Suggested Science-Based Criteria for Site Selection, Design, and Evaluation of Wisconsin Wetland Mitigation Banks

Elizabeth Haber[a,b]

Editors
Pat Trochlell[a] and Tom Bernthal[a]

Acknowledgements
Caroline Oswald[a,b] , Pam Schense[a], Sally Gallagher[a], Joy Zedler[b], and Jim Doherty[b]

[a] Wisconsin Department of Natural Resources, 101 S. Webster St., Madison, WI 53703
[b] Department of Botany, University of Wisconsin-Madison, 430 Lincoln Dr., Madison, WI 53706

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Introduction

Wetland compensatory mitigation across the country has not been successful in restoring lost wetland ecosystem structure (NRC 2001) or function (Moreno-Mateos *et al*. 2012). Wetland mitigation projects can fail for many reasons; however, recent research has given scientists and restoration practitioners enhanced understanding of wetland restoration principles with the hope of increasing compliance and functional equivalency of mitigation wetlands.

This document details suggested science-based criteria to assist in the process of establishing a wetland mitigation bank. Beginning at the site selection stage, then progressing to the preparation of the Compensation Site Plan, to assigning quantifiable performance standards to assess wetland restoration progress, this document aims to advise and guide restoration practitioners using scientific literature. Specific suggestions in the text are **<u>bolded and underlined</u>**. For more information about required components of the prospectus and the Compensation Site Plan, please refer to the Guidelines for Wetland Compensatory Mitigation in Wisconsin (WDNR *in review*).

Site Selection Requirements

1. Location

Choosing the location for a project is the first step to establishing a mitigation bank. The location of a bank project is arguably the most important decision sponsors can make; it is much easier to establish vegetation and achieve performance standards on a good site than a poor site. Table 1 lists several aspects that describe good and poor potential mitigation bank sites.

Acceptable Wetland Mitigation Bank Sites	Non-Acceptable Wetland Mitigation Bank Sites
The site was historically a wetland, but has since been drained or otherwise altered.	The site is composed of primarily non-hydric soils and requires extensive wetland creation.
The site is isolated from disturbances; i.e. away from high traffic roads and developed areas.	The site is surrounded by disturbed areas.
The site is upstream from invasive species stands to avoid invasive plant seeds and propagules which are spread by flowing water.	The site is surrounded by invasive species which are likely to colonize.
The site is a degraded wetland, but the sources of degradation can be reversed.	The site is an existing, high-functioning wetland.
The site is privately owned, purchased without state or federal money.	The property was purchased with federal or state money.
The site receives no stormwater or can be designed to eliminate or minimize stormwater inputs.	The site is designed to treat storm water or receives storm water as a main source of hydrology.
Restoring hydrology will not affect neighboring properties, or flowage easements have been obtained.	The hydrology of the site cannot be restored without affecting neighboring properties.

Table 1: Attributes of good and poor wetland mitigation sites. This table is for general guidance and does not include all elements of good and poor sites.

The DNR has several tools to help bank sponsors and consultants locate potential mitigation bank sites. These tools are the Potentially Restorable Wetlands layer and the Wisconsin Wetland Inventory layer, both of which can be found in the DNR's Surface Water Data Viewer. Below is a step-by-step guide to using these tools.

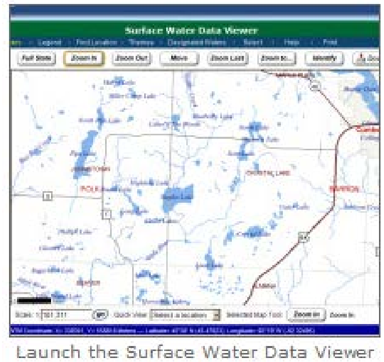


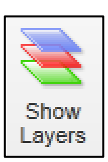
Figure 1: The Surface Water Data Viewer portal appears on the DNR's surface water website. Click on the map to launch the viewer.

1. Open the DNR's Surface Water Data Viewer.
   a. Go to the DNR homepage, [dnr.wi.gov.](dnr.wi.gov)
   b. Type "surface water" in the search box.
   c. You will automatically be taken to the DNR's surface water website. On the right-side banner, you will see a picture of a map with "Launch the Surface Water Data Viewer" as a caption underneath the map (see Figure 1). Click on the map to launch the viewer.
   d. The viewer will open in a new browser window. A disclaimer will pop up. Read the disclaimer and click OK to begin using the viewer.
2. Navigate to an area on the map.
   You may have an idea of the area where you'd like to focus your search. If so, there are several ways that you can navigate to that area:

   i. Use the "Zoom In" button.
      On the top banner of the viewer, you will find several buttons. One is the "Zoom In" button. Click on that button and draw a rectangle around the part of the state that you wish to zoom to.

   ii. Use the "Pan" button in conjunction with the mouse scroll wheel.
      If you have a mouse with a scroll wheel, you can scroll away from you to zoom in, and scroll toward you to zoom out on the map. On the top banner you can find the "Pan" button. Use this button to drag the map to the desired location.

   iii. Search by city, town, or county.
      If you want to search for a city, county, or township, you can do so by first clicking the orange drop-down menu at the top left corner of the map that says "I want to…". Click on the arrow and you will see a drop-down menu. The first choice in the menu is "Find Location". Click that, and you will see a list of parameters that you can search by to the left of the map. If you want to zoom to Iowa County, you can click on the circle next to "County" and click the grey "Find" button. You will then be taken to a drop-down menu. Choose Iowa County and Click "Find". The map will automatically zoom to Iowa County.
3. Show the Potentially Restorable Wetlands layer.

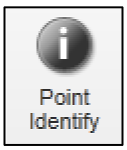


   i. Click on the "Show Layers" button on the top banner of the viewer. You will then see a list of layers on the left side of the map.

ii. About half-way down the list, you will see a category called "Wetlands & Soils". Click on the plus sign next to that category to expand the menu options for wetlands and soils layers.

iii. Check the box next to the Potentially Restorable Wetlands layer. The potentially restorable wetland layer will show areas with potentially restorable wetlands in orange crosshatch. It may also be useful to check the box next to the "Wetland Indicator" layer. This layer shows areas with wetland soils. Wetland indicators are mapped as areas with hot pink stipple.

> **<u>Help</u>**<u>: I checked a box next to the layer I want to see, but nothing happened</u>!
>
> You may notice that the name of the layer you want to see is greyed and nothing happens when you check the box next to it. This means that you are zoomed out too far for the layer to display. Try zooming in until the layer name turns from grey to black. Then check the box next to it.



iv. You can find more information about an area on the map by clicking the "Point Identify" button on the top banner of the viewer. Once the "Point Identify" button is highlighted, click on the area of the map that you'd like more information about. This could be an area highlighted as potentially restorable wetland. Once you click on the area you wish to identify, you'll see a menu to the left of the map detailing information about each layer of the map. If you've checked the Wetland Indicator layer, you'll see what type of wetland soil the area has.

Figure 2 shows an area mapped as potentially restorable wetland in the town of Brigham, Iowa County. To the left of the map are the results of a point identify click on the lower section of the potentially restorable wetland with the letters "Pd" in the center. The two-letter labels in the middle of the wetland polygons are abbreviations for different soil types found in Wisconsin. "Pd" stands for deep peat and muck soils, as shown in

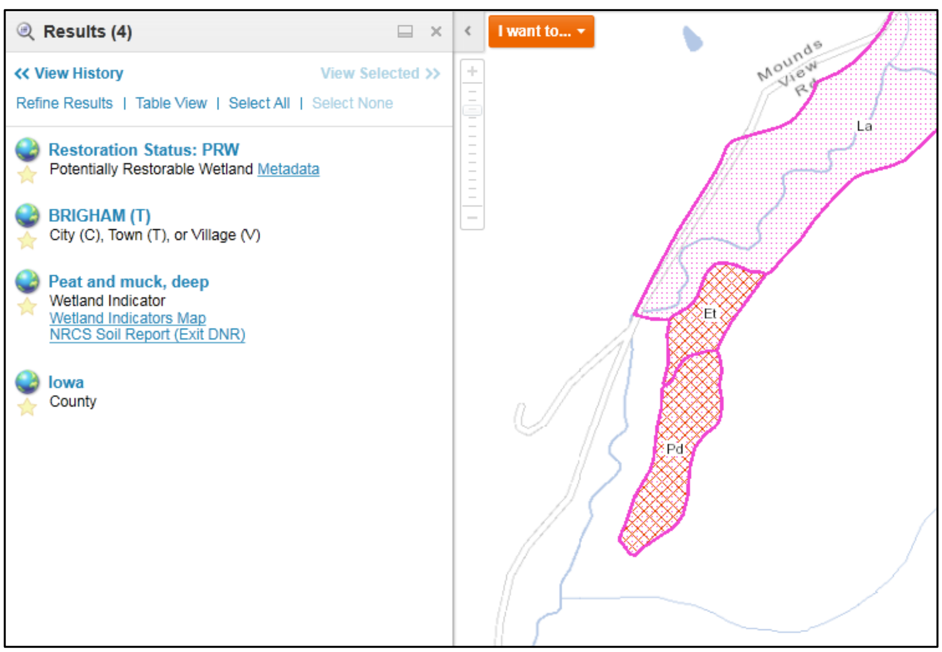


Figure 2: A potentially restorable wetland in Iowa County. The orange crosshatch highlight the potentially restorable wetland while the pink stipple shows areas with wetland soil indicators.

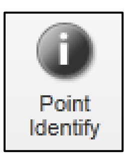
the results menu. “Et” stands for Ettrick silt loam, a hydric soil. The restoration status of “PRW” means that this is a Potentially Restorable Wetland. This particular site is currently being restored by the Empire-Sauk chapter of The Prairie Enthusiasts.

The Potentially Restorable Wetland layer is a valuable resource for locating potential mitigation bank sites, but sponsors should not rely solely on it to choose a site. One drawback to the Potentially Restorable Wetlands layer is that it only maps areas that are not currently wetlands. Wetlands that are degraded can be potential mitigation banks if sufficient enhancement is planned; however, these types of wetlands would not be included in the Potentially Restorable Wetlands layer. It is recommended that a detailed soil analysis and a site visit be conducted to verify the recommendations of the Potentially Restorable Wetlands layer.

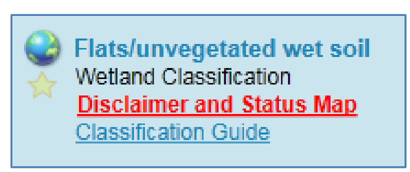
Another layer in the Surface Water Data Viewer that can bank sponsors find potential mitigation bank sites is the Wisconsin Wetland Inventory layer. This layer is particularly useful for finding restorable farmed wetlands. Below is an example of how to navigate the Wisconsin Wetland Inventory layer to find potentially restorable farmed wetland.

1. Turn on the Wisconsin Wetland Inventory layer
    a. If you are not already in a Surface Water Data Viewer session, open one by following the instructions above for opening Surface Water Data Viewer.

    b. Click “Show Layers” in the top banner of the viewer. Click the “plus” sign next to the “Wetlands & Soils” category. You will see a list of available wetlands and soils layers. Check the box next to “Wisconsin Wetland Inventory” to show the Wisconsin Wetland Inventory layer.
    c. Zoom in until the layer is visible. You will see that wetlands are shaded in orange stipple.
    d. Zoom in further and you will see letters and numbers labelling each wetland area. A key to the wetland labelling scheme can be found by doing the following steps.



        i. Click the “Point Identify” button on the top banner of the viewer. Then click an area of wetland that you wish to identify.
        ii. You’ll see a results menu to the left of the map. One of the results will say “Wetland Classification” next to a star. Below that you will see two links – click on the second link that says “Classification Guide”. This guide will show you a key to the wetland inventory labels.



        iii. Potentially restorable farmed wetlands can have several labels. The most common labels are F0Kf and FOKa. Figure 3 shows an example of several potentially restorable farmed wetlands in Kenosha County.

Note: The Wisconsin Wetland Inventory layer is available for most, but not all Wisconsin counties. If, after zooming in, you're still unable to see the layer, then your county may not have the digital layer wetland inventory data available. Use the following steps to see a map of the statewide availability of the Wisconsin Wetland Inventory layer.

1. Go to dnr.wi.gov and type "Wetland Inventory" into the search box. Click on the third search result titled "Wetlands Inventory – Wisconsin DNR". This will take you to the Wetland Mapping webpage.
2. Scroll down past the text until you see several hyperlinked bullet points. Click on the third bullet point that says "Wisconsin Wetland Inventory Digital Status Map".

You will then be taken to a map showing the Wisconsin Wetland Inventory status of the state by county. Peach-colored counties do not yet have a digital wetland layer available. DNR is currently working to finish digitizing these counties.

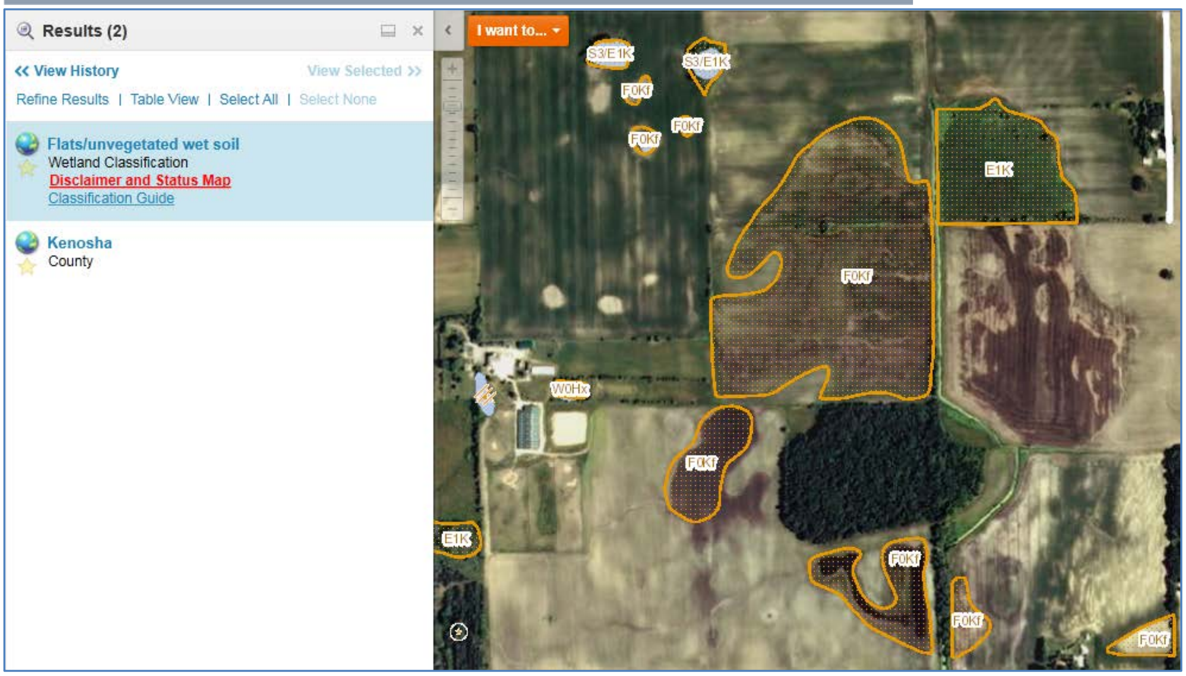


Figure 3: Potentially restorable farmed wetlands in Kenosha County. Farmed wetlands are labeled "F0Kf". Data from the Wisconsin Wetland Inventory layer in the Surface Water Data Viewer.

2. Reference Wetlands

Brinson and Rheinhardt (1996) were among the first to argue for using reference wetlands as the basis of standards against which wetland mitigation sites can be graded. By setting performance standards based on an appropriate reference wetland condition, a mitigation site can be evaluated how well it is replacing lost wetland functions. **Therefore, at least one appropriate reference wetland must be specified at the beginning a mitigation bank project**.

Ideally, reference standards should represent the highest functioning wetlands of a geographic and/or community type group (Brinson & Rheinhardt 1996). **Measures of soil, water, and vegetation attributes should be gathered from reference wetlands to help set performace standards for the**

mitigation bank. Floristic Quality Assessment variables have been studied for vegetation, specifically FQI and mean C, in the Southeastern Wisconsin Till Plains for sedge meadow, shrub-carr, and lowland hardwood forested wetland types (See section 1.b. under Quantifiable Performance Standards in this document, Bernthal *et al.* 2007). **If a study of reference wetlands is not available in an area of the state where a mitigation bank project is proposed, then sponsors may work with DNR scientists to choose one or more appropriate reference wetlands**. At minimum, an appropriate reference wetland should achieve the following criteria.

- The wetland should be in the same or similar geologic and landscape setting as the mitigation bank site.
- The wetland should contain the same habitat type[s] as is [are] desired to restore in the mitigation bank site.
- The wetland should be as highly functioning and undisturbed as possible.
- The wetland should be within the same Bank Service Area (BSA) and ideally within 20 miles of the mitigation bank site.

3. Species of Greatest Conservation Need

It may be desirable to tailor the location and restoration activities at the bank site to match the habitat needs of certain species. Mitigation banks could target habitat needed for Species of Greatest Conservation Need (WDNR 2005). For example, the Yellow Rail (*Coturnicops noveboracensis*) is a state threatened species in Wisconsin. It prefers Northern Sedge Meadow and Open Bog habitats in Wisconsin. Therefore, mitigation bank sponsors who wish to provide habitat for the Yellow Rail can plan to restore Northern Sedge Meadow habitat (open bog habitat is extremely difficult to restore). To view a list of the Species of Greatest Conservation Need (SGCN) in Wisconsin, go to dnr.wi.gov and type "Species of Greatest Conservation Need" into the search box. Click on the first link to find a list of species separated by phylum. Clicking on a species name brings you to a website with the species profile, which includes the habitats in which the species can be found.

Re-establishing habitat for SGCN can be included as a goal or objective in a Mitigation Bank Instrument. In some circumstances, re-establishing habitat or the presence of the species themselves may be acceptable performance standards.

4. Soil

Although measuring soil characteristics throughout the monitoring period to assess soil recovery trajectories may not be feasible, using baseline soil integrity measures can help with site evaluation and restoration planning. Soils at wetland creation sites tend to have more sand and less clay than natural reference sites (Bishel-Machung *et al.* 1996; Stolt *et al.* 2000). Higher soil sand content can slow organic matter deposition if the soil is well-drained (but not if it ponds water), which is the basis for many wetland soil functions. Soil organic matter tends to be significantly less in wetland creation sites than in reference sites (Bishel-Machung *et al.* 1996; Stolt *et al.* 2000; Bruland & Richardson 2006). Choosing a site with higher soil organic matter may increase the probability of compliance for a wetland mitigation bank. One study, based on data from a restoration site near Chicago, IL, suggested that a site must have at least 3% soil organic matter in order for adequate soil microbial activity to occur (Vepraskas *et al.*

1995), while Mitsch and Gosselink (2000) indicate that hydrologic conditions are present at 5% soil organic matter. **Soil organic matter levels in creation sites must be above 3% in order to be considered.** Usually it is apparent during a site visit whether or not a soil meets this criterion; however, a lab test may be recommended if a visual inspection of the soil estimates a low amount of soil organic matter.

Compensation Site Plan Requirements

It is imperative that much attention be paid to site design and construction for wetland restoration projects. Gutrich *et al.* (2009) found that construction sites with more initial effort tended to have greater plant species richness, number of native species, and number of hydrophytes, as compared to sites with low initial effort. Many mitigation banks have credit releases associated with construction completion. **An as-built report shall be submitted and approved by the IRT before construction credits are released.** This report must include the information outlined in section H and figure 5.2 of the Guidelines for Wetland Compensatory Mitigation in Wisconsin (WDNR 2013).

1. Vegetation

a. Invasive Species

Invasive species pose serious risks to wetland restoration. Invasions by non-native plants like hybrid cattail (*Typha* x *glauca*) and reed canarygrass (*Phalaris arundinacea*) can dramatically reduce the plant species diversity found at a site (Doherty & Zedler *in press*; Kercher & Zedler, 2004). Therefore, it is imperative to minimize the presence of invasive species on a site and their potential to colonize a site. See section 1.d. in Quantifiable Performance Standards for maximum allowable percent areal cover of invasive species.

i. Best Management Practices

Excellent guidance exists for reducing the impact of invasive species in wetlands (WDNR *in press*). These guidelines should be followed whenever applicable throughout construction and monitoring activities. To find a copy of the document, go to dnr.wi.gov and search for the document titled "Best Management Practices for Preventing the Spread of Invasive Species in Wetlands". Below are some highlights from this document that are especially relevant to wetland restoration projects:

- Inspect and clean outerwear, footwear, and gear for dirt, seeds, plant parts, and invertebrates before and after wetland activities.
- Inspect and clean machinery and tools before and after wetland activities.
- Scout areas on the site that have invasive species and avoid those areas if possible.
- Avoid unnecessary soil disturbance. Stabilization measures must occur after soil disturbance.
- Do not bring in external fill material unless it can be certified as propagule-free.
- Avoid using fertilizers or nutrient additives.
- Avoid planting invasive species.

- Long-term invasive species monitoring and removal must be written into the Compensation Site Plan.

ii. Reed Canarygrass Specific Recommendations

In Wisconsin, reed canarygrass (*Phalaris arundinacea*) dominates almost 500,000 acres of wetlands (Hatch & Bernthal 2008). Along with being widespread, reed canarygrass is also extremely successful at both establishing at new locations and persisting to form monocultures. Therefore, it is imperative that control measures be taken if reed canarygrass is present at a site. The Wisconsin Reed Canary Grass Management Working Group has published a guide with detailed treatment and management strategies of reed canarygrass at restoration sites (2009). These strategies include prescribed burning, herbicide application, and mowing, among other suggestions. **We recommend that mitigation bank sponsors use this document as a reference and/or starting point to planning and implementing reed canarygrass control at a mitigation bank site**. To find the report, go to dnr.wi.gov and search for "Reed Canary Grass Management Working Group".

Although mature trees and shrubs can effectively shade out reed canarygrass, a thick carpet of this invasive grass can impede woody plant establishment. To find the most effective method of establishing woody plants in wetlands dominated by *Phalaris arundinacea*, researchers tested four pre-planting treatments and measured woody plant survival (Hovick & Reinartz 2007). They found that a fall herbicide application followed by spring plowing produced the highest woody plant survival of the most species, but the other herbicide treatments (herbicide alone and herbicide followed by prescribed burn) all produced significantly higher woody plant survival than the control. To reduce immediate light competition between planted saplings and potential reed canarygrass re-sprouts, fiber mats (or mats made of other biodegradable material) can be placed around each planted stem. **These practices could help the establishment of woody plants in sites dominated by *Phalaris arundinacea*.**

b. Site Preparation

Several practices can be implemented during site construction to improve the quality of the soil and the likelihood of survival for woody plants.

1. Soil Compaction and Soil Bulk Density

Constructed wetlands tend to have higher soil bulk density than reference wetlands (Bishel-Machung *et al.* 1996). Compacted soils with high bulk density can impair for plant root growth and soil microbial processes. **Although heavy machinery may be necessary for wetland restoration, wetland construction plans should include measures to minimize soil compaction (e.g. swamp mats, restricted routes, and rehabilitation of compacted areas**. For example, heavy machinery could follow prescribed paths when travelling to and from certain parts of a construction site. After construction is finished, those designated paths can be rehabilitated.

2. Soil Organic Matter/Soil Organic Carbon

Soil organic matter is correlated with important wetland functions such as denitrification (Ahn & Peralta 2012); however, it does not significantly increase during a typical monitoring period of eight years (Bishel-Machung *et al.* 1996). Therefore, it is imperative that wetland restoration projects take care to preserve the integrity of the soil on the project site. Created wetlands tend to have significantly lower soil organic carbon than comparable reference wetlands (Gwin & Kentula, 1996; Bishel-Machung *et al.* 1996). Tilling exposes the soil to oxygen, thus accelerating microbial decomposition or the soil organic matter. **Adopting a no-till planting plan could reduce loss of soil organic carbon, especially in created wetlands.**

3. Soil Amendments

Many wetland restoration projects use soil additives to stimulate soil function. Common additives include topsoil, salvaged marsh soil, compost, straw, and biochar. Ballantine *et al.* (2012) tested three of these amendments in wetland restoration sites in New York: topsoil, straw, and biochar, as well as an even mixture of biochar and straw. They concluded that biochar and topsoil were the most effective soil additives in their study because their addition significantly increased soil carbon. Topsoil-amended soils also had significantly higher nitrogen, although higher soil nutrients in restoration sites tend to be conducive to invasive species (Woo & Zedler 2002). A valid concern about soil additives is their potential to introduce propagules from non-native species into the restoration site. **Soil starting conditions and benefits and drawbacks of soil additives must be considered before their implementation in wetland restoration plans**.

4. Microtopography

Microtopography is an important structural component in natural wetlands that is often missing created and restored wetlands. Natural processes, such sediment accumulation, erosion, tree fall, root growth, litterfall, animal burrowing, and animal tracks can create microtopography but usually occur over long time periods. Stolt *et al.* (2000) mapped microtopography in constructed vs reference wetlands and found that constructed wetlands had 40-60% less elevational change across the site and less microtopography than reference sites. They concluded that lack of microtopography may limit plant and animal diversity.

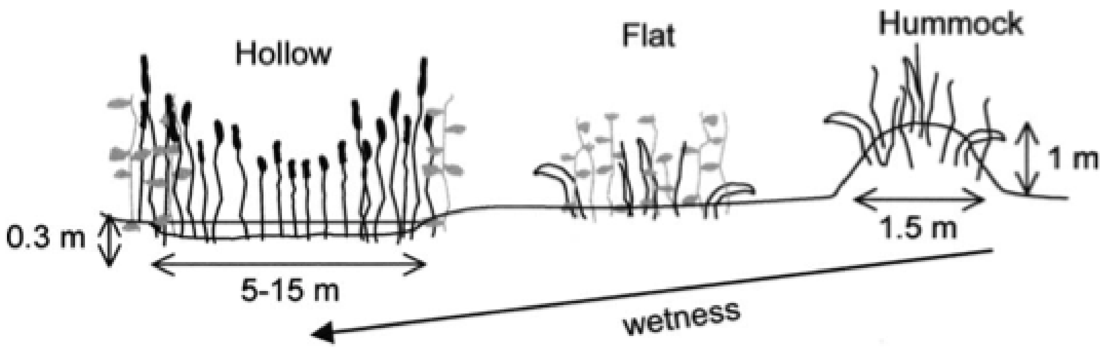


Figure 4: Suggested microtopography template for created wetlands from Bruland & Richardson (2005).

<u>Although natural changes in microtopography may not be measureable within a typical monitoring period, establishment of microtopogrphay could be a part of site design</u>. **<u>Elevational changes and microtopography should be designed according to conditions in reference sites.</u>** Bruland & Richardson (2005) studied microtopography in reference wetlands in North Carolina and designed hummocks to mimic mounds created by treefall (see Figure 4). Barry *et al.* (1996) provide a detailed description of the process they used to create microtopography in a New Hampshire site (see Figure 5 for a diagram of mound and hollow microtopography). Microtopography can increase planted tree survival by allowing for drier environments at the tops of mounds. *Thuja occidentalis* seedling survival was significantly better on hummocks than in hollows in two Northern Michigan mitigation sites (Kangas 2013).

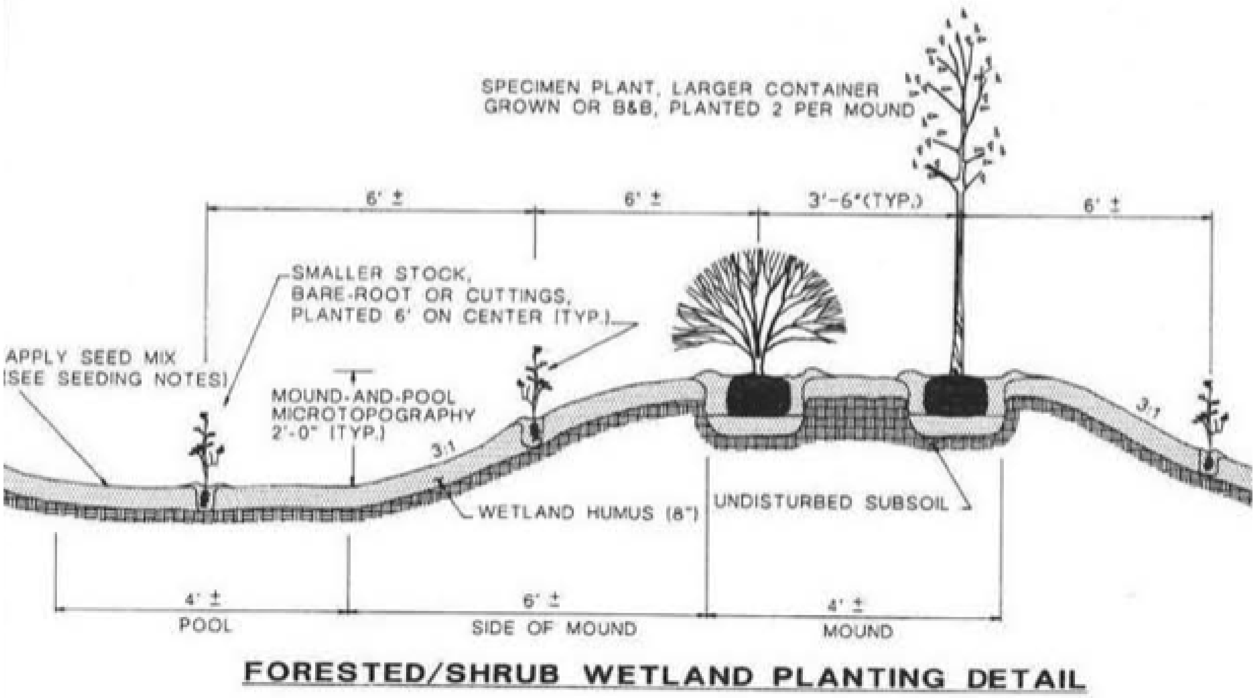


Figure 5: Cross-sectional diagram of mound and hollow design for a New Hampshire wetland (Barry *et al.* 1996). Mounds were designed to have an average width of 4.9 meters and average height of 0.6 meters.

5. *Tree Planting and Microtopography*

Microtopography is especially important in forested sites for both planted tree survival and adapting to a changing environment. As a forested wetland matures and hydrologic conditions change, microtopographic variation will help ensure that at least part of the site will experience appropriate hydrology (Bruland & Richardson 2005). **<u>Therefore, it is recommended that trees in forested mitigation sites be planted on mounds.</u>**

6. Coarse Woody Debris

Coarse woody debris provides for critical functions of wetlands by supplying habitat for insects, mammals, and amphibians, fodder for decomposition, and environmental heterogeneity. Woody debris is a natural characteristic of mature wooded wetland habitats, and is often absent in wetland restorations. Coarse woody debris has been shown to increase species richness and biomass of insects, which are an important part of wetland food chain interactions (Alsfeld *et al.* 2009).

Several measurements have been used to quantify coarse woody debris. Total volume of downed logs > 10 cm diameter at the middle point and stumps was measured in Delaware wetlands (Alsfeld *et al.* 2009). Washington wetland performance standards include volumetric measures as well, but also add a size class requirement for 30% of logs, recommend a conifer:hardwood woody debris ratio, and suggest a minimum number of snags per acre (Azous *et al.* 1998). Only one Wisconsin mitigation bank has incorporated coarse woody debris into the construction plan and no mitigation banks have performance standards for coarse woody debris. **Coarse woody debris should be incorporated into Wisconsin mitigation banks where appropriate. Quantifying coarse woody debris should be done using one or more of the following measurements: total volume, size class, and snag density.**

Importing coarse woody debris into mitigation sites must be done carefully. Debris should ideally come from on-site locations to limit the potential for introduced pests. Wisconsin has enacted strict firewood movement laws to combat the spread of tree pests such as the Emerald Ash Borer. **Therefore, woody debris should come from a maximum of 25 miles from the mitigation site and from outside of a quarantine area.** The following website shows a map of the quarantined counties in Wisconsin: http://dnr.wi.gov/topic/invasives/firewood.html.

c. Planting Plan

Appropriate planting is key to achieving restoration goals. Planted species must not only be native to Wisconsin, but must be appropriate for the region and wetland type being restored or created. A GIS-based analysis can be done to help choose a suitable wetland community for a mitigation bank site. This paired with a preliminary soil and hydrology analysis can give a more accurate description of the types of communities that were previously found on the site and/or communities that the site can support.

1. Seed Bank Viability Studies

It is recommended that sites be seeded with appropriate native seeds in order to establish vegetation. **If a sponsor does not think the site needs to be seeded, the sponsor must conduct a seed bank viability experiment to prove adequate seed bank integrity.** Below is a suggested method for studying seed bank viability adapted from two wetland seed bank studies from the upper Midwest, Frieswyk and Zedler (2006) and Weinhold and van der Valk (1989).

1. Collect soil samples from the site.
    a. Samples should be collected mid-summer (July) to quantify the persistent seed bank only. Collecting at this time avoids oversampling of transient annual species that germinate during the spring high water period and occurs before most of the current year's seeds have matured (Baskin & Baskin 1998).
    b. At least one transect should be established that either spans the longest axis of the site, or perpendicular habitat borders. Random sampling quadrats should be placed along the transects and up to five soil samples should be taken at each quadrat.
    c. Soil samples should be taken to a depth of 5 cm with either a soil corer of at least 5 cm in diameter or with a 200 cm^2 template. Soils with allochthonous soil deposition (by alluvium, topsoil addition, etc…) should be sampled underneath the deposited layer.
    d. All soil samples from each quadrat should be merged into one composite sample.
2. Process samples.
    a. Each composite sample should be sorted to remove rhizomes and litter
    b. The sorted composite samples should then be homogenized.
3. Germinate the seed bank in a greenhouse and identify seedlings.
    a. Arrange soil in trays and arrange trays randomly in a greenhouse.
    b. Allow for a control by interspersing trays with sterile soil with the experimental trays. Any species found germinating from the control trays should be removed from the results.
    c. Watering should be done daily or enough to ensure the soil remains wet for the entire duration of the experiment. Alternatively, samples may be subjected to differing watering regimes to assess the seed germination rates based on a range of water conditions.
    d. Identify and count seedlings as they emerge. If identification is difficult, allow seedlings to mature for up to 40 weeks, or until positive identification is possible. Count the seedlings that die and remove them from the trays.

The duration of time that a site has been drained has an effect on the number of species present in the seed bank. Weinhold and van der Valk (1989) found that seed bank species richness decreased with time in prairie pothole wetlands; sites that were drained and farmed for 70 years had an average of only 160 seeds/m^2 as compared to reference sites with 3600 seeds/m^2. Potential mitigation sites in Wisconsin are generally on prior agriculture fields, many of which have been drained and farmed for years. Although recently drained sites (< 5 years) contained more seeds/m^2 than reference wetlands, **sites that have been drained for more than ten years contained less than half of the seeds/m^2 than reference wetlands (Weinhold & van der Valk 1989) and may not have enough of a seed bank to warrant a seed bank study**.

2. Gradual Planting

Drought, torrential rain, and other environmental extremes can occur during the first year of seedling establishment, which can kill or seriously harm much of a planted crop. Also, some later successional species require pioneer species establishment before they can germinate. For these two reasons, **a gradual planting plan is recommended to increase the establishment success of planted seeds**.

A recent study of Great Lakes sedge meadows identifies common plant communities with *Carex stricta* (tussock sedge) as the matrix species. Johnston and Zedler (2013) called these assemblages "preferential associates" to tussock sedge, and suggested planting them along with *Carex stricta* in sedge meadow restorations (see Table 2). **In sedge meadow restorations, we suggest planting a matrix of *Carex stricta*, along with these twelve species, at the beginning of a sedge meadow restoration. As the tussocks develop, more species can be added to the site**. This planting method embraces adaptive management of mitigation banks and will help avoid instances of low seedling establishment that lead to invasions of non-native species.

Species Name	Guild
Campanula aparinoides	Vine-like, stems climb or drape over tussocks
Galium trifidum	
Lathyrus palustris	
Persicaria sagittata	
Acorus americanus	Forbs, can grow in the shaded sub-canopy of tussocks
Cicuta bulbifera	
Impatiens capensis	
Lysimachia thyrsiflora	
Scutellaria galericulata	
Calamagrostis canadensis	Graminoids
Carex lacustris	
Carex stricta	

Table 2: Preferential associates of tussock sedge (*Carex stricta*) from Johnston and Zedler (2013). Species are grouped alphabetically by guild.

For plant communities other than sedge meadows, it may be helpful to base planting plans on a similar method as described above. For example, if a target community is fresh/wet meadow, practitioners may wish to choose Canada blue-joint grass (*Calamagrostis canadensis*) as the matrix species and plant several other fresh/wet meadow species along with it during the first planting occasion. More fresh/wet meadow species can be added in subsequent plantings to increase diversity.

3. Species Selection

Plant species chosen for a mitigation bank shall not only be native to Wisconsin, but native to the part of the state where they are to be planted, as well as being

appropriate for the site's soils and hydrologic regime. The Wisconsin State Herbarium website displays details for all plant species found in Wisconsin including their native/non-native status and the counties in which they are found. To search for a species' origin status or county distribution, go to www.botany.wisc.edu/herbarium and click on "Wisflora". Below is an example of how to search for a species in Wisflora.

1. Go to www.botany.wisc.edu/herbarium and click on the "Wisflora" link.
2. Click on the "Name" link under the "Search" heading in the grey box to search for a species by name.
3. Type in the name of the species that you want to research and click "Search" (Figure 6). You may search using the Latin name or a common name. This example will use *Penstemon digitalis* (false foxglove), a species that is not native to Wisconsin but is often found in prairie seed mixes. Other similar species that are not native to Wisconsin but are commonly found in wetland planting mixes include *Acorus calamus* (sweet-flag) and *Echinacea purpurea* (Eastern purple coneflower).
4. Click on the hyperlinked Latin name of the species you wish to see from the Results list.
5. You will be directed to a species profile page (Figure 7). On that page, you will see a photo of the species (if available), a Wisconsin map highlighting the counties in which the species is found, the species origin status, and other important information such as the species' coefficient of conservatism and wetland indicator status.

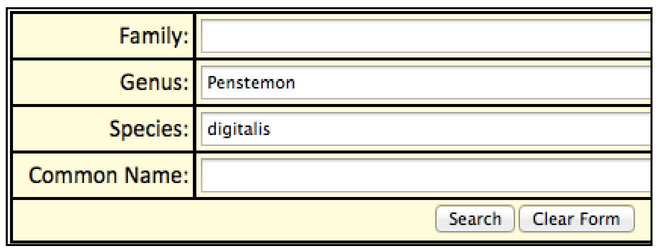


Figure 6: Example Wisflora searchbox using *Penstemon digitalis* (false foxglove), a species not native to Wisconsin but commonly found in prairie seed mixes.

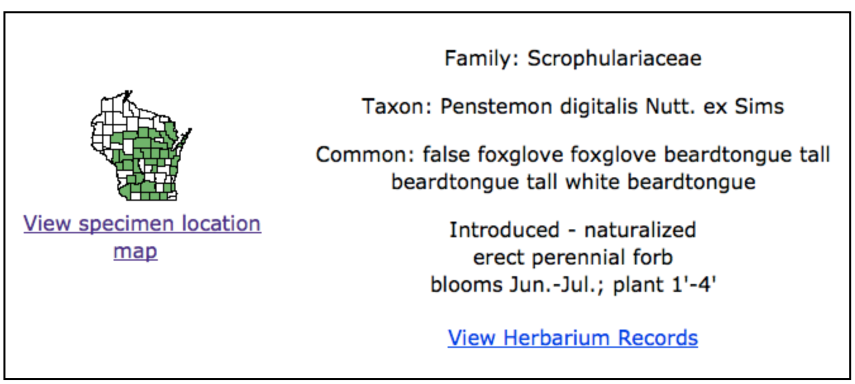


Figure 7: Partial species profile for *Pentemon digitalis* (false foxglove) in Wisflora. *Penstemon digitalis* is a non-native species, as indicated by the "Introduced – naturalized" status in the species description. To the left of the description is a Wisconsin map indicating the counties in which this species has naturalized.

3. Cover Crop Selection

At the beginning of restoration projects, the site is usually dominated by bare ground. A common restoration practice is to plant a cover crop to discourage invasive and non-native species from dominating the site before the seeded plants can establish. Usually, the chosen cover crop is either oats (*Avena sativa*) or winter rye (*Secale cereale*); although these species do not tend to persist at the site, they are not native to Wisconsin. **As an alternative, annual wetland species could be selected as a cover crop, such as *Bidens cernua* or *Bidens frondosa*** (Doherty & Zedler *in press*). Moreover, native smartweeds (native *Polygonum* spp.) or short-lived native grasses (*Poa palustris*) can also function as cover crops.

4. Tree and Shrub Selection

Appropriate trees and shrubs should be planted according to the conditions present and envisioned at the site and communities found in appropriate reference wetlands. See Tables 6 and 7 for lists of potential tree and shrub species to plant in mitigation banks.

5. Vegetation Sampling Methods

a. Plot Establishment

In order to adequately assess the establishment of desired vegetation, permanent vegetation sampling plots or transects are usually constructed following the first planting. The appropriate number of sampling plots per wetland mitigation bank must be high enough to glean an accurate understanding of vegetation dynamics on the site, but not too high so that the understanding gained from extra plots is not offset by the effort spent to sample them. **The minimum allowable number of sampling plots per mitigation bank is eight** (per the methods of Johnston *et al.* 2007). Most mitigation banks will require more than eight plots, based on their size and complexity. **A representative number of plots for each vegetation community type must also be established.** The bank sponsor, consultant, and DNR scientist will agree upon an appropriate number of sampling plots per site after a site visit has been conducted and a planting plan is proposed.

b. Plotless Timed Meander

While traditional sampling plots can give valuable information about the density and cover of vegetation, they often fall short of providing a representative list of species found at a site (Huebner 2007; but see Adaptive Cluster Sampling, Thompson 1991). The timed meander method is a way to gather a more complete species list at a site, as it is capable of locating rare species at a site that may be missed when using plots (Goff *et al*. 1982). **If species richness-based performance standards are chosen for a bank site (such as FQI, number of native plant species, etc…), a timed meander survey with percent cover estimates for each species may be required to produce an adequate species list.** Methods for the timed meander process are described in detail in Goff *et al*. (1982) and briefly excerpted below.

1. Delineate different vegetation communities.

Practitioners should perform a timed meander search in each of the separate community types at the bank site. For example, a bank site containing shrub-carr, sedge meadow, and wet prairie community types should have at least three separate timed meander surveys, one in each contiguous community type.

2. Plan the meander tracks.
   Meander tracks should have both planned and adaptive components. Tracks should be designed to cover gradients in elevation, hydrologic conditions, and vegetation within each community. Tracks should also traverse throughout the entire site. In the field, practitioners may observe areas with high species diversity. Tracks can be modified to include such areas.
3. Conduct timed meander survey and record species.
   a. Begin recording species at the point of entry for the site. Known species can be written down, while unknown species can be keyed in the field or collected for later keying.
   b. Tracks should be broken down into 10 minute segments. Pause the stopwatch while keying, collection, or any other type of interruption take place. If no new species are added within a 10 minute segment, and an adequate portion of the community has been surveyed, then the track can be considered finished.
   c. The final product should be a list of species found in each track with percent cover estimates for each species.

2. Hydrology

The interval at which hydrology data are collected depends on what kind of data is required for computing performance standards. Water level data have been collected daily at midnight (Shaffer *et al.* 2000), daily during the non-growing season and hourly during the growing season (Hunt *et al.* 1999), at 6-hour (Cole & Brooks 2000; Johnson *et al.* 2012) and 12-hour (Cole *et al.* 2006) intervals, at 30-minute intervals (Kurtz *et al.* 2007; Skalbeck *et al.* 2009), and at 15-minute intervals (Booth & Loheide 2012). A preliminary analysis comparing daily measurements to measurements taken every three hours found no significant differences between the two time intervals; therefore, daily measurements were used in one study to consolidate data storage space (Shaffer *et al.* 2000).

Shaffer *et al.* (2000) found that monthly water level measurements are sufficient to perceive general trends in water level for a site; however, more detailed information requires a shorter measurement interval (see Table 3). Measurements requiring enhanced accuracy or capturing infrequent events necessitate a different measurement apparatus or a higher resolution sampling interval. For example, the maximum water level is a transient event and should be measured either using a crest gauge or by daily water level measurements. Approved quantitative hydrology standards for Wisconsin wetland mitigation banks rely on threshold statistics such as minimum soil saturation and maximum inundation periods (see Table 5). For threshold measurements, it not only matters how often water levels are measured, but also the days on which measurements are taken. Therefore, Shaffer *et al.* (2000) suggest taking **daily measurements if threshold exceedance performance standards are used**. Hunt *et al.* (1999) suggest **hourly measurements to accurately characterize wetland hydrology for at least the first growing season, which can then be used to verify whether a less frequent sampling interval is adequate.**

	Measurement	1-day	2-day	4-day	7-day	14-day	28-day
Annual and short-term changes in water level	Annual pattern	Reference	Annual pattern is well-defined in all measurement intervals.				
	Short-term change	Reference	Hydrograph conveys high resolution information about short-term changes in water level.	Choppy hydrographs suggest that there is variability in water levels, but there is no information about frequency, magnitude, or duration of short-term changes in water levels.		Hydrographs convey no information about short-term changes in water level.	
Water level stage measurements	Stage distribution (minimum, median, 25^{th} and 75^{th} percentile)	Reference	Mean stage values were consistently close to reference values.				
			Variability is small – all stage estimates were within 0.035 m of reference values			All estimates were within 11% of reference values	
	Stage distribution (maximum)	Reference	Average error consistently increased with increasing sampling interval				
			Average error = 0.11 m				Average error = 0.25 m
	Stage range estimate error (interquartile range)	Reference	All errors within 2% of reference values.				
	Stage range estimate error (seasonal range)	Reference	Errors within 2% of reference values				Errors within 8% of reference values
	Stage range estimate (total range)	Reference			Average range 87% of reference		Average range 71% of reference
Monthly mean	Average monthly mean water level error	Reference	0.5%	1.5%	2.5%	5.6%	9.3%
Threshold statistics	Water within root zone (< 30 cm from surface)	Reference	Average range = 0.5 days	Average range = 2.5 days	Average range = 8 days	Average range = 17 days	Unable to measure
	Standing water	Reference	Average range = 2.3 days	Average range = 4 days	Average range = 5.3 days	Average range = 12 days	Unable to measure

Table 3: Description of hydrology graphs, water level stage, monthly mean water level, and threshold statistics for different sampling intervals from Shaffer *et al.* 2000. Stage is defined as the percentile of water level distribution and is measured in five categories: minimum, 25^{th} percentile, median (50^{th} percentile), 75^{th} percentile, and maximum. Cells highlighted in yellow and orange are those where there is significant deviation from reference values; orange cells have high deviance from reference values.

3. Buffer

A buffer needs to function as a protecting strip around the wetland, insulating it from nutrient runoff, invasive species, and other edge effects. Therefore, a buffer must be located at an appropriate place on the site in order for it to function correctly. Below are some recommendations for designing and maintaining a buffer.

a. Buffer Size

The desired function of a buffer dictates its appropriate width. For example, buffer widths for intended removal of >85% of sediment load from adjacent land were between 80 and 200 feet, while those effective at removing excess nitrogen and phosphorus ranged from 15 to 300 feet wide (Castelle *et al.* 1994). Since wetland mitigation bank buffers must achieve various functions, Castelle *et al.* (1994) recommend a minimum buffer width of 98 feet to protect chemical, physical, and biological components of wetlands. **A fixed buffer width of 100 feet is recommended for Wisconsin mitigation banks**. According to the mitigation guidelines, buffers can achieve a 0.25:1 compensation ratio and cannot account for more than 25% of the proposed bank credits (WDNR 2013).

b. Buffer Composition

A buffer must be composed of the appropriate vegetation type for its location. For example, it does not make sense to construct a prairie buffer in a part of Wisconsin that lacks prairies and if the mitigation bank is surrounded by forest. **To ensure appropriate buffer habitat, practitioners may access land cover GIS layers to assess the land cover type within a 20-mile radius of the mitigation site. If historical or remnant prairie does not occur within the radius then it is not a suitable buffer candidate.** Natural community habitat types found in Wisconsin are detailed on the DNR website. Go to dnr.wi.gov and search for "Natural Communities of Wisconsin".

c. Buffer Maintenance

Adequate buffer maintenance should be included in the monitoring plan. Budgeting for buffer maintenance could include setting funds aside for one or more of the following activities: prescribed burns to maintain prairie habitat; herbicide applications; and/or possible re-seeding or planting.

4. Wildlife

Wisconsin mitigation banks provide excellent opportunities to restore wetland wildlife habitat quality since half of threatened or endangered species in the U.S. depend on wetlands in some way (Trochlell & Bernthal 1998).

At times the habitat needs of different animal species may conflict with each other or the guidelines for Wisconsin mitigation banks. For example, amphibians require standing water for most of the growing season, whereas large expanses of open water are discouraged on mitigation sites (WDNR 2013).

Realistically, small wetland restoration sites may not be able to satisfy the needs of every animal species. **If wildlife performance standards are called for, practitioners may wish to tailor those standards to certain animal groups.**

A study of Southern Wisconsin wetland mitigation sites focused on avian and amphibian population monitoring (Wilcox 2009). Monitoring methods for both guilds were tested for accuracy and ease of use. Birds were monitored using callback recordings, while amphibians were monitored using both callback recordings and traps. Detailed information about monitoring methods and efficacy can be found in the report (Wilcox 2009). In concordance with Wilcox's (2009) report, **we recommend that a highly trained biologist be employed to survey the site if species richness performance standards are required, whereas a less-experienced naturalist may be employed if only certain species are targeted**.

5. Monitoring Reports

Annual or semi-annual monitoring reports shall be submitted on the status of the wetland mitigation bank. **Reports shall be submitted by December 31 of each growing season that requires a monitoring report.** Failure to submit timely monitoring reports will result in delay of approval of any remaining credits, as well as a delay in formal release from future monitoring requirements. Delays will stand until tardy reports are submitted and approved by the IRT.

Quantifiable Performance Standards

1. Vegetation

Vegetation is usually the easiest structural component of wetland restoration sites to measure. Permanent sampling plots can be established to represent the site and monitor changes in vegetation over time. Thus, vegetation standards are often measured in wetland mitigation sites to assess restoration progress.

a. Cover

A simple vegetation parameter to measure is vegetation cover. Thus, performance standards tend to be based on vegetation cover, without knowing if they are measuring wetland function (Cole 2002). Cole (2002) compared vegetative cover to six wetland functions (short-term surface water storage, long-term surface water storage, maintenance of a high water table, transformation and cycling of nutrients, retention and removal of dissolved elements, and accumulation of inorganic sediments). He found that vegetative cover correlated with only one function, retention and removal of dissolved elements. The plants provide a scaffold, both above and below ground, on which microbial reactions take place to remove dissolved elements. Since Wisconsin mitigation banks cannot be constructed to function as storm water treatment sites, the measurement of vegetative cover for the function of water quality improvement may be inappropriate.

Nevertheless, measuring vegetative cover may help assess progress of a mitigation site. Native plant cover performance standards indicate limits to invasive species cover. Vegetation cover standards also indicate limits on bare ground or open water. In a review of performance standards compliance in wetland mitigation banks, Matthew & Endress (2008) found a similarly high compliance rate for vegetation cover of 77%. It is recommended that absolute cover performance standards for vegetation be included in performance criteria to set limits on invasive species, bare ground, and open water at mitigation banks. **Maximum cover of open water and bare soil should not exceed 10% and 5% for an entire site (wetland area plus buffer), respectively**.

Cover for open water and bare soil should be measured and presented as the absolute areal cover of those areas throughout the entire site. The following sentences describe an example of how open water and bare soil could be measured:

> Practitioners observe an area of persistent open water at the bank site. They then use a portable GPS device to record a track as they walk around the edges of the open water. This process is repeated for all other areas of persistent open water at the bank site. The practitioners then upload their recorded tracks into GIS software to create a map of open water at the bank site. The total area of open water can also be calculated in the GIS software. The total area of open water can then be divided by the total area of the bank site to present the total absolute areal cover of open water. This process can be repeated for areas of bare soil.

b. Floristic Quality Assessment

A floristic quality assessment (FQA) is a standardized and repeatable way to measure the natural integrity of a plant community. There are two components to the FQA: the mean coefficient of conservatism (mean C) and the floristic quality index (FQI). The mean C is a value, from zero to ten, given to a plant species based on its likelihood of indicating pre-European settlement conditions in Wisconsin. A species with a low mean C indicates weediness while a high mean C suggests a species that can seldom persist outside of relatively pristine habitats. The FQI for a community takes into account species richness and mean C to produce a numerical metric of habitat quality. The following equation is used to calculate FQI: $FQI = \overline{C} \times \sqrt{N}$, where $\overline{C}$ is mean C and N is species richness. For more information about the Wisconsin floristic quality assessment, see Bernthal (2003).

FQI and mean coefficient of conservatism have been widely used to characterize the vegetation of wetland sites. In a study of restoration trajectories for vegetation indices in restored wetlands, FQI was found to rebound to and even surpass reference levels relatively quickly (Matthews *et al.* 2009). The fast increase of FQI may be misleading; other vegetation indicators such as mean C did not reach reference levels even after nine years, meaning that fewer conservative species were present and indicating that the sites' vegetation had not completely recovered. The decoupling of FQI from vegetation recovery could be explained by the FQI's dependence on species richness. Species richness can to be high in restoration sites because of their disturbed nature (Matthews *et al.* 2009). Mean C may be a more reliable indicator of vegetation recovery because it does not rely on species richness.

A comprehensive survey of wetlands in Southeast Wisconsin produced a set of thresholds for low, medium, high, and excellent quality wetlands (Bernthal *et al.* 2007). **Based on these thresholds, Wisconsin mitigation banks in Southern Wisconsin should strive for at least medium quality in both FQI and mean C by the middle of the monitoring period, and reach high quality by the final monitoring year** (see Table 4 and Figure 8). These figures may be adjusted based on plant community, location, or new data based on more recent research. Threshold values for locations in the rest of Wisconsin are in the process of being evaluated.

Wetland Type	Interim Performance Standards		Final Performance Standards	
	Mean C	FQI	Mean C	FQI
All Wetland Types	≥ 2.4	≥ 12.5	≥ 4.2	≥ 22.8
Sedge Meadow	≥ 2.4	≥ 11.6	≥ 4.5	≥ 26.1
Shrub-Carr	≥ 2.4	≥ 11.6	≥ 4.5	≥ 26.1
Lowland Hardwood	NA	NA	≥ 3.3	≥ 16.5

Table 4: Interim and final mean C and FQI performance standard threshold values for three wetland types in Southeast Wisconsin (sedge meadow, shrub-carr, and lowland hardwood) as well as general wetland thresholds. Table values are adapted from Bernthal *et al.* 2007.

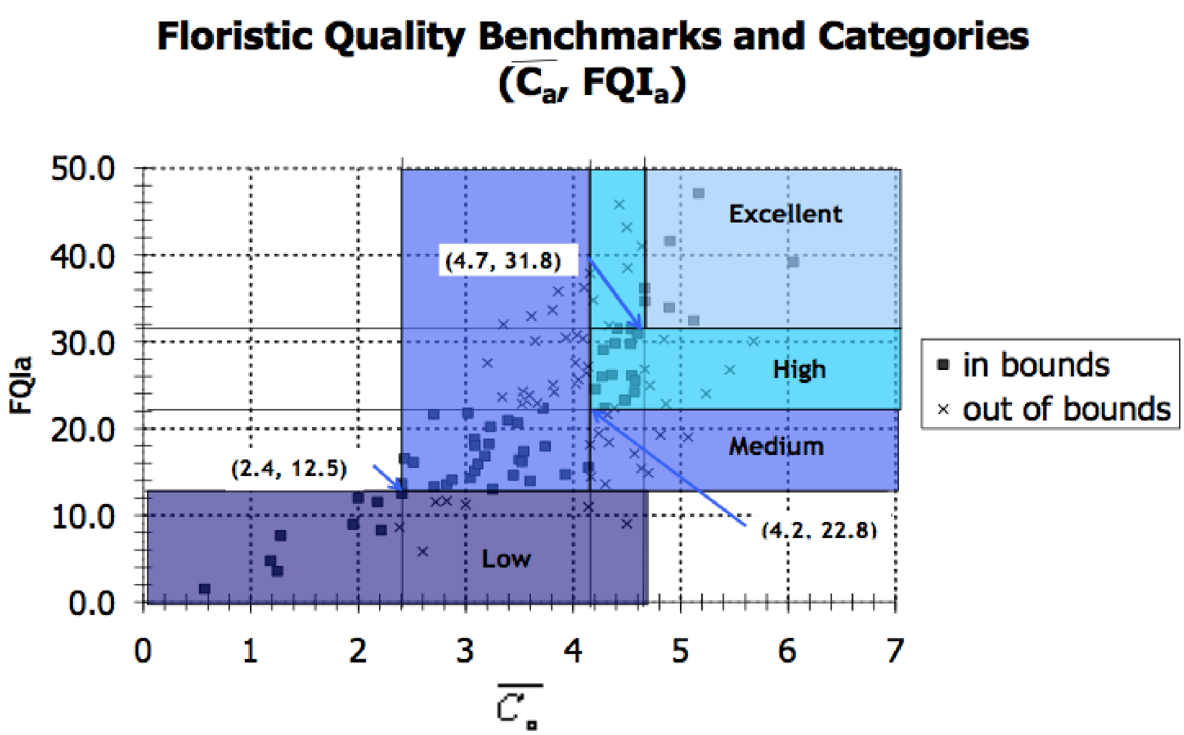


Figure 8: Thresholds for mean C and FQI from Bernthal *et al.* 2007. Thresholds are based on data from 116 wetlands in Southeast Wisconsin.

c. Species Composition and Dominance

A study done by Matthews *et al.* (2009) analyzed the restoration trajectories of various vegetation measurements in constructed and reference wetlands. They found that native species richness, FQI, conservative species richness, *Carex* species richness, and number of native genera in restored wetlands approached or even exceeded those measures in reference wetlands within nine years, though *Carex* species richness increased at the slowest rate among this group. On the other hand, proportion of native species, mean C, proportion of perennial species, and the three importance value measurements in restored wetlands were not approaching reference levels after nine years. The authors concluded that metrics that rely on species richness, such as FQI, tend to be high in recently restored wetlands and can give a false indication of restoration progress, whereas metrics that are based on species composition or dominance were better at distinguishing low and higher quality restoration sites (Mathews *et al.* 2009).

Based on the results from Matthews *et al.* (2009), **<u>we recommend establishing vegetation performance standards based on the following indicators: mean C, proportion of perennials, and proportion of native species</u>**. **<u>Standards should be set based upon conditions in appropriate reference wetlands</u>**.

Measures of plant dominance could be helpful in quantifying the progression of the plant communities on a mitigation bank site. Ideally, measures of dominance are quantifiable and are known to change as the plant communities change. Three measures of dominance, the 50/20 rule (Federal Interagency Committee for Wetland Delineation [FICWD] 1989), importance values for woody plants, and the Species Dominance Index (SDI) (Frieswyk *et al.* 2007), can be used to quantify species dominance in wetland communities.

d. Invasive Species

To minimize the presence and prevalence of invasive species at a mitigation bank, maximum percent areal cover performance standards may be implemented. Prohibited invasive species, as noted in Wisconsin Invasive Species Rule (Wis. Adm. Code ch. NR 40), are both a large threat to Wisconsin's natural communities and are not yet found in Wisconsin or found in small populations that can be eradicated. Therefore, **<u>prohibited species shall not be present</u>**. Invasive species cover should be measured as absolute areal cover of the vegetated areas over the entire site. See paragraph 1.a. Cover in this section for an example of how invasive species cover can be measured. If invasive species are scattered throughout the site, a timed meander approach will need to be done to estimate absolute percent cover.

Restricted invasive species, as noted in Wisconsin Invasive Species Rule (Wis. Adm. Code ch. NR 40), are both a large threat to Wisconsin's natural communities and are present in multiple areas of the state, making eradication improbable. Although *Phalaris arundinacea* (reed canarygrass) is not listed as an invasive species under Wisconsin's Invasive Species Rule, its prevalence and aggressiveness causes serious problems in wetland habitats. Therefore, for wetland mitigation purposes *Phalaris arundinacea* (reed canarygrass) is treated as an invasive species. Wetland invasive species may include, but are not limited to, *Alnus glutinosa* (European alder), *Arundo donax* (giant reed), *Cirsium arvense* (Canada thistle), *Lythrum salicaria* (purple loosestrife), *Phalaris arundinacea* (reed canarygrass), *Phragmites australis* (common reed), *Typha angustifolia* (narrow-leaved cattail), and *Typha* x *glauca* (hybrid cattail). Upland buffer invasive species may include, but are not limited to, *Dipsacus* spp. (teasels), *Elaeagnus umbellata* (autumn-olive), *Euphorbia esula* (leafy spurge), *Pastinaca sativa* (wild parsnip), and *Rosa multiflora* (multiflora rose). **The combined maximum absolute areal cover of invasive species in vegetated areas over the entire site (wetland plus buffer area) shall be no more than 20% by the end of the monitoring period, unless otherwise indicated by the Interagency Review Team**.

2. Hydrology

Wisconsin hydrology performance standards are based on saturation within a certain measure of the soil surface for a period of consecutive days (see Table 5). This metric attempts to characterize the soil moisture within the root zone of wetland plants; however, there may be a more direct way of measuring root zone saturation. Shaffer *et al.* (2000) note that water levels in one wetland did not remain within the root zone for a period of 14 consecutive days, but that the root zone was saturated in 19 days out of a 20-day period. This wetland would fall short of threshold hydrology performance standards, although the conditions experienced in the root zone may be similar to what might have occurred if the root zone was saturated for 14 consecutive days. Hunt *et al.* (1999) suggest measuring the "root zone probability", which is the proportion of measurements where water was at or above the root zone (defined as 30 cm below soil surface). A drawback to relying solely on the root zone probability to characterize water residence time within the root zone is illustrated in the following example:

> [A] system where the water table moves into the root zone every other day (50% root-zone probability) will likely differ from one with the water table in the root zone only during the first half of the growing season (also 50% probability) (Hunt *et al.* 1999).

Therefore, a comprehensive root zone probability by contiguous days of saturation statistic may be more indicative of the root zone saturation regime. Alternatively, soil surface effective saturation may be a better way to compare soil moisture to wetland vegetation (Booth & Loheide 2012). **Measuring surface effective saturation proved more informative for predicting vegetation composition than depth to water level measurements.**

Although hydrology is measured by depth to water table, Hunt *et al.* (1999) note that we may be ignoring an important feature of soil moisture: capillary fringe. Soils with smaller pore spaces (clays, peat) can pull water above the water table by capillary action. Therefore, the root zone can experience saturated conditions when the water table is well below the root zone. Hunt *et al.* (1999) measured soil moisture potential using a gypsum block installed 15 cm below the soil surface. Though this method may not be appropriate for wetlands restored on coarse-textured mineral soils (which have less capillary fringe potential), it would give a better picture of the moisture content of the soil in the root zone. **Gypsum blocks or soil moisture meters could be used to assess soil moisture in mitigation sites**

with either thick deposits of lacustrine clay or soils with high clay proportions that preclude water table monitoring with wells.

ARE WE CREATING WETLANDS THAT ARE TOO WET?

Two studies from the east coast comparing hydrology in reference and created wetlands and have found that created wetlands are on average wetter than their reference counterparts (Cole & Brooks 2000; Cole *et al.* 2006). Cole and Brooks (2000) compared two floodplain forest reference sites to two mitigation floodplain wetlands in Pennsylvania. They found that created wetlands had a median depth to water table that was much less and had water in the root zone much more frequently than the reference wetlands. In New York, Cole *et al.* (2006) compared three palustrine forest/scrub-shrub wetlands to five palustrine mitigation sites and again found the median depth to water table in created wetlands to be much shallower than the reference sites. They also found that three of the five created wetlands were inundated for considerable lengths of time, something that the reference wetlands rarely experienced. The researchers attribute wet conditions in created wetlands to the practice of scraping the wetland surface down to the groundwater table, thus creating expansive areas of ponded water. The desire to achieve regulatory standards of wetland hydrology, combined with the short term of many monitoring periods, pushes wetland restoration projects to create hydrology that is too wet and therefore may not be indicative of conditions in nearby reference wetlands. **In order to establish appropriate hydrology on a mitigation site, restoration practitioners should focus on filling ditches, removing drain tile, and removing allochthonous material, rather than scraping soil down to the groundwater table**.

Wetland Type	Minimum Soil Saturation to Inundation			Maximum Inundation		
	Saturation (from soil surface)	Inundation	Duration (minimum)	Measure	Duration (maximum)	Storm Event
General	Within 12 inches	≤ 6 inches	28 consecutive days or two 14-day hydroperiods	–	–	–
Shallow Marsh	0 inches	≤ 6 inches	56-60 consecutive days, two 28-30 day or four 14-15 day hydroperiods	≤ 18 inches	30 days	≥ 2 year
Sedge Meadow	Within 12 inches	–	28 consecutive days or two 14 day hydroperiods	≤ 6 inches	14 days	≥ 10 year
Wet Meadow	Within 12 inches	–	28 consecutive days or two 14 day hydroperiods	≤ 6 inches	14 days	≥ 10 year
Shrub-Carr	Within 6-12 inches	≤ 6 inches	28-30 consecutive days, or two 14-15 day hydroperiods	6-12 inches	14-15 days, except in hollows	≥ 10 year
Hardwood Swamp	Within 6-12 inches	≤ 6 inches	28-30 consecutive days, or two 14-15 day hydroperiods	6-12 inches	14-15 days, except in hollows	≥ 10 year

Table 5: Approved quantitative hydrology performance standards for Wisconsin wetland mitigation banks. Performance standards are separated by wetland type. Standards are for normal to wet-normal years. Note: There are no approved individual hydrology performance standards for Wet Prairies and Floodplain Forests in Wisconsin.

Wetland soils are arguably the slowest physical factor to recover after restoration, therefore quantifiable performance standards based on soil characteristics changing with time may not be appropriate. Several studies have shown that soil characteristics are significantly different in created and restored wetlands as compared to reference wetlands (Bishel-Machung *et al.* 1996; Stolt *et al.* 2000; Cole *et al.* 2001; Bruland & Richardson 2006). The time it takes for some soil characteristics, like soil organic matter content, to recover can be very long. A Pennsylvania study found no relationship between soil organic matter and time elapsed since construction, indicating that soil organic matter does not accumulate within the time period usually allotted to monitoring mitigation sites (Bishel-Machung *et al.* 1996).

a. Hydric Soil Indicators

Several Wisconsin mitigation banks have performance standards requiring a mid-course wetland delineation, usually at year five of a ten-year monitoring plan. Not only does the delineation describe the jurisdictional boundary of the wetland at the mitigation site, but it can also assess the development of wetland soil characteristics. Vepraskas *et al.* (1999) found several indicators of hydric soils to be present within five years of wetland construction. These indicators were presence of organic bodies, loamy gleyed matrix, depleted matrix, redox dark surface, and depleted dark surface (see Table 6 for definitions). **Creation sites in Wisconsin mitigation banks**

could compare measures of the indicators listed in Table XX, along with other hydric soil indicators such as hydrogen sulfide odor, depleted below dark surface, and sandy redox, with baseline data from the site during an intermediate wetland delineation to assess hydric soil development. See the Regional Supplement to the Corps of Engineers Wetland Delineation Manual (USACE 2012) and Field Indicators of Hydric Soils in the United States (USDA & NRCS 2010) for detailed descriptions of all hydric soil indicators.

This study was conducted in a constructed deep marsh with relatively stable soil saturation throughout the growing season. Soils in wetlands with a more fluctuating hydrologic regime may experience color change more slowly due to less frequent saturation. It must be mentioned that these are indicators of hydric soils, and not necessarily indicators of soil function. The assumption is that if hydric soil structure develops then hydric soil function will follow, although it is not certain how long soils will take to regain hydric functions.

Hydric Indicator Name	Definition
Organic Bodies	Presence of 2% or more organic bodies of muck or a mucky modified mineral texture, approximately 1 to 3 cm in diameter, starting within 15 cm of the soil surface
Loamy Gleyed Matrix	A gleyed matrix that occupies 60% or more of a layer starting within 30 cm of the soil surface.
Depleted Matrix	A layer at least 15 cm thick with a depleted matrix that has 60% or more chroma 2 or less starting within 25 cm of the surface. Two percent or more redox concentrations are required if the value/chroma are: 4/1, 4/2, or 5/2.
Redox Dark Surface	A layer at least 10 cm thick entirely within the upper 30 cm of the mineral soil that has: a. matrix value 3 or less and chroma I or less and 2% or more distinct or prominent redox concentrations as soft masses or pore linings, or b. matrix value 3 or less and chroma 2 or less and 5% or more distinct or prominent redox concentrations as soft masses or pore linings.
Depleted Dark Surface	Redox depletions, with value 5 or more and chroma 2 or less, in a layer at least 10 cm thick entirely within the upper 30 cm of the mineral soil that has: a. matrix value 3 or less and chroma 1 or less and 10% or more redox depletions, or b. matrix value 3 or less and chroma 2 or less and 20% or more redox depletions.

Table 6: Names and definitions of hydric soil indicators that can potentially be measured in Wisconsin mitigation wetlands. Modeled after Table 4 from Vepraskas *et al.* 1999.

b. Soil Microbiome

With the advent of molecular technology, direct characterization and quantification of the organisms responsible for many wetland soil functions is now possible. Although the Wisconsin DNR does not have DNA sequencing capabilities, wetland mitigation banks could partner with research institutions to help characterize the microbial communities in wetland soils. Peralta *et al.* (2013) found soil microbial diversity to be very high in reference wetlands, while microbial community composition in created wetlands was more homogenous. They also found that soil microbial communities were correlated with different soil conditions. Therefore, characterizing wetland soil microbiomes could be used as a bioindicator of soil microbial processes and soil condition. A review of potential biological indicators used to measure soil function found molecular methods characterizing soil bacteria, fungi, and lipid profiles can be used to measure soil functions such as carbon, nitrogen, and phosphorus cycling, decomposition rates, and soil microbial activity (Ritz *et al.* 2009). **Such measurements change over time as soil microbial communities change and would be good candidates for mitigation bank performance standards.**

5. Buffer

Percent vegetative cover and maximum percent invasive species cover performance standards shall be the same as mentioned in sections 1.a. and 1.d. in Quantifiable Performance Standards. To reiterate those standards, **total areal cover must not exceed:**

- **five (5) percent for bare ground,**
- **zero (0) percent for prohibited invasive species, and**
- **twenty (20) percent for other invasive species.**

These numbers are total allowable percent covers for the entire mitigation site, which means the wetland area plus the buffer percent covers cannot exceed these thresholds.

6. Functional Values

A functional assessment following the Wisconsin Rapid Assessment Methodology (WDNR 2012) can be done at the beginning and the end of the monitoring period to assess the increase in function of the wetland mitigation bank. If performance standards are adopted based on WRAM functional values, **at least five of the eight listed wetland functional values shall rank as high or exceptional by the end of the monitoring period**.

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Table 7: Desirable native tree species for wetland mitigation bank projects.

Scientific Name	Common Name	Coefficient of Conservatism	Wetland Indicator	Wetland Habitat Preference	Soil Preference	Notes
Abies balsamea	Balsam Fir	5	FAC[1] FACW[2]	Northern wet to wet-mesic forests in Northern Wisconsin	Prefers acidic soils	
Acer nigrum	Black Maple	5	FACU	Can be found in floodplain forests	Acidic, sandy forest soils	
Acer rubrum	Red Maple	3	FAC	Variable; Southern (and less frequently Northern) hardwood swamps, White Pine – Red Maple swamps, and Floodplain forests	Variable, can survive on a wide range of soils but will not tolerate sedimentation	
Acer saccharinum	Silver Maple	2	FACW	Floodplain forests	Mostly found on alluvial soils, but can grow on other well-drained wet soils	
Betula alleghaniensis	Yellow Birch	7	FAC	Northern and Southern hardwood swamps	Can grow in rocky soil but does best in well-drained loam	
Betula nigra	River Birch	6	FACW	Floodplain forests in western Wisconsin	Found on alluvial soils and is tolerant of sedimentation	
Carpinus caroliniana	Musclewood	6	FAC	Found on edges of deciduous swamps, slopes of floodplain forests	Cannot tolerate prolonged flooding, prefers well-drained alluvial soils	Shade-tolerant; understory tree
Carya cordiformis	Bitternut Hickory	6	FAC[1] FACU[2]	Moist forests, stream banks	Prefers deep loamy soils	

[1] Wetland indicator for Northcentral/Northeast Region according to The National Wetland Plant List (Lichvar 2013)
[2] Wetland indicator for Midwest Region according to The National Wetland Plant List (Lichvar 2013)
Species with no footnote after the wetland indicator have the same wetland indicator for both regions.

Table 7: Desirable native tree species for wetland mitigation bank projects.

Scientific Name	Common Name	Coefficient of Conservatism	Wetland Indicator	Wetland Habitat Preference	Soil Preference	Notes
Celtis occidentalis	Hackberry	4	FAC	Floodplain forests	Non-acidic soils, but other than that it doesn't have much of a preference	
Crataegus mollis	Downy Hawthorn	2	FAC	Wooded stream valleys	Various soils	
Fraxinus nigra	Black Ash	8	FACW	Northern and Southern hardwood swamps	Prefers peat and muck soils, but can grow on sands and loams if the underlying layer is less permeable. Can tolerate a large range of pH	Susceptible to Emerald Ash Borer beetles; beetles bore through bark and eventually kill the tree. Beetles are spreading throughout Wisconsin.
Fraxinus pennsylvanica	Green Ash	2	FACW	Floodplain forests	Alluvial soils, pH neutral to slightly basic	Susceptible to Emerald Ash Borer beetles; beetles bore through bark and eventually kill the tree. Beetles are spreading throughout Wisconsin.
Gymnocladus dioicus	Kentucky Coffee Tree	7	NA	Terraces above floodplain forests	Moist, but not saturated, alluvial soils of neutral or slightly basic pH	Special Concern; uncommon in floodplain forests in Southern Wisconsin
Juglans cinerea	Butternut	6	FACU	Stream banks, very rare	Loamy or alluvial soils, can grow on sandy soils if saturated	Special Concern; severely affected by butternut canker, which eventually kills the trees
Larix laricina	Tamarack	8	FACW	Northern wet forests, Southern tamarack swamps	Moist, well-drained soils (mainly sands and peat), ranges from very acidic pH to circumneutral	

Table 7: Desirable native tree species for wetland mitigation bank projects.

Scientific Name	Common Name	Coefficient of Conservatism	Wetland Indicator	Wetland Habitat Preference	Soil Preference	Notes
Morus rubra	Red Mulberry	10	FACU	Floodplain forests in Southern Wisconsin, scattered distribution	Well-drained moist soils along rivers or streams	Invasive *Morus alba* (White Mulberry) looks similar, but leaf undersides are densely hairy over the entire surface in *Morus rubra*
Nyssa sylvatica	Black Gum	7	FAC	Swamp edges, Stream banks, Wet-mesic forests in Kenosha County	Well-drained alluvial soils	Special Concern - Found only in Kenosha County; climate change may expand range northward
Picea mariana	Black Spruce	8	FACW	Bogs, Northern wet to wet-mesic forests	Slightly to very acidic pH, often found on peat, especially Sphagnum moss	
Pinus strobus	Eastern White Pine	5	FACU	Found on mounds in swamps and floodplains	Can grow on sand, clay, and loam	Cannot tolerate prolonged inundation
Platanus occidentalis	Sycamore	8	FACW	Floodplain forests, stream banks, lake shores	Alluvial, sandy loam, or loam soils that have a high water table except during the growing season	Special Concern - Found in Southern Wisconsin; climate change may expand range northward
Populus balsamifera	Balsam Poplar	4	FACW	Swamps, floodplains, and stream banks of Northern Wisconsin	Mineral soils or alluvium, circumneutral pH	
Quercus bicolor	Swamp White Oak	7	FACW	Floodplain forests, Southern swamps	Variable, can be found on poorly-drained mineral or organic soils	

Table 7: Desirable native tree species for wetland mitigation bank projects.

Scientific Name	Common Name	Coefficient of Conservatism	Wetland Indicator	Wetland Habitat Preference	Soil Preference	Notes
Quercus macrocarpa	Bur Oak	5	FACU[1] FAC[2]	Floodplain forests, Northern and Southern hardwood swamps	Found on calcareous soils derived from limestone, but also on sandy or gravelly substrates	
Quercus palustris	Northern Pin Oak	8	FACW	Bottomlands, swamp borders, floodplain forests in extreme southern Wisconsin	Variable, occurs on sandy to clay soils, and acidic to basic soils	Special Concern, tolerates saturated conditions in spring but not continuously saturated soils
Salix amygdaloides	Peach-Leaf Willow	4	FACW	Floodplain forests, stream banks	Alluvial soils, can tolerate sedimentation	
Salix nigra	Black Willow	4	OBL	Floodplain forests, Lakeshores, Shallow marshes	Moist sandy or silty alluvial soils	
Thuja occidentalis	Eastern White Cedar	9	FACW	Cedar swamps	Calcareous to moderately acidic peat substrates	Young Cedars are very susceptible to deer browsing
Tilia americana	American Basswood	5	FACU	Elevated portions of river floodplains	Alluvial soils	
Ulmus americana	American Elm	3	FACW	Floodplain forests, Northern and Southern hardwood swamps	Mineral soils, prefers calcareous loams	Susceptible to Dutch Elm disease, which eventually kills mature trees

Table compiled using the following resources: Michigan Trees (Revised Edition) (Barnes & Wagner, Jr. 2004); Silvics of North America (USDA 1990); Trees and Shrubs of Minnesota (Smith 2008); Wisconsin Natural Community Abstracts (Epstein *et al.* 2002 [WDNR]).

Table 7: Desirable native tree species for wetland mitigation bank projects. Trees are displayed alphabetically with mean C and wetland indicator status (if known). Several native tree species are purposefully omitted from this table because of their propensity to be extremely weedy. These are (in alphabetical order for Latin name): *Acer negundo*, *Betula papyrifera*, *Populus deltoides*, *Populus grandidentata*, *Populus tremuloides*. Wetland indicator status values are based on the 2013 USACE updates for the North Central/Northeast and Midwest regions.

[1] Wetland indicator for Northcentral/Northeast Region according to The National Wetland Plant List (Lichvar 2013)
[2] Wetland indicator for Midwest Region according to The National Wetland Plant List (Lichvar 2013)
Species with no footnote after the wetland indicator have the same wetland indicator for both regions.

Table 8: Desirable native shrub species for wetland mitigation bank projects.

Scientific name	Common name	Coefficient of Conservatism	Wetland Indicator	Wetland Habitat Preference	Soil Preference	Notes
Alnus incana* ssp. *rugosa	Speckled Alder	4	FACW	Alder thickets	Acidic soils	Capable of nitrogen fixation, thus conferring a competitive advantage on sandy sites with low nutrients
Alnus viridis* ssp. *crispa	American Green Alder	8	FAC	Lakeshores, stream banks, prefers drier habitats than Speckled Alder	Sandy or rocky nutrient-poor sandy soils	
Amelanchier sanguinea	Low Shadblow	7	UPL	Found on lakeshores and river banks	Usually sandy or loamy soils, but can be found on clay and peat soils	
Amorpha fruticosa	Desert Indigo-Bush	6	FACW	Open lakeshores, river banks, and shallow marshes in Southern and Western Wisconsin		Good for stabilizing sandy shores
Andromeda polifolia	Bog-Rosemary	10	OBL	Bogs, Black spruce and Tamarack swamps	Acidic substrate, grows on saturated Sphagnum moss	
Aronia melanocarpa	Black Chokeberry	7	FAC[1] FACW[2]	Tamarack swamps	Acidic, sandy soils	Does not compete well with Dogwoods, Willows

[1] Wetland indicator for Northcentral/Northeast Region according to The National Wetland Plant List (Lichvar 2013)
[2] Wetland indicator for Midwest Region according to The National Wetland Plant List (Lichvar 2013)
Species with no footnote after the wetland indicator have the same wetland indicator for both regions.

Table 8: Desirable native shrub species for wetland mitigation bank projects.

Scientific name	Common name	Coefficient of Conservatism	Wetland Indicator	Wetland Habitat Preference	Soil Preference	Notes
Betula pumila	Bog Birch	7	OBL	Shrub-Carr wetlands, open-canopy Tamarack and Spruce swamps	Prefers calcareous to neutral pH	
Cephalanthus occidentalis	Button Bush	9	OBL	Floodplains, lakeshores, open wet habitats	Variable, but must be saturated	
Chamaedaphne calyculata	Leather-Leaf	9	OBL	Bogs, Muskegs, Black Spruce and Tamarack Swamps	Acidic, nutrient-poor, peat soils (usually Sphagnum spp.)	
Cornus amomum	Silky Dogwood	4	OBL	Shrub-Carr	Non-acidic soils, mostly loams	
Cornus racemosa	Gray Dogwood	2	FAC	Edges of Shrub-Carr wetlands, river floodplains	Sandy or loamy soil, does not tolerate flooding and sedimentation	Weedy species, can be extremely aggressive
Cornus sericea* subsp. *sericea	Red-Osier Dogwood	3	FACW	Shrub-Carr, swamps, lakeshores, river and stream banks	Cannot tolerate extremely acidic habitats, but otherwise is a generalist	
Dasiphora fruticosa	Shrubby Cinquefoil	9	FACW	Wet prairies, fens, seepage swamps	Calcareous substrates	Many cultivars are available - be sure to choose a native genotype
Decodon verticillatus	Swamp Loosestrife	7	OBL	Edges of deep marshes, Lake shores, grows in standing water	Ranges from very acidic to neutral substrates	

Table 8: Desirable native shrub species for wetland mitigation bank projects.

Scientific name	Common name	Coefficient of Conservatism	Wetland Indicator	Wetland Habitat Preference	Soil Preference	Notes
Dirca palustris	Eastern Leatherwood	9	FAC	Understory shrub of damp mesic forests	Rocky, sandy, or loamy soil	Understory shrub of mature forests
Euonymus atropurpureus	Eastern Wahoo	7	FACU[1] FAC[2]	Stream banks, Floodplain forests	Alluvial soil, damp sandy soil	Burning-bush (*Euonymus alatus*) is commonly planted but not native. It tends to spread into natural areas and should be avoided.
Hypericum kalmianum	Kalm's St. John's-wort	9	FACW	Calcareous wet meadows, lake shores, and occasionally fens	Sandy or rocky calcareous soil	
Ilex mucronata	Cat-berry	8	OBL	Shrub-Carr, Alder thickets, and Tamarack and Black Spruce swamps	Acidic soils, peat or wet sand substrate	
Ilex verticillata	Common Winterberry	7	FACW	Mainly Shrub-Carr, Alder thickets, and Tamarack swamps. Can also be found on lake shores, marsh edges	Neutral to weakly acidic peat over sand	
Kalmia polifolia	Bog-Laurel	10	OBL	Bogs, poor fens, muskegs	Acidic sites on Sphagnum moss	

[1] Wetland indicator for Northcentral/Northeast Region according to The National Wetland Plant List (Lichvar 2013)
[2] Wetland indicator for Midwest Region according to The National Wetland Plant List (Lichvar 2013)
Species with no footnote after the wetland indicator have the same wetland indicator for both regions.

Table 8: Desirable native shrub species for wetland mitigation bank projects.

Scientific name	Common name	Coefficient of Conservatism	Wetland Indicator	Wetland Habitat Preference	Soil Preference	Notes
Lonicera canadensis	Fly Honeysuckle	8	FACU	Wet forests, Swamp forests	Acidic soils, peat or wet sand substrate	A shrub of mesic forest understories that sometimes occurs in wetlands
Lonicera hirsuta	Hairy Honeysuckle	7	FAC	Openings and edges of swamp forests	Often in sandy or rocky substrate, but also grows in peat	A low, scrambling shrub or liana
Lonicera oblongifolia	Swamp Fly Honeysuckle	9	OBL	Conifer swamps, Alder thickets, Shrub-Carr	Moderately acidic pH, wet peat or loam substrate	
Lonicera villosa	Mountain Fly Honeysuckle	10	FACW	Conifer swamps, Alder thickets, Shrub-Carr	Moderately acidic pH, wet peat or loam substrate	
Myrica gale	Sweet Gale	9	OBL	Lakeshores, occasionally Alder thickets, Shrub-Carr	Acidic, nutrient-poor wet substrates	Capable of nitrogen fixation, thus conferring a competitive advantage on sandy sites with low nutrients
Physocarpus opulifolius	Common Ninebark	6	FACW	River banks, lake shores	Sandy, gravelly, or rocky soils	Many cultivars are available - be sure to choose a native genotype
Rhamnus alnifolia	Alder Buckthorn	8	OBL	Conifer swamps, Wet forests, marshes	Weakly to moderately acidic soil, found on peat or mineral substrates	Two non-native buckthorns also occur in Wisconsin: *Rhamnus cathartica* (common buckthorn) and *Rhamnus frangula* (glossy buckthorn)

Table 8: Desirable native shrub species for wetland mitigation bank projects.

Scientific name	Common name	Coefficient of Conservatism	Wetland Indicator	Wetland Habitat Preference	Soil Preference	Notes
Rhododendron groenlandicum	Labrador-Tea	8	OBL	Bogs, Conifer swamps, edges of Alder thickets	Found on Sphagnum moss or wet sand	
Ribes americanum	American Black Currant	4	FACW	Lakeshores, Riverbanks, marshes	Moderately acidic to basic soils; can grow in sand, silt, loam, and peat substrates	
Ribes glandulosum	Skunk Currant	7	FACW	Conifer bogs and swamps in northern Wisconsin	Weakly to moderately acidic soil, found on moist peat or humus	"Fruits taste much like a skunk smells" - Trees and Shrubs of Minnesota
Ribes hirtellum	Hairy-Stem Gooseberry	6	FACW	Tamarack swamps, Shrub-Carr, lakeshores	Weakly to moderately acidic soil, found on moist peat or humus	
Ribes hudsonianum	Canadian Black Currant	10	OBL	Tamarack or Cedar swamps in northern Wisconsin	Peat soil	
Ribes lacustre	Bristly Black Currant	9	FACW	Conifer swamps (Tamarack, Cedar, Black Spruce)	Peat soil	
Ribes triste	Swamp Red Currant	8	OBL	Conifer swamps, especially Tamarack swamps, Hardwood swamps	Moderately acidic peaty soils	
Rosa palustris	Swamp Rose	7	OBL	Lakeshores, marshes, swamps	Slightly acidic, wet peaty soils	

Table 8: Desirable native shrub species for wetland mitigation bank projects.

Scientific name	Common name	Coefficient of Conservatism	Wetland Indicator	Wetland Habitat Preference	Soil Preference	Notes
Rubus arcticus	Arctic Raspberry	NA	FACW	Cold conifer swamps in Ashland County	Acidic Sphagnum moss	Rare, small raspberry only found in Ashland County in Wisconsin
Rubus hispidus	Swamp Dewberry	4	FACW	Swamps, peatlands	Grows in acidic peat, also wet sand and wet sandy shores	
Rubus idaeus* var. *strigosus	American red raspberry	3	FACU	Variable, found in many open wetland habitats	Variable, can grow in sand, loam, rocks, or peat and ranges from circumneutral to acidic	
Rubus pubescens	Dwarf Raspberry	7	FACW	Cedar swamps, fens	Sand, loam, or peat; pH ranges from weakly acidic to slightly basic	
Salix bebbiana	Beaked Willow	7	FACW	Shrub-Carr, Alder thickets, Stream banks, Swamps	Can tolerate almost any wetland condition except for very acidic pH and sedimentation	
Salix candida	Sage-Leaved Willow	10	OBL	Peatlands, fens, minerotrophic conifer swamps	Calcareous or circumneutral substrate	

Table 8: Desirable native shrub species for wetland mitigation bank projects.

Scientific name	Common name	Coefficient of Conservatism	Wetland Indicator	Wetland Habitat Preference	Soil Preference	Notes
Salix discolor	Pussy Willow	2	FACW	Shrub-Carr, Alder thickets, Conifer swamps, Hardwood Swamps, Riverbanks, Lake shores	Variable, can grow in calcareous to acidic pH (absent from extreme acidic conditions), grows in both mineral and peat soils	
Salix eriocephala	Diamond Willow	4	FACW	Floodplains, lakeshores, open wet habitats	Prefers wet loamy soils, but can be found in sand, silt, clay, or thin peat; does not grow in extremely acidic bogs	
Salix interior	Sandbar Willow	2	FACW	Variable, found in floodplains, river banks, sandbars, lake shores, and shallow marshes	Mineral soils, usually sand, silt, or loam	
Salix lucida	Shining Willow	5	FACW	Lakeshores, Shrub-Carr, Alder thickets, Riverbanks	Slightly basic to moderately acidic pH, does not tolerate sedimentation	
Salix myricoides	Bayberry Willow	8	FACW	Lakeshores, Calcareous swamps	Calcareous substrates; sandy, gravelly, or alluvial soils	
Salix pedicellaris	Bog Willow	8	OBL	Shrub-Carr, Conifer swamps	Moderately acidic pH, Sphagnum substrate	

Table 8: Desirable native shrub species for wetland mitigation bank projects.

Scientific name	Common name	Coefficient of Conservatism	Wetland Indicator	Wetland Habitat Preference	Soil Preference	Notes
Salix petiolaris	Meadow Willow	6	FACW[1] OBL[2]	Shrub-Carr, Riverbanks, Lakeshores	Peat or wet loamy soils, pH ranges from calcareous to moderately acidic, cannot tolerate sedimentation	
Salix pyrifolia	Balsam Willow	7	FACW	Conifer swamps, especially Tamarack and Black Spruce Swamps, Shrub-Carr	Wet, acidic peat soils	
Salix sericea	Silky Willow	10	OBL	Stream banks	Moist rocky soils	Special Concern
Salix serissima	Autumn Willow	8	OBL	Fens, Conifer swamps, Shrub-Carr	Weakly acidic to circumneutral pH, can tolerate strongly basic conditions; peat or sometimes wet mineral soils	
Sambucus nigra* subsp. *canadensis	Elderberry	3	FACW	Floodplains, Marsh edges, Streambanks	Calcareous to circumneutral silt, loam, or peat	
Spiraea alba	White meadowsweet	4	FACW	Shrub-Carr, Shallow marshes, Lakeshores	Weakly acidic to somewhat basic pH, shallow peat or wet mineral soil	

[1] Wetland indicator for Northcentral/Northeast Region according to The National Wetland Plant List (Lichvar 2013)
[2] Wetland indicator for Midwest Region according to The National Wetland Plant List (Lichvar 2013)
Species with no footnote after the wetland indicator have the same wetland indicator for both regions.

Table 8: Desirable native shrub species for wetland mitigation bank projects.

Scientific name	Common name	Coefficient of Conservatism	Wetland Indicator	Wetland Habitat Preference	Soil Preference	Notes
Spiraea tomentosa	Steeplebush	6	FACW	Openings in Tamarack swamps, Shrub-Carr, Alder thickets	Acidic habitats, in peat or wet sandy soils	
Staphylea trifolia	American Bladdernut	7	FAC	Floodplain forests	Tolerates sedimentation	Understory shrub or small tree of mature forests
Vaccinium angustifolium	Low Sweet Blueberry	4	FACU	Bogs	Strongly to weakly acidic Sphagnum peat	
Vaccinium corymbosum	High-bush Blueberry	10	FACW	Swamps, wet woodlands, borders of bogs	Wet sand or peat	Commerce blueberry; be sure to select a native, non-cultivar source
Vaccinium macrocarpon	Large Cranberry	9	OBL	Tamarack swamps, floating sedge mats	Moderately acidic Sphagnum peat	Commerce cranberry; be sure to select a native, non-cultivar source
Vaccinium myrtilloides	Velvet-leaf Blueberry	6	FACW	Bogs and Conifer swamps	Low-nutrient acidic Sphagnum peat	
Vaccinium oxycoccos	Small Cranberry	9	OBL	Bogs, Black spruce and Tamarack swamps, Muskegs	Very acidic Sphagnum peat	
Viburnum lentago	Nannyberry	4	FAC	Lakeshores, Riverbanks, Floodplains, Pond margins	Mineral soils or sometime shallow peat	

Table 8: Desirable native shrub species for wetland mitigation bank projects.

Scientific name	Common name	Coefficient of Conservatism	Wetland Indicator	Wetland Habitat Preference	Soil Preference	Notes
Viburnum opulus* ssp. *trilobum	American Cranberry-Bush	6	FACW[1] FAC[2]	Hardwood and Coniferous swamps, Shrub-Carr, Lakeshores, Riverbanks and Stream banks		Subspecies *opulus* is a non-native invasive
Zanthoxylum americanum	Prickly-Ash	3	FACU	Floodplains	Non-acidic loamy, sandy, or alluvial soils	

Table compiled using the following resources: Michigan Flora Online (Reznicek *et al.* 2011); Shrubs of Ontario (Soper & Heimburger 1982); Trees and Shrubs of Minnesota (Smith, 2008).

Table 8: Desirable native shrub species for wetland mitigation bank projects. Shrubs are displayed alphabetically with mean C and wetland indicator status (if known). Wetland indicator status values are based on the 2013 USACE updates for the North Central/Northeast and Midwest regions.

[1] Wetland indicator for Northcentral/Northeast Region according to The National Wetland Plant List (Lichvar 2013)
[2] Wetland indicator for Midwest Region according to The National Wetland Plant List (Lichvar 2013)
Species with no footnote after the wetland indicator have the same wetland indicator for both regions.