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Natural Resource Stewardship and Science

# Wetland Monitoring Protocol for Cuyahoga Valley National Park

*Narrative*

Natural Resource Report NPS/HTLN/NRR—2016/1336

**ON THIS PAGE**
Mud is an occupational hazard when monitoring wetlands. Photo by Doug Marcum.

**ON THE COVER**
Wetland monitoring in Cuyahoga Valley National Park. Tapes delineate 10-m x 10-m modules within a larger sampling array. Photo by Sonia Bingham.

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# Executive Summary

**Photo 1.** Volunteers assist with wetland monitoring in Cuyahoga Valley National Park. This protocol requires robust involvement of citizen scientists. Photo by Sonia Bingham.

Cuyahoga Valley National Park includes nearly 2,000 wetlands within its legislative boundary. These wetlands consist of three dominant types: 1) riverine wetlands located adjacent to river and stream courses, 2) headwater and slope wetlands where groundwater first emerges to the surface, and 3) depressional wetlands where the topography supports the accumulation of water from various sources. These wetlands provide important habitats and ecological services within the park. Because of their sensitivity to surrounding land use, we have chosen to monitor wetlands as part of the National Park Service's vital signs monitoring program.

To monitor wetlands, we will use standard protocols that have been developed by the Ohio Environmental Protection Agency. The methods include options for *rapid assessment* and *intensive assessment*. We will rapidly assess 250 wetlands throughout the park. We will also intensively assess 60 wetlands. These wetlands are located in watersheds that show varying relative levels of human disturbance (i.e., low, medium, and high). We hope that allocating our sample in this way will allow us to understand how changes in wetlands may result from surrounding land uses. Finally, using the intensive methods, we will sample eight wetlands of management concern and eight reference sites. Wetlands of management concern are important to the park for explicit management reasons, while reference wetlands reflect our perceptions of a very high quality, undisturbed example of a wetland. In addition to vegetation monitoring, we will also measure changes in hydrology (especially water depth) and water quality within each wetland. These data will be managed using standard GIS and database programs.

Over time, the results of this work should provide an overview of the condition of wetlands within Cuyahoga Valley National Park. In addition, we should be able to assess negative or positive changes within these wetlands as measured by vegetation, hydrology, and water quality. These data will help the park explain to surrounding communities how the actions in the surrounding landscape affect wetland systems within parks. While these data may indeed help to detect and diagnose changes in these park resources, we urge park managers to act boldly to protect park wetlands even in the absence of data that immediately identify effects of degradation. Monitoring and management work best as a unified rather than isolated approach to natural resource stewardship.

# Acknowledgments

We would like to acknowledge the hard work and dedication of numerous biological technicians who have assisted in pilot testing and conducting much of the field work required to develop this protocol: Doug Marcum, Brandon Piper, Luke Biscan, Bethany Wallace, and Alex Harnocz. We also thank Kevin Skerl for managing early protocol development and for providing critical guidance at key decision points in protocol development. We thank Meg Plona and Lisa Petit for their work on the early protocol development and for their commitment to and encouragement for the project. The partnership between the network and park has endured because of their leadership.

# Acronyms

CEQ: Council on Environmental Quality
CSE: Council of Science Editors
CUVA: Cuyahoga Valley National Park
DEM: Digital Elevation Model
EPA: Environmental Protection Agency
ESA: Ecological Society of America
FEMA: Federal Emergency Management Agency
FOM: Field Operations Manual
GIS: Geographic Information System
GLWQA: Great Lakes water Quality Agreement
GPS: Global Positioning system
GRTS: Generalized Random Tessellation Stratified
HGM: Hydrogeomorphic Class
HTLN: Heartland Inventory and Monitoring Network
HUC: Hydrologic Unit Code
IJC: International Joint Commission
I&M: Inventory and Monitoring Program
km: kilometer
LaMP: Lake Erie Management Plan
LDI: Landscape Development Intensity Index
NCGICC: North Carolina Geographic Information Coordinating Council
NETN: Northeast Temperate Network
NLCD: National Landcover Dataset
NPS: National Park Service
NWCA: National Wetland Condition Assessment
NWI: National Wetland Inventory
OAC: Ohio Administrative Code
OEPA: Ohio EPA
ORAM: Ohio Rapid Assessment Method
PVC: Polyvinyl chloride
ROMN: Rocky Mountain Network
sej: solar emergy joules
SOP: Standard Operating Procedures
UCSA: Union of Concerned Scientists of America
USACE: United States Army Corps of Engineers
USEPA: United States Environmental Protection Agency
USGS: US Geological Survey
VIBI: Vegetation Index of Biotic Integrity
WOMC: Wetlands of Management Concern


**Photo 2.** Sonia Bingham and Doug Marcum following the final deployment of monitoring well in Cuyahoga Valley National Park. Photo by Sonia Bingham.

# Introduction

A basic premise of biological monitoring is that organisms integrate the effects of numerous environmental variables over time. As such, the abundance or physiological condition of organisms, population structure, or composition of biological communities may serve as indicators that provide more efficient and robust detection of environmental problems than examining variables in isolation. Taking such an approach to the measurement of “biological integrity” (Karr 1981) led us to monitor wetlands in Cuyahoga Valley National Park (CUVA) (Figure 1) following methods outlined by the Ohio Environmental Protection Agency (Mack 2001, Mack and Gara 2015). These methods are similar to those used for the National Wetland Condition Assessment (USEPA 2011).

### Wetlands in the U.S. and Ohio are a Vulnerable and Protected Natural Resource

In 1827, the Ohio and Erie Canal became the first major source of transportation connecting the cities of Cleveland, Akron, and Canton to Columbus and the Ohio River. The canal paralleled the Cuyahoga River between Akron and Cleveland and created opportunities for trading and manufacturing along the river banks. While the industrial and municipal settlement was welcomed, environmental degradation was a consequence. Unregulated dumping of wastes such as oil, paint, metals and raw sewage were pervasive pollution sources in the river and resulted in numerous fires on the Cuyahoga River as early as 1868 (Ohio History Central 2016). River fires continued for nearly a decade before catching the attention of *Time* magazine in 1969 when the Cuyahoga River was declared as one of the most polluted rivers in the U.S. This national attention raised the awareness of the general public and contributed to the passing of the 1972 Clean Water Act (Latson 2015).

Over half of global wetlands have been destroyed over the past two centuries (Fraser and Keddy 2000, 2005), and many of the remaining habitats have been degraded by pollution and invasion by exotic species (Dahl and Allord 1996, Dahl and Johnson 1991, Kentula 1996, Tiner 1984). While wetland loss in the conterminous United States is estimated at nearly 51% (from 89 million to 43 million ha or 220 to 107 million acres), wetland area within Ohio has diminished almost 90% (1.8 million to 195,000 ha or 4.4 million to 481,900 acres) (Dahl 2006, Mitsch and Gosselink 2000). Furthermore, most extant Ohio wetlands have undergone some degree of physical, chemical or other biological alterations as a result of extensive deforestation during settlement (CEQ 1989) and current agricultural (52%) and urban (14%) landuse (Ohio Legislative Service Commission 2006).

Many wetlands are water bodies of the United States (40 CFR 122.2, 40 CFR 230.3, and 40 CFR 232.2) and protected under the Clean Water Act [Section 502(7)]. In Ohio, Ohio EPA wetland assessment methods can be used to determine restrictions on the use or development of particular wetlands. These anti-degradation categories include 1) limited quality wetland habitats (*Category 1)*, 2) restorable wetland habitat (*Modified 2)*, 3) wetland habitat *(Category 2)*, and 4) superior wetland habitat (*Category 3*).

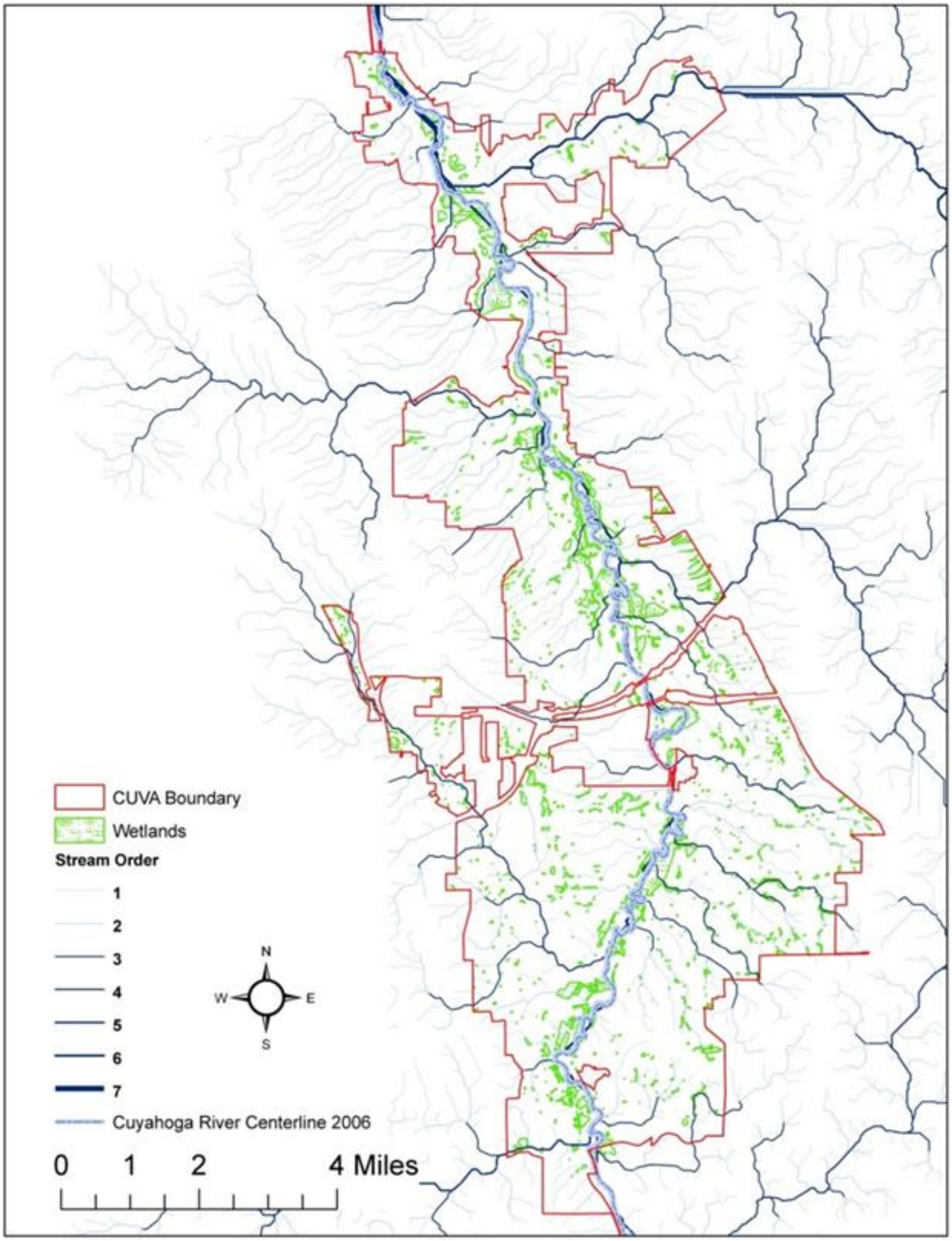



**Figure 1.** Distribution of wetlands throughout Cuyahoga Valley National Park (CUVA).

### Wetlands Support Biodiversity in Healthy Landscapes

Most wetlands (77.7%) in the 2,106 $km^2$ (813 $mi^2$) Cuyahoga River watershed are in good to excellent condition based on the Ohio Rapid Assessment Method (ORAM) for evaluating wetland integrity (Fennessy et al. 2007). The highest rates of degradation are documented in wetlands within the lower sub-basin of the Cuyahoga River, which includes CUVA. However, rapid assessments within CUVA boundaries to date indicate that 74% of the wetlands (n=595) and 89% of total wetland area within the park are still in good to excellent condition (Bingham, unpublished data). The protected landscape provides an important buffer for over 43 small watersheds that flow into the lower Cuyahoga River sub-basin. CUVA wetlands are an integral part of this landscape, as they intercept, retain, filter, and recharge surface and groundwater as it flows from the upper watersheds outside of the park, through the park and into its stream system. These wetlands are complex ecological systems that provide nursery, resting, feeding, and breeding grounds for numerous species of amphibians, birds, fish, and other wildlife. For example, CUVA wetlands are known to support at least 12 species of amphibians that spend a portion of their life cycle in water. The park supports populations of at least 4 partially aquatic mammals, including *Mustela vison* (American mink), *Castor canadensis* (beaver), *Ondatra zibethicus* (muskrat), and *Lontra Canadensis*, (Northern river otter), which was once extirpated from Ohio, have but have been reproducing in the Beaver Marsh since 2013. The Beaver Marsh, Fawn Pond, and several other important wetlands in the park are known breeding grounds for over 45 different bird species (Marcum and Bingham 2017). More recently in 2016, we documented a second occurrence of the state threatened, *Clemmys guttata* (spotted turtle) in the Beaver Marsh and nearby in an old canal wetland (Plona, unpublished). These species use a variety of wetland features such as dense vegetation, large woody debris (logs) deep water, hummock topography, and standing dead trees as their homes.

The variety of wetland types in CUVA respond differently to environmental stress based on their water source and position in the landscape (i.e., hydrogeomorphic class or HGM). Ecological communities are impacted from air and water-born pollutants, physical damage, changes in groundwater levels or increased flooding, etc. (Brown and Vivas 2004). Nutrients and toxins carried in the runoff will negatively affect surface water and groundwater and any wetlands dependent on these water sources in affected watersheds (i.e., Slope and Riverine Wetlands), which include the majority of our wetlands (Table 1). Modifications to the inflow and outflow of surface and groundwater within a watershed will also result in measureable changes to wetland systems over time since wetland plant communities are sensitive to water level and water quality changes (Mitsch and Gosselink 2000). We expect that land-use practices will influence wetland integrity as a whole within CUVA boundaries more than any other environmental variable. Consequently, we will quantify land-use change over time using a Landscape Development Intensity Index (LDI), which is a land use based index of potential human disturbance (Brown and Vivas 2005). The LDI integrates land use into a single quantitative score. Emergy coefficients developed for the State of Florida and landcover datasets (30 m pixels) from the National Landcover Database (NLCD) in mapping zone 47 are used to calculate the LDI score. The NLCD data are available from the Multi-Resolution Land Characteristics Consortium website (MRLC 2016). New datasets will be available approximately every five years.

**Table 1**. Wetland number and area distribution among the five major Hydrogeomorphic (HGM) classes at CUVA.

| HGM | # Wetlands | % Wetlands | Area (acre / hectare) | % Wetland Area |
|---|---|---|---|---|
| DP | 402 | 25.28% | 259.61 / 105.06 | 13.26% |
| SP | 765 | 48.11% | 794.75 / 321.62 | 40.59% |
| RM | 174 | 10.94% | 611.97 / 247.66 | 31.26% |
| RH | 233 | 14.65% | 220.13 / 89.08 | 11.24% |
| IMP | 16 | 1.01% | 71.40 / 28.89 | 3.65% |
| Total | 1590 | 100.00% | 1957.86 / 792.32 | 100.00% |

Previous studies have shown how land use varies along the Cuyahoga River. Suburban development reduced forest and agricultural lands by nearly 25% in park subwatersheds between 1959 and 2002 (aerial photos 1959 and 2000/2002) (Skerl, unpublished). Fortunately, forested land increased within the park boundaries as agricultural fields reverted to forest. Changes in land-use were minimal between 2001 and 2011 in park watersheds (Bingham, unpublished), according to the LDI.

### Wetlands Support Water Quality and Reduce Flooding Even in Degraded Landscapes

In addition to supporting biodiversity, wetlands function as “nature’s kidneys” because of their capacity to improve water quality, especially in degraded landscapes (Dahl 2006, Carter 1996, Mitsch and Gosselink 2000). Wetlands are capable of trapping and transforming heavy sediments, nutrients, trace metals, and organic materials that are transported in surface and ground water (Carter 1996), which reduces agricultural and municipal pollution and the need for costly technological solutions (USEPA 1993a). Wetlands also assist in the retention of surface water. In densely populated watersheds, impervious surfaces create unusually high peak flows during storm events. These flows result in stream channel re-adjustments, severe erosion in some areas, heavy sediment deposition in others, extensive flooding, and aquatic habitat degradation. Wetlands provide storage to reduce the impact from peak flows. While wetlands can be resilient to small changes, cumulative impacts over time may permanently reduce the capacity of wetlands to provide these important ecosystem services (Brinson 1988). The “filtering” role of wetlands is prevalent in many areas of the park, particularly within the Cuyahoga River floodplain, where industry and urbanization were once prevalent or continue to persist.

In 1972, the United States and Canada, through the International Joint Commission, established a Great Lakes Water Quality Agreement to identify pollution sources from both countries and to recommend remedial actions (IJC 2005). In a 1987 protocol amendment, the Cuyahoga River was designated as one of twenty-six areas of concern within the U.S that flow into the Great Lakes. The designation was given to the most severely degraded watersheds that failed to meet the objectives of the agreement (GLWQA 1987). Lake Erie was the first of the Great Lakes to experience major eutrophication problems, mostly from elevated nutrient levels (mainly phosphorus) that led to over-production of algae and oxygen deprivation (Environment Canada and USEPA 2000). While phosphorus reduction has been a major goal since then, a Total Maximum Daily Load report for the

Cuyahoga River watershed also lists organic enrichment, bacteria, and toxicity from industrial and municipal point sources as primary sources of impairment to the river and many of its tributaries (OEPA 2003), and ultimately, Lake Erie. Riverine wetlands are particularly important in offsetting these impacts, as their pulsing hydroperiod results in high rates of biomass production and decomposition, which increases nutrient cycling and can help to process pollutants quickly (Mitsch and Gosselink 2000, USEPA 2001). The protection and restoration of natural landforms and systems such as wetlands that mitigate the impacts of urban, industrial and agricultural land use are the most significant actions that can be taken to restore the Lake Erie ecosystem (Environment Canada and USEPA 2008).

Riverine wetland restoration has been proposed in many Great Lakes watersheds as a viable solution to help combat eutrophication (Mitsch and Gosselink 2000). Within the Lower Cuyahoga River sub-basin, CUVA includes some of the largest expanses of natural floodplain and protected riparian corridors (Holmes and Goebel 2008). These floodplains provide substantial flood storage and are likely one of the most important regional nutrient and sediment sinks in the lower sub-basin of the Cuyahoga River. CUVA protects over 247.7 hectares (612.0 acres) of wetlands within the Cuyahoga River floodplain. A 6-inch rise in water over a 10-acre wetland places more than 1.5 million gallons of water in storage (Niering 1966, Goodwin and Niering 1975). CUVA is regarded regionally as a protected green corridor, but the benefits of its wetland resources are not fully understood.

### Monitoring Data Improves Decision-making and Builds Consensus for Protection

Wetland systems take time to understand. Hydrology is a fundamental driver in wetland communities, but can be difficult to study since water is often only present below ground and can change annually due to climate variation. The Sentinel Sites, including wetlands of management concern, were included in monitoring for the distinct purpose of diagnosing problems that may require management action. At these sites, management issues such high visitation, flooding, protection of rare plants and animals, and restoration of disturbed sites, require more attention and are monitored more closely, to make quicker decisions when needed.

Vegetation and water level monitoring data at intensively studied sites can be combined to develop plants species lists for targeted hydrologic regimes at restoration sites, leading to more successful projects. In wetlands with rare plant populations, monitoring data can be used to direct or prioritize EPMT efforts, if desired. Similarly, information learned from monitoring highly visited sites such as the Beaver Marsh can be used to assist with proper interpretation of our natural resources to the public through the Interpretation Education and Visitor Services division and help lead higher quality educational programs.

CUVA protects many cultural resources and historic infrastructure that often requires work in or near wetlands for maintenance. Working in or near wetlands with heavy equipment is especially difficult and can be very problematic in surface water systems that have sensitive aquatic communities. Insights gained from this effort can bring awareness to park staff and help divisions work together to develop solutions and SOP's for anticipated work such as invasive species removal, dam decommissioning, debris removal from flooding, etc. Larger scale planning efforts also benefit from awareness of the park's wetland systems. Locations for proposed parking lots and trails are modified based on the spatial distribution and condition of wetlands in the park. We also expect that these data may be used to build consensus when working with stakeholders including consensus among co-workers, administrators, regulating agencies, and the public. For example, trends resulting from Survey Sites data may lead to scientific insights that link to wetland condition to watershed stress, which could lead to more specific research or lead to agreement on projects such as stream and wetland restoration projects.

## Wetland Types in Cuyahoga Valley National Park

CUVA is situated within the Erie Gorges subregion of the Erie-Ontario Drift and Lake Plains ecoregion (Figure 2). The Erie Gorges are a transition zone between the Central Lowland plains to the west and the mountainous terrain of the Appalachian Plateau to the east (Woods et al. 1998). Steep slopes, rocky outcrops and high erosion rates characterize the plateau. CUVA protects a complex of fluvial landforms within this ecoregion, including a 35 km (22 mile) corridor of the Cuyahoga River, its floodplain, and adjacent ravines that contain over 300 km (186 miles) of perennial tributaries.

Topographic and hydrologic characteristics partition the park's wetlands into four major hydrogeomorphic (HGM) classes (i.e., Riverine, Slope, Depressional, and Lacustrine Fringe) (Table 1) which are defined by three fundamental factors: geomorphic setting, water source, and hydrodynamics (Brinson 1993, Smith et al. 1995) (Figure 3). These factors influence wetland vegetation and function since the quality and quantity of incoming water influences the biogeochemical properties of soil and water, and the location within the watershed will affect the extent to which the wetland transforms the water moving through it (Smith et al. 1995). Wetlands within each HGM class tend to have similar biological communities that respond similarly to disturbances (Fennessy et al. 2007, USEPA 2002f).

### *Riverine Mainstem Wetlands*

Riverine mainstem wetlands cover 245.4 ha (606.3 acres) or 31% of the total wetland area, while only accounting for 11.3% of the number of wetlands (average size=1.5 ha/3.7 ac). Generally confined to lower elevations in the park, overbank flow from larger 4$^{th}$ order streams (Sagamore Creek, and Furnace Run below Rock Creek) and greater (5th order: Brandywine Creek, Chippewa Creek, and Yellow Creek; 6$^{th}$ order: Tinker's Creek, 7$^{th}$ order: Cuyahoga River) dominates the hydrological regime of these wetlands for much of the year. This classification is different from Mack (2004), who also included wetlands along all 3$^{rd}$ order and 4$^{th}$ order streams. In CUVA, stream orders of 4 and less within CUVA generally have smaller drainage areas (between 2-3 square miles) as a result of the park's steep gradients and numerous ephemeral stream channels. Streams with drainages less than 25.9 km$^2$ (10 mi$^2$) are still classified as headwaters by the OEPA Division of Surface Water (1989). For this reason, we reserved the mainstem designation for the largest tributaries in the park.

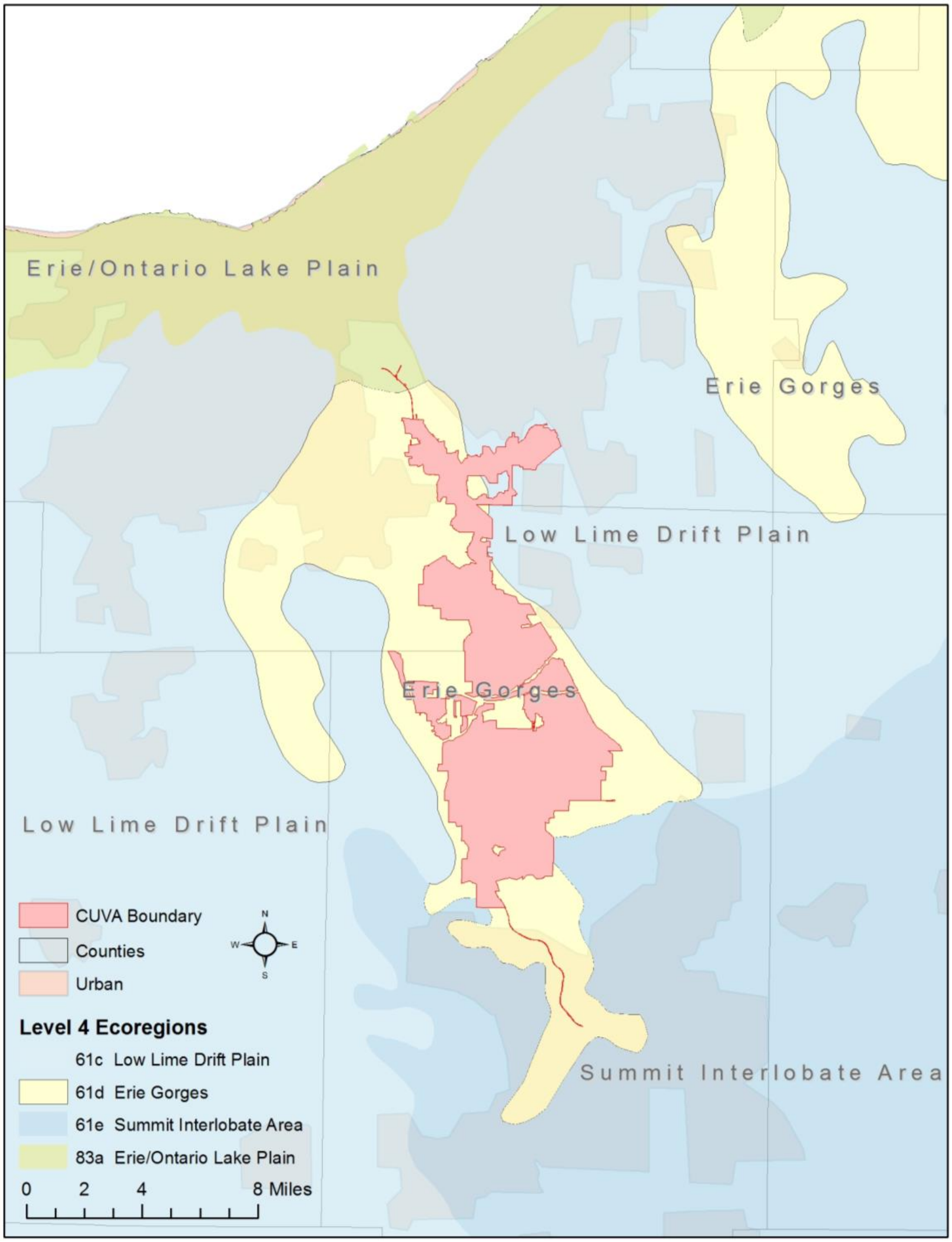



**Figure 2.** Cuyahoga Valley National Park (CUVA) is situated within the Erie Gorges ecoregion (Woods et al. 1998).

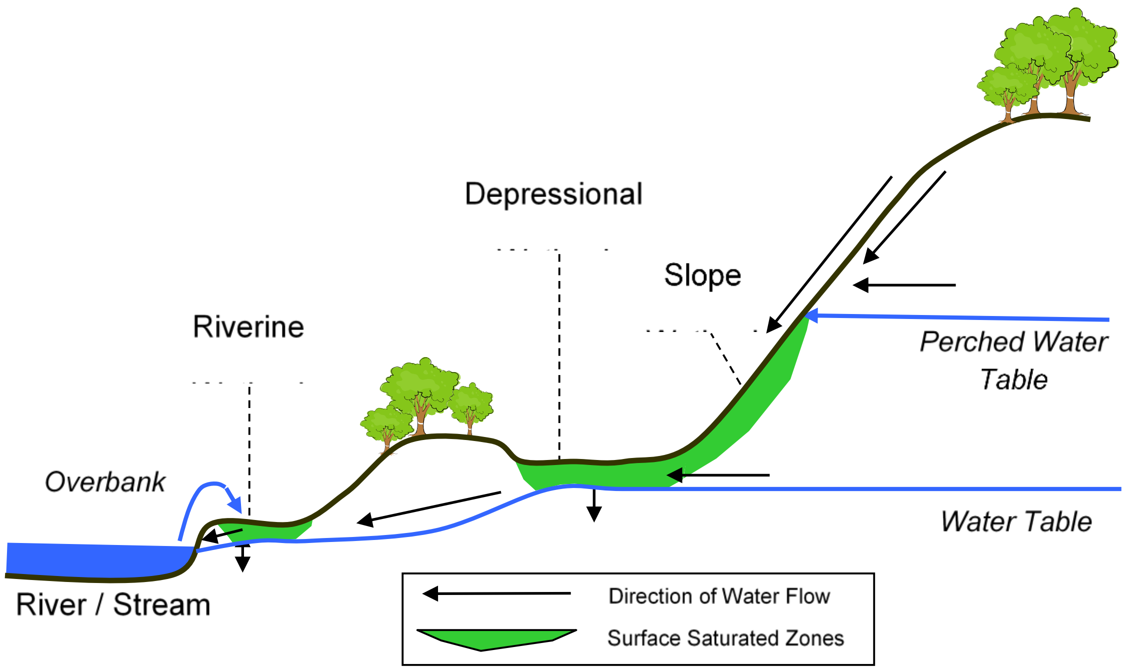



**Figure 3.** Cross-sectional view of dominant wetland hydrogeomorphic classes (depressional, riverine, slope) in Cuyahoga Valley National Park.

River discharge records from USGS gauging stations located upstream (Old Portage: 04206000) and downstream (Independence: 04208000) of the park indicate that the Cuyahoga River floods 0-2 times during most years for an average duration of 1 or 2 days, but can be much longer (Figure 4). In addition to these "flood pulses", many wetlands in the Cuyahoga River floodplain are seasonally flooded from tributaries and groundwater seeps at the base of the valley walls. This is a switch from the overbank flow regime to a vertical hydrologic pathway (Figure 3). River reaches with natural bank levees may retain water from these pulses long enough to characterize large areas as wetlands (e.g., bottomland floodplain forests) (Mitch and Gosselink 2000). In other areas, the natural processes of sediment transport, erosion and deposition create sandy ridges, vernal pools, and oxbows that are common CUVA wetland landforms. Beavers (*Castor canadensis*) are also responsible for water retention in several wetlands in the park, including Ira Road Beaver Marsh, Kendall Lake, Fawn Pond, and Vaughn Road (Figure 5).

Currently, most riverine forests in CUVA include silver maple (*Acer saccharinum*), red maple (*Acer rubrum*), box elder (*Acer negundo*), cottonwood (*Populus deltoides*), sycamore (*Platanus occidentalis*), and black willow (*Salix nigra*) as dominants in the canopy, and green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*), and Ohio buckeye (*Aesculus glabra*) as common understory dominants. The recent vegetation map using the National Vegetation Classification Standard (Hop et al. 2013), classified these communities as Midwestern cottonwood - Black willow Floodplain Forest (CEGL002018), and Silver maple - Elm Forest association (CEGL002586). This would also include gravelbar types, such as the very common Japanese Knotweed Temporarily Flooded Herbaceous Vegetation association (CEGL008472).

**Figure 4.** Typical bottomland hardwood forest during a flooded year in Fawn Pond, Cuyahoga Valley National Park.

**Figure 5.** Beaver dam affecting hydrological regime at Vaughn Road, Cuyahoga Valley National Park.

As open systems that allow lateral and longitudinal exchange of energy and materials, riverine wetlands are susceptible to landscape and watershed degradation (Mitsch and Gosselink 2000, Tickner et al. 2001). Water contaminated with nutrients, pesticides and/or metals, along with stormwater impacts such as erosion, sedimentation and altered flood regimes are common disturbances within CUVA (Stewart et al. 1998, URS Corporation 1986, Skerl and Plona 2007).

Invasive plant species also threaten the sensitive native plants and wildlife communities that depend on these habitats (Vorac 2003, Dengg 2004, Djuren and Young 2007). Two of the common plant species in riverine wetlands in CUVA, reed canarygrass (*Phalaris arundinacea*) and purple loosestrife (*Lythrum salicaria*), are known to have high ecological impact based on NatureServe I-rank subranks (Morse et al. 2004).

***Riverine Headwater Wetlands***

Riverine headwater wetlands maintain surface water connections to headwater streams, which in Cuyahoga Valley include 1st order – small $4^{th}$ order streams (i.e., headwaters; Figure 6). Many CUVA headwater streams are referred to with names: Adam Run, Boston Run, Brookside Creek, Columbia Run, CMA Creek, Dickerson Run, Langes Run, Ira Creek, Haskell/Ritchie Run, Oak Hill Creek, Peninsula Creek, Railroad Creek, Robinson Run, Sagamore Creek, Salt Run, Sand Run, Slipper Run, Spring Creek, Stanford Run, Stone Road Creek, Woodward Creek. Others are referred to as Unnamed Tributaries 1, 2, 3, 4, 5, 6, 7, 8, 9,10,11,12,13,14,15, 16 and RM 15.11.

**Figure 6.** Headwater slope wetland feeding a first order stream in Cuyahoga Valley National Park.

Riverine headwater wetlands that depend only on surface water may dry intermittently, while stable groundwater tables may ensure perennial water supply to others (Richardson and Daheny 2007). These differences in water source also affect the size and composition of riverine headwater wetlands (Hupp and Osterkamp 1996). Covering 95.6 ha (236.2 acres) in the park with an average size of 0.61 hectares (1.5 acres), steep ravines and slopes typically buffer these wetlands from development, although entrenchment from flashy storm water has led to gradual drying in some areas (Bingham, per obs.). The topographic position on alluvial benches results in wetlands that are narrow and long.

The dominant canopy species in riverine headwater wetlands include American elm, green ash, sugar maple (*Acer saccharum*), tulip tree (*Liriodendron tulipifera*), slippery elm (*Ulmus rubra*), sycamore, and yellow buckeye (Holmes and Goebel 2008). Spicebush (*Lindera benzoin*) and hawthorn species (*Craetegus* spp.) are common understory trees. Herbaceous understory plant composition is highly variable in these systems. Many flooded and swamp forest communities are classified in CUVA as Tuliptree - Elm species - Green Ash Forests (CEPS006684) (Hop et al. 2013).

### *Slope wetlands*

Slope wetlands, with an average size of 0.5 hectare (1.1 acre) in CUVA, are at the origin of and feed many 1$^{st}$ order streams in the park (Figure 6). They can also be found at mid-slope along steep ravines and are very common on low-gradient slopes at the base of the valley. In contrast to riverine headwater wetlands, wetlands within the slope HGM class are groundwater dependent and do not have an obvious surface water connection with a river or stream. In CUVA, groundwater often intersects the surface at topographic breaks and stratigraphic layers, such as the base of the valley walls and at impervious rock or soil layers (Figure 3). These groundwater seeps create the hydrology needed for wetlands to develop along slopes. More wetlands (49%) fall within the slope HGM class than any of the other major classes and altogether cover nearly 311.6 hectares (770 acres) of land within park boundaries. Slope wetlands vary in size and plant composition depending on whether they are recharged by stable volumes of groundwater or more influenced by local water tables and precipitation (Stein et al. 2004).

The bedrock geology can also influence the concentration of minerals in the groundwater, possibly leading to the formation of fens. The accumulation of peats characterizes fens, the influx of groundwater minerals and higher pH differentiates fens from other wetlands. Fens are groundwater dependent and fall within the slope HGM class.

Many species with high coefficients of conservatism (0= minimum; 10=maximum) show a high degree of fidelity to slope wetlands (Figure 7; Andreas 2004). These species include skunk cabbage (*Symplocarpus foetidus*,7), swamp thistle (*Cirsium muticum*,8), Queen of the prairie (*Filipendula rubra*, 8), American beak grass (*Diarrhena americana*, 7), various sedges such as the hairy fruited sedge (*Carex trichocarpa*, 8) and brome sedge (*Carex bromoides*, 7), and several less common understory shrubs such highbush blueberry (*Vaccinium corymbosum*, 6). Spicebush (*Lindera benzoin*), dogwoods (*Cornus* spp.) and viburnum (*Viburnum* spp.) are common native shrubs within slope wetlands in CUVA. Many wetlands within the slope HGM class are Skunk-cabbage Seepage

Meadows (CEGL002385) or have a mixed sedge community typical of the Lake Sedge Herbaceous Vegetation (CEGL002256) association (Hop et al. 2013).

**Figure 7.** Queen of the prairie (*Filipendula rubra*) found in a slope wetland in Cuyahoga Valley National Park.

#### *Depressional wetlands*

With an average size of 0.3 ha (0.69 acre), depressional wetlands are found throughout the Cuyahoga Valley landscape and account for about 13.5% of the wetland area. These wetlands form in topographic depressions and have a closed contour that allows water to accumulate (Smith et al. 1995). Isolated depressional wetlands often depend on a limited water supply, which limits the size of the wetland. As such, these wetlands are highly influenced by land-use changes that affect the quality and quantity of their surface water inputs. Depressional wetlands may form naturally in glacial depressions, but also and along floodplain terraces or in disturbed areas with poor drainage from broken drain tiles, settling after erosion, or from past construction activities. Hydrological regimes in these wetlands are often dominated by precipitation, surface water runoff, and evapotranspiration (Kirkman et al. 2000), although they can also be recharged by and discharge to groundwater. Smaller wetlands generally have less regulatory protection than larger wetlands, which leaves many depressional wetlands susceptible to draining or filling (Snodgrass et al. 2000, Kirkman et al. 2000). Mapped plant community associations that correspond with depressional wetlands in CUVA are numerous, including the higher quality Common Buttonbush / Sedge species Northern

Shrubland (CEGL002190) and lower quality Common Reed Eastern North American Temperate Semi-natural Herbaceous Vegetation associations (CEGL004141) (Hop et al. 2013).

Intermittently inundated depressional wetlands have conservation value as breeding habitat for many amphibian species. Since many depressional wetlands are isolated and seasonal in nature, amphibians are at the top of the food chain, rather than fish and reptiles which dominate more permanent pools (Miccachion 2004). Stable amphibian populations also require upland buffers within their terrestrial home range, which is generally a165 m radius around the wetland, but can be up to 1 km for some species (Semlitsch 1998).

For example, the spotted salamander (*Ambystoma maculatum*, coefficient of conservatism = 9) cannot survive in depressional wetlands that are close to roads and without forest buffers (Miccachion 2004). Within CUVA, we found egg masses of Ambystomid salamanders in very small (<0.10 acre) pools within large, intact forested tracts (pers. obs, Figure 8).

**Figure 8.** Egg mass of Ambystomid salamander found in small pool on an abandoned floodplain terrace.

***Lacustrine fringe wetlands***

Sixteen wetlands within CUVA are classified within the lacustrine fringe HGM class. These wetlands form along the edges of man-made ponds and impoundments where the water table is maintained primarily by the lake levels (Smith et al. 1995). At the headwaters of an impoundment, it is common for fringe wetlands to intergrade with slope and riverine headwater wetlands. Conditions become suitable for vegetation establishment along lake edges where light can penetrate into the sediment and the soil is occasionally exposed to oxygen (Smith et al. 1995). The vegetation in fringe wetlands is typically classified within the Cattail species Midwest Herbaceous Vegetation (CEGL002233) type (Hop et al. 2013).

Then water quality in lacustrine fringe wetlands is usually driven by surface water quality, although groundwater may contribute relatively unpolluted water. In Virginia Kendall Lake, river water and ground water are responsible for water level recharge (Figure 9). Fringe wetlands can have bidirectional flow (water flow direction changes as the impoundment is filling or draining) depending on the amount of incoming surface water. Multiple water sources create a variety of habitats and conditions for a wide range of plant and animal communities. Conversely, in the smaller man-made ponds in the park, water levels are controlled more by precipitation and evapotranspiration, usually resulting in less diverse habitats, higher water temperatures, tolerant plants with high biomass, and mid-summer algal blooms.

**Figure 9.** Lacustrine fringe wetlands at Virginia Kendall Lake, Cuyahoga Valley National Park.

# Methods

## Survey Design Decisions

Designing ecological surveys requires that we balance sampling objectives with respect to parameter variability and available effort. Like many complex decisions involving trade-offs, the final decision is usually worked out in an iterative rather than a linear manner. Below we outline several of the critical decisions that led to the final survey design for the wetland monitoring protocol.

Our first critical decision was to use two existing Ohio EPA wetland assessment protocols, which include: 1) the Ohio Rapid Assessment Method or ORAM, and 2) a protocol that intensively measures vegetation to calculate the Vegetation Index of Biotic Integrity or VIBI (Mack 2001, Mack and Gara 2015). We opted to use these wetland assessment protocols rather than develop indicators from scratch (see Fraser 2004). The primary advantage was that the early development work to test and calibrate these protocols was already complete. Secondly, as an Ohio-specific protocol, the methods used would match those of numerous other datasets in Ohio. Finally, the availability of rapid and intensive methods offered the opportunity to survey park wetlands extensively and intensively.

Next, we opted to include multiple HGM types in our sample rather than a single HGM type. To reduce the natural variability associated with different wetland types, we opted to rely on the use of type-specific VIBI scores to relativize wetland condition amongst HGM types (Mack and Gara 2015).

We also adopted the LDI as part of this protocol to quantify human disturbance across park watersheds (unit of influence) and use it as a basis for stratification to examine with wetland condition based on the theory that the condition of ecological communities within a landscape is strongly related to levels of human activity (Brown and Vivas 2005, Mack 2006). Landscape intensity values range from natural on the lower end of the scale to commercial on the opposite end of the scale. Both ends of this spectrum are represented in CUVA watersheds. Indices such as the ones we use in this protocol (ORAM and VIBI), have significant relationships with the LDI score, according to a large reference wetland dataset from Ohio (Mack 2006), particularly when analyses are completed within a 100-250 meter buffer of the wetland (Brown and Vivas 2005, Mack 2006, Fennessy 2007).

Our available sampling effort was a major limiting factor. The actual effort required over a five-year period is outlined in Table 2.

**Table 2.** Intensive survey work, including the Vegetation Index of Biotic Integrity (VIBI) and water level monitoring is completed at Sentinel Sites (Wetlands of Management Concern and Reference Sites) and Intensive Survey Sites. This table shows the number of sampling arrays (SAs) allocated among four annual rotating panels at these sites as well as the number of extensive survey sites, where the Ohio Rapid Assessment Method (ORAM) is completed.

| | **Wetland Location** | **# SAs** | **Panel 1** | **Panel 2** | **Panel 3** | **Panel 4** |
|---|---|---|---|---|---|---|
| Sentinel Site: Wetland of Management Concern | Pleasant Valley | 5+ | | 5+ | | |
| | Fawn Pond | 5 | | 5 | | |
| | Stumpy Basin | 3 | | 3 | | |
| | Kendall Lake | 3 | | 3 | | |
| | Beaver Marsh | 5 | | 5 | | |
| | Rockside Mitigation | + | | + | | |
| | Krejci Remediation | 2 | | 2 | | |
| | Stanford Rd | 4 | | 4 | | |
| Sentinel Site: Reference | Fitzwater Bridge | 1 | | 1+ | | |
| | Snowville Rd | 1 | | 1 | | |
| | Columbia Rd | 1 | | 1 | | |
| | Boston Mills Rd | 1 | | 1 | | |
| | Stumpy Basin | 1 | | 1 | | |
| | Kendall Lake | 1 | | 1 | | |
| | Langes Run | 1 | | 1 | | |
| | Bath Rd | 1 | | 1 | | |
| Survey Site: Intensive | Stanford Run Ws | 7 | | | 4 | 3 |
| | Railroad Creek Ws | 7 | | | 3 | 4 |
| | Ira Creek Ws | 4 | | | 3 | 1 |
| | 100-yr Floodplain | 7 | | | 4 | 3 |
| | CMA Creek Ws | 7 | | | 3 | 4 |
| | Chippewa Creek Ws | 7 | | | 3 | 4 |
| | Brandywine Creek Ws | 7 | | | 3 | 4 |
| | Tinker’s Creek Ws | 7 | | | 3 | 4 |
| | Unnamed 7 Ws | 3 | | | 1 | 2 |
| | Unnamed 15 Ws | 4 | | | 3 | 1 |
| Total Intensive Sites (VIBI) | | 95 | | 35 | 30 | 30 |
| Total Extensive Sites (ORAM) | | 250 | 250 | | | |

*Wetland is classified as both a Wetland of Management Concern and a Survey Site.

+Wetland is included in the probabilistic sample.

Ws= watershed

We also considered our sampling design relative to several assumptions about spatial variability and sample size. To account for geographic variation, we employed a generalized random tessellation stratified (GRTS) design with reverse hierarchical ordering (Stevens and Olsen 2004) for the 250 wetlands to be assessed rapidly (i.e., with the ORAM). We chose this design because summary statistics can be calculated much like a simple random sample to provide a measure of wetland condition across CUVA. Since we capture approximately 17% of park wetlands with ORAM methods, wetland condition summaries based on variables such as HGM class and watershed disturbance will be possible. For the wetlands that we sample intensively (i.e., with the VIBI), we chose to cluster our 60+ samples within watersheds with varying levels of disturbance, based on our assumption that differences in watershed disturbance account for much of the variability in wetland condition. The clustering up to 6 wetlands per watershed will also allow us to look more comprehensively at averages aggregated up to the watershed level of organization as well. To guide sample stratification, we calculated the level of anthropogenic disturbance in each watershed using the Landscape Development Intensity index (LDI).

While we realized that probabilistic designs were required to extrapolate our findings across the park, we also recognized that some wetlands in the park warranted study, even if not included in our sample. Collectively referred to as sentinel sites, these sites are further categorized as “reference” wetlands and “wetlands of management concern”. Reference wetlands reflect our perceptions of a very high quality, undisturbed example of a particular HGM type. Wetlands of management concern are generally large wetland complexes with multiple contiguous HGM and plant community types.

Wetlands of management concern were selected for at least one of the following reasons:

1. The wetland provides habitat for rare plant or animal species.
2. The wetland reflects a history of restoration efforts, including invasive plant control.
3. The wetland is listed in the Cuyahoga Valley National Park degraded wetland restoration plan (NPS 2005).
4. The wetland is covered in the Cuyahoga Valley National Park pond management plan (NPS 1993).
5. The wetland may be the subject of local planning efforts focusing on flood management.

Although not required for either rapid or intensive wetland assessments, we decided to collect basic hydrological data and water chemistry data. These ancillary data may more directly or immediately reflect changes in environmental factors, including those that may change in response to human activity. It is also possible that changes in these factors may help to explain changes observed in wetland vegetation. Although perhaps a longer-term prospect, hydrological monitoring may also detect diminished water levels resulting from climate change. Such changes are projected to affect streams and wetlands in the Great Lakes region (Kusler 2006, USEPA 2014).

### Sampling Objectives

The survey design decisions outlined allowed us to more carefully explain the sampling objectives of the wetlands monitoring protocol for CUVA:

1. Using a rapid assessment method (i.e., ORAM), understand temporal and, possibly, spatial patterns of average wetland condition across CUVA.

2. Using intensive methods (i.e., VIBI), identify temporal changes in wetland condition across a watershed disturbance gradient in CUVA.

3. Construct hydrological signatures for water depth and water quality that characterize the wetlands and may identify impacts to wetlands and explain changes in vegetation.

## Overview of Ohio EPA Methods

### *Ohio Rapid Assessment Method*

The Ohio Rapid Assessment Method (ORAM, Mack 2001) is a rapid assessment that is primarily used to categorize wetlands with respect to Ohio's Wetland Anti-degradation Rule (May 1, 1998). The rule categorizes wetlands based on their function, sensitivity to disturbance, rarity, and irreplaceability, and places restrictions on development ranging from avoidance to minimization to mitigation. The categories are as follows:

Category 1: Wetlands with minimal wetland function and/or integrity.
Category 2: Wetlands with moderate wetland function and/or integrity.
Category 3: Wetlands with superior wetland function and/or integrity.

As shorthand, these categories can be thought of as poor, good, and excellent, respectively. An implied fourth category is a modified Category 2, which reflects fair condition. In this protocol, we use ORAM scores to spatially characterize the condition of wetlands across the park.

The ORAM is calculated based on six categorical metrics – 1) wetland size; 2) buffers and surrounding landuse; 3) hydrology; 4) habitat alteration and development; 5) special wetland communities; and 6) vegetation, interspersion and microtopography – that characterize wetland condition (SOP 3). The protocol has been validated for use with other independent measures of ecological condition such as macroinvertebrate, bird, amphibian, and vegetation data (Mack 2001, Andreas et al. 2004, Micacchion 2004, Stapanian et al. 2004, Stein et al. 2009).

### *Vegetation Index of Biotic Integrity*

The VIBI analyzes vegetation metrics as integrators and indicators of cumulative anthropogenic disturbance impacting wetlands. To customize the VIBI for different wetland types, we use three VIBI types: the VIBI-Emergent, the VIBI-Forest, and VIBI-Shrub. Each VIBI is designed to be used for wetlands dominated by emergent, forest, or shrub vegetation, respectively. Among the three VIBIs, there are 19 metrics, although each VIBI type consists of only 10 metrics (Table 3). Individual metrics can receive a score of 0, 3, 7, or 10. The VIBI is calculated by summing the 10 metric scores, yielding a potential score of between 0 and 100 (Mack and Gara 2015, SOP 10). Generally speaking, scores above 57 and 70 fall within the Category 2 and 3 anti-degradation ranges discussed above, respectively. However, reference ranges are specific to HGM type and plant community (Table 4).

**Table 3.** The 19 metrics associated with the Vegetation Index of Biotic Integrity (VIBI) for emergent, shrub, and forested wetlands. Each specific VIBI consists of ten individual metrics.

| VIBI-Emergent | VIBI-Forest | VIBI-Shrub |
|---|---|---|
| Percent sensitive | Percent sensitive | Percent sensitive |
| Percent tolerant | Percent tolerant | Percent tolerant |
| FQAI score | FQAI score | FQAI score |
| Carex | Shade | Carex |
| Hydrophyte, native | Seedless Vascular Plants | Hydrophyte, native |
| Dicot, native | Percent hydrophyte | Dicot, native |
| Shrub, native, wetland | Pole timber density | Shrub, native, wetland |
| Annual/Perennial Ratio | Subcanopy IV | Subcanopy IV |
| Percent invasive graminoid | Canopy IV | Seedless Vascular Plants |
| Biomass | Percent bryophyte | Percent bryophyte |

**Table 4.** Vegetation Index of Biotic Integrity scoring ranges for specific plant communities and landscape position (i.e., hydrogeomorphic [HGM] class). Limited quality wetland habitat (LQWLH) corresponds with the anti-degradation Category 1, restorable wetland habitat (RWLH) corresponds with the anti-degradation category Modified 2, wetland habitat (WLH) corresponds with the anti-degradation Category 2, and superior wetland habitat (SWLH) or Category 3.

| HGM Class | Plant Community | Category 1 (LQWLH) | Modified Category 2 (RWLH) | Category 2 (WLH) | Category 3 (SWLH) |
|---|---|---|---|---|---|
| Depressional | Swamp Forest, Marsh, Shrub swamp | 0-30 | 30-60 | 61-75 | 76-100 |
| | Meadow | 0-29 | 30-59 | 60-75 | 76-100 |
| Slope | Wet meadow, fen, forest seep | 0-29 | 30-59 | 60-75 | 76-100 |
| Riverine | Wet meadow | 0-29 | 30-59 | 60-75 | 76-100 |
| | Other communities (headwater) | 0-27 | 28-56 | 57-69 | 70-100 |
| | Other communities (mainstem) | 0-29 | 30-56 | 57-73 | 74-100 |
| Impoundment | Marsh, Shrub swamp | 0-26 | 27-52 | 53-66 | 67-100 |
| | Wet meadow | 0-29 | 30-59 | 60-75 | 76-100 |

## Sampling Procedures

The sections below describe in greater detail the procedures that were required to implement the survey design.

### *Reference Frame Development*

We developed a reference frame of 1,476 wetlands within the Cuyahoga Valley National Park legislative boundary. Multiple data sources that we refer to as “constituent files” (Appendix A) contributed to the development of the reference frame. Wetlands were often mapped rapidly and not necessarily in accordance with the requirements of a jurisdictional delineation. However, observers used the classic delineation criteria - hydric soils, hydrophytic vegetation, and wetland hydrology – to map all wetland boundaries.

### *Sample Selection for Rapidly Assessed Wetlands*

To monitor wetlands using the ORAM, we selected 250 wetlands using a generalized random tessellation stratified (GRTS) design with reverse hierarchical ordering for spatial balance (Stevens and Olsen 2004). We excluded, however, wetlands that we cannot access safely, that we do not have permission to access, or that no longer exist. The number of wetlands selected for each HGM class was roughly proportional to the estimated abundance of that class throughout the park. A similar ORAM study at the scale of the entire Cuyahoga River watershed indicated that means, variances, and confidence intervals of ORAM scores improved minimally beyond 100 samples (Fennessy et al. 2007). We completed 250 samples, however, to increase our chances for meaningful post-hoc analyses.

### *Sample Selection for Intensively Assessed Wetlands*

Our use of a disturbance gradient to stratify intensively sampled wetlands required that we first map watersheds within CUVA and then calculate the degree of human disturbance in each watershed before selecting our sample.

#### Watershed Mapping

We developed a set of watersheds that matched the scale of management interest on the park (Skerl 2004). We attempted to use USGS basins at the HUC-14 scale. HUC-14s range in size from 4,000 acres to 50,000 acres. Basins at this scale are generally useful for “project activities, resource inventories, and reporting conservation activities” (NCGICC 2014). Nine HUC-14 basins covered our study area. We retained five of these that delineated the five major tributaries to the Cuyahoga River (i.e., Brandywine Creek, Chippewa Creek, Furnace Run, Tinkers Creek, and Yellow Creek). Using the spatial analyst basin tool in ArcGIS 9.1, we further divided four basins in to 38 smaller watersheds that drained directly in to the Cuyahoga River. We mapped these watersheds using 30 m x 30 m digital elevation models with each watershed at least 51.75 ha (127.9 acres) in size. Each of these watersheds contained a single, relatively small tributary, so we mapped these watersheds from the main stem back to the headwaters. Grouping these small watersheds within HUC-14s would have obscured local factors affecting wetlands within the park.

#### Landscape Development Intensity Index for Watersheds

To characterize the impact of human activities in each watershed, we calculated the Landscape Development Intensity Index (LDI) for watersheds using ArcGIS (SOP 1, Figure 10). The LDI characterizes the human-disturbance gradient on a scale from relatively natural (score 1) to highly impacted (score 7) by human activities. The index is calculated using emergy values that quantify the amount of non-renewable energy needed to maintain each landcover type on a per area (hectare) and per unit of time (year) basis, expressed as solar emergy joules (sej) per hectare-year. Non-renewable energy sources include electricity, fuels, fertilizers, pesticides, and water.

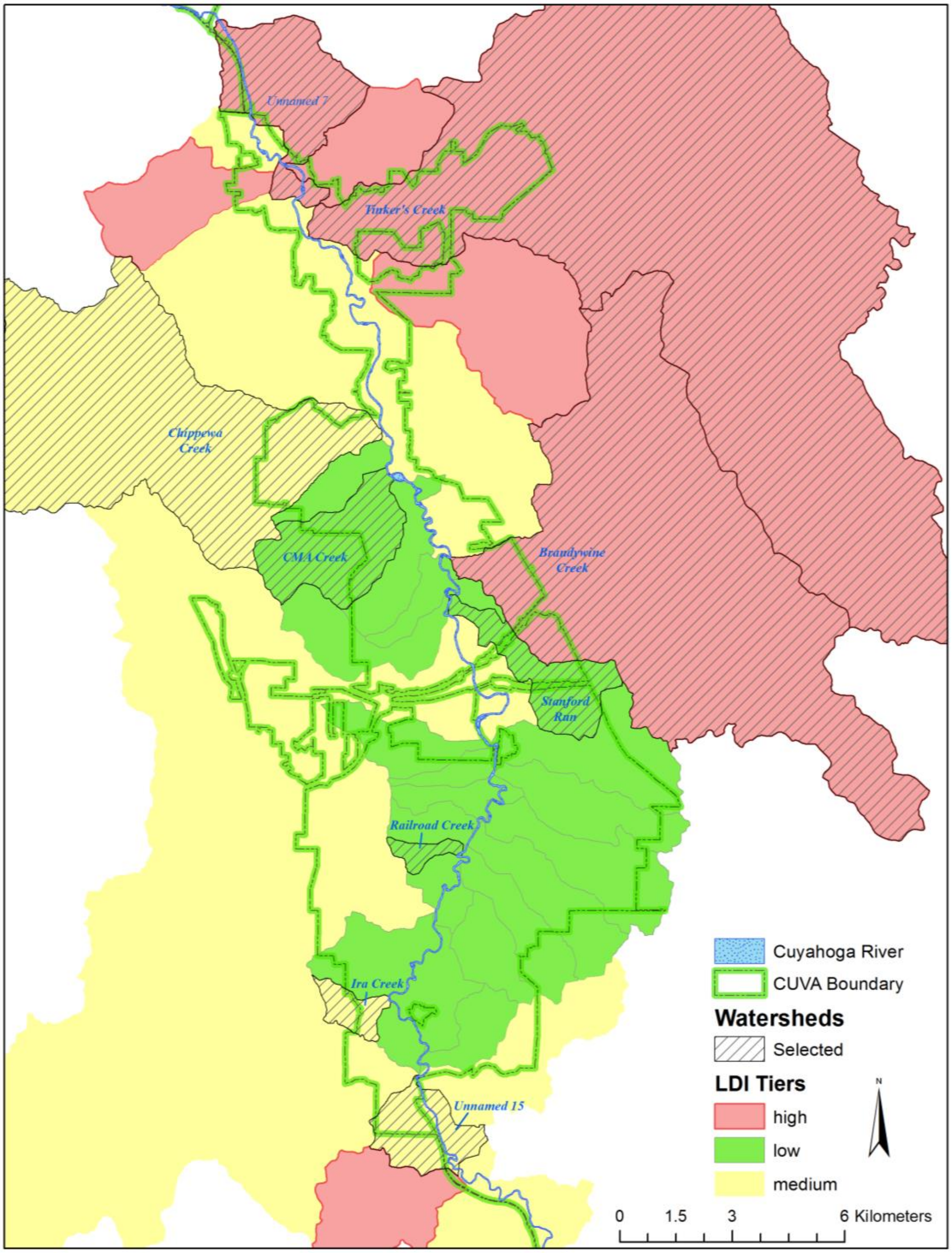



**Figure 10.** Map of watersheds in Cuyahoga Valley National Park (CUVA) mapped with low, medium, and high landscape development intensity (LDI) scores

To calculate this index, land cover classes from the national landcover dataset (2001) were matched with emergy coefficients. For this study, we used the emergy coefficients developed for Florida (Brown and Vivas 2005), given that LDIs developed for different states generally agree with each other (Campbell 2010, Table 5). To calculate and compare LDI in each watershed (n=43), we multiplied the percentage of area within each landcover type by the appropriate emergy coefficient, and summed the resulting products. The equation for this is as follows: LDI Total $= \sum \% \, LU_i * LDI_i$, where $\%LU_i$ = percent of the total area of influence in land use and $LDI_i$ = landscape development intensity coefficient for land use i.

After completing these calculations, we then used natural breakpoints to rank-order watersheds in high (> 4.7), medium (2.7 – 4.7) and low (< 2.7) LDI categories (Figures 10 and 11). This approach prevented subsequent selection of watersheds on the border of a category and only a few hundredths of an LDI score away from another category as might be the case with quartile or standard deviation methods. An LDI Index score of 2.0 was proposed as a conservative breakpoint to classify a minimally affected reference condition by Brown and Reiss (2006).

<u>Sample Selection</u>

Selecting wetlands for intensive assessment using the VIBI required a two-stage sample (Table 6). Prior to selection, we excluded 11 watersheds with fewer than 5 wetlands from the sample. From the remaining 32 watersheds, we selected a stratified random sample of three watersheds from the low, medium, and high LDI classes (Figure 11). The watersheds selected ranged in drainage area from 0.96 $km^2$/0.37 $mi^2$ (Railroad Creek) to 248.95 $km^2$/96.12 $mi^2$ (Tinker's Creek) and contained from 5 wetlands (Unnamed 15 and 7) to 84 wetlands (Stanford Run) within park boundaries (Table 4). We expected a low capture of wetlands within the riverine mainstem HGM type because riverine mainstem wetlands are spatially limited and less numerous than other HGM types. To compensate for this, we delineated the 100 year floodplain (FEMA 2014) and included the wetlands in this area as a tenth "floodplain" stratum. In the second stage, we selected 7 wetlands from 9 of the selected watersheds using a generalized random tesselation stratified (GRTS) design. In the two watersheds that contained only 5 wetlands within park boundaries (Unnamed 7 and Unnamed 15), we selected all wetlands. This led to the inclusion of 66 wetlands in our probabilistic design.

Next we evaluated each wetland in the field to verify that the wetland was suitable for sampling. We chose not to eliminate wetlands in the sample population based on size as over 40% of CUVA wetlands are smaller than 0.1 acre (0.04 ha), and 60 % are smaller than 0.25 acre (0.1 ha). Wetlands were not suitable if we could not sample the wetland safely, did not have permission to access from landowners, or could not fit at least a single 10 x 10 m module in the wetland. We replaced each excluded wetland with the next available wetland in the oversample list. In three watersheds, however, we exhausted all available samples, resulting in six fewer wetlands in those watersheds than originally expected. We segregated the final sample of 60 (Table 7) wetlands into 2 panels (Table 2).

**Table 5.** National Landcover Database (NLCD) land-use classes identified within Cuyahoga Valley National Park that correspond with the Florida land-use classes, and the Landscape Development Intensity (LDI) coefficients (i.e. emergy coefficients) that were used to calculate the LDI scores in this study (Mack 2006)

| NLCD land-use classes | LDI coefficients | NLCD Land-use Code | Florida land-use classes | Definition |
|---|---|---|---|---|
| 1. Deciduous Forest,<br>2. Evergreen Forest,<br>3. Mixed Forest,<br>4. Woody Wetlands,<br>5. Emergent Herbaceous Wetlands<br>6. Palustrine Aquatic Bed | 1.00 | 41, 42, 43, 90, 95, 99 | Natural system | Open water, upland, or wetland with very low manipulations (i.e. state parks, refuges, preserves and other protected lands). Does not include tree plantations and reservoirs. |
| Open Water | 1.00 | 11 | Natural open water | |
| Shrub/Scrub | 2.02 | 52 | Woodland pasture (with livestock) | Native rangeland and woodland pasture with presence of livestock. |
| Grassland/Herbaceous | 3.41 | 71 | Low intensity pasture (with livestock) | Areas where the natural vegetation has been altered by drainage, irrigation, etc., for the grazing of domestic animals with a density of less than 1.2 animals/ha. |
| Pasture/Hay | 3.74 | 81 | High intensity pasture (with livestock) | Areas where the natural vegetation has been altered by drainage, irrigation, etc., for the grazing of domestic animals with a density of more than 1.2 animals/ha. |
| Cultivated Crops | 4.54 | 82 | Row crops | Areas devoted to the production of all types of vegetables usually grown in rows, whether producing or not. |
| Developed, Open Space | 6.92 | 21 | Recreational/open space (high intensity) | Applies to stadiums not associated with institutions such as schools and universities, golf courses, and racetracks (horse, dog, car). |
| Developed, Low Intensity | 7.47 | 22 | Single family residential (medium density) | Areas that are predominantly residential units with a density between 10 and 20 units/ha. |
| Developed, Medium Intensity | 7.55 | 23 | Single family residential (high density) | Areas that are predominantly residential units with a density of more than 20 units/ha. |
| Barren Land (Rock/Sand/Clay) | 8.32 | 31 | Industrial | Land uses include manufacturing, assembly or processing of materials/products and associated buildings and grounds. Also includes extractive areas and mining operations, water supply plants, and solid wastes disposal facilities. |
| Developed, High Intensity | 9.42 | 24 | Central business district (average 2 stories) | Central business districts with an average of 2 stories. |

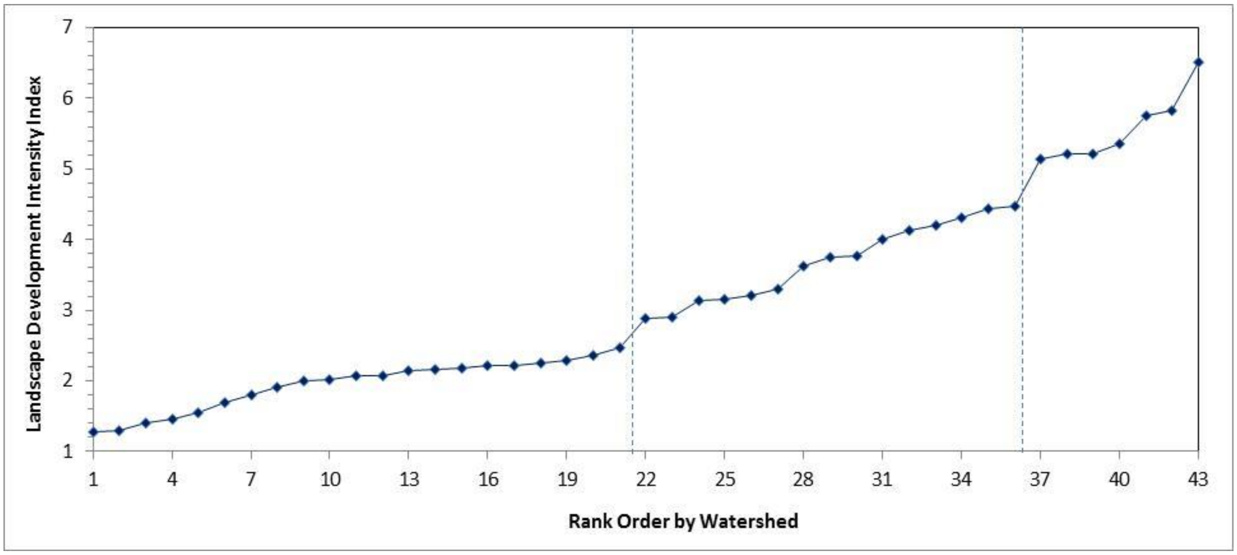



**Figure 11.** Watersheds in Cuyahoga Valley National Park ranked and ordered by landscape development intensity index (LDI). Index scores range from 1 to 7, representing low to high anthropogenic energy inputs. Dashed lines indicate the natural breakpoints that separate the low, medium, and high disturbance classes.

**Table 6.** Summary of the watershed and wetland inclusion probabilities for those selected in the two-stage sample using a generalized random tessellation stratified design in Cuyahoga Valley National Park for intensively assessed wetlands. The watershed drainage area, landscape development index (LDI) category and score are also shown in the table.

| Watershed | LDI Category (Score) | Inclusion Probability (watershed) | Inclusion Probability (wetland) | Drainage Area ($mi^2$) |
|---|---|---|---|---|
| Railroad | Low (1.3) | 0.15 | 0.70 | 0.37 |
| CMA | Low (2.0) | 0.15 | 0.28 | 3.25 |
| Stanford | Low (2.2) | 0.15 | 0.14 | 2.17 |
| Ira Creek | Medium (2.9) | 0.25 | 0.58 | 0.66 |
| Unnamed 15 | Medium (3.3) | 0.25 | 1.00 | 1.83 |
| Chippewa | Medium (4.4) | 0.25 | 0.44 | 18.02 |
| Brandywine | High (5.2) | 0.60 | 0.21 | 27.20 |
| Tinkers | High (5.2) | 0.60 | 0.26 | 96.12 |
| Unnamed 7 | High (6.5) | 0.60 | 1.00 | 4.05 |
| Floodplain | NA | 1.00 | 0.10 | NA |

**Table 7.** List of 60 Survey Sites (Plot ID) with number of Modules, dominant vegetation type, the azimuth of the centerline, array of modules, and coordinates (UTM Zone 19 N, NAD 1983).

| Plot Number | PlotID | Module # | Dominant Type | Azimuth | Array | X_Coord | Y_Coord |
|---|---|---|---|---|---|---|---|
| 1 | 28 | 4 | emergent | 0° | 2 x 2 | 451777.581025 | 4556542.604980 |
| 2 | 29 | 4 | emergent | 0° | 2 x 2 | 451744.953057 | 4556417.829690 |
| 3 | 30 | 4 | forested | 0° | 2 x 2 | 451567.317857 | 4556481.756470 |
| 4 | 32 | 4 | emergent | 0° | 2 x 2 | 451701.756513 | 4556610.150200 |
| 5 | 39 | 1 | emergent | 154° | 1 x 1 | 450669.051872 | 4558116.003000 |
| 6 | 43 | 4 | emergent | 0° | 2 x 2 | 451012.282593 | 4558823.953720 |
| 7 | 56 | 1 | emergent | 0° | 1 x 1 | 450705.570784 | 4558052.159670 |
| 8 | 192 | 8 | forested | 0° | 2 x 4 | 454624.701284 | 4568648.855750 |
| 9 | 305 | 4 | scrub-shrub | 0° | 2 x 2 | 451364.481121 | 4563056.698940 |
| 10 | 306 | 10 | forested | 0° | 2 x 5 | 451638.873953 | 4562915.342010 |
| 11 | 307 | 4 | scrub-shrub | 0° | 2 x 2 | 451649.450593 | 4563096.249790 |
| 12 | 309 | 4 | emergent | 0° | 1 x 4 | 452040.173794 | 4562811.307580 |
| 13 | 310 | 10 | forested | 0° | 2 x 5 | 451875.898721 | 4562600.682300 |
| 14 | 311 | 4 | forested | 24° | 1 x 4 | 451654.102625 | 4562718.043840 |
| 15 | 317 | 1 | emergent | 13° | 1 x 1 | 452850.252642 | 4563056.045760 |
| 16 | 343 | 4 | emergent | 35° | 1 x 4 | 452409.010402 | 4562153.677500 |
| 17 | 351 | 4 | emergent | 15° | 1 x 4 | 453854.080355 | 4565508.463170 |
| 18 | 363 | 4 | emergent | 0° | 2 x 2 | 451921.862369 | 4560185.249210 |
| 19 | 413 | 4 | emergent | 0° | 2 x 2 | 451164.030689 | 4571937.473220 |
| 20 | 416 | 4 | forested | 0° | 2 x 2 | 451122.701409 | 4572508.956740 |
| 21 | 422 | 3 | forested | 47° | 1 x 3 | 450723.714912 | 4572133.494470 |
| 22 | 623 | 10 | forested | 90° | 2 x 5 | 456680.706150 | 4566818.020030 |
| 23 | 627 | 10 | forested | 0° | 2 x 5 | 456457.029478 | 4566936.435270 |
| 24 | 669 | 4 | emergent | 282° | 1 x 4 | 456382.839782 | 4567221.824830 |
| 25 | 676 | 6 | forested | 90° | 2 x 3 | 455713.429093 | 4566435.258940 |
| 26 | 692 | 2 | forested | 19° | 1 x 2 | 455246.545893 | 4568347.035330 |
| 27 | 697 | 1 | emergent | 100° | 1 x 1 | 455021.954148 | 4569147.234500 |
| 28 | 743 | 4 | forested | 72° | 1 x 4 | 450104.692704 | 4570065.576640 |
| 29 | 748 | 1 | forested | 142° | 1 x 1 | 450527.364320 | 4570521.015490 |
| 30 | 867 | 5 | forested | 342° | 1 x 5 | 453773.423843 | 4569071.938760 |
| 31 | 885 | 4 | emergent | 0° | 2 x 2 | 454596.012004 | 4570635.722050 |
| 32 | 887 | 10 | forested | 90° | 2 x 5 | 454423.620708 | 4570653.665730 |

**Table 7 (continued).** List of 60 Survey Sites (Plot ID) with number of Modules, dominant vegetation type, the azimuth of the centerline, array of modules, and coordinates (UTM Zone 19 N, NAD 1983).

| Plot Number | PlotID | Module # | Dominant Type | Azimuth | Array | X_Coord | Y_Coord |
|---|---|---|---|---|---|---|---|
| 33 | 889 | 10 | forested | 280° | 2 x 5 | 454343.165028 | 4571188.327370 |
| 34 | 927 | 10 | forested | 30° | 2 x 5 | 450161.365984 | 4573601.061580 |
| 35 | 939 | 10 | forested | 90° | 2 x 5 | 449017.253343 | 4571730.991810 |
| 36 | 941 | 4 | emergent | 290° | 1 x 4 | 450207.123808 | 4572417.442500 |
| 37 | 947 | 4 | emergent | 0° | 2 x 2 | 448799.970398 | 4574860.206660 |
| 38 | 950 | 4 | forested | 48° | 2 x 2 | 449111.307487 | 4574445.562570 |
| 39 | 951 | 2 | emergent | 335° | 1 x 2 | 449294.112991 | 4574414.774220 |
| 40 | 953 | 1 | emergent | 0° | 1 x 1 | 449873.339743 | 4573945.344460 |
| 41 | 957 | 4 | emergent | 0° | 2 x 2 | 447986.716766 | 4573651.887050 |
| 42 | 970PV | 10 | forested | 320° | 2 x 5 | 449911.815264 | 4578266.878800 |
| 43 | 1007 | 4 | emergent | 331° | 2 x 2 | 453053.023714 | 4580239.639370 |
| 44 | 1017 | 3 | emergent | 43° | 1 x 3 | 454069.788643 | 4580087.319760 |
| 45 | 1034 | 1 | forested | 34° | 1 x 1 | 452024.840162 | 4580873.768780 |
| 46 | 1036 | 4 | forested | 0° | 2 x 2 | 454279.313892 | 4582030.014420 |
| 47 | 1058 | 4 | forested | 0° | 2 x 2 | 449573.221087 | 4579978.605010 |
| 48 | 1068 | 4 | emergent | 0° | 2 x 2 | 448833.754591 | 4580355.474000 |
| 49 | 1069 | 4 | emergent | 0° | 2 x 2 | 448920.449247 | 4580681.236810 |
| 50 | 1070 | 1 | emergent | 317° | 1 x 1 | 448956.769247 | 4580865.931210 |
| 51 | 1079RS2 | 4 | emergent | 0° | 2 x 2 | 447083.081309 | 4582432.915790 |
| 52 | 1188 | 4 | emergent | 0° | 2 x 2 | 455060.180708 | 4566663.475140 |
| 53 | 1196 | 4 | emergent | 0° | 2 x 2 | 455166.456292 | 4566309.502780 |
| 54 | 1205 | 1 | forested | 162° | 1 x 1 | 450575.992032 | 4558387.495350 |
| 55 | 1221 | 4 | emergent | 0° | 2 x 2 | 453719.447523 | 4569918.084040 |
| 56 | 1351 | 4 | forested | 0° | 2 x 2 | 452025.379682 | 4572319.294020 |
| 57 | 1364 | 4 | emergent | 0° | 2 x 2 | 450720.061664 | 4574064.138700 |
| 58 | 1468 | 4 | emergent | 0° | 2 x 2 | 449315.453535 | 4573663.379270 |
| 59 | 1485 | 4 | emergent | 352° | 2 x 2 | 452570.421730 | 4581354.468300 |
| 60 | 1104(1620) | 3 | emergent | 38° | 1 x 3 | 449206.282591 | 4579936.302030 |

We marked plot corners using 1-m lengths of PVC and rebar that we drove into the ground to the point of refusal. The length of PVC above the ground was typically 30 to 60 cm. A china marker was used to write the wetland ID on each corner stake and an NPS arrowhead decal was affixed to each stake. All set up details were recorded on a site establishment datasheet (Appendix B).

We recognize that we must be cautious in basing our sample on strata that are subject to change over time (National Park Service 2012). In comparing LDI scores of park watersheds between 2001 and 2006, LDI scores changed minimally and did not result in any changes in strata assignment. We will continue to reassess land-use changes in the watersheds as the NLCD is updated. We expect few changes as lands outside of park boundaries are largely built out with residential, commercial, and industrial uses, while conservation easements protect most remaining green spaces. We accept the risk that if LDI scores change substantially in the future, we will lose the ability to use the strata to reduced variability in analyses. In the short-term, however, understanding changes in wetlands in terms of watershed condition will be more important for guiding park management.

#### *Sample Selection for Sentinel Sites*

We purposively selected 35 “sentinel” sites, including 8 reference sites and 27 sites in 8 wetlands of management concern (Table 2). Comparing metrics from our probabilistic sample against metrics of reference wetlands may provide a means to assess wetland quality against the “best attainable condition” (Stoddard et al. 2006).

### Field Procedures

#### *Field Methods for Rapidly Assessed Wetlands*

The Ohio Rapid Assessment Method (Mack 2001) requires an observer to walk the perimeter of a wetland, categorizing and scoring six metrics – wetland size; buffers and surrounding landuse; hydrology; habitat alteration and development; special wetland communities; and vegetation, interspersion and microtopography – that characterize wetland condition (SOP 3). The approximate wetland perimeter should also be surveyed with a GPS unit for a more accurate depiction of the wetland size and location (SOP 4). We conduct these surveys between April 15 and June 1, prior to intensive vegetation surveys.

#### *Sampling Terminology*

For the intensively assessed wetlands and sentinel sites, we explain the terminology needed to understand the field procedures. The primary sampling unit is the wetland. For all intensively assessed sites and reference wetlands, a single sampling array is sampled to characterize the vegetation. Each sampling array consists of between 1 and 10 modules. All modules are 10-m x 10-m in size (i.e., 100 $m^2$ squares). The shape of the array is described in terms of the length and width of the modules. For example, a 2x5 array is 2 modules wide and 5 modules long, resulting in a sampling array of 10 modules (Figure 12).

#### *Field Methods for Intensively Assessed Wetlands*

<u>Sampling Array Placement</u>

To place sampling arrays within intensively assessed wetlands, we first delineated each wetland (n=60) in the sample frame using vegetation, water, and soil indicators according to the criteria required for a jurisdictional delineation (USACE 1987). We then mapped the perimeter using a GPS unit. We completed baseline delineations between 3/12/2012 and 05/15/2013. Delineation work was completed year-round as long as the ground was free of snow and not frozen. In all cases, the delineation resulted in a change to the wetland as originally delineated in the reference frame.

A flowchart summarizes the decisions we made to guide the random placement of a sampling array within the delineated wetland (SOP 5). The preferred sampling array was a 2 x 2 array of 100 $m^2$ square modules in aquatic bed, emergent, and shrub-scrub wetlands and a 5 x 2 array of 100 $m^2$ square modules in forested wetlands (Figure 12). We visited up to 10 random points to assess the "fit" of the preferred array around that point. The point was evaluated as a possible location for the sampling array if: 1) work could be conducted safely, and 2) the sampling array reflected the dominant vegetation type. If the waypoint met these conditions, we attempted to fit the preferred sampling array using the waypoint as the centroid and with the long axis oriented in the following directions: 1) north to south, 2) east to west, or 3) a customized azimuth when the other options did not work (i.e., any azimuth that worked). We did allow a centroid shift up to half the distance of the long axis of the array in any direction to find the best "fit" possible for the array. If the array included a high cover of uplands, we moved to the next available waypoint. If all 10 waypoints were exhausted without successful placement of the preferred array, we repeated the process using arrays of different sizes as shown in Figure 13, in order of decreasing preference, until at least a single 100 $m^2$ module was placed. The four sampling array corners were marked using 1" PVC stakes and the spatial location was recorded with a GPS unit. Alternative arrays and customized azimuths were common. We documented all sampling array placement decisions on the site establishment datasheet (SOP 5).

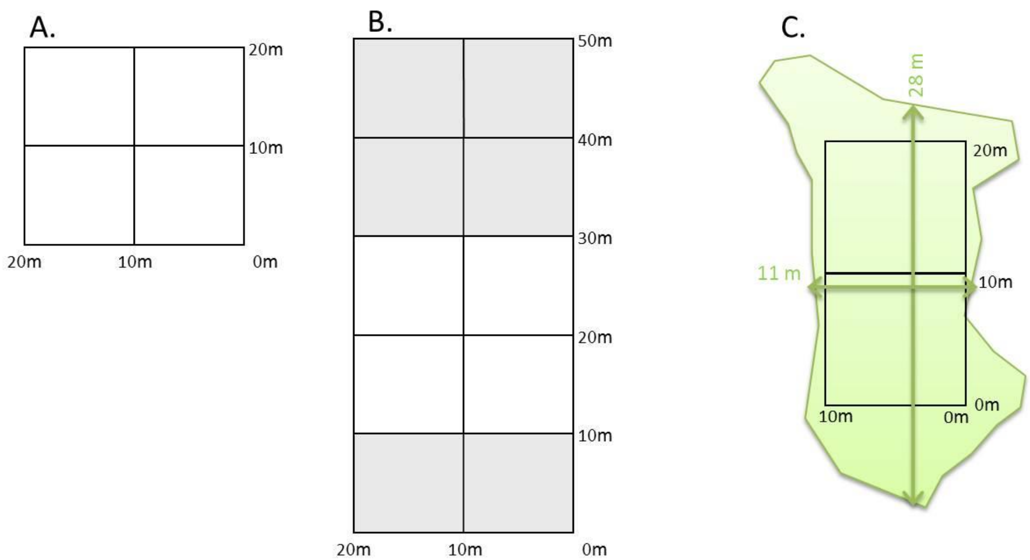
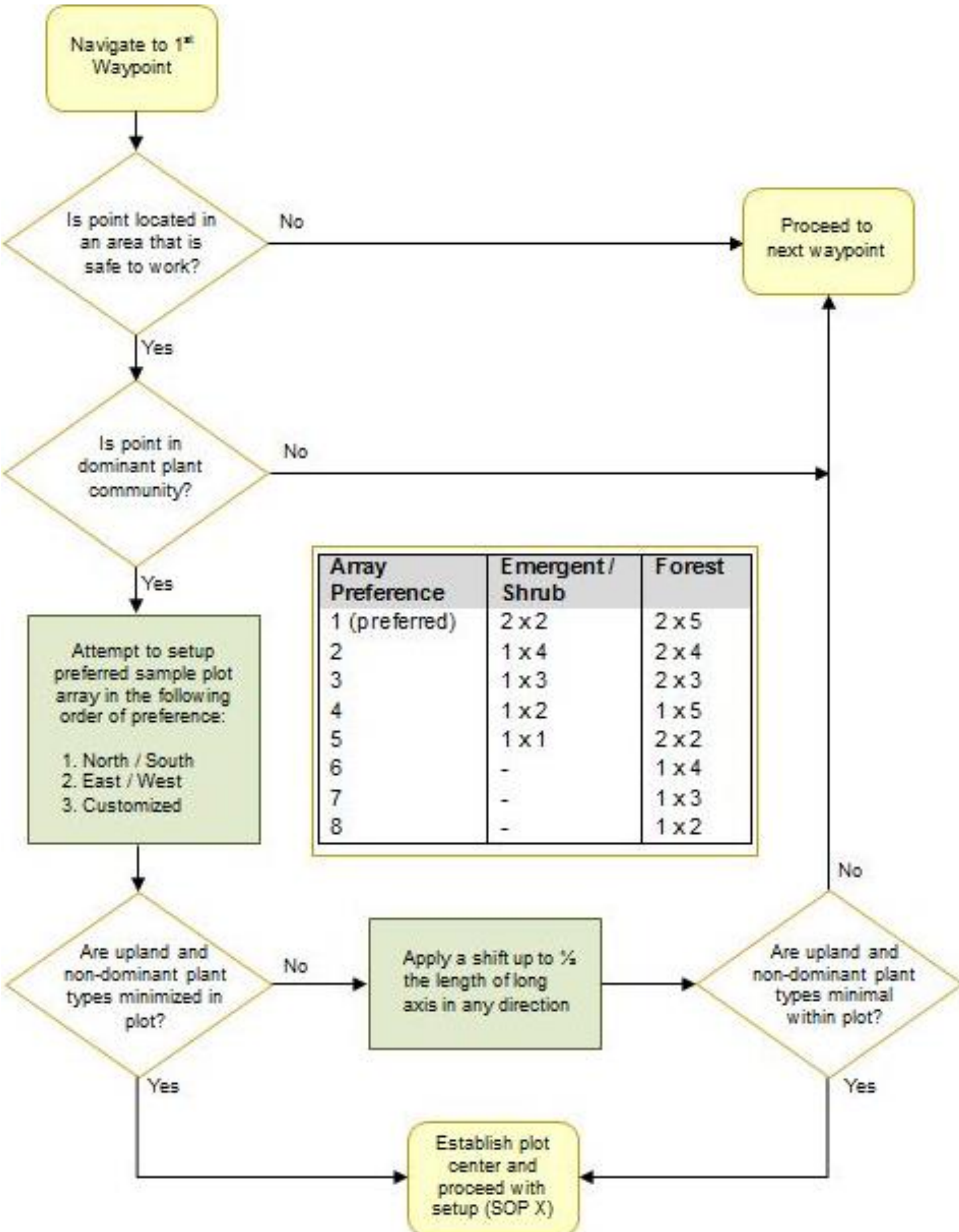



**Figure 12**. The preferred sampling array for (A) emergent, aquatic bed, and scrub-shrub wetlands, (B) forested wetlands, and (C) an example alternative sampling array for situations where the preferred array was not possible because of wetland shape, size, or vegetative composition.




| Array Preference | Emergent / Shrub | Forest |
|---|---|---|
| 1 (preferred) | 2 x 2 | 2 x 5 |
| 2 | 1 x 4 | 2 x 4 |
| 3 | 1 x 3 | 2 x 3 |
| 4 | 1 x 2 | 1 x 5 |
| 5 | 1 x 1 | 2 x 2 |
| 6 | - | 1 x 4 |
| 7 | - | 1 x 3 |
| 8 | - | 1 x 2 |

**Figure 13**. Flowchart for sampling array (SA) placement in intensively assessed wetlands. Up to ten points were visited in random order. We first followed the flow chart using the preferred SA of 10m x 10m modules for emergent/shrub or forested wetlands. If all points were exhausted and the preferred array did not fit within the wetland, we followed the same procedure using arrays of different sizes in a preferred order until we found a point that met the desired SA conditions.

Vegetation Sampling

We use at least a 2-person team to sample vegetation. In accordance with Mack et al. (Mack and Gara 2015), we conduct this work between June 15th and October15th when key plant identification characteristics are most visible. Identifying sedge (*Carex* spp.) and willow (*Salix* spp.) species may require additional visits as these species are difficult to identify outside of the flowering and/or fruiting stages. The cover of all vascular plant species, the density and identity of woody stems less than 3 ft. tall, the diameter and identity of all woody stems greater than 3 feet tall, and biomass (for emergent wetlands only – SOP 11) are measured within the assessment area and recorded separately within each 100 $m^2$ module. Because VIBI calculations require highly accurate identification of plants to the species-level, we voucher unknown specimens for later identification in the lab or in consultation with an experienced plant taxonomist. A working reference collection of wetland plant specimens also assists with plant identification (SOP 12). The reference specimens are in a herbarium cabinet located at the HTLN satellite field office at Cuyahoga Valley National Park.

### *Field Methods for Sentinel Wetlands*

Sampling Array Placement in Wetlands of Management Concern

Based on a review of aerial photography and field work, we delineated the wetlands and mapped the plant communities and HGM classes for eight wetland complexes (see Table 1 for wetland listing, Table 8 for plot locations). We then purposively sampled one assessment area in each HGM-dominant plant community type combination in these wetlands, resulting in multiple arrays per wetland. We will complete the eighth and final wetland complex in 2015. We attempted to control the bias to some extent by first attempting to place the sampling array near a randomly selected location.

In the field, we adjusted sampling array locations slightly as necessary to avoid transitional areas and areas that were clearly not representative (e.g. minor, localized areas of disturbance). Sampling arrays were established and baseline vegetation surveys were completed between 2008 and 2014.

Sampling Array Placement in Reference Sites

A single sampling array was purposively selected and established in each reference wetland to represent the highest quality vegetation community within the HGM class of interest (SOP 7).

Vegetation Sampling in Sentinel Sites

Vegetation sampling in sentinel sites followed that used in intensively sites (see Vegetation Sampling in Intensively Assessed Wetlands above).

**Table 8.** List of 37 intensively-assessed wetland sites, identified by PlotID, and showing wetland name, sample set (reference or wetland of management concern [WOMC]), dominant vegetation type, azimuth of the center line, array shape of modules, and location coordinates (UTM Zone 19 N, NAD 1983).

| Plot No | PlotID | WetlandName | SampleSet | Dominant Veg. Type | Azimuth Center Line | Array | X_Coord | Y_Coord |
|---|---|---|---|---|---|---|---|---|
| 1 | 1427 | Bath | Reference | forested | 90° | 2 x 5 | 451956.239329 | 4557257.599160 |
| 2 | 683 | BostonMills | Reference | shrub-shrub | 0° | 2 x 5 | 455170.534500 | 4567589.166150 |
| 3 | 554 | Columbia | Reference | emergent | 0° | 1 x 4 | 452285.982562 | 4568972.745800 |
| 4 | 970 | Fitzwater | Reference | forested | 0° | 2 x 5 | 449863.854815 | 4578175.339980 |
| 5 | 124 | Langes | Reference | shrub-scrub | 0° | 2 x 2 | 453847.660515 | 4562127.533240 |
| 6 | 398 | Snowville | Reference | emergent | 290° | 1 x 4 | 451543.095649 | 4570712.221000 |
| 7 | 526 | Stumpy | Reference | emergent | 0° | 2 x 5 | 454408.745700 | 4567140.493890 |
| 8 | 241K | Virginia Kendall | Reference/WOMC | emergent | 90° | 2 x 2 | 456153.332325 | 4562776.202940 |
| 9 | 970PV | Pleasant Valley | Survey / WOMC | forested | 144° | 2 x 5 | 449911.815264 | 4578266.878800 |
| 10 | 1079RS2 | Rockside | Survey / WOMC | emergent | 0° | 2 x 2 | 447083.081309 | 4582432.915790 |
| 11 | 365BM3 | Beaver Marsh | WOMC | emergent | 0° | 2 x 2 | 451391.660641 | 4559358.737340 |
| 12 | 365BM2 | Beaver Marsh | WOMC | emergent | 0° | 2 x 2 | 451198.660833 | 4559529.238070 |
| 13 | 365BM4 | Beaver Marsh | WOMC | forested | 180° | 2 x 5 | 451522.806753 | 4559879.213630 |
| 14 | 365BM5 | Beaver Marsh | WOMC | emergent | 330° | 2 x 2 | 451519.373793 | 4560095.169720 |
| 15 | 365BM6 | Beaver Marsh | WOMC | emergent | 302° | 2 x 4 | 451670.046817 | 4560334.262460 |
| 16 | 977FP1 | Fawn Pond | WOMC | forested | 90° | 2 x 5 | 450005.749088 | 4576513.516750 |
| 17 | 977FP2 | Fawn Pond | WOMC | emergent | 0° | 2 x 2 | 449807.231839 | 4576607.576390 |
| 18 | 977FP3 | Fawn Pond | WOMC | emergent | 0° | 2 x 2 | 450018.577504 | 4576854.829130 |
| 19 | 977FP4 | Fawn Pond | WOMC | emergent | 0° | 2 x 2 | 449929.178976 | 4577019.816780 |
| 20 | 977FP5 | Fawn Pond | WOMC | forested | 0° | 2 x 5 | 449938.991456 | 4577374.911440 |
| 21 | 968PV968 | Pleasant Valley | WOMC | emergent | 42° | 2 x 5 | 449100.999519 | 4578760.580940 |
| 22 | 969 | Pleasant Valley | WOMC | emergent | 120° | 2 x 5 | 449697.402975 | 4578825.406030 |
| 23 | 1043 | Pleasant Valley | WOMC | emergent | 355° | 2 x 5 | 448684.948318 | 4578711.000270 |
| 24 | 1047 | Pleasant Valley | WOMC | emergent | 323° | 2 x 5 | 448901.416287 | 4579130.870090 |
| 25 | 1049 | Pleasant Valley | WOMC | forested | 95° | 2 x 5 | 449676.377567 | 4579000.803530 |
| 26 | 526SB3 | Stumpy Basin | WOMC | forested | 0° | 2 x 5 | 454333.341924 | 4566853.348930 |
| 27 | 526SB2 | Stumpy Basin | WOMC | forested | 0° | 2 x 5 | 454293.667428 | 4567145.250500 |
| 28 | 526SB1 | Stumpy Basin | WOMC | emergent | 0° | 2 x 2 | 454278.286180 | 4567261.859910 |
| 29 | 241VK4 | Virginia Kendall | WOMC | emergent | 102° | 1 x 3 | 455927.332453 | 4562814.243520 |

**Table 8 (continued).** List of 37 intensively-assessed wetland sites, identified by PlotID, and showing wetland name, sample set (reference or wetland of management concern [WOMC]), dominant vegetation type, azimuth of the center line, array shape of modules, and location coordinates (UTM Zone 19 N, NAD 1983).

| Plot No | PlotID | WetlandName | SampleSet | Dominant Veg. Type | Azimuth Center Line | Array | X_Coord | Y_Coord |
|---|---|---|---|---|---|---|---|---|
| 30 | 242VK1 | Virginia Kendall | WOMC | emergent | 86° | 2 x 2 | 456096.224485 | 4563161.566650 |
| 31 | 242VK2 | Virginia Kendall | WOMC | forested | 110° | 2 x 5 | 456306.969061 | 4563191.892160 |
| 32 | 540SF1 | Stanford | WOMC | emergent | 0° | 2 x 2 | 453130.287675 | 4569393.440660 |
| 33 | 540SF2 | Stanford | WOMC | emergent | 0° | 2 x 2 | 453113.750898 | 4569463.449830 |
| 34 | 540SF3 | Stanford | WOMC | emergent | 0° | 2 x 2 | 453209.960396 | 4569427.511180 |
| 35 | 540SF4 | Stanford | WOMC | emergent | 0° | 2 x 2 | 453244.011986 | 4569513.765510 |
| 36 | 1622KR1 | Krejci | WOMC | emergent | 0° | 2 x 2 | 454954.070943 | 4568242.931670 |
| 37 | 1627KR2 | Krejci | WOMC | emergent | 0° | 2 x 2 | 454728.741149 | 4568433.300940 |

### *Field Methods for Hydrological Monitoring*

Well Deployment and Soil Analysis

Within all sampling arrays, we established a shallow groundwater monitoring well (n=89) (SOP 8). The well was deployed at or near the sampling array centroid. The well locations were recorded using GPS and sketched on Site Deployment Sheets (SOP 8). During well installation, we used the soil profile that was removed to characterize soil stratigraphy (SOP 9). We recorded the soil horizons, matrix and mottle color, and soil texture on a detailed well deployment log that also included details on the well depth and backfill materials. Matrix color and mottle characteristics are secondary indicators of the hydrologic regime. Mottles often occur in soils that alternate between anaerobic (reduced) and aerobic (oxidized) condition. Strongly gleyed soils indicate exposure to prolonged anaerobic conditions, created by the presence of water.

Hydrological Monitoring

To characterize the hydrological regime of the monitored wetlands, we measure shallow groundwater in each of the 88 groundwater wells (Table 9). Manual measurements are made at least biweekly from early spring (mid-March) through late fall (late October) using a hydrolite (SOP 8). A hydrolite consists of a 'sensor', a measuring tape, and an LED light or buzzer that flashes or buzzes when the sensor makes contact with the water surface. We also measure ground water depths in 8 reference wetlands using digital loggers (Ecotones™) (SOP 8). Ecotones™ digitally record water depth automatically at 12 hour intervals. Surface water depths are measured at 4 staff gauges, in areas where surface water frequently precludes visitation.

Water Chemistry Monitoring

In wells within wetlands with a water level less than 1 m below the surface during the early growing season, we measure water temperature, pH, dissolved oxygen, and conductivity using a Eureka

Manta multiprobe. Standing water is bailed out and wells are allowed to refill before extraction and measurement. These measurements are made monthly from March through October in ground water or surface water wells (SOP 13). We expect 90-100% of the wetlands in the intensive survey to be measurable during the early growing season (March, April, May) with roughly 60% of the wetlands measurable through October.

## Field Safety

Safety is paramount during all field operations of NPS staff, partners, and volunteers. Standing dead trees, downed woody debris, thick vegetation, and mucky soils can make walking through wetlands a daunting task. Trapped heat and high humidity can increase the odds of heat stroke and dehydration when working in wetland environments. Ticks, mosquitos, and chiggers can also be prevalent near wetland areas. Field personnel need to be aware of the common hazards, follow the network safety plan (Heartland Network 2012), wear or use the appropriate personal protective equipment, and be able to respond and communicate with park staff or first responders in case of an emergency (SOP 16).

**Table 9.** Location and number of monitoring wells, staff gauges, and digital Ecotone™ water level measuring devices in wetlands that we monitor in Cuyahoga Valley National Park.

| Complex | Well # | Staff Gauge | Ecotone™ | Initial monitoring date |
|---|---|---|---|---|
| Pleasant Valley | 6 | 1 | - | September 12, 2008 |
| Fawn Pond | 5 | 1 | - | July 3, 2009 |
| Stumpy Basin | 3 | - | - | March 15, 2011 |
| Virginia Kendall | 4 | 1 | - | July 6, 2009 |
| Beaver Marsh | 5 | 1 | - | June 25, 2009 |
| Rockside | 1 | - | - | April 2013 |
| Krejci | 0 | 2 | - | 2015 |
| Stanford | 4 | - | - | 2015 |
| Survey Sites | 60 | - | - | 2014 |
| Reference Sites | - | - | 8 | November 2010 |
| Total | 88 | 6 | 8 | |

# Data Processing, Analysis, and Reporting

Data processing typically involves the following steps: data entry, data verification, data validation, and backups/storage (see SOP17). The wetland biologist in coordination with the data manager is responsible for all phases of data processing.

## Databases

Data is managed in four databases that are designed to store and display specific types of monitoring data: 1) a geodatabase with spatially referenced wetland and watershed locations (wetlnd.gdb), 2) an Access database that stores LDI scores; data associated with the Ohio Rapid Assessment Method and Vegetation Index of Biotic Integrity; and hydrological data (wetlnd.mdb), 3) an Aquarius database that stores automated digital water level data collected at 8 reference sites, and 4) NPSTORET.mdb, a water quality database that contributes data to the national repository of water quality monitoring data in a common format accessible on-line, as required in The Natural Resources Management Guideline (NPS 1991). Spatial data will be managed in accordance with NPS standards, which includes the use of FGDC compliant metadata.

## Data Entry

Traditional field data forms are used in the field for ORAM and VIBI data collected, and data is entered in the office. However, we hope to eventually enter data directly into the wetland.mdb using the Trimble YUMA 2 field computer (SOP 14). The wetlnd.mdb user interface is organized in an intuitive way with digital dataforms that closely mimic the original field forms. Data entry using NPStoret and Aquarius require close adherence to SOP 14.

## Data Verification and Validation

Data verification is required immediately following data entry and involves checking computerized records against the original source, usually paper field records. The paper forms are archived and the electronic version is used for subsequent analyses.

Data validation involves checking the accuracy of data against independent controls or specifications. There are three types of controls used in wetland.mdb. They are: 1) checks for referential integrity, 2) limited pick lists for nominal data, and 3) controls to only allow reasonable values for continuous data. For example, data entry forms in the database contain check boxes and lists that link to referenced lookup tables so that only valid names or measures may be entered. Data verification is also an integral step for preparing water level and water quality data for entry into the STORET.mdb and Aquarius database.

## Data Protection

Frequent backups are critical for preventing data loss. Full backup copies of the monitoring project will be stored at an off-site location, including on the Heartland Network’s server and Cuyahoga Valley National Park’s server. The Heartland Network uses a RAID design to protect data (Rowell et al. 2005).

## Data Analysis and Reporting

### *Data analysis*

A primary objective of this monitoring protocol is to detect change in wetland conditions over time. In our analyses, we focus on detection of change rather than trend per se (where change can be defined as any alteration of an attribute over any time period, whereas a trend can be defined as a gradual increase or decrease in an attribute over time). It can be difficult to reliably detect trends because of the uncertainties in distinguishing a true directional trend from multiyear cyclical variability or erratic fluctuations. Additionally, wetlands may reveal an abrupt change due to a single event such as a natural disturbance or management action, rather than a gradual increase or decrease over time. Thus in environmental monitoring programs it is usually preferable to search for change rather than attempt to detect trends per se (Rowland and Vojta 2013).

In determining the appropriate statistical approaches for this monitoring protocol, it is important to take into account the primary audience of the various reports that will result. This audience will consist of park resource managers, park superintendents, and other park staff. Park resource managers and staff may not have an in-depth background in statistical methods, and park superintendents may have limited time to devote to such reports. Additionally, protocols such as this may provide much data on many different types of variables. To the extent possible, the core data analyses and presentation methods should provide a standard format for evaluation of numerous variables, be relatively straightforward to interpret, be quickly updated whenever additional data become available, and be used for many different types of indicators, whether univariate or multivariate. Additionally, the type and magnitude of variability or uncertainty associated with the results should be easily discernible, and a threshold for potential management action ideally will be indicated.

There are three main statistical approaches that could be employed with data from long-term monitoring projects: (1) hypotheses testing, (2) parameter estimation, and (3) application of Bayesian methods. When analyzing ecological data, statisticians predominantly employ frequentist methods, so many resource managers are not familiar with the interpretation of Bayesian approaches. Bayesian methods are not widely used because they are often difficult to apply, and many researchers are not comfortable specifying subjective degrees of belief in their hypotheses (Utts 1988, Hoenig and Heisey 2001). Thus, we do not advocate a Bayesian approach as our main method of data analysis.

Most hypothesis testing approaches involve a null hypothesis of no difference or no change. The problem with such approaches is that the hypothesis under test is often trivial (Cherry 1998, Johnson, 1999, Anderson et al. 2000, 2001). No populations or communities will be exactly the same at different times. As such, we are not really interested in whether these are changing per se, but rather in the magnitude of change, and whether it represents something biologically important. Null hypothesis significance testing relies heavily on $P$-values, and results primarily in yes – no decisions (reject or fail to reject the null hypothesis). $P$-values are strongly influenced by sample size, however, and one may, with a large enough sample size, obtain a statistically ‘significant’ result that is not biologically important. Alternatively, with a small sample size, one may determine that a biologically important result is not statistically significant (Yoccoz 1991). We aim for our analyses to be more concerned about whether the data support our scientific hypotheses and are biologically significant (Kirk 1996; Hoenig and Heisey 2001).

Parameter estimation, including the use of confidence intervals, provides more information than hypothesis testing, is more straightforward to interpret, and easier to compute (*e.g*., Steidl et al. 1997, Gerard et al. 1998, Johnson 1999, Anderson et al. 2000, 2001, Colegrave and Ruxton 2003, Nakagawa and Foster 2004). Parameter estimation emphasizes the magnitude of effects and the biological significance of the results, rather than making binary decisions (Shaver 1993, Stoehr, 1999). There is no formal classification of error associated with parameter estimation. It is assumed that the estimate is not accurate, and the width of the confidence interval provides information on the degree of uncertainty (Simberloff 1990). One of the primary recommendations from a workshop on environmental monitoring organized by the Ecological Society of America was that trend studies should focus on description of trends and their uncertainty, rather than hypothesis testing (Olsen et al. 1997). The use of confidence intervals was recommended over statistical testing when comparing two monitoring periods in a technical wildlife monitoring guide published by the USDA (Rowland and Vojta 2013).

We will also employ control charts in data organization and analysis. Control charts, developed for industrial applications, indicate when a system is going 'out of control', by plotting through time some measure of a stochastic process with reference to its expected value (*e.g*., Beauregard et al. 1992, Gyrna 2001, Montgomery 2001). Control charts may be univariate or multivariate and can represent many different types of variables. Control charts have been applied to ecological data (McBean and Rovers 1998, Manly 2001), including fish communities (Pettersson 1998, Anderson and Thompson 2004) and natural resources within the I&M program (Atkinson et al. 2003). Control charts contain upper and lower control limits specifying thresholds beyond which variability in the indicator reveals that a biologically important change is occurring. Control limits can be set to any desired level.

We did not conduct a formal power analysis for this protocol for three reasons: (1) In many analyses sample size will equate with number of years; in this case, analyses will simply become more powerful over time. (2) Statistical power is dependent upon the hypothesis under test and the statistical test used. Over the course of this long-term monitoring program, we will be interested in many different questions and could potentially evaluate a number of different hypotheses. Thus there is no single 'power' relevant to the overall protocol. Estimating power at this point in the context of such a long-term, multifaceted monitoring program could be potentially misleading, as the test this power is based upon may rarely (or never) actually be employed. (3) Most of our data analyses will take the form of parameter estimation with associated confidence intervals, rather than null hypothesis significance testing. When estimating parameters, there is no associated statistical power. It is assumed that the estimate is not accurate, and the width of the confidence interval provides information on the degree of uncertainty. In general, statistical power analyses are frequently mis-used and misinterpreted in ecological contexts (Morrison 2007), and alternative approaches to evaluating the degree of uncertainty associated with our data will be evaluated and used when applicable.

Although our primary approach to organizing and analyzing data will consist of parameter estimation with associated confidence intervals, combined with the use of control charts, we do not entirely rule out the use of any statistical methods at this time. Depending upon the question of interest to resource managers, a hypothesis testing framework may be used. Because of the nature of this long-term monitoring program, other approaches (some of which may not have even been developed yet) may be appropriate at different points in time, depending upon the needs of the resource managers and questions of interest.

The protocol is designed to allow the calculation of the ORAM and VIBI metrics, and these scores will be among the primary results. Analyses will be focused on the distribution of ORAM scores and categories, providing an overall review of wetland condition. The large sample size associated with the ORAM data will provide more opportunities to examine variables post hoc. Data analyses from the intensive survey will include a combination of species diversity metrics, as well as several metrics developed for the Vegetation Index of Biotic Integrity (Mack and Gara 2015) (Table 2). For the status report, we will use descriptive statistics to describe wetland condition and compare species metrics (richness and evenness, FQAI score, cover weighted C of C, % sensitive, % invasive species) across all wetlands. These values will also be averaged for watersheds and compared among watersheds and LDI levels (poor, fair, good) using regression analysis and repeated measures ANOVA. Change analyses comparing metrics over time will be performed after 2 cycles of intensive sampling. Relationships with explanatory variables such as wetland size, average water levels, water type, HGM class, and dominant plant community will also be explored.

#### *Reporting*

We will produce a status report after all survey wetlands have been sampled. Long-term changes are reported every five years thereafter. The report will follow the standard format required in the CSE Style Manual (2014) (SOP 16). The natural resource technical report template for NPS documents is also required (http://www.nature.nps.gov/publications/NRPM/index.cfm).

# Operational Requirements

## Personnel Requirements

The network's wetland biologist serves as the project manager and normally as the crew leader for this protocol. The wetland biologist is duty-stationed at Cuyahoga Valley National Park, but is supervised by the network coordinator or his/her designee in coordination with the park's chief of resource management. Data management is the shared responsibility of the project manager and network data manager(s). Typically, the project manager oversees data collection, data entry, data verification and validation, as well as data summary, analysis, and reporting. The data manager designs the database and oversees data validation procedures, security, archiving, and dissemination.

## Qualifications and Training

The lead wetland biologist must be skilled in plant identification and practiced in wetland ecology, quantitative vegetation surveys, GPS navigation, GIS, data entry, and basic data analysis. The wetland scientist should have or receive training in ORAM and VIBI methodology through the Ohio Environmental Protection Agency. All field observers must be well-organized, work well as a team member, be comfortable in the field, and work methodically under difficult conditions.

Training is essential for developing competent observers (see SOP 1). Observers will review wetland plant identification using herbarium specimens, keys, and photographs. The wetland biologist will provide training to all biological technicians, interns, and volunteers (SOP 11). Observers will be tested frequently on their ability to identify plant species in the field.

## Annual workload

Monitoring will require a two- to three-person crew each year. Annual field work varies over a 5-year period and is outlined in Table 2. In addition, we complete hydrological monitoring between March 15 and October 15. In years in which we complete rapid assessments, the ORAM Survey begins in May, but can be conducted through late October. Intensive surveys (i.e., VIBI) surveys begin on June 15 and end by October 15. In preparation for the field season, the project leader must oversee and organize seasonal hiring; volunteer recruitment; permit preparation; equipment testing, calibration, and maintenance; procurement; and training (SOP 14). The remainder of the year is reserved for voucher handling, data analysis, reporting, and administrative requirements.

## Hiring Seasonal Biotechnicians

At least one seasonal biotechnician is hired annually to assist with the hydrological monitoring and vegetation surveys. The job recruitment announcement for this seasonal wetland biotechnician should be prepared and posted in November of the previous year to make sure the employee is cleared to begin work in late February or early March (SOP 14). New employees will need special job-specific training that will be provided as they enter on duty.

## Volunteers

The wetland monitoring project relies on a cadre of dedicated volunteer "wetland monitors". The volunteer effort began in 2009 (SOP 15) with volunteers since then dedicating thousands of hours toward hydrological monitoring. As of 2016, many volunteers are returning for a sixth year to monitor the same location, while we have recruited to re-fill other volunteer positions. Wetland Monitors:

- Measure water levels once a week in groundwater wells or at staff gauges
- Complete presence / absence surveys for frogs and toads in our breeding wetlands using Frog Watch USA protocols
- Maintain our plant reference collection
- Assist with data entry

New volunteer recruitment and training begins early in the year through the assistance of the Conservancy for Cuyahoga Valley National Park. Space is reserved for Wetland Monitors at the Savacoal House, where volunteers can use an access code to enter the building at any point during the day. At this location, volunteers find park radios, field supplies, and data forms to guide their field work. The project leader seeks to maintain the volunteer's productivity, interest, and morale through regular updates on the impacts of their information, in-field training, response to questions, and through an annual social gathering or workshops.

### Annual budget

Annual personnel, equipment, and training costs required to run the wetland monitoring program are nearly $160,000.00 (Table 10). The funding source is primarily from the Heartland Network's Vital Signs funds, with in-kind support (~$27,100) provided from the host park for overhead expenses in the form of an office space, a vehicle, computer, GPS, radios, and other equipment. Personnel expenses for field work are based on a portion of the supervisor's salary and 100% of the salary of permanently stationed field crew members: one full-time botanist or wetland ecologist (GS-9) and one to two seasonal biological technicians (GS-5). Administrative and data management expenses are staff personnel costs associated with the network coordinator, administrative officer, and data managers. Data analysis and reports are produced collaboratively with these individuals. Equipment costs were estimated using five year, annualized start-up costs.

**Table 10.** Estimated annual budget for required for wetland monitoring in Cuyahoga Valley National Park.

| **Category** | **Cost** |
|---|---|
| Personnel | $108,350 |
| Administrative | $8,500 |
| Data Management | $10,000 |
| Equipment (5-year annualized) | $3,665 |
| CUVA In-Kind Contributions (office, truck, gps, etc.) | $27,100 |
| Certifications / Training | $ 2,700 |
| TOTAL | $160,315.00 |

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# Appendix A:

# Wetland Monitoring Reference Frame

The following constituent files were used to create the reference frame for wetland monitoring in Cuyahoga Valley National Park. This reference frame was used to randomly select wetlands for inclusion in the sample of intensively- (and rapidly) assessed wetlands. Files from three major versions are listed. The names of the original constituent files were shortened for inclusion in the attribute table of the original reference frame (compare *Original File Name* and *HTLN File Name*). Other attribute information available for each constituent file listed in includes the year of the wetland survey, if wetlands were delineated using U.S. Army Corps of Engineers methodology (yes/no/in-part), and whether Ohio Rapid Assessment Method (ORAM) data were collected.

| **Original File Name** | **HTLN File Name** | **Original Projection** | **Year (of survey)** | **File Version** | **Source** | **Delineated? (Y/N/IP)** | **ORAM** |
|---|---|---|---|---|---|---|---|
| OldFarmWetlands_added120208 | FarmWetland | UTM Zone 17N, NAD1983 | 2002-2004 | 2009 | NPS | IP | Y |
| urs_wetlands_1183_rev120908 | UrsWetland | UTM Zone 17N, NAD1927 | 2002-2004 | 2009 | URS | IP | Y |
| wet_determ_offering2005 | WetDeterm | UTM Zone 17N, NAD1927 | 2004 | 2009 | NPS | IP | Y |
| wetlands_081806_corrected_120108 | RuralWetland | State Plane, Ohio North, NAD 1983, feet | 2006 | 2009 | NPS | IP | Y |
| Davey wetlands 060801 | Davey | UTM Zone 17N, NAD1927 | 1999-2000 | 2009 | Davey | N | N |
| Brookside2008_wetpolyUTM | Brookside2008 | UTM Zone 17N, NAD1983 | 2008 | 2010 | NPS | Y | Y |
| FawnPond1041_wetpoly2009UTM | FawnPond1041 | UTM Zone 17N, NAD1983 | 2009 | 2010 | NPS | Y | Y |
| FawnPond1041slope_wetpoly_2009UTM | FawnPond1041Slope | UTM Zone 17N, NAD1983 | 2009 | 2010 | NPS | Y | Y |
| IRA343_wetpoly_2008UTM | Ira343 | UTM Zone 17N, NAD1983 | 2008 | 2010 | NPS | Y | Y |
| Kendall195_wetpoly_2008UTM | Kendall195 | UTM Zone 17N, NAD1983 | 2008 | 2010 | NPS | Y | Y |
| Kendall205_2008wetpoly_UTM | Kendall205 | UTM Zone 17N, NAD1983 | 2008 | 2010 | NPS | Y | Y |
| Kendall206_2008wetpoly_UTM | Kendall206 | UTM Zone 17N, NAD1983 | 2008 | 2010 | NPS | Y | Y |
| Kendall206b_2008wetpoly_UTM | Kendall206b | UTM Zone 17N, NAD1983 | 2008 | 2010 | NPS | Y | Y |
| PleasantValley1045_2008wetpoly_UTM | PleasantValley1045 | UTM Zone 17N, NAD1983 | 2008 | 2010 | NPS | Y | Y |

| Original File Name | HTLN File Name | Original Projection | Year (of survey) | File Version | Source | Delineated? (Y/N/IP) | ORAM |
|---|---|---|---|---|---|---|---|
| PleasantValley1046_2008wetpoly_UTM | PleasantValley1046 | UTM Zone 17N, NAD1983 | 2008 | 2010 | NPS | Y | Y |
| PleasantValley1106_2008wetpoly_UTM | PleasantValley1106 | | 2008 | 2010 | NPS | Y | Y |
| PleasantValley1108_2008wetpoly_UTM | PleasantValley1108 | UTM Zone 17N, NAD1983 | 2008 | 2010 | NPS | Y | Y |
| PleasantValley1110_2008wetpoly_UTM | PleasantValley1110 | UTM Zone 17N, NAD1983 | 2008 | 2010 | NPS | Y | Y |
| PleasantValley1112_2008wetpoly_UTM | PleasantValley1112 | UTM Zone 17N, NAD1983 | 2008 | 2010 | NPS | Y | Y |
| PleasantValley1128_2008wetpoly_UTM | PleasantValley1128 | UTM Zone 17N, NAD1983 | 2008 | 2010 | NPS | Y | Y |
| RocksideRestoration_2008wetpoly_UTM | RocksideRestoration | UTM Zone 17N, NAD1983 | 2008 | 2010 | NPS | Y | Y |
| StumpyBasin2008_wetpoly_UTM | StumpyBasin | UTM Zone 17N, NAD1983 | 2008 | 2010 | NPS | Y | Y |
| USACE_Wetlands | USACE | State Plane, Ohio North, NAD 1983, feet | 2009 | 2010 | ES | IP | Y |
| SummitMP_Wetlands_2010Clip | SummitMP | State Plane, Ohio North, NAD 1983HARN, feet | 2003-2010 | 2010 | MPSSC | Y | Y |
| CombinedWL0506_2010CVNPClip | CombinedWL0506 | State Plane, Ohio North, NAD 1983, feet | 2005-2006 | 2010 | CMP | N | Y |
| CUVADelineations2010 | CUVADelineations2010 | UTM Zone 17N, NAD1982 | 2010 | 2013 | NPS | Y | Y |
| CUVADelineations2012 | CUVADelineations2012 | UTM Zone 17N, NAD1983 | 2012-2013 | 2013 | NPS | Y | Y |
| MPSSC_2013updates | MPSSC_2013updates | State Plane, Ohio North, NAD 1983HARN, feet | 2010-2013 | 2013 | MPSSC | Y | Y |

# Appendix B:

# Site Establishment Datasheet for Wetland Monitoring

Form A-1

Site Establishment Datasheet for Wetland Monitoring

| | |
|---|---|
| Park: | Evaluator (s): |

**A. General Site Information**

Directions to the Wetland (include X, Y coordinates):

Latitude (X) Longitude (Y)

| | | | | | |
|---|---|---|---|---|---|
| 1 | Sample Type: (Base or Oversample) | | 6 | Approx wetland Size: | |
| 2 | Site ID: | | 7 | Natural or Mitigation: | |
| 3 | Circle Visit Type: (if revisit, please indicate which) | 1st visit: / Revisit: | 8 | Dominant Plant Community (Table 1) | |
| 4 | Access Permission Requirements: | | 9 | HGM Class: (Table 2) | |
| 5 | GPS File Name: (Delineation) | | 10 | Percent Invasive Cover: | |

**B. Plot Setup and Demarcation**

| | | | | | |
|---|---|---|---|---|---|
| 11 | Establishment Date: | | 12 | *Plot Setup Scenario Number: (1-4) | |

| 13 | Plot Selection Details | | Shifted Centroid | | Final | | Comments |
|---|---|---|---|---|---|---|---|
| WP | ** NS Code | Centerline Az | Distance | Azimuth | Array | Mod (l x w) | |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | | | |
| 8 | | | | | | | |
| 9 | | | | | | | |
| 10 | | | | | | | |

***Possible Plot Setup Scenarios**

| | |
|---|---|
| 1 | The wetland was an emergent, aquatic bed, or shrub-scrub plant community and a standard 2x2 array of 10x10-m modules fit within the wetland. |
| 2 | The wetland was a forested plant community and a standard 2x5 array of 10x10-m modules fit within the wetland. |
| 3 | If the wetland was an emergent, aquatic bed, or shrub-scrub plant communit but a standard 2x2 array of 10x10-m modules did not fit within the desired community type (even after shifting), the following procedures were followed to customize the array and/or plot size. |
| 4 | If the wetland was a forested plant community but a standard 2x5 array of 10x10-m modules did not fit within the desired community type (even after shifting), the following procedures were followed to customize the array and/or plot size. |

****Non-Sample Codes (NS Code)**

| | |
|---|---|
| i | The plot includes areas judged to protect significant cultural or natural resources. |
| ii | The plot is located in an area in which observers can not safely work. |
| iii | The plot, if located on private lands, could not be accessed with permission from the landowner. |
| iv | The plot, once established around the centroid, did not fall entirely within the dominant vegetation type. |

**Additional Comments:**

# Form A-1
## Site Establishment Datasheet for Wetland Monitoring

Table 1. Plant Commmunity Modifiers for Ohio Wetlands (Table 8b, Mack 2007). Highlighted communities are not known to occur in CUVA.

| 1 | Forest | 2 | Emergent | 3 | Shrub |
|---|---|---|---|---|---|
| *a* | *Swamp Forest* | *a* | *Marsh* | *a* | *Shrub Swamp* |
| (i) | oak-maple | (i) | submergent marsh | (i) | buttonbush swamp |
| (ii) | oak-maple-ash | (ii) | floating-leaved marsh | (ii) | alder swamp |
| (iii) | maple-ash | (iii) | mixed emergent marsh | (iii) | mixed shrub swamp |
| (iv) | pin-oak | (iv) | cattail marsh | (iv) | other (specify) |
| (v) | pumpkin ash | *b* | *Wet Meadow* | *b* | *Bog shrub swamp* |
| (vi) | mixed forest | (i) | wet prairie | (i) | tall shrub bog |
| (vii) | red maple | (ii) | oak openings sand prairie | (ii) | leatherleaf bog |
| (viii) | white pine | (iii) | prairie sedge meadow | *c* | *Tall Shrub Fen* |
| (ix) | cottonwood | (iv) | fen | | |
| (x) | river birch | (v) | reed canary grass meadow | | |
| (xi) | other (specify) | (vi) | other (specify) | | |
| *b* | *Bog Forest* | *c* | *Sphagnum Bog* | | |
| (i) | tamarack bog | | | | |
| (ii) | tamarack-hardwood bog | | | | |
| *c* | *Forest Seep* | | | | |
| (i) | skunk cabbage seep | | | | |
| (ii) | sedge seep | | | | |
| (iii) | skunk cabbage-sedge seep | | | | |
| (iv) | other (specify) | | | | |

Table 2. Hydrogeomorphic Classes for Ohio Wetlands (Table 8a, Mack 2007). Highlighted classes are not known to occur in CUVA.

| Class | | Class modifiers | | Comments |
|---|---|---|---|---|
| I | Depression | A | Surface water (sheet flow, precipitation) | Including areas that could be considered flats, e.g. "wet woods" |
| | | B | Ground water (seasonal to permanent input) | |
| II | Impoundment | A | Beaver | |
| | | B | Human | |
| III | Riverine | A | Headwater depression ($1^{st}$ or $2^{nd}$ order) | |
| | | B | Mainstem depression ($3^{d}$ order or higher) | |
| | | C | Channel | |
| IV | Slope | A | Riverine | Including hillside fens, mound fens, and lacustrine fens |
| | | B | Isolated | |
| | | C | Fringing | |
| V | Fringing | A | Reservoir | Does not include lacustrine fens |
| | | B | Natural lake | |
| VI | Coastal | A | Open embayment | |
| | | B | Closed embayment | |
| | | C | Barrier-protected | |
| | | D | River mouth (barred and open) | |
| | | E | Diked – managed | |
| | | F | Diked – unmanaged | |
| | | G | Diked – failed | |
| VII | Bog | A | Strongly ombrotrophic | |
| | | B | Moderately ombrotrophic | |
| | | C | Weakly ombrotrophic | |
| add code | Mitigation | | Add appropriate pre-code to HGM class | e.g. "mrII" = mitigation, restoration, impoundment |
| | | mr | Mitigation, restoration | |
| | | mc | Mitigation, creation | |

| **C. Site Sketch** |
|---|
| Please provide a sketch to highlight key features at the established site. At a minimum, include the plot boundary, position of the final sample point centroid, the Assessment Area boundaries, bearings and estimates of important distances (e.g. shifted plots), environmental gradients (e.g. water bodies, slopes) a north-arrow, general plant community types, and key witness features / attributes) |
| |

# Appendix C:

# Wetland Studies from Cuyahoga Valley National Park

## 1996+ Great Lakes Marsh Monitoring Program

With financial support from the United States Environmental Protection Agency and the Great Lakes Protection Fund, the Great Lakes Marsh Monitoring Program (MMP) was launched as a bi-national program between the United States and Canada in 1995 (Crewe et al. 2006). The program relies on partnerships between citizen scientists, foundations, governments, and non-governmental organizations to implement bird and amphibian monitoring in marshes within the Great Lakes Region. The MMP protocol was first used in Cuyahoga Valley National Park (CUVA) in 1996. Since then, the protocol has been used to monitor bird and amphibian populations in five marshes: Brookside, Heron Pond, Jaite, Lock 29, and Ira Beaver Marsh.

Between 1995 and 2004, 166 bird routes and 170 amphibian routes were surveyed in the Lake Erie Region. At these sites, populations of mallards (*Anas platyrhynchos*) and yellow warblers (*Dendroica petechial*) increased. Area-sensitive nesters, on the other hand, such as American coot (*Fulica americana*), least bittern (*Ixobrychus exilis*), swamp sparrow (*Melospiza georgiana*) and Virginia rail (*Rallus limicola*) declined, as did obligate marsh-nesting species such as the marsh wren (*Cistothorus palustris*) and common moorhen (*Gallinula chloropus*) (Bird Studies Canada 2006). During the same time period, spring peeper (*Pseudacris crucifer*) and chorus frog (*Pseudacris triseriata*) populations increased at sites within the Lake Erie Basin, whereas bullfrogs (*Rana catesbeiana*) and northern leopard frogs (*Rana pipiens*) declined (Crewe et al. 2006).

Regional trends from 1995 to 2012 within the entire Great Lakes Region also indicated that marsh breeding birds were declining (Tozer 2013). Ten of 19 marsh-associated breeding species (53%) showed population declines across the Great Lakes basin. Amphibian populations appeared stable overall. Marsh ecosystem health in the region was lower in coastal marshes and high priority conservation areas (i.e., "areas of concern") than in inland marshes and lower priority areas (Tozer 2013).

## 1999-2000 Wetland Survey

Davey Resources Group mapped 1,217 wetlands covering 1,669 acres in CUVA during a 1999-2000 survey to identify potential mitigation and restoration sites (Davey 2001). Surveyors focused on wetlands greater than 1 acre in size in all fee-owned areas to identify opportunities for restoration or mitigation in the park. Information such as wetland size, accessibility, types of impacts, and dominant species was collected for each wetland to estimate restoration feasibility.  Compatible land use parcels and other parcels leased from the park service or privately-owned were surveyed when permitted. As polygons were digitized while in the field, the accuracy in the estimated size, shape, and location depended on the accuracy of the aerial photographs, topographic layers, and the field biologist's visual estimate of the wetland boundary. As designed, the survey provided a broad overview of wetland location, size, and distribution within the park, but was not comprehensive.

### 2003 Rural Landscape Management Program Survey (Countryside Initiative)

Wetland surveys were completed as part of the Rural Landscape Management Program (National Park Service 2003). To protect wetlands within the vicinity of agricultural areas, park staff surveyed approximately 210 wetlands between 2000 and 2006. This included 121 new wetlands not previously identified during the Davey Resource Group inventory (Davey 2001). Information collected for each wetland conformed to the NPS Procedural Manual 77-1 guidelines (National Park Service 2008). Wetlands located within a 50 m (164 feet) buffer of agricultural fields were delineated using a sub-meter accurate GPS, and the Ohio Rapid Assessment Method (ORAM) was used to determine quality. Large wetlands that extended beyond the 50 m boundary were not mapped to their entirety and other data sources (wetland inventory, NWI, or aerial photos) were used to estimate the total wetland size. Specific setback criteria were used as a guideline for buffer zone establishment depending on wetland quality (ORAM category/setback distance+: 1/25 to 50 ft.; 2a/50-125 ft.; 2b/125-200 ft.; 3/>200 ft.

### 2005 Degraded Wetland Restoration Plan

Cuyahoga Valley National Park prepared a Degraded Wetland Restoration Plan in 2005 (National Park Service 2005), following existing legislation and NPS policies that emphasize an obligation to restore degraded wetlands on National Park Service lands to the extent possible, including NPS 77 (1991), Executive Order 11990 (1977), D.O. 77-1 (2008), CVNP's General Management Plan (1977), and CVNP's Resource Management Plan (1999). The Degraded Wetland Restoration Plan provides guidance for site selection, planning, project approval and compliance. The plan is categorically excluded from NEPA compliance.

The restoration assessment completed by Davey Resource Group (Davey 2001) identified a number of wetlands that were degraded by invasive species, fill, modified hydrology, or dumping. Resource Management staff used the 2001 assessment to develop immediately actionable restoration sites in CUVA as of 2004 (Rockside Road, Pleasant Valley Road, Stone Road, Tinker's Creek Road, and Hillside Road). The plan also listed some sites listed that did not seem actionable at the time because of natural recovery (Fawn Pond, Lock 29, Terra Vista) and sites that should be added to the Small Disturbed Sites action plan (Snowille, Bedford, and Volkert) and prioritized for restoration under that plan. The Degraded Wetland Restoration Plan should be appended from time to time, and newly discovered restoration sites should be treated in a manner consistent with the plan (2005).

### 2005-2006 Assessment of Wetlands in the Cuyahoga River Watershed of Northeast Ohio

In 2005 and 2006, Ohio Environmental Protection Agency (Ohio EPA) investigators and partners completed an assessment of wetlands in the Cuyahoga River watershed (Fennessy et al. 2007). A total of 243 wetlands, including 10 wetlands within CUVA, were assessed for condition and land-use impacts. Three different approaches were used to assess wetland quality: 1) a landscape analysis, calculated using remotely sensed data, as a "landscape development intensity index" (LDI), 2) qualitative, rapid, field-based indices, including the ORAM, and 3) detailed plant and animal data used to calculate Vegetation Index of Biotic Integrity (VIBI) and the Amphibian Index of Biotic

Integrity (AmphIBI). The Ohio Wetland Inventory was used as the sample frame for the population of wetlands in the watershed, and the generalized random tesselation stratified (GRTS) survey design was used for site selection. The assessment was designed to allow comparison of wetland quality across different wetland types. The study included depressional (n = 87), riverine (n = 93), man-made or beaver-made impoundments (n = 16), slope wetlands (n = 35), fringing wetlands (n = 9), and bogs (n = 3).

The average ORAM score for all wetlands in the study was "good" (55.6, Category 2). Across the entire Cuyahoga River watershed, the ORAM showed that 9.1% of individual wetlands were in poor condition (Category 1), 13.2% in fair condition (Modified 2), 51.0% in good condition (Category 2), and 26.7% in excellent condition (Category 3). There were no statistically significant differences in average ORAM scores by condition category for HGM class or plant community. However, depressional wetlands tended to score lower than other HGM types. The percentage of wetlands in the highest quality Category (3) declined from the upper basin to the middle basin and also the lower basin where CUVA is located.

An analysis of variance suggested that the predictive power of the LDI was low for assigning condition categories to individual wetlands. However, at the population level, the LDI provided good estimates for the number of wetlands that fell within the three major condition categories. Land uses within relatively narrow buffer distances from the wetlands (100 m and 250 m buffers) were important indicators of wetland condition, and wetlands with lower intensity land uses within the 100 m buffer corresponded with better condition. LDI scores at greater buffer distances tended to homogenize. Fennessy et al. recommended limiting un-natural land uses within the 100 m buffer zone for wetland protection. Not all wetlands reacted similarly to the same land uses and HGM classes appeared to be an important variable for understanding wetland response to stressors.

The low sample size of the VIBI and AmphiBI (n = 20) and the lack of Category 1 wetlands inhibited the ability to calibrate the LDI and rapid methods with the VIBI data. However, there was 60% agreement between the VIBI and the ORAM. The ORAM over-categorized in all cases, usually within one condition class, raising a "fair" VIBI score (modified Category2) to a "good" ORAM score (Category 2).

### 2003 Developing Indicators of Wetland Health

In 2003, researchers from the University of Akron initiated a study to identify potential ecological indicators of wetland health in park wetlands (Fraser 2004). Using the Davey Resource Group study as the sample frame, investigators selected 48 wetlands based on wetland type, size (<1 acre or >1 acre), and disturbance. A range of ecological variables from five major categories (water, vegetation, soils, biology, and landscape) were monitored at each wetland between July 2003 and March 2004 (Table A1). Frequency graphs and quartile tables were developed for each ecological parameter to determine normal ranges and identify values that may be potential warning signs of degradation. Three-way ANOVAs were used to examine the effects of wetland type, wetland size, and distance to disturbance on each variable.

Potential indicators were grouped into good, fair, and poor categories based on their frequency distributions. Properties that fell within the "good" frequency category were considered good indicators because the data were normally distributed with a median at the midway point of the range of values and with evident tails at the lower and upper range. The ANOVAs ($p < 0.1$) and correlation matrix indicated relationships ($p < 0.05$) between several key parameters and measures of disturbance.

Based on this analysis, the studied identified the following functional relationships.

- Invasive species cover and species richness were higher in wetlands that were closer to a disturbance.
- Conductivity, total dissolved solids, and phosphate ($PO_4$) levels were lower and ammonium ($NH_4$) values were higher in wetlands located further away from disturbance.
- Conductivity, total dissolved solids, and soil magnesium (Mg) values within wetlands increased with watershed disturbance.
- Biomass measurements were generally always higher in marsh and wet meadow wetlands.
- ORAM scores were highest in large wetlands and wetlands furthest from disturbance.

Researchers recommended devoting more attention to nine ecological parameters:  soil Mg, soil nitrogen, plant species per $m^2$, plant biomass , size of watershed, percent of watershed classified as disturbed, water depth, ammonium, conductivity, and total dissolved solids (ppm) for wetland vital signs monitoring programs.

**Table C1.** Summary statistics (Median, lower 25%, and upper 75%) and frequency distribution categories of variables collected from wetlands in the Fraser (2004) study (n = 48 wetlands).  For future monitoring efforts, Fraser suggested that measurements found below the 25th lower limit and above the 75th upper limit are thought to be outside the normal range and should be used to direct further observation and management. Parameters were classified into good, fair, and poor frequency distribution categories based on whether they were normally distributed.

| PARAMETERS | LOWER 25% | MEDIAN | UPPER 75% | Frequency Distribution Category |
|---|---|---|---|---|
| ***Soils*** | | | | |
| Moisture (%) | 34.37 | 40.98 | 53.37 | Good |
| CEC (meq/100g) | 12.7 | 13.95 | 17.0 | Good |
| K Saturation (%) | 1.1 | 1.3 | 1.6 | Fair |
| *Mg Saturation (%) | 10.15 | 11.95 | 14.20 | Good |
| Ca Saturation (%) | 57.25 | 71.00 | 81.10 | Fair |
| pH | 6.25 | 6.80 | 7.10 | Good |
| Organic Matter (%) | 1.85 | 2.20 | 3.30 | Fair |
| P (lbs/A) | 10.0 | 16.5 | 21.0 | Good |
| K (lbs/A) | 116.5 | 137.5 | 166.0 | Fair |
| *Mg (lbs/A) | 329.5 | 388.5 | 500.0 | Good |
| Ca (lbs/A) | 2775.0 | 4136.0 | 5653.5 | Poor |
| *N (%) | 0.190 | 0.265 | 0.380 | Fair |

**Table C1 (continued).** Summary statistics (Median, lower 25%, and upper 75%) and frequency distribution categories of variables collected from wetlands in the Fraser (2004) study (n = 48 wetlands). For future monitoring efforts, Fraser suggested that measurements found below the 25th lower limit and above the 75th upper limit are thought to be outside the normal range and should be used to direct further observation and management. Parameters were classified into good, fair, and poor frequency distribution categories based on whether they were normally distributed.

| PARAMETERS | LOWER 25% | MEDIAN | UPPER 75% | Frequency Distribution Category |
|---|---|---|---|---|
| ***Vegetation*** | | | | |
| Total # of species | 19.0 | 31.5 | 41.5 | Poor |
| *# of species per $m^2$ | 3.0 | 6.0 | 8.0 | Fair |
| *Biomass/m2 | 146.01 | 326.33 | 428.82 | Fair |
| ***Landscape*** | | | | |
| ORAM | 52.25 | 58.25 | 63.00 | NA |
| Watershed size (acres) | 2.595 | 12.870 | 34.890 | Poor |
| ***Biology*** | | | | |
| Decomposition 1 (%) | 38.50 | 49.06 | 64.17 | Good |
| Decomposition 2 (%) | 83.43 | 88.75 | 96.38 | Poor |
| ***Water JULY 2003*** | | | | |
| *Depth (inches) | -0.08 | 1.33 | 4.10 | Good |
| pH | 6.67 | 6.88 | 7.16 | Poor |
| *Conductivity (mS) | 323.33 | 465.50 | 899.67 | Fair |
| *TDS (ppm) | 152.33 | 236.83 | 455.00 | Fair |
| DO (%) | 0.733 | 1.800 | 2.825 | Fair |
| $NH_4$ (ppm) | 0.123 | 0.270 | 0.530 | Fair |
| *$NO_3$ (ppm) | 0.037 | 0.207 | 0.368 | Poor |
| $PO_4$ (ppm) | 0.673 | 2.668 | 5.180 | Fair |
| ***Water OCTOBER 2003*** | | | | |
| *Depth (inches) | 1.83 | 5.78 | 11.63 | Fair |
| pH | 6.42 | 6.76 | 7.15 | Good |
| *Conductivity (mS) | 365.3 | 592.3 | 823.5 | Good |
| *TDS (ppm) | 169.2 | 297.3 | 397.5 | Good |
| DO (%) | 0.350 | 0.933 | 1.717 | Fair |
| $NH_4$ (ppm) | 0.178 | 0.462 | 1.425 | Fair |
| *$NO_3$ (ppm) | 0.022 | 0.078 | 0.167 | Fair |
| $PO_4$ (ppm) | 1.733 | 4.000 | 5.833 | Fair |
| ***Water MARCH 2004*** | | | | |
| *Depth (inches) | -1.67 | -0.46 | 0.83 | Good |
| pH | 6.36 | 6.78 | 7.18 | Good |
| *Conductivity (mS) | 333.5 | 483.7 | 742.0 | Good |
| *TDS (ppm) | 170.3 | 273.5 | 524.8 | Good |
| DO (%) | 0.850 | 1.417 | 2.783 | Fair |
| $NH_4$ (ppm) | 0.028 | 0.108 | 0.310 | Fair |
| *$NO_3$ (ppm) | 0.127 | 0.177 | 0.282 | Good |
| $PO_4$ (ppm) | 0.233 | 1.200 | 3.133 | Fair |

*Identified as an important indicator for wetland vital signs monitoring as a result of the study

## 2006 Hydrology Study

A graduate student at the University of Akron studied relationships between hydrology, plant community structure, and watershed disturbance in 16 wetlands in CUVA (Manning 2006). The wetlands were selected from the 48 wetlands in the Fraser et al. (2004) study. He selected four wetlands from each Cowardin (1979) type (emergent, forested, shrub, and wet meadow), and for each type, he selected two wetlands from each of two watershed disturbance groups (high or low). Mapped disturbances included roads, golf courses, housing developments, and agricultural land. The wetlands were classified into high or low categories of disturbance after calculating the percentage of the watershed that was considered disturbed.

The results of this study indicated that the effects of disturbance on water levels, biomass, and conductivity were only significant in combination with wetland and watershed size, suggesting that the effects of disturbance may be mitigated or exacerbated by wetland and watershed size. In combination, however, watershed size and disturbance explained 99.6% of the variation in water level and biomass, while neither component strongly predicted water level individually. Wetland type, size, disturbance, and watershed size all affected the plant species richness, which was higher at disturbed sites (44.3) than non-disturbed sites (29.4). Larger wetlands and emergent types also had higher species richness. Invasive, non-native plants were among the top three dominant species in 10 of the 16 sites.

## 2004 Vernal Pool Study

Researchers from Case Western Reserve University examined the changes in physicochemical properties related to disturbance in vernal pools in (n = 10) and around (n = 20) CUVA (Carrino-Kyker and Swanson 2007). Specifically, researchers examined dissolved oxygen, pH, conductivity, and average water depth monthly, from snow melt (March) to dry down (June). They also measured nitrate, phosphate, ammonia, nitrogen, chloride, and silica in May and June. The overriding hypothesis was that the water quality of the vernal pools within disturbed watersheds would be affected by winter pollutants such as deicing salts and spring/summer fertilizers and pesticides due to recharge by surface runoff and groundwater that may contain these pollutants. The percentage of agriculture/grass, urban, suburban, open water/stream, wooded, shrub/scrub, and barren land uses were calculated within the study watersheds to examine the effects of land use.

From March to June, mean temperatures increased from 6.4°C, 13.6°C, 17.9°C, and 17.4°C, respectively, and were accompanied by a decrease in dissolved oxygen from 9.05 mg/L in March, 3.94 mg/L in April, 3.30 mg/L in May, to 2.19 mg/L in June. The temperature increase likely resulted from a temperature increase in the water recharge source (snowmelt vs rain water). Of the 30 pools, six dried in May, 17 dried in June, and seven did not dry during the study period (Carrino-Kyker and Swanson 2007). Conductivity and pH changes over time were relatively minor, although conductivity measurements were higher in pools near agriculture. Water depth in the pools was highest in March and April. Water depth was negatively correlated with urban development and positively correlated with agriculture. Most nutrients were present in low concentrations, however, chloride and silica values were considered high in May and June, ranging from 8–485 mg/L, and 0.8–

15 mg/L. Elevated chloride could be the influence of more runoff from icing salts, but elevated silica concentrations may be regional, influenced by the presence of Berea sandstone, which is a natural source of silica.

### Floristic Surveys

Several vegetation surveys dating back to 1969 provided useful information regarding rare plant occurrences and community types within area in CUVA that included wetlands. Affiliates of the Kent State University, University of Akron, and Cleveland State University completed the majority of these studies (Andreas 1986, Brown et al. 1981, DeWitt 1990, Holeski 1969, Kroonemeyer 1990, Mazzer 1980, Mazzer 1989, Wilder and McCombs 1995, Wilder and McCombs 1999).

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# Appendix D:

# Wetland Sampling Workflow for Intensively Sampled Wetlands

The wetland monitoring protocol for Cuyahoga Valley National Park includes a number of relatively complex steps. These steps include watershed ranking, wetland selection, wetland delineation, plot placement, well installation, vegetation measurement, and hydrological measurement. The diagram below (Figure B1) is designed to provide a heuristic that visually summarizes these complex steps. Field workers involved in implementing the protocol may benefit from using the diagram to review the steps and for facilitating communication about various protocol steps.

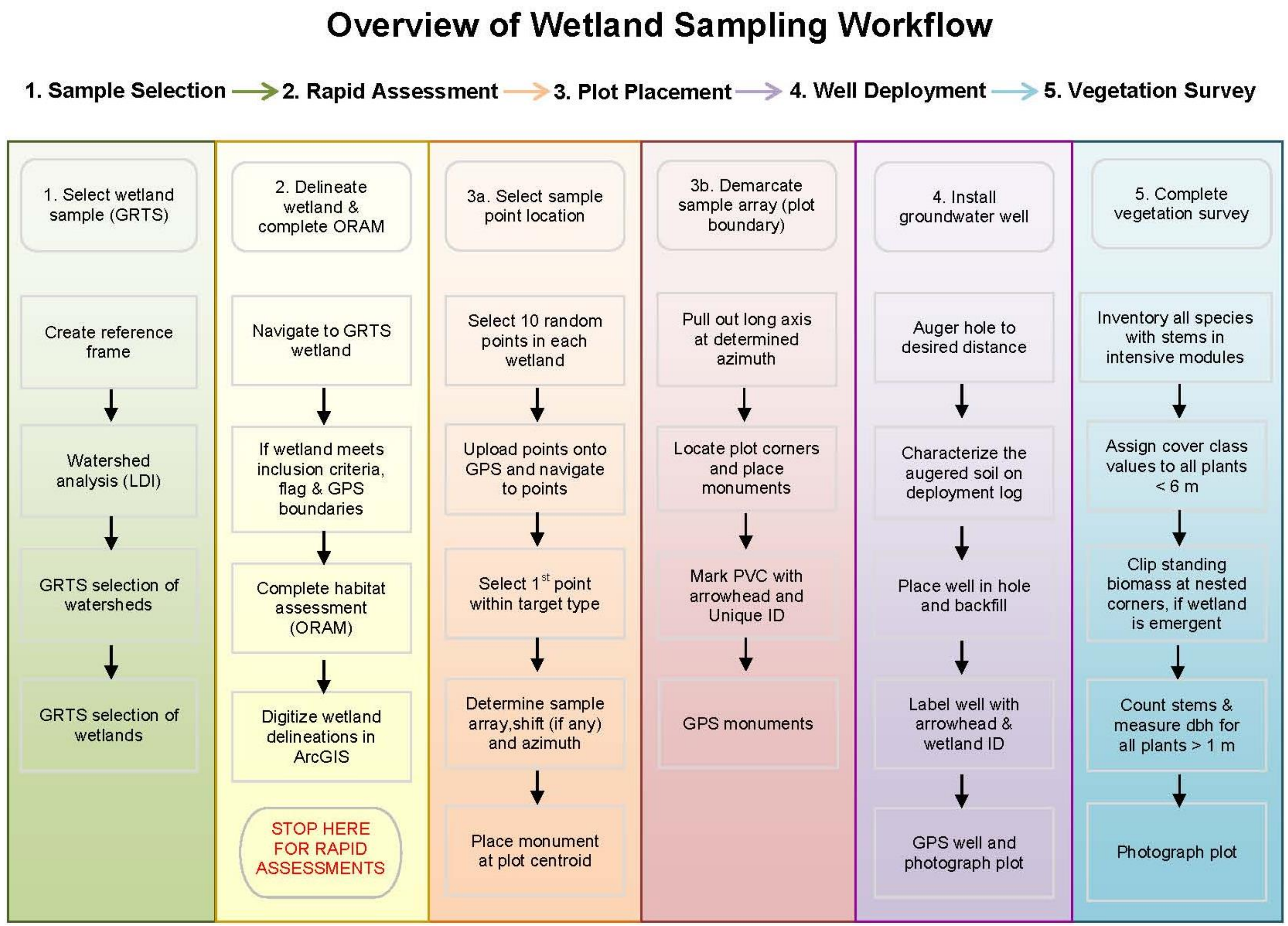


**Figure B1.** Diagram of steps required to assess wetlands using the “Wetland Monitoring Protocol for Cuyahoga Valley National Park”.

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