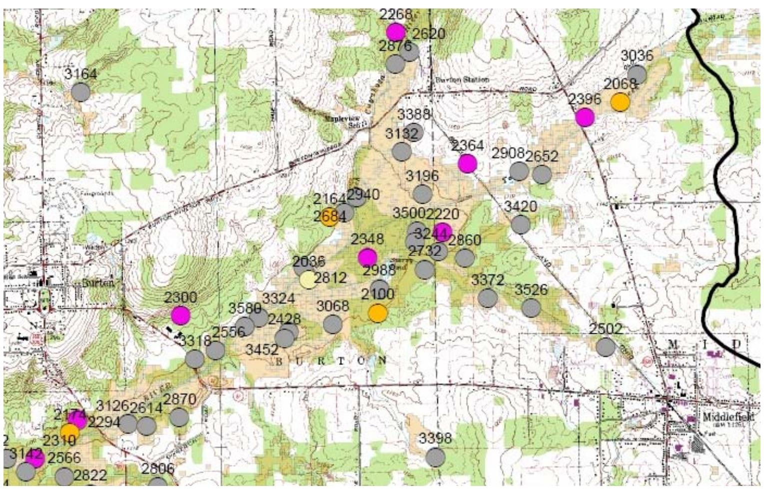
State of Ohio
Environmental Protection Agency

Wetland Ecology Group
Division of Surface Water

ASSESSMENT OF WETLANDS IN THE CUYAHOGA RIVER WATERSHED OF NORTHEAST OHIO

Cuyahoga, Geauga, Medina, Portage, Stark, and Summit Counties

Ohio EPA Technical Report WET/2007-4



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Photographs cover page. Top of page: Tare Creek marsh complex (J. J. Mack); Bottom of page: Forest seep wetland on south valley side of Tare Creek complex (J. J. Mack).

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NOTICE TO USERS

Ohio EPA adopted Wetland Water Quality Standards (WWQS; Ohio Administrative Code 3745-1) regulations in May 1998. These criteria consist of narrative standards, chemical criteria, and a wetland antidegradation rule that requires wetlands to be categorized by their quality and functions and values. Category 1 wetlands are wetlands of limited quality, functions or values. Category 2 wetlands are wetlands of moderate quality, functions, or values but also includes wetlands that have been degraded but a have reasonable potential for restoration (modified Category 2). Category 3 wetlands are wetlands of superior quality, functions, or values. A wetland's category is determined by using the Ohio Rapid Assessment Method for Wetlands (ORAM) v. 5.0. The ORAM has been calibrated by comparing ORAM scores to results from detailed assessments.

Ohio EPA has proposed Wetland Tiered Aquatic Life Uses based on a wetland's ecoregion (Woods et al. 1998), hydrogeomorphic class (Brinson 1993) and dominant plant community. These criteria are derived from the Vegetation Index of Biotic Integrity and the Amphibian Index of Biotic Integrity. Supporting documentation for these criteria can be found at:

http://www.epa.state.oh.us/dsw/wetlands/WetlandEcologySection.html

ASSESSMENT OF WETLANDS IN THE CUYAHOGA RIVER WATERSHED OF NORTHEAST OHIO

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ABSTRACT

We used an assessment approach combining the USEPA EMAP probabilistic sampling design with existing Ohio wetland assessment tools, including the Ohio rapid assessment method (ORAM), the modified Penn State Stressor Checklist, the Vegetation IBI and the Amphibian IBI, along with a landscape analysis (the Landscape Development Intensity Index) to evaluate the ecological condition of wetlands in the 1,300 km^2 Cuyahoga River watershed. Sample sites were selected using the Generalized Random Tesselation Stratified (GRTS) survey design, which provides a geospatially balanced, stratified random sample. The Ohio Wetland Inventory was used as the sample frame for the population of wetlands in the watershed. We evaluated 366 mapped wetland sites and assessed 243 wetlands to determine condition and report on their response to surrounding land-use. Of the 366 sites, we determined that 243 points (66.4 %) were wetlands while the remainder (16.4 %) were characterized as non-wetlands (n = 60) or duplicate points (n = 18). In 12.3 % of the cases (n = 45), field crews were denied site access by property owners. For the wetlands sampled, ORAM scores were normally distributed with a minimum of 16.0, a maximum of 94.0, and a mean of 55.6 (± 14.5 SD). Across the entire watershed, 9.1% of wetlands were in poor condition, 13.2% in fair condition, 51.0% in good condition, and 26.7% in very good condition. There was dramatic decline in the numbers of Category 3 wetlands from the upper parts of the watershed in Geauga county (49.3% of all wetlands sampled), to the middle parts of the watershed in Portage (18.5% and Summit (19.6%) counties, and the near disappearance of Category 3 wetlands in Cuyahoga county (8.3%). Using the Landscape Development Index (LDI), we evaluated the scale at which the effects of land-use are strongest over six buffer widths: 100, 250, 500, 1000, 2000, and 4000 m. ORAM scores were negatively correlated with increasing intensity of land use (high LDI scores) for depressional, riverine, and slope wetlands for each buffer width to a distance of 1000 m, with the strongest correlations for the 100 and 250 m buffer distances. For impoundments, land-use in the first three buffer distances through 500 m did not relate to ORAM score. Overall, land use intensity in the watershed can be characterized as in "low" to "moderately-low". Wetlands in Geauga county had significantly lower LDI scores across most buffer distances than wetlands

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Summit, and Portage counties, particularly for the 1000 m, 2000 m, and 4000 m buffers. The predictive in

in Cuyahoga, Summit, and Portage counties, particularly for the 1000 m, 2000 m, and 4000 m buffers. The predictive power of the Level 1 LDI assessment at the individual site level for all wetlands was low (R^2 = 12-17%; $p < 0.05$) for 100 m to 1000 m buffer classes, and no significant correlations were found at the 2000 m or 4000 m distances. Classification and regression tree analysis indicates that wetland size is also a strong predictor of wetland condition, probably as a function of landscape fragmentation. The utility of the Level 3 data collected in this study was limited by insufficient sample size, restricting our ability to calibrate and validate the Level 1 and 2 protocols with Level 3 data. In particular the Level 3 vegetation data was absent for Category 1, poor condition wetlands. However, the VIBI distribution still had sufficient breadth in disturbance to be highly correlated with the Level 2 assessment tools. The limitation of small sample size was even more of a problem for amphibian data and prevented its use in validation. A secondary objective of this project was to explore key biogeochemical properties of the wetlands being assessed through soil analysis and the development of a soil spectral library. Soil samples were collected at 202 of the wetlands assessed. Soil data showed no consistent trends with condition category. We found depressions contained significantly higher nutrient concentrations (total nitrogen, total phosphorus and total carbon) than riverine sites, and attribute the difference to the accumulation of organic matter in the longer, more stable hydroperiod characteristic of depressional settings. This project demonstrates that the State of Ohio has developed the prerequisite tools required to successfully implement a statewide wetland-monitoring program using statistically- based water quality assessment approaches.

INTRODUCTION

Overview

The State of Ohio has been developing wetland assessment methods since 1996 with the goal of incorporating statewide wetland monitoring into its existing rotating basin surface water monitoring program. Strategies for designing an effective monitoring program are described in what is known as the "three-tier framework" for wetland monitoring and assessment (U.S. EPA 2006). Wetland monitoring and assessment programs in the U.S. are designed to report on the ambient condition of wetland resources, evaluate restoration success, and report on the success of management activities. The "three-tier framework" is a strategy for designing effective monitoring programs. This approach breaks assessment procedures into a hierarchy of three levels that vary in the degree of effort and scale, ranging from broad, landscape assessments using readily available data (known as Level 1 methods), to rapid field methods (Level 2), to intensive biological and physico-chemical measures (Level 3) (Brooks 2004, Fennessy et al. 2004). Rapid methods are well-suited for assessing the ecological condition of a large number of wetlands in a relatively short time frame.

The overall project objective was to assess the ecological condition of wetlands in the Cuyahoga River watershed[1] in northeast Ohio using existing Ohio wetland assessment tools. There were also several secondary objectives: 1) evaluate using the Landscape Development Index (LDI), Ohio Rapid Assessment Method v. 5.0 (ORAM) and the Amphibian IBI (AmphIBI) and Vegetation IBI for Ohio wetlands (VIBI) for performing watershed scale wetland assessments, and 2) develop standardized protocols for performing future assessments.

In addition to these main objectives, the random sample design presented an opportunity for exploring key biogeochemical properties of the wetlands being assessed through the development of a soil spectral library that could then be used in future projects for the rapid characterization of soil parameters. This was accomplished by developing a comprehensive regional soil library of spectral signatures in the visible and near infrared spectrum. With this library, the optical properties of soils can be correlated to soil chemical, physical and biological characteristics of interest, such as total phosphorus and nitrogen, phosphate sorption capacity, or soil enzyme activity. With the development of a soil library, future assessments of wetland soil characteristics in the Cuyahoga basin, and perhaps in the surrounding region, could be completed very cost-effectively and rapidly (i.e., ~$1 per sample, and hundreds of samples a day) (Cohen et al. 2005).

Wetland Water Quality Standards

The State of Ohio adopted Wetland Water Quality Standards and a Wetland Antidegradation Rule on May 1, 1998. The rules categorize wetlands based on their quality and impose differing levels of protection based on the wetland's category (OAC rules 3745-1-50 through 3745-1-54). The regulations specify three wetland categories: Category 1, Category 2, and Category 3 wetlands. These categories correspond to wetlands of poor, good and excellent quality. There is also an implied fourth category (fair) in the definition of Category 2 wetlands, i.e. wetlands that are degraded but restorable (modified Category 2). These potentially restorable wetlands are Category 2 wetlands and receive the same level of regulatory protection as other Category 2 wetlands.

Category 1 Wetlands

Ohio Administrative Code Rule 3745-1-54(C)(1) defines Category 1 wetlands as wetlands which "...support minimal wildlife

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1 The Ohio EPA has previously developed a site-suitability model for estimating the land in the Cuyahoga River watershed available for wetland restoration (White and Fennessy 2005).

habitat, and minimal hydrological and recreational functions," and as wetlands which "...do not provide critical habitat for threatened or endangered species or contain rare, threatened or endangered species." Category 1 wetlands are often hydrologically isolated, have low species diversity, no significant habitat or wildlife use, little or no upland buffers, limited potential to achieve beneficial wetland functions, and/or have a predominance of non-native species. Category 1 wetlands are defined as "limited quality waters" in OAC Rule 3745-1-05(A). They are considered to be a resource that has been so degraded or with such limited potential for restoration, or of such low functionality, that no social or economic justification and lower standards for avoidance, minimization, and mitigation are applied. Category 1 wetlands would include wetlands in "poor" ecological condition.

Restorable (modified) Category 2 Wetlands

Ohio Administrative Code Rule 3745-1-54(C) states that wetlands that are assigned to Category 2 constitute the broad middle category that "...support moderate wildlife habitat, or hydrological or recreational functions," but also include "...wetlands which are degraded but have a reasonable potential for reestablishing lost wetland functions" creating an implied fourth category of wetlands (modified Category 2 wetlands). Modified Category 2 wetlands include wetlands in "fair" ecological condition.

Category 2 Wetlands

Ohio Administrative Code Rule 3745-1-54(C)(2) defines Category 2 wetlands as wetlands which "...support moderate wildlife habitat, or hydrological or recreational functions," and as wetlands which are "...dominated by native species but generally without the presence of, or habitat for, rare, threatened or endangered species..." Category 2 wetlands constitute the broad middle category of "good" quality wetlands. In comparison to Ohio EPA's stream designations, they are equivalent to "warmwater habitat" streams, and thus can be considered a functioning, diverse, healthy water resource that has ecological integrity and human value. Some Category 2 wetlands are relatively lacking in human disturbance and can be considered to be naturally of moderate quality; others may have been Category 3 wetlands in the past, but have been disturbed "down to" Category 2 status. Category 2 wetlands would include wetlands in "good" ecological condition.

Category 3 Wetlands

Wetlands that are assigned to Category 3 have "...superior habitat, or superior hydrological or recreational functions." They are typified by high levels of diversity, a high proportion of native species, and/or high functional values. Category 3 wetlands include wetlands which contain or provide habitat for threatened or endangered species, are high quality mature forested wetlands, vernal pools, bogs, fens, or which are scarce regionally and/or statewide. Category 3 would include wetlands of "excellent" condition.

Wetland Tiered Aquatic Life Uses

The State of Ohio has proposed draft rules which would revise OAC Rules 3745-1-50 to -54 and include an expansion of the OAC Rule 3745-1-53 with Wetland Tiered Aquatic Life Uses (WTALUs) (Tables 1, 2, and 3). The WTALUs generally correspond to the antidegradation categories with the exception that a wetland can be degraded but still exhibit a residual function or value at moderate or high levels such that it is Categorized as Category 2 or 3 but has a lower WTALU use designation. Narrative WTALU categories based on the Vegetation IBI were first proposed in Mack (2001) and have been subsequently updated (Mack 2004b; Mack and Micacchion 2006) and are summarized in Table 1. WTALUs have also been proposed using the Amphibian IBI. In addition to the tiered uses, special uses (values or ecological services) provided by wetlands can be assigned (Table 2). The WTALUs were developed by partitioning the 95th percentile of VIBI scores for that TALU category into sextiles and combining the sextiles into the 4 aquatic life use categories proposed as numeric biological criteria for Ohio wetlands: limited quality wetland habitat (LQWLH) (1st and 2nd sextiles), restorable wetland habitat (RWLH) (3rd and 4th sextiles), wetland habitat (5th sextile), and superior wetland habitat (SWLH) (6th sextile). Numeric TALUs (biological criteria) for Ohio wetlands were developed based on VIBI scores, ecoregion, landscape position, and plant community (Table 3). In the context of this study, the WTALUs were used as true wetland condition categories for evaluating the results of the Level 1, 2, and 3 assessments.

WATERSHED OVERVIEW[2]

Landscape setting of Cuyahoga River Watershed

The Cuyahoga River basin drains 2107 km^2 (813 mi^2) and includes 1963 km (1220 mi) of streams spanning parts of Cuyahoga, Geauga, Portage, and Summit counties with minor amounts of the watershed located in Medina and Stark Counties, emptying into Lake Erie at Cleveland. The Cuyahoga River is one of the few rivers in the world that changes flow direction (south then north), creating a U-shaped watershed. Land use patterns vary greatly from the upper basin (forest-agricultural-rural) to the lower basin (densely urban-industrial). Agriculture is still the predominant land use in the upper basin, and while less prevalent in the middle basin, soils in the Middle Cuyahoga are highly erodable and can cause significant sedimentation and nutrient loadings to streams and wetlands. Resource extraction (e.g. sand and gravel mining) and hydromodification of streams and wetlands are localized throughout the basin, rather than widespread as in western Ohio. The waters of heavily populated areas of the middle and lower basin are strongly influenced by urban and construction site runoff, industrial and municipal point sources, combined sewer overflows, and land disposal of waste.

The basin is located in the Erie-Ontario Drift and Lake Plains (EOLP) ecoregion (Woods et al. 1998) which is part of the glaciated Allegheny Plateau (Figure 1). The EOLP ecoregion is a glacial plain that lies between the unglaciated Allegheny Plateau region to the south and the relatively flat, more fertile, Eastern Corn Belt Plain ecoregion to the west. It is characterized by glacial formations that can have significant local relief and has a mosaic of cropland, pasture, woodland and urban areas. Soils are mainly derived from glacial till and lacustrine deposits from former pro-glacial lakes. There are five subregions with the EOLP, three of which are significant in the Cuyahoga watershed: Low Lime Drift Plain (rolling landscape of low rounded hills with scattered end-moraines and kettles with lower fertility soils than the till plains to the west), Erie Gorges (steep dissected areas along Chagrin, Cuyahoga and Grand Rivers with many rock exposures, and the Summit Interlobate Area (a region of numerous lakes, wetlands, sphagnum bogs, sluggish streams, kames, and kettles with outwash derived sand and till soils).

Many of the glacial features characteristic of the EOLP ecoregion are found in the Cuyahoga River watershed. The northern and eastern boundaries of the watershed are largely defined by terminal moraines. The retreating glaciers buried ancient river valleys with glacial outwash. The river generally follows the course of the buried ancient river valleys but does traverse a ridge of erosion-resistant sandstone near Akron which caused the southerly flowing river to form falls and cascades at Cuyahoga Falls and to turn northwest at the confluence of the Little Cuyahoga River just north of Akron. The river then winds through the outwash terraces, till plains, till ridges, and the Erie Gorges zones in the Cuyahoga Valley National Park before passing through a narrow band of flat lake plain in Cleveland.

The upper, middle, and lower Cuyahoga River

The Cuyahoga River basin has been divided by Ohio EPA into three sub-basins for stream TMDL purposes and these sub-basins are also useful for characterizing the amount, type, and quality of the wetland resource in the Cuyahoga watershed: the upper Cuyahoga from the headwaters to the Lake Rockwell dam; the middle Cuyahoga from below the Lake Rockwell

[2] Text from this section is drawn liberally (with thanks to the authors of those reports) from the following Ohio EPA Reports: Total Maximum Daily Loads for the Upper Cuyahoga River, Total Maximum Daily Loads from the Middle Cuyahoga River, and Total Maximum Daily Loads for the Lower Cuyahoga River available at http://www.epa.state.oh.us/dsw/tmdl/index.html.

dam to the Munroe Falls dam; and the lower from below Munroe Falls dam to the mouth at Cleveland and Lake Erie.

Upper Cuyahoga River Watershed

The upper Cuyahoga watershed drains 534 km^2 (208 mi^2) with 565 km (351 mi) of principal streams (Figure 2). It originates in northeastern Geauga County and flows southwest to Kent through relatively hilly kame and kettle topography. This area is well known as a hotspot of rare and listed plant and animal species. Based on Ohio EPA's wetland reference work since 1996, this region is also home to one of the largest and highest quality wetland complexes remaining in the state of Ohio. Figure 3 is a schematic of the upper watershed showing locations of point sources, tributaries, reservoirs and large wetland areas. Land use in the upper basin is primarily forest and agriculture (Figure 4). Approximately 12% of the land in the upper Cuyahoga basin is owned by the City of Akron and was purchased, in many instances decades ago, to protect its drinking water sources. Many of the largest and best quality wetland complexes on the Cuyahoga floodplains are now owned and protected by Akron. A 40 km (25 mi) segment of the Cuyahoga River from the Troy-Burton Township line to State Route 14 in Portage County has been designated a State Scenic River and several stream segments are designated State Resource Waters. Three large water supply reservoirs for the City of Akron are located in the upper basin: the 173 ha (428 ac) East Branch Reservoir, the 627 ha (1550 ac) LaDue Reservoir, and the 253 ha (625 ac) Lake Rockwell Reservoir, where the Akron drinking water plant is located.

Middle Cuyahoga River Watershed

The middle Cuyahoga River is located northeast of Akron and covers portions of Portage, Summit, and Stark Counties (Figure 5). It drains 350 km^2 (135 mi^2) and extends from the Lake Rockwell reservoir northeast of the City of Kent and flows through the urban areas of Kent and Munroe Falls. The downstream boundary of the middle watershed is Waterworks park in Cuyahoga Falls. A major tributary is Breakneck Creek. A large portion of the wetland resource in

The middle Cuyahoga is located in the Breakneck Creek watershed (eastern and southern Portage County). Figure 6 is a schematic of the middle watershed showing locations of point sources, tributaries, reservoirs and large wetland areas. The middle Cuyahoga is characterized by glacial formations and in general, low gradients and velocities. Land use in the western half of the middle Cuyahoga River watershed is urban and suburban; in the Breakneck Creek region of eastern Portage County, agriculture, forest, and wetland land uses predominate (Figure 7).

Lower Cuyahoga River Watershed

The lower Cuyahoga River is located predominately in Cuyahoga, Medina and Summit Counties with a very small area in Geauga County (Figure 8). It drains 1217 km^2 (470 mi^2) from the Waterworks Park in Cuyahoga Falls to Lake Erie in downtown Cleveland, and includes the heavily urbanized Little Cuyahoga River sub-basin in Akron. Figures 9a, 9b, and 9c are a schematic of the middle watershed showing locations of point sources, tributaries, reservoirs and large wetland areas. The lower Cuyahoga is characterized by its passage through the expansive valley of the Cuyahoga Valley National Park (Erie Gorges subregion) and by the extensive and pervasive influence of current and historical industry and urbanization associated with Cleveland and Akron (Figure 10). The lower Cuyahoga has been identified as an Area of Concern by the International Joint Commission and has been the subject of extensive planning and restoration under the auspices of the Cuyahoga River Remedial Action Plan (Cuyahoga River RAP). The Cuyahoga River was also designated an American Heritage river in 1998. Cleveland and Summit County metroparks both have extensive land holdings in the lower Cuyahoga.

The lower Cuyahoga also includes Tinkers Creek, the largest tributary in the entire Cuyahoga watershed (Figure 9c). Tinkers Creek drains 250 km^2 (96 mi^2) and its watershed includes portions of 4 counties (Cuyahoga, Geauga, Portage Summit). The upper part of the Tinkers Creek watershed has extensive complexes of wetlands which are very similar to the wetland complexes of the upper Cuyahoga watershed in appearance and genesis. Lower Tinkers Creek transitions from a "wetland stream" to a more classic riffle-pool stream as it passes Twinsburg, Ohio and moves into the Tinkers Creek gorge before debauching into the mainstem Cuyahoga.

METHODS

Site selection and Statistical Design

Sample sites were selected using the Generalized Random Tesselation Stratified (GRTS) survey design for an areal resource, with reverse hierarchical ordering, developed by the U.S. EPA's EMAP program (Diaz-Ramos et al. 1996, Herlihy et al. 2000, Olsen et al. 1998, Stevens 1997, Stevens and Olsen 1999, Stevens and Urquhart 1999, Stevens and Olsen 2004). This method provides a geospatially balanced, stratified random sample. The Ohio Wetland Inventory was used as the sample frame for the population of wetlands in the Cuyahoga River watershed. The target population included wetlands mapped as woods on hydric soils, shallow marsh, scrub-shrub, wet meadow, open water with an area less 0.45 ha (1.11 acres) (equivalent to five 30 m x 30 m OWI pixels), and farmed wetland. For several reasons, this study took the approach of assessing a "wetland" versus a fixed area around a point (See Discussion infra.). We recognized that attempting to assess "wetlands" as part of probabilistic condition assessment designs presented data collection hurdles that point-based or area-based approaches can avoid. These include mapping a boundary in the field or in the office, accounting for multiple sample points being dropped in the same "wetland", and practical difficulties in the field of physically exploring the wetland, especially if it is large and part of a contiguous complex of wetlands. To address these problems, we developed "large-site" modifications to ORAM's scoring boundary rules, evaluated the frequency of multiple points being dropped on the same "wetland", and developed procedures for determining and digitizing the scoring boundary.

The study goal was to sample at least 200 wetlands. Because some points selected may not conform to target population rules (e.g. due to mis-mapped features, conversion of wetlands to other land uses) or access to a point may be refused by the landowner, an additional 1400 points were dropped as an over sample, for a total of 1600 points (Appendix F; Figure 11) All points were given in decimal degrees based on the NAD83 datum.

The GRTS design stipulates that the sites must be assessed in numerical order as indicated by the site ID number. In addition, the statistical analysis of this data may require that appropriate weighting variables be used. There were concerns that the average condition of publicly-owned wetlands would be higher than privately-owned wetlands and that potential differences might exist between large and small wetlands since large wetlands had a higher probability of having multiple points dropped on them. Statistical analysis of data after sampling indicated no significant differences between public/private sites and large/small wetlands, so no weighting variables were used in subsequent analyses. Preliminary examination of sample points was done using digital aerial photos, supplied by Cuyahoga, Summit, Portage and Geauga counties. These images had a one-meter ground resolution and were orthorectified (Figure 12).

Each sample location was plotted on the airphoto and the land use at that point examined. Points were excluded from further consideration if 1) the point and the 60 m radius around the point were located on buildings, houses, driveways, parking lots, truck depots, etc., unless a portion of the 60 m area around the point was vegetated (if this occurred the point was ground-truthed since a wetland or portion of a wetland could have been have occurred in the 60 m radius); 2) the point and buffer 60 m buffer area were located in a quarry; and 3) the point was located on an interstate highway. All other points were retained for sampling. A log was compiled listing the excluded points, along with a detailed explanation for their elimination (Appendix E). If no wetland was found at the EMAP point, but a wetland was located within or intersected with the area defined by a 60 m radius of the point (width of two LandSat pixels), then new coordinates were taken at the approximate point where the wetland boundary was closest to the original EMAP point. The new point (termed the "modified EMAP point") was also recorded by indicating its location on the high- resolution aerial photos included in each site folder. If more than one wetland was located within or intersected with the area defined by the 60 m radius circle then the wetland closest to the original EMAP point was sampled.

Assessment Approach

Recent approaches to wetland assessment have advocated a multi-level approach which incorporates assessments based on landscape (remote sensing) data (level 1), on-site but "rapid" methods using checklists of observable stressors and other observable wetlands features (level 2), and intensive methods where quantitative floral, faunal, and/or biogeochemical data is collected (level 3) (USEPA 2006; Brooks 2004; Fennessy et al. 2004, 2007). We collected four types of data: 1) GIS data (land use information and other information obtained from existing geographic information system data layers); 2) rapid assessment data obtained from a site visit and recorded on a background information form, a wetland determination form, the Penn State Stressor Checklist (Brooks 2004) and scores from the Ohio Rapid Assessment of Wetlands v. 5.0 (Mack 2001) (Appendix A); 3) quantitative ecological data on vegetation, amphibian, macroinvertebrate assemblages and soil and water chemistry data (at 10% of the sites sampled); and 4) soil chemical, physical and spectral data at 202 of the 242 wetlands assessed.

Sampling methods - Level 1 Landscape Assessment

Wetland sample points were selected using the Ohio Wetland Inventory (OWI) database (ODNR 1988). The OWI maps used LandSat satellite data (30 m x 30 m pixels) and presence of hydric soils to produce the OWI maps. The satellite data reflect conditions at the time that LandSat Thematic Mapper data was acquired (May 1987 for northeast Ohio). The accuracy of the OWI map was evaluated in the field by determining 1) whether or not a wetland actually existed at the point, 2) if a wetland was not located at the point, was a wetland(s) located within a 60 m radius (2 times the pixel width) of the point, and 3) if a wetland was located, was it of the same type as indicated for that location on the OWI. This represented the first systematic field check of the accuracy of the OWI. Handheld geographic position system units, with an accuracy of 0.5 m to 5 m, were used to determine the latitude and longitude of wetlands sampled in this study.

Land Use

Land-use surrounding the wetland sites included in this study was characterized using the Ohio Digital land-use survey database. Land-use was classified into the following categories (Frohn 2005): 1) forest (a combination of evergreen and deciduous forest cover); 2) pasture (areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops); 3) crop (areas used for the production of crops such as corn, soybeans, and wheat); 4) residential (includes both heavily built up urban centers (high intensity residential) and areas with a mixture of constructed materials and vegetation (low intensity residential) and included apartment complexes, row houses, and single-family housing units); 5) commercial (includes infrastructure (e.g. roads, railroads, etc.) and all highways and all developed areas not classified as residential); 6) wetland (a combination of wooded wetland and herbaceous wetland cover); 7) open water; and 8) bare /mined lands.

Upon completion of all field work we used ArcGIS v. 9.0 to digitize all wetland boundaries as indicated by field teams on the airphoto of the site. We then characterized land-uses at various distances beyond the wetland perimeter. We evaluated land-use at distances of 100 m, 250 m, 500 m, 1000 m, 2000 m and 4000 m from the scoring boundary of each site (Houlahan and Findlay 2004). The percent land use for each buffer distance was calculated starting at the wetland perimeter, so the actual area of each land-use type varies with the size of the wetland.(Brooks et al. 2004; Rheinhardt et al. 2006, Wentworth 2006). State-wide land cover data for Ohio, available from Frohn (2005), were used to calculate land cover characteristics. The composition of each land cover class as well as a series of landscape metrics were calculated using a specifically programmed ArcView 3.3 (ESRI 2002) project that automates the processing of multiple polygons (Bishop & Lehning 2007). The program incorporates the landscape metrics included with the ArcView extension software Patch Analyst (Rempel 2007) with several more standard geographic information system (GIS) functions that provide for buffering designated distances away from selected polygons. For this study, the polygons are the digitized wetlands boundaries that were sampled. The program was used to calculate all metrics from within each wetland boundary as well as all specified buffer distances listed above.

Land-use proportions were converted to a Landscape Development Intensity (LDI) index which integrates the impacts of human land use on a given site (Brown and Vivas 2005). The LDI scores were calculated based on assignment of land-use coefficients (Table 4). Coefficients were calculated as the normalized natural log of emergy per area per time, a measurement used to quantify human activity (Brown and Vivas 2005). In terms of the LDI index, emergy is energy corrected for different qualities and includes all non-renewable energies, such as electricity and water. The LDI_{total} is calculated as a weighted average, such that:

$$LDI_{total} = \sum \%LU_i * LDI_i.$$

where, LDI_{Total} = the LDI score, $\%LU_i$ = percent of total area in that land use *i*, and LDI_i = landscape development intensity coefficient for land use *i* (Brown and Vivas 2005). What is unique to this calculation is that it integrates all land-uses into one score rather than looking at each land-use separately. By using this method (level 1 assessment) in combination with the level 2 and 3 assessments, we could evaluate the response of wetland ecosystems as the human impact on surrounding land-use increases.

The LDI index was calculated for each of the six buffer distances by analyzing the different land-uses from the wetland boundary edge. We classified LDI scores to correspond to four wetland condition categories by quadrisecting the 95^{th} percentile of LDI scores for each buffer distance. We also classified into general land-use categories ("natural", "agriculture", and "urban") for simplicity in some analyses: natural (LDI scores of 0-100), agricultural (100-350), and urban (>350). Two different sets of LDI coefficients were used in the analysis: coefficients that were developed for the land uses and climatic conditions of southern Minnesota (Brandt-Williams and Campbell 2006) and a second set of coefficients calculated for Florida (Brown and Vivas 2005) (Table 4). The two sets of coefficients are scaled differently, so their absolute values are not comparable. The LDI score using the Minnesota coefficients can range from 0 to 465; the score using the Florida coefficients can range from 1 to 10. We multiplied the Florida scores by 100 to put them on approximately the same scale as the Minnesota scores. Because of the extremely high correlation between the scores from the two sets of coefficients (see Results), and the fact that climate and land use patterns in Minnesota are more similar to those in Florida, we only used the LDI coefficients for Minnesota in all of our level 1 analyses.

Sampling methods - Level 2 Rapid Assessment

The ORAM assessment was performed at each wetland point in accordance with the *Ohio Rapid Assessment Method for Wetlands v. 5.0, User's Manual and Scoring Forms*, Ohio EPA Technical Report WET/2001-1. In addition to ORAM, the Penn State Stressor Checklist (also a Level 2 condition assessment) was completed at each site (Brooks 2004). The Checklist is made up of a set of indicators used to identify probable stressors, such as sedimentation, hydrologic modification, and habitat fragmentation. Data was collected in accordance with all documentation on the appropriate use of the stressor checklist. A Background Field Data form was also completed at each site. Finally, a streamlined Routine Wetland Delineation Form (Environmental Laboratory 1987) was completed to confirm that a jurisdictional wetland was sampled at each location. All forms were completed using the EMAP protocol for handling data forms.

Wetlands were located on the ground using the GPS device and orienteering to the point. Upon arrival at the EMAP point a determination was made as to whether or not the point was within a wetland. If the point was within a wetland, then this point (location) was, by definition, located inside the wetland's "scoring boundary." The scoring boundary (assessment unit) was defined by rules outlined in the ORAM v. 5.0 User's Manual (Mack 2001) as follows:

1. Boundaries between contiguous or connected wetlands were established where the volume, flow, source, or velocity of water moving through a wetland changed significantly. Areas with of the same HGM class or with a high degree of hydrologic interaction were included within the same scoring boundary. In many instances, especially for small, depressional wetlands the scoring boundary was the same as the jurisdictional boundary.

2. Boundaries were also established between contiguous wetlands of different HGM classes, e.g. between contiguous slope and riverine wetlands.

3. Wetlands that form a "patchwork" on a landscape were scored together (the wetlands were usually 0.4 ha (1 ac.) in size, part of a mosaic of wetlands that were usually less than 30 m (100 ft) apart, and more than 50% of the assessment area was defined as wetland using the 1987 Delineation Manual (Environmental Laboratory 1987).

4. Scoring boundaries were established without regard to property boundaries or boundaries between political jurisdictions.

5. Scoring boundaries were established without regard to roads or railroad embankments provided there was a surface water connection between the two parts of the wetland at least some time during the year.

6. Scoring boundaries of wetlands fringing lakes and reservoirs were established around the entire lake or reservoir and all of its fringing wetlands where the area of open water was less than 8 ha (20 ac.); Scoring boundaries were established around fringing wetlands separately where the area of open water around the lake or reservoir was greater than 8 ha.

7. Scoring boundaries of riverine wetlands were established where a) more than 60 m (200 ft) of non-wetland riparian corridor separated the two wetlands, b) more than 60 m of river channel separated wetlands on either side of a river (except as modified in No. 8 below), or c) at the point where a narrow (<15 m) fringe of wetlands along a stream extending for more than 60 m expands into a broader wetland.

8. In addition to these rules, several supplemental "large-site" rules were developed specifically for this project because of the many very large wetland complexes in the upper Cuyahoga watershed. Where the point fell in a wetland >20 ha (50 ac) in size and this wetland was contiguous to other large wetland areas, streams or roads that bisected the wetland complex were allowed to be used to define assessment unit boundaries.

If no wetland was present within the 60

m radius area, the type of land use found at the original EMAP point was recorded as follows: 1) the site was developed and there was no way to know whether a wetland existed there originally or not; 2) the site was farmed, or was otherwise vegetated, and a soil sample collected to a depth of 10 cm using a push corer indicated that hydric soils were not present; 3) the site was farmed, or was otherwise vegetated, and a soil sample collected to a depth of 10 cm using a push corer soil core indicates that hydric soils were present; 4) a determination could not be made.

Sampling methods - Level 3 Intensive Assessment

Vegetation. A plot-based vegetation sampling method was used to sample wetland plant communities (Peet et al., 1998). Sampling was performed in accordance with *Field Manual for Vegetation Index of Biotic Integrity v. 1.3* (Mack 2004c). At most sites, a "standard" 20 m x 50 m plot was established (0.1 ha). The location of the plot was qualitatively selected by the investigator based on site characteristics and rules for plot location (Mack 2004c). Presence and areal cover was recorded for herb and shrub stratums; stem density and basal area was recorded for all woody species >1m. Percent cover was estimated using cover classes of Peet et al. (1998) (solitary/few, 0-1%, 1-2.5%, 2.5-5%, 5-10%, 10-25%, 25-50%, 50-75%, 75-90%, 90-95%, 95-99%). Woody stems were recorded using diameter classes of Peet et al. (1998) (0-1 cm, 1-2.5 cm, 2.5-5 cm, 5-10 cm, 10-15 cm, 15-20 cm, 20-25 cm, 25-30 cm, 30-35 cm, 35-40 cm, >40 cm stems individually measured). The midpoints of the cover and diameter classes were used in all analyses. Other data collected included standing biomass (g/m^2 from eight $0.1m^2$ clip plots) and various physical variables (e.g. % open water, depth to saturated soils, amount of coarse woody debris, etc.). A soil pit was dug in the center of every plot and soil color, texture, and depth to saturation were recorded.

Amphibians and Macroinvertebrates. Funnel traps were used in sampling both the macroinvertebrate and amphibians present in wetlands. Sample methods followed macroinvertebrate and amphibian IBI protocols in Micacchion (2004) and Knapp (2004). Funnel traps were constructed of aluminum window screen cylinders with fiberglass window screen funnels at each end. The funnel traps were similar in shape to commercially available minnow traps but with a smaller mesh-size. Ten funnel traps were placed evenly around the perimeter of the wetland and the trap location marked with flagging tape and numbered sequentially. Traps were set at the same location throughout the sample period. Each wetland was sampled three times between March and July. Some sites did not have sufficient water present by the 2nd or 3rd trapping run and were only trapped 1-2 times. Traps were unbaited and left in the wetland for twenty-four hours in order to ensure unbiased sampling for species with diurnal and nocturnal activity patterns. Upon retrieval, the traps were emptied by everting the funnel and shaking the contents into a white collection and sorting pan. Organisms that could be readily identified in the field (especially adult amphibians and larger fish) were counted and released. The remaining organisms were transferred to wide-mouth one liter plastic bottles and preserved with 95% ethanol. Laboratory analysis of the funnel trap macroinvertebrate and fish samples followed standardized Ohio EPA procedures (Ohio EPA 1989). Amphibian analysis was performed using the keys of Walker (1946) and Pfingsten and Downs (1989).

Soil and Water Sampling

Water sampling. At all level 3 sites, a grab sample was collected and analyzed for the parameters listed in Table 5a. Field grab samples were analyzed at the Ohio EPA laboratory. Grab samples were collected by directly filling three one-quart containers with water from the wetland. Care was taken while obtaining the water samples not to capture stirred up sediments suspended by researchers traversing the wetland by foot. 10% blank and 10% duplicate samples were taken. The samples were preserved and transferred to the Ohio EPA Laboratory.

Soil sampling at random points. Six soil cores (10 cm deep) were obtained from each wetland using a standard soil probe. Samples were distributed throughout each site (>20m between sample locations) to represent the variability in hydrologic conditions and vegetation communities. Before sampling, the duff layer (the top layer of undecomposed organic material), if present, was removed. Five of the cores measured 2.5 cm in diameter and were taken with a metal punch-core, while the sixth core had a diameter of 8 cm and was taken using a butyrate tube. Cores were taken in a random order to prevent bias in the sampling location of the 8-cm core. Samples were designated as either 'in' or 'out', a qualitative judgment of whether the soil sample was from the interior of the wetland or around the periphery. Samples were bagged and stored at 4°C after leaving the site. Samples were shipped to the Wetland Biogeochemistry Laboratory at the University of Florida, Gainesville for analysis.

The 8-cm core from each wetland was analyzed for the following: pH, conductivity, bulk density, total phosphorous (TP), total organic carbon (TC), total nitrogen (TN), loss on ignition (LOI), H_2O-extractable phosphorous (H_2O-P), HCl-extractable phosphorous (HCl-P), nitrate-nitrogen (NO_3-N), phosphorous sorption capacity (P-sorption), and extractable Al, Fe, and Ca (USEPA 1991, USEPA 1993, Cohen 2005) (Table 5b). All soil parameters were analyzed using methods detailed in the Standard Operating Procedure Manual of the Wetland Biogeochemistry Laboratory, University of Florida, Gainesville. Soil samples were analyzed for 202 wetland sites of the 242 total wetland sites visited.

All soil samples were scanned for their optical response properties using a post-dispersive spectroradiometer in the visible and near infrared region of the electromagnetic spectrum. The laboratory optical set-up for obtaining reflectance spectra consisted of a high-energy tungsten filament bulb emitting light through a 2-cm fore-optic at the sample surface. Diffuse reflectance spectra were obtained between 350 and 2500 nm in 1-nm bands. The measured reflectance is a composite function of harmonic oscillations of various chemical bonds within the soil structure of each sample; these data may be interpreted to describe both the composition the soil matrix and concentrations of numerous constituents (Malley et al. 2004). The measured laboratory concentrations of particular parameters of importance were correlated to the spectral signature of the given soil sample. As additional samples were processed and deviance approximated, relationships between spectra and soil properties were evaluated (Shepherd and Walsh 2002). A spectral library was constructed and chemometrics that correlate spectra with laboratory observations were developed and carefully evaluated for predictive efficiency. When a sufficiently reliable chemometric is developed subsequent soil characterization will require that a sample need only undergo preparation and spectral characterization; the expected value and confidence interval for the parameter of interest can then be calculated based on the chemometrics developed from the library.

Soil Sampling in Vegetation Plots. Additional soil sampling stations were located within the intensive modules of the wetland vegetation sampling plot, following previously established Ohio EPA sampling procedures. Soil samples were taken from the top 12 cm of soil using a 8.25 cm x 25 cm stainless steel bucket auger (AMS Soil Recovery Sampler), with a butyrate plastic liner. Samples were collected by inserting the auger to half its depth, filling the liner half-way. These soil samples were analyzed at the Ohio EPA laboratory. The soil samples were analyzed for parameters listed in Table 5a. In addition, the dominant soil color (matrix), mottles, clay films, concretions and any other feature that may be recorded. Colors were determined using an appropriate hue from the Munsell Soil Color Charts. Notations, within a particular hue, were made to the nearest chroma and value.

Data analysis

Minitab v. 12.0 was employed for the analyses of ORAM scores, LDI scores and soil measurements. One-way analysis of variance was used to detect differences in continuous variables such as ORAM and LDI scores between HGM classes, wetland condition categories, and wetland size categories. Regression models were applied to examine the correlations between the Level 1, 2, and 3 assessments. Classification and Regression Tree (CART) analysis was used to explore variation in an ORAM scores using the LDI and soil data as predictor variables. CART is a useful tool in building models to predict specific variable thresholds in wetland quality because the model is capable of dealing with continuous or categorical variables. It is a nonparametric analysis using recursive partitioning for multivariate analysis. This tool is effective at exploring relationships without having a prior model, it handles large problems easily, and the results are interpretable based on the tree that the test builds (JMP v. 5.0). CART groups the data by choosing a threshold in the predictor variable that best explains variance in the response variable.

We created three CART models, one for all wetlands assessed as part of the study, and one for riverine and depressional wetlands since these represented the dominant HGM classes in the watershed. Our goal was to predict variable thresholds by partitioning ORAM scores as the response variable. Our model included the soil variables TC, TN, TP, HCl-P and H_2O-P, the LDI scores for each buffer distance, and wetland size as predictors for total ORAM scores minus metric 1 (size of assessment area) and metric 2 (buffer characteristics). Metrics 1 and 2 were removed from the score to maintain independence of the response and predictor variables. Thus the scoring range for ORAM in the CART analysis was 5 – 70. Using binary splits, CART partitions the data into exclusive groups by choosing the variable that best explains the observed variance in ORAM scores. The optimal number of splits was determined using a cross-validation method in which a random sample of the data (k=10) was tested against the model. This provided an estimate of how well the model performed by calculating a cross-validation r-square value (JMP v. 5.0).

RESULTS

Overview of Results

Of the first 400 randomly selected points, 5 were determined to be outside of the watershed, 12 points were not assessed, and 17 points were "stranded" (i.e. they were assessed but a preceding point was not assessed so that the data from the stranded point could not be used without violating the GRTS study design). Of the 17 stranded points, 8 were duplicate points located within the same wetland assessment area as a lower numbered point. Field crews visited the remaining 366 points, primarily between late June and early August, 2005, although a few sites were assessed in September and early October. Of the 366 sites, we determined that 243 points (66.4 %) were wetlands while the remainder (21.3 %) were characterized as non-wetlands (n = 60) or duplicate points (n = 18) (Figure 13). In only 12.3 % of the cases (n = 45), field crews were denied access to the site by property owners.

Of the 243 wetlands assessed, the majority were either depressional (n = 87) or riverine (n = 93) (Figure 14). The remaining sites constituted a combination of natural (beaver) and man-made impoundments (n = 16), slope wetlands (n = 35), fringing wetlands (n = 9), and bogs (n = 3). ORAM scores ranged from a low of 16 to a high of 90, capturing virtually the entire range of ecological condition as indicated by ORAM scores. ORAM has an effective range of 6 to 90 with a scores occasionally of <6 or >90 for a few sites that receive point subtractions or additions under Metric 5 (Figure 15). The size of the assessment areas sampled (as determined by the ORAM scoring boundary rules) varied widely, ranged from 0.004 ha to 263.2 ha. The size distribution of all wetlands sampled showed that the largest proportion of wetlands, regardless of HGM class fell in the 0.12 to <1.2 ha (0.33 to 3.0 ac) size category (Figure 16).

Evaluation of the Ohio Wetland Inventory

An ancillary result of this study was to perform the first quantitative assessment of the accuracy of the OWI mapping procedure, which used single-day LandSat photography with 30 m x 30 m resolution supplemented by hydric soil maps to create the wetland inventory maps. The mapping accuracy of the OWI can be considered in terms of "Type I" and "Type II" errors. We considered Type I mapping errors to be where the OWI mapped a wetland but field verification determined there was not a wetland at that point or within 60 m (twice the LandSat pixel width) of the point. Type II errors would be when the OWI failed to map a wetland when in fact a wetland was actually present. This study provided an evaluation of Type I error-rate of the OWI. Of the non-wetland areas evaluated in the 366 points we assessed, 10.4% (n = 38) were the result of apparent mapping errors in the OWI (Figure 13). Of the remaining points, we determined that 4.1% (n = 15) were the result of filling or conversion (e.g. developing, farming, impounding) of the wetland since the production of the OWI map. For 2.2% (n = 8) of the points, we were unable to determine the reason for not finding a wetland at the point (i.e. it could have been a mapping error or subsequent conversion). We conclude that the OWI over-maps (i.e. maps wetlands where they actually do not exist) about 10-15% of the time. This result has implications for estimating total wetland acreage remaining in Ohio since it suggests that the estimates of wetland acreage based on the OWI may somewhat over-estimate actual wetland acreage.

Resources Necessary to Assess Wetlands in a HUC8 Watershed

The six field crews spent 124 combined field days and averaged 2.5 sites per day.
The total budget for this project was $356,007 for a per point evaluated cost of approximately $929 (366 plus 17 stranded points). If only points where a wetland was found are considered (242 + 18 duplicate points), per wetland costs were approximately $1370 (This includes additional

time and resources to perform Level 3 sampling at 22 sites). The per site cost includes sample handling and processing, laboratory analysis of soil and water samples, data management and analysis, voucher processing, and report writing time. It does not include data management time performed by EMAP.

Level 1 Landscape Assessment

In earlier work evaluating the LDI as an assessment tool, Ohio EPA used the coefficients derived for Florida land uses (Mack 2006), although developers of the LDI recommend use of more regionally calibrated weighting factors (Brown and Vivas 2005). We calculated LDI scores using recently developed coefficients for southern Minnesota (Brandt-Williams and Campbell 2006), which has a climate much more similar to Ohio, and Florida (Brown and Vivas 2005). We found a nearly exact correspondence in LDI scores ($R^2 > 0.96$, $p = 0.000$, for all buffer distances) (Figure 17), suggesting no, or at most only an incremental, improvement in resolution when these regionally calibrated coefficients are derived and used. Deviations in scores between LDI scores using the Minnesota and Florida coefficients, although small overall, were greatest at higher LDI scores where land use intensity and differences in coefficient values were greatest.

Mean LDI scores for all points assessed ranged from 70.4 (100 m) to 152.0 (4000 m) in the Cuyahoga Watershed. Overall, watershed-wide land use intensity could thus be characterized as "low" to "moderately-low" (Table 6). Wetlands in Geauga County had significantly lower LDI scores across most buffer distances than wetlands in Cuyahoga, Summit, and Portage Counties, although these differences were most pronounced when land use data from the 1000 m, 2000 m, and 4000 m buffers were used (Table 7).

LDI scores increased (and standard deviations tended to decrease) as land use data from larger "buffer" areas were used to calculate the score (Tables 6 and 7; Figure 18). The score distributions for LDI scores at 100 m and 250 m, and to some extent 500 m, are strongly left-skewed, reflecting the predominance of sites with low intensity land uses in the first few hundred meters from the wetland (Figure 19). For example, within the 100 m buffer, Cuyahoga County wetlands had an average LDI (79) score similar to Summit and Portage Counties wetlands (88 and 81 respectively) and not significantly different from Geauga County wetlands (38), but had a significantly higher score (232) than all the other counties' wetlands at the 4000 m distance. Score distributions become more normal when land use data at 1000, 2000, or 4000 meters was used (Figure 19). The increase in average LDI scores by buffer class continued to be observed when sites were stratified by condition categories (Table 8). Mean Category 2 wetland LDI scores increase from 66 to 156, and mean Category 3 wetland scores increased from 52 to 138 over the different buffer distances (Table 8) (Category 1 and modified Category 2 scores also increased in the same manner), although the 95th percentile of LDI scores by buffer distance did not change substantially (95th percentiles of LDI scores by buffer class: 100 m = 252; 250 m = 269; 500 m = 280; 1000 m = 264; 2000 m = 274; 4000 m = 255; average = 266). From a practical perspective, results from a level 1 LDI assessment are strongly scale-dependent.. This also suggests that the land use is more heterogeneous at shorter buffer distances (reflected in the higher standard deviations at narrower buffer distances) (Tables 6 and 7).

The predictive power of the level 1 LDI assessment at the individual site level for all wetlands was low ($R^2 = 12\text{-}17\%$; $p < 0.05$) for 100 m to 1000 m buffer classes; and no interpretable correlations were observed at the 2000 m or 4000 m distances (Figure 20). However, at the population level, the LDI assessment could distinguish between at least two significantly different condition categories (Category 1 and Category 3) at every buffer distance except 4000 m (Table 8; Figure 21). The best graphical separation of 25th and 75th percentile boxplots of all four condition categories was observed at the 100 m, 250 m, and 500 m buffer distances (Figure 21a, b, and c). The lowest p-values and highest F statistic were observed at the 100 m, 250 m and 2000 m buffer distances (Table 8).

LDI scores were also evaluated by the four most common HGM classes (depression, riverine, slope, impoundment). LDI scores increased significantly as the distance from the wetland boundary increased for all HGM classes (Figure 22) in the same manner observed for the entire data set (Table 6). Mean LDI scores increased such that the 4000 m buffer had a mean LDI score over twice the value for the 100 m buffer. Similarly, variability in scores within HGM classes decreased as the buffer distance increased (as measured by reduced standard deviations at the largest buffer distances), i.e., the landscape at this scale is more homogeneous.

The intensity of land-use as measured by LDI scores also varied substantially between HGM classes. Depressional wetlands had the highest mean LDI scores at each buffer distance, with significantly higher mean LDI values at 100 m, 250 m and 500 m. For the 100 m buffer, depressional wetlands showed the highest mean LDI score of 95.7 indicating that depressional wetlands tend to be surrounded by more intense surrounding land-uses. In contrast, riverine and slope wetlands had mean LDI values that were 31% and 40% lower, respectively. Impounded wetlands showed an extremely low mean LDI value of 19.8 at 100 m (Figure 22). This is likely due to the predominance of open water in their immediate vicinity. Open water is given a 0.0 weighting factor even if it is was created as part of a managed reservoir. This pattern of land use differences as a function of HGM class persisted to 4000 m, with depressional wetlands showing the highest and impounded wetlands the lowest LDI scores.

We tested LDI scores for the four main HGM classes for their ability to predict ecological condition. As with regressions of the entire data set, we observed a low but significant negative correlation for all HGM classes such that as the intensity of land use increased, ORAM scores decreased (Table 9; Figure 23). While this negative trend was seen to a distance of 4000 m, the significance of the regressions declined as the buffer distances increased beyond 1000 m for depressional, riverine, and slope wetlands (Table 9; Figure 23). This suggests that land-uses at distances of 2000 m and 4000 m influence wetland condition less than buffers at 100 m, 250 m, and 500 m. Regression models for impounded wetlands showed the opposite pattern. LDI scores for impounded wetlands showed no significant correlation with ORAM scores until 2000 m, at which distance the variance explained in the ORAM scores was nearly 45%.

We repeated the above analysis using the Florida LDI coefficients (Figure 24A) with nearly identical results. We also investigated the influence of individual land uses including, percent forest in the buffer area, percent agricultural land, and percent suburban/urban lands, on ORAM scores (Figure 24B – 24D). The explanatory power of the individual land uses in predicting ORAM scores was consistently lower than either version of the LDI.

In order to equate LDI score to potential wetland condition, LDI scores were grouped into condition categories based on the intensity of surrounding land use. Condition categories were determined by quadrisecting the 95th percentile for each buffer distance. The overall report card of wetland condition based on the Level 1 assessment again varied depending on the scale at which the landscape around the wetland was evaluated (Figure 25). From 100 m to 500 m, two-thirds to four-fifths of the wetland resource in the Cuyahoga Watershed would be expected to be in good to excellent condition, one-tenth to one-fifth in fair to good condition and about one-tenth of the resource in poor to fair condition, respectively (Table 10). At the 1000 m and 2000 m buffer distances one-third to one-half of the resource is predicted to be in good to excellent condition, one-fifth to one-third in fair to good condition, and one-fifth in poor to fair condition, respectively (Table 10). Finally, at the 4000 m distance, about two-fifths of the resource is predicted to be in good to excellent condition, two-fifths in fair to good condition, and one-fifth in poor to fair condition (Table 10).

Level 2 Rapid Assessment

For the wetlands sampled in the Cuyahoga watershed, ORAM scores were normally distributed with a minimum of 16.0, a maximum of 94.0, and a mean of 55.6 (± 14.5 SD, n = 243) (Figure 26A, B). For the Level 2 ORAM assessment, wetland condition was evaluated by comparing ORAM scores to the State of Ohio's wetland antidegradation categories: Category 1 (poor), modified Category 2 (fair), Category 2 (good), and Category 3 (excellent). Across the entire watershed, 9.1% of individual wetlands were in poor condition, 13.2% in fair condition, 51.0% in good condition, and 26.7% in excellent condition (Figure 27A). On an areal basis, 3.0% of the wetland area assessed was Category 1, 6.1% was modified Category 2, 35.2% was Category 2, and 55.7% was Category 3 (Figure 27B). Wetland condition by percentage and acreage of wetlands was also evaluated by county (Cuyahoga, Geauga, Portage, Summit) and TMDL (Total Maximum Daily Load) Report region (Upper Cuyahoga, Middle Cuyahoga, Lower Cuyahoga, and Tinkers Creek). The percentage of individual wetlands in each county that would be considered degraded (Category 1, modified Category 2) was relatively constant across the watershed with about 24-25% of wetlands in Cuyahoga, Portage, and Summit Counties and 16.4% in Geauga County (Figure 28a, b, c, d). When viewed from the perspective of the TMDL report regions, the Upper Cuyahoga, Middle Cuyahoga, and Tinkers Creek regions had equivalent percentages of degraded wetlands (22.3%, 18.2%, 22.2% respectively) while the Lower Cuyahoga region had 28.9% of its wetlands classified as Category 1 or modified Category 2 (Figure 29a, b, c, d).

There was dramatic decline in the numbers of Category 3 wetlands from the upper parts of the watershed in Geauga County (49.3%), to the middle parts of the watershed in Portage (18.5% and Summit (19.6%) Counties, and the near disappearance of Category 3 wetlands in Cuyahoga County (8.3%). This constitutes a "dumbing down" of the wetland resource across the watershed and can be seen in the increasing percentages of Category 2 wetlands across Geauga (34.3%), Portage (57.4%), Summit (55.4%), and Cuyahoga Counties (66.7%) (Figure 28 a, b, c, d). However, this pattern was not observed when wetlands were grouped by TMDL region boundaries (Figure 29a, b, c, d). The percentages in the Middle Cuyahoga region were attributable to the inclusion of additional high quality wetlands in the Summit Interlobate area of Summit County in the counts; the higher percentages in the Lower Cuyahoga were due to the inclusion of additional high quality wetlands from the Cuyahoga Valley and Hudson Swamp/Brandywine Swamp areas.

When acreages of Category 1, modified Category 2, Category 2, and Category 3 wetlands are considered, a somewhat different picture of the wetland resource in the Cuyahoga watershed emerges. In Geauga County, 83.9% of the wetland area was Category 3; this fell quickly to 32.3% and 32.1% in Portage and Summit Counties, respectively; only 14.3% of the wetland area in Cuyahoga County was Category 3 (Table 11; Figure 28d, e, f, g). Acreage of Category 1 and modified Category 2 wetlands increased from a low of 3.6% in Geauga County to a high of 15.7% in Summit County.

Across the TMDL report regions, acreage of Category 3 wetlands was 29.8%, 69.5%, 32.9%, and 51.7% in the Upper Cuyahoga, Middle Cuyahoga, Tinkers Creek, and Lower Cuyahoga regions, respectively (Table 12; Figure 29d, e, f, g). Acreage of degraded wetlands increased from the upper to lower parts of the watershed from lows of 4.5% and 5.6% in the Upper and Middle Cuyahoga regions, to highs of 20.0% and 19.3% in the Tinkers Creek and Lower Cuyahoga regions (Figure 29d, e, f, g).

These patterns in the number of wetlands and wetland area by condition class are also reflective of the size of wetlands and landscape fragmentation. Median size of wetlands in the four condition categories was significantly different (df = 3, H = 46.53, p = 0.000) (Kruskal-Wallis) (Category 1 = 0.29 ha (0.71 ac), modified Category 2 = 0.77 ha (1.91 ac), Category 2 = 1.66 ha (4.10 ac), Category 3 = 5.19 ha (12.83 ac) (Tables 11 and 12; See also Figure 16). This helps explain why the Lower Cuyahoga region (an area with more intensive land use), had over 50% of its wetland area as Category 3 wetlands: the remaining Category 3 wetlands were very large relative to other wetland types. Conversely, in the Upper and Middle Cuyahoga, both the number of individual Category 3 and the acreage of Category 3 wetlands was high.

Wetland condition was also evaluated by stratifying wetlands by HGM and plant community classes (Tables 13A, 13B). There were no significant (or in most instances not even observable) differences in average ORAM scores by condition category for HGM class or plant community (Tables 13A, 13B). When all sites were compared, depressional wetlands had significantly lower ORAM scores than other HGM classes, but this was due to differential patterns of disturbance and not due to any inherent bias against depressions by ORAM (Table 13A). These results are an important verification of a fundamental approach adopted in ORAM: a single set of metrics calibrated to allow all wetland types to score well or poorly in a similar manner.

With the exception of depressions, the number and area of wetlands in each condition varied by HGM class (Figure 30). For depressions the relative proportion between the number and acreage of wetlands in each condition category was nearly the same, due to most depressions being relatively small. For riverine wetlands, the number of Category 1 or modified Category 2 wetlands was higher than the area of these wetlands, while the area of Category 3 riverine wetlands was higher than their number (due to the large size of many Category 3 riverine wetlands). Similar, differences between the number and area of wetlands in each condition class were observed for slope and impoundment wetlands.

Causes and sources of wetland degradation

There are lists of the stressors provided in ORAM Metrics 3e (hydrologic alteration) and 4c (Habitat alteration). Category 2 and 3 wetlands had significantly lower numbers of hydrologic stressors than Category 1 and modified Category 2 wetlands and Category 3 wetlands had significantly lower numbers of habitat stressors than all other condition categories (Table 14). The most important hydrologic stressors related to condition category were ditching, dikes, stormwater input, filling, and roads (Table 15). Some regional differences in percentages were observed. Ditching was highest in Portage County and stormwater inputs in Summit County, while filling and roads were equivalent across all counties (Table 15). Hydrologic stressors by TMDL region, HGM class, and plant community were approximately equivalent except for impoundments which (not unexpectedly) had much higher percentages of dikes, filling, and roads (Table 15).

Supplementing the Level 2 ORAM assessment, the Penn State Stressor Checklist (the Checklist) was also used (Appendix A). The Checklist has 10 stressor categories (with an associated list of 54 individual stressors): hydrologic modification (10 stressors), high BOD (4 stressors), sedimentation (7 stressors), toxic contaminants (5 stressors), vegetation alteration (10 stressors), eutrophication and nutrient enrichment (6 stressors), thermal alteration (3 stressors), salinity (2 stressors), acidification (5 stressors), and turbidity (2 stressors). While the original Checklist only allowed for checking the presence or absence of a stressor, low (L), medium (M), and high (H) qualifications were added for this study in order to allow an approximation of the amount of the stressor present (Appendix A). The data from the Checklist was analyzed by evaluating the number of stressors (out of 54) that were checked per site and also by weighting the low, medium, and high stressors with weighting factors of 1 (low), 3 (medium), or 5 (high) and summing all of the weights into a single stressor score (Weighted Stressor Score). The weighted stressor score had a range of 0 to a theoretical maximum of 270 (if every stressor was checked and had a high amount), although in this data set the maximum score was 40, reflecting a practical, real-world maximum of around 50.

Similar to LDI distributions at the 100 m and 250 m buffer distances, the number of stressors and Weighted Stressor Score were strongly left-skewed for stressor data from the Checklist (Figure 31A, B), reflecting that most sites had very few countable stressors. Comparing the number of stressors and Weighted Stressor Score to the wetland condition categories previously used showed significant differences in mean scores for Category 1 and Category 3 and some intermediate categories (Table 17; Figure 32A, B). There was substantial overlap in 25th and 75th percentile box plots for the number of stressors (Figure 32A). The Weighted Stressor Score had better separation in its score distribution than the unweighted stressor counts especially for Category 1/modified Category 2 and Category 3. To obtain a comparable report card on wetland health from this alternate Level 2 assessment, the 95th percentile of the number of stressors (95th = 7.9) and the Weighted Stressor Scores (95th = 22.9) was calculated and divided into quartiles. The percentages for these two approaches were nearly identical (Figure 33A, B). Comparing just the Weighted Stressor Scores to the percentages from the ORAM assessment, 11.1% of wetlands were poor, 9.9% fair, 23.5% good and 55.6% excellent (compared to 9.1% of wetlands in poor condition, 13.2% in fair condition, 51.0% in good condition, and 26.7% in excellent condition from the ORAM Level 2 assessment). ORAM and the Weighted Stressor Score were in very close agreement at the "poor" to "fair" range, but disagreed by 25% in the "good" and "excellent" ranges: ORAM estimated ~25% more "good" wetlands and ~25% fewer "excellent" wetlands.

Finally, score distributions of ORAM and the Checklist were compared (Figure 34A, B). A critical tipping point in wetland condition for Category 2 and 3 wetlands appears to be reached when the number of stressors is greater than 4 (Figure 34A); when the Weighted Stressor Score is considered (which weights the severity of the stressor in addition to counting its presence), two tipping points can be observed: the number of Category 3 wetlands declines substantially beyond a score of 5; the number of Category 2 wetlands declines substantially beyond a score of 10 (Figure 34B).

The overall report card of wetland condition based on the Level 2 data varied across the watershed by county and TMDL region, with the best condition (in terms of individual wetlands and acreage) occurring in the upper parts of the watershed, although significant high quality wetland resource still remains in Summit and Portage counties despite the high urban and agricultural land uses in these counties. This is likely due to the regional glacial geology (the Summit Interlobate subregion) which caused a very high number of wetlands to develop, often with strong ground water influences and includes the large, relatively intact complexes of the Breakneck Creek watershed. Many of these wetlands still remain because of the difficulties in converting them to other land uses. As a general characterization, approximately two-thirds to three-fourths of the wetland resources in the Cuyahoga Watershed are in good or better condition according to the two Level 2 assessment tools used and approximately one-quarter to one-third are in poor to fair condition.

Level 3 Intensive Assessment - Biological Measures

Level 3 biological data was collected for vegetation, amphibians and macroinvertebrates. Results for macroinvertebrate data are reported elsewhere (Knapp 2007). The vegetation data allowed for the calculation of the Vegetation Index of Biotic Integrity (VIBI). The VIBI is calibrated for most wetland types in Ohio. The amphibian sampling provided data to calculate the Amphibian Index of Biotic Integrity (AmphIBI). This IBI is designed primarily for use in forested wetlands (and shrub wetlands embedded in upland forests) located in upland or riverine depressional landscape positions. Because the final list of sample points was not obtained until February 2005 and amphibian sampling had to commence by late March 2005, there was not sufficient time to perform reconnaissance to obtain a sample of 20 amphibian sampling sites that met the criteria for use of the AmphIBI. Accurate AmphIBI scores generally require at least 2 and preferably 3 separate sampling events (early, middle, late spring). Of the 15 sites that were able to be trapped, 1 was sampled once, 9 were sampled twice, and 5 were sampled three times. Only 6 of the first 22 sites evaluated (27.3%) were of the correct type of wetland (depressional in forest contexts) to support the kind of forest-dependent amphibian populations that the AmphIBI was designed to evaluate. Considering the entire data set, 32 sites (13.2%) were depressions with greater than 50% forest cover within 250 m of the wetland boundary (Semlitsch 1998). Of these sites only, 21 (8.6%) were forested wetlands or shrub swamps. An additional 24 riverine mainstem depressions had more than 50% forest cover within 250 m for total potential "AmphIBI" sites of 55 (23%). The difficulty in finding sufficient trappable wetlands that could be habitat for pond-breeding salamanders and forest-dependent frog species is at least in part due to the relative scarcity of these wetlands in the Cuyahoga Watershed. Amphibian IBI data is in Appendix B.

The original study goal was to perform Level 3 assessment at 10% of the Level 2 sites (goal = 200). Level 3 vegetation data was collected at 22 sites, which was 11% of the study goal of 200 Level 2 sites and 9% of 243 Level 2 sites actually assessed. The scores from the VIBI were converted to Wetland Tiered Aquatic Life Use categories (Table 3), which are directly related to wetland condition. Based on the Level 3 vegetation data, about 5% of the resource is poor quality, 32% fair quality, 18% good quality, and 45% excellent quality (Figure 35). VIBI scores were strongly and significantly correlated with ORAM v. 5.0 scores (Figure 36), however from the score distribution it is apparent that the low end of the condition gradient was not represented in the first 22 sites of the sample, so the distribution is truncated below the "fair" range. VIBI scores were also significantly correlated with the Weighted Stressor Score derived from the PA Stressor checklist (Figure 38) but were not correlated to a simple count of the number of stressors (Figure 37).

The GRTS design requires that sites be sampled in the order that they were randomly picked in order to obtain a spatially balanced random sample. Either by chance, or by the fact that we chose to only sample 10% of the level 2 sites with level 3 methods, it appears that we only obtained a partially representative Level 3 sample. This truncated distribution may partially explain the poor and opposite correlations between the Level 3 and Level 1 assessments that were observed (Figure 39). However, it may also be due to the precision of the land use data and weighting factors. Open water has the same weighting factor as other natural land uses even if it is located in a highly managed reservoir. This resulted in very low LDI scores for several fringing wetlands located in reservoirs with VIBI scores in the poor to fair range. In addition, several other sites had had recent or relatively recent severe on-site disturbances but were otherwise located in landscapes that were dominated by second growth forest in National Park land. When these sites are removed from the data set, the relationship between condition and land use intensity begins to follow expected patterns (Figure 40), although there is a very wide range of conditions even at high land use intensities.

Level 3 Intensive Assessment - Soils

Of the 243 wetlands assessed in this study, soil samples were taken from 202 sites, the majority of which were depressional or riverine sites, followed by slopes, and impoundments. The soil study was implemented in two phases: the first phase was full laboratory analysis of one soil sample from each site for a full range of biogeochemical indicators; the second phase was the development of predictive models between these observed indicators and high resolution diffuse reflectance spectra, which is an emerging technique for rapid, low-cost characterization of environmental samples. The spectral technique (visible/near infrared reflectance spectroscopy or VINRS) provided characterization of 21 soil properties for all six soil samples. The general conclusion of the spectral study is that VINRS represents a useful tool for characterization of chemical and physical properties of environmental samples. For some analytes (organic matter, total N, total C, total P, total Ca), prediction efficiency was excellent. For another group of analytes (pH, HCl-extractable P, bulk density, P-sorption capacity, total metals [K, Mg, Zn, Cu, Fe, Al, Pb, Na]), prediction efficiencies were adequate for applications in which high sample throughput is required (e.g. resource or condition mapping as in this study), but less than adequate for high-accuracy applications (e.g. regulatory compliance testing). For a few analytes, prediction efficiency was not good for any purpose (KCl-extractable nitrates, water-extractable P, total conductivity. Refer to Appendix C for a detailed discussion of the VINRS predictive models.

Figure 41 (A-K) summarizes the results from the laboratory analysis of the soil data for each of 11 parameters (soil pH, conductivity, percent carbon (C), percent nitrogen (N), total carbon (TC, ug cc^{-1}), total nitrogen (TN, ug cc^{-1}), total phosphorus (TP, ug cc^{-1}), acid-extractable phosphorus (HCl-P, a measure of calcium bound P), water-extractable phosphorus (H_2O-P, a measure of available P), phosphorus sorption capacity, and total nitrate extracted nitrogen (ug cc^{-1}) in four different analyses. The first graph compares data by HGM class (panel “a” in each figure), the second compares by county (panel “b”), the third by wetland condition category (“c”), and the last by land use type, grouping sites into those on agricultural, natural, and urban land use settings at buffer distances from 100 m to 1000 m (panel “d”). Soil pH values differed significantly by condition category and county, although differences were small. Conductivity also showed significant differences by county. Percent C and N did not vary significantly by condition category as predicted, although %N did show a strong trend of N enrichment as condition decreased (Figure 41 C and D). Soils collected in Cuyahoga county were significantly lower for TC and TN than in other counties (Cuyahoga is the most urbanized of the counties in the study area). Similarly, the data show that wetlands surrounded by urban land (regardless of county) had substantially lower percent C (Figure 41C(d), and the lowest percent N (Figure 41D(d)). On a volumetric basis (ug cc^{-1}), both TC and TN varied significantly by HGM class and county (Figure 41E and F). Total carbon (TC) was 20% higher in depressional wetlands than in riverine or slope wetlands, and 34% higher than impoundments; this is likely due to the fact that impounded wetlands are “younger” than other types so carbon has not had as much time to accumulate (ANOVA, $F = 3.97$, $p = 0.009$). TN varied in a similar pattern where impoundments had significantly lower TN levels. Geauga county had significantly more total C and N, and is the least developed of the 4 counties that make up the watershed.

Total phosphorus varied significantly by county (Figure 41G) and, as with TN and TC, the highest levels were found in Geauga county. No differences were seen when sites were stratified by HGM class or condition class. HCl- and water-extractable phosphorus showed similar patterns (Figure 41H and I), although water-extractable P was significantly lowest in category one wetlands. We measured P-sorption capacity as an estimate of the potential for wetlands in the watershed to bind and store phosphorus (Figure 41J). Soil nitrate levels (Figure 41K) varied significantly by HGM class (again, lowest in impoundments) and county (lowest in Geauga county). Wetland size category was an important classifier in detecting relationships between wetlands and soil traits. Wetlands of the two smallest size categories with areas less than 0.12 ha showed approximately 56% higher levels of total phosphorus than wetlands larger than 0.12 ha (data not shown, ANOVA, F=3.77, p=0.002). HCl-extractable phosphorus was also higher in small wetlands (0.04 – 0.12 ha) than in larger wetlands (ANOVA, F=2.20, p=0.046). These results may be the result of runoff from adjacent uplands.

Condition of soils and estimates of assimilative capacity for nutrients

Phosphorus retention is an essential ecological function of wetlands to the landscape, especially in watersheds (like the upper Cuyahoga) that are dominated by agriculture and are consequently fighting the degradation of water quality due to the influence of nonpoint source nutrient inputs and downstream (i.e. Lake Erie) eutrophication. The annual load of phosphorus to Lake Erie is estimated to be 17,474 t/yr (Keddy 2000). The total phosphorus contained in the upper 10 cm of the 202 wetlands sampled in this study was 1,481 t, accounting for nearly 10% of this annual P load (Table 18). Based on these data, it is estimated that the cumulative available phosphorus sorption capacity of the wetlands sampled in this study is equivalent to more than 5 times the annual load of P to Lake Erie from all sources.

Comparison of Level 1-2-3 Assessment Approach Results

The relationships between the Level 1, 2, and 3 assessments approaches have been discussed above (See e.g. Figures 20, 21, 23, 36, 39, 40). While the predictive power of the LDI Level 1 Assessment at the individual wetland level is low, significant differences between average LDI score and wetland condition categories derived from ORAM scores were observed (Figure 20). And, although the sample size was too low to evaluate differences statistically, similar patterns were observed when Level 3 vegetation data was evaluated (Figure 40). Mean ORAM score by land use intensity categories were significantly different at all buffer distances (Table 19; Figure 42). However, the strength of the differences in mean scores (as shown be declining F statistics), and the amount of overlap in the 25th and 75th percentiles increased, at buffer distances greater than 1000 m with the best separation occurring at 100 m and 250 m (Table 19; Figure 42).

Even though correlations between LDI scores and ORAM scores were low (and in the reverse direction for LDI and VIBI scores), what ultimately matters for purposes of state wetland monitoring programs is that there is agreement between the different assessment approaches in assigning a wetland to a condition category. The 95th percentile of LDI scores for each buffer distance was calculated and quadrisected to create LDI land use intensity classes which could then be equated to the ORAM wetland antidegradation condition classes and the WTALU classes derived from the Vegetation IBI ("low" land use intensity = Category 3/SWLH;

"medium" land use intensity = Category 2/WLH; "high" land use intensity = modified Category 2/RWLH); "very high" land use intensity = Category 1/LQWLH)[3]. The condition categories as derived from each of the assessments were then compared. If the same result was reached, the data point was coded "same category"; if the LDI categorized the site as better than the ORAM (or VIBI) condition category, the site was code as "over" by 1, 2, or 3 categories depending on how many condition categories greater than ORAM (or VIBI) the LDI categorized the site by, e.g. LDI category for a wetlands was "low" (wetland predicted to be Category 3) but ORAM category was "modified Category 2" the site was coded as "over by 2 categories." Similarly, sites were coded as "under" (by 1, 2, or 3 categories), if the LDI condition category was lower than the ORAM (or VIBI) derived category. Depending on the purpose for the assessment, under- or over-categorization by a Level 1 assessment method can have different effects. Generally, in regulatory permit programs, the "better," conservative mistake is to over-categorize since this will generally result in a wetland receiving greater protections. In a wetland monitoring program, consistent over-categorization might result in the erroneous conclusion that wetlands in a watershed are in better condition than they actually are, resulting in the diversion of restoration resources to other watersheds.

The highest levels of condition category agreement between LDI and ORAM were observed at the 100 m and 250 m buffer distances (Figure 43). Over-categorization was also more likely to occur at the narrower buffer classes 41.6%, 33.0%, and 29.7%, respectively, for 100 m, 250 m, and 500 m buffers; under-categorization was more likely to occur at the wider buffer classes: 42.4%, 50.2%, and 63.4%, respectively, for the 1000 m, 2000 m, and 4000 m buffers (Figure 43). Percent agreement does not tell the whole story in evaluating the relationship between the methods. Average ORAM scores of sites in the seven agreement categories were compared (Table 20; Figure 44). At the 100 m , 250 m, and 500 m buffer distances under-categorization does not result in significantly different average ORAM scores from the "same category" class (i.e. the scores of under-categorized sites tend to balance out such that the average picture of condition is not different from sites where the LDI and ORAM assessments agreed on the condition category (Table 20; Figure 44). The "over by 1 category" class also has scores similar to the "same category" class at the 100 m and 250 m buffer distances. At greater buffer distances, F statistics and number of classes with significantly different average ORAM scores increases steadily from 1000 m to 4000 m (i.e. the scores are not "balancing out") (Table 20; Figure 44).

Comparing agreement between condition class assignments of Level 1 and Level 3 results, we found that only the LDI scores from the 100 m buffer had a high percentage of agreement with the WTALU condition categories derived from the Level 3 VIBI assessment (Figure 45). Despite the small Level 3 sample size, patterns of under- and over- assessment (Table 21; Figure 46) were similar to those observed for the Level 1:Level 2 comparison (Figure 44) with differences in mean VIBI between under-categorized and same-category sites increasing after 100 m.

The Level 2 and Level 3 assessment methods were compared (Table 22). The Weighted Stressor Score agreed with ORAM 36.4% of the time and the VIBI (WTALU categories) 27.3% of the time (Table 22). The Weighted Stressor Score tended to consistently under-categorize compared to ORAM (assess sites as worse condition than ORAM) 59.1% of the time. The WSS under- and over-categorized about one-third of the time compared to the WTALU categories (Table 22). However, the Level 3 vegetation data still had strong and

3 SWLH = Superior Wetland Habitat, WLH = Wetland Habitat, RWLH = Restorable Wetland Habitat, LQWLH = Limited Quality Wetland Habitat. Refer to Tables 1-3 for more detail.

significant correlations with both Level 2 assessment methods (Figures 36 and 38) (ORAM R^2 = 76.1%; Weighted PA Stressor Score = 46.3%). Agreement on condition class assignments was very high between ORAM and VIBI (59.1%) (Table 22). No wetlands were under-assessed and only 4.5% of the sites were over-assessed by more than one condition category (36.4% of sites were over-categorized by ORAM. Over-assessment was mostly due to ORAM assessing wetlands as Category 2 when the VIBI assessed them as Restorable Wetland Habitat which is equivalent to modified Category 2) (Table 22). This was likely due to the conservative biases designed into the ORAM questions (i.e. because of its use in the state permit program, ORAM will err on the side of over-assessment in the absence of evidence to the contrary).

CART Models - Results

Three separate models were generated using CART analysis to identify thresholds in wetland condition regarding soil measurements, LDI scores, and wetland size. In the first model wetlands of all HGM classes were used (Figure 47A). The model initially split the sample into two groups based on an LDI score of 144 for the 100 m buffer such that sites with an LDI score greater than 144 had a mean adjusted ORAM score of 37.7, while those with lower LDI scores had a mean adjusted ORAM score of 44.5. Subsequent splits were based on wetland sizes of 0.3 ha and 4.6 ha. The model continued to partition the data into further groups based on LDI scores in the wider landscape (2000 m buffer) and soil total P. Ultimately, small wetlands (<0.3 ha) with high LDI scores had a mean ORAM score equivalent to category 1 wetlands, while large wetlands (>4.6 ha) with low LDI scores had the highest mean ORAM score.

The CART model for depressional sites identified water-soluble P, wetland size and total soil N as the major discriminating variables (Figure 47B). The first split separated the highest scoring depressional wetlands with higher mean water-soluble P levels (>4.5 ug/cc) from the rest of the sample. Further splits partitioned lower scoring wetlands according to size (again at 0.3 ha), and TN levels such that lower scoring sites were relatively enriched in N . The lowest category wetlands were characterized by low P levels and very small size (<0.3 ha). For riverine sites, a CART analysis also partitioned the sites according to LDI score in the 100 m buffer, followed by a size threshold of 4.6 ha (Figure 47C).

DISCUSSION

Condition of Wetlands in the Cuyahoga Watershed

All three assessments concur that two-thirds to three-fourths of the wetlands in the Cuyahoga River watershed are in good or better condition (Table 23). ORAM places twice the number of wetlands in the "good" class, and about half as many in the "excellent" class, than the Level 1 (LDI100 m, LDI250 m) or the alternate Level 2 assessment (PA Weighted Stressor Score). The Level 3 VIBI assessment categorized more than twice as many wetlands as "fair" than the Level 1 or 2 assessments, and about half as many as "good." It is clear, though, that the good to high quality wetland resource is not evenly distributed across the entire 8 digit HUC watershed (Figures 28 and 29) or by wetland type (Figure 30) with the Upper and Middle Cuyahoga parts of the watershed accounting for most of the high quality wetland in terms of both number and acreage. While proportions of poor or fair wetlands (Category 1, modified Category 2) stayed relatively constant by county, or watershed region, urbanization and agriculture clearly tend to truncate the wetland resource, such that "good" becomes the maximum attainable expectation.

The State of Ohio has only completed one other probabilistic wetland assessment for urban wetlands in Franklin County, Ohio (Mack and Micacchion 2007; Gamble et al. 2007). In order to put the results from the Cuyahoga assessment into perspective, we compared the average Level 2 and 3 assessment values from the Cuyahoga and Urban wetland assessments to average values from Ohio EPA's reference wetland data set for antidegradation and WTALU categories (Table 23; Figures 48A, B). Average ORAM score from the Cuyahoga watershed was nearly identical to average ORAM score for Category 2 wetlands (Figure 48A). Average scores from the Cuyahoga and Urban wetland assessments were significantly different (Table 23); urban wetlands ORAM scores were not significantly different from the modified Category 2 wetlands scores (Table 23). Comparing VIBI scores, the 25th and 75th percentile of wetlands in the Cuyahoga project overlapped the upper part of the WLH habitat box and the lower part of the SWLH box (Figure 48B); average VIBI scores were not significantly different from average WLH scores but were significantly different from average scores from Urban wetlands (Table 23).

Compared to the results from the Urban wetland study (where the wetland resource is only in fair condition on average, the overall "report card" for the Cuyahoga is a good one. Average scores for the Level 2 and 3 assessments are equivalent to "good" condition when compared to reference wetlands in Ohio.

Evaluating the Level 1-2-3 Assessment Paradigm

Probabilistic studies of wetland condition have only been performed a few times in the United States. Other studies in the Nanticoke watershed of Delaware and Maryland (Whigham et al., in press) and the Juniata watershed of Pennsylvania (Wardrop et al., in press) used intensive Level 3 sampling at <100 sites (in addition to Level 1 and 2 assessments). This study evaluated the approach of 1) increasing sample size and 2) decreasing field time by performing Level 2 assessments at all sites and only doing Level 3 sampling at a percentage of all sites in order to verify the Level 2 results. This approach was very successful: we evaluated 378 points (366 plus 17 stranded); actually assessed 260 wetlands (243 plus 17 stranded points) in a single field season; and performed Level 3 biological assessments on 22 sites and soil sampling at 202 sites.

Level 1 - Uses and Limitations

Ecological condition responded to different gradients of land use. As land use is converted from forest to agriculture wetlands become more degraded. Other studies have yielded similar results (Guntenspergen et al. 2002, Houlahan and Findlay 2004, Johnson and Rejmankova 2005, Houlahan et al. 2006). Guntenspergen et al. (2002) and Houlahan et al. (2006) both found a positive affect of forest cover on plant species richness. Houlahan et al. (2006) also found a negative relationship between forest cover and exotic plant species richness, suggesting that loss of forest cover facilitates the infiltration of exotic plant species. The extensive evaluation of the Landscape Development Index performed in this study has provided much information on the uses, advantages, and limitations of the LDI and landscape data in general. While arguably only as good as the land use data that is used to calculate it, the LDI is simply not very good at telling you the condition of any particular wetland. The land use data we used was the most up to date available for Ohio and is characteristic of the type of data available elsewhere in the country. This under- and over-assessment problem was noted in Mack (2006), which compared the LDI to Ohio EPA's reference data set. Importantly, at the population and watershed level, the LDI does appear to yield similar proportions of wetlands by condition class, as Level 2 and 3 assessments.

In nearly every way we evaluated the LDI data, the scores derived from buffer distances of 100 m and 250 m (and in few instances up to 1000 m) were the most accurate and interpretable. At least in the relatively fragmented landscapes of northeast Ohio, land use tends to homogenize above 250-500 m (in effect everything becomes "medium"); it is the heterogeneity in land use at the narrow buffer distances that appears to provide the information content for predicting the condition of the population of wetlands being sampled.

The lack of one to one correspondence between LDI score and Level 2 and 3 scores has implications for the use of the LDI and other purely landscape based methods as disturbance gradients in the development of Level 2 and 3 assessment methods. At least during indicator evaluation and metric selection, an on-site component to characterizing the level of disturbance at reference wetlands seems to be necessary.

Another surprising result was the nearly 1:1 correlation between the LDI scores derived from the Minnesota and Florida coefficients. It was expected that the coefficients developed for southern Minnesota (with land uses and climate much more similar to Ohio than Florida) would significantly improve the LDI as an assessment tool. In fact, no difference at all was observed between scores derived from the alternate emergy coefficients. There are several possible explanations for this. One, the land use data used here was too coarse to allow for distinctions in the different coefficients to become apparent. Two, the process for developing the coefficients may standardize them such that the overall LDI index scores are the same. Or three, the coefficients may have broader regional or national applicability than is presently understood.

The LDI does have the important advantage of being able to integrate multiple types of land use into a single score which can provide accurate population estimates of condition. However, alternate approaches which use multivariate techniques to distill multiple land uses and stressors into a single "score" are also being developed which may avoid issues regarding the development or applicability of the emergy weighting factors (Danz et al. 2004; Brazner et al. 2007). Based on the data collected here, the LDI could definitely provide a first approximation, Level 1 assessment, of wetland condition which would guide watershed prioritization and study design in future watershed scale assessments.

Finally, for impoundments, these data showed that the land-use in the first three buffer distances through 500 m did not relate to the ORAM scores. However, as the distances increased to 1000, 2000, and 4000 m, the negative correlation became significant and was the strongest at 4000 m. The lack of correlation for the 100, 250, and 500 m buffer zones is likely due to the nature of impoundment creation. Impounded wetlands are often human-made constructs adjacent to large reservoirs. Because the LDI calculations consider open water as a natural area, the LDI scores for the immediate buffers around impoundments are low, indicating low impact. Thus, the extremely low scores recorded for impoundments failed to mirror the variability in ORAM score.

Level 2 -Validation and Sample Size

The ORAM assessment approach performed very well in its role of as Level 2 assessment tool. Some minor modifications were made to the scoring boundary rules to accommodate some of the very large contiguous complexes in the upper Cuyahoga (Many of these more difficult to evaluate wetlands were assessed by the project PIs rather than the student field crews). We possibly observed a tendency to not be a "hard-grader" on the part of the student field crews although no discernible patterns from our QA/QC data and cross-site scoring were actually measured. Whether or not this was occurring, we did obtain nearly the full range of possible ORAM scores. In addition, the similar percentages of poor to fair across Level 1, 2, and 3 and between ORAM and the PA Weighted Stressor Score provided assurances that there was no systematic bias.

Other recently developed rapid assessment approaches have taken a multi-score sheet approach for dominant HGM classes or other wetland types. For example, the California Rapid Assessment Method (CRAM) has unique questions and score sheets associated with each major HGM type (Collins et al. 2006). The ORAM specifically took a "single-score sheet" approach with precisely calibrated point totals such that all wetland types can score well or poorly on the same set of questions. This data set provided the most comprehensive evaluation of this approach and the design of ORAM v. 5.0. We observed no significant (or in most instances even observable) differences in average ORAM scores by condition category for HGM class or plant community (Tables 13A, 13B). In fact, average scores for Category 3 depressions, riverine mainstem, riverine headwater, slope and impoundments were 71.0, 73.3, 73.1, 73.8, and 73.0, respectively (Table 13A). So, attainable expectations for reference standard wetlands were nearly equal across major HGM classes and similar results were obtained when we compared major plant communities (Table 13B). When all sites were evaluated we did observe that depressional wetlands had significantly lower ORAM scores than other HGM classes, but this was due to differential patterns of disturbance and not due to any inherent bias against depressions by ORAM (Table 13A).

The expanded stressor list in the Penn State Stressor Checklist was a very positive addition to the Level 2 data collected in this study with only very modest increase in time. The stressor lists were much more detailed than the checklists provided in ORAM and made it easier to answer the critical ORAM intactness questions (Metrics 3e, 4a, and 4c). We felt the Checklist was improved by the addition of high, medium, and low modifiers to the stressor descriptions. This additional data allowed the development of a Weighted Stressor Score which was significantly correlated with ORAM and the VIBI. The Weighted Stressor Score was good enough to be disturbance gradient in its own right for index development. In contrast, the simple enumeration of stressors had much less predictive power than a more integrative, weighted score. We also observed tipping points in the number of stressors above which the likelihood of being Category 3 (or Category 2) was very low. Future versions of ORAM should include an expanded stressor checklist and perhaps use a weighted stressor score in Metrics 3e, 4a, and 4c.

Although when faced with a watershed with the number and diversity of wetlands as the Cuyahoga Watershed, 200 sites does not sound like very many sites, we determined the sample size was more than adequate. We calculated condition class percentages, mean and standard deviation of ORAM scores, and 95% confidence intervals for all sites and from the first 50, 100, 125, 150, 200 sites (Tables 25 and 26; Figure 49A, B, C, D). We determined that beyond 100 to 125 sites, there was only incremental improvements in estimates of percent of the resource by four condition categories and narrowing of confidence intervals. Mean, standard deviation, median, 25th and 75th percentiles were nearly identical no matter how few or many points were sampled beyond 100 points. The largest issue with this data set was the relative paucity of Category 1 wetlands in the watershed (admittedly a good problem to have), which tended to skew estimates of resource at the lower sample sizes (see discussion below for Level 3 data). This may in part be due to the fact that the most disturbed wetlands are those that have been completely removed from the landscape and so are not available for sampling.

Level 3 - Sample Size, Verification, and "Fair" condition

Insufficient sample size was the main problem with the Level 3 data collected in this study. This restricted our ability to calibrate and validate the Level 1 and 2 protocols with Level 3 data. In particular the Level 3 Vegetation data set was truncated below "fair" condition (22nd point assessed) (Category 1 wetlands did not show up until the 30th and 42nd sample points, respectively). However, the VIBI distribution still had sufficient breadth in disturbance to be highly correlated with both Level 2 assessment tools (Figures 36 and 38).

Sample size was even more problematic for the Amphibian data. Due to logistical constraints, reconnaissance could not be completed before trapping had to commence. In future probabilistic studies, site selection for Amphibian sites should reject inapplicable sites (like marshes) that are not habitat for pond-breeding salamanders and forest-dwelling anurans and continue evaluating points until there are sufficient numbers of AmphIBI sites in the data set. In addition, the relative scarcity of this type of resource may need to be taken into consideration during study design.

Finally, because of its genesis as a regulatory categorization tool, ORAM has built in checks that could result in over-categorization of wetlands since this is a conservative mistake that will result in the wetland receiving greater regulatory protections. For example, a wetland in an agricultural landscape with medium to wide buffers and without affirmative evidence of more recent human disturbances would often tend to score into the Category 2 range. The residual effects of past-disturbances or more subtle on-going effects can be detected by Level 3 protocols. We chose to use ORAM "as is" for this study including its very conservative requirements for deducting points for disturbances. Despite this, we found nearly 60% agreement between ORAM and the VIBI, 0% under-categorization but 36% over-categorization by one condition class and 4% over-categorization by two classes. Most of the sites over-categorized by ORAM were Category 2 wetlands which the VIBI score assessed as Restorable Wetland Habitat[4] or "fair" (There were two sites ORAM categorized as Category 3 and the VIBI as Category 2, Wetland Habitat; there was one LQWLH site ORAM categorized as a 2. This was a large recently impounded swamp forest with dying trees that was in a landscape of mature second growth forest within protected parkland). It is recommended that future efforts to perform ambient condition assessment of the wetland resource should modify or relax the restrictions on deducting points for disturbances especially if each field crew is led by a full-time wetland

4 It should be noted that for regulatory purposes this would not be an over-categorization since modified Category 2 wetlands are regulated as Category 2 wetlands (OAC Rule 3745-1-54).

ecologist. This should resolve the moderate over-categorization by ORAM vis-a-vis a Level 3 assessment.

Buffer Distance, Land Use and Wetland Condition

Surrounding land-use does affect wetland condition. In particular, the land-use in the 100 m buffer surrounding most wetlands was an important variable, such that low intensity land-uses corresponded with

wetlands of better condition. We saw evidence that not all wetlands react similarly to the same land-uses.

The variation that exists between wetland responses to disturbance indicates that HGM class is a key variable in understanding wetland response to stressors.

Our data suggests that a sound approach for wetland protection is limiting the intensity of land-use in the 100 m buffer. Leaving this area in natural land use appears to shield the wetland from the damaging stressors of agricultural and urban land-uses up to 4 km away. This conclusion was reinforced by the CART analysis, which show that overall, land-use in the 100 m buffer was a significant variable in differentiating wetland condition. Furthermore, the CART models for all wetlands together, and riverine wetlands separately, partitioned the samples based on LDI scores between 144 to 158 in the 100 m buffer, scores that signify low intensity agriculture. Thus it appears that even low intensity land-use within the 100 m buffer can lead to inferior ecological condition.

Similar results have been shown for streams and wetlands. In a study of stream health, Patty et al. (1997) showed that riparian grass buffers 6-18 m wide along a stream were efficient at removing nearly 100% of all water contaminants, leading to higher functioning streams. Wetlands surrounded by low intensity land-use in the 1 km radius area surrounding a site have been found to be more ecologically intact than wetlands with higher intensity land-use (Brooks 2004). Assessing seven separate watersheds in Pennsylvania, Brooks (2004) evaluated wetland condition based on a continuum of human-disturbance and compared it to the land-use in the immediate 1 km area. They found that as land-use shifted from forest and wetland areas to agricultural and urban uses, wetland disturbance scores increased.

Soil Studies

Soil chemical and physical parameters measured in this study were found to be consistent with values reported in the literature. Reports of soil TP, TN, and TC range widely (Verhoeven et al 2001, Aldous et al. 2005, Pierzynski et al. 2005), and this variability is seen in the wetlands sampled in this study. Wetland soil pH can range from extremely acidic to slightly alkaline (Hogan et al. 2004, D'Angelo 2005, Pierzynski et al. 2005). Soils sampled in this study tended to be slightly acidic, consistent with the mid range of soil pH reported in previous studies. Conductivity was also consistent with reported values (Van Hoewyk et al. 2000). We found depressions contained significantly higher nutrient concentrations (TN, TP and TC) than riverine sites, and attribute the difference to the accumulation of organic matter in the longer, more stable hydroperiod characteristic of depressional settings. Craft and Casey (2000) identified a similar phenomenon in their comparison of depressional and floodplain forested wetlands. Johnson and Rejmankova (2005) similarly found that agricultural activity heavily impacted wetlands, finding not only a greater presence of competitive dominant plant species, but also higher levels of P in marshes down slope from agricultural activity. Johnson and Rejmankova (2005) also found that soil P was the variable that most strongly influenced the abundance of competitive dominant species, implicating eutrophication as the major culprit in the degradation of wetlands impacted by agricultural activity. High nutrient levels cause a simplification of an ecosystem by removing nutrient limitation as a factor influencing plant competition and distribution.

Study Design - Assessing Wetlands versus Points

Because the ORAM assessment tool was designed to assess "wetlands", the decision was made early during the study design process to use the method "as-is" and assess "wetlands" versus a fixed area around the sample point. Other probabilistic surveys that have been undertaken (Wardrop et al, in press; Whigham et al., in press) have taken an area-based approach rather than assessing a "wetland." This approach avoids 1) the need for determining an assessment unit boundary (which can become difficult in large contiguous complexes of wetlands), 2) measuring the area of the assessment unit. It also allows points to fall onto disturbed and undisturbed areas of wetlands and be separately assessed, which avoids having multiple sample points being dropped on the same "wetland" (since the available digital sample frames will probably not correspond to assessment units defined by the assessment unit rules of the sample protocol). We found that defining an assessment unit boundary was relatively straightforward at majority of sites since most wetlands in the watershed were less than 1.2 ha (3 ac) in size (Figure 16). For the most complex sites we used field crews comprised of the study PIs (rather than the student interns) who were more adept at quickly defining assessment unit boundaries at complicated sites. We found it fairly easy to obtain digitized assessment unit boundaries and area estimates by having the field crews draw the assessment unit directly onto the aerial photo and digitizing this by hand in ArcView. This allowed us to obtain more accurate land use percentages from fixed distances from a polygon rather than a point in a wetland. Finally, even given the large complexes in the Upper Cuyahoga and Breakneck Creek regions, only 7.4% of the points were duplicate points.

Given these straightforward practical fixes to assessing "wetlands", we continue to conclude that assessing "wetlands" versus points is a viable approach with several distinct advantages. First, the basic "currency" in Clean Water Act Section 401/404 regulation of wetlands is something called a "wetland" and this is also the common understanding: a "wetland" is a definable piece of real estate that can be mapped and walked around. There are substantial pragmatic and legal considerations in developing a condition assessment protocol that cannot assess "wetlands." We conclude that the advantages of having a single set of assessment tools which can be used in a wetland permit program as well as in an ambient condition assessment program outweighed the potential disadvantages.

Full implementation of a Statewide Wetland Monitoring and Assessment Program for Ohio

The starting point for the final discussion of this report is two documents: *Application of Elements of State Water Monitoring and Assessment Programs* (the "Elements" document) (USEPA 2006) and the latest *Surface and Ground Water Monitoring Assessment Strategy 2005-2009* (Monitoring Strategy) prepared by Ohio EPA. The most recent Monitoring Strategy document states (p. 30), that

"The final step [in Wetland Monitoring objectives] will be to perform a fully integrated assessment of both wetlands and flowing waters (streams, rivers) in a watershed. This will involve the inclusion of ambient wetland assessments as part of Ohio EPA's routine intensive biological and water quality surveys, or "biosurveys," on a systematic basis statewide. Such an integrated survey would be an interdisciplinary monitoring effort coordinated on a watershed scale. Such efforts may involve a relatively simple setting focusing on a small watershed or a much more complex effort including entire large river drainage basins and multiple and overlapping stressors. Wetlands would be included in the routine, annual, biosurveys Ohio EPA already conducts in 20-25 U.S. Geological Survey 11-digit HUB-based Watershed Assessment Units (WAUs) and 2-3 Large River Assessment Units (LRAUs)."

The monitoring strategy estimates that full implementation of a wetland biosurvey program will require up to 8 wetland field crews. The State of Ohio has developed the prerequisite "tools" required to implement an "adequate" monitoring program as outlined in the Elements document, and is at the point where it could begin actual implementation. The main impediment to implementation is the lack of federal funding to expand the assessment program to include wetlands.

With this as background, staffing scenarios in order to achieve full, rotating basin wetland condition assessment are outlined. These scenarios presume that current (ca2007) levels of technical support, training, and program development will need to be maintained. 5 These four staffing scenarios (+0, +2, +4, and +6 FTE) are summarized in Table 27 and can be termed "nominal", "minimal", "partial", and "full" implementation of a statewide wetland monitoring and assessment program. The basis for this assessment is the experience of Ohio EPA that one fish field crew (full time biologist plus 2 interns) can assess approximately five HUC11 basin per field season (in recent years, Ohio EPA has fielded five fish crews for a total of about twenty-five total basins per field season). Our experience in this project is that wetland assessment will require an equivalent level of staffing, i.e. about 1 FTE wetland ecologist per HUC11 per taxa-group assessed. Note, this assumes each wetland field crew will also have 2 interns (i.e. 12 wetland field interns). The +6 scenario assumes 2-3 FTEs per year will be used for wetland activities not related to rotating basin assessment (401 support, new research, mitigation assessment, training, etc.).

5 Our present level of WEG staffing (2 FTE Ecologists) is barely sufficient to sustain our current level of 401 Program support, training, and research commitments. We expect that even implementing the "nominal" scenario will require a reduction of our current level of 401 program activities.

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Table 1. General Wetland Aquatic Life Use Designations.

code	designation	definition
SWLH	Superior Wetland Habitat	Wetlands that are capable of supporting and maintaining a high quality community with species composition, diversity, and functional organization comparable to the vegetation IBI score of at least 83% (five-sixths) of the 95th percentile for the appropriate wetland type and region as specified in Table 11.
WLH	Wetland Habitat	Wetlands that are capable of supporting and maintaining a balanced, integrated, adaptive community having a species composition, diversity, and functional organization comparable to the vegetation IBI score of at least 66% (two-thirds) of the 95th percentile for the appropriate wetland type and region as specified in Table 11.
RWLH	Restorable Wetland Habitat	Wetlands which are degraded but have a reasonable potential for regaining the capability of supporting and maintaining a balanced, integrated, adaptive community of vascular plants having a species composition, diversity, and functional organization comparable to the vegetation IBI score of at least 33% (one-third) of the 95th percentile distribution for the appropriate wetland type and region as specified in Table 11.
LQWLH	Limited Quality Wetland Habitat	Wetlands which are seriously degraded and which do not have a reasonable potential for regaining the capability of supporting and maintaining a balanced, integrated, adaptive community having a species composition, diversity, and functional organization comparable to the vegetation IBI score of less 33% (one-third) of the 95th percentile for the appropriate wetland type and region as specified in Table 11.

Table 2. Special wetland use designations.

subscript	special uses	description
A	recreation	wetlands with known recreational uses including hunting, fishing, birdwatching, etc. that are publicly available
B	education	wetlands with known educational uses, e.g. nature centers, schools, etc.
C	fish reproduction habitat	wetlands that provide important reproductive habitat for fish
D	bird habitat	wetlands that provide important breeding and nonbreeding habitat for birds
E	T or E habitat	wetlands that provide habitat for federal or state endangered or threatened species
F	flood storage	wetlands located in landscape positions such that they have flood retention functions
G	water quality improvement	wetlands located in landscape positions such that they can perform water quality improvement functions for streams, lakes, or other wetlands

Table 3. Wetland Tiered Aquatic Life Uses (WTALUs) for specific plant communities and landscape positions. tbd = to be developed. LQWLH = limited quality wetland habitat, RWLH = restorable wetland habitat, WLH = wetland habitat, SWLH = superior wetland habitat.

HGM class	HGM subclass	plant community	ecoregions	LQWLH (Category 1)	RWLH (modified Category 2)	WLH (Category 2)	SWLH (Category 3)
Depression	all	Swamp forest, Marsh, Shrub swamp	EOLP	0 - 30	31 - 60	61 - 75	76 - 100
			all other regions	0 - 24	25 - 50	51 - 62	63 - 100
	all	Wet Meadow (incl. prairies and sedge/grass dominated communities that are not slopes)	all regions	0 - 29	30 - 59	60 - 75	76 - 100
Impoundment	all	Swamp forest, Marsh, Shrub Swamp	EOLP	0 - 26	27 - 52	53 - 66	67 - 100
			all other regions	0 - 24	25 - 47	48 - 63	64 - 100
		Wet Meadow (incl. prairies and sedge/grass dominated communities that are not slopes)	all regions	0 - 29	30 - 59	60 - 75	76 - 100
Riverine	Headwater	Swamp forest, Marsh, Shrub swamp	EOLP	0 - 27	28 - 56	57 - 69	70 - 100
			all other regions	0 - 23	24 - 47	47 - 59	60 - 100
	Mainstem	Swamp forest, Marsh, Shrub swamp	EOLP	0 - 29	30 - 56	57 - 73	74 - 100
			all other regions	0 - 20	21 - 41	42 - 52	53 - 100
	Headwater or Mainstem	Wet Meadow (incl. prairies and sedge/grass dominated communities that are not slopes)	all regions	0 - 29	30 - 59	60 - 75	76 - 100
Slope	all	Wet meadow (fen), tall shrub fen, forest seep	all regions	0 - 29	30 - 59	60 - 75	76 - 100
Fringing[1]	Natural Lakes (excluding lacustrine fens) and reservoirs	tbd	tbd	tbd	tbd	tbd	tbd
Coastal[2]	closed embayment, barrier-protected, river mouth	Swamp forest, Marsh, Shrub swamp	all regions	0 - 24	25 - 49	50 - 61	62 - 100
	open embayment, diked (managed unmanaged failed)	tbd	tbd	tbd	tbd	tbd	tbd
Bog	weakly ombrotrophic	Tamarack-hardwood bog, Tall shrub bog	all regions	0 - 32	33 - 65	66 - 82	83 - 100
	moderately to strongly ombrotrophic	Tamarack forest Leatherleaf bog Sphagnum bog	all regions	0 - 23	24 - 47	48 - 59	60 - 100

Table 4. List of land use categories and their associated LDI coefficients (Brown and Vivas, 2005; Brandt-Williams and Campbell, 2005). MN = Minnesota coefficients, FL = Florida coefficients.

Land Use	Description	MN	FL
Deciduous Forest	Areas dominated by trees where 75% or more of the tree species shed foliage simultaneously during season change.	0.00	1.000
Evergreen Forest	Areas characterized by trees where 75% or more of the tree species maintain their leaves all year. Canopy is never without green foliage.	0.00	1.000
Open Water	Areas of open water, generally with 25% or greater cover of water.	0.00	1.000
Pasture	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.	1.08	2.985
Urban/Recreational Grasses	Vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.	3.566	4.375
Crop	Areas used for the production of crops (corn, soybeans, vegetables, tobacco, cotton).	3.247	5.073
Residential	Includes both heavily built up urban centers (high intensity residential) and areas with a mixture of constructed materials and vegetation (low intensity residential).	4.04	7.989
Commercial/Industrial/ Transportation	Includes infrastructure and all highways and all developed areas not classified as residential.	4.65	8.635

Table 5a. Soil and water parameters for Level 3 sampling and sent to the Ohio EPA laboratory, Ohio EPA method numbers, references, and reporting limits.

parameter	water	soil	OEPA method	Method	soil reporting limit	water reporting limit
pH	x	x	120.2 (soil)	SW846-9045C (soil)	na	na
Temperature	x		na	na	na	na
Ammonia (NH_4-N)	x		250.1	USEPA 350.1 (water)	na	0.050mg/l
Total Kjeldahl N	x		250.2	USEPA 351.2	na	0.20mg/l
Nitrate-nitrite	x		250.3	USEPA 353.2	na	0.10mg/l
Nitrite	x		250.4	ASTM D3867-90A	na	0.020mg/l
Phosporus, total	x		260.1	USEPA 365.4	na	0.050mg/l
Total Organic Carbon	x	x	335.1	USEPA 415.1	2	2.0mg/l
particle size		x	160.1	USACOE Method	na	na
Total suspended solids	x		130.3	USEPA 160.2	na	5mg/l
Total solids	x		130.1	USEPA 160.3	na	10mg/l
Chloride	x		230.1	USEPA 325.1	na	5.0mg/l
Aluminum	x	x	401.1	USEPA 200.7	160	200
Barium	x	x	401.1	USEPA 200.7	12	15
Calcium	x	x	401.1	USEPA 200.7	1600	2000
Chromium	x	x	401.1	USEPA 200.7	24	30
Copper	x	x	401.1	USEPA 200.7	8	10
Iron	x	x	401.1	USEPA 200.7	40	50
Magnesium	x	x	401.1	USEPA 200.7	800	1000
Manganese	x	x	401.1	USEPA 200.7	8	10
Lead	x	x	401.1	USEPA 200.7	32	2
Nickel	x	x	401.1	USEPA 200.7	32	40
Potassium	x	x	401.1	USEPA 200.7	1600	2000
Sodium	x	x	401.1	USEPA 200.7	4000	5000
Strontium	x	x	401.1	USEPA 200.7	24	30
Zinc	x	x	401.1	USEPA 200.7	16	10

Table 5b. Soil and water parameters for soil spectral study collected at random points.

parameter	Method	reporting limit	description
pH	Thomas 1996	0.1 ph units	Thomas, G.W. 1996 Soil pH and soil acidity. In Bigham, J.W. (ed.) Methods of Soil Analysis. Part 3. Chemical Methods. Soil Science Society of America
Moisture	3 point balance		
Conductivity	USEPA 120.1 in a 2:1 water:soil slurry	0.1umho/cm	EPA 1993. Methods for the Determination of Inorganic Substances in Environmental Samples
Loss on ignition (LOI)	ashing of 2 g of sample at 550 ^{o}C for 4 hours		
Phosporus, total	USEPA 365.1	0.05 mg/l	EPA 1993. ashing of 2 g of sample at 550 ^{o}C for 4 hours followed by digestion in 0.27N HCl followed by autoanalysis of SRP using ascorbic acid method
Phosphorus, H_2O	Kuo 1996		Kuo, S. 1996. Phosphorus. In Bigham, J.W. (ed.) Methods of Soil Analysis. Part 3. Chemical Methods. Soil Science Society of America
Carbon, total	Elemental Analyzer	0.030 mg	Gas chromotograph elemental analyzer after dry combustion (Carlos-Erba NA-1500 CNS Analyzer)
Nitrogen, total	Elemental Analyzer	0.020 mg	Gas chromotograph elemental analyzer after dry combustion (Carlos-Erba NA-1500 CNS Analyzer)
Nitrate, KCL	Mulvaney 1996		Mulvaney, R.L. 1996. Nitrogen-Inorganic Forms. In Bigham, J.W. (ed.) Methods of Soil Analysis. Part 3. Chemical Methods. Soil Science Society of America
Isotherms	Nair et al. 1998	na	Nair et al. 1998. Dairy manure influences on phosphorus retention capacity of spodosols. J. Environmental Quality 27:522-527
Aluminum	USEPA 200.7	0.15 mg/l	ICP Analysis after ashing/digestion in 6N
Iron	USEPA 200.7	0.05 mg/l	ICP Analysis after ashing/digestion in 6N

Table 6. Descriptive statistics for LDI scores (Minnesota coefficients) at different buffer distances.

	100 m	250 m	500 m	1000 m	2000 m	4000 m
mean	70.4	97.3	114.8	130.5	141.4	152.0
st dev	85.3	85.2	81.5	73.5	65.3	55.5
minimum	0.0	0.0	0.0	0.0	19.6	37.0
1st quartile	0.0	22.5	47.0	82.5	99.6	113.5
median	46.0	87.0	107.0	120.0	131.8	139.0
3rd quartile	110.5	143.5	166.5	177.5	182.8	179.5
maximum	414.0	404.0	405.0	368.0	336.4	352.0
N	232	232	232	232	232	232

Table 7. Average (standard deviation) LDI scores by COUNTY for different buffer distances. Means without shared letters significantly different (p <0.05) after Tukey's multiple comparison test (df = 3, N = 232).

	100 m	250 m	500 m	1000 m	2000 m	4000 m
Cuyahoga	79(103)ab	133(109)a	164(104)a	191(105)a	212(107)ab	232(89)a
Summit	88(98)b	112(96)a	131(92)a	147(89)ab	161(86)b	175(72)b
Portage	81(83)b	109(83)a	124(77)a	138(66)ab	104(33)b	157(35)b
Geauga	38(55)ac	60(62)b	78(61)b	95(46)ac	147(49)ac	112(23)c
F statistic	5.00	6.49	7.43	9.95	15.12	30.39
p value	0.002	0.000	0.000	0.000	0.000	0.000

Table 8. Average (standard deviation) LDI scores by antidegradation categories for different buffer distances. Antidegradation categories defined by ORAM score as follows: Category 1 = 0-34.9, Modified Category 2 = 35.0-44.9, Category 2 = 45.0-64.9, Category = 65.0-10. Means without shared letters significantly different (p <0.05) after Tukey's multiple comparison test (df = 3, N = 231).

	100 m	250 m	500 m	1000 m	2000 m	4000 m
Category 1	114 (126)a	137(113)a	148(111)a	152(105)	186(71)a	169(63)
Modified Cat 2	99(103)a	124(97)a	130(77)a	130(73)	150(73)a	157(63)
Category 2	66(76)ab	95(79)ab	116(79)a	137(72)	144(65)b	156(56)
Category 3	52(60)b	76(73)b	96(75)b	112(62)	117(50)c	138(47)
F statistic	4.58	4.10	2.82	2.29	7.12	2.27
p value	0.004	0.007	0.040	0.079	0.000	0.081

Table 9. Regression results (R^2) comparing LDI score to ORAM scores by HGM class. * p < 0.05, ** p <0.01, *** p <0.001. Note differences in R^2 for slope wetlands in Table 9 and Figure 23 due to the removal of Point 2367 which was a clear outlier in the residual analysis of this regression and which was inflating regression results.

	100 m	250 m	500 m	1000 m	2000 m	4000 m
Depression	0.136**	0.105**	0.078*	0.058*	0.022	0.014
Impoundment	0.100	0.000	0.032	0.176	0.377*	0.439**
Riverine	0.161***	0.180***	0.165***	0.084**	0.045	0.029
Slope	0.087	0.127*	0.155*	0.165*	0.017	0.100

Table 10. Percentage of wetlands surrounded by low, medium, or high intensity surrounding land uses (and the associated wetland condition class) by increasing buffer distances around the wetland.

	Low Excellent Condition	Medium Good Condition	High Fair Condition	Very High Poor Condition
100 m	57.9	22.7	12.4	6.9
250 m	44.2	29.2	16.7	9.9
500 m	33.9	32.2	22.3	11.6
1000 m	21.0	38.2	22.7	18.0
2000 m	14.6	38.2	30.5	16.7
4000 m	1.7	35.6	42.5	20.2

Table 11. Descriptive statistics of wetland area by county and condition category.

County	Condition Category	mean (st dev) (acres)	median (acres)	total (acres)	% of total acres	N
Cuyahoga	Cat 1	0.7	0.7	0.7	1%	1
	mod Cat 2	3.9(2.2)	3.9	7.8	8%	2
	Cat 2	8.9(3.6)	3.9	71.1	76%	8
	Cat 3	13.5	13.5	13.5	14%	1
Summit	Cat 1	15.4(31.4)	1.4	92.2	7%	6
	mod Cat 2	13.5(18.0)	5.0	107.8	8%	8
	Cat 2	21.4(56.1)	6.3	664.2	52%	31
	Cat 3	37.1(42.4)	18.4	408.1	32%	11
Portage	Cat 1	1.2(2.2)	0.5	12.9	2%	11
	mod Cat 2	4.3(9.8)	1.0	64.6	9%	15
	Cat 2	6.4(14.1)	1.8	397.0	57%	62
	Cat 3	11.3(13.7)	4.5	226.1	32%	20
Geauga	Cat 1	2.7(2.3)	2.1	10.7	1%	4
	mod Cat 2	7.6(9.9)	2.9	53.0	3%	7
	Cat 2	9.7(15.9)	6.5	222.3	12%	23
	Cat 3	45.3(112.9)	16.0	1494.2	84%	33

Table 12. Descriptive statistics of wetland area by TMDL region and condition category.

Region	Condition Category	mean (st dev) (acres)	median (acres)	total (acres)	% of total acres	N
Upper Cuyahoga	Cat 1	1.7(2.5)	0.5	18.9	2%	11
	mod Cat 2	1.7(1.9)	0.8	16.8	2%	10
	Cat 2	9.2(16.2)	3.3	517.5	66%	56
	Cat 3	13.8(13.4)	12.7	235.0	30%	17
Middle Cuyahoga	Cat 1	4.1(4.5)	2.6	12.4	1%	3
	mod Cat 2	9.6(11.6)	2.4	105.9	5%	11
	Cat 2	16.9(57.1)	3.1	506.2	25%	30
	Cat 3	43.2(114.3)	11.5	1424.3	75%	33
Tinkers Creek	Cat 1	1.0(0.5)	0.9	3.9	2%	4
	mod Cat 2	19.0(26.2)	19.0	37.9	18%	2
	Cat 2	5.8(5.3)	5.8	98.3	47%	17
	Cat 3	17.2(9.7)	18.0	68.7	33%	4
Lower Cuyahoga	Cat 1	20.3(39.2)	1.0	81.2	10%	4
	mod Cat 2	8.0(15.7)	2.1	72.4	9%	9
	Cat 2	11.1(17.8)	5.4	232.7	29%	21
	Cat 3	37.6(34.8)	32.9	413.8	52%	11

Table 13a. Average (standard deviation) ORAM scores by five HGM classes for four wetland condition categories. Means without shared letters significantly different after Tukey's multiple comparison test ($p < 0.05$)

	ANOVA results	depression	riverine headwater	riverine mainstem	impound-ment	slope
All sites	df = 230, F = 6.11, p = 0.000	49.2(14.4)a	57.0(14.9) b	59.8(12.1) b	58.3(17.7) b	58.5(13.7) b
Category 1	df = 21, F = 1.51, p = 0.244	24.1(7.7)	28.3(4.2)	34.0(0.0)	31.0(1.7)	25.0(4.2)
modified Cat 2	df = 29, F = 2.30, p = 0.087	39.8(2.4)	42.1(2.5)	38.5(0.7)	43.0(0.0)	42.3(1.5)
Cat 2	df = 116, F = 1.03, p = 0.393	53.5(5.2)	54.8(6.3)	54.9(5.5)	57.1(3.7)	55.9(5.2)
Cat 3	df = 61, F = 0.42, p = 0.797	71.0(5.2)	73.1(4.5)	73.3(4.8)	73.0(10.2)	73.6(4.6)

Table 13b. Average (standard deviation) ORAM scores by five PLANT COMMUNITY classes for four wetland condition categories.

	ANOVA results	forest seep	marsh	shrub swamp	swamp forest	wet meadow
All sites	df = 236, F = 1.63, p = 0.167	61.7(14.7)	54.5(16.1)	51.6(14.5)	55.7(11.9)	54.1(14.6)
Category 1	df = 20, F = 1.59, p = 0.230	---	26.0(8.1)	23.7(5.8)	33.8(0.8)	28.0(3.0)
modified Cat 2	df = 31, F = 1.55, p = 0.225	---	39.8(2.1)	41.5(2.3)	41.1(2.4)	38.7(3.8)
Cat 2	df = 120, F = 0.68, p = 0.605	55.1(6.1)	54.0(5.9)	55.0(5.4)	55.4(5.0)	53.0(4.1)
Cat 3	df = 61, F = 0.73, p = 0.572	74.1(5.3)	73.3(6.3)	70.1(4.4)	72.7(4.9)	71.4(4.1)

Table 14. Average (standard deviation) number of hydrologic (Metric 3e), Habitat (Metric 4c) or combined stressors by wetland condition category. Means without shared letters significantly different ($p < 0.05$) after Tukey's multiple comparison test.

	Metric 3e	Metric 4c	Metric 3e + 4c
Category 1	2.0 (1.3)a	1.6(1.1)ab	3.6(1.7)a
mod Category 2	2.1(1.3)a	2.0(1.6)a	4.1(2.1)a
Category 2	1.2(1.3)b	1.1(1.4)b	2.4(2.2)b
Category 3	0.9(1.1)c	0.5(1.1)c	1.4(1.8)c
df	242	242	242
F statistic	8.54	10.27	14.25
p value	0.000	0.000	0.000

Table 15. Percentage of Metric 3e (Hydrologic alteration) stressors by condition category, county, TMDL region, HGM class, and plant community.

Condition category	N	ditching	tiling	dikes	weirs	stormwater input	point source	filling	roads	dredging	other
Category 1	22	27%	9%	9%	0%	36%	0%	50%	45%	5%	18%
mod Category 2	32	53%	6%	16%	9%	9%	3%	38%	31%	13%	31%
Category 2	124	31%	3%	10%	2%	2%	0%	18%	33%	4%	18%
Category 3	65	11%	3%	8%	2%	3%	3%	18%	31%	2%	14%
County											
CUYAHOGA	12	17%	8%	0%	8%	0%	0%	33%	33%	0%	25%
GEAUGA	67	25%	3%	9%	1%	3%	1%	24%	36%	1%	28%
PORTAGE	108	35%	5%	12%	3%	6%	2%	22%	33%	6%	12%
SUMMIT	56	21%	4%	9%	4%	13%	0%	23%	30%	7%	18%
TMDL region											
a Upper	94	33%	5%	12%	3%	10%	0%	18%	29%	3%	16%
b Middle	77	27%	1%	4%	0%	6%	3%	31%	40%	6%	23%
c Lower	45	27%	7%	13%	2%	4%	2%	24%	38%	7%	20%
d Tinkers Creek	27	19%	4%	15%	11%	0%	0%	19%	22%	0%	11%
HGM class											
depression	87	37%	8%	9%	2%	9%	1%	22%	28%	5%	15%
fringing	9	22%	0%	22%	11%	0%	0%	11%	0%	0%	44%
headwater	40	28%	3%	8%	0%	5%	0%	23%	30%	3%	20%
impoundment	16	6%	0%	25%	0%	13%	0%	44%	63%	0%	13%
mainstem	53	30%	4%	6%	4%	4%	2%	23%	47%	9%	21%
slope	35	20%	0%	9%	6%	6%	3%	26%	29%	3%	20%
Plant community											
forest seep	18	17%	0%	6%	0%	6%	6%	22%	28%	0%	17%
marsh	85	31%	5%	13%	4%	8%	2%	22%	42%	4%	21%
shrub swamp	42	24%	0%	12%	7%	7%	0%	21%	31%	10%	14%
swamp forest	65	34%	6%	8%	2%	5%	0%	17%	20%	5%	15%
wet meadow	27	26%	7%	4%	0%	7%	0%	44%	44%	4%	26%

Table 16. Percentage of Metric 4c (Habitat Alteration) stressors by condition category, county, TMDL region, HGM class, and plant community.

Condition class	N	mowing	grazing	clear-cuttin	select cutting	woody debris removal	sedi-mentation	toxic pollut.	shrub removal	aq bed removal	farming	nutrient enrichment	dredg-ing
Category 1	22	55%	14%	14%	9%	14%	14%	0%	9%	0%	14%	23%	5%
mod Category 2	32	59%	3%	3%	19%	16%	16%	3%	25%	0%	16%	13%	9%
Category 2	124	25%	2%	2%	19%	8%	9%	2%	10%	1%	10%	10%	7%
Category 3	65	8%	3%	3%	5%	2%	8%	0%	3%	0%	6%	5%	5%
County													
CUYAHOGA	12	25%	0%	0%	8%	0%	0%	0%	8%	0%	8%	0%	0%
GEAUGA	67	21%	10%	10%	7%	4%	9%	0%	9%	0%	6%	12%	6%
PORTAGE	108	31%	2%	2%	23%	9%	9%	0%	12%	1%	15%	10%	6%
SUMMIT	56	30%	0%	0%	7%	11%	14%	5%	9%	0%	7%	11%	9%
TMDL Region													
a Upper	94	32%	4%	4%	15%	5%	4%	1%	11%	0%	5%	4%	6%
b Middle	77	25%	4%	4%	10%	12%	16%	1%	12%	1%	14%	18%	8%
c Lower	45	29%	2%	2%	16%	9%	13%	2%	11%	0%	13%	11%	9%
d Tinkers Creek	27	19%	4%	4%	22%	4%	7%	0%	4%	0%	11%	7%	0%
HGM class													
depression	87	32%	1%	1%	20%	10%	8%	1%	11%	0%	13%	9%	6%
fringing	9	22%	0%	0%	33%	11%	22%	0%	0%	11%	11%	33%	11%
headwater	40	30%	5%	5%	15%	10%	8%	0%	20%	0%	5%	5%	5%
impoundment	16	13%	6%	6%	13%	13%	19%	0%	0%	0%	13%	13%	0%
mainstem	53	25%	6%	6%	11%	2%	9%	2%	4%	0%	11%	11%	9%
slope	35	29%	6%	6%	3%	6%	11%	3%	14%	0%	9%	11%	9%
Plant comm.													
forest seep	18	22%	0%	0%	11%	6%	11%	0%	11%	0%	11%	6%	11%
marsh	85	24%	5%	5%	11%	7%	7%	0%	5%	1%	13%	13%	7%
shrub swamp	42	31%	2%	2%	14%	10%	12%	2%	12%	0%	5%	12%	5%
swamp forest	65	35%	2%	2%	26%	9%	8%	2%	14%	0%	9%	5%	6%
wet meadow	27	22%	11%	11%	4%	4%	22%	4%	11%	0%	15%	19%	7%

Table 17. Average (standard deviation) number stressors and average Weighted Stressor Score from the PA Stressor checklist. Means without shared letters significantly different ($p < 0.05$) after Tukey's multiple comparison test.

Condition category	Number of Stressors	Weighted Stressor Score
Category 1	5.2 (2.8)a	14.7(10.2)ab
mod Category 2	4.0(2.5)a	8.1(6.3)a
Category 2	2.7(2.1)b	5.6(4.9)b
Category 3	1.8(1.6)c	3.4(4.2)c

Table 18. Average values for wetland soil paramters. Total area of all wetlands where soil samples were collected, mean (standard deviation) soil nutrient levels and the resultant cumulative nutrient content (for upper 10cm of each wetland) as determined by multiplying areal nutrient content by wetland area and summing the results for the entire wetland population sampled in the watershed (note Mg = 10^6 g).

Wetland area or soil paramete	Mean for all Wetlands, (g/m^2)	Total for sampled population
Area (Ha)		1174.35 (n=202)
Total phosphorus	122.39(59.30)	1,481.8 Mg
Total nitrogen	636.74(323.18)	8,087.0 Mg
Total carbon	9333.71(4963.69)	113,979.4 Mg
HCl-phosphorus	46.98(38.22)	751.9 Mg
H_2O-phosphorus	0.32(0.43)	3,765.2 kg
Nitrate-N	0.37(0.88)	2,939.9 kg
Phosphorus-sorption	9630(4048)	100,829.6 Mg

Table 19. Average (standard deviation) ORAM scores (N = 232) by land use intensity categories for different buffer distances. Land use intensity categories defined by quadrisecting 95th percentile of LDI distribution for each buffer distance category. Means without shared letters significantly different (p <0.05) after Tukey's multiple comparison test.

	100 m	250 m	500 m	1000 m	2000 m	4000 m
low	59.2 (12.9)a	59.6(13.3)a	60.8(12.9)a	61.6(13.5)a	60.6(12.6)a	54.3(5.3)ab
medium	54.6(14.6)ab	55.2(14.1)ab	56.2(14.0)ab	54.3(13.5)ab	56.8(14.2)a	59.1(14.3)a
high	47.3(13.2)bc	52.5(12.3)bc	50.6(13.1)bc	52.3(12.4)bc	55.6(13.3)a	53.9(14.0)b
very high	37.2(12.2)c	39.5(14.3)d	44.3(16.0)c	46.8(16.5)c	45.7(16.0)b	50.9(15.7)ab
df	3	3	3	3	3	3
F statistic	17.3	14.5	12.2	10.1	8.1	3.9
p value	0.000	0.000	0.000	0.000	0.000	0.011

Table 20. Agreement between LDI and ORAM assessments. Mean (standard deviation) of ORAM scores (N =232) by "agreement" categories for different buffer distances. Means without shared letters significantly different (p <0.05) after Tukey's multiple comparison test. "Under" by 1, 2, or 3 means the LDI predicted the wetland to be in worse condition than ORAM. "Over" by 1, 2, or 3 means the LDI predicted the wetland to be in better condition than ORAM. "Same category" means LDI and ORAM were in agreement. LDI land use intensity categories and ORAM equated as follows: low ~ Category 3, medium = Category 2, high ~ modified Category 2, very high ~ Category 1.

	100 m	250 m	500 m	1000 m	2000 m	4000 m
under by 3	---	---	67.8(1.9)ab	72.1(6.1)a	71.2(7.7)ab	72.2(6.0)a
under by 2	55.8(6.7)abc	61.0(10.2)ab	60.6(11.4)ad	59.1(9.0)ab	63.3(11.0)a	63.9(10.0)ab
under by 1	59.6(13.4)a	60.5(12.3)a	59.9(11.9)a	61.3(12.2)a	59.9(12.5)a	59.5(12.0)bc
same category	61.2(15.0)a	57.8(16.3)ab	57.6(16.2)ad	54.0(16.2)b	52.3(15.0)bc	47.1(11.8)d
over by 1	51.3(9.9)b	51.5(8.6)b	48.7(10.9)be	47.3(10.9)bc	45.5(10.5)c	37.8(11.1)e
over by 2	38.1(7.5)c	36.8(10.7)c	35.0(7.0)ce	35.2(3.3)c	30.6(6.6)cd	29.4(4.0)e
over by 3	31.9(2.3)cd	31.9(2.3)cd	31.5(2.1)cde	30.0	---	---
df	5	5	6	6	5	5
F statistic	17.6	12.2	9.9	10.8	16.2	33.3
p value	0.000	0.000	0.000	0.000	0.000	0.000

Table 21. Agreement between LDI and VIBI. Mean (standard deviation) of VIBI scores by "agreement" categories for different buffer distances. Categories grouped into "under-categorized", "same category" and "over-categorized" due to small sample size of Level 3 data. Means without shared letters significantly different ($p < 0.05$) after Tukey's multiple comparison test. "Unde-categorized" means the LDI predicted the wetland to be in worse condition than VIBI. "Over-categorized" means the LDI predicted the wetland to be in better condition than VIBI. "Same category" means LDI and VIBI were in agreement. LDI land use intensity categories and VIBI equated as follows: low ~ SWLH, medium = WLH, high ~ RWLH, very high ~ LQWLH.

	100 m	250 m	500 m	1000 m	2000 m	4000 m
under-categorized	71.3(21.6)a	82.4(10.9)a	79.1(12.7)a	71.2(21.0)a	75.1(13.5)a	74.8(14.8)a
same category	77.1(11.3)a	69.0(11.6)a	57.7(10.0)ab	67.0(13.4)ab	72.5(26.2)a	75.0ab
over-categorized	53.9(22.0)b	46.1(15.2)b	44.2(17.4)b	39.7(6.4)b	38.0(9.6)b	38.0(9.5)b
df	2	2	2	2	2	2
F statistic	3.5	17.1	13.3	3.7	13.6	13.6
p value	0.051	0.000	0.000	0.044	0.000	0.000
N	21	21	21	21	21	21

Table 22. Agreement in condition category assignment between ORAM Antiegradation condition classes, PA Weighted Stressor Score condition classes and Wetland Tiered Aquatlc Life Uses (WTALU) categories for 22 Level 3 assessment sites.

Site	site name	ORAM	Antideg Category	PA Weighted Stressor Score	Stressor Class	VIBI score	WTALU categories	%agree ORAM-PA	%agree WTALU-PA	%agree ORAM-WTALU
2001	Alexander Rd	48	Cat2	14	fair	60	WLH	under by 1	under by 1	same category
2005	Old Forge Rd	74	Cat3	1	good	94	SWLH	under by 1	under by 1	same category
2008	Bartholomew Rd	52	Cat2	18	fair	47	RWLH	under by 1	same category	over by 1
2013	Ward	62	Cat2	12	fair	50	RWLH	under by 1	same category	over by 1
2014	Brecksville	51	Cat2	21	fair	24	LQWLH	under by 1	over by 1	over by 2
2015	Black Rd	40	mod Cat2	6	excellent	36	RWLH	over by 2	over by 2	same category
2016	Wake Robin	74	Cat3	1	excellent	75	WLH	same category	over by 1	over by 1
2017	Quail Hollow	59	Cat2	1	good	50	RWLH	same category	over by 1	over by 1
2020	Thut	70	Cat3	0	excellent	84	SWLH	same category	same category	same category
2023	Bath Rd	49	Cat2	1	good	36	RWLH	same category	over by 1	over by 1
2025	Rhinehart	65	Cat3	11	fair	74	SWLH	under by 2	under by 2	same category
2027	Hasbrouck	77	Cat3	1	excellent	94	SWLH	same category	same category	same category
2028	Bridge Creek	62	Cat2	3	good	47	RWLH	same category	over by 1	over by 1
2029	Twinsburg	70	Cat3	3	excellent	74	SWLH	same category	same category	same category
2031	Miller	49.5	Cat2	8	poor	54	RWLH	under by 1	same category	over by 1
2032	Aquilla Rd	73	Cat3	3	good	84	SWLH	under by 1	under by 1	same category
2033	Good Year	78	Cat3	9	good	84	SWLH	under by 1	under by 1	same category
2034	Oak Knolls	71	Cat3	10	excellent	69	WLH	same category	over by 1	over by 1
2036	Tare Creek	74	Cat3	15	fair	80	SWLH	under by 2	under by 2	same category
2037	Wingfoot Lake	50	Cat2	21	fair	53	WLH	under by 1	under by 1	same category
2040	South Rider Rd	78	Cat3	4	good	91	SWLH	under by 1	under by 1	same category
2042	Marsh Wetlands	75	Cat3	3	good	77	SWLH	under by 1	under by 1	same category
							under by 2	9.1%	9.1%	0.0%
							under by 1	50.0%	31.8%	0.0%
							same	36.4%	27.3%	59.1%
							over by 1	0.0%	27.3%	36.4%
							over by 2	4.5%	4.5%	4.5%

Table 23. Percentage of wetlands by condition category for LDI 100 m, LDI 200 m, ORAM, Weighted Stressor Score (PA WSS), and the VIBI. * n = 22 and VIBI distribution is truncated below the "fair" class.

	LDI100 m	LDI250 m	ORAM	PA WSS	VIBI*
Poor	6.9	9.9	9.1	11.1	4.5
Fair	12.4	16.7	13.2	9.9	31.8
Good	22.7	29.2	51.0	23.5	18.2
Excellent	57.9	44.2	26.7	55.6	45.5

Table 24. ANOVA summary table for comparison of mean ORAM and VIBI scores from Ohio EPA's reference wetland dataset and results from Cuyahoga and Urban Wetland Study. Means without shared letters significantly different after Tukey's multiple comparison test ($p < 0.05$).

Antidegradation Categories	ORAM v. 5	WTALU categories	VIBI score
Category 1	26.0(6.1)a	LQWLH	13.8(7.5)a
modified Cat 2	39.3(2.4)b	RWLH	41.8(9.1)b
Category 2	55.8(5.2)c	WLH	61.3(8.6)c
Category 3	74.8(6.5)d	SWLH	78.4(11.1)d
Cuyahoga	55.5(14.4)c	Cuyahoga	64.4(21.6)c
Urban	43.9(12.6)eb	Urban	36.3(14.6)eb
---	---	Mitigation	30.0(14.1)eb
---	---	Bank	38.2(16.8)eb
df	5	df	6
F statistic	101.81	F statistic	126.36
p value	0.000	p value	0.000
N	468	N	297

Table 25. Summary statistics for ORAM scores based on first 50, 100, 125, 150, 200, and 243 points sampled.

Number of points sampled	Mean	st dev	95% CI	25th percentile	median	75th percentile
50 points	60.2	13.7	3.8	50.0	60.3	73.3
100 points	56.8	15.4	3.0	45.0	55.5	71.8
125 points	55.6	15.5	2.7	44.0	54.5	69.3
150 points	55.0	15.4	2.5	44.8	53.5	66.1
200 points	55.4	14.7	2.0	46.6	54.8	66.4
243 points	55.1	14.6	1.8	46.5	54.5	66.0

Table 26. Descriptive statistics of wetland area by TMDL region and condition category.

Number of Points Sampled	Condition Category	mean	st dev	95% CI	N	% of total resource
1st 50 points	Cat 1	32.5	2.1	2.9	2	4%
	mod Cat 2	39.3	2.6	2.3	5	10%
	Cat 2	55.1	5.3	2.2	23	46%
	Cat 3	74.0	4.5	2.0	20	40%
1st 100 points	Cat 1	27.3	6.2	4.9	6	6%
	mod Cat 2	40.4	2.3	1.0	19	19%
	Cat 2	54.2	4.9	1.5	41	41%
	Cat 3	74.3	5.8	1.9	34	34%
1st 125 points	Cat 1	28.3	6.4	3.6	12	10%
	mod Cat 2	40.5	2.6	1.0	20	16%
	Cat 2	54.3	5.4	1.3	55	44%
	Cat 3	74.1	5.6	1.9	38	30%
1st 150 points	Cat 1	27.0	6.6	3.3	15	10%
	mod Cat 2	40.6	2.3	0.9	22	15%
	Cat 2	54.0	5.2	1.2	70	47%
	Cat 3	73.7	5.9	1.8	43	29%
1st 200 points	Cat 1	26.5	6.8	3.2	17	9%
	mod Cat 2	40.5	2.6	1.0	27	14%
	Cat 2	54.4	5.4	1.1	99	50%
	Cat 3	72.8	5.6	1.5	57	29%
All 243 points	Cat 1	26.6	6.8	2.8	22	9%
	mod Cat 2	2.5	2.5	0.9	31	13%
	Cat 2	5.4	5.4	1.0	123	51%
	Cat 3	5.5	5.5	1.3	64	26%

Table 27. Summary of staffing scenarios to achieve full rotating basin wetland monitoring and assessment by 2013 with Level 3 sampling for ONE indicator taxa group. Numbers should be doubled for each additional taxa group.

work load	**year(s)**	**Scenario 1: NOMINAL +0 FTEs**	**Scenario 2: MINIMAL +2 FTEs**	**Scenario 3: PARTIAL +4 FTEs**	**Scenario 4: FULL +6 FTEs**
Continue current WPD grant commitments	2007-2009	YES	YES	YES	YES
Maintain 2007 Levels of 401 Program Technical Support: enforcement, litigation, MBRT reviews, permit reviews, WRRSP, ORAM reviews, Mitigation review, Rule Development, etc.)	2007+	NO	YES	YES	YES
Maintain 2007 Levels of ORAM and IBI Training	2007+	NO	YES	YES	YES
Pilot Integrated Wetland-Stream Assessment Project	2009-2010	YES	YES	YES	YES
Expanded Mitigation Assessment (Monitor 5-10% of "open" projects per year)	2008+	NO	YES	YES	YES
Number of New WPD Research Projects	2010, 2012	2	2	2	2
Degree to which full statewide monitoring and assessment can be achieved by 2013	2011+	NOMINAL 5 HUC11 every other year	MINIMAL 5 HUC11 each year	PARTIAL 10-15 HUC11 each year	FULL 25 HUC11 each year
	TOTAL FTEs	2	4	6	8

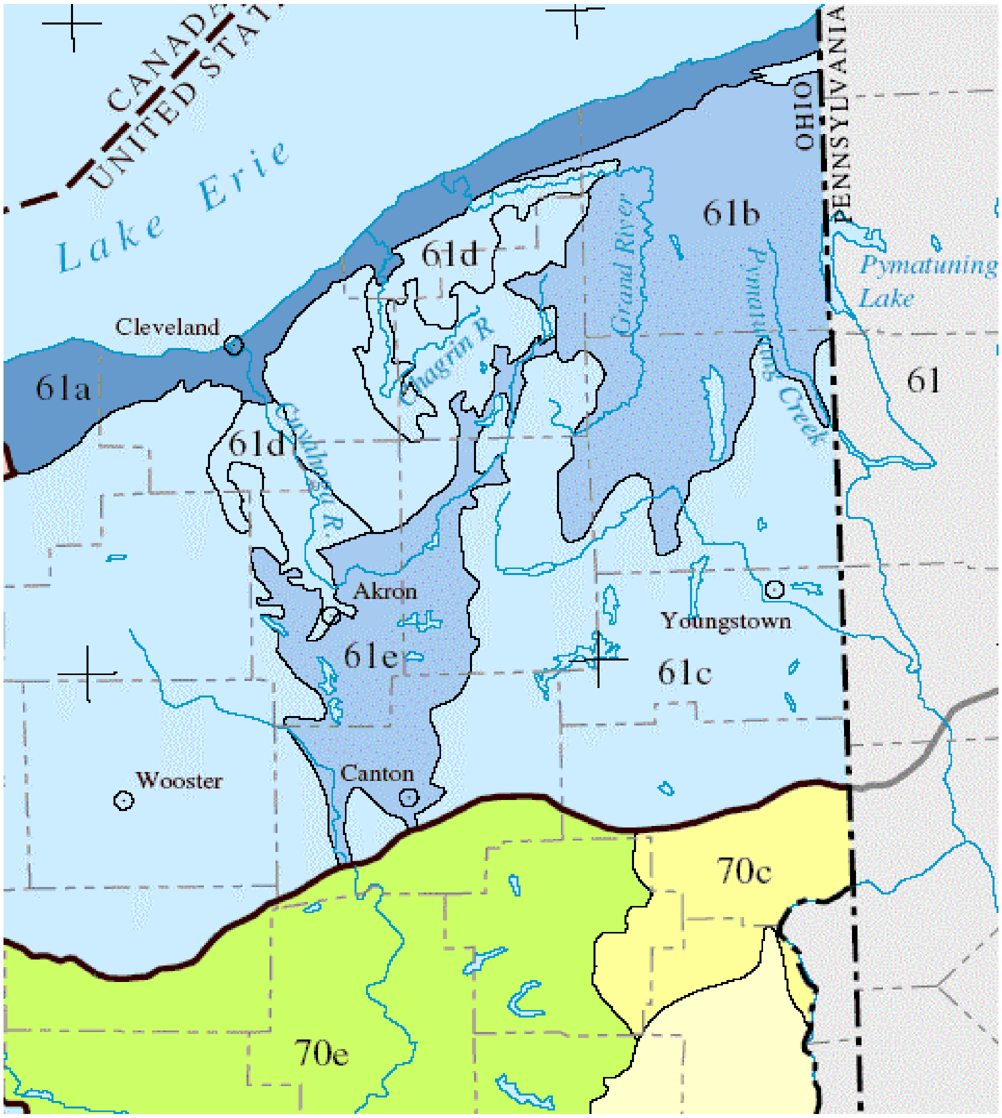


Figure 1. Ecoregions of the Cuyahoga Watershed and surrounding areas. Subregion 61a = Erie Lake Plain, 61b = Mosquito Creek/Pymatuning Lowlands, 61c = Low Lime Drift Plain, 61d = Erie Gorges, 61e = Summit Interlobate Area.

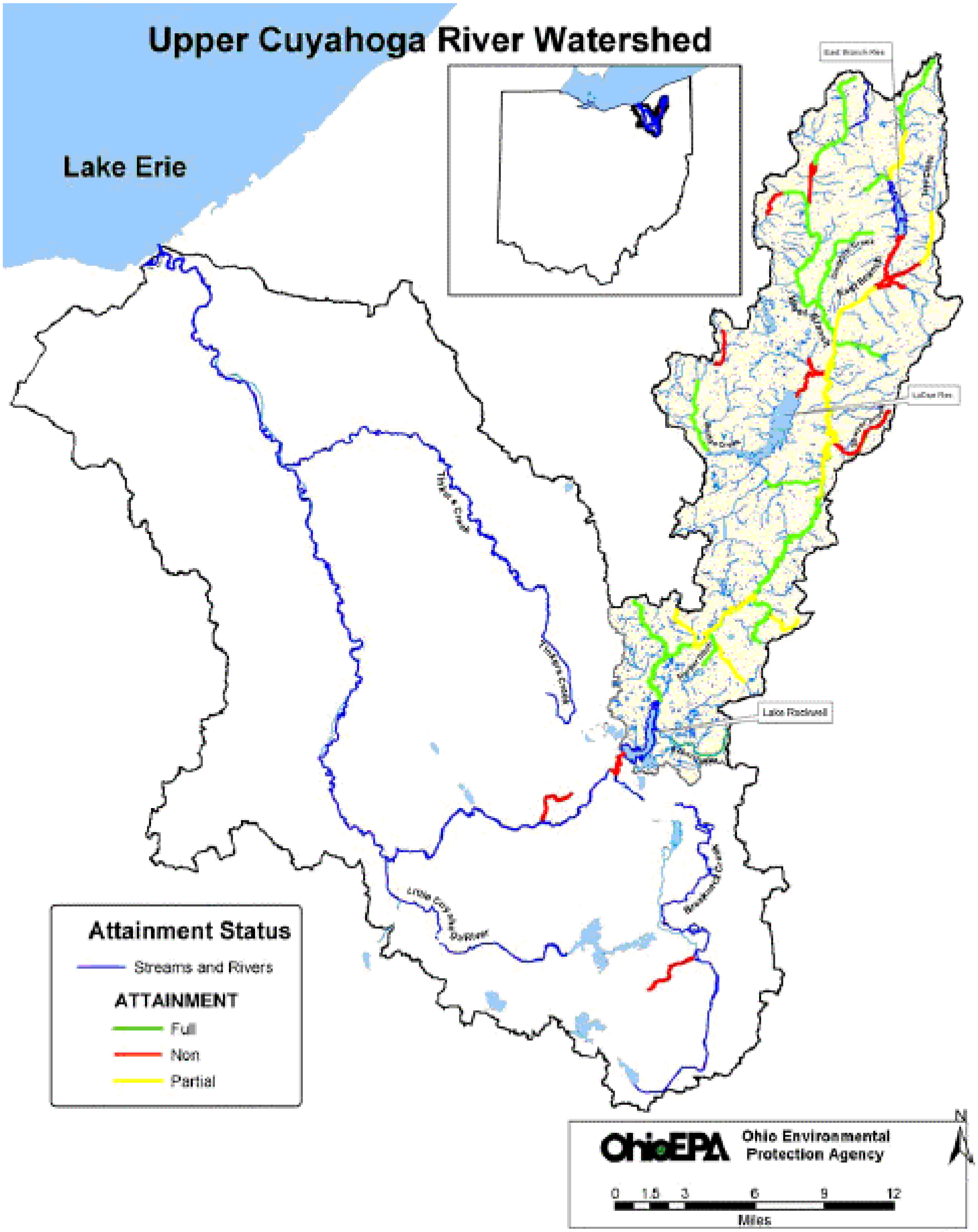


Figure 2. Upper Cuyahoga River Map and Attainment Status as of 2003. From *Total Maximum Daily Loads for the Upper Cuyahoga River Final Report September 2004*.

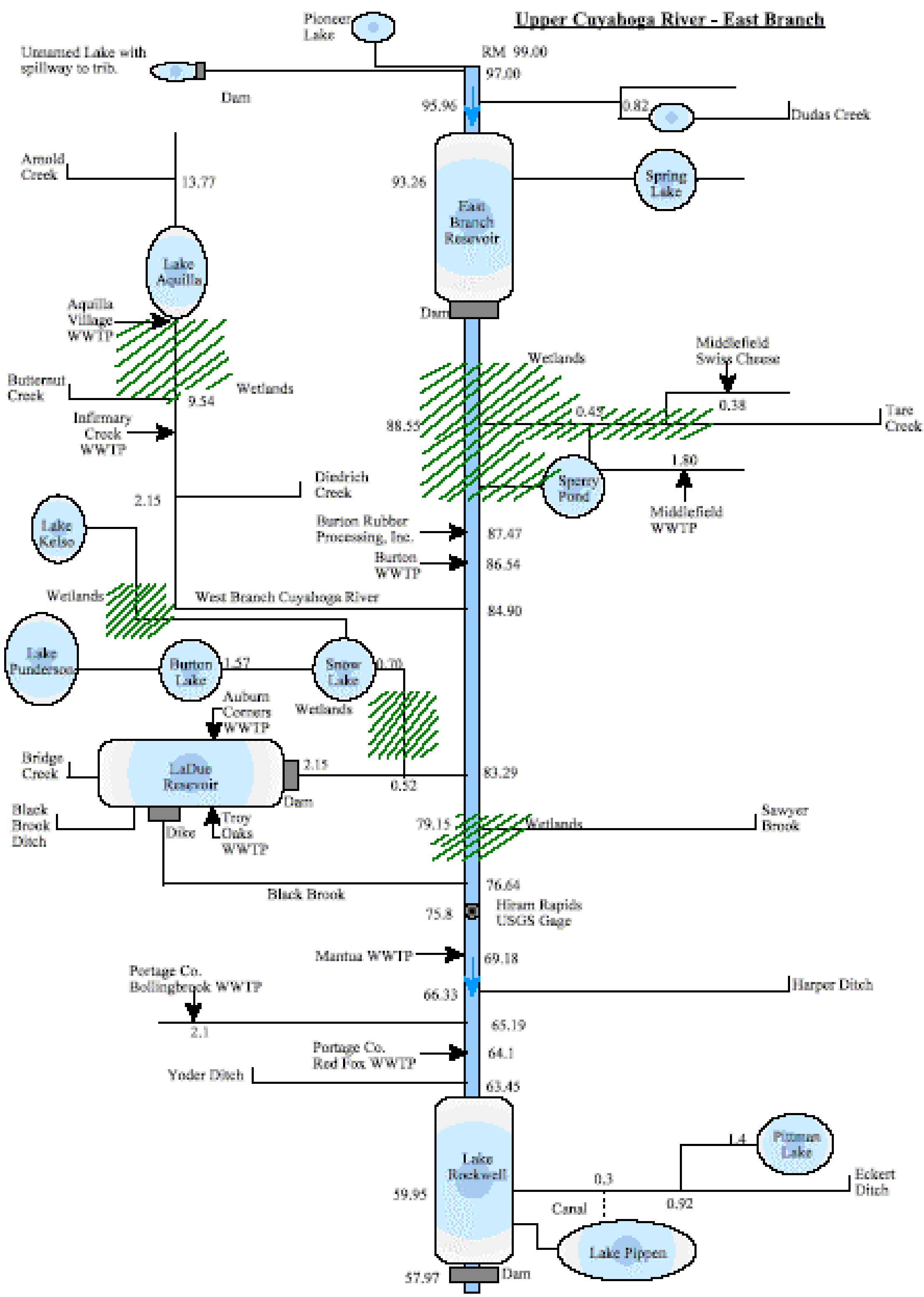


Figure 3. Schematic representation of Upper Cuyahoga River Watershed. From *Total Maximum Daily Loads for the Upper Cuyahoga River Final Report September 2004.*

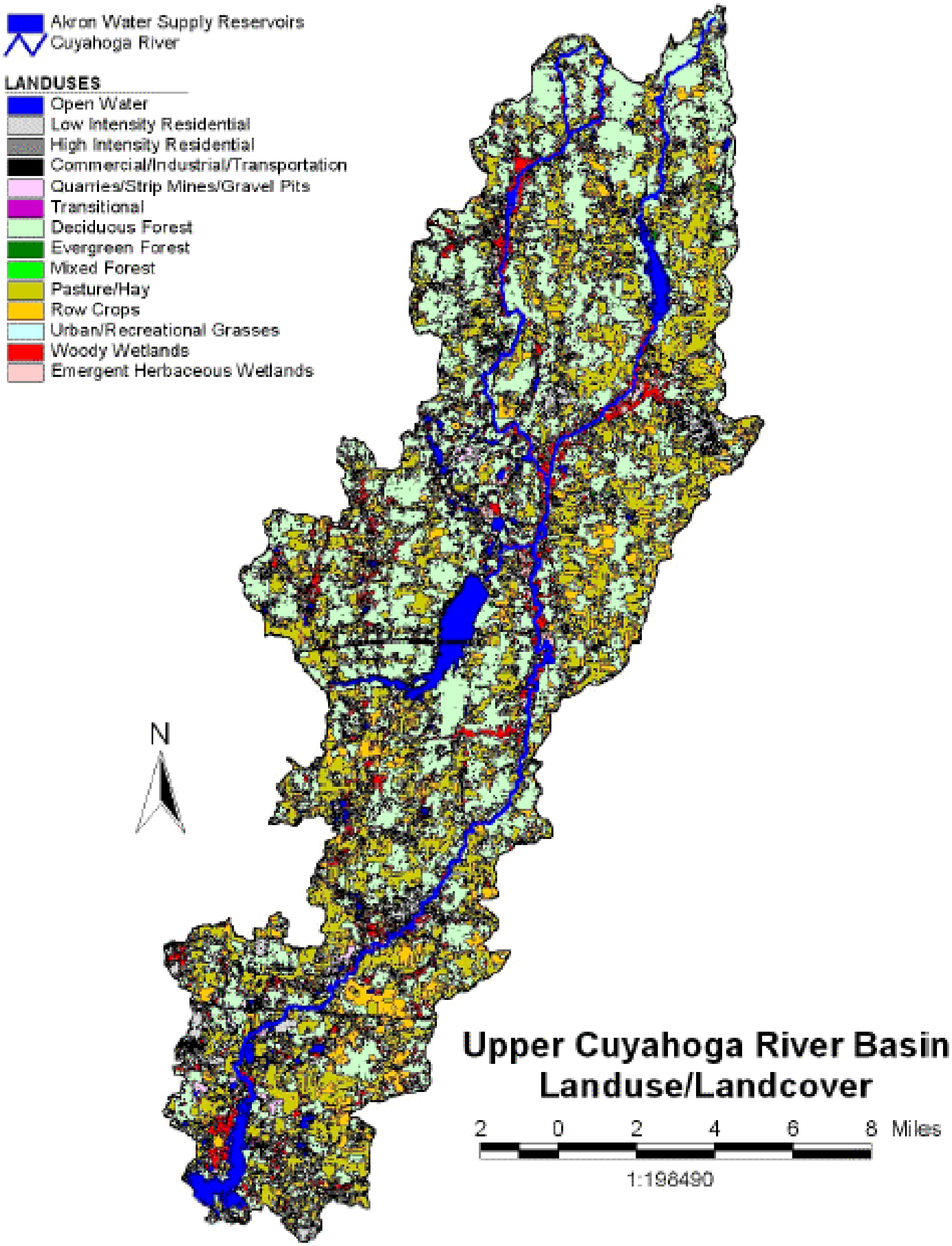


Figure 4. Land use/land cover of Upper Cuyahoga River Basin. From *Total Maximum Daily Loads for the Upper Cuyahoga River Final Report September 2004.*

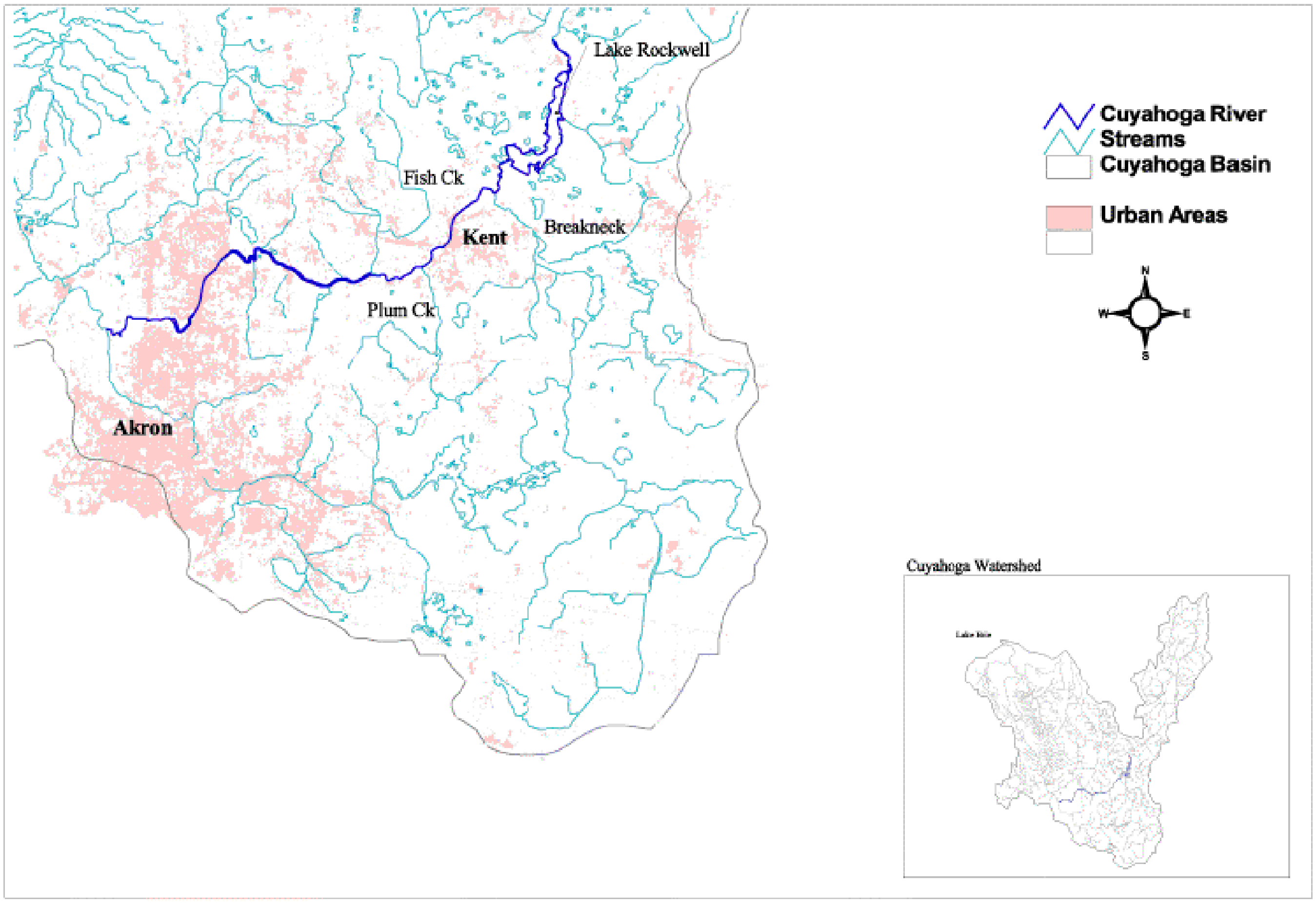


Figure 5. Middle Cuyahoga River. From *Total Maximum Daily Loads for the Middle Cuyahoga River Final Report March 2000*.

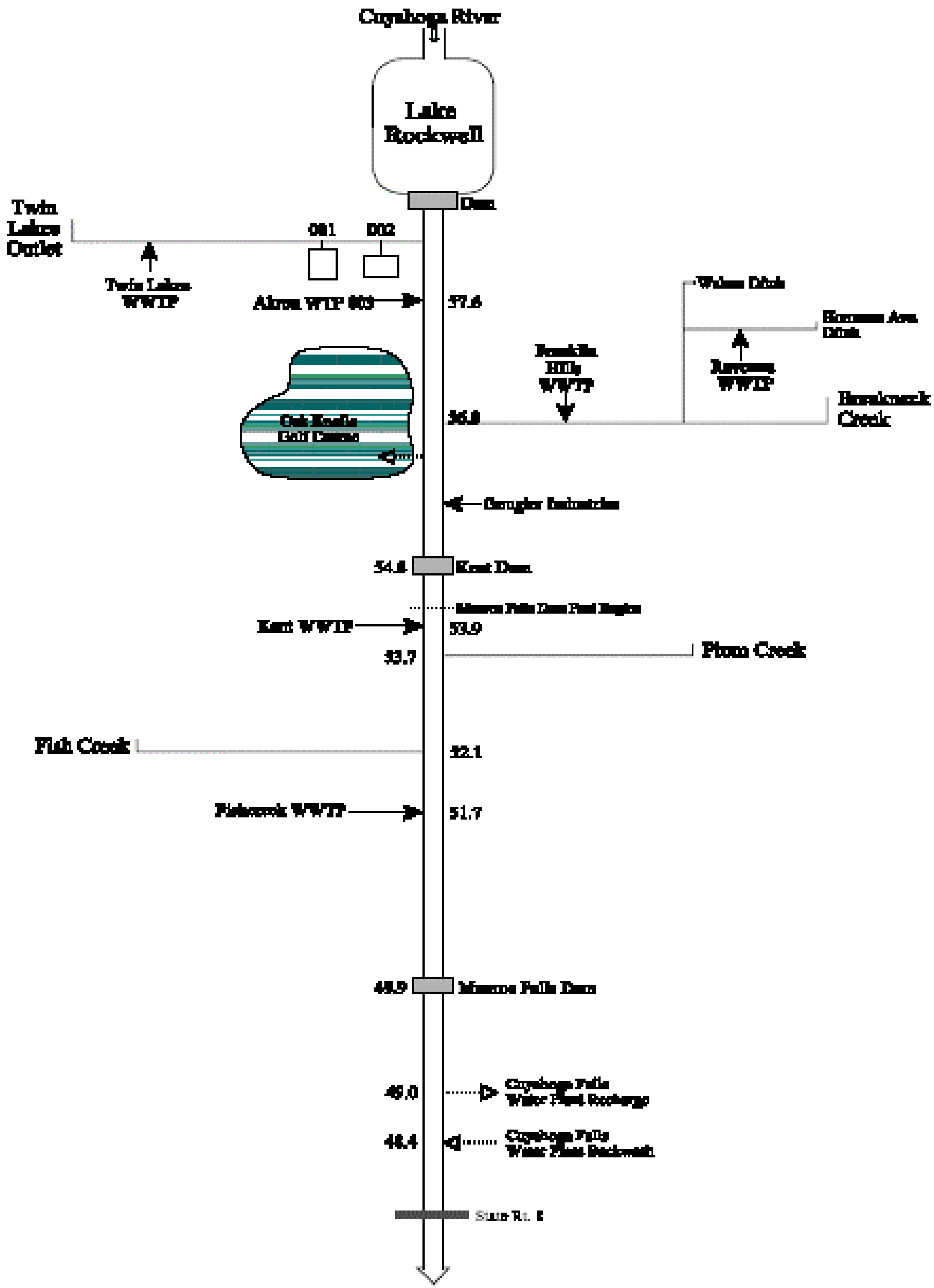


Figure 6. Schematic representation of Middle Cuyahoga River watershed. From *Total Maximum Daily Loads for the Middle Cuyahoga River Final Report March 2000*.

Figure 7. Land use/land cover in Middle Cuyahoga River Watershed. From *Total Maximum Daily Loads for the Middle Cuyahoga River Final Report March 2000*.

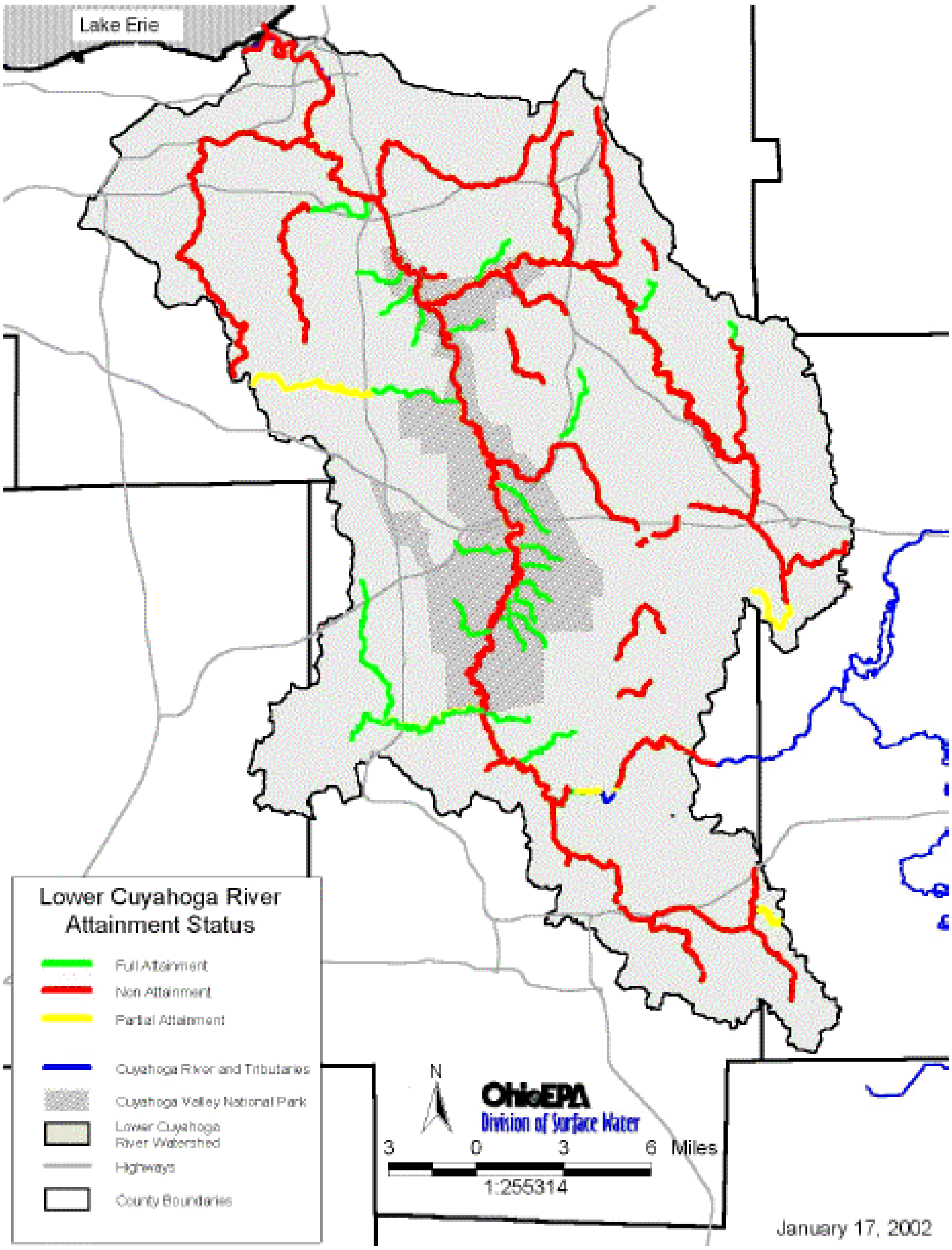


Figure 8. Lower Cuyahoga River Watershed. From *Total Maximum Daily Loads for the Lower Cuyahoga River Final Report September 2003*.

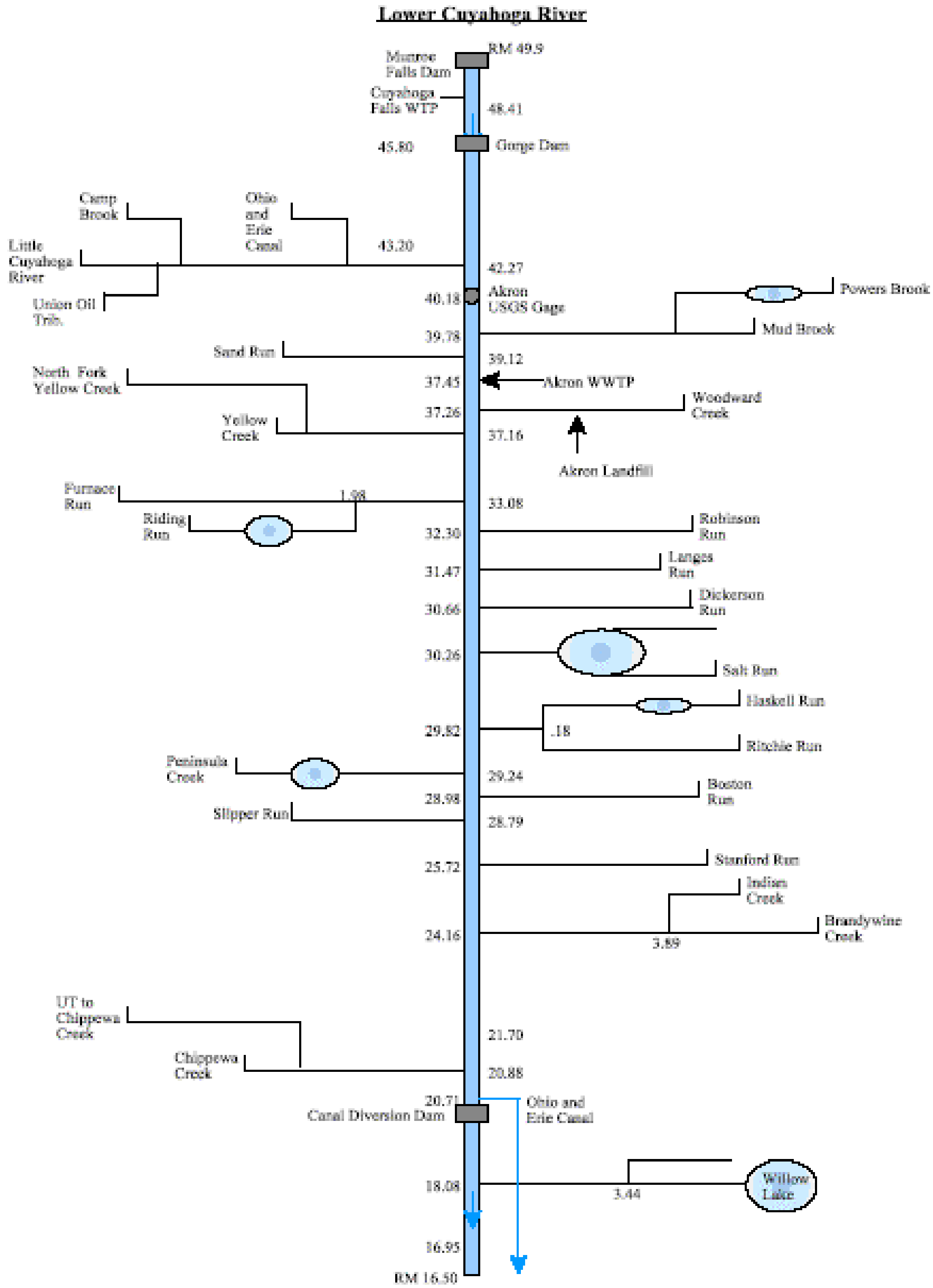


Figure 9a. Schematic representation of the Lower Cuyahoga River Watershed. From *Total Maximum Daily Loads for the Lower Cuyahoga River Final Report September 2003*.

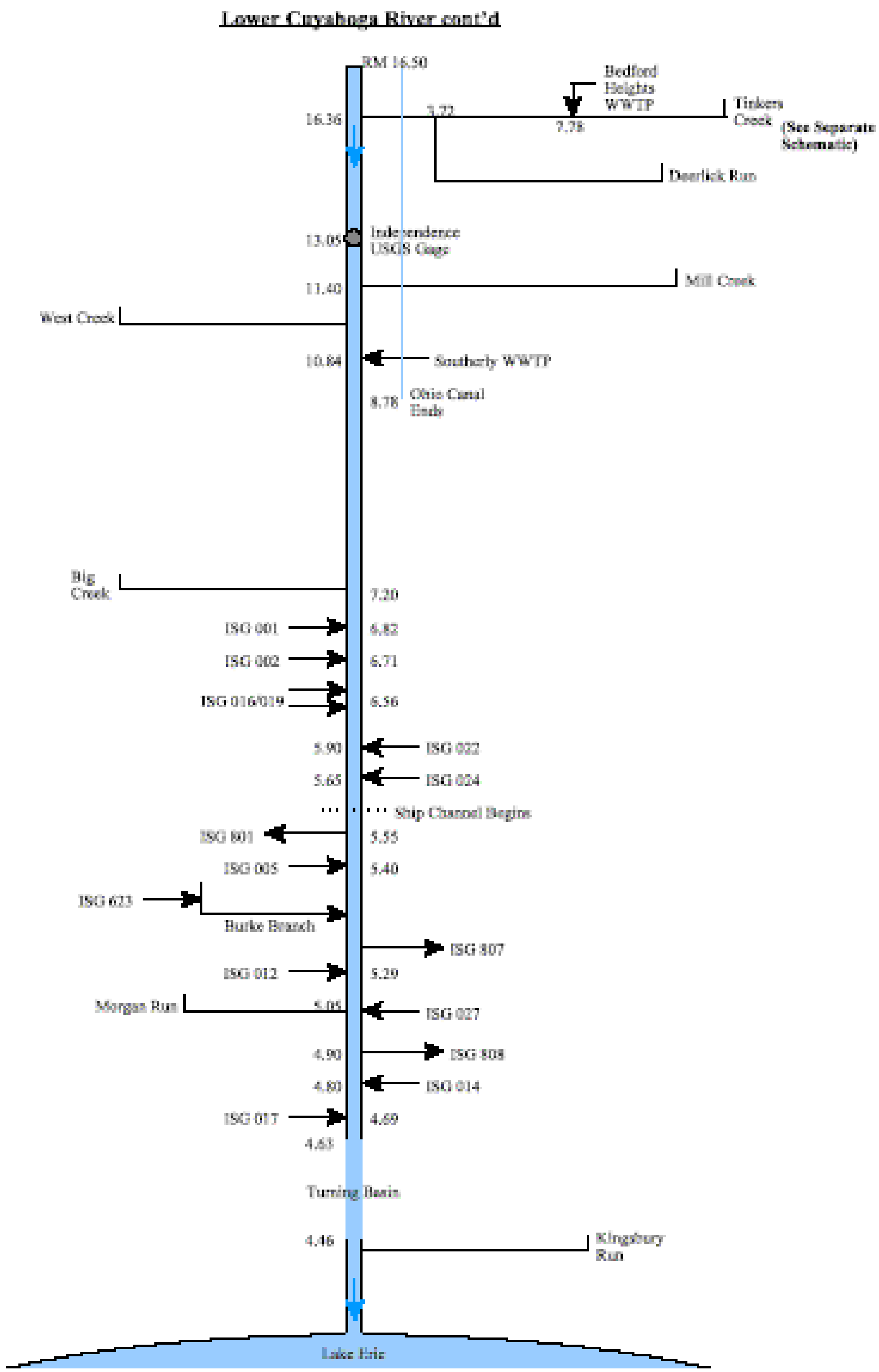


Figure 9b. Schematic representation of the Lower Cuyahoga River watershed. From *Total Maximum Daily Loads for the Lower Cuyahoga River Final Report September 2003*.

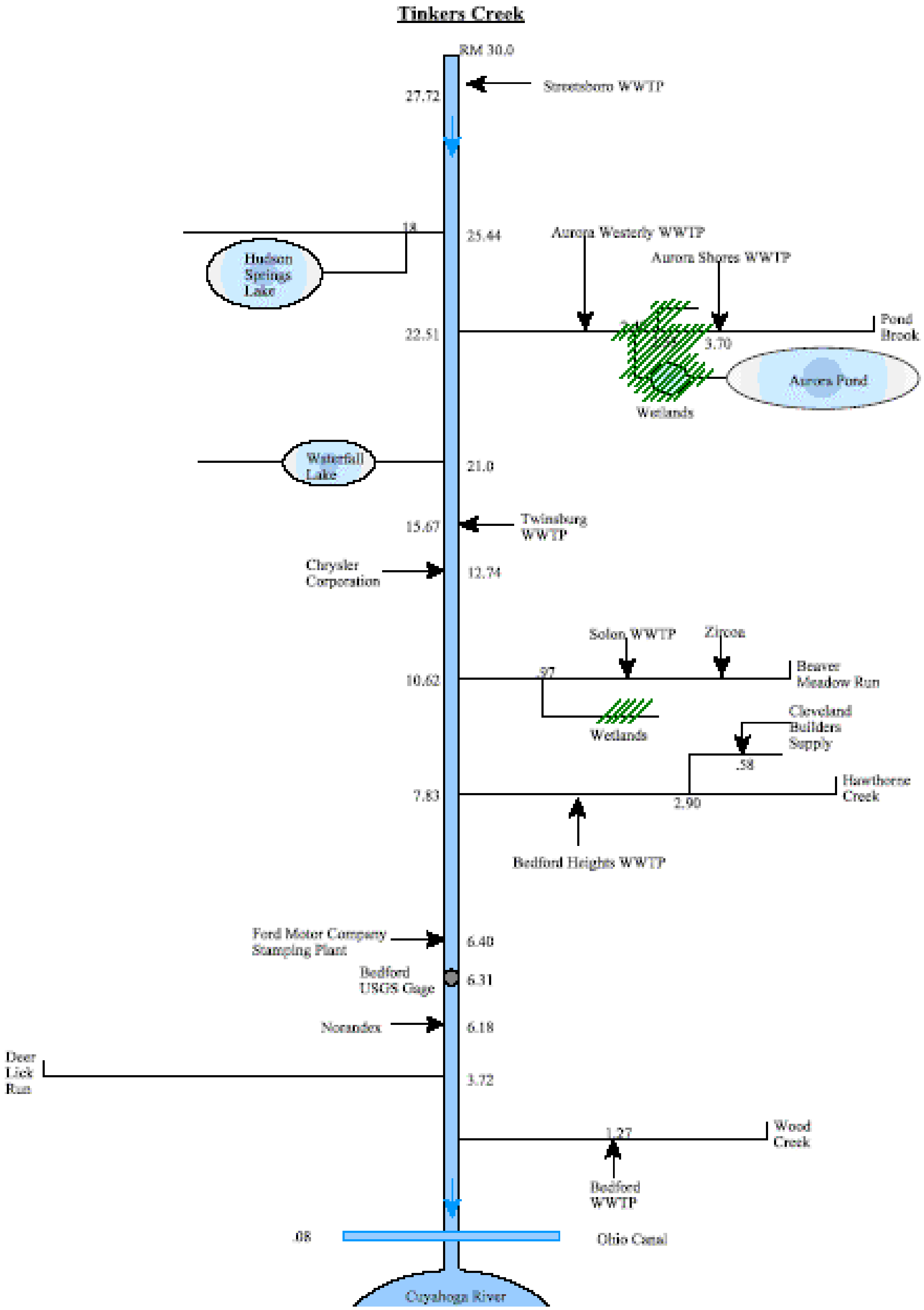


Figure 9c. Schematic representation of Tinkers Creek portion of Lower Cuyahoga River watershed. From *Total Maximum Daily Loads for the Lower Cuyahoga River Final Report September 2003*.

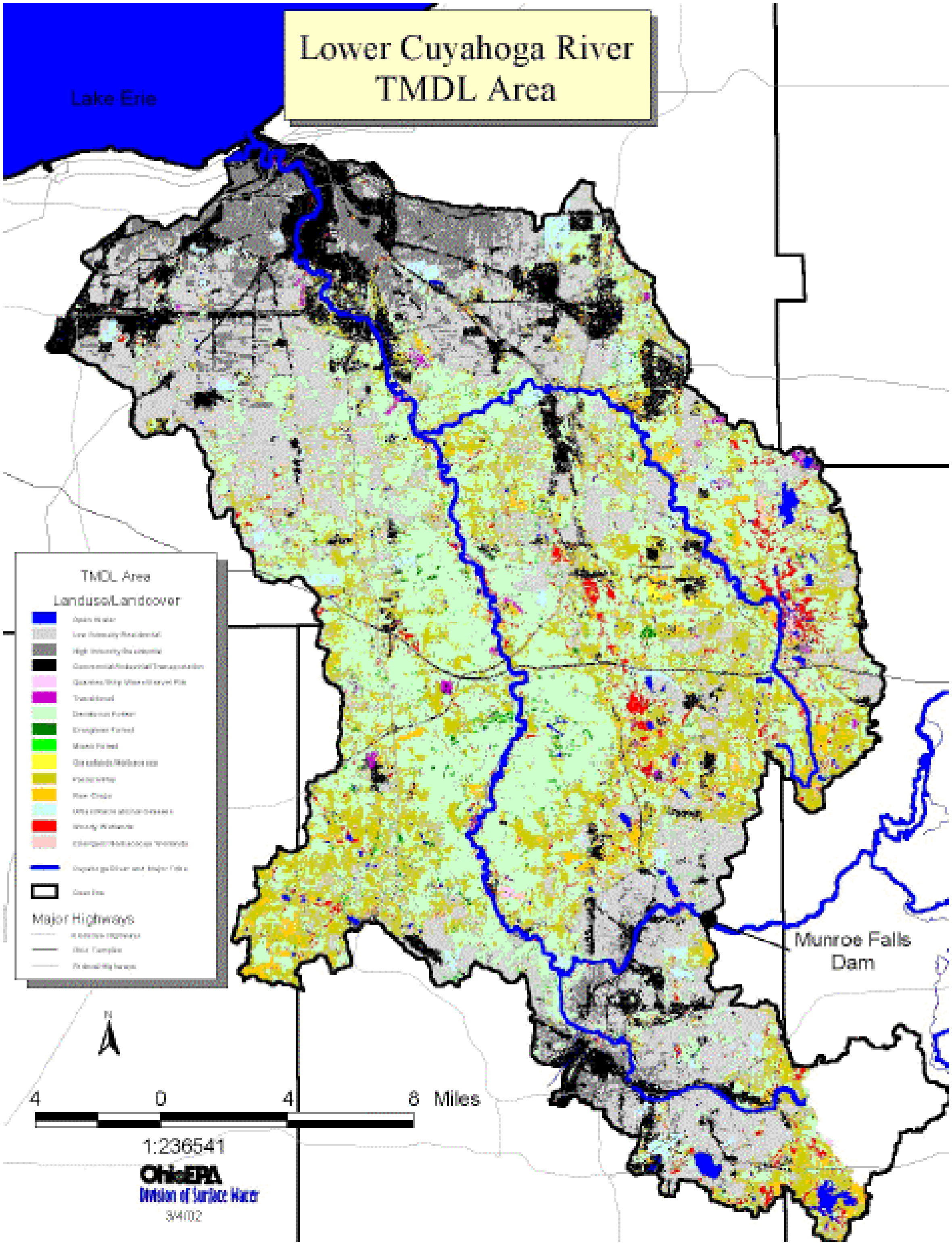


Figure 10. Land use/land cover in the Lower Cuyahoga River watershed. From *Total Maximum Daily Loads for the Lower Cuyahoga River Final Report September 2003*.

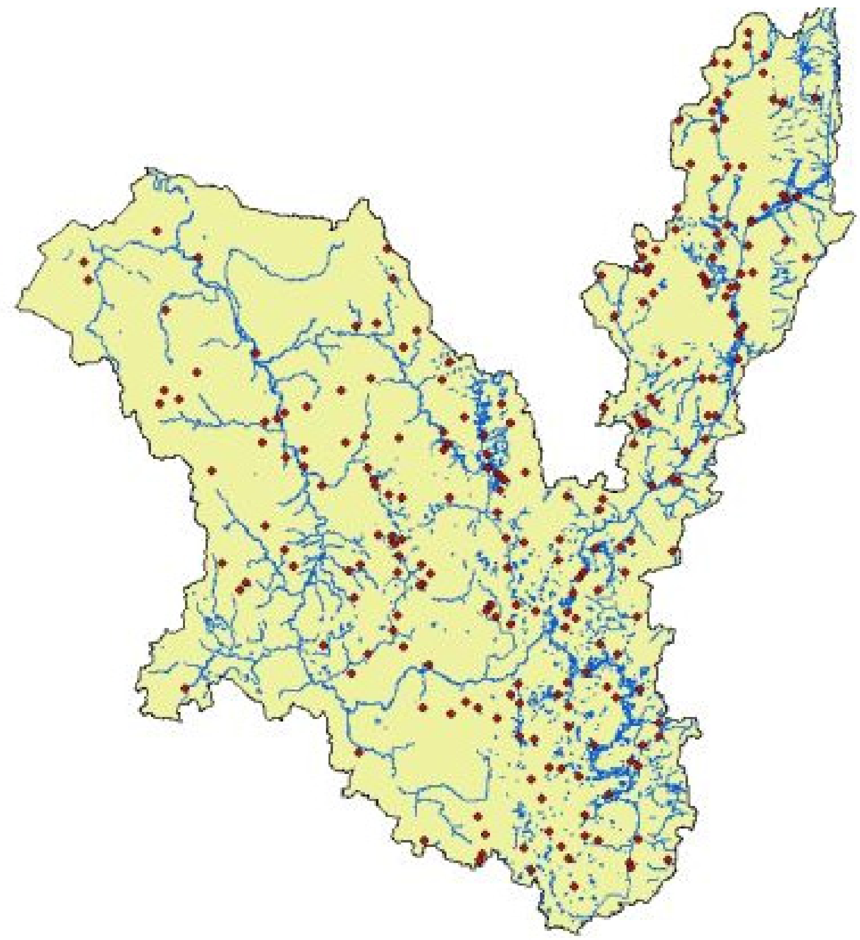


Figure 11. GRTS map showing the four hundred initial sampling points in the CRW of which 242 wetlands were evaluated (Mack and Fennessy 2005).

Figure 12. Preliminary examination of sample points was done using digital aerial photos, supplied by Cuyahoga, Summit, Portage and Geauga counties. These images had a one-meter ground resolution and were orthorectified. Each sample location was plotted on the airphoto and the land use at that point examined. Points were excluded from further consideration if it was clear that a wetland no longer existed at that point.

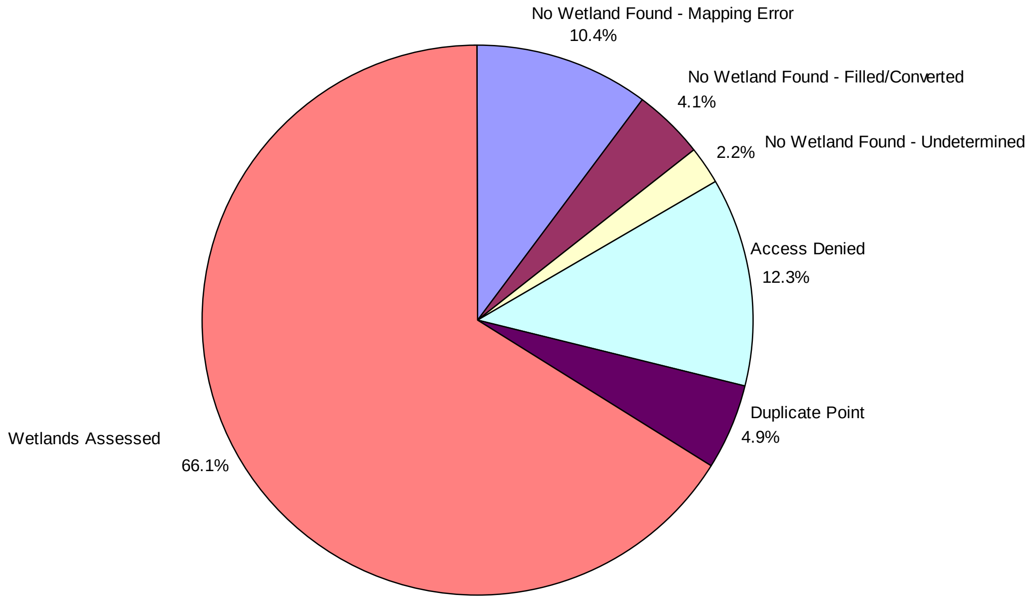


Figure 13. The fate of wetland points included in this study, including wetlands sampled using ORAM (n = 242) and level 3 techniques (n = 26), duplicate points (more than one sampling point was dropped in a single wetland assessment area, n = 18), access to the site was denied by landowners (n = 45), and no wetland was at the point or within 60 m of it and this was due to mapping errors in the OWI (n = 38), filling/conversion of a mapped wetland (n = 8), or the cause was unable to be determined (n = 15).

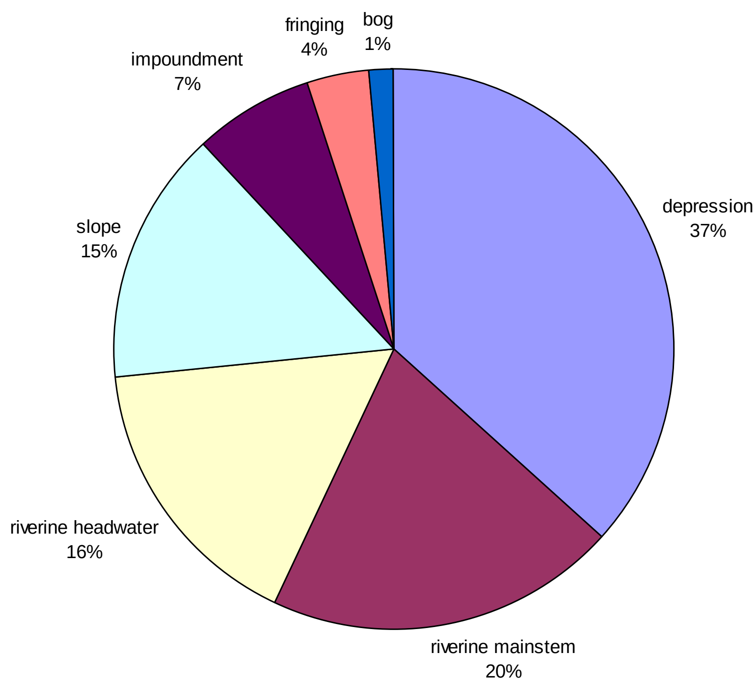


Figure 14. The distribution of wetlands over the seven HGM classes (sensu Brinson 1993).

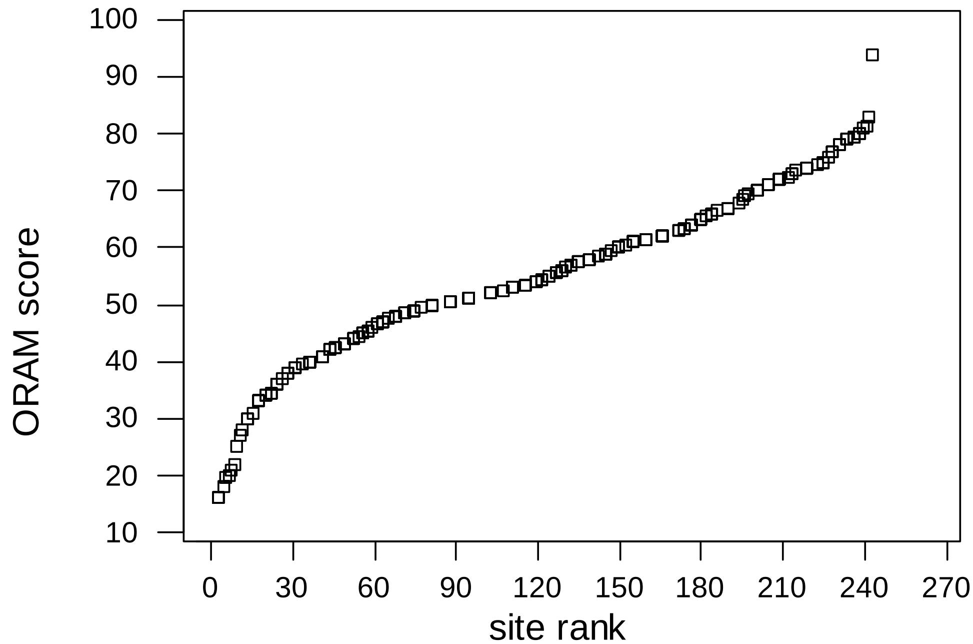


Figure 15. Plot showing all sites sampled ordered by ORAM score. The ORAM scoring range is 0 to 100; sites sampled in this probabilistic design ranged from scores of 16 to 94.

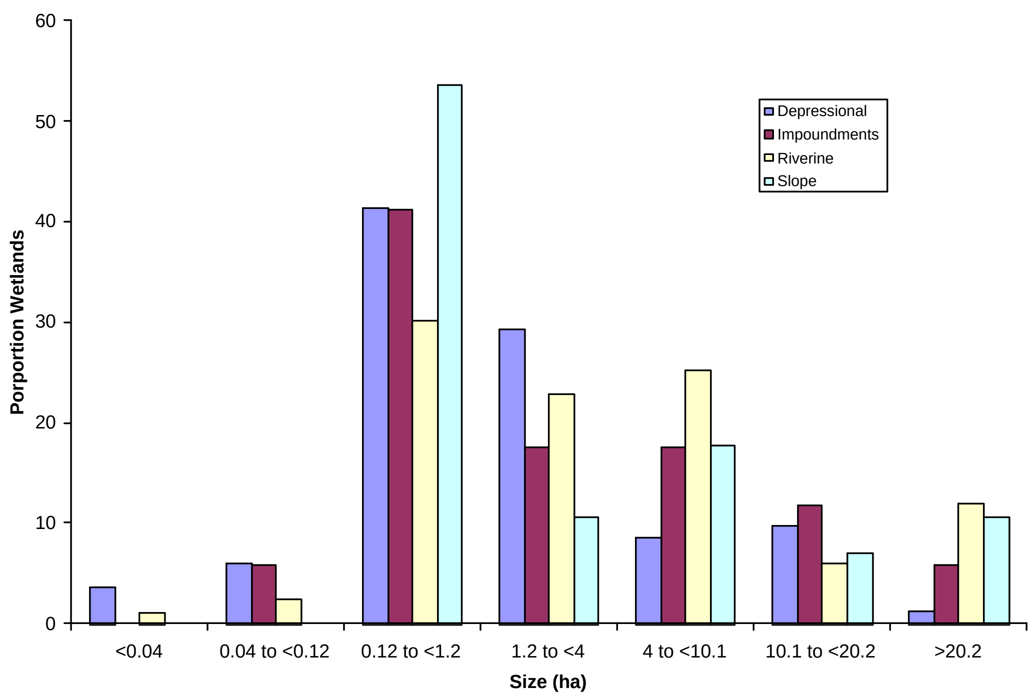


Figure 16. The size distribution of wetlands within major HGM classes. Note the large percentage of all wetlands within the size category 0.12 to <1.2 ha.

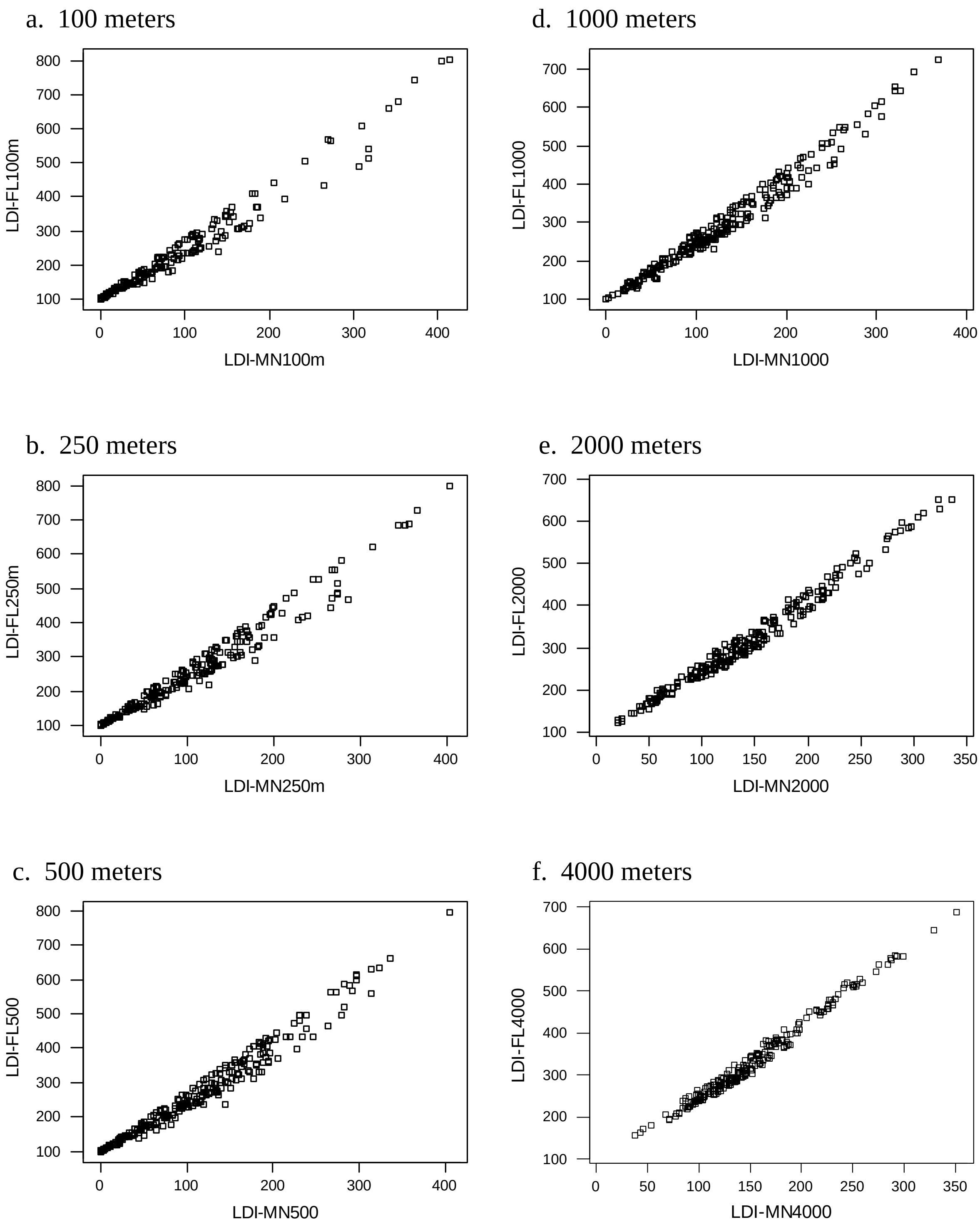


Figure 17. Scatterplots of LDI score calculated from Minnesota coefficients (LDI-MN) and LDI score calculated from Florida coefficients (LDI-FL) for different buffer distances (100 m, 250 m, 500 m, 1000 m, 2000 m, 4000 m). All $R^2 > 96.9\%$ and $p < 0.001$.

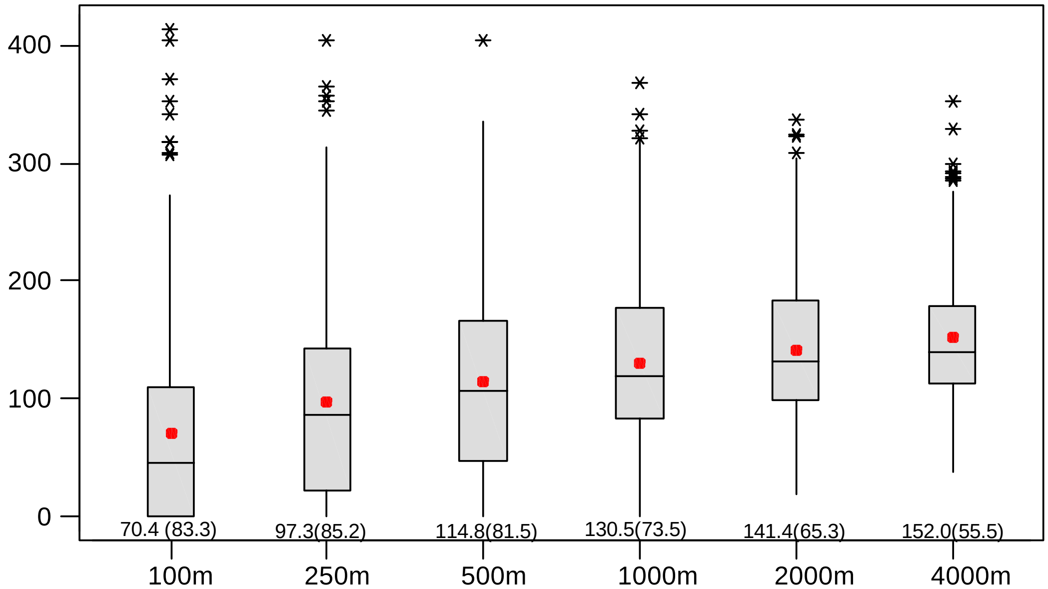


Figure 18. Box and whisker plots of mean (standard deviation) LDI scores (using Minnesota coefficients) for each buffer distance (n = 233, df = 5, F = 38.01, p = 0.000).

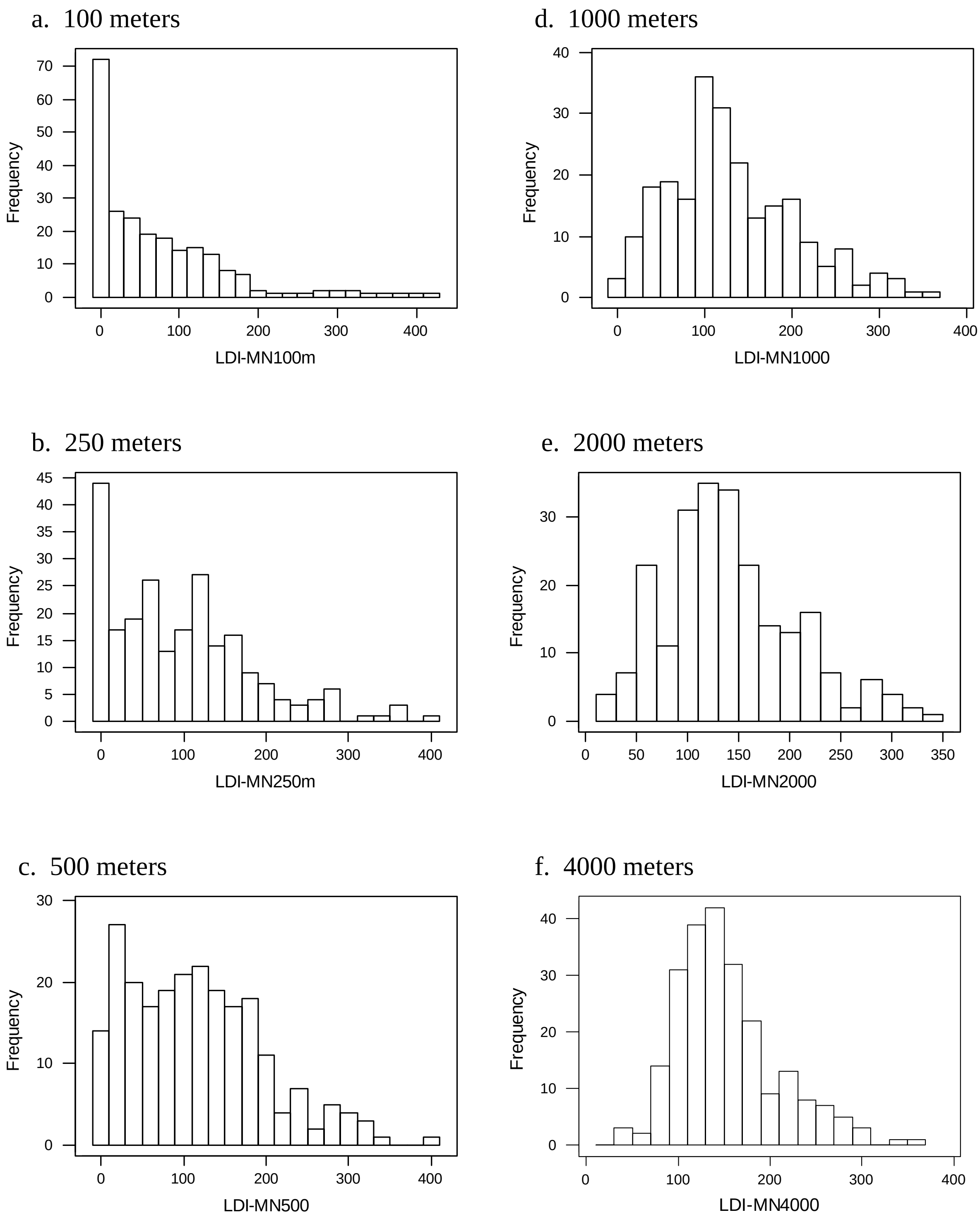


Figure 19. Histograms of LDI scores (Minnesota coefficients) by different buffer distances (100 m, 250 m, 500 m, 1000 m, 2000 m, 4000 m).

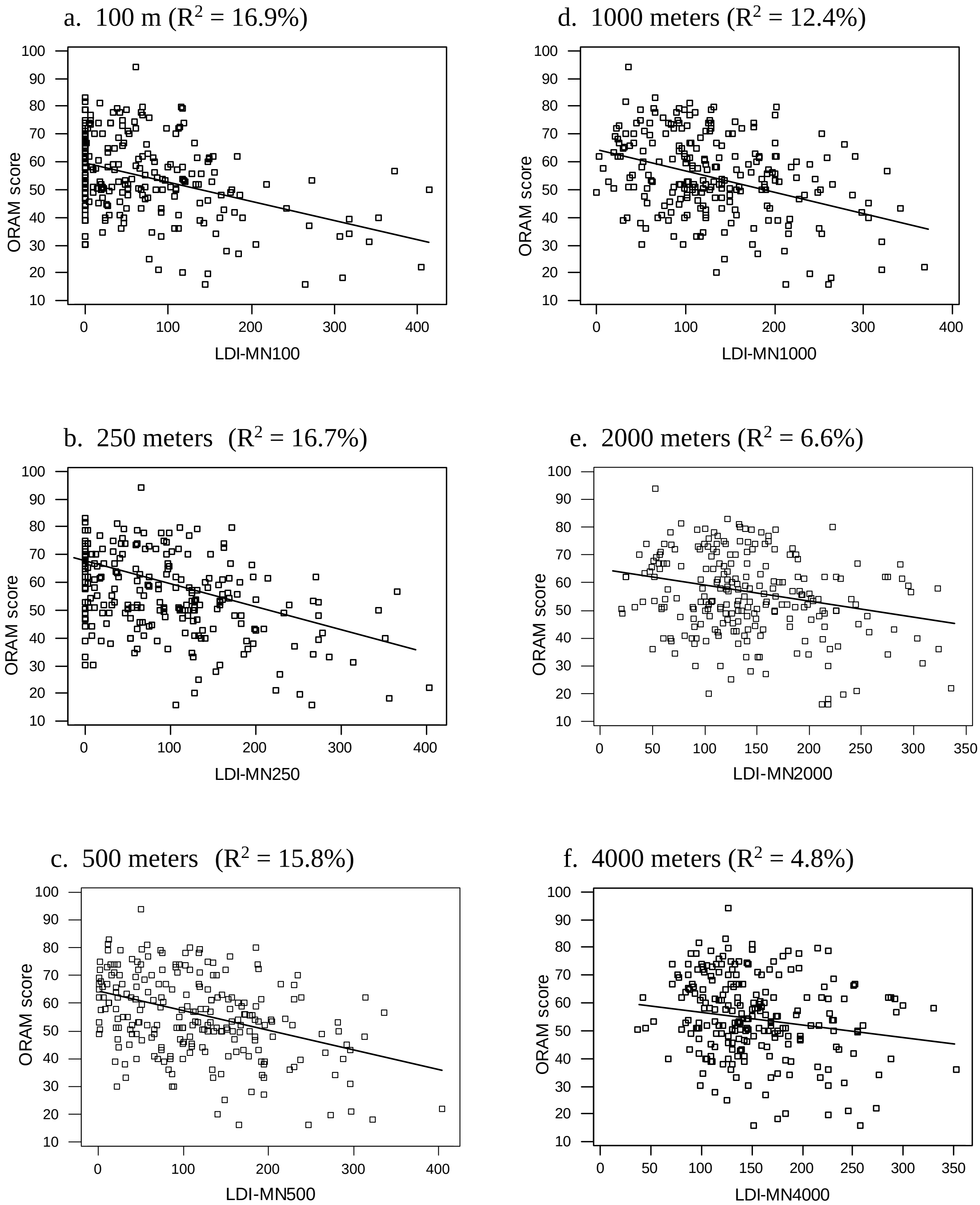


Figure 20. Scatterplots (and regression line) of LDI scores (Minnesota coefficients) and ORAM scores (df = 232, $p < 0.001$).

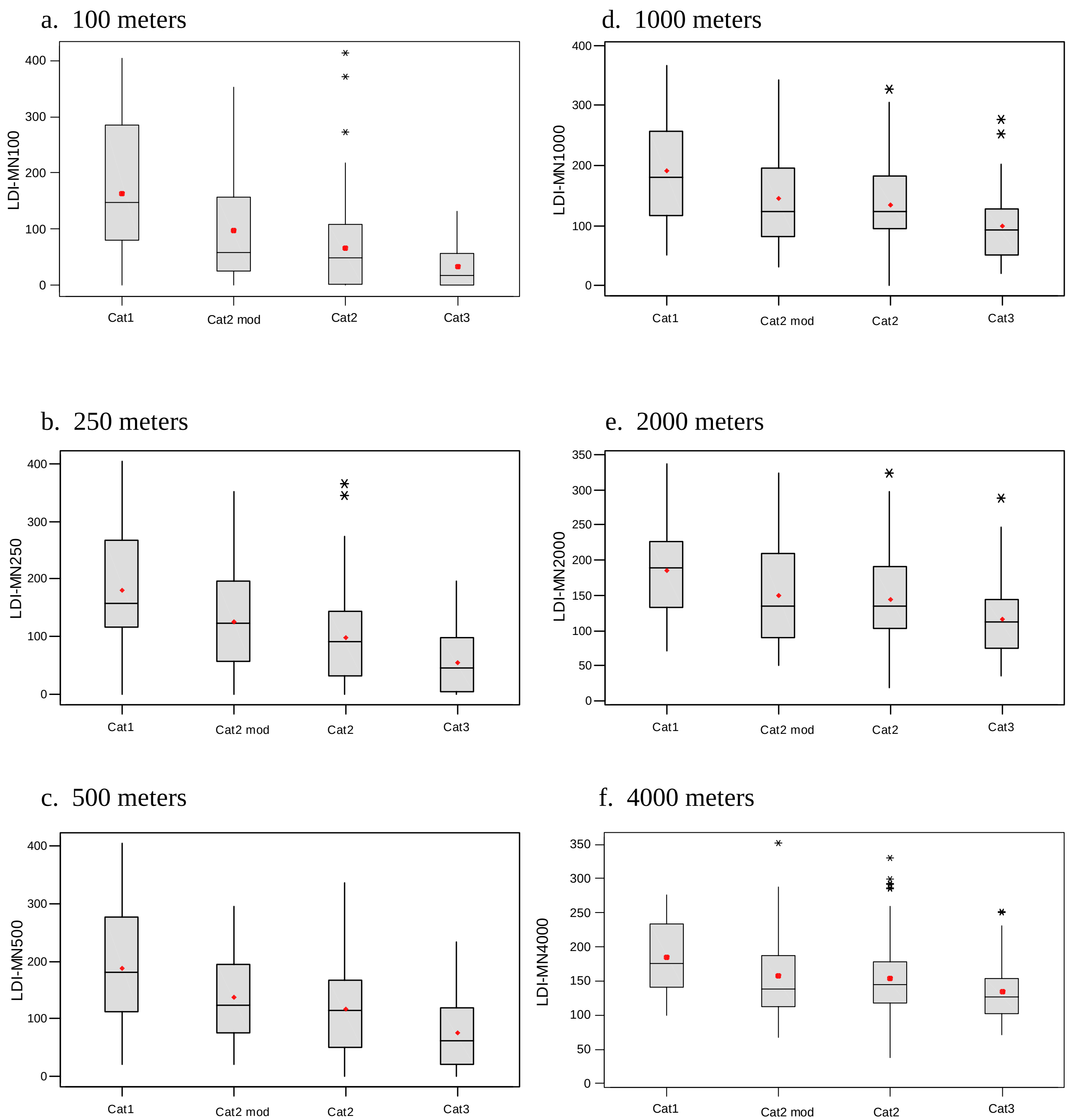


Figure 21. Box and whisker plots of LDI scores (Minnesota coefficients) for different wetland condition categories at different buffer distances (100 m, 250 m, 500 m, 1000 m, 2000 m, 4000 m).

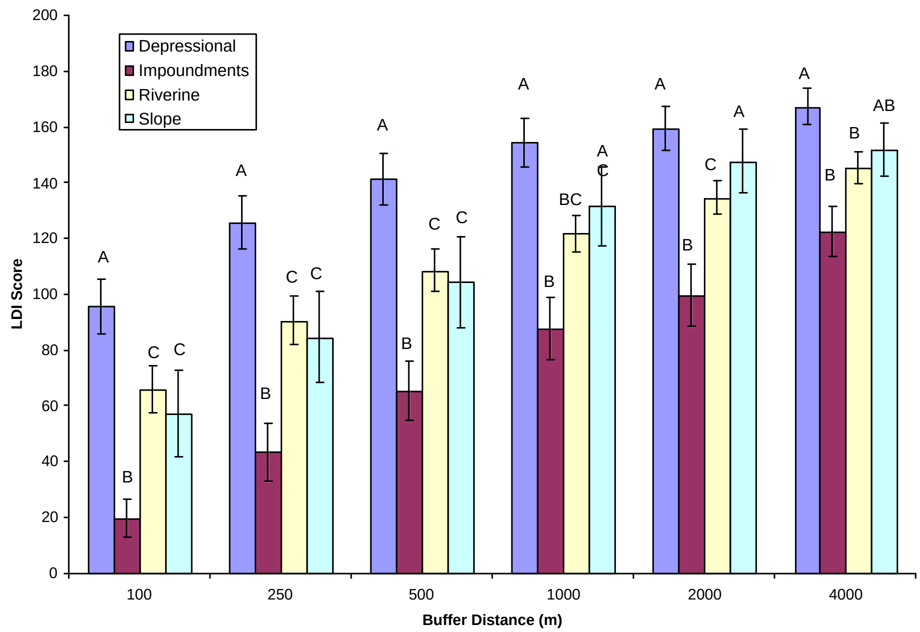


Figure 22. Mean LDI scores (using Minnesota coefficients) for each buffer distance stratified by HGM class. Different letters indicate statistically significant differences between HGM classes for that buffer distance (letters indicate significant differences for different HGM classes for each buffer distance). Error bars are the standard error of the mean (ANOVA, 100 m: F=5.17, p=0.002; 250 m: F=6.14, p=0.001; 500 m: F=5.65, p=0.001; 1000 m: F=5.55, p=0.001; 2000 m: F=5.09, p=0.002; 4000 m: F=4.28, p=0.006.

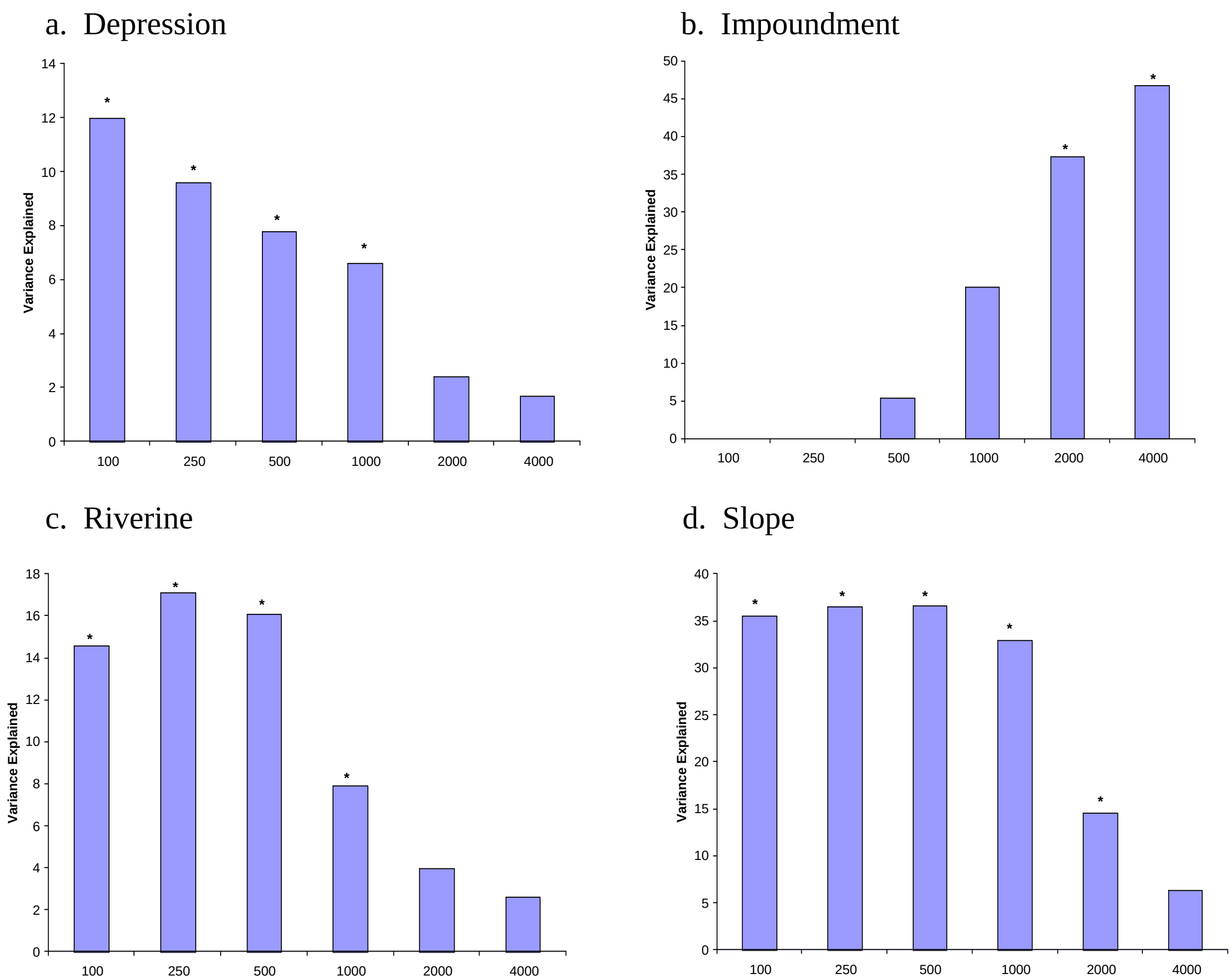


Figure 23. Percent variance explained (y-axis) in ORAM scores calculated from regression analyses showing the predictability of ORAM scores by LDI scores (based on MN coefficients) for each buffer distance (x-axis). (a) depressional, (b) impoundments, (c) riverine, and (d) slope (* denotes significant values as determined by $p<0.05$ in the regression analyses).

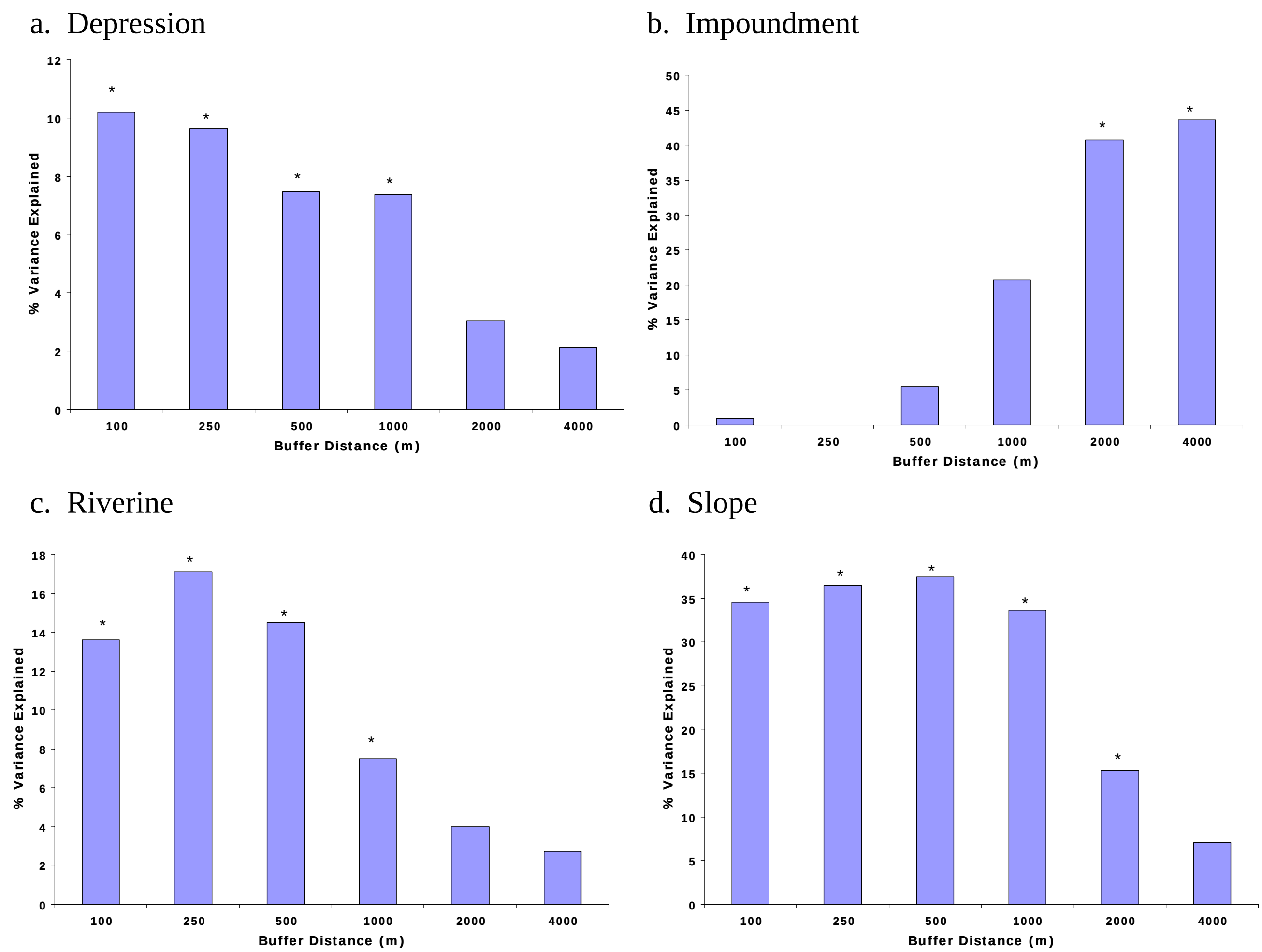


Figure 24A. Percent variance explained in ORAM scores (y-axis) calculated from regression analyses showing the predictability of ORAM scores by LDI score (FL coefficients) for each buffer distance (x-axis). (a) depressional, (b) impoundments, (c) riverine, (d) slope (* denotes significant values as determined by p<0.05 from analyses of variance).

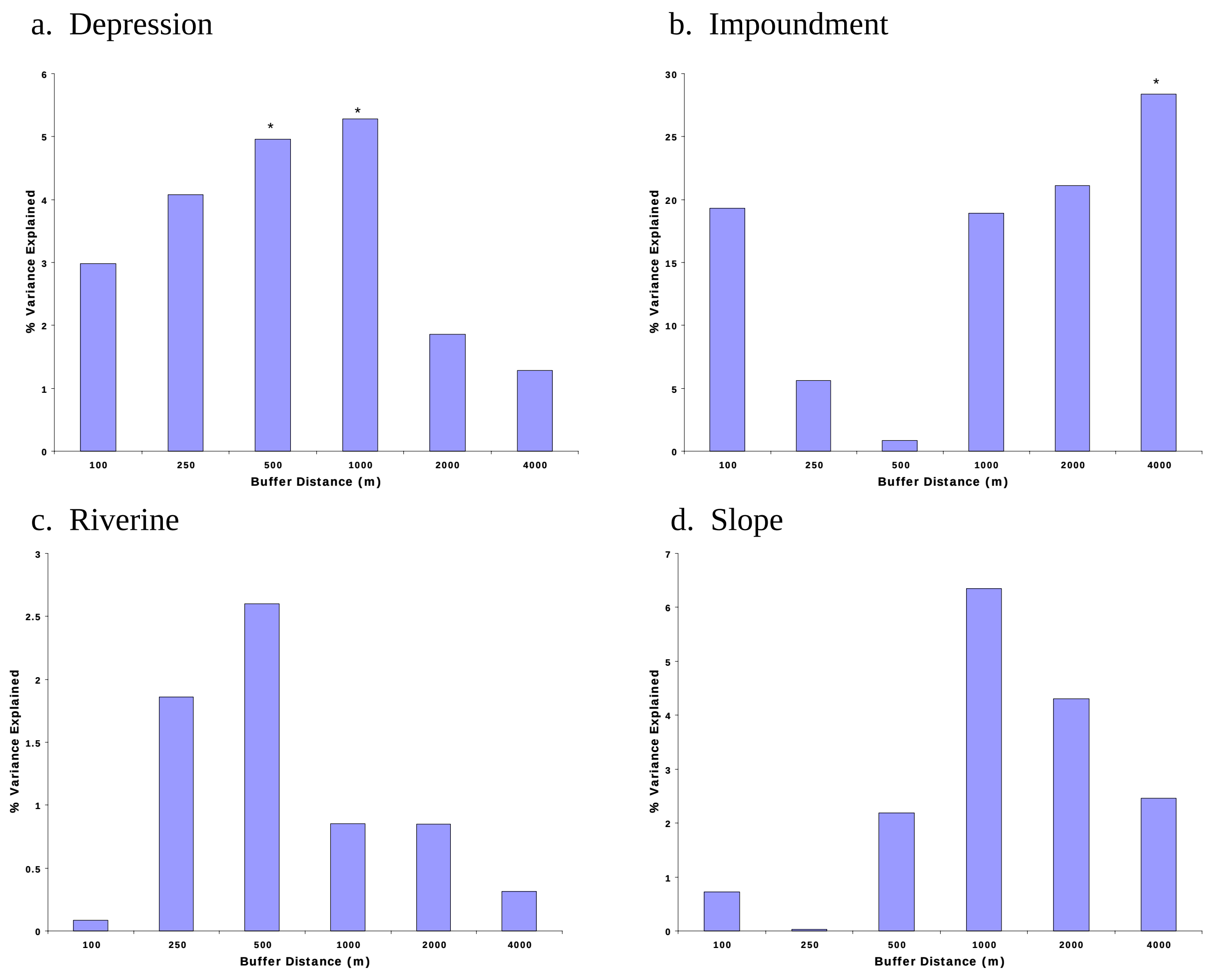


Figure 24B. Percent variance explained in ORAM scores (y-axis) calculated from regression analyses showing the predictability of ORAM scores by the proportion of forest in each buffer distance (x-axis). (a) depressional, (b) impoundments, (c) riverine, (d) slope (* denotes significant values as determined by $p<0.05$ from analyses of variance).

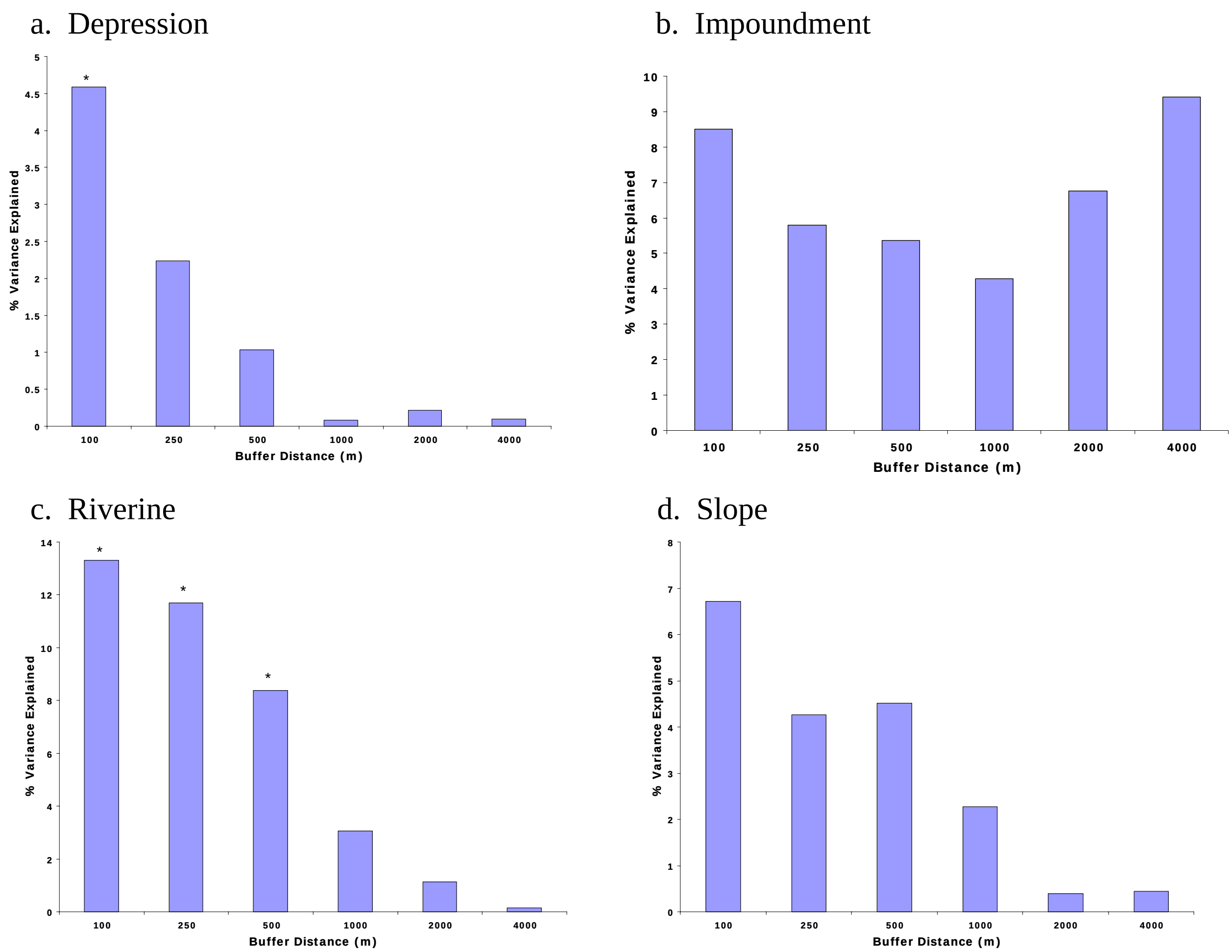


Figure 24C. Percent variance explained in ORAM scores (y-axis) calculated from regression analyses showing the predictability of ORAM scores by the proportion of agricultural/pastoral land in each buffer distance (x-axis). (a) depressional, (b) impoundments, (c) riverine, (d) slope (* denotes significant values as determined by $p<0.05$ from analyses of variance).

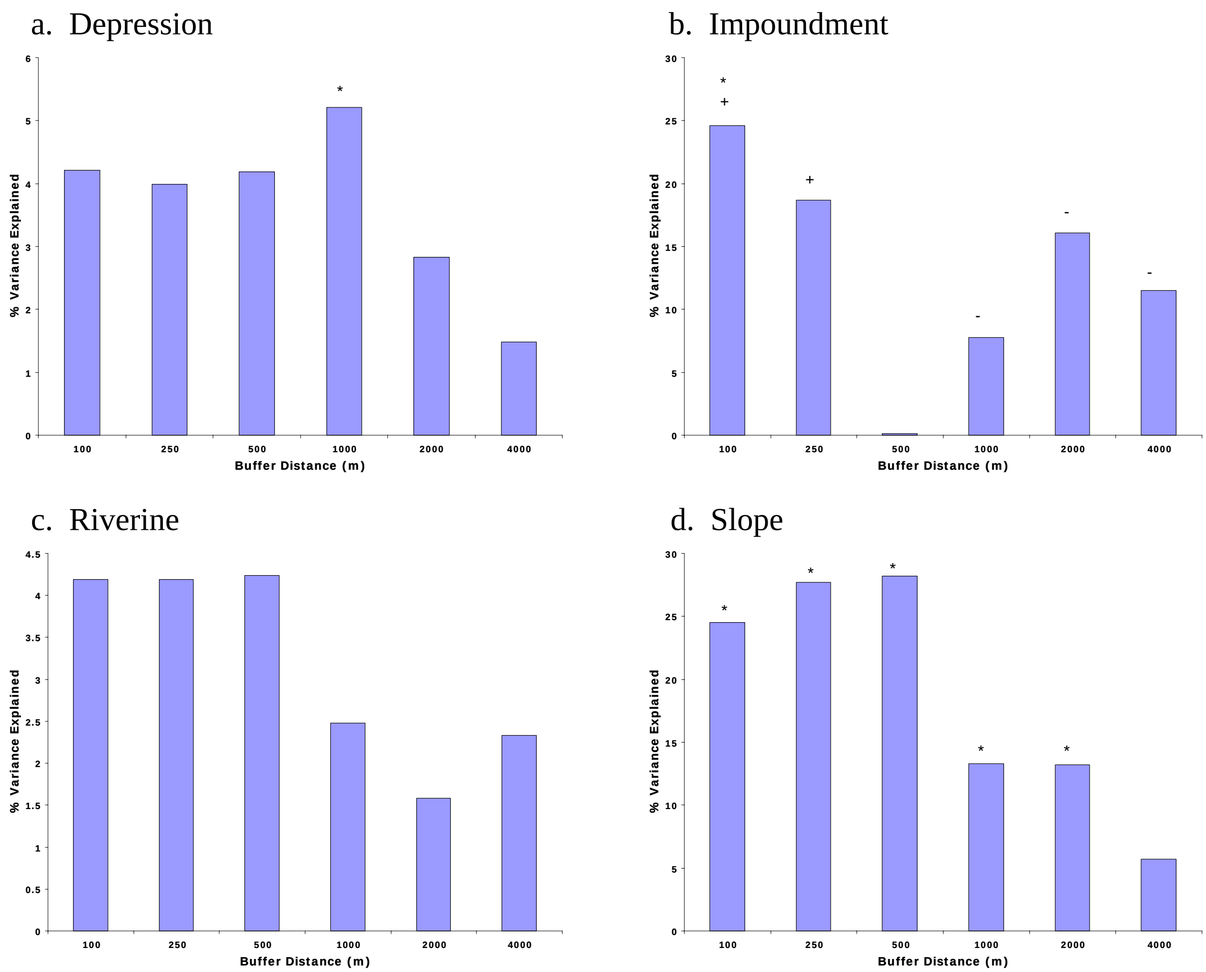


Figure 24D. Percent variance explained in ORAM scores (y-axis) calculated from regression analyses showing the predictability of ORAM scores by the proportion of urban/residential land in each buffer distance (x-axis). (a) depressional, (b) impoundments – note the change from a positive slope to negative slope at 1000 m, (c) riverine, (d) slope (* denotes significant values as determined by $p<0.05$ from analyses of variance).

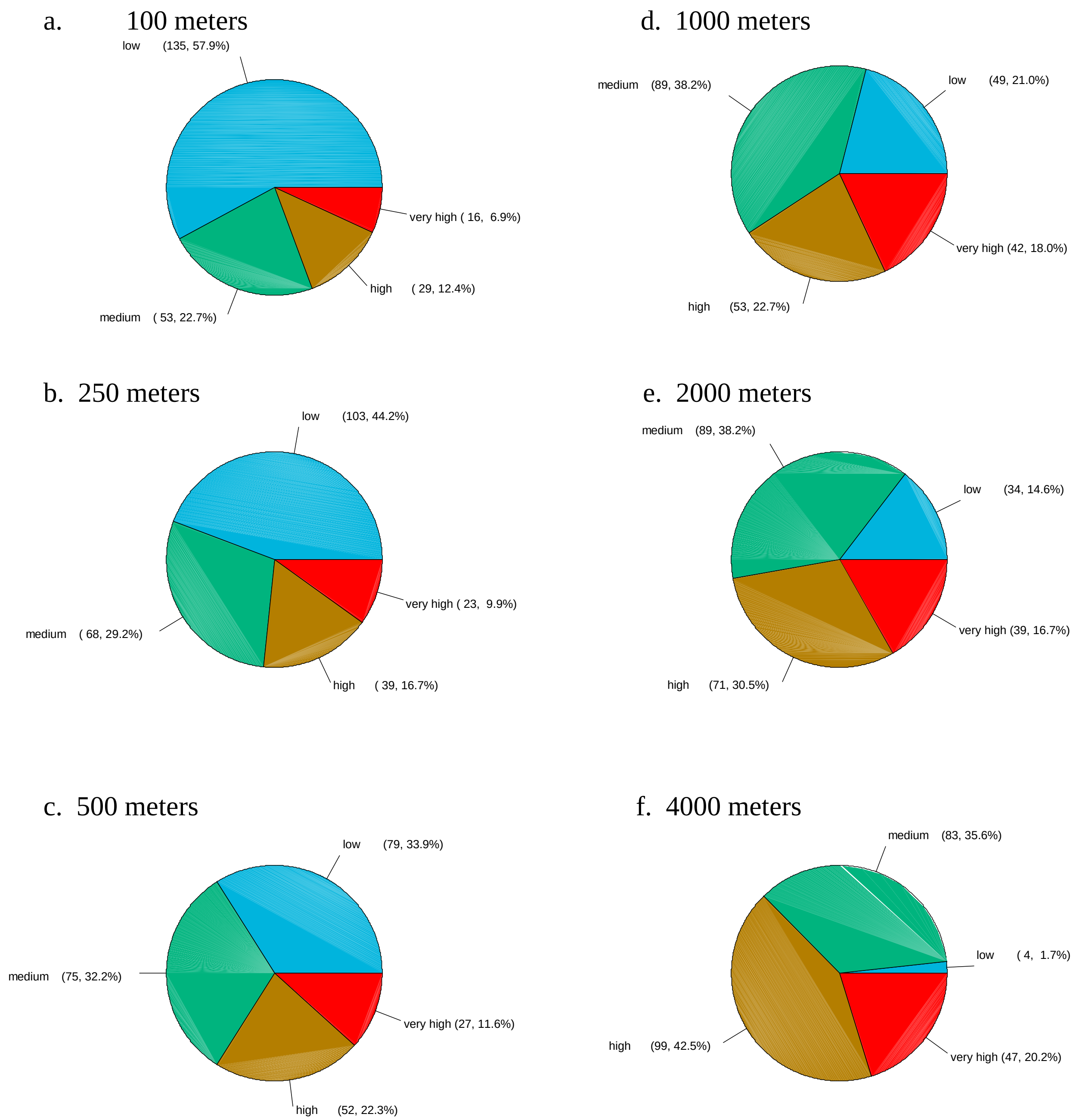


Figure 25. Pie charts of LDI scores (Minnesota coefficients) for different buffer distances (100 m, 250 m, 500 m, 1000 m, 2000 m, 4000 m). "Low", "medium", "high", and "very high" refer to the intensity of the land uses within the buffer distance. Low = 0-99, medium = 100-199, high = 200-299, very high = 300+.

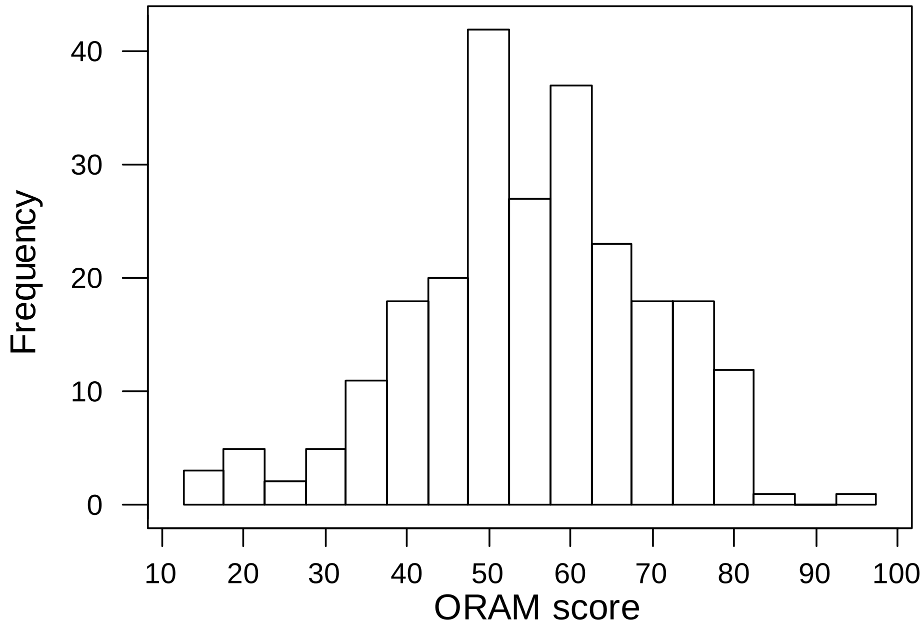


Figure 26A. Frequency histogram of ORAM scores. The ORAM scoring range is 0 to 100; sites sampled in this probabilitic design ranged from scores of 16 to 94.

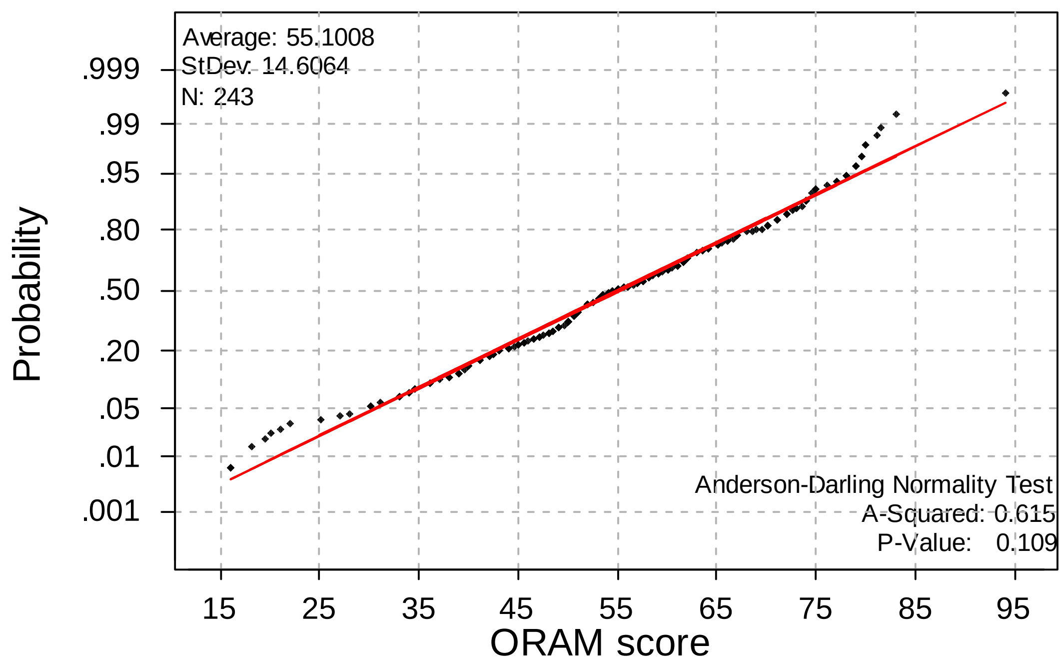


Figure 26B. Probability plot and Anderson-Darling Normality Test.

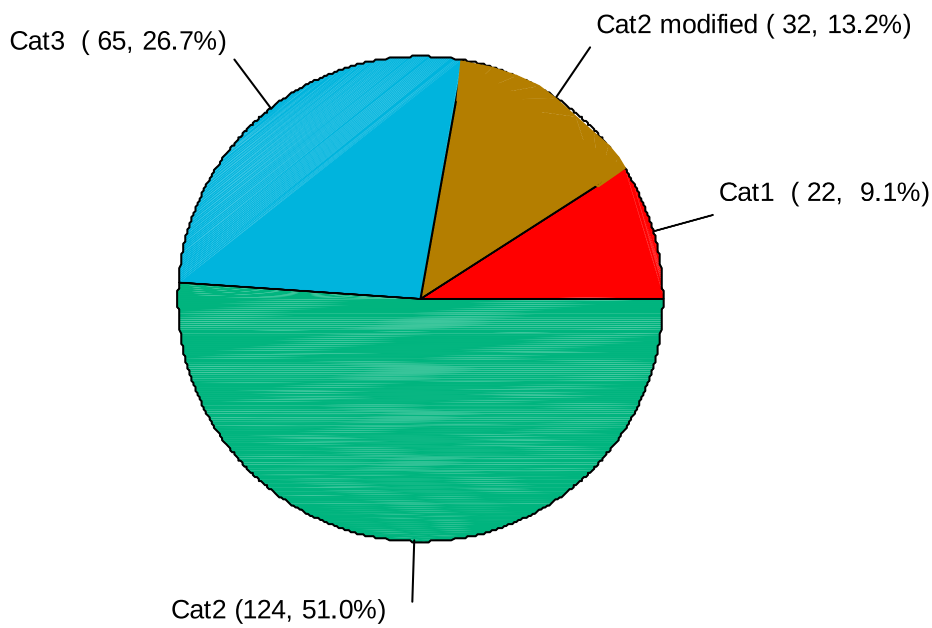


Figure 27A. The distribution of individual wetlands across the wetland category scheme (n=243).

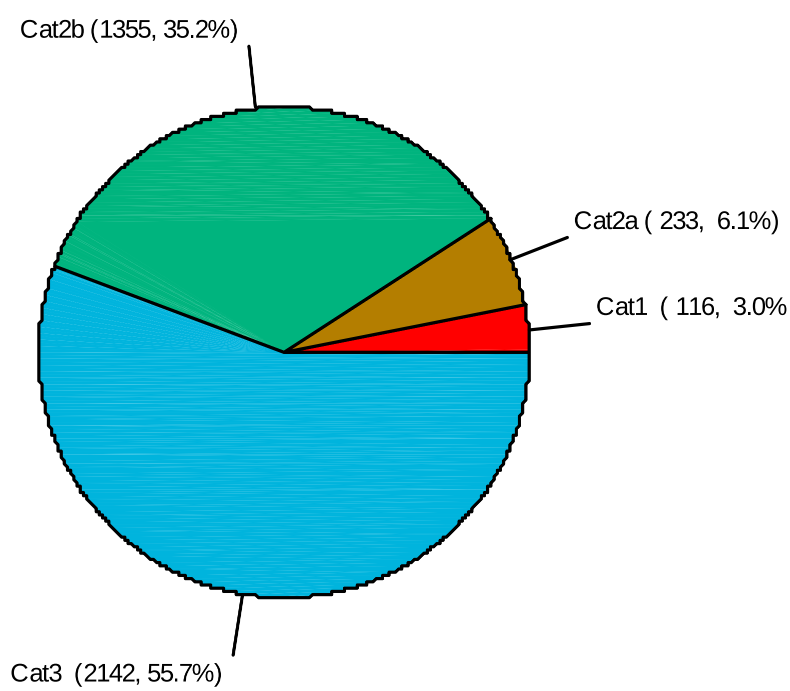


Figure 27B. The distribution of acreage of wetlands (acres) across the wetland category scheme (n=243).

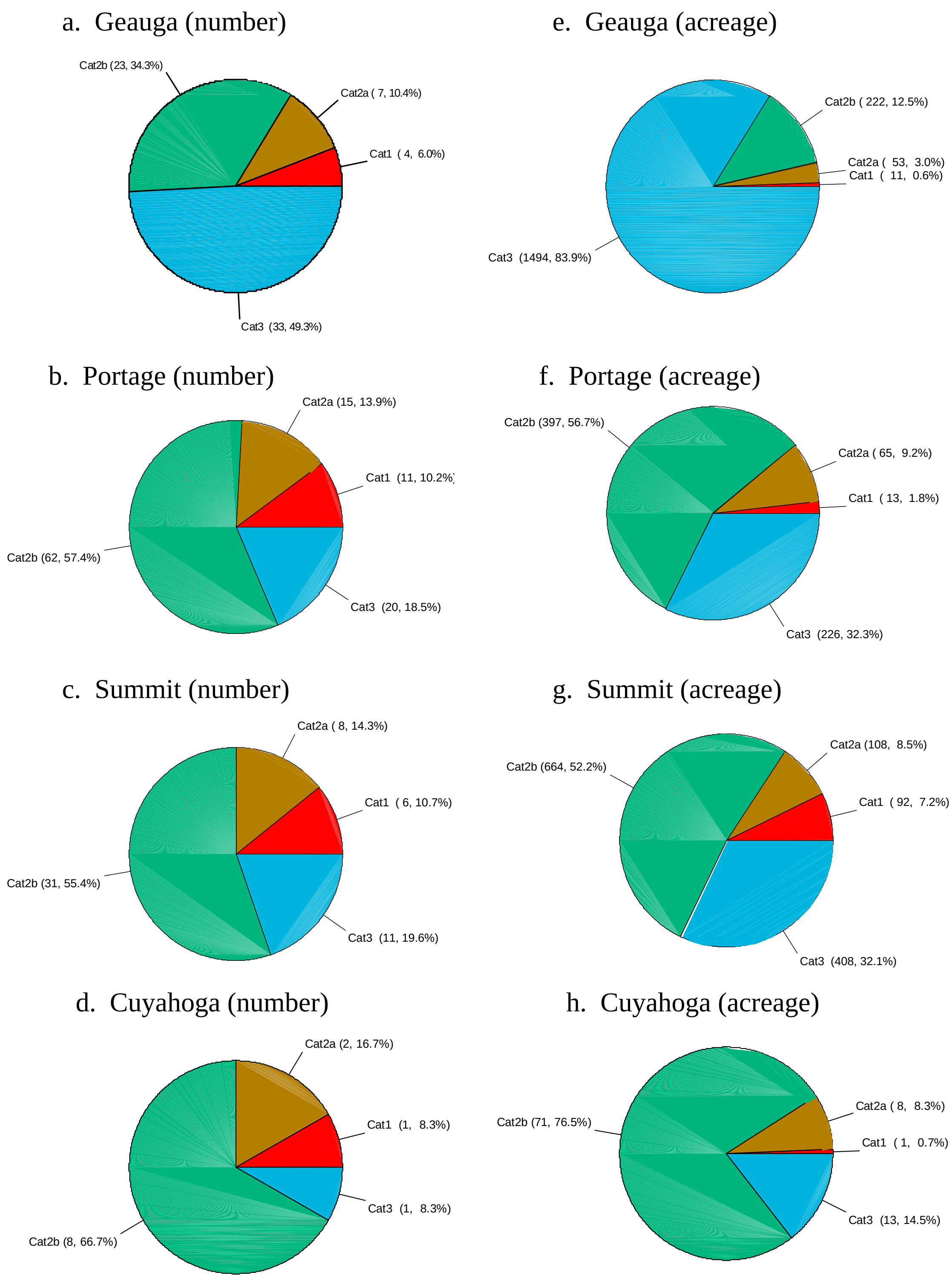


Figure 28. Pie charts of percentage of wetlands (a, b, c, d) and acreage of wetlands (d, e, f, g) by four counties and four antidegradation condition categories: Cat1 = Category 2, Cat 2a = modified Category 2, Cat2b = Category 2, Cat3 = Category 3.

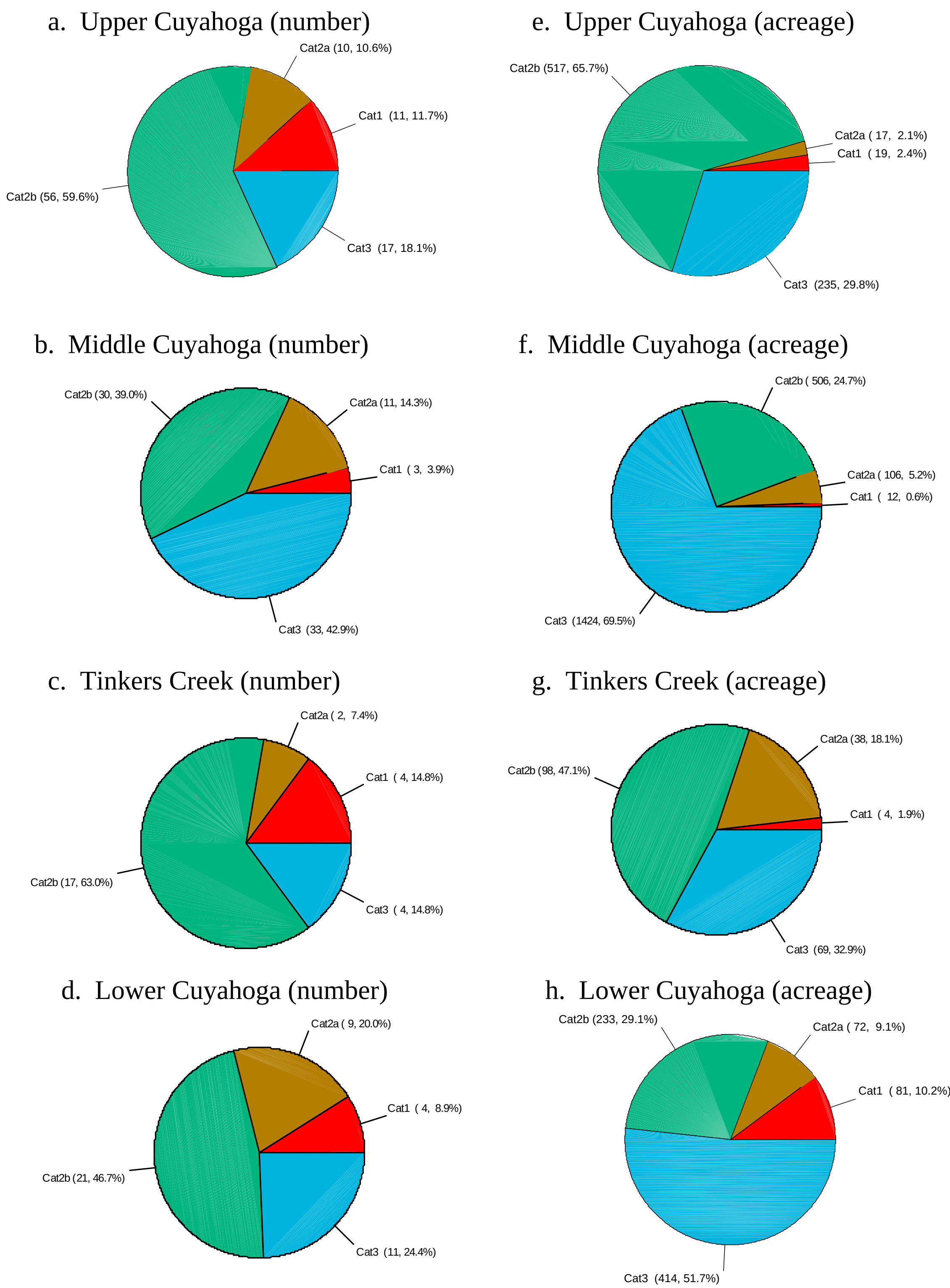


Figure 29. Pie charts of percentage of wetlands (a, b, c, d) and acreage of wetlands (d, e, f, g) by TMDL report region and four antidegradation condition categories: Cat1 = Category 2, Cat 2a = modified Category 2, Cat2b = Category 2, Cat3 = Category 3.

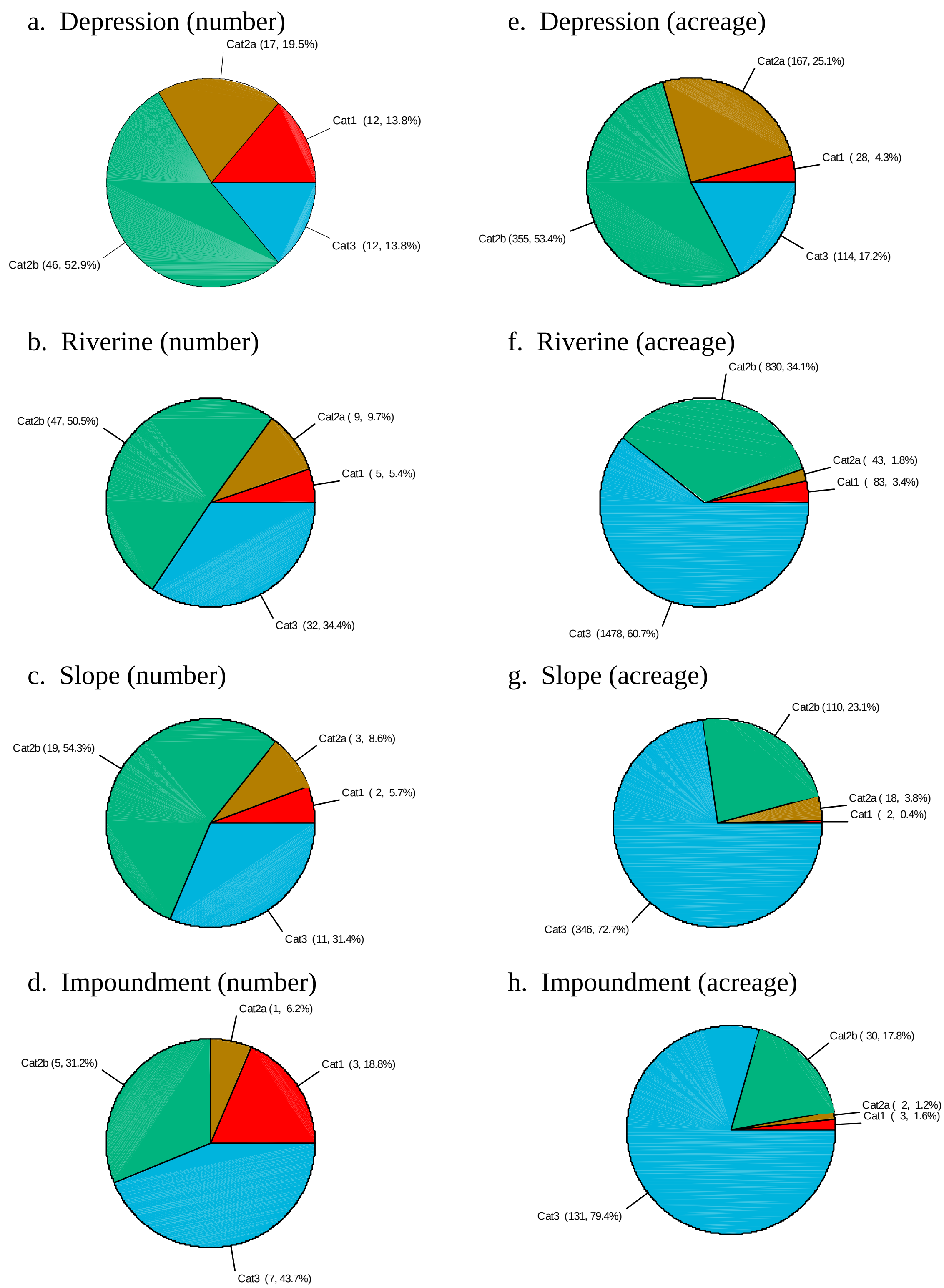


Figure 30. Pie charts of percentage of wetlands (a, b, c, d) and acreage of wetlands (d, e, f, g) by HGM Class and four antidegradation condition categories: Cat1 = Category 2, Cat 2a = modified Category 2, Cat2b = Category 2, Cat3 = Category 3.

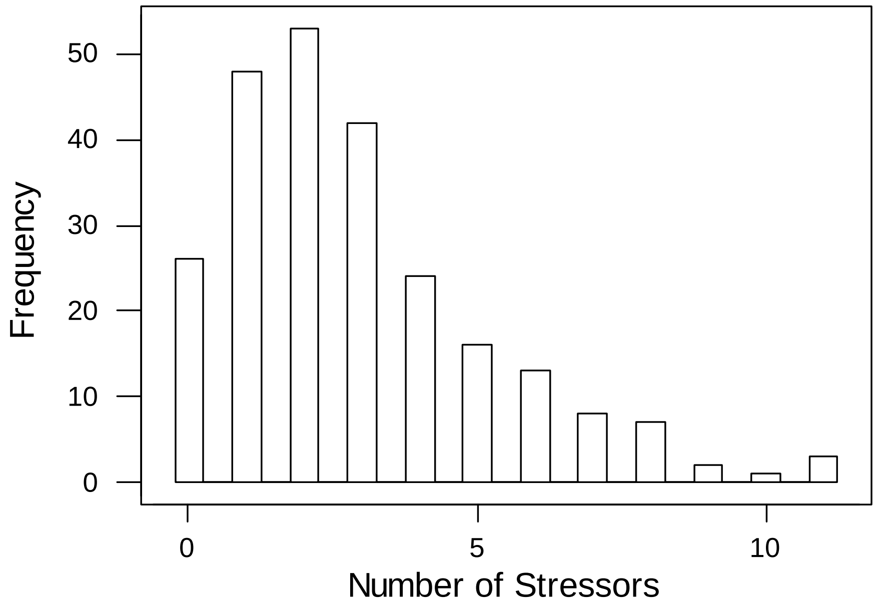


Figure 31A. Frequency histogram of number of stressors from the PA Stressor Checklist. The scoring range is 0 to 54; sites sampled in this probabilitic design ranged from scores of 0 to 11.

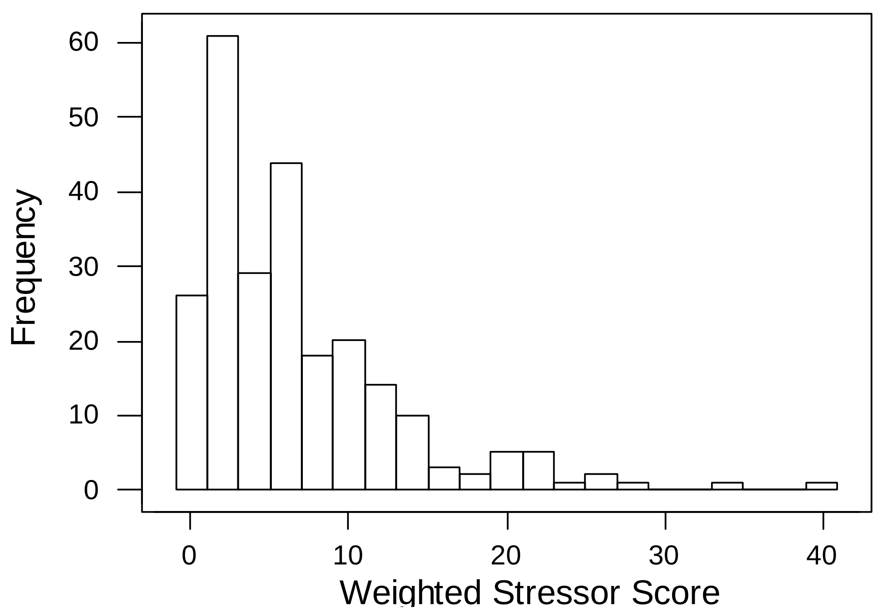


Figure 31B. Frequency histogram of Weighted Stressor Score derived from the PA Stressor Checklist. The scoring range is 0 to ~50; sites sampled in this probabilistic design ranged from scores of 0 to 40.

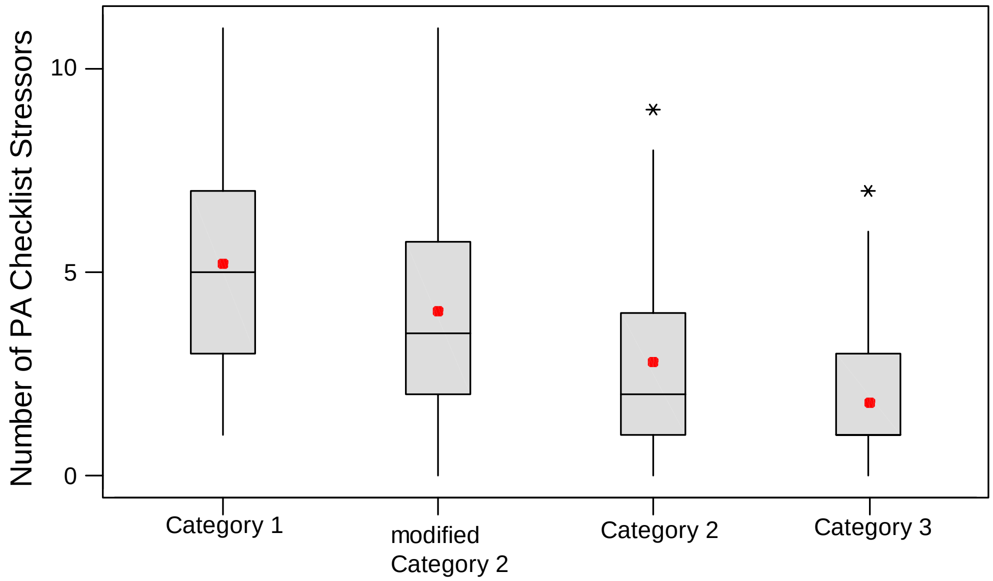


Figure 32A. Box and whisker plots of number of stressors by wetland condition category. All means significantly different except Category 1 and modified Category 2 (df = 242, F = 17.91, p = 0.000).

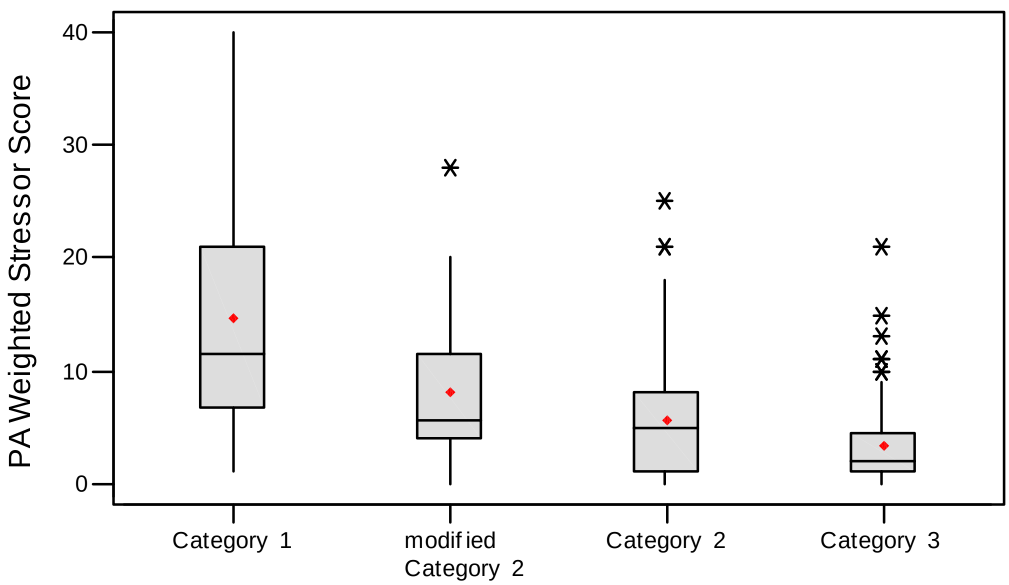


Figure 32B. Box and whisker plots of weighted stressor score by wetland condition category. All means significantly different except modified Category 2 and Category and Category 2 and Category 3 (df = 242, F = 24.07, p = 0.000).

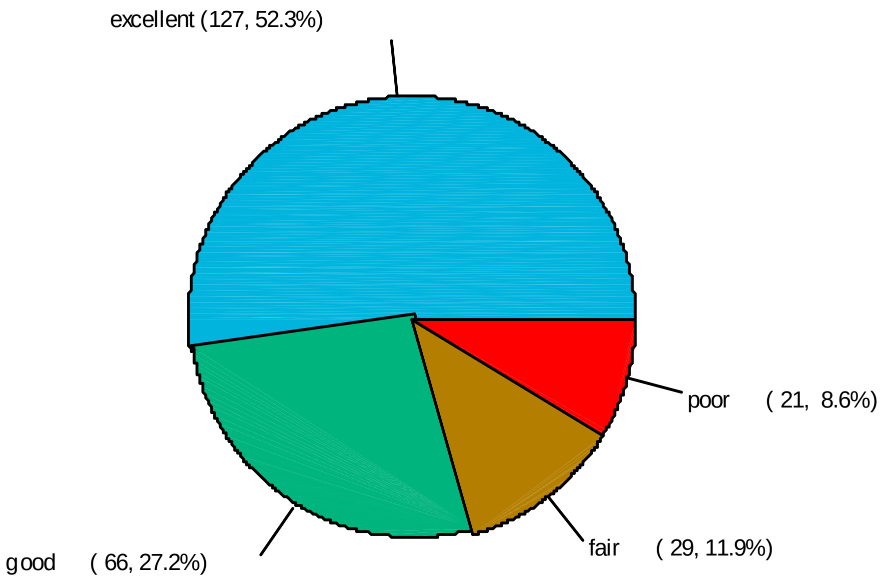


Figure 33A. Percentage of wetlands in poor, fair, good, and excellent condition as determined by the number of stressors from from the PA Stressor Checklist.

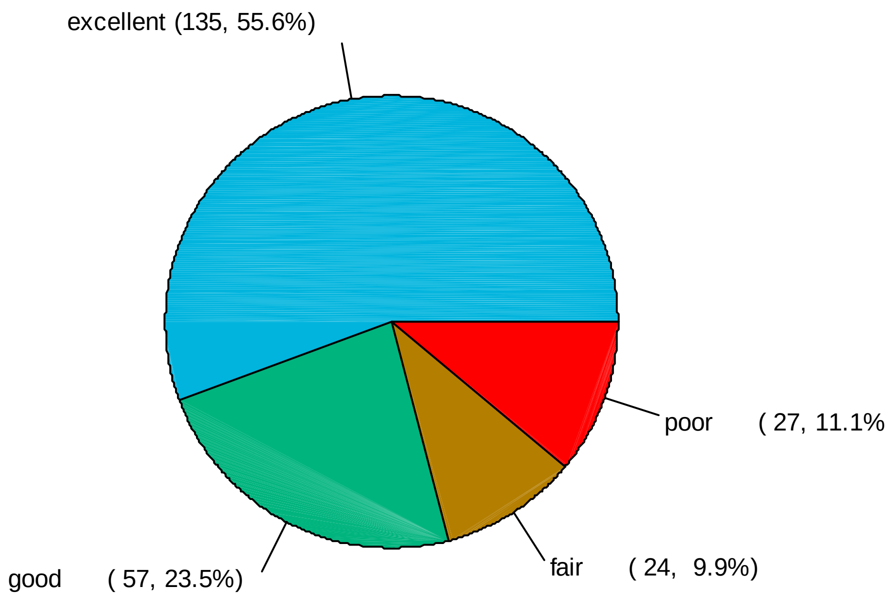


Figure 33B. Percentage of wetlands in poor, fair, good, and excellent condition as determined by the Weighted Stressor Score derived from the PA Stressor Checklist.

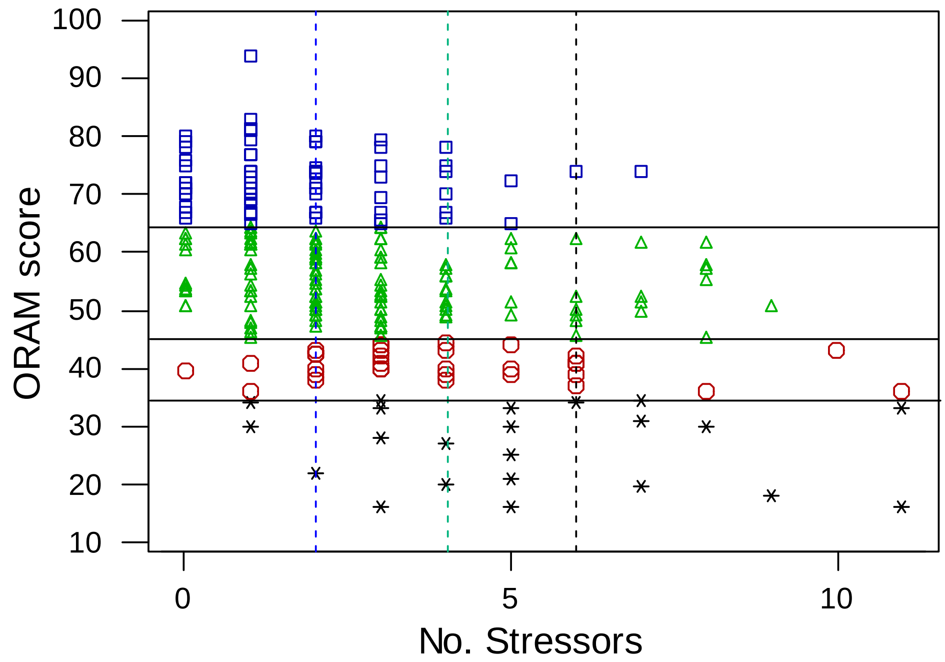


Figure 34A. Scatterplot of No. of Stressors and ORAM score. Horizontal solid lines are Ohio wetland condition categories (see text). Vertical dashed lines represent quartiles of 95th percentile of no. of stressor: poor (>6.0), fair(4.1-6.0), good (2.1-4.0), and excellent (0-2.0) (df = 242, R^2 = 19.3%, F = 57.8, p = 0.000).

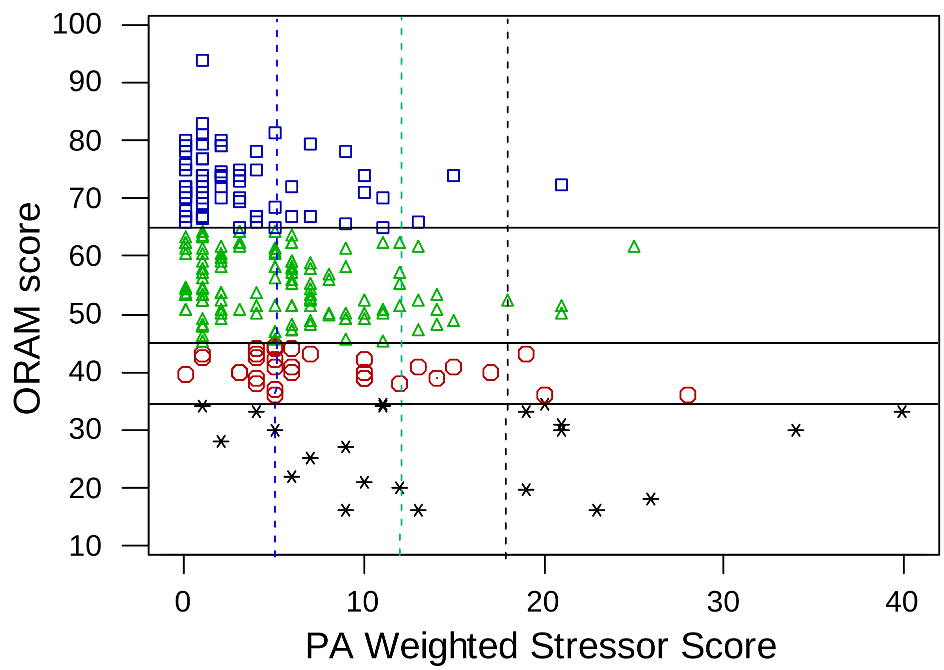


Figure 34B. Scatterplot of PA Weighted Stressor Score and ORAM score. Horizontal solid lines are Ohio wetland condition categories (see text). Vertical dashed lines represent quartiles of 95th percentile of stressor scores: poor (>17), fair(12-17), good (6-12), and excellent (0-6) (df = 242, R^2 = 21.7%, F = 66.8, p = 0.000).

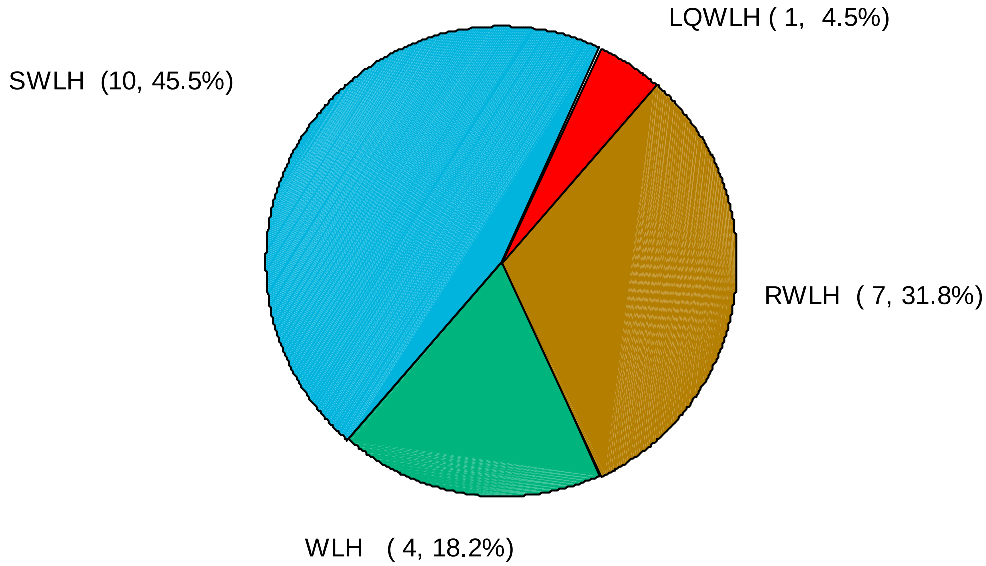


Figure 35. Percentage of wetlands in LQWLH (poor), RWLH (fair), WLH (good), and SWLH (excellent) condition as determined by Vegetation IBI scores. LQWLH = limited quality wetland habitat, RWLH = restorable wetland habitat, WLH = wetland habitat, SWLH = superior wetland habitat.

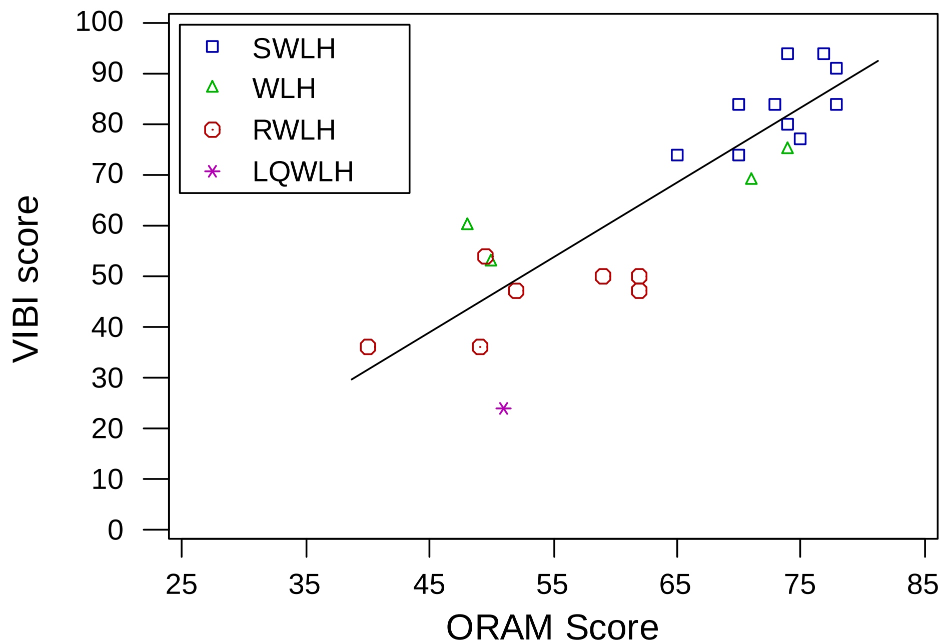


Figure 36. Scatterplot of VIBI score versus ORAM score. Line is regression line (df = 21, F = 63.7, R^2 = 76.1%, p = 0.000.

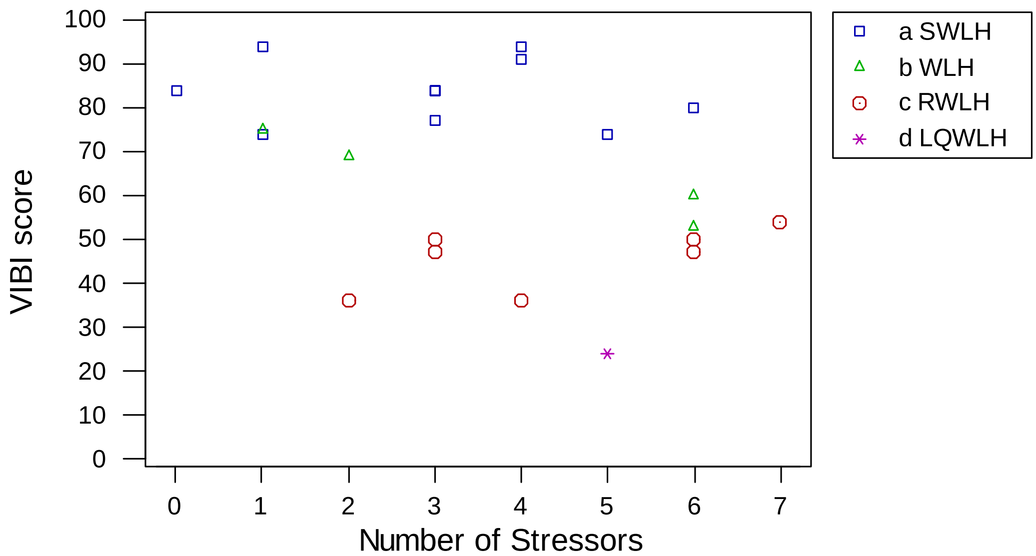


Figure 37. Scatterplot of VIBI score versus Number of Stressors from PA Stressor Checklist. Regression not signficant (p = 0.091).

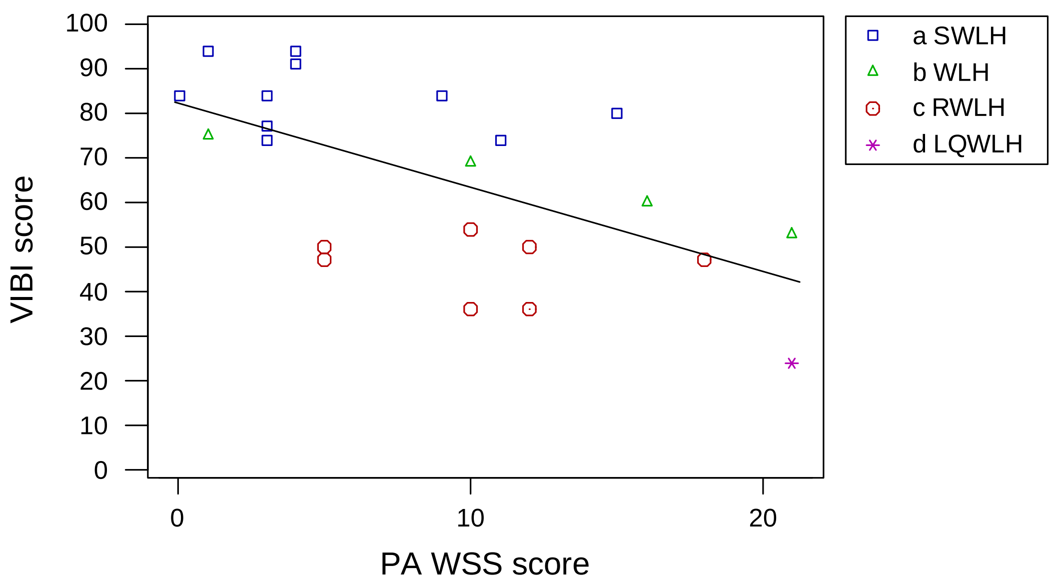


Figure 38. Scatterplot of VIBI score versus Weighted Stressor Score derived from the PA Stressor Checklist. Line is regression line (df = 21, F = 14.64, R^2 = 42.3%, p = 0.001).

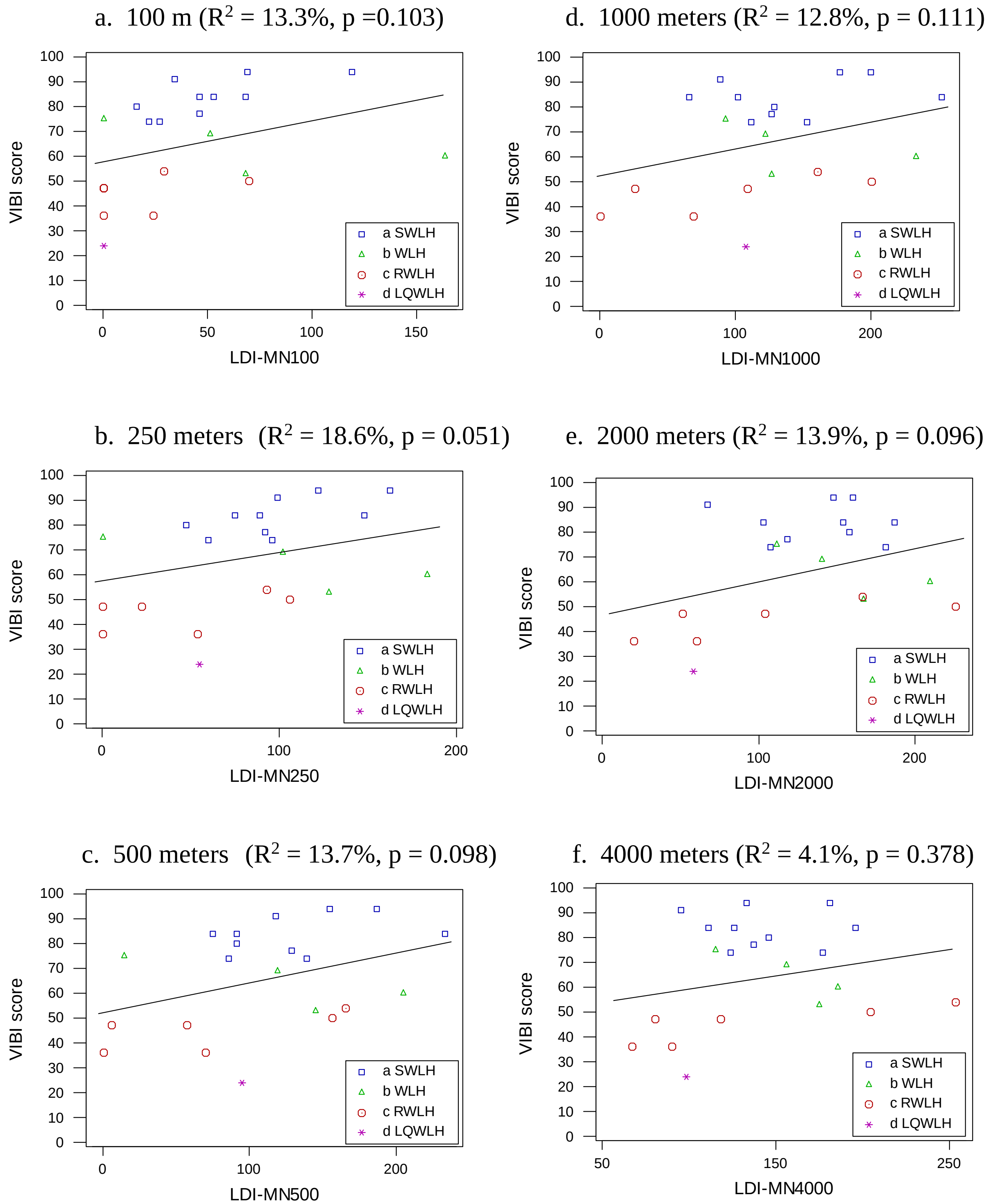


Figure 39. Scatterplots (and regression line) of LDI scores (Minnesota coefficients) and VIBI scores scores (df = 20).

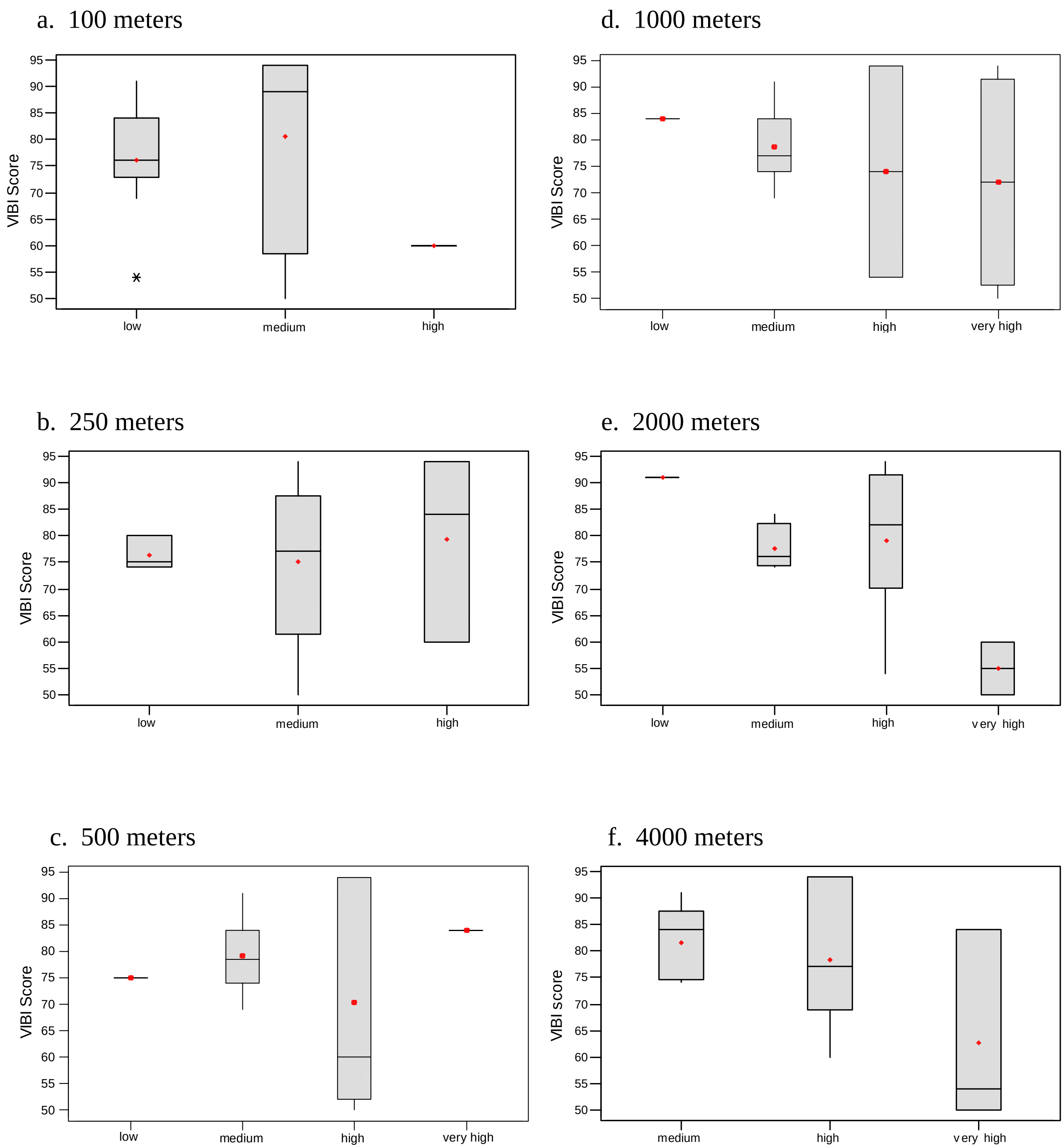


Figure 40. Box and whisker plots of VIBI scores for different land use intensity classes derived from LDI scores at different buffer distances (100 m, 250 m, 500 m, 1000 m, 2000 m, 4000 m).

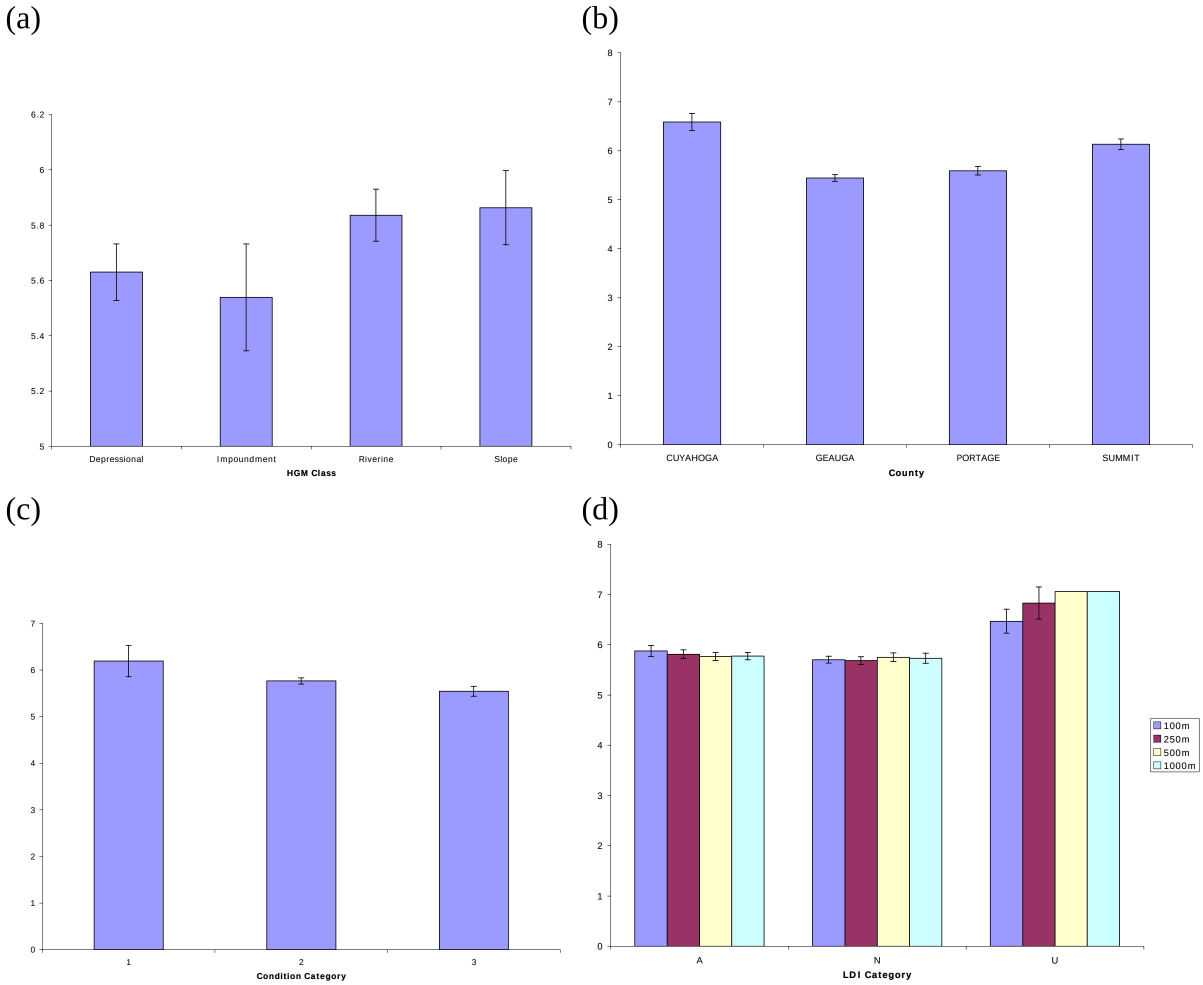


Figure 41A. Mean pH values for each (a) HGM class, (b) County, (c) Condition category, and (d) LDI categories; error bars represent the standard error of the mean. Stratification based on county, condition category, and LDI category 250 m showed significant differences, while other differences did not. Note that the comparison made in part (d) was between categories within the same buffer distances, not between different buffer distances, such that wetlands with agricultural, natural, and urban land-uses in the 250 m buffer had significantly different pH values; land-use categories for the 100, 500, and 1000 m buffers showed no such pH difference.

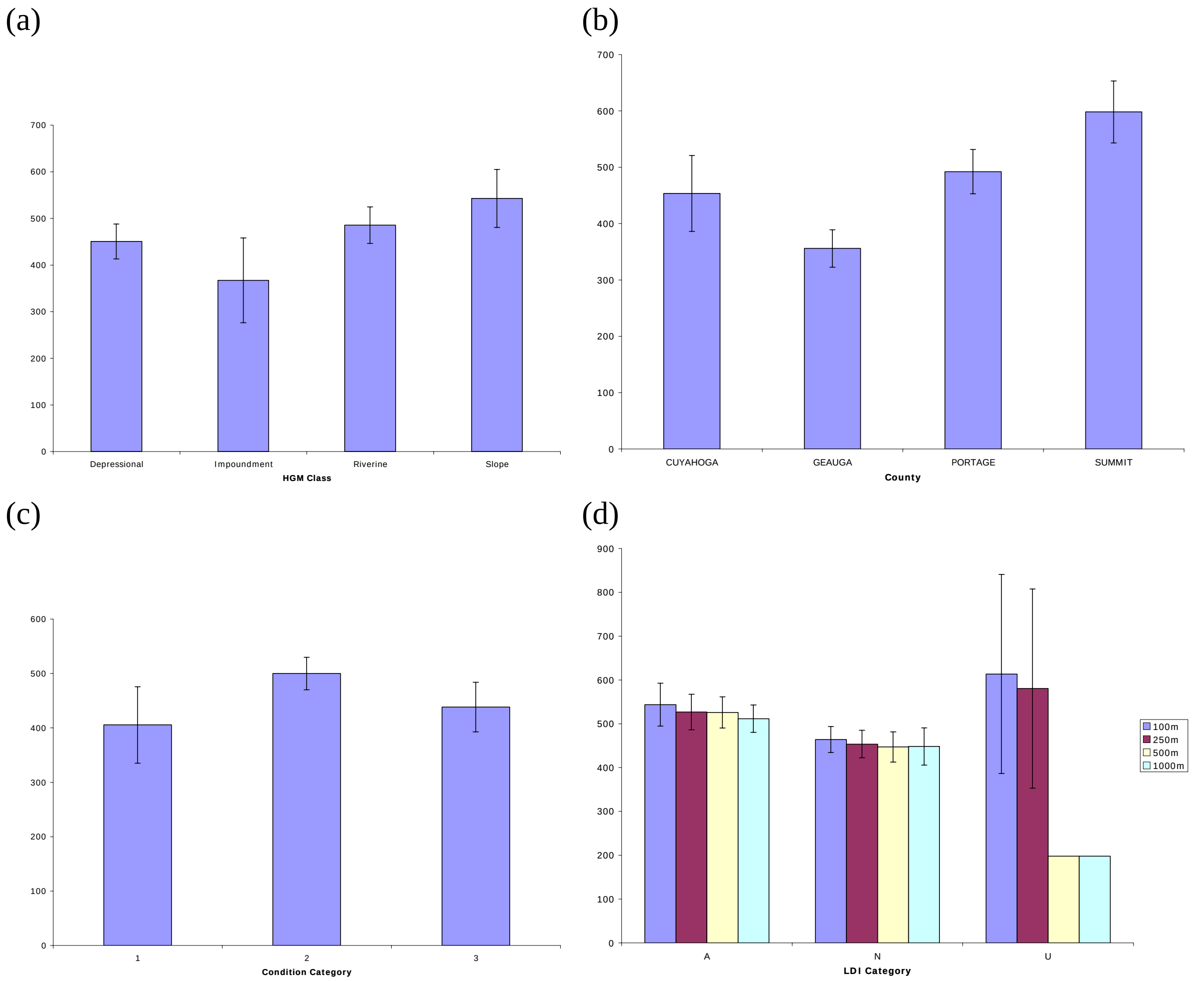


Figure 41B. Mean conductivity values for each (a) HGM class, (b) County, (c) Condition category, and (d) LDI categories; error bars represent the standard error of the mean. Stratification based on county only showed significant differences. Note that the comparison made in part (d) was between categories within the same buffer distances, not between different buffer distances.

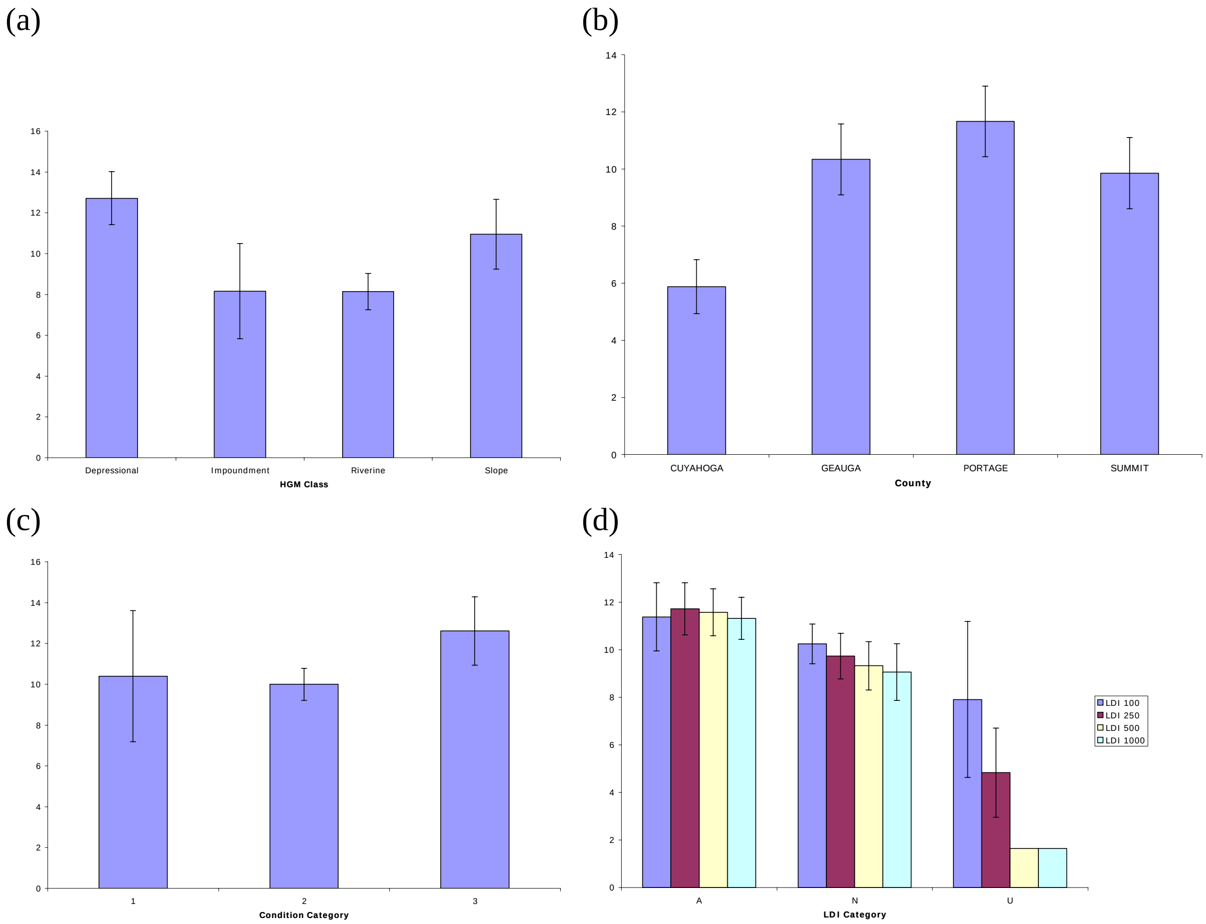


Figure 41C. Mean percent total carbon values for each (a) HGM class, (b) County, (c) Condition category, and (d) LDI categories; error bars represent the standard error of the mean. Stratification showed significant differences between counties. Note that the comparison made in part (d) was between categories within the same buffer distances, not between different buffer distances.

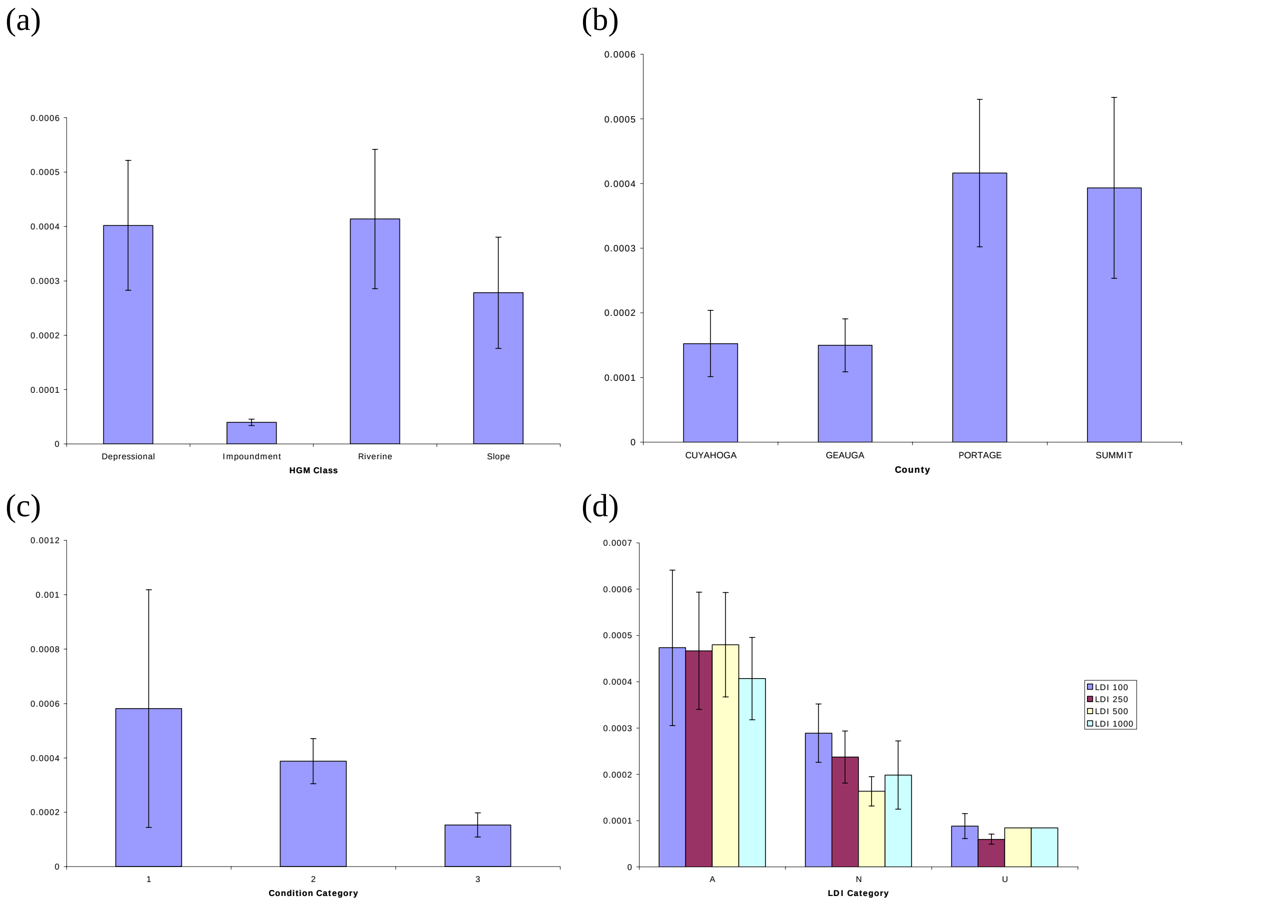


Figure 41D. Mean total percent nitrogen values for each (a) HGM class, (b) County, (c) Condition category, and (d) LDI categories; error bars represent the standard error of the mean. Stratification based oncounty and LDI categories in the 500 m buffer showed significant differences while other differences did not. Note that the comparison made in part (d) was between categories within the same buffer distances, not between different buffer distances, such that wetlands with agricultural, natural, and urban land-uses in the 500 m buffer had significantly different percent nitrogen values; land-use categories for the 100, 250, and 1000 m buffers showed no such difference.

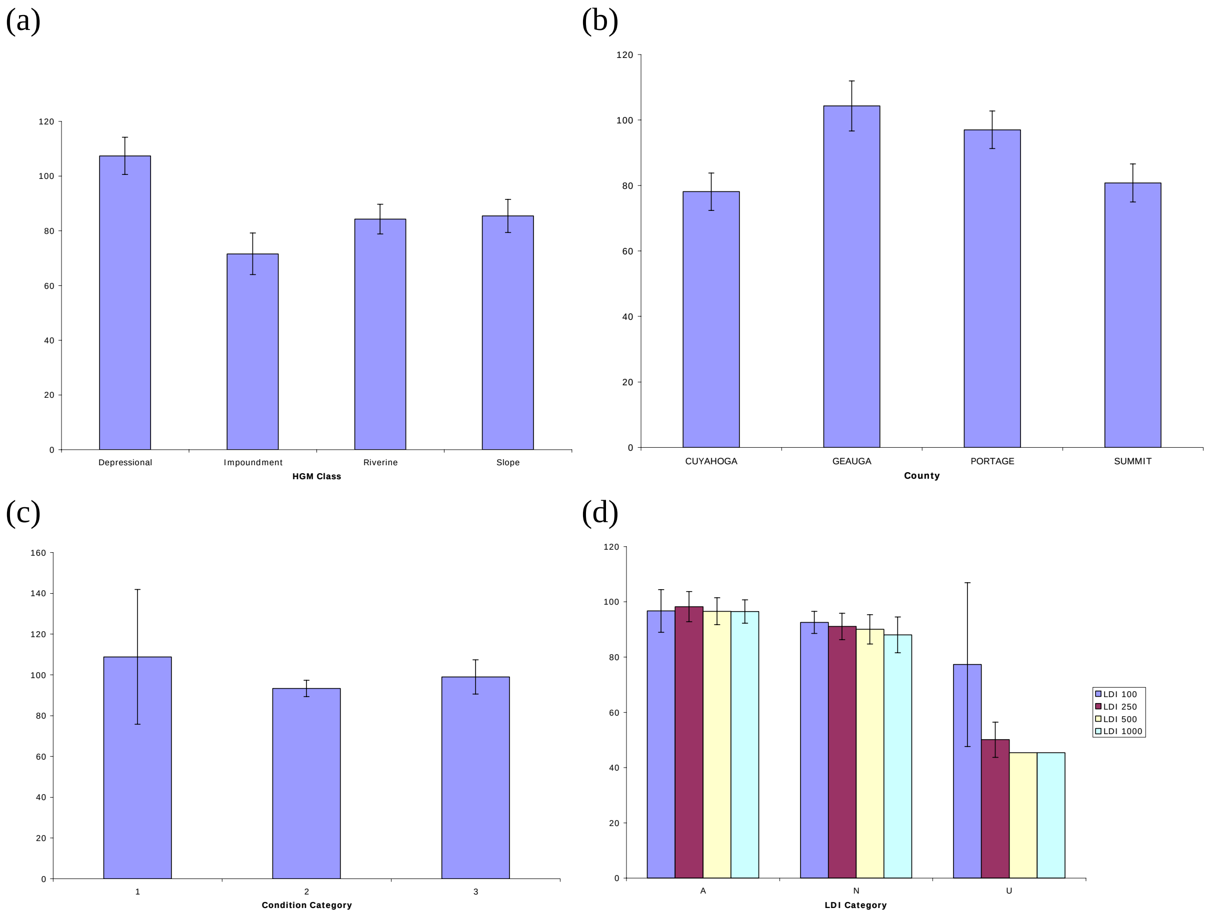


Figure 41E. Mean total carbon (ug/cc) values for each (a) HGM class, (b) County, (c) Condition category, and (d) LDI categories; error bars represent the standard error of the mean. Stratification based on HGM and county showed significant differences, while other differences did not. Note that the comparison made in part (d) was between categories within the same buffer distances, not between different buffer distances.

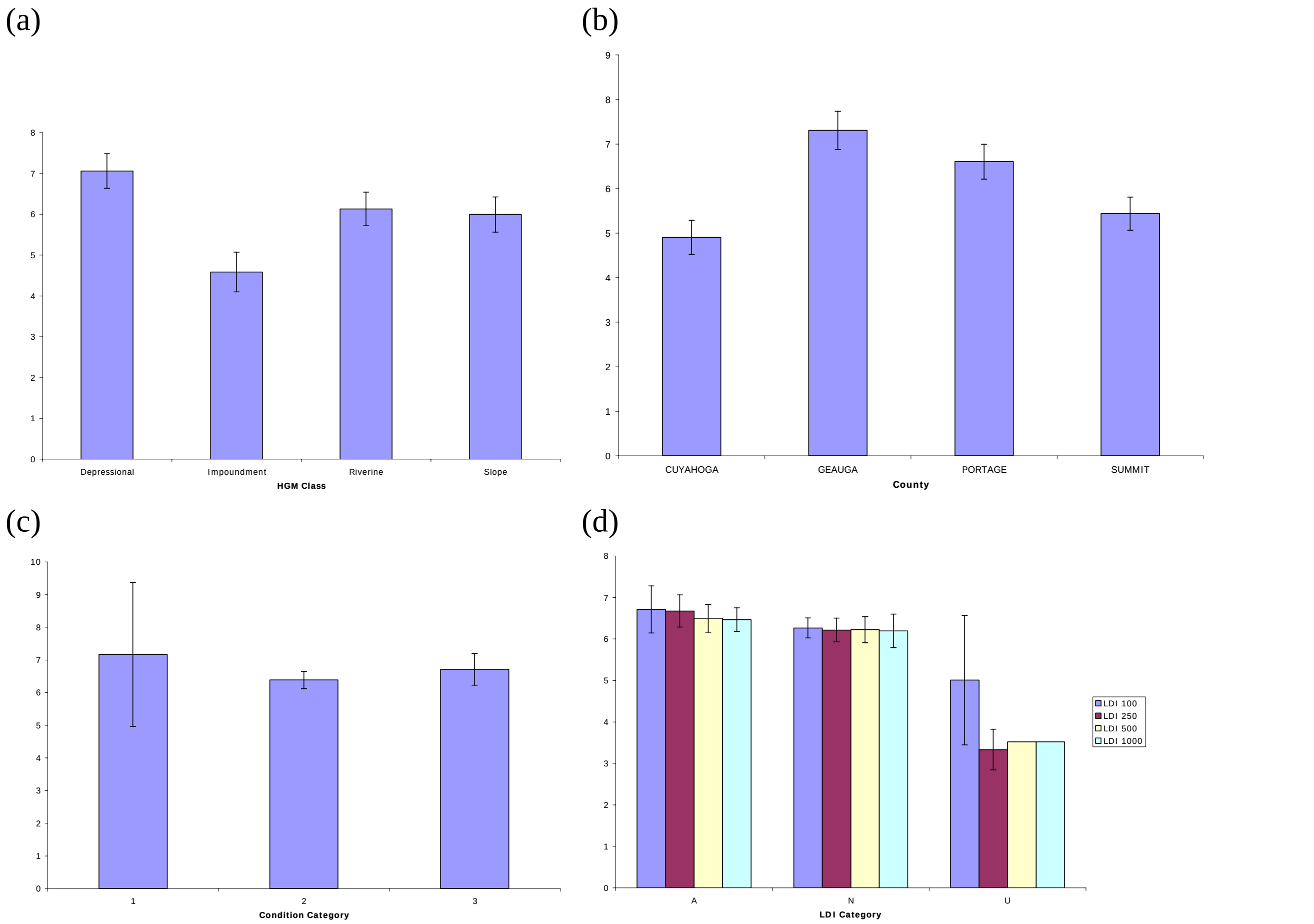


Figure 41F. Mean total nitrogen (ug/cc) values for each (a) HGM class, (b) County, (c) Condition category, and (d) LDI categories; error bars represent the standard error of the mean. Stratification based on HGM and county showed significant differences, while other differences did not. Note that the comparison made in part (d) was between categories within the same buffer distances, not between different buffer distances.

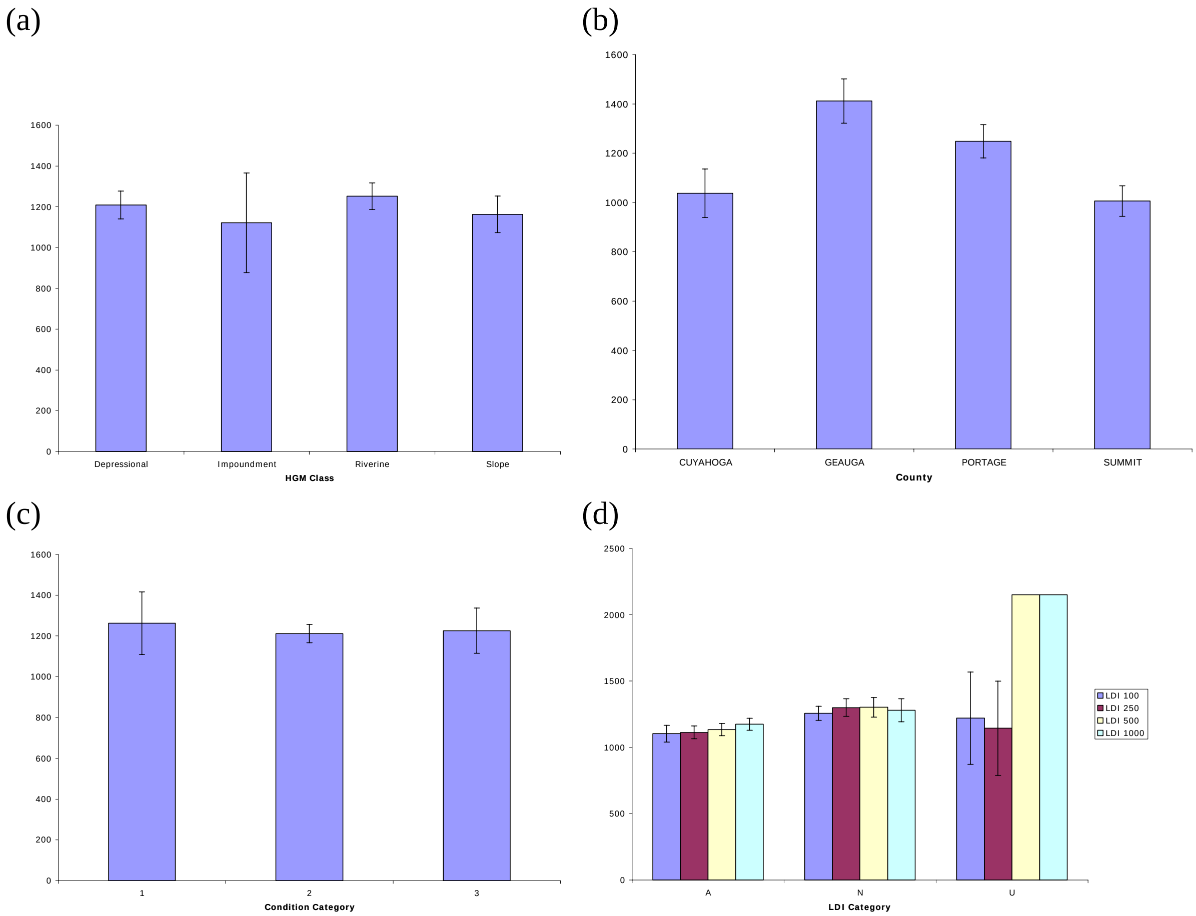


Figure 41G. Mean total phosphorus (ug/cc) values for each (a) HGM class, (b) County, (c) Condition category, and (d) LDI categories; error bars represent the standard error of the mean. Stratification based on county and LDI category 500 m showed significant differences, while other differences did not. Note that the comparison made in part (d) was between categories within the same buffer distances, not between different buffer distances, such that wetlands with agricultural, natural, and urban land-uses in the 500 m buffer had significantly different TP values; land-use categories for the 100, 250, and 1000 m buffers showed no such difference.

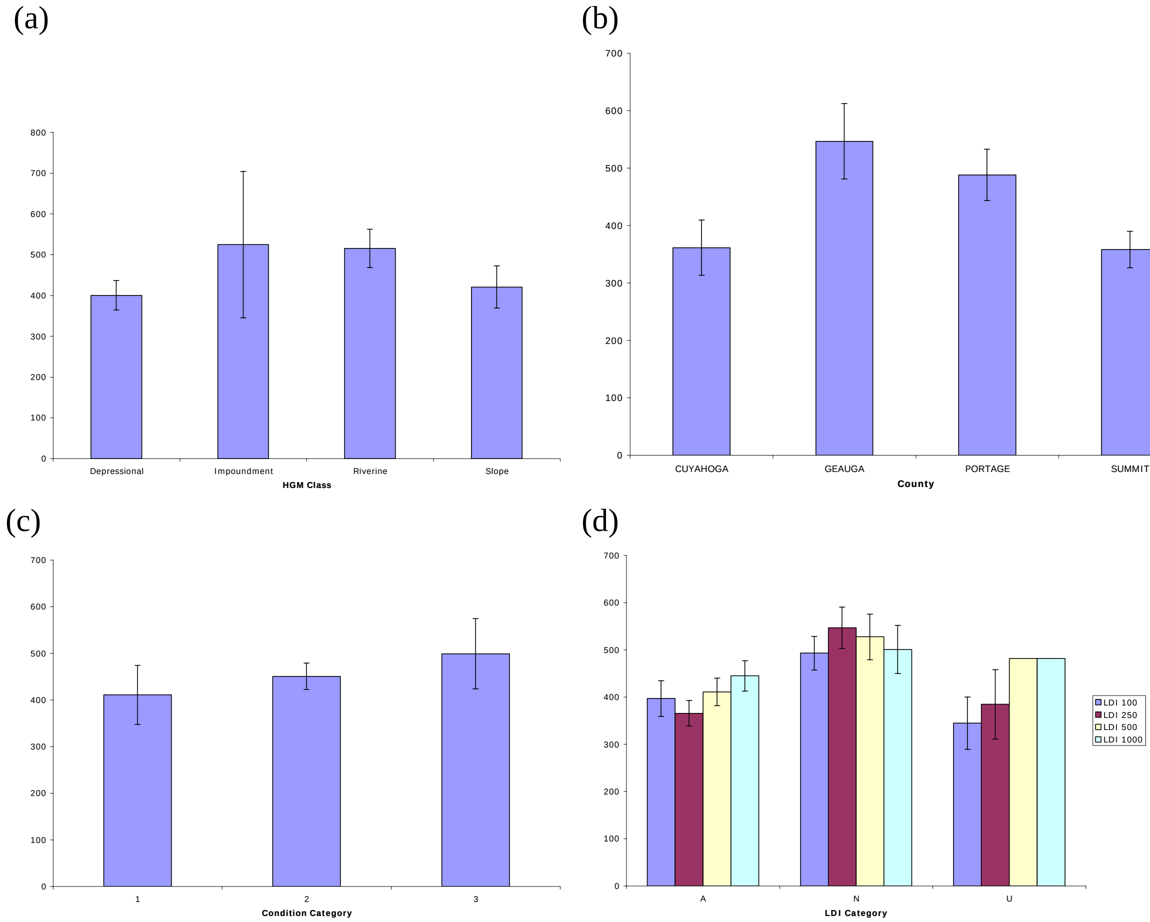


Figure 41H. Mean total HCl extracted phosphorus (ug/cc) values for each (a) HGM class, (b) County, (c) Condition category, and (d) LDI categories; error bars represent the standard error of the mean. Stratification based on county and LDI categories in the 250 m buffer showed significant differences while other differences did not. Note that the comparison made in part (d) was between categories within the same buffer distances, not between different buffer distances, such that wetlands with agricultural, natural, and urban land-uses in the 250 m buffer had significantly different HCl extratable phosphorus values; land-use categories for the 100, 500, and 1000 m buffers showed no such difference.

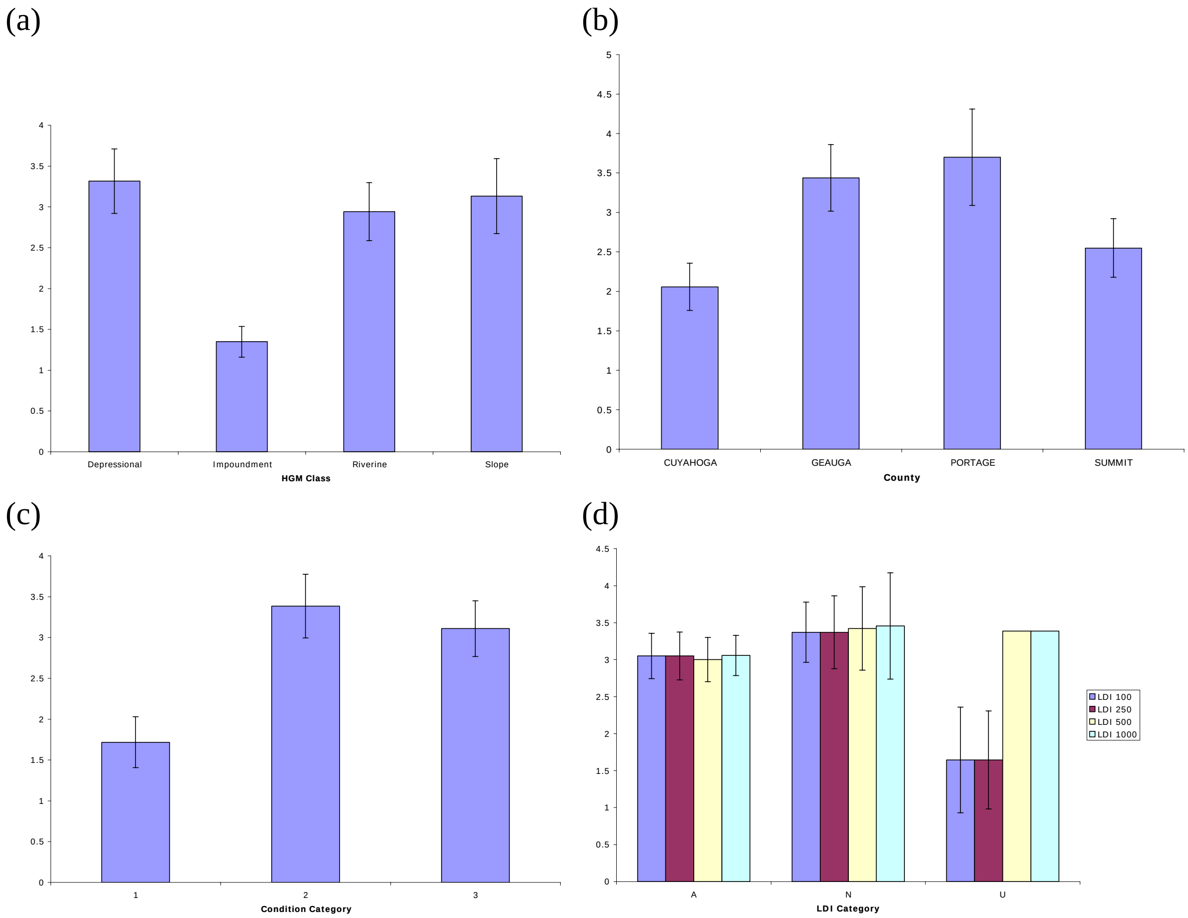


Figure 41I. Mean total water extracted phosphorus (ug/cc) values for each (a) HGM class, (b) County, (c) Condition category, and (d) LDI categories; error bars represent the standard error of the mean. Stratification based on HGM class, county and condition category showed significant differences while others did not. Note that the comparison made in part (d) was between categories within the same buffer distances, not between different buffer distances.

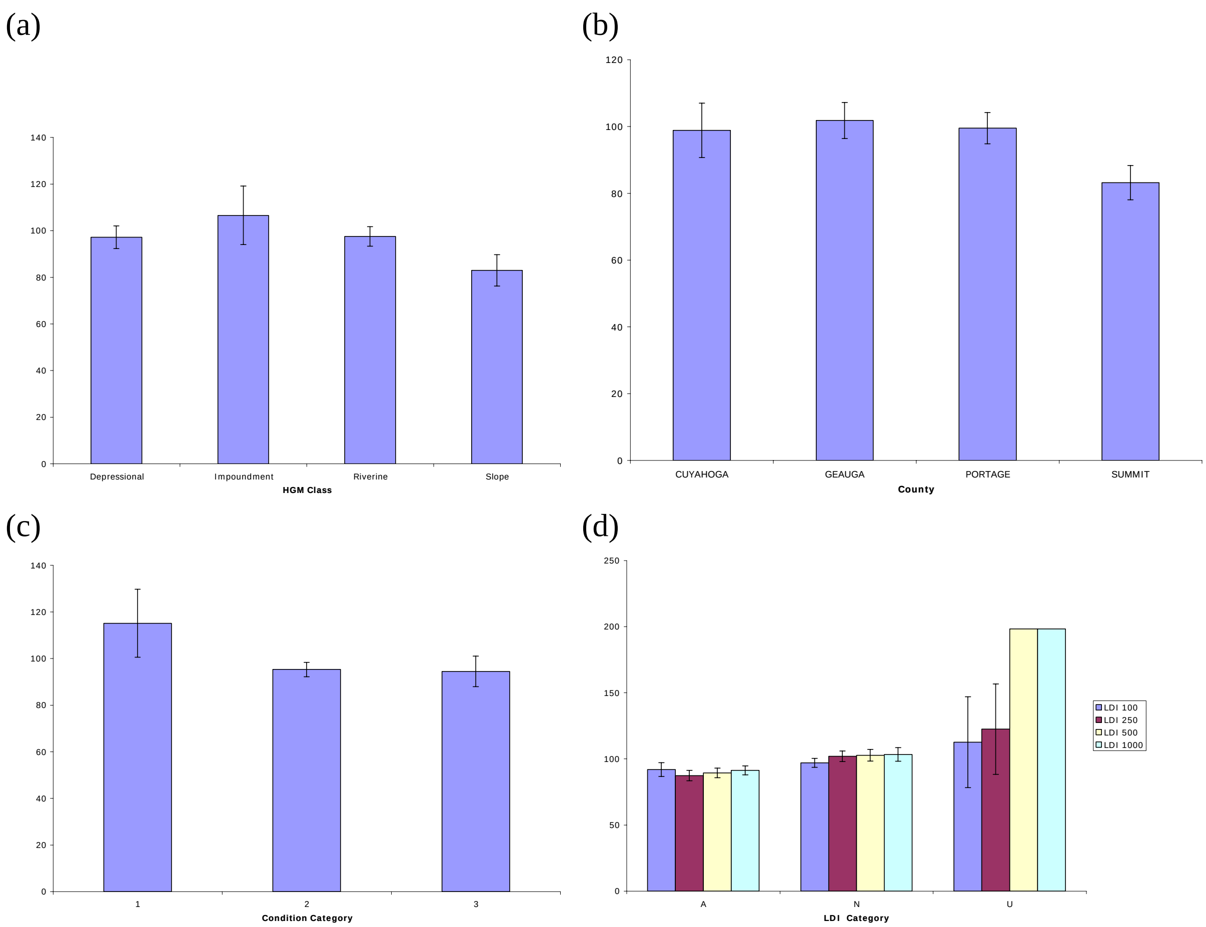


Figure 41J. Mean total phosphorus-sorption (ug/cc) values for each (a) HGM class, (b) County, (c) Condition category, and (d) LDI categories; error bars represent the standard error of the mean. Stratification based on LDI categories in the 250 and 500 m buffer showed significant differences while other differences did not. Note that the comparison made in part (d) was between categories within the same buffer distances, not between different buffer distances, such that wetlands with agricultural, natural, and urban land-uses in the 250 and 500 m buffer had significantly different phosphorus sorption values; land-use categories for the 100 and 1000 m buffers showed no such difference.

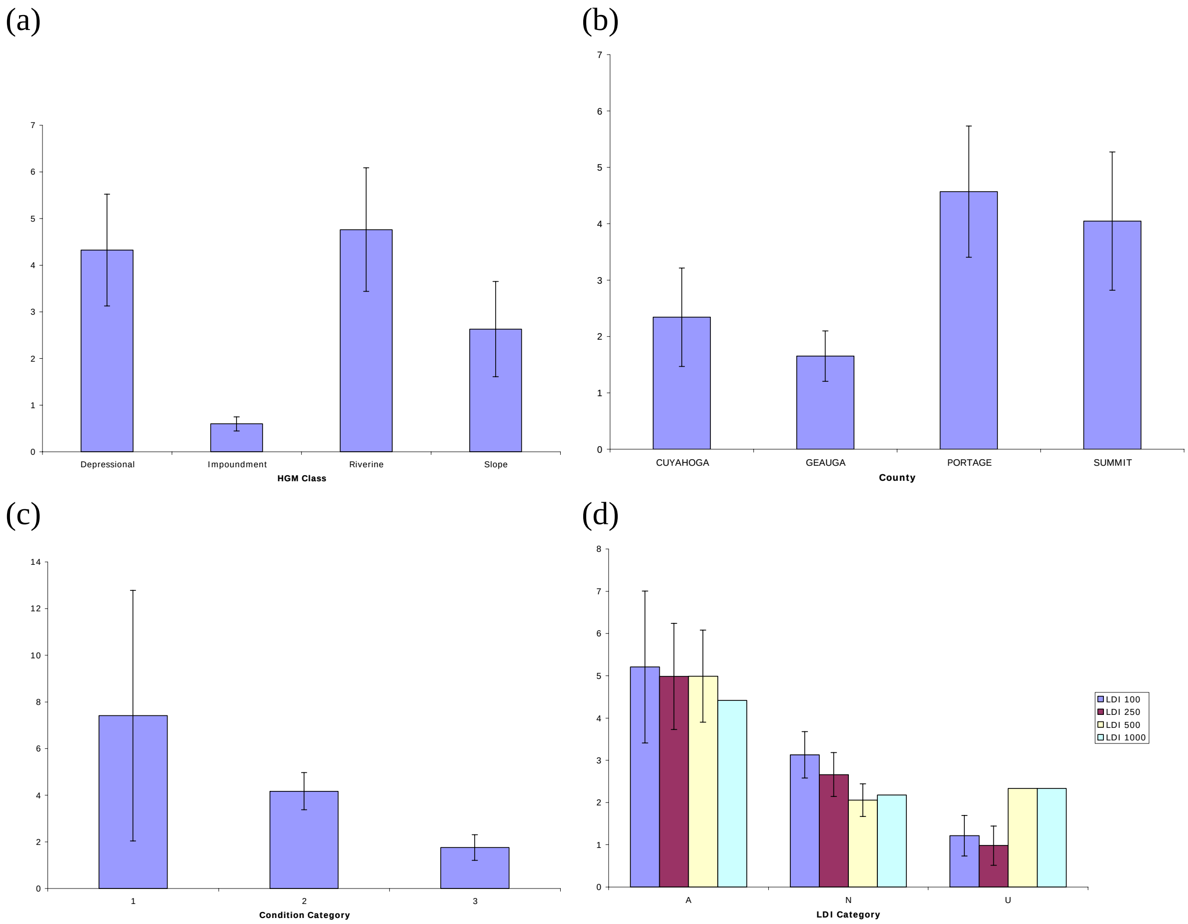


Figure 41K. Mean total nitrate extracted nitrogen (ug/cc) values for each (a) HGM class, (b) County, (c) Condition category, and (d) LDI categories; error bars represent the standard error of the mean. Stratification based on HGM class and county showed significant differences while others did not. Note that the comparison made in part (d) was between categories within the same buffer distances, not between different buffer distances.

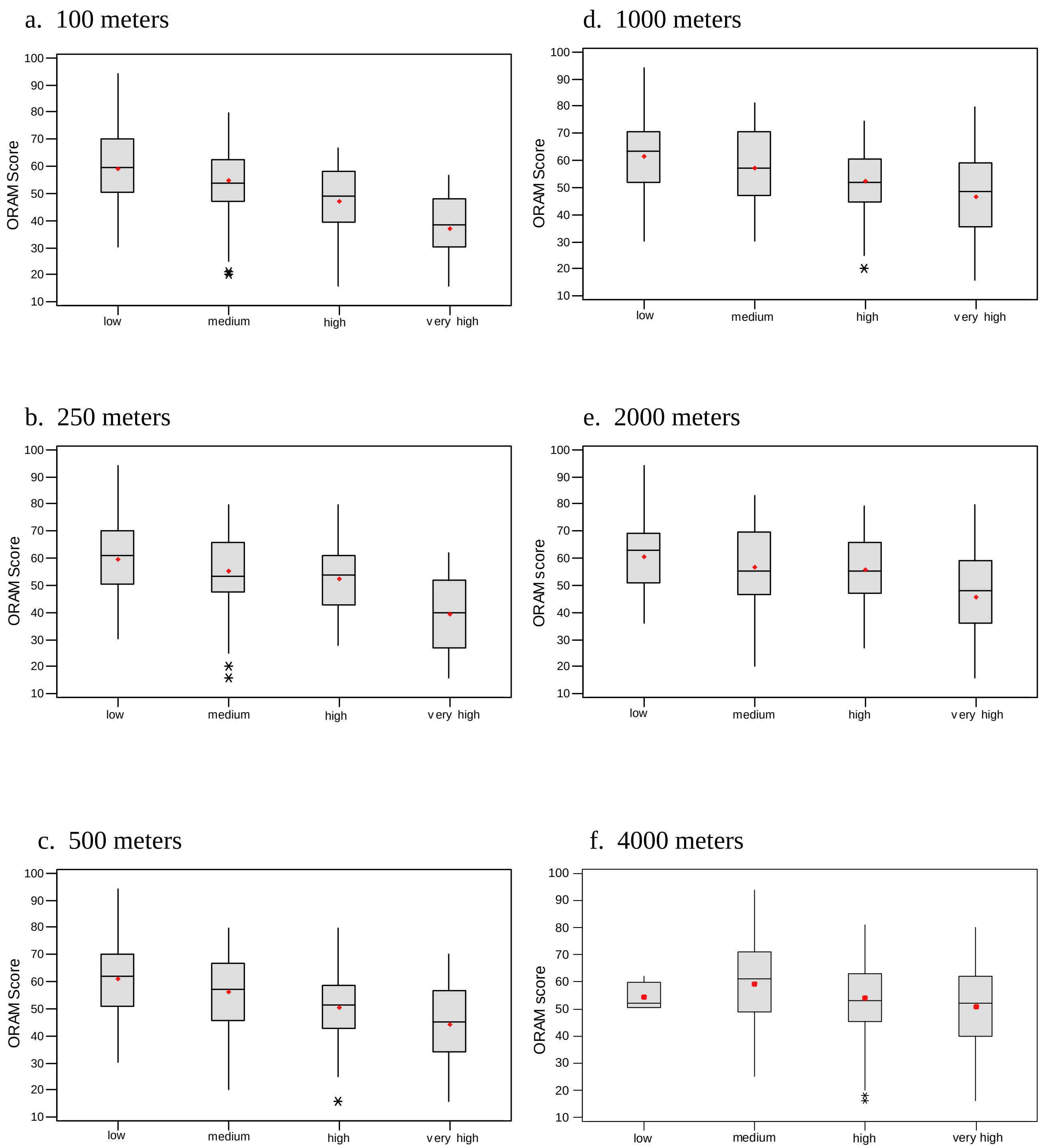
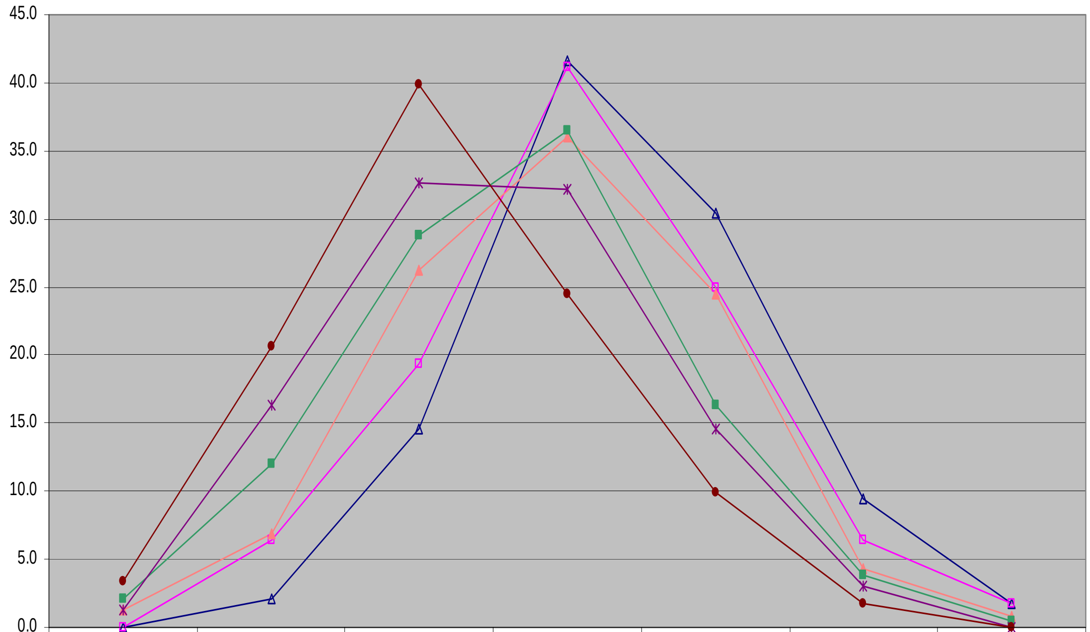


Figure 42. Box and whisker plots of ORAM scores for different buffer distances (100 m, 250 m, 500 m, 1000 m, 2000 m, 4000 m).



	under by 3	under by 2	under by 1	same category	over by 1	over by 2	over by 3
100 m	0.0	2.1	14.6	41.6	30.5	9.4	1.7
250 m	0.0	6.4	19.3	41.2	24.9	6.4	1.7
500 m	1.3	6.9	26.2	36.1	24.5	4.3	0.9
1000 m	2.1	12.0	28.8	36.5	16.3	3.9	0.4
2000 m	1.3	16.3	32.6	32.2	14.6	3.0	0.0
4000 m	3.4	20.6	39.9	24.5	9.9	1.7	0.0

Figure 43. The percent agreement between the Level 1 and Level 2 (ORAM) assessments for each buffer distance. Under (by 1, 2, or 3) means the LDI score derived land use class under categorized the wetland lower that what the Level 2 on-site assessment determined, i.e. the wetland was in better condition than predicted by the LDI score; Over (by 1, 2, or 3) means the LDI score over-categorized the wetland, i.e. the wetland was in worse condition than predicted by the LDI score; same category means the LDI and ORAM assessments reached the same result. Note how at the 2000 m and 4000 m buffers, there is an increased tendency to under-categorize wetlands; the opposite is the case at lower buffer distances.

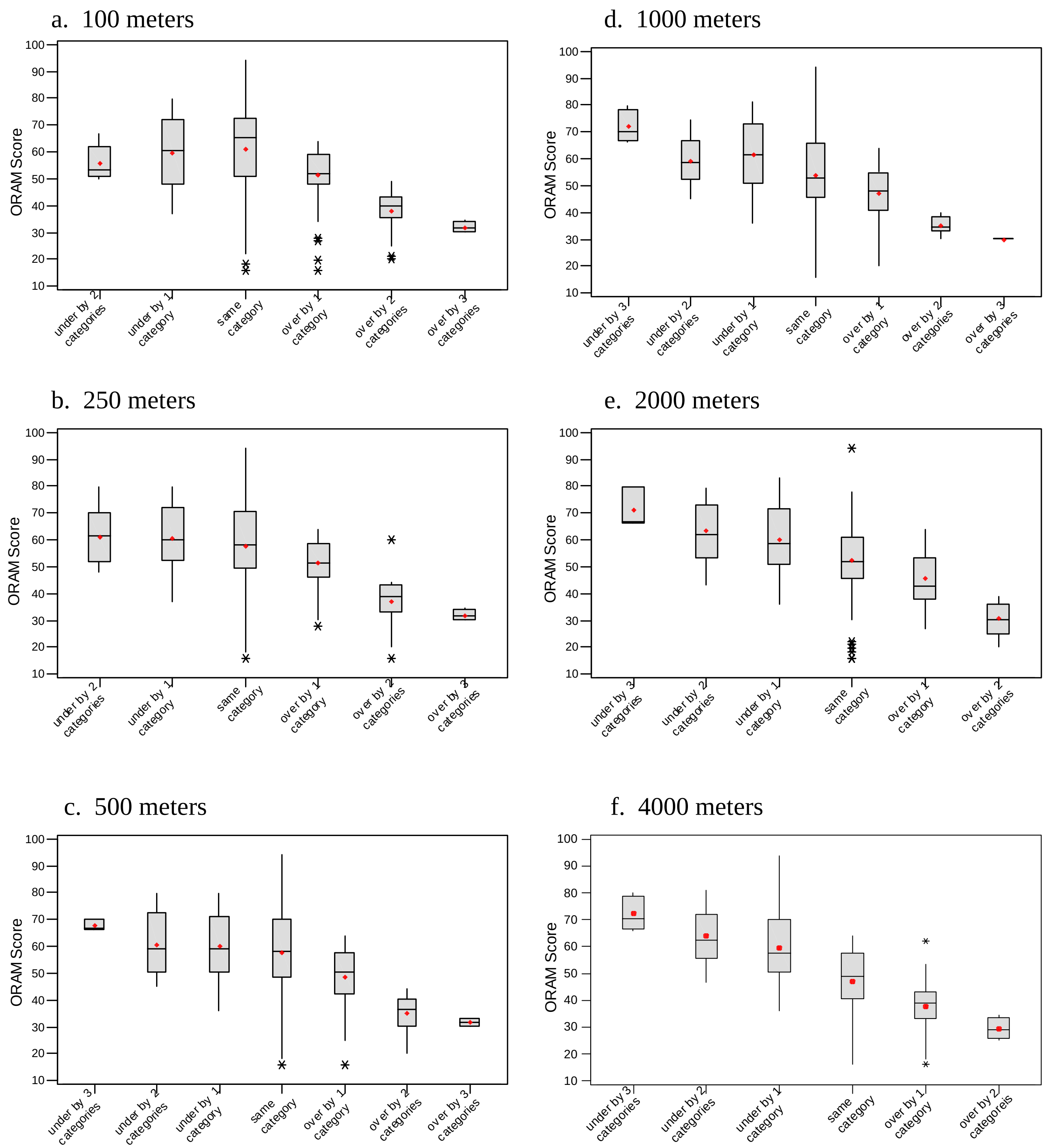
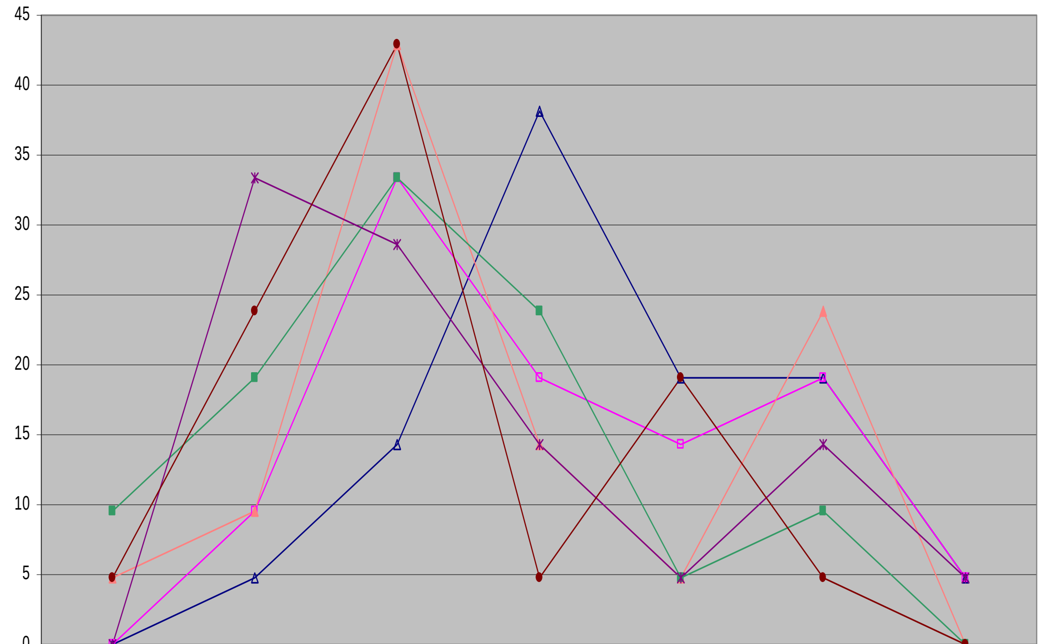


Figure 44. Box and whisker plots of average ORAM scores for different Level1:Level2 “agreement” categories for different buffer distances (100 m, 250 m, 500 m, 1000 m, 2000 m, 4000 m). Under (by 1, 2, or 3) means the LDI score derived land use class under categorized the wetland lower that what the Level 2 on-site assessment determined, i.e. the wetland was in better condition than predicted by the LDI score; Over (by 1, 2, or 3) means the LDI score over-categorized the wetland, i.e. the wetland was in worse condition than predicted by the LDI score; same category means the LDI and ORAM assessments reached the same result.



	under by 3	under by 2	under by 1	same category	over by 1	over by 2	over by 3
100 m	0	4.7619	14.2857	38.0952	19.0476	19.0476	4.7619
250 m	0	9.5238	33.3333	19.0476	14.2857	19.0476	4.7619
500 m	4.7619	9.5238	42.8571	14.2857	4.7619	23.8095	0
1000 m	9.5238	19.0476	33.3333	23.8095	4.7619	9.5238	0
2000 m	0	33.3333	28.5714	14.2857	4.7619	14.2857	4.7619
4000 m	4.7619	23.8095	42.8571	4.7619	19.0476	4.7619	0

Figure 45. The percent agreement between the Level 1 and Level 3 (VIBI) assessments for each buffer distance. Under (by 1, 2, or 3) means the LDI score derived land use class under categorized the wetland lower that what the Level 3 on-site assessment determined, i.e. the wetland was in better condition than predicted by the LDI score; Over (by 1, 2, or 3) means the LDI score over-categorized the wetland, i.e. the wetland was in worse condition than predicted by the LDI score; same category means the LDI and VIBI assessments reached the same result.

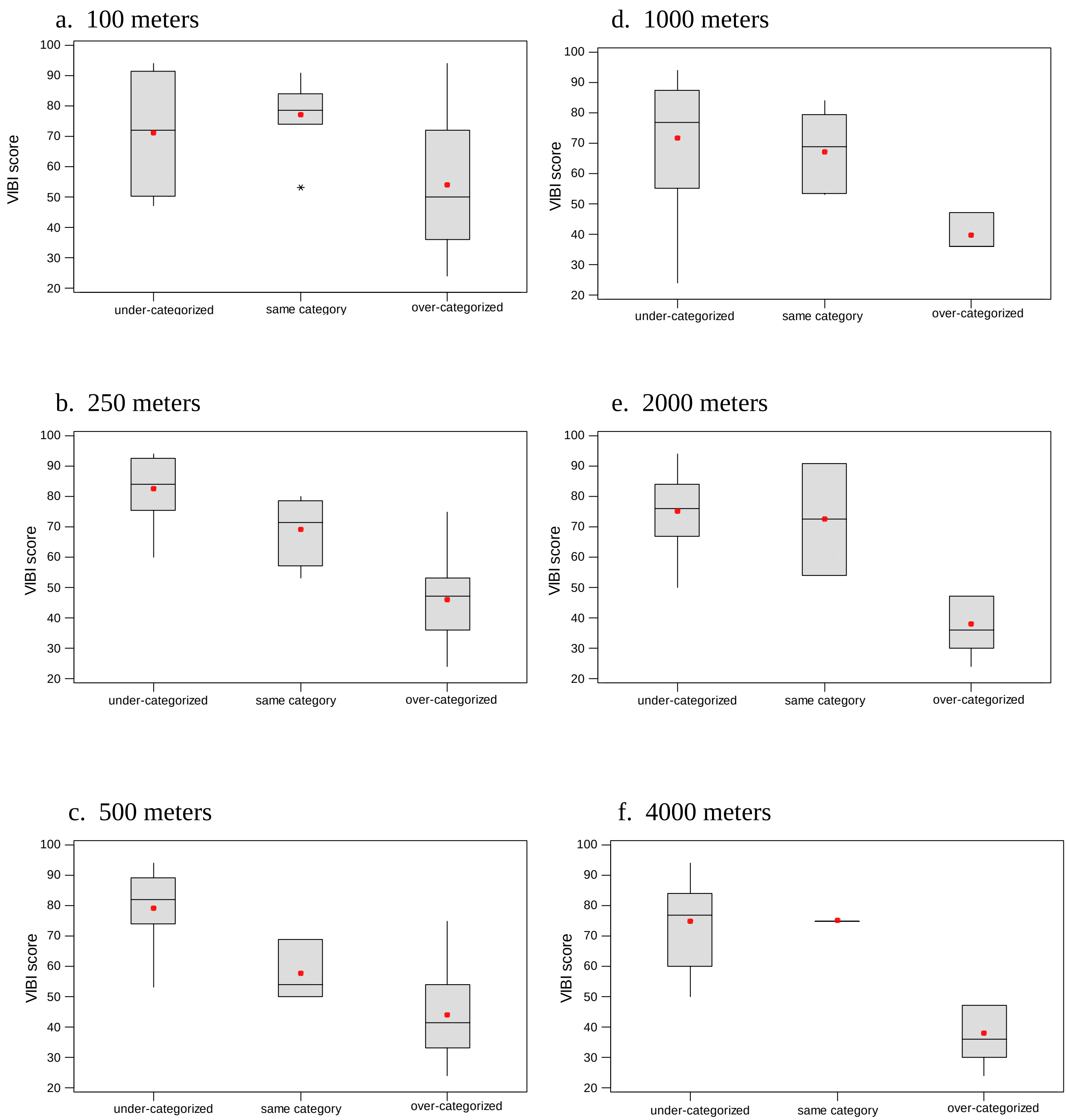


Figure 46. Box and whisker plots of average VIBI scores different Level1:Level3 "agreement" categories for different buffer distances (100 m, 250 m, 500 m, 1000 m, 2000 m, 4000 m). Under (by 1, 2, or 3) means the LDI score derived land use class under categorized the wetland lower that what the Level 2 on-site assessment determined, i.e. the wetland was in better condition than predicted by the LDI score; Over (by 1, 2, or 3) means the LDI score over-categorized the wetland, i.e. the wetland was in worse condition than predicted by the LDI score; same category means the LDI and ORAM assessments reached the same result.

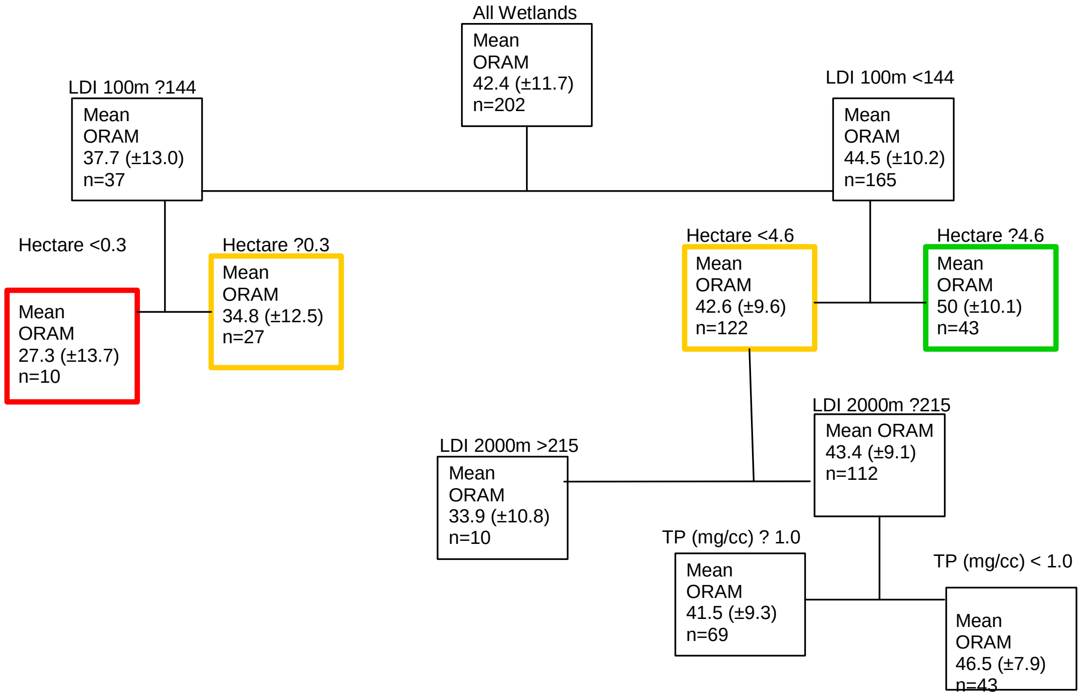


Figure 47A. CART model for ORAM scores for all wetlands and their expected thresholds based on CART analysis (overall R^2=0.28, cross-validation k=10, R^2=0.22). ORAM scores are modified for this analysis by subtracting scores for metric 1 (wetland size) and metric 2 (buffer), making a scoring range of 5 – 70. Red box approximates ORAM score for category 1, gold boxes represent category 2 scores, and green box approximates cut-off for category 3 wetlands.

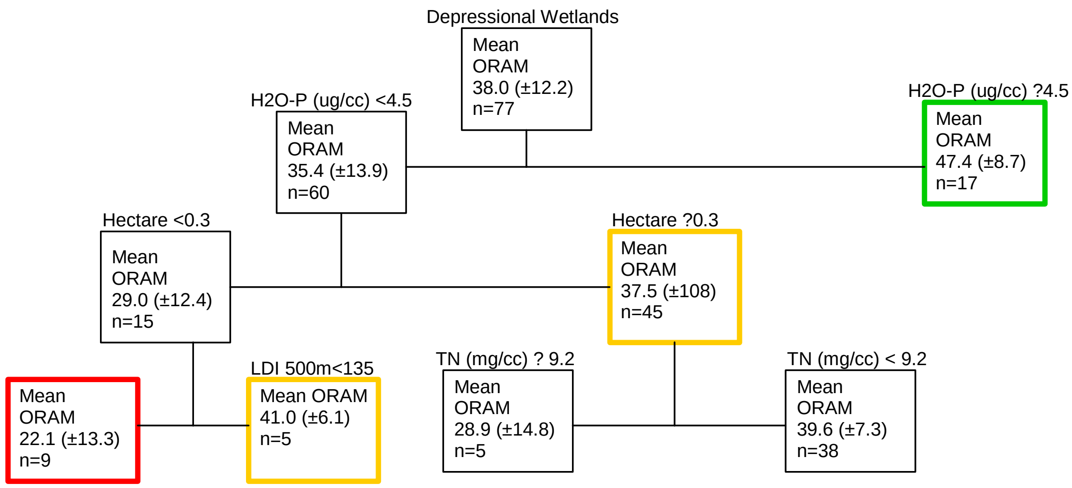


Figure 47B. CART model for ORAM scores for depressional wetlands and their expected thresholds based on CART analysis (overall R^2=0.50, crossvalidation k=10, R^2=0.36). ORAM scores are modified for this analysis by subtracting scores for metric 1 (wetland size) and metric 2 (buffer), making a scoring range of 5 – 70. Red box approximates ORAM score for category 1, gold boxes represent category 2 scores, and green box approximates cut-off for category 3 wetlands.

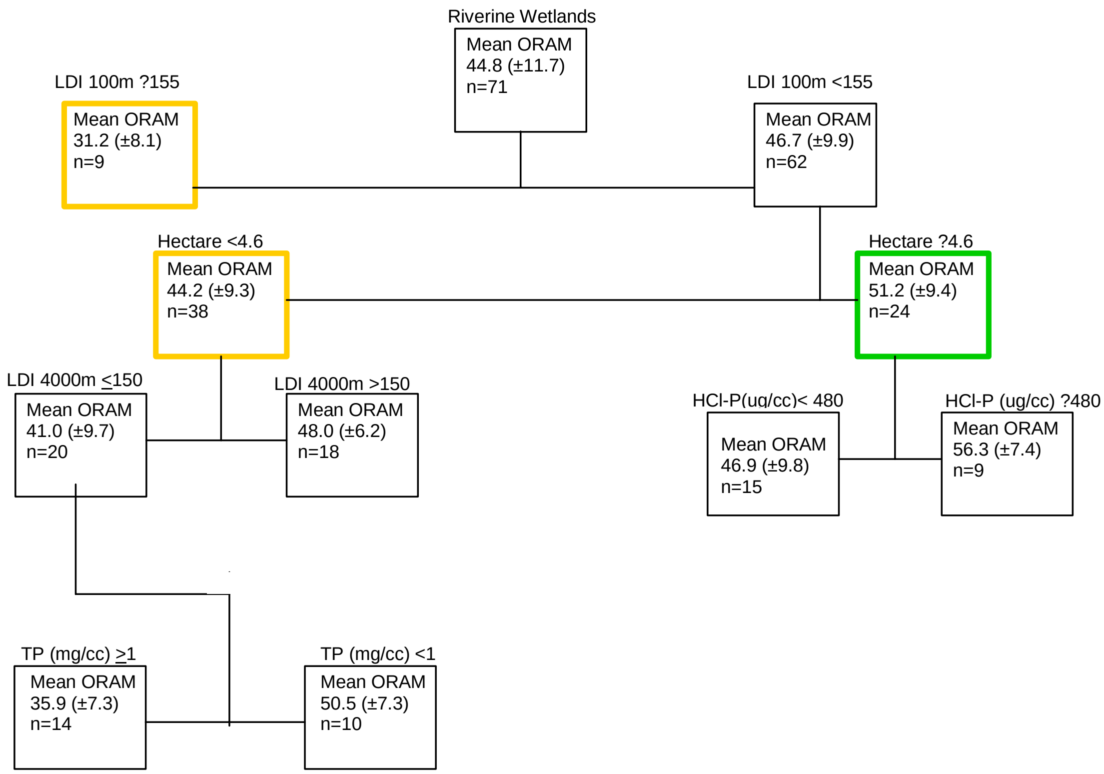


Figure 47C. CART model for ORAM scores for riverine wetlands and their expected thresholds based on CART analysis (overall R^2=0.52, crossvalidation k=10, R^2=0.45). ORAM scores are modified for this analysis by subtracting scores for metric 1 (wetland size) and metric 2 (buffer), making a scoring range of 5 – 70. Gold boxes represent category 2 scores, and green box approximates cut-off for category 3 wetlands.

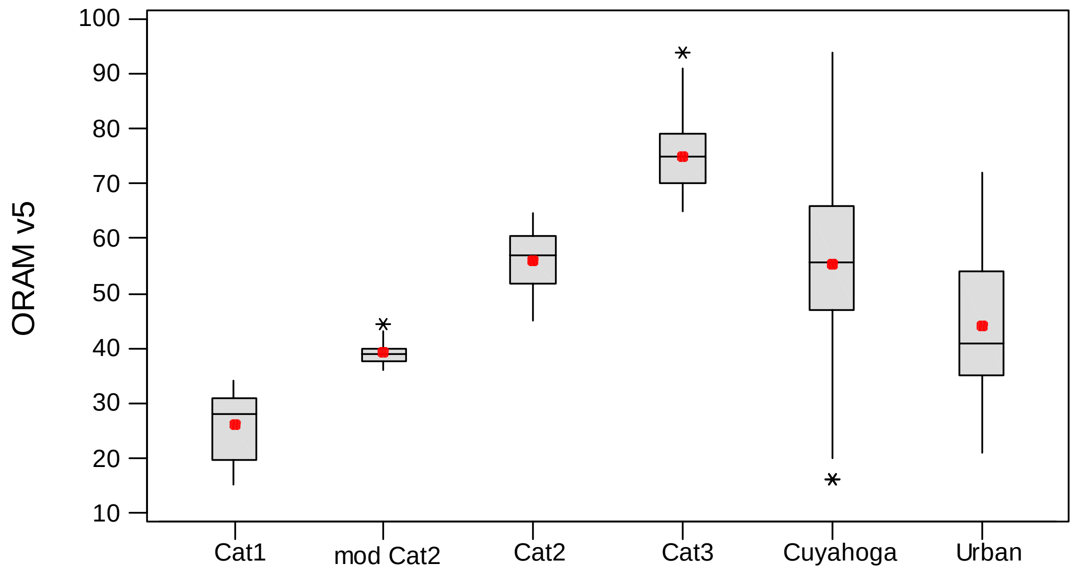


Figure 48A. Comparison of mean ORAM scores in Cuyahoga watershed and Urban wetlands in Franklin County with mean scores from Ohio EPA's reference wetland dataset. See Table 24 for ANOVA and multiple comparison results.

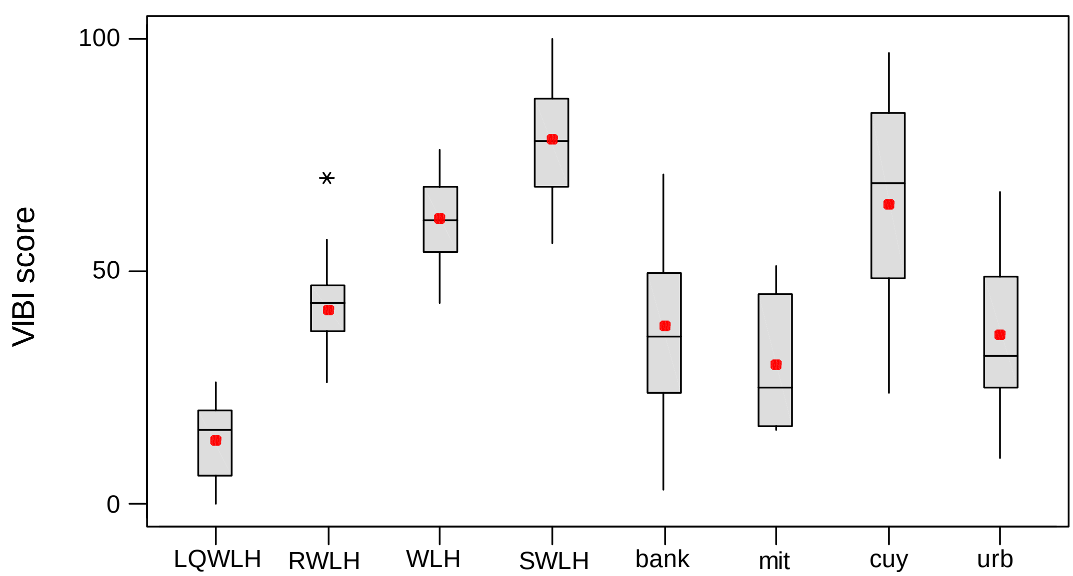


Figure 48B. Comparison of mean VIBI scores in Cuyahoga watershed, Urban wetlands in Franklin County, mitigation bank sites (bank), individual mitigation sites (mitigation) with mean scores from Ohio EPA's reference wetland dataset. See Table 24 for ANOVA and multiple comparison results.

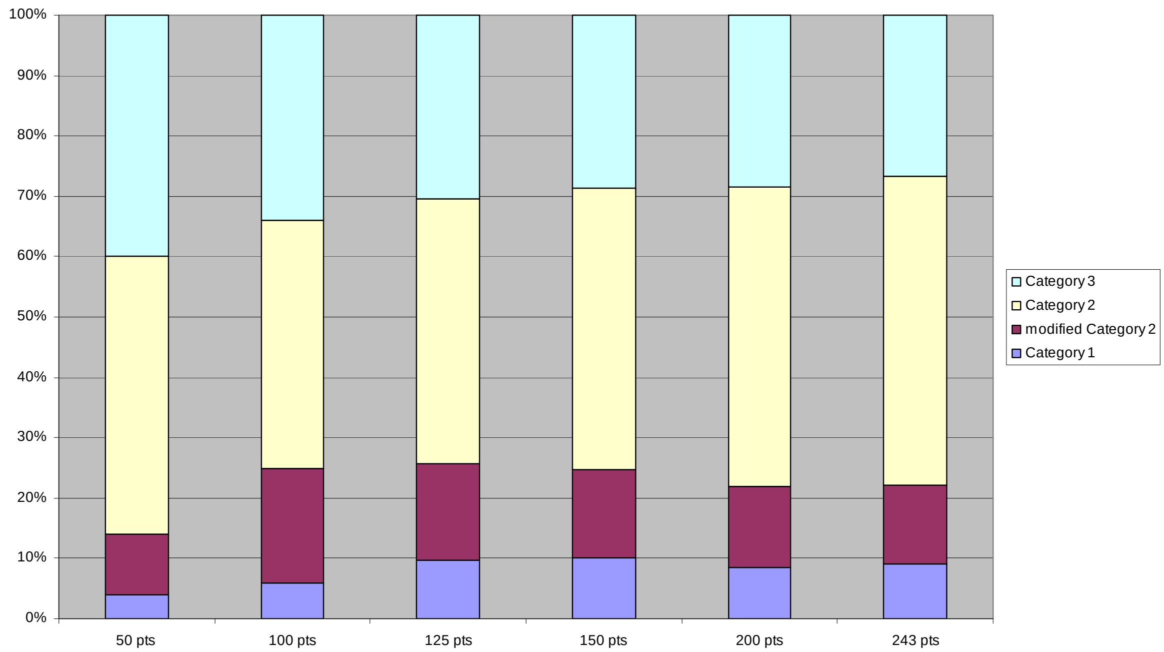


Figure 49A. Percentage of WETLAND RESOURCE in four categories based on samples of first 50, 100, 125, 150, 200, and 243 points. Refer to Table 24 for actual values.

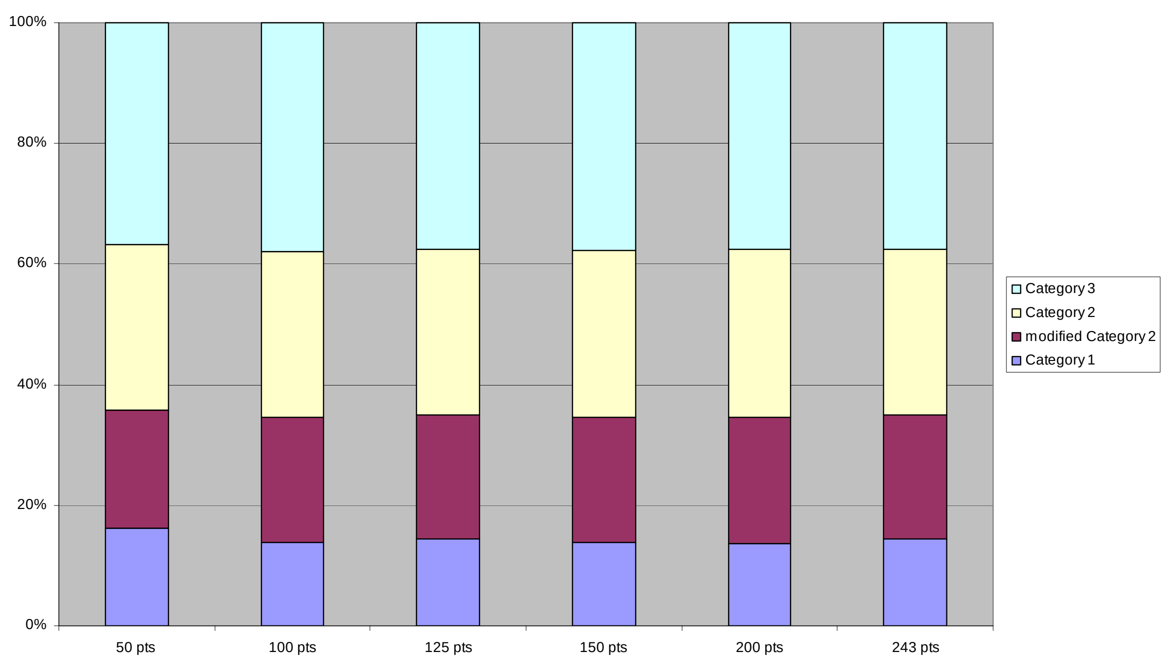


Figure 49B. Percentage of AVERAGE ORAM SCORES by four categories based on samples of first 50, 100, 125, 150, 200, and 243 points. Refer to Table 24 for actual values.

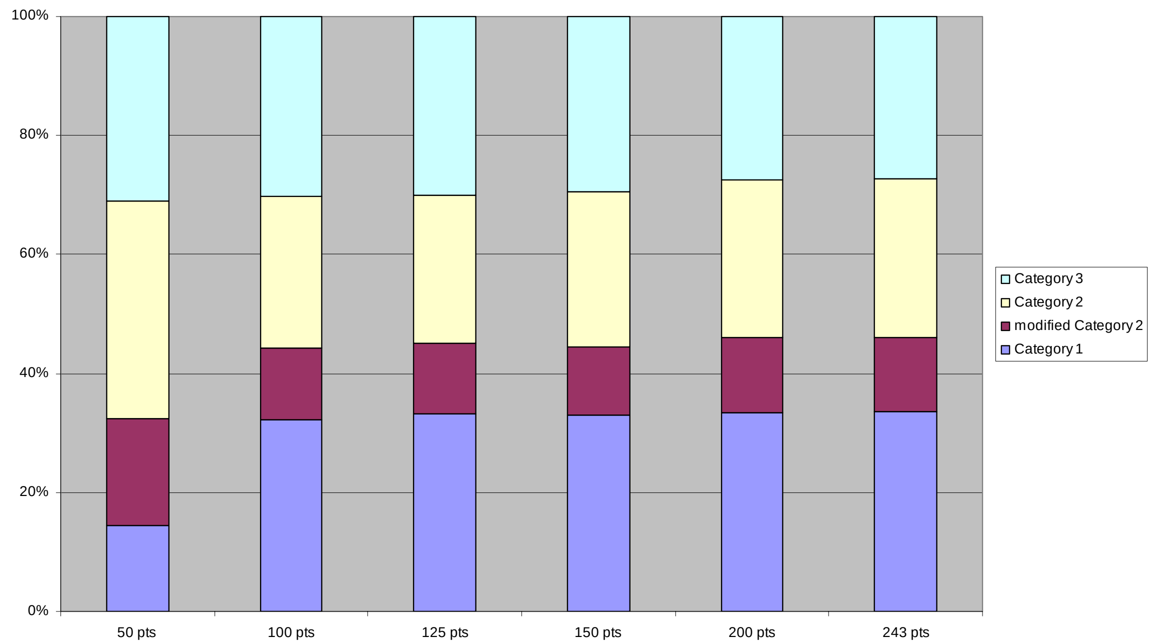


Figure 49C. Percentage of ORAM score STANDRD DEVIATION in four categories based on samples of first 50, 100, 125, 150, 200, and 243 points. Refer to Table 24 for actual values.

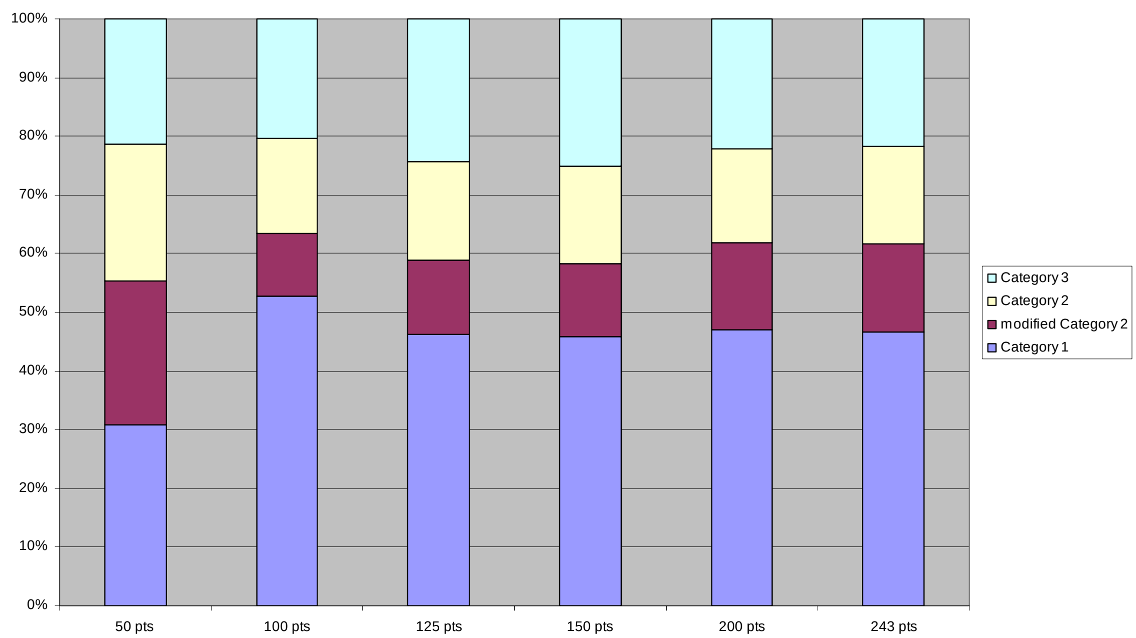


Figure 49B. Percentage of ORAM score 95% CONFIDENCE INTERVAL by four categories based on samples of first 50, 100, 125, 150, 200, and 243 points. Refer to Table 24 for actual values.

Appendices

Appendix A - Field Data Sheets

Appendix B - Amphibian Data

Appendix C - Soil Spectral Study

Appendix D - Site List

Appendix E (digital) - Vegetation Data

Appendix F (digital) - Site Data

Appendix G (digital) - Point Maps

Form Review ______

BACKGROUND INFORMATION

SITE NAME: ______________________ SITE ID: ______________________

DATE: ___ / ___ / 2 0 0 5 DATA RECORDED BY: ______________________

CLASSIFICATION

	Primary	Secondary	Tertiary
HGM Class (codes on back)			
Plant Community Class (codes on back)			

LOCATION

		Latitude	Longitude
Point Number		.	.
Modified Point Number (if applicable)	M	.	.
County			

DATA QUALITY CONTROL

		Comment required if item answer is no
180 degree photograph taken.	Y N	
Site sketch made (aerial or topo.)	Y N	
ORAM form completed.	Y N	
Stressor checklist completed.	Y N	
Wetland determination completed.	Y N	
Soil samples (6) collected.	Y N	
Photo log filled out with photograph numbers.	Y N	
Data sheets QAed after sampling completed.	Y N	

WETLAND PRESENCE

Was there a wetland at the point? If NO, go to next question. If YES, stop.	Y N	
Was there a wetland within 60 m of the point? If NO, go to next question. If YES, stop.	Y N	

NONWETLAND CHARACTERIZATION -- Pick One of the Three Options Below.

☐ The soils are NOT hydric and the area at the point is...	☐ The soils ARE hydric and the area at the point is...	☐ No determination can be made. Explain below.
☐ Developed with buildings, road, pavement, fill	☐ Developed with buildings, road, pavement, fill	
☐ Farmed	☐ Farmed	
☐ Other (specify)	☐ Other (specify)	
______________________	______________________	

24290

APPENDIX A

BACKGROUND INFORMATION

Form Review________

SITE ID: ______________________________ DATE: __ __ / __ __ / 2 0 0 5

COMMENTS, SITE SKETCHES, ETC.

HYDROGEOMORPHIC CLASSIFICATION

Class		Subclass	
I	Depression	A	Permanent inundation
		B	Regular inundation
		C	Seasonal inundation
		D	Seasonal saturation
II	Impoundment	A	Beaver
		B	Human
III	Riverine	A	Headwater
		B	Mainstem
		C	Channel
IV	Slope	A	Headwater
		B	Mainstem
		C	Isolated
		D	Fringing
V	Fringing	A	Reservoir
		B	Natural lake
VI	Coastal	Not applicable	
VII	Bog	A	Strongly ombrotrophic
		B	Moderately ombrotrophic
		C	Weakly ombrotrophic

PLANT COMMUNITY CLASSIFICATION

Class		Subclass	
1	Forest	A	Swamp forest
		B	Bog forest
		C	Forest seep
2	Emergent	A	Marsh
		B	Wet meadow
		C	Open bog
3	Shrub	A	Shrub swamp
		B	Tall shrub bog
		C	Tall shrub fen

24290

WETLAND DETERMINATION FORM

SITE NAME: ____________________ DATE: ___ / ___ / 2 0 0 5

INVESTIGATORS: ____________________ POINT NO.: ____________

COUNTY: ____________________

MODIFIED LATITUDE: ___ . _____

MODIFIED LONGITUDE: ___ . _____

WETLAND VEGETATION

Y N U	Is the canopy dominated by wetland tree species?
Y N U	Is the subcanopy (shrubs, small trees) dominated by wetland shrub or tree species?
Y N U	Is the herb layer dominated by wetland species?
Y N U	Is the overall vegetation of the area dominated by hydrophytic vegetation? (If no (N) or unable to determine (U), explain in comments.)

HYDROLOGY INDICATORS

Primary

- ☐ Inundated
- ☐ Saturated in upper 30 cm (12 in)
- ☐ Water marks
- ☐ Drift lines
- ☐ Sediment deposits
- ☐ Drainage patterns in wetland

Secondary

- ☐ Oxidized root channels in upper 30 cm (12 in)
- ☐ Water stained leaves
- ☐ Other ____________________

SOIL CHARACTERISTICS

	Matrix Color	Mottle Color	% Mottle	Oxid. Roots	Texture	Hydr. Cond.
5 cm				Y N		
20 cm				Y N		

TEXTURE:
LM = Loam SAL = Sandy loam SIL = Silty loam
CL = Clay loam SACL = Sandy clay loam
SICL = Silty clay loam C = Clay SAC = Sandy clay
SIC = Silty clay P = Peat M = Muck

HYDR. COND.:
I = Inundated S = Saturated M = Moist D = Dry

HYDRIC SOIL INDICATORS

- ☐ Histosol (peat or muck upper 80 cm)
- ☐ Histic epipedon (peat or muck upper 40 cm)
- ☐ Sulfur odor
- ☐ Aquic moisture regime
- ☐ Gleyed or low chroma soils
- ☐ Concretions
- ☐ High organic content in sandy soils
- ☐ Organic streaking in sandy soils
- ☐ Listed local hydric soil list
- ☐ Listed national hydric soil list

WETLAND DETERMINATION

Y N Hydrophytic vegetation present

Y N Wetland hydrology present

Y N Hydric soils present

Y N Is this sampling point within a wetland

COMMENTS

53294

Common Wetland Trees
- Silver maple
- Red maple
- Green ash
- Black ash
- Swamp white oak
- Pin oak
- American elm
- Slippery elm

Common Wetland Shrub and Subcanopy Tree Species
- Spicebush (Lindera)
- Winterberry (Ilex)
- Chokecherry (Aronia)
- Buttonbush (Cephalanthus)
- Musclewood (blue beech) (Carpinus)
- Willows (Salix spp.)
- Arrowwood (Viburnum)
- Highbush blueberry (Vaccinium)
- Poison sumac (Toxicodendron)
- Alder (Alnus)
- Swamp rose (Rosa)
- Dogwood (Cornus)
- Spiraea
- Buckthorn (Rhamnus)

Common Emergent Wetland Forbs
- Angelica
- Aster spp.
- Bedstraw (Galium)
- Beggar ticks (Bidens)
- Boneset (Eupatorium)
- Ditch stonecrop (Penthorum)
- False nettle (Boehmeria)
- Godenrods (Solidago, Euthamia)
- Hedge nettles (Stachys)
- Horehounds (Lycopus)
- Iris spp.
- Jewelweed (Impatiens)
- Joe-pye weeds (Eupatorium)
- Marsh marigold (Caltha)
- Marsh St. John's Wort (Triadenum, Hypericum)
- Marsh violets (Viola)
- Mountain mints (Pycnanthemum)
- Lobelias (cardinal flower, great lobelia)
- Loosestrife, native (Lysamachia)
- Loosestrife, purple (Lythrum salicaria)
- Loosestrife, swamp (Decodon)
- Loosestrife, winged (Lythrum alatum)
- Skullcaps (Scutellaria)
- Skunk cabbage (Symplocarpus)
- Smartweeds (Polygonum)
- Spring cress (Cardamine)
- Swamp buttercups (Ranunculus)
- Swamp dock (Rumex)
- Swamp mallow (Hibiscus)
- Swamp milkweed (Asclepias)
- Swamp saxifrage (Saxifraga)
- Swamp thistle (Cirsium)
- Sweet flag (Acorus)
- Water hemlock (Cicuta)

Other Trees Sometimes Encountered in Wetlands
- Black gum
- White pine
- American beech
- Tulip tree
- Birches (Betula)
- Cottonwood
- Swamp cottonwood
- Pumpkin ash

Common Wetland Graminoid Species
- Sedges (Carex)
- Bulrush (Scirpus, Schoenoplectus, Bolboschoenus)
- Spikerush (Eleocharis)
- Umbrella sedge (Cyperus)
- Three-way sedge (Dulichium)
- Twigrush (Cladium)
- True rush (Juncus)
- Bur-reed (Sparganium)
- Manna grasses (Glyceria)
- Wood reed (Cinna)
- Bluejoint grasses (Calamagrostis)
- Prairie cord grass (Spartina)
- Reed canary grass (Phalaris)
- Giant reed (Phragmites)
- Cutgrass (Leersia)
- Cattails (Typha)

Common Aquatic Wetland Forbs
- Arrowheads (Sagittaria)
- Bladderworts (Utricularia)
- Buttercups, aquatic (Ranunculus flabellaris, R. longirostris)
- Coontails (Ceratophyllum)
- Duckweeds, common (Lemna minor)
- Duckweeds, uncommon (Lemna trisulca)
- Duckweed, large (Spirodela)
- Mermaid weed (Proserpinaca)
- Milfoils (Myriophyllum)
- Naiads (Najas)
- Pickerel weed (Pontederia)
- Pondweeds (Potamogeton)
- Spatterdocks (Nuphar)
- Water lilies (Nymphaea)
- Water meal (Wolffia)
- Water plaintain (Alisma)
- Watershield (Brasenia)

Common Wetland Ferns
- Cinnamon fern (Osmunda cinnamomea)
- Horsetail ferns (Equisetum)
- Royal fern (Osmunda regalis)
- Sensitive fern (Onoclea)
- Spinulose shield fern (Dryopteris carthusiana)

OHIO RAPID ASSESSMENT METHOD

Form Review ______

SITE NAME: ______________________ SITE ID: ______________________

DATE: ___ / ___ / 2 0 0 5 DATA RECORDED BY: ______________________

Metric 1. Wetland Area (size)

- ○ 6 >50 acres (>20.2 ha)
- ○ 5 25 to <50 acres (10.1 to 20.2 ha)
- ○ 4 10 to <25 acres (4 to <10.1 ha)
- ○ 3 3 to <10 acres (1.2 to <4 ha)
- ○ 2 0.3 to <3 acres (0.12 to <1.2 ha)
- ○ 1 0.1 to <0.33 acres (0.04 to <0.12 ha)
- ○ 0 <0.1 acres (0.04 ha)

Metric 2. Upland buffer and surrounding land use

2a. Calculate average buffer width. Select only one and assign score.

- ○ 7 WIDE-Buffers average 50 m (164 ft) or more around wetland perimeter
- ○ 4 MEDIUM-Buffers average 25 to <50 m (82 to <164 ft) around wetland perimeter
- ○ 1 NARROW-Buffers average 10 to <25 m (32 to <82 ft) around wetland perimeter
- ○ 0 VERY NARROW-Buffers average <10 m (<32 ft) around wetland perimeter

2b. Intensity of surrounding land use. Select one or take average of two.

- ○ 7 VERY LOW - 2nd growth or older forest, prairie, savannah, wildlife area, etc.
- ○ 5 LOW - Old fields (>10 years), shrubland, young second growth forest
- ○ 3 MODERATELY HIGH - Residential, fenced pasture, park, conservation tillage, new fallow field
- ○ 1 HIGH - Urban, industrial, open pasture, row cropping, mining, construction

SCORE

Metric 1 ☐ (max 6 pts)

Metric 2 ☐ (max 14 pts)

Metric 3. Hydrology

3a. Sources of water. Score all that apply. 3a ☐

- ○ 5 High pH groundwater
- ○ 3 Other groundwater
- ○ 1 Precipitation
- ○ 3 Seasonal/intermittent surface water
- ○ 5 Perennial surface water (lake or stream)

3b. Connectivity. Score all that apply. 3b ☐

- ○ 1 100 year flood plain
- ○ 1 Between stream/lake and other human use
- ○ 1 Part of wetland/upland (e.g. forest) complex
- ○ 1 Part of riparian or upland corridor

3c. Maximum water depth. Select only one and assign score. 3c ☐

- ○ 3 >0.7 m (>27.6 in)
- ○ 2 0.4 to 0.7 m (15.7 to 27.6 in)
- ○ 1 <0.4 m (<15.7 in)

3d. Duration inundation/saturation. Score one or take average of two. 3d ☐

- ○ 4 Semi to permanently inundated/saturated
- ○ 3 Regularly inundated/saturated
- ○ 2 Seasonally inundated
- ○ 1 Seasonally saturated in upper 30 cm (12 in)

3e. Modifications to natural hydrologic regime. Score one or take average of two. 3e ☐

- ○ 12 None or none apparent
- ○ 7 Recovered
- ○ 3 Recovering
- ○ 1 Recent or no recoverey

Metric 3 ☐ (max 30 pts)

Check all disturbances observed

- ☐ Ditch ☐ Dike ☐ Stormwater input ☐ Filling/grading ☐ Dredging
- ☐ Tile ☐ Weir ☐ Point source (non-stormwater) ☐ Roadbed/RR track ☐ Other

Metric 4. Habitat Alteration and Development

4a. Substrate disturbance. Score one or take average of two. 4a ☐

- ○ 4 None or none apparent
- ○ 3 Recovered
- ○ 2 Recovering
- ○ 1 Recent or no recoverey

4b. Habitat development. Select only one and assign score. 4b ☐

- ○ 7 Excellent
- ○ 6 Very good
- ○ 5 Good
- ○ 4 Moderately good
- ○ 3 Fair
- ○ 2 Poor to fair
- ○ 1 Poor

4c. Habitat alteration. Score one or take average of two. 4c ☐

- ○ 9 None or none apparent
- ○ 6 Recovered
- ○ 3 Recovering
- ○ 1 Recent or no recoverey

Check all disturbances observed

- ☐ Mowing ☐ Toxic pollutants
- ☐ Grazing ☐ Shrub/sapling removal
- ☐ Clearcutting ☐ Herbaceous/aquatic bed removal
- ☐ Selective cutting ☐ Farming
- ☐ Woody debris removal ☐ Nutrient enrichment
- ☐ Sedimentation ☐ Dredging

Metric 4 ☐ (max 20 pts)

SUBTOTAL - Page 1 ☐

OHIO RAPID ASSESSMENT METHOD

Form Review ______

SITE ID: ____________________ DATE: ___ / ___ / 2 0 0 5

Metric 5. Plant Communities, interspersion, microtopography — SCORE

5a. Wetland Vegetation Communities. Circle the score of all present using 0 to 3 cover scale using tables 1-3 as a guide.

Aquatic bed	0	1	2	3
Emergent	0	1	2	3
Shrub	0	1	2	3
Forest	0	1	2	3
Mudflats	0	1	2	3
Open water	0	1	2	3
Other (list below)	0	1	2	3

5a [ ]

5b. Horizontal (plan view) interspersion. Select only one.

- ○ 5 High
- ○ 4 Moderately high
- ○ 3 Moderate
- ○ 2 Moderately low
- ○ 1 Low
- ○ 0 None

5b [ ]

5c. Coverage of invasive plants. Add or deduct points for coverage.

- ○ -5 Extensive >75% cover
- ○ -3 Moderate 25-75% cover
- ○ -1 Sparse 5-25% cover
- ○ 0 Nearly absent <5% cover
- ○ 1 Absent

5c [ ]

5d. Microtopography. Circle the score of all present using 0 to 3 cover scale using table 4 as a guide.

Vegetated hummucks/tussucks	0	1	2	3
Coarse woody debris >15 cm (6 in)	0	1	2	3
Standing dead >25 cm (10 in) dbh	0	1	2	3
Amphibian breeding pools	0	1	2	3

5d [ ]

Table 1. Vegetation Community Cover Scale

(see table 2 for description of quality)

0	Present but <0.1 ha (0.247 a) contiguous area.
1	Present and either comprises small part of wetland's vegetation and is of moderate quality, or comprises a significant part, but is of low quality.
2	Present and either comprises significant part of wetland's vegetation and is of moderate quality, or comprises a small part and is of high quality.
3	Present and either comprises significant part, or more, of wetland's vegetation and is of high quality.

Table 2. Narrative Description of Vegetation Quality

Low	Low spp diversity and/or predominance of nonnative or disturbance tolerant native species.
Mod	Native spp are dominant component of the vegetation, although nonnative and/or disturbance tolerant native spp can also be present, and species diversity moderate to moderately high, but generally w/o presence of rare threatened or endangered spp.
High	A predominance of native species, with nonnative spp and/or disturbance tolerant native spp absent or virtually absent, and high spp diversity and often, but not always, the presence of rare, threatened or endangered spp.

Table 3. Mudflat and Open Water Class Quality

0	Present but <0.1ha (0.247 acres) contiguous area
1	Low 0.1 to <1ha (0.247 to 2.47 acres)
2	Moderate 1 to <4ha (2.47 to 9.88 acres)
3	High 4ha (9.88 acres) or more

Page 1 Subtotal [ ]

Table 4. Microtopography Cover Scale

0	Functionally absent (present in very small amounts.)
1	Present small amounts or, if more common, of marginal quality.
2	Present in moderate amounts, but not of highest quality or in small amounts of highest quality.
3	Present in moderate or greater amounts and of highest quality.

Metric 5 [ ] (max 20 pts)

Condition Score (Page 1 + Metric 5) (Max 90 points) [ ]

Metric 6. Special Wetlands

Mark all that apply and score as indicated.

- ○ 10 Bog
- ○ 10 Fen
- ○ 10 Old growth forest
- ○ 5 Mature forested wetland
- ○ 10 Lake plain sand prairies (Oak Openings)
- ○ 10 Relict wet prairies
- ○ 10 Lake Erie coastal/tributary wetland - unrestricted hydrology
- ○ 5 Lake Erie coastal/tributary wetland - restricted hydrology
- ○ 10 Known occurence state/federal threatened or endangered species
- ○ 10 Significant migratory songbird/water fowl habitat or useage
- ○ -10 Category 1 wetland. See question 1 qualitative rating

Metric 6 [ ] (max 10 pts)

Grand Total (max 100 pts) [ ]

PENN STATE STRESSOR CHECKLIST

_______ Form Review

SITE NAME: ______________________ **SITE ID:** ______________________

DATE: ___ / ___ / 2 0 0 5 **DATA RECORDED BY:** ______________________

CHECK BOX IN CATEGORY HEADING IF ANY OF THE STRESSOR TYPES LISTED FOR THE CATEGORY ARE CHECKED.

☐ HYDROLOGIC MODIFICATION

Mark all observed.

- L M H TILE DRAIN
- L M H DITCH
- L M H Dike
- L M H Weir/dam
- L M H STORMWATER INPUTS/CULVERTS
- L M H POINT SOURCE (NON-STORMWATER)
- L M H Filling, grading, dredging (of wetland/waterbody or immediate buffers)
- L M H Roadbed/railroad
- L M H Dead/dying trees
- L M H Other ______________________

☐ HIGH BOD

Mark all observed.

- L M H Excessive denisity of aquatic plants or algal mats in water column.
- L M H Excessive deposition or dumping of organic waste (e.g. leaves, grass, clippings, woody debris, etc.).
- L M H Direct discharges of organic wastewater or material (e.g. milkhouse waste, food-processing waste, other wastewater sources).
- L M H Other ______________________

☐ SEDIMENTATION

Mark all observed.

- L M H Active/recently active adjacent construction, plowing, heavy grazing or forest harvesting
- L M H Dominant presence (>50% of vegetation) of sediment tolerant plants (see list)
- L M H Sediment deposits/plumes
- L M H Siltiness on ground or vegetation
- L M H URBAN/ROAD STORMWATER INPUT/CULVERT
- L M H Eroding banks/slopes
- L M H Other ______________________

☐ TOXIC CONTAMINANTS

Mark all observed.

- L M H Severe vegetation stress
- L M H OBVIOUS SPILLS, DISCHARGES, PLUMES, ODORS
- L M H Wildlife impacts (e.g. tumors, abnormalities, etc.)
- L M H Adjacent industrial sites, proximity of railroad
- L M H Other ______________________

☐ VEGETATION ALTERATION

Mark all observed.

- L M H Dominant presence (>50% of the vegetation) of exotic or aggressive plant species (see list)
- L M H Mowing
- L M H Grazing
- L M H Tree cutting (>50% canopy removal)
- L M H Brush cutting (mechanized removal of shrubs/saplings)
- L M H Removal of woody debris
- L M H Aquatic weed control (mechanical or herbicide)
- L M H Excessive herbivory (deer, muskrat, geese, carp, etc.)
- L M H Evidence of chemical defoliation
- L M H Other ______________________

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PENN STATE STRESSOR CHECKLIST

_______ Form Review

SITE ID: ____________________ DATE: __ __ / __ __ / 2 0 0 5

CHECK BOX IN CATEGORY HEADING IF ANY OF THE STRESSOR TYPES LISTED FOR THE CATEGORY ARE CHECKED.

☐ EUTROPHICATION AND NUTRIENT ENRICHMENT

Mark all observed.

- L M H Dominant presence (>50% of vegetation) of nutrient tolerant species (e.g. uniform stand of exotic/aggressive species)
- L M H DIRECT DISCHARGES FROM AG. FEEDLOT, MANURE PITS, ETC.
- L M H DIRECT DISCHARGES FROM SEPTIC OR SEWAGE TREATMENT SYSTEMS
- L M H Heavy or moderate formation of algal mats
- L M H Other (e.g. signs of excess nutrients - methane odor, dead fish, etc.)

____

☐ THERMAL ALTERATION

Mark all observed.

- L M H Significant increase in water temperature
- L M H Moderate increase in water temperature
- L M H Other ____________________

☐ SALINITY

Mark all observed.

- L M H Obvious increase in concentration of dissolved salts
- L M H Other (e.g. evident use of road salt)

____

☐ ACIDIFICATION

Mark all observed.

- L M H ACID MINE DRAINAGE DISCHARGES
- L M H ADJACENT MINED LANDS/SPOIL PILES
- L M H Excessively clear water
- L M H Absence of expected biota
- L M H Other ____________________

☐ TURBIDITY

Mark all observed.

- L M H High concentration of suspended solids in water column.
- L M H Moderate concentration of suspended solids in water column.
- L M H Other ____________________

Buffer Type*	Buffer Width (m)				
	>100	30-100	10-30	3-10	0-3
Natural Forest	14	12	10	8	6
Shrub/Sapling	12	10	8	6	4
Perennial Herb	10	8	6	4	2
Other	0	0	0	0	0

*If exactly one-half of two buffer types, take half the sum.

Buffer Type

- ☐ Natural Forest
- ☐ Shrub/Sapling
- ☐ Perennial Herb

____

- ☐ Other (list)

Buffer Width (m) __________

Buffer Score (from table) __________

45684

APPENDIX B
AMPHIBIAN DATA

SiteCode	Site	Applicable type	AmphIBI	AQAI	AQAI Metric	RA Tol	RA Tol Metric	RA Sen	RA Sen Metric	Sal.Sp.	Sal. Metric	WF/SS	WF/SS Metric	comments
SITE2001	Alexander Rd	not sampleable	*	*	*	*	*	*	*	*	*	*	*	
SITE2005	Old Forge Rd	no, bog	0	2.25	0	1	0	0	0	0	0	no	0	2 passes (1&2)
SITE2008	Bartholomew Rd	no, marsh	0	0	0	0	0	0	0	0	0	no	0	no amphibians collected
SITE2013	Ward Rd	no, marsh	3	3	3	1	0	0	0	0	0	no	0	
SITE2014	Brecksville	yes	30	4.13	3	0.723	3	0.1702	7	3	7	yes	10	
SITE2015	Black Rd	yes	10	3	3	0.5	7	0	0	1	0	no	0	2 passes (1&2)
SITE2016	Wake Robin	not sampleable	*	*	*	*	*	*	*	*	*	*	*	
SITE2017	Quail Hollow	yes	30	6.86	10	0.029	10	0.97066	10	0	0	no	0	
SITE2020	Thut	no, riverine forest	6	3.15	3	0.976	0	0.02439	3	1	0	no	0	
SITE2023	Bath Rd	yes	0	2.86	0	1	0	0	0	0	0	no	0	2 passes (1&2)
SITE2025	Rhinehart	no, riverine marsh	3	3	3	1	0	0	0	0	0	no	0	2 passes (1&2)
SITE2027	Hasbrouck	yes	40	6.87	10	0.034	10	0.96585	10	1	0	yes	10	
SITE2028	Bridge Creek	not sampleable	*	*	*	*	*	*	*	*	*	*	*	
SITE2029	Twinsburg	no, riverine	3	3	3	1	0	0	0	0	0	no	0	2 passes (1&2)
SITE2031	Miller	no, marsh	0	0	0	0	0	0	0	0	0	no	0	1 pass (1)
SITE2032	Aquilla Rd	no, riverine marsh	0	2.15	0	1	0	0	0	0	0	no	0	
SITE2033	Goodyear	yes	40	6.9	10	0.025	10	0.975	10	0	0	yes	10	2 passes (1&2)
SITE2034	Oak Knolls	no, riverine forest	0	2.2	0	1	0	0	0	0	0	no	0	2 passes (2&3)
SITE2036	Tare Creek	no, riverine marsh	0	2.87	0	1	0	0	0	0	0	no	0	
SITE2037	Wingfoot Lake	no, marsh	3	3	3	1	0	0	0	0	0	no	0	
SITE2040	South Rider Rd	no, riverine marsh	*	*	*	*	*	*	*	*	*	*	*	
SITE2042	Marsh Wetlands	no, riverine marsh	*	*	*	*	*	*	*	*	*	*	*	

APPENDIX B
AMPHIBIAN DATA

Site #	Site Name	Jefferson sal. AMBJEF	spotted sal. AMBMAC	sm. mouth sal. AMBTEX	red spot. newt NOTVIR	spring peeper PSECRU	w. chorus frog PSETRI	bullfrog RANCAT	green frog RANCLA	leopard frog RANPIP	wood frog RANSYL
2001	Alexander Rd	*	*	*	*	*	*	*	*	*	*
2005	Old Forge Rd	*	*	*	*	0.75	*	0.25	*	*	*
2008	Bartholomew Rd	*	*	*	*	*	*	*	*	*	*
2013	Ward	*	*	*	*	*	1.00	*	*	*	*
2014	Brecksville	0.11	0.09	*	0.09	*	*	0.07	0.64	0.02	*
2015	Black Rd	*	*	0.50	*	0.50	*	*	*	*	*
2016	Wake Robin	*	*	*	*	*	*	*	*	*	*
2017	Quail Hollow	*	*	*	*	0.02	0.01	0.00	0.00	*	0.97
2020	Thut	*	*	*	0.02	*	*	*	0.98	*	*
2023	Bath Rd	*	*	*	*	0.14	*	*	0.86	*	*
2025	Rhinehart	*	*	*	*	*	*	*	1.00	*	*
2027	Hasbrouck	*	0.01	*	*	*	0.01	*	0.02	0.00	0.95
2028	Bridge Creek	*	*	*	*	*	*	*	*	*	*
2029	Tinkers Oxbow	*	*	*	*	*	*	*	1.00	*	*
2031	Miller	*	*	*	*	*	*	*	*	*	*
2032	Aquilla Rd	*	*	*	*	0.06	*	0.01	0.12	0.82	*
2033	Goodyear Bog	*	*	*	*	*	*	*	0.25	*	0.98
2034	Oak Knolls	*	*	*	*	*	*	0.80	0.20	*	*
2036	Tare Creek	*	*	*	*	*	*	*	0.87	0.13	*
2037	Wingfoot Lake	*	*	*	*	*	*	*	1.00	*	*
2040	South Rider Rd	*	*	*	*	*	*	*	*	*	*
2042	Marsh Wetlands	*	*	*	*	*	*	0.51	0.49	*	*

APPENDIX C

OHIO ENVIRONMENTAL PROTECTION AGENCY

BIOGEOCHEMICAL CHARACTERIZATION AND SPECTRAL CALIBRATION OF WETLAND SOIL SAMPLES FROM THE CUYAHOGA RIVER BASIN

FEBRUARY 14, 2006

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Summary

This report summarizes the findings of an examination of wetland soils from throughout the Cuyahoga River basin in northern Ohio. The soil study was implemented in two phases; the first phase was analysis of a subset of the 1685 soil samples collected for a full range of biogeochemical indicators; the second phase was development and use of predictive models between these observed indicators and high resolution diffuse reflectance spectra. The latter method is an emerging technique for rapid, low-cost characterization of environmental samples. In this work, the spectral technique (visible/near infrared reflectance spectroscopy – VNIRS) allowed comprehensive characterization (21 soil properties) of a large number of wetland soils (>1400 samples). This report summarizes the laboratory analyses, calibration efficiency between VNIR spectra and site-level variability in soil properties. Our general conclusion is that VNIRS represents a useful tool for characterization of chemical and physical properties of environmental samples; for some analytes, prediction efficiency is excellent (organic matter, total nitrogen, total carbon, total phosphorus, total calcium), while for others it is inadequate (KCl-extractable nitrates, water-extractable phosphorus, total conductivity). For the remaining analytes (pH, HCl-extractable P, bulk density, P-sorption capacity, total metals [K, Mg, Zn, Cu, Fe, Al, Pb, Na]) prediction efficiencies were adequate for applications in which high-sample throughput is required (e.g., resource or condition mapping), but less than adequate for high-accuracy applications (e.g., regulatory testing).

Introduction and Background

Analytical spectroscopy is a proven technology for the rapid non-destructive assessment of materials, including plastics, industrial reagents, minerals and agricultural products. Spectral reflectance signature libraries of numerous material samples and composites have been cataloged (e.g. Clark 1999); from these libraries, unknown samples are interpreted for functional and qualitative properties. There are many platforms and analytical schemes for obtaining and interpreting spectral properties of samples. The application used in this work, which measures diffuse visible/near infrared reflectance (VNIR), involves collecting high-resolution optical signatures (e.g. 1-nm bandwidths) from a sample illuminated by a high intensity full spectrum light source in the visible (350-750 nm) and near-to-mid infrared (750-2500 nm) regions of the electromagnetic spectrum.

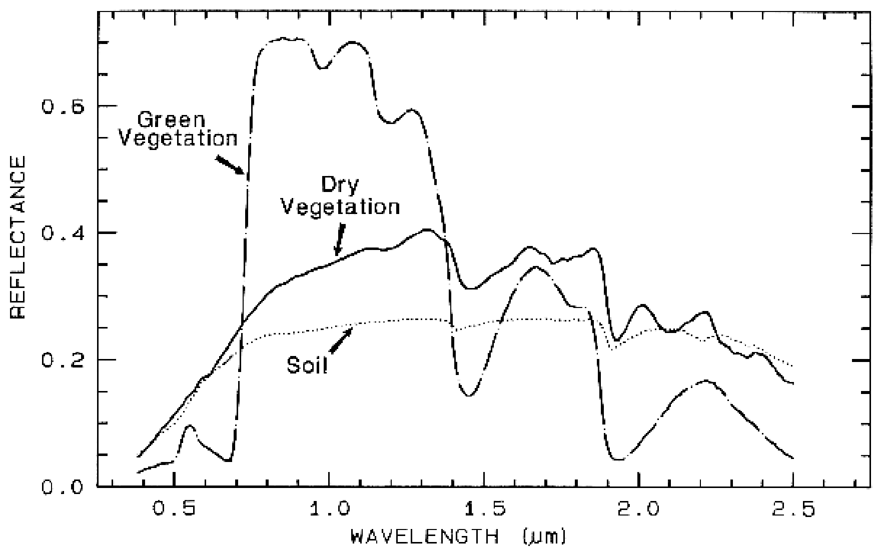

Fig. 1 – Typical spectral responses of green vegetation, dry vegetation (litter) and soil. Optical absorbance and reflectance features are composite responses of the organic and inorganic constituents of each material (USGS 1999).

Under controlled conditions, reflectance signatures arise due to electronic excitation of atoms and vibrational stretching and bending of structural groups of atoms that form molecules and crystals. For example, fundamental vibrational features for organic matter functional groups are observed in the mid- to thermal-infrared (2.5-25 μm) portion of the spectrum; however, overtones of these fundamental features occur at fractions of the fundamental frequency, which fall within the range typical of DRS (700-1000 nm and 1000-2500 nm). Clay minerals and common cations also exhibit distinctive spectral reflectance characteristics due to light interference, facilitating rudimentary mineralogical description.

Despite the widespread application of analytical/descriptive spectroscopy to the characterization of relatively pure molecular mixtures, quantitative inference of soil quality indicators from spectral reflectance is limited by the heterogeneous character of the soil system. In particular, soil represents a complex mixture of spectrally active constituents, and efforts to unmix spectral responses for characterization efforts on bulk samples have been relatively unsuccessful. Quantitative spectroscopy treats the characterization question differently; rather than trying to use diagnostic features of a spectrum for inferring presence of particular organic functional groups or minerals, multivariate analytical tools are used to infer composition and concentration indirectly (i.e., statistically) from complex, strongly co-linear reflectance spectra. The emergence and proliferation in the last decade of powerful statistical data mining tools (e.g. Partial Least Squares [PLS] regression, Classification and Regression Trees [CART] and Multivariate Adaptive Regression Splines [MARS]) has allowed researchers to develop efficient predictive correlations between spectral response characteristics and a wide array of standard soil and plant functional parameters (Ben- Dor and Banin 1995, Kooistra et al. 1997, Foley et al. 1998, Gillon et al. 1999, Chen et al. 2002). The method continues to be tested in a wide array of ecological regions; recent work (Cohen et al. 2005) demonstrated applicability to a wide array of potential ecosystem indicators in wetland systems with low ash-content soils.

Formal methods for analyzing soil archives for which laboratory evaluations have been performed have been developed (Shepherd and Walsh 2002). This approach is founded on the development of Spectral Reflectance Libraries (SRLs). SRLs consist of archived soils for which spectral response curves and controlled laboratory analyses of functional indicators have been collected. From the SRLs, calibrations are developed to correlate reflectance to functional measurements; validated models can then be used to infer soil properties in incoming sample soils for the suite of laboratory indicators without direct analysis. The indicator analytes that have exhibited association with spectra in other studies include cation concentrations (Ca, Mg, Fe, Al, Na), soil organic matter and ash content, soil texture and soil phosphorus. Preliminary evidence suggests that reliable models can be developed to infer organic carbon quality (e.g. lignin content - citation), organic mineralization rates (Bouchard et al. 2003, Fystro 2002), soil hydraulic properties (Cohen et al. submitted), and various measures of toxic contamination

(Kooistra et al. 1997). While for many of these parameters, it is strong co-linearity with readily observable soil attributes (e.g. soil carbon, soil clay content) and not direct reflectance effects that are being observed, our research (Cohen et al. 2005) has shown that spectral observations provide a measure of the soil system that offer non-redundant information about its composition.

The approach proposed for this study will facilitate rapid quantitative inference of a suite of soil physical and chemical properties directly from reflectance characteristics. Our experience suggests that, given effective data and sample management protocols, 100-200 samples can be processed by a single technician in one day, and spectral quality assurance and prediction can be automated so that results emerge for all parameters simultaneously in real-time. Given extremely basic sample pre-processing, this offers tremendous throughput potential. Further, the cost of analysis are significantly reduced compared with conventional laboratory costs, which allows strategic spatial and temporal sampling, high-resolution surveys of soil condition and statistically powerful inference of the effects of human activities on soil function to be developed with relative ease.

Study Objectives and Protocols

As part of a large assessment study of wetlands throughout the Cuyahoga River basin, soils were collected from 287 wetlands sites. At each site, 6 samples were collected (total N = 1685); from 231 sites, one sample selected for full laboratory characterization (see Table 1 for list of selected analytes). All samples were analyzed spectrally (details given below). Our objectives were:

1) Develop statistical predictive relationships between the measured soil properties and soil spectra, and use standard prediction evaluation methods to determine which analytes can be successfully predicted using a samples spectral signature.
2) Apply the predictive relationship to the 1454 samples for which only spectral data were obtained.
3) Determine within- and between-site variability in spectrally predicted soil properties.

Below, we present the methods used for soil characterization and obtaining spectral signatures. Our results are reported in three stages: 1) soil biogeochemistry, 2) soil spectra and predictive modeling, and 3) model extension and site level summary.

Methods

Soil Biogeochemical Measurements

The list of soil analytes under examination in this work includes bulk soil properties (pH, conductivity, organic matter content, bulk density), nutrient pools (total P, total N, total C, HCl-extractable P, water extractable P, KCl-extractable nitrates), P sorption capacity, and total metals (K, Na, Ca, Mg, Al, Fe, Cd, Pb, Cu, Zn).

Soil pH and conductivity were determined by a Fisher Scientific multi-meter on 10 g wet soil after equilibrating with 20 mL of distilled deionized water. Organic matter content (%) was determined from residue after ashing at 550 ^{o}C (Anderson, 1976). Total P was determined by combusting approximately 0.2-0.5 g oven-dried, finely ground soil at 550^{o} C for 4 hrs, digesting the ash with 6M HCl and continuous heating on a hot plate, and filtering through No. 41 Whatman filter (Anderson 1976), followed by analysis of P by automated ascorbic acid method (Method 365.1: USEPA 1993). Total C and N were determined on dried, ground soil samples by dry combustion (Nelson and Sommers 1996) using a Carlo-Erba NA-1500 CNS Analyzer (Haak-Buchler Instruments, Saddlebrook, NJ). HCl-extractable P was determined by extraction of 0.5 g dry soil in 25 mL 1 N HCl with shaking for 3 hrs, filtration through 0.45μm membrane filter, and analysis of P by automated ascorbic acid method (Method 365.1: USEPA 1993). Water extractable P was determined by extraction of the wet soil equivalent of 2.5 g soil dry weight in 25 mL of distilled deionized water with shaking for 1 hr, followed by filtration through 0.45 μm membrane filter (Kuo 1996) and analysis of P by automated ascorbic acid method (Method 365.1: USEPA 1993). KCl-extractable NO_3^- was determined by extraction of 2 g of dry soil in 25 mL of 2.0 M KCl with shaking for 1 hour, centrifuging and filtration through a Whatman #41 filter followed by colorimetric nitrate determination (Mulvaney 1996). P sorption was done using single point isotherms with 1.0 g of dry soil in 10 mL of 0.01 M KCl solution with 100 ppm phosphate followed by 24 hours of shaking, filtration through 0.45 μm filters and analysis of P by automated ascorbic acid method (Method 365.1: USEPA 1993). Total metals concentrations were determined using the solution from the Total P protocol, followed by analysis using ICP (EPA method 200.7). All analyses were performed by the Wetland Biogeochemistry Laboratory except ICP measures of total metals, which was performed at UF's Analytical Research Laboratory (ARL).

Collecting Reflectance Spectra

All soils were scanned using a full NIR-range post-dispersive spectroradiometer made by Analytical Spectral Devices (Boulder CO); the instrument is a FieldSpec Pro, which scans in the visible (350-750 nm) and near infrared (750-2500 nm) and has the additional capability of field deployment for use in future research. Soils were scanned using a mug probe containing a high temperature (3000 K) tungsten filament bulb with soil samples contained in quartz glass dishes. The FieldSpec Pro unit uses integrated fiber optics to deliver a diffuse reflectance spectrum to three internal radiometers (350-1000 nm; 1000-1700 nm; 1700-2500 nm). The spectral resolution of the radiometers is approximately 3-nm, but data are interpolated to provide spectrographs with 1-nm resolution, or 2150 data points per scan. The radiometers are calibrated to a white reference (Spectralon – LabSphere, Hutton NH), which was updated every 30 minutes during soil scanning to prevent sensor drift. Each saved sample scan consists of an integrated average of 25 observations made by the spectrometers; to provide additional precision information, we took four replicates of each sample. Measures of among-replicate variance were used to define a precision index (PI), for which a stringent operational threshold was set (3% maximum error between samples; most samples had replicate precision error less than 1%). Sample scans failing to meet this PI threshold were rejected during data pre-processing (see database development below) and rescanned.

The scanning process is extremely efficient; a single technician can readily scan 100-200 samples per day. Our protocol introduced several QAQC steps that slowed the process down somewhat, but efforts developed herein to automate data pre- and post-processing, and database acquisition greatly accelerate sample throughput. We estimate that routine spectral analysis of 300 samples per day can be performed by a single technician; models developed in this research can be used to make sample predictions in near real-time using our in-house database schema along with some additional (pending) software development.

Summarizing Sample Reflectance Data

After scanning was complete, we used simple post-processing algorithms to prepare the data for further analysis, and employed several well known techniques to visualize the resulting data. First, dataset end-members were identified based on organic matter content (% loss-on-ignition), and plotted to offer an example of the spectral variability.

Data post-processing is an optional step in the data analysis process, but one shown to have significant influence on model prediction efficiency. For this effort, data post-processing consisted of spectral resampling (reduce by a factor of 10 the dimensionality of the spectra to permit more manageable analysis) and derivative transformation (to eliminate between sample effects due to ambient light conditions, optical set-up and specular reflectance). Other post-processing techniques (scatter correction, normalization) were not done because previous efforts indicated that these conferred no advantage in spectral predictive modeling.

To visualize the spectral data prior to analysis, we used a principal components analysis on the derivative transformed, resampled data. This step is particularly useful to ascertain if the calibration data subsample (231 laboratory analyzed samples) is spectrally representative of the population. The PCA also permits the identification of spectral outliers that may exert significant leverage on the calibration procedure.

Developing Spectral Prediction Models

After acquiring and pre-processing the spectral data, and consolidating/normalizing the soil biogeochemical data, multivariate spectral modeling was started. Two methods were initially compared because the research literature contains examples where both have been shown to be superior with respect to prediction accuracy and model stability. The first and most commonly applied is called partial least squares regression; this technique is also known as projection-to-latent structures regression or PLS. The basic concept of this approach is to extract canonical variables from the predictor data (spectra in this case) that are observed to be correlated with the target variable (soil chemical properties). The decomposition of the predictor-by-sample matrix into principal components is done conditioned to maximize the covariance between the PCs and the target parameters.

PLS is a classical linear statistical tool and, as such, sensitive to certain anomalies in predictor and target variables. Among these are the assumption of normality and presence of outliers; for this reason, post-processing tools and visualization are critical.

Another method gaining favor in the research literature (Brown et al. 2005) for its flexibility and accuracy is a non-parametric data mining tool called stochastic gradient boosted tree regression (GBT). Tree-based analytical methods are based on recursive binary splitting of the target data; it is analogous to well-known decision trees. At each binary split (or parent node), the algorithm identifies the variable and level that maximizes the purity or minimizes the within-node deviance of the resulting two nodes (daughter nodes). This algorithm, applied recursively, allows partitioning of the original data into increasingly pure subsets based on simply decision rules. In a regression setting, each sample allocated to a particular terminal node is given the mean value of that node, and this value is compared to the observed value.

There are several primary problems with tree-based regression including optimality problems and over-fitting. In gradient boosted tree (GBT) models, large sets of smaller trees (n_{nodes} ~ 3; selecting the single best split from among all predictors) are grown, each building on the last by incorporating the previous residuals in an additive weighted expansion; observations with larger residuals are preferentially weighted in subsequent iterations. This generic algorithm is rapid to implement, allows inclusion of predictors for which pairwise associations are relatively weak, and can be used to develop fits with non-normal data and for non-linear responses (Friedman 2002).

For soft-modeling of spectra, or chemometric modeling, one critical requirement is a data set large enough to permit separation of the sample data into a training data set and a verification data set. Many of the statistical tools have a propensity to over-fit to the training data, so to provide a reasonable measure of predictive accuracy under implantation conditions, a hold-out validation data set is retained. In our work, model development was performed using only the 231 training samples; we explored the accuracy and stability of the calibrations under various calibration and validation set conditions (50-80% for calibration). Assessing model utility is always made based on the efficiency of predicting hold-out validation observations.

Model Diagnostics

Because the process of chemometric modeling is inferential and not mechanistic, a set of robust diagnostics are required to ensure that observed relationships are not spurious, and to compare between model types. Further, model diagnostics provide the necessary information to determine if the prediction efficiency meets the minimum requirements of the desired application. We use a set of well established diagnostics to evaluate the fit between predicted and observed values for each of the soil properties evaluated.

There are three primary model diagnostics for continuous prediction. The first is the familiar coefficient of determination (r^2), which describes the goodness-of-fit between predicted an observed as a fraction of the total variance in the latter. While this index is familiar to most analysts, there are no well-defined utility thresholds for discriminating between useful and less useful models. Model significance (that is, the probability that the observed relationship is nill given the data) is of no utility for this effort. We report the r^2 value because of its general appeal.

A second index is mean error (standard error of calibration or validation), which measures the average deviation between predicted and observed values. Because the regression error terms are typically normal, the mean squared error is strongly influenced by samples with large residuals. However, the SEC/SEV value is of considerable utility for evaluating the accuracy of the model, particularly where the level of accuracy necessary for a given application can be specified. The SEC/SEV is not a useful index for comparing across models to determine relative accuracy; for that measure we use an index developed in the chemical engineering literature for chemometrics. The RPD value scales the SEV value by the population standard deviation (i.e. RPD = SD/SEV). Large values indicate high relative efficiency. The research literature consistently interprets values greater than 2.0 as having immediate predictive utility, values less than 1.5 are of limited utility for even first-estimate applications, while parameters with model RPD values between 1.5 and 2 are of variable utility depending on the application.

Finally, we use the slope and intercept of the fitted line to determine model bias. The expected slope is 1.0 and models that deviate significantly from that value systematically over-estimate large observed values and underestimate small observed values. Slopes less than 1 reverse this problem, with low and high observations predicted closer to the population mean. The intercept value is indicative of systematic over- or under-estimation over the entire data range. Intercept errors are unusual, but slope errors are common, mainly for model algorithms that average multiple predictions (e.g. GBT).

Model Application and Site Level Summary

Once validated models have been selected, they can be immediately applied to the remaining samples for which spectral information is available. There are two levels of error to contend with for these data – first, there is error associated with the spectral prediction, which can be evaluated based on the information obtained during the calibration. The second type of error, which emerges when the multiple (n ~ 6) samples at each site are evaluated is associated with internal spatial variability resulting from hydrologic and nutrient enrichment gradients. After application of the spectral model to the full soil dataset, we examined the error (variability) associated with each site. Sites were rank ordered by site mean concentration for each of the 20 analytes, and plotted with error bars representing the standard deviation around the site mean. This gives both an estimate of the within-site variability (especially when the within-site variability is compared with the population standard deviation) and between-site variability. The direct interpretation of the linkages between the site mean (and variability) and indicators of ecological condition represent an important next step in the use of these data.

Results I: Soil Biogeochemical Characterization

Table 1 summarizes the observed concentrations of the soil biogeochemical indicators; note that cadmium was measured, but the data were eliminated from further analysis because nearly all the samples were below the analytical detection limit. Some of the analytes required normalization to meet the assumptions of the analytical methods – these are listed in Table 1.

Table 1. Summary of soil observations from wetlands in the Cuyahoga River basin.

Soil Parameter	N	Mean	Minimum	Maximum	Std.Dev.	Transform
pH	231	5.71	3.74	7.61	0.82	none
Cond. (μmhos)	231	487.48	1.07	2050.00	340.51	Ln
Bulk Dens. (g/cm^3)	230	1.31	0.18	2.77	0.60	none
Moisture Content (%)	230	0.45	0.08	0.90	0.18	none
LOI (%)	231	0.24	0.03	0.87	0.18	Ln
TP (mg/kg)	231	1076.01	260.07	3712.32	569.26	Ln
TN (g/kg)	231	6.82	0.63	29.41	5.94	Ln
TC (g/kg)	231	102.93	6.81	475.65	94.87	Ln
HCl-P (mg/kg)	231	413.37	27.69	2530.90	393.83	Ln
H2O-P (mg/kg)	231	3.38	0.23	70.58	6.58	Ln
NO3-N (mg/kg)	231	3.60	0.16	67.60	9.30	Ln
P-Sorption (mg/g)	231	78.47	36.16	134.33	18.38	none
Potassium (mg/kg)	231	23.63	1.75	52.90	11.09	none
Calcium (mg/kg)	231	28.48	2.41	129.50	24.96	Ln
Magnesium (mg/kg)	231	14.63	1.23	47.60	5.90	Ln
Zinc (mg/kg)	231	0.55	0.14	2.37	0.26	Ln
Copper (mg/kg)	231	0.06	0.00	0.66	0.06	Ln
Iron (mg/kg)	231	127.79	0.00	2080.40	145.66	Ln
Aluminum (mg/kg)	231	121.73	17.96	264.70	46.03	none
Cadmium (mg/kg)	231	0.00	0.00	0.03	0.00	Ln
Lead (mg/kg)	231	0.18	0.03	1.21	0.12	Ln
Sodium (mg/kg)	231	2.49	1.01	26.54	1.95	Ln

Figure 2 shows the inter-correlations between the observed soil properties. Among the criticisms of the spectral method is that it measures only organic matter content; because OM content is correlated with many other aspects of soil performance, spectral predictive relationships are spurious. While there is some merit to this critique, the degree to which this is indeed the case can be assessed by examining the correlation structures in Figure 2. Further, Table 2 summarizes the correlations with OM for all 20 analytes.

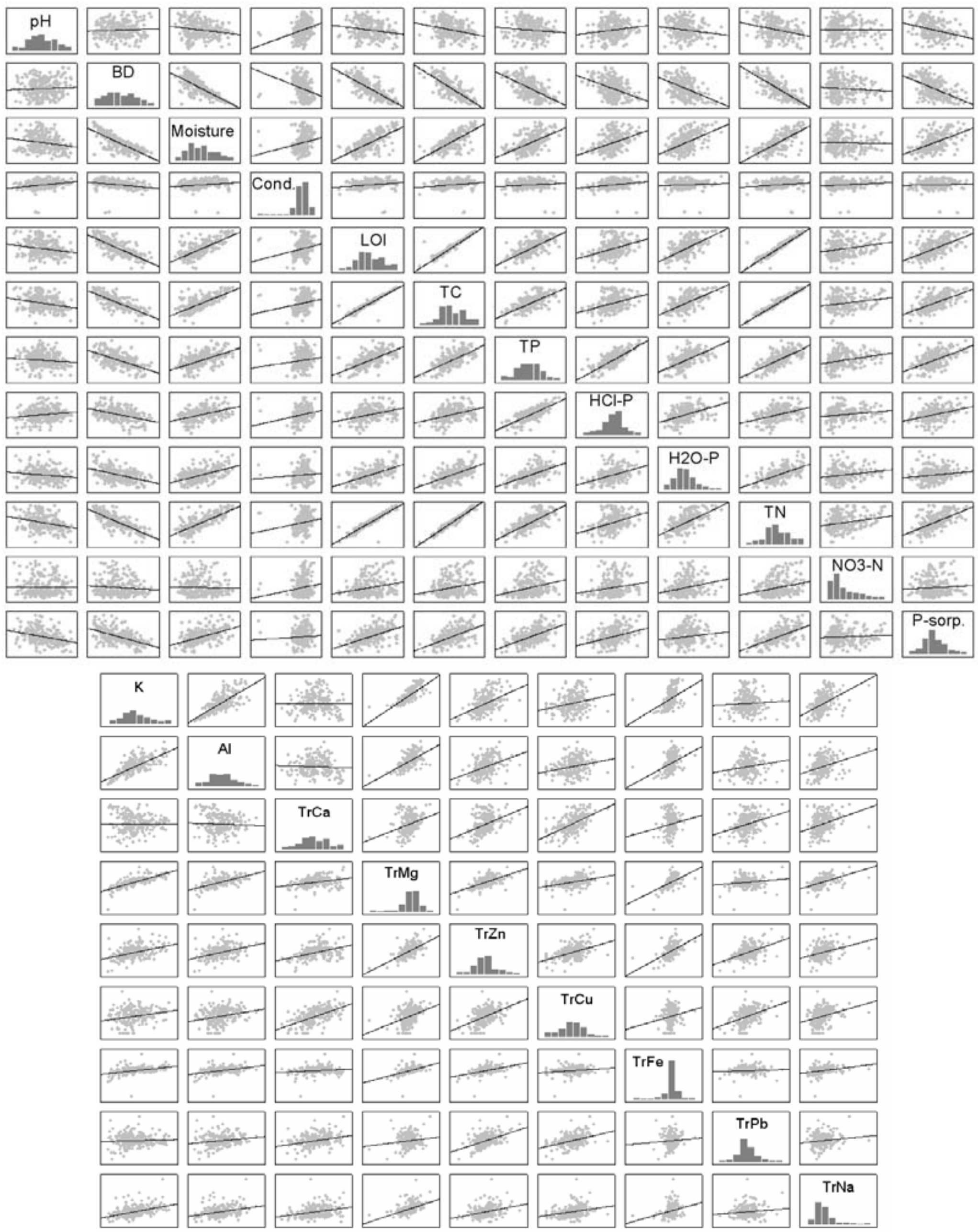

Fig. 2 – Matrix plots of a) bulk soil parameters measured and b) soil total metal concentrations. Shown are correlation structures and histograms for normality transformed data (see Table 1).

Table 2. Summary of correlation structure for soil biogeochemical observations.

	pH	Bulk Dens.	P-Sorption (mg/g)	TrCond	TrLOI	TrTP	TrTN	TrTC	TrHCl-P	TrH2O-P	TrNO3-N	K	Al	TrCa	TrMg	TrZn	TrCu	TrFe	TrPb
Bulk Dens.	0.05	-																	
P-Sorption (mg/g)	-0.29	-0.53	-																
TrCond	0.30	-0.30	0.08	-															
TrLOI	-0.19	-0.78	0.56	0.22	-														
TrTP	-0.10	-0.61	0.56	0.13	0.68	-													
TrTN	-0.28	-0.79	0.61	0.19	0.95	0.74	-												
TrTC	-0.25	-0.79	0.58	0.21	0.95	0.69	0.98	-											
TrHCl-P	0.17	-0.42	0.35	0.22	0.36	0.78	0.41	0.38	-										
TrH2O-P	-0.14	-0.47	0.16	0.07	0.61	0.60	0.62	0.61	0.44	-									
TrNO3-N	0.00	-0.09	0.06	0.15	0.24	0.30	0.25	0.23	0.19	0.24	-								
K	0.22	0.06	0.08	0.11	-0.18	0.15	-0.16	-0.21	0.25	-0.15	0.17	-							
Al	0.03	-0.02	0.18	-0.03	-0.04	0.31	-0.01	-0.06	0.24	-0.04	0.12	0.75	-						
TrCa	0.40	-0.56	0.27	0.43	0.65	0.48	0.60	0.63	0.46	0.39	0.27	-0.01	-0.06	-					
TrMg	0.49	0.06	0.01	0.24	-0.16	0.13	-0.17	-0.17	0.31	-0.18	0.20	0.80	0.59	0.30	-				
TrZn	0.29	-0.28	0.21	0.19	0.21	0.48	0.21	0.20	0.57	0.18	0.21	0.44	0.40	0.43	0.60	-			
TrCu	0.23	-0.41	0.24	0.27	0.42	0.49	0.40	0.42	0.51	0.30	0.32	0.25	0.26	0.59	0.39	0.51	-		
TrFe	0.31	0.00	0.11	0.10	-0.08	0.19	-0.09	-0.11	0.27	-0.36	0.07	0.39	0.38	0.15	0.49	0.46	0.20	-	
TrPb	-0.10	-0.40	0.33	0.12	0.47	0.50	0.50	0.53	0.29	0.37	0.17	0.04	0.17	0.31	0.12	0.49	0.42	0.06	-
TrNa	0.27	-0.13	0.21	0.21	0.10	0.16	0.08	0.08	0.26	-0.02	0.13	0.46	0.31	0.31	0.49	0.32	0.29	0.26	0.12

We observe that there are indeed strong associations with organic matter content (particularly for some of the metals, Cu and Pb, that may be harder to determine spectrally). Only comparison of these Pearson correlation coefficients (r-values) with the observed model efficiencies (summarized using r^2-values) will illustrate the degree to which this confounding factor is problematic.

Results II: Soil Spectral Characterization and Predictive Modeling

Spectral Summary

A summary of the full spectral data set is not possible graphically; to demonstrate the degree of difference, we have selected nine representative samples from the entire gradient of organic matter contents observed in the training data set. The spectra (derivative transformed) are shown in Fig. 3 in an effort to demonstrate the relatively subtle differences that permit prediction of soil chemical properties.

We can summarize the full data set by data compression techniques. Principal components analysis permits the full data set (n = 1685) to be displayed using a reduced number of latent variables that describe most of the data set variance. Principal components 1 through 4 captured nearly 90% of the original data set variance, and are plotted in scatterplots in Fig. 4. Notably, while most of the dataset variance can be explained with this small number of independent variables, the rotation techniques used for spectral calibration (PLS in particular) often observe important predictive information from many more predictive axes (PCs). This suggests that, while data compression is useful for visualizing bulk variability, more subtle methods are critical for direct interpretation of the spectral response.

The maximal utility of the PCA method for dataset visualization is to determine the degree to which the 231 training samples adequately represent the full dataset. In Fig. 4, the PCA was done on all data simultaneously, but the points representing the 231 training samples are delineated from the other samples. The results suggest that, in general the training data set is representative of the population except for along PC4 (Fig. 4b).

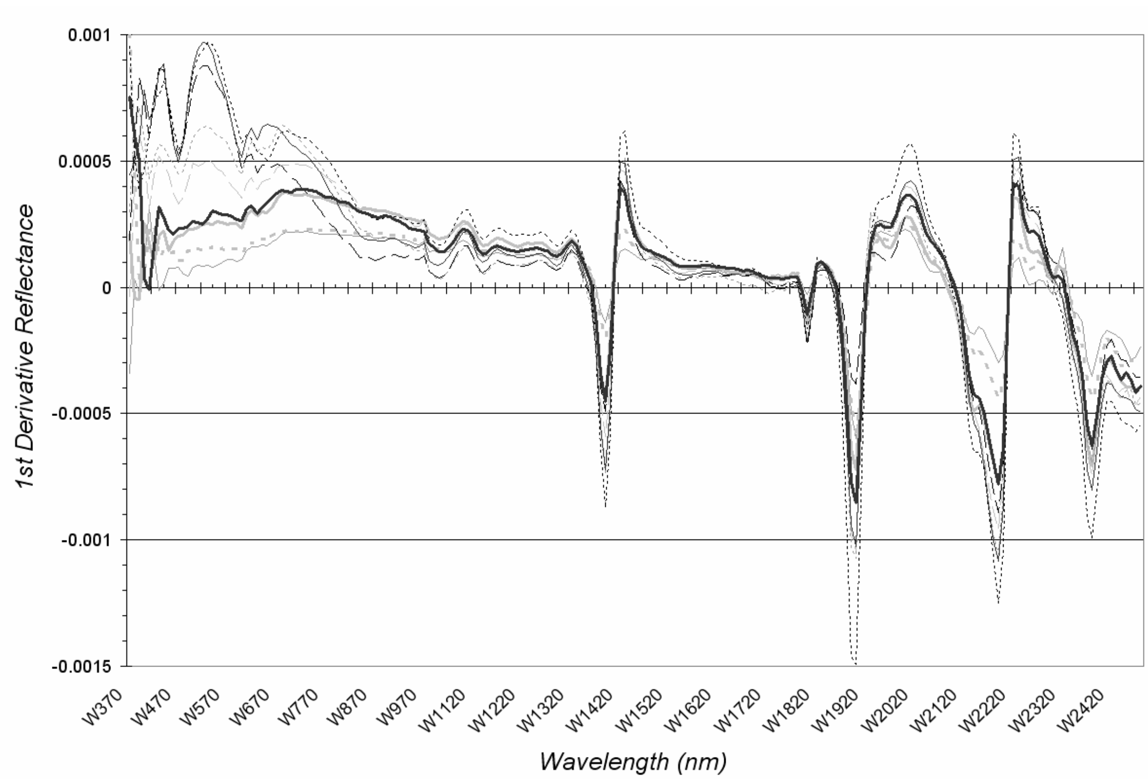

Fig. 3 – Selected spectrographs for Cuyahoga wetlands spectral database. Spectrographs were selected along a gradient of organic matter content (LOI), and are reported as 1st derivative relative reflectance. Spectral diagnostic features are the location and depth of soil reflectance and absorbance bands. For organic matter content, the depth of absorbance in bands 1360 and 2210 are particularly diagnostic. Similarly, for phosphorus prediction, the spectral response at band 1920 is important.

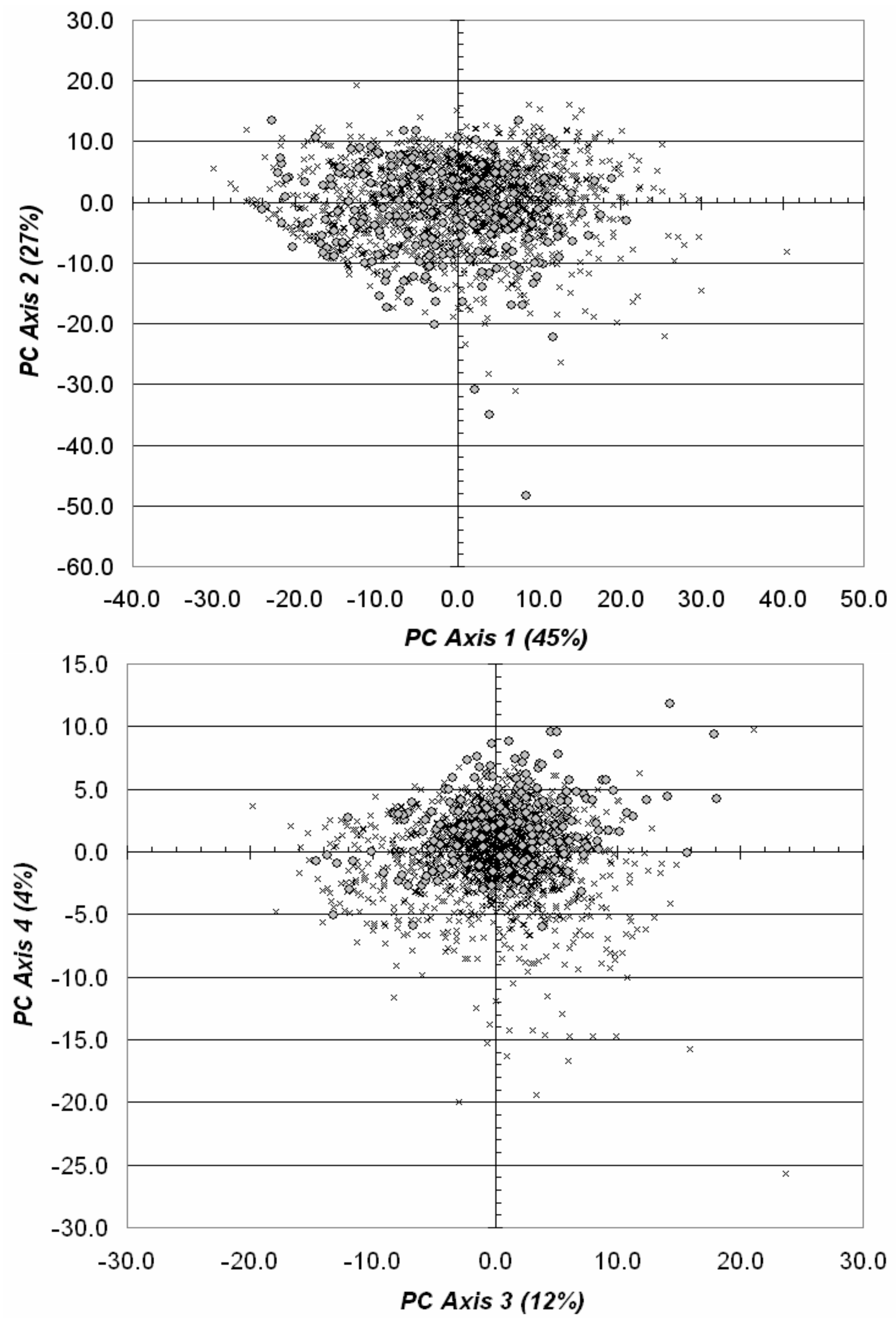

Fig. 4 – Principal components analysis for all spectral samples; crosses represent the 1454 samples with spectra only and the grey circles represent the 231 calibration samples. Four PC axes are presented which in total explain nearly 90% of the total dataset spectral variance. Note, however, that the partial least squares (PLS) algorithm used for spectral predictive modeling often employs more than four latent components for prediction.

Chemometric Model Results

After comparison of the two methods (PLS and GBT) for spectral prediction, we concluded that the additional time required to develop GBT models was not warranted; in most cases PLS provided improved validation accuracy, reduced model complexity and much greater model portability. As such, the results of the GBT effort are omitted from this report.

The PLS results are summarized in Figures 5 and 6. The individual fits (for calibration and validation) are shown in Figures 7-26. For all models, we selected the cross-validation scheme where 80% of the data were used for calibration and models were evaluated using the remaining 20% (selected randomly). The reason for this are summarized in Figure 27; we observe across almost all parameters that the use of a smaller fraction of the 231 training samples resulted in weaker models. This may suggest that there is some lower bound to the number of samples necessary to develop a reliable and generic spectral reflectance library. We note that for calibrations developed using much larger data sets (n > 2000) we generally observe that validation accuracy starts to level off at between 300 and 500 samples in the training set. Using 190 samples for training appears to be adequate, but future and broader iterations of this effort should consider the need for a larger SRL from which to determine the necessary spectral relationships.

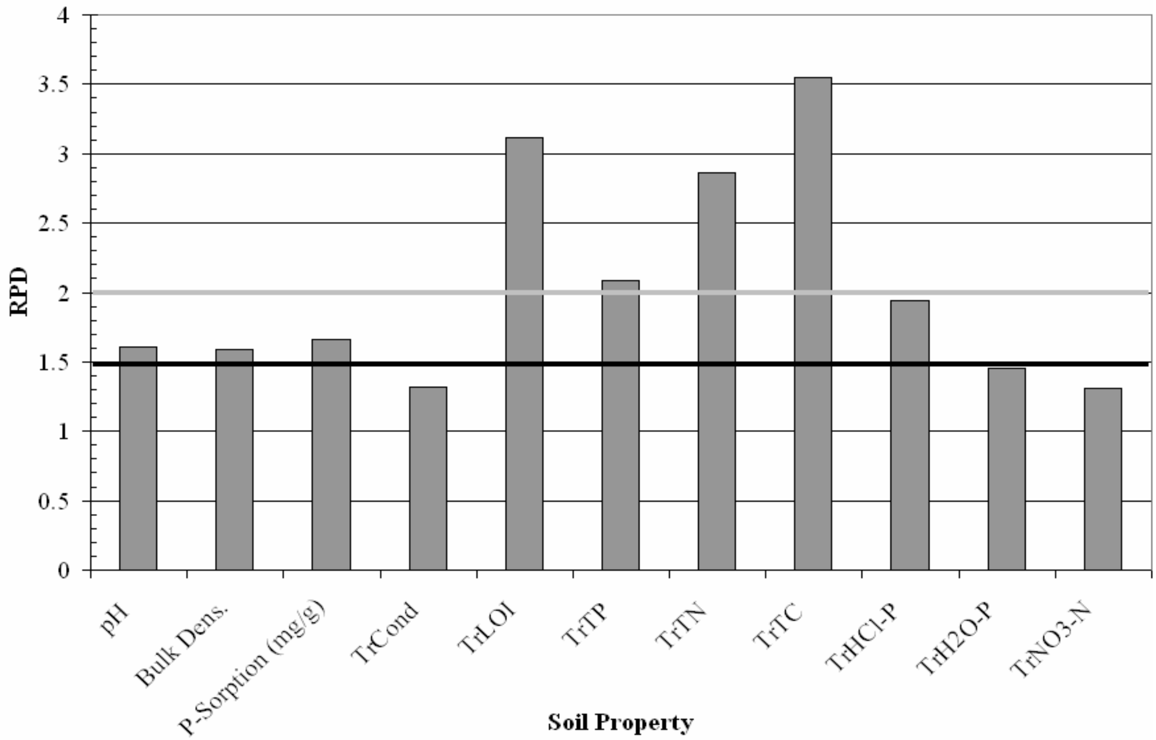

Fig. 5 – Validation relative performance determinant (RPD) for standard soil properties. Thresholds of 1.5 and 2.0 are marked. Properties are in raw units unless preceded by Tr, which indicates natural log transform prior to calibration.

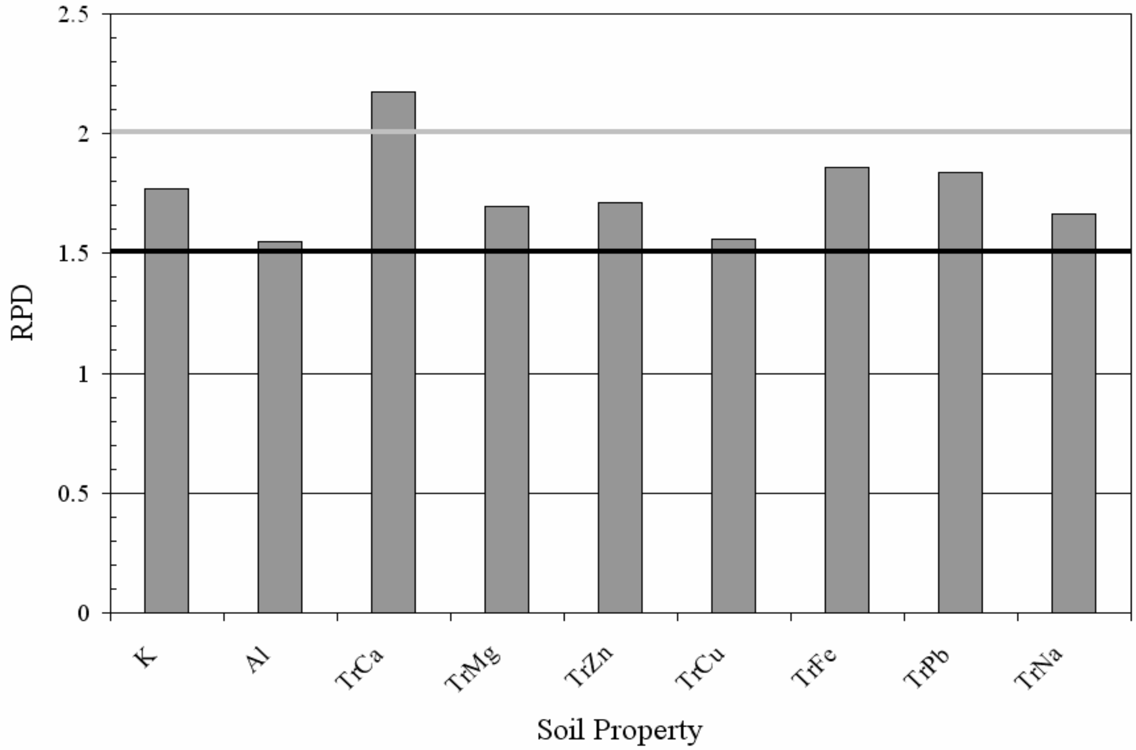

Fig. 6 – Validation relative performance determinant (RPD) for total metals concentrations. Thresholds of 1.5 and 2.0 are marked. Properties are in raw units(mg/kg) unless preceded by Tr, which indicates natural log transform prior to calibration.

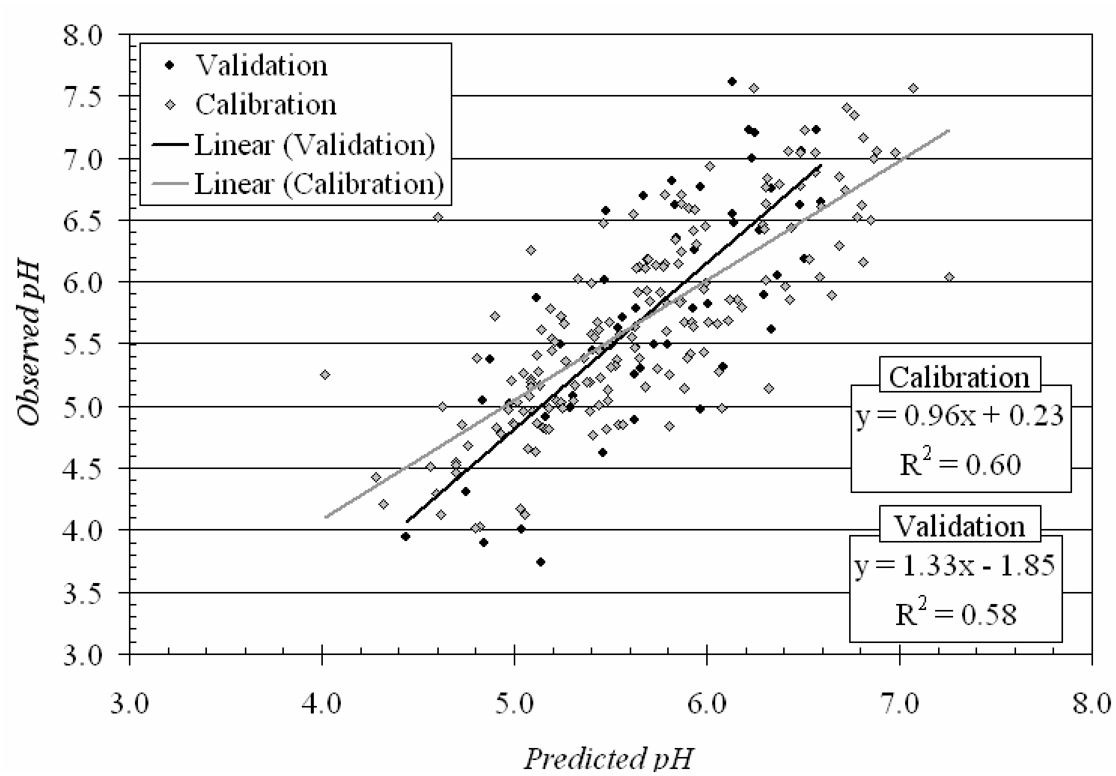

Fig. 7 – Predicted vs. observed pH for calibration (80%) and validation (20%).

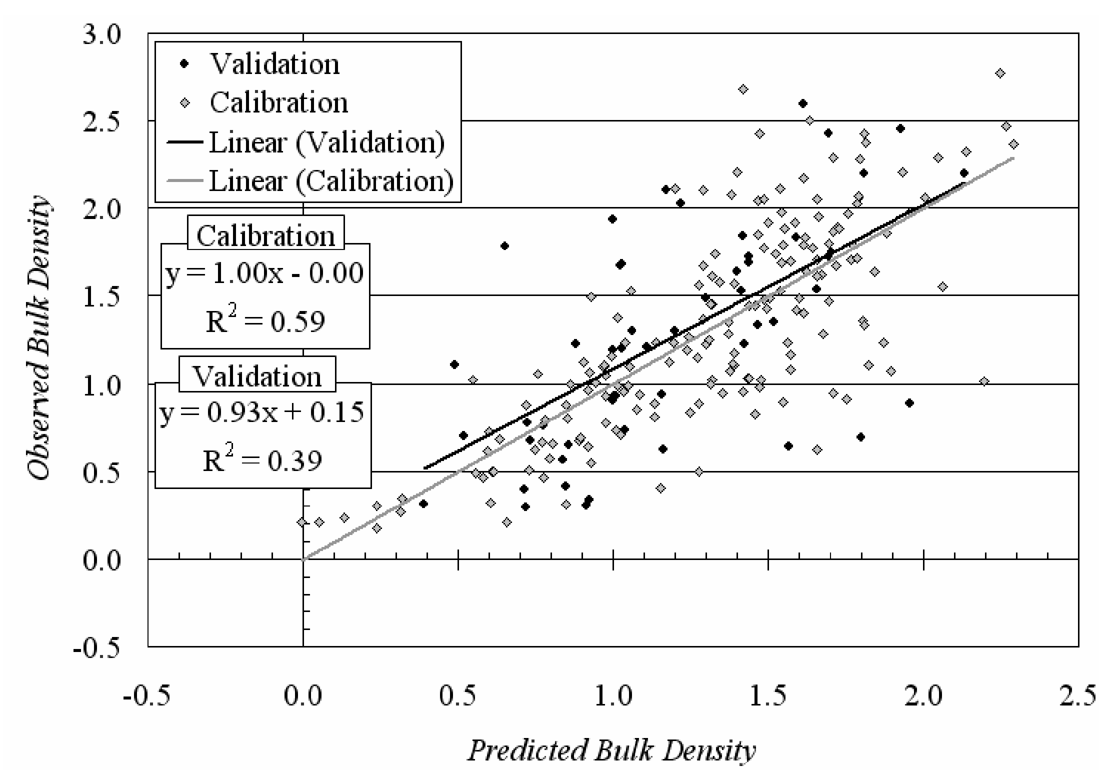

Fig. 8 – Predicted vs. observed bulk density for calibration (80%) and validation (20%).

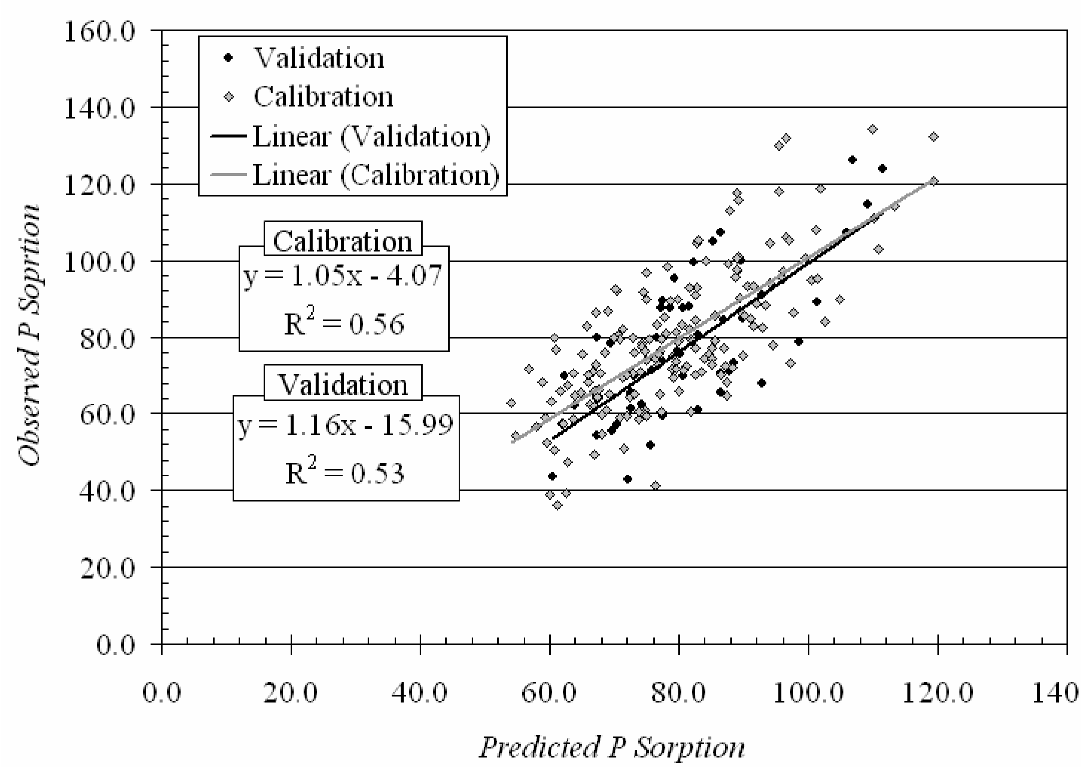

Fig. 9 – Predicted vs. observed P sorption for calibration (80%) and validation (20%).

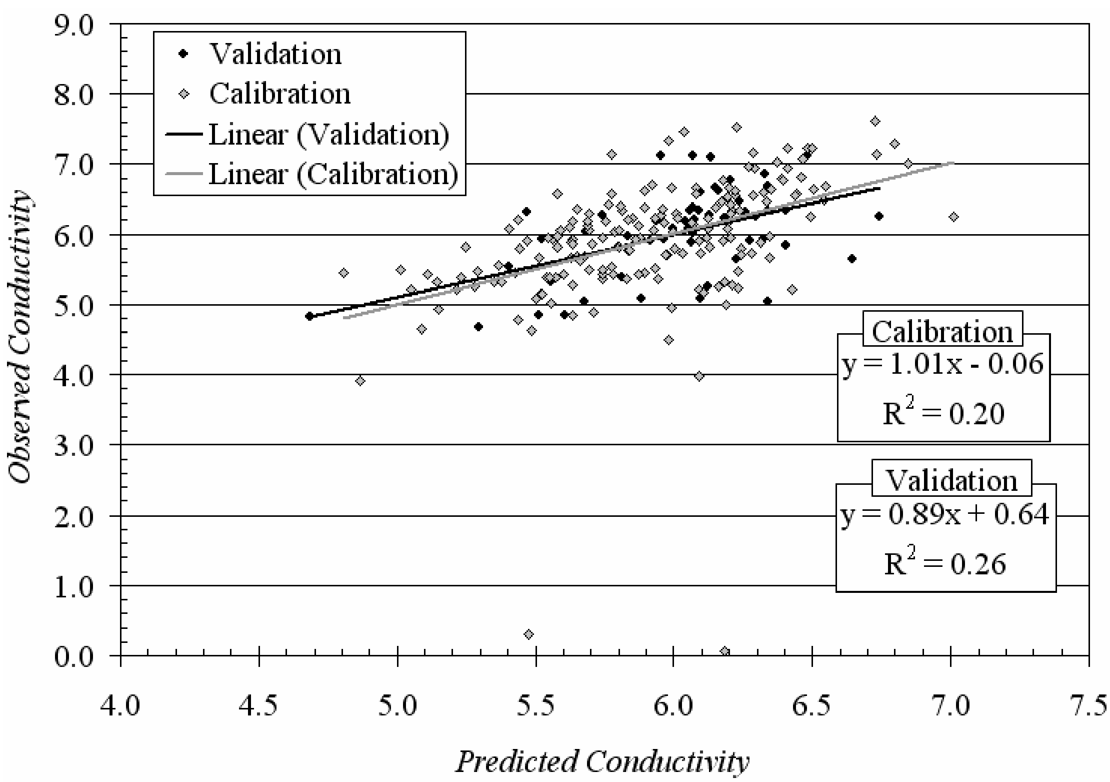

Fig. 10 – Predicted vs. observed total conductivity for calibration (80%) and validation (20%). Values are natural log transformed prior to calibration.

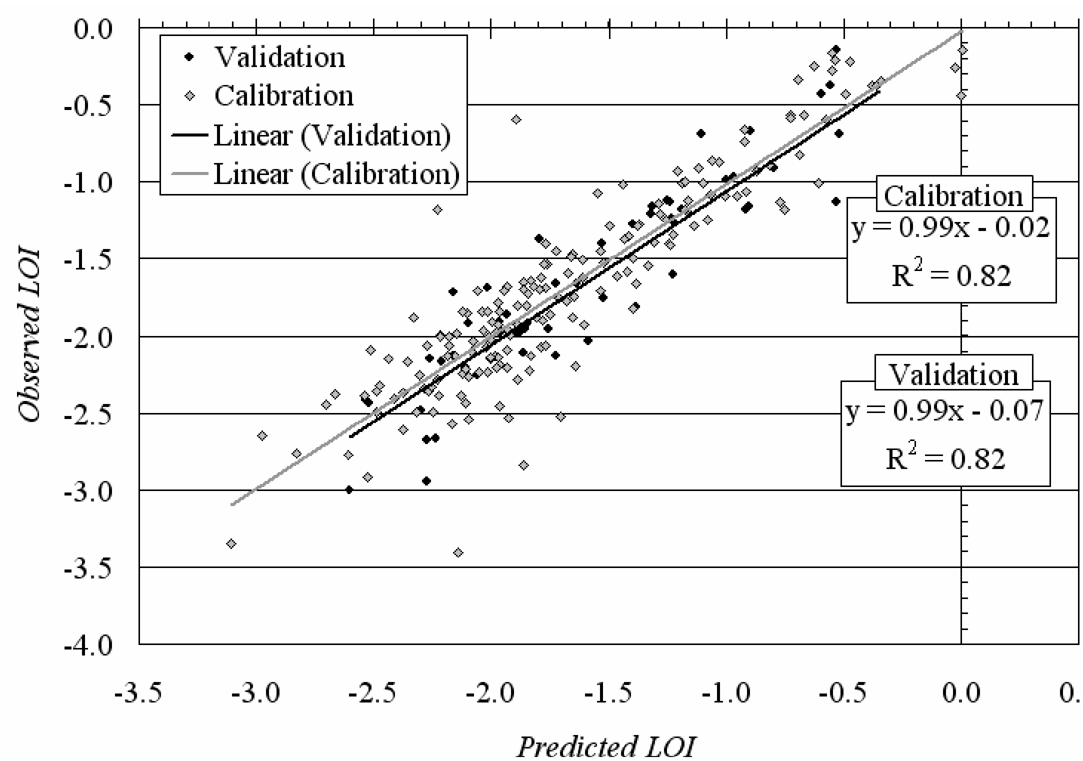

Fig. 11 – Predicted vs. observed organic matter (loss-on-ignition; LOI) for calibration (80%) and validation (20%). Values are natural log transformed prior to calibration.

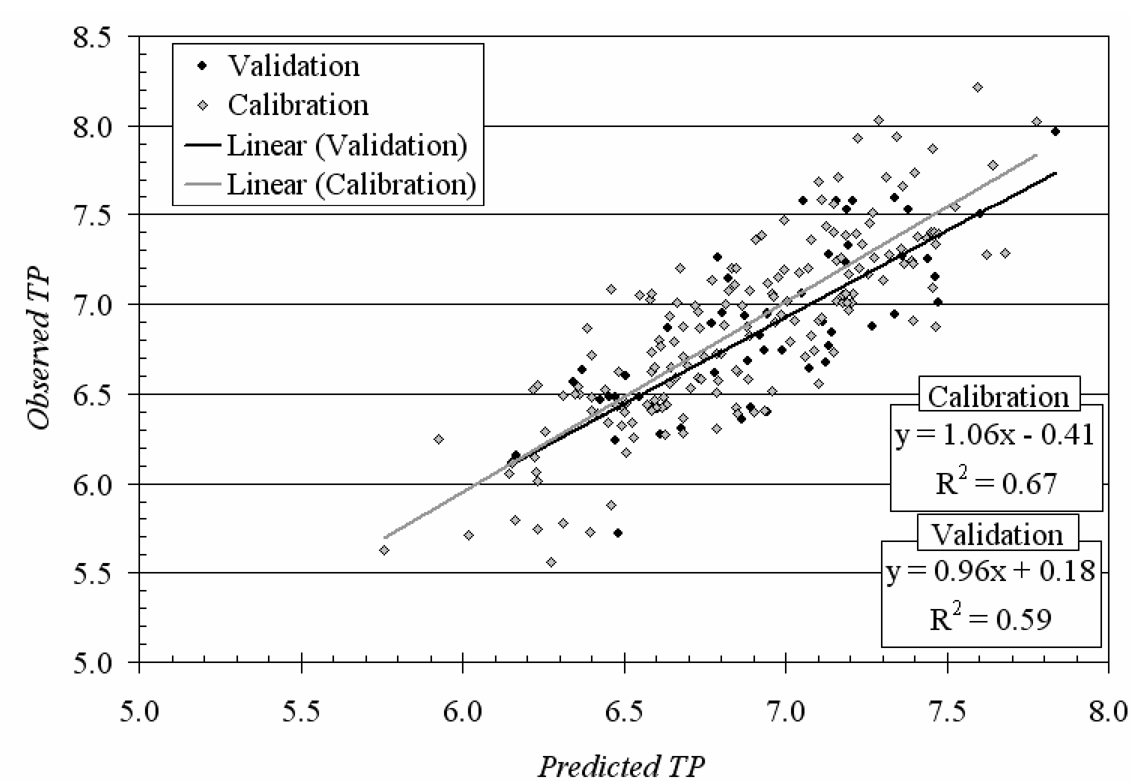

Fig. 12 – Predicted vs. observed total phosphorus for calibration (80%) and validation (20%). Values are natural log transformed prior to calibration.

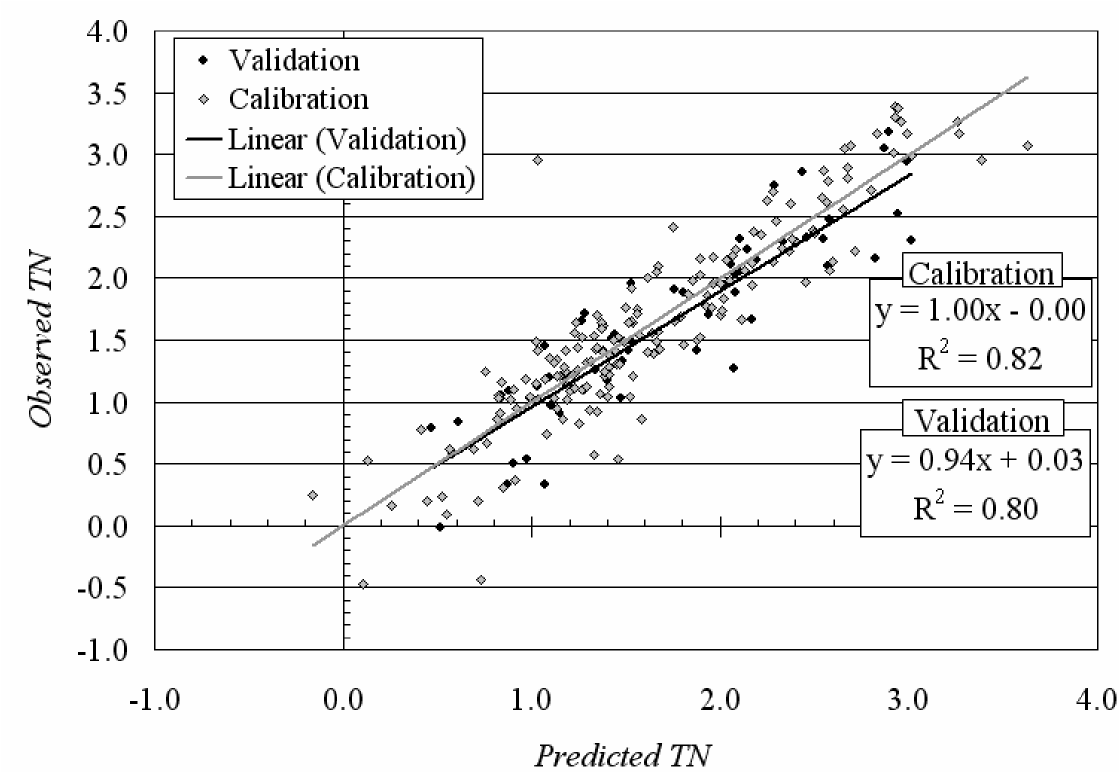

Fig. 13 – Predicted vs. observed total nitrogen for calibration (80%) and validation (20%). Values are natural log transformed prior to calibration.

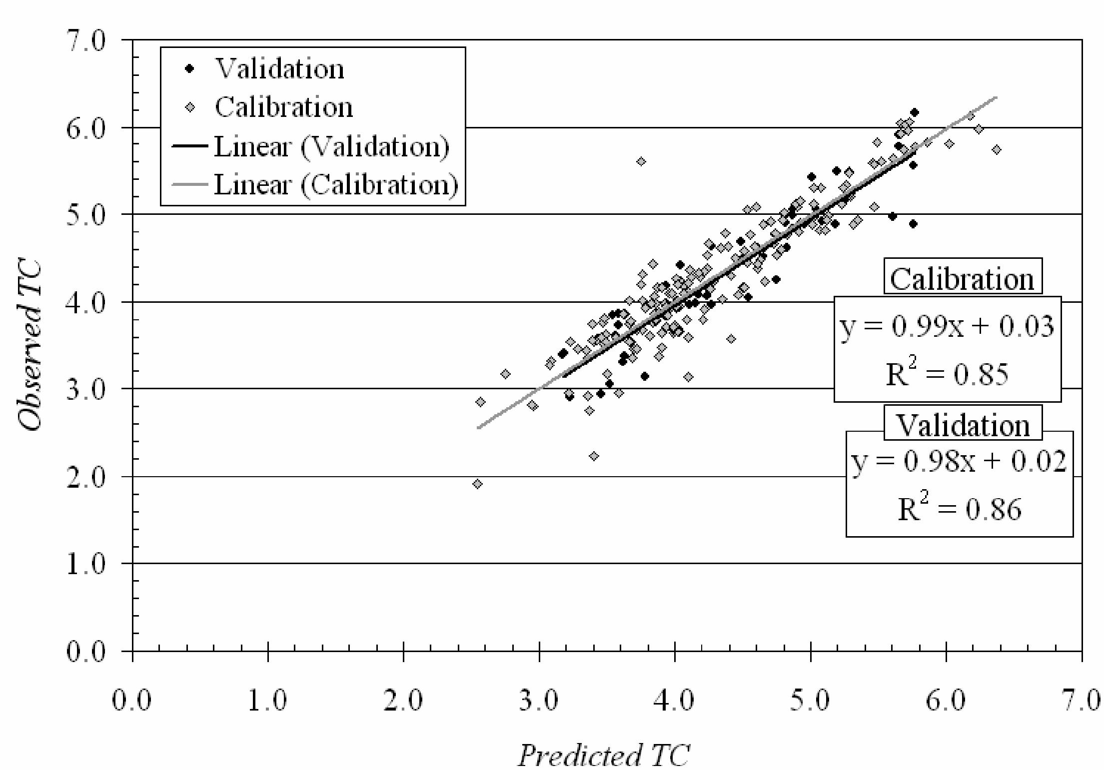

Fig. 14 – Predicted vs. observed total carbon for calibration (80%) and validation (20%). Values are natural log transformed prior to calibration.

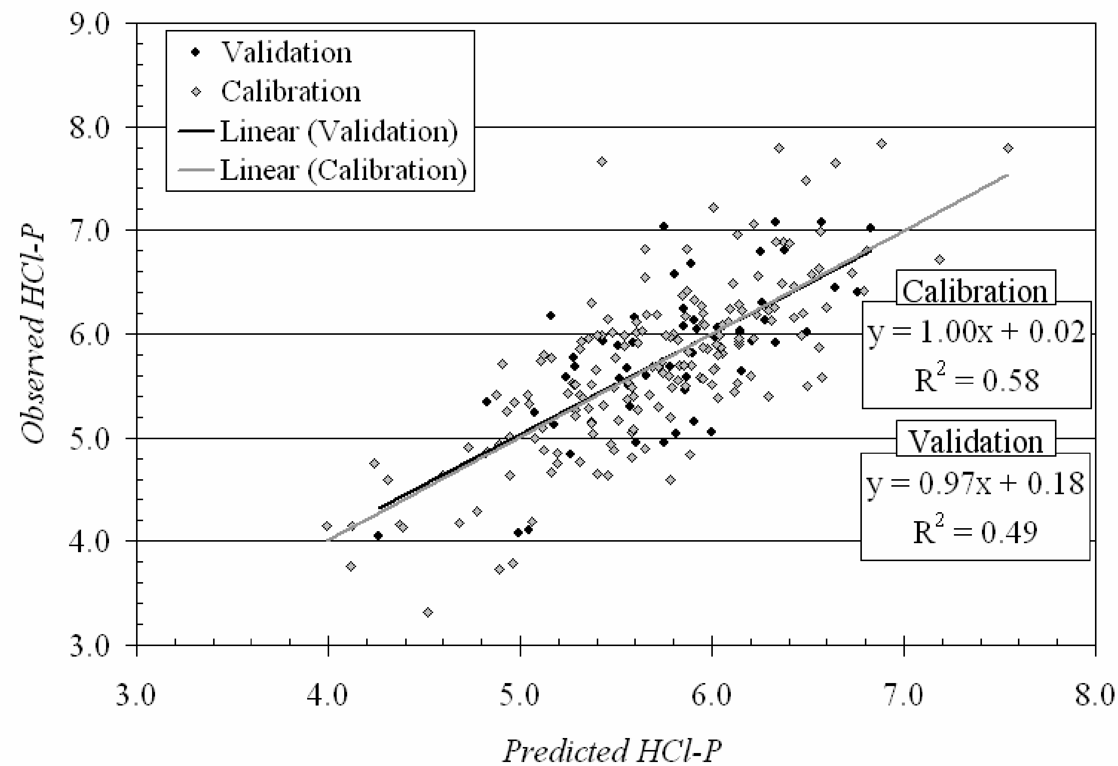

Fig. 15 – Predicted vs. observed HCl-extractable phosphorus for calibration (80%) and validation (20%). Values are natural log transformed prior to calibration.

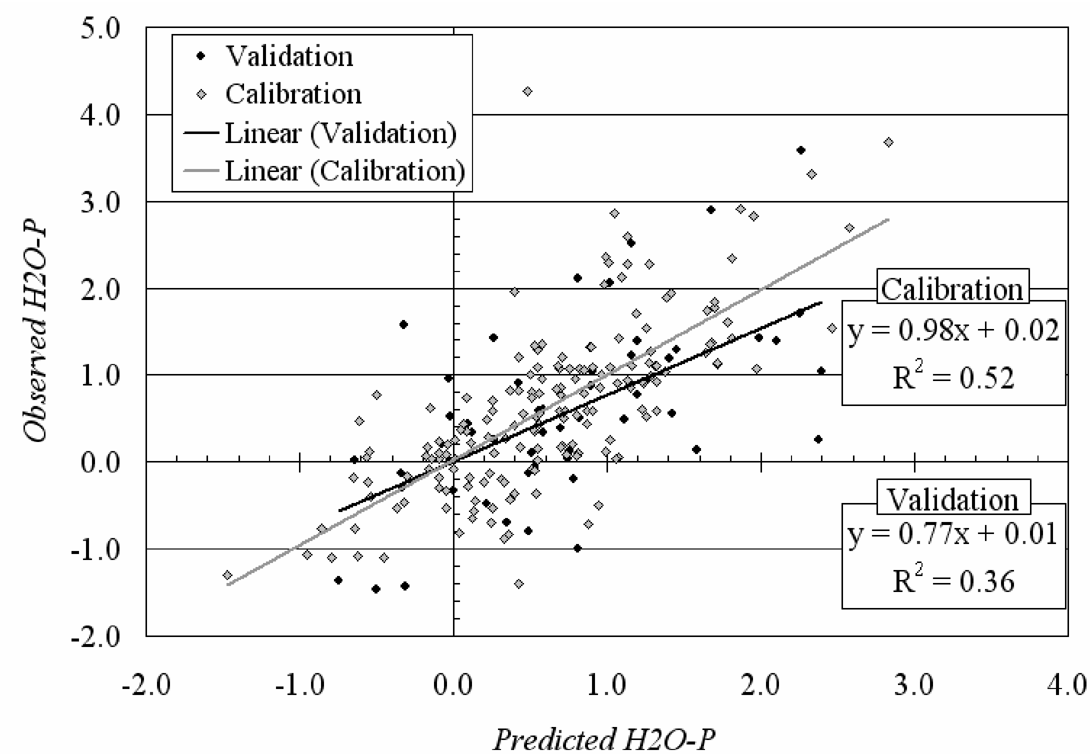

Fig. 16 – Predicted vs. observed water extractable phosphorus for calibration (80%) and validation (20%). Values are natural log transformed prior to calibration.

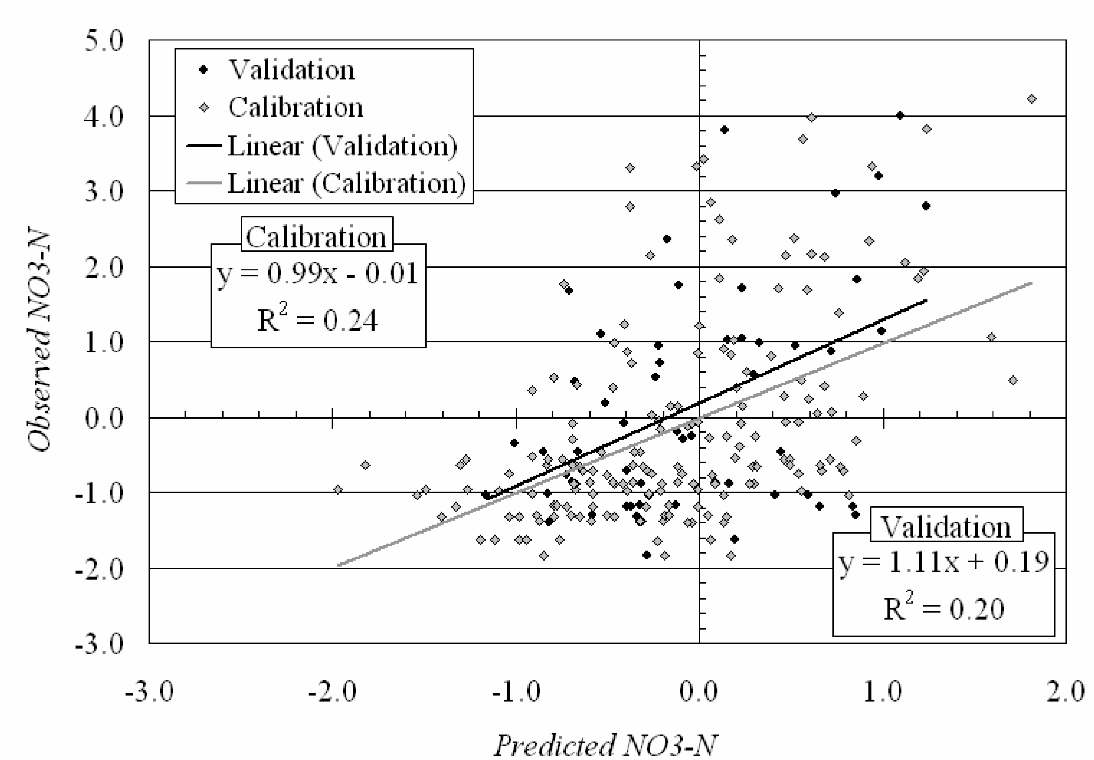

Fig. 17 – Predicted vs. observed KCl-extractable nitrate for calibration (80%) and validation (20%). Values are natural log transformed prior to calibration.

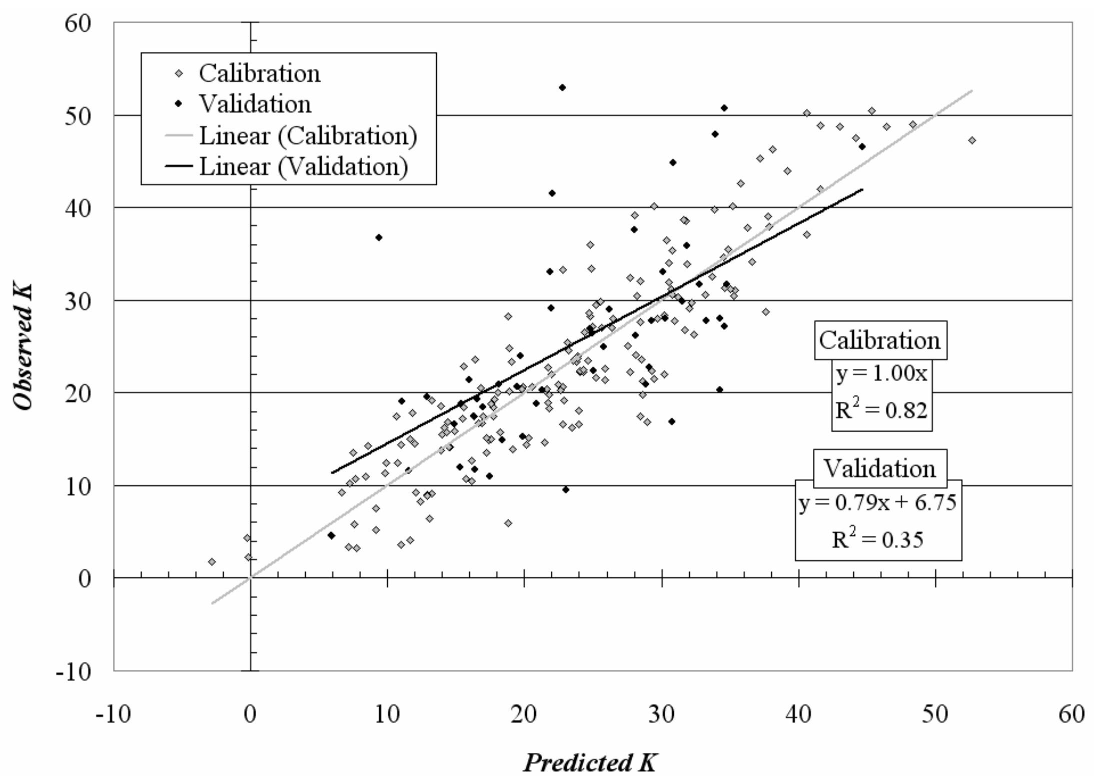

Fig. 18 – Predicted vs. observed total potassium for calibration (80%) and validation (20%).

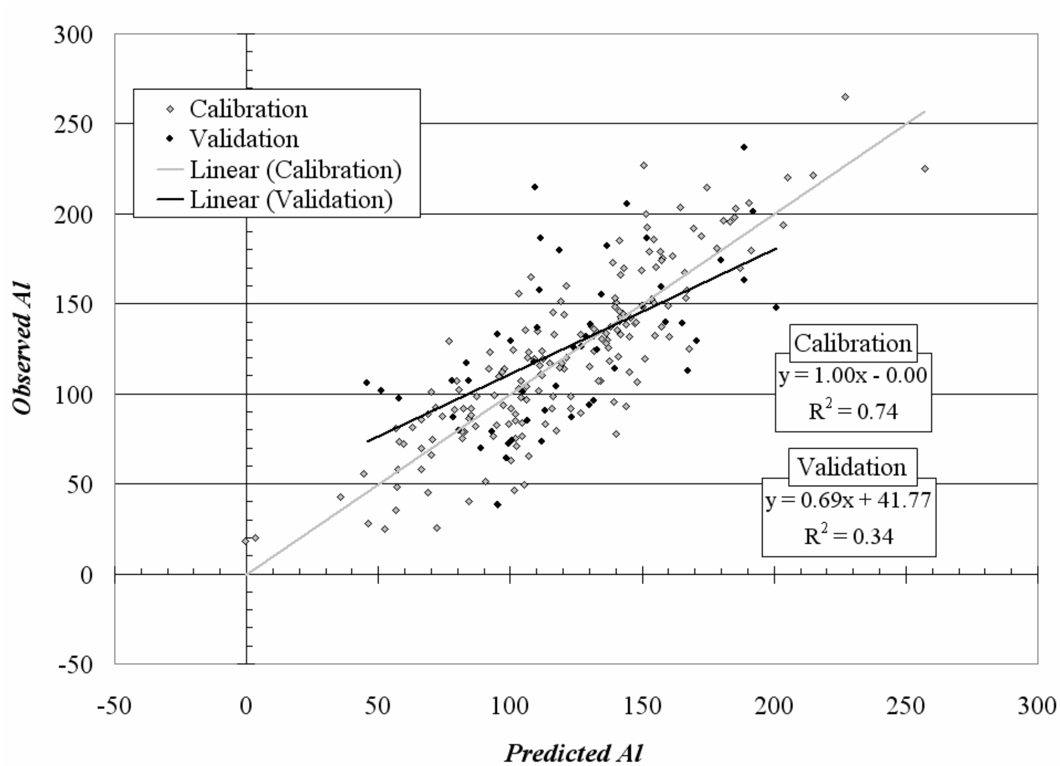

Fig. 19 – Predicted vs. observed for total aluminum for calibration (80%) and validation (20%).

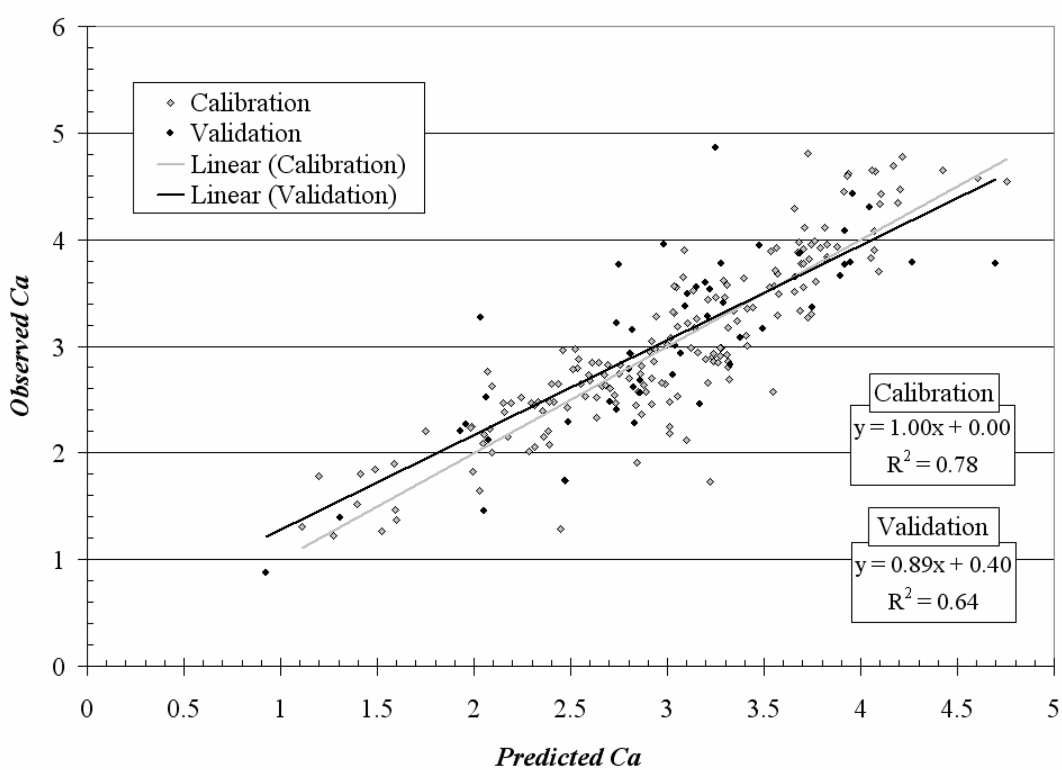

Fig. 20 – Predicted vs. observed total calcium for calibration (80%) and validation (20%). Values are natural log transformed prior to calibration.

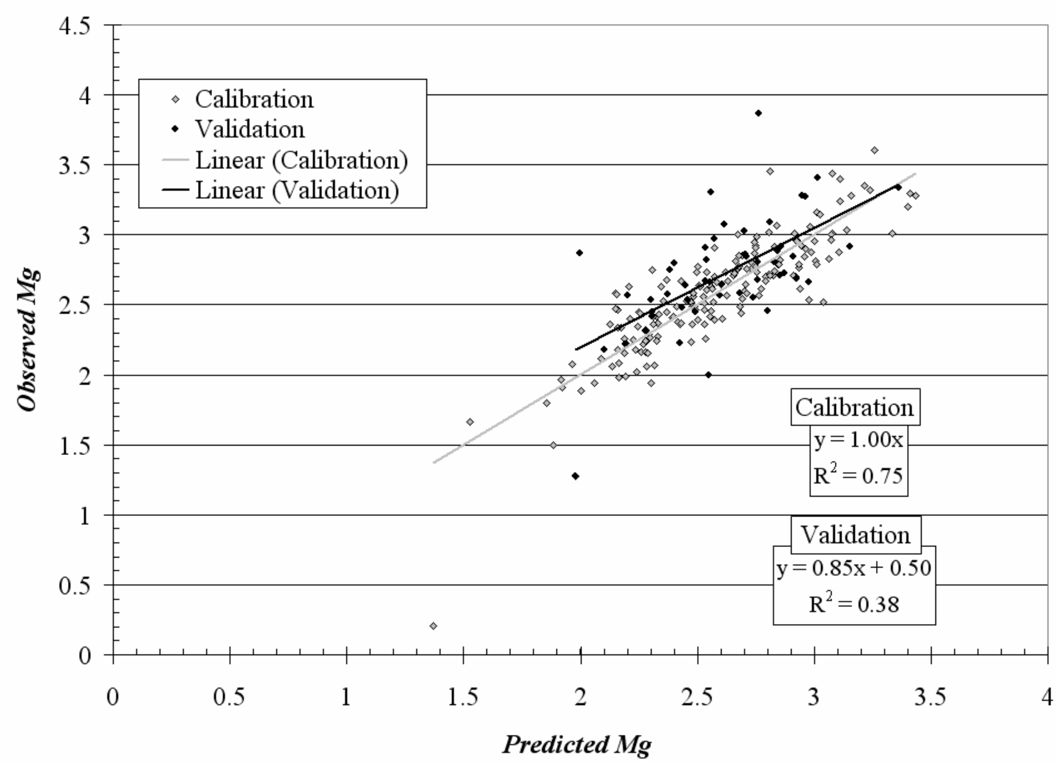

Fig. 21 – Predicted vs. observed total magnesium for calibration (80%) and validation (20%). Values are natural log transformed prior to calibration.

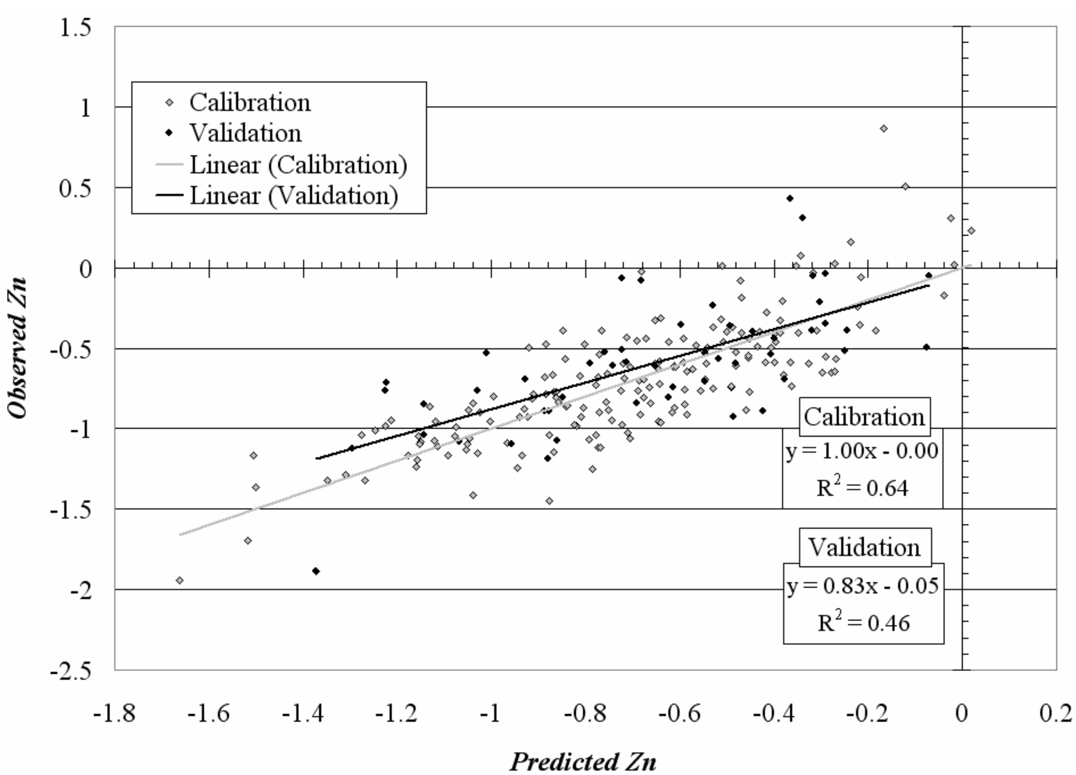

Fig. 22 – Predicted vs. observed total zinc for calibration (80%) and validation (20%). Values are natural log transformed prior to calibration.

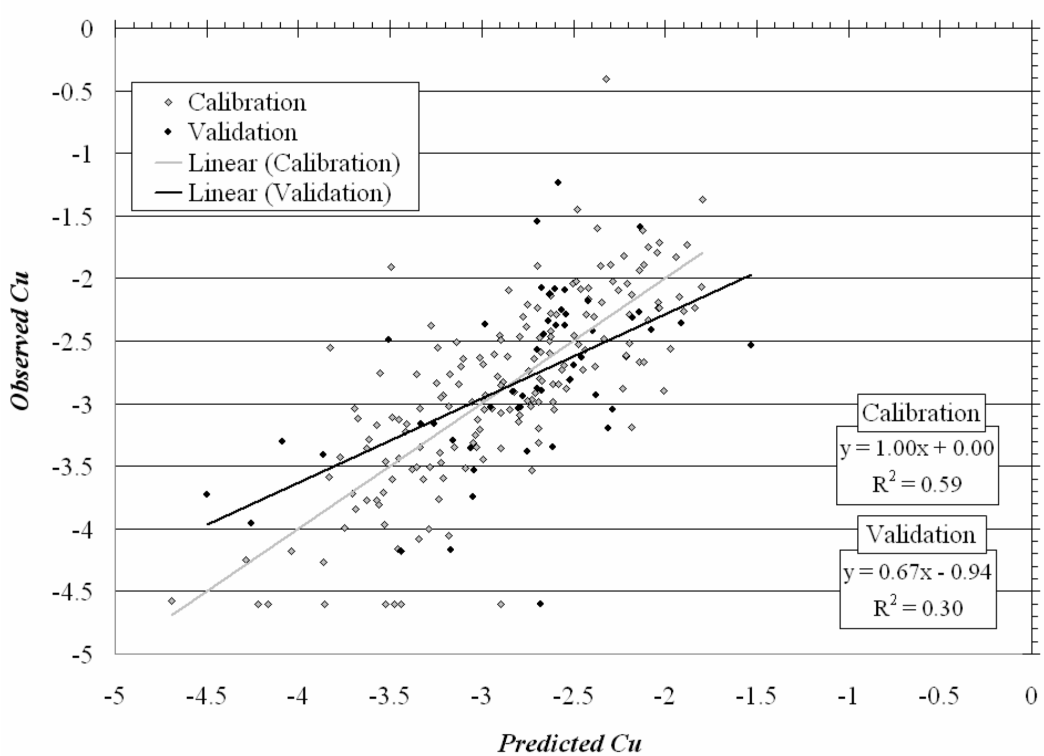

Fig. 23 – Predicted vs. observed total copper for calibration (80%) and validation (20%). Values are natural log transformed prior to calibration.

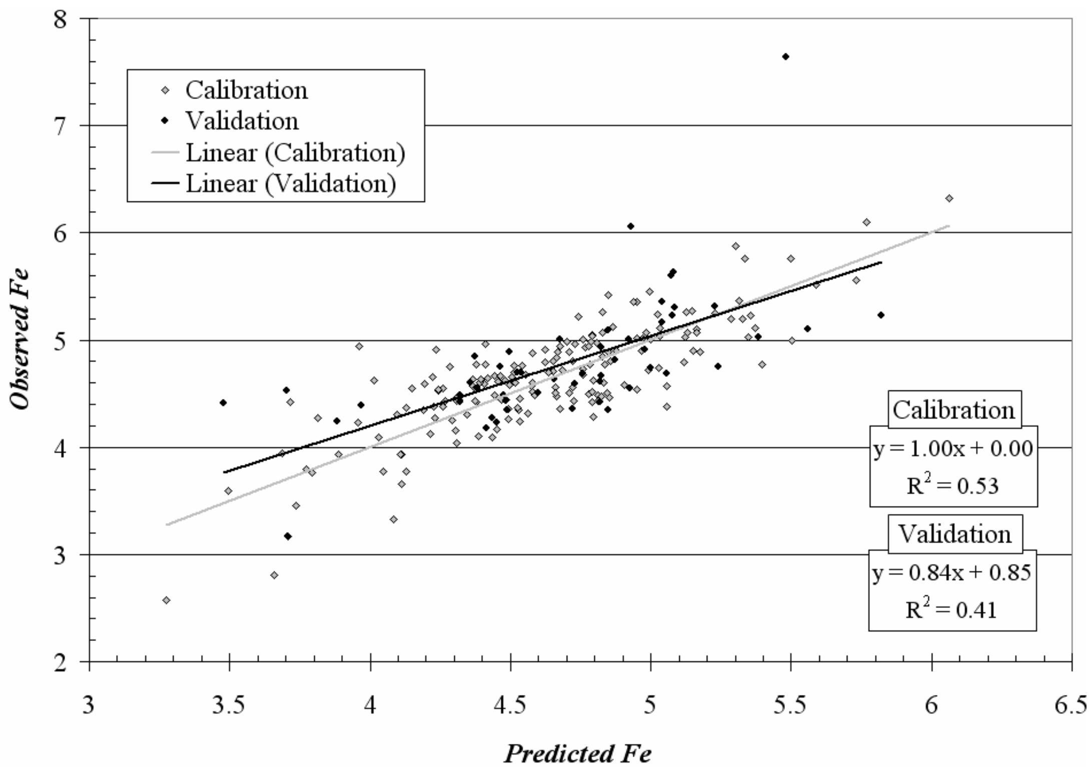

Fig. 24 – Predicted vs. observed total iron for calibration (80%) and validation (20%). Values are natural log transformed prior to calibration.

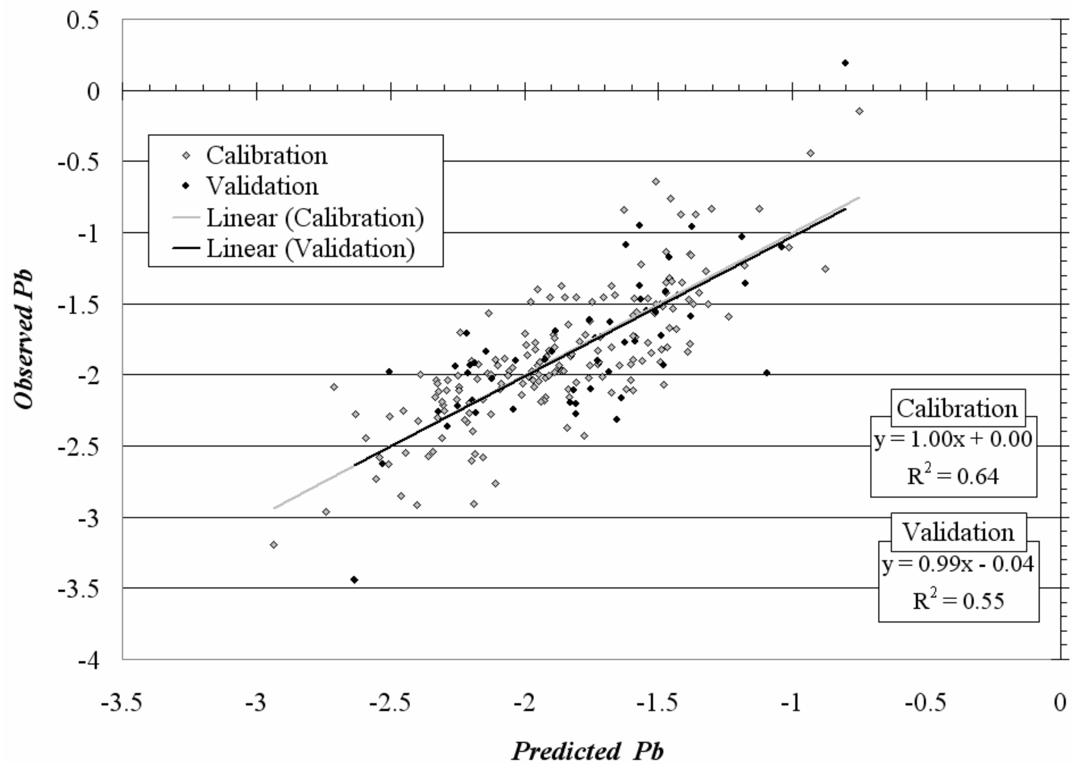

Fig. 25 – Predicted vs. observed total lead for calibration (80%) and validation (20%). Values are natural log transformed prior to calibration.

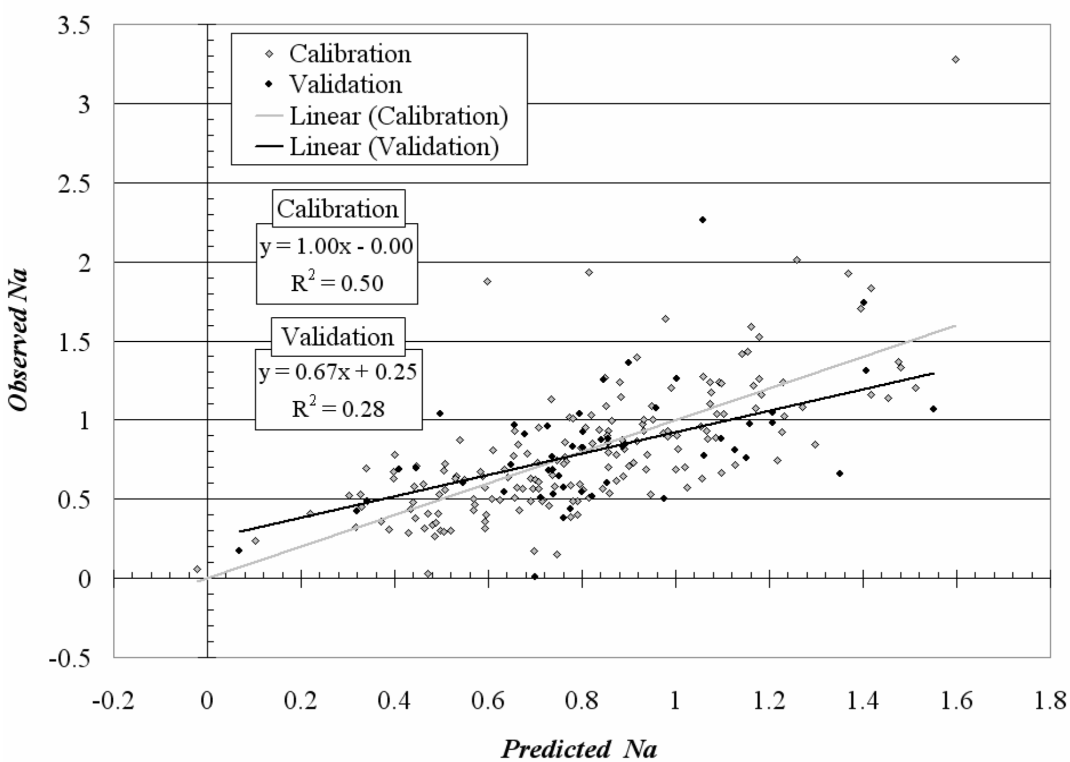

Fig. 26 – Predicted vs. observed total sodium for calibration (80%) and validation (20%). Values are natural log transformed prior to calibration.

Results III: Spectral Prediction of Soil Properties and Site-Level Synthesis

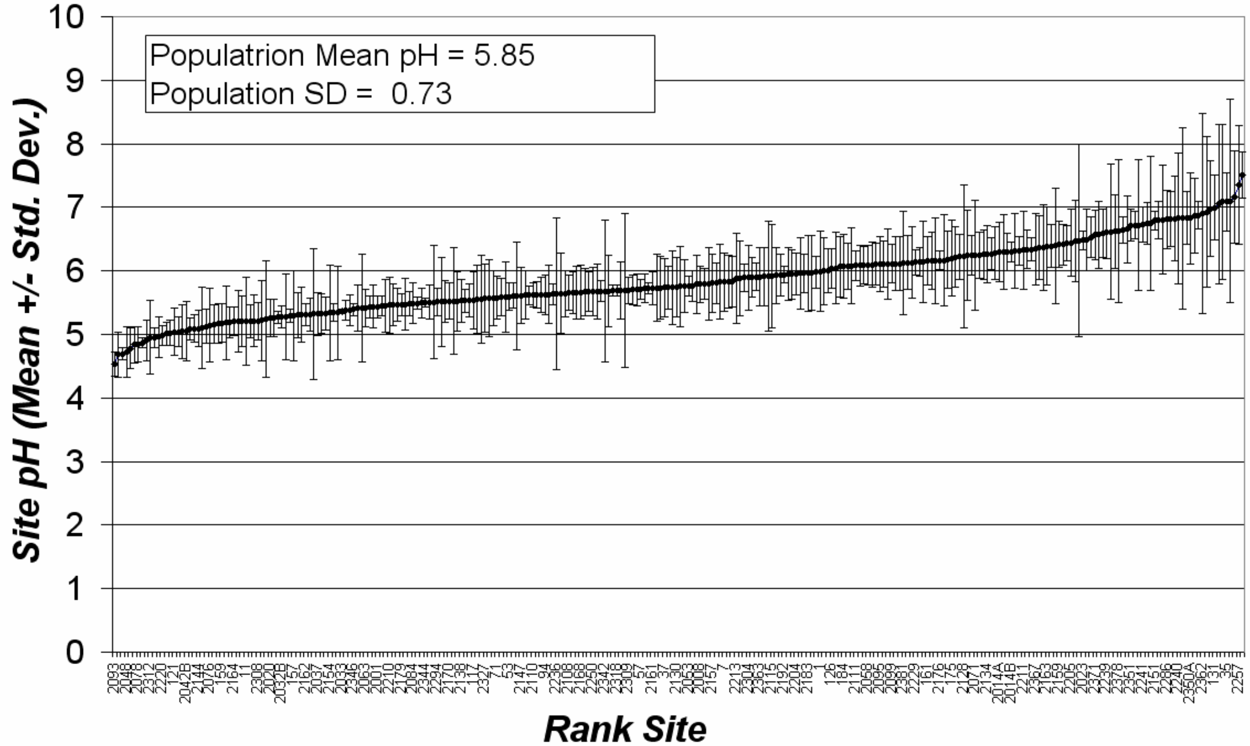

Fig. 27 – Summary of site level mean and distribution for spectrally predicted pH.

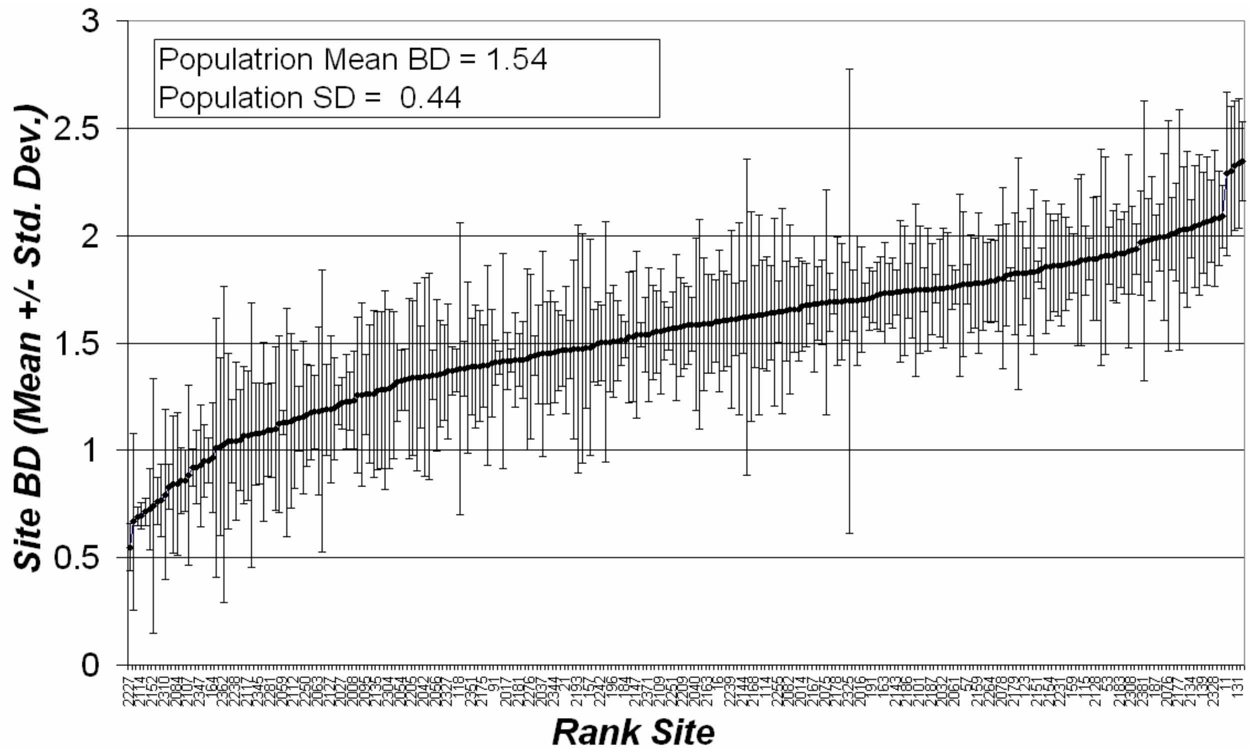

Fig. 28 – Summary of site level mean and distribution for spectrally predicted bulk density.

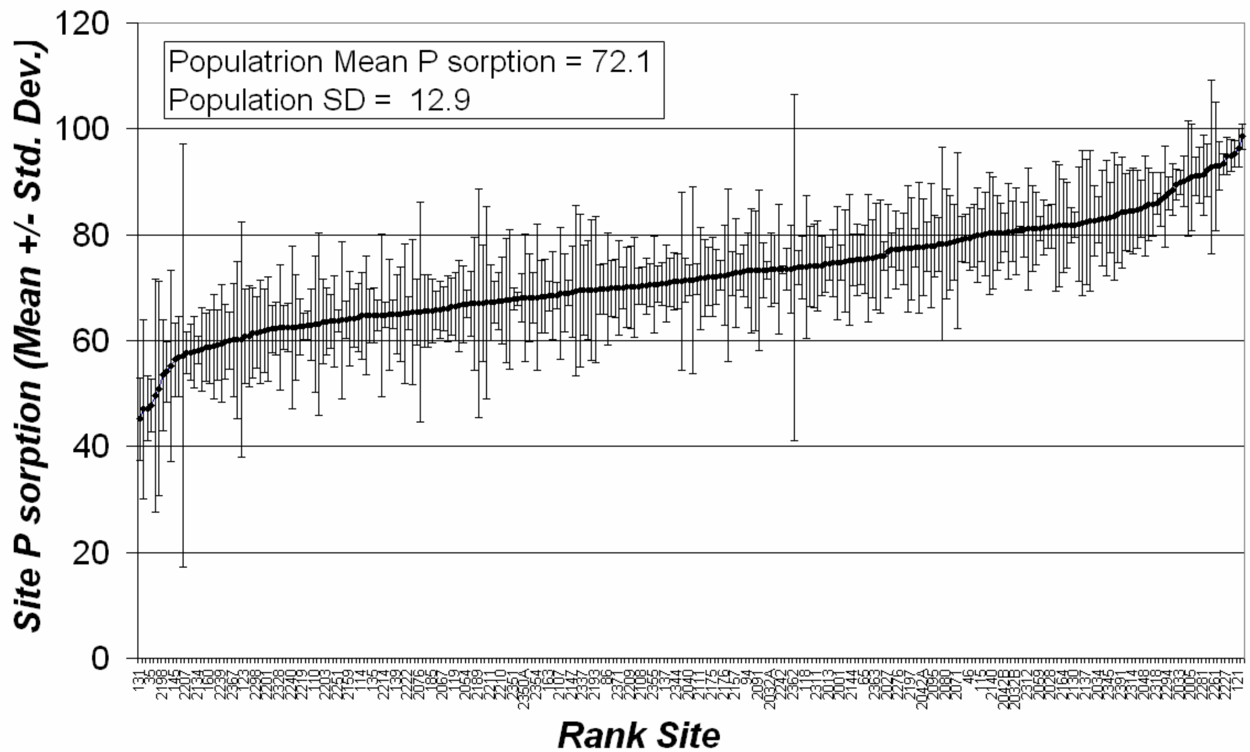

Fig. 27 – Summary of site level mean and distribution for spectrally predicted P sorption.

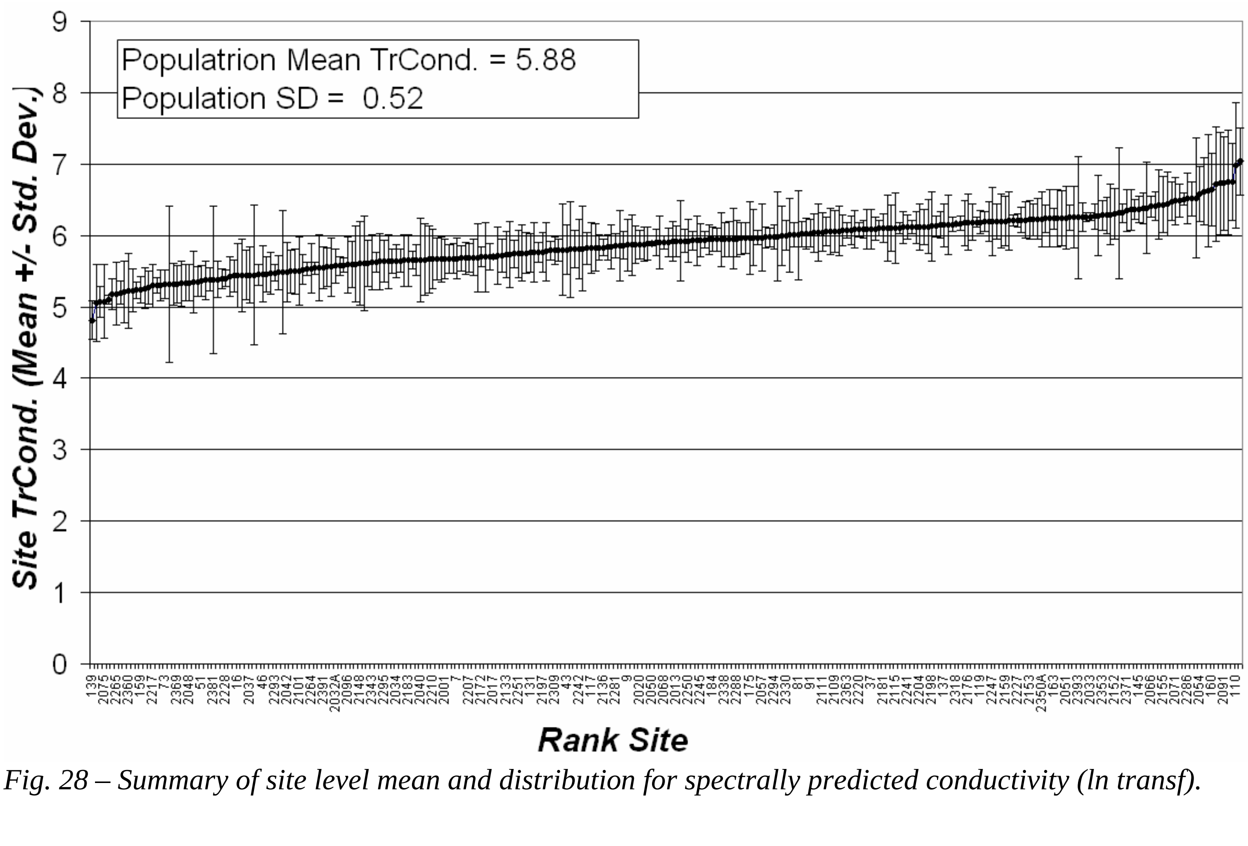

Fig. 28 – Summary of site level mean and distribution for spectrally predicted conductivity (ln transf).

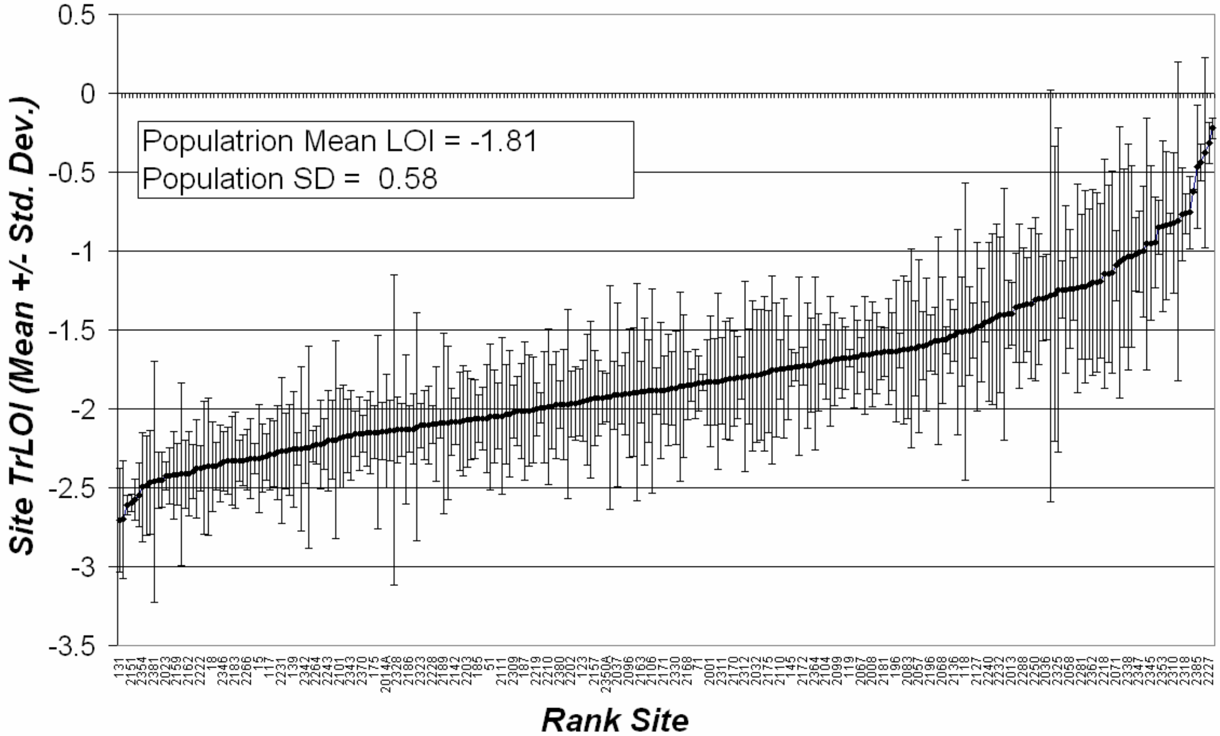

Fig. 29 – Summary of site level mean and distribution for spectrally predicted loss-on-ignition (ln transf.)

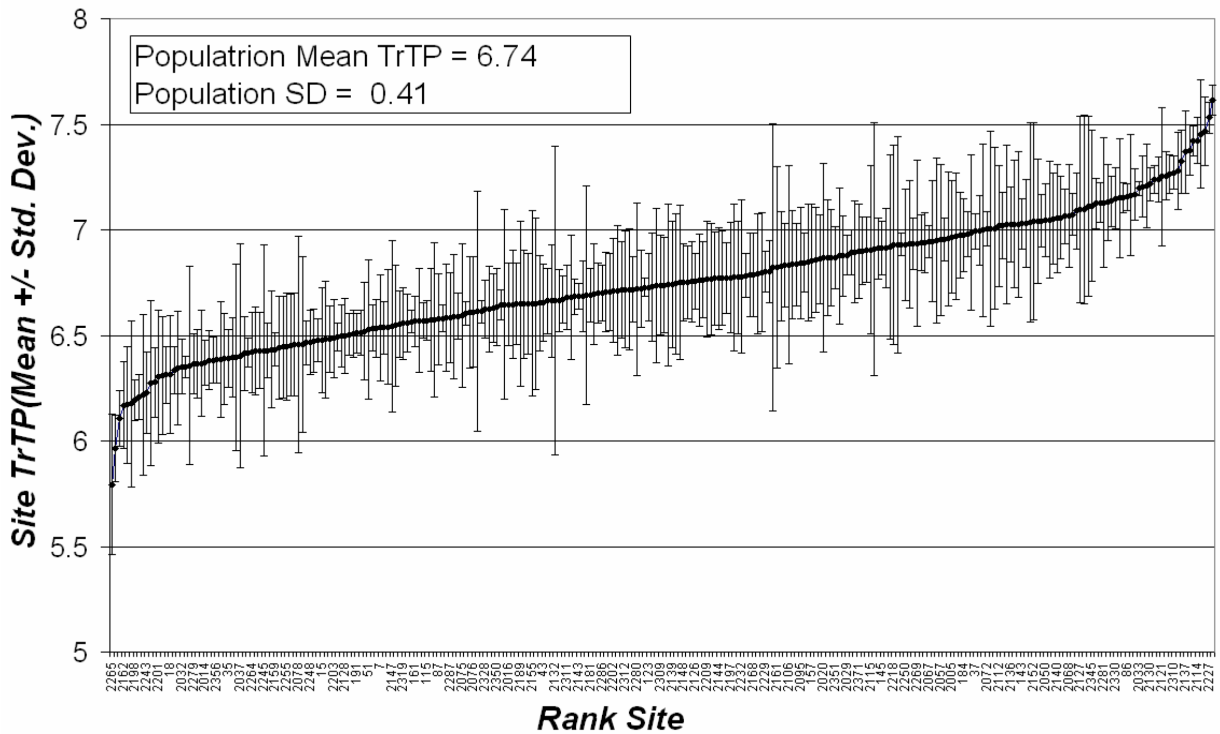

Fig. 30 – Summary of site level mean and distribution for spectrally predicted total P (ln transf.).

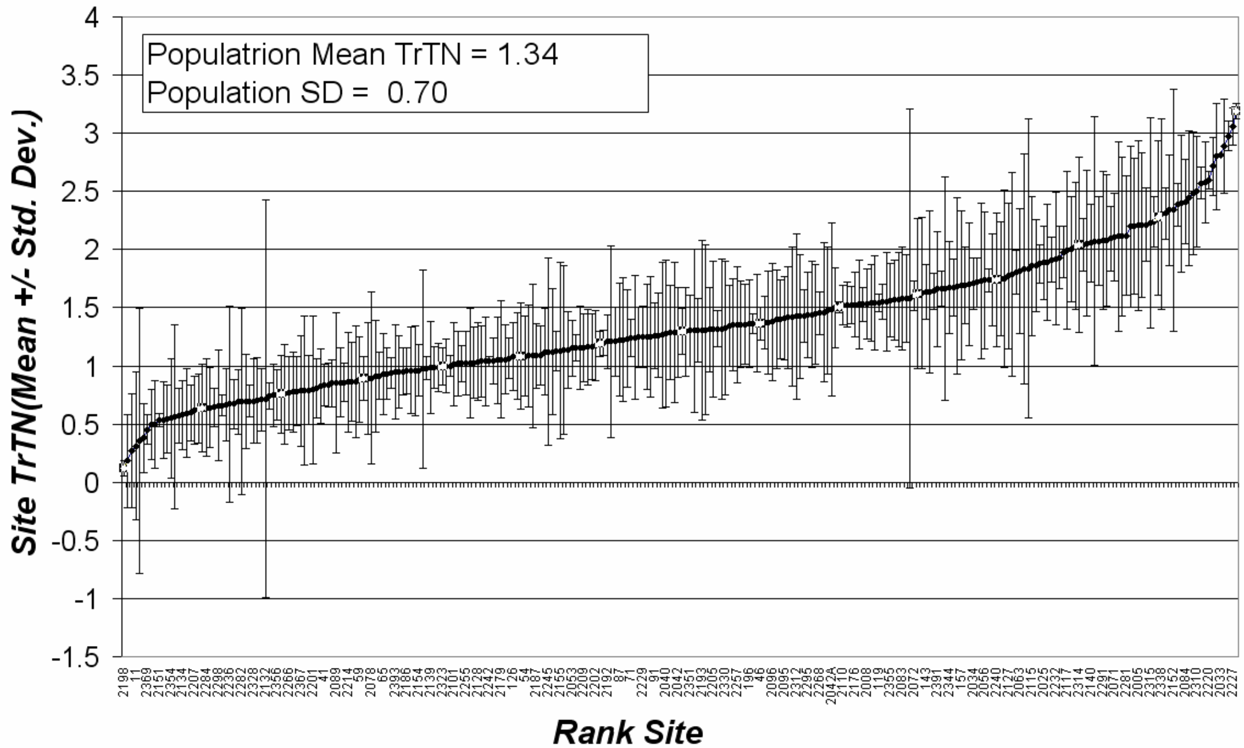

Fig. 31 – Summary of site level mean and distribution for spectrally predicted total N (ln transf.).

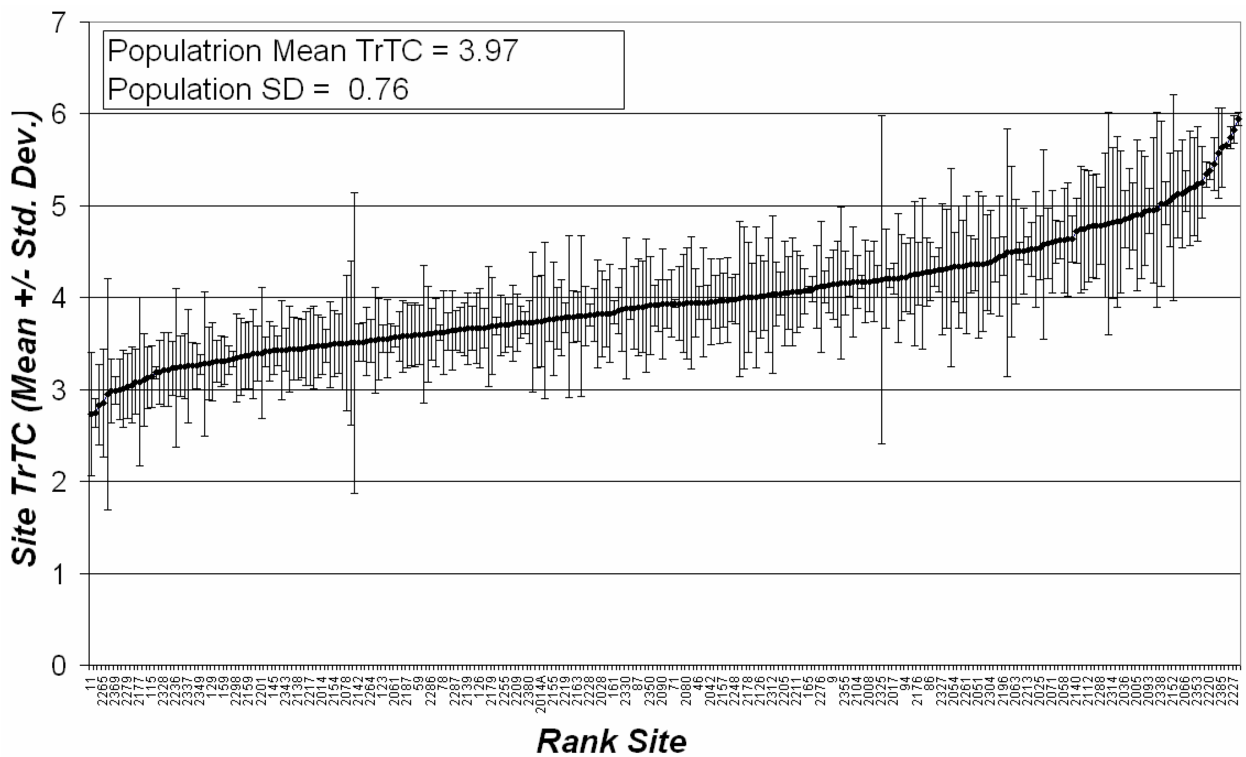

Fig. 32 – Summary of site level mean and distribution for spectrally predicted total C (ln transf.).

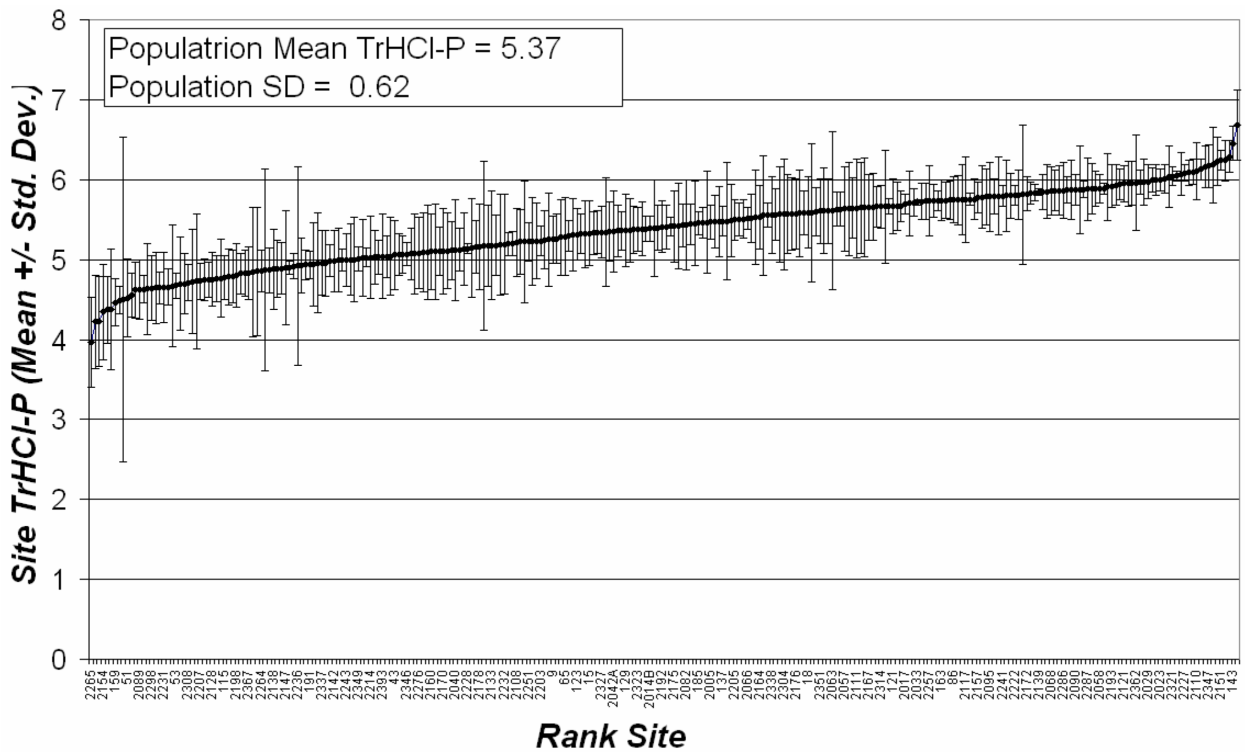

Fig. 33 – Summary of site level mean and distribution for spectrally predicted HCl-P (ln transf.).

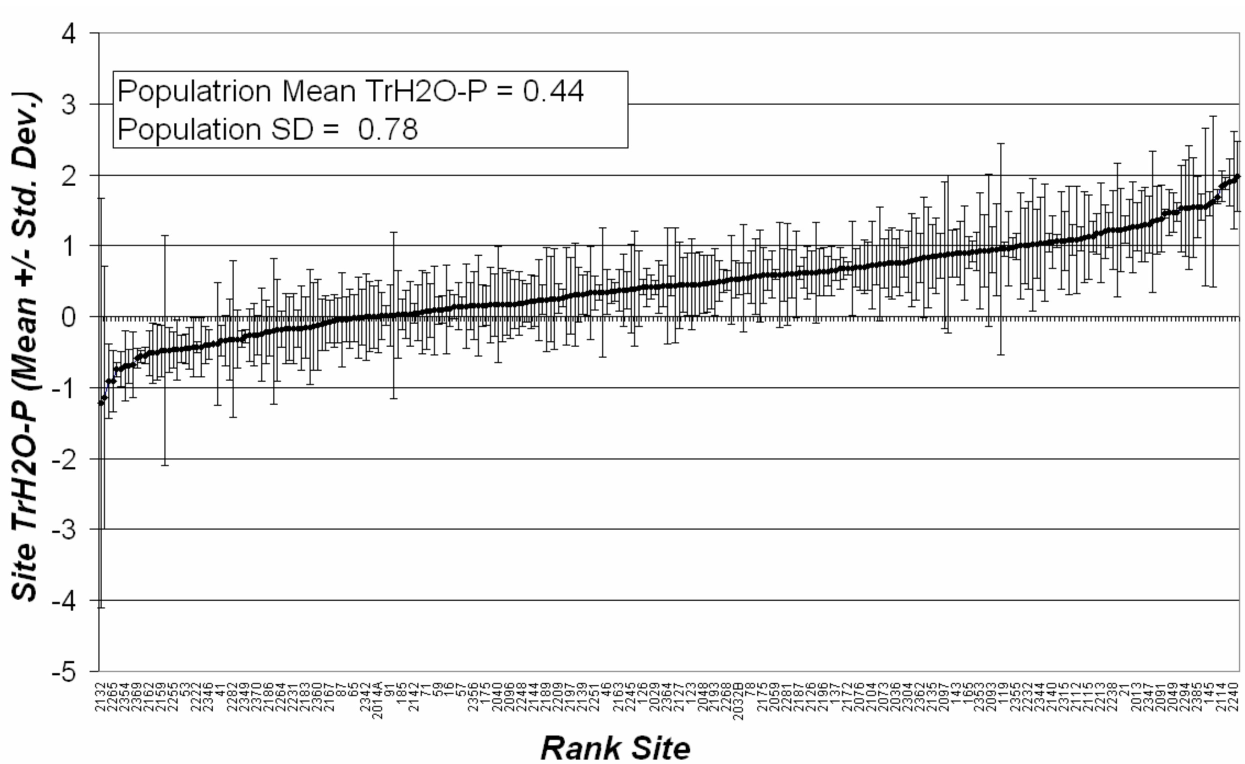

Fig. 34 – Summary of site level mean and distribution for spectrally predicted HCl-P (ln transf.).

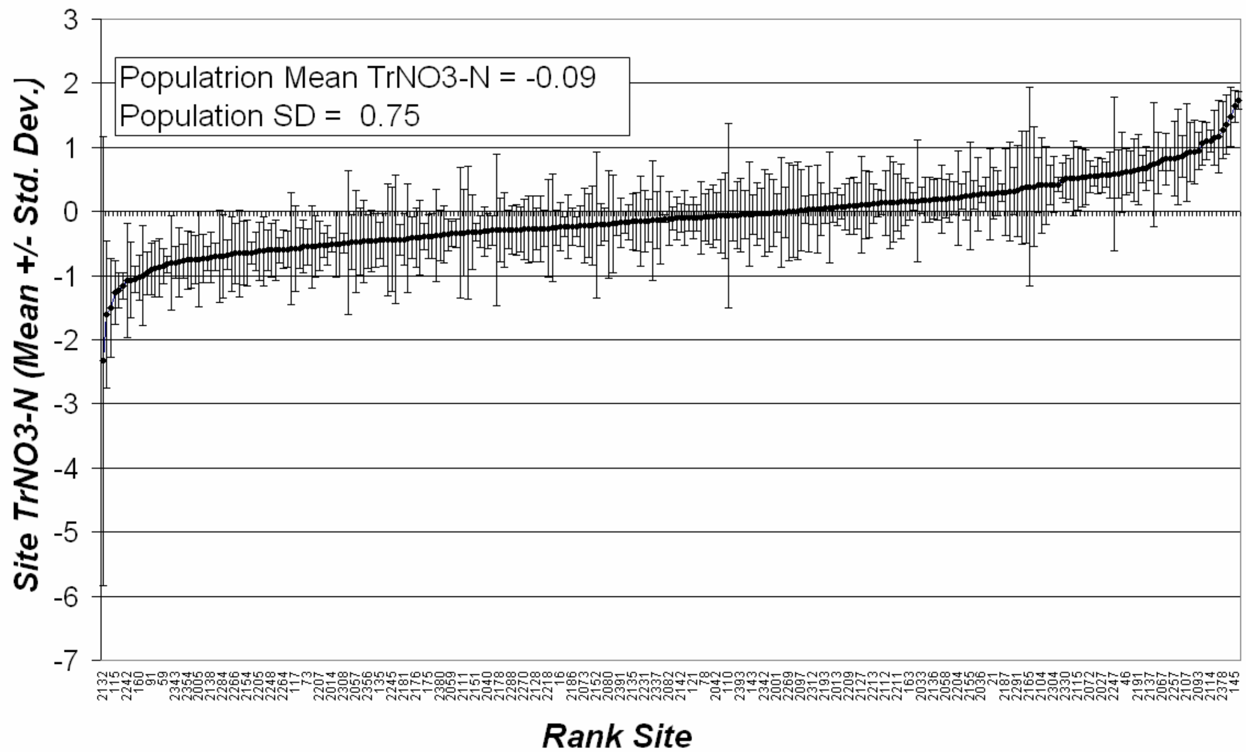

Fig. 35 – Summary of site level mean and distribution for spectrally predicted NO3-N (ln transf.).

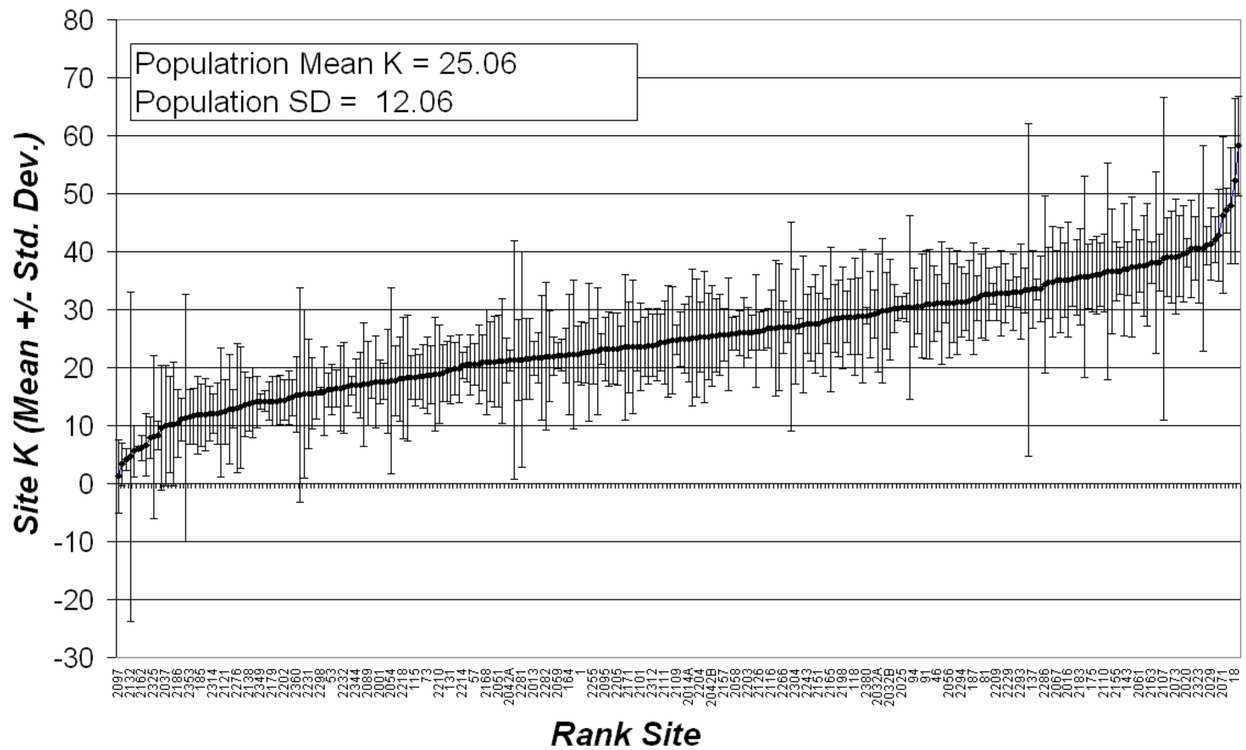

Fig. 36 – Summary of site level mean and distribution for spectrally predicted Total K.

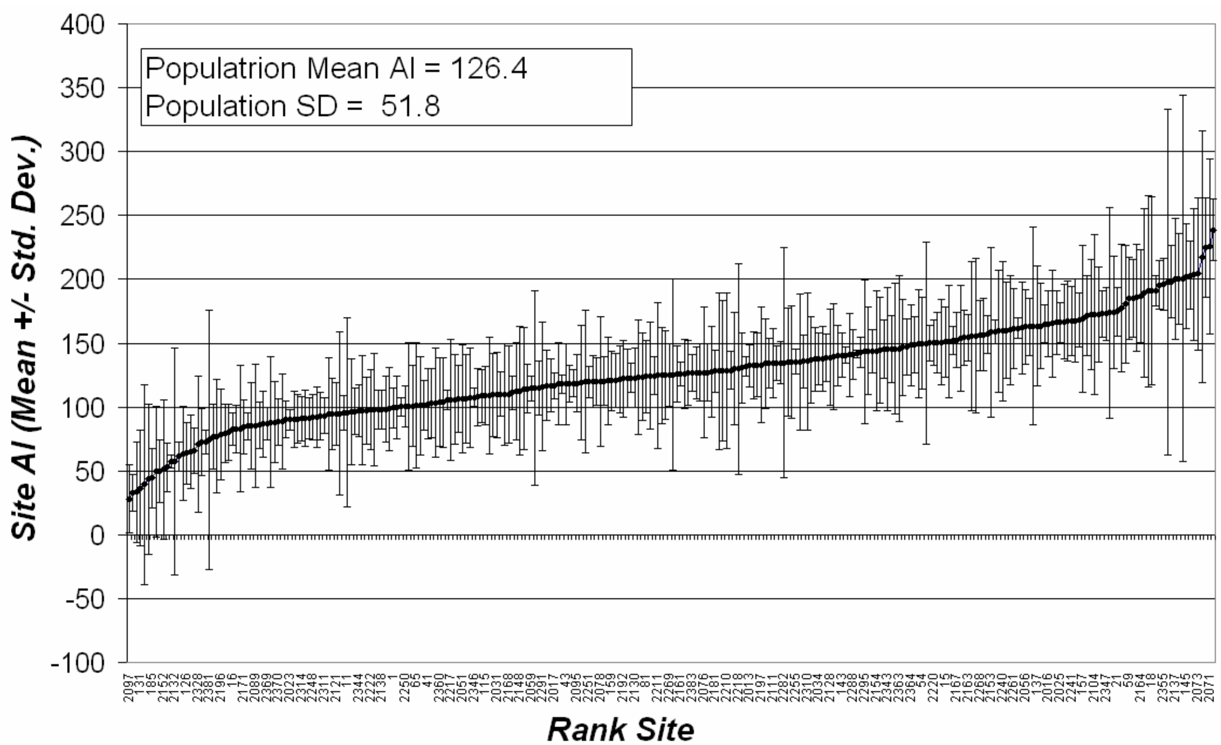

Fig. 37 – Summary of site level mean and distribution for spectrally predicted Total Al.

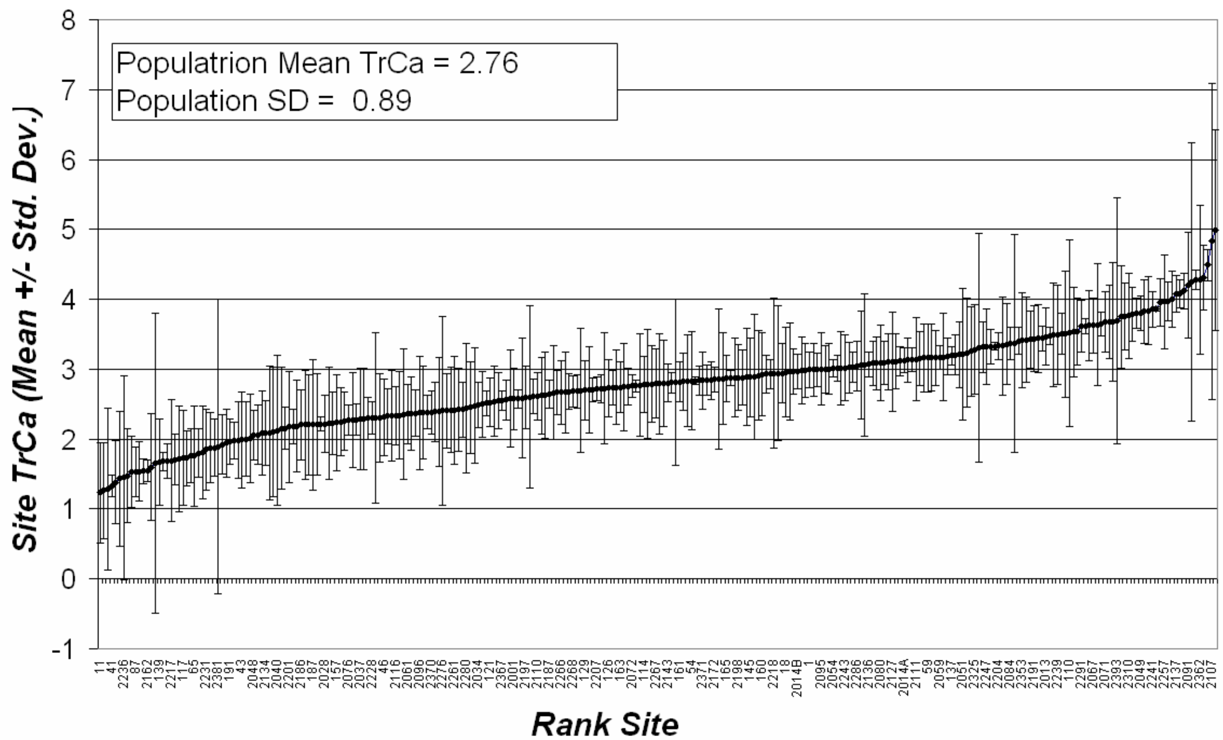

Fig. 38 – Summary of site level mean and distribution for spectrally predicted total Ca (ln transf.).

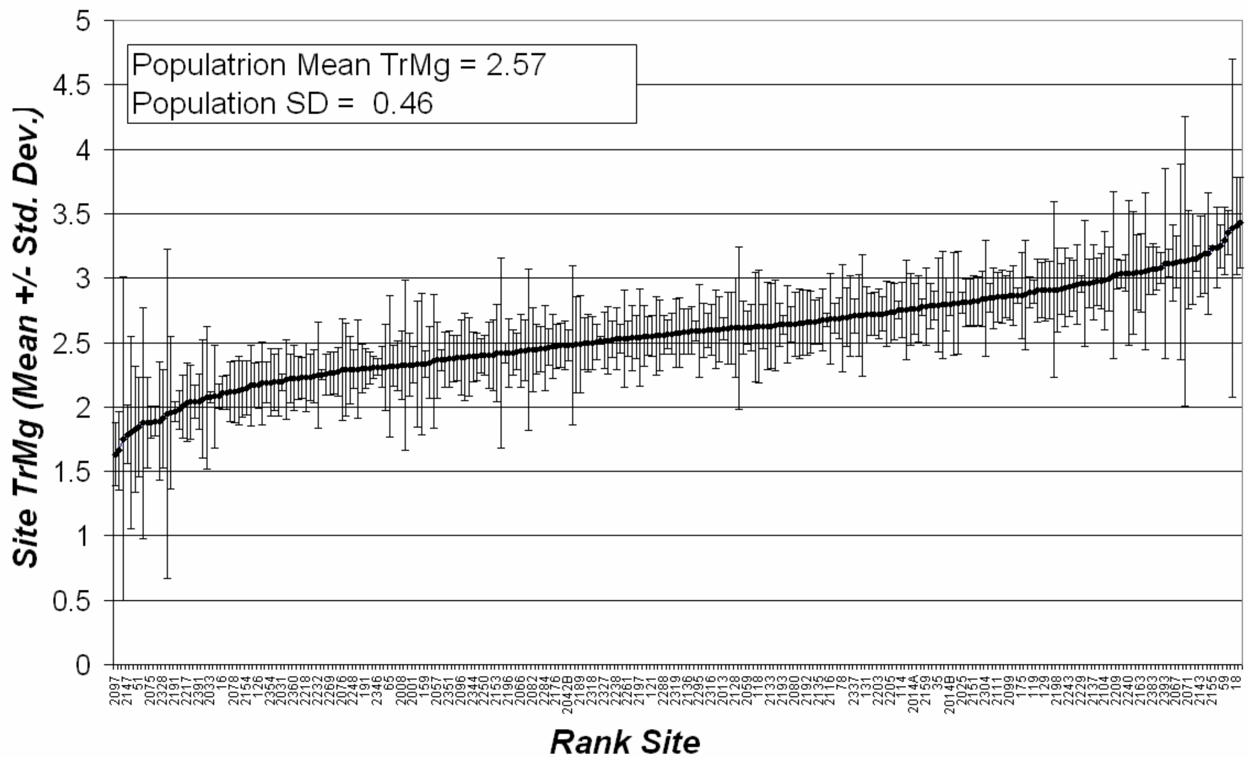

Fig. 39 – Summary of site level mean and distribution for spectrally predicted total Mg (ln transf.)

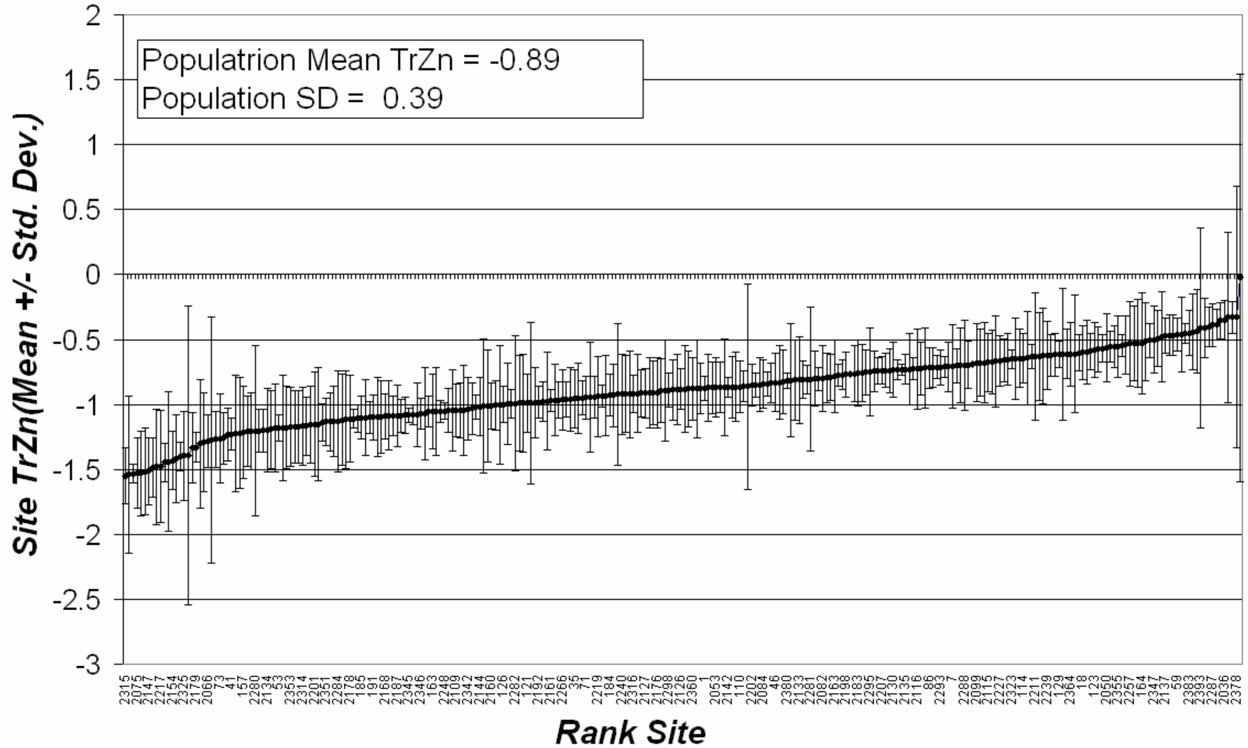

Fig. 40 – Summary of site level mean and distribution for spectrally predicted total Zn (ln transf.).

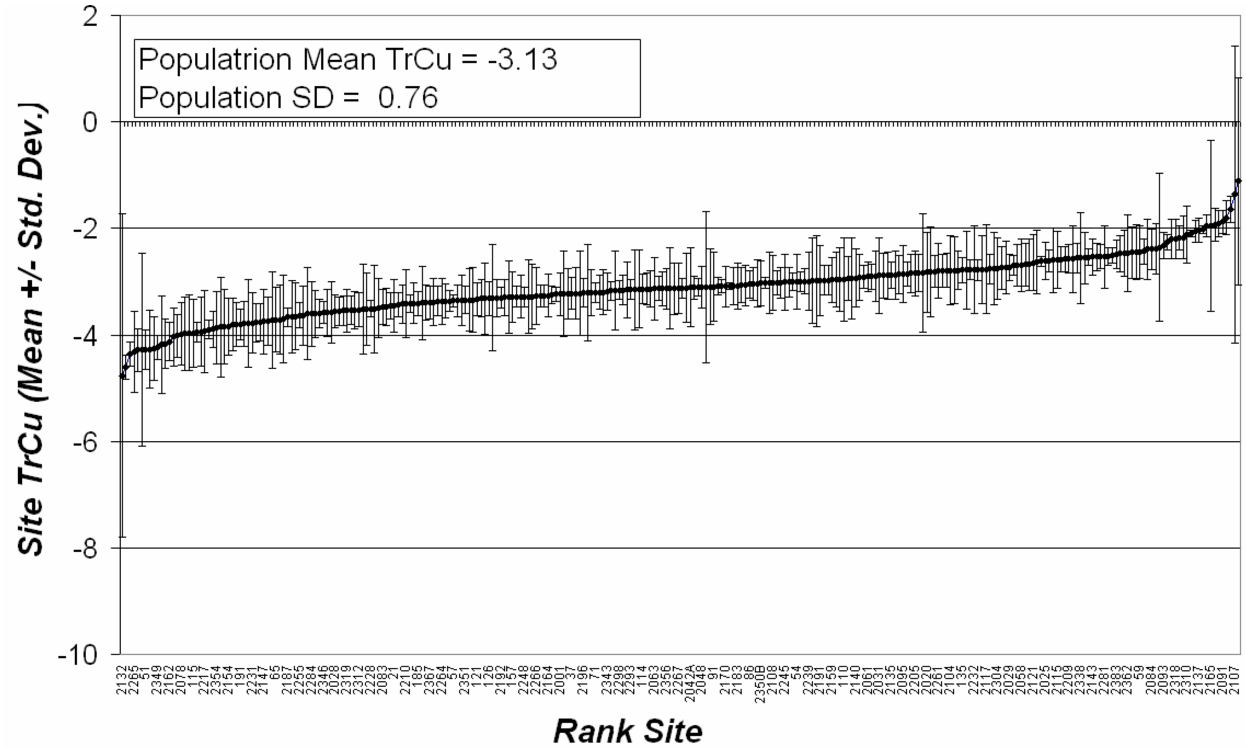

Fig. 41 – Summary of site level mean and distribution for spectrally predicted total Cu (ln transf.).

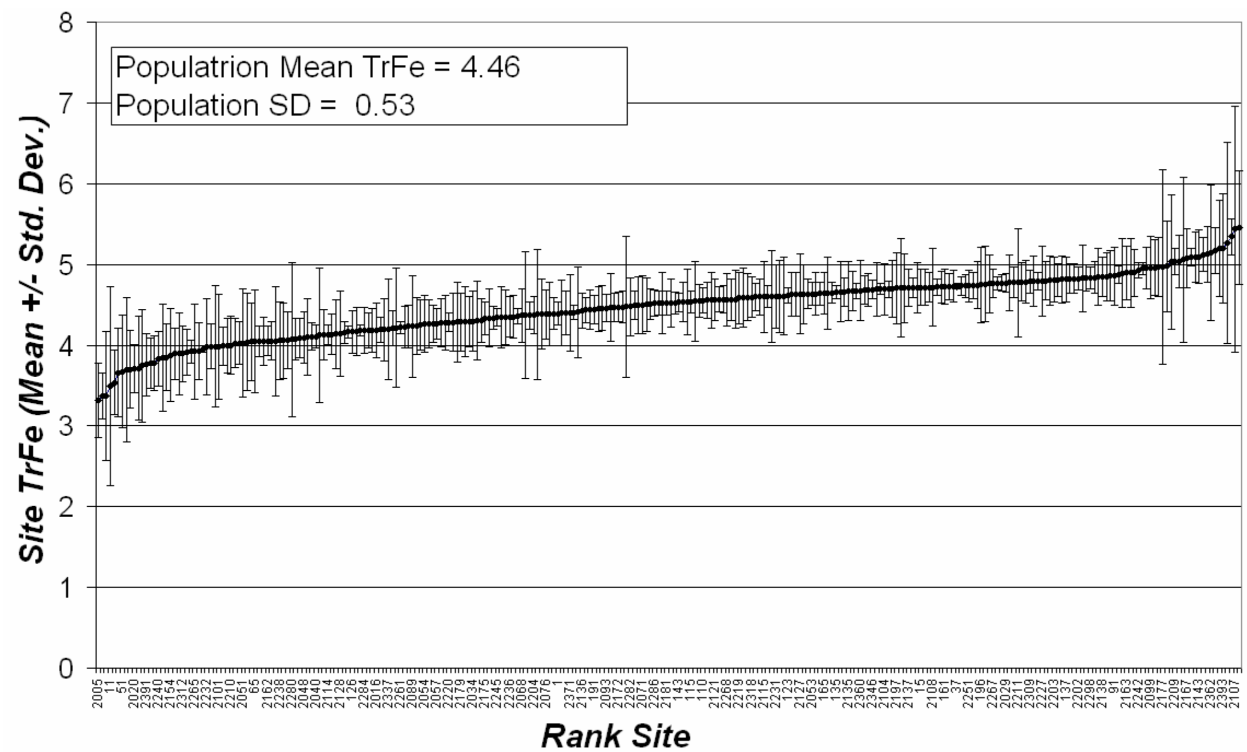

Fig. 42 – Summary of site level mean and distribution for spectrally predicted total Fe (ln transf.).

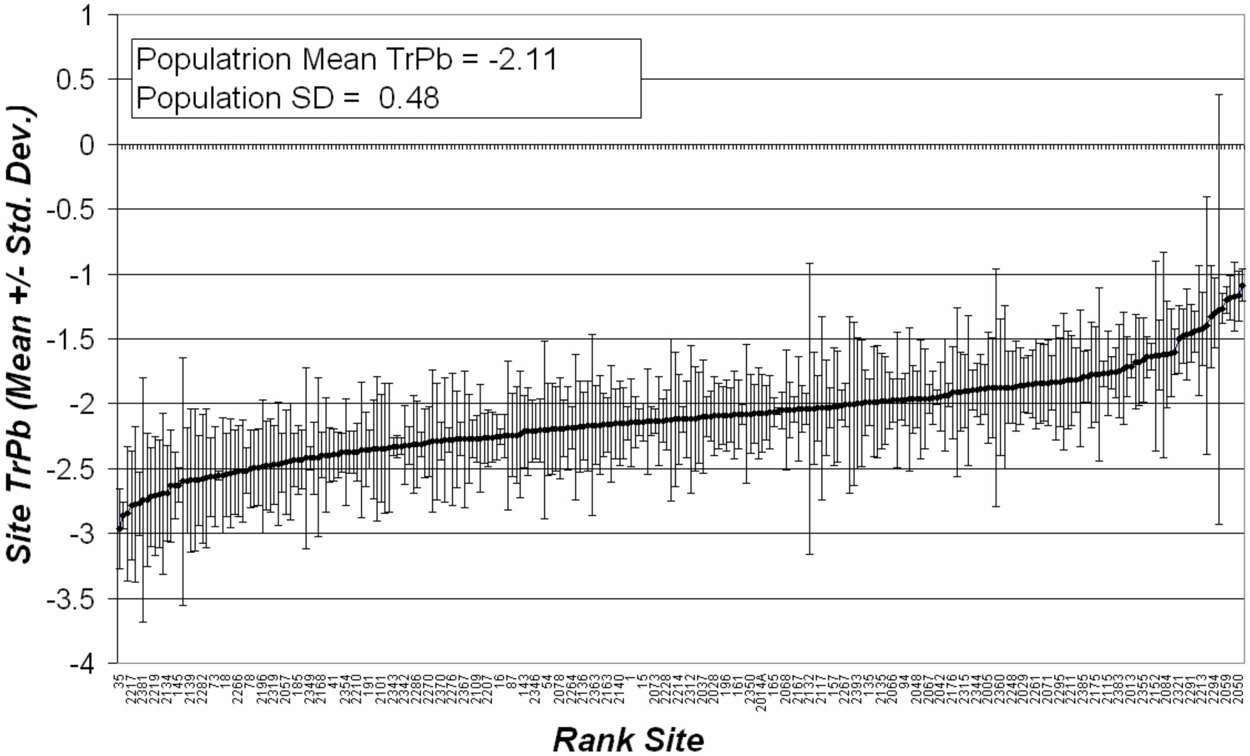

Fig. 43 – Summary of site level mean and distribution for spectrally predicted total Pb (ln transf.).

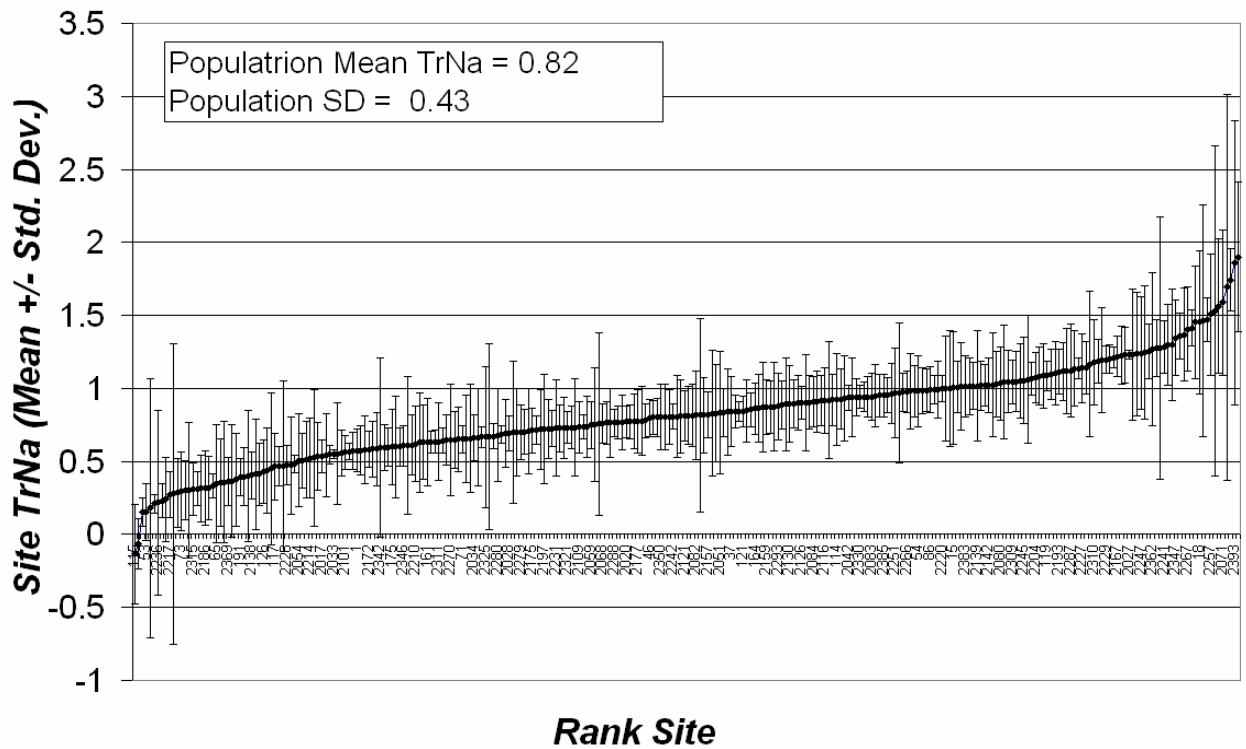

Fig. 44 – Summary of site level mean and distribution for spectrally predicted total Na (ln transf.).

Discussion and Conclusions

Future Work

This work has measured biogeochemical properties at 231 wetland sites throughout the Cuyahoga River basin, and developed predictive models that relate a much less expensive soil property (spectral response) to these expensive measures of soil condition; these models were extrapolated to an additional 1454 samples for which only spectral response information was available. This report presents the absolute and relative efficiencies of spectral prediction for each of the 20 analytes, and suggests that for many of them spectral prediction may be a useful rapid assessment tool. Given this observation, we project three important tasks to be accomplished in future work:

1) Understand the spatial and temporal variability of the spectral predictions for purposes of efficient sampling and interpretation.
2) Examination of relationships between soil biogeochemical indicators and measures of biological condition based on community composition and landscape matrix.
3) Development of direct spectral correlates with assessed biological/ecological condition.

This work can be accomplished as the data for biogeochemical condition and ecological condition are fused.

APPENDIX D
SITE LIST

SITE_ID	Site	Same as1	Same as2	Group	type	Modified**	Fate***	If not Wetland	Area name	LONG_DDN83	LAT_DDN83
WCW02352-2001	2001			OEPA	1	N	5		Congress Lake Region	-81.256167	41.024223
WCW02352-2002	2002			OEPA	0	na	0	on slope, no wetland w/in 60m	Breakneck Cr Region	-81.328714	41.162531
WCW02352-2003	2003			OEPA	3		3		Hudson Swamp - Brandwine Cr Swamp	-81.499664	41.276865
WCW02352-2004	2004			OEPA	1	N	3		Middle Upper Cuyahoga River	-81.079486	41.545586
WCW02352-2005	2005			OEPA	1	N	5		Breakneck Cr Region	-81.320538	41.079073
WCW02352-2006	2006			OEPA	0		0	Area filled or never wetland	Cuyahoga County	-81.770699	41.436833
WCW02352-2007	2007	2119	2335	OEPA	3		3		Hudson Swamp - Brandwine Cr Swamp	-81.481719	41.235575
WCW02352-2008	2008			OEPA	1	N	5		Middle Upper Cuyahoga River	-81.227580	41.367039
WCW02352-2009	2009			OEPA	3		3		Breakneck Cr Region	-81.253966	41.129797
WCW02352-2010	2010			OEPA	0		0	prior converted farmland	Lower Upper Cuyahoga (Portage Co.)	-81.248942	41.317215
WCW02352-2011	2011			OEPA	0	N	0	Streetsboro school built on site	Streetsboro - L Rockwell Region	-81.326165	41.236681
WCW02352-2012	2012			OEPA	3		3		Middle Upper Cuyahoga River	-81.232495	41.354750
WCW02352-2013	2013			OEPA	1	N	5		Greater Akron -Mogadore Res Region	-81.399283	41.029004
WCW02352-2014	2014			OEPA	1	N	5		Cuyahoga Valley Region	-81.591098	41.325138
WCW02352-2015	2015			OEPA	1	N	5		Cuyahoga Valley Region	-81.602523	41.249462
WCW02352-2016	2016			OEPA	1	Y	5		Middle Upper Cuyahoga River	-81.284601	41.422496
WCW02352-2017	2017			OEPA	1	Y	5	Stark Co site	Congress Lake Region	-81.312969	40.973292
WCW02352-2018	2018			OEPA	3		3		Breakneck Cr Region	-81.320611	41.119225
WCW02352-2019	2019			OEPA	0	na	0	reservoir deep water	Streetsboro - L Rockwell Region	-81.308356	41.209325
WCW02352-2020	2020			OEPA	1	N	5		Middle Upper Cuyahoga River	-81.272509	41.334236
WCW02352-2021	2021			OEPA	0		0		Cuyahoga Valley Region	-81.586547	41.204961
WCW02352-2022	2022			OEPA	0	N	0	Point located in WWT lagoon	Cuyahoga County	-81.663454	41.438815
WCW02352-2023	2023			OEPA	1	Y	5		Cuyahoga Valley Region	-81.573615	41.171461
WCW02352-2024	2024			OEPA	3		3		Middle Upper Cuyahoga River	-81.237796	41.428703
WCW02352-2025	2025			OEPA	1	N	5		Breakneck Cr Region	-81.271396	41.071575
WCW02352-2026	2026			OEPA	0	N	0	Not a wetland	Lower Upper Cuyahoga (Portage Co.)	-81.188279	41.306222
WCW02352-2027	2027			OEPA	1	Y	5		Hudson Swamp - Brandwine Cr Swamp	-81.405358	41.227069
WCW02352-2028	2028			OEPA	1	N	5	2028, 2108, 2356 all separate assessment u	Middle Upper Cuyahoga River	-81.184677	41.417910
WCW02352-2029	2029			OEPA	1	Y	5		Upper Tinkers Creek	-81.430100	41.305162
WCW02352-2030	2030			OEPA	3		3		Middle Upper Cuyahoga River	-81.124362	41.434071
WCW02352-2031	2031			OEPA	1	Y	5		Greater Akron -Mogadore Res Region	-81.405671	41.118388
WCW02352-2032	2032	2360		OEPA	1	N	5	includes 2360	Upper Cuyahoga River	-81.175500	41.525006
WCW02352-2033	2033			OEPA	1	N	5		Greater Akron -Mogadore Res Region	-81.357623	41.003634
WCW02352-2034	2034			OEPA	1	Y	5		Streetsboro - L Rockwell Region	-81.336436	41.174959
WCW02352-2035	2035			OEPA	3		3		Streetsboro - L Rockwell Region	-81.375481	41.217519
WCW02352-2036	2036	2348		OEPA	1	Y	5	includes 2348	Upper Cuyahoga River	-81.114302	41.472940
WCW02352-2037	2037			OEPA	1	Y	5		Greater Akron -Mogadore Res Region	-81.363799	41.019140
WCW02352-2038	2038			OEPA	0		0	No wetland w/in 60m of point	Cuyahoga County	-81.682389	41.338641
WCW02352-2039	2039			OEPA	0		0	No wetland w/in 60m of point	Hudson Swamp - Brandwine Cr Swamp	-81.507418	41.157946
WCW02352-2040	2040			OEPA	1	Y	5		Upper Cuyahoga River	-81.177514	41.469216
WCW02352-2041	2041			OEPA	3		3		Breakneck Cr Region	-81.246726	41.095693
WCW02352-2042	2042			OEPA	1	N	5		Lower Upper Cuyahoga (Portage Co.)	-81.219181	41.278899
WCW02352-2043	2043				6		6				

APPENDIX D
SITE LIST

SITE_ID	Site	Same as1	Same as2	Group	type	Modified**	Fate***	If not Wetland	Area name	LONG_DDN83	LAT_DDN83
WCW02352-2044	2044			OEPA	1	N	5		Upper Cuyahoga River	-81.249860	41.390145
WCW02352-2045	2045	2173		OEPA	1	N	5	2173 is part of this	Upper Tinkers Creek	-81.379889	41.291183
WCW02352-2046	2046			OEPA	3		3		Middle Upper Cuyahoga River	-81.091257	41.433660
WCW02352-2047	2047			OEPA	0		0	Not a wetland	Greater Akron -Mogadore Res Region	-81.505987	41.090288
WCW02352-2048	2048			OEPA	1	N	5		Upper Cuyahoga River	-81.158522	41.561185
WCW02352-2049	2049			OEPA	1	N	5		Breakneck Cr Region	-81.255583	41.076206
WCW02352-2050	2050			G3	1	N	1		Breakneck Cr Region	-81.275536	41.152416
WCW02352-2051	2051			K1-ECS	1	N	1		Lower Upper Cuyahoga (Portage Co.)	-81.289030	41.257712
WCW02352-2052	2052			SF	0		4	photo	Cuyahoga County	-81.435363	41.350455
WCW02352-2053	2053			P+L	1	N	1		Cuyahoga Valley Region	-81.700705	41.165488
WCW02352-2054	2054			K1 +P&J	1	N	1		Hudson Swamp - Brandwine Cr Swamp	-81.508512	41.311518
WCW02352-2055	2055			S4	0	na	0	park	Cuyahoga Valley Region	-81.525104	41.217126
WCW02352-2056	2056			G3	1	N	1		Upper Cuyahoga River	-81.161051	41.451921
WCW02352-2057	2057			S4	1	N	1		Congress Lake Region	-81.306229	41.027131
WCW02352-2058	2058			K1-ECS	1	N	1		Lower Upper Cuyahoga (Portage Co.)	-81.268061	41.181854
WCW02352-2059	2059	2387		G3+J	1	Y	1	2387 is part of this	Greater Akron -Mogadore Res Region	-81.451442	41.149842
WCW02352-2060	2060			JMMM	1	N	1		Middle Upper Cuyahoga River	-81.155693	41.379179
WCW02352-2061	2061	2389		K1-LE	1	N	1	2389 not near 2061	Upper Tinkers Creek	-81.434982	41.313643
WCW02352-2062	2062			JMMM	1	N	1		Middle Upper Cuyahoga River	-81.157761	41.417770
WCW02352-2063	2063			K2-John	1	N	1		Breakneck Cr Region	-81.354409	41.129467
WCW02352-2064	2064				3		3		Upper Cuyahoga River	-81.061791	41.564237
WCW02352-2065	2065			S4	3		3		Congress Lake Region	-81.264890	41.007416
WCW02352-2066	2066			K1-L&E	1	N	1		Streetsboro - L Rockwell Region	-81.370649	41.180422
WCW02352-2067	2067			K2	1	N	1		Upper Tinkers Creek	-81.392363	41.272757
WCW02352-2068	2068	2396		John	1	N	1		Upper Cuyahoga River	-81.077686	41.488135
WCW02352-2069	2069				3		3		Breakneck Cr Region	-81.297125	41.091143
WCW02352-2070	2070			K2	0	na	0	deep forest	Cuyahoga Valley Region	-81.582712	41.296851
WCW02352-2071	2071			S4	1	N	1		Hudson Swamp - Brandwine Cr Swamp	-81.484282	41.174592
WCW02352-2072	2072			G3	1	N	1		Middle Upper Cuyahoga River	-81.212950	41.455334
WCW02352-2073	2073			G3	1	N	1		Breakneck Cr Region	-81.264893	41.106165
WCW02352-2074	2074	2138	2242	K1-ECS	1	N	1	points probably different assessment units, v	Lower Upper Cuyahoga (Portage Co.)	-81.218384	41.262410
WCW02352-2075	2075			K1-LECS	1	N	1		Upper Tinkers Creek	-81.378143	41.280096
WCW02352-2076	2076			K3+L	1	N	1		Middle Upper Cuyahoga River	-81.245475	41.403908
WCW02352-2077	2077				3		3		Upper Tinkers Creek	-81.394654	41.297774
WCW02352-2078	2078			G3	1	N	1		Cuyahoga County	-81.485812	41.443910
WCW02352-2079	2079			S4	3		3		Hudson Swamp - Brandwine Cr Swamp	-81.501157	41.280426
WCW02352-2080	2080			P+L	1	Y	1		Upper Cuyahoga River	-81.142670	41.565163
WCW02352-2081	2081			G3	0	N	0	CODED WRONG = 0 DEVELOPED ON HYI	Breakneck Cr Region	-81.235383	41.096588
WCW02352-2082	2082			G3	1	N	1		Breakneck Cr Region	-81.303600	41.143077
WCW02352-2083	2083			K1-ECS	1	N	1		Streetsboro - L Rockwell Region	-81.319245	41.267903
WCW02352-2084	2084			K3	1	N	1		Cuyahoga County	-81.428200	41.363667
WCW02352-2085	2085	2361		K2	1	N	1		Cuyahoga Valley Region	-81.679363	41.134178
WCW02352-2086	2086			SF	0		4	photo	Cuyahoga County	-81.502001	41.351932

APPENDIX D
SITE LIST

SITE_ID	Site	Same as1	Same as2	Group	type	Modified**	Fate***	If not Wetland	Area name	LONG_DDN83	LAT_DDN83
WCW02352-2087	2087			K2	1	N	1		Cuyahoga Valley Region	-81.565758	41.291064
WCW02352-2088	2088			G3	0	N	0		Middle Upper Cuyahoga River	-81.169723	41.444172
WCW02352-2089	2089			K2-CC	1	N	1		Greater Akron -Mogadore Res Region	-81.312007	41.069657
WCW02352-2090	2090	2258	2386	K1-ECS	1	N	1		Lower Upper Cuyahoga (Portage Co.)	-81.254807	41.181534
WCW02352-2091	2091			K1-L&E	1	N	1		Upper Tinkers Creek	-81.371103	41.199310
WCW02352-2092	2092	2260		K1-L&CS	1	N	1		Lower Upper Cuyahoga (Portage Co.)	-81.181029	41.349130
WCW02352-2093	2093			K3+L	1	N	1		Upper Tinkers Creek	-81.396923	41.320982
WCW02352-2094	2094			JMMM	0	na	0	pond	Middle Upper Cuyahoga River	-81.166377	41.406559
WCW02352-2095	2095	2263		G3	1	N	1	points probably different assessment units, v	Streetsboro - L Rockwell Region	-81.366313	41.121788
WCW02352-2096	2096			K1+E	0	na	0		Upper Cuyahoga River	-81.143297	41.583162
WCW02352-2097	2097			S4	1	N	1		Congress Lake Region	-81.317593	40.991791
WCW02352-2098	2098			K1	0	na	0	forest/hydric soil	Streetsboro - L Rockwell Region	-81.311828	41.180911
WCW02352-2099	2099			K2-L	1	N	1		Upper Tinkers Creek	-81.375382	41.235354
WCW02352-2100	2100			John	1	Y	1	2100 not same point as 2036 and 2348	Upper Cuyahoga River	-81.106327	41.469932
WCW02352-2101	2101			K2	1	Y	1		Cuyahoga Valley Region	-81.628059	41.166347
WCW02352-2102	2102			K2	0	N	0	river bank	Cuyahoga Valley Region	-81.604675	41.362154
WCW02352-2103	2103			S4	3	na	3		Cuyahoga County	-81.549464	41.164063
WCW02352-2104	2104			G3	1	Y	1		Middle Upper Cuyahoga River	-81.243950	41.444460
WCW02352-2105	2105			K2-L	3		3	John has folder 2005	Greater Akron -Mogadore Res Region	-81.327805	41.074364
WCW02352-2106	2106			K1-LE	1	N	1		Lower Upper Cuyahoga (Portage Co.)	-81.185885	41.322789
WCW02352-2107	2107			K1-L&E	1	N	1		Streetsboro - L Rockwell Region	-81.385536	41.179589
WCW02352-2108	2108			John	1	N	1	2028, 2108, 2356 all separate assessment u	Middle Upper Cuyahoga River	-81.189637	41.421814
WCW02352-2109	2109	2373		K1+P&J	1	N	1		Upper Tinkers Creek	-81.392697	41.288553
WCW02352-2110	2110			G3	1	N	1		Upper Cuyahoga River	-81.151613	41.442390
WCW02352-2111	2111			K1-L&E	1	N	1		Streetsboro - L Rockwell Region	-81.410328	41.138300
WCW02352-2112	2112			P+L	1	N	1		Upper Cuyahoga River	-81.172130	41.544179
WCW02352-2113	2113			G3	0	na	0	forest upland, developed	Breakneck Cr Region	-81.275734	41.125319
WCW02352-2114	2114			K1+E	1	N	1		Lower Upper Cuyahoga (Portage Co.)	-81.251778	41.324031
WCW02352-2115	2115			K1+P	1	N	1		Streetsboro - L Rockwell Region	-81.336539	41.232994
WCW02352-2116	2116			G3	1	Y	1		Cuyahoga County	-81.479993	41.422476
WCW02352-2117	2117	2341		K3	1	N	1	inclues 2341	Greater Akron -Mogadore Res Region	-81.403097	41.015477
WCW02352-2118	2118			K2	0	N	0	upland area near creek	Cuyahoga County	-81.575394	41.355325
WCW02352-2119	2119	2007	2335	Marie	3		3	John denied	Hudson Swamp - Brandwine Cr Swamp	-81.483669	41.240610
WCW02352-2120	2120			John	1	N	1		Middle Upper Cuyahoga River	-81.287623	41.419016
WCW02352-2121	2121			K2	1	Y	1		Streetsboro - L Rockwell Region	-81.367450	41.098409
WCW02352-2122	2122			SF	0		4	photo	Cuyahoga County	-81.767086	41.423655
WCW02352-2123	2123			Marie	3		3	according to John	Hudson Swamp - Brandwine Cr Swamp	-81.474122	41.238336
WCW02352-2124	2124	2208		JMMM	1	N	1	2208 is part of this	Middle Upper Cuyahoga River	-81.152342	41.385137
WCW02352-2125	2125				3		3		Hudson Swamp - Brandwine Cr Swamp	-81.486760	41.270618
WCW02352-2126	2126			K1+E	1	N	1		Upper Cuyahoga River	-81.118766	41.545087
WCW02352-2127	2127			K1	1	Y	1		Streetsboro - L Rockwell Region	-81.396124	41.152039
WCW02352-2128	2128			K1+E	1	Y	1		Middle Upper Cuyahoga River	-81.129192	41.564141
WCW02352-2129	2129				6		6				

APPENDIX D
SITE LIST

SITE_ID	Site	Same as1	Same as2	Group	type	Modified**	Fate***	If not Wetland	Area name	LONG_DDN83	LAT_DDN83
WCW02352-2130	2130			G3	1	N	1		Breakneck Cr Region	-81.322113	41.135659
WCW02352-2131	2131				3		3		Upper Tinkers Creek	-81.429808	41.267149
WCW02352-2132	2132			K1+E	1	N	1		Upper Cuyahoga River	-81.101469	41.509007
WCW02352-2133	2133	2237		K2-CC	1	M	1		Greater Akron -Mogadore Res Region	-81.330123	41.084798
WCW02352-2134	2134			G3	1	N	1		Cuyahoga County	-81.701238	41.336107
WCW02352-2135	2135			G3	1	Y	1		Hudson Swamp - Brandwine Cr Swamp	-81.448837	41.213580
WCW02352-2136	2136			P+L	1	Y	1		Upper Cuyahoga River	-81.175140	41.490248
WCW02352-2137	2137			G3	1	N	1		Breakneck Cr Region	-81.251594	41.090947
WCW02352-2138	2138	2074	2242	K1-ECS	2	N	2	points probably different assessment units, v	Lower Upper Cuyahoga (Portage Co.)	-81.228190	41.260334
WCW02352-2139	2139			K1-L&E	1	N	1		Streetsboro - L Rockwell Region	-81.343657	41.194364
WCW02352-2140	2140			K1+E	1	N	1		Lower Upper Cuyahoga (Portage Co.)	-81.240361	41.345864
WCW02352-2141	2141	2235	2245	K3	1	N	1	part of 2235, 2245	Upper Tinkers Creek	-81.381413	41.282533
WCW02352-2142	2142			G3	1	Y	1		Cuyahoga County	-81.495624	41.391138
WCW02352-2143	2143			S4	1	N	1		Cuyahoga Valley Region	-81.559343	41.214061
WCW02352-2144	2144			K1+E	1	N	1		Upper Cuyahoga River	-81.175124	41.572112
WCW02352-2145	2145			S4	1	N	0	development	Congress Lake Region	-81.287484	40.980174
WCW02352-2146	2146			G3	0	N	0	development	Breakneck Cr Region	-81.284223	41.132192
WCW02352-2147	2147			K2-L	1	N	1		Lower Upper Cuyahoga (Portage Co.)	-81.293226	41.229919
WCW02352-2148	2148			K1-LECS	1	Y	1		Upper Tinkers Creek	-81.380157	41.333012
WCW02352-2149	2149			K2	0	na	0	farm pond	Cuyahoga Valley Region	-81.644205	41.223341
WCW02352-2150	2150			K2 (-CS)	0	na	0	housing development	Cuyahoga Valley Region	-81.530839	41.344495
WCW02352-2151	2151			S4	1	Y	1		Cuyahoga Valley Region	-81.572522	41.192028
WCW02352-2152	2152			G3	1	N	1		Middle Upper Cuyahoga River	-81.178459	41.434514
WCW02352-2153	2153			S4	1	N	1		Breakneck Cr Region	-81.289215	41.054034
WCW02352-2154	2154			K2	1	N	1		Lower Upper Cuyahoga (Portage Co.)	-81.220410	41.227473
WCW02352-2155	2155			K2	1	N	1		Streetsboro - L Rockwell Region	-81.396202	41.187490
WCW02352-2156	2156			K3CB	1	Y	1		Lower Upper Cuyahoga (Portage Co.)	-81.199277	41.344096
WCW02352-2157	2157			K3	1	N	1		Upper Tinkers Creek	-81.414116	41.324505
WCW02352-2158	2158			JMMM	1	N	1		Middle Upper Cuyahoga River	-81.157029	41.414746
WCW02352-2159	2159			K2	1	N	1		Breakneck Cr Region	-81.366149	41.117400
WCW02352-2160	2160			P+L	1	N	1		Upper Cuyahoga River	-81.209193	41.531241
WCW02352-2161	2161			S4	1	N	1		Congress Lake Region	-81.321715	41.011405
WCW02352-2162	2162			K1	1	N	1		Streetsboro - L Rockwell Region	-81.314176	41.198588
WCW02352-2163	2163			K2-L	1	N	1		Streetsboro - L Rockwell Region	-81.359811	41.234873
WCW02352-2164	2164			John	1	N	1		Upper Cuyahoga River	-81.111773	41.478440
WCW02352-2165	2165			S4	1	Y	1		Congress Lake Region	-81.339816	41.031008
WCW02352-2166	2166			G3	0	N	0	field, no soil sample	Cuyahoga County	-81.665720	41.357790
WCW02352-2167	2167			S4	1	Y	1		Cuyahoga Valley Region	-81.520058	41.197896
WCW02352-2168	2168			G3	0	N	1		Upper Cuyahoga River	-81.173178	41.462179
WCW02352-2169	2169			SF	0		4	need boat	Greater Akron -Mogadore Res Region	-81.355704	41.067856
WCW02352-2170	2170			K1-ECS	1	N	1		Lower Upper Cuyahoga (Portage Co.)	-81.213888	41.277356
WCW02352-2171	2171			K2-L	1	N	1		Upper Tinkers Creek	-81.357826	41.284595
WCW02352-2172	2172			K3+L	1	N	1		Middle Upper Cuyahoga River	-81.259034	41.371982

APPENDIX D
SITE LIST

SITE_ID	Site	Same as1	Same as2	Group	type	Modified**	Fate***	If not Wetland	Area name	LONG_DDN83	LAT_DDN83
WCW02352-2173	2173	2045		John	2	N	2	part of 2045	Upper Tinkers Creek	-81.380371	41.289949
WCW02352-2174	2174			K2-CC	1	N	1		Upper Cuyahoga River	-81.142389	41.459833
WCW02352-2175	2175			K3	1	N	1		Greater Akron -Mogadore Res Region	-81.430583	41.114354
WCW02352-2176	2176			P+L	1	N	1		Upper Cuyahoga River	-81.177450	41.538048
WCW02352-2177	2177			S4	1	Y	1		Breakneck Cr Region	-81.228189	41.062966
WCW02352-2178	2178			L+Sam	1	Y	1		Lower Upper Cuyahoga (Portage Co.)	-81.239245	41.274087
WCW02352-2179	2179			K2-CC	1	Y	1		Lower Upper Cuyahoga (Portage Co.)	-81.260059	41.235170
WCW02352-2180	2180			SF	0		4	photo	Cuyahoga County	-81.458625	41.385752
WCW02352-2181	2181			G3+J	1	Y	1		Greater Akron -Mogadore Res Region	-81.406594	41.041905
WCW02352-2182	2182			K2	0	na	0	moist crevasse	Cuyahoga Valley Region	-81.566304	41.302325
WCW02352-2183	2183			S4	1	N	1		Hudson Swamp - Brandwine Cr Swamp	-81.496904	41.242021
WCW02352-2184	2184			G3	3		3		Upper Cuyahoga River	-81.174367	41.451476
WCW02352-2185	2185			S4	0	N	0	development	Breakneck Cr Region	-81.307166	41.042307
WCW02352-2186	2186			K2-CC	1	N	1		Lower Upper Cuyahoga (Portage Co.)	-81.265147	41.213536
WCW02352-2187	2187	2199		G3	1	N	1	includes 2199	Hudson Swamp - Brandwine Cr Swamp	-81.456227	41.206415
WCW02352-2188	2188				3		3		Middle Upper Cuyahoga River	-81.163385	41.364897
WCW02352-2189	2189			K3	1	N	1		Upper Tinkers Creek	-81.476602	41.309730
WCW02352-2190	2190			K3CB	1	Y	1		Middle Upper Cuyahoga River	-81.140944	41.423250
WCW02352-2191	2191			K2	1	Y	1		Streetsboro - L Rockwell Region	-81.374044	41.127504
WCW02352-2192	2192			P+L	1	Y	1		Upper Cuyahoga River	-81.098232	41.575223
WCW02352-2193	2193			Rogers	0	N	0		Congress Lake Region	-81.276803	40.986500
WCW02352-2194	2194			K1-L&E	3		3	mining	Streetsboro - L Rockwell Region	-81.350432	41.186633
WCW02352-2195	2195			K2-L	1	N	1		Upper Tinkers Creek	-81.385174	41.256928
WCW02352-2196	2196			P+L	1	N	1		Upper Cuyahoga River	-81.163571	41.498451
WCW02352-2197	2197	2301		K2-CC	1	N	1	includes 2301	Greater Akron -Mogadore Res Region	-81.368660	41.051881
WCW02352-2198	2198			K2	0	na	0		Cuyahoga County	-81.652482	41.288254
WCW02352-2199	2199	2187		G3	2	N	2	part of 2187	Hudson Swamp - Brandwine Cr Swamp	-81.458522	41.205359
WCW02352-2200	2200				3		3		Upper Cuyahoga River	-81.211305	41.469211
WCW02352-2201	2201			S4	1	Y	1		Congress Lake Region	-81.229894	41.009222
WCW02352-2202	2202			K2	1	Y	1		Streetsboro - L Rockwell Region	-81.366875	41.134993
WCW02352-2203	2203			S4	1	N	1		Hudson Swamp - Brandwine Cr Swamp	-81.474395	41.268317
WCW02352-2204	2204			K1+CS	1	N	1		Upper Cuyahoga River	-81.111072	41.542752
WCW02352-2205	2205			K2-CC	1	N	1		Streetsboro - L Rockwell Region	-81.352727	41.096264
WCW02352-2206	2206			G3	0	N	0	forest/hydric soil	Cuyahoga County	-81.694726	41.402577
WCW02352-2207	2207			G3	1	N	1		Hudson Swamp - Brandwine Cr Swamp	-81.479823	41.215108
WCW02352-2208	2208	2124		JMMM	2		2	same as 2124	Middle Upper Cuyahoga River	-81.151149	41.385313
WCW02352-2209	2209			G3	1	N	1		Breakneck Cr Region	-81.248289	41.108452
WCW02352-2210	2210			K1-LE	1	n	1		Lower Upper Cuyahoga (Portage Co.)	-81.255777	41.304056
WCW02352-2211	2211			K1-ECS	1	N	1		Lower Upper Cuyahoga (Portage Co.)	-81.285564	41.265039
WCW02352-2212	2212			SF	0		4	photo	Cuyahoga County	-81.471093	41.374051
WCW02352-2213	2213			K3-S+EH	1	Y	1		Greater Akron -Mogadore Res Region	-81.457026	41.025788
WCW02352-2214	2214			G3	1	Y	1		Cuyahoga County	-81.515797	41.389487
WCW02352-2215	2215				3		3		Hudson Swamp - Brandwine Cr Swamp	-81.480776	41.249099

APPENDIX D
SITE LIST

SITE_ID	Site	Same as1	Same as2	Group	type	Modified**	Fate***	If not Wetland	Area name	LONG_DDN83	LAT_DDN83
WCW02352-2216	2216				3		3		Middle Upper Cuyahoga River	-81.271445	41.393989
WCW02352-2217	2217			S4	1	Y	1		Congress Lake Region	-81.309452	40.984353
WCW02352-2218	2218			K1	1	Y	1		Cuyahoga Valley Region	-81.314949	41.193498
WCW02352-2219	2219			K2-L	1	Y	1		Upper Tinkers Creek	-81.368907	41.250834
WCW02352-2220	2220			John	1	N	1	not part of 2036, 2348	Upper Cuyahoga River	-81.098623	41.476971
WCW02352-2221	2221			S4	0	Y	0	development	Congress Lake Region	-81.328904	41.019890
WCW02352-2222	2222			G3	1	N	1		Cuyahoga County	-81.617793	41.380489
WCW02352-2223	2223			K3	0	na	0	island	Greater Akron -Mogadore Res Region	-81.513541	41.123302
WCW02352-2224	2224				3		3		Upper Cuyahoga River	-81.164378	41.457682
WCW02352-2225	2225			K2-CC	1	N	1		Greater Akron -Mogadore Res Region	-81.346343	41.053595
WCW02352-2226	2226			K1L+CS	0	na	0	upland	Lower Upper Cuyahoga (Portage Co.)	-81.177825	41.323141
WCW02352-2227	2227			K1+P	1	Y	1		Greater Akron -Mogadore Res Region	-81.387994	41.183028
WCW02352-2228	2228			K3+L	1	N	1		Middle Upper Cuyahoga River	-81.261537	41.383794
WCW02352-2229	2229			K1+P&J	1	N	1		Upper Tinkers Creek	-81.396257	41.287716
WCW02352-2230	2230			JMMM	1	N	1		Middle Upper Cuyahoga River	-81.145769	41.443049
WCW02352-2231	2231			G3+J	1	N	1		Greater Akron -Mogadore Res Region	-81.416082	41.123529
WCW02352-2232	2232			L+Sam	1	N	1		Upper Cuyahoga River	-81.172105	41.545448
WCW02352-2233	2233			S4	3		3		Congress Lake Region	-81.263495	41.004370
WCW02352-2234	2234			K1-L&E	0	N	0	development	Streetsboro - L Rockwell Region	-81.374417	41.177751
WCW02352-2235	2235	2141	2245	K3	2	N	2	part of 2141, 2245	Upper Tinkers Creek	-81.381836	41.272786
WCW02352-2236	2236			L+Sam	1	Y	1		Upper Cuyahoga River	-81.149221	41.498163
WCW02352-2237	2237	2133		K2-CC	2	N	2	dup with 2133	Greater Akron -Mogadore Res Region	-81.329627	41.090123
WCW02352-2238	2238			K2	1	Y	1		Cuyahoga Valley Region	-81.605380	41.308473
WCW02352-2239	2239			S4	1	N	1		Hudson Swamp - Brandwine Cr Swamp	-81.480050	41.184220
WCW02352-2240	2240			G3	1	N	1		Middle Upper Cuyahoga River	-81.207755	41.455858
WCW02352-2241	2241	2257	2397	G3	1	N	1		Breakneck Cr Region	-81.289032	41.089418
WCW02352-2242	2242	2074	2138	K1-ECS	2	N	2		Lower Upper Cuyahoga (Portage Co.)	-81.228228	41.253671
WCW02352-2243	2243			K1	1	N	1		Streetsboro - L Rockwell Region	-81.362348	41.211073
WCW02352-2244	2244				3		3		Middle Upper Cuyahoga River	-81.240446	41.424446
WCW02352-2246	2245	2141	2235	K3	2	Y	2	part of 2141, 2235	Upper Tinkers Creek	-81.385137	41.284217
WCW02352-2245	2246				6		6				
WCW02352-2247	2247			S4	1	N	1		Hudson Swamp - Brandwine Cr Swamp	-81.505844	41.289552
WCW02352-2248	2248			K1+E	1	N	1		Upper Cuyahoga River	-81.162782	41.571013
WCW02352-2249	2249			K2-CC	1	N	1		Breakneck Cr Region	-81.235635	41.106624
WCW02352-2250	2250			G3	1	N	1		Breakneck Cr Region	-81.273956	41.155334
WCW02352-2251	2251			K2-L	1	N	1		Lower Upper Cuyahoga (Portage Co.)	-81.290982	41.200989
WCW02352-2252	2252			K1-LECS	0	na	0	developed	Upper Tinkers Creek	-81.371414	41.319665
WCW02352-2253	2253				6		6				
WCW02352-2254	2254			K2	1	N	1		Cuyahoga Valley Region	-81.563248	41.332632
WCW02352-2255	2255			K2 (C+C)	1	N	1		Cuyahoga Valley Region	-81.549268	41.276718
WCW02352-2256	2256			JMMM	1	N	1		\	-81.177734	41.426233
WCW02352-2257	2257	2241	2397	G3	2	N	2		Breakneck Cr Region	-81.299433	41.074989
WCW02352-2258	2258	2090	2386	K1-ECS	2	Y	2		Lower Upper Cuyahoga (Portage Co.)	-81.252459	41.183844

APPENDIX D
SITE LIST

SITE_ID	Site	Same as1	Same as2	Group	type	Modified**	Fate***	If not Wetland	Area name	LONG_DDN83	LAT_DDN83
WCW02352-2259	2259			K1-ECS	3		3		Streetsboro - L Rockwell Region	-81.367902	41.190821
WCW02352-2260	2260	2092		K1-L+CS	2	N	2	same as 2092	Lower Upper Cuyahoga (Portage Co.)	-81.190050	41.348872
WCW02352-2261	2261			K3	1	N	1		Upper Tinkers Creek	-81.396416	41.311752
WCW02352-2262	2262			JMMM	1	N	1		Middle Upper Cuyahoga River	-81.163098	41.412896
WCW02352-2263	2263	2095		G3	2	N	2		Streetsboro - L Rockwell Region	-81.366764	41.127155
WCW02352-2264	2264			K1+E	1	N	1		Upper Cuyahoga River	-81.141464	41.593036
WCW02352-2265	2265				3		3		Congress Lake Region	-81.256805	41.038434
WCW02352-2266	2266			G3	1	N	1		Breakneck Cr Region	-81.315730	41.142214
WCW02352-2267	2267			S4	1	N	1		Upper Tinkers Creek	-81.431810	41.264012
WCW02352-2268	2268			John	1	N	1		Upper Cuyahoga River	-81.103718	41.494527
WCW02352-2269	2269			G3	1	N	1		Greater Akron -Mogadore Res Region	-81.320229	41.104314
WCW02352-2270	2270			G3	1	N	1	NOT A DUP, no other points nearby	Cuyahoga County	-81.696122	41.345388
WCW02352-2271	2271			K2 (CC)	0	N	0	house	Hudson Swamp - Brandwine Cr Swamp	-81.477433	41.226465
WCW02352-2272	2272			G3-HS	3		3		Upper Cuyahoga River	-81.199078	41.501019
WCW02352-2273	2273				3		3		Breakneck Cr Region	-81.261398	41.129066
WCW02352-2274	2274			K1-LE	0	N	0	fallow field	Lower Upper Cuyahoga (Portage Co.)	-81.243145	41.318525
WCW02352-2275	2275			K1	1	Y	1		Streetsboro - L Rockwell Region	-81.316253	41.201838
WCW02352-2276	2276	2340		K1-LE	1	N	1	includes 2340	Lower Upper Cuyahoga (Portage Co.)	-81.239343	41.335901
WCW02352-2277	2277			K3	0	na	0	near canal downtown	Greater Akron -Mogadore Res Region	-81.517914	41.088244
WCW02352-2278	2278			K2(-CS)	0	N	0	farm field	Cuyahoga Valley Region	-81.583620	41.328422
WCW02352-2279	2279			S4	1	Y	1		Cuyahoga Valley Region	-81.576638	41.220546
WCW02352-2280	2280			K3+L	1	N	1		Middle Upper Cuyahoga River	-81.249931	41.426860
WCW02352-2281	2281			S4	1	Y	1		Congress Lake Region	-81.303891	40.977420
WCW02352-2282	2282			G3	1	N	1		Middle Upper Cuyahoga River	-81.314039	41.114421
WCW02352-2283	2283			Rogers	1	Y	1	need boat	Lower Upper Cuyahoga (Portage Co.)	-81.304245	41.214037
WCW02352-2284	2284			K1-LE	1	N	1		Lower Upper Cuyahoga (Portage Co.)	-81.283525	41.329575
WCW02352-2285	2285			K2	1	N	1		Cuyahoga Valley Region	-81.621188	41.208979
WCW02352-2286	2286			G3	1	N	1		Cuyahoga County	-81.660677	41.434420
WCW02352-2287	2287			K2	1	Y	1		Cuyahoga Valley Region	-81.602563	41.157103
WCW02352-2288	2288			K3+L	1	N	1		Middle Upper Cuyahoga River	-81.244508	41.435229
WCW02352-2289	2289			S4	1	N	1		Breakneck Cr Region	-81.273087	41.064357
WCW02352-2290	2290			JMMM	0	na	0	mature mesic forest	Middle Upper Cuyahoga River	-81.156161	41.362610
WCW02352-2291	2291			K2	1	N	1		Streetsboro - L Rockwell Region	-81.392264	41.190864
WCW02352-2292	2292			JMMM	1	N	1		Lower Upper Cuyahoga (Portage Co.)	-81.167177	41.348894
WCW02352-2293	2293			K3+L	1	N	1		Upper Tinkers Creek	-81.418099	41.292562
WCW02352-2294	2294			G3	1	N	1		Upper Cuyahoga River	-81.141480	41.460908
WCW02352-2295	2295			K2	1		1		Streetsboro - L Rockwell Region	-81.387137	41.110876
WCW02352-2296	2296			P+L	0	na	0	ditch	Upper Cuyahoga River	-81.165966	41.532529
WCW02352-2297	2297			S4	3		3		Congress Lake Region	-81.268643	41.020701
WCW02352-2298	2298			K1-L&E	1	N	1		Streetsboro - L Rockwell Region	-81.321917	41.174623
WCW02352-2299	2299			Rogers	1	Y	1		Upper Tinkers Creek	-81.375788	41.228675
WCW02352-2300	2300				3		3	no access	Upper Cuyahoga River	-81.129307	41.469993
WCW02352-2301	2301	2197		K2-CC	2	N	2	dup with 2197	Greater Akron -Mogadore Res Region	-81.368620	41.051592

APPENDIX D
SITE LIST

SITE_ID	Site	Same as1	Same as2	Group	type	Modified**	Fate***	If not Wetland	Area name	LONG_DDN83	LAT_DDN83
WCW02352-2302	2302			K2 (-CS)	0	na	0	stream	Cuyahoga Valley Region	-81.649546	41.328420
WCW02352-2303	2303			SF	0		4	photo	Hudson Swamp - Brandwine Cr Swamp	-81.474790	41.162559
WCW02352-2304	2304			G3	1	Y	1		Upper Cuyahoga River	-81.178843	41.464342
WCW02352-2305	2305			K2-CC	1	N	1		Greater Akron -Mogadore Res Region	-81.338069	41.047411
WCW02352-2306	2306			K2-CC	1	Y	1		Lower Upper Cuyahoga (Portage Co.)	-81.207422	41.297453
WCW02352-2307	2307			K2-L	0	na	0	developed	Streetsboro - L Rockwell Region	-81.357408	41.256744
WCW02352-2308	2308			K3+L	1	Y	1		Middle Upper Cuyahoga River	-81.235433	41.410146
WCW02352-2309	2309			K1-LECS	1	N	1		Upper Tinkers Creek	-81.379302	41.313023
WCW02352-2310	2310			G3	1	N	1		Upper Cuyahoga River	-81.146535	41.457615
WCW02352-2311	2311			G3	1	N	1		Greater Akron -Mogadore Res Region	-81.396624	41.071215
WCW02352-2312	2312			P+L	1	N	1		Upper Cuyahoga River	-81.162514	41.549662
WCW02352-2313	2313			G3	3	na	3		Breakneck Cr Region	-81.263251	41.079491
WCW02352-2314	2314			G3	1	N	1		Breakneck Cr Region	-81.289720	41.162529
WCW02352-2315	2315			K1-ECS	1	Y	1		Lower Upper Cuyahoga (Portage Co.)	-81.294164	41.255468
WCW02352-2316	2316			G3	1	N	1		Upper Tinkers Creek	-81.453642	41.350245
WCW02352-2317	2317				6		6				
WCW02352-2318	2318			S4	1	N	1		Hudson Swamp - Brandwine Cr Swamp	-81.526016	41.307724
WCW02352-2319	2319			S4	1	Y	1		Cuyahoga Valley Region	-81.513467	41.220370
WCW02352-2320	2320			G3	3	N	3	couldn't access, poison sumac	Middle Upper Cuyahoga River	-81.170480	41.446710
WCW02352-2321	2321			S4	1	Y	1		Congress Lake Region	-81.293729	41.023634
WCW02352-2322	2322			K2-L	0	na	0	developed	Lower Upper Cuyahoga (Portage Co.)	-81.268935	41.230991
WCW02352-2323	2323			S4	1	Y	1		Hudson Swamp - Brandwine Cr Swamp	-81.456764	41.220474
WCW02352-2324	2324			JMMM	1	N	1		Middle Upper Cuyahoga River	-81.161607	41.393931
WCW02352-2325	2325			K1-LECS	1	N	1		Upper Tinkers Creek	-81.395369	41.328844
WCW02352-2326	2326			JMMM	1	N	1		Middle Upper Cuyahoga River	-81.153265	41.422291
WCW02352-2327	2327			K2	1	N	1		Breakneck Cr Region	-81.329596	41.127603
WCW02352-2328	2328			K1	1	N	1		Upper Cuyahoga River	-81.126790	41.576942
WCW02352-2329	2329			S4	3		3		Congress Lake Region	-81.262228	41.021338
WCW02352-2330	2330			K1	1	Y	1		Breakneck Cr Region	-81.326070	41.159608
WCW02352-2331	2331			S4	3		3		Hudson Swamp - Brandwine Cr Swamp	-81.500718	41.278493
WCW02352-2332	2332			John	3		3		Upper Cuyahoga River	-81.076006	41.544465
WCW02352-2333	2333			K2-CC	0	na	0	blackberry bramble	Greater Akron -Mogadore Res Region	-81.339860	41.076347
WCW02352-2334	2334			SF	0		4	photo	Cuyahoga County	-81.702436	41.458387
WCW02352-2335	2335	2007	2119	S4	3		3	denied John	Hudson Swamp - Brandwine Cr Swamp	-81.483327	41.236784
WCW02352-2336	2336			K3CB	0	na	4	photo	Middle Upper Cuyahoga River	-81.213684	41.360962
WCW02352-2337	2337			G3	1	N	1		Breakneck Cr Region	-81.236856	41.114131
WCW02352-2338	2338			K1-LE	1	N	1		Lower Upper Cuyahoga (Portage Co.)	-81.249465	41.320647
WCW02352-2339	2339			K1	3		3		Streetsboro - L Rockwell Region	-81.328815	41.222564
WCW02352-2340	2340	2276		K1-LE	2	N	2		Lower Upper Cuyahoga (Portage Co.)	-81.234494	41.331659
WCW02352-2341	2341	2117		K3	2	N	2		Greater Akron -Mogadore Res Region	-81.405276	41.011131
WCW02352-2342	2342			K2	1	N	1		Cuyahoga Valley Region	-81.602246	41.322314
WCW02352-2343	2343			S4	1	N	1		Cuyahoga Valley Region	-81.585032	41.231768
WCW02352-2344	2344			K3+L	1	Y	1		Middle Upper Cuyahoga River	-81.265588	41.402096

APPENDIX D
SITE LIST

SITE_ID	Site	Same as1	Same as2	Group	type	Modified**	Fate***	If not Wetland	Area name	LONG_DDN83	LAT_DDN83
WCW02352-2345	2345			S4	1	Y	1		Congress Lake Region	-81.337898	40.971679
WCW02352-2346	2346			K1	1	Y	1		Streetsboro - L Rockwell Region	-81.320273	41.185784
WCW02352-2347	2347			K2-L	1	N	1		Upper Tinkers Creek	-81.377051	41.238983
WCW02352-2348	2348	2036		John	2	N	2	part of 2036	Upper Cuyahoga River	-81.107439	41.474814
WCW02352-2349	2349			K2	1	N	1		Cuyahoga Valley Region	-81.626702	41.204217
WCW02352-2350	2350			G3	1	N	1		Cuyahoga County	-81.609036	41.371632
WCW02352-2351	2351			K2 -CC	1	Y	1		Greater Akron -Mogadore Res Region	-81.523729	41.144525
WCW02352-2352	2352			K3CB	1	Y	1		Middle Upper Cuyahoga River	-81.232092	41.440682
WCW02352-2353	2353			S4	1	Y	1		Breakneck Cr Region	-81.284107	41.056494
WCW02352-2354	2354			K1-LE	1	Y	1		Lower Upper Cuyahoga (Portage Co.)	-81.195631	41.326701
WCW02352-2355	2355			K1	1	N	1		Hudson Swamp - Brandwine Cr Swamp	-81.408428	41.216690
WCW02352-2356	2356			John	1	N	1	2028, 2108, 2356 all sep assess units jjm	Middle Upper Cuyahoga River	-81.184734	41.415755
WCW02352-2357	2357				3		3		Upper Tinkers Creek	-81.434271	41.301128
WCW02352-2358	2358			K3	0	na	0		Upper Cuyahoga River	-81.109827	41.444903
WCW02352-2359	2359			K3	0	na	0	residential pond	Greater Akron -Mogadore Res Region	-81.456359	41.119398
WCW02352-2360	2360	2032		K1	2	N	2		Upper Cuyahoga River	-81.174901	41.528192
WCW02352-2361	2361	2085		K2	2	N	2		Cuyahoga Valley Region	-81.278196	40.984437
WCW02352-2362	2362			K1+P	1	N	1		Streetsboro - L Rockwell Region	-81.339395	41.183751
WCW02352-2363	2363			K2-L	1	Y	1		Upper Tinkers Creek	-81.389602	41.261476
WCW02352-2364	2364			John	1	N	1	separate point, not part of 2036, 2348	Upper Cuyahoga River	-81.095583	41.482897
WCW02352-2365	2365			K2-CC	0	N	0	upland lake	Greater Akron -Mogadore Res Region	-81.368335	41.062261
WCW02352-2366	2366			S4	0	na	0	no wetland vegetation	Cuyahoga Valley Region	-81.621517	41.320041
WCW02352-2367	2367			K1-EL	1	Y	1		Hudson Swamp - Brandwine Cr Swamp	-81.430797	41.188675
WCW02352-2368	2368			G3	0	N	0		Middle Upper Cuyahoga River	-81.198662	41.476092
WCW02352-2369	2369			G3	1	N	1		Breakneck Cr Region	-81.282880	41.107019
WCW02352-2370	2370			K1-ECS	1	Y	1		Lower Upper Cuyahoga (Portage Co.)	-81.238504	41.242026
WCW02352-2371	2371			K1-LECS	1	N	1		Upper Tinkers Creek	-81.371264	41.277739
POINTS AFTER 2371 WERE STRANDED OR NOT ASSESSED											
WCW02352-2372	2372				7		7		Middle Upper Cuyahoga River	-81.239729	41.410857
WCW02352-2373	2373	2109		K1+P&J	2	N	8		Upper Tinkers Creek	-81.389719	41.291057
WCW02352-2374	2374				7		7		Upper Cuyahoga River	-81.109436	41.445185
WCW02352-2375	2375			K3	8	na	8	upland forest	Greater Akron -Mogadore Res Region	-81.457800	41.078089
WCW02352-2376	2376				7		7		Upper Cuyahoga River	-81.163625	41.554116
WCW02352-2377	2377				7		7				
WCW02352-2378	2378			K1-EL	8	N	8		Streetsboro - L Rockwell Region	-81.277693	41.173184
WCW02352-2379	2379			K1-ECS	8	na	8	camp ground	Streetsboro - L Rockwell Region	-81.307007	41.258190
WCW02352-2380	2380			K1-LECS	8	Y	8		Cuyahoga County	-81.439081	41.366090
WCW02352-2381	2381	2085		K2	2	N	8		Cuyahoga Valley Region	-81.678594	41.130137
WCW02352-2382	2382			K1-LECS	8	na	8		Hudson Swamp - Brandwine Cr Swamp	-81.491146	41.315620
WCW02352-2383	2383			S4	8	N	8		Cuyahoga Valley Region	-81.574844	41.292937
WCW02352-2384	2384				7		7		Middle Upper Cuyahoga River	-81.198962	41.432375
WCW02352-2385	2385			S4	8	N	8		Congress Lake Region	-81.298502	41.024205
WCW02352-2386	2386	2090	2258	K1-ECS	2	N	8		Streetsboro - L Rockwell Region	-81.260247	41.182316

APPENDIX D
SITE LIST

SITE_ID	Site	Same as1	Same as2	Group	type	Modified**	Fate***	If not Wetland	Area name	LONG_DDN83	LAT_DDN83
WCW02352-2387	2387	2059		G3+J	2	N	8		Greater Akron -Mogadore Res Region	-81.451427	41.150583
WCW02352-2388	2388				7		7		Middle Upper Cuyahoga River	-81.156705	41.381688
WCW02352-2389	2389	2061		K1-LE	8	N	8		Upper Tinkers Creek	-81.433153	41.315858
WCW02352-2390	2390				7		7		Middle Upper Cuyahoga River	-81.162897	41.408012
WCW02352-2391	2391			K2	8	N	8		Breakneck Cr Region	-81.339733	41.128197
WCW02352-2392	2392				7		7		Upper Cuyahoga River	-81.086051	41.585870
WCW02352-2393	2393			S4	8	Y	8		Congress Lake Region	-81.224747	41.041203
WCW02352-2394	2394			K1+P	8	na	8		Streetsboro - L Rockwell Region	-81.366605	41.163957
WCW02352-2395	2395				3		7	major holder says no	Upper Tinkers Creek	-81.422891	41.258016
WCW02352-2396	2396	2068			7		7		Upper Cuyahoga River	-81.081865	41.486829
WCW02352-2397	2397	2241	2257	G3	2	N	8		Breakneck Cr Region	-81.301586	41.084881
WCW02352-2398	2398			John	8	N	8		Cuyahoga Valley Region	-81.625237	41.268588
WCW02352-2399	2399				7		7		Hudson Swamp - Brandwine Cr Swamp	-81.473101	41.206572
WCW02352-2400	2400				7		7		Upper Cuyahoga River	-81.171908	41.512115
		41	13								
		17%	5%								
Counts	Number	Percentage									
0	51	12.8%	No wetland found								
1	217	54.3%	Wetlands as								
2	18	4.5%	Duplicate point								
3	45	11.3%	Access denied								
4	9	2.3%	No wetland based on photo								
5	26	12.0%	Level 3 assessment also completed								
6	5		Points located outside of Cuyahoga Watershed and Deleted								
7	12		Points not assessed in first 400								
8	17		stranded assessed points								
Total sites	400	100.0%									
Count											
0+4	60	15.0%	No wetland found (16%)								
1+5	243	60.8%	Wetlands assessed (level 2 + level 3; 66%)								
3	45	11.3%	Access denied (12%)								
2	18	5%	Duplicate point								
	37	10.1%	No Wetland Found - Map error								
	15	4.1%	No Wetland Found - Undetermined								
	8	2.2%	No Wetland Found - Filled/Converted								
	45	12.3%	Access Denied								
	18	4.9%	Duplicate Point								
	243	66.4%	Wetlands Assessed								
	366										