User Guide for Wetland Assessment and Monitoring in Natural Resource Damage Assessment and Restoration

Patrick J. Comer, Don Faber-Langendoen, Shannon Menard, Ryan O’Connor, Phyllis Higman, Yu Man Lee, and Brian Klatt

NatureServe
A Network Connecting Science With Conservation

Michigan Natural Features Inventory
Discover. Define. Deliver.
MICHIGAN STATE UNIVERSITY | Extension

WISCONSIN DEPT. OF NATURAL RESOURCES

page intentionally left blank

User Guide for Wetlands Assessment and Monitoring in Natural Resource Damage Assessment and Restoration

June 2017

Cover photos by Patrick Comer, Ryan O'Connor, and Phyllis Higman

Suggested Citation: Comer, P.J. D. Faber-Langendoen, S. Menard, R. O'Connor, P. Higman, Y.M. Lee, B. Klatt. 2017. User Guide for Wetland Assessment and Monitoring in Natural Resource Damage Assessment and Restoration. Prepared for DOI Natural Resource Damage Assessment and Restoration Program. NatureServe, Arlington VA.

User Guide for Wetland Assessment and Monitoring in Natural Resource Damage Assessment and Restoration

Abstract

The mission of the U.S. Department of Interior (DOI) Natural Resources Damage Assessment and Restoration (NRDAR) Program (hereafter "Restoration Program") is to restore natural resources injured from oil spills or hazardous substance releases into the environment. The Restoration Program assessments provide the basis for determining the restoration needs that address the public's loss and use of these resources. Damage assessments are conducted in partnership with other affected state, tribal, and federal trustee agencies. DOI and other trustee agencies use funds acquired through settlements with responsible parties to restore, replace, rehabilitate or acquire the equivalent resources that were lost or injured. As part of its policies and operating principles for natural resource restoration activities, DOI encourages its practitioners to develop restoration performance criteria to evaluate the effectiveness of restoration projects and take into consideration contingencies if monitoring results suggest corrective action is necessary. Criteria for damage assessments rely on scientifically-defensible and validated methods for characterizing and quantifying injury to natural resources and the services they provide, including human uses. As part of the damage assessment, Natural Resources Trustees (Trustees) are required to determine the physical, chemical, and biological baseline conditions and associated baseline services for injured resources in the assessment area.

Ecological integrity assessment (EIA) provides valuable information for documenting wetland conditions, and ecologically-based monitoring. The goal is to provide a succinct assessment of the composition, structure, processes, and connectivity of a wetland occurrence. Ecological integrity is interpreted considering reference conditions based on natural ranges of variation, and with a practical interpretation of site information that can inform restoration activities over time. In this guide, we outline a series of steps to develop and implement an EIA in wetland-focused NRDAR projects. These steps include:

Step 1 – **Getting Started** – Review site documentation and applicable data pertaining to the project area and plan your project;
Step 2 – **Reconnaissance Site Visit** – Visit to the restoration site, taking into consideration actions needed to compensate for natural resource impacts from a spill or release, and identify extant restoration goals, objectives, existing plans or actions;
Step 3 – Characterize Reference Conditions – Identify existing reference site data, establish conceptual models, and create field sampling design and protocols within the impact area, and among all reference sites;
Step 4 – Document Reference and Baseline Site Conditions – Implement field sampling protocols and analyze data to produce text and tabular summaries for each wetland type from the project site;
Step 5 – Establish a Site Monitoring Plan – Determine measures suitable for monitoring at the restoration site, and;
Step 6 – Documentation – Organize and populate databases, for analysis, assessment, and monitoring.

We conclude by discussing the role that these assessments have in other ecosystem-based assessments. This guide is accompanied by a database designed for management, analysis, and reporting of EIA data for wetland assessments.

Contents

Abstract iii

Introduction to this Guide 1

Great Lakes Demonstration Sites 3

Step 1 – Getting Started 5

1.1. Project Checklist 6

1.2. Plan Your Time 7

Step 2 – Reconnaissance Site Visit 9

2.1. Restoration Goals and Objectives 10

2.2. Identify Wetland Types 10

Step 3 Characterize Reference Conditions 13

3.1. Ecological Integrity Assessment 13

3.2. Components of a Wetland Assessment 14

3.3. Conceptual Ecological Models 14

3.4. What is Natural Range of Variability? 17

3.5. Select Reference Sites 18

3.6. Three Levels of Effort for Indicator Measurement 22

3.7. Select Indicators and Metrics 25

Step 4. Document Reference and Baseline Site Conditions 29

4.1. Set Assessment Points 29

4.2. Gather Field Data 31

4.3. Analyze Data 34

4.4. Report the Results: The EIA Scorecard 36

4.4. Need to Restate Restoration Objectives? 38

Step 5. Establish a Site Monitoring Plan 39

5.1. Baseline Monitoring 39

5.2. Effectiveness Monitoring 40

5.3. Validation Monitoring 42

Step 6. Documentation 43

6.1. Protocols for Metrics 43

6.2. Reference Site Databases 43

6.3. Quality Assurance and Quality Control 43

Linking Wetland Assessment and Monitoring to other Ecosystem-based Assessments 44

Watershed, Landscape, and Ecoregional Assessments 44

Ecosystem Service Assessments 44

Managing for Wetland Resiliency 45

Conclusion **45**
References **46**
ACKNOWLEDGEMENTS **51**
ABOUT THE AUTHORS **51**
APPENDICES **53**
Appendix 1 – NRDAR Wetland Project Checklist **53**
Appendix 2 – Example Conceptual Model and EIA Indicators **55**
Appendix 3 – Examples of Level 1-3 Indicators for Ecological Integrity Assessments **63**
Appendix 4 – Methods and Forms for Measurement of Ecological Integrity **72**


Photo by Diann Payne

List of Figures and Tables

Figure 1. Step-by-step project workflow for NRDAR wetland assessment and monitoring plans 2

Figure 2. Restoration and reference sites on Green Bay, Wisconsin 3

Figure 3. Restoration sitess and reference sites on Saginaw Bay, Michigan. 4

Figure 4. Natural community "element occurrences" from Natural Heritage Programs. 5

Figure 5. Restoration site at Point Au Sable on Green Bay, Wisconsin 9

Figure 6. Cross-sectional diagram to illustrate patterns of vegetation and water levels. 15

Figure 7. Generalized conceptual ecological model for assessing ecological integrity 15

Figure 8. Levels of ecological integrity reflect response to levels of stressors and can help to specify restoration goals and objectives 18

Figure 9. Restoration and reference sites for coastal marshes in Saginaw Bay, MI 20

Figure 10. Aerial imagery and interpreted land cover classes for use with landscape context metrics...... 22

Figure 11. Diagram of Rapid Floristic Quality Assessment (FQA) criteria... 30

Figure 12. Example of delineated Assessment Areas (AAs) at Charles Pond SNA, WI 33

Figure 13. Comparison of Badour 2 hardwood swamp restoration site to reference sites, based on the Floristic Quality metric ("cover-weighted mean C") 34

Figure 14. Correlation of Landscape Context scores with on-site Condition scores, using rapid assessment metrics 35

Figure 15. Testing relationships among Rapid (level 2) and Intensive (level 3) metrics 35

Figure 16. Distribution and component EIA ratings of riparian condition within and adjacent to Great Basin National Park 37

Figure 17. Flow diagram of steps involved with restoration monitoring..40

Figure 18. Location of sample transects relative to marsh gradient and dikes at Robinson restoration site, Saginaw Bay, MI 41

Table 1. Generalized ecologically-based definitions of a wetland condition gradient............................... 21

Table 2. Summary of 3-level approach to conducting ecological integrity assessments. 25

Table 3. Summary of metrics applied to wetland ecological integrity assessments................................... 27

Table 4. Example of an ecological integrity scorecard, showing metric ratings for a hypothetical wetland...36

Table 5. Ecological integrity summary for four metrics used to assess montane riparian communities at Great Basin NP, NV.. 37

Introduction to this Guide

The mission of the U.S. Department of Interior (DOI) Natural Resources Damage Assessment and Restoration (NRDAR) Program (hereafter "Restoration Program") is to restore natural resources injured from oil spills or hazardous substance releases into the environment. The Restoration Program assessments provide the basis for determining the restoration needs that address the public's loss and use of these resources. Damage assessments are conducted in partnership with other affected state, tribal, and federal trustee agencies. DOI and other trustee agencies use funds acquired through settlements with responsible parties to restore, replace, rehabilitate or acquire the equivalent resources that were lost or injured. As part of its policies and operating principles for natural resource restoration activities, DOI encourages its practitioners to develop restoration performance criteria to evaluate the effectiveness of restoration projects and take into consideration contingencies if monitoring results suggest corrective action is necessary.

Criteria for damage assessments rely on scientifically-defensible and validated methods for characterizing and quantifying injury to natural resources and the services they provide, including human uses. As part of the damage assessment, Natural Resources Trustees (Trustees) are required to determine the physical, chemical, and biological baseline conditions and associated baseline services for injured resources in the assessment area. Goal of restoration is then to return to baseline conditions.

Baseline data should:
1) reflect conditions that would have been expected at the assessment area "but for the release of contaminants;"
2) include the normal range of physical, chemical, or biological conditions for the assessment area or injured resources;
3) be as accurate, precise, complete, and representative of the resources as possible, and;
4) be restricted to those necessary for conducting the assessment at reasonable cost.

Baseline condition can be difficult and time consuming to characterize, sometimes leading to the Trustees and responsible parties using best professional judgment to estimate baseline condition in lieu of ground-based assessments. Nevertheless, Trustees need guidance on how to best apply existing scientific tools to assess baseline condition of natural resources.

In addition to damage assessments, monitoring the progress of ecological restorations can be data intensive, and requires the application of established monitoring protocols. There are many techniques for evaluating the condition or function of ecosystems. Therefore, deciphering which practices are most appropriate for measuring performance of various restoration project types can be difficult for NRDAR practitioners.

This document provides Restoration Program Trustees and restoration practitioners with decision support for assessment and monitoring of wetlands. By providing conceptual background and description of technical steps using demonstration sites from the Great Lakes region, we illustrate how NRDAR restoration practitioners can use available monitoring funds to secure staffing support and meet data requirements for their projects. The ability to evaluate, measure, and report the success of restoration projects will enhance the Restoration Program's mission and benefit restoration outcomes.

Here we present an overview of assessment and monitoring methods for use by NRDAR restoration practitioners for all types of wetlands. We first introduce a step-by-step process for organizing and carrying out a wetland-focused project. We then address each step, providing necessary conceptual background, and illustrating typical circumstances and decision points. We address the role of wetland ecosystem classification and the geographic extent and time scale of the assessment, through the development of conceptual models, identification of indicators, assessment points and thresholds, and ending with the reporting results through briefs, scorecards, and reports. We also illustrate where outcomes from certain steps might suggest revisiting prior decisions as new information comes to light. We conclude this guide by highlighting common interconnections between wetland assessment and other related assessments.

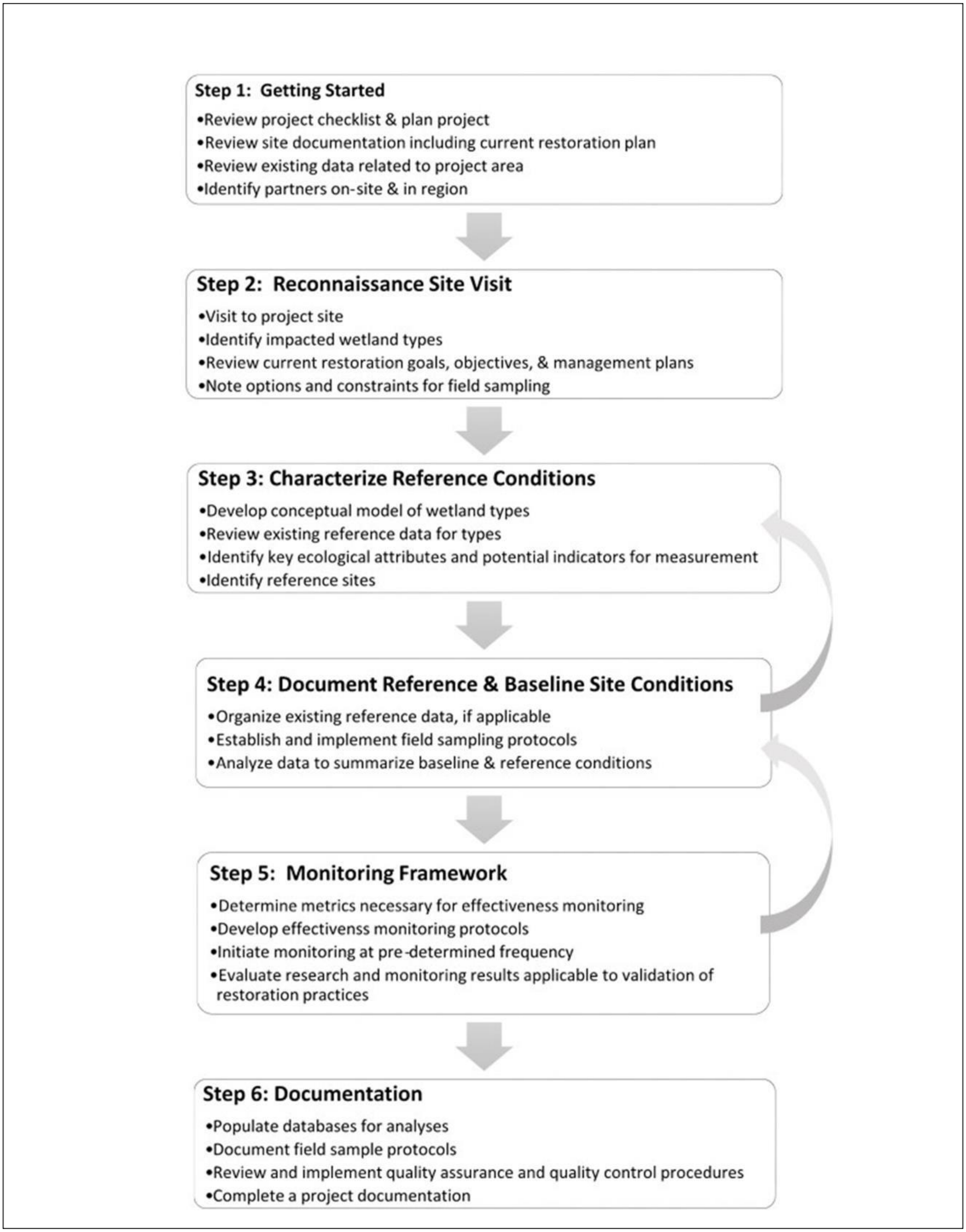


Figure 1. Step-by-step project workflow for NRDAR wetland assessment and monitoring plans.

NRDAR Project Steps

There are a series of key steps that characterize each NRDAR restoration and monitoring project (Figure 1). These steps include:

Step 1 – Getting Started – Review site documentation and applicable data pertaining to the project area. Plan your project.

Step 2 – Reconnaissance Site Visit – Visit to the restoration site, and potential reference sites, taking into consideration actions needed to compensate for natural resource impacts from a spill or release, and identify extant restoration goals, objectives, existing plans or actions.

Step 3 – Characterize Reference Conditions – Establish conceptual model of wetlands, and identify key ecological attributes and indicators for assessment. Identify reference sites and existing data.

Step 4 – Document Reference and Baseline Site Conditions – Design and implement field sampling protocols. Analyze data to produce text and tabular summaries for each wetland. This could result in your revisiting objectives and refining the conceptual model for the wetland type.

Step 5 – Establish a Site Monitoring Plan – Determine measures suitable for monitoring at the restoration site, and if feasible, at reference sites. Selecting a subset of measures to document effectiveness of restoration actions. This could trigger more reassessment of restoration objectives.

Step 6 – Documentation – Organize and populate databases, for analysis, assessment, and monitoring. Complete a project report.

Great Lakes Demonstration Sites

To help illustrate steps in this document, we will use a set of wetland sites in Green Bay, Wisconsin (Figure 2) and Saginaw Bay, Michigan (Figure 3). These pertain to NRDAR projects, and include sites targeted for off-site or compensatory restoration; that is, none were the originally-impacted site, but instead were selected for restoration using resources derived from nearby damage cases. Each site includes coastal marsh, sedge meadow, and/or forested swamp. They occur on lands managed either by state agencies or public universities.

The sites include:

- Fox River/Green Bay, Lake Michigan - Point Au Sable Nature Preserve: Point Au Sable Marsh - Great Lakes marsh and wet meadow restoration

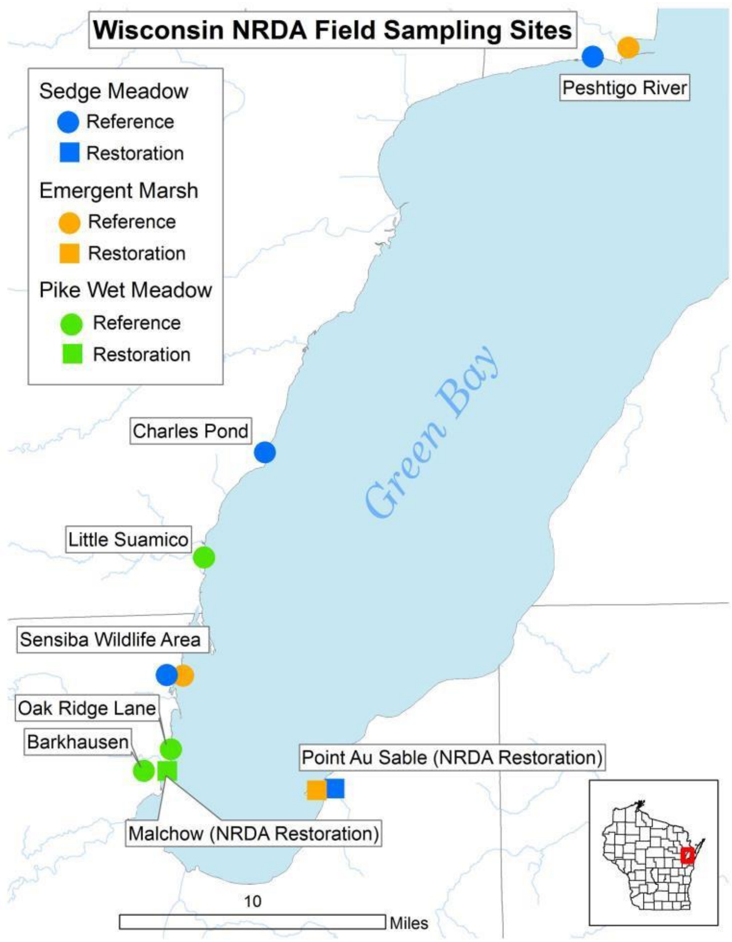


Figure 2. Restoration and reference sites on Green Bay, Wisconsin

- Fox River/Green Bay, Lake Michigan - West Shore wetlands, Malchow: Northern pike spawning and meadow habitat restoration
- Saginaw Bay, Lake Huron – Wigwam Bay Wildlife Management Area: Robinson Marsh - Great Lakes marsh restoration

- Saginaw Bay, Lake Huron – Bay City Area: Badour 2– hydrology and hardwood swamp restoration

All 4 sites appear to have been previously impacted by drains or dikes that affected hydrologic flows and interact with effects of fluctuations in Great Lakes water levels.

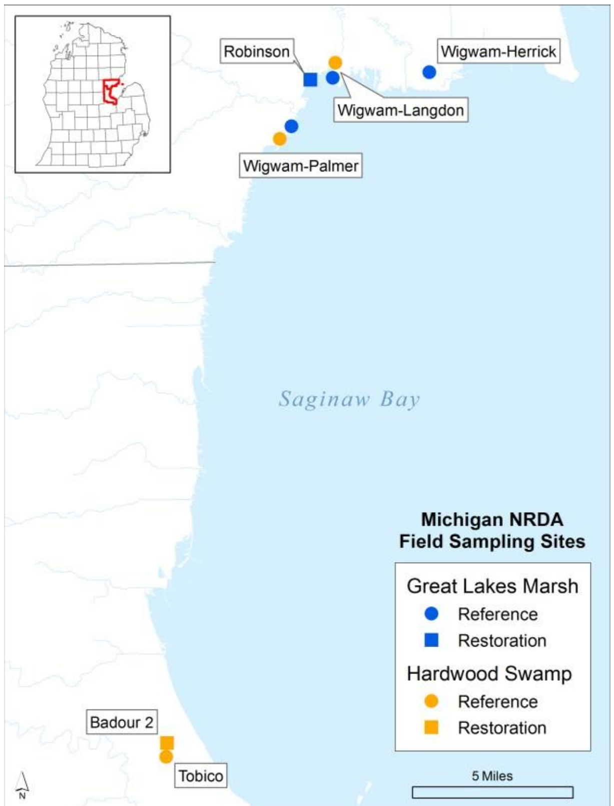


Figure 3. Restoration sites and reference sites on Saginaw Bay, Michigan.

Step 1 – Getting Started

The primary objective of this step is to identify the wetland types that may have been impacted or are the focus of restoration, and to gather extant and relevant information for documenting reference conditions for those types. This primarily involves review of existing descriptive material on wetland classifications, and maps that might pertain to affected sites.

Natural Heritage Program scientists in each state, along with NatureServe scientists[1] bring considerable expertise to the determination of baseline conditions at each site. The primary mandate of each Natural Heritage Program is to advance an inventory of biodiversity features across their jurisdiction. These biodiversity inventories include "element occurrences" which embody a detailed documentation of the location, type, and condition of a given at-risk species location or natural community type (Figure 4). The natural community occurrence data amount to over 65,000 locations, but are concentrated in states east of the Rocky Mountains.

The extensive field experience of Natural Heritage Program scientists allows them to bring important local perspectives for interpreting landscape conditions and applying expert judgment on the types of wetlands that might have been impacted and their relative condition prior to the impact.

NatureServe functions as a coordinating institution for the network of state/tribal based Natural Heritage Programs. NatureServe specialists work extensively across multi-state jurisdictions and collaborate with Natural Heritage Program staff to standardize methods and data sets for application to conservation decisions. For this reason, NatureServe ecologists provide leadership and coordination for the advancement of wetland classifications, regional map products, and methods for site assessment that apply equally well across state jurisdictions.

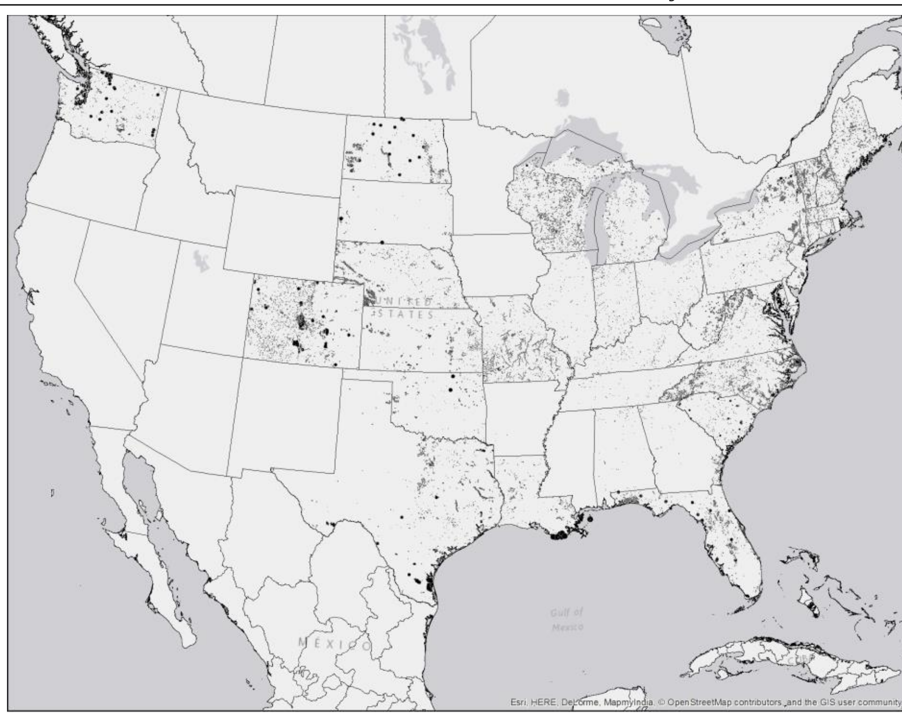


Figure 4. Natural community "element occurrences" from Natural Heritage Programs. *(n = ~65,000; source: NatureServe).*

[1] http://www.natureserve.org/natureserve-network/directory

In this step for our Great Lakes examples, ecologists pooled available information from coastal zones encompassing each restoration site. These data included a) wetland classifications (NatureServe, state, local), b) maps (National Wetland Inventory, NatureServe, state and local), c) reference site data (wetland element occurrences), EPA National Wetland Condition Assessment sites and other forms of field observation data applicable to project site.

Great Lakes coastal wetlands have received considerable attention for ecological assessment and monitoring. The Great Lakes Coastal Wetlands Monitoring Program (GWMP)[2] has established wetland monitoring sites throughout the region. Available sample data were accessed and reviewed for applicability.

It can be useful to create a data dictionary to document the location, utility, and any use restrictions associated with data sets identified for the restoration site. A typical data dictionary will be a table capturing key information for each data set. This information includes the name, location (.url), brief description, geographic coverage, and limitations, to help locate and utilize each data set.

1.1. Project Checklist

Both initiating and overseeing a wetland restoration project can seem overwhelming. Identifying specific information, partners, and expertise is essential to plan and implement a high-quality effort.

Needs for specialized expertise may vary based on project characteristics, and over the life of the project. One should plan for expertise in wetland ecology, botany, soils, GIS analysis, and database management. Botanical expertise is typically required in baseline monitoring sufficient to identify most wetland plants, while in effectiveness monitoring, focal indicators might only require recognition of few dominant species.

The NRDAR practitioner could utilize the following checklist (Box A; Appendix 1) to plan their time, secure needed information and expertise, and fully utilize material included in this guide throughout each step of the process.

Box A - PROJECT CHECKLIST

	Task	Guide Section
☐	Locate impacted and/or restoration site	Step 1
☐	Contact site management staff ○ Identify existing information about the site	Step 1
☐	Is there a current restoration plan?	Step 1
☐	Identify existing ecological assessments of area and establish data dictionary	Step 1
☐	Identify potential partners, stakeholders, and technical experts relevant to restoration site	Step 1
☐	Identify needed expertise (wetland ecologist, spatial analyst, database manager)	Step 1
☐	Review existing documentation on site ○ Wetland descriptions ○ Published documents ○ Wetland sample data ○ Land use/land cover maps and aerial photos	Step 1
☐	Carry out reconnaissance site visit ○ Identify wetland type(s) impacted ○ Identify wetland type(s) targeted for restoration ○ Identify type similarities ○ Visit potential reference sites	Step 2
☐	Document specific restoration goals and timelines ○ Are restoration goals stated? ○ Are restoration objectives specified? ○ Are restoration objectives specified along a timeline?	Step 2
☐	Establish site boundaries to be included in restoration ○ Relevant landscape context of restoration site	Step 2
☐	Identify potential reference sites ○ Same wetland type nearby ○ Same wetland type within major watershed	Step 2
☐	Identify existing documentation of reference conditions ○ Complete conceptual model of wetland type ○ Describe reference conditions in terms of key ecological attributes (KEA) ○ Identify primary indicators and metrics for each KEA	Step 3
☐	Complete sample design for Level 2-3 metrics ○ Restoration site	Step 4

[2] http://www.greatlakeswetlands.org/Home.vbhtml

	○ Reference sites (as needed)	
☐	Identify field equipment and documentation methods ○ Developed field data form ○ Collected field equipment	Step 4
☐	Identify field crew	Step 4
☐	Complete initial field sampling ○ Restoration site ○ Reference sites (as needed) ○ Populate sample database	Step 4
☐	Complete Level 1 measurements in office	Step 4 (Example, Appendix 2a)
☐	Analyze data to establish assessment points and metric ratings for each metric	Step 4 (Metric examples, Appendix 2)
☐	Complete assessment scorecard	Step 4
☐	Document baseline ratings ○ Re-assess restoration objectives given baseline assessment	Step 4
☐	Establish monitoring plan ○ Establish effectiveness measures in terms of metrics ○ Restate short-term objectives in terms of metric ratings (3-5 years) ○ Restate medium term objectives in terms of metric ratings (6-10 years) ○ Restate long-term objectives in terms of metric ratings (11-30 years)	Step 5
☐	Document needs for Validation Monitoring	Step 6
☐	Package and disseminate site report and database	Step 6

1.2. Plan Your Time

After reviewing the checklist, the amount of time and effort for the baseline assessment and creation of a monitoring plan can be estimated. This will vary based on the assessment level desired. Level 3 intensive assessments (see Section 3.6) are the most time intensive and require higher levels of expertise. For all levels of assessment, the minimal staff expertise should include a lead scientist (e.g., wetland ecologist), a botanist, a spatial analyst, and a data manager. The lead scientist should be familiar with the wetland types within the region being considered for monitoring including a basic understanding of soils, hydrology, and vegetation. A spatial analyst is needed to locate sample locations, complete Level 1 assessments, and if applicable, help field crews identify plot locations. A data manager can add data collected to a database and continue to manage this database with future monitoring efforts.

Level 2 and 3 assessments require field data collection and will require a lead field botanist/ecologist and field assistant to collection and record data on-site. For level 2 assessments, knowledge of common wetland species and basic hydrology and soils is needed. For level 2 and 3 assessments, field crew expertise should be akin to that needed for wetland delineation; that is, field crews should have some knowledge of hydrology, soils, and vegetation, sufficient to assess hydrologic dynamics, perhaps examine a soil core for mottling and other features. The botanist should be able to identify, and train field crews to identify, the most wetland plants they are likely to encounter, and/or be prepared to gather specimens for subsequent laboratory identification.

For level 2 rapid assessments, a two-person field crew should be able to assess one site within 2-4 hours (excluding travel time to/from the site), plus two-hour preparation time evaluating remote imagery. Field forms are essentially complete on site.

For intensive assessments, determine the number of plots and subplots (quadrats) needed to characterize the vegetation and abiotic site conditions. A minimum of three sample plots should be used. Box B below contains a baseline time estimate for each position to complete a level 3 intensive assessment for one restoration site with three associated reference sites. The lead scientist (with help from the lead field botanist) would be responsible for all gathering baseline information, contacting site managers, developing the field forms, etc., developing the monitoring plan, and completing any final documentation. The spatial data manager time includes time to locate spatial data for the site and complete a level 1 assessment. It is assumed that field time to complete levels 2 & 3 assessments would be approximately 1 sampling day per site with 6-9 replicate intensive plots taken at each site with additional time included as a contingency for difficult access, inclement weather, etc. Data manager time includes time to enter the field data into a database (see Section

6.2) and generate reports from the database necessary for the lead scientist to complete the monitoring framework. These time and effort by staff should be adjusted based on the number of potential restoration sites and the level of assessment for a specific project. For example, those sites that have difficult access or highly diverse vegetation may require more field time for an intensive level 3 assessment. If only a level 2 assessment is required, the site sampling time could be greatly reduced.

Box B: Time in hours per task by staff expertise for baseline assessment and monitoring plan. These estimates assume Level 3 intensive assessment of one restoration site with three reference sites.

Task	Lead Scientist	Field Botanist/ Ecologist	Field Assistant	Spatial Data Analyst	Database Manager
Baseline Information Development	40			24	16
Reference Site & Field Design	40	24	40	40	
Reference & Restoration Site Visit	24	24			
Field Site Sampling		40			
Data Entry& Analysis		8		10	40
Develop Monitoring Framework	80				16
Final Report	40			8	
Total	**224**	**96**	**40**	**82**	**72**

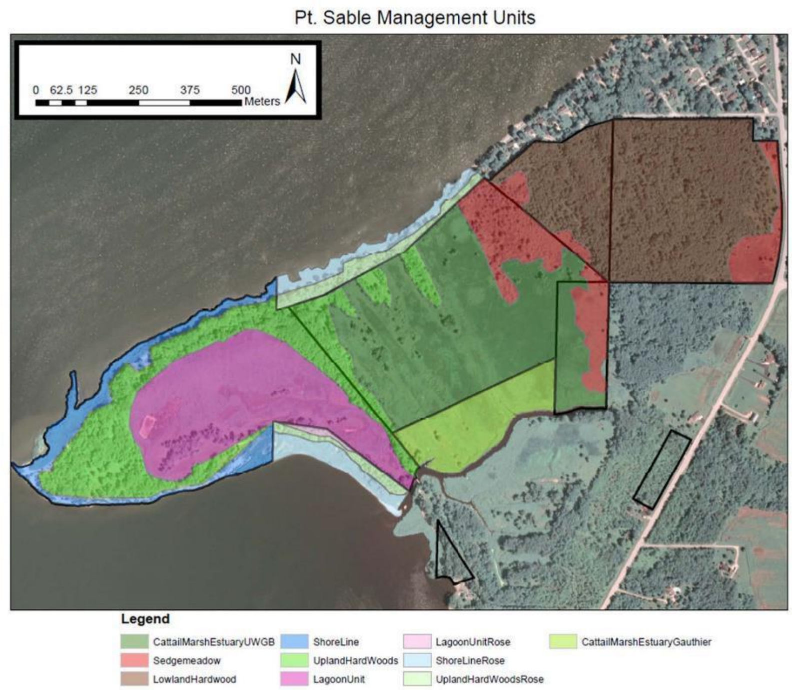


Figure 5. Restoration site at Point Au Sable on Green Bay, Wisconsin.

Step 2 – Reconnaissance Site Visit

One or more reconnaissance visits should include wetland experts and managers from the restoration site. During the visit, the team should make a final determination of the wetland type or types that were impacted and/or will be the focus of restoration. Prior information gathering should have narrowed the possible range of wetland types involved, and so the site visit should attempt to make a final determination.

Second, the team should clarify the nature of any impact that occurred on the site. For example, they should determine if the impact was limited to a specific impacting event, resulted in alteration of wetland hydrology, resulted in the introduction of invasive species, and/or removed or killed vegetation. They should also attempt to discern causes of impacts (e.g., contaminants versus other stressors) and whether prior alterations (e.g., land/water use decisions) may have influenced wetland condition.

A third outcome is to clarify any restoration goals and objectives that have been established for the site. With greater specificity in restoration objectives, assessment and monitoring can be more precisely designed for project needs.

Additional outcomes from a site visit could include updates on any existing plans or actions already implemented for wetland restoration. There may be ongoing actions on site that will directly influence subsequent analysis steps, such as field sample design.

In one demonstration site, the restoration project at Point Au Sable on Green Bay is managed by the University of Wisconsin, Green Bay (Figure 5). Wetlands here formed in a "dune and swale" complex with changing lake levels over the past several thousand years. The large lagoon adjoining Green Bay are directly affected by lake level fluctuations while interdunal swales further inland are more strongly influenced by stream inputs and adjacent lands.

With low water levels in recent years, the lagoon became infested with invasive giant reed (*Phragmites australis*) which forms dense patches that displace other plant species. The management objectives here were generally stated as enhancing habitat quality for migratory birds and for habitat diversity. Herbicide treatments had been applied to several established management compartments on the site at the time of site reconnaissance.

2.1. Restoration Goals and Objectives

Within a wetland restoration context, goals can be generalized statements of desired outcomes from restoration (Ramsar Convention, 2002). Example goals might include "recovering the hydrology, soil, and plant species composition of the wetland as it occurred prior to the impacting incident." At the Point Au Sable site on Green Bay, restoration goals were stated generally to "restore and maintain migratory bird habitat" and restore the marsh to "native plant and animal dominance and diversity."

Restoration objectives tier down from each goal statement to more precisely express actions and outcomes that may be measured through monitoring over set timeframes. Objective statements should lend themselves to measuring progress toward specific milestones that might be reached over one or more years. Restoration objectives relate directly to restorative practices, in that those practices often form the near-term actions to be taken in the site (Box C).

Another of Green Bay demonstration sites, at Malchow Pike Meadow, specifically aimed to restore breeding habitat for Northern Pike *(Esox lucius)* with a goal stated simply as "breeding success." But in addition, acknowledging the importance of wetland hydrology and vegetation, specific objectives were stated in terms of vegetation structure and composition (a native, wet sedge/grass meadow, and sufficient water depth during the Pike's April-May breeding season.

2.2. Identify Wetland Types

Ecological classifications serve a similar function to taxonomies for plants and animals. They help managers to identify a given wetland type at their site, and then identify other locations where the same wetland type occurs today, or could be restored. Classifications help managers to understand natural variability within and among sites, and thus play an important role in helping to distinguish sites that differ across gradients of conditions and stressors (Collins et al. 2006). For example, the hydrologic characteristics of tidal salt marshes are distinct from that of Great Lakes coastal marshes, inland depression marshes, floodplain forests, or boreal peatlands. Wetland classifications provide a means to establishing "ecological equivalency;" that is, that a marsh restoration in the Great Lakes region is based on the regional character, rather than a distinct wetland type found at other environmental settings.

Wetlands can be defined and classified broadly or narrowly, and from a variety of different perspectives, all depending on the needs of the user (Box D). Some wetland classification systems aim to describe characteristics of environmental setting and hydrology, so that they may inform management issues such as flood control, sediment stabilization, and other wetland functions (Brinsen 1993). Others integrate biotic components of wetlands – such as vegetation structure and composition - where applications to biodiversity and wildlife habitat conservation are required (Cowardin et al. 1979, Comer et al. 2003, Faber-Langendoen et al. 2014).

Box C. Restoration Goals and Objectives

A generalize goal statement, such as "restore and maintain wildlife habitat" is appropriate to communicate the overall desired outcome, but you should state specific objectives pertaining to restoring hydrology, soils, and plant species composition. A restoration objective for hydrology in a site might include "removal of current diking or drain tiles to re-establish natural flooding regime." That natural flooding regime might be more precisely stated to include influences from varying sources on the site, such as inland stream inputs vs. lake or tidal level fluctuations in coastal wetlands. Objectives pertaining to soil could specify re-establishment of organic layers accumulated by recovering vegetation and organic decomposition. Objectives pertaining to plant species composition might specify "reduction of invasive plants to <5% cover in favor of native plant species."

Ecological classifications are often structured hierarchically, and so the level of classification specificity is sometimes referred to as the "thematic" scale. For example, in North America, we can identify the forested swamps in one category that encompasses all their variation across the southeastern United States. Further down in the classification hierarchy, the typical vegetative structure and composition for swamps would be used to differentiate Pond-cypress basin swamps from hardwood-loblolly pine flatwoods occurring on the Atlantic Coastal Plain.

Photo by Shannon Menard

In choosing a classification for use in ecological assessment, restoration, and monitoring, one should favor those that a) are multi-scaled (so different projects can identify the thematic scale appropriate to the study), b) use both biotic and abiotic factors in defining types (so that the overall natural variability of ecosystems is accounted for), and c) are well-established, and used by multiple agencies and organizations. Where the latter is true, it increases the likelihood of accessing available data from other studies.

Several wetland classifications are available for describing types at restoration and reference sites (see Box D).

Photo by Patrick Comer

Box D: Common Wetland Classification Systems

Several wetland classification systems are in common usage for description and mapping across the United States (EPA 2002). These include the National Wetlands Inventory (NWI), hydrogeomorphic classification (HGM), NatureServe Terrestrial Ecological Systems, and the U.S. National Vegetation Classification.

National Wetlands Inventory (NWI) (https://www.fws.gov/wetlands/): This Fish and Wildlife Service program produces maps of wetlands from aerial imagery, labeling map classes using the classification of wetland and deepwater habitats (Cowardin et al.1979). The hierarchical classification includes three levels (System, Subsystem, Class) for marine, estuarine, riverine, lacustrine, and palustrine habitats systems. Wetlands, if defined to include rooted or floating vegetation, are described under the palustrine and lacustrine systems. (https://www.fgdc.gov/standards/projects/wetlands/nvcs-2013).

Hydrogeomorphic (HGM) classification (https://wetlands.el.erdc.dren.mil/class.html): This environmentally-based approach to wetland classification supports functional condition assessment (Smith 1995) of a specific wetland referenced to data collected from wetlands across a range of physical conditions. It utilizes geomorphic position and hydrologic characteristics to group wetlands into seven different wetland classes as defined by Brinson (1993). The seven classes are: depressional, riverine, mineral flats, organic flats, tidal fringe, lacustrine fringe, and sloping. See example from Great Lakes coastal marshes (Albert et al. 2005).

NatureServe Terrestrial Ecological Systems (http://explorer.natureserve.org/): This classification of terrestrial environments integrates vegetation communities with landscape setting, soils, hydrology, and other natural dynamics. Some 150 wetland, riparian, and floodplain types have been mapped nationally using this classification under regional and national efforts of the USGS Gap Analysis Program (e.g., Comer and Schulz 2007) and inter-agency LANDFIRE (Rollins 2009).

The EcoVeg approach (Faber-Langendoen et al. 2014) integrates vegetation and ecology into a multi-tiered hierarchy of vegetation types, both upland and wetland. The approach is used by, the U.S. National Vegetation Classification (www.usnvc.org). Wetlands may be described at six levels of detail from formation, division, macrogroup, group, alliance, and association (FGDC 2008).

Together these classifications meet several important needs for wetland assessment and restoration, including:

- using a multi-level, ecologically based structure that allow users to address conservation and management concerns at the level relevant to their work.
- creating a comprehensive list of ecosystem types across the landscape or watershed, both upland and wetland.
- integrating biotic and abiotic components that is effective at constraining both biotic and abiotic variability within a type.
- in some examples, information on the relative rarity or at-risk status of ecosystem types (e.g., “endangered” ecosystems) is available.
- support federal standards (e.g., the NWI and USNVC) are federal standards for U.S. federal agencies, facilitating sharing of information on ecosystem types.
- access to readily available web-based information
- inform comprehensive maps of ecosystems at varying levels of spatial and thematic detail.

Some state agencies have either adopted these classifications directly (e.g., Hoagland 2000), or developed closely compatible classifications. See examples from Michigan (https://mnfi.anr.msu.edu/communities/) and Florida (http://fnai.org/naturalcommguide.cfm). Natural Heritage Programs can be a resource for identifying wetland classification and map information in each state.

Step 3 Characterize Reference Conditions

Once we understand the types of wetlands on site, how they were impacted, and site managers' goals and objectives for restoration, we can concentrate on the primary step of wetland assessments. We now want to organize information to assess ***ecological condition, integrity, or 'health'*** of the targeted wetlands on site. This will involve organizing information about each affected wetland type and analysis of data gathered from similar sites so that we can document ***reference conditions*** of each target wetland type.

Wetland ecosystems are complexes of plants, animals, soils, water that provide critical benefits to society, such as water quality maintenance, flood control, carbon storage, wildlife habitat, and aesthetic enjoyment. But their complexity also makes it challenging to characterize their ecological condition. Assessing that condition has become important, as stressors such as land conversion, invasive species, and climate change alter the processes that underpin how they function, and in turn, limit the benefits they provide. For that reason, ecologists have pursued a variety of methods to track and respond to declines in ecosystem condition, including methods focused on the concept of "ecological integrity."

Building on the related concepts of biological integrity and ecological health, ecological integrity is a core concept for assessing and reporting on ecological condition (Harwell et al. 1999, Andreasen 2001).

Ecological integrity can be defined as "*the structure, composition, function, and connectivity of an ecosystem as compared to reference ecosystems operating within the bounds of natural or historical disturbance regimes*" (Parrish et al. 2003).

The U.S. Forest Service defines ecological integrity as "*the quality or condition of an ecosystem when its dominant ecological characteristics (for example, composition, structure, function, connectivity, and species composition and diversity) occur within the natural range of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human influence"* (36 CFR 219.19).

To have integrity, an ecosystem should be relatively unimpaired across a range of ecological attributes and both spatial and temporal scales. The concept of integrity depends on an understanding of how the presence and impact of human activity relates to natural ecological patterns and processes. This information provides restoration practitioners with critical information on factors that may be degrading, maintaining, or helping recovery of the wetland.

3.1. Ecological Integrity Assessment

NatureServe, in collaboration with a variety of agency partners, have developed methods for ecological integrity assessment (EIA) applicable to wetlands and other ecosystem types (NatureServe 2002, Unnasch et al. 2008, Faber-Langendoen et al. 2012, 2016c).

A first essential requirement for assessment is a conceptual ecological model for each wetland type that helps identify the key ecological attributes for which measurable indicators are most needed. Identifying the attributes most needed to assess and monitor is essential to making management decisions that will maintain ecological integrity (Noon 2003). The process of modeling and indicator selection leads to a practical set of metrics for assessment.

This EIA framework is like other multi-metric approaches, such as the Index of Biotic Integrity and the Tiered Aquatic Life Use frameworks for aquatic systems (Karr and Chu 1999, Davies and Jackson 2006), and a variety of state-based wetland rapid assessment methods (see Fennessy et al. 2007a, Wardrop et al. 2013), and EPAs Vegetation Multi-Metric Index (USEPA 2016).

Common to each of these methods is that each metric is rated by comparing measured values with values expected under relatively unimpaired conditions. These unimpaired conditions are called the "reference standard." Rating multiple metrics, across multiple key ecological factors provides a picture of the overall integrity of the wetland. Therefore, metric ratings provide a standard "biophysical exam" indicating how well a wetland type is doing at a given location.

3.2. Components of a Wetland Assessment

Ecological integrity assessments include the following six components:

1. Develop a general conceptual model that draws from information on historical ranges of variation, as well as current studies from similar sites, to identify the key ecological attributes of the wetland type. Summarize the model using a narrative description, including how the attributes are impacted by various natural dynamics and stressors.
2. Identify the indicators and related metrics that best represent each key ecological attribute and any available data related to these metrics. This can be an iterative process, based on a variety of criteria, including scientific, management, and operational considerations.
3. Use a three-level measurement structure to organize indicators, including (i) remote sensing, (ii) rapid ground, and (iii) intensive ground-based measurements. The 3-level structure provides both increasing accuracy of ecological integrity ratings when all three levels are used, and increased flexibility in choosing a level of assessment suitable for the application.
4. Gather data using consistent sampling protocols from the project site and reference sites with the same wetland type, and then analyze the data to document the variability within each metric.
5. Identify assessment points and thresholds that guide the ratings for each metric along a continuum or into categories from "high" to "low" integrity.
6. Analyze data to test relative similarities among restoration and reference sites, and compare condition to stressor metrics.
7. Complete scorecards and reports that facilitate interpretation of the integrity measures to establish a baseline status and detectable trends, and for subsequent monitoring.

Below, we describe each component in more detail.

3.3. Conceptual Ecological Models

Conceptual ecological models are developed to clarify our knowledge of ecosystem structure and dynamics (Noon 2003, Bestelmeyer et al. 2010). They identify key system components, linkages, and processes that are the "key ecological attributes" of the wetland type. Once key attributes are identified, measurable indicators and specific metrics can be chosen to better understand the response of the wetland to specific drivers and stressors, and then inform restoration actions. These models typically take the form of summary narratives, cross-sectional illustrations (Figure 6), and/or "box and arrow" diagrams that summarize the relationships among ecological components, natural dynamics, and their responses to stressors. See **Appendix 1** for an example conceptual model for Great Lakes coastal marsh.

We can summarize the conceptual ecological modeling as follows (see Mitchell et al. 2006):

Identify recurring pattern and drivers: Identify the most important phases or states and drivers of those states for the wetland type.

Example: Describe relation of open marsh, wet meadow, and shrub swamp that characterizes lacustrine coastal marshes in the Great Lakes region.

Example: Describe the states and transitions of Great Lakes coastal marsh with natural lake-level fluctuations and coastal dynamics from storm surges and winter ice scour.

Example: Describe the relation of tree and shrub swamp in shallow to deep water levels in a swamp forest.

Example: Describe the successional dynamics of tree and shrub swamp mosaics with decadal-patterns of water level fluctuations.

Identify Stressors and Sources: Identify the most important human-caused stressors acting upon the wetland type, and common sources of each stressor.

Example: Identify common vegetation patterns resulting from installation of wetland diking, shoreline hardening, disruption of inland stream flows into coastal marshes.

Example: Describe the response of swamp forest successional dynamics to installation of drainage tiles.

Identify Diagnostic Species, Ecological Dynamics, and Transitions: Identify the selected taxa, internal ecological dynamics, and transitions between states that are relevant to restoration decisions affecting the wetland.

Example: Describe the diagnostic or most indicative plant species within each vegetation zone, and/or focal resident bird species in a coastal marsh.

Example: Describe the diagnostic or most indicative tree and shrub species within each vegetation zone of a forested swamp, and/or focal resident amphibian species.

Example: Identify core abiotic and biotic water quality indicators linked to eutrophication (water N & P).

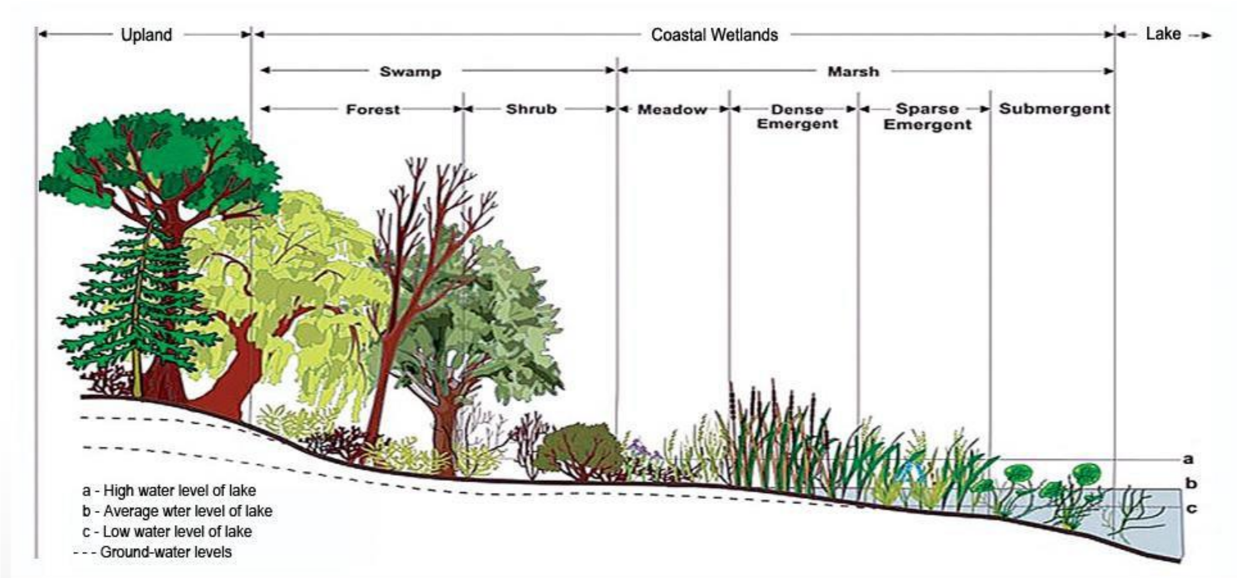


Figure 6. Cross-sectional diagram to illustrate patterns of vegetation and water levels.
(from the International Joint Commission (http://www.ijc.org/loslr/en/background/w_wetlans.php).

Despite the natural diversity of wetland types and conditions, they often share broadly common components. For most wetland models, key ecological attributes can be organized into categories of landscape context (i.e., surrounding landscape dynamics and stressors), on-site condition (plant and animal composition, hydrology, soil), and the size of the wetland relative to other examples of the same type (NatureServe 2002, Parkes et al. 2003, Oliver et al. 2007) (Figure 7). The model should address both the "inner workings" (condition), like water level fluctuations, and productivity and the "outer workings" (landscape context) of an ecosystem (Leroux et al. 2007), and both may be influenced by the size of the wetland occurrence.

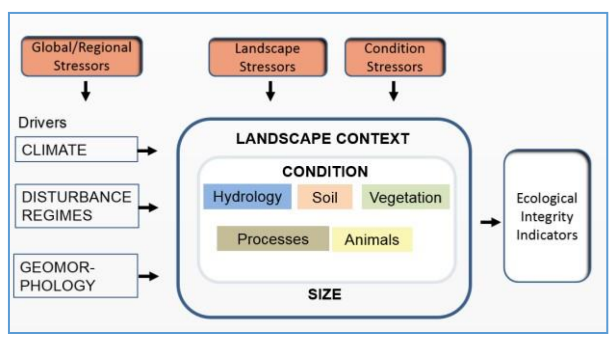


Figure 7. Generalized conceptual ecological model for assessing ecological integrity.

The model can be detailed to include specific attributes, such as native vs. invasive species, and ecological processes (specific hydrologic regime) or functions (e.g., flood storage capacity, fish and wildlife productivity).

Specific attributes may then include natural effects of animal behavior (e.g., beaver activity), soil and water chemistry, and ecological processes (e.g., flooding, and productivity) as they occur at landscape and within-wetland scales.

Attributes can also be the primary stressors, such as removal of beaver activity, toxic pollution or eutrophication from nutrient inputs, altered hydrology, and sensitive native species displacement by invasive species.

The following terminology is commonly used in developing conceptual models:

- **Ecosystem drivers** are major external driving forces such as climate, hydrology, and natural disturbance regimes (e.g., hurricanes, droughts, fire) that have broad and pervasive influences on natural ecosystems.
- **States** are the characteristic combination of biotic and abiotic components that define types or phases of ecosystems (e.g., early, mid, and late seral stages). States both control and reflect ecological processes.
- **Stressors** are human-caused physical, chemical, or biological perturbations to a system that are either foreign to that system, or natural to the system but occurring at an excessive or deficient level. Stressors cause cascading effects to other components, patterns, and processes within natural systems. Examples include water withdrawal, native species displacement, land-use change effects, and water pollution.
- **Key Ecological Attributes** (KEA) are subset of ecological factors that are critical to the ecosystem's response to both natural ecological processes and human-caused stressors (Parrish et al. 2003). Change in key ecological attributes can result in degradation or "collapse" of the wetland occurrence.
- **Indicators** are the measurable form of key ecological attributes. That is, they are the ecosystem features or processes that can be measured and their values are indicative of the integrity of the wetland where they are measured. One or more indicators should be identified for each KEA.
- **Focal taxa** are a special kind of indicator that – due to their sensitivity or exposure to stress, their association with other taxa, or their life history characteristics - might serve as useful indicator species of ecological integrity. Focal taxa might include 'keystone species,' such as beaver (*Castor canadensis*) that can be considered ecosystem engineers (Ellison et al. 2005).
- **Metrics** are the specific form of an indicator to be measured, specifying both a) the *units of measurement* needed to evaluate the indicator, and b) the *assessment points and ratings* (e.g., "high" to "low") by which those measures are informative of the integrity of the wetland occurrence. For example, *measures* of percent cover and "coefficients of conservatism" are needed for each plant species occurring in the wetland when applying the floristic quality index metric. The metric defines the equation (e.g., "weighted mean C") and the *assessment points* that determine the rating assigned to the values (e.g., the range of weighted mean C values = A-rating for high quality) (Swink and Wilhelm 1979, Bourdaghs 2012). See Section 4.1 for further details on assessment points.

What About Created Wetlands?
Conceptual models are often developed for natural wetland types, but depending on the restoration goals, there may also be a need to develop models for reclaimed areas and created wetlands that have no clear natural analog. For example, in the Great Lakes study, we evaluated wet meadows created from former farm fields with an intent to provide spawning habitat for northern pike. The goals were to create wet meadows primarily to meet the hydrologic and vegetation cover required by the pike, and only secondarily to encourage native plant species characteristic of natural wet meadows. In this case, the conceptual model and metric selection would need to primarily emphasize the specific hydrologic and vegetation structure requirements for pike spawning.

3.4. What is Natural Range of Variability?

Species have evolved and native ecosystems have developed within dynamic environments over millennia. Vegetation structure and species composition of any wetland type naturally varies over time and across regions, and each location experiences varying disturbances from fire, drought, wind impact, or flooding. Natural resource managers often use the concept of a natural range of variability (NRV) (synonymous with historical range of variability, or HRV) to describe these historical characteristics of ecosystems (e.g., Landres et al. 1999, Romme et al. 2012). Our knowledge of NRV is based on studies of historical conditions, research on current condition of sites that are relatively free of human stressors, and through simulation models of ecosystem dynamics (Parrish et al. 2003, Stoddard et al. 2006, Brewer and Menzel 2009). This knowledge provides important clues about the ecological processes and natural disturbances that shape ecosystems, the flux and succession of species, and the range of conditions one might expect to encounter in relatively unaltered "reference standard." It also provides a reference for gauging the effects of current anthropogenic stressors (Landres et al. 1999). For these reasons, understanding NRV is an important part of conceptual ecological modeling (See Box E).

With accelerating land use and climate change, concerns are commonly raised that natural and historical information is no longer relevant. But, there are a several ways in which NRV remains an important guide for our conceptual models of ecological integrity, and for adaptive ecological restoration (Higgs 2003, Higgs and Hobbs 2010):

- First, ***it is the knowledge of natural variability*** that informs our goals, objectives and evaluations of current conditions. This knowledge does not *a priori* constrain how we state desired conditions for good ecological integrity.
- Second, given our limited current knowledge of the complexities of natural ecosystems, to suggest that we can simply "engineer" wetlands without understanding NRV is to invite failure.

Box E. Natural Range of Variability (NRV) and Indicators

Great Lakes coastal wetlands typically include recurring zones of open to densely vegetated marsh, sedge-rich wet meadow, and woody swamp of shrubs and trees. In sites unaltered by human development, these zones vary in width and abundance in large part due to lake water level fluctuations of several centimeters; which in turn vary along seasonal, annual, and decadal cycles (Lenters 2001).

Keddy and Reznicek (1986) described the interactions of water level fluctuations with vegetation dynamics. Seed banks are exposed during low water levels, allowing many species to regenerate, while high levels kill dominant herbaceous and woody species and create gaps to be filled by less common species.

Therefore, both lake levels fluctuations themselves, and the relative abundance of distinct vegetation zones can serve as strong indicators of coastal wetland dynamics.

Albert et al. (2005) described a hierarchy of hydrogeomorphic classes describing the primary setting (*lacustrine, riverine, barrier-protected*) and then physical features or shoreline processes. These classes place any given wetland with sites that have a similar NRV in lake level fluctuations and dynamic vegetation zones. That is, depending on the hydrogeomorphic class, one can anticipate distinct responses of vegetation zones in seasonal, annual, and decadal cycles.

Alteration of the hydrological dynamics, through diking, diversions, other disruption of coastal processes, and introductions of invasive species, can interact with the multiple forms of coastal wetlands with increasingly predictable responses. For example, Tulbure et al. (2007) illustrated the interactions of abnormally low lake levels, mudflat exposure, and subsequent exploitation by an aggressive genotype of *Phragmites australis.*

- Third, understanding NRV will better prepare us to ***forecast change and emphasize resilience*** in restoration efforts.

Thus, when discussing NRV, our goal is not to simplistically distinguish "natural" as referring only to "lacking all human influence." That is not tenable, given the long (and often unknowable) interactions between humans and the environment. But neither do we want to conflate human activity (culture) into an extension of natural processes, as if humans are just another animal species. Rather we can look at how socio-ecological systems are "knitted together over time;" that is, both culture and ecology have histories, and consideration of current ecological integrity reflects both histories, without suggesting that they are one and the same (Angermeier 2000, Higgs 2003, Gibbons et al. 2008). For example, our current concepts of ecological integrity with respect to fire and succession in temperate forests and grasslands include many likely effects of Native American use of fire because a) relative densities of human populations were low relative to modern industrial-age societies in the Americas, and b) it is not possible to distinguish their effects from lightning-sources fires and how they both varied over recent millennia. But these assumptions need to be made explicit so that our expectations for the range of conditions in ecosystems can be realistic for modern management decisions.

3.5. Select Reference Sites

Our models and understanding of the NRV need not be interpreted solely from the historical record; rather, we can bring in information from "reference sites" present today. As described by Brooks et al. (2016), reference sites ideally represent places with minimal human disturbance; i.e., they reflect the "reference standard" or "exemplary ecosystem occurrences." In effect, they contribute to our understanding of the current range of conditions. However, given the extensive loss of wetlands in many jurisdictions, current ecological conditions may only represent a portion of the NRV, and it will typically include current conditions that are outside the NRV.

Thus, an important part of this process is to determine which conditions most closely resemble the NRV. Where such conditions exist, these sites can serve as the minimally disturbed reference condition (MDC). Where current conditions no longer reflect the NRV, the MDC can sometimes be inferred from other studies. Failing that, the least disturbed condition (LDC) or best attainable condition (BAC) may be used[3] (Sutula et al. 2006).

This information can be used to set levels of ecological integrity along a gradient from minimally disturbed (reference standard) conditions to severely impacted sites, i.e. the "condition gradient" (Davies and Jackson 2006). We use this approach as a guide for our conceptual modeling, using a general narrative that identifies the typical characteristics of a reference standard based on NRV, and a gradient of conditions that reflect increasing anthropogenic impacts that degrade the system (Figure 8; Table 1).

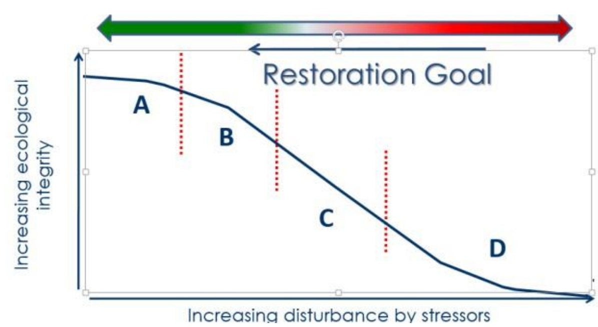


Figure 8. Levels of ecological integrity reflect response to levels of stressors and can help to specify restoration goals and objectives.

[3] When choosing a reference standard, one needs to choose whether such a standard represents the Minimally Disturbed Condition (MDC) or Least Disturbed Condition (LDC), or a combination of the two, based on best attainable condition (BAC). Huggins and Dzialowski (2005) note that MDC and LDC set the high and low end of what could be considered reference standard condition. They go on to say that "these two definitions can be used to help define the Best Achievable Conditions (BAC's), which are conditions that are equivalent to LDC's where the best possible management practices are in use. The MDC's and LDC's set the upper and lower limits of the BAC's. Using the population distribution of measures of biological condition associated with a reference population might provide some insights regarding the potential relationship between the MDC and LDC for a particular region."

Reference sites are identified based on a combination of factors, including wetland type similarity, restoration goals and objectives, reference site naturalness, current ecological integrity, and evidence of human disturbances. Naturalness and integrity are often judged by a full complement of native species, characteristic species dominance and productivity, presence of typical ecological processes such as fire, flooding, and windstorms, and minimal evidence of anthropogenic stressors (Woodley 2010).

Photo by Shannon Menard

In each of our Great Lakes wetland examples, we first utilized element occurrence records from the Michigan and Wisconsin Natural Heritage Programs to identify 3-5 sites for each restoration site within Saginaw Bay and Green Bay watersheds, respectively. In each case, the state wetland classification formed the basis for identifying most-similar sites to the restoration. Figure 8 depicts one set of sites on Saginaw Bay, Michigan.

There are pitfalls or limitation to the use of reference sites. First, some regions may be lacking high quality reference sites for the type being restored. One may still be able to make reasonable estimates based on historic data or inferred species-habitat relationships (Brewer and Menzel 2009). One could also expand the regional envelope to include more distant examples of the type or closely related types. Third, reference sites based on current and historic similarities to the site that is being restored may no longer be appropriate targets of the restoration, which may focus on desired functions, rather than structural or compositional similarity.

Photo by Patrick Comer

Finally, given the dynamic and variable nature of systems response to changing climatic conditions, it may be increasingly difficult in later decades of the 21st century to know which reference sites are most suitable.

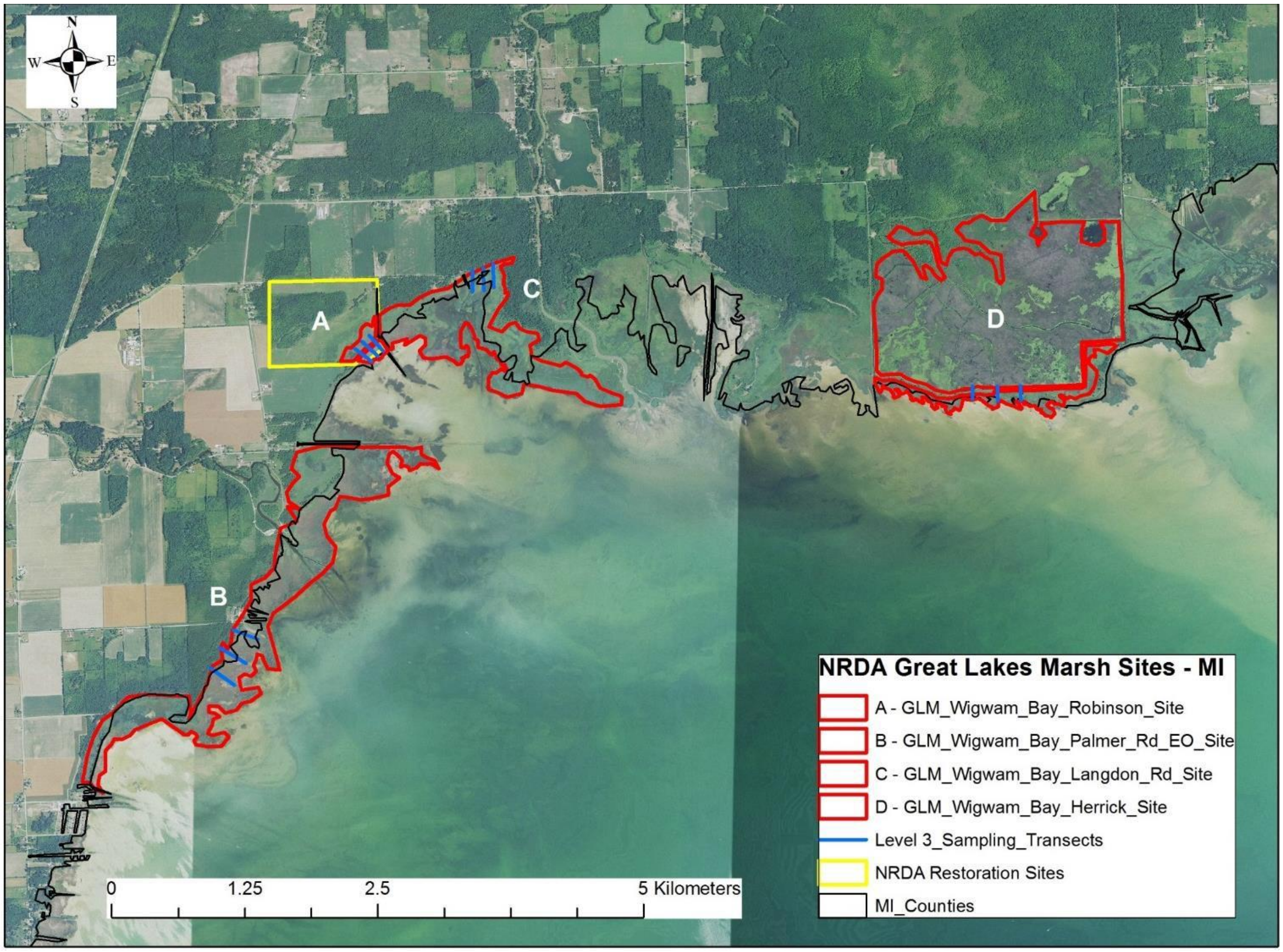


Figure 9. Restoration and reference sites for coastal marshes in Saginaw Bay, MI

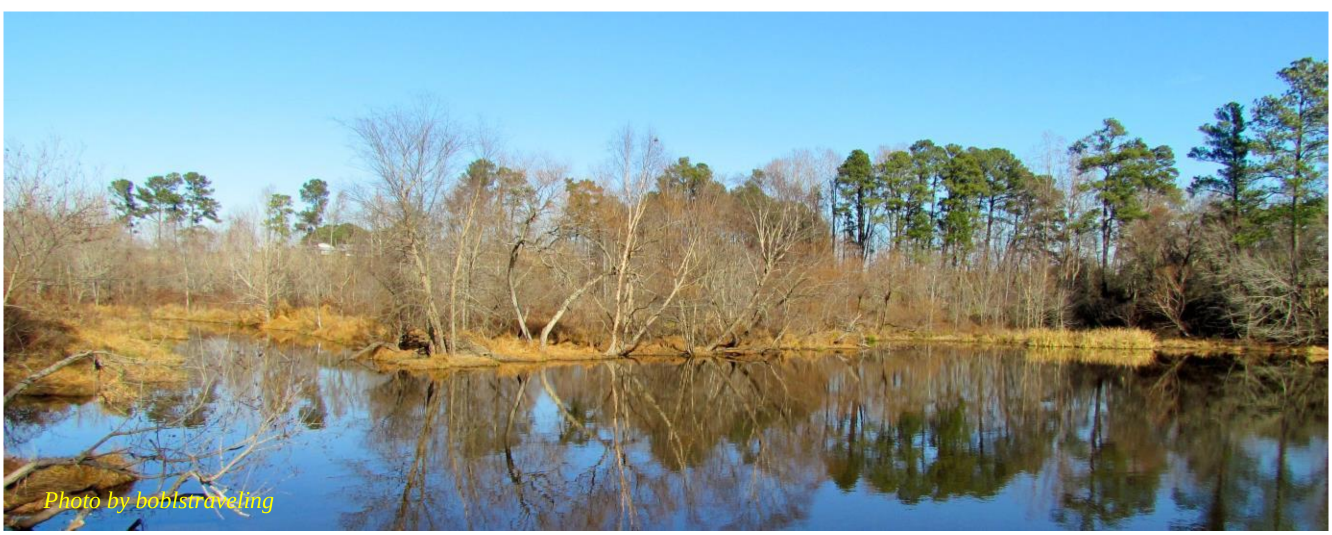


Table 1. Generalized ecologically-based definitions of a wetland condition gradient.
(see also Figure 8)

Rating	Description
A (the "reference standard" i.e., intact, excellent;)	Location unquestionably meets the reference standard with respect to key ecological attributes functioning within the bounds of natural range of variability. Characteristics include: • **landscape context** contains natural habitats that are essentially unfragmented (reflective of intact ecological processes) and with little to no apparent stressors; • **condition,** including vegetation structure and composition, soil status, and hydrological function are well within natural ranges of variation; invasive or non-native are essentially absent or have negligible negative impact; and a comprehensive set of key plant and animal indicators are present; • **size** is very large or much larger than area required to support spatial character of dynamic disturbance processes.
B (minimally disturbed, good)	Location is not among the highest quality examples thought to have occurred**,** but nevertheless exhibits favorable characteristics with respect to key ecological attributes functioning within the bounds of natural disturbance regimes. Characteristics include: • **landscape context** contains largely natural habitats that are minimally fragmented with few stressors; • **condition**, including vegetation structure and composition, soils, and hydrology are functioning within natural ranges of variation; invasive or non-native are present in only minor amounts, or have minor negative impact; and many key plant and animal indicators are present; • **size** is large or above the area required to support spatial character of dynamic disturbance processes.
C (moderately disturbed, fair)	Location has multiple unfavorable characteristics with respect to key ecological attributes. Characteristics include: • **landscape context** contains natural habitats that are moderately fragmented, with several apparent stressors; • **condition**, including vegetation structure and composition, soils, and hydrology are altered somewhat outside their natural range of variation; invasive or non-native may be a sizeable minority of the species abundance, or have moderately negative impacts; and many keyplant and animal indicators are absent; • **size** is relatively small or just below the area required to support spatial character of dynamic disturbance processes. Some management is needed to maintain or restore[4] these key ecological attributes.
D (severely disturbed, poor)	Location has severely altered characteristics with respect to key ecological attributes. Characteristics include: • **landscape context** contains little natural habitat, is very fragmented, with many stressors; • **condition**, including vegetation structure and composition, soils, and hydrology are severely altered well outside their natural range of variation; invasive or non-native exert a strong negative impact; and most, if not all, key plant and animal indicators are absent; • **size** is very small or well below the area required to support spatial character of dynamic disturbance processes. There may be little long-term conservation value without substantial restoration, and such restoration may be highly uncertain.[5]

[8]By ecological restoration, we mean "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed… Restoration attempts to return an ecosystem to its historical trajectory" (see SER 2004 for details).
[5]D-ranked sites present challenges. Whether a degraded type has "crossed the line" ("transformed" in the words of SER 2004) into a new ruderal or cultural type is a matter of classification criteria. Here we include D ranked examples as still identifiable to the type based on sufficient diagnostic criteria present.

3.6. Three Levels of Effort for Indicator Measurement

Indicators of ecological integrity can come in multiple forms, reflecting different levels of effort for their measurement, (Brooks et al. 2004, U.S. EPA 2006, Wardrop et al. 2013). A three-level structure is helpful to organize indicators into categories that reflect the type of information involved and effort that will be required for their measurement.

- Level 1 (Remote Assessment) relies primarily on remote sensing-based indicators.
- Level 2 (Rapid Field Assessment) uses relatively simple semi-quantitative or qualitative wetland condition indicators that are readily observed in the field, often supplemented by a stressor checklist (see below).
- Level 3 (Intensive Field Assessment) requires detailed quantitative field measurements, and may include intensive versions of some of the rapid metrics (Stein et al. 2009).

This 3-level structure allows the flexibility to develop data for many sites that cannot readily be visited or intensively studied, permits more widespread assessment, while still allowing for detailed measurement at selected sites (Table 2). Because the purpose is the same for all three levels of assessment - to measure the status and trends in ecological integrity of a site - it is important that the identification of ecological attributes and the selection of metrics be coordinated. That is, if invasive or woody species encroachment are identified as key stressors, metrics that address these key issues should be identified at one or more level (Solek et al. 2011).

Some projects may focus on one level of measurement (e.g., many wetland rapid assessments focused on level 2 measures); others have multiple levels that are designed to work together. For example, the U.S. Forest Service Forest Inventory and Analysis program conducts regular surveys of forests across the U.S. by remote sensing of the presence of forests and their patch size (P1 = Level 1 in Table 2), rapid plots that characterize tree species (P2), and intensive plots that characterize shrub, herb and nonvascular species (P3). Sampling can also be stratified by these levels, whereby a comprehensive set of sites are rated using Level 1 indicators, a subset is sampled using Level 2 indicators, and finally, a select set are sampled with Level 3 indicators. The process should lead to an increasing accuracy and confidence in the overall assessment (Solek et al. 2011).

Level 1 assessments are becoming increasingly powerful, as remote-sensing indicators are calibrated against ground data, and as we gain a better understanding of the key stressors that affect the ecological integrity of wetlands. They also offer increasing opportunities for repeat measurement for multi-year monitoring plans.

For example, the proportion of contiguous natural land cover within one or more buffer zones surrounding the target wetland can be readily calculated (Figure 10).

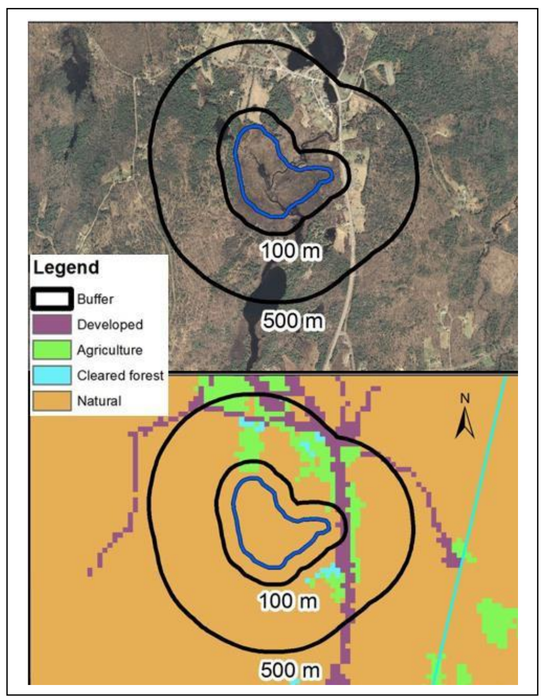


Figure 10. Aerial imagery and interpreted land cover classes for use with landscape context metrics.
**Includes 100m buffer and 500m landscape.*

Given increasing availability of spatial data /integrate multiple layers of information into an overall synthetic spatial index. NatureServe's Landscape Condition model builds on the growing body of published methods for spatially based ecological effects assessment across landscapes (Comer et al. 2013, Comer & Faber-Langendoen 2013, Rocchio et al. 2015, Hak & Comer 2017). The overall index can also be decomposed into individual stressors or sets of stressors, to determine which may be most important. This types of spatial index applies well to circumstances where analysis over large areas (e.g., major watersheds) is needed.

Level 2 (rapid, field-based) assessments evaluate ecological condition using a set of readily observable field indicators. They are structured to combine scientific understanding of ecosystem structure, composition, processes, and connectivity with best professional judgment in a consistent, systematic, and repeatable manner (Sutula et al. 2006). Level 2 assessments rely primarily on relatively rapid field-based site visits, but this may vary, depending on the purposes of the assessment and the size and complexity of the assessment area. They have proven to be very effective in wetland assessment, mitigation, and restoration, and they are in use by many state wetland programs (Fennessy et al. 2007a). (see Box F)

Applications vary from spatial scales of individual sites to multiple sites across watersheds, landscapes and regions, and temporal scales from a one time, snapshot assessment to monitoring over long timeframes. Spatial scales can vary along two common endpoints. The small spatial scale endpoint includes assessing one or several target sites, sometimes comparing them to other sites (e.g., a restoration site compared to reference sites). At the large spatial scale endpoint, all locations of a wetland type across a jurisdiction or region are chosen and assessed. The temporal scale is also important, and includes consideration of the timing of data collection (e.g., summer only or year-round) and the planned duration (e.g., one time or repeated).

In either case, how sites are chosen varies from preferential sampling to statistical sampling. For example, preferential sampling is used when the goal is to document all wetland occurrences in a watershed (Rolecek et al. 2007, Michalcová et al. 2011). Statistical sampling is used where sites need to be located objectively, so that inferences about status and trends can be made. Such designs could be applied to a local area (e.g., all wetlands within a given local watershed), or across an entire state or nation (e.g. the National Wetland Condition Assessment program by U.S. Environmental Protection Agency (2016).

Identifying spatial and temporal scales are essential for data collection, and helps guide the development of the conceptual diagram and indicators (Mitchell et al. 2014). Some indicators are only feasible if temporal considerations are brought in (e.g., development and dynamics of wetland zonation); others are only interpretable at certain spatial scales (e.g., species composition of a given wetland).

Box F. The Merits of Rapid Assessments for Restoration Monitoring

Level 2 (rapid, field-based) assessments evaluate ecological conditions using readily observable field metrics with pre-established assessment points, which have preferably been rigorously tested for their accuracy, ecological meaningfulness, relevance to management decision making, and cost effectiveness (Sutula et al. 2006, Stein et al. 2009, Faber-Langendoen et al. 2012a). They are often applied at stand scales, covering acres at a time. Observers walk through the site, and consider the full range of observable ecological features, scoring various indicators based on qualitative or semi-quantitative data, as well as photo points, that are sufficiently repeatable to guide restorations. With careful attention to training and database management, they can be a valuable and core component of restoration monitoring. They often benefit from supplemental information on a subset of sites with more intensive metrics, such as a full floristic quality assessment, soil characteristics, or hydrologic monitoring.

Level 3 (intensive field based) assessments develop data that are rigorously collected, often with an explicit sampling design, to provide better opportunities to assess trends in ecological integrity over time. The quantitative aspect of the indicators lends themselves to more rigorous testing of the criteria for metric selection (see below). Because of their cost and complexity, Level 3 methods are often highly structured, with detailed protocols that ensure a consistent, systematic, and repeatable method (Sutula et al. 2006); and are typically limited to a small number of sites.


Photo by Patrick Comer

Where information is available for all three levels across multiple sites, it is desirable to calibrate the levels, to ensure that there is an increase in accuracy of the assessment as one goes from Level 1 to Level 3. For example, data from Level 2 or Level 3 metrics can be used to calibrate the Level 1 remote-sensing based indicators (Mack 2006, Mita et al. 2007, Stein et al 2009, Hak and Comer 2017).


Photo by Ryan O'Connor

Table 2. Summary of 3-level approach to conducting ecological integrity assessments.
(adapted from Brooks et al. 2004, U.S. EPA 2006).

Level 1 – Remote Assessment	Level 2 – Rapid Assessment	Level 3 – Intensive Assessment
General description: Remote or GIS-based measurement	*General description:* Rapid field-based measurement	*General description:* Intensive field-based measurement
Evaluates: Integrity of both on and off-site conditions around individual sites/occurrences using • Indicators on-site that are detectable with remote sensing data • Indicators in the surrounding landscape / watershed	*Evaluates:* Integrity of individual sites using relatively simple field indicators • Very rapid assessment (visual observations with narrative) • Rapid assessment (standard indicators) • Hybrid assessment (rapid + some intensive indicators; e.g., vegetation data from plots)	*Evaluates:* Integrity of individual sites using quantitative field indicators • Metrics based on detailed knowledge of historic NRV and statistically analyzed data • Quantitative field sampling methods
Based on: • GIS and remote sensing data • Layers typically include: spectral data, aerial photography, interpreted and cover / land use types • Stressor metrics (e.g., road location, size, density, proximity to impervious surfaces, land use types)	*Based on:* • On-site condition metrics (e.g., vegetation, hydrology, and soils) • Stressor metrics (e.g., ditching, road crossings, and pollutant inputs) • Buffer metrics observed on site	*Based on:* • On-site condition metrics (e.g., vegetation, hydrology, and soils) • Stressor metrics (e.g., ditching, road crossings, and pollutant inputs)
Potential uses: • Identify least impacted sites • Identify status and trends of acreages across the landscape • Identify land use factors influencing to condition of wetland types across the landscape	*Potential uses:* • Relatively inexpensive field observations across multiple sites • Informs monitoring for implementation of restoration, mitigation, or management projects • Landscape / small watershed planning • General conservation and management planning	*Potential uses:* • Detailed field observations, with repeatable measurements, and statistical interpretations • Inform status and trend measurements, monitoring for restoration, mitigation, and management projects

3.7. Select Indicators and Metrics

Having identified the wetland type (Step 1), worked through the conceptual ecological model to identify the KEAs for which indicators and metrics are needed, and a series of reference sites to further characterize reference conditions (Step 2), the next step is to select appropriate indicators and metrics. As stated above, metrics first need to specify the *measures* needed to evaluate the indicators of the integrity of the wetland occurrence. For example, *aboveground primary production* is an indicator of the

Primary Production KEA for salt marshes. But it can be measured using a variety of methods, including a) by clipping once at the end of the season, b) sequentially during the growing season, or c) using proxy methods based on stem density or height (Day et al. 1989). Each of these methods uses different field measures and generates somewhat different numerical values; some may be hard to measure; others, expensive to measure. Thus, a specific metric of the indicator needs to be selected.

In coastal salt marshes, the metric *Aboveground Standing Live Biomass* is a simple and effective proxy measure for biomass based on measuring stem height of the dominant grass, and can be used to quantify the Aboveground Primary Production indicator. Similarly, *Nonnative plant taxa* is a widely-used indicator of ecological integrity, but various metrics are available to measure it, including *percent nonnative species richness, relative cover of nonnative taxa*, *absolute cover of nonnative taxa* or the *ratio of native to invasive abundance*. Ultimately, any assessment or monitoring of ecological integrity needs to specify the metric used for any indicator.

The selection of metrics is focused on those that can detect changes in KEAs, particularly changes caused by stressors (Box G). Metrics that address a key ecological attribute and are sensitive to changes from stressors are referred to as "**Condition metrics;**" that is, metrics that directly measure changes to the KEAs (e.g., hydroperiod, native species richness, coarse woody debris). Across a series of undisturbed reference locations for your targeted wetland type, one can expect that these measures to fall within some expected range; i.e., the Natural Range of Variability (NRV). Where condition metrics fall increasingly outside of that expected NRV, there is a clear indication of departure from NRV, and an increasing indication of ecological degradation.

In contrast, "**Stressor metrics**" directly measure stressors (e.g., number of ditches or hydrologic obstructions in a wetland, presence and abundance of invasive species. Proportion of land converted in buffer zone), and are used to infer the condition or integrity of the wetland. In many instances these may be the only metrics one can feasibly address. While it is most desirable to focus on condition metrics because they are the clearest measure of departure relative to NRV, with independent assessment of the correlations between stressors and condition measures, stressor-based measures may be sufficient. In these cases, there is no NRV for the stressor (other than "absence"), and so with increasing impact of the stressor, one is presuming that KEAs related to natural conditions are becoming increasingly departed from their expected NRV.

Metrics can be identified using a variety of expert-driven processes and through a series of data driven calibration tests. The scientific literature should first be reviewed to identify existing and tested metrics that are useful for measuring ecological integrity. For example, when developing the NatureServe wetland assessment method, a variety of existing rapid assessment and monitoring materials were reviewed; particularly the California Rapid Assessment Manual (Collins et al. 2006, Stein et al. 2011) and the Ohio Rapid Assessment Manual (Mack 2001), (Faber-Langendoen et al. 2008). Subsequently field testing and statistical analysis validated the metrics (Faber-Langendoen et al. 2012, 2016b).

Candidate metrics can be filtered through a series of screening criteria (Andreasen et al. 2001, Tierney et al. 2009, Mitchell et al. 2014). When choosing metrics, the following four fundamental questions should be addressed (Kurtz et al. 2001):

1) Is the metric ecologically relevant? Conceptually relevant metrics are related to the KEAs of the wetland or to the stressors that affect its integrity.

2) Can the metric be feasibly implemented? The most feasible metrics can be sampled and measured using methods that are technically sound, appropriate, efficient, and inexpensive.

3) Is the response variability understood? Every metric has an associated measurement error,

temporal variability, and spatial variability. The best metrics will have low error and variability compared to the NRV. In other words, good metrics have high discriminatory ability, and the signal from the metric is not lost in measurement error or environmental noise. Ideally the metric has been measured across a range of sites that span the gradient of stressor levels (DeKeyser et al. 2003) and verified to show a clear response to the stressor.

4) Is the metric interpretable and useful? The best metrics provide information on ecological integrity that is meaningful to resource managers in that it can inform restoration actions.

Box G. Screening Metrics: EPA's National Wetland Condition Assessment.

An example of metric screening comes from EPA's 2011 National Wetland Condition Assessment (USEPA 2016). EPA found that the composition and abundance of plant species at a site reflected and influenced other ecological processes related to hydrology, water chemistry, and soil properties. Plants integrate different wetland processes, and they respond to physical, chemical, and biological disturbances, making them a particularly valuable attribute to track. After careful screening of many candidate metrics, four plant-based metrics were chosen for inclusion in the VMMI:

- Floristic Quality Assessment Index (FQAI);
- Relative Importance of Native Plant Species;
- Number of Plant Species Tolerant to Disturbance; and
- Relative Cover of Native Monocot Species.

These metrics were then integrated into a national-scale **Vegetation Multimetric Index (VMMI),** as the best national indicator of biological condition of wetlands.

Table 3 provides a summary of standard metrics for use in wetland condition assessments. These metrics have been established in freshwater, non-coastal wetlands across the United States, and can serve as a starting point for metric selection for all wetland types. These metrics have been organized in to factors of Landscape Context, Condition, and Size, and encompass Level 1-3 forms of measurement.

Each metric is abbreviated using a combination of the organizing factor and subcategory. For example, Contiguous Natural Land Cover is abbreviated LAN1, indicating that it is a first landscape context metric. Condition of Natural Buffer is listed as BUF2 because within the landscape context metrics, it is the second in sequence. Several metrics are listed as optional in that they may be most informative for certain wetland types, but are less informative for others.

Landscape context metrics aim to address conditions affected by land conversion and fragmentation surrounding the wetland of interest. Intactness of the buffer surrounding the wetland and the watershed containing the wetland has substantial effects on the natural flows of ground and surface water, nutrients, and exchange of plants and animals.

Table 3. Summary of metrics applied to wetland ecological integrity assessments.
(Faber-Langendoen et al. 2016a).

Organizing Factor	METRIC NAME
LANDSCAPE CONTEXT	LAN1. Contiguous Natural Land Cover
	LAN2. Land Use Index
	BUF1. Perimeter with Natural Buffer
	BUF2. Width of Natural Buffer
	BUF3. Condition of Natural Buffer
CONDITION	VEG1. Native Plant Species Cover
	VEG2. Invasive Nonnative Plant Species Cover
	VEG3. Native Plant Species Composition
	VEG4. Vegetation Structure
	VEG5. Woody Regeneration [opt.]
	VEG6. Coarse Woody Debris [opt.]
	HYD1. Water Source
	HYD2. Hydroperiod
	HYD3. Hydrologic Connectivity
	SOI1. Soil Condition
SIZE	SIZ1. Comparative Patch Size
	SIZ2. Change in Size [opt.]

Condition metrics focus on plant species composition, hydrology, and soil of the wetland. The expected composition of native plant species is a primary condition metric, and is directly affected by the presence and abundance of non-native and/or invasive species. This metric can be more rigorously assessed using data from Floristic Quality Assessments (Box H). Displacement of native taxa affects a host of other interactions among plants animals, and some physical processes of a given wetland. Hydrologic metrics address natural water sources often disrupted by diversions and obstructions, hydroperiod influencing sediment dynamics, and hydrologic connectivity affects a broad set of exchanges, including water, sediments, nutrients, organic carbon, and species dispersal. Soil condition metrics address storage capacity for water and carbon, and provide the medium for plant establishment.

Size metrics may not always be essential to wetland assessment, depending on the wetland type. Comparative patch size addresses wetland types that naturally vary in their natural size, and that variation in size accounts for the existence of important ecological attributes, such as the presence of vegetation zones that support certain characteristic species, but only appear in relatively large examples of the wetland type. Size might also factor into common natural responses to disturbance, such as effects of periodic large flooding events or natural wildfires entering from adjacent upland areas.

The metric for change in size addresses stress induced by wetland conversion through drainage; with greater proportions of a given wetland location lost to land conversion, there increasing degradation of most or all key ecological attributes for the wetland type.

Box H. What is a Floristic Quality Assessment?

Floristic Quality Assessment (FQA) is a robust, botanically based method for assessing species composition of ecological communities and natural areas (Taft et al. 1997). Integral to the method is that each native plant species in a state or region is assigned a Coefficient of Conservatism or C-value based on its response to stressors, with species of high C-values (7-10) expected to be largely restricted to areas with minimal human disturbance and species with low C-values (1-3) expected to be largely found in ruderal or highly disturbed habitats. Non-natives are often assigned a zero C-value.

Integrating the response of all species at a site into an index provides a valuable indicator of the condition at a site (Miller and Wardrop 2006). Because of its effectiveness in distinguishing the range of conditions in wetlands, FQAs, and particularly the "cover-weighted mean C metric, have received wide interest from state wetland programs.

The C-value scale below is taken from Taft et al. (1997). Other users, such as Bried et al. (2012), restrict the 0 to exotics only; that scale is provided in parentheses.

CoC Criteria

0-1 (0): taxa adapted to severe disturbances, particularly anthropogenic disturbances, occurring so frequently that often only brief periods are available for growth and reproduction [0 can be used for exotics only]

2-3 (1-2): taxa associated with somewhat more stable, though degraded, environments. [tolerant of major disturbances]

4-6 (3-5): taxa that are dominant or matrix species for several natural habitats; they have a high consistency of occurrence within given community types, [tolerate moderate disturbances].

7-8 (6-8): taxa associate mostly with natural areas, but that can be found persisting where the habitat has been degraded somewhat [tolerate minor disturbances]

9-10: taxa considered to be restricted to high-quality natural areas [low tolerance for disturbances]

The cover-weighted Coefficient of Conservatism (*wC*), or weighted mean C, has proven to be an informative metric for assessing wetland condition (Bourdaghs 2012). It is the sum of each species' proportional abundance (*p*) multiplied by its *C*-value: $wC = \sum pC$

Availability of FQA methods varies across the country. See http://universalfqa.org/ for various state and regional lists.

Step 4. Document Reference and Baseline Site Conditions

4.1. Set Assessment Points

Metrics are the specific form of an indicator that can be measured, specifying both a) the *units of measurement* needed to evaluate the indicator, and b) the *assessment points and ratings* (e.g., "high" to "low") by which those measures are informative of the integrity of the wetland occurrence. For many monitoring projects, the latter components will be available as part of established methodologies that set these points based on field testing and literature review of NRV. See Appendix 2 for a worked example.

Using our knowledge of NRV as a guide to reference condition, we can determine both the natural variation in a metric and the departure from that variation caused by stressors. Thus, the first step in gathering baseline conditions is to establish ecological "assessment points" that distinguish expected or acceptable conditions from undesired ones that warrant further evaluation or management action (see Bennetts et al. 2007 regarding "assessment points" versus "thresholds" as guides for assessing ecosystem condition). By basing our monitoring on these metrics, these assessment points provide the information regarding the trajectory of a metric, whether it is moving away from NRV and towards an undesirable ecological threshold and possible ecological collapse, followed by a transition to a novel wetland type.

To integrate the general reference condition framework introduced at the outset, we now use the established assessment points based on the NRV and our knowledge from current reference sites to assess ecological integrity (Table 1). The basic characterization of these points would be:
A (Excellent) – the metric value lies well within its range of natural variability,
B (Good) - The metric value lies within but is approaching the edge of it's the range of natural variability,
C (Fair) - the metric value lies outside its range of natural variability, and represents a modest degree of ecological integrity degradation, and;
D (Poor) - the metric value lies well outside range of natural variability and represents significant ecological degradation, perhaps irreversible.

Intermediate assessment points (e.g., A-, B-, C-) can be added where metric response is well understood from many reference locations, and is known to be tightly linked to increasing stressor levels.

There are a variety of existing protocols that contain metrics and assessment points, built on the conceptual modeling process in Step 3, such as the EIA presented here (see also Fennessy et al. 2007, Brooks et al. 2016). These protocols providing the practitioner with practical methods for documenting their sites.

Figure 11 (from Bourdaghs 2012) illustrates this concept using one Level 3 indicator, the weighted mean C (see Box F). The metric was developed using plant species list gathered from multiple sites and wetland types in Minnesota that span the NRV, from "minimally Impacted" to "Severely Impacted."

The NRV data can then be used to determine the assessment points for the Level 3 weighted mean C metric by wetland type. Bourdaghs (2012) provided the following assessment points for types in Minnesota:
Emergent Marsh
A: >4.9, B: 4.3-4.9, C: 1.6-4.2, D: < 1.6
Hardwood Swamp
A: >4.6, B: 4.2-4.6, C: 2.5-4.2, D: <2.5.
Sedge Meadow
A: > 4.2, B: 4.0-4.2, C: 1.3-4.1, D < 1.3

Because similar studies have not been done in Michigan or Wisconsin, these assessment points are viewed as preliminary.

An example of completed Level 2 metrics and assessment points for Great Lakes Coastal Marsh is found in Appendix 2.

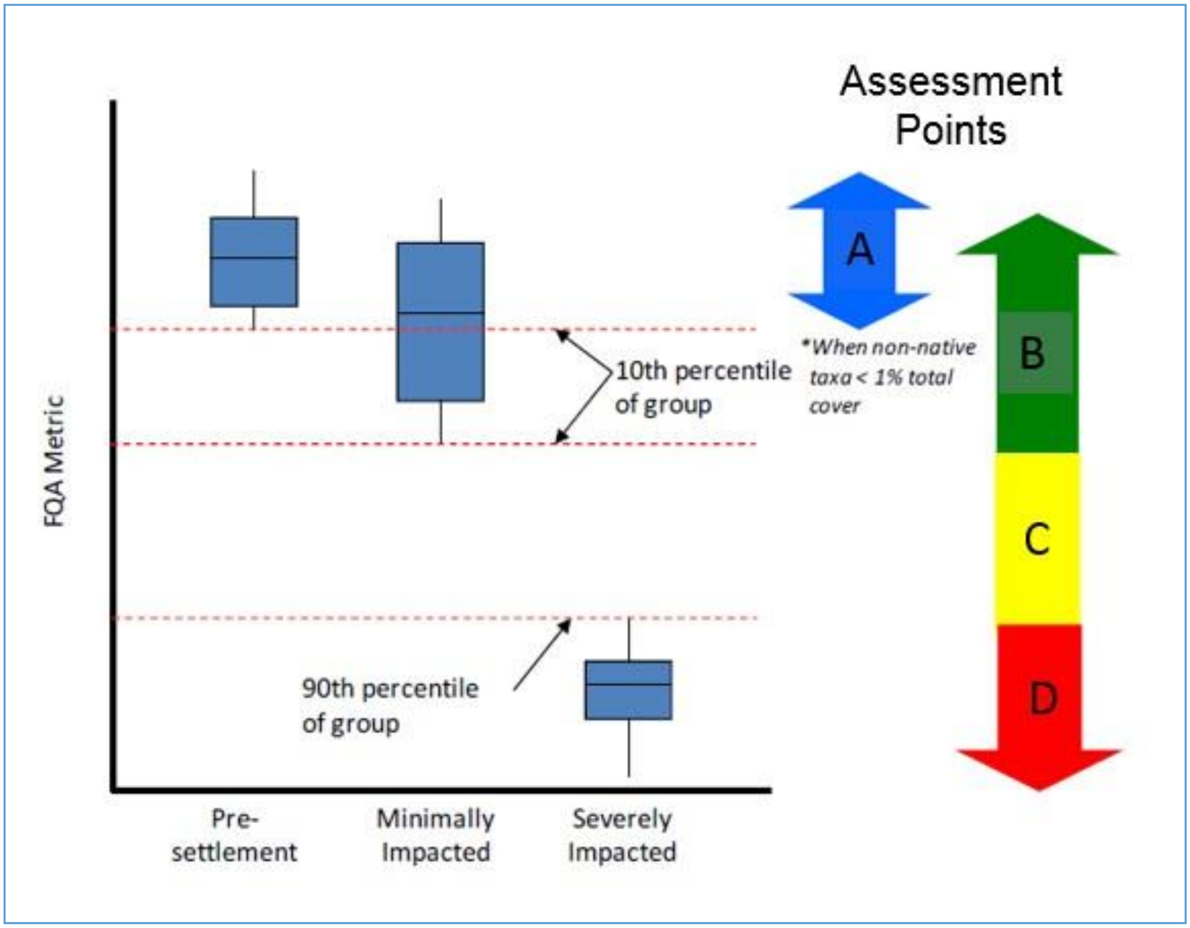
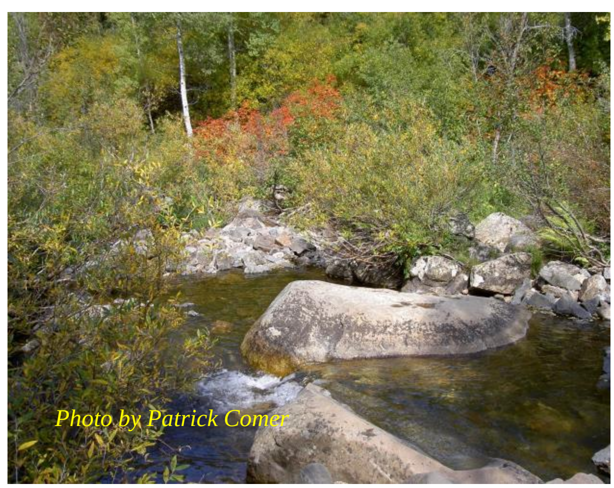


Figure 11. Diagram of Rapid Floristic Quality Assessment (FQA) criteria.
It shows assessment point development (adapted from Bourdaghs 2012). Sites are assigned to data analysis groups ("Presettlement" [A], "Minimally Impacted" [B], and "Severely Impacted" [D]). Assessment points, are set at designated percentiles of the FQA metric for each data analysis group. Three types of assessment points are provided: 1) Desired condition (A/B), 2) Early warning (B/C), and 3) Imminent collapse (C/D)

In some circumstance, it is not feasible to distinguish Excellent from Good ratings, and a 3-category scale (Good, Fair, Poor) is sufficient. Selection of metric thresholds varies, depending on how fine-scaled types respond. For example, some metrics used for emergent marshes are the same across multiple similar types, whereas others have ratings specific to certain marsh types.



4.2. Gather Field Data

Once appropriate metrics have been identified, and existing information on assessment points has been utilized, consistent sampling protocols need to be applied to both the project site and the reference sites.

Where metrics can be assessed from the office, compile the needed information for the office part of the assessment. Many sources of information can help determine the condition and threats to a site (see Rocchio 2007):

- Aerial photographs
- Satellite imagery
- Digital Orthophoto Quadrangles (1 m resolution)
- GIS layers (e.g., roads, utility lines, trails, mines, wilderness areas, National Land Cover Datasets [USGS and NatureServe sources], irrigation, ditching, and groundwater wells),
- Element occurrence records from Natural Heritage Programs
- State or Federal Agency surveys
- Digital Soils Survey maps (SSURGO)

Field methods depend, in part on the sampling design of the project. Many of the details of the field method are guided by the protocols for the specific metrics (see Appendix 5).

One critical step in conducting field work is defining the Assessment Area (AA). Two common choices are points and polygons. A **point based approach** (per Fennessy et al. 2007b, e.g., USEPA 2016) uses a fixed area around a point. The point is typically relatively small (0.5-2 ha). This approach offers a simplicity in terms of sampling design because:

- No mapped boundary of ecosystem type is required for an AA.
- Limits practical difficulties in the field of assessing a large AA.
- Repeat sampling/monitoring is relatively straightforward.

A **polygon or stand-level approach** (per Fennessy et al. 2007b, Faber-Langendoen et al. 2012) typically uses a mapped polygon that represents the local extent of a specific ecosystem type. The polygon could vary widely in size, from less than 1 hectare to many thousands of hectares. Using a polygon approach can be advantageous because:

- Mapping the boundaries of a wetland observation facilitates whole wetland and landscape interpretations.
- Decision makers and managers are often more interested in “stands” or “occurrences,” rather than points.
- Size of the wetland observations can be integrated into the assessment.
- Comprehensive maps that display the range of conditions of a wetland across the entire landscape or watershed are possible.

Guidelines for field sampling protocols include:

1. Locate and map the wetland type boundary. Locations may be based on office information, or from previous field visits. Establish a preliminary Assessment Area (AA) (Figure 12).
2. Classify the type (see Box D).
3. Specific protocols for how to measure the metrics and field forms are found in Appendix 5.
4) For rapid assessments, the entire AA should be assessed, including, as much as is feasible within the 100m buffer around the AA (typically aided by aerial photos). Assessment will consist of a walk-around, scoring metrics for buffer, vegetation, hydrology and soils based on visual observations. It can also include establishment of photo-points (Box I)
5) For intensive assessments, vegetation sample plots will be placed in an unbiased manner, through either a random or systematic sampling design, stratified, if desired, by wetland sub-types. Sampling units should be large enough to capture typical heterogeneity of a type to ensure adequate representation of local, micro-variations produced by such things as hummocks, water tracks, side-channels, pools, wetland edge, and micro-topography in the floristic data. For many purposes, a minimum of 100 m^2 is sufficient (Peet et al. 1998, Peet and Roberts 2013).

Vegetation data will consist of comprehensive vascular plant species list, with abundance measures based on cover, and for woody species, a measure of stem size. Soil data can be collected to assess abiotic site conditions, such as percent or depth of organic matter and bulk density of mineral layers. Hydrology data are difficult to gather in a one-time assessment, but some measure of hydrology or water quality may be appropriate for monitoring (e.g., maximum flood depth).

The following guidelines can be used to determine plot locations within the AA:

- The plots can be located using a series of unbiased selected points in the AA or sub-AA.
- Large upland areas and other substantial inclusions which differ from the targeted type should be excluded from plots; however, mesic micro-topographic features such as hummocks, if present, can be included in the plots.
- Localized, small areas of human-induced disturbance can be included in the plot per their relative representation of the AA. Large areas of human-induced disturbance should be delineated as a separate sub-AA.

Box I: Photo Monitoring
Another qualitative method for validating field data and tracking vegetation changes over time and includes taking photo points at each sample plot before starting other measures on plot (Woodward and Hollar 2011). Georeferenced digital photos can be stored with field data in a database. Photos of each data transect should be taken using a fixed point at the corner of the plot with a predetermined aspect (e.g., due N, or all four cardinal directions) into the transect and with a standard camera height. Include one photo of a Photo ID board at the beginning of each transect with descriptive information (e.g. site name, transect ID, date, photo number) so that the photo points can easily repeated in multiple years. Also, include a section on the field plot form to add information (e.g., defining characteristics of site/transect, unique landmarks) about each photo (see Appendix 5 for example). Be sure to download photos and rename to common naming convention to be able to easily locate and identify photos for future use.

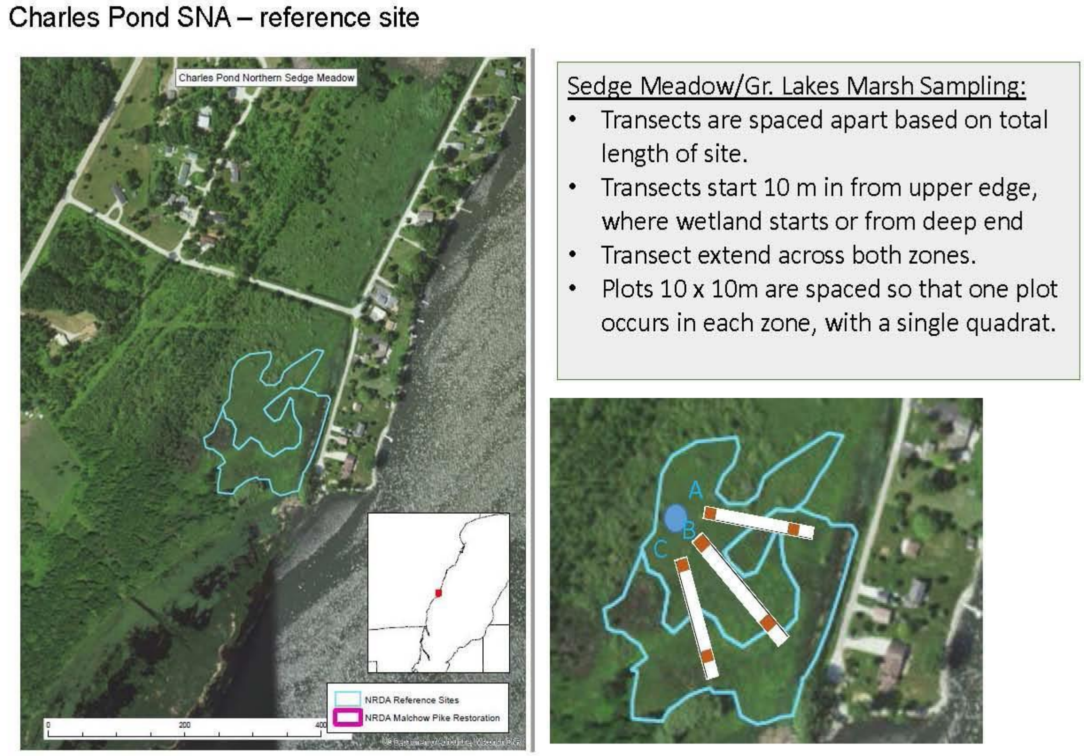


Figure 12. Example of delineated Assessment Areas (AAs) at Charles Pond SNA, WI.
Although contiguous with each other, the marsh and sedge meadow were delineated as distinct AAs because they were distinct wetland types. Each might be divided into sub-AAs due to a human-induced disturbance (e.g., ditching) which could significantly alter a large portion of an otherwise contiguous wetland type (e.g., intact vs. disturbed marsh). A decision as to whether to formally recognize two sub AAs within a larger AA or to simply incorporate the variation into a single evaluation depends on the observed differences in integrity and the size of the AA versus sub-AAs (adapted from Rocchio 2007).

The ability to assess restorations and to guide management activities benefits from compiling information on stressors. As part of the assessment, a stressor checklist can be used to systematically score the scope (percent area occupied) and severity of each stressor present at a site. See example in Appendix 5. The stressors are integrated into a stressor index that is used to rate the overall impact of stressors to various metrics and to overall ecological integrity.

All assessment data can be entered or imported into NatureServe’s Ecological Observations Database (EcoObs); which has been provided with this guide. The database is structured to match field data protocols, including fields for General Site Description, Environmental Description, Vegetation Plot Data (either dominants with cover by strata, or full species list with cover by strata), Level 2 metrics, Level 2 stressor checklists, Level 2 scorecard, Level 3 metrics, and descriptive soils data. After metric scores are entered, they are used to generate an EIA scorecard. EcoObs also facilitates other kinds of metric scoring, including indices related to the Floristic Quality Assessment (FQA) methodology (Bourdaghs et al. 2006). EcoObs is currently managed by NatureServe staff and is in use in several states.

4.3. Analyze Data

As noted above (Section 4.1), metrics are the specific form of an indicator that can be measured, specifying both a) the *units of measurement* needed to evaluate the indicator, and b) the *assessment points and ratings* (e.g., “high” to “low”) by which those measures are informative of the integrity of the wetland occurrence. The latter components are arrived at, or simply verified, through analysis of gathered sample data. Additional data analysis can test the responsiveness of the metrics or aggregate scores (such as overall condition) to stressors, can also be reviewed to ensure that metrics are tracking the ecologically relevant factors present at the site.

Comparing Restoration to Reference Sites

A primary focus on a reference-based approach is to determine how well the restoration site is recovering, relative to other sites, either benchmark sites, or a site anywhere along the reference gradient. A variety of specific metrics or indicators can be compared, or the overall scorecard rating can be used. These comparisons provide a means of clarifying how the restoration site compares to reference conditions.

Figure 13 illustrates output from analysis of one metric – the floristic quality index “Weighted Mean C” statistic, applied to reference and restoration sites associated the hardwood swamp restoration at Badour 2 on Saginaw Bay. In a “box and whisker plot” scores from each sample plot are tallied to characterize their variability within the site. The relative size of the box (and “whisker” extending beyond the box, indicates the degree of variability in scores at the site. This same statistic has been compared with a wide range of reference data to suggest that a) all the reference sites fall within a narrow range of values (weighted mean C = 3.2 – 3.4), and b) those reference sites appear to score moderately outside of NRV (recall that, based on Bourdaghs 2012 Minnesota data, the Hardwood Swamp assessment points were A: >4.6, B: 4.2-4.6, C: 2.5-4.2, D: <2.5).

In contrast, the Badour 2 site scores very low; in the D range (< 2.5). This is to be expected given the relatively long time required for hardwood swamps to recover native diversity and develop more mature vegetation structure. The sampling design included three 100 m^2 replicate plots at each site. In this case, the low score at the Badour 2 site is significantly different from the mean of the three reference sites.

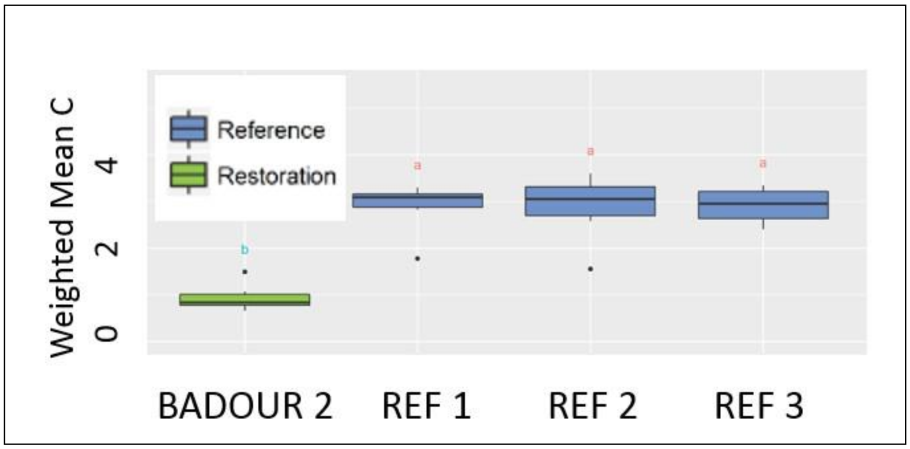


Figure 13. Comparison of Badour 2 hardwood swamp restoration site to reference sites, based on the Floristic Quality metric ("cover-weighted mean C").

Correlating Overall Condition and Individual Stressor Metrics

A next type of the analyses may be to ask how condition metrics for a restoration or reference site correlate with stressor metrics at the site. Because many stressor-based metrics are easier to measure, and may require less specialized expertise, it can be helpful to know these correlations and support decisions about which metrics to focus on for subsequent monitoring. A variety of correlation and regression analyses can be completed to examine these relationships. Figure 14 depicts the correlation between landscape and buffer scores (typically stressor-based metrics), and on-site condition scores across the Great Lakes sites. The data suggest a relatively strong predictive power for these landscape metrics, which can be measured with aerial photos.

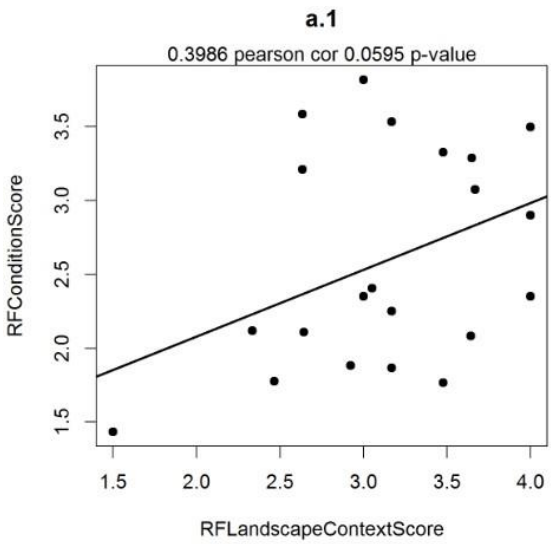


Figure 14. Correlation of Landscape Context Scores with on-site Condition scores, using rapid assessment metrics.

As landscape context conditions improve, so do on-site condition scores. Both Condition and Landscape context are scaled from 1 (D or Poor) to 4 (A or Excellent). See Table 4 for details.

Predictive Power of Rapid (Level 2) and Intensive (Level 3) Metrics

We can also test how well various metrics are correlated at different levels of assessment. This knowledge could provide additional help in determining which metrics to apply to a monitoring program. For example, Figure 15 shows a good correlation between the rapid assessment of overall condition and the intensive assessment of floristic quality, an informative but somewhat botanically-demanding metric to measure. Condition also shows a good correlation between overall nonnative cover metric, a simpler metric to measure. This both informs us on the relationship between native species patterns and non-natives, but could also suggest that for monitoring vegetation, a relatively simple set of metrics may be sufficient, including the percent cover of non-natives on site, and the landscape and buffer metrics (Figure 15). Additional data and analyses would be desirable for hydrology.

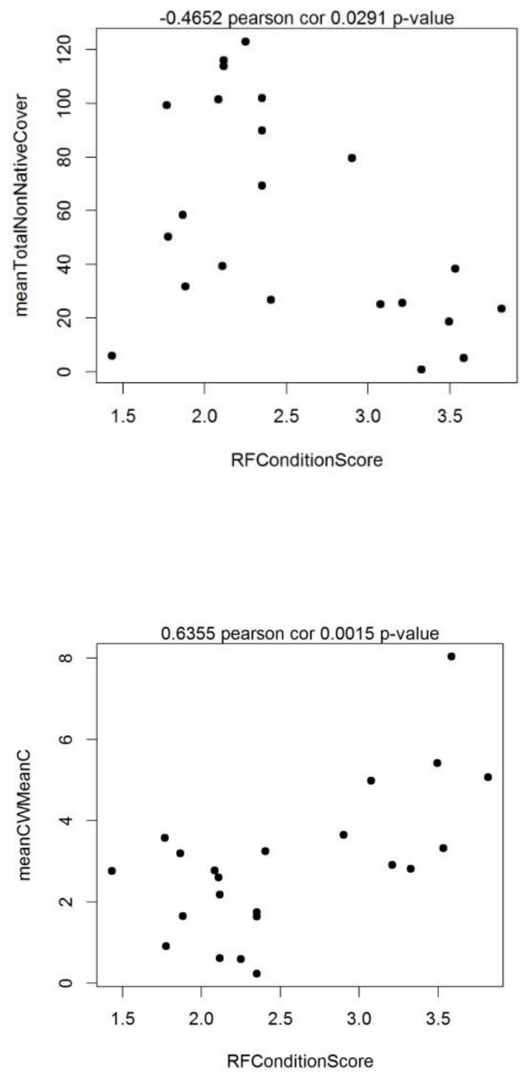


Figure 15. Testing relationships among Rapid (level 2) and Intensive (level 3) metrics.

The top figure shows the strong correlation between cover-weighted Mean C, a botanically demanding L3 metric) and on-site Condition (L2 rank factor). The lower figure shows the correlation between Total Nonnative Cover (simpler L2 or L3 metric) and on-site Condition. Condition is scaled from 1 (D rating) to 4 (A rating).

4.4. Report the Results: The EIA Scorecard

After metrics are rated in the field and office, their ratings can be reported into a variety of forms. The goal is to ensure that the results appear in formats that are accessible and useful for a broad range of user needs. This could vary from a short factsheet that highlights the overall results of the EIA findings from multiple sites, to a detailed report that includes results of each metric at one site.

One common approach for summarizing ecological integrity is a scorecard that displays the ratings for each metric (Table 4). This scorecard brings information together in a transparent way, allowing users to understand the status of various components of ecological integrity.

Metrics ratings can be aggregated into key or major ecological attributes, such as Vegetation, Hydrology, and Soil, and in turn, broader ratings for Landscape Context, Condition, and Size. Ultimately, these ratings contribute to an overall Ecological Integrity rating (Table 4).

Table 4 illustrates results for a hypothetical wetland within a freshwater coastal marsh. Scoring here has been distinguished for marsh and wet meadow zones. The scorecard includes individual metric scores (A-D). For example, while broader Landscape metric ratings were A and B, whereas metrics used to assess vegetation mostly fell into the C and D range, primarily driven by the proportional cover of Invasive Nonnative Plant Species. Native Plant Species Composition scored similarly between Marsh and Wet Meadow zones, whereas Marsh hydrology and soil conditions were better than Wet Meadow.

As summarized in Table 4, individual metrics were aggregated to indicate good scores (A- and B+ respectively for Marsh and Wet Meadow) for Landscape Context, and C scores (C+ and C-) for Condition. The overall EIA ratings were B- for the Marsh zone and C+ for the Wet Meadow zone.

Table 4. Example of an ecological integrity scorecard, showing metric ratings for a hypothetical wetland.

The individual metric ratings can be viewed individually or as aggregate scores, including overall EIA rating.

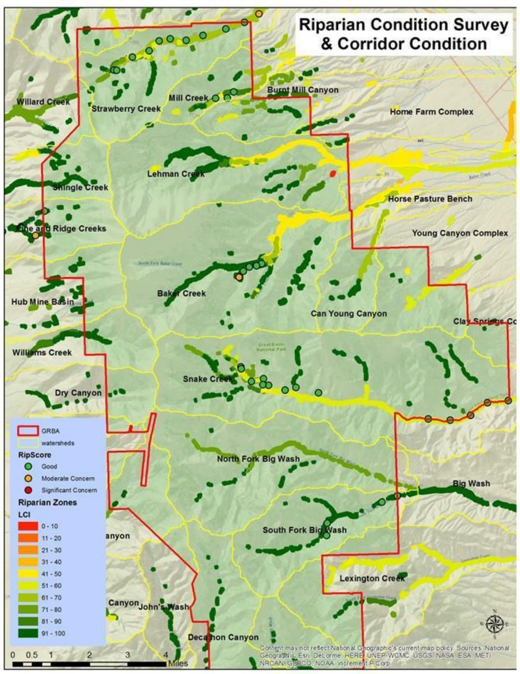
Primary Factor / Major Attribute / Metric		EXAMPLE SCORECARD Marsh	Wet Meadow
ECOLOGICAL INTEGRITY		B-	C+
LANDSCAPE CONTEXT	[0.3]	A-	B+
Landscape	[0.33]	A+	A-
L1. Contiguous Natural Land Cover		A	B
L2. Land Use Index		A	A
Buffer	[0.66]	B+	B+
B1. Perimeter with Natural Buffer		B	B
B2. Width of Natural Buffer		A	A
B3. Condition of Natural Buffer		NR	NR
CONDITION	[0.7]	C+	C-
Vegetation	[0.55]	D	D
V1. Native Plant Species Cover		D	D
V2. Invasive Nonnative Plant Species Cover		D	D
V3. Native Plant Species Composition		C	C
V4. Vegetation Structure		NR	NR
V5. Woody Regeneration (opt.)		NA	NA
V6. Coarse woody debris (opt.)		NA	NA
Hydrology	[0.35]	B+	B-
H1. Water Source		B	B
H2. Hydroperiod		B	C
H3. Hydrologic Connectivity		B	B
Soil	[0.1]	B+	D
S1. Soil Condition		B	D

The scorecard approach is important, in that while any one metric may be failing (e.g., a D score), the scorecard provides a multi-factorial view of the system, and provide some context for interpreting the significance of any individual rating.

Specific restoration actions tend to be directed at individual metrics and/or small groups of closely related metrics. The C rating for Native Plant Species Composition in the wetland site's Wet Meadow zone can be explained by the dominance of an invasive grass species, such as reed canary grass. Targeted herbicide application, combined with prior actions to restore hydrologic connectivity (currently scored as B) may be the specific suggested actions. These specific metrics may be targeted for periodic re-measurement over the upcoming years (see section 5.2. Effectiveness Monitoring).

Other users of the results may be more interested in aggregate scores and/or other forms of reporting that facilitate recognition of broader patterns within and among multiple restoration sites. Maps, generalized tabular summaries, and other forms of infographics may be suitable for these types of applications.

Figure 16 includes one form of summarizing results in map form. In this case, taken from a Natural Resource Condition Assessment of Great Basin National Park in east-central Nevada, summarizes two metric ratings for multiple riparian reaches across the targeted distribution of a type within the park and immediate surroundings.



Riparian Reach Condition ratings by 2009-2011 field survey location in and around Great Basin NP, overlaid on Riparian Corridor Landscape Condition Index scores by occurrence.

Figure 16. Distribution and component EIA ratings of riparian condition within and adjacent to Great Basin National Park.
(*Source:* Comer et al. 2016)

Here, colors along a spectrum from red to green are used to depict current conditions for each metric. These include a landscape condition metric, addressing relative land use intensity displayed in a buffered zone along each stream reach, and a second metric based on stream samples gathered in point locations along selected reaches.

Generalize tabular formats can be used to provide a concise summary of overall conditions within the project area. Table 5 includes a tabular summary for the same riparian community type within Great Basin National Park. Again, the need here is to summarize overall conditions across all stream reaches relevant to park managers. This includes options for table formatting and infographics that depict current condition, trend, and uncertainty associated with each metric, suitable to informing park managers and the public about riparian resource.

Table 5. Ecological integrity summary for four metrics used to assess montane riparian communities at Great Basin NP, NV.

The table names each indicator, briefly describes each metric, provides a graphical depiction of status, trend, and confidence, and a brief rationale for each. Green indicates that the assessed distributions in the park are within NRV. Yellow indicates moderate departure from NRV. Horizontal arrows indicate steady trends with the downward arrow indicating a degrading trend.

Summary of indicators for condition of montane riparian woodlands in Great Basin NP.
Source: Comer, P.J., et al..2016. Great Basin National Park: Natural Resource Condition Assessment. Natural Resource Report NPS/GRBA/NRR—2016/1105. National Park Service.

Montane Riparian Woodlands			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Watershed Landscape Condition	Landscape Condition Index (LCI) assessed at scale of watersheds (addresses both water quality and quantity)		Mostly high LCI scores for watershed condition at all elevations; no evidence to evaluate trend. However, indicator provides only indirect information on condition of resource.
Riparian Corridor Landscape Condition	LCI assessed at scale of a 200 m buffer along stream corridor (addresses both water quality and quantity)		Mostly high LCI scores for riparian corridor condition at higher elevations; mixed for lower elevations; no evidence to evaluate trend. However, indicator provides only indirect information on condition of resource.
Riparian Reach Condition	Index of riparian vegetation seral stage condition at individual stream reaches, GAWS field methodology, 2009-2011		Almost all locations scored in the "Good" range, with little change from conditions observed in 1997, although that study used a different methodology. Both studies rely on potentially subjective ratings of field conditions.
Fire Regime Departure	Index of departure of fire regime condition class (FRCC) from expected natural range of variation, measured specifically for montane riparian woodlands		FRCC indicates 26% ecological departure for montane riparian woodlands, involving shift toward later-successional vegetation (i.e., woody vegetation encroachment) due to fire suppression. 2003-2004 inventory recorded woody encroachment at ~23% of springs in the park, all in montane riparian woodlands.

4.4. Need to Restate Restoration Objectives?

Scorecards provide detailed insights into current conditions at the restoration site. These may in fact be the "baseline" conditions of the impacted site, or they could reflect conditions resulting from prior restoration actions. The latter may be the case where the impacted site occurred elsewhere, and the project involved off-site restoration.

For example, the Badour 2 site on Saginaw Bay had previously been an irrigated farm field where development rights had been acquired and drain tiles had been broken to re-establish natural flooding regime. Initial sampling occurred at this site several years after those prior actions were taken.

In any case, the individual metric ratings should be compared against any prior assumptions about restoration goals and objectives.

Some key questions to consider include:

- *Are the assumed drivers of current conditions still as prominent as previously thought?*

For example, it may be that prior alterations to hydrology were presumed to be the primary driver of site degradation, but after baseline measurement, it becomes clear that invasive species are now well established and feasibility of their control is quite uncertain.

- *Are the prior or proposed restoration practices directed towards conditions with lower ratings?*

For example, it may be that prior assumptions that herbicide use on patches of invasive plants might be better alleviated by restoring hydrologic dynamics, or even using experimental flooding and draw down prior to that restoration.

- *Are these the highest-priority conditions to treat now?*

There may now be important insights into the sequence of restoration practices. For example, at the Malchow Pike Meadow site on Green Bay, reestablishing water flows with sufficient water depth during Northern Pike breeding might be sequenced prior to considering enrichment plantings of wet meadow species. Restoring vegetation structure (with lower species richness) might take precedence in early years.

- *Are your restoration milestones still appropriate?*

For example, many wetland restoration projects involve components of restoring hydrologic regimes, physical structures that influence hydrodynamics and habitat formation, manipulating vegetation structure or composition, and/or restoring desired species composition. Each of these components can feasibly occur very quickly (i.e., <1 year) to decades. Often, establishing what could be realistically achieved within 5 years is important for regulatory purposes. Key questions include:

- *Are you restoring a forested, shrub, or herbaceous wetland type?*

It can take just a few years for annual, biennial, and perennial herbaceous plants to become well established, while it can take decades for treed swamp forests to regain mature age class distributions and structural characteristics.

- *Are your baseline conditions close to desired conditions or are you "starting from scratch"?*

Each of these questions should be asked, and any adjustments to project goals and objectives should be made, prior to moving on to Step 5, Establishing a Site Monitoring Plan.

Step 5. Establish a Site Monitoring Plan

Following site assessment, a site monitoring plan provides support for ongoing management decisions regarding wetland restoration. For each site with a restoration plan in place, a monitoring plan will be highly recommended to assist with measuring progress towards stated objectives. Data from reference sites describe the ecological characteristics and metric ratings needed to achieve stated restoration objectives, as well as any characteristic stages along the way.

Generally, monitoring may be segmented into two types of activities; including on the one hand, implementation, and on the other, site monitoring. Implementation monitoring aims to answer the question: *did we do what we said we would do?* That is, once we have established a plan of action, be it including restorative practices and/or measuring the effects of those practices, implementation monitoring forces us to periodically re-evaluate and be sure that those agreed-upon steps have in fact been implemented. In contrast, site monitoring addresses the actual site conditions and effects of restoration practices relative to stated goals and objectives. Site monitoring activities are briefly depicted in Figure 17.

Site managers and restoration practitioners should utilize ecological integrity metrics to specify restoration objectives in measurable form. For example, at the Pointe Au Sable site on Green Bay, with treatments and hydrologic regime restoration, the stated objective might be to achieve a B rating for the Invasive Nonnative Plant Species Cover metric.

There is also a need to specify realistic timeframes or for achieving desired condition milestones. For example, it may be realistic to state that a satisfactory rating (B) at Pointe Au Sable is achievable within 3 years, while achieving an optimal rating (A) for this metric, or other components of wetland conditions, might require much longer to achieve.

Whereas ecological integrity assessments aim to quantify conditions at one point in time, ecological integrity monitoring primarily aims to ***measure change in those conditions over time***. Therefore, while some or all metrics selected for documenting reference conditions could apply, the appropriate focus for monitoring could differ because it must support the reliable detection of specific changes over a given time-period.

Data generated from the ecological integrity assessments in the Great Lakes sites are used below to illustrate how practitioners can implement three basic categories of site monitoring, including a) baseline, 2) effectiveness/structural/short-term, and 3) validation/functional/long-term (Macdonald et al. 1991).

5.1. Baseline Monitoring

Baseline monitoring establishes ***conditions that would have existed had the discharge of oil or release of the hazardous substance under investigation not occurred***. It documents the relevant attributes, such as vegetation, hydrology and soils, that will be the focus of restoration. Thus, the baseline measures will correspond with those of EIA metrics at the project site. The practitioner can then review these conditions relative to restoration objectives for the site, and determine if all or just a subset of metrics might be addressed in monitoring.

It is important to distinguish “baseline” conditions from “reference” conditions. As defined previously in section 3.5, a “reference standard” describes wetland conditions that are completely (or nearly) unaltered by past land uses. The “baseline” conditions *may or may not* reflect those unaltered conditions. That is, there may have been *prior forms* of wetland alteration or degradation – disruption of natural hydrology, introduction of invasive species, etc.- *that preceded the impact event*. These conditions are the relevant “baseline” conditions for purposes of NRDAR project assessment and monitoring.

Hypothetically, a site with an overall score of D might reflect conditions resulting from environmental impact occurring at a site, which prior to the impact, had a baseline overall score of B. Any loss of ecological or human use services during the period the wetland is in a degraded (D or C) condition is termed "interim loss" and is therefore compensable. Objectives would ideally be to restore the site to at least the B condition, and the responsible party would be liable for costs to return the wetland to that B condition. The compensation could come in the form of improving the impacted wetland to a condition above B baseline (e.g., 'A condition' or better than baseline condition) or by doing additional restoration off-site.

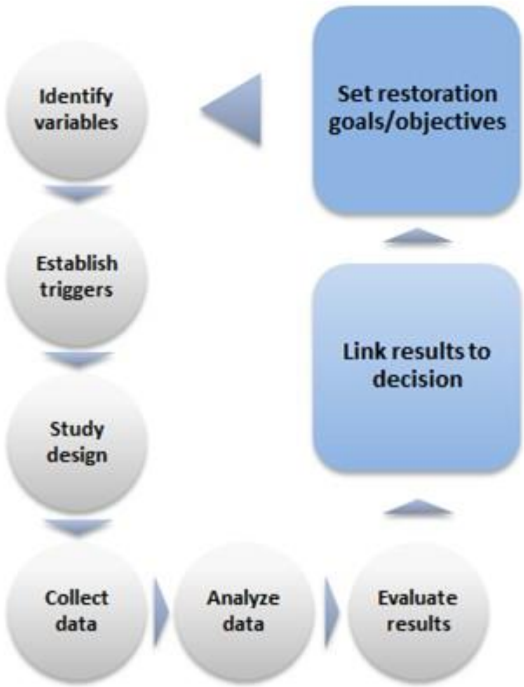


Figure 17. Flow diagram of the basic steps involved with site monitoring, beginning with setting goals/objectives. Monitoring methods and results should be evaluated throughout the life of a monitoring program. Monitoring should be able to demonstrate that restoration was effective with respect to wetland restoration goals and objectives, or identify whether restoration prescription should by modified to attain more desirable results.

5.2. Effectiveness Monitoring

Effectiveness monitoring aims to measure ***progress towards desired conditions*** as established in the restoration plan. It should target component metrics that are most responsive to restoration actions, and should be designed to be sufficiently sensitive to detect change within the stated timeframe. One or more of the EIA metrics will serve as the primary basis for effectiveness monitoring. The effectiveness of the restoration can be determined by comparing the metric scores at the restoration site to scores from baseline measures at the site.

It may be that an initial focus on the lowest scoring metrics is warranted to show most clear progress toward restoration objectives. Monitoring of other metrics scored as A and/or B might be called for if the near-term monitoring objective includes ensuring that these relative high scores are maintained (Box J).

The type of sampling needed to detect change includes the statistical need for avoiding “type II” errors (i.e., the failure to detect change that has in fact occurred). Practically, this requires sample numbers that will ensure sufficient statistical power. This could suggest an alternative sample design and sampling density at the restoration site, as compared with the established design for characterizing baseline condition[6].

[6]https://www.epa.gov/sites/production/files/documents/wetlands_4studydesign.pdf

Figure 18 depicts the sample array on either side of a now-breached dike at the Robinson Marsh site on Saginaw Bay. Although the rapid and intensive assessments provided a clear understanding of the current vegetation condition (e.g., VEG1-VEG3 in Table 4, in Section 4.4), an expanded design might be needed, if the goal is to detect desired changes in native or exotic species cover within a 3-to-5-year timeframe.

Effectiveness measures may also address structural considerations such as revegetation, reduction of other on-site stressors, and other kinds of short-term activities that aim to recover habitat and functional losses. The desire in those cases is to clearly document the location and type of restoration practices so that near-term changes in metrics can be confidently shown as being responsive.

Again, as referenced under Baseline Monitoring, practitioners may elect to focus on just subset metrics for effectiveness monitoring within set timeframes (near-term, medium-term, etc.) to maximize the return on investment in time and effort for re-measurement.

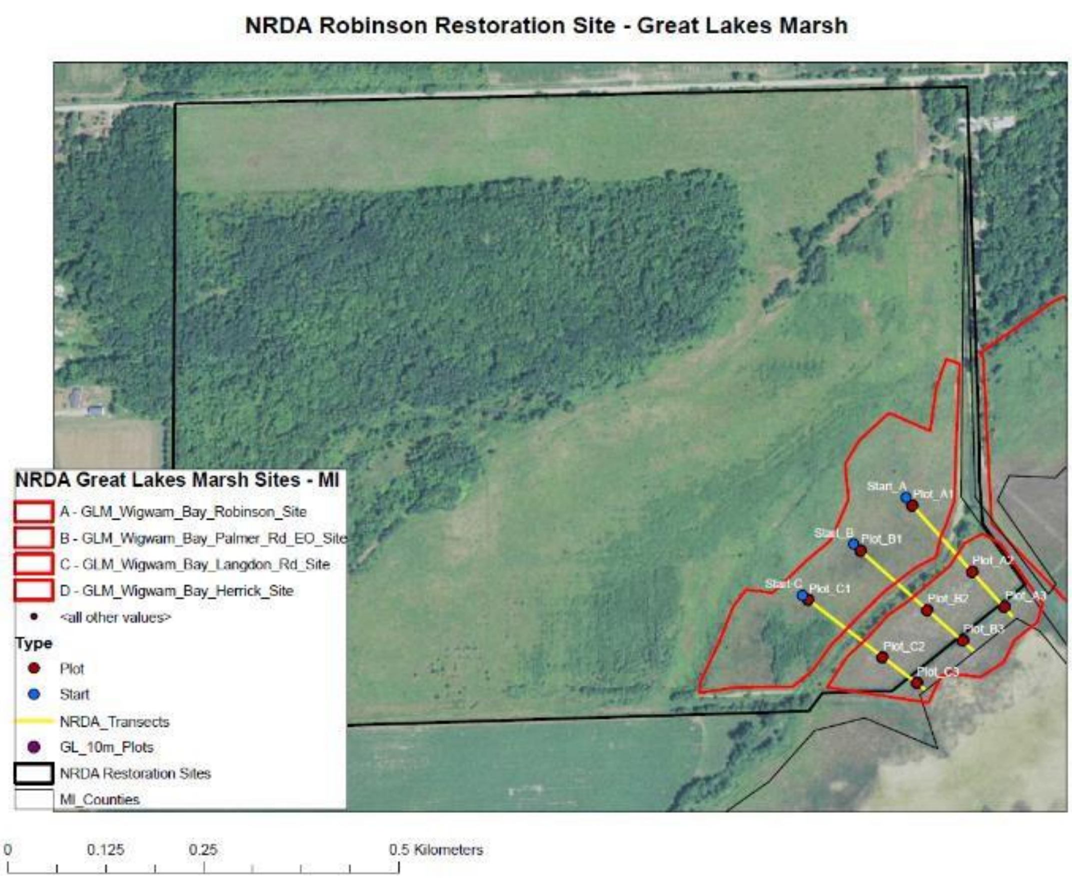


Figure 18. Location of sample transects relative to marsh gradient and dikes at Robinson restoration site, Saginaw Bay, MI.

Box J. Level 2 Rapid Assessment Metrics for Effectiveness Monitoring

As noted previously in section 3.6, Level 2 (rapid, field-based) metrics are suited to evaluating ecological conditions with readily observable field metrics. They are often applied at local patch or stand scales, covering acres at a time. Observers walk through the site, and consider the full range of observable ecological features, scoring various indicators based on qualitative or semi-quantitative data, as well as photo points, that are sufficiently repeatable to guide restorations.

Level 2 metrics can be a practical focus for effectiveness monitoring, as they tend to include vegetation, hydrology, and soil-based metrics than can be observed in a rapid site visit. Where these metrics should be indicative of progress towards stated restoration objectives, practitioners should consider their use to maximize efficiency of effectiveness monitoring.

5.3. Validation Monitoring

Validation monitoring is typically applied over long timeframes and sites, and aims to ***test assumptions about the causal linkages between the implementation of restoration practices and their outcomes***. While effectiveness monitoring aims to measure relatively short-term progress towards an established desired condition, validation monitoring aims to establish a clear linkage between each restoration practice (e.g., restored hydrologic regime) and their assumed outcome (e.g., sediment flows and plant regeneration). The combination of effectiveness/short term and validation/long term monitoring is particularly important and complimentary (Lee and Bradshaw 2004), as it provides a sound scientific basis for restoration practice and makes investments in restoration increasingly defensible.

In many instances, the most effective way to address this is to continue comparing the restoration site to the references sites over time.

To validate our restoration, we need to ensure that the ecological characteristics of our reference sites continue to provide the relevant values. For example, if some of our reference sites contain a range of hydrological and vegetation characteristics that begin to diverge from our restoration sites, we may want to eliminate the use of those sites. Thus, the validation of the restoration site success also means validating our presumed reference site selection and their conditions. This will likely require additional consideration of sample design and intensity between the restoration site and the reference site.

The Upper Midwest and Great Lakes Landscape Conservation Cooperative established the Coastal Conservation Working Group.[7] This is an example of a group that envisions a diverse assemblage of federal, state, tribal governments, and private interests collaborating to conserve and restore Great Lakes coastal habitats that provide key ecosystems functions and values essential for water quality, fish and wildlife, and people throughout the Great Lakes Basin. Groups such as this can provide a foundation for a "learning network" linking restoration practitioners engaged with similar types of ecosystems.

The Great Lakes Coastal Wetlands Monitoring Program (CWMP)[8] is also an example where a wetland monitoring site network has been established throughout the region. Sample protocols and associated data are maintained by affiliated member institutions, and research findings from ongoing efforts provide a foundation for validating a wide variety of restoration practices in these wetland types.

Networks linking practitioner engaged in both restoration and monitored can be an essential source of knowledge to adapt and validate restoration practices over time.

[7] https://greatlakeslcc.org/group/coastal-conservation-working-group

[8] http://www.greatlakeswetlands.org/Home.vbhtml

Step 6. Documentation

6.1. Protocols for Metrics

Protocols are needed to ensure that consistent and clear methods used for each metric. We have developed a standard format for documentation of each metric that includes the following pieces of information:

- definition of metric
- rationale for selection of the metric
- measurement protocol
- metric ratings
- rationale for scaling metric ratings
- citations

Protocols are now available for many NatureServe rapid assessment protocols (Level 2). The most developed and tested protocols include the NatureServe wetland rapid assessment metrics, both across states (Faber-Langendoen et al. 2012, 2016c) and for specific states (Colorado – Lemly and Gilligan 2015, New Hampshire – Nichols and Faber-Langendoen 2012, New Jersey – Walz et al. in prep, Washington – Rocchio and Crawford 2011). Other rapid assessment protocols cover all ecosystems in a state. Examples include Arkansas (Foti et al. 2016) and Washington (Rocchio and Crawford (2011). Finally, remote-sensing based protocols have been developed for entire ecoregions in the west, e.g. the BLM Central Basin and Range (Comer et al. 2013) or specific managed areas (Comer et al. 2016). NatureServe maintains a comprehensive set of all metrics used for its EIA methods in the EcoObs database (see below).

6.2. Reference Site Databases

As information accumulates on the status of wetlands across a jurisdiction or geographic region, management of that data becomes critical. Given the large number of ecological condition assessments available, it is becoming increasingly important to manage these data. Tools currently exist, ranging from the single metric database of the Universal Floristic Quality Assessment Calculator (Freyman et al. 2016) to multi-metric databases for CRAM, Riparia, and many others (Brooks et al. 2016). Discussions have begun to make wetland reference sites available through a National Reference Wetlands Registry (RWR) (Brooks et al. 2016, Faber-Langendoen et al. 2016c). The RWR can become an important source of information for conservation, restoration, and mitigation of wetlands.

NatureServe uses a combination of databases ***EcoObs*** and ***Biotics*** to track ecological integrity scores of all ecosystem types. The EcoObs (Ecological Observations) database manages basic site information, rapid and intensive plot data on vegetation, soils, and hydrology, and information on indicators and metrics, including floristic quality indices (Faber-Langendoen et al. 2016c). Biotics is an integrated, web-enabled platform that provides for managing taxonomic and conservation status information, a well as locational information on ecosystem types, plants and animals. Used by members of the NatureServe network, the system provides built-in support for shared methodology and data standards.

6.3. Quality Assurance and Quality Control

Throughout the process, it is important to monitor data collection methods and quality of data being collected. Quality assurance (QA) involves continual monitoring of data being collected. Standard methodology in field data collection and recording will help avoid sampling errors (Herrick et al. 2015). Field crews should be thoroughly trained in the sampling methods before data collection commences. They are responsible for ensuring that the data are consistently and accurately collected and need to constantly check measurements as they are being taken in the field. After the field data, have been collected, the data manager can implement a Quality Control (QC) step, which involves checking the data once it has been collected to be sure that it follows correct protocols. The database manager should check to make sure all data are accurately entered and data among plots within a site are consistent. If an error is detected, the data manager can determine if the error level is acceptable and unlikely to impact future analyses. Those data that do not meet the standard need to be removed from the analyses to avoid misinterpretation and false conclusions.

Linking Wetland Assessment and Monitoring to other Ecosystem-based Assessments

The EIA method can be applied in multiple ways, reflecting the importance of assessing ecological condition (Box K). NatureServe has developed a series of general EIA templates that are broadly applicable (Faber-Langendoen et al. 2012). These general templates can be customized for local applications. EIAs have been developed for upland, wetland, and riparian ecosystem types throughout the United States (Faber-Langendoen 2008; Unnasch et al. 2009; Faber-Langendoen et al. 2012, Comer et al. 2013, Nordman et al. 2016) and within specific states (Lemly and Rocchio 2009, Rocchio and Crawford 2011, Nichols and Faber-Langendoen 2012, Lemly and Gilligan 2015).

Although assessing the ecological integrity of a wetland or other habitat type occurrence can be the primary goal of this method, such assessments can be one component of a more complex ecosystem assessment. We highlight three types of cases.

Watershed, Landscape, and Ecoregional Assessments

By-and-large, the EIA methods discussed here focus on the wetland as the target of evaluation, whether broadly defined (all wetlands) or finely defined (Great Lakes coastal marsh). But it may also be necessary to address the condition of entire watersheds and landscapes. An assessment of the ecological integrity of the component ecosystems can be integrated into these assessments, even as new indicators are needed to track issues of fragmentation and other functions at these larger scales. Examples of the integration of site-based EIAs with watershed and landscape assessments include that of an ecoregion (Comer et al. 2013), a state (Sorenson et al. 2015), and a national park (Comer et al 2016).

Box K: Some Existing EIA Applications

- Determine range in integrity of a wetland type within a landscape or watershed (Lemly et al. 2013).
- Identify all occurrences with the highest levels of integrity within a jurisdiction (Rocchio et al. 2015).
- Rapid assessment of current conditions for all major ecosystem types occurring within and ecoregion (Comer et al. 2013)
- Assessment of natural resource condition in support of stewardship strategy development on a National Park unit (Comer et al. 2016)
- Assess restoration and mitigation efforts based on reference standard sites (Brooks et al. 2016).

From a conservation and resource management perspective, the integration of site-based ecological integrity assessments with broader landscape, watershed, and regional assessments is essential to address mandates and concerns for multiple-use management and preventing range wide decline of ecosystem types.

Strategic Habitat Conservation (SHC) has been spearheaded by the U.S. Fish and Wildlife Service to support multi-scaled assessment, planning, implementation, and monitoring, of population-habitat relations for trust species. It offers many opportunities to integrate EIA methods in the assessment and monitoring of important habitats at regional scales. The SHC Handbook[9] provides much additional guidance for organizing and carrying out landscape conservation design, where EIA methods can play a critical role.

Ecosystem Service Assessments

Understanding the services that wetlands provide depends in part on understanding its ecological integrity. As initially defined under the Millennium Ecosystem Assessment (b), four categories used to assess ecosystem services include a) sustaining services, b) provisioning services, c) regulating services, and d) cultural

[9] https://www.fws.gov/landscape-conservation/pdf/SHCHandbook.pdf

services. Ecological integrity underpins the functioning of ecosystems, and therefore, while the measurable services provided by ecosystems to people (be it from a-d) is typically viewed as one step away from the ecosystems themselves, their provision can be directly tied back to the relative integrity of local ecosystem types. In addition, since the EIA method results in greater transparency as to the factors and indicators of integrity, inevitable trade-offs between provision of certain favored ecosystem services over others (e.g., flood storage over wildlife habitat values), when those decisions are taken, can be made more explicit. With ecosystem service assessments growing in prominence, there are new planning frameworks and tools coming available to help integrate ecosystem services into other types or resource assessments. One such resource for this integration is the Federal Resource Management and Ecosystem Services Guidebook.[10]

Managing for Wetland Resiliency

Changes in the magnitude, timing, frequency, and duration of climate-driven ecological processes are now being observed. The interactions of these process changes with other ecosystem stressors, from increasing drought to more severe weather events may be creating wetland conditions that are outside any range of natural variation experienced on earth in recent millennia (i.e., “novel climates” of Williams et al. 2007). Thus, measures of ecological integrity can contribute to our understanding of the ability of ecosystems to resist, and be resilient to, climate change effects. This does not make the past and current states irrelevant; rather, as Millar et al. (2007) note: “Historical ecology becomes ever more important for informing us about environmental dynamics and ecosystem response to change.”

To that end, NatureServe’s Habitat Climate Change Vulnerability Index[11] includes several major components – Climate Change Exposure, addressing direct effects of climate change on ecological processes, is scored against measures of climate change Resilience, which is in turn made up of measures for Sensitivity and Adaptive Capacity (Comer et al. 2012). For ecosystem and habitat types, climate change sensitivity is measured through indicators of ecological integrity. Thus, our assessment of ecological integrity will directly inform how wetland ecosystems are likely to become vulnerable to climate change, and that knowledge will assist with clarifying adaptive restoration and management strategies.

Conclusion

The wetland EIA methodology documented in this guide provides a succinct assessment of the composition, structure, processes of a given occurrence of a wetland type. This method uses a metrics-based approach, guided by a conceptual model reference conditions, key ecological attributes and measurable indicators, and knowledge of their natural ranges of variation. It can utilize indicators aiming to measure either ecological condition or specific wetland stressors. It can be applied using remote sensing (Level 1), rapid field-based (Level 2) or intensive field-based (Level 3) measurements to individual sites or across watershed, landscapes, regions and states.

Practitioners apply the methodology to initially assess baseline conditions, and then monitor change in those conditions across a wide range of ecosystem types, including all types of wetland, but also in upland desert scrub, temperate forest, and grassland. By improving our measurement of ecological integrity, we provide the critical information needed to restore natural ecosystem pattern and process, and to maintain the species and services that depend on those ecosystems.

[10] https://nespguidebook.com/assessment-framework/framework-overview/

[11] http://www.natureserve.org/conservation-tools/climate-change-vulnerability-index-ecosystems-and-habitats

References

Albert, D.A., Wilcox, D.A., Ingram, J.W. and Thompson, T.A., 2005. Hydrogeomorphic classification for Great Lakes coastal wetlands. *Journal of Great Lakes Research*, *31*, pp.129-146.

Andreasen, J. K., R. V. O'Neill, R. Noss, and N. C. Slosser. 2001. Considerations for the development of a terrestrial index of ecological integrity. Ecological Indicators 1: 21–35.

Angermeier, P.L., 2000. The natural imperative for biological conservation. *Conservation Biology*, *14*(2), pp.373-381.

Assessment, M.E., 2005. Millennium ecosystem assessment. Ecosystems and Human Well-Being: Biodiversity Synthesis, Published by World Resources Institute, Washington, DC.

Bennetts, R.E., J.E. Gross, K. Cahill, C. McIntyre, B.B. Bingham, A. Hubbard, L. Cameron, and S.L. Carter. 2007. Linking monitoring to management and planning: Assessment points as a generalized approach. The George Wright Forum 24(2): 59-77.

Bestelmeyer, B.T., K. Moseley, P.L. Shaver, H. Sanchez, D.D. Briske, and M.E. Fernandez-Gimenez. 2010. Practical guidance for developing state-and-transition models. Rangelands 32:23-30

Bourdaghs, M. 2012. Development of a Rapid Floristic Quality Assessment. Minnesota Pollution Control Agency, St. Paul, MN.

Bourdaghs, M., Johnston, C.A. and Regal, R.R., 2006. Properties and performance of the floristic quality index in Great Lakes coastal wetlands. *Wetlands*, *26*(3), pp.718-735.

Brewer, J.S. and T. Menzel. 2009. A method for evaluating outcomes of restoration when no reference sites exist. Restoration Ecology 17:4-11.

Bried, J.T., K.L. Strout, and T. Portante. 2012. Coefficients of Conservatism for the Vascular Flora of New York and New England: Inter-state Comparisons and Expert Opinion Bias *Northeastern Naturalist* Vol. 19, Special Issue 6: 101-114

Brinson, M.M., 1993. A hydrogeomorphic classification for wetlands. East Carolina University.

Brooks, R.P., D.H. Wardrop, and J.A. Bishop. 2004. Assessing wetland condition on a watershed basis in the Mid-Atlantic region using synoptic land-cover maps. Environmental Monitoring and Assessment 94:9-22.

Brooks, R.P., D. Faber-Langendoen, G. Serenbetz, J. Rocchio, E.D. Stein, and K. Walz. 2016. Toward creating a national Reference Wetlands Registry. National Wetlands Newsletter 38(3):7-11.

Cohen, J.G., M.A. Kost, B. Slaughter, D. Albert. 2015. A Field Guide to the Natural Communities of Michigan. Michigan State University Press

Collins, J. N., E. D. Stein, M. Sutula, R. Clark, A. E. Fetscher, L. Grenier, C. Grosso, and A. Wiskind. 2006. California Rapid Assessment Method (CRAM) for Wetlands and Riparian Areas. Version 4.2.3. 136 pp.

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological Systems of the United States: A Working Classification of U.S. Terrestrial Systems. NatureServe, Arlington, VA.

Comer, P. J., B. Young, K. Schulz, G. Kittel, B. Unnasch, D. Braun, G. Hammerson, L. Smart, H. Hamilton, S. Auer, R. Smyth, and J. Hak. 2012. Climate Change Vulnerability and Adaptation Strategies for Natural Communities: Piloting methods in the Mojave and Sonoran deserts. Report to the U.S. Fish and Wildlife Service. NatureServe, Arlington, VA.

Comer, P. and D. Faber-Langendoen. 2013. Assessing ecological integrity of wetlands from national to local scales: exploring the predictive power, and limitations, of spatial models. National Wetlands Newsletter (May-June 2013): 20-22.

Comer, P.J., P.J. Crist, M.S. Reid, J. Hak, H. Hamilton, D. Braun, G. Kittel., I. Varley, B. Unnasch, S. Auer, M. Creutzburg, D. Theobald, and L. Kutner. 2013. A Rapid Ecoregional Assessment of the Central Basin and Range Ecoregion. Report, appendices, and databases provided to the Bureau of Land Management.

Comer, P.J., D.P. Braun, M.S. Reid, R.S. Unnasch, J.P. Hak, K.A. Schulz, G. Baker, B. Roberts, and J. Rocchio. 2016. Great Basin National Park: Natural Resource Condition Assessment. Natural Resource Report NPS/GRBA/NRR—2016/1105. National Park Service, Fort Collins, Colorado.

Cowardin, L.M., Carter, V., Golet, F.C. and LaRoe, E.T., 1979. Classification of wetlands and deepwater habitats of the United States. US Department of the Interior, US Fish and Wildlife Service.

Cvetkovic, M. and Chow-Fraser, P., 2011. Use of ecological indicators to assess the quality of Great Lakes coastal wetlands. *Ecological Indicators*, *11*(6), pp.1609-1622.

Davies, S.P., and S.J. Jackson. 2006. The biological condition gradient: a descriptive model for interpreting change in aquatic ecosystems. Ecological Applications 16:1251–1266.

Day, J.W.Jr., C.A.S. Hall, W.M. Kemp, A. ez-Arancibia. 1989. Estuarine Ecology. Wiley-Interscience, 1rst edition. 576 pp.

DeKeyser, E.S., D.R. Kirby, and M.J. Ell. 2003. An index of plant community integrity: development of the methodology for assessing prairie wetland plant communities. Ecological Metrics 3: 119-133.

Ellison, A.A., M.S. Bank, B. D. Clinton et al. 2005. Loss of foundation species: consequences for the structure and dynamics of forested ecosystems. Frontiers in Ecology and the Environment 3:479-486.

EPA. 2002. Methods for evaluating wetland condition #7 Wetland Classification. EPA-822-R-02-107.

Faber-Langendoen, D., G. Kudray, C. Nordman, L. Sneddon, L. Vance, E. Byers, J. Rocchio, S. Gawler, G. Kittel, S. Menard, P. Comer, E. Muldavin, M. Schafale, T. Foti, C. Josse, J. Christy. 2008. *Ecological Performance Standards for Wetland Mitigation based on Ecological Integrity Assessments.* NatureServe, Arlington, VA. + Appendices.

Faber-Langendoen, D., C. Hedge, M. Kost, S. Thomas, L. Smart, R. Smyth, J. Drake, and S. Menard. 2012. Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach. Part A. Ecological Integrity Assessment overview and field study in Michigan and Indiana. EPA/600/R-12/021a. U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Faber-Langendoen, D., T. Keeler-Wolf, D. Meidinger, D. Tart, B. Hoagland, C. Josse, G. Navarro, S. Ponomarenko, J.-P. Saucier, A. Weakley, P. Comer. 2014. EcoVeg: A new approach to vegetation description and classification. Ecological Monographs 84:533-561 (erratum 85:473).

Faber-Langendoen, D., W. Nichols, K. Strakosch Walz, J. Rocchio, J. Lemly, L. Gilligan, and G. Kittel. 2016a. NatureServe Ecological Integrity Assessment: Protocols for Rapid Field Assessment of Wetlands. NatureServe, Arlington, VA

Faber-Langendoen, D., W. Nichols, F.J. Rocchio, J. Cohen, J. Lemly, Kathleen Walz. 2016b. Ecological Integrity Assessments and the Conservation Value of Ecosystem Occurrences: *General Guidance on Core Heritage Methodology for Element Occurrence Ranking.* NatureServe, Arlington, VA.

Faber-Langendoen, D., W. Nichols, J. Rocchio, K. Walz, J. Lemly, R. Smyth and K. Snow. 2016c**.** Rating the condition of reference wetlands across states: NatureServe's Ecological Integrity Assessment method. National Wetlands Newsletter 38 (3):12-16.

Fennessy, M. S., A. D. Jacobs, and M. E. Kentula. 2007a. An evaluation of rapid methods for assessing the ecological condition of wetlands. Wetland 27:543-560.

Fennessy, M. S., J. J. Mack, E. Deimeke, M. T. Sullivan, J. Bishop, M. Cohen, M. Micacchion and M. Knapp. 2007b. Assessment of wetlands in the Cuyahoga River watershed of northeast Ohio. Ohio EPA Technical Report WET/2007-4. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, Ohio.

FGDC (Federal Geographic Data Committee). 2008. FGDC-STD-005-2008. National Vegetation Classification Standard, Version 2. Vegetation Subcommittee, U.S. Geological Survey, Reston, VA. 55 pp. + Appendices.

Foti, T., M. Pyne, R. White, D. Faber-Langendoen. 2017. Arkansas Natural Community Classification and Ecological Integrity Assessment Protocols: Rapid Assessment Metrics [draft May, 2017]. NatureServe and Arkansas Natural Heritage Commission, Little Rock AR.

Freyman, W.A., L. A. Masters, and S. Packard. 2016. The Universal Floristic Quality Assessment (FQA) Calculator: an online tool for ecological assessment and monitoring. Methods in Ecology and Evolution 7:380-383.

Frieswyk, C.B. and Zedler, J.B., 2007. Vegetation change in Great Lakes coastal wetlands: deviation from the historical cycle. *Journal of Great Lakes Research*, *33*(2), pp.366-380.

Gibbons, P., Briggs, S.V., Ayers, D.A., Doyle, S., Seddon, J., McElhinny, C., Jones, N., Sims, R. and Doody, J.S., 2008. Rapidly quantifying reference conditions in modified landscapes. *Biological Conservation*, *141*(10), pp.2483-2493.

Hak, J.C. and P.J. Comer. 2017. Modeling Landscape Condition for Biodiversity Assessment – Application in Temperate North America. *Ecological Indicators* (in press)

Harwell, M.A., V. Myers, T. Young, A. Bartuska, N. Gassman, J. H. Gentile, C. C. Harwell, S. Appelbaum, J. Barko, B. Causey, C. Johnson, A. McLean, R. Smola, P. Templet, and S. Tosini.

1999. A framework for an ecosystem integrity report card. BioScience 49: 543-556.

Hayward, G.D., T.T. Veblen, L.H. Suring, and B. Davis. Challenges in the application of historical range of variation to conservation and land management. Pp. 32-45, *In* J.A. Wiens, G.D. Hayward, H.D. Safford, and C.M. Giffen. Historical Environmental Variation in Conservation and Natural Resource Management. Wiley and Sons Ltd, Hoboken, NJ.

Herrick, J.E., J. W. Van Zee, S. E. McCord, E. M. Courtright, J. W. Karl, and L. M. Burkett. 2015. Volume I: Core Methods; Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems, Second Edition Advance Copy. USDA – ARS Jornada Experimental Range. Las Cruces, New Mexico. 77 pp.

Herrick, J., S. Wills, J. Karl, and D. Pyke. 2010. Terrestrial Indicators and Measurements: Selection Process & Recommendations. Final – August 9, 2010. Unpublished Report. USDA-ARS Jornada Experimental Range, Las Cruces, New Mexico.

Higgs, E. 2003. Nature by Design; People, Natural Process, and Ecological Restoration. The MIT Press, Cambridge, Massachusetts. 341 p.

Higgs, E.S., and R.J. Hobbs. 2010. Wild design: Principles to guide interventions in protected areas. Pp 234-251 In D.N. Cole and L. Yung. Beyond naturalness: Rethinking park and wilderness stewardship in an era of rapid change. Island Press, Washington, DC.

Hoagland, B. 2000. The vegetation of Oklahoma: a classification for landscape mapping and conservation planning. The Southwestern Naturalist 45: 385-420.

Huggins, D.G. and A. Dzialowski. 2005. Identification and Quantification of Reference Conditions Associated with Lotic Ecosystems of the Central Plains and Surrounding Regions: A summary of approaches and factors and regional approach. Report 134 of the Kansas Biological Survey. University of Kansas, Lawrence, KS.

Karr, J.R. and E.W. Chu. 1999. Restoring life in running waters: better biological monitoring. Washington (DC). Island Press, 206 pp.

Keddy, P.A. and Reznicek, A.A., 1986. Great Lakes vegetation dynamics: the role of fluctuating water levels and buried seeds. *Journal of Great Lakes Research*, *12*(1), pp.25-36.

Keough, J.R., Thompson, T.A., Guntenspergen, G.R. and Wilcox, D.A., 1999. Hydrogeomorphic factors and ecosystem responses in coastal wetlands of the Great Lakes. *Wetlands*, *19*(4), pp.821-834.

Kurtz, J. C., L. E. Jackson, and W. S. Fisher. 2001. Strategies for evaluating indicators based on guidelines from the Environmental Protection Agency's Office of Research and Development. *Ecological Indicators* 1:49–60.

Landres, P.B., P. Morgan and F.J. Swanson. 1999. Overview of the use of natural variability concepts in managing ecological systems. Ecological Applications 9(4): 1179-1188.

Lenters, J.D., 2001. Long-term trends in the seasonal cycle of Great Lakes water levels. *Journal of Great Lakes Research*, *27*(3), pp.342-353.

Lemly, J. and J. Rocchio. (2009) Vegetation Index of Biotic Integrity (VIBI) for headwater wetlands in the Southern Rocky Mountains. Version 2.0: Calibration of selected VIBI models. Unpublished report prepared for U.S. Environmental Protection Agency Region 8 and Colorado Division of Wildlife, Denver, CO. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO.

Lemly, J, B. Johnson, L. Gilligan and E Carlson. 2013. Se Setting Mitigation in the Watershed Context: Demonstration and Description of Colorado's Watershed Approach to Wetland Compensatory Mitigation (prepared for US EPA Region 8). Colorado State University, Colorado Natural Heritage Program, Ft. Collins, CO. 210 pp.

Lemly, J. and L. Gilligan. 2015. Ecological Integrity Assessment (EIA) for Colorado wetlands field manual, version 2.0. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO.

Leroux, S. J., F. K. A. Schmiegelowa, R. B. Lessard, and S. G. Cumming. 2007. Minimum dynamic reserves: A framework for determining reserve size in ecosystems structured by large disturbances. Biological Conservation 138: 464–473.

MacDonald, L.H., A.W. Smart, R.C. Wissmar. 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska. U.S. Environmental Protection Agency, Region 10, NPS Section, Seattle.

Mack, J.J., 2001. Ohio rapid assessment method for wetlands v. 5.0, user's Manual and scoring forms. Ohio EPA Technical Report WET/2001-1. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, Ohio.

Mack, J. J. 2006. Landscape as a predictor of wetland condition: An evaluation of the Landscape Development Index (LDI) with a large reference wetland dataset from Ohio. Environmental Monitoring and Assessment 120: 221–241.

Michalcová, D., Lvončík, S., Chytrý, M. & Hájek, O. (2011) Bias in vegetation databases? A comparison of stratified-random and preferential sampling. *Journal of Vegetation Science 22*, 281-291.

Millar C.I., N.L. Stephenson, S. L. Stephens. 2007. Climate change and forests of the future: managing in the face of uncertainty. Ecological Applications 17:2145–2151.

Mita, D., E. DeKeyser, D. Kirby, and G. Easson. 2007. Developing a wetland condition prediction model using landscape structure variability. Wetlands 27:1124-1133.

Mitchell B.R., W.G. Shriver, F. Dieffenbach, T. Moore, D. Faber-Langendoen, G. Tierney, P. Lombard, and J. Gibbs. 2006. Northeast Temperate Network Vital Signs Monitoring Plan. Woodstock, VT: National Park Service.

Mitchell, Brian R., G. L. Tierney, E. W. Schweiger, K. M. Miller, D. Faber-Langendoen, and J. B. Grace. 2014. Getting the message across: Using ecological integrity to communicate with resource managers. Chapter 10. *Pp. 199 – 230* In: Guntenspergen, G. R., editor. Application of Threshold Concepts in Natural Resource Decision Making. Springer, 327 pp.

NatureServe. 2002. Element Occurrence Data Standard. On-line at http://www.natureserve.org/prodServices/eodata.jsp

NatureServe. 2011. Central Basin and Range. Rapid Ecoregional Assessments, Final Memorandum I-3-C (March 4, 2011). Department of the Interior, Bureau of Land Management, Rapid Ecoregional Assessments, Denver, Colorado. NatureServe, Washington DC.

Nichols, W. F. and D. Faber-Langendoen. 2012. Level 2.5 Ecological Integrity Assessment Manual: Wetland Systems. New Hampshire Natural Heritage Bureau & NatureServe, Concord, NH. +Appendices.

Noon, B. R. 2003. Conceptual issues in monitoring ecological systems. Pages 27-71 *in* D. E. Busch and J. C. Trexler, editors. Monitoring ecosystems: Interdisciplinary approaches for evaluating ecoregional initiatives. Island Press, Washington, DC., USA 447 pp.

Nordman, C., R. White, R. Wilson, C. Ware, C. Rideout, M. Pyne, and C. Hunter. 2016. Rapid Assessment Metrics to Enhance Wildlife Habitat and Biodiversity within Southern Open Pine Ecosystems, Version 1.0. U.S. Fish and Wildlife Service and NatureServe, for the Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative. March 31, 2016.

Oliver, I., H. Jones, and D.L. Schmoldt. 2007. Expert panel assessment of attributes for natural variability benchmarks for biodiversity. Austral Ecology 32: 453–475.

Parkes, D., G. Newell and D. Cheal. Assessing the quality of native vegetation: The 'habitat hectares' approach Ecological Management & Restoration, Vol. 4 Supplement: 2003 S29-S38.

Parrish, J.D., D. P. Braun, and R.S. Unnasch. 2003. Are we conserving what we say we are? Measuring ecological integrity within protected areas. BioScience 53: 851-860.

Ramsar Convention. 2002. Conference of Contracting Parties to the Convention on Wetlands. 2002. Principles and guideline for wetland restoration. Adopted Resolution VIII.16 of the Ramsar Convention.

Rocchio, F.J. and R.C. Crawford. 2011. Applying NatureServe's Ecological Integrity Assessment Methodology to Washington's Ecological Systems. Natural Heritage Report 2011-10. Washington Natural Heritage Program, Washington Department of Natural Resources. Olympia, Washington.

Rocchio, F.J., R.C. Crawford, and R. Niggemann. 2015. Wetland Ecosystem Conservation Priorities for Washington State. An Update of Natural Heritage Classification, Inventory, and Prioritization of Wetlands of High Conservation Value. Natural Heritage Program Report 2015-05. Washington Dept. of Natural Resources, Natural Heritage Program. Olympia, WA.

Rolecek, J., Chytry, M., Háyek, M., Lvoncik, S. & Tichý, L. (2007) Sampling in large-scale vegetation studies: Do not sacrifice ecological thinking to statistical puritanism. Folia Geobotanica, 42, 199-208.

Rollins, M.G., 2009. LANDFIRE: a nationally consistent vegetation, wildland fire, and fuel assessment. *International Journal of Wildland Fire*, *18*(3), pp.235-249.

Romme, W.H., J.A. Wiens, and H.D. Safford. 2012. Setting the stage: theoretical and conceptual background of historical range of variation. Pp 3-18 *In* Wiens, J.A., G.D. Hayward, H.D. Safford, and C.M. Giffen. Historical Environmental Variation in Conservation and Natural Resource Management. John Wiley and Sons, Hoboken, NJ.

Smith, R.D., A. Ammann, C. Bartoldus, and M.M. Brinson. 1995. An approach for assessing wetland functions using hydrogeomorphic classification, reference wetlands, and functional indices. Technical Report WRP–DE–9, U.S. Corps of Engineers, Army Engineer Waterways Experiment Station, Vicksburg, MS.

Society for Ecological Restoration (SER) International Science & Policy Working Group. 2004. *The SER International Primer on Ecological Restoration*. www.ser.org & Tucson: Society for Ecological Restoration International. 13 p.

Swink, F. and G. Wilhelm. 1979. Plants of the Chicago Region. Revised and expanded edition with keys. The Morton Arboretum, Lisle, IL.

Solek, C.W., E.D. Stein, and M. Sutula. 2011. Demonstration of an integrated watershed assessment using a three-tiered assessment framework. Wetlands Ecology and Management 19: 459-474.

Sorenson, E., R. Zaino, J. Hike, and E. Thompson. 2015. Vermont Conservation Design: Maintaining and Enhancing an Ecologically Functional Landscape. Vermont Fish and Wildlife Department and Vermont Land Trust. 24 pp.

Stein, E. D., A. E. Fetscher, R. P. Clark, A. Wiskind, J. L. Grenier, M. Sutula, J. N. Collins, and C. Grosso. 2009. Validation of a wetland rapid assessment method: use of EPA's level 1-2-3 framework for method testing and refinement wetlands. Wetlands 29: 648–665.

Stoddard, J.L., D.P. Larsen, C.P. Hawkins, R.K. Johnson, and R.H. Norris. 2006. Setting expectation for the ecological condition of streams: the concept of reference condition. Ecological Applications 16(4): 1267-1276.

Sutula, M.A., E.D. Stein, J.N. Collins, A.E. Fetscher, and R. Clark. 2006. A practical guide for development of a wetland assessment method: the California experience. J. Amer. Water Resources Association 42:157-175.

Taft, J.B., G.S. Wilhelm, D.M. Ladd, and L.A. Masters. 1997. Floristic quality assessment for vegetation in Illinois: A method for assessing vegetation integrity. Erigenia 15:3–95.

Tierney, G.L., D. Faber-Langendoen, B.R. Mitchell, W.G. Shriver, J.P. Gibbs. 2009. Monitoring and evaluating the ecological integrity of forest ecosystems. Frontiers in Ecology and the Environment 7:308-316.

Tulbure, M.G., Johnston, C.A. and Auger, D.L., 2009. Rapid invasion of a Great Lakes coastal wetland by non-native Phragmites australis and Typha.

Unnasch, R.S., D. P. Braun, P. J. Comer, G. E. Eckert. 2008. The Ecological Integrity Assessment Framework: A Framework for Assessing the Ecological Integrity of Biological and Ecological Resources of the National Park System**.** Report to the National Park Service.

U.S. Environmental Protection Agency (USEPA). 2006. Elements of a state water monitoring and assessment program for wetlands. Washington, DC. 12pp.

U.S. Environmental Protection Agency (USEPA). 2016. National Wetland Condition Assessment: Technical Report. EPA 843-R-15-006. U.S. EPA, Washington, DC.

U.S. EPA. 2011. USA RAM Manual, Version 11. (co-authors, Josh Collins, Siobhan Fennessy). U.S. Environmental Protection Agency, Washington, DC.

Wardrop, D. H., M.E. Kentula, R. P. Brooks, M.S. Fennessy, S.J. Chamberlain, K.J. Havens, and C. Hershner. 2013. Monitoring and assessment of wetlands: concepts, case studies and lessons learned. Pp. 318-419, *In* R. P. Brooks and D.H. Wardrop (eds). Mid-Atlantic Freshwater Wetlands: Advances in Wetlands Science, Management, Policy and Practice. Springer, NY.

Wilcox, D.A., 2012. Great Lakes coastal marshes. Wetland Habitats of North America: Ecology and Conservation Concerns.

Wilcox, D.A. and Whillans, T.H., 1999. Techniques for restoration of disturbed coastal wetlands of the Great Lakes. *Wetlands*, *19*(4), pp.835-857.

Williams, J.W., S.T. Jackson, and J. Kutzbach. 2007. Projected distributions of novel and disappearing climates by 2100 AD. PNAS 104: 5738-5742.

Woodley, S. 2010. Ecological integrity: a framework for ecosystem-based management. Pp 106-124 *In* D.N. Cole and L. Yung. Beyond Naturalness: Rethinking Park and Wilderness Stewardship in an Era of Rapid Change. Island Press, WA.

Woodward, A., and Hollar, K. 2011. Monitoring habitat restoration projects: U.S. Fish and Wildlife Service Pacific Region Partners for Fish and Wildlife Program and Coastal Program Protocol: U.S. Geological Survey Techniques and Methods 2-A11, 36p.

ACKNOWLEDGEMENTS

We are grateful for financial assistance from the U.S. Department of Interior, and the leadership and project support provided by John Isanhart. U.S. Fish and Wildlife Service staff, including Betsy Galbraith, Lisa Williams, and Clark McCreedy facilitated access to pilot sites in Michigan and Wisconsin, and provided invaluable insight and perspectives throughout this effort.

Developing the overall methodology for ecological integrity assessments has been a team effort over many years. From 1999-2002 a team of ecologists from The Nature Conservancy and Natural Heritage Programs initiated refinements to original methods for use in regional assessments and conservation action planning at sites. Multiple efforts – often in collaboration with the National Park Service, US EPA, and Bureau of land Management, enabled refinement and practical applications in a variety of management and regulatory settings. From 2009-2012, a team of ecologists worked through a field application and testing of wetland EIA methods in Michigan and Indiana. That led to substantive improvements to the overall methodology, and the adoption of the methodology across other states.

Kristin Snow, with Mary Harkness's assistance, has developed the EcoObs database to manage all EIA information. Stephanie Auer provided excellent statistical skills as we tested the strength of our EIA metrics.

ABOUT THE AUTHORS

Patrick Comer is Chief Ecologist for NatureServe, directed the NatureServe Ecology Department with staff ecologists working throughout the Americas. Since the 1980s, he has developed and applied ecological classifications to natural resource inventory, assessment, conservation planning, and monitoring throughout the Americas.
pat_comer@natureserve.org

Don Faber-Langendoen is Senior Research Ecologist in the Ecology Department at NatureServe. He has helped developed ecological classifications (including the U.S. National Vegetation Classification), ecological integrity assessments, and endangered ecosystem assessments to support NatureServe's core methods, in use across the NatureServe Network and by other conservation partners.
don_faber-langendoen@natureserve.org

Shannon Menard is Midwest Senior Regional Ecologist in the Ecology Department at NatureServe. She has contributed to developing ecological classifications, vegetation mapping, and ecological integrity assessments, to support NatureServe's core methods and data, in use across the Midwest region.

Ryan O'Connor is an ecologist and coordinates and conducts biotic inventories of natural communities for the Wisconsin DNR's Natural Heritage Conservation program. Ryan has a Master's Degree from the University of Michigan and has worked as a botanist and ecologist in the Great Lakes region for 15 years, where he focuses on providing land managers with high-quality data to make better decisions, monitoring natural communities, developing adaptation resources, and documenting rare species as well as new populations of invasive plants.

Phyllis Higman is a Senior Conservation Scientist with the Michigan Natural Features Inventory with 25 years of field-based experience studying Michigan's native ecosystems and vulnerable species. She conducts surveys and delivers workshops focused on biodiversity conservation and is working statewide to promote early detection, mapping and strategic control of invasive species –one of the biggest threats to biodiversity conservation.

Yu Man Lee is a Conservation Scientist with the Michigan Natural Features Inventory with 20 years of field-based experience studying Michigan's native ecosystems and vulnerable species, particularly amphibians and reptiles. She conducts surveys, research, and

monitoring, and provides education and outreach to inform biodiversity conservation. Yu Man has been working with partners statewide to promote awareness and conservation of vernal pools and other vulnerable wetlands and associated species in Michigan.

Brian Klatt is the Director of the Michigan Natural Features Inventory at Michigan State University. He is certified as a Senior Ecologist by the Ecological Society of America, has taught environmental impact analysis at Michigan State University, and wetland science and policy at the University of Michigan. He has over 30 years of experience in biodiversity conservation and currently serves an expert to the United Nations on biodiversity assessment and sustainability.

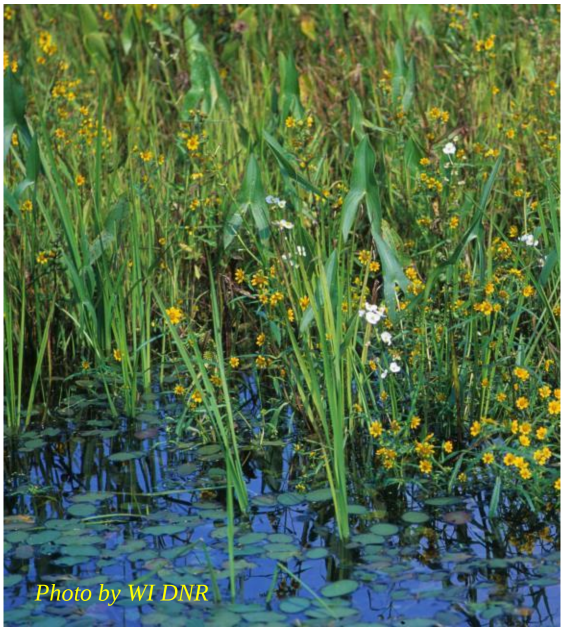


Photo by WI DNR

Photo by Patrick Comer

APPENDICES

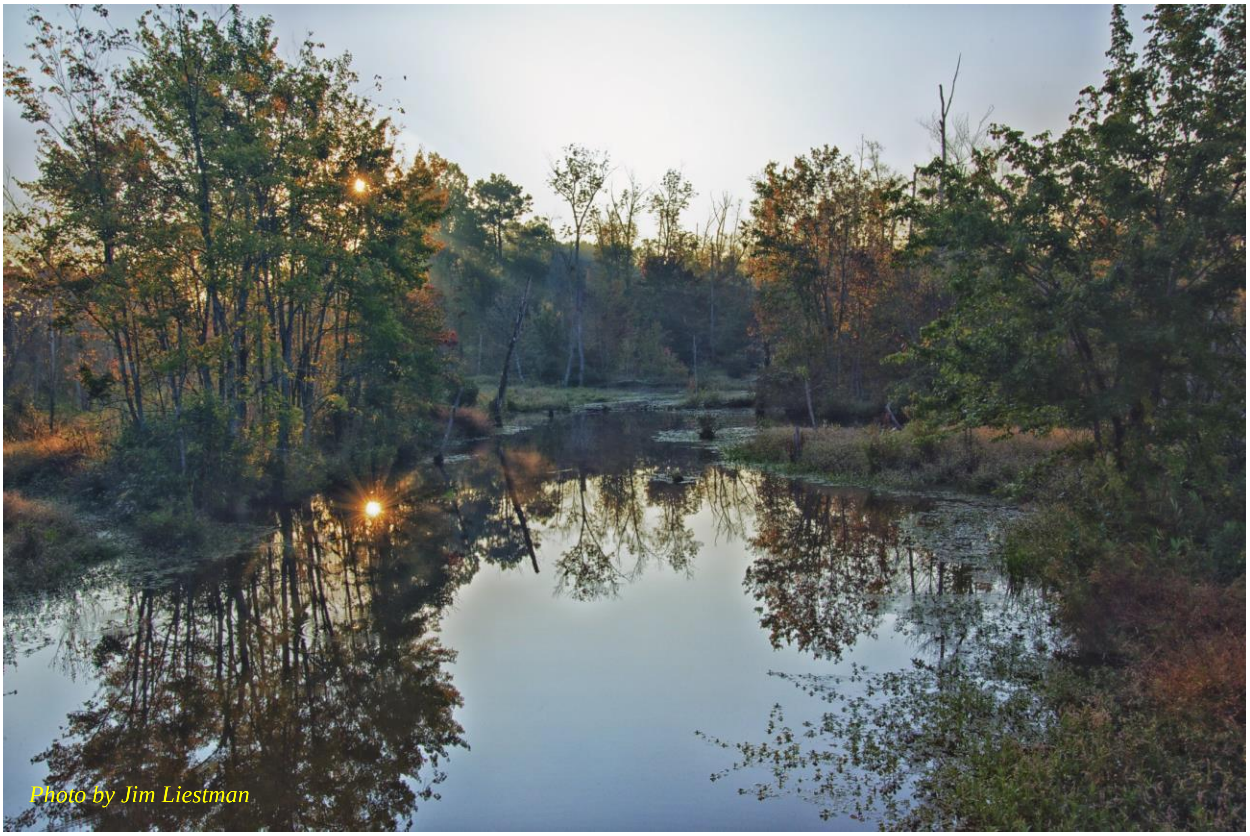


Photo by Jim Liestman

Appendix 1 – NRDAR Wetland Project Checklist

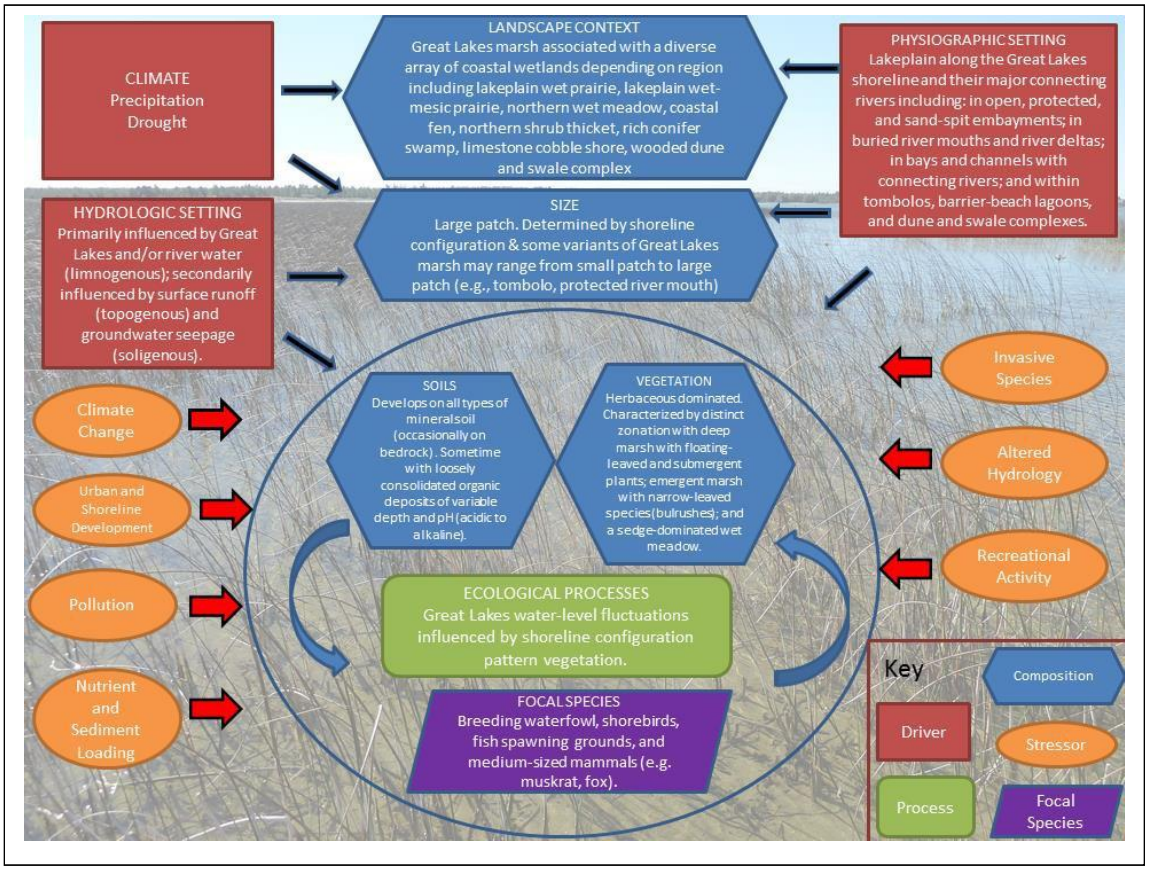
Box A - PROJECT CHECKLIST		
	Task	Guide Section
☐	Locate impacted and/or restoration site	Step 1
☐	Contact site management staff ○ Identify existing information about the site	Step 1
☐	Is there a current restoration plan?	Step 1
☐	Identify existing ecological assessments of area and establish data dictionary	Step 1
☐	Identify potential partners, stakeholders, and technical experts relevant to restoration site	Step 1
☐	Identify needed expertise (wetland ecologist, spatial analyst, database manager)	Step 1
☐	Review existing documentation on site ○ Wetland descriptions ○ Published documents ○ Wetland sample data ○ Land use/land cover maps and aerial photos	Step 1
☐	Carry out reconnaissance site visit ○ Identify wetland type(s) impacted ○ Identify wetland type(s) targeted for restoration; and relative similarities and differences between wetland types ○ Visit potential reference sites	Step 2
☐	Document specific restoration goals and timelines ○ Are restoration goals stated? ○ Are restoration objectives specified? ○ Are restoration objectives specified along a timeline?	Step 2
☐	Establish site boundaries to be included in restoration ○ Relevant landscape context of restoration site	Step 2
☐	Identify potential reference sites ○ Same wetland type nearby ○ Same wetland type within major watershed	Step 2
☐	Identify existing documentation of reference conditions ○ Complete conceptual model of wetland type ○ Describe reference conditions in terms of key ecological attributes (KEA) ○ Identify primary indicators and metrics for each KEA	Step 3
☐	Complete sample design for Level 2-3 metrics ○ Restoration site ○ Reference sites (as needed)	Step 4
☐	Identify field equipment and documentation methods ○ Developed field data form ○ Collected field equipment	Step 4
☐	Identify field crew	Step 4
☐	Complete initial field sampling ○ Restoration site ○ Reference sites (as needed) ○ Populate sample database	Step 4
☐	Complete Level 1 measurements in office	Step 4 (Example, Appendix 2a)
☐	Analyze data to establish assessment points and metric ratings for each metric	Step 4 (Metric examples, Appendix 2)
☐	Complete assessment scorecard	Step 4
☐	Document baseline ratings ○ Re-assess restoration objectives given baseline assessment	Step 4
☐	Establish monitoring plan ○ Establish effectiveness measures in terms of metrics ○ Restate short-term objectives in terms of metric ratings (3-5 years) ○ Restate medium term objectives in terms of metric ratings (6-10 years) ○ Restate long-term objectives in terms of metric ratings (11-30 years)	Step 5
☐	Document needs for Validation Monitoring	Step 6
☐	Package and disseminate site report and database	Step 6

Appendix 2 – Example Conceptual Model and EIA Indicators for Natural Communities of Michigan - Ecological Integrity Assessment

Palustrine Class
Marsh Group
Great Lakes Marsh (S3)
Physiographic Setting: Lakeplain along the Great Lakes shoreline and associated major connecting rivers including: in open, protected, and sand-spit embayments; in buried river mouths and river deltas; in bays and channels with connecting rivers; and within tombolos, barrier-beach lagoons, and dune and swale complexes.
Distribution: Great Lakes marshes occur along all the Great Lakes and their connecting rivers, including the Detroit, St. Clair, and St. Mary's Rivers.

Great Lakes marsh, Duck Bay, Marquette Island, Aldo Leopold Nature Preserve, Mackinac County (Photo by Joshua G.

NatureServe Ecological System Crosswalk: Northern Great Lakes Coastal Marsh and Great Lakes Freshwater Estuary and Delta. Michigan's natural community classification of Great Lakes Marsh includes both coastal marsh and freshwater estuary and delta marsh.
Soils: Great Lakes marsh develops on all types of mineral soil (occasionally on bedrock) with loosely consolidated organic deposits of variable depth and pH (acidic to alkaline).
Nutrient Status and pH: Where bedrock is at or near the surface, bedrock chemistry affects wetland species composition and soil pH. Soils derived from Precambrian crystalline bedrock along Lake Superior are generally acid. In contrast, soils derived from marine deposits in the lower Great Lakes, including shale and marine limestone, dolomite, and evaporites, and typically more calcareous (less acid), creating the preferred habitat for calciphilic aquatic plant species and development of more minerotrophic systems.
Spatial Pattern: Typically, large patch but depends on shoreline configuration. Some variants of Great Lakes marsh may range from small patch to large patch (e.g., tombolo, protected river mouth)
Size: Eighty-Two Great Lakes marsh element occurrences have been documented in Michigan to date. Acreage of EOs ranges from 15 to 4,155 acres with an average of 463 acres.
Suggested size rankings: A (>300 acres); B (100-300 acres); C (30-100 acres); and D (< 30 acres). A-ranked and B-ranked sites are typically large enough to sustain breeding waterfowl, shorebirds, fish spawning grounds, and some medium-sized mammals (e.g. muskrat, fox).



Vegetation: Dominated by herbaceous species. Characterized by distinct zonation that often includes deep marsh with floating-leaved and submergent plants; emergent marsh with narrow-leaved species (bulrushes); and sedge-dominated wet meadow. Characteristic plants include bulrushes (*Schoenoplectus* spp. and *Scirpus* spp.), spike-rushes (*Eleocharis* spp.), rushes (*Juncus* spp.), broad-leaved cat-tail (*Typha latifolia*), blue-joint (*Calamagrostis canadensis*), sedges (*Carex* spp.), sweet-scented waterlily (*Nymphaea odorata*), yellow pond-lilies (*Nuphar variegata* and *N. advena*), duckweeds (*Lemna* spp.), coontail (*Ceratophyllum demersum*), and pondweeds (*Potamogeton* spp.).
Invasive Plant Species: Invasive plant species are a significant threat to Great Lakes marsh, especially in southern Lower Michigan. Species of concern include reed (*Phragmites australis* subsp. *australis*), narrow-leaved cat-tail (*Typha angustifolia*), hybrid cat-tail (*Typha* x*glauca*), reed canary grass (*Phalaris arundinacea*), purple loosestrife (*Lythrum salicaria*), frogbit (*Hydrocharis morsus-ranae*), watercress (*Nasturtium microphyllum*), European marsh thistle (*Cirsium palustre*), and flowering rush (*Butomus umbellatus*).
Water Source: Primarily influenced by Great Lakes and/or connecting river water (limnogenous); secondarily influenced by surface runoff (topogenous) and groundwater seepage (soligenous).
Hydroperiod: Most examples exhibit a broad flood regime gradient from permanently inundated (deep marsh zone) to semi-permanently inundated (emergent marsh zone) to seasonally inundated conditions (meadow zone).
Stressors: Urban and shoreline development, fragmentation, altered hydrology (e.g., dikes, drainage ditches, dredging), boating traffic, invasive species (especially non-native plants), pollution, and nutrient and sediment loading.
Reference Condition Example: Great Lakes marsh, Duck Bay, Marquette Island, Aldo Leopold Nature Preserve, Mackinac County (AB-Ranked Element Occurrence).

References

Albert, D.A. 2001. Natural community abstract for Great Lakes marsh. Michigan Natural Features Inventory, Lansing, MI. 11 pp.
Albert, D.A. 2003. Between land and lake: Michigan's Great Lakes coastal wetlands. Michigan Natural Features Inventory. Michigan State University Extension, East Lansing, MI. Bulletin E-2902. 96 pp.
Albert, D.A., D.A. Wilcox, J.W. Ingram, and T.A. Thompson. 2005. Hydrogeomorphic classification for Great Lakes coastal wetlands. Journal of Great Lakes Research. 31(1): 129-146.
Albert, D.A., J.G. Cohen, M.A. Kost, B.S. Slaughter, and H.D. Enander. 2008. Distribution Maps of Michigan's Natural Communities. Michigan Natural Features Inventory, Report No. 2008-01, Lansing, MI. 174 pp.
Albert, D.A., G. Reese, S. Crispin, L.A. Wilsmann, and S.J. Ouwinga. 1987. A Survey of Great Lakes Marshes in Michigan's Upper Peninsula. MNFI report for Land and Water Management Division of Michigan DNR, Coastal Zone Management Program (CZM Contract 9C-10). 73 pp.
Albert, D.A., G. Reese, S.R. Crispin, M.R. Penskar, L.A. Wilsmann, and S.J. Ouwinga. 1988. A Survey of Great Lakes Marshes in the Southern Half of Michigan's Lower Peninsula. MNFI report for Land and Water Management Division of Michigan DNR, Coastal Zone Management Program (CZM Contract 10C-3). 116 pp.
Albert, D.A., G. Reese, M.R. Penskar, L.A. Wilsmann, and S.J. Ouwinga. 1989. A Survey of Great Lakes Marshes in the Northern Half of Michigan's Lower Peninsula and Throughout Michigan's Upper Peninsula. MNFI report for Land and Water Management Division of Michigan DNR, Coastal Zone Management Program (CZM Contract 10C-3). 124 pp.
Cohen, J.G., M.A. Kost, B.S. Slaughter, and D.A. Albert. 2014. A Field Guide to the Natural Communities of Michigan. Michigan State University Press, East Lansing, MI. 362 pp.
Faber-Langendoen, D., W. Nichols, J. Rocchio, J. Cohen, J. Lemly, and K. Walz. 2015. Ecological Integrity Assessments and the Conservation Value of Ecosystem Occurrences: General Guidance on Core Heritage Methodology for Element Occurrence Ranking. NatureServe, Arlington, VA.
Faber-Langendoen, D., W. Nichols, K. Strakosch Walz, J. Rocchio, J. Lemly, L. Gilligan, and G. Kittel. 2015. NatureServe Ecological Integrity Assessment: Protocols for Wetland Rapid Assessment Method. NatureServe, Arlington, VA.
Faber-Langendoen, D., J. Lemly, W. Nichols, J. Rocchio, and K. Walz. 2016. Introduction to Natureserve's Ecological Integrity Assessment Method. NatureServe, Arlington, VA.
Herdendorf, C.E., S.M. Hartley, and M.D. Barnes, eds. 1981. Fish and wildlife resources of the Great Lakes coastal wetlands within the United States. Volume 1, Overview. U.S. Fish and Wildlife Service, FWS/OBS-81/02-v1.
Keddy, P.A., and A.A. Reznicek. 1986. Great Lakes vegetation dynamics: The role of fluctuating water levels and buried seeds. Journal of Great Lakes Research 12: 25-36.
Keough, J.R., T.A. Thompson, G.R. Guntenspergen, and D.A. Wilcox. 1999. Hydrogeomorphic factors and ecosystem responses in coastal wetlands of the Great Lakes. Wetlands 19: 821-834.
Kost, M.A., D.A. Albert, J.G. Cohen, B.S. Slaughter, R.K. Schillo, C.R. Weber, and K.A. Chapman. 2007. Natural Communities of Michigan: Classification and Description. Michigan Natural Features Inventory, Report No. 2007-21, Lansing, MI. 314 pp.
Michigan Natural Features Inventory (MNFI). 1988 Draft criteria for determining natural quality and condition grades, element occurrence size-classes and significance levels for palustrine and terrestrial natural communities in Michigan. Michigan Natural Features Inventory, Lansing, MI. 39 pp.
Michigan Natural Features Inventory (MNFI). 2016. Biotics Database. Michigan Natural Features Inventory, Lansing, MI.
Minc, L.D. 1997. Great Lakes coastal wetlands: An overview of abiotic factors affecting their distribution, form, and species composition. A report in three parts. Michigan Natural Features Inventory, Lansing, MI. 307 pp.
Minc, L.D. 1997. Vegetative Response in Michigan's Great Lakes Marshes to Great Lakes Water-Level Fluctuations. A Report Submitted to Michigan Natural Features Inventory, April, 1997. Funded by EPA Great Lakes National Program Office (Federal Grant GL9 95810-02), through The Nature Conservancy's Great Lakes Program Office. 135 pp.
Minc, L.D. and D.A. Albert. 1998. Great Lakes Coastal Wetlands: Abiotic and Floristic Characterization. Michigan Natural Features Inventory. 36 pp.
Nichols, W.F. 2015. Rank Specifications for Wetland Systems in New Hampshire. NH Natural Heritage Bureau, Concord, NH.
Rocchio, F.J. 2011. Ecological Integrity Assessment Scorecard for the Temperate Pacific Freshwater Marsh. Ecological System. Washington Department of Natural Resources, Natural Heritage Program. Olympia, WA.
Rocchio, F.J. and R.C. Crawford. 2011. Ecological Integrity Assessment Scorecards for Washington's Ecological Systems. Washington Department of Natural Resources, Natural Heritage Program. Olympia, WA.
Wilcox, D.A., J.E. Meeker, and J. Elias. 1993. Impacts of Water-Level Regulation on Wetlands of the Great Lakes. Phase 2 Report to Working Committee 2, International Joint Commission, Great Lakes Water Level Reference Study, Natural Resources Task Group.

Level 2 EIA. Great Lakes Coastal Marsh

Metric	Justification	Rank			
		A (4 pts.)	**B (3 pts.)**	**C (2 pts.)**	**D (1 pts.)**
Rank Factor: LANDSCAPE CONTEXT					
Key Ecological Attribute: ***Landscape Connectivity and Intactness***					
LAN1. Contiguous Natural Land Cover	Less fragmentation increases connectivity between natural ecological systems and thus allows for natural exchange of species, nutrients, and water.	**Intact:** Embedded in 90-100% natural habitat around assessment area	**Variegated:** Embedded in 60-90% natural habitat	**Fragmented**: Embedded in 20-60% natural habitat	**Relictual:** Embedded in < 20% natural habitat
LAN2. Land Use Index	The intensity of human activity in the landscape has a proportionate impact on the ecological processes of natural ecosystems.	Average Land Use Score = 9.5–10 (Minimal Land Use)	Average Land Use Score = 8.0–9.4 (Moderate Land Use)	Average Land Use Score = 4.0–7.9 (Severe Land Use)	Average Land Use Score = <4.0 (Intense Land Use)
Key Ecological Attribute: ***Local Connectivity***					
BUF1. Perimeter with Natural Buffer	The intactness of the buffer or edge contributes to the ecological integrity of the adjacent assessment area.	Natural buffer is 100% of perimeter	Natural buffer is 75-99% of perimeter	Natural buffer is 25-74% of perimeter	Natural buffer is <25% of perimeter
BUF2. Width of Natural Buffer		Average buffer width is >100m, after adjusting for slope	Average buffer width is 75–99 m, after adjusting for slope	Average buffer width is 25–74 m, after adjusting for slope	Average buffer width is < 25m, after adjusting for slope
BUF3 Condition of Natural Buffer [opt]		>95% cover native vegetation, intact soils and hydrology	75–95% cover of native vegetation, intact or moderately disrupted soils and hydrology	25–75% cover of native vegetation, moderate or extensive soil and hydrologic disruption	< 25% native vegetation, highly disrupted soils and hydrology
Rank Factor: CONDITION					
Key Ecological Attribute: ***Vegetation***					
VEG1. Native Plant Species Cover	Native species dominate an ecosystem when it has excellent ecological integrity.	>99% relative cover of native vascular plant species across strata	95-99% relative cover of native vascular plant species across strata	60-94% relative cover of native vascular plant species across strata	<60% relative cover of native vascular plant species across strata

Metric	Justification	Rank			
		A (4 pts.)	B (3 pts.)	C (2 pts.)	D (1 pts.)
VEG2. Invasive Nonnative Plant Species Cover	Negative impacts of invasive species include loss of habitat, loss of native biodiversity, altered soils, hydrology, and nutrient cycling.	Invasive nonnative plant species absent	Invasive non-native plant species present but sporadic in any stratum (1-3% cover)	Invasive non-native plant species somewhat common in any stratum (10-30% cover)	Invasive non-native plant species abundant in any stratum (> 30% cover)
VEG3. Native Plant Species Composition	The integrity of ecosystems is optimized when a characteristic native plant species composition dominates the plant community and suitable habitat exists for multiple animal species. Vegetation composition reflects the interactions between plants and physical processes, especially hydrology.	Typical range of native diagnostic species present Native species sensitive to anthropogenic degradation (native decreasers) all present Native species indicative of anthropogenic disturbance (i.e., increasers, weedy or ruderal species) absent to minor.	Some native diagnostic species absent or substantially reduced in abundance At least some native species sensitive to anthropogenic degradation (native decreasers present) Native species indicative of anthropogenic disturbance (increasers, weedy or ruderal species) are present with low cover.	Many native diagnostic species absent or substantially reduced in abundance No native species sensitive to anthropogenic degradation (native decreasers) present Native species indicative of anthropogenic disturbance (increasers, weedy or ruderal species) are present with moderate cover.	Most or all native diagnostic species absent, a few may remain in very low abundance No native species sensitive to anthropogenic degradation (native decreasers) present Native species indicative of anthropogenic disturbance (increasers, weedy or ruderal species) are present in high cover.
Key Ecological Attribute: *Vegetation Structure*					
VEG4. Overall Vegetation Structure	Vegetation structure is strongly correlated with wildlife habitat. In addition, vegetation structure can have an important controlling effect on composition and processes.	Vegetation structure is at or near minimally disturbed natural conditions. Little to no structural indicators of degradation evident. Full complement of vegetative zones present.	Vegetation structure shows minor alterations from natural conditions. Structural indicators of degradation are minor. Full complement of vegetative zones slightly diminished by anthropogenic disturbance.	Vegetation structure is moderately altered from natural conditions. Structural indicators of degradation are moderate. Full complement of vegetative zones moderately diminished by anthropogenic disturbance.	Vegetation structure is greatly altered from natural conditions. Structural indicators of degradation are strong. Missing full complement of vegetative zones.
Key Ecological Attribute: *Hydrologic Regime*					

Metric	Justification	Rank			
		A (4 pts.)	B (3 pts.)	C (2 pts.)	D (1 pts.)
HYD1. Water Source	Natural inflows of water to a wetland are important to its ability to persist as a wetland.	Water source is natural: site hydrology is dominated by lacustrine inputs, precipitation, and groundwater. There is no indication of direct artificial water sources. Lacks point source discharges into or adjacent to the site.	Water source is mostly natural, but site directly receives occasional or small amounts of inflow from anthropogenic sources. Indications of anthropogenic input include developed land or agricultural land (<20%) in the immediate drainage area of the site, small storm drains, ditches, or other local discharges emptying into the site; road runoff; or the presence of scattered homes along the wetland that probably have septic systems. No large point sources discharge into or adjacent to the site.	Water source is moderately impacted by anthropogenic sources, but are still a mix of natural and non-natural sources. Indications of moderate contribution from anthropogenic sources include developed land or irrigated agriculture that comprises 20–60% of the immediate drainage basin, the presence of many small storm drains or a few large ones, or moderate amounts of road runoff.	Water source is substantially impacted by anthropogenic sources (e.g., urban runoff, direct irrigation, pumped water, artificially impounded water, or other artificial hydrology). Indications of substantial artificial hydrology include >60% developed or agricultural land adjacent to the site, and the presence of major point sources that discharge into or adjacent to the site, or large amounts of road runoff.
HYD2. Hydroperiod	Hydroperiod is a major determinant of wetland function. Sediment storage, import, and export, soil type, and plant recruitment and maintenance are dependent on hydroperiod	Hydroperiod is characterized by natural patterns of filling, inundation, saturation and drying or drawdowns. There are no major hydrologic stressors that impact the natural hydroperiod.	Hydroperiod filling or inundation patterns deviate slightly from natural conditions due to presence of stressors such as: small ditches, channels, dikes, and roads. Outlets may be slightly constricted.	Hydroperiod filling or inundation and drying patterns deviate moderately from natural conditions due to presence of stressors such as: ditches (1-3 feet deep), channels, dikes, culverts adequate for base stream flow but not flood flow, and two lane roads. Outlets may be moderately constricted, but flow is still possible. If wetland is artificially controlled, the management regime approaches a natural analogue.	Hydroperiod filling or inundation and drawdown deviate substantially from natural conditions from high intensity alterations such as: a 4-lane highway; large dikes impounding water; diversions > 3ft. deep that withdraw a significant portion of flow; large amounts of fill; shipping channels; or heavy flow additions. Outlets may be significantly constricted, blocking most flow. Hydroperiod is dramatically different from natural. If wetland is artificially controlled, hydroperiod does not mimic natural seasonality.

Metric	Justification	Rank			
		A (4 pts.)	B (3 pts.)	C (2 pts.)	D (1 pts.)
HYD3. Hydrologic Connectivity	Hydrologic connectivity between wetlands and uplands and wetlands and Great Lakes supports key ecological processes, such as exchange of water, sediment, nutrients, and organic carbon.	Marsh receives unimpeded hydrologic input from Great Lakes. No unnatural obstructions to lateral or vertical movement of waves, seiches, groundwater, or surfacewater. Total absence of dikes or human-made channels Rising water in the site has unrestricted access to adjacent upland, without levees, excessively high banks, artificial barriers, or other obstructions to the lateral movement of flood flows.	Slightly impeded hydrologic input from Great Lakes. Minor restrictions to the lateral or vertical movement of waves, seiche, groundwater or surfacewater by unnatural features, such as levees, human-made channels, or dikes. Less than 25% of the site is restricted by barriers to drainage and/or flow. Flood flows may exceed the obstructions, but drainage back to the wetland is incomplete due to impoundment. Culvert, if present, is of large diameter and does not significantly change flow, as evidenced by similar vegetation on either side of the culvert.	Moderately impeded hydrologic input from Great Lakes. Moderate restrictions to the lateral or vertical movement of waves, seiches, groundwater or surfacewater by unnatural features, such as levees, human-made channels, or dikes. Between 25–75% of the site is restricted by barriers to drainage and/or flow. Flood flows may exceed the obstructions, but drainage back to the wetland is incomplete due to impoundment. Hydrology is somewhat impeded by small culvert size, as evidenced in obvious differences in vegetation on either side of the culvert.	Severely impeded hydrologic input from Great Lakes. Severe restrictions to the lateral or vertical movement of waves, seiches, groundwater or surfacewater by unnatural features, such as levees, human-made channels, or dikes. Greater than 75% of wetland is restricted by barriers to drainage and/or flow. Hydrology is totally or almost totally impeded by obstructed culverts.
Key Ecological Attribute: *Substrate support to plants*					
SOI1. Soil Surface Condition	Soils store water and provide media for plant establishment and growth	**Soil-disturbance Class 0** *Undisturbed* • No evidence of past equipment. • No depressions or wheel tracks. • No dredged channels or spoil levees. • No soil displacement evident. • No management-created soil compaction.	**Soil-Disturbance Class 1** *Slightly Disturbed* • Wheel tracks or depressions evident, but faint and shallow. • Infrequent dredged channels and spoil levees. • Surface soil has not been displaced. • Soil compaction is shallow (0 to 4 inches). • Soil structure is changed from undisturbed conditions.	**Soil Disturbance Class 2** *Disturbed* • Wheel tracks or depressions are evident and moderately deep. • Dredged channels and spoil levees occasional to common. • Surface soil partially intact and maybe mixed with subsoil. • Soil compaction is moderately deep (up to 12 inches). • Soil structure is changed from undisturbed conditions.	**Soil Disturbance Class 3** *Extremely Disturbed* • Wheel tracks or depressions are evident and deep. • Dredged channels and spoil levees common. • Surface soil is displaced. • Soil compaction is persistent and deep (greater than 12 inches) • Soil structure is changed from undisturbed.

Metric	Justification	Rank			
		A (4 pts.)	B (3 pts.)	C (2 pts.)	D (1 pts.)
Rank Factor: SIZE					
Key Ecological Attribute: *Area-dependence*					
SOI2. Comparative Size	Diversity of animals and plants may be higher in larger occurrences than smaller occurrences. Larger wetlands may be more resistant to hydrological stressors and more resistant to invasion by non-native species. Eighty-two Great Lakes marsh element occurrences have been documented in Michigan to date. Acreage of EOs ranges from 15 acres to 4,155 acres with an average of 463 acres.	Very large size (> 300 acres) compared to other examples of the same type, based on current and historical spatial patterns; all or almost all the area-sensitive indicator species within the range of the type are present. Sustain breeding waterfowl, shorebirds, fish spawning grounds, and some medium-sized mammals (e.g. muskrat, fox).	Large size (100-300 acres) compared to other examples of the same type, based on current and historical spatial patterns; some of the expected area-sensitive indicator species are absent. Sustain breeding waterfowl, shorebirds, fish spawning grounds, and some medium-sized mammals (e.g. muskrat, fox).	Medium to small size (30-100 acres) compared to other examples of the same type, based on current and historical spatial patterns; several to many of the expected area-sensitive indicator species are absent.	Small to very small size (< 30 acres), based on current and historical spatial patterns; most to all area-sensitive indicator species are absent.
SOI3 Relative Size	Change in size is an indication of the amount of wetland change caused by human-induced disturbances.	Site is at or minimally reduced from natural extent (>95% remains)	Occurrence is only modestly reduced from its original natural extent (80-95% remains)	Occurrence is substantially reduced from its original natural extent (50-80% remains)	Occurrence is severely reduced from its original natural extent (<50% remains)

Appendix 3 – Examples of Level 1-3 Indicators for Ecological Integrity Assessments

Appendix 3a. Example of Level 1 (remote sensing based) ecological integrity indicators for wetlands and streams, intended for continuous measures (0.0 = worst -1.0 = best) by 5th level watershed. Developed for BLM Rapid Ecoregional Assessment of the Central Basin and Range ecoregion (from Comer et al 2013).

Indicator	Definition	Justification
Key Ecological Attribute: Landscape Intactness		
Landscape Condition Index	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance.	This indicator is measured by intersecting the mapped area or habitat distribution map of the CE with the LCM layer and reporting the average LCM index value for the CE or habitat within each 5th level watershed, or 4x4 km square units for species. Landscape Condition Index is a 90X90m square unit resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. The results are a score for landscape condition from 0 to 1 with 1 being very high landscape condition and values close to 0 likely having very poor condition.
Key Ecological Attribute: Surrounding Watershed Land Use Stress		
Perennial Flow Network Fragmentation by Dams	Indicator of the degree of fragmentation of continuous aquatic habitat.	Number of intersections with NHD perennial streams. Total per HUC.
Key Ecological Attribute: Extent / Size		
Riparian Corridor Fragmentation	Unfragmented riparian corridors support individual animal movement, gene flow and natural flooding and sediment deposition and scour processes upon which aquatic and wetland species depend.	Indicates the degree to which the riparian areas (buffered by 200 m) exhibit an uninterrupted corridor. A measure of the linear, continuous unfragmented riparian corridor based on Landscape Condition Index (LCI), to measure how many fragments are created by the interruption of the natural riparian corridor by non-natural land use.
Key Ecological Attribute: Stressors on Biotic Condition		
Invasive Aquatic Index	Impacts from invasive species are of equal importance with habitat loss and global climate change as the primary causal factors responsible for the world's rapidly decreasing biodiversity and altered ecosystem functioning.	The number of invasive taxa (known status).
Presence of Invasive Plant Species	Increased non-native plant species reduces habitat quality for numerous wildlife species, decreases forage for livestock, reduces ecosystem native species richness,	Number of known locations of non-native introduced tamarisk, Russian olive, and annual grasses.

Indicator	Definition	Justification
	increases soil erosion potential and decreases ecosystem resiliency and resistance to damage from impacts, including climate change.	
Key Ecological Attribute: Stressors on Hydrologic Condition		
Condition of Groundwater Recharge Zone	Hard surface development within a groundwater recharge zone can divert and reduce the amount water entering the groundwater.	Measures the landscape condition of the likely groundwater recharge zone (areas above 2000 m within each 10 digit HUC) by percent area in hard-surface development as determined in LCI.
Flow Modification by Dams	The greater the storage capacity is an indicator of greater the impact to natural flow regimes of the downstream river or stream segments.	"F" Index (Theobald et al. 2010) Dams and their storage capacity relative to annual stream discharge.
Ground Water Use	Data show the degree to which surface water is being consumed for human use relative to availability within each watershed. The greater the use, the less water is available to support aquatic species, specifically higher ground water use is likely to draw down water tables and therefore springs.	Ratio of total flow per watershed (calculated from NHD) to Ground water use as defined by USGS SWPA study.
Perennial Flow Modification by Diversion Structures	Indication of the amount of flow modification and change in hydrologic regime.	Number of aqueducts intersecting or branching from NHD perennial streams. Total per HUC.
Surface Water Use	Data show the degree to which surface water is being consumed for human use relative to availability within each ten digit HUC. The greater the use, the less water is available to support aquatic species.	Ratio of total watershed flow (calculated from NHD) to surface water use as defined by USGS SWPA study.
Key Ecological Attribute: Stressors on Water Quality		
Sediment Loading Index	Different surrounding land uses contributes to the sediment loading in adjacent waters. Increased sediment clogs fish gills, reduce successful spawning, decrease visibility and increase pollutant loadings, especially heavy metals.	Index values of total Suspended Sediment (developed by NSPECT) which are based on percent of land uses (NLCD) that contribute excess sedimentation and suspended solids via surface water runoff and overland flow into a wetland, as measured within the 200m buffer area.
State-Listed Water Quality Impairments	This indicator is a direct measure of pollutants, turbidity and sediments that exceed state standards. Polluted water negatively affects aquatic species health and ability to successfully reproduce.	Measures the integrity of water quality conditions in individual water bodies based on the presence and severity of state listings of water quality impairments for State 303(d) reporting requirements under the federal Clean Water Act – excluding nutrient enrichment, which is addressed by a separate key ecological attribute.

Appendix 3b. Example of a Level 2 (rapid field based) Ecological Integrity Assessment, developed for *Temperate Flooded & Swamp Forest*, with HGM Depression hydrology (Faber-Langendoen et al. 2012, 2016).

Level 2 EIA. Flooded & Swamp Forest, Depression

Metric	**Justification**	**Rank**			
		A (4 pts.)	**B (3 pts.)**	**C (2 pts.)**	**D (1 pts.)**
Rank Factor: LANDSCAPE CONTEXT					
Key Ecological Attribute: *Landscape Connectivity and Intactness*					
LAN1. Contiguous Natural Land Cover	Less fragmentation increases connectivity between natural ecological systems and thus allows for natural exchange of species, nutrients, and water.	**Intact:** Embedded in 90-100% natural habitat around assessment area	**Variegated:** Embedded in 60-90% natural habitat	**Fragmented**: Embedded in 20-60% natural habitat	**Relictual:** Embedded in < 20% natural habitat
LAN2. Land Use Index	The intensity of human activity in the landscape has a proportionate impact on the ecological processes of natural ecosystems.	Average Land Use Score = 9.5–10 (Minimal Land Use)	Average Land Use Score = 8.0–9.4 (Moderate Land Use)	Average Land Use Score = 4.0–7.9 (Severe Land Use)	Average Land Use Score = <4.0 (Intense Land Use)
Key Ecological Attribute: *Local Connectivity*					
BUF1. Perimeter with Natural Buffer	The intactness of the buffer or edge contributes to the ecological integrity of the adjacent assessment area.	Natural buffer is 100% of perimeter	Natural buffer is 75-99% of perimeter	Natural buffer is 25-74% of perimeter	Natural buffer is <25% of perimeter
BUF2. Width of Natural Buffer		Average buffer width is >100m, after adjusting for slope	Average buffer width is 75–99 m, after adjusting for slope	Average buffer width is 25–74 m, after adjusting for slope	Average buffer width is < 25m, after adjusting for slope
BUF3. Condition of Natural Buffer [opt]		>95% cover native vegetation, intact soils and hydrology	75–95% cover of native vegetation, intact or moderately disrupted soils and hydrology	25–75% cover of native vegetation, moderate or extensive soil and hydrologic disruption	< 25% native vegetation, highly disrupted soils and hydrology
Rank Factor: CONDITION					
Key Ecological Attribute: *Native Vegetation Composition*					

Metric	Justification	Rank			
		A (4 pts.)	B (3 pts.)	C (2 pts.)	D (1 pts.)
VEG1. Native Plant Species Cover	Native species dominate an ecosystem when it has excellent ecological integrity.	>99% relative cover of native vascular plant species across strata	95-99% relative cover of native vascular plant species across strata	60-94% relative cover of native vascular plant species across strata	<60% relative cover of native vascular plant species across strata
VEG2. Invasive Nonnative Plant Species Cover	Negative impacts of invasive species include loss of habitat, loss of native biodiversity, altered soils, hydrology, and nutrient cycling.	Invasive nonnative plant species absent	Invasive non-native plant species present but sporadic in any stratum (1-3% cover)	Invasive non-native plant species somewhat common in any stratum (10-30% cover)	Invasive non-native plant species abundant in any stratum (> 30% cover)
VEG3. Native Plant Species Composition	The integrity of ecosystems is optimized when a characteristic native plant species composition dominates the plant community and suitable habitat exists for multiple animal species. Vegetation composition reflects the interactions between plants and physical processes, especially hydrology.	Typical range of native diagnostic species present Native species sensitive to anthropogenic degradation (native decreasers) all present Native species indicative of anthropogenic disturbance (i.e., increasers, weedy or ruderal species) absent to minor.	Some native diagnostic species absent or substantially reduced in abundance At least some native species sensitive to anthropogenic degradation (native decreasers present) Native species indicative of anthropogenic disturbance (increasers, weedy or ruderal species) are present with low cover.	Many native diagnostic species absent or substantially reduced in abundance No native species sensitive to anthropogenic degradation (native decreasers) present Native species indicative of anthropogenic disturbance (increasers, weedy or ruderal species) are present with moderate cover.	Most or all native diagnostic species absent, a few may remain in very low abundance No native species sensitive to anthropogenic degradation (native decreasers) present Native species indicative of anthropogenic disturbance (increasers, weedy or ruderal species) are present in high cover.
Key Ecological Attribute: *Vegetation Structure*					
VEG4. Overall Vegetation Structure	Vegetation structure is strongly correlated with wildlife habitat. In addition, vegetation structure can have an important controlling effect on composition and processes.	Canopy a mosaic of small patches of different ages or sizes, including old trees and canopy gaps containing regeneration, AND number of live stems of medium size (30–50 cm / 12-20” dbh) and large size (>50 cm / >20” dbh) well within expected range.	Canopy largely heterogeneous in age or size, but with some gaps containing regeneration or some variation in tree sizes, AND number of live stems of medium and large size within or very near expected range.	Canopy somewhat homogeneous in age or size, AND number of live stems of medium and large size below but moderately near expected range.	Canopy very homogeneous, in size or age OR number of live stems of medium and large size well below expected range.

<table>
<tr><th>Metric</th><th>Justification</th><th colspan="4">Rank</th></tr>
<tr><th></th><th></th><th>A (4 pts.)</th><th>B (3 pts.)</th><th>C (2 pts.)</th><th>D (1 pts.)</th></tr>
<tr><td>VEG5. Woody Regeneration</td><td>The tree regeneration and shrub layers provide independent information on the structural characteristics, ecological processes, and stressors (such as herbivore browsers) found at the site, and indicate potential future canopy composition</td><td>Native tree saplings and/or seedlings or shrubs common to the type present in expected amounts and diversity; obvious regeneration.</td><td>Native tree saplings and/or seedlings or shrubs common to the type present but less amounts and diversity than expected</td><td>Native tree saplings and/or seedling or shrubs common to the type present but low amounts and diversity; little regeneration</td><td>No, or essentially no regeneration of native woody species common to the type</td></tr>
<tr><td>VEG6. Coarse Woody Debris [opt.]</td><td>Woody debris plays a critical role in a variety of wetland systems, especially riparian systems. There is extensive documentation of the importance of in stream wood for altering channel form and characteristics, enhancing aquatic and riparian habitat, retention of organic matter and nutrients</td><td colspan="2">• Wide size-class diversity of standing snags and CWD (downed logs).
• Larger size class (>30 cm dbh/12” dbh and >2 m/6’ long) present with 5 or more snags per ha (2.5 ac), but not excessive numbers (suggesting disease or other problems).
• CWD in various stages of decay.</td><td>• Moderate size-class diversity of standing snags or downed CWD;
• Larger size class present with 1–4 snags per ha, or moderately excessive numbers (suggesting disease or other problems).
• CWD in various stages of decay.</td><td>• Low size-class diversity of downed CWD and snags.
• Larger size class present with <1 snag per ha, or very excessive numbers (suggesting disease or other problems).
• CWD mostly in early stages of decay.</td></tr>
<tr><td colspan="6">Key Ecological Attribute: Hydrologic Regime</td></tr>
</table>

Metric	Justification	Rank			
		A (4 pts.)	B (3 pts.)	C (2 pts.)	D (1 pts.)
HYD1. Water Source [Depression]	Natural inflows of water to a wetland are important to its ability to persist as a wetland.	Water source is natural: site hydrology is dominated by precipitation, groundwater, natural runoff from an adjacent freshwater body. There is no indication of direct artificial water sources. Land use in the local drainage area of the site is primarily open space or low density, passive uses. Lacks point source discharges into or adjacent to the site.	Water source is mostly natural, but site directly receives occasional or small amounts of inflow from anthropogenic sources. Indications of anthropogenic input include developed land or agricultural land (<20%) in the immediate drainage area of the site, small storm drains or other local discharges emptying into the site, or some road runoff. No large point sources discharge into or adjacent to the site.	Water source is moderately impacted by anthropogenic sources, but are still a mix of natural and non-natural sources. Indications of moderate contribution from anthropogenic sources include developed land or irrigated agriculture that comprises 20–60% of the immediate drainage basin or many small storm drains or a few large ones, or moderate road runoff.	Water source is substantially impacted by anthropogenic sources (e.g., urban runoff, direct irrigation, pumped water, artificially impounded water, or other artificial hydrology). Indications of substantial artificial hydrology include >60% developed or agricultural land adjacent to the site, and the presence of major point sources that discharge into or adjacent to the site, or large amounts of road runoff.
HYD2. Hydroperiod	Hydroperiod is a major determinant of wetland function. Sediment storage, import, and export, soil type, and plant recruitment and maintenance are dependent on hydroperiod	Hydroperiod is characterized by natural patterns of filling, inundation, saturation and drying or drawdowns. There are no major hydrologic stressors that impact the natural hydroperiod.	Hydroperiod filling or inundation patterns deviate slightly from natural conditions due to presence of stressors such as: small ditches or diversions; berms or roads at/near grade; minor pugging by livestock; or minor flow additions. Outlets may be slightly constricted. Playas are not significantly impacted pitted or dissected. If wetland is artificially controlled, the management regime closely mimics a natural analogue (it is very unusual for a purely artificial wetland to be rated in this category).	Hydroperiod filling or inundation and drying patterns deviate moderately from natural conditions due to presence of stressors such as: ditches or diversions 1–3 ft. deep; two lane roads; culverts adequate for base stream flow but not flood flow; moderate pugging by livestock that could channelize or divert water; shallow pits within playas; or moderate flow additions. Outlets may be moderately constricted, but flow is still possible. If wetland is artificially controlled, the management regime approaches a natural analogue. Site may be	Hydroperiod filling or inundation and drawdown of the AA deviate substantially from natural conditions from high intensity alterations such as: a 4-lane highway; large dikes impounding water; diversions >3ft. deep that withdraw a significant portion of flow, deep pits in playas; large amounts of fill; significant artificial groundwater pumping; or heavy flow additions. Outlets may be substantially constricted, blocking most flow. If wetland is artificially controlled, the site is actively managed and not connected to any natural

Metric	Justification	Rank			
		A (4 pts.)	B (3 pts.)	C (2 pts.)	D (1 pts.)
				passively managed, meaning that the hydroperiod is still connected to and influenced by natural high flows timed with seasonal water levels	season fluctuations, but the hydroperiod supports natural functioning of the wetland.
HYD3. Hydrologic Connectivity	Hydrologic connectivity between wetlands and uplands and wetlands and Great Lakes supports key ecological processes, such as exchange of water, sediment, nutrients, and organic carbon.	No unnatural obstructions to lateral or vertical movement of ground or surface water. Rising water in the site has unrestricted access to adjacent upland, without levees, excessively high banks, artificial barriers, or other obstructions to the lateral movement of flood flows. If perched water table, then impermeable soil layer (fragipan or duripan) intact.	Minor restrictions to the lateral or vertical movement of ground or surface waters by unnatural features, such as levees or excessively high banks. Less than 25% of the site is restricted by barriers to drainage. Restrictions may be intermittent along the site, or the restrictions may occur only along one bank or shore. Flood flows may exceed the obstructions, but drainage back to the wetland is incomplete due to impoundment. If perched then impermeable soil layer partly disturbed (e.g., from drilling or blasting).	Moderate restrictions to the lateral or vertical movement of ground or surface waters by unnatural features, such as levees or excessively high banks. Between 25– 75% of the site is restricted by barriers to drainage. Flood flows may exceed the obstructions, but drainage back to the wetland is incomplete due to impoundment. If perched, then impermeable soil layer moderately disturbed (e.g., by drilling or blasting).	Essentially no hydrologic connection to adjacent wetlands or uplands. Most or all water stages are contained within artificial banks, levees, sea walls, or comparable features. Greater than 75% of wetland is restricted by barriers to drainage. If perched, then impermeable soil layer strongly disturbed
Key Ecological Attribute: *Substrate support to plants*					

Metric	Justification	Rank			
		A (4 pts.)	B (3 pts.)	C (2 pts.)	D (1 pts.)
SOI1. Soil Surface Condition	Soils store water and provide media for plant establishment and growth	**Soil-disturbance Class 0** *Undisturbed* • No evidence of past equipment. • No depressions or wheel tracks. • No dredged channels or spoil levees. • No soil displacement evident. • No management-created soil compaction.	**Soil-Disturbance Class 1** *Slightly Disturbed* • Wheel tracks or depressions evident, but faint and shallow. • Infrequent dredged channels and spoil levees. • Surface soil has not been displaced. • Soil compaction is shallow (0 to 4 inches). • Soil structure is changed from undisturbed conditions.	**Soil Disturbance Class 2** *Disturbed* • Wheel tracks or depressions are evident and moderately deep. • Dredged channels and spoil levees occasional to common. • Surface soil partially intact and maybe mixed with subsoil. • Soil compaction is moderately deep (up to 12 inches). • Soil structure is changed from undisturbed conditions.	**Soil Disturbance Class 3** *Extremely Disturbed* • Wheel tracks or depressions are evident and deep. • Dredged channels and spoil levees common. • Surface soil is displaced. • Soil compaction is persistent and deep (greater than 12 inches) • Soil structure is changed from undisturbed.
Rank Factor: SIZE					
Key Ecological Attribute: *Area-dependence*					
SOI2. Comparative Size	Diversity of animals and plants may be higher in larger occurrences than smaller occurrences. Larger wetlands may be more resistant to hydrological stressors and more resistant to invasion by non-native species.	Very large size (> 300 acres) compared to other examples of the same type, based on current and historical spatial patterns; all or almost all the area-sensitive indicator species within the range of the type are present.	Large size (100-300 acres) compared to other examples of the same type, based on current and historical spatial patterns; some of the expected area-sensitive indicator species are absent.	Medium to small size (30-100 acres) compared to other examples of the same type, based on current and historical spatial patterns; several to many of the expected area-sensitive indicator species are absent.	Small to very small size (< 30 acres), based on current and historical spatial patterns; most to all area-sensitive indicator species are absent.
SOI3 Relative Size	Change in size is an indication of the amount of wetland change caused by human-induced disturbances.	Site is at or minimally reduced from natural extent (>95% remains)	Occurrence is only modestly reduced from its original natural extent (80-95% remains)	Occurrence is substantially reduced from its original natural extent (50-80% remains)	Occurrence is severely reduced from its original natural extent (<50% remains)

Appendix 3c: Example of Level 3 (intensive field based) Ecological Integrity Assessment. Metrics were developed for northeast U.S. temperate forest ecosystems in the National Park Service's Northeast Temperate Network. Medium to large trees are ≥ 30 cm diameter-at-breast-height. Tree regeneration stocking index varies by national park. Priority 1 pests are Asian long horned beetle, emerald ash borer, and sudden oak death. Priority 2 pests are hemlock wooly adelgid, balsam wooly adelgid, beech bark disease and butternut canker. See Tierney et al. (2009) for more details.

Metric type	**Metric**	**Rating**		
		Good	**Caution**	**Significant Concern**
Landscape structure	Forest patch size	> 50 ha	10 - 50 ha	< 10 ha
	Anthropogenic land use	< 10%	10 - 40%	> 40%
Vegetation Structure	Stand structural class	>= 70% of stands are late-successional	< 70% of stands are late-successional in northern hardwood, hemlock-hardwood, or upland-spruce-hardwood forest	
		>= 30% of stands are late-successional	< 30% of stands are late-successional in lowland spruce-hardwood forest	
		>= 25% of stands are late-successional	< 25% of stands are late-successional in oak forest	
	Snag abundance	>= 10% standing trees are snags and >=10% med-lg trees are snags	< 10% standing trees are snags or < 10% med-lg trees are snags	< 5 med-lg snags/ ha
	Coarse woody debris volume	> 15% live tree volume	5 - 15% live tree volume	< 5% live tree volume
Vegetation Composition	Tree regeneration	Seedling ratio >= 0	Seedling ratio < 0	Stocking index outside acceptable range
	Tree condition	Foliage problem < 10% <u>and</u> no priority 1 or 2 pests	Foliage problem 10-50% <u>or</u> priority 2 pest	Foliage problem > 50% <u>or</u> priority 1 pest
	Biotic homogenization	No change	Increasing homogenization	
	Indicator species - invasive exotic plants	No key invasive exotic plant species on most plots	1 to 3 key species per plot	4 or more key species per plot
	Indicator species - deer browse	No decrease in frequency of most browse-sensitive species	Decrease in frequency of most browsed species <u>or</u> increase in frequency of browse-avoided species	Decrease in frequency of most browsed species <u>and</u> increase in frequency of browse-avoided species
Vegetation Processes	Tree growth and mortality rates	Growth >= 60% mean and Mort <= 1.6%	Growth < 60% mean or Mort > 1.6%	
Soil	Soil chemistry - acid stress	Soil Ca:Al ratio > 4	Soil Ca:Al ratio 1 - 4	Soil Ca:Al ratio < 1
	Soil chemistry - nitrogen saturation	Soil C:N ratio > 25	Soil C:N ratio 20 - 25	Soil C:N ratio < 20

Appendix 4 – Methods and Forms for Measurement of Ecological Integrity

Site Name: **Site Code:** **Date** (yyyy-mm-dd)**:**
Community Type: **Primary Surveyor:**
Obs. Area Name: ________________________________

A. LANDSCAPE CONTEXT METRICS

LAN1. Contiguous Natural Land Cover

Measurement Protocol: Select the statement that best describes the **contiguous natural land cover** within the 500 m envelope and connected to the AA. To determine the rating, identify the percent of natural land cover that is directly connected to the AA within the 500 m envelope. Water is included, along with terrestrial natural land cover. Where water may be a degrading factor (e.g., a wetland next to a boat club may be exposed to excessive wave action), it can be scored as such in the Land Use Index metric and Condition of Natural Buffer metric. Well-traveled dirt roads and major canals break unfragmented blocks, but vegetated two-track roads, hiking trails, hayfields, low fences and small ditches can be included. See definitions in the field manual of natural land cover types.

Example:

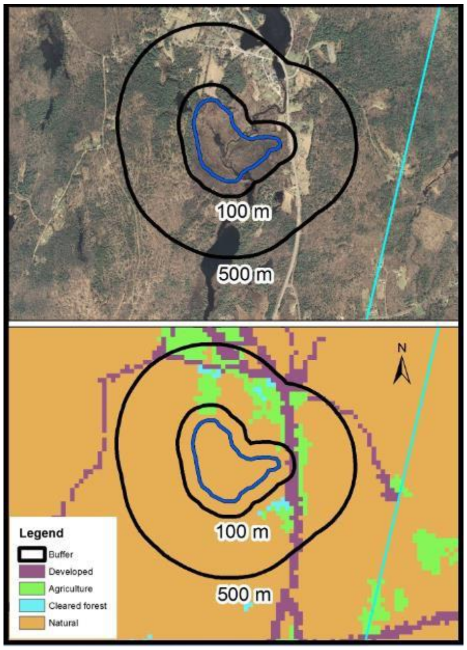
Figure 1. Contiguous Natural Land Cover evaluation based on percent natural vegetation directly connected to the AA. Raw imagery and example from Colorado Front Range (AA 12473). Yellow line separates contiguous natural land cover within in the 500 m radius zone surrounding the AA boundary (the red polygon). The AA is embedded in a fragmented, natural landscape block, rated at 20–60% of the 500 m zone. In this example, non-natural land cover is predominantly a gravel mining operation and related development. Figure by Joanna Lemly

Table 1. Contiguous Natural Cover Metric Rating.

Metric Rating	*Contiguous Natural Land Cover: ALL WETLANDS*	Total 0–500 m	Subzones [not required]	
			Inner 0–100 m	Outer 100–500 m
EXCELLENT (A)	**Intact:** Embedded in 90–100% natural habitat around AA.			
GOOD (B)	**Variegated:** Embedded in 60–90% natural habitat.			
FAIR (C)	**Fragmented**: Embedded in 20–60% natural habitat.			
POOR (D)	**Relictual**: Embedded in <20% natural habitat.			

LAN2. Land Use Index

Measurement Protocol: The Land Use Index metric is measured by documenting the surrounding land use(s) within the inner and outer landscape areas. The assessment should be completed in the office using remote sensing imagery, such as aerial photographs or satellite imagery, then, where feasible, verified in the field, using roads or transects to verify land use categories. Ideally, both field data as well as remote sensing tools are used to identify an accurate percent of each land use within the landscape area, but remote sensing data alone can be used.



The metric could be measured by defining the landscape area based on the watershed or catchment landscape area, rather than the more general landscape area used here, which could include areas outside the watershed. Testing is needed to determine how sensitive the ratings may be to this approach.

To calculate a Total Land Use Score,
Estimate the percent of each Land Use type and multiply by the corresponding coefficient, divide by 100 (Table 2) following equation:
Do this for each land use separately within the inner landscape (inner sub-zone 0–100m) and outer landscape sub-zone (100–500 m), then sum Sub-Land Use Score to arrive at a Total Land Use Score across the two areas. For example, if 30% of the outer Landscape area was under moderate grazing (0.3 * 6 = 1.8), 10% composed of unpaved roads (0.1 * 1 = 0.1), and 60% was a natural area (e.g., no human land use) (0.6 * 10 = 6.0), the Total Outer Landscape Land Use Score = 7.9 (1.8 + 0.1 + 6.0). The score can then be rated using Table 10 (i.e., C or Fair) and combined with the Inner Landscape Score (unweighted is currently preferred, else inner weighted 0.6, outer weighted 0.4 (Table 2).

Figure 2. Application of land use coefficients to assess the Land Use Index metric in the core and supporting landscapes (Nichols and Faber-Langendoen 2012). The Land Use Index is calculated for the inner sub-zone (0–100 m) and the outer sub-zone (100–500 m). The percent area of each land use is recorded in Table 9, and a weight is assigned to the land use based on the degree of non-naturalness. In this case, because the land uses are very general, Developed - weight of 1, Agriculture - 3, Cleared Forest - 5, and Natural – 10 (see Table 9). Figure by Bill Nichols.

LUI Metric Rating	Average LUI Score Rating	
EXCELLENT (A)	9.5-10.0	
GOOD (B)	8.0-9.4	
FAIR (C)	4.0-7.9	
POOR (D)	<4.0	

Table 2. Land Use Index Worksheet. Sub-zone LU Score = Coefficient x Percent Area /100)

Land Use Categories (LU)	**Land Use (LU) Categories-Aggregated**	**Coef-ficient**	**Inner Sub-zone** (0-100 m)		**Outer Sub-zone** (100-500 m)		**Comment (Field adjusts?)**
			% Area	**Score**	**% Area**	**Score**	
Paved roads / parking lots	Developed – High Intensity	0					
Domestic, commercial, or publicly developed buildings and facilities (non-vegetated)	Developed – High Intensity	0					
Gravel pit / quarry / open pit / strip mining	Developed – High Intensity	0					
Unpaved roads (e.g., driveway, tractor trail, 4-wheel drive, logging roads)	Developed – Moderate Intensity	1					
Agriculture: tilled crop production	Agriculture – Cultivated Crop, Annual	2					
Intensively developed vegetation (golf courses, lawns, etc.)	Developed – Low Intensity	2					
Vegetation conversion (chaining, cabling, roto-chopping, clearcut)	Veg – Highly Altered	3					
Agriculture: permanent crop (vineyard, orchard, nursery, hayed pasture, etc.)	Agriculture – Cultivated Crop – Perennial	4					
Intense recreation (ATV use / camping / popular fishing spot, etc.)	Veg – Highly Altered	4					
Military training areas (armor, mechanized)	Veg – Highly Altered	4					
Heavy grazing by livestock on pastures or native rangeland	Veg – Highly Altered	4					
Heavy logging or tree removal (50-75% of trees >30 cm dbh removed)	Veg– Moderately Altered	5					
Commercial tree plantations / holiday tree farms	Veg – Moderately Altered	5					
Recent old fields and other disturbed fallow lands dominated by ruderal and exotic species	Veg – Moderately Altered	5					
Dam sites and flood disturbed shorelines around water storage reservoirs and motorized boating	Veg – Moderately Altered	5					
Moderate grazing of native grassland	Veg – Moderately Altered	6					
Moderate recreation (high-use trail)	Veg – Moderately Altered	7					
Mature old fields and other fallow lands with natural composition	Veg–Moderately Altered	7					
Selective logging or tree removal (<50% of trees >30 cm dbh removed)	Veg – Lightly Altered	8					
Light grazing or haying of native rangeland	Veg – Lightly Altered	9					
Light recreation (low-use trail)	Veg – Lightly Altered	9					
Natural area / land managed for native vegetation	Veg – Not/Minimally Altered	10					
	A ≥9.5, B = 8.0–9.5, C = 4.0–7.9, D = <4.0 Total Land Use Score						
	Sub-Zone Land Use Index Rating						
	Combined Land Use Index Score (Inner sub-zone score x 0.6) + (Outer sub-zone score x 0.4)		0.6		0.4		
	Combined Land Use Index Rating						

*= High to Moderate

B. BUFFER METRICS

BUF1. Perimeter with Natural Buffer (mark on attached aerial photograph)

Estimate the length of the AA perimeter contiguous with a natural buffer. Use a 10 m minimum buffer width and length. (Faber-Langendoen et al. (2012b) used a 5 m minimum buffer width and length, but this is difficult to apply with aerial photography, and not possible from remote sensing imagery). Perimeter includes open water. For example, natural buffer is counted if it is at least 10 m width and 10 m in extent. Thus 6 m of non-buffer + 8 m buffer + 7 m non-buffer = 25 m non-buffer. When using remote means, high resolution imagery (1-2 m raster) may be necessary to measure the width of natural vegetation in the buffer.

Land Covers INCLUDED in Natural Buffers	Land Covers EXCLUDED from Natural Buffers
Natural upland habitats and plant communities; open water; vegetated levees; old fields; naturally vegetated rights-of-way; rough meadows; natural swales and ditches; native or naturalized rangeland, non-intensive plantations	Parking lots; commercial and private developments; roads (all types), intensive agriculture; intensive plantations†; orchards; vineyards; dry-land farming areas; railroads; planted pastures (e.g., from low intensity to high intensity horse paddock, feedlot, or turkey ranch); planted hayfields; lawns; sports fields; traditional golf courses; Conservation Reserve Program pastures

Metric Rating	Perimeter with Natural Buffer (%)
EXCELLENT (A)	Natural buffer is 100% of perimeter
GOOD (B)	Buffer is >75–99% of perimeter
FAIR (C)	Buffer is 25–75% of perimeter
POOR (D)	Buffer is <25% of perimeter

Land Covers Crossing and Breaking Natural Buffers
bike trails; foot trails; horse trails; dirt, gravel or paved roads; residential areas; bridges; culverts; paved creek fords; railroads; sound walls; fences that interfere with movements of water, sediment, or wildlife species that are critical to the overall functions of the wetland (>10m break in buffer)

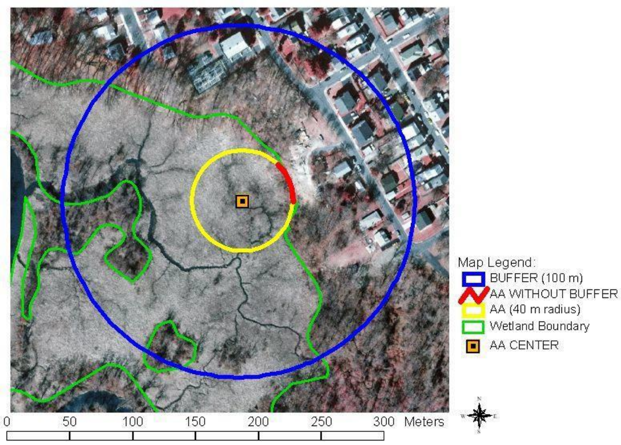


Figure 3. Example of calculation for Perimeter with Natural Buffer, with simple AA.
The wetland boundary is marked by a thin green line. The assessment area (AA) is shown by the inner circle; yellow indicates portions of the AA perimeter that contain buffer land cover (see "Measurement Protocol" text for definitions). The red indicates where AA perimeter lacking a buffer. In this case, about 86% of the AA perimeter has a buffer. Figure by Kathleen Walz

Table 3 Perimeter with Natural Buffer rating.

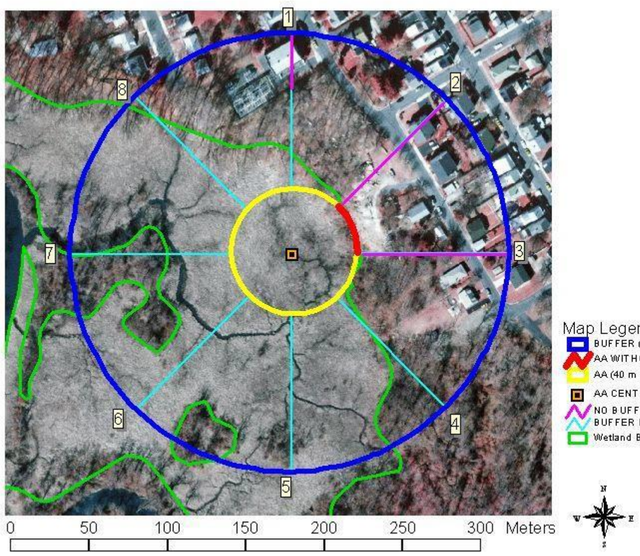
Metric Rating	Perimeter with Natural Buffer (%)	ALL WETLANDS
EXCELLENT (A)	100% of perimeter	
GOOD (B)	75–99% of perimeter	
FAIR (C)	25–74% of perimeter	
POOR (D)	<25% of perimeter	

BUF2. Width of Natural Buffer

Circular (more-or-less) AA: Metric is adapted from Collins et al. (2006) and USA RAM (US EPA 2011).

1. Determine the areas considered to be natural buffer.
2. Draw eight straight lines from the edge of the AA out through the buffer area at regular intervals in the portions of perimeter that are considered buffer (see Figure 6 below). Drawing the lines on the printed map makes verification and Quality Assurance procedures easier.
3. Measure the buffer width, up to 100 m.
4. Assign a metric score based on the average buffer width.

Note that in the example shown in figure 6, the buffer is applied to the AA rather than the wetland polygon; accordingly, this buffer value may not be indicative of the buffering capacity for the entire wetland if the wetland is large. Extending the landscape metrics from 500 m to 1000m may partially address this issue when assessing the overall role of Landscape Context on onsite condition.



Polygon-based AA with complex shapes

Using the most recent aerials, draw on a printout eight spokes. For wetland polygons lacking a centroid from which eight spokes could reasonably radiate from, draw a line as near to the center of the wetland polygon's long axis as possible where the line follows the broad shape of the polygon, avoiding finer level twists and turns. Once you have determined the length of the line along the wetland's long axis, divide the line by five to create four equally spaced points along the axis. At each of the four points, draw a line perpendicular to the axis such that it extends out 100 m beyond each side of the wetland system's perimeter. See Faber-Langendoen et al. (2016) for additional guidance.

Figure 4. Example of Width of Natural Buffer calculation.
The wetland boundary is marked by a thin green line; the AA circular perimeter is yellow; the 100 m buffer assessment area around the AA is dark blue, and the eight transect lines are assessed for the buffer width. The blue segment of each transect indicates buffer is present and the purple segment indicates non-buffer land use. For example, transect 1 (north) has 63 m of buffer (see Table 13). An additional level of evaluation may be completed by having field crews walk the four cardinal direction lines to assess buffer condition, if logistically feasible. Figure by Kathleen Walz.

Measuring Width of Natural Buffer		
Line	Cardinal Direction	Buffer Width (m) (max = 100 m)
1	N	
2	NE	
3	E	
4	SE	
5	S	
6	SW	
7	W	
8	NW	
Average Buffer Width (m)		/8=

Metric Ratings	Width of Natural Buffer (m)	ALL
EXCELLENT (A)	Average buffer width is 100 m, adjusted for slope.	
GOOD (B)	Average buffer width is 75 -99 m, after adjusting for slope.	
FAIR (C)	Average buffer width is 25 -74 m, after adjusting for slope.	
POOR (D)	Average buffer width is <25 m, after adjusting for slope.	

BUF3. Condition of Natural Buffer

Measurement Protocol:
Estimate the overall condition of vegetation cover within that part of the perimeter that has a natural buffer. That is, if natural buffer length is only 30% of the perimeter, then assess condition within that 30%. Condition is based on percent cover of native vegetation, disruption to soils, signs of reduced water quality, amount of trash or refuse, various land uses, and intensity of human visitation and recreation, including from foot or boat traffic. The evaluation can be made by scanning an aerial photograph in the office, followed by ground-truthing, as needed.

Metric Ratings	Natural Buffer Condition	ALL
EXCELLENT (A)	Buffer characterized by abundant (>95%) cover of native vegetation, with intact soils, no evidence of loss in water quality & little or no trash or refuse.	
GOOD (B)	Buffer characterized by substantial (75–95%) cover of native vegetation, intact or moderately disrupted soils, minor evidence of loss in water quality, moderate or lesser amounts of trash or refuse, and minor intensity of human visitation or recreation.	
FAIR (C)	Buffer characterized by a low to moderate (25–74%) cover of native vegetation, barren ground and moderately to highly compacted or otherwise disrupted soils, moderate to strong evidence of loss in water quality, with moderate or greater amounts of trash or refuse, and moderate or greater intensity of human visitation or recreation.	
POOR (D)	Very low (<25%) cover of native plants, dominant (>75%) cover of nonnative plants, extensive barren ground and highly compacted or otherwise disrupted soils, moderate to great amounts of trash, moderate or greater intensity of human visitation or recreation, OR no buffer at all.	

SIZE METRICS [leave for post field work]

Size of Level 2 polygon_______

SIZE				
COMPARATIVE SIZE ***SEE WETLAND SYSTEM RANK SPEC***			**CHANGE IN SIZE** ***OPTIONAL***	
Very large compared to other examples of the same type (see system rank spec or Comparative Size Rank Table in manual)	**A**		Occurrence is at or only minimally reduced (<5%) from its original natural extent due to human activity	**A**
Large compared to other examples of the same type (see system rank spec or Comparative Size Rank Table in manual)	**B**		Occurrence is somewhat modestly reduced (5–10%) from its original natural extent	**B**
Medium to small compared to other examples of the same type (see system rank spec or Comparative Size Rank Table in manual)	**C**		Occurrence is modestly reduced (10–30%) from its original natural extent	**C**
Small to very small compared to other examples of the same type (see system rank spec or Comparative Size Rank Table in manual)	**D**		Occurrence is substantially reduced (>30%) from its original natural extent	**D**
Explain rank if adjusted from one given in system rank spec or Comparative Size Rank Table: **Current size =_______**			Explain rank if B, C, or D: **Reduced ______**	

HYDROLOGY METRICS

List any observable issues in the comments field relating to these metrics from the imagery.
Do not rate the metrics; rather add comments that may guide your field evaluation (e.g. evidence of ditches, culverts, dikes)

See Level 2 field forms for details on the rating criteria for each metric.

HYD1 Water Source (water coming into the wetland)

Metric Rating	*V2. Depression, Lacustrine, Slope*	Comments
Excellent (A)		
Good (B)		
Fair (C)		
Poor (D)		

HYD2 Hydroperiod (water patterns within the wetland, regardless of source)

Metric Rating	*V2. Depression, Lacustrine, Slope*	Comments
Excellent (A)		
Good (B)		
Fair (C)		
Poor (D)		

HYD3 Hydrologic Connectivity (water exchange between wetlands & surrounding systems, regardless of patterns within the wetland)

Metric Rating	*V2a. Depression, Lacustrine, Slope*	V2b. Lacustrine – Great Lakes	Comments
Excellent (A)			
Good (B)			
Fair (C)			
Poor (D)			

SOILS

List any observable issues relating to this metric from the imagery

SOI1 Soil Condition (indirect measure of disturbance based on stressors that increase the potential for erosion or sedimentation, assessed by evaluating intensity of human and other impacts to soils on the site (e.g. trampling, compaction, excavation, erosion)

Metric Rating	*V1. All Freshwater Non-tidal Wetlands (FLOODED & SWAMP FOREST, FRESHWATER MARSH, WET MEADOW & SHRUBLAND, BOG & FEN, AQUATIC VEGETATION)*	Comments
Excellent (A)		
Good (B)		
Fair (C)		
Poor (D)		

Obs. Area Name________________________________L2. Date: 20   /_____/_____

SCOPE of Threat (% of AA or Buffer affected by direct threat)	
1 = Small	Affects a small (1-10%) proportion of the AA or Buffer
2 = Restricted	Affects some (11-30%)
3 = Large	Affects much (31-70%)
4 = Pervasive	Affects all or most (71-100%)
SEVERITY of Threat within the defined Scope (degree of degradation to AA or Buffer)	
1 = Slight	Likely to only slightly degrade/reduce
2 = Moderate	Likely to moderately degrade/reduce
3 = Serious	Likely to seriously degrade/reduce
4 = Extreme	Likely to extremely degrade/destroy or eliminate

STRESSOR CHECKLIST for Human Stressor Index (HSI)

Stressors: *direct threats*; "the proximate (human) activities or processes that have caused, are causing, or may cause the destruction, degradation, and/or impairment of biodiversity and natural processes" or altered disturbance regime (e.g. flooding, fire, or browse).

AA = Assessment Area

Some Important Points about Stressors Checklists:

1. The Stressors Checklist must be completed for the AA (Veg, Soils, Hydro) and the Buffer (0-100m)
2. Assessment is of stressors found only within the AA and in the buffer, not outer landscape. Rely on imagery in combination with what you can field check.
3. Assess Buffer stressors and their effects within the Buffer 0-100m (*NOT how buffer stressors may impact the AA*)
4. Stressors for Vegetation, Soils, and Hydrology are assessed across the full AA.
5. Some stressors may overlap. E.g. 10 (low impact recreation) may overlap with 24 (Trampling). Choose only 1, note overlap
6. **Severity has been pre-assigned for many stressors. If the severity differs from the pre-assigned rating, cross it out and note the true severity. If there is more than one pre-assigned value, circle the appropriate value.**

		BUFFER Subzone (100 m)			ASSESSMENT AREA (AA)									
					Vegetation MEF			Soil / Subs MEF			Hydrology MEF			
	STRESSORS CHECKLIST	Scope	Severity	IMPACT*	Scope	Severity	IMPACT*	Scope	Severity	IMPACT*	Scope	Severity	IMPACT*	Comments (circle stressor #)
	1. Residential, recreational buildings, associated pavement		4											1
D	2. Industrial, commercial, military buildings, associated pavement		4											2
E	3. Utility/powerline corridor		1,2,3			1,2,3								3
V	4. Sports field, golf course, urban parkland, expansive lawns		2											4
E	5. Row-crop agriculture, orchard, nursery		3											5
L	6. Hay field		2,3											6
O	7. Livestock grazing (low=2, mod=3, high=4), excessive herbivory (deer =3)		2,3,4			2,3,4								7
P	8. Roads (gravel = 2, paved=3, highway=4), Railroad=3		2,3,4											8
	9. Other [specify]:													9
R	10. Low impact recreation (hunting, fishing, camping, hiking, bird-watching, canoe/kayak)		1			1								10
E	11. High impact recreation (ATV, mountain biking, motor boats)		3			3								11
C	12. Other [specify]:													12
	13a. Tree resource extraction (e.g., Clearcut = 3 for Buffer or =4 for AA; Selective cut = 2 or 3)		2,3,4			2,3,4								13a
	13 b. Shrub / Herb resource extraction (e.g. medicine, horticulture)		2,3			2,3								13b
V	14. Vegetation management: cutting, mowing		2			2								14
E	15. Excessive animal herbivory or insect pest damage		1,2,3			1,2,3								15
G	16. Invasive plant species (SEE LIST)		3,4			3,4								16
G	17. Pesticide or vector control, chemicals (give onsite evidence)		2,3			2.3								17
	18. Other [specify]:													18
Nat	19. Altered natural disturb regime [specify expected regime]		1,2,3			1,2,3								19
Dis	20. Other [specify]:													20

Obs. Area Name________________________________L2. Date: 20 /____/____

		BUFFER subzone (100 m)			ASSESSMENT AREA (AA)									
					Vegetation MEF			Soil / Subs MEF			Hydrology MEF			
	STRESSORS CHECKLIST	Scope	Severity	IMPACT*	Scope	Severity	IMPACT*	Scope	Severity	IMPACT*	Scope	Severity	IMPACT*	Comments (circle stressors)
	21. Excessive sediment or organic debris (recently logged sites), gullying, excessive erosion, excessive loss of organic matter		3						3					21
S	22. Trash or refuse dumping													22
O	23. Filling, spoils, excavation													23
I	24. Soil disturbance: trampling (2), livestock (3), skidding (3), Vehicle (4)		2,3,4						2,3, 4					24
L	25. Grading, compaction, plowing, disking, fire lines		4						4					25
	26. Physical resource extraction: rock, sand, gravel, etc.		3						3					26
	27. Other [specify]: e.g. landfill, soil loss/root exposure													27
H	28. PS discharge (waste water treatment water, non-storm discharge, septic)		3									3		28
Y	29. NPS discharge (urban/storm water runoff, agricultural drainage or excess manure, mine runoff, oil/gas discharge)		3									3		29
D	30. Dam, ditch, diversion, dike, levee, unnatural inflow, reservoir		3,4									3,4		30
R	31. Groundwater extraction (small well=2, several wells=3, extensive extraction causing significant lowering of water table =4)		2,3,4									2,3, 4		31
O	32. Flow obstructions (culverts, paved stream crossings)		4									4		32
L	33. Engineered channel (riprap, armored channel bank, bed)		4									4		33
O	34. Actively managed hydrology (e.g. lake levels controlled)		3									3		34
G	35. Tide gate, weir/drop structure, dredged inlet/channel		3									3		35
Y#	36. Other [specify]: e.g. wall/ riprap, impervious surface													36
	Stressors Very Minimal or Not Evident (check box, if true)	☐			☐			☐			☐			
	SUM OF Stressor IMPACTS -- Score & Rating by MEF (Buffer, Veg, Soils, Hydro) and for Site (from Table B)	Sum Score:	MEF Rating:		Sum Score:	MEF Rating:		Sum Score:	MEF Rating:		Sum Score:	MEF Rating:		
	TOTAL (Site) HSII: Multiply each MEF Impact Rating by the following weights then sum them to calculate the HSI Rating. See Table B for HSI Site Rating)	_____ x 0.3 =			_____ x 0.3 =			_____ x 0.1 =			_____ x 0.3 =			HSI Total Score: _____ HSI Total Rating:_____

*For impact score, see Table A below.

Hydrology stressors may cross between buffer and AA. E.g., ditches in the buffer may directly impact hydrology of the AA. Minimize listing in both columns unless you are sure of the impacts.

A. Stressor IMPACT Calculator		**Stressor SCOPE**			
		Pervasive = 4	**Large = 3**	**Restricted = 2**	**Small = 1**
Stressor SEVERITY	**Extreme = 4**	VERY HIGH = 10	High = 7	Medium = 4	Low = 1
	Serious = 3	High = 7	High = 7	Medium = 4	Low = 1
	Moderate = 2	Medium = 4	Medium = 4	Low = 1	Low = 1
	Slight = 1	Low = 1	Low = 1	Low = 1	Low = 1

B. MEF & SITE (HSI) STRESSOR RATING	
MEF Sum of Impact Scores	**MEF / Site Stressor RATING**
10+	**Very High**
7 – 9.9	**High**
4 – 6.9	**Medium**
1 – 3.9	**Low**
0 – 0.9	**Absent**

Appendix A. Evaluation form used for draft list of indicators for Gulf Coast ecosystems (Goodin, pers. comm.). Criteria can be scored using a rating scale, such as: 1=minimally effective, 2=less effective, 3=moderately effective, 4=more effective, 5=extremely effective. Comments may be added to each rating. Adapted from Herrick et al. (2010).

	Evaluation Criteria	**Criteria Definition**
Ecologically Relevant	Informative of ecological condition	Ecologically relevant and can be used to assess current ecological condition. Reference values (i.e., the value or range of values expected for a site when it is at its ecological potential) exist.
	Applicable at multiple scales	Applicable to management at multiple scales (plot to Gulf-wide). Characterization of indicator at one scale can be extrapolated to other scales (assuming an appropriate sampling design) to facilitate interpretation of current condition or provision of services.
Feasible	Low Cost for data collection	Cost, including field and analysis expense and time, necessary to obtain the required number of measurements with a sufficient level of precision, accuracy and repeatability (across years) is relatively low.
	Currently collected in the Gulf	Currently collected in the Gulf by existing monitoring programs.
	Can be collected more cheaply by remote sensing	Remote sensing detection currently or soon possible at less than field cost at observation level with high resolution imagery or satellite imagery.
Response Variability (statistically sound)	Detects Long Term Trends	High signal:noise ratio (sensitive to detecting long-term trends and insensitive to short-term variability, such as differences associated with short-term weather patterns and time since disturbance).
	Repeatable	Can be measured with a methodology that provides consistent results by different observers. Low susceptibility to bias. Relatively easy to standardize measurement or observation of indicator across observers.
Management	Precision suitable for analyses that support management applications	Can be quantified with selected sampling design with sufficient level of precision at scale(s) relevant to management needs.
	Applicable to multiple management objectives	Can be consistently applied to address multiple management objectives including LMRs
	Can be easily explained to and applied by managers	Can be applied by trained mangers with undergraduate or master's level knowledge of relevant resource management. Does not require specialized expertise to apply.

Obs. Area Name_________________________________L2. Date: 20 /____/____

LEVEL 2 FIELD FORM

Project Obs: NRDA Pilot WI-MI

DATE:

Observation Area Code: NRDA._ _.L2._ _ _

Site Name: [see Site Form] ______________________________________

Observation Area (AA) Name: ________________________________EO #:_______ State______

Field Crew Team Members:

Leader:____________________________Assistants:____

Photographer:__________________________Photos of Observation: _

AA Shape: [project default =] Polygon

AA Dimensions (ac/ha):_______ac________ha

County:_______________Twp:__________Quad:_______________

Ownership:____________________________Contact Person: ____

Access Comments (e.g. Permit Required, Locked Gate, Access difficulties? (describe difficulties): ____________________________

____

OBSERVATION AREA DESCRIPTION:

(Note whether this is a restoration site or a reference site)

GPS Unit:_____________[take 4 GPS points at up to 4 key outer boundary locations]					
UTM Zone: _____	Acc:_______m / ft PDOP. # Sats:_	Acc:____m / ft PDOP. # Sats:_	Acc:____m / ft PDOP. # Sats:_	Acc:____m / ft PDOP. # Sats:_	
LAT: dec.deg (e.g. 40.654321)	*1*	2	3	4	
LONG: dec deg (e.g.- 074.123456)	-	-	-	-	

Classification

HGM Class: (see page below):

NVC Formation: 1) Flooded & Swamp Forest, 2) Freshwater Marsh, Wet Meadow & Shrubland; 3) Bog & Fen, 4) Salt Marsh 5) Aquatic

NVC Group: ____

NVC Association: ____

State Natural Community Type: ____

Classification Comments:

GENERAL DRAWING Provide a drawing of the assessment area, including its boundaries, as either aerial view or transect view.

DETAILED DESCRIPTION OF LANDSCAPE, BUFFER, and AA
LANDSCAPE CONTEXT [on-site evaluation as check to office assessment)
SURROUNDING LANDSCAPE AND BUFFER DESCRIPTION:
What's your impression of the condition/integrity of the BUFFER? Circle one: Excellent, Good, Fair, Poor Comments:
SIZE
SIZE DESCRIPTION: List the acreage of Assessment Area and of full extent of type, if AA is a subset.
ON-SITE CONDITION
AA LANDSCAPE PATTERN (e.g. zonation within AA)
AA VEGETATION (composition, structure, invasives, vegetation management)
AA HYDROLOGY Description (water source, hydroperiod, hydrologic connectivity, evidence of disturbance)
AA SOILS Description (soil type, soil condition, evidence of disturbance)
AA ASSOCIATED FAUNA (species noted in AA)
What's your impression of the CONDITION/INTEGRITY of the on-site community? Circle one: Excellent, Good, Fair, Poor. Comments:

VEGETATION PROFILE

ALWAYS COMPLETE THESE COLUMNS Cover scale: FS ECODATA – see next column			**Cover Scale: < 1%, 3% (**1-5), **10% (**5-14), **20%** (15-24**), 30%** (25-34), **40%** (35-44), **50%** (45-54), **60%** (55-64) **70%** (65-74), **80% (**75-84), **90%** (85-94), **98%** (95-100)	
Growth forms / strata	**Cover (%)**	**Ht (m)**	**Dominants:** List **all** species **with** cover class **if >5% cover, List all exotics with cover class if > 1%. Optional:** list other characteristics < 5%.	
Tm. Mature (tall) Tree (>5m)		____ To nearest 5 m.	*e.g. Acer rubrum – 10%*	
Ts. Sapling (medium) Tree (2-5m)				
Te. Seedling (small) Tree (< 2 m)				
S1. Tall Shrub (≥ 2 m)				
S2. Short / Dwarf-shrub (< 2 m)				
H. Herb (Field, Emergent)				
A1. Floating-leaved Aquatic		X		
A2. Submerged Aquatic		X		
N. Non-vascular - Moss		X		
- Lichen		X		
- Algae		X		
V. Vine / Liana				

VEGETATION STRUCTURE PROFILE [forest types only]

Structural Stage: Estimate the % aerial cover of all trees in each structural stage to nearest 10%. Evaluate only the top canopy layer (i.e. view canopy from above, but canopy might be sapling layer). Total should add to 100%. [dbh ranges – eastern N.A. temperate]

_____% woody stages **absent** or **seedlings** (i.e. stems < 2m) _____% **Sapling**: stems < 10 cm (< 4") dbh _____%**Pole:** stems 10-30 cm (4 – 12") dbh _____%**Large**: stems 30—50 cm (12-20") dbh _____%**Very Large:** stems >50 cm (20") dbh	**Standing Snags Comments:** Describe presence & abundance of snags > 30 cm (12") dbh (e.g. do snags appear to be recently dead, etc.).
Structural Stage Comments: (e.g. is tree or tall shrub structure more or less even across the AA)	**Dead Fallen Logs (CWD):** Comment on the presence and characteristics of CWD greater than 10 cm dbh.

Obs. Area Name__________________________________L2. Date: 20 /____/____

ENVIRONMENTAL PROFILE

Topo Position: colluvial lowslope, alluvial toeslope, low level terrace, narrow channel bed, basin floor/depression

Elevation (topo map):______m/______ft

Slope: Clinometer *degrees or %*

flat	0°	0%
gentle	0-5°	1-9%
moderate	6-14°	10-25%
somewhat steep	15-24°	26-49%
steep	25-44°	50-99%
very steep	45-69°	100-274%
abrupt	70-100°	275-300%
overhanging	>100°	>300%

Aspect (compass) *downslope*: or variable

Landform Comment:

SOIL DESCRIPTION [req'd for plot data]:
Record an average from several readings)

Depth to Impervious Layer (cm) :
(If > 50 cm, put > 50)________(cm)
Record Organic and Mineral Layers separately

Soil Classification (NRCS) check one:
__ORGANIC (>40cm in upper 80cm)
(Histosol - true organic soil)
__MINERAL (<40cm organic and/or mineral)
(Histic Epipedon, Clayey/Loamy or Sandy)
______Depth of Organic Layer
__Muck, Sapric (von Post H7-10)
__Peat, Hemic (von Post H4-6)
__Peat, Fibric (von Post H1-3)
______Depth of Mineral Layer
___Histic Epipedon(<40cm Org over Min)
__Clayey/Loamy (incl. sandy loam)
__Sandy (sands and loamy sands)

Soil Comments: **additional substrate characteristics (e.g. marl layers, stoniness etc):**

UNVEGETATED SURFACE
[req'd for plot data]
(does not need to add to 100%; mentally remove plant layers; ignore below water):
_____% Surface Water
_____% Litter, duff, wood < 10 cm dbh
_____% Wood >10 cm dbh
_____% Rock
_____% Bare surface
_____% Other (describe):

HYDROLOGIC REGIME:

[WT=water table; GS=growing season]
___Saturated: saturated to surface for extended periods during GS; surface water seldom present, isolated pools may be present.
___Seasonally saturated: saturated to surface but absent by end of most GS
___Permanently flooded: water covers surface throughout year in all years
___Semi-permanently flooded: water covers surface and persists throughout GS in most years (excl. droughts); when absent, WT usually at/very near surface
___Seasonally flooded: water covers surface and is present early in GS, but absent end of season in most years; when absent, WT often near surface
___Temporarily flooded: water covers surface for brief periods in GS, but WT usually well below surface for most of season; upland & wetland plants present
___Intermittently flooded: flooded for variable periods w/out detectable seasonal periodicity; months or years may occur between floods
___Artificially flooded: flooding by pumps, siphons etc., not "altered natural."
___Upland (not wetland, very rarely flooded)
___Unknown

SOIL DRAINAGE:
___Rapidly Drained (Somewhat Excessively Drained) no gleying in entire profile; typically coarse textured or on steep slope
___Well Drained: usually free of mottling in upper 3'; B red, brown, or yellowish
___Moderately Well Drained: commonly mottled in lower B and C or below 2'
___Somewhat Poorly Drained: soil moisture in excess of field capacity remains in horizon for moderately long periods during year; commonly mottled in B and C
___Poorly Drained: soil moisture in excess of field capacity in all horizons for large part of year; soils usually very strongly gleyed
___Very Poorly Drained: free water remains at/within 12" of surface most of year; strongly gleyed

HYDROLOGICAL Conditions
[req'd for plot data]:
(Record an average from several readings)

Depth of Surface Water deepest point: _______
Estimated High Water Depth: ______________
Evidence of High Water:__________________

If no Surface Water:
Depth to Saturated Layer
(If > 50 cm, put > 50)_______(cm)
Depth to Water Table:
(If > 50 cm, put > 50)_______(cm)

WATER SOURCE:

Pick one primary (write "1"), up to two others ("2"), as needed.
___Direct precipitation
___Surface/overland flow: run-off
___Groundwater
___ Discharge: released into wetland
___ Saturation: wetland near WT surface
___Water body inundation: surface water from marsh/swamp due to adjacent river/lake
___Overbank flow: flooding river/stream
___Inbank flow: contained within river channel
___Anthropogenic
____ Direct input: irrigation, pumped
____ Overland flow - urban
____ Overland flow - rural
___Other (describe):

HGM CLASS:
Pick one primary (write "1"); if needed, pick a secondary (write "2")
___Riverine (intermittent, headwater complex, floodplain complex, perennial - upper, - lower, Impounded – human, - beaver)
___Slope (topographic, stratigraphic)
___Sliverine (slope/riverine headwater seep)
___Depression (seasonal, perennial, impounded)
___Flats - Mineral Soil Flats
___Flats - Organic Soil Flats
___Estuarine Fringe (lunar intertidal, wind intertidal, subtidal, impounded)
___Lacustrine Fringe (permanently, semi-perm, intermittently flooded)

HGM Class Comments:

Environmental Comments (any other characteristics worth noting, e.g., stoniness, hardpans, drainage, water flow):

EIA 2016 CONDITION RANKING DATE: Obs. Area Name:

modified from New Jersey 2016 Field Forms

VEGETATION METRICS

VEG1 Native Plant Species Cover (Relative) (use worksheet and score metrics)

Metric Rating	All	*Submetric: Tree Stratum*	*Submetric: Shrub / Herb Stratum*
Excellent (A) >99%			
Very Good (B) 95-99%			
Good (C) 85-94%			
Fair (C-) 60-84%			
Poor (D) <60%			
%Native / %Nonnative		____/______	______/________
Comment			

VEG2 Invasive Nonnative Plant Species Cover (Absolute)

☐ EXCELLENT (A) <1%	☐ GOOD (B) 1-3%	☐ FAIR (C) 4-10%	☐ FAIRLY POOR (C-) 10-30%	☐ POOR (D) >30%

List invasive nonnative species:

VEG3 Native Plant Species Composition

Metric Rating	All	*Submetric: Diagnostic Species*	*Submetric: Weedy or Ruderal Species*	*Submetric: Native Increasers (e.g. CC= 1,2)*	*Submetric: Native Decreasers (e.g. CC=8,9,10)*
Excellent (A)					
Good (B)					
Fair (C)					
Poor (D)					
Comment (note species that support rating)					

	NATIVE PLANT SPECIES COMPOSITION ***Guidance***
Excellent (A)	Native vegetation composition with expected species abundance and diversity: • Typical range of native diagnostic species present, including those native species sensitive to anthropogenic degradation, and Native species indicative of anthropogenic disturbance (aggressive and weedy natives) absent to minor
Good (B)	Native vegetation composition with minor alterations from expected due to human factors: • Some native diagnostic species absent or substantially reduced in abundance (including those sensitive to anthropogenic degradation), and/or Native species indicative of anthropogenic disturbance (aggressive and weedy natives) are present in low cover
Fair (C)	Native vegetation composition moderately altered from expected due to human factors: • Many native diagnostic species absent or substantially reduced in abundance (including those sensitive to anthropogenic degradation), and/or Native species indicative of anthropogenic disturbance (aggressive and weedy natives) are present in moderate cover
Poor (D)	*Native vegetation composition substantially altered from expected due to human factors:* • *Most or all native diagnostic species absent (including those sensitive to anthropogenic degradation), a few may remain in very low abundance, or* *Native species indicative of anthropogenic disturbance (aggressive and weedy natives) are present in high cover*

VEG4 Overall Vegetation Structure

Metric Rating		*V1. Flooded & Swamp Forest*
Excellent (A)		Canopy a mosaic of patches of different ages or sizes; gap sizes also vary; # of live tree stems 12-20" and >20" dbh well within expected range; *using a quick qualitative approach and where applicable to type*, there exists a very wide size-class diversity of downed logs and standing snags and characteristic woody species are regenerating with expected abundance and diversity, so no human-related degradation to vegetation structure evident
Good (B)		Canopy largely heterogeneous in age or size; # of live tree stems of medium and large size slightly below expected range; wide size-class diversity of downed logs and standing snags; characteristic woody species regenerating but present in somewhat lower abundance and/or diversity than expected due to human-related factors, so slight degradation to vegetation structure evident (e.g., low levels of cutting, browsing, and/or grazing)
Fair (C)		Canopy somewhat homogeneous in age or size; # of live tree stems of medium and large size moderately below expected range; moderate size-class diversity of downed logs and standing snags; characteristic woody species with noticeably reduced regeneration, abundance, and/or diversity than expected due to human-related factors, so moderate degradation to vegetation structure evident (e.g., intermediate levels of cutting, browsing, and/or grazing)
Poor (D)		Canopy very homogeneous in age or size; # of live tree stems of medium and large size substantially below expected range; low size-class diversity of downed logs and standing snags (or absent); characteristic woody species with severely reduced regeneration, abundance, or diversity than expected due to human-related factors, so substantial degradation to vegetation structure evident (e.g., high levels of cutting, browsing, or grazing)
Comment		

Metric Rating		Freshwater Marsh, Wet Meadow & Shrubland
Excellent (A)		Characteristic woody species present with expected abundance and diversity, so no human-related degradation to vegetation structure evident; some very wet peatlands or marshes may naturally not have any woody vegetation or only scattered stunted individuals; standing tree snags, dead shrubs, downed woody debris, and litter due to natural factors
Good (B)		Characteristic woody species somewhat lower in abundance and/or diversity than expected due to human-related factors, so slight degradation to vegetation structure evident (e.g., low levels of cutting, browsing, grazing, and/or mowing); standing tree snags, dead shrubs, downed woody debris, and/or litter with minor alterations from human disturbances
Fair (C)		Characteristic woody species moderately lower in abundance and/or diversity than expected due to human-related factors, so moderate degradation to vegetation structure evident (e.g., intermediate levels of cutting, browsing, grazing, and/or mowing); standing tree snags, dead shrubs, downed woody debris, and/or litter with moderate alterations from human disturbances
Poor (D)		Characteristic woody species strongly altered in abundance or diversity than expected due to human-related factors, so substantial degradation to vegetation structure evident (e.g., high levels of cutting, browsing, grazing, or mowing); standing tree snags, dead shrubs, downed woody debris, or litter with substantial alterations from human disturbances
Comment		

VEG5 Woody Regeneration (*opt*)

Metric Rating		V1 Flooded & Swamp Forest
Excellent (A)		Native tree saplings and/or seedlings or shrubs common to the type present in expected amounts and diversity
Good (B)		Native tree saplings and/or seedlings or shrubs common to the type present but less amounts and diversity than expected.
Fair (C)		Native tree saplings and/or seedling or shrubs common to the type present but low amounts and diversity; little regeneration.
Poor (D)		No, or essentially no regeneration of native woody species common to the type.
Comment		

VEG6 Coarse Woody Debris (*opt*)

Metric Rating		V1 Flooded & Swamp Forest
Excellent / Good (A/B)		Wide size-class diversity of standing snags and CWD (downed logs). Moderate size class (>30 cm dbh and >2 m long) common with 5 or more snags per ha (2.5 ac), but not excessive numbers (suggesting disease or other problems). CWD and snags representing diverse decay classes and diversity of canopy species.
Fair (C)		Moderate size-class diversity of standing snags or downed CWD. Larger size class present with 1–4 snags per ha, or moderately excessive numbers (suggesting disease or other problems). CWD and snags in various stages of decay but with fewer examples in the most advanced decay classes and less representation of canopy species
Poor (D)		Low size-class diversity of downed CWD and snags. Larger size class absent or infrequent with <1 snag per ha, or very excessive numbers (suggesting disease or other problems). CWD and snags mostly in early stages of decay and representing only early-successional component of canopy.
Comment		

HYDROLOGY METRICS

HYD1 Water Source (water coming into the wetland)

Metric Rating		*V2. Depression, Lacustrine, Slope*
Excellent (A)		Water source is natural; hydrology is dominated by precipitation, groundwater, natural runoff, and/or overbank flow; there is no indication of direct artificial water sources; land use in the wetland's local drainage area is primarily open space or low density, passive uses
Good (B)		Water source contains slight amounts of inflow from anthropogenic sources; indications of anthropogenic input include developed land (<20%) in the immediate drainage area of the wetland, some road runoff, small storm drains, and/or minor point source discharges into or adjacent to the wetland
Fair (C)		Water source contains moderate amounts of inflow from anthropogenic sources; indications of anthropogenic input include 20-60% developed land adjacent to the wetland, moderate amounts of road runoff, moderately-sized storm drains, and/or moderate point source discharges into or adjacent to the wetland
Poor (D)		Water source contains substantial amounts of inflow from anthropogenic sources; indications of anthropogenic input include >60% developed land adjacent to the wetland, large amounts of road runoff, large-sized storm drains, or major point source discharges into or adjacent to the wetland
Comment		

HYD2 Hydroperiod (water patterns within the wetland, regardless of source)

Metric Rating		*V2. Depression, Lacustrine, Slope*
Excellent (A)		Natural patterns of inundation & drawdown, saturation, and/or seepage discharge; stressors that impact the natural hydroperiod absent
Good (B)		Deviates slightly from natural patterns of inundation & drawdown, saturation, and/or seepage discharge due to stressors (e.g., small ditches/diversions, minor artificial groundwater pumping, and/or minor flow additions); outlets may be slightly constricted by dam (if managed water levels, they closely mimic natural hydroperiod patterns)
Fair (C)		Deviates moderately from natural patterns of inundation & drawdown, saturation, and/or seepage discharge due to stressors (e.g., ditches/diversions 1–3 ft. deep, moderate artificial groundwater pumping, and/or moderate flow additions); outlets may be moderately constricted by dam, but flow still possible (if managed water levels, they less closely mimic natural hydroperiod patterns)
Poor (D)		Deviates substantially from natural patterns of inundation & drawdown, saturation, and/or seepage discharge due to stressors (e.g., ditches/diversions >3 ft. deep & withdraw a significant portion of flow, significant artificial groundwater pumping, or heavy flow additions); outlets may be significantly constricted by dam, blocking most flow (if managed water levels, they are disconnected from natural seasonal fluctuations)
Comment		

HYD3 Hydrologic Connectivity (water exchange between wetlands & surrounding systems, regardless of patterns within the wetland)

Metric Rating		*V2a. Depression, Lacustrine, Slope*		*V2b. Great Lakes Variant*
Excellent (A)		No unnatural obstructions to lateral and vertical movement of ground or surface water; rising water in the wetland has unrestricted access to adjacent upland, without obstructions to the lateral movement of flood flows; if perched water table then impermeable soil layer intact		Marsh receives unimpeded hydrologic input from Great Lakes. No unnatural obstructions to lateral or vertical movement of waves, seiches, groundwater, or surface water. Total absence of dikes or human-made channels Rising water in the site has unrestricted access to adjacent upland, without levees, excessively high banks, artificial barriers, or other obstructions to the lateral movement of flood flows.
Good (B)		Slight restrictions (impacting <25% of the wetland) to the lateral and/or vertical movement of ground or surface waters by unnatural features (e.g., levees and/or excessively high banks); restrictions may be intermittent along the wetland, or the restrictions may occur only along one bank or shore; flood flows may exceed the obstructions, but drainage back to the wetland is incomplete due to impoundment; if perched then impermeable soil layer slightly disturbed (e.g. drilling,blasting)		Slightly impeded hydrologic input from Great Lakes. Minor restrictions to the lateral or vertical movement of waves, seiche, groundwater or surface water by unnatural features, such as levees, human-made channels, or dikes. Less than 25% of the site is restricted by barriers to drainage and/or flow. Flood flows may exceed the obstructions, but drainage back to the wetland is incomplete due to impoundment. Culvert, if present, is of large diameter and does not significantly change flow, as evidenced by similar veg. on either side of culvert.
Fair (C)		Moderate restrictions (impacting 25-75% of the wetland) to the lateral and/or vertical movement of ground or surface waters by unnatural features (e.g., levees and/or excessively high banks); flood flows may exceed the obstructions, but drainage back to the wetland is incomplete due to impoundment; if perched then impermeable soil layer moderately disturbed (e.g., by drilling or blasting)		Moderately impeded hydrologic input from Great Lakes. Moderate restrictions to the lateral or vertical movement of waves, seiches, groundwater or surface water by unnatural features, such as levees, human-made channels, or dikes. Between 25–75% of the site is restricted by barriers to drainage and/or flow. Flood flows may exceed the obstructions, but drainage back to the wetland is incomplete due to impoundment. Hydrology is somewhat impeded bysmall culvert size, as evidenced in obvious differences in veg. on either side of the culvert
Poor (D)		Substantial restrictions (impacting >75% of the wetland) to the lateral or vertical movement of ground or surface waters by unnatural features (e.g., levees or excessively high banks); most or all water stages are contained within the obstructions; if perched then impermeable soil layer substantially disturbed (e.g., by drilling or blasting)		Severely impeded hydrologic input from Great Lakes. Severe restrictions to the lateral or vertical movement of waves, seiches, groundwater or surfacewater by unnatural features, such as levees, human-made channels, or dikes. Greater than 75% of wetland is restricted by barriers to drainage and/or flow. Hydrology is totally or almost totally impeded by obstructed culverts.
Comment				

SOIL (Physio-Chemical) METRICS

SOI1 Soil Condition (indirect measure of disturbance based on stressors that increase the potential for erosion or sedimentation, assessed by evaluating intensity of human and other impacts to soils on the site (e.g. trampling, compaction, excavation, erosion)

Metric Rating	*V1. All Freshwater Non-tidal Wetlands (FLOODED & SWAMP FOREST, FRESHWATER MARSH, WET MEADOW & SHRUBLAND, BOG & FEN, AQUATIC VEGETATION)*	
Excellent (A)		Disturbed or bare soil limited to natural causes such as flood deposition or wildlife trails
Good (B)		Small amounts of disturbed or bare soil due to human causes (e.g., small areas of soil removal or additions; sedimentation due to human causes; unnatural hummocks/hollows; evidence of past ploughing or soil leveling; erosion by wind or water from over-grazing or other activities that remove protective vegetation cover; compaction by machinery or trampling; pockmarking by livestock; and/or ruts from vehicles); extent and impact is minimal
Fair (C)		Moderate amounts of disturbed/degraded soil due to human causes (e.g., moderate areas of soil removal or additions; sedimentation due to human causes; unnatural hummocks/hollows; evidence of past ploughing or soil leveling; erosion by wind or water from over-grazing or other activities that remove protective vegetation cover; compaction by machinery or trampling; pockmarking by livestock; and/or ruts from vehicles); extent and impact is moderate
Poor (D)		Substantial amounts of disturbed/degraded soil due to human causes (e.g., substantial areas of soil removal or additions; sedimentation due to human causes; unnatural hummocks/hollows; evidence of past ploughing or soil leveling; erosion by wind or water from over-grazing or other activities that remove protective vegetation cover; compaction by machinery or trampling; pockmarking by livestock; or ruts from vehicles); extent and impact is substantial and long lasting
Comment		

EIA CONDITION RANKING DATE: Obs. Area Name:

LANDSCAPE CONTEXT [USE PRE-FIELD METRIC FORMS, IF AVAILABLE]

LAN2. Land Use Index – FIELD CHECK of GIS Inner Landscape (0-100m) & Outer Landscape (100-500m) surrounding AA

Surrounding Land Use Categories	Aggregated Land Use Categories	Co-e	inner	outer
Paved roads / parking lots	Developed – High to Moderate Intensity	0		
Domestic, commercial, or publicly developed buildings and facilities (non-vegetated)	Developed – High to Moderate Intensity	0		
Gravel pit / quarry / open pit / strip mining	Developed – High to Moderate Intensity	0		
Unpaved roads (e.g., driveway, tractor trail, 4-wheel drive, logging roads)	Developed – High to Moderate Intensity	1		
Agriculture: tilled crop production	Agriculture – Cultivated Crop, Annual	2		
Intensively developed vegetation (golf courses, lawns, etc.)	Developed – Low Intensity	2		
Vegetation conversion (chaining, cabling, roto-chopping, clearcut)	Vegetation – Highly Altered	3		
Agriculture: permanent crop (vineyard, orchard, nursery, hayed pasture, etc.)	Agriculture – Cultivated Crop – Perennial	4		
Intense recreation (ATV use / camping / popular fishing spot, etc.)	Vegetation – Highly Altered	4		
Military training areas (armor, mechanized)	Vegetation – Highly Altered	4		
Heavy logging or tree removal (50-75% of trees >30 cm dbh removed)	Vegetation – Moderately Altered	5		
Commercial tree plantations / holiday tree farms	Vegetation – Moderately Altered	5		
Recent old fields and other disturbed fallow lands dominated by Ruderal and exotic species	Vegetation – Moderately Altered	5		
Vegetated Right-of-Ways (wetland or upland)	Vegetation – Moderately Altered	5		
Dam sites and flood disturbed shorelines around water storage reservoirs and boating	Vegetation – Moderately Altered	5		
Moderate recreation (high-use trail)	Vegetation – Moderately Altered	7		
Mature old fields and other fallow lands with natural composition	Vegetation – Moderately Altered	7		
Selective logging or tree removal (<50% of trees >30 cm dbh removed)	Vegetation – Lightly Altered	8		
Light recreation (low-use trail)	Vegetation – Lightly Altered	9		
Natural area / land managed for native vegetation	Vegetation – No/ Minimally Altered	10		
Divide Sum of Land Use Index (LUI) Scores by number of Co-efficient checked off	*AVERAGE LUI Score =*	/		

BUFFER METRICS

Land Covers INCLUDED in Natural Buffers	Land Covers EXCLUDED from Natural Buffers
Natural upland habitats and plant communities; open water; vegetated levees; old fields; naturally vegetated rights-of-way; rough meadows; natural swales and ditches; native or naturalized rangeland, non-intensive plantations	Parking lots; commercial and private developments; roads (all types), intensive agriculture; intensive plantations†; orchards; vineyards; dry-land farming areas; railroads; planted pastures (e.g., from low intensity to high intensity horse paddock, feedlot, or turkey ranch); planted hayfields; lawns; sports fields; traditional golf courses; Conservation Reserve Program pastures

LUI Metric Rating	Average LUI Score Rating	ALL
EXCELLENT (A)	9.5-10.0	
GOOD (B)	8.0-9.4	
FAIR (C)	4.0-7.9	
POOR (D)	<4.0	

BUF1. Perimeter with Natural Buffer (mark on attached aerial photograph)

Metric Rating	Perimeter with Natural Buffer (%)	Comment
EXCELLENT (A)	Natural buffer is 100% of perimeter	Est. % =
GOOD (B)	Buffer is >75–99% of perimeter	
FAIR (C)	Buffer is 25–75% of perimeter	
POOR (D)	Buffer is <25% of perimeter	

Land Covers Crossing and Breaking Natural Buffers
bike trails; foot trails; horse trails; dirt, gravel or paved roads; residential areas; bridges; culverts; paved creek fords; railroads; sound walls; fences that interfere with movements of water, sediment, or wildlife species that are critical to the overall functions of the wetland (>10 m break in buffer)

BUF2. Width of Natural Buffer

Measuring Width of Natural Buffer		
Line	Cardinal Direction	Buffer Width (m) (max = 100 m)
1	N	
2	NE	
3	E	
4	SE	
5	S	
6	SW	
7	W	
8	NW	
Average Buffer Width (m)		/8=

Metric Ratings	Width of Natural Buffer (m)	ALL
EXCELLENT (A)	Average buffer width is 100 m, adjusted for slope.	
GOOD (B)	Average buffer width is 75 -99 m, after adjusting for slope.	
FAIR (C)	Average buffer width is 25 -74 m, after adjusting for slope.	
POOR (D)	Average buffer width is <25 m, after adjusting for slope.	

BUF3. Condition of Natural Buffer

Metric Ratings	Natural Buffer Condition	ALL
EXCELLENT (A)	Buffer characterized by abundant (>95%) cover of native vegetation, with intact soils, no evidence of loss in water quality & little or no trash or refuse.	
GOOD (B)	Buffer characterized by substantial (75–95%) cover of native vegetation, intact or moderately disrupted soils, minor evidence of loss in water quality, moderate or lesser amounts of trash or refuse, and minor intensity of human visitation or recreation.	
FAIR (C)	Buffer characterized by a low to moderate (25–74%) cover of native vegetation, barren ground and moderately to highly compacted or otherwise disrupted soils, moderate to strong evidence of loss in water quality, with moderate or greater amounts of trash or refuse, and moderate or greater intensity of human visitation or recreation.	
POOR (D)	Very low (<25%) cover of native plants, dominant (>75%) cover of nonnative plants, extensive barren ground and highly compacted or otherwise disrupted soils, moderate to great amounts of trash, moderate or greater intensity of human visitation or recreation, OR no buffer at all.	

Obs. Area Name:________________________Date: ____________________

NRDAR PLOT FORM

LOCATION AND GENERAL INFORMATION

Site Name [project site name. e.g., Charles Pond]:____Site ID [EcoObs office]______________

ASSESSMENT AREA

Transect /Plot Code: [e.g. A1]_______

ObsArea ID:______________________ObsArea Name: [e.g. Charles Pond Sedge Meadow A1]____

Date:_______________________Team Members:____

Directions to Point: [include transect Letter, distance to point] [e.g. Transect A, 30 m)

Access Comments (note permit requirements or difficulties accessing the site):

ENVIRONMENTAL DESCRIPTION AND CLASSIFICATION OF ASSESSMENT AREA

Ecological System: (see manual for key and pick the *best match*)   Fidelity: High Med Low

USNVC Classification Confidence: High Med Low (see manual and pick *one each* of Group, Alliance and Association) State Community Classification	HGM Class: (pick *only one*) Fidelity: High Med Low ____Riverine* ____Lacustrine Fringe ____Depressional _____Slope _____Flats _____Novel (Irrigation-Fed) Riverine / Slope **Specific classification and metrics apply to the Riverine HGM Class*

ENVIRONMENTAL AND CLASSIFICATION COMMENTS

Classification Issues (important for sites with medium or low confidence to one or more classification systems):
Note any upland inclusions, and if present, a rough % of the plot.
Note the degree to which the type occurs on natural site, or a human disturbed site (post ag, etc).

VEGETATION PLOT REPRESENTATIVENESS

Is Vegetation Plot representative of the larger polygon (surrounding landscape)? ☐ Yes ☐ No
Comments:

Obs. Area Name:________________________Date: ____________________

VEGETATION PLOT

VEGETATION PLOT

GPS COORDINATES AND PHOTOS OF VEGETATION PLOT (See Plot layout below)

Transect Distance:___m WP #:___________LAT:________.________________LONG: -________.________________Accuracy (+/-): ______

Photo #:_______ Aspect:______________Comment:____

Plot GPS Coordinates: 10 m (optional)

Transect Distance:___m WP #:___________:LAT________.________________LONG: -________.____________________Accuracy (+/-): __________

Photo #:_______ Aspect:______________Comment:____

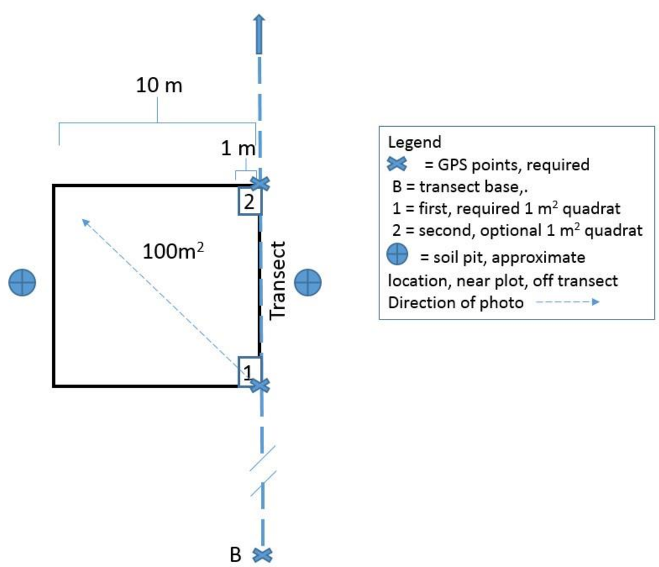
LAYOUT OF VEGETATION PLOT (See reference card for more details. Include vegetation plot on site sketch.)

_____Standard Layout (see figure below)

_____Alternative Layout (explain)____

Plot Layout Comments (note which plot is treated as residual):

Add north arrow and approx. scale bar. Document **habitat features** and **biotic and abiotic zones** (particularly open water), inflows and outflows, and indicate direction of drainage. Include location of **AA points, soil pits,** and **water chemistry** samples. If appropriate, add a **cross-sectional diagram** and indicate slope of side.



Stratum Profile

Strata		Ht											
Tm	Tree Mature (> 5 m)												
Ts	Tree Sapling (2-5 m)												
Te	Tree Seedling (< 2 m)												
S1	2 m+												
S2	< 2 m												
VI	Woody Vine/Liana												
H	Herb												
A1	Aquatic Floating												
A2	Aquatic Submerged												
NV	Nonvascular												
Unveg													
% cov			<10	10→	20→	30→	40→	50→	60→	70→	80→	90→	100→

Obs. Area Name:______________________Date: ___________________

VEGETATION PLOT SPECIES TABLE													
Strata List. Tm, Ts, Te, S1, S2, VL, H, A1, A2, NV			**Quadrat/Plot →**	**1 m^2 Q-quadrat**		**1 m^2 Q (opt)**		**100 m^2 plot**					
			Presence / Cover →	**P**	**C**	**P**	**C**	**P**	**C**	**P**	**C**	**P**	**C**
Cover Scale: < 1%, 3% (1-5), **10% (**5-14), **20%** (15-24**), 30%** (25-34), **40%** (35-44), **50%** (45-54), **60%** (55-64) **70%** (65-74), **80% (**75-84), **90%** (85-94), **98%** (95-100)													
Scientific Name or Pseudonym	**Stra-tum**	**Coll #**	**Photos**										

Obs. Area Name:________________________ Date: ____________________

VEGETATION PLOT SPECIES TABLE													
Strata List. Tm, Ts, Te, S1, S2, VL, H, A1, A2, NV **Quadrat/Plot →**				**1 m² Q-quadrat**		**1 m² Q (opt)**		**100 m² plot**					
Presence / Cover →				**P**	**C**	**P**	**C**	**P**	**C**	**P**	**C**	**P**	**C**
Cover Scale: < 1%, 3% (1-5), **10% (**5-14), **20%** (15-24**), 30%** (25-34), **40%** (35-44), **50%** (45-54), **60%** (55-64) **70%** (65-74), **80% (**75-84), **90%** (85-94), **98%** (95-100)													
Scientific Name or Pseudonym	**Stra-tum**	**Coll #**	**Photos**										

Obs. Area Name:______________________Date: __________________

VEGETATION STEM PROFILE. 10 x 10 m

Species	1-9.9 cm dbh (2-5 m tall)	10-19	20-29	30-39	40-49	50+ cm dbh (write each stem)
Example: Acer rubrum		III	I		III	*71, 53*
Standing snags > 10 cm dbh Species ID not needed.	X					
Fallen Logs > 10 cm diameter (dia): record dia. and length within plot (only include length where stem is > 10 cm dia.). Species ID not needed.	X					
Example (note:if > 50 cm, record both the dbh and the length)	*X*	*7 m*	*3 m, 9 m*	*11m*	*6 m*	*61 dbh-10 m*

Obs. Area Name:________________________Date: ____________________

ENVIRONMENTAL PROFILE [Same as Level 2 Environmental Profile = Y / N. If no, complete form below.]

Topo Position: colluvial lowslope, alluvial toeslope, low level terrace, narrow channel bed, basin floor/depression

Elevation (topo map):______m/______ft

Slope: Clinometer *degrees or %*

flat	0°	0%
gentle	0-5°	1-9%
moderate	6-14°	10-25%
somewhat steep	15-24°	26-49%
steep	25-44°	50-99%
very steep	45-69°	100-274%
abrupt	70-100°	275-300%
overhanging	>100°	>300%

Aspect (compass) *downslope*: or variable

Landform Comment:

SOIL DESCRIPTION [req'd for plot data]:

Record an average from several readings)

Depth to Impervious Layer (cm) :
(If > 50 cm, put > 50)________(cm)

Record Organic and Mineral Layers separately, do not exceed 100 cm total.

Soil Classification (NRCS) check one:

__ORGANIC (>40cm in upper 80cm)
(Histosol - true organic soil)

__MINERAL (<40cm organic and/or mineral)
(Histic Epipedon, Clayey/Loamy or Sandy)

______Depth of Organic Layer

HYDROLOGIC REGIME:

[WT=water table; GS=growing season]

___Saturated: saturated to surface for extended periods during GS; surface water seldom present, isolated pools may be present.

___Seasonally saturated: saturated to surface but absent by end of most GS

___Permanently flooded: water covers surface throughout year in all years

___Semi-permanently flooded: water covers surface and persists throughout GS in most years (excl. droughts); when absent, WT usually at/very near surface

___Seasonally flooded: water covers surface and is present early in GS, but absent end of season in most years; when absent, WT often near surface

___Temporarily flooded: water covers surface for brief periods in GS, but WT usually well below surface for most of season; upland & wetland plants present

___Intermittently flooded: flooded for variable periods w/out detectable seasonal periodicity; months or years may occur between floods

____Artificially flooded: flooding by pumps, siphons etc., not "altered natural."

___Upland (not wetland, very rarely flooded)

___Unknown

HYDROLOGICAL Conditions [req'd for plot data]:

(Record an average from several readings)

Depth of Surface Water deepest point:
____

Estimated High Water Depth:
____

Evidence of high water:___________________

Depth to Saturated Layer
(If > 50 cm, put > 50)________(cm)

Depth to Water Table:
(If > 50 cm, put > 50)________(cm)

WATER SOURCE:

Pick one primary (write "1"), up to two others ("2"), as needed.

___Direct precipitation

___Surface/overland flow: run-off

___Groundwater

____Discharge: released into wetland

____Saturation: wetland near WT surface

___Water body inundation: surface water from marsh/swamp due to adjacent river/lake

___Overbank flow: flooding river/stream

___Inbank flow: contained within river channel

___Anthropogenic

_____ Direct input: irrigation, pumped

_____ Overland flow - urban

_____ Overland flow - rural

___Other (describe):

Obs. Area Name:________________________Date: ____________________

_Muck, Sapric (von Post H7-10) _ Peat, Hemic (von Post H4-6) _ Peat, Fibric (von Post H1-3) ______Depth of Mineral Layer _ Histic Epipedon(<40cm Org over Min) _ Clayey/Loamy (incl. sandy loam) _ Sandy (sands and loamy sands) Soil Comments: **additional substrate characteristics (e.g. marl layers, stoniness etc):**	SOIL DRAINAGE: ___Rapidly Drained (Somewhat Excessively Drained) no gleying in entire profile; typically, coarse textured or on steep slope ___Well Drained: usually free of mottling in upper 3'; B red, brown, or yellowish ___Moderately Well Drained: commonly mottled in lower B and C or below 2' ___Somewhat Poorly Drained: soil moisture in excess of field capacity remains in horizon for moderately long periods during year; commonly mottled in B and C ___Poorly Drained: soil moisture in excess of field capacity in all horizons for large part of year; soils usually very strongly gleyed ___Very Poorly Drained: free water remains at/within 12" of surface most of year; strongly gleyed	HGM CLASS: Pick one primary (write "1"); if needed, pick a secondary (write "2") ____Riverine (intermittent, headwater complex, floodplain complex, perennial - upper, - lower, Impounded – human, - beaver) ____Slope (topographic, stratigraphic) ____Sliverine (slope/riverine headwater seep) ____Depression (seasonal, perennial, impounded) ____Flats - Mineral Soil Flats ____Flats - Organic Soil Flats ____Estuarine Fringe (lunar intertidal, wind intertidal, subtidal, impounded) ____Lacustrine Fringe (permanently, semi-perm, intermittently flooded)
UNVEGETATED SURFACE [req'd for plot data] (does not need to add to 100%; mentally remove plant layers; ignore below water): _____% Surface Water _____% Litter, duff, wood < 10 cm dbh _____% Wood >10 cm dbh _____% Rock _____% Bare surface _____% Other (describe):		HGM Class Comments:
	Environmental Comments (any other characteristics worth noting, e.g., stoniness, hardpans, drainage, water flow):	