU	4	210
Rudbeckia triloba	Three-lobed coneflower	FAC-	4	211
Rumex crispus	Curly dock (I)	FAC+		212
Sagittaria latifolia	Arrowhead	OBL	3	213
Salix amygdaloides	Peach-leaf willow	FACW	4	24
Salix babylonica	Weeping willow (I)	FACW		37
Salix bebbiana	Beaked willow	FACW+	7	25
Salix discolor	Pussy willow	FACW	2	26
Salix eriocephala	Diamond willow	FACW+	4	27
Salix exigua	Sandbar willow	OBL	2	28
Salix nigra	Black willow	OBL	4	29
Salix pedicellaris	Bog willow	OBL	8	30
Salix petiolaris	Meadow willow	FACW+	6	31
Salix sp.	Willow species			38
Sambucus canadensis	Common elder	FACW-	3	32
Schizachyrium scoparium	Little bluestem	FACU-	4	214
Scirpus acutus	Hardstem bulrush	OBL	6	215
Scirpus atrovirens	Dark green bulrush	OBL	3	216
Scirpus cyperinus	Woolgrass	OBL	4	217
Scirpus validus	Softstem bulrush	OBL	4	219
Scutellaria galericulata	Marsh skullcap	OBL	5	323
Sedum purpureum	Live forever			259
Senecio aureus	Heart-leaved groundsel	FACW	6	220
Setaria glauca	Yellow foxtail (I)	FAC		223
Sicyos angulatus	Bur-cucumber	FACW-	5	268
Silene latifolia	White campion (I)			224
Silphium integrifolium	Prairie rosin-weed		6	225
Silphium perfoliatum	Cup-plant	FACW-	4	252
Silphium terebinthinaceum	Basal-leaved rosin-weed	FACU	7	226
Sium suave	Water-parsnip	OBL	5	263
Solanum dulcamara	Bittersweet (I)	FAC		227
Solidago canadensis	Common goldenrod	FACU	1	229
Solidago gigantea	Goldenrod	FACW	3	230
Solidago riddellii	Riddell's goldenrod	OBL	7	278
Solidago rigida	Stiff goldenrod	FACU-	5	232
Sonchus arvensis	Sow thistle (I)			233
Sorghastrum nutans	Indian grass	FACU+	5	235
Sparganium eurycarpum	Bur-reed	OBL	5	236
Spiraea alba	Meadowsweet	FACW+	4	39
Symplocarpus foetidus	Skunk-cabbage	OBL	8	260
Taraxacum officinale	Dandelion (I)	FACU		237
Toxicodendron radicans	Poison ivy	FAC+	4	272
Thuja occidentalis	Northern white cedar	FACW	9	33

Species	Common name	W.I.S.	CC	Species #
Tilia americana	Basswood	FACU	5	34
Triadenum fraseri	Bog St. John's-wort	OBL	8	257
Trifolium hybridum	Aslike clover (I)	FAC-		238
Trifolium pratense	Red clover (I)	FACU+		239
Trifolium repens	White clover (I)	FACU+		240
Typha spp.	Cattail (I)	OBL		241
Ulmus americana	American elm	FACW-	3	271
Urtica dioica	Stinging nettle	FAC+	1	242
Utricularia vulgaris	Common bladderwort	OBL	7	243
Verbascum thapsus	Mullein (I)			244
Verbena hastata	Blue vervain	FACW+	3	245
Verbena urticifolia	White vervain	FAC+	2	329
Veronica anagallis-aquatica	Water speedwell	OBL	4	327
Vernonia fasciculata	Common ironweed	FACW	5	246
Veronica peregrina	Purslane speedwell	FACW+	0	277
Vitis riparia	River-bank grape	FACW-	2	35
Vicia angustifolia	Narrow-leaved vetch (I)			248
Vicia sativa	Common vetch (I)			249
Xanthium strumarium	Common cocklebur	FAC	1	262
Zanthoxylum americanum	Prickly ash		3	36
Mystery plant 2 Ricci				251

Appendix D. Listing of all birds identified during 1994 (wetland ages 2-6 years) and 2002-2004 (wetland ages 11-15 years) censusing of 30 Ozaukee County wetland restorations sites: * observed only in1994, ** observed only during 2002-2004, species listed in **bold** observed during both surveys.

Genus	Species	Common Name
Actitis	***macularia***	**Spotted Sandpiper**
Agelaius	***phoeniceus***	**Red-winged Blackbird**
Aix	***sponsa***	**Wood Duck**
Anas	*acuta*	Northern Pintail*
Anas	*americana*	American Wigeon*
Anas	*clypeata*	Northern Shoveler*
Anas	*crecca*	Green-winged Teal*
Anas	***discors***	**Blue-winged Teal**
Anas	***platyrhynchos***	**Mallard**
Anas	*strepera*	Gadwall*
Archilochus	*colubris*	Ruby-throated Humminbird**
Ardea	***herodias***	**Great Blue Heron**
Aythya	*affinis*	Lesser Scaup*
Aythya	*americana*	Redhead*
Aythya	*collaris*	Ring-necked Duck*
Aythya	*marila*	Greater Scaup*
Bartramia	*longicauda*	Upland Sandpiper**
Bombycilla	***garrulus***	**Cedar Waxwing**
Botaurus	*lentiginosus*	American Bittern*
Branta	***canadensis***	**Canada Goose**
Bucephala	*albeola*	Bufflehead*
Buteo	*jamaicensis*	Red-tailed Hawk**
Butorides	*striatus*	Green Heron*
Calidris	*minutilla*	Least Sandpiper*
Cardinalis	***cardinalis***	**Northern Cardinal**
Carduelis	***tristis***	**American Goldfinch**
Carpodacus	*mexicanus*	House Finch**
Cathartes	*aura*	Turkey Vulture**
Ceryle	***alycon***	**Belted Kingfisher**
Chaetura	*pelagica*	Chimney Swift**
Charadrius	***vociferus***	**Killdeer**
Circus	***cyaneus***	**Northern Harrier**
Cistothorus	*palustris*	Marsh Wren*
Cistothorus	*platensis*	Sedge Wren**
Colaptes	*auratus*	Northern Flicker**
Corvus	***brachyrhynchos***	**American Crow**
Cuanocitta	*cristata*	Blue Jay**
Dendroica	*petechia*	Yellow Warbler**

Genus	Species	Common Name
Dolichonyx	***oryzivorus***	**Bobolink**
Dumetella	***carolinensis***	**Gray Catbird**
Empidonox	***traillii***	**Willow Flycatcher**
Falco	*sparverius*	American Kestrel**
Fulica	***americana***	**American Coot**
Gallinago	*gallinago*	Wilson's Snipe*
Geothiypis	***trichas***	**Common Yellowthroat**
Grus	*canadensis*	Sandhill Crane**
Hirundo	*pyrrhonota*	Cliff Swallow**
Hirundo	***rustica***	**Barn Swallow**
Icteria	*virens*	Yellow-breasted Chat**
Icterus	***galbula***	**Northern Oriole**
Larus	*argentatus*	Herring Gull*
Larus	*philadelphia*	Bonaparte's Gull*
Limnodromus	*griseus*	Short-billed Dowitcher*
Melanerpes	*carolinus*	Red-bellied Woodpecker**
Melospiza	*georgiana*	Swamp Sparrow*
Melospiza	***melodia***	**Song Sparrow**
Molothrus	***ater***	**Brown-headed Cowbird**
Oxyura	*jamaicensis*	Ruddy Duck*
Parus	*atricapillus*	Black-capped Chickadee**
Passer	*domesticus*	House Sparrow*
Passerculus	***sandwichensis***	**Savannah Sparrow**
Phasianus	*colchicus*	Ring-necked Pheasant*
Picoides	*pubescens*	Downy Woodpecker**
Piranga	*olivacea*	Scarlet Tanager**
Podilymbus	***podiceps***	**Pied-billed Grebe**
Porzana	***carolina***	**Sora**
Quiscalus	***quiscula***	**Common Grackle**
Rallus	***limicola***	**Virginia Rail**
Sayornis	*phoebe*	Eastern Phoebe**
Sialia	*sialis*	Eastern Bluebird**
Sitta	*carolinensis*	White-breasted Nuthatch
Spizella	*arborea*	American Tree Sparrow*
Spizella	*pallida*	Clay-colored Sparrow**
Spizella	*passerina*	Chipping Sparrow**
Spizella	***pusilla***	**Field Sparrow**
Steigidopteryx	*ruficollis*	Northern Rough-winged Swallow*
Sturnella	***magna***	**Easterm Meadowlark**
Sturnus	***vulgaris***	**European Starling**
Tachycineta	***bicolor***	**Tree Swallow**
Tringa	*flavipes*	Lesser Yellowlegs*
Tringa	*melanoleuca*	Greater Yellowlegs*

Genus	Species	Common Name
Tringa	*solitaria*	Solitary Sandpiper*
Troglodytes	*aedon*	House Wren**
Turdus	***migratorius***	**American Robin**
Tyrannus	***tyrannus***	**Eastern Kingbird**
Vireo	*gilvus*	Warbling Vireo**
Zenaida	***macroura***	**Mourning Dove**
Zonotrichia	*albicollis*	White-throated Sparrow*

Appendix E. A summary of attributes for 120 Ozaukee County wetland restoration sites. Age Group, assigned age class: 1-5 years = 1, 6-9 years = 2, 10-13 years = 3, 14-17 years = 4. Wetland Size, area of wetland basin in hectares. Watershed Size, area of local surface water drainage area in hectares. % Ag. In Watershed, percentof watershed in active agricultural practices. Project Type, assigned construction class: Creation, Enhancement, Restoration. Distance to thethe nearest: Active Agricultural Tract, Road, Restored Wetland, Woodland, and Natural Wetland in meters. Seeded sites are in bold.

							Distance (m) to the Nearest:				
Site #	**Age Sampled**	**Age Group**	**Wetland Size (ha)**	**Watershed Size (ha)**	**% Ag. In Watershed**	**Project Type**	**Active Ag. Tract**	**Road**	**Restored Wetland**	**Woodland**	**Natural Wetland**
1	6	2	0.08	1.18	14.86	Restoration	0	39	8	551	1413
2	6	2	0.20	1.77	87.91	Restoration	0	241	70	70	1125
3	8	2	0.15	0.97	37.10	Creation	0	3	165	13	106
4	9	2	0.16	0.84	0.00	Restoration	33	558	82	149	283
5	10	3	0.16	0.59	0.00	Creation	110	68	51	424	355
6	7	2	0.51	3.02	12.00	Creation	45	60	976	103	448
7	10	3	0.07	3.52	78.18	Restoration	0	209	0	464	70
8	**12**	**3**	0.06	**1.16**	**0.00**	**Restoration**	**22**	**9**	**604**	**312**	**599**
9	**12**	**3**	0.04	**0.57**	**0.00**	**Creation**	**71**	**676**	**102**	**17**	**107**
10	11	3	0.01	0.14	49.62	Enhancement	16	85	42	486	0
11	**12**	**3**	0.12	**1.07**	**0.00**	**Restoration**	**98**	**24**	**>3000**	**62**	**31**
12	**12**	**3**	0.12	**0.80**	**0.00**	**Restoration**	**43**	**212**	**72**	**370**	**330**
13	13	3	0.09	0.45	0.00	Creation	42	292	477	294	232
14	11	3	0.15	2.46	0.00	Creation	205	924	6	139	182
15	6	2	0.12	0.41	72.33	Creation	0	31	57	125	273
16	6	2	0.11	22.93	66.30	Enhancement	66	214	90	842	0
17	6	2	0.12	2.37	0.00	Restoration	40	409	67	115	37
18	11	3	0.08	0.57	0.00	Restoration	432	512	280	25	6
19	13	3	0.52	1.61	55.15	Restoration	0	81	15	776	37
20	8	2	0.30	3.64	68.47	Restoration	0	24	387	278	129
21	9	2	0.10	0.93	0.00	Restoration	84	213	19	186	17
22	9	2	0.04	0.11	0.00	Restoration	124	191	19	200	61
23	13	3	0.17	0.58	0.00	Creation	21	6	182	171	563
24	13	3	0.03	0.31	0.00	Restoration	43	30	112	254	145
25	13	3	0.01	0.13	0.00	Restoration	52	39	112	355	180
26	11	3	0.07	1.20	0.00	Restoration	115	121	38	359	296

							Distance (m) to the Nearest:				
Site #	**Age Sampled**	**Age Group**	**Wetland Size (ha)**	**Watershed Size (ha)**	**% Ag. In Watershed**	**Project Type**	**Active Ag. Tract**	**Road**	**Restored Wetland**	**Woodland**	**Natural Wetland**
27	13	3	0.08	0.90	24.87	Restoration	27	465	34	96	97
28	13	3	0.06	0.67	0.00	Restoration	394	222	20	377	238
29	10	3	0.20	1.64	10.75	Restoration	15	407	82	10	404
30	13	3	0.74	2.23	0.00	Restoration	74	422	6	804	363
31	11	3	0.01	0.12	0.00	Restoration	35	12	29	384	365
32	11	3	0.05	0.67	0.00	Creation	163	223	38	563	422
33	7	2	0.07	2.23	0.00	Creation	31	15	265	750	952
34	15	4	0.04	0.61	0.00	Creation	33	429	37	933	811
35	15	4	0.19	1.43	0.00	Creation	113	408	57	917	882
36	13	3	0.06	1.01	0.00	Restoration	201	207	56	337	490
37	15	4	0.22	2.60	0.00	Restoration	364	401	50	585	709
38	15	4	0.15	0.89	0.00	Restoration	472	316	50	676	657
39	7	2	0.10	0.95	32.34	Restoration	0	77	8	576	1359
40	12	3	0.21	1.14	0.00	Restoration	38	5	611	240	29
41	6	2	0.10	1.89	0.00	Restoration	0	302	16	255	260
42	15	4	0.24	1.14	0.00	Creation	158	131	0	550	648
43	6	2	0.08	1.53	28.25	Restoration	46	431	59	354	205
44	6	2	0.09	7.56	36.02	Restoration	146	411	59	440	230
45	14	4	0.42	1.34	55.25	Enhancement	0	180	15	686	0
46	15	4	1.02	12.87	52.77	Enhancement	0	287	0	1032	0
47	10	3	0.12	2.28	13.54	Restoration	31	521	720	23	50
48	7	2	0.12	3.04	33.78	Restoration	3	173	252	225	543
49	7	2	0.14	5.12	4.60	Enhancement	42	161	38	309	0
50	7	2	0.14	4.07	82.36	Creation	1	266	1333	531	192
51	14	4	0.56	2.62	74.26	Restoration	0	65	73	807	95
52	6	2	0.20	2.35	80.57	Creation	0	190	898	81	62
53	15	4	0.15	3.64	0.00	Enhancement	391	622	932	23	0
54	15	4	0.35	2.43	0.00	Creation	232	469	155	1170	618
55	15	4	0.33	3.28	0.00	Restoration	235	636	155	1362	501
56	16	4	0.14	0.33	10.63	Creation	3	277	48	205	939
57	16	4	0.06	0.67	0.00	Creation	3	275	48	201	949
58	13	3	0.10	1.82	0.00	Restoration	56	297	191	394	264

Site #	Age Sampled	Age Group	Wetland Size (ha)	Watershed Size (ha)	% Ag. In Watershed	Project Type	Distance (m) to the Nearest: Active Ag. Tract	Road	Restored Wetland	Woodland	Natural Wetland
59	17	4	0.07	0.77	78.06	Restoration	0	409	5	129	115
60	17	4	0.56	7.09	62.35	Restoration	0	238	5	156	131
61	15	4	2.18	6.34	0.00	Restoration	73	43	0	553	531
62	15	4	0.30	1.34	0.00	Restoration	62	306	25	813	166
63	14	4	0.18	4.16	0.00	Restoration	340	618	45	599	160
64	16	4	0.11	2.82	0.00	Creation	192	130	53	731	708
65	14	4	0.20	2.41	7.16	Restoration	25	419	0	932	522
66	16	4	0.37	2.21	2.40	Restoration	77	289	110	856	714
67	16	4	0.24	4.15	36.76	Restoration	26	141	110	1052	552
68	14	4	0.09	1.89	0.00	Restoration	151	533	0	818	417
69	14	4	0.06	5.34	0.00	Creation	219	152	182	322	400
70	15	4	0.55	1.62	41.36	Restoration	0	329	53	834	351
71	13	3	0.10	1.35	0.00	Restoration	127	618	45	566	160
72	14	4	0.10	2.16	0.00	Creation	138	25	194	446	189
73	13	3	0.13	0.80	0.00	Creation	220	12	54	314	720
74	15	4	0.47	13.37	47.80	Restoration	104	280	357	628	323
75	12	3	0.12	0.83	0.00	Restoration	105	12	51	351	470
76	13	3	0.27	1.74	0.00	Restoration	255	22	51	93	1234
77	15	4	0.67	2.30	53.94	Restoration	0	118	1	1033	490
78	13	3	0.04	1.42	0.00	Restoration	155	53	193	270	275
79	15	4	0.03	0.56	47.51	Creation	0	227	1	979	466
80	15	4	0.04	0.27	0.00	Restoration	91	366	25	775	145
81	9	2	0.03	4.83	10.77	Enhancement	145	329	45	44	0
82	8	2	0.09	5.16	2.70	Restoration	125	521	55	238	77
83	7	2	0.05	1.08	40.76	Restoration	19	9	467	487	360
84	6	2	0.13	1.80	42.28	Restoration	67	304	0	342	65
85	6	2	0.10	0.95	32.29	Restoration	76	271	0	300	108
86	6	2	0.04	0.79	0.00	Enhancement	107	646	84	266	0
87	8	2	0.42	7.30	28.85	Restoration	18	39	917	201	271
88	7	2	0.09	0.38	0.00	Restoration	27	179	1088	384	42
89	9	2	0.08	3.10	59.34	Restoration	27	180	107	495	415
90	6	2	0.44	4.06	22.06	Restoration	95	164	964	574	42

							Distance (m) to the Nearest:				
Site #	**Age Sampled**	**Age Group**	**Wetland Size (ha)**	**Watershed Size (ha)**	**% Ag. In Watershed**	**Project Type**	**Active Ag. Tract**	**Road**	**Restored Wetland**	**Woodland**	**Natural Wetland**
91	5	1	0.09	0.76	0.00	Restoration	243	92	156	230	923
92	4	1	0.31	1.65	9.54	Restoration	67	263	29	18	123
93	3	1	0.09	0.37	0.00	Restoration	134	123	25	799	47
94	3	1	0.04	0.49	0.00	Restoration	106	95	25	827	64
95	4	1	0.54	1.90	28.86	Restoration	22	7	30	262	361
96	3	1	0.11	1.72	77.99	Creation	0	248	44	33	258
97	3	1	0.02	2.63	28.36	Restoration	115	390	87	80	122
98	4	1	0.28	1.71	22.09	Restoration	87	128	67	0	134
99	4	1	0.42	6.70	49.18	Restoration	8	105	105	240	145
100	4	1	0.31	2.83	69.58	Restoration	9	347	126	132	246
101	5	1	0.15	0.25	0.00	Enhancement	49	12	16	78	0
102	2	1	0.15	0.89	0.00	Restoration	472	316	50	676	657
103	2	1	0.22	2.60	0.00	Restoration	364	401	50	585	709
104	2	1	0.24	4.15	36.33	Restoration	26	141	110	1052	552
105	2	1	0.37	2.20	2.51	Restoration	77	289	110	856	714
106	2	1	2.17	6.34	0.00	Restoration	73	43	0	553	531
107	1	1	0.11	1.58	72.56	Restoration	0	106	6	1192	740
108	1	1	0.11	0.65	81.57	Restoration	0	154	6	1164	745
109	1	1	0.30	4.45	84.37	Restoration	0	241	10	1060	657
110	1	1	0.25	1.25	78.50	Restoration	0	154	22	1067	545
111	**1**	**1**	0.46	**2.19**	**0.00**	**Restoration**	**136**	**627**	**0**	**412**	**681**
112	**2**	**1**	0.46	**2.19**	**0.00**	**Restoration**	**136**	**627**	**0**	**412**	**681**
113	**1**	**1**	0.04	**0.57**	**0.00**	**Creation**	**71**	**676**	**102**	**17**	**107**
114	**2**	**1**	0.04	**0.57**	**0.00**	**Creation**	**71**	**676**	**102**	**17**	**107**
115	**1**	**1**	0.12	**1.07**	**0.00**	**Restoration**	**98**	**24**	**>3000**	**62**	**31**
116	**2**	**1**	0.12	**1.07**	**0.00**	**Restoration**	**98**	**24**	**>3000**	**62**	**31**
117	**1**	**1**	0.05	**1.15**	**0.00**	**Restoration**	**22**	**9**	**604**	**312**	**599**
118	**2**	**1**	0.05	**1.15**	**0.00**	**Restoration**	**22**	**9**	**604**	**312**	**599**
119	**1**	**1**	0.12	**0.80**	**0.00**	**Restoration**	**43**	**212**	**72**	**370**	**330**
120	**2**	**1**	0.12	**0.80**	**0.00**	**Restoration**	**43**	**212**	**72**	**370**	**330**
Means	**9.12**		**0.22**	**2.33**	**19.50**		**88.56**	**244.23**	**156.28**	**440.56**	**356.23**

Appendix F. Matrix of pairwise Pearson Correlation coefficients of all summary variables measured on 104 unseeded wetlands. Significant correlations (P<0.05) are in bold.

Correlation coefficients >0.20 have P<0.05; Correlation coefficients >0.25, P<0.01; Correlation coefficients >0.32, P<0.001. Variable name abbreviations listed on page F3.

							Distance to Nearest														
						Water			Const.		Natur.										
	Age	Acls	Size	Shape	Peri	Depth	Ag	Road	Wet	Wood	Wet	PAg	Soil	NInd	PInd	Drain	BWR	Ret15	Ret30	Ret46	Ret61
Age	1.00																				
Acls	**0.97**	1.00																			
Size	0.04	0.06	1.00																		
Shape	0.13	0.14	-0.05	1.00																	
Peri	0.04	0.06	**0.91**	-0.16	1.00																
WatDep	**-0.27**	**-0.26**	0.11	-0.10	0.10	1.00															
Ag	0.17	0.17	-0.11	-0.01	-0.14	-0.17	1.00														
Road	0.18	**0.23**	-0.14	0.14	-0.11	-0.12	**0.33**	1.00													
ConWet	-0.08	-0.07	-0.03	-0.02	0.02	-0.02	-0.04	-0.05	1.00												
Wood	0.11	**0.22**	0.18	0.06	0.19	0.05	-0.01	0.02	**-0.21**	1.00											
NatWet	0.02	0.05	0.04	0.09	0.04	0.02	0.08	-0.16	**-0.20**	**0.29**	1.00										
PAg	**-0.27**	**-0.22**	0.05	-0.10	0.15	0.16	**-0.52**	-0.18	0.08	0.12	-0.09	1.00									
Soil	**0.32**	**0.26**	0.01	0.11	-0.12	-0.11	**0.36**	0.04	**-0.20**	-0.03	0.10	**-0.77**	1.00								
NInd	**0.29**	**0.24**	-0.01	0.08	-0.11	-0.13	**0.41**	0.14	**-0.21**	-0.03	0.15	**-0.91**	**0.87**	1.00							
PInd	**0.31**	**0.27**	0.00	0.09	-0.09	-0.16	**0.39**	0.16	**-0.20**	-0.03	0.15	**-0.88**	**0.87**	**0.99**	1.00						
Drain	-0.01	0.03	**0.35**	-0.18	**0.41**	0.12	-0.06	0.03	0.11	0.16	-0.16	**0.26**	**-0.29**	**-0.30**	**-0.29**	1.00					
BWR	-0.09	-0.08	-0.19	-0.07	**-0.23**	0.13	0.04	0.09	0.00	-0.07	**-0.20**	0.10	-0.14	-0.15	-0.14	**0.59**	1.00				
Ret15	0.08	0.03	0.12	0.05	0.17	-0.05	-0.11	**-0.23**	-0.12	-0.02	0.01	-0.07	**0.28**	0.15	0.15	**-0.35**	**-0.43**	1.00			
Ret30	0.08	0.03	0.13	0.05	0.19	-0.05	-0.11	**-0.22**	-0.12	-0.02	0.02	-0.07	**0.27**	0.14	0.15	**-0.35**	**-0.43**	**1.00**	1.00		
Ret46	0.07	0.03	0.15	0.06	**0.22**	-0.04	-0.11	**-0.21**	-0.12	-0.01	0.03	-0.06	**0.25**	0.13	0.14	**-0.33**	**-0.43**	**1.00**	**1.00**	1.00	
Ret61	0.07	0.03	0.17	0.07	**0.25**	-0.04	-0.11	**-0.20**	-0.11	0.00	0.04	-0.05	**0.23**	0.12	0.13	**-0.31**	**-0.42**	**0.99**	**0.99**	**1.00**	1.00
Rich	0.09	0.02	0.06	0.05	0.06	0.12	**0.24**	0.16	**0.26**	**-0.24**	-0.05	**-0.32**	0.10	0.17	0.13	-0.07	-0.05	0.04	0.05	0.06	0.07
H	0.00	-0.02	0.08	0.07	0.06	0.03	**0.25**	0.13	0.17	0.01	0.12	**-0.40**	0.19	**0.30**	**0.27**	-0.14	-0.14	0.04	0.05	0.07	0.08
Native	0.15	0.09	0.02	0.08	0.00	0.12	**0.27**	**0.22**	**0.28**	**-0.25**	-0.17	**-0.38**	0.15	**0.22**	0.18	-0.06	0.00	0.02	0.03	0.04	0.05
PNat	**0.30**	**0.24**	-0.16	0.11	**-0.23**	0.04	**0.21**	**0.20**	0.18	**-0.31**	**-0.44**	**-0.46**	**0.34**	**0.38**	**0.37**	-0.05	0.16	-0.01	-0.02	-0.02	-0.03
NNWS	0.17	0.10	0.00	0.08	-0.02	0.18	**0.29**	**0.21**	**0.29**	**-0.23**	-0.15	**-0.40**	0.16	**0.24**	**0.20**	-0.05	0.02	0.01	0.02	0.03	0.04
MeanC	**0.29**	**0.26**	-0.04	-0.09	-0.05	**0.25**	0.11	0.01	0.08	0.00	-0.04	**-0.24**	0.18	0.19	0.19	0.13	0.09	-0.13	-0.13	-0.14	-0.15
WFQI	**0.23**	0.16	-0.06	0.07	-0.08	**0.21**	**0.32**	**0.21**	**0.29**	**-0.27**	-0.16	**-0.46**	**0.24**	**0.31**	**0.27**	-0.05	0.05	-0.03	-0.03	-0.02	-0.01
WdCov	**-0.40**	**-0.41**	-0.14	-0.16	-0.13	0.08	0.03	0.04	0.04	**-0.31**	-0.08	-0.02	0.03	-0.02	-0.02	-0.11	0.05	0.00	-0.01	-0.01	-0.02
Open	**-0.22**	-0.18	0.05	-0.04	0.04	0.06	-0.12	0.10	-0.14	0.18	0.11	**0.30**	**-0.28**	**-0.29**	**-0.30**	0.03	-0.03	-0.13	-0.12	-0.12	-0.12
RCG	-0.04	-0.04	-0.07	-0.08	-0.04	0.18	**-0.19**	-0.08	0.04	-0.12	-0.12	0.11	-0.14	-0.14	-0.12	0.17	**0.24**	-0.11	-0.11	-0.12	-0.12
Typh	0.12	0.09	-0.01	0.16	-0.01	-0.10	**0.19**	-0.05	-0.16	0.09	0.05	-0.12	**0.29**	0.19	**0.20**	-0.08	-0.03	0.16	0.16	0.15	0.15
Lem	-0.03	-0.01	-0.04	0.10	-0.01	0.17	-0.07	0.03	-0.13	-0.09	**0.23**	**0.19**	-0.12	-0.16	-0.16	0.00	0.06	-0.06	-0.06	-0.05	-0.05
SalExi	**0.25**	**0.25**	0.04	**0.21**	0.02	-0.17	-0.05	-0.03	0.00	**0.24**	0.12	-0.01	-0.04	0.04	0.04	0.10	-0.01	-0.09	-0.09	-0.09	-0.08
ElyRep	**-0.50**	**-0.43**	**0.25**	-0.01	**0.20**	0.10	0.14	-0.05	-0.13	**0.32**	**0.26**	0.13	-0.08	-0.09	-0.08	0.00	-0.10	0.01	0.02	0.02	0.03
Wild	0.06	0.08	**0.26**	0.13	**0.23**	0.07	**0.21**	**0.23**	0.10	0.06	0.16	-0.16	0.11	0.06	0.06	0.19	0.13	-0.02	-0.02	0.00	0.01

	Rich	H	Native	PNat	NNWS	MeanC	WFQI	WdCov	Open	RCG	Typh	Lem	SalExi	ElyRep	Wild
Age															
Acls															
Size															
Shape															
Peri															
WatDep															
Ag															
Road															
ConWet															
Wood															
NatWet															
PAg															
Soil															
NInd															
PInd															
Drain															
BWR															
Ret15															
Ret30															
Ret46															
Ret61															
Rich	1.00														
H	**0.74**	1.00													
Native	**0.97**	**0.69**	1.00												
PNat	**0.42**	0.19	**0.60**	1.00											
NNWS	**0.94**	**0.65**	**0.98**	**0.62**	1.00										
MeanC	-0.03	-0.15	0.06	**0.29**	0.13	1.00									
WFQI	**0.86**	**0.58**	**0.93**	**0.70**	**0.94**	**0.37**	1.00								
WdCov	**-0.21**	**-0.22**	**-0.23**	-0.12	-0.21	0.01	-0.17	1.00							
Open	**-0.29**	**-0.22**	**-0.32**	**-0.49**	**-0.31**	**-0.20**	**-0.40**	0.04	1.00						
RCG	-0.19	**-0.47**	-0.13	0.19	-0.07	**0.35**	0.01	0.09	**-0.24**	1.00					
Typh	-0.14	-0.17	-0.13	0.07	-0.12	0.03	-0.10	0.02	**-0.27**	**-0.23**	1.00				
Lem	0.01	**-0.28**	-0.05	-0.10	-0.05	-0.01	-0.04	0.08	**0.22**	0.18	0.03	1.00			
SalExi	0.19	**0.21**	**0.21**	0.11	**0.20**	-0.05	0.14	**-0.84**	0.02	-0.10	-0.10	-0.06	1.00		
ElyRep	**-0.33**	-0.04	**-0.39**	**-0.51**	**-0.39**	**-0.42**	**-0.49**	0.13	**0.38**	**-0.27**	0.15	-0.09	-0.07	1.00	
Wild	**0.42**	0.20	**0.44**	0.19	**0.44**	0.04	**0.45**	-0.06	-0.16	0.15	-0.03	0.17	0.08	0.07	1.00

Definitions of variable name abbreviations used in the correlation matrix on pages F1-2.

Variable name	Definition
Age	Age in years
Acls	Age class 1-5; 6-9; 10-13; 14-17
Size	Hectares
Shape	Shape index
Peri	Perimeter (m)
WatDep	1 = dry; 2 = seasonally wet; 3 = permanently wet
Ag	Distance to nearest active Ag field (m)
Road	Distance to nearest road (m)
ConWet	Distance to nearest constructed wetland (m)
Wood	Distance to nearest woodland (m)
NatWet	Distance to nearest natural wetland (m)
PAg	Percentage of active ag land in the drainage basin
Soil	% decrease in soil erosion
NInd	Nitrogen loading index
PInd	Phosphorus loading index
Drain	Area of local surface drainage in hectares
BWR	Ratio of drainage basin size to wetland size
Ret15	cm runoff retained at 15 cm drawdown
Ret30	cm runoff retained at 30 cm drawdown
Ret46	cm runoff retained at 46 cm drawdown
Ret61	cm runoff retained at 61 cm drawdown
Rich	Richness
H	Shannon-Weiner diversity index of all species
Native	Number of native species
PNat	Percent native species
NNWS	Number of native wetland species
MeanC	Mean C
WFQI	Wisconsin Floristic Quality Index
WdCov	Inverse of woody plant cover (i.e. the mean percent open area not covered by woody plants)
Open	Mean percent open space in herbaceuous quadrats
RCG	Mean percent cover reed canary grass
Typh	Mean percent cover Typha
Lem	Mean percent cover Lemna
SalExi	Mean percent cover Salix exigua
ElyRep	Mean percent cover Elytrigia repens
Wild	Number of wildlife species

Appendix G. Ozaukee County Wetland Restoration Standard Field Monitoring Methods:

The following methods are intended to provide a quick, site-intensive assessment of biological function in privately owned small wetland restorations over time. A field monitoring form has been developed to record data (attached). The methods require one investigator with background in plant and wildlife identification to physically visit the site. Thirty wetland restoration sites will be selected from the Ozaukee County Wetland Restoration Inventory geodatabase each year and with landowner permission, field sampled. All site visits will occur mid August through the end of September between 10:00 A.M. and 2:00 P.M.

Sightings and signs (i.e. vocalizations and physical evidence) of birds, mammals and anurans will be recorded as "sight" and "sign" respectively within a 100-foot buffer in each site. This data will be utilized during assessment of wildlife use. The number of wildlife species recorded during site visits will serve as an index of wildlife habitat use.

Using permanent marker, label the outside of the investigator's right hip-wader in increments of centimeters (0-70 cm from bottom to top of boot). The maximum surface water measurement will be recorded (up to 70 cm, or > 70 cm). Estimate percent of wetland currently filled with water by locating the outflow point and utilizing the following scale: 0 (dry basin) to 100% (full basin).

The following indices will be recorded and calculated for vegetation: 1) A flora (complete species list) to estimate floristic richness (# of species), 2) number of native plants present, 3) number of native wetland plants present (native plants with wetland indicator status of obligate, facultative wetland, or facultative) (Reed 1997), 4) Mean Coefficient of Conservatism (Bernthal et al. 2003), and 5) Wisconsin Floristic Quality Index (Bernthal et al. 2003).

Wildlife and plant indices for each site visited will be recorded in the Ozaukee County Wetland Restoration GIS database.

References:

Bernthal, T.W. 2003. Development of a Floristic Quality Assessment Methodology for Wisconsin. Wisconsin Department of Natural Resources, Bureau of Fisheries Management and Habitat protection, Madison, WI.

Reed, P.B. 1997. Revision of the National List of Plant Species that occur in Wetlands. Washington, DC, U.S. Department of the Interior, U.S. Fish and Wildlife Service.

INVESTIGATOR: ________________________ **SITE #:** _______ **DATE:** _______________

COMMENTS:

WILDLIFE **Signs:** ____ **Total # Species** _________

Sightings:____

WATER **Max Depth:** _________ **% Full Basin:** ____________

PLANT **# Species:** ________ **# Native Species:** _______ **# Nat Wet Species:** ________

Mean C: ________ **WFQI (Mean C * square root of # Native Species):** ________

Species	Common name	Native	W.I.S.	CC	Species #

Species	Common name	Native	W.I.S.	CC	Species #

Appendix H Landowner Survey

INTRODUCTION

Over the past 20 years, federal, state, and local government agencies have constructed 326 wetland restorations covering more than 350 acres on private land in Ozaukee County, Wisconsin. These efforts are continuing, with several additional wetlands appearing on the landscape each year through incentives such as those provided by the Natural Resources Conservation Service (NRCS), United States Fish & Wildlife Service (USFWS), Wisconsin Department of Natural Resources (WDNR), and County Priority Watershed Wetland Restoration Programs. These programs use 10 to 15 year easement contracts to encourage landowners to remove highly erodible land from agricultural/grazing use and restore natural plant communities. Not intended to restore the pre-settlement (primarily forested) wetland communities of the county, the restoration program goals are to: increase wildlife habitat and plant diversity, reduce soil erosion, improve water quality by filtering pollutants and sediments, and provide storm water storage to reduce flooding.

Ozaukee County has recently completed a Geographic Information System (GIS) inventory of these wetlands. As a result of this effort, many attributes of the wetlands can now be described and the wetlands can be added to the state wetland database.
While wetland inventory is an important component, inventory alone does not constitute a comprehensive wetland restoration assessment and monitoring program. Much effort is needed beyond the initial inventory to examine how the wetlands currently function as components of the larger county landscape as well as to monitor future development and functional status. The GIS approach to inventorying wetlands allows us to evaluate the current ecologic functions and estimate the resulting impacts on the landscape utilizing a combination of landscape, rapid, and intensive wetland assessment levels. As part of this evaluation, a landowner survey was developed to aid in the identification of: 1) the most common and immediate management concerns, 2) human and wildlife use, and 3) general landowner satisfaction as implied by the survey responses. This information, along with the functional assessment results, will be used to develop a County monitoring plan that can be utilized by all agencies participating in the restorations.

METHODS

After conducting preliminary on-site visits in over one-third of the restored wetlands, we were aware of many management concerns voiced by the landowners such as controlling invasive species and herbivores, repairing structures, and maintaining the grassland buffer. In conjunction with the UW-Milwaukee Center for Urban Initiatives and Research (UWM-CUIR), NRCS, USFWS, WDNR, and Ozaukee County Planning, Resources and Land Management Department staff, a survey was developed (see pages H6-H11 for a sample survey form). The Ozaukee County digital parcel map was utilized to update wetland restoration ownership and mailing address in the GIS database. The survey was mailed to 141 private owners of 286 restored basins as identified by the GIS database. Forty wetland basins restored on public lands owned by NRCS, USFWS, WDNR, and Ozaukee County were not included in the study.

We implemented a single mailing procedure; including a stamped and addressed return envelope for convenience. As an incentive, a complimentary copy of *"Managing Your Restored Wetland"* (Pennsylvania State University, 2000) was offered and mailed to owners who completed and returned their survey within two weeks. Survey responses were digitally recorded by UWM-CUIR. Analysis and summary were completed by Jill Hapner, GeoBotany Systems.

RESULTS

66 percent of the surveys were returned (n = 93). 58 percent were completed (n = 82, confidence interval of +/- 11%); representing 67% of the county's privately owned restored wetland basins (n = 191, confidence interval +/- 7%). Many owners (40%) have restored multiple wetlands on their land. A respondent could provide different answers to the survey questions for each wetland they own. Survey responses were therefore summarized based on the number of owners providing each response and the number of wetlands for which responses were given (pages H12-17). Attributes of the restored wetland basins described in the survey responses are graphed (pages H18-19), and are highly representative of the entire county population.

According to the survey results, 84% of the restored wetland basins (for which owners completed surveys) remain under the management of the original landowner who initiated the contract. 76 percent of the owners plan to maintain 70% of the restored basins in the county landscape beyond the contract period, while 20% are undecided. 2 percent of responding owners reported current grazing or cropping practices in the formerly restored areas. The majority (59%) of the owners requested additional contact, or would like to have additional land evaluated for conservation practices. This information was given to the appropriate agency staff for follow-up contact.

63 percent of owners reported that they had performed no management in 61% of the basins, while weed removal, mowing, and native plantings were conducted in 18%, 10%, and 8% of the wetlands respectively. 9 wetlands (5%) have had their berms or dikes repaired and additional drain tile was removed in 4 of the restored wetlands (2%).

According to the owner responses, 45% of the basins are 'always wet', 28% are 'occasionally wet', 12% are 'occasionally dry', and 7% are 'always dry'. Many respondents commented that their restored wetland dried for the first time during the 2003 growing season.

Landowners reported no management concerns for 50% of the wetlands. Management concerns expressed for the remaining basins include: weedy plant species (20%), inadequate water levels (18%), berm/dike failure (4%), and troublesome wildlife (5%).

33 percent of the responding owners have installed nest boxes in 23% of the restored wetlands, while nest platforms and other nesting structures have been installed in 9%. Of these wetlands, the nesting structures are used every year in 21% of the basins, most years in 10%, occasionally in 16%, and not used in 13% of the basins.

Recreational use of the wetlands includes: bird watching (66% of owners in 50% of the wetlands), hunting (35% of owners in 38% of the wetlands), plant identification (26% of owners in 21% of the wetlands), and fishing (4% of owners in 2% of the wetlands). Ice-skating and ecological education were also reported uses by respondents.

89 percent of the owners report waterfowl use in 77% of the restored wetland basins. Other wildlife observed utilizing the wetlands include: deer (75%), songbirds (72%), frogs/salamanders (60%), pheasants (55%), and muskrat/beaver (40%). Additional wildlife listed by the owners include: coyote, fox, hawks, snakes, toads, raccoons, turkey, pine martins, possum, sandhill cranes, turtles, and skunk.

DISCUSSION & RECOMMENDATIONS

76 percent of the landowners plan to maintain 70% of the restored basins in the county landscape beyond the contract period. The majority (59%) of the landowners requested additional contact or to have additional land evaluated for conservation practices. This response, along with the high survey return, implies that the majority of the landowners are generally satisfied with the wetland restorations, and that the conservation practices may be long-term. Kitchen (2002), also found similar results with his questionnaire involving USFWS wetlands.

During 2002-2004, field data was collected in 82 of the 191 wetlands included in the survey responses. While the landowners reported a concern for weedy plant species in only 20% of the basins, reed canary grass (*Phalaris arundinacea*) and hybrid cattail (*Typha x glauca*) actually have substantial cover (> 20%) in 38% of those wetlands. Canada thistle (*Cirsium arvense*), Queen Anne's lace (*Daucus carota*), and purple loosestrife (*Lythrum salicaria*) are also introduced species recorded in most of the wetlands. This lack of management concern by the owners may be due to lack of knowledge concerning non-native, invasive plant species identification. According to the survey results, only 26% of the owners practice plant identification in the restored wetlands.

16 percent of the respondents report mowing primarily for trail access to the wetland. Field visits have revealed that paths are often mowed within the vegetation ecotone between emergent plants/open water and the upland/wetland margin. This ecotone is very important for plant establishment and wildlife habitat, and a mowed trail would best be located upslope from the wetland/upland boundary.

27 percent of the responding owners reported inadequate water levels in 18% of the wetlands. Kitchen (2002) found that owners were generally dissatisfied with ephemeral

wetlands and attributed it to a lack of understanding of wetland types, hydrological considerations, and wetland ecology. According to survey results, 45% of the basins are 'always wet', 28% are 'occasionally wet', 12% are 'occasionally dry', and 7% are 'always dry'. These responses reflect surface water levels recorded in the basins during the 2002-2004 field visits. We recommend field investigation and evaluation for wetlands that are permanently dry. These basins may need additional tile removed or blocked, or the site may be determined unsuitable for wetland restoration. However, a combination of permanently inundated and ephemeral, or seasonally flooded wetlands is an asset to the county landscape. The latter wetlands are essential habitat for reproduction of many amphibian species. Information concerning the function of wetlands with variable hydoperiods should be shared with owners.

Many respondents commented that their restored wetland(s) dried for the first time during the 2003-growing season. With this in mind, rainfall records recorded at the UW-Milwaukee Field Station (centrally located to the project area), along with rainfall records collected by the National Weather Service in Milwaukee were used for comparison of long-term average monthly rainfall. 2003 was a drought year compared to normal precipitation for our area. Total precipitation recorded in Milwaukee during 2003 (22.3", 566 mm) was the lowest in a 30-year period of record. Average annual precipitation is 31.5" (800 mm). November 2002 through October 2003 precipitation at the Field Station totaled 21.4" (544 mm) compared to the 31.5" average, and 8.0" (204 mm) of that total fell in just two months (April – May 2003).

Bird watching is a popular recreation in the restored wetlands with 66% of the owners participating in 50% of the wetlands. Nesting structures have been installed in 32% of the wetlands, and waterfowl and songbirds are reported using 77% and 72% of the wetlands respectively. Landowner responses concerning observation of wildlife may be slightly skewed due to this high interest in avian species.

Fishing was reported as a recreation in 4% of the wetlands. Field visits have revealed the presence of fish in some of the restored basins. A few landowners have intentionally stocked fish, but most were surprised to find fish present. During the 2003 drought, dead fish were observed in many dry basins. Although there has been little investigation as to the mechanism of fish immigration to the restored basins, it is quite possible that the eggs are delivered to the wetlands by waterfowl.

REFERENCES

Cole, C.A., Serfass, T.L., Brittingham, M.C., and Brooks, R.P. 2000. Managing Your Restored Wetland. The Pennsylvania State University, University Park, PA.

Kitchen, A. 2002. An Assessment of Landowner Participation and Habitat Accomplishments. Partners For Fish and Wildlife Program Monitoring Report for Wisconsin. U.S. Fish and Wildlife Service: Wisconsin Private Lands Office, Madison, WI.

National Climatic Data Center (NCDC). Local Climatological Data, Annual Summary with Comparative Data, Milwaukee, Wisconsin. National Climatic Data Center, Ashville, North Carolina.

University of Wisconsin - Milwaukee Field Station (UWMFS). Archived Weather Records. UWM Field Station, Saukville, WI.

March 16, 2004

Dear Landowner,

Jill Hewitt, a local graduate student, is currently studying how small wetlands restored on private lands function in our County landscape. Many landowners have already been personally contacted and had their wetlands visited by Jill over the past two years. Her work will continue during the 2004 field season and is funded in part through a United States Environmental Protection Agency (USEPA) grant. As part of her research, we are mailing a survey to Ozaukee County residents who have restored wetland habitats on their land.

Please take a few minutes to complete the enclosed survey and return it using the envelope provided. **Your responses are an important part of this research**. Through the efforts and cooperation of landowners, like you, we have been able to restore over 300 acres of wetland habitat on private lands in Ozaukee County over the past 17 years. We want to know your likes, dislikes, and concerns related to the wetland restorations. This will help us to give you management advice as well as to improve future wetland restoration methods.

In appreciation of your conservation efforts and contributions to this survey, all landowners who return surveys by **March 31, 2004** will receive a complimentary copy of the publication *Managing Your Restored Wetland* by mail (description enclosed).

Thank you for your time and conservation efforts,

Andy Holschbach, Director
Ozaukee County Planning, Resources
& Land Management Department
(262) 238-8270

Jill Hewitt, Biologist
GeoBotany Systems
(262) 242-7398

Wetland Restoration Landowner Survey

Only adult individuals (18 years or older) are eligible to participate. By completing and returning the survey, the individual acknowledges that they are an adult, and grants permission for the survey information to be used.

1. Are you the original landowner who initially volunteered to restore the wetland(s)? (**Check one**).
   _____ Yes
   _____ No, I have owned the property for _____ years.

2. Do you plan to keep your wetland(s) past the contract expiration date? (**Check one**).
   _____ Yes **(Please continue to question #3).**
   _____ No **(Please continue to question #3).**
   _____ Undecided **(Please continue to question #3).**
   _____ Area is currently grazed or cropped **(Please continue to question #11).**

NEXT PAGE, PLEASE

For questions 3 through 10, we realize that many of you have more than one wetland basin, and your answers may be different for each basin. In that event, please refer to the enclosed aerial photograph and check the wetland identfication number(s) on the line corresponding to the answer(s) that generally describes each wetland.

3. Have you used any of the following management, maintenance, or repairs to the wetland(s)?		**3a**. Please check corresponding wetland(s) where management, maintenance, or repairs occurred.								
		94	**95**	**96**	**97**	**98**	**99**	**100**	**101**	**102**
______	None									
______	Mowing									
______	Weed removal									
______	Plantings									
______	Berm or dike repair									
______	Additional drain tile removal									
______	Other *(Please specify):*									

4. Which of the following best describes the typical water level in your wetland(s)?		**4a**. Please check corresponding wetland(s) where described water levels occur.								
		94	**95**	**96**	**97**	**98**	**99**	**100**	**101**	**102**
______	Always wet									
______	Always dry									
______	Occasionally wet									
______	Occasionally dry									
______	Don't know									
______	Other *(Please specify):*									

NEXT PAGE, PLEASE

5. Do you have any of the following management concerns?		**5a**. Please check corresponding wetland(s) where management concern(s) apply.								
		94	**95**	**96**	**97**	**98**	**99**	**100**	**101**	**102**
______	None									
______	Weedy plant species									
______	Troublesome wildlife									
______	Water levels									
______	Berm or dike failure									
______	Other *(Please specify):*									

6. Have you installed any nesting structures for birds?		**6a**. Please check corresponding wetland(s) where structures were installed.								
		94	**95**	**96**	**97**	**98**	**99**	**100**	**101**	**102**
______	None (Please continue to question #8)									
______	Nest boxes									
______	Nest platforms									
______	Other *(Please specify):*									

7. If you installed nesting structures, how often are they used?		**7a**. Please check corresponding wetland(s) where described use(s) apply.								
		94	**95**	**96**	**97**	**98**	**99**	**100**	**101**	**102**
______	Every year									
______	Most years									
______	Occasionally									
______	Never									
______	Don't know									
______	No answer									

NEXT PAGE, PLEASE

8. How often do you see waterfowl in your wetland(s)?		**8a**. Please check corresponding wetland(s) where waterfowl has or has not been observed.								
		94	**95**	**96**	**97**	**98**	**99**	**100**	**101**	**102**
______	Every year									
______	Most years									
______	Occasionally									
______	Never									
______	Don't know									

9. Do you or others use your wetland(s) for any of the following recreation?		**9a**. Please check corresponding wetland(s) where recreation has or has not occurred.								
		94	**95**	**96**	**97**	**98**	**99**	**100**	**101**	**102**
______	Hunting									
______	Fishing									
______	Bird watching									
______	Plant identification									
______	None									
______	Other *(Please specify):*									

10. Have you seen any of the following wildlife in using your wetland(s)?		**10a**. Please check corresponding wetland(s) where wildlife has or has not been seen.								
		94	**95**	**96**	**97**	**98**	**99**	**100**	**101**	**102**
______	Deer									
______	Muskrats/Beaver									
______	Waterfowl/Shorebirds									
______	Pheasants									
______	Songbirds									
______	Frogs/Salamanders									
______	Don't know									
______	Other *(Please specify):*									

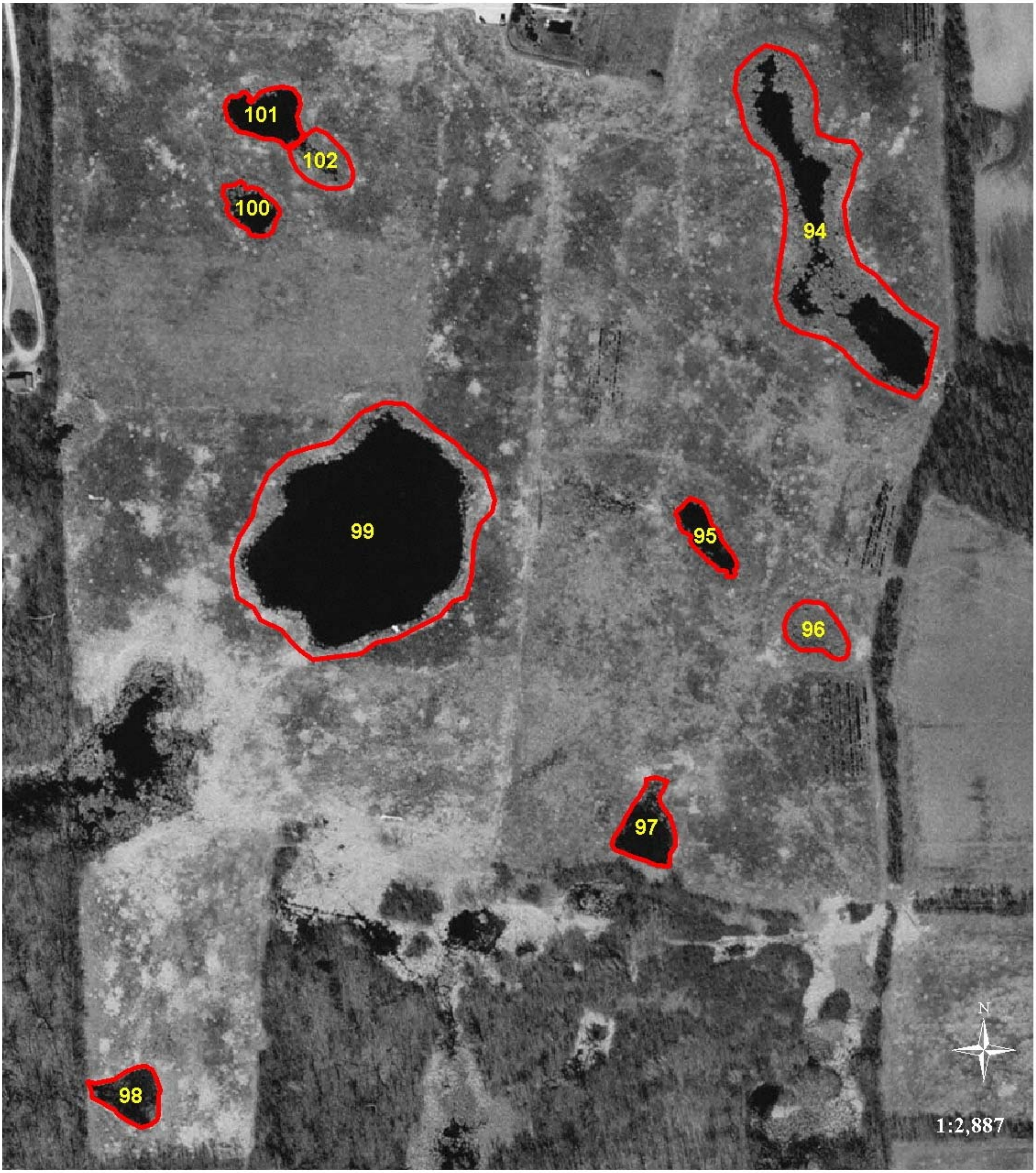
NEXT PAGE, PLEASE

11. Would you like to be contacted concerning your wetland restoration (s) or to have additional land evaluated for conservation practices?

_____ Yes, Name: _________________________ Phone No.: ____________
_____ No

Please make additional comments here:

Please return this survey in the envelope provided (you may keep the aerial photograph as our gift). Thank you very much for responding; your comments will help us to improve our restoration programs for the benefit of our County's wildlife and natural resources.


101
102
100
94
99
95
96
97
98
N
1:2,887

Summary of survey responses: 93 of 141 surveys sent were returned (66%), of which 82 were completed and utilized in analysis (58%). Survey question responses are summarized for each wetland basin (n = 191, confidence interval +/- 7%) and individual owners (n = 82, confidence interval +/- 11%), except where noted on survey question #7.

---

1. Are you the original landowner who initially volunteered to restore the wetland(s)?

	Wetlands	Owners
Yes	160 (84%)	64 (78%)
No (owned for 1-18 years)	31 (16%)	18 (22%)

2. Do you plan to keep your wetland(s) past the contract expiration date?

	Wetlands	Owners
Yes	134 (70%)	62 (76%)
No	0 (0%)	0 (0%)
No answer	3 (2%)	2 (2%)
Undecided	50 (26%)	16 (20%)
Area is currently grazed/cropped	4 (2%)	2 (2%)

3. Have you used any of the following management, maintenance, or repairs to the wetland(s)?

	Wetlands	Owners
None	122 (61%)	52 (63%)
Mowing	19 (10%)	13 (16%)
Weed removal	35 (18%)	13 (16%)
Plantings	15 (8%)	12 (15%)
Berm/Dike repair	9 (5%)	9 (11%)
Additional draintile removal	4 (2%)	4 (5%)
Other	10 (5%)	8 (10%)

Other list: “I mow a path on my lot’s perimeter and a path on one side of the wetland for access”, “I’m leaving it alone because ducks are out there and lots of birds and animals hang out on this pond area”, “Raised drain pipe and added rocks to prevent muskrat damage”, “Digging deeper and expanding”, “Muskrat damage needs repair”, “Repaired washed-out exit tile”, “Sprayed to kill willows and brush burned off by DNR”, “Trees (ash) are coming up on their own”.

4. Which of the following best describes the typical water level in your wetland?

	Wetlands	Owners
Always wet	86 (45%)	55 (67%)
Occasionally dry	22 (12%)	15 (18%)
Occasionally wet	54 (28%)	30 (37%)
Always dry	14 (7%)	5 (6%)
Don’t know	10 (5%)	4 (5%)
Other	14 (7%)	11 (13%)

Other List: “2003 drought dried it out completely, generally always wet”, “Fall 2003 it was the driest ever, almost dries up, but not quite!”, “Almost dried up summer of 2003”, “Birds and animals who like shallow waters like this area”, “Dry only in a very dry year”, “Fills up in spring but drains dry within 4-6 weeks”, “It was always wet until last summer (2003) now it is filling up again”, “Public using pond, they litter, urinate, and defecate and are obnoxious”, “They will dry up sometimes in a dry hot summer but are always wet in spring for ducks to nest in”, “Too early to tell, wet so far”

5. Do you have any of the following management concerns?

	Wetlands	Owners
None	95 (50%)	39 (48%)
Weedy plant species	38 (20%)	23 (28%)
Water levels	35 (18%)	22 (27%)
Berm/dike failure	8 (4%)	8 (10%)
Troublesome wildlife	9 (5%)	6 (7%)
Other	8 (4%)	5 (6%)

Other list: “Cattails”, “Dike damage, not failure, want to install fence wire in berm in 2004”, “Does not seem to retain water”, Erosion of sides”, “It’s too shallow to maintain water levels”, “Might need dredging pretty soon??”

6. Have you installed any nesting structures for birds?

	Wetlands	Owners
None	112 (59%)	53 (65%)
Nest boxes	44 (23%)	27 (33%)
Nest platforms	14 (7%)	7 (9%)
Other	4 (2%)	4 (5%)

Other list: “Experimented with juice containers – didn’t work”, “Has something, not sure”, “Nest boxes were present”, “Prior owners must have but they are never used”

7. If you installed any nesting structures, how often are they used? (wetlands n = 62 as defined by question #6, confidence interval of +/- 13%; landowners n=38, confidence interval of +/- 16%)

	Wetlands	Owners
Every year	13 (21%)	6 (16%)
Most years	6 (10%)	3 (8%)
Occasionally	10 (16%)	9 (24%)
Never	8 (13%)	8 (21%)
Don’t know	17 (27%)	11 (29%)

8. How often do you see waterfowl in your wetland(s)?

	Wetlands	Owners
Every year	142 (74%)	71 (87%)
Most years	7 (4%)	6 (7%)
Occasionally	17 (9%)	7 (9%)
Never	6 (3%)	5 (6%)
Don't know	17 (9%)	7 (9%)

9. Do you or others use your wetland(s) for any of the following recreation?

	Wetlands	Owners
Bird watching	95 (50%)	54 (66%)
Hunting	72 (38%)	29 (35%)
Plant ID	41 (21%)	21 (26%)
Fishing	3 (2%)	3 (4%)
None	33 (17%)	18 (22%)
Other	15 (8%)	7 (9%)

Other list: "High School biology field trips", "Kids ice skating", "My wife for school projects for kids", "Neighbors hunt their section of the wetland", "Subdivision amenity with walking trail access", "There has been unauthorized hunting", "Unauthorized hunting", "Winter skating, meditation, appreciation"

10. Have you seen any of the following wildlife using your wetland(s)?

	Wetlands	Owners
Waterfowl	148 (77%)	73 (89%)
Deer	143 (75%)	67 (82%)
Songbirds	138 (72%)	66 (80%)
Frogs/salamanders	114 (60%)	56 (68%)
Pheasants	106 (55%)	45 (55%)
Muskrat/beaver	76 (40%)	43 (52%)
Don't know	17 (9%)	6 (7%)
Other	25 (13%)	14 (17%)

Other list: "Coyotes", "Coyotes, fox", "Coyotes, hawks, snakes", "Fish, toads, mink, raccoons, and turkey", "Pine martins", "Raccoons, fox, possum, skunk", "Raccoon, cranes, geese, coyotes", "Snakes, turtles, hawks", "Snapping turtles", "Turkey", "Turtles, skunk, fox, coyotes", "Turtles, turkeys, hawks"

11. Would you like to be contacted concerning your wetland restoration(s) or to have additional land evaluated for conservation practices?

	Wetlands	Owners
Yes	97 (51%)	48 (59%)
No	94 (49%)	34 (41%)

Additional comments made by landowners:

"Mallards and geese love this pond"

"Concerns on the continued increase in subdividions in Ozaukee County (specifically Town of Cedarburg) and the resultant effect it will have on wetlands, wildlife, water tables, etc. – Very concerning! Dry conditions the past 2-3 summers (and winter) has dramatically affected the water levels – while there is water standing now (March), it will disappear quickly if dry conditions continue – Thanks for all your work!"

"Need help with area between ponds to get rid of canary grass. Ponds have always had water except for the last 2 years which were very dry. One pond had a lot of big bullheads that died winter 02-03."

"I'm interested in ideas to control Canada thistle (non-chemical) other than cutting, which I am already doing."

"Making some basins bigger may be helpful."

"Would like to keep water level up."

"Basin is adjacent to planted prairie which was burned spring 03."

"I am going to repair the dam due to muskrat damage. Who can help do this?"

"The last time I renewed my CRP contract, they (the government) made a separate contract for wetlands which paid a lot less per acre. I think I got the short end of the stick on this one! You people talk us landowners into restoring wetlands and how good this is for environment and wildlife. Then the government turns around and starts paying us less for CRP land and wetlands than they did at the start of these programs!"

"Cattails, cattails, cattails! As you can see by the photos our "scrape" has evolved into nothing more than 160 x 66 ft. plot of cattails. Red-winged Blackbirds and chorus frogs seem to be the only wildlife presents on a yearly basis. This was a failure! I'm glad to have the contract over and when I can find the funds I will have my scrape dug to a depth that will not encourage the overpopulation of cattails! Suggestions are welcome."

"Our wetland is a part of a larger wetland and neighbors have expressed an interest in having the whole wetland looked at for possible restoration."

"Our pond is much healthier since we had it dug deeper and expanded the size – we did this in 2001. We really love our pond and feel it adds beauty and wildlife to our property."

"Come over anytime! Thank you!"

"Would like to know when my present contract expires."

"You are welcome to come out to study, research, etc. We have had UWM projects etc."

"During the last 10 years the Common Snipe has been absent. They nested in the grass on the property but this was before the pond was installed. There also has been a noticeable decrease in

Spring peepers and Chorus frogs. The same go's for Leopard frogs and Toads, but this may be due to the lower annual precipitation. Buckthorn is invading the northwest corner of the pond. Purple loosestrife is invading the Milwaukee River and its tributaries at an alarming rate. I hope you get a good number of surveys returned."

"I would have liked to have been informed as to the type of tree plantings before the wetland was put together. I'm not sure of the species of tree used on the berm itself. I think they look scruffy and would have asked for a different type of tree to be planted there. I would still like to have a different tree planted on the berm even today. When the contract is over, I'll probably cut those ugly trees down and plant some cedars, pine, and birch."

"I love my wetland. I would like to improve on it."

"Come out and tell us what we can do to improve the pond walls and shoreline. Also, we'd plant and buy a variety of fish there if you'd advise on what kind and when to do it."

"I would like to have you contact and visit my wetland restoration. Please call first. Keep up the good work."

"We would like to talk with someone regarding this project. We need advice on how to maintain water even in dry years. All the other wetlands on our farm maintain at least some water year around. Thank you."

"Do not have knowledge of the success of one wetland as it was just done (2003)."

"I am very satisfied with all of these wetland restorations. They are serving their intended purposes quite well. They are a great source of enjoyment and recreation for family and friends."

"I will not separate 35 acres of surrounding land so it stays in wetlands – We have 10+ acres of wetlands along Sucker Brook, which we would like to have it stay beyond development. Have you any suggestions how to protect it? I had that area surveyed and adjacent to the creek we made a pond used by all kinds of wildlife."

"This project was poorly conceived and even worse in execution. Not a very effective restoration. Area is much too sandy and scrapes drain rapidly. Pretty much just mud holes!"

"Please help keep our taxes low on this land."

"Sorry I didn't return this sooner – I was out-of-town and this was buried in some old mail."

"As most of my land is in CRP, it gives wildlife a good home, and a good source for us to enjoy viewing them."

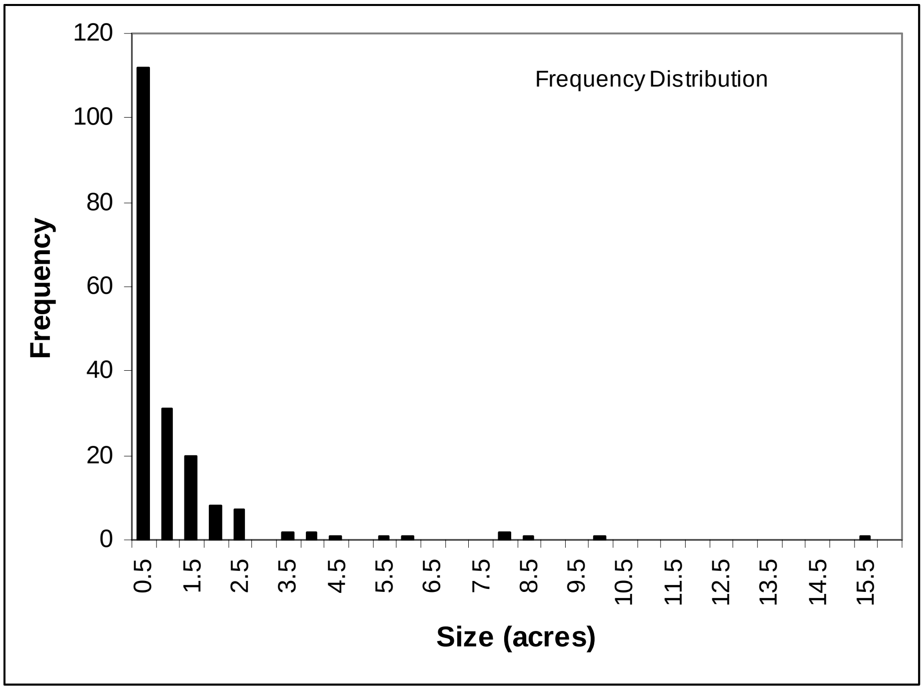
"I have no problems as of yet. Am happy with the set up."

"One pond has been repaired several times and water still disappears. In another pond, we've had some problems with willows and brush; trying to keep them under control with spraying. In another pond, Cattails, Cattails, Cattails! Serious problem. 90-95% take-over by cattails."

“One pond only holds water until the frost is out of the ground. Apparently, there are unplugged or un-removed tiles in this area. A clay or fabric seal should help. The other wetland holds water until the lack of additional moisture causes drying.”

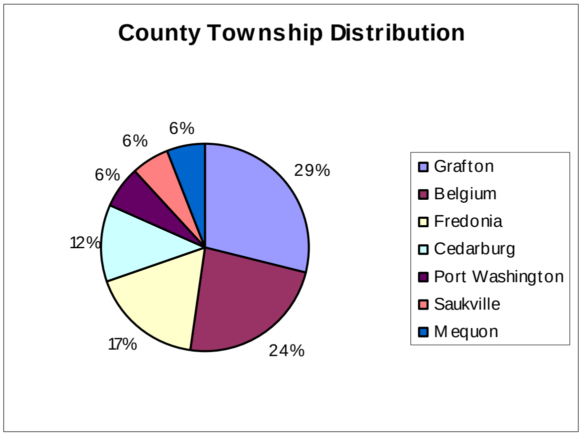
“I think they are great.”

“The water levels depend on how wet the spring weather is. The last 2 years the area has been dry. This year it is very wet. Is there any possible way to dig it deeper? My 10 years may end in the next few years.”



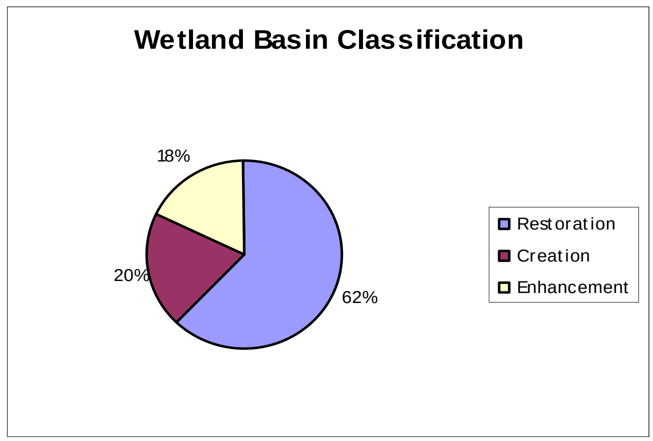
The basins range from 0.02 to 40.88 acres with 59% (n=112) of the wetlands less than ½ acre in size. One wetland covers more than 40 acres and is not shown.

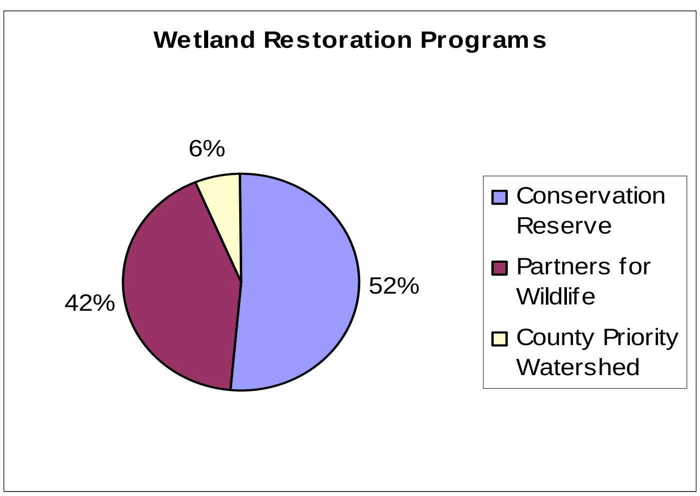
The basin restorations are 2 to 16 years post-construction with a mean age of 10.84 years (standard deviation 3.67).



More than half of the restored wetlands are located in Belgium and Grafton Townships.

Using methods developed for USEPA Grant# CD96509801-0, the majority of the restored wetlands were classified as restorations.





More than 90% of the wetlands were restored through the joint efforts of NRCS, USFWS, and WDNR through the Conservation Reserve and Partner's for Wildlife Habitat Programs.