**AN ASSESSMENT OF WETLAND IMPACTS AND COMPENSATORY
MITIGATION IN THE CUYAHOGA RIVER WATERSHED, OHIO, USA**

A Thesis

Presented in Partial Fulfillment of the Requirements for the

Degree Master of Science in the

Graduate School of The Ohio State University

By

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**The Ohio State University
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ABSTRACT

Current federal and state regulations allow wetlands to be destroyed as long as impacts are mitigated through restoration, creation, enhancement, or preservation of additional wetlands. In this research, we explore how effective these regulations are and if any cumulative changes to wetland and landscape structure are occurring as a result of wetland policy. A watershed-based assessment of wetland impacts and compensatory mitigation was conducted for the Cuyahoga River watershed in northeastern Ohio, USA. Twenty-three Section 401 certifications and Ohio Isolated Wetland permits were evaluated with regards to permit compliance, wetland structure, and landscape context.

Although there was a net gain in wetland area as a result of the 23 permits, the Cuyahoga River watershed experienced a net loss of wetlands due to the exportation of mitigation. The majority of projects (67%) that restored or created wetlands independently (not at a mitigation bank) were not successful at meeting permit requirements. The comparison of impacted and mitigation wetland vegetation types revealed an increase in emergent and open water wetland area and a decrease in scrub/shrub and forested wetlands. There was a decrease in the number of wetlands from impacted wetlands (134) to mitigation wetlands (65). Impacted wetlands were also significantly smaller than replacement wetlands ($p = 0.027$, $df = 74$, $t = 2.26$). Landscape composition was variable for the 9 mitigation projects that were evaluated, varying from

17-75% natural land uses and from 18-82% human land uses.

Results indicate that an improvement in compliance with permit requirements is necessary. Current wetland policy allows for the exportation of wetlands for mitigation purposes which can result in the loss of wetland function from some hydrologic units. The consideration of wetland structure needs to be incorporated into the regulatory process in order to avoid a shift in wetland types that are present. Instead of reviewing projects on a site-by-site basis, a landscape approach should be taken in order to avoid the loss of upland-wetland heterogeneity and the placement of wetlands in harsh landscapes which could potentially threaten wetland function.

For Mom and Dad

Thanks for everything you've done to make all of this possible

ACKNOWLEDGMENTS

I would like to thank my advisor, Virginie Bouchard, for her endless knowledge, support, and patience.

I thank Steven Gordon and Dale White for their assistance with planning, development, and revision of this research and thesis.

I am grateful to Mick Micacchion, John Mack, and Laura Fay from The Ohio Environmental Protection Agency for their support and the opportunity to conduct this research.

I am indebted to Deni Porej for the use of data from a previous report to the Ohio Environmental Protection Agency as well as continued support and friendship.

I would also like to thank many others from The Ohio Environmental Protection Agency for their varied contributions: Randy Bournique, Jeff Boyles, Pete Clingan, Art Coleman, Brian Gara, Michelle Hammond, Dan Osterfeld, Mike Smith, Dave White, and Barb Wooldridge.

I owe thanks to all of those who helped me with fieldwork, planning, and revision, especially Chris Anderson, Janice Gilbert, Kyle Herrman, Katie Hossler, Kelly Powell, Abby Rokosch, Erin Rothman, and Kyle Snowdon.

This research was supported by the United States Environmental Protection Agency grant number CD97576201-0 and the Ohio Environmental Protection Agency.

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CHAPTER 1

INTRODUCTION

In the United States, under Sections 401 and 404 of the Clean Water Act (CWA), unavoidable impacts to wetlands must be mitigated through creation, restoration, enhancement, or preservation of wetlands. In the state of Ohio, the Ohio Environmental Protection Agency (OEPA) is responsible for issuing Section 401 certifications for impacts to wetlands that are connected to “navigable waters.” Navigable waters fall under federal jurisdiction, so impacts to these waters require a permit from the federal and state governments. The OEPA also issues Ohio Isolated Wetland permits for impacts to those wetlands that do not fall under federal jurisdiction (i.e., isolated wetlands). When impacts to wetlands are permitted, they must be mitigated through the creation, restoration, enhancement, or preservation of additional wetland area. Wetland creation is the establishment of wetland in an upland area. Wetland restoration is the re-establishment of a wetland that has been previously eliminated by drainage or fill. Wetland enhancement includes any activity which improves the quality of a degraded wetland and wetland preservation is the legal protection of wetlands from future impacts. A host of research papers have been published regarding the success of compensatory wetland mitigation in the United States (e.g., Allen and Feddema 1996, Robb 2000, Brown and Veneman 2001, Cole and Shafer 2002, Morgan and Roberts 2003, Porej

2003, Kettlewell 2005). Mitigation success is generally measured by evaluating compliance with permit requirements or by comparing mitigation wetlands to natural “reference” wetlands (Mitsch and Wilson 1996, Ambrose 2000, Kentula 2000). Studies that assess compliance with permit requirements generally evaluate wetland area and to a lesser extent, wetland vegetation. These studies tell us whether a net gain of wetlands is occurring and also what types of wetlands are being successfully constructed (e.g., marsh, floodplain, scrub/shrub). Research that evaluates the function of mitigation wetlands is less common (Ambrose 2000). Functional evaluations have been conducted on a smaller scale by comparing natural reference wetlands with mitigation wetlands (e.g., Simenstad and Thom 1996, Zampella and Laidig 2003). Few assessments have compared the wetlands that were impacted with the mitigation wetlands that replaced them (see Cole and Shafer 2002 and Minkin and Ladd 2003). Such comparisons are the ideal approach to understanding whether or not mitigation policy is effective (Zedler 1996). In order to understand what changes in wetland area, structure, and function have occurred within a region as a result of mitigation efforts, we must compare what is being lost to what is being produced.

Recent publications have also emphasized the need for a watershed-based approach for research and management related to wetlands (Bedford and Preston 1988, Zedler 1996, ELI 2004). Watershed and landscape based approaches are recommended because many wetland functions can be affected by conditions and activities in the surrounding landscape (Mitsch and Gosselink 2000, Amezaga and others 2002). Despite this understanding, few studies of wetland mitigation have taken such an approach (but see Kelly 2001). The lack of studies with a watershed or landscape based approach may

be due to the fact that many mitigation projects are conducted on a site by site basis, without considering the broader landscape (Bedford and Preston 1988, Race and Fonseca 1996). There is concern that wetland impacts and mitigation efforts are resulting in a spatial re-configuration of wetlands within the landscape (Bedford 1996, Kelly 2001). This re-configuration could include changes in 1) the spatial extent of wetlands including size, number, and location, 2) wetland characteristics such as hydrogeomorphic (HGM; Brinson 1993) class or vegetation type, and 3) land uses surrounding wetlands. HGM is a classification system for wetlands that focuses on hydrologic and geomorphic controls (Brinson 1993). Such re-configuration can be expected to have an impact upon the functions that wetlands are able to provide within the landscape (Tilton 1995, Faulkner 2004). Mitsch and Gosselink (2000) have predicted that wetland value to humans becomes the greatest when the landscape surrounding wetlands is comprised of both natural and human land uses. If human land uses become extremely dense, the impacts upon wetland water quality can be severe and wetland value will suffer as a result of functional decline. However, the use of such generalizations should be done with care. There are undoubtedly many wetland functions that can provide optimal benefit to human society within an urban setting. Other wetland functions, such as providing habitat to certain wetland dependent species, require a more natural setting. For example, research has shown that some amphibian species such as the mole salamanders (*Ambystoma* spp.) and wood frogs (*Rana sylvatica*) require large core areas of forest and wetland habitat (Semlitsch and Bodie 2003, Colburn 2004). Amphibians are good indicators of ecosystem health due to their permeable skin, biological, and life history characteristics (Hecnar 2004). The presence of urban land has been shown to have negative correlations

with these species (Findlay and Houlihan 1996, Knutson and others 1999, Houlihan and Findlay 2003). Many of these species are maintained within metapopulations requiring a heterogeneous forest-wetland landscape for population survival. A metapopulation is a group of subpopulations that are maintained through the active exchange of individuals between subpopulations (Molles 2002). Amphibians serve as one example where landscape composition is important for wetland function. Landscape effects upon other wetland characteristics include exotic plant species (Ehrenfeld and Schneider 1991), bird communities (Croonquist and Brooks 1993), and water quality variables (Houlihan and Findlay 2004).

A complete assessment of wetland mitigation would include an evaluation of compliance with permit requirements and a comparison of wetland functions between impacted wetlands and replacement wetlands. A watershed-based approach should be taken to include an evaluation of the spatial configuration of wetlands in the landscape as well as an evaluation of surrounding land use effects upon wetland characteristics. In review of wetland mitigation literature from 1993 to present, only one publication was found which has taken such an approach (Johnson and others 2002). One difficulty in this type of assessment is the analysis of wetland function, especially for impacted wetlands because they have already been eliminated for development. Instead, we have to rely upon information that has already been collected for these wetlands prior to their destruction. Such information lies mostly within assessment reports that are submitted for Section 401 certifications and Ohio Isolated Wetland permits. Information within these reports is generally limited to structural components, especially vegetation descriptions. Johnson and others (2002) noted that their functional comparison of

impacted and mitigation wetlands was particularly subjective in nature due to a lack of information about wetlands that had already been destroyed. If subjectivity is to be avoided, the comparison of impacted wetlands and mitigation wetlands is limited to the level of information that is contained within Section 401 and Ohio Isolated Wetland permit files.

The purpose of this study was to conduct an assessment of wetland mitigation using the approach outlined above. The structure of the assessment included an evaluation of permit compliance, a comparison of impacted and mitigation wetlands, an analysis of wetland configuration and situation in the landscape, and a watershed-based approach. The lack of data on impacted wetlands limited the comparison of impacted and mitigation wetlands to strictly structural metrics. The Cuyahoga River watershed (CRW) in northeastern Ohio, USA was chosen as the study area for the assessment. The CRW covers an area of 2,106 km² of both urban and rural areas including a portion of the Cuyahoga Valley National Park (USEPA 2003). Twenty-three Section 401 and Ohio Isolated wetland permits that were issued between January 1, 1995 and January 1, 2003 were evaluated. More specifically, the objectives of the study were to

- 1) Assess the level of compliance with permit requirements and net gain/loss of wetland area for each permit and within the watershed
- 2) Determine whether any changes in wetland structure have occurred as a result of wetland impacts and mitigation efforts
- 3) Describe the landscape setting of mitigation wetlands with respect to human and natural land uses
- 4) Assess the potential of mitigation landscapes to support a specific function - amphibian habitat

Mitigation locations were also compared to a study of wetland restoration potential for the CRW conducted by White and Fennessy (2005) in order to compare site selection with compliance success rates.

CHAPTER 2

METHODOLOGY

2.1 Wetland and Permit Assessment

The Section 401 certifications and Ohio Isolated Wetland permits issued by the Ohio Environmental Protection Agency (OEPA) for impacts to surface waters within the Cuyahoga River watershed were reviewed. Only those permits which required mitigation for impacts to wetlands were considered. Additionally, only permits that were issued between January 1, 1995 and January 1, 2003 were selected. In order to allow sufficient time for wetland characteristics to develop, the permits for which mitigation wetland construction was not completed before January 1, 2003 were excluded. Twenty-six permits fit these criteria. Two permits were excluded because only temporary impacts were permitted and mitigation requirements were constrained to the re-establishment of wetland within the impacted area. One additional permit was excluded because existing wetlands adjacent to the mitigation wetland made it impossible to determine the location of the mitigation boundary. The remaining twenty-three permits provided the basis for this study (Figure 2.1; Appendix A).

Figure 2.1 Map of study area and locations of impacted and mitigation wetlands associated with the 23 Section 401 certifications and Ohio Isolated Wetland permits.

Information regarding the area and the type of vegetation of impacted wetlands was taken from permit files made available to me by the OEPA. These permits also contained the amount of required wetland mitigation and maps showing the location and extent of impacted wetlands. Information provided by the applicant was used to determine the area of open water/submergent, emergent, scrub/shrub, and forested wetland for each impacted wetland. Open water/submergent vegetation was defined as wetland area where there was no vegetation emerging above the surface of the water. Emergent vegetation wetland was dominated by herbaceous plants that were either emerging above the surface of the water or growing directly out of the soil. Scrub/shrub vegetation wetland was dominated by shrub species that were either emerging above the surface of the water or growing directly out of the soil. Forested vegetation wetland was dominated by tree species that were either emerging above the surface of the water or growing directly out of the soil. Many applicants failed to discriminate between open water/submergent and emergent wetland area, so these two categories were combined for analysis. Applicants and consultants were contacted in order to gain access to mitigation wetland sites.

Field work was conducted between June 1, 2004 and October 1, 2004 to delineate areas and assess vegetation type for each mitigation wetland. These data were then compared with the data concerning impacted wetlands to 1) calculate net gain or loss of wetland area 2) determine compliance with permit requirements and 3) assess any changes in vegetation types as a result of mitigation efforts. Percentage of vegetation types (open water/submergent, emergent, scrub/shrub, and forest) were visually estimated in the field for each mitigation wetland. Even with previous experience (3 years) in

estimating wetland vegetation percentages, it is possible that some error may have been introduced by using this method. In order to verify that estimations were acceptable measures, aerial photographs were consulted and compared with vegetation estimates for two wetlands. Nonetheless, this measurement is subjective and should be treated as an estimate of wetland vegetation. Additionally, vegetation types could change over time as wetlands evolve. Mitigation wetlands were delineated using the United States Army Corps of Engineers 1987 wetland delineation procedure (USACOE 1987). Wetland boundaries were mapped using the Trimble[®] GeoXT handheld Global Positioning System (GPS). To standardize coordinate data collection, a point was taken at each location where the wetland boundary turned 10° or more (based upon visual estimation). Point data were later processed and differential correction was conducted using stationary files from the nearest base station. Boundary data were then imported into ArcGIS[®] software (ESRI, Inc.) and converted to polygons in order to calculate wetland area. A portion of the mitigation wetlands for one project - project #12 - was created as 23 forested vernal pools. GPS data for these 23 created vernal pools could not be collected due to heavy forest canopy. The areas of these wetlands were calculated by scanning and geo-referencing an as-built survey within ArcGIS. The as-built survey was created by the applicant using standard surveying techniques to map the outline of the vernal pools. Polygons were then created for each vernal pool and area was calculated. The vernal pools accounted for 0.299 ha while other wetlands for project #12 which were calculated with GPS accounted for 1.221 ha. A list of the analyses that were conducted for each project along with any special considerations that were necessary is located in Appendix B.

During delineation of mitigation wetlands, two problems were encountered which resulted in an over-estimation of wetland area: 1) presence of deep open water habitat and 2) wetlands that were present on the mitigation site before wetland construction began. Two mitigation sites contained deep open water habitat which was fringed by emergent and submergent vegetation wetland. It was impractical to delineate the open water-wetland boundary given time and methodological constraints. Although the open water areas would not normally be counted for wetland mitigation credit by OEPA, they were included in this study. Additionally, at three other sites, project maps revealed wetlands that were located adjacent to or within mitigation wetland boundaries. Essentially, existing wetlands were expanded during the mitigation construction process. Because the boundary between the natural and mitigation wetlands was not clear, these areas were also included with mitigation area. Although rough estimates of these areas were possible, they would have introduced unwanted assumptions and inconsistencies in the scale of data collection. A mitigation inventory prepared for OEPA includes estimates of the open water areas and existing wetlands that were not considered in this study (Kettlewell 2005).

2.2 Landscape Analyses

Landscapes were analyzed with the intention of answering three questions: 1) has mitigation caused a shift in wetland spatial configuration, 2) what is the general composition of the landscape, and 3) based upon the landscape composition, what is the potential of mitigation sites to support certain amphibian species? Wetland spatial configuration was defined as the number, size, and distance between wetlands on a

project site. Landscape composition was defined as the amount of different land uses that were present surrounding mitigation wetlands. The FRAGSTATS Spatial Pattern Analysis Program, Version 3.3 (McGarigal and others 2002) was used to assess wetland spatial configuration and landscape composition. FRAGSTATS calculates a suite of metrics for landscape data that are represented in raster form.

For each of the three questions listed above, generic landscapes were created in order to analyze the behavior of different landscape metrics provided by FRAGSTATS. Results from the generic landscapes along with a review of the literature were used to select several class-level metrics for each portion of landscape analysis. Class-level metrics are calculated by averaging the metric values of each patch for a specific land use. All generic landscapes were created using a landscape area of 4.16 ha and cell size of 3.048 m. The landscape area (4.16 ha) reflects the size of a landscape around the average size of mitigation wetlands (0.4 ha) using a 300 m buffer to create the landscape boundary. A cell size of 3.048 m was used to remain consistent with the average minimum width of patches in actual landscapes. For comparison of wetland spatial configuration of impacted versus mitigation wetlands (Question 1 above), 12 indices were analyzed using four different wetland configurations (Appendix C). Of these 12 indices, patch density (# wetlands/100 ha) was chosen because it distinguished between many, clustered wetlands and few, scattered wetlands well. For questions 2 and 3 above, 12 indices were analyzed using five different landscapes (Appendix C). For general landscape description (Question 2 above), percent of landscape was chosen because it gave a direct description of the amount of land uses within landscape. The percent of landscape metric is found by taking the sum of the area of all patches of a particular land

use and calculating what percentage of the landscape that land use comprises. For amphibian potential (Question 3 above), percent of landscape for each land use, radius of gyration, and proximity index were selected. Radius of gyration can be interpreted by visualizing an organism that is placed and travels randomly within a patch (Neel and others 2004). The radius of gyration is the average distance that the organism can travel and remain within the focal patch. The proximity index, developed by Gustafson and Parker (1992), is an index that measures both the size and proximity of patches of the same land use that are within a specified search distance of the focal patch (McGarigal and others 2002). The index is measured for each patch (focal patch) of a certain land use and then averaged, giving a single value for each land use. Proximity increases as the distance to other patches of the same land use decreases and as the contiguity of those patches increases. For this study, a search distance of 300 m was used for proximity index so that all patches of the same land use would be considered by FRAGSTATS. The equations for landscape metrics that were used are located in Appendix D.

Landscapes were created by using the buffer tool within ArcGIS[®] (ESRI, Inc.) to measure a distance of 300 m and 1000 m from the edge of mitigation wetlands. As a result, there were two landscapes for each mitigation wetland. The availability of high resolution aerial photographs proved to be the limiting resource for digitizing land uses (used for Questions 2 and 3). This was not a factor for Question 1 because only wetland land uses (impacted and mitigation wetlands) were used for the calculation of wetland spatial configuration. Aerial photographs were only available for recent years. Since wetland impacts occurred 2 to 8 years ago, these photographs were not a reliable source of landscape composition around impacted wetlands. As a result, it was impossible to

make a comparison impacted and mitigation landscapes. County level aerial photos with six inch (15.24 cm) cell sizes were used to digitize land uses into thirteen different classes: agriculture, construction, forest, industrial, mitigation wetland, mowed, oldfield, park, pond, residential, road, waterway, and wetland. Oldfield was defined as early successional, upland, herbaceous vegetation which was generally present in areas that were human land use and recently abandoned. Six inch (15.24 cm) resolution, county level aerial photos taken between 2000 and 2002 were. Appendix E contains a list of different land uses which were included within each class. Some wetlands, especially small, forested wetlands, may have been inadvertently excluded due to low visibility in aerial photos. Land uses were digitized using ArcGIS[®] (ESRI, Inc.) at a map scale of 1:2000-1:4000. Ten feet (3.048 m) was the approximate average minimum width of digitized land uses. Land use areas were converted from vector to raster format using a 3.048 m cell size in order to remain consistent with the minimum width of land use polygons. Raster files were then converted to ASCII text files for use within FRAGSTATS. Raster and ASCII files were reviewed in order to remove stray cells which would be treated as a single patch by the FRAGSTATS software.

2.2.1 Wetland Spatial Configuration

The number and size of impacted wetlands were compared with mitigation wetlands using information from permit files (for impacted wetlands) and GPS data (for mitigation wetlands) for all 23 projects (Question 1). Comparisons were made for the sum of all impacted and mitigation wetlands as well as for impacted versus mitigation wetlands for each project. Although some mitigation banks sell wetland credits for more

than one wetland, they do not specify exactly where these credits are located within the bank. For the 8 projects in this study that utilized a mitigation bank, it was assumed that wetland credits were located within a single wetland. For independent projects ($n = 12$), the spatial configuration of impacted wetlands was compared to that of mitigation wetlands on a per-project basis using patch density (# wetlands/100 ha) within FRAGSTATS. This analysis did not include any land uses other than impacted and mitigation wetlands. Impacted wetland polygons were created by scanning and georeferencing projects maps supplied by the permit holder. The scale and quality of these maps were variable. However, the sizes of wetlands were verified by the Army Corps of Engineers during field investigations before impacts were allowed. The ACOE – verified wetland sizes were compared with digitized wetland sizes to ensure that maps were accurate. Any error that was introduced by using the project maps would have been small and had very minimal effects upon the results of this study. Mitigation polygons were created using GPS data collected in the field (and digitized vernal pool polygons for project #12 as described above). Landscapes (with only impacted and mitigation wetland land uses) were created for each impact and mitigation site using a buffer of 1000 m from wetland edges for all twelve independent projects. The area of 1000 m landscapes surrounding impacted wetlands varied from 44.3 to 115.8 ha while the area of 1000 m landscapes surrounding mitigation wetlands varied from 45.6 to 57.4 ha (Appendix F). Mitigation wetlands were constructed at two different locations for project #5. Patch density for the two mitigation locations associated with this project were combined for this portion of analysis.

2.2.2 Composition of the Surrounding Landscape

For a general description of land uses (Question 2) surrounding mitigation sites (n = 9), landscapes were created using buffers of 300 m and 1000 m from the edge of mitigation wetlands (Figure 2.2). The area of 300 m landscapes surrounding mitigation wetlands varied from 5.55 to 8.88 ha (Appendix F). Analysis was only feasible for eight of the twelve projects because high resolution aerial photographs were not available for Geauga and Portage Counties, where 4 projects were located. During this portion of analysis, the two mitigation locations for project #5 analyzed separately. Land use classes were collapsed into human, natural, and surface water categories in order to gain an understanding of the overall landscape setting of mitigation wetlands. The number of wetlands located within the landscape was compared between 1000 m and 300 m landscapes for each project.

Project #6
OTC

Figure 2.2 1000 m land use map for project #6. Additional land use maps are located in Appendix G.

2.2.3 Amphibian Potential

For amphibian habitat potential analysis (Question 3), 300 m landscapes were used for those mitigation sites ($n=9$) where aerial photos were available. Information from the literature regarding landscape effects upon amphibian communities was used to select appropriate metrics for this portion of analysis. Amphibians have been shown to utilize a core habitat of 159 to 290 m from the edge of aquatic habitats (Semlitsch and Bodie 2003). A 300 m buffer from wetland edge was used in order to include the amount of area that would be required by amphibians. Amphibians have been shown to be positively correlated with area of forest, number of wetlands, and area of wetlands and negatively correlated with area of urban land use and road density (Findlay and Houlihan 1996, Knutson and others 1999, Houlihan and Findlay 2003, Porej and others 2004).

Amphibian habitat information extracted from the literature was used to create three amphibian potential scenarios (Table 2.1) which were applied to each mitigation site. Some of the landscape metrics that were used for amphibian potential analysis had a wide range of values and had to be standardized for comparison. For each scenario, landscape indices were standardized in two different ways. Set A was created by normalizing landscape indices using Minitab and assigning each site a value of 1 to 9. Values were transformed linearly by assigning the lowest value to 1 and the highest value to 9. Set B was created by plotting histograms for each index with five even break-points and assigning each site a value of 1 to 5. Due to correlations between landscape indices (Appendix H), variables for amphibian potential analysis were reduced to percentage of landscape (forest, wetland, road, and urban land uses were used) and radius of gyration

(forest and road land uses were used). The urban land use was created by adding the percentages for industrial and residential land uses.

Scenario 1	Scenario 2	Scenario 3
%forest	%forest	forest_gyrate
%wetland	%wetland	%wetland
%road		road_gyrate
%urban*		%urban*
* %urban = %residential + %industrial		

Table 2.1 Landscape metrics that were used for each amphibian potential scenario. Each scenario was standardized in two different ways, creating two datasets (Set A and Set B).

2.3 Data Analysis and Interpretation

Minitab statistical software Version 12.23 was used for all statistical analysis.

Descriptive statistics, Pearson's correlations, normalization, histograms, two sample t-tests, and paired t-tests were used. Pearson's correlations were used to select landscape indices for various portions of land use analysis. Correlations were also used to test whether variance in landscape area affected metric values. A Pearson's coefficient of $r > 0.700$ or $r < -0.700$ was used to indicate metrics that were significantly correlated.

Normalization and histograms were used to create standardized values for amphibian habitat potential analysis. Two sample t-tests were used to compare impacted and mitigation wetland characteristics when all projects were combined. Paired t-tests were used to compare impacted and mitigation characteristics on a per-project basis. A 95% confidence level was used to test significance. Several articles regarding the use of landscape metrics were consulted during the interpretation of FRAGSTATS output

(Gustafson 1998, Moilanen and Nieminen 2002, Brooks 2003, Li and Wu 2004, Neel and others 2004) along with the FRAGSTATS users manual (McGarigal and others 2002).

2.4 Wetland Restoration Potential

To determine whether site selection was a factor in permit compliance success, locations of the mitigation wetlands were compared with data from a study of wetland restoration potential for the Cuyahoga River watershed (White and Fennessy 2005). White and Fennessy (2005) developed a GIS-based model using soils information, land use, topography, stream order, slope, and flow accumulation to create three different versions of wetland restoration potential for the Cuyahoga River watershed (Base Model, Alternative Weights Variation, and the Transmissivity Variation). The Transmissivity Variation (White and Fennessy 2005), which includes soil drainage potential within the topography factor, was used for this study. Each mitigation wetland project in the Cuyahoga River watershed ($n = 11$) was compared to the restoration potential map using ArcGIS and given a value of 0-100 as specified by White and Fennessy (2005). Mitigation wetlands were converted to raster form with a 3.048 m cell size. Each cell within the mitigation wetland was then assigned a value based upon the restoration potential map (25 m cell size). The mean of all cells for each mitigation project was used as the restoration potential value. Wetland restoration potential values were then compared with permit compliance.

CHAPTER 3

RESULTS

3.1 Permit Compliance

Eight of the 23 projects purchased “wetland credits” at various pooled mitigation banks within the Ohio portion of the Lake Erie basin. None of these mitigation banks were located within the Cuyahoga River watershed. One project was mitigated at a bank owned by the applicant within the watershed. Two projects that impacted wetlands within the watershed were mitigated entirely through wetland preservation. Twelve projects relied upon independent creation or restoration efforts to mitigate for wetland losses (i.e., not at a bank). Of these 12 projects, 11 were located within the Cuyahoga River watershed. Nine of the 12 independent mitigation projects were constructed “on-site” while 3 sites were constructed at a location other than the impact site. A total of sixty-five wetlands were constructed as mitigation for 134 impacted wetlands. Because several wetlands can be impacted or constructed for each permit, the number of projects does not reflect the number of wetlands that were impacted.

For the 23 permits, 14.95 ha of wetland were lost, 27.78 ha of created or restored wetland were required, and 26.27 ha of mitigation wetlands were constructed. The 26.27 ha of mitigation wetlands assumes that requirements for the 8 mitigation bank projects

were adequately met. The result is a net gain of 11.32 ha of wetlands at a replacement ratio of 1.76:1. A total of 5.24 ha (10 projects) of wetlands were purchased from a pooled mitigation bank and 0.77 ha (1 project) of wetlands were created within a private mitigation bank. Another 20.26 ha (12 projects) of wetlands were either created or restored by the applicant independently. An additional 2.11 ha of wetland enhancement and 21.30 ha of wetland preservation were proposed, although these areas were not evaluated for compliance.

Within the Cuyahoga River watershed, 14.58 ha of wetlands were lost and only 11.36 ha of wetlands were created or restored. The remaining 14.91 ha of wetland mitigation were exported from the watershed (Figure 3.1). Two independently constructed projects were responsible for 9.67 ha of exported wetland area and 5.24 ha of exported wetland area were the result of purchasing mitigation bank credits. The majority of the 12 independent projects ($n = 8$) did not achieve the required wetland area (Figure 3.2).

Figure 3.1 Area of wetlands that were mitigated in the Cuyahoga River watershed and wetland area that was exported from the watershed.

* A small portion of wetland associated with project #12 was located outside of the Cuyahoga River watershed.

Figure 3.2 Percent deviation from the required mitigation wetland area. Projects with bars above the zero line constructed more wetland than necessary while those below the zero line failed to meet mitigation requirements.

3.2 Vegetation Types

The vegetation types of wetlands that were impacted and constructed for the 12 independent projects were assessed (Figure 3.3). The majority of mitigation wetlands were comprised of open water/emergent vegetation (82.8%) followed by scrub/shrub vegetation (14.7%) and then forested vegetation (2.5%). Based on information contained in permit files, impacted wetlands were also dominated by open water/emergent vegetation (42.5%), followed by scrub/shrub (41.0%) and then forested (16.5%). Emergent wetlands were replaced at a ratio of 3.6:1 (constructed:impacted), scrub/shrub wetlands were replaced at a ratio of 0.65:1, and forested wetlands were replaced at a ratio of 0.28:1. If only the wetland impacts and mitigation in the Cuyahoga River watershed are considered, emergent wetlands were replaced at a ratio of 2.3:1 and scrub/shrub wetlands were replaced at a ratio of 0.03:1 (all forested wetland impacts were mitigated within the CRW). Vegetation types were analyzed on a per-project basis for wetland area for each vegetation type and also for presence/absence of vegetation types (Table 3.1). There was a significant increase in open water/emergent wetland area per project ($p = 0.014$, $df = 11$, $t = -2.91$) and a significant decrease in scrub/shrub wetland area ($p = 0.019$, $df = 11$, $t = 2.75$). The change in forested wetland area was not significant at a 95% confidence level ($p = 0.088$, $df = 11$, $t = 1.87$). For the presence/absence analysis of vegetation types, forested vegetation was present more often in impacted wetlands than mitigation wetlands ($p = 0.017$, $df = 11$, $t = 2.80$). Changes in the presence/absence of open water/emergent and scrub/shrub wetlands were not significant ($p = 0.082$, $df = 11$, $t = -1.91$ and $p = 0.191$, $df = 11$, $t = 1.39$, respectively).

Figure 3.3 Vegetation types of impacted and mitigation wetlands. The wetland areas shown in white were exported to other watersheds.

Project #	Impacts			Mitigation		
	Emergent/OW	Forested	Scrub/Shrub	Emergent/OW	Forested	Scrub/Shrub
1	1.125	0.313	0	1.372	0	0
2	0	0.567	0	0.931	0.052	0.052
3	0.291	0.101	0.170	1.424	0	0
4	0	0	0.371	1.587	0	0.084
5	1.576	0.310	3.096	5.780	0	2.847
6	0.121	0.134	0.178	0.617	0.154	0
7	0.295	0.202	0	2.440	0	0
8	0.745	0.146	0	0.771	0	0
9	0.069	0	0	0.108	0	0
10	0.024	0	0	0.277	0	0
11	0	0	0.231	0.243	0	0
12	0.437	0.045	0.473	1.216	0.304	0
Totals	4.684	1.818	4.519	16.766	0.510	2.982

Table 3.1 Vegetation types by wetland area for impacted and mitigation wetlands.

3.3 Landscape Analyses

3.3.1 Generic Versus Actual Landscapes

Generic landscapes were designed to be excessively simple in order to understand the behavior of landscape metrics. As a result, the metric values for generic landscapes were often quite different from those of actual landscapes. For example, the average percent of landscape for land use classes in generic landscapes was 21.8% and ranged from 0.09% to 73.8%. The values for 300 m actual landscapes averaged 8.2% and ranged from 0.04% to 44.7%. Interspersion and Juxtaposition Index (IJI) values for generic landscapes averaged 13.6 and ranged from 0 to 62.7 while IJI values for 300 m actual landscapes averaged 49.4 and ranged from 0 to 87.3. The 300 m actual landscapes also differed from 1000 m landscapes for some metrics. For example, due simply to the difference in landscape size, the 1000 m landscapes had more patches per landscape than did 300 m landscapes.

The landscape metrics for the actual landscapes in this study were also compared to those in other studies that have used FRAGSTATS to assess landscape composition and configuration. Other studies that used the same landscape metrics generally assessed large regions (macro-scale) while this study was conducted at a micro-scale. One study that assessed landscape structure in northwest China used IJI, among other landscape metrics (Li and others 2001). IJI values for this region tended to be smaller ($\bar{x} = 44.2$) than in the smaller landscapes used for this study ($\bar{x} = 49.4$ for 300 m landscapes; $\bar{x} = 54.8$ for 1000 m landscapes). Another study in northwest USA assessed disturbance in riparian areas using variable buffer sizes around streams and rivers (Staus and others 2002). Patch density was smaller ($\bar{x} = 0.5$ patches/100 ha) in these riparian areas than in

the mitigation landscapes described herein ($\bar{x} = 5.54$ patches/100 ha for 300m landscapes; $\bar{x} = 3.07$ patches/100 ha for 1000 m landscapes).

3.3.2 Wetland Spatial Configuration

Overall, there was a decrease in the number of wetlands from 134 to 65. The decrease in the number of wetlands within the CRW was from 134 to 50. The decrease in number of wetlands on a per-project basis was not significant ($p = 0.064$, $df = 22$, $t = 1.95$); however, when one outlier was removed (project #12) the decrease became significant ($p = 0.004$, $df = 21$, $t = 3.26$). Project #12 led to the creation of 25 of 65 mitigation wetlands. Mitigation wetlands ($n = 65$) for all projects were significantly larger than impacted wetlands ($n = 134$) ($p = 0.027$, $df = 74$, $t = 2.26$; Figure 3.4). If two outliers were removed, the significance became greater ($p = 0.002$, $df = 66$, $t = 3.21$). There was a decrease in the number of wetlands as a result of impacts and mitigation efforts for the majority of projects ($n = 17$). Wetland density (# of wetlands/100 ha) was calculated for the 12 independent projects using FRAGSTATS. Although there was a slight decrease in wetland density, the difference was not significant ($p = 0.723$, $df = 11$, $t = 0.36$).

Figure 3.4 Size-ranked display of all impacted (open white) and mitigation (gray) wetlands. The y-axis shows the area of each wetland. The x-axis ranks each wetland by size showing 65 mitigation and 134 impacted wetlands.

3.3.3 Composition of the Surrounding Landscape

Land uses within 300 m and 1000 m landscapes were analyzed based upon the percent of landscape for each land use. The land uses that were located immediately adjacent to the mitigation wetland perimeters were also analyzed by measuring the length of edge that was shared by the mitigation wetlands and each land use. Forest was the dominant land use within 300 m and 1000 m landscapes surrounding the majority of the 9 mitigation projects that were analyzed (Table 3.2). The second and third most common land uses were residential and oldfield for the 300 m landscapes and residential and industrial for the 1000 m landscapes (Table 3.2). The most common land uses along

mitigation wetland edges (n = 8 projects) were oldfield, mowed grass, and forest (Table 3.2)

1000 m land uses													
Proj #	Ag	Const	For	Ind	Mit	Mow	Old	Park	Pond	Res	Road	Wway	Wet
1	0	4.0	44.8	1.7	0.4	6.2	14.3	0	0	15.0	4.3	4.2	5.0
2	5.4	3.6	40.9	0	0.3	7.7	5.8	0	0.3	30.3	4.2	0	1.6
3	0	6.4	19.9	23.1	0.4	7.9	12.6	0	0.3	15.2	14.1	0	0.1
4	0	2.3	12.5	20.3	0.6	2.6	0.5	4.1	0	41.4	15.3	0.3	0
5a	15.8	0.7	37.7	0	0.4	3.0	9.2	0	1.1	27.8	1.5	2.3	0.4
5b	14.4	1.7	33.6	4.0	1.6	2.4	15.1	4.7	2.0	16.7	1.5	1.4	0.9
6	3.4	15.2	16.8	32.7	0.2	4.8	15.0	3.9	1.0	0	2.9	3.9	0.1
7	0.9	5.7	48.1	3.9	0.6	4.4	4.1	2.0	0.5	24.4	2.8	1.4	1.1
8	0	5.1	40.7	12.6	0.2	11.0	11.2	0.7	0.9	10.6	5.3	1.2	0.5
300 m land uses													
Proj #	Ag	Const	For	Ind	Mit	Mow	Old	Park	Pond	Res	Road	Wway	Wet
1	0	1.9	36.1	0	2.7	9.3	31.9	0	0	1.6	5.8	0	10.8
2	0	4.0	34.0	0	1.9	7.9	1.3	0	0.1	46.0	4.3	0	0.3
3	0	4.4	7.9	4.9	2.7	20.0	24.9	0	0	0	35.3	0	0
4	0	13.7	35.7	3.2	4.0	5.3	0	0	0	25.7	11.7	0.6	0
5a	26.7	0	45.8	0	2.4	0.5	2.8	0	0.1	12.5	1.2	6.0	2.0
5b	9.4	2.0	11.5	5.4	10.2	1.9	29.2	5.7	6.0	15.5	1.1	0	2.1
6	0	9.3	26.3	1.8	1.9	6.7	23.4	19.0	0	0	2.9	7.6	1.2
7	0	2.0	59.0	0	4.4	2.5	12.2	4.4	0.4	11.0	2.2	0.1	1.8
8	0	12.0	43.3	14.5	1.7	8.6	9.2	0	0.1	5.5	2.1	3.2	0
Land uses along mitigation wetland edges													
Proj #	Ag	Const	For	Ind	Mit	Mow	Old	Park	Pond	Res	Road	Wway	Wet
1	0	0	8	0	0	16	41	0	0	0	0	0	34
2	0	0	23	0	0	73	0	0	0	4	0	0	0
3	0	0	0	0	0	34	66	0	0	0	0	0	0
4	0	33	61	0	0	5	0	0	0	0	0	0	0
5	57	0	9	0	0	0	26	0	0	0	0	0	8
6	0	0	82	0	0	0	0	18	0	0	0	0	0
7	0	2	33	0	0	0	61	0	0	0	4	0	0
8	0	0	0	0	0	100	0	0	0	0	0	0	0

Ag = Agriculture, Const = Construction, For = Forest, Ind = Industrial, Mit = Mitigation wetland
Mow = Mowed grass, Old = Oldfield, Res = Residential, Wway = Waterway, Wet = Wetland

Table 3.2 Land uses percentages for each project. Bold numbers indicate the dominant land use for each project.

Within 300 m landscapes, natural land uses ranged from 33% to 75% and human land uses ranged from 18% to 65% of total landscape area (Figure 3.5). At the 300 m level, 3 projects were dominated by human land uses and 5 were dominated by natural land uses. Natural land uses within 1000 m landscapes ranged from 17% to 59% of total landscape area and human land uses ranged from 31% to 82% (Figure 3.6). At the 1000 m level, 5 projects were dominated by human land uses and 3 were dominated by natural land uses. Within 300 m landscapes, projects #2 and #3 had the highest amount of human land use and lowest natural land use while projects #1, #6, and #7 had the lowest human land use and highest natural land use. At the 1000 m level, projects #3 and #4 had the highest human land use and lowest natural land use while projects #1, #5b, and #7 had the lowest human land use and highest natural land use. At the 1000 m level, projects #3 and #4 had the highest human land use and lowest natural land use while projects #1, #5b, and #7 had the lowest human land use and highest natural land use.

Figure 3.5 Combined land use percentages for 300 m landscapes.

Figure 3.6 Combined land use percentages for 1000 m landscapes.

The number of wetlands located in 300 m and 1000 m landscapes (excluding mitigation wetlands) was calculated using FRAGSTATS. At the 300 m level, the number of wetlands ranged from 0 to 8 and at the 1000 m level, the number of wetlands ranged from 0 to 19. Within 300 m landscapes, projects #3, #4, and #8 contained the least amount of wetlands (0) and project #1 had the most wetlands (8). Within 1000 m landscapes, project #4 had the least amount of wetlands (0) and project #7 had the most wetlands (19). When mitigation wetlands were included, the number of wetlands ranged from 1 to 10 at the 300m level and from 1 to 20 at the 1000 m level.

3.3.4 Amphibian Potential

Although some variation was present, projects #1 and #7 had the highest potential for amphibian communities while projects #2 and #3 had the lowest potential (Table 3.3). Most of the variation was associated with Scenario 3, which included radius of gyration and proximity index in addition to percent of landscape for land uses. The results for Set A were significantly different for Scenarios 1 and 2 ($p < 0.001$, $df = 8$, $t = 6.03$) and for Scenarios 1 and 3 ($p = 0.011$, $df = 8$, $t = 3.29$) but not for Scenarios 2 and 3 ($p = 0.09$, $df = 8$, $t = -1.93$). The results for Set B were significantly different only for Scenarios 1 and 2 ($p = 0.001$, $df = 8$, $t = 5.55$).

Set A					
Project #	Scenario 1	Scenario 2	Scenario 3	Average	Std Dev
1	7.8	7.2	5.3	6.8	1.3
2	3.9	3.2	3.0	3.4	0.5
3	2.9	1.0	2.3	2.0	0.9
4	4.2	3.2	3.8	3.7	0.5
5a	6.4	4.7	5.5	5.5	0.8
5b	4.7	2.0	3.4	3.4	1.3
6	5.8	2.9	4.9	4.5	1.5
7	6.8	5.7	6.5	6.3	0.6
8	5.5	3.8	5.8	5.0	1.1

Set B					
Project #	Scenario 1	Scenario 2	Scenario 3	Average	Std Dev
1	4.3	4.0	3.5	3.9	0.4
2	2.5	2.0	1.3	1.9	0.6
3	2.0	1.0	2.8	1.9	0.9
4	2.8	2.0	3.0	2.6	0.5
5a	3.8	3.0	3.3	3.3	0.4
5b	2.8	1.5	2.5	2.3	0.7
6	3.3	1.5	3.3	2.7	1.0
7	4.0	3.5	2.8	3.4	0.6
8	3.3	2.5	2.0	2.6	0.6

Table 3.3 Results for amphibian habitat potential analysis. Shaded cells indicate the two highest values for each scenario and the average. Bolded text indicates the two lowest values for each scenario and the average.

3.4 Landscape Area Variability

The area of landscapes was variable (Appendix F) because they were created using a buffer distance (300 m and 1000 m) from the edge of mitigation wetlands which were of different sizes and shapes. This variability has the potential to affect landscape metrics calculated by FRAGSTATS (McGarigal and others 2002). Correlations were calculated for wetland spatial configuration metrics, land use percentages, and amphibian potential metrics to determine if landscape area affected results. According to Pearson's correlations, construction percent of landscape and residential percent of landscape for 1000 m landscapes were the only metrics that were affected by variability in landscape area (Appendix I). The only analysis that would be affected by these metrics is the general description of landscape setting (Section 3.3.2). Although construction percent of landscape did not comprise a large portion of landscapes ($\bar{x} = 5.0\%$), residential percent of landscape was responsible for a substantial amount of landscape area ($\bar{x} = 22.7\%$). Since these metrics were combined with other land uses, the effects of landscape area should be diminished. Nonetheless, interpretation of the results in Section 3.3 should be done with the effects of landscape area in mind.

3.5 Restoration Potential

The average restoration potential (as calculated following White & Fennessy (2005)) for the 11 mitigation sites in the Cuyahoga River watershed ranged from 0 to 44.6. The four projects that constructed at least the required wetland area had four of the five lowest restoration potential values. The relationship between restoration potential and compliance was not significant ($p = .735$, $df = 10$, $t = 0.35$).

CHAPTER 4

DISCUSSION

4.1 Permit Compliance

Recent studies of wetland permit compliance have re-enforced uncertainties about our abilities to create wetland ecosystems. Some reports have found most permit-holders to be in compliance with permit conditions (e.g., Cole and Shafer 2002, Minkin and Ladd 2003). Others have found that the majority of permit-holders were unable to successfully meet permit requirements (e.g., Johnson and others 2000, Brown and Veneman 2001). A net-gain of wetland area has been reported by some studies (e.g., Johnson and others 2000, Breaux and others 2005) and a net-loss has been reported by others (e.g., Sudol and Ambrose 2002, Morgan and Roberts 2003). The majority of the CRW projects that were evaluated did not meet wetland area requirements. Although there has been a net gain in wetland area overall as a result of these projects, the CRW experienced a net loss of wetland area. Only 77.9% of the area of wetlands impacted is now present as mitigation wetlands within the watershed. These results highlight one of the problems associated with “off-site” mitigation

Nine of the 21 projects that created or restored wetlands for mitigation did so entirely within a watershed other than the CRW. Eight of these projects mitigated for impacts by purchasing wetland credits at a mitigation bank. Mitigation banks have been

designed to allow permit-holders who are impacting small areas of wetland to mitigate for impacts by purchasing “wetland credits” instead of creating or restoring wetlands “on-site” (Reppert 1992). The question then, is to what extent we should allow wetland functions to be trans-located geographically. Within Ohio, permit-holders are restricted to using mitigation banks that are located within the United States Army Corps of Engineers (USACOE) district (i.e., Buffalo or Huntington) but are permitted to mitigate in different watersheds for lower quality wetlands (Ohio Administrative Code 3745-1-54). Such authorization of wetland exportation should consider the function and context of the impacted wetlands and the mitigation bank. If the impacted wetlands are functionally inferior and located within intensive urban settings, then their replacement with a higher quality mitigation bank may be justified. However, a portion of the lower Cuyahoga River has been declared by the United States EPA as an area of concern (USEPA 2003). Areas of concern are designed to focus efforts to clean up the most polluted areas of the Great Lakes region. The exportation of wetland mitigation from the CRW has resulted in a net loss of wetland functions (Faulkner 2004) which potentially could have had a positive impact upon the pollution problem in the Cuyahoga River.

4.2 Wetland Structure

Impacted and mitigation wetlands were both dominated by emergent vegetation and open water. However, the percentage of wetlands that were emergent/open water nearly doubled as a result of mitigation efforts. The amount of forested and scrub/shrub wetlands both decreased in area as a result of mitigation policy. A shift from forested and scrub/shrub wetlands to emergent/open water dominated systems has been reported

by many wetland mitigation studies (e.g., Brown and Veneman 2001, Cole and Shafer 2002, Minkin and Ladd 2003). It has been hypothesized that this shift is occurring because emergent/open water wetlands are easier to construct than forested or scrub/shrub wetlands (Cole and Shafer 2002, Porej 2003). Construction of a deep open water/emergent depression also seems to be the most reliable way (Porej 2003) to meet the hydrology, soil, and vegetation requirements set forth by the USACOE wetland definition (USACOE 1987). Such a shift in wetland types is likely to cause a regional shift in biodiversity (Gwin and others 1999) and will probably also indicate a shift in wetland function (Minkin and Ladd 2003).

In addition to changes in wetland type, there has also been a change in wetland spatial structure in the CRW. A total of 134 wetlands were impacted and only 50 replacement wetlands were constructed in the CRW. The average size of impacted wetlands was 0.11 ha and the average size of CRW replacement wetlands was 0.23 ha. Essentially, the landscape is experiencing a consolidation of many small wetlands into fewer, larger ecosystems. Amezcaga and others (2002) stated that the maintenance of a rich distribution of wetlands in the landscape is just as important as maintaining high quality wetlands. The loss of many small wetlands has obvious consequences upon landscape heterogeneity and metapopulation dynamics (Semlitsch and Bodie 1998). Although the impact of such spatial re-configuration upon many ecosystem and landscape functions is still unknown, research has suggested that effects upon organism persistence and nutrient distribution are likely to occur (Kelly 2001 and references therein).

4.3 Composition of the Surrounding Landscape

There was considerable variation in land uses for the nine mitigation projects that were studied as part of the investigation of general landscape composition. Three of the projects were situated within particularly harsh areas, with urban land uses comprising more than 50% of the landscape (projects #2, 3, and 4). Mitigation wetlands associated with project #2 were predominantly open water wetlands located within a suburban housing development. Project #3 was located immediately adjacent to a highway intersection for which wetland impacts associated with this project were necessary. The mitigation wetland associated with project #4 was a fringe wetland surrounding a storm-water retention basin within a very urban area. In contrast, the two projects that were located in the most natural landscapes (projects #1 and 5b) were both located within parks. It appears from these results that mitigation wetlands are being constructed in a wide variety of landscape settings. This will allow these wetlands to serve varied functions to society. For example, the wetlands located in park settings will very likely provide wildlife and recreational functions to the surrounding community. The highway wetland will hopefully provide the same filtration for water leaving the interstate that the impacted wetlands did. One concern is that the wetlands located in highly human-impacted landscapes could become overwhelmed and some functions could be sacrificed (Mitsch and Gosselink 2000). As expected, some of the projects that were located within urban areas also had the lowest number of wetlands present in the surrounding landscape. Three projects (#3, 4, and 8) did not have any wetlands within 300 m that were visible in aerial photographs. There were no visible wetlands within the 1000 m landscape for project #4. In fact, the only surface water present in the 1000 m landscape for this project

was the urban stream and storm-water retention basin within which the mitigation wetlands were constructed. This disconnectedness from other wetlands and water bodies in the landscape can be expected to have effects upon the biodiversity and maintenance of species populations within wetlands (Amezaga and others 2002). The consolidation of impacted wetlands into fewer, larger replacement wetlands has already been discussed. The same issues also need to be scaled to the landscape level. The presence of wetlands and other water bodies in the surrounding landscape needs to be taken into consideration during mitigation planning in order to maintain landscape heterogeneity and species populations.

4.4 Amphibian Potential

The two projects with the lowest amphibian potential (projects #2 and 3) were located within landscapes that were dominated by residential areas and roads, respectively. In contrast, the two projects with the highest amphibian potential (projects #1 and 7) were both located in landscapes dominated by forest. Even with the documentation of landscape components that are positively (forest, wetlands) and negatively (urban, roads) correlated with amphibians, there are no definite threshold levels (Knutson and others 1999, Houlahan and Findlay 2003, Porej et al. 2004). As a result, it is not possible to specify which of these projects would be able to support certain amphibian species. Additionally, there are other compounding factors, including wetland characteristics that have been shown to be correlated with amphibian populations (e.g., hydroperiod, fish presence; Porej 2004). Consequently, the analysis provided here

is only useful for ranking wetlands with regards to the potential to provide amphibian habitat.

None of the permits listed amphibian habitat as a goal for the mitigation wetlands. In fact, none of the permits listed any functional requirements at all. The amphibian potential analysis was not designed to determine whether or not projects were successful. Instead, the purpose was to provide a method for considering landscape setting in the planning stages of wetland mitigation. If validated, the amphibian scenarios used here could be used as a tool for locating wetlands that would have the potential to provide amphibian habitat. Such a method is possible for amphibians because there is a wealth of information regarding the terrestrial requirements for such species as mole salamanders and wood frogs. Similar tools could be designed for other wetland functions where land use effects are well understood.

4.5 Restoration Potential

Comparing the wetland restoration potential data by White and Fennessy (2005) with permit compliance did not reveal any significant relationships. The lack of correlation is not surprising because site selection is one of many factors that must be considered when creating and restoring wetlands. The inability of some projects to achieve the required wetland area could have been a result of a variety of factors, including poor site engineering or planning, instead of poor site selection.

CHAPTER 5

CONCLUSION

Although the permits studied resulted in an overall net gain of wetlands, the Cuyahoga River watershed has experienced a net loss of wetland area. The functions provided by the majority of mitigation wetlands have been exported to other watersheds in the state. This exportation has occurred as a result of off-site mitigation, including the purchasing of wetland credits from mitigation banks. The net loss of wetland area from the watershed is also partly due to the inability of permit-holders to construct the required amount of mitigation wetland area. The majority of independent mitigation projects (i.e., not at a mitigation bank) did not construct enough wetland area to fulfill permit requirements. More rigorous follow-up and enforcement is necessary to ensure that wetland impacts and permit requirements are being adequately addressed. Also, permit-holders and regulatory agencies need to consider the locations of wetland impacts and mitigation instead of relying solely upon a site-by-site review.

The Cuyahoga River watershed has experienced a shift in wetland structural characteristics as a result of wetland mitigation efforts. There is a consolidation of many small wetlands into fewer, larger systems. This shift could indicate an increase in the distance between wetlands and a loss of upland-wetland complexes. Many of the forested and

scrub/shrub wetlands that are destroyed are being replaced with emergent vegetation and open water wetlands. Although these structural characteristics are not measures of wetland function, they could be indicators that some functional changes are occurring both within wetlands and across the landscape. Incorporating landscape setting into the permitting process would allow for a more comprehensive understanding of any changes that are resulting from mitigation efforts. Additional research is necessary to understand how landscape structure affects the functioning of wetlands themselves and their ability to improve downstream water resources.

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APPENDIX A
PROJECT LOCATION INFORMATION

Project #	Project Name	Impacts Latitude	Impacts Longitude	Mitigation Latitude	Mitigation Longitude
1	I-80 Bridges	41 15 26.24	-81 33 7.46	41 21 29.35	-81 36 29.86
2	Four Seasons	41 16 51.30	-81 39 52.17	41 16 51.30	-81 39 52.17
3	Harvard Road	41 27 0.96	-81 29 35.65	41 27 0.96	-81 29 35.65
4	Kerruish	41 25 36.32	-81 33 9.47	41 25 36.32	-81 33 9.47
5a	Lombardo North	41 24 10.25	-81 39 37.94	41 19 22.98	-81 54 50.34
5b	Lombardo South	41 24 10.25	-81 39 37.94	41 18 29.80	-81 55 30.44
6	OTC	41 16 24.29	-81 38 3.95	41 25 43.86	-81 39 53.81
7	Twinsburg	41 19 30.40	-81 26 38.67	41 19 30.40	-81 26 38.67
8	Whitlach	41 18 26.85	-81 26 2.59	41 18 26.85	-81 26 2.59
9	Admore Drive	41 09 14.02	-81 22 47.12	41 09 14.02	-81 22 47.12
10	Kent State	41 08 17.27	-81 20 22.24	41 08 17.27	-81 20 22.24
11	Rapids Road	41 27 5.79	-81 09 30.49	41 27 5.79	-81 09 30.49
12	Geauga Lake	41 21 18.26	-81 23 5.29	41 21 18.26	-81 23 5.29
13	Whisp Meadows	41 19 50.45	-81 42 33.74	Mitigation Bank*	
14	Dayton Freight	41 06 38.46	-81 22 59.29	Mitigation Bank*	
15	Nesbitt Road	41 19 48.80	-81 34 24.48	Mitigation Bank*	
16	Ambina Road	41 22 23.50	-81 28 23.20	Preservation Only**	
17	Old River Bed	41 29 26.51	-81 43 25.82	Mitigation Bank*	
18	North Point	41 09 54.39	-81 30 6.26	Mitigation Bank*	
19	Cameratta	41 24 34.01	-81 38 31.76	Mitigation Bank*	
20	GOJO	41 10 39.62	-81 29 59.43	Mitigation Bank*	
21	Hudson Industrial	41 12 43.66	-81 25 42.03	Preservation Only**	
22	Seabreeze	41 13 5.87	-81 38 32.80	Mitigation Bank*	
23	Wilcox	41 14 41.36	-81 21 45.00	41 14 41.36	-81 21 45.00

* Mitigation requirements were met through the purchase of credits at a mitigation bank.

** Mitigation requirements were met entirely by preserving existing wetlands.

Table A.1 Latitude and longitude coordinates for impacted and mitigation wetlands for each project. Projects that mitigated at a bank or through preservation only were not visited and therefore no location is given.

APPENDIX B

PROJECT ANALYSES AND SPECIAL CONSIDERATIONS

Project Number	Project Name	Permit Compliance	Wetland Number and Size	Vegetation Types	Restoration Potential
1	I-80 Bridges	X	X	X	X
2	Four Seasons	X	X	X	X
3	Harvard Road	X	X	X	X
4	Kerruish	X	X	X	X
5a	Lombardo North	X	X	X	
5b	Lombardo South	X	X	X	
6	OTC	X	X	X	X
7	Twinsburg	X	X	X	X
8	Whitlach	X	X	X	X
9	Admore Drive	X	X	X	X
10	Kent State	X	X	X	X
11	Rapids Road	X	X	X	X
12	Geauga Lake	X	X	X	X
13	Whisp Meadows	X	X*		
14	Dayton Freight	X	X*		
15	Nesbitt Road	X	X*		
16	Ambina Road	X	X*		
17	Old River Bed	X	X*		
18	North Point	X	X*		
19	Cameratta	X	X*		
20	GOJO	X	X*		
21	Hudson Industrial	X	X*		
22	Seabreeze	X	X*		
23	Wilcox	X	X*		

* For comparison of number and size of impacted versus mitigation wetlands, it was assumed that wetland credits purchased at a mitigation bank were located within a single wetland.

** These two projects were combined for the calculation of mitigation wetland perimeter land uses

Continued

Table B.1 Analyses that were conducted for each project.

Table B.1 continued

Project Number	Project Name	Land Use Analysis	Wetland Perimeter Land Uses	Amphibian Potential
1	I-80 Bridges	X	X	X
2	Four Seasons	X	X	X
3	Harvard Road	X	X	X
4	Kerruish	X	X	X
5a	Lombardo North	X	X**	X
5b	Lombardo South	X	X**	X
6	OTC	X	X	X
7	Twinsburg	X	X	X
8	Whitlach	X	X	X
9	Admore Drive			
10	Kent State			
11	Rapids Road			
12	Geauga Lake			
13	Whisp Meadows			
14	Dayton Freight			
15	Nesbitt Road			
16	Ambina Road			
17	Old River Bed			
18	North Point			
19	Cameratta			
20	GOJO			
21	Hudson Industrial			
22	Seabreeze			
23	Wilcox			

* For comparison of number and size of impacted versus mitigation wetlands, it was assumed that wetland credits purchased at a mitigation bank were located within a single wetland.

** These two projects were combined for the calculation of mitigation wetland perimeter land uses

Project #	Project Name	Open Water*	Wetlands**	GIS***	Watershed****
1	I-80 Bridges				
2	Four Seasons	X	X		
3	Harvard Road				
4	Kerruish	X			
5a	Lombardo North				
5b	Lombardo South				
6	OTC				
7	Twinsburg		X		
8	Whitlach				
9	Admore Drive				
10	Kent State				
11	Rapids Road				
12	Geauga Lake		X	X	X
13	Whisp Meadows				
14	Dayton Freight				
15	Nesbitt Road				
16	Ambina Road				
17	Old River Bed				
18	North Point				
19	Cameratta				
20	GOJO				
21	Hudson Industrial				
22	Seabreeze				
23	Wilcox				

* Mitigation wetland size was over-estimated because deep open water habitat (non-wetland) was included in wetland delineation

** Mitigation wetland size was over-estimated because natural wetlands located within or adjacent to mitigation wetlands were included in delineation of mitigation area

*** The area of forested vernal pools were estimated using an as-built survey and GIS techniques

**** A small portion of wetland associated with this project was located outside of the watershed but was included within compliance calculations

Table B.2 Special circumstances that were noted during delineation of mitigation wetlands and calculation of permit compliance.

APPENDIX C

ANALYSIS OF GENERIC LANDSCAPES USING FRAGSTATS

Figure C.1 Generic landscapes that were analyzed using FRAGSTATS to calculate landscape metrics for general landscape composition and amphibian potential analysis (see Figure C.2).

Figure C.2 Results for four different landscape metrics that were calculated by FRAGSTATS using the generic landscapes shown in Figure C.1.

Figure C.3 Generic landscapes that were analyzed using FRAGSTATS to give landscape metrics (see Figure C.4).

Figure C.4 Results for four different landscape metrics that were calculated by FRAGSTATS using the generic landscapes shown in Figure C.3.

APPENDIX D
LANDSCAPE METRIC EQUATIONS

The equations for landscape metrics as calculated by the FRAGSTATS software package are listed below as defined within the FRAGSTATS documentation (McGarigal and others 2002). See McGarigal and others (2002) for a more detailed description of these metrics.

$$\text{Percent of Landscape (\%)} = P_i = \frac{\sum_{j=1}^n a_{ij}}{A} (100)$$

where: P_i = proportion of landscape occupied by patch type (land use) i

a_{ij} = area (m^2) of patch ij

A = total landscape area (m^2)

$$\text{Patch Density (\# patches/100 ha)} = \frac{n_i}{A} (10,000)(100)$$

where: n_i = number of patches in the landscape of patch type (land use) i

A = landscape area (m^2)

$$\text{Radius of Gyration (m)} = \frac{\sum_{r=1}^z h_{ijr}^2}{z}$$

where: h_{ijr} = distance (m) between cell ijr (located within patch ij) and the centroid of patch ij (the average location), based on cell center to center distance

z = number of cells in patch ij

r = pixel r

$$\text{Proximity Index (unitless)} = \sum_{s=1}^n \frac{a_{ijs}}{h_{ijs}^2}$$

where: a_{ijs} = area (m²) of patch ijs within specified neighborhood (m) of patch ij

h_{ijs} = distance (m) between patch ij and patch ijs , based upon patch edge to edge distance, computed from cell center to cell center

$$\text{Interspersion and Juxtaposition Index (\%)} = \text{IJI} = \frac{\sum_{k=1}^m \left[\left(\frac{e_{ik}}{\sum_{k=1}^m e_{ik}} \right) \ln \left(\frac{e_{ik}}{\sum_{k=1}^m e_{ik}} \right) \right]}{\ln(m-1)} (100)$$

where: e_{ik} = total length (m) of edge in landscape between patch types (land uses) i and j

m = number of patch types (land uses) present in the landscape

APPENDIX E

LAND USE CLASSES AND DIGITIZATION PROTOCOL

Land Use Class	Description
Agriculture	Actively farmed row crops. Included barns and all farm buildings except for farmhouses which were included within the Residential class. Did not include hay fields which were included in the Mowed class.
Construction	Areas under active construction for which the planned land use was unclear. Included dirt roads and all areas with exposed, unvegetated soil (excluding plowed agriculture fields).
Forest	All forests. Small groups of trees (1-15) were not delineated as forest but were included within the nearby land use class. Some ephemeral wetlands and streams may have been included within the Forest class.
Industrial	Included all industrial complexes, office buildings, and associated parking lots.
Mitigation Wetland	Mitigation wetlands that were delineated in the field using the Army Corps of Engineers protocol (ACOE 1987).
Mowed	Included recently abandoned farm fields, hay fields, orchards, roadside grassways, and all areas that were clearly mowed. Small yards associated with residential areas were included in the Residential class.
Oldfield	Oldfield was defined as early successional , upland, herbaceous vegetation. Oldfield is generally found on an area that has recently been abandoned by humans. Oldfield, prairie, scrub/shrub upland, and patchy, very early successional forest. Also included thin (<10ft wide) strips of trees between other land use classes.
Park	Small, paved walkways within parks were included in the Park class. Also included recreational facilities such as tennis courts and baseball fields. Included cemeteries.
Pond	Ponds and quarries that were comprised of >90% open water.
Residential	All houses, apartment and condominium complexes, and associated yards and parking lots.
Road	All paved and gravel roads that were >10ft in width. Roads located within high density residential areas were digitized at a scale of 1:5000 to aid processing speed (other land use classes were digitized at a scale of 1:2000 - 1:4000). Included railways.
Waterway	All streams, ditches, rivers, and canals greater than 10 feet in width. Small islands and sandbars were included in the Waterway class.
Wetland	All wetlands that were <90% open water. Some ephemeral wetlands, especially forested wetlands, may have been excluded.

Table E.1 Descriptions of land use classes used for landscape analysis.

APPENDIX F
LANDSCAPE AREAS

Project #	Project Name	Rows	Columns	Area (ha)
1	I-80 Bridges	879	1317	115.8
2	Four Seasons	777	828	64.3
3	Harvard Road	907	878	79.6
4	Kerruish	705	704	49.6
5	Lombardo	887	774	68.7
6	OTC	1038	1051	109.1
7	Twinsburg	839	803	67.4
8	Whitlach	754	742	55.9
9	Admore Drive	669	665	44.5
10	Kent State	665	666	44.3
11	Rapids Road	741	667	49.4
12	Geauga Lake	774	797	61.7

Table F.1 Area of landscapes for impacted wetlands (1000 m). These landscapes were used only for wetland spatial configuration analysis, specifically the calculation of wetland density (# wetlands/100 ha).

Project #	Project Name	Rows	Columns	Area (ha)
1	I-80 Bridges	245	287	7.0
2	Four Seasons	243	309	7.5
3	Harvard Road	312	250	7.8
4	Kerruish	273	309	8.4
5a	Lombardo North	284	293	8.3
5b	Lombardo South	269	330	8.9
6	OTC	249	223	5.6
7	Twinsburg	285	296	8.4
8	Whitlach	261	253	6.6

Table F.2 Area of landscapes for mitigation wetlands (300 m). These landscapes were used for wetland spatial configuration, general landscape setting, and amphibian potential analyses.

Project #	Project Name	Rows	Columns	Area (ha)
1	I-80 Bridges	704	746	52.5
2	Four Seasons	703	769	54.1
3	Harvard Road	771	709	54.7
4	Kerruish	732	768	56.2
5a	Lombardo North	743	752	55.9
5b	Lombardo South	728	789	57.4
6	OTC	709	682	48.4
7	Twinsburg	744	756	56.2
8	Whitlach	720	712	51.3
9	Admore Drive	671	679	45.6
10	Kent State	788	693	54.6
11	Rapids Road	719	666	47.9
12	Geauga Lake	790	709	56.0

Table F.3 Area of landscapes for mitigation wetlands (1000 m). These landscapes were used for wetland spatial configuration and general landscape setting analyses.

APPENDIX G
LAND USE MAPS

Project #1
I-80 Bridges

Figure G.1 1000 m land use map for project #1.

Project #2
Four Seasons

Figure G.2 1000 m land use map for project #2.

Project #3
Harvard Road

Figure G.3 1000 m land use map for project #3.

Project #4
Kerruish

Figure G.4 1000 m land use map for project #4.

Project #5a
Lombardo North

Figure G.5 1000 m land use map for project #5a.

Project #5b
Lombardo South

Figure G.6 1000 m land use map for project #5b.

Project #7
Twinsburg

Figure G.7 1000 m land use map for project #7.

Project #8
Whitlach

Figure G.8 1000 m land use map for project #8

APPENDIX H

PEARSON'S CORRELATIONS FOR LANDSCAPE INDICES

	Ag	Const	For	Ind	Mit	Mow
Const	-0.505					
For	0.144	-0.057				
Ind	-0.186	0.531	-0.223			
Mit	0.207	-0.268	-0.374	0.083		
Mow	-0.535	0.167	-0.567	0.219	-0.390	
Old	-0.173	-0.299	-0.572	0.041	0.423	0.286
Park	-0.128	0.187	-0.172	-0.112	0.104	-0.166
Pond	0.250	-0.278	-0.453	0.193	0.961	-0.350
Res	0.025	0.002	0.125	-0.249	0.103	-0.285
Road	-0.286	0.075	-0.590	0.063	-0.176	0.855
Wway	0.421	0.185	0.180	0.002	-0.363	-0.272
Wet	0.010	-0.446	0.102	-0.359	0.043	-0.041

	Old	Park	Pond	Res	Road	Wway
Park	0.392					
Pond	0.467	0.158				
Res	-0.608	-0.315	0.104			
Road	0.164	-0.258	-0.234	-0.231		
Wway	-0.112	0.594	-0.254	-0.336	-0.330	
Wet	0.543	-0.088	0.019	-0.313	-0.201	-0.166

Ag = Agriculture, Const = Construction, For = Forest, Ind = Industrial, Mit = Mitigation wetland
Mow = Mowed grass, Old = Oldfield, Res = Residential, Wway = Waterway, Wet = Wetland

Table H.1 Pearson's correlations (r) for 300 m land use percentages.

	Ag	Const	For	Ind	Mitig	Mow
Const	-0.395					
For	0.172	-0.377				
Ind	-0.430	0.749	-0.854			
Mitig	0.524	-0.382	0.051	-0.254		
Mow	-0.522	0.207	0.231	0.072	-0.568	
Oldf	0.253	0.348	0.034	0.146	0.175	0.172
Park	0.169	0.213	-0.476	0.400	0.633	-0.612
Pond	0.760	-0.044	0.114	-0.109	0.643	-0.281
Res	0.117	-0.721	0.011	-0.418	0.117	-0.385
Rd	-0.564	-0.055	-0.673	0.505	-0.190	0.110
Water	0.083	0.404	0.156	0.044	-0.125	-0.193
Wet	-0.172	-0.171	0.563	-0.514	-0.048	0.113

	Oldf	Park	Pond	Res	Rd	Water
Park	0.005					
Pond	0.511	0.448				
Res	-0.842	-0.033	-0.348			
Rd	-0.395	0.010	-0.599	0.349		
Water	0.552	0.068	0.146	-0.561	-0.541	
Wet	0.247	-0.359	-0.319	-0.086	-0.283	0.505

Ag = Agriculture, Const = Construction, For = Forest, Ind = Industrial, Mit = Mitigation wetland
Mow = Mowed grass, Old = Oldfield, Res = Residential, Wway = Waterway, Wet = Wetland

Table H.2 Pearson's correlations (r) for 1000 m land use percentages.

Construction	%Land	#Patch	Density	Area	Gyrate	Proxim
#Patch	0.153					
Density	0.259	0.945				
Area	0.858	-0.290	-0.248			
Gyrate	0.659	-0.236	-0.302	0.893		
Proxim	0.242	0.841	0.912	-0.187	-0.209	
IJI	0.798	0.702	0.741	0.443	0.345	0.689
Forest	%Land	#Patch	Density	Area	Gyrate	Proxim
#Patch	0.474					
Density	0.375	0.976				
Area	0.590	-0.356	-0.448			
Gyrate	0.434	-0.459	-0.545	0.938		
Proxim	0.882	0.333	0.245	0.576	0.402	
IJI	0.827	0.425	0.391	0.429	0.303	0.785
Industrial	%Land	#Patch	Density	Area	Gyrate	Proxim
#Patch	0.854					
Density	0.736	0.979				
Area	0.322	-0.206	-0.376			
Gyrate	0.341	-0.178	-0.341	0.920		
Proxim	0.946	0.969	0.899	0.001	0.038	
IJI	0.620	0.185	-0.018	0.742	0.768	0.420
Mitigation	%Land	#Patch	Density	Area	Gyrate	Proxim
#Patch	-0.339					
Density	-0.457	0.974				
Area	0.986	-0.471	-0.586			
Gyrate	0.752	-0.687	-0.823	0.835		
Proxim	-0.366	0.463	0.576	-0.417	-0.600	
IJI	0.429	-0.445	-0.504	0.430	0.497	-0.604
Mowed	%Land	#Patch	Density	Area	Gyrate	Proxim
#Patch	0.256					
Density	0.269	0.973				
Area	0.798	-0.290	-0.293			
Gyrate	0.815	-0.104	-0.165	0.871		

%Land = percent of landscape, #Patch = number of patches, Density = patch density (#/100 ha)
Area = area of landscape, Gyrate = radius of gyration, proxim = proximity index

Continued

Table H.3 Pearson's correlations (r) for 300 m landscape metrics by land use class.

Table H.3 continued

Mowed (contd)	%Land	#Patch	Density	Area	Gyrate	Proxim
Proxim	0.744	0.564	0.532	0.306	0.514	
IJI	0.674	0.556	0.567	0.463	0.443	0.592
Oldfield	%Land	#Patch	Density	Area	Gyrate	Proxim
#Patch	0.533					
Density	0.456	0.976				
Area	0.684	-0.178	-0.255			
Gyrate	0.708	-0.057	-0.159	0.931		
Proxim	0.731	0.604	0.517	0.272	0.410	
IJI	0.742	0.198	0.114	0.731	0.830	0.271
Park	%Land	#Patch	Density	Area	Gyrate	Proxim
#Patch	0.994					
Density	0.993	1.000				
Area	-0.796	-0.859	-0.862			
Gyrate	-0.007	-0.12	-0.125	0.611		
Proxim	0.994	1.000	1.000	-0.859	-0.120	
IJI	0.967	0.932	0.930	-0.615	0.249	0.932
Pond	%Land	#Patch	Density	Area	Gyrate	Proxim
#Patch	0.997					
Density	0.997	1.000				
Area	0.989	0.993	0.989			
Gyrate	0.959	0.969	0.962	0.991		
Proxim	0.999	0.992	0.993	0.982	0.947	
IJI	0.699	0.728	0.711	0.774	0.831	0.676
Residential	%Land	#Patch	Density	Area	Gyrate	Proxim
#Patch	0.506					
Density	0.503	0.988				
Area	0.737	-0.089	-0.123			
Gyrate	0.342	-0.194	-0.256	0.785		
Proxim	0.882	0.069	0.089	0.881	0.454	
IJI	-0.211	-0.119	-0.049	-0.094	-0.123	-0.015

%Land = percent of landscape, #Patch = number of patches, Density = patch density (#/100 ha)

Area = area of landscape, Gyrate = radius of gyration, proxim = proximity index

Continued

Table H.3 continued

Road	%Land	#Patch	Density	Area	Gyrate	Proxim
#Patch	0.643					
Density	0.577	0.959				
Area	0.856	0.270	0.201			
Gyrate	-0.387	-0.741	-0.854	0.058		
Proxim	0.966	0.500	0.456	0.817	-0.364	
IJI	0.282	0.400	0.520	0.163	-0.523	0.239
Waterway	%Land	#Patch	Density	Area	Gyrate	Proxim
#Patch	0.702					
Density	0.710	0.997				
Area	0.625	-0.111	-0.106			
Gyrate	0.363	-0.260	-0.239	0.770		
Proxim	0.702	1.000	0.997	-0.111	-0.260	
IJI	0.351	0.630	0.632	-0.205	0.187	0.630
Wetland	%Land	#Patch	Density	Area	Gyrate	Proxim
#Patch	0.935					
Density	0.968	0.990				
Area	0.663	0.489	0.523			
Gyrate	0.019	-0.013	-0.034	0.678		
Proxim	0.969	0.955	0.985	0.482	-0.140	
IJI	0.617	0.507	0.547	0.410	-0.053	0.542

%Land = percent of landscape, #Patch = number of patches, Density = patch density (#/100 ha)

Area = area of landscape, Gyrate = radius of gyration, proxim = proximity index

APPENDIX I
PEARSON'S CORRELATIONS FOR LANDSCAPE AREA

300 m Patch Density		1000 m Patch Density	
	Landscape Area		Landscape Area
Patch Density	-0.248	Patch Density	0.536

300 m Land Use Percentages		1000 m Land Use Percentages	
	Landscape Area		Landscape Area
Ag	0.403	Ag	0.407
Const	-0.413	Const	-0.800
For	0.021	For	0.163
Ind	-0.182	Ind	-0.530
Mit	0.614	Mit	0.635
Mow	-0.336	Mow	-0.518
Old	-0.193	Old	-0.429
Park	-0.525	Park	0.110
Pond	0.467	Pond	0.131
Res	0.375	Res	0.729
Road	0.086	Road	0.143
Wway	-0.551	Wway	-0.530
Wet	-0.110	Wet	-0.102

300 m Combined Land Uses		1000 m Combined Land Uses	
	Landscape Area		Landscape Area
Human %land	0.416	Human %land	0.149
Natural %land	-0.514	Natural %land	-0.123
Water %land	0.108	Water %land	-0.229

300 m Amphibian Metrics	
	Landscape Area
Forest %land	0.015
Wetland %land	-0.117
Road %land	0.087
Urban %land	0.313
Forest Gyrate	0.635
Road Gyrate	0.383

Ag = Agriculture, Const = Construction, For = Forest, Ind = Industrial, Mit = Mitigation wetland
Mow = Mowed grass, Old = Oldfield, Res = Residential, Wway = Waterway, Wet = Wetland
%Land = percent of landscape, Patch Density = # patches/100 ha

Table I.1 Pearson's correlations (*r*) for landscape sizes (ha) and all landscape metrics.

APPENDIX J

PERMIT COMPLIANCE DATA

Projects that created or restored mitigation wetlands independently								
Project #	Imp	Req	Mit	Compliance	Net Gain	CRW Impacts	CRW Mit	Exp Mit
1	1.44	1.45	1.37	-0.08	-0.07	1.44	1.37	0.00
2	0.57	2.02	1.03	-0.99	0.47	0.57	1.03	0.00
3	0.56	0.93	1.42	0.49	0.86	0.56	1.42	0.00
4	0.37	0.81	1.67	0.86	1.30	0.37	1.67	0.00
5	4.98	10.12	8.63	-1.49	3.65	4.98	0.00	8.63
6	0.43	0.43	0.77	0.34	0.34	0.43	0.77	0.00
7	0.50	1.63	2.44	0.81	1.94	0.50	2.44	0.00
8	0.89	1.75	0.77	-0.98	-0.12	0.89	0.77	0.00
9	0.07	0.13	0.11	-0.03	0.04	0.07	0.11	0.00
10	0.02	0.51	0.28	-0.23	0.25	0.02	0.28	0.00
11	0.23	0.42	0.24	-0.17	0.01	0.23	0.24	0.00
12	0.96	1.57	1.520*	-0.05	0.57	0.59	0.48	1.04
Subtotal	11.02	21.77	20.26	-1.51	9.24	10.65	10.59	9.67
Projects that purchased mitigation bank credits or preserved wetlands for mitigation								
Project #	Imp	Req	Mit	Compliance	Net Gain	CRW Impacts	CRW Mit	Exp Mit
13	0.16	0.35	0.35	0.00	0.19	0.16	0.00	0.35
14	0.05	0.12	0.12	0.00	0.07	0.05	0.00	0.12
15	0.08	0.15	0.15	0.00	0.08	0.08	0.00	0.15
16	0.27	0.00	0.00	0.00	-0.27	0.27	0.00	0.00
17	0.23	0.45	0.45	0.00	0.22	0.23	0.00	0.45
18	0.99	1.54	1.54	0.00	0.55	0.99	0.00	1.54
19	0.17	0.32	0.32	0.00	0.16	0.17	0.00	0.32
20	0.17	0.28	0.28	0.00	0.11	0.17	0.00	0.28
21	0.36	0.00	0.00	0.00	-0.36	0.36	0.00	0.00
22	1.08	2.02	2.02	0.00	0.94	1.08	0.00	2.02
23	0.37	0.77	0.77	0.00	0.40	0.37	0.77	0.00
Subtotal	3.93	6.01	6.01	0.00	2.08	3.93	0.77	5.24
TOTAL	14.95	27.78	26.27	-1.51	11.31	14.58	11.36	14.91
Imp = area (ha) of impacted wetlands, Req = area (ha) of required mitigation								
Mit = area (ha) of constructed mitigation, Compliance = deviation (ha) from required mitigation area								
Net Gain = gain or loss of wetland area								
CRW Impacts = area (ha) of impacts that occurred in the Cuyahoga River watershed								
CRW Mit = area (ha) of mitigation that was constructed in the Cuyahoga River watershed								
Exp Mit = area (ha) of mitigation that was exported from the Cuyahoga River watershed								

Table J.1 Data for wetland impacts and mitigation used for calculation of permit compliance and net gain/loss of wetland area.

APPENDIX K
WETLAND STRUCTURE DATA

Project #	Project Name	Impacts Emerg/OW	Impacts Forested	Impacts Scrub/Shrub	Mitigation Emerg/OW	Mitigation Forested	Mitigation Scrub/Shrub
1	I-80 Bridges	1.13	0.31	0.00	1.37	0.00	0.00
2	Four Seasons	0.00	0.57	0.00	0.93	0.05	0.05
3	Harvard Road	0.29	0.10	0.17	1.42	0.00	0.00
4	Kerruish	0.00	0.00	0.37	1.59	0.00	0.08
5	Lombardo	1.58	0.31	3.10	5.78	0.00	2.85
6	OTC	0.12	0.13	0.18	0.62	0.15	0.00
7	Twinsburg	0.30	0.20	0.00	2.44	0.00	0.00
8	Whitlach	0.74	0.15	0.00	0.77	0.00	0.00
9	Admore Drive	0.07	0.00	0.00	0.11	0.00	0.00
10	Kent State	0.02	0.00	0.00	0.28	0.00	0.00
11	Rapids Road	0.00	0.00	0.23	0.24	0.00	0.00
12	Geauga Lake	0.44	0.05	0.47	1.22	0.30	0.00
TOTAL		4.68	1.82	4.52	16.77	0.51	2.98

All vegetation areas are in hectares (ha)

Emerg/OW = Emergent and open water

Table K.1 Area of vegetation types for wetland impacts and mitigation for all projects that created or restored mitigation wetlands independently.

Project #	Project Name	Wetland Size (ha)	Project #	Project Name	Wetland Size (ha)
1	I-80 Bridges	0.048	5	Lombardo	0.478
1	I-80 Bridges	0.045	5	Lombardo	4.504
1	I-80 Bridges	0.013	6	OTC	0.004
1	I-80 Bridges	0.062	6	OTC	0.012
1	I-80 Bridges	0.160	6	OTC	0.016
1	I-80 Bridges	0.417	6	OTC	0.016
1	I-80 Bridges	0.504	6	OTC	0.004
1	I-80 Bridges	0.013	6	OTC	0.004
1	I-80 Bridges	0.002	6	OTC	0.016
1	I-80 Bridges	0.012	6	OTC	0.008
1	I-80 Bridges	0.002	6	OTC	0.004
1	I-80 Bridges	0.003	6	OTC	0.073
1	I-80 Bridges	0.049	6	OTC	0.174
1	I-80 Bridges	0.007	6	OTC	0.057
1	I-80 Bridges	0.016	6	OTC	0.032
1	I-80 Bridges	0.013	6	OTC	0.012
1	I-80 Bridges	0.008	7	Twinsburg	0.235
1	I-80 Bridges	0.062	7	Twinsburg	0.008
2	Four Seasons	0.033	7	Twinsburg	0.154
2	Four Seasons	0.025	7	Twinsburg	0.040
2	Four Seasons	0.135	7	Twinsburg	0.061
2	Four Seasons	0.038	8	Whitlach	0.016
2	Four Seasons	0.197	8	Whitlach	0.004
2	Four Seasons	0.062	8	Whitlach	0.004
2	Four Seasons	0.076	8	Whitlach	0.020
3	Harvard Road	0.028	8	Whitlach	0.016
3	Harvard Road	0.049	8	Whitlach	0.036
3	Harvard Road	0.016	8	Whitlach	0.040
3	Harvard Road	0.045	8	Whitlach	0.008
3	Harvard Road	0.125	8	Whitlach	0.745
3	Harvard Road	0.065	9	Admore Drive	0.069
3	Harvard Road	0.036	10	Kent State	0.024
3	Harvard Road	0.008	11	Rapids Road	0.008
3	Harvard Road	0.036	11	Rapids Road	0.004
3	Harvard Road	0.049	11	Rapids Road	0.004
3	Harvard Road	0.012	11	Rapids Road	0.008
3	Harvard Road	0.093	11	Rapids Road	0.206
4	Kerruish	0.028			
4	Kerruish	0.037			
4	Kerruish	0.089			
4	Kerruish	0.216			

Continued

Table K.2 Size (ha) of impacted wetlands.

Table K.2 continued

Project #	Project Name	Wetland Size (ha)	Project #	Project Name	Wetland Size (ha)
12	Geauga Lake	0.138	18	North Point	0.397
12	Geauga Lake	0.024	18	North Point	0.255
12	Geauga Lake	0.012	18	North Point	0.186
12	Geauga Lake	0.045	18	North Point	0.036
12	Geauga Lake	0.190	18	North Point	0.057
12	Geauga Lake	0.546	18	North Point	0.061
13	Whisp Meadows	0.008	19	Cameratta	0.020
13	Whisp Meadows	0.015	19	Cameratta	0.057
13	Whisp Meadows	0.063	19	Cameratta	0.089
13	Whisp Meadows	0.005	20	GOJO	0.174
13	Whisp Meadows	0.001	21	Hudson Industrial	0.049
13	Whisp Meadows	0.006	21	Hudson Industrial	0.017
13	Whisp Meadows	0.006	21	Hudson Industrial	0.007
13	Whisp Meadows	0.011	21	Hudson Industrial	0.275
13	Whisp Meadows	0.002	21	Hudson Industrial	0.001
13	Whisp Meadows	0.003	21	Hudson Industrial	0.002
13	Whisp Meadows	0.018	21	Hudson Industrial	0.007
13	Whisp Meadows	0.004	21	Hudson Industrial	0.004
13	Whisp Meadows	0.019	22	Seabreeze	0.252
14	Dayton Freight	0.049	22	Seabreeze	0.072
15	Nesbitt Road	0.036	22	Seabreeze	0.760
15	Nesbitt Road	0.012	23	Wilcox	0.012
15	Nesbitt Road	0.028	23	Wilcox	0.004
16	Ambina Road	0.170	23	Wilcox	0.069
16	Ambina Road	0.093	23	Wilcox	0.053
16	Ambina Road	0.008	23	Wilcox	0.008
17	Old River Bed	0.154	23	Wilcox	0.223
17	Old River Bed	0.020			
17	Old River Bed	0.053			

Project #	Project Na	Area (ha)	Project #	Project Na	Area (ha)
1	I-80 Bridges	0.180	12	Geauga Lake	0.188
1	I-80 Bridges	1.192	12	Geauga Lake	1.033
2	Four Seasons	0.509	12	Geauga Lake	0.001
2	Four Seasons	0.525	12	Geauga Lake	0.002
3	Harvard Road	1.424	12	Geauga Lake	0.004
4	Kerruish	1.671	12	Geauga Lake	0.005
5	Lombardo	0.020	12	Geauga Lake	0.005
5	Lombardo	0.060	12	Geauga Lake	0.005
5	Lombardo	0.061	12	Geauga Lake	0.005
5	Lombardo	0.092	12	Geauga Lake	0.005
5	Lombardo	1.258	12	Geauga Lake	0.006
5	Lombardo	7.136	12	Geauga Lake	0.007
6	OTC	0.771	12	Geauga Lake	0.008
7	Twinsburg	2.440	12	Geauga Lake	0.009
8	Whitlach	0.134	12	Geauga Lake	0.010
8	Whitlach	0.637	12	Geauga Lake	0.010
9	Admore Drive	0.108	12	Geauga Lake	0.011
10	Rapids Road	0.025	12	Geauga Lake	0.011
10	Rapids Road	0.209	12	Geauga Lake	0.012
10	Rapids Road	0.009	12	Geauga Lake	0.012
11	Kent State	0.009	12	Geauga Lake	0.014
11	Kent State	0.011	12	Geauga Lake	0.018
11	Kent State	0.011	12	Geauga Lake	0.021
11	Kent State	0.012	12	Geauga Lake	0.021
11	Kent State	0.015	12	Geauga Lake	0.097
11	Kent State	0.016	13	Whisp Meadows	0.348
11	Kent State	0.018	14	Dayton Freight	0.121
11	Kent State	0.020	15	Nesbitt Road	0.154
11	Kent State	0.021	16	Ambina Road	0.000*
11	Kent State	0.023	17	Old River Bed	0.445
11	Kent State	0.121	18	North Point	1.538
			19	Cameratta	0.324
			20	GOJO	0.283
			21	Hudson Industrial	0.000*
			22	Seabreeze	2.024
			23	Wilcox	0.769

* Impacts were mitigated entirely through wetland preservation; no wetlands were created or restored for mitigation

Table K.3 Size (ha) of mitigation wetlands.

Project #	Project Name	# Impacted Wetlands	# Mitigation Wetlands
1	I-80 Bridges	18	2
2	Four Seasons	7	2
3	Harvard Road	12	1
4	Kerruish	4	1
5	Lombardo	2	6
6	OTC	14	1
7	Twinsburg	5	1
8	Whitlach	9	2
9	Admore Drive	1	1
10	Kent State	1	11
11	Rapids Road	5	3
12	Geauga Lake	6	25
13	Whisp Meadows	13	1
14	Dayton Freight	1	1
15	Nesbitt Road	3	1
16	Ambina Road	3	0*
17	Old River Bed	3	1
18	North Point	6	1
19	Cameratta	3	1
20	GOJO	1	1
21	Hudson Industrial	8	0*
22	Seabreeze	3	1
23	Wilcox	6	1
TOTAL		134	65

* Impacts were mitigated entirely through wetland preservation; no wetlands were created or restored for mitigation

Table K.4 Number of impacted and mitigation wetlands for each project.

APPENDIX L
LANDSCAPE DATA

Project #1 (I-80 Bridges)						
Land Use	# Patches	PD	CA	Gyrate	Proxim	IJI
Ag	NA	NA	NA	NA	NA	NA
Const	1	1.53	0.93	51.3	0.0	37.9
For	6	9.18	3.01	65.7	276.0	77.8
Ind	NA	NA	NA	NA	NA	NA
Mit	2	3.06	0.68	35.5	7.3	63.9
Mow	2	3.06	2.32	75.6	0.6	80.5
Old	11	16.84	1.45	52.4	348.4	65.4
Park	NA	NA	NA	NA	NA	NA
Pond	NA	NA	NA	NA	NA	NA
Res	1	1.53	0.80	36.0	0.0	54.4
Road	1	1.53	2.88	234.9	0.0	56.5
Wway	NA	NA	NA	NA	NA	NA
Wet	8	12.25	0.67	27.8	23.4	65.7

Project #2 (Four Seasons)						
Land Use	# Patches	PD	CA	Gyrate	Proxim	IJI
Ag	NA	NA	NA	NA	NA	NA
Const	4	5.73	0.55	52.8	51.8	60.9
For	10	14.34	1.85	59.6	100.9	60.1
Ind	NA	NA	NA	NA	NA	NA
Mit	2	2.87	0.52	42.1	3.3	30.9
Mow	10	14.34	0.43	42.9	30.3	67.0
Old	3	4.30	0.24	19.7	0.0	45.0
Park	NA	NA	NA	NA	NA	NA
Pond	1	1.43	0.07	10.8	0.0	0.0
Res	7	10.03	3.58	76.6	1961.2	51.6
Road	1	1.43	2.36	261.0	0.0	39.6
Wway	NA	NA	NA	NA	NA	NA
Wet	1	1.43	0.16	15.8	0.0	32.4

Ag = Agriculture, Const = Construction, For = Forest, Ind = Industrial, Mit = Mitigation wetland

Mow = Mowed grass, Old = Oldfield, Res = Residential, Wway = Waterway, Wet = Wetland

Patches = number of patches in the landscape, PD = patch density (# patches/100 ha)

CA = mean patch area (m²) for land use, Gyrate = radius of gyration (m)

Proxim = proximity index (unitless), IJI = interspersation and juxtaposition index (%)

Continued

Table L.1 Landscape data for 300 m landscapes.

Table L.1 continued

Project #3 (Harvard Road)						
Land Use	# Patches	PD	CA	Gyrate	Proxim	LJI
Ag	NA	NA	NA	NA	NA	NA
Const	3	4.14	0.80	55.6	0.0	53.8
For	3	4.14	1.43	48.3	18.7	45.7
Ind	2	2.76	1.32	53.8	0.3	57.1
Mit	1	1.38	1.45	83.8	0.0	34.6
Mow	4	5.52	2.72	122.5	72.4	73.3
Old	6	8.28	2.26	55.2	10.0	87.3
Park	NA	NA	NA	NA	NA	NA
Pond	NA	NA	NA	NA	NA	NA
Res	NA	NA	NA	NA	NA	NA
Road	4	5.52	4.80	111.4	1001.3	61.6
Wway	NA	NA	NA	NA	NA	NA
Wet	NA	NA	NA	NA	NA	NA
Project #4 (Kerruish)						
Land Use	# Patches	PD	CA	Gyrate	Proxim	LJI
Ag	NA	NA	NA	NA	NA	NA
Const	2	2.55	4.05	115.3	12.3	64.1
For	4	5.10	5.28	96.7	483.4	70.8
Ind	2	2.55	0.96	36.9	0.0	60.1
Mit	1	1.28	2.38	90.9	0.0	43.6
Mow	7	8.93	0.45	55.4	54.7	74.0
Old	NA	NA	NA	NA	NA	NA
Park	NA	NA	NA	NA	NA	NA
Pond	NA	NA	NA	NA	NA	NA
Res	14	17.86	1.09	47.9	130.3	51.4
Road	5	6.38	1.38	115.4	51.5	53.5
Wway	1	1.28	0.35	183.9	0.0	52.5
Wet	NA	NA	NA	NA	NA	NA

Ag = Agriculture, Const = Construction, For = Forest, Ind = Industrial, Mit = Mitigation wetland

Mow = Mowed grass, Old = Oldfield, Res = Residential, Wway = Waterway, Wet = Wetland

Patches = number of patches in the landscape, PD = patch density (# patches/100 ha)

CA = mean patch area (m²) for land use, Gyrate = radius of gyration (m)

Proxim = proximity index (unitless), LJI = interspersed and juxtaposition index (%)

Table L.1 continued

Project #5a (Lombardo North)						
Land Use	# Patches	PD	CA	Gyrate	Proxim	LJI
Ag	6	7.76	2.74	62.0	40.6	41.2
Const	NA	NA	NA	NA	NA	NA
For	5	6.47	5.63	109.4	469.9	68.4
Ind	NA	NA	NA	NA	NA	NA
Mit	4	5.17	0.37	27.6	8.3	10.3
Mow	1	1.29	0.29	21.8	0.0	0.0
Old	2	2.59	0.86	36.4	0.0	47.1
Park	NA	NA	NA	NA	NA	NA
Pond	1	1.29	0.08	11.5	0.0	25.2
Res	3	3.88	2.57	123.0	403.2	51.8
Road	1	1.29	0.73	188.8	0.0	14.3
Wway	1	1.29	3.72	264.8	0.0	14.8
Wet	2	2.59	0.60	38.0	0.0	13.9
Project #5b (Lombardo South)						
Land Use	# Patches	PD	CA	Gyrate	Proxim	LJI
Ag	4	4.85	1.64	51.5	109.3	60.3
Const	2	2.43	0.70	38.1	3.4	46.4
For	4	4.85	1.99	76.8	1.9	60.4
Ind	2	2.43	1.86	51.1	0.5	58.6
Mit	1	1.21	7.12	108.3	0.0	47.2
Mow	2	2.43	0.66	35.8	0.0	45.1
Old	4	4.85	5.07	92.8	144.8	86.9
Park	1	1.21	3.93	82.9	0.0	28.9
Pond	9	10.91	0.46	23.4	3.7	40.4
Res	4	4.85	2.69	79.5	732.8	71.6
Road	1	1.21	0.80	202.3	0.0	51.3
Wway	NA	NA	NA	NA	NA	NA
Wet	3	3.64	0.48	33.8	0.6	59.5

Ag = Agriculture, Const = Construction, For = Forest, Ind = Industrial, Mit = Mitigation wetland

Mow = Mowed grass, Old = Oldfield, Res = Residential, Wway = Waterway, Wet = Wetland

Patches = number of patches in the landscape, PD = patch density (# patches/100 ha)

CA = mean patch area (m²) for land use, Gyrate = radius of gyration (m)

Proxim = proximity index (unitless), LJI = interspersed and juxtaposition index (%)

Table L.1 continued

Project #6 (OTC)						
Land Use	# Patches	PD	CA	Gyrate	Proxim	IJI
Ag	NA	NA	NA	NA	NA	NA
Const	4	7.75	0.96	34.2	71.6	69.7
For	7	13.57	1.55	58.5	241.0	68.7
Ind	3	5.82	0.24	21.0	0.8	29.1
Mit	1	1.94	0.77	39.9	0.0	22.3
Mow	5	9.69	0.55	35.9	29.4	64.0
Old	10	19.39	0.96	41.1	133.3	71.5
Park	6	11.63	1.30	70.1	186.1	72.2
Pond	NA	NA	NA	NA	NA	NA
Res	NA	NA	NA	NA	NA	NA
Road	3	5.82	0.40	62.1	0.5	71.5
Wway	3	5.82	1.04	111.3	160.1	58.2
Wet	1	1.94	0.49	35.1	0.0	44.6
Project #7 (Twinsburg)						
Land Use	# Patches	PD	CA	Gyrate	Proxim	IJI
Ag	NA	NA	NA	NA	NA	NA
Const	2	2.55	0.60	38.6	0.2	40.5
For	8	10.21	4.38	84.9	1011.5	81.6
Ind	NA	NA	NA	NA	NA	NA
Mit	1	1.28	2.59	79.1	0.0	39.9
Mow	3	3.83	0.50	64.7	0.1	31.0
Old	5	6.38	1.45	64.4	101.9	80.3
Park	1	1.28	2.59	61.7	0.0	3.7
Pond	2	2.55	0.12	13.4	0.0	27.8
Res	5	6.38	1.31	40.9	38.2	40.2
Road	2	2.55	0.67	200.2	0.4	52.1
Wway	1	1.28	0.08	14.0	0.0	0.0
Wet	4	5.10	0.26	29.3	5.1	19.6

Ag = Agriculture, Const = Construction, For = Forest, Ind = Industrial, Mit = Mitigation wetland

Mow = Mowed grass, Old = Oldfield, Res = Residential, Wway = Waterway, Wet = Wetland

Patches = number of patches in the landscape, PD = patch density (# patches/100 ha)

CA = mean patch area (m^2) for land use, Gyrate = radius of gyration (m)

Proxim = proximity index (unitless), IJI = interspersed and juxtaposition index (%)

Table L.1 continued

Project #8 (Whitlach)						
Land Use	# Patches	PD	CA	Gyrate	Proxim	IJI
Ag	NA	NA	NA	NA	NA	NA
Const	2	3.26	2.74	62.3	0.6	59.8
For	15	24.45	1.32	45.0	534.7	75.1
Ind	6	9.78	1.10	41.9	146.1	64.6
Mit	2	3.26	0.38	31.2	25.8	0.0
Mow	8	13.04	0.49	35.4	37.7	74.3
Old	9	14.67	0.47	32.3	6.1	59.3
Park	NA	NA	NA	NA	NA	NA
Pond	1	1.63	0.03	8.1	0.0	0.0
Res	6	9.78	0.42	21.0	13.5	73.1
Road	1	1.63	0.95	158.6	0.0	61.3
Wway	1	1.63	1.45	207.3	0.0	26.3
Wet	NA	NA	NA	NA	NA	NA

Ag = Agriculture, Const = Construction, For = Forest, Ind = Industrial, Mit = Mitigation wetland

Mow = Mowed grass, Old = Oldfield, Res = Residential, Wway = Waterway, Wet = Wetland

Patches = number of patches in the landscape, PD = patch density (# patches/100 ha)

CA = mean patch area (m²) for land use, Gyrate = radius of gyration (m)

Proxim = proximity index (unitless), IJI = interspersion and juxtaposition index (%)

Project #1 (1-80 Bridges)			
Land Use	# Patches	CA	IJI
Agriculture	NA	NA	NA
Construction	6	2.57	57.1
Forest	22	7.76	78.6
Industrial	6	1.09	52.8
Mitigation	2	0.68	54.6
Mowed	42	0.56	71.6
Oldfield	43	1.27	72.6
Park	NA	NA	NA
Pond	1	0.08	30.3
Residential	28	2.04	42.2
Road	8	2.06	71.6
Waterway	4	4.00	55.2
Wetland	10	1.90	56.7
Project #2 (Four Seasons)			
Land Use	# Patches	CA	IJI
Agriculture	3	7.14	61.1
Construction	9	1.58	50.5
Forest	31	5.21	70.7
Industrial	NA	NA	NA
Mitigation	2	0.52	30.8
Mowed	25	1.21	72.1
Oldfield	13	1.77	63.6
Park	NA	NA	NA
Pond	6	0.17	17.3
Residential	31	3.87	58.3
Road	5	3.32	50.6
Waterway	NA	NA	NA
Wetland	2	3.10	39.9

Patches = number of patches in the landscape, CA = mean patch area (m²) for land use, IJI = interspersion and juxtaposition index (%)

Continued

Table L.2 Landscape data for 1000 m landscapes.

Table L.2 continued

Project #3 (Harvard Road)			
Land Use	# Patches	CA	IJI
Agriculture	NA	NA	NA
Construction	11	2.32	63.6
Forest	21	3.75	65.4
Industrial	7	13.07	71.2
Mitigation	1	1.45	29.1
Mowed	12	2.61	76.9
Oldfield	19	2.63	76.5
Park	NA	NA	NA
Pond	4	0.27	49.3
Residential	9	6.69	60.2
Road	5	11.16	73.7
Waterway	NA	NA	NA
Wetland	5	0.06	42.0
Project #4 (Kerruish)			
Land Use	# Patches	CA	IJI
Agriculture	NA	NA	NA
Construction	3	3.18	58.3
Forest	11	4.64	81.3
Industrial	12	6.90	33.0
Mitigation	1	2.39	37.9
Mowed	11	0.98	69.4
Oldfield	3	0.74	44.3
Park	1	16.64	44.1
Pond	NA	NA	NA
Residential	71	2.38	31.8
Road	6	10.40	44.3
Waterway	2	0.69	47.8
Wetland	NA	NA	NA
Project #5a (Lombardo North)			
Land Use	# Patches	CA	IJI
Agriculture	12	5.44	54.0
Construction	2	1.53	40.6
Forest	18	8.64	76.0
Industrial	NA	NA	NA
Mitigation	5	0.30	10.3
Mowed	9	1.39	63.6
Oldfield	13	2.91	49.1
Park	1	0.12	5.4
Pond	19	0.24	53.9
Residential	23	4.99	62.1
Road	6	1.00	32.2
Waterway	1	9.56	14.0
Wetland	3	0.49	9.7

Patches = number of patches in the landscape, CA = mean patch area (m^2) for land use, IJI = interspersion and juxtaposition index (%)

Table L.2 continued

Project #5b (Lombardo South)			
Land Use	# Patches	CA	IJI
Agriculture	14	4.47	48.4
Construction	3	2.39	61.5
Forest	20	7.28	79.6
Industrial	6	2.88	73.3
Mitigation	1	7.13	45.5
Mowed	9	1.17	58.8
Oldfield	25	2.61	77.0
Park	4	5.08	56.9
Pond	23	0.37	58.2
Residential	25	2.90	66.7
Road	2	3.35	55.3
Waterway	2	3.02	28.4
Wetland	8	0.48	35.4
Project #6 (OTC)			
Land Use	# Patches	CA	IJI
Agriculture	2	6.10	61.7
Construction	13	4.14	77.1
Forest	22	2.71	83.7
Industrial	22	5.28	71.4
Mitigation	1	0.77	20.1
Mowed	24	0.71	77.6
Oldfield	33	1.61	85.4
Park	4	3.44	67.5
Pond	5	0.69	33.2
Residential	NA	NA	NA
Road	5	2.05	71.2
Waterway	4	3.42	59.0
Wetland	1	0.49	40.7
Project #7 (Twinsburg)			
Land Use	# Patches	CA	IJI
Agriculture	1	3.71	45.9
Construction	10	2.27	63.0
Forest	20	9.57	80.8
Industrial	6	2.57	79.3
Mitigation	1	2.59	36.6
Mowed	24	0.73	66.4
Oldfield	18	0.90	96.6
Park	2	4.00	61.0
Pond	12	0.17	64.7
Residential	26	3.74	47.1
Road	7	1.62	56.4
Waterway	1	5.73	42.7
Wetland	19	0.23	19.2

Patches = number of patches in the landscape, CA = mean patch area (m²) for land use, IJI = interspersion and juxtaposition index (%)

Table L.2 continued

Project #8 (Whitlach)			
Land Use	# Patches	CA	IJI
Agriculture	NA	NA	NA
Construction	10	1.89	71.8
Forest	42	3.58	79.1
Industrial	21	2.21	66.6
Mitigation	2	0.39	0.0
Mowed	46	0.88	70.2
Oldfield	36	1.14	66.7
Park	2	1.31	50.0
Pond	8	0.44	56.8
Residential	26	1.50	58.4
Road	4	4.89	63.5
Waterway	1	4.48	41.0
Wetland	10	0.17	42.0

Patches = number of patches in the landscape, CA = mean patch area (in²) for land use, IJI = interspersion and juxtaposition index (%)

300 meter landscapes			
Project #	Human	Natural	Water
1	18.5	68.0	13.5
2	62.3	35.4	2.4
3	64.6	32.8	2.7
4	59.7	35.7	4.6
5a	40.9	48.6	10.5
5b	35.4	46.3	18.3
6	20.6	68.7	10.7
7	17.8	75.5	6.7
8	42.6	52.5	4.9
1000 meter landscapes			
Project #	Human	Natural	Water
1	31.3	59.2	9.6
2	51.2	46.7	2.1
3	66.8	32.5	0.7
4	81.9	17.1	0.9
5a	48.9	46.9	4.2
5b	40.8	53.3	5.9
6	59.1	35.7	5.2
7	42.2	54.1	3.7
8	44.5	52.6	2.8

Human land uses = agriculture, construction, industrial, mowed, residential, road
Natural land uses = forest, oldfield, park
Water = mitigation wetland, pond, waterway, wetland

Table L.3 Percent of human, natural, and surface water land uses on mitigation landscapes.

APPENDIX M
RESTORATION POTENTIAL DATA

Project #	Compliance	Restoration Potential
1	-5.46	33.9
2	-48.90	0
3	52.99	13.7
4	106.45	17.2
6	78.05	10.1
7	49.61	0
8	-55.90	39.9
9	-19.13	30.6
10	-45.24	24.1
11	-41.70	32.2
12	-2.95	44.6

Table M.1 Compliance (% deviation from required mitigation) and restoration potential data.