Lower Green Bay and Fox River Area of Concern (AOC)

Fish and Wildlife Habitat Assessment

Wildlife Habitat and Water Quality Opportunities

February 2018

Prepared by The Nature Conservancy

ACKNOWLEDGEMENTS:

The Nature Conservancy would like to acknowledge the following people for their writing, reviewing, assessing, mapping, modeling, and in other ways contributing to this project and report.

Mike Grimm, Nick Miller, Nicole Van Helden, John Wagner, Matthew Silveira, David Harlan Christiana Bartelme, Michele Kille (The Nature Conservancy)

Robert Howe, Amy Wolf, Erin Giese, and other faculty and students (University of Wisconsin-Green Bay)

Matthew Axler, Thomas Bernthal, Matt Diebel, Donalea Dinsmore, Brianna Kupsky, Megan O'Shea, Vic Pappas, Christopher Smith, Kendra Axness and Steve Galarneau (Wisconsin Department of Natural Resources)

Joanne Kline (Conservation Strategies Group)

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Outagamie County Land Conservation Department

Kevin O'Donnell and Courtney Winter (Environmental Protection Agency)

All the Lower Green Bay and Lower Fox River Area of Concern Stakeholders

This project was made possible through Great Lakes Restoration Initiative funding from the U.S. Environmental Protection Agency and through generous donations from supporters of The Nature Conservancy.

<u>Funding Information:</u>

This project was completed under a subaward from the University of Wisconsin-Green Bay as part of their grant "Phase 1 of the Lower Green Bay and Fox River AOC Fish and Wildlife Habitat and Populations Assessment" in collaboration with the State of Wisconsin Department of Natural Resources' Office of Great Waters, funded thru the Environmental Protection Agency under grant number GL-00E01312. It began January 27, 2015 and concluded December 31, 2017.

EXECUTIVE SUMMARY

This report contains The Nature Conservancy's (TNC) assessment of the Lower Fox River and Green Bay Area of Concern (LFR&GB AOC) watershed to support removal of the "Degradation of Fish and Wildlife Populations" and "Loss of Fish and Wildlife Habitat" beneficial use impairments (BUIs) of this AOC. This report is a companion to the report produced by the University of Wisconsin – Green Bay under the "Phase 1 of the Lower Green Bay and Fox River AOC Fish and Wildlife Habitat and Populations Assessment" funded thru the Environmental Protection Agency under grant number GL-00E01312.

The Nature Conservancy focused on three assessments for the Area of Concern and its watershed. These include:

1. A Watershed Assessment of the Lower Fox River watershed for wetland projects that can benefit water quality in the AOC. The Watershed Assessment identifies and ranks wetland-based conservation opportunities throughout the Lower Fox Basin. The opportunities are ranked according to their potential to purify water (i.e., retain phosphorus and sediments) and thus improve the quality of fish and wildlife habitat and support AOC fish and wildlife populations. It should be noted that while this assessment was conducted to find opportunities to benefit the BUIs related to fish and wildlife populations and habitats, the results of this assessment have significant relevance to the Eutrophication BUI for this AOC.

2. A Fish Connectivity Assessment for tributaries of the AOC, identifying locations to remove fish barriers to restore access to spawning habitat for those fish species which run up the tributaries of the AOC. Barrier removal recommendations are optimized based on the amount of habitat available for fish if the barrier was removed. The assessment includes small streams and rivers that flow into the LFR&GB AOC and streams and rivers that empty into the lower Fox River below the dam in the city of De Pere. Wetlands that are or could be restored for fish habitat based on GIS-assessment were also identified.

3. An East River and Duck Creek Habitat Assessment to identify opportunities to improve, protect, create or restore fish and wildlife habitat along these riparian corridors that would have positive impacts on fish and wildlife populations targeted for recovery in the AOC. The East River and Duck Creek Habitat Assessment was a field assessment of the lower portions of the East River and Duck Creek corridors to locate existing and potentially restorable fish and wildlife habitat that provide support for priority AOC species, and identify management actions that would support these species.

Results from these three assessments can be viewed in an online decision support tool Wildlife Recovery: Lower Green Bay & Fox River AOC Explorer (AOC Explorer) accessible at this web address: maps.freshwaternetwork.org/wisconsin/.

Lastly, a list of recommended projects is included that relate management recommendations to the AOC Objectives, potential project sites and AOC priority species and habitats that would benefit by implementing recommendations at the sites. These recommendations are a companion to those in the report produced by the University of Wisconsin – Green Bay.

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INTRODUCTION

Lower Green Bay at the mouth of the Fox River is one of the great freshwater estuaries of the Great Lakes. It is a major commercial waterway, a well-used recreational area, a very productive fishery, and supports an ecologically diverse biological system.

Since the time of settlement by European fur traders and later commercial ventures this rich Great Lakes aquatic and coastal system has changed drastically. By the mid 1900's the cumulative effects of these human activities had resulted in the decline in the ecological diversity and structure, biological abundance and multiple beneficial human uses of the lower Fox River and Green Bay. The concern by citizens and government agencies over this decline of natural resource quality led the International Joint Commission to identify the Lower Fox River and Green Bay in the late 1980's as one of 42 Great Lakes "Areas of Concern." Because of this designation, the Wisconsin Department of Natural Resources with support from other agencies, researchers and citizens developed a remedial action plan (RAP) to guide the recovery or improvement of lost or impaired beneficial uses and ecological quality through a set of recommended actions.

This report contains The Nature Conservancy's (TNC) assessment of the Lower Fox River and Green Bay Area of Concern (LFR&GB AOC) watershed to support removal of the "Degradation of Fish and Wildlife Populations" and "Loss of Fish and Wildlife Habitat" beneficial use impairments (BUIs) of this AOC. This report is a companion to the report produced by the University of Wisconsin – Green Bay (UWGB) under the "Phase 1 of the Lower Green Bay and Fox River AOC Fish and Wildlife Habitat and Populations Assessment" funded thru the Environmental Protection Agency under grant number GL-00E01312. As these are companion documents produced in cooperation under the same project proposal, have interacting components, and supplement each other; the two reports should be consulted jointly for guidance on recommendations for actions that will improve the biological diversity and abundance of targeted species and species groups and the quality and extent of the habitat these species need to persist and increase in the Lower Fox River and Green Bay system. The UWGB report focuses on the fish and wildlife habitat and population assessment of the open water and shoreline of lower Green Bay and the lower Fox River below the dam at De Pere. In addition, they assessed a buffer area within 1km of the shoreline. The Conservancy's complementary assessment covers the larger watershed of the lower Fox River and lower Green Bay, as well as the lower riparian corridors of the two main tributaries to lower Green Bay; i.e., Duck Creek and the East River. The UWGB report in addition contains information on historic conditions of the AOC; the identification and ranking of priority wildlife habitats and priority species groups; the establishment of a numeric condition score for these two BUIs that would justify removal of the BUIs; habitat and population metrics to track progress toward recovery of the BUIs; and maps of the habitats of the AOC.

The justification for The Nature Conservancy's assessment of the Lower Fox River and Green Bay Area of Concern (LFR&GB AOC) watershed is based on the identified need in the initial Lower Green Bay Remedial Action Plan to link the recovery of this AOC with conditions in its watershed[i]. As delineated by map, the Lower Green Bay and Fox River Area of Concern comprised the open water of Lower Green Bay south of a line running from Point au Sable across the bay to Long Tail Point and the section of the lower Fox River below the dam in De Pere. This mapped delineation did not include fringing habitat along the shore of the Bay, the riparian habitat of the Fox River, or any of the AOC's watershed. However, as mentioned, it was recognized in the initial Lower Green Bay Remedial Action Plan that actions would have to be taken outside the original delineated Lower Green Bay and Fox River Area of Concern boundary to facilitate recovery of targeted fish and wildlife populations and habitats within the AOC. Several recommended actions in the initial RAP under “Key Action #6: Protect Wetlands, and Manage Habitat and Wildlife” identified actions and potential partners outside the delineated AOC boundary. Examples included recommended actions 6.1 (Continue west shore land acquisition), 6.5 (Encourage private wetland preservation), 6.9 (Develop and use habitat enhancement methods) and 6.14 (Provide upland bird nesting habitat). Acknowledging the importance of the East River and Duck Creek to the recovery of the impaired beneficial uses of the AOC, recommended action 6.5 specifically identified the need for private landowners to protect and improve wildlife habitat along Duck Creek and the East River. Recommended action 6.9 called for the identification of methods to enhance fish and wildlife habitat in tributary streams including Duck Creek and the East River.

The recognition in the original Remedial Action Plan of the dependency of the fish and wildlife populations of the AOC on conditions of the surrounding landscape and contributing watershed formed the basis for the need to assess the ecological conditions and habitat beyond the mapped delineation of the AOC, particularly up the major tributaries of the AOC, to look for management action opportunities that could support the identified AOC priority species, species groups and habitats.

The Conservancy’s approach to a watershed assessment to support habitat and species recovery in this AOC was guided by several principles. Protection, management, restoration, or rehabilitation of altered large aquatic systems such as lower Green Bay and its tributaries (like the East River and Duck Creek) requires attention be given to processes and patterns at both a site level habitat scale and the larger watershed scale. It should be emphasized that much of the habitat quality of Green Bay and the lower stretches of the Fox River; Duck Creek and the East River are affected and perhaps most dependent on the quality of the water received from the upper watershed. Thus, the goal of improving and maximizing habitat quality at small scales in the open water, coastal and riparian zones of the AOC must be accompanied by addressing the larger landscape scale (i.e., watershed) issues that affect water quality, particularly, in this watershed, sediment and nutrient loading. In addition, the ability of species to move from the open waters of Green Bay to spawning or breeding sites in the watershed and back again is critical for some species of priority for the AOC.

To address these issues of watershed water quality, habitat quality on major tributaries to the AOC and aquatic connectivity in the tributary network for priority fish species of the AOC, the Conservancy assessed the geography of the AOC watershed in three separate ways, with different approaches and methods. An online AOC Explorer visually displays results.

Assessment Components

This report is divided into four sections:

4. A Watershed Assessment of the Lower Fox River watershed for wetland projects that can benefit water quality in the AOC. The Watershed Assessment identifies and ranks wetland-based conservation opportunities throughout the Lower Fox Basin. The opportunities are ranked according to their potential to purify water (i.e., retain phosphorus and sediments) and thus improve the quality of fish and wildlife habitat and support AOC fish and wildlife populations. Conservation opportunities considered and assessed for their water quality improvement potential included current wetlands (preservation opportunities) and former wetlands that have

been drained and converted to upland (restoration opportunities). The locations and relative functional potential of these sites can be used in site-specific or watershed-scale planning, capitalizing on the capacity for wetland conservation to contribute to AOC goals. It should be noted that while this assessment was conducted to find opportunities to benefit the BUIs related to fish and wildlife populations and habitats, the results of this assessment have significant relevance to the Eutrophication BUI for this AOC.

5. A Fish Connectivity Assessment for tributaries of the AOC, identifying locations to remove fish barriers to restore access to spawning habitat for those fish species which run up the tributaries of the AOC. Barrier removal recommendations are optimized based on the amount of habitat available for fish if the barrier was removed. The Fish Connectivity Assessment used the data, methodology and model from the 2011-2013 project (report in Appendix A) to create a subset of barriers that are on tributaries that are connected to the Area of Concern. This includes small streams and rivers that flow into the Lower Fox River and Green Bay AOC area, and streams and rivers that empty into the lower Fox River below the dam in the city of De Pere. Wetlands that are likely to provide fish habitat, as well as former wetlands that could be restored for this purpose, were identified via GIS assessment and are displayed with the Fish Connectivity Assessment results.

6. An East River and Duck Creek Habitat Assessment to identify opportunities to improve, protect, create or restore fish and wildlife habitat along these riparian corridors that would have positive impacts on fish and wildlife populations targeted for recovery in the AOC. The East River and Duck Creek Habitat Assessment was a field assessment of the lower portions of the East River and Duck Creek corridors with two main objectives: 1) to locate existing and potentially restorable fish and wildlife habitat that provide support for priority AOC species; 2) identify management actions that would support these species.

7. A Wildlife Recovery: Lower Green Bay & Fox River AOC Explorer (AOC Explorer) developed to visually display the results of the above three components. The Wildlife Recovery: Lower Green Bay & Fox River AOC Explorer (AOC Explorer) is an online decision support tool, one of several tools accessible at this web address: maps.freshwaternetwork.org/wisconsin/. In addition to the data layers for the components discussed here, there is also a layer for AOC habitat types assessed by UWGB with a link to their report for this joint project. In combination, this information can be used to consider AOC projects that can benefit fish, wildlife and water quality.

BODY OF REPORT

1) Watershed Assessment for wetland projects that can benefit water quality in the AOC

Overview

Wetlands play a key role in reducing nutrient and sediment loads in watersheds. According to the TMDL for the Lower Fox River Basin and Lower Green Bay, wetland restoration could reduce a significant amount of particulate phosphorus and sediment[ii]. Strategic, targeted restoration and preservation of wetlands in the Lower Fox Basin can contribute to nutrient and sediment reduction goals (i.e. eutrophication), as well as improve water quality within the Area of Concern for fish and wildlife.

In this portion of the project, we identified and ranked wetland-based conservation opportunities throughout the Lower Fox Basin, according to their potential to purify water (i.e., retain phosphorus and sediments) and thus improve the quality of fish and wildlife habitat and support AOC fish and wildlife populations. Conservation opportunities considered and assessed for their water quality improvement potential included current wetlands (preservation opportunities) and former wetlands that have been drained and converted to upland (restoration opportunities). The locations and relative functional potential of these sites can be used in site-specific or watershed-scale planning, capitalizing on the capacity for wetland conservation to contribute to AOC goals (both fish and wildlife-related and eutrophication).

The results of these wetland ecosystem service assessments and rankings are housed in the online decision support tool, Wildlife Recovery: Lower Green Bay & Fox River AOC Explorer (AOC Explorer), along with results from other aspects of this project.

While GIS-based assessment of wetland conservation potential provides crucial information for siting decisions and watershed planning it cannot be used, in isolation, to pre-select sites for restoration or preservation. Instead, it helps to winnow options from the thousands found within the Lower Fox Basin to a manageable number with the highest water quality improvement potential. The information in the AOC Explorer provides a starting point for further assessments and pre-screens sites to then follow up with field visits to determine the restorability and feasibility of projects. The Field-based Assessment section illustrates how GIS-based and on-the-ground assessments may be used in conjunction to guide conservation investments toward actually-restorable sites with the greatest potential water quality returns at a watershed scale.

Why a Watershed Approach?

Many wetlands provide important services, whether for wildlife or people, but they are not all important in the same way. Wetlands vary widely in the number, type, and degree of services they provide. This variability is a result of many factors including the dominant type of vegetation, how water flows through wetlands, the seasonal availability of water, soil characteristics, whether a wetland is connected to a stream or waterbody, and the land-use and condition of the surrounding upland. Watershed context and relative position play major roles in how services are distributed among wetlands.[iii,iv,v] For example, a 2-acre marsh surrounded by cropland likely has greater opportunity to improve water quality than a similar 2-acre marsh embedded in a more natural, forested landscape, because the cropland delivers more runoff to its associated wetland. Streamside wetlands are more effective at improving water quality for downstream habitats than wetlands not connected to waterways.

In the absence of assessing an entire watershed, a "watershed approach", it is difficult to compare the relative ecosystem service potential of the range of wetland restoration and protection opportunities. In a more traditional approach that does not include a watershed perspective, sites may be selected based on field assessments of their individual attributes, land availability and cost, accessibility, and other feasibility factors. These site-level aspects are essential to success and a watershed approach is not intended to replace them. Instead, a watershed approach in the Lower Fox Basin complements and improves the site selection process, leading to higher efficiency, cost-effectiveness, and greater likelihood of generating wetland service returns toward AOC goals.

Methods: GIS-based Assessment

Watershed and wetland assessment methods for the AOC were adapted from *Wetlands by Design: A Watershed Approach for Wisconsin*[vi] (WbD). Applications of these methods to the AOC differ in: (1) the use of additional datasets available for the Lower Fox that were not available for the statewide analysis (i.e., field soil phosphorus data and the location of drainage tile); (2) tailoring of WbD methods to AOC-specific goals and to capitalize on the availability of better data in the Lower Fox, and (3) field visits to assess the feasibility of restoring priority sites. The following description of methods provide a high-level overview of WbD methods and detailed description of how these methods were adapted and improved for application in the Lower Fox Basin. For more details on WbD-specific methods, see the report for that project.

Gathering and integrating geospatial datasets

Appendix B lists each dataset used in this project with its source, a brief description, publication date, spatial resolution, and how the dataset was applied.

> *Lower Fox Basin Improvements: Better data on phosphorus contributions*
>
> The potential for a wetland to retain phosphorus, or for a converted wetland to retain phosphorus if restored, is influenced by many factors including phosphorus loading from surrounding fields and the contributing watershed. Application of statewide *Wetlands by Design* methods to the Lower Fox Basin allowed for the production and use of more precise data, not available at the statewide scale. As part of this project, Outagamie County Land Conservation Department created two datasets to more precisely map potential phosphorus contributions in the Lower Fox watershed (see Appendix C). Fields with drain tile were mapped for all agriculture acres by analyzing multiple years of aerial imagery for drain tile signatures in fields. Soil phosphorus data were obtained from available nutrient management plans (NMP) from farms in the watershed. Maps were created to summarize the results across the Lower Fox Basin. Figure 1 and 2 show results from the report (Appendix C).

Figure 1: Tile Drained Agriculture Fields in Lower Fox

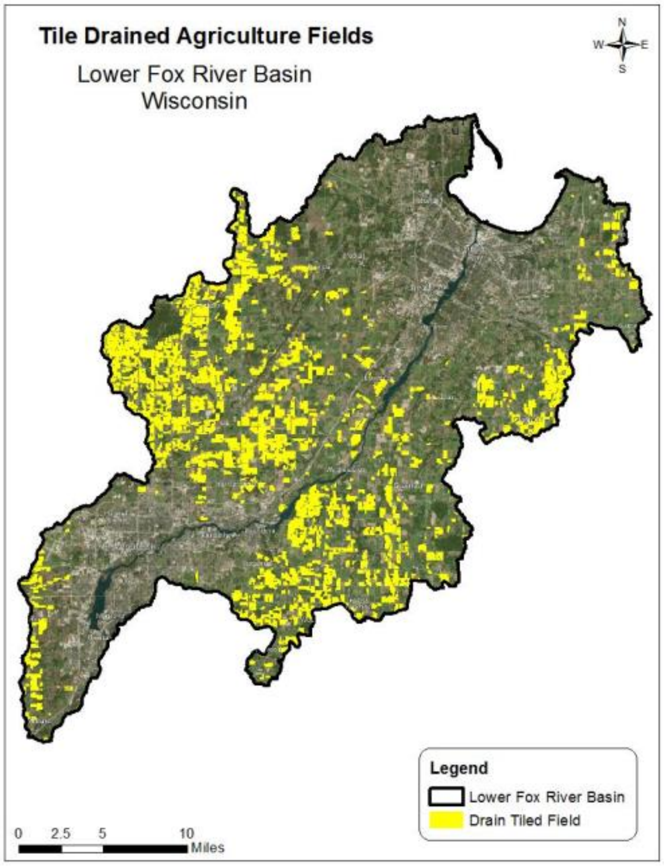
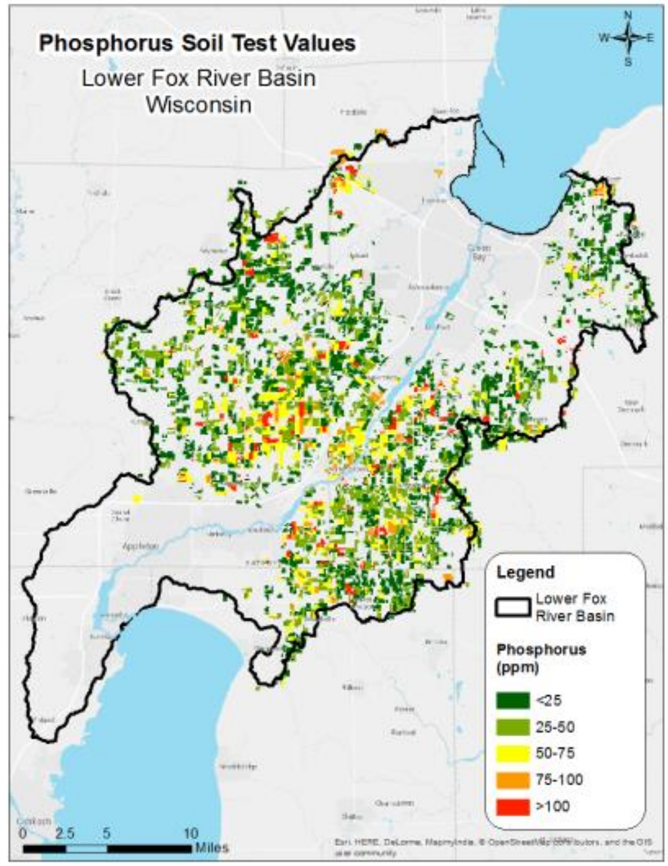


Figure 2: Phosphorus Soil Test Values in Lower Fox



Identifying potential preservation and restoration sites

Wetland preservation and restoration opportunities are collectively referred to as "sites" in this portion of the report. Of the range of possible restoration-type activities (re-establishment, rehabilitation, enhancement, and creation), only re-establishment opportunities were assessed. Re-establishment opportunities, also known as "potentially restorable wetlands" (PRW's), were historically wetland but converted to upland through drainage or fill. These sites offer the greatest potential to *increase* wetland services within the watershed. Wetlands that have not been drained and converted to other land uses—current wetlands--*maintain* what wetland services remain in the Lower Fox Basin. Current wetlands that have been degraded through alterations to hydrology or vegetation (wetland rehabilitation opportunities) have not been identified and ranked for their restoration potential, nor have wetland enhancement opportunities (because they may increase one service, but at the likely expense of others) or creation of wetlands from upland (which are best identified through on-the-ground site assessments).

The current extent of wetlands in Wisconsin is mapped by the Wisconsin Wetland Inventory (WWI)[vii] These mapped wetlands have all been considered as preservation opportunities. Potentially restorable wetlands (reestablishment opportunities) have been mapped statewide in the Wisconsin Department of Natural Resource's PRW data layer (WDNR is currently improving the PRW data layer; check online for most recent version). Restoration potential was determined based on soil characteristics in combination with flow accumulation modeling to identify where water tends to pond on the landscape.

Current and potentially restorable wetlands were combined to create complexes, more accurately reflecting how wetlands function and provide services across the landscape. These complexes were created by merging adjacent wetland and potentially restorable wetlands, and then bisecting them with roads and watershed boundaries.

Assessing ecosystem service potential of sites

<u>Assessing services using Wetlands by Design (statewide approach)</u>

In the Lower Fox Basin, wetlands and potentially restorable wetland sites were prioritized based on their relative potential to retain phosphorus and sediment.

At each site, the phosphorus and sediment retention services were assessed using a suite of criteria in these categories:

- The *opportunity* for the service to be performed, and
- The *effectiveness* of the wetland in providing the service.

For example, a site receiving high sediment inputs from the surrounding watershed has the *opportunity* to purify water. If that same site occurs in a topographic depression and has dense, persistent vegetation, it may slow flows, cause sediments to settle out of the water column, and *effectively* retain sediments.

For a complete list of assessment criteria for phosphorus retention and sediment retention, see Appendix D.

<u>Ranking sites using Wetlands by Design (statewide approach)</u>

Once the criteria (see Appendix D) were applied to each site for each service, the sites were scored using the following rubric and ranked relative to others in the same watershed:

- For both services, connection to surface water was determined to be necessary for a site to provide the service. For sites that failed to meet this criterion, the rank for that service was considered “not applicable.”
- For each service, criteria were assigned to two categories: 1) *Opportunity (O)* for the service to be performed, 2) *Effectiveness (E)* of the wetland in providing the service.
- For each service, the total number of O and E criteria that a site met was divided by the total possible number of O and E criteria for a value between zero and one.
- For both services the relevance of a site increases according to its size; therefore, site scores were multiplied by size factors. Each wetland was compared to all other wetlands within the HUC-8 in which they reside, and each PRW was compared all other PRW’s within the HUC8 in which they reside. Scores of wetlands or PRWs in the top third of sizes were multiplied by 2; scores for sites in the second third were multiplied by 1.5; and scores for those in the smallest third were multiplied by one.
- Within each 12-digit HUC, sites were ranked by score quantiles and designated as Very High, High, Moderate, or Low/Not Applicable for each service.

Ranking sites with improved Lower Fox Basin data and methods

As part of this project, Outagamie County Land Conservation Department provided additional data (see Appendix C) that enabled us to modify and improve the above-described site rankings. County data were combined with Wetlands by Design data for a total of four ranking criteria:

1. the likelihood that a given site would **retain sediment** relative to other sites in its (HUC12) watershed (from WbD).
2. the likelihood that a given site would **retain phosphorus** relative to other sites in its (HUC12) watershed (from WbD),
3. the likely presence of field **tile drainage** (County data), and
4. the **soil phosphorus level** for each field, as determined from nutrient management plans (County data).

Sites were scored against each of the above four criteria as follows:

1. **WbD Sediment Retention**: Sites were ranked as Very High (VH), High (H), or Moderate (M) in Wetlands by Design based on their potential to reduce sediment loads.
2. **WbD Phosphorus Retention**: Sites were ranked as Very High (VH), High (H), or Moderate (M) in Wetlands by Design based on their potential to reduce phosphorus loads.
3. **Tile**: Sites within 10 meters of a tiled field scored as "1"; all others scored "0"
4. **Soil Phosphorus**: Sites within 10 meters of a field with high phosphorus (above the median value for all field in the watershed) scored as "1"; all others scored "0"

Finally, each site was ranked according to the rubric described in Table 1.

Table 1: Rubric for ranking current and potentially restorable wetlands within the Lower Fox Basin, based on 1) sediment retention rank from Wetlands by Design (WbD) 2) phosphorus retention rank from WbD, 3) proximity to tiled fields, and 4) proximity to field with high soil phosphorus.

Rank	1. WbD Sediment	2. WbD Phosphorus	3. Tile	4. Soil Phosphorus
Very High	VH or H	VH or H	1	0
Very High	VH or H	VH or H	0	1
Very High	VH or H	VH or H	1	1
High	M	VH or H	1	0
High	VH or H	M	0	1
High	M	M	0	1
High	M	M	1	0
High	VH	VH	0	0
Moderate	H or M	VH	0	0
Moderate	VH	H or M	0	0
Moderate	H	H	0	0
Moderate	H	M	0	0
Moderate	M	H	0	0

All current and potentially restorable wetlands in the Lower Fox Basin were ranked using the scoring rubric described above. Each ranked polygon was assigned a unique ID. "Wetland ID"s for current wetlands in this project match those for polygons in the Wisconsin Wetland Inventory.

Methods: Field-based Assessment

Assessing restorability and feasibility of priority sites

As noted in the overview section, a GIS-based assessment of potential wetland conservation sites helps to winnow options from the thousands of current or potentially restorable wetland sites found in the Lower Fox watershed to a manageable number with the highest water quality improvement potential. As noted in the overview section, a GIS-based assessment of potential wetland conservation sites helps to winnow options from the thousands of current or potentially restorable wetland sites found in the Lower Fox watershed to a manageable number with the highest water quality improvement potential. Then field-based assessments can be done to determine the restorability and feasibility of a site.

First, sites were selected for field-based assessments using the spatial data analysis described in Table 1 above. Only potentially restorable wetlands (PRWs) that ranked Very High or High were considered. Restoration sites were chosen over current wetlands since restorations present an opportunity to add, rather than maintain or improve, phosphorus and sediment retention capacity in the watershed. This list of high ranked PRWs include hundreds and hundreds of sites in the Lower Fox.

To narrow the list further, Conservancy staff applied a filter that highly ranked PRWs needed to be in a subwatersheds that had an approved or in-progress Nine-Key Element Plan (watershed recovery plan). In the Lower Fox, subwatersheds with Nine-Key Element Plans have been a focus of water quality improvement work. Wetland restorations combined with other conservation practices like cover crops, reduced tillage, and streambank restorations in the same subwatershed have a much higher likelihood of sustaining their water quality function.

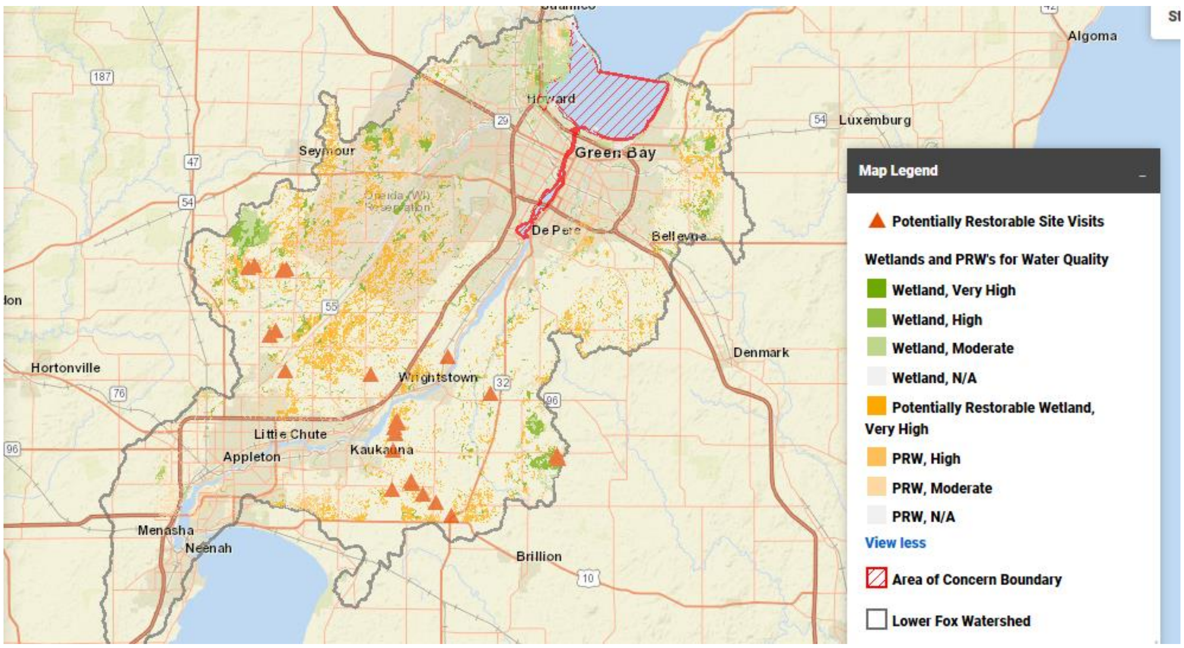
Finally, the high ranked PRWs in subwatersheds with Nine-Key Element Plans were visually assessed in the office by a wetland restoration professional to identify those with the greatest potential and feasibility based on GIS overlays such as ownership boundaries, aerial photography, topography, and the DNR's surface waters layer. The most likely sites were then intersected with a parcel ownership layer. Seventy-two sites owned by fifty-three different owners were identified.

The resulting list of owners was discussed with county conservationists for their input on the likelihood of site access and landowner willingness and method of contact. All but four sites were privately owned, and The Nature Conservancy sent a letter describing the field assessment process and followed up with phone calls to secure landowner permission for visitation. Restorability and feasibility criteria were developed and the data sheet (Appendix E) was created. The restorability questions focused on factors that influence how successful re-establishing a wetland would be (e.g. can the hydrology be restored?). Feasibility criteria focused on the ease with which a restoration project might occur (e.g.s how many landowners would be affected; how physically accessible is the site; what is a rough estimate of cost of restoring the site?). Some of the criteria are yes/no responses and others rely on professional expert opinion. An experienced wetland restoration professional was hired to conduct the field visits and a set of maps was provided to help. Sites were evaluated over the period from May 26 to June 27, 2017. After data forms were completed, the contractor summarized his findings and provided a list of sites with high restorability.

Results for GIS-based and Field-based Assessments

The results of the GIS-based assessment are best viewed on the AOC Explorer. The Explorer gives users an interactive presentation of all data and results of the Watershed Assessment portion of this project, including both the GIS and field-based assessments. Figure 3 is a screenshot of the Watershed Assessment data available to view. Zooming in provides more site detail. Online users can also turn on additional data layers that may be useful.

Figure 1: Screenshot of AOC Explorer tool, illustrating results of Lower Fox Watershed Assessment (ranked wetlands and potentially restorable wetlands and site visit locations).



Regarding the field-based assessments, landowner response was an impressive 64%. Landowner permission was secured to visit 27 of the 72 sites. About 19 landowners denied permission or were removed from the list based on partner advice. The two most common reasons for not granting access were concern about surveyor disturbing newly planted crops and no interest in restoration or taking any land out of production. This latter concern about not being interested in restoration was echoed by several landowners that did grant permission for the assessment. About 26 landowners never responded to our communications and permission could not be secured. Nearly half the 27 sites assessed were determined to have high or medium restorability/feasibility. The contractor considered all restorability and feasibility criteria and then gave the site an overall score. Some feasibility factors were easier to assess than others and some factors, like a landowner saying they were not interested in restoration, may or may not make a project infeasible depending on available cost-sharing, future agricultural plans, past crop success in a wet area, etc. The contractor relied more heavily on how restorable a site would be and how it could improve water quality, while still considering but deemphasizing feasibility factors. A summary of potential restorations site scoring is included below in Table 1. Site locations and scores can also be viewed in the AOC Explorer. All hand-written field data sheets, maps, and sketches reside in The Nature Conservancy's Northeast Wisconsin Project Office at 242 Michigan Street, Sturgeon Bay, WI 54235.

Table 2: Summary of site visits to potentially restorable wetlands to assess site restorability as of 2017

Site ID (aka Map ID)	Site Restorability
19	High
20	High
31	High
34	High
44	High
46	High
58	High
60 (East)	High
9	Medium
55	Medium
66	Medium
73	Medium
60 (West)	Medium
1	Low
36	Low
41	Low
54	Low
56	Low
61	Low
68	Low
69	Low
71	Low
72	Low
~~38~~	NA- Not restorable
~~45~~	NA- Existing Wetland
~~53~~	NA- Existing Wetland
~~64~~	NA- Developed

Discussion Specific to Watershed Assessment

Potentially restorable wetland sites listed in Table 2 above as having high or medium restorability potential should be considered as an important part of the watershed recovery effort. Additional discussions will be needed to determine how to best engage private landowners in helping restore watershed health through restoring wetlands and their functions. Table 2 is just a starting place, and additional priority sites identified through the GIS-based Watershed Assessment should also be considered. As other watershed recovery work proceeds, partners should consider wetlands as one of the tools to improve water quality.

It is worth noting that wetlands not prioritized as “very high,” “high,” or “moderate” for assessed services may still be of value. For example, small sites may be omitted in some areas due to limited source data; numerous wetlands that individually provide services at a low level may, collectively, be of high value within a watershed; and wetlands do provide additional services that were not assessed as part of this project. One example of a wetland service not assessed as part of this project is a wetland’s ability to transform nitrogen. Since the lower Fox River and Lower Green Bay are impaired by excessive phosphorus and sediment loading (pollutants identified in the TMDL for reductions to recover the biological health and social values of the area), the AOC watershed assessment focused on wetlands that could contribute to that remediation. The Wetlands by Design Explorer which was completed for all watersheds in Wisconsin including the Lower Fox River watershed can be used to explore additional services (e.g. nutrient transformation including nitrogen, flood abatement, shoreline protection, carbon storage, surface water supply, wetland wildlife habitat) that were not assessed in this AOC-focused project.

One of the key strategies for increased natural resilience under the modeled change in this region’s climate will be the rebuilding of the landscape’s green infrastructure. In this project wetland functions of nutrient transformation, sediment retention, and wildlife habitat were assessed under the hypothesis that wetlands are structural components of a landscape that confer critical environmental stability to a watershed and provide multiple ecological and social benefits. This ability to dampen the impacts of precipitation extremes predicted by climate models for the Great Lakes region will be critically needed in the future if the watershed is to perform any regulating function on the high sediment loads carried by the flashy, ungoverned flow of surface water across the current landscape.

As part of the field assessments, the data form included questions to try to determine the feasibility of a restoration (e.g. estimated cost, number of landowners affected if restored, landowner interest). Many of these questions were difficult to ascertain in the field, particularly those related to landowners. Some landowners were not home or rent their agricultural land to other producers. Some expressed disinterest in wetland restoration. Without a detailed survey, it was often difficult to determine restoration boundaries and which landowners might be affected. Landowners might be interested in restoration if monetary incentives were discussed or an analysis of crop yields in low lying areas was explored. While surveying sites for restorability was a valuable step in identifying potential projects, further steps are needed to truly identify feasible projects. We recommend further exploration with private landowners to determine the true feasibility of restoration.

In general, the contracted wetland restoration professional’s impression after assessing the specific sites selected and about the Lower Fox watershed was that there are a lot of potential restoration sites but many of the sites are owned by landowners with dairy operations who sound hesitant to take land out of production. This is a challenge that would need to be overcome.

Justification for assessing AOC wildlife habitat in a different way

This project originally proposed ranking existing and potentially restorable wetlands and associated uplands for AOC wildlife value using the Wildlife Tool[viii], the method used in the *Wetlands by Design: A Watershed Approach for Wisconsin*. Though the Wildlife Tool has several attributes that make it suitable for this application—e.g., ranks wetlands based on the life history habitat requirements of target wildlife species, can be tailored to local conditions based on judgments by local wildlife resource experts, and uses analysis (habitat x species association matrices) from the Wisconsin Wildlife Action Plan—the decision was made to forgo it's development based on conditions presented by the developed and fragmented nature of the Lower Fox River and Green Bay Area of Concern (AOC) watershed and specific requirement of this project.

The main goal of this project was to identify opportunities to protect, restore and/or improve habitat in the watershed of the AOC of value for priority species and habitat recovery within the AOC. To meet this goal while looking for valuable habitat using the Wildlife Tool in the AOC watershed assumed that species would be able to move equally well from any site in the watershed to interact and support the populations of the AOC; i.e., there is a level of landscape or watershed connectivity that would facilitate the movement of these priority species from breeding / spawning/ feeding / roosting habitats in the watershed to the AOC and back either daily, seasonally or during the life of the species. (Connectivity could be understood as species movement across the landscape with no or surmountable barriers; so that the aerial distance for flying species (bats, birds, insects) would be small enough to not constitute a barrier, or that habitat is not separated by impassable conditions (roads, development, housing, etc.) for terrestrial or aquatic species). Given the large and highly fragmented nature of the AOC watershed it would be difficult to assume priority species could easily move from the upper reaches of the watershed to the AOC. This need for connectivity between watershed habitat and the AOC placed highest value on those habitats of importance nearest and best connected to the AOC.

Also, it was understood that the wetland habitats in the watershed may not correspond in structure or biological diversity to the wetland habitats of the core AOC. The dynamic hydrology of Green Bay subject the coastal wetlands of the AOC to daily, seasonal and yearly water level fluctuations, as well as periodic high energy storm events; and large spring ice shove events. These conditions are not replicated at inland wetlands and may have limited the ability to accurately rank the value of inland wetlands in supplying favorable habitat conditions to AOC priority species.

To overcome the limitations of the modeled approach, the size and severely fragmented nature of the AOC watershed, and the dynamic hydrology of the AOC wetlands, an alternative approach employing field surveys to locate and evaluate habitats of value to priority AOC species was utilized. See the East River and Duck Creek Habitat Assessment section for details, as well as the companion report from University of Wisconsin-Green Bay.

2) Fish Connectivity Assessment for tributaries of the AOC

Overview

AOC priority fish have been documented utilizing tributaries of the AOC for spawning and other life history needs.[ixx] To facilitate recovery of these targeted fish populations, The Nature Conservancy identified spawning migration barriers on tributaries entering the Area of Concern (lower Green Bay and Fox River below the De Pere dam, see Figure 4). Tributary fish, including northern pike, are an AOC priority species group. Assessing barriers for migratory northern pike was particularly valuable because pike are poor swimmers and jumpers. Barriers that are made passable for northern pike will allow pike and other tributary fish species to reach spawning and other habitat.

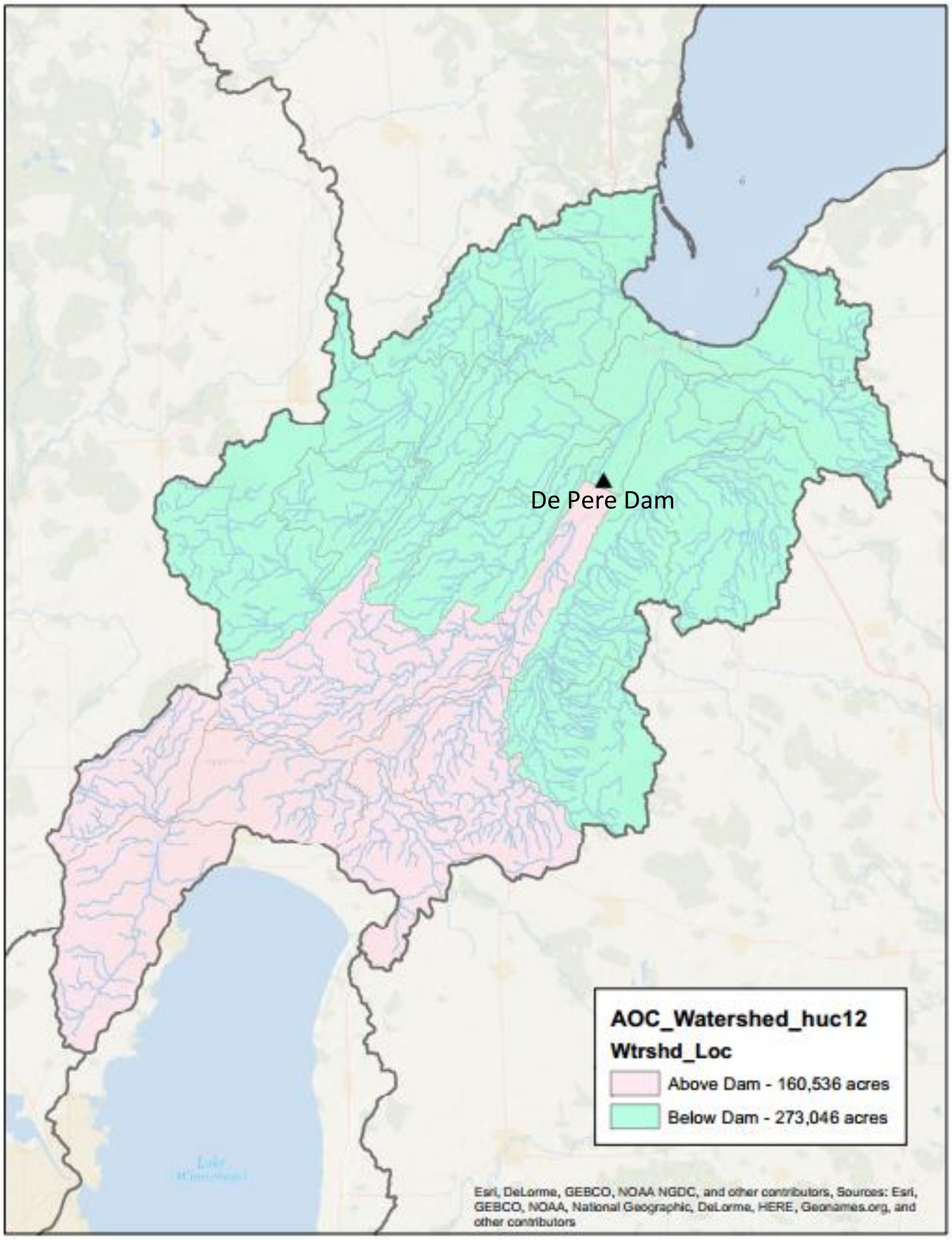
Methods

In 2011 The Nature Conservancy worked with Wisconsin Department of Natural Resources and the University of Wisconsin Madison to develop a systematic method to identify migration barriers for northern pike moving from Green Bay to their upstream wetland spawning areas. The objectives of that project were to:

1. Conduct an intensive field survey to identify barriers to fish passage on all tributaries to Green Bay.
2. Identify factors that influence northern pike spawning habitat suitability.
3. Estimate the cost of replacing each fish passage barrier.
4. Prioritize barrier removals that will open up the most high-quality habitat for the least cost.

For this AOC project, we used the data, methodology and model from the 2011-2013 project (Appendix A) to identify a subset of barriers that are on tributaries connected to the Area of Concern. This includes small streams and rivers that flow into the Green Bay AOC area, and streams and rivers that empty into the Lower Fox River below the De Pere dam. This geographic subset of surveyed barriers was then prioritized, using the model from the 2011-2013 report.

Figure 2: Fish Barrier Assessment Area for AOC Tributary Fish shown in green



Results

The results of the prioritized barrier assessment are available in the [AOC Explorer](). The road-stream crossings are classified based on their passability score (i.e. likelihood that northern pike can pass upstream through the structure during typical April stream flow conditions; primarily based on water velocity through the structure and whether the structure has an outlet drop). Categories include impassable (complete barrier to fish passage), partially passable (partial barrier), unknown (not surveyed, often privately owned and unable to contact owner), passable (completely passable for fish) and made passable (self-reported projects that have remedied previous barriers). There were 123 impassable or partially passable barriers identified, and they are labeled with numbers indicating the optimal order for barrier removal (starting with number 1). Some barriers have an astericks following the number. This indicates that more than one barriers with that number needs to be fixed in order to realize the projected benefit.

In addition to the barrier data, we have provided fish and aquatic habitat rankings from *Wetlands by Design: A Watershed Approach for Wisconsin* (WbD)[vi]. The intent in providing this data is to illustrate the relative opportunity of wetland and restoration sites to provide fish and aquatic habitat in relation to projects aiming to restore stream connectivity for fish passage. Fish and aquatic habitat were assessed in the statewide WbD assessment and, for this project, were simply clipped to the same geographic area as the barrier assessment.

Please consider that this data is not informed by local datasets, like the "Identifying potential preservation and restoration sites" section of our assessment is, and users are encouraged to use this data as a guide for field assessments. Also, this data was not used in the barrier removal prioritization.

For a complete list of assessment criteria for fish and aquatic habitat, along with assessment methods and datasets used, see Appendix D.

Discussion Specific to Fish Connectivity Assessment

The Fish Connectivity Assessment used data collected in 2011-13 and was updated to reflect self-reported barrier remediation projects completed since then. It only included field checks of publicly accessible barriers. The barrier prioritization is meant to be used as guidance to focus barrier removal at locations where there is a high return on investment. We recommend checking the current status of any barrier of interest and also verifying any downstream private crossings that might not have been mapped. Local partners like Brown County Land Conservation Department have been focused on barrier removal for many years and would also be a good resource for local barrier knowledge. Barrier survey data and photos collected in the 2011-13 project are available from The Nature Conservancy upon request. As noted above, coupling opportunities for stream connectivity restoration work and wetland or aquatic habitat restoration can be advantageous. AOC Explorer users are encouraged to look at these layers together to design a project with maximum impact for AOC fish and aquatic species.

3) The East River and Duck Creek Habitat Assessment for AOC fish and wildlife populations

Overview

There were two main objectives for the habitat assessments of the East River and Duck Creek corridors:

1) to locate and map existing and potentially restorable fish and wildlife habitat that provide support for priority AOC species and;

2) to identify management actions that would support these species.

As noted in Justification for assessing AOC wildlife habitat earlier in this report, the Conservancy opted for on-the-ground field assessments of AOC wildlife habitat rather than a modeled approach. The habitats, species and geography covered are discussed below.

AOC Habitats and Species Assessed:

The suite of plant community types, here after called habitats, to target for mapping was based on the suite of habitats present or historically present within the delineated AOC boundary and considered critical for all or some critical aspect of the life history requirements of those species and species groups identified for recovery or protection in the initial Remedial Action Plan. These habitats were identified and described through research into historic conditions and the 2016-17 AOC field inventories conducted by the University of Wisconsin – Green Bay. These habitats are listed below in Table 3 and a detailed description of these same habitats can be found in Appendix F.

Table 3: AOC Habitat Types

Habitats of the Lower Green Bay and Fox River Area of Concern (AOC)	
Emergent Marsh (High Energy Coastal)	Submerged Aquatic Vegetation
Emergent Marsh (Inland)	Submergent Marsh
Emergent Marsh (Riparian)	Shrub Carr
Emergent Marsh (Roadside)	Southern Dry Mesic Forest
Fox River Open Water	Southern Sedge Meadow
Great Lakes Beach	Surrogate Grassland (Old Field)
Hardwood Swamp	Surrogate Grassland (Restored)
Northern Mesic Forest	Surrogate Grassland (Roadside)
Open Water Inland	Tributary Open Water
Green Bay Open Water	Wasteland
Other Forest	

The list of AOC priority species or species groups were defined by the University of Wisconsin – Green Bay for this project. Please see their website for information on the development and selection of these. The AOC priority species / species groups considered in the assessment are listed in Table 4.

Table 4: AOC Priority Species and Species Groups

Priority Species or Species Group of the Lower Green Bay and Fox River Area of Concern (AOC)	
Anurans[1]	Nearshore Invertebrates
Bald Eagle (winter)	Piping Plover
Bats	Shorebirds (migratory)
Coastal Birds (breeding season)	Shoreline Fish
Coastal Wetland Mustelids[2]	Stream Invertebrates
Coastal Wetland Aquatic Macroinvertebrates	Tributary Fish
Fox River Fish	Turtles
Freshwater Unionid Mussels	Waterfowl (migratory)
Landbirds (migratory)	Wetland Terns
Marsh Breeding Birds	Wooded Wetland Birds (breeding season)
Muskrat	Colonial waterbirds (breeding season)

Geographic scope of the assessment:

To complement UWGB's assessment of habitats within the AOC boundary and a buffer area within approximately 1km of the shoreline, The Nature Conservancy focused on the riparian corridors of lower Duck Creek and the lower East River. These areas were identified as holding the best opportunities for locating existing or potentially restorable habitat that could be of value to priority AOC species or species groups.

The field surveys focused on geographies in the AOC watershed that were:

- Near enough to the AOC to reasonably expect (based on species ability and expert opinion) priority AOC species to be able to move from the watershed habitat to the AOC in daily or seasonal movements;
- Well connected to the AOC, i.e., not barred by fragmented landscape or impassable barriers (habitat gaps, culverts, roads, etc.); and
- Subjected to similar hydrologic dynamics as the coastal wetlands of the AOC; i.e., water level changes occurring in Green Bay also impacted the wetlands of the assessed geography.

Methods

For the East River and Duck Creek, existing or potentially restorable habitats of interest were delineated in the field with GPS or using April 2017 aerial photos based on field visits and subsequently digitized using ArcGIS Version 10.3.1. The 2017 aerial photos were obtained from either "BrownDog" GIS mapping application for Brown County Wisconsin or the "GeoPrime" multi-purpose GIS map for Brown County. Additional information obtained from these Brown County land information sources to assist in delineating the habitat boundaries included land form analysis, elevation data, Wisconsin Department of Natural Resources (WDNR) wetland delineations, the Brown County Environmentally Sensitive Area and Brown County Flood Zone Area maps. Data was extracted from these sources throughout the project. Soils information from the USDA-NRCS web soil survey and the Brown County land information website were also utilized. Historic context for the areas assessed was gained through examination of aerial images of the region archived by the Cofrin Center for Biodiversity at the University of Wisconsin-Green Bay. These images were used to gain insight into the land cover and land use changes in the East River and Duck Creek corridors over the past 80 years. The National Oceanic and Atmospheric Administration's Lake Level Viewer was used to facilitate understanding the impacts of water level variation and fluctuation. Other sources which were accessed for relevant ecological, biological, and water quality information included the WDNR's Surface Water Data Viewer and the WDNR's SWIMS database.

Field visits to the East River corridor occurred on 5/17, 5/23, 6/15, 6/20, 6/21, 6/27, 7/11, 7/21, 8/11, 8/19, 8/31, and 11/30 of 2017. Field visits to the Duck Creek corridor occurred on 4/5, 5/5, 5/9, 5/10, 5/12, 5/24, 6/6, 6/8, 6/7, and 7/9 of 2017. All field visits were made either on foot or by canoe. Field assessments were conducted by staff (Michael Grimm) of The Nature Conservancy with occasional assistance from a Conservancy volunteer (Shirley Weese Young). All hand-written field notes, maps, sketches and photographs reside in The Nature Conservancy's North-East Wisconsin Project Office at 242 Michigan Street, Sturgeon Bay, WI 54235.

Habitat Quality

A necessary characteristic of the quality of the habitat within the East River and Duck Creek corridors, and thus the significance of any fish and wildlife habitat, is the relationship of that habitat to a life history need or seasonal usage of that habitat by a AOC priority group or priority species.

Table 5 below indicates the potential utilization of one of the habitats present by a member of a priority species group or priority species. An 'x' indicates that the species or species group utilizes this habitat to satisfy some life history need during the year. Examples of life history needs may include, spawning or breeding habitat, feeding areas, resting sites, migration habitat, or areas of refuge for juveniles.

Table 5: Potential utilization of the habitats present in the East River and Duck Creek corridor by a member of a priority species group or priority species.

	Emergent marsh (Riparian)	**Hardwood swamp**	**Open water inland**	**Tributary Open water**	**Other forest**	**S. dry mesic forest**	**S. sedge meadow**	**Surrogate Grassland Old field**	**Surrogate grassland (restored)**	**Shrub carr**	**Number of habitats serving this species group**
Colonial water birds (breeding season)	x			x							**2**
Freshwater Unionid mussels				x							**1**
Marsh breeding birds	x						x	x	x	x	**5**
Shorebirds (migratory)	x		x				x	x	x		**5**
Tributary fish	x			x							**2**
Coastal wetland mustelids	x	x		x			x			x	**5**
Anurans	x	x	x	x			x	x	x	x	**8**
Bats	x	x	x	x	x	x	x				**7**
Stream macroinvertebrates			x	x							**2**
Turtles	x	x	x	x			x			x	**6**
Coastal birds (breeding season)	x			x							**2**
Fox River fish	x			x							**2**
Wetland terns	x			x							**2**
Wooded wetland birds (breeding season)		x								x	**2**
Land birds (migratory)		x			x	x		x	x	x	**6**
TOTAL Species x habitat relationships	**11**	**6**	**5**	**11**	**2**	**2**	**6**	**4**	**4**	**6**	

Table 5 underscores the importance of the aquatic and wetland habitats of the East River to priority species and species groups of the AOC. The tributary water and riparian emergent marsh habitats hold most of the life history relationships with the priority species and species groups of the AOC. The other wetland habitats; i.e., sedge meadow, shrub carr and hardwood swamp, also hold a considerable number of relationships to the life history requirements for the priority species groups.

Another insight offered by this matrix is the small number of habitat relationships for a few of the priority species groups, pointing to the importance of those habitats in the East River and Duck Creek corridor. For example, freshwater unionid mussels have a life history relationship with only one habitat type, the tributary open water habitat. Wooded wetland breeding birds, stream macroinvertebrates and Fox River fish have only 2 habitat relationships within the East River and Duck Creek corridors. Those habitats that supply life history needs to a species group that is supported in few other habitats should be considered important for protection, restoration or improvement.

The significance any habitat for this project is also dependent on the degree of connectivity of that habitat patch to the core AOC (open waters of Green Bay and the Fox River) and the dispersal abilities of the priority species group or priority species. Larger members of more mobile taxa like birds and fish in general have a higher dispersal ability, and habitat utilized by such taxa would have a higher significance for habitat protection, restoration or enhancement projects to facilitate BUI delisting. Secondly the significance of any habitat for this project was judged by the degree of connectivity of that habitat patch to the other areas of the AOC, especially the coastal areas of lower Green Bay, and the dispersal abilities of the priority species group or priority species. The degree of connectivity of any habitat patch of the Duck Creek corridor to the other habitats of the AOC was estimated subjectively by field investigation and aerial photo interpretation. The dispersal abilities of the priority species groups or species was judged subjectively based on life history patterns and physiological abilities of the species in question.

Estimating Habitat Quality

Habitat quality along the East River and Duck Creek was judged by several factors including habitat patch size, habitat context, diversity of native species, amount of disturbance, age of the stand (forest patches), and presence and dominance of invasive species. Table 6 below identifies the rational used in judging the quality of habitat along the East River.

Table 6: Characteristics used in judging habitat quality

QUALITY	JUDGING HABITAT QUALITY
Excellent	Judged as having a high degree of intact landform, high age of habitat in undisturbed condition, lack of invasive species, lack of threat (i.e., good viability without major management needs), good buffering context, and judged as able to provide habitat for species of AOC interest. A habitat of this quality would be considered to have important value to AOC BUI delisting and warrants conservation with no or minor investments in within site habitat restoration or improvement of natural connectivity to the AOC or one its priority sites.
Good	May have many features of an excellent condition but lacking in some critical features, e.g., may have excellent quality habitat but poor connection to AOC, or in current state may have little relevance to AOC BUIs. A site of this quality may be considered to have sufficient value to AOC BUI delisting to warrant conservation but would require some investments in within site habitat restoration or improvement of a natural connection to the AOC or one its priority sites.
Marginal	Has few habitat features of an excellent or good quality habitat but may be considered to have sufficient value to AOC BUI delisting to warrant conservation if it has strong natural connection to the AOC, or with investments to within site habitat restoration or the improvement of a natural connection to the AOC or one its priority sites some

	improvement to the AOC BUI could be expected.
Poor	Has few habitat features of an excellent or good quality habitat, and only through significant investment in habitat restoration or connectivity could the habitat contribute to AOC BUI improvement.

Results of Field Survey of East River Corridor

General Description

The stretch of the East River riparian corridor considered for this assessment extends from County Road G in De Pere (44.435632 / -88.024887) downstream approximately 12.5 km (7.8 miles) to the Mason Street crossing (44.498975 / -87.994804) in the city of Green Bay. Through this stretch the East River flows slowly as a sinuous to meandering warm water, 5th order stream influenced both by the hydrology and water quality of the upstream watershed and the periodic upstream flow of water from Green Bay via the Fox River during high water seiche events. The landscape covered in this assessment comprises patches of riparian forest, both upland and lowland or floodplain; extensive wetlands fringing the main stem of the river or bordering the mouths of small tributaries; working and abandoned agricultural fields; recreational parks; and to a small degree, areas of commercial and residential development.

For the most part, the assessed area lies within the mapped Environmentally Sensitive Areas (ESAs) and Shoreline Zones for Brown County. The ESAs for Brown County include floodways and their 35 foot buffers, wetlands with a 35-foot buffer, navigable and non-navigable streams with 75 and 35 foot buffers respectively and several other natural features. The assessed area lies entirely within the mapped Flood Hazard Areas (Zones A and AE: the 100-year floodplain, i.e., areas subject to inundation by the 1 percent annual chance flood event) of the East River.

Geology and landform

This section of the East river flows through the "Preble Plains" land type association within the Central Lake Michigan Coastal Ecological Landscape of Wisconsin. The characteristic landform of the river corridor is a nearly level alluvial lake plain of offshore stratified sediments of the Nipissing Lake plain. These sediments have been determined to be several up to 10 meters thick (Need, 1983). Soils of this association are predominantly well drained silt loams, e.g., Oshkosh, Bellevue, Manawa and Poyan silty clay loams, over the calcareous clay lacustrine sediment or till. Near the upper end of the assessment area units of sandy loam soils are found intermixed with the silt loams. The water level of the main stem of the river drops about 3 feet through this stretch, and the river has a sinuous and meandering character with oxbow wetlands present in the floodplain of the river, especially at its confluence with Bower Creek. The most significant oxbows are present in the villages of Allouez and Bellevue above County Road XX (Hoffman Road) (44.456633 / -88.017536). (Figure 5).

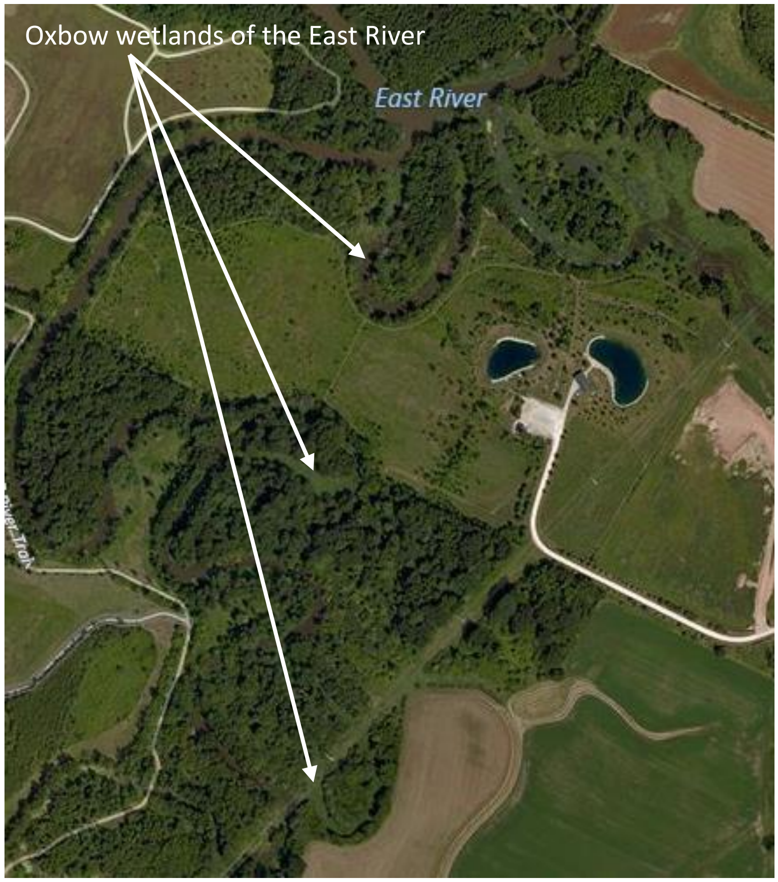


Figure 5. Oxbow wetlands of the East River, Village of Bellevue

Hydrology
Surface water originates in this stretch of the East River predominantly from the main stem of the upper East River, with significant inputs from tributaries such as Bower and Willow Creek, storm water retention ponds and laterally connected wetlands which fringe the main stem of the river. Ground water input is unknown but appears to be minimal in this stretch of the river. This stretch of the river is also under the influence of periodic flows of water from Green Bay and the Fox River during storm or high water seiche events originating on the bay. These seiche events can elevate the water level upwards of two feet in the East River temporarily reversing the flow beyond the confluence of Bower Creek and the main stem of the river. Sieche events can also lower the water level in the river to a similar extent.

Because of its relatively flat alluvial position, the water levels of Green Bay (Lake Michigan) have a major influence on the hydrology of the river and its fringing wetlands. This is particularly true for the oxbow wetlands. During high water, these wetlands may be flooded and confluent with the main stem of the river with river water flowing through the wetland. At lower water levels, the oxbow may only receive water and later drain at a lower elevation open crevasse, usually at the downstream end of the oxbow. Other oxbows in the stretch are completed isolated from the surface flow of the river and have hydrologic dynamics resembling ephemeral ponds.

The East River and its primary tributary in this section, Bower Creek, are classified as Impaired by phosphorus and sediment under section 303(d) of the Clean Water Act, with impairments negatively impacting in-stream habitat, and creating high turbidity and elevated temperatures in the river's water. According to the Total Maximum Daily Load plan for the Lower Fox River Basin and Lower Green Bay, the East River is a major contributor of total phosphorus (13.9%) and total suspended solids (21.3%) to the Lower Fox River and subsequently Green Bay.

While of lesser extent in the riparian area of the river which was assessed, agriculture is the dominant land use in the Upper East River watershed and considered the main contributor to the poor water quality of the river. The recently completed Nonpoint Source Implementation Plan for the Upper East River Watershed contains additional information regarding the conditions of the upper watershed.

General habitat notes

Although already impacted by settlement of this area by European immigrants in the late 1700s to early 1800s, land surveyor records of the 1830's indicate a landscape comprising forests of oak, maple and basswood with extensive areas holding marsh, wet prairies and sedge meadows near the lower reaches of the river. Extensive clearing of these forests for agriculture and over time the growth of the city of Green Bay, De Pere and the villages of Allouez, Ledgeview and Belleview left only small patches of isolated forest along the river corridor by the 1940s. However, the wetlands fringing the river and oxbow wetlands persisted through this period of extensive agricultural and urban expansion as areas harvested for marsh hay or cropped fields during periods of low water. Aerial photos taken in the late 1930's show a landscape dominated by agricultural fields, wetlands and a few remnant forest patches. Since the mid 1930's agriculture has declined, though not completely left, this riparian corridor and significant patches of young to pole stage forests now line the river and fringing wetlands. Currently, the upper reach of the assessed area is more heavily dominated by natural cover (i.e., forest and fringing wetlands), while the lower extent finds more old fields, fringing wetlands and development along the shoreline.

Edge habitat or ecotone conditions dominate the East River riparian corridor, with the average habitat patch size for forest and wetland habitats being about 6.5 acres. In addition to small patch size, the bordering residential communities and the banks and open water of the river itself added to the fragmented nature of the assessed area. For the most part, the ecotones of the assessed area are softened by a mix of diverse shrub species, native and non-native, and young native trees. A rich suite of native shrubs including gray and red twig dogwood, hawthorn, nannyberry, sumac, choke cherry, prickly ash, ninebark, wild grape and several non-native species including bush honeysuckle, apple trees and buckthorn (*Rhamnus cathartica*) mix with young trees and old field herbs along the borders of the woods and grassy old fields. The prevalence of this situation is reflected in the high number of edge bird species recorded during the assessment (Appendix I).

Scattered through the upper reaches of the assessed corridor are several patches of high quality sedge meadow, shrub carr and southern dry-mesic forest. The complex of land comprising the City of De Pere East River Parkway, the Village of Belleview's Osprey Point Conservancy, Allouez's Wiese Park and private lands, is a mix of sedge meadows in the connected to isolated oxbow wetlands, shrub carr and emergent wetlands, restored grasslands, mature upland forests of white and red oak, and sugar maple; and lowland forests of basswood, green ash, box elder and cottonwood. This landscape holds the highest quality habitat along the assessed section of the river as it is least fragmented natural cover, highest quality representations of the natural communities found along the river, and least presence of invasive plants, though not completely without several patches needing attention.

In 1989 Henry Quinlan (Quinlan, 1989) ran transects across the East River at several locations within the reach assessed for this project. He found the river bed from Mason Street upstream to the confluence with Bower Creek to have fine sediments occupying the thalwig and side slopes of the channel. Sand if present was found on the side slopes. Organic matter occupied the shallow nearshore zone at the toe of the bank. Above the confluence with Bower Creek, the East river narrows noticeably and Quinlan found a mix of fine sediment, sand, gravel and some rock in the deepest part of the channel, with any organic matter found in the shallow near shore water.

Given the high sediment load and impaired nature of the East River, the habitat quality of the open water of the main stem of the river is considered fair to poor. However, despite the heavy turbidity of the river several submerged aquatic plant species were noted and in some cases formed large stands in the river. *Ceratophyllum demersum, Potamogeton nodosus* and *Stuchenia pectinata* were the most commonly encountered species, and as mentioned often formed large stands in the river particularly upstream of the Highway 172 bridge. The complete cataloguing of the submerged vegetation, stream bed morphology, and macroinvertebrate community of the river is needed to fully assess the habitat quality and guide habitat restoration work in the river itself.

The natural pattern of high cut or scoured banks on the outside of the meanders and low bars extending into the channel on the inside curve of the meanders generally holds true on the East River, though many stretches of the river have been armored by additions of rip-rap of concrete rubble to the stabilize the banks. It was common to see high banks 6 to 8 feet above the water level at the time of this assessment armored with concrete slabs.

Special Features

The East River corridor has several geomorphic, ecologic, hydrologic and anthropomorphic features of significance for AOC target species and habitats. These include:

- Several intact oxbow wetlands each with unique hydrology but in general holding patches of fair to superior quality sedge meadows (Figure 6);

Figure 6. Sedge meadow of an oxbow wetland near the confluence of Bower Creek and the East River

- Large river fringing wetlands with varying, but mostly good, connectivity to the open water of the river and holding examples of both inland emergent marshes and sedge meadows, though in most cases the wetter areas have become dominated by non-native *Phragmites* and the sedge meadows in several settings have been invaded by reed canary grass;
- Unimpeded open water access for Green Bay migratory fish to wetlands fringing the main stem of the river and several small tributaries of the river (Figure 7);

Figure 7. Female northern pike captured during the spawning run on a small tributary to Bower Creek.

- Small patch to large blocks of riparian forests situated in both low areas holding lowland hardwood swamps and on higher banks holding stands of southern dry mesic forest (one patch holding a stand of old growth red and white oak and red maple). While not on the AOC coast of Green Bay, or perhaps sufficient in size to support area sensitive species, several wetland to upland blocks of forest occur along the East River that can serve as temporary resource sites for mobile species (e.g., birds, bats) that migrate through the region or have extensive daily foraging patterns.
- Significant amounts of coarse woody debris exist throughout this stretch of the river and increasing amounts can be expected as the riparian trees on the scoured outer cutbanks of the meanders mature and eventually fall into the river. (See Figure 8). The upper reaches of the assessment area have the largest amount of this structural feature;

Figure 8. Large green ash (Fraxinus pennsylvanica) which was undercut by the stream and toppled into the East River during the assessment. The tree completely crosses the stream. Note height of scoured bank below tree roots.

- Much of the floodplain of the river is in public ownership and it appears the communities which line the banks of the river (Green Bay, Allouez, De Pere, and Belleview) are seeking to protect these riparian lands as sites for recreation and storm water management projects. This high percentage of public ownership may represent opportunities to partner with these communities for consolidating public ownership of the riparian area for multiple public benefits including protecting, restoring or rehabilitating fish and wildlife habitat for AOC target species and habitats.

General Habitat / Natural Community / Species Comments

The habitat types (communities) identified in the section of the East River corridor assessed and their total coverage are listed in Table 9 below. Please refer to the UWGB website for descriptions of the habitat types identified in this report.

Table 9. Habitat types and acreage on the East River.

EAST RIVER	
Habitats	**Acres**
Active Rowcrop Ag	404.6
Emergent marsh inland	344.5
Floodplain Forest	80.6
Hardwood swamp	318.6
Open water	191.9
Open water inland	43.4
Other forest	9.6
Shrub carr	71.7
Southern dry mesic forest	161.8
Southern sedge meadow	70.9
Surrogate grassland (old field)	1400.7
Surrogate grassland restored	41.7
Other	107.1
TOTAL	**3247.1**

Table 10. Summary Field Assessment Notes on Priority Species or Species Group

Priority Species or Species Group	Comments on Presence in East River Assessed Area
Anurans	Frogs utilize several wetland types in the assessed area, river fringing wetlands, oxbow wetlands, isolated ponds, natural flow channels, storm water management ponds. Green grey tree and frogs were the most common representative species.
Bats	No information
Coastal birds (breeding season)	n/a
Coastal wetland aquatic macroinvertebrates	n/a
Coastal wetland mustelids	None observed in 2017
Colonial water birds (breeding season)	Cormorants and red-breasted mergansers are seen resting or feeding on the river through the summer into late fall until ice up.
Fox River fish	n/a
Freshwater Unionid mussels	No Information
Land birds (migratory)	Many species of warblers, flycatchers, finches and other species of land birds were encountered in May (see Appendix I) utilizing the river and habitat patch edges in the assessment area. The roughly north-south orientation of the river corridor favors the usage of the river corridor by birds for extended periods during migration. The abundance of fruit bearing shrubs found at habitat edges favors fall migrating species dependent on this resource.
Marsh breeding birds	Green, great blue, and black-crowned night herons, mallards, Canada geese, wood ducks, and great egrets found throughout the summer in fringing and tributary wetlands. Sandhill cranes seen feeding during migration in fringing wetlands unknown if they breed here.
Nearshore invertebrates	n/a
Shorebirds (migratory)	Spotted sandpipers seen along the river utilizing the narrow mudflats which edge the river below the dense shade of overhanging *Salix nigra* and *Acer negundo*.
Shoreline fish	n/a
Stream macroinvertebrates	Macroinvertebrates (e.g., caddis fly larvae, Grammaridae, Asellidae) found in submerged aquatic vegetation. Other invertebrates (e.g., Odonates, see Appendix I) found associated with oxbow wetlands and main stem of river.
Tributary fish	See Appendix I for list of fish found in the East River and Bower Creek.
Turtles	Snapping turtles seem on main stem of river.
Wetland terns	None observed in 2017.
Wooded wetland birds (breeding season)	The most common breeding species of lowland hardwood forests encountered during the assessment included blue-gray gnatcatcher, American redstart, black-capped chickadee, warbling vireo, Baltimore oriole, wood duck (See Appendix I).

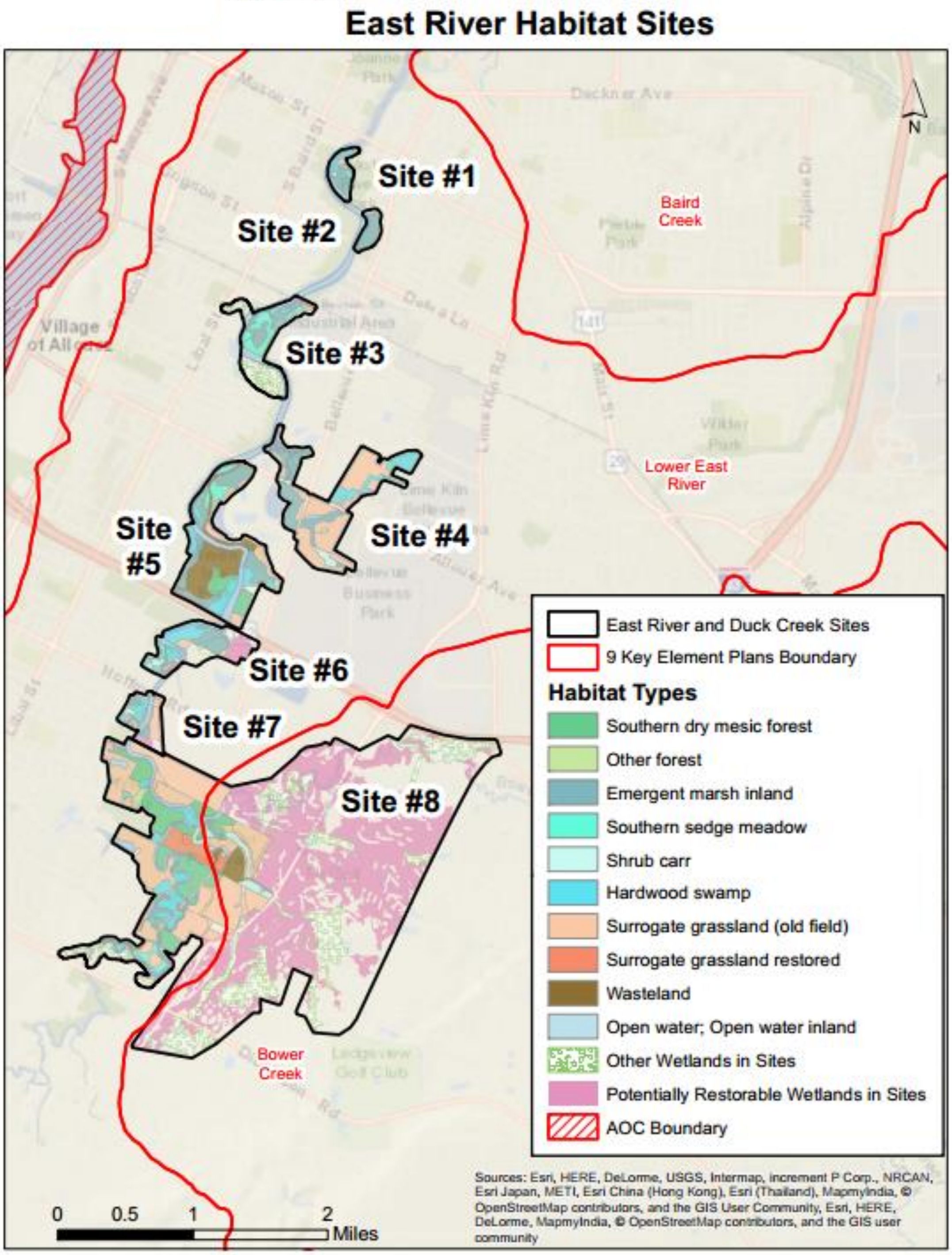
Significant Invasive Species and Management Issues

The partially urbanized corridors of the East River hold many plant species considered not native to the area. The disturbance history of the area has open many of the habitat patches to multiple new species which have become established, and in some cases, dominate the habitat patches. For example, the riparian emergent marshes along the East River are now heavily infested with Phragmites spp,; *Phalaris arundinacea*, (reed canary grass) and *Typha angustifolia* (narrow-leaved cattail). On damp soil sites supporting sedge meadow and shrub carr habitats, *Rhamnus frangula (*alder buckthorn*) and Phalaris arundinacea* are often common species. On drier upland forest habitats *Rhamnus cathartica* (common buckthorn*), Clynoglosum officinale (*hound's tongue*), Hesperis matronalis (*dame's rocket*),* and *Lonicera tatarica (*honeysuckle*),* or other non-native species of the *Lonicera* genus were commonly encountered. These species have become naturalized into this landscape and it is unrealistic to assume or expect that control or management measures needed to remove them from the landscape will be possible. The best approach may be to accept their presence and impact in the landscape and apply any control management efforts to the remnant habitat patches of highest (i.e., least invaded) quality; incorporate easily sustained ecological and hydrological processes into restoration projects that discourage invasion by target non-native species; and monitor the habitats or sites of highest interest to detect new species at the earliest date.

Table 11. Summary field notes regarding non-native plants found during the East River assessment.

Habitat Types	Significant Invasive Species Encountered
Surrogate Grassland Old field	Generally dominated by non-native grasses (e.g., *Bromus inermis, Phalaris arundinacea*) and non-native herbs (e.g., *Cirsium arvense, Daucus carota, Melilotus alba, Coronilla varia*)
Agriculture	n/a
Hardwood swamp	*Phalaris arundinacea; Rhamnus frangula, R. cathartica*
S. dry mesic forest	*Rhamnus cathartica, Clynoglosum officinale, Hesperis matronalis, Lonicera tatarica, or other non-native species of the Lonicera genus*
Emergent marsh (riparian)	*Phragmites australis* (though treated in 2016 and most stands showed major dieback), *Phalaris arundinacea, Typha angustifolia*
S. sedge meadow	*Phalaris arundinacea, Typha angustifolia*
Shrub carr	*Rhamnus frangula, Phalaris arundinacea*
Surrogate grassland (restored)	There were few invasives on these restored and managed sites
High impact	n/a
Open water inland	Data gap
Other forest	*Rhamnus cathartica, Lonicera tatarica, or other non-native species of the Lonicera genus*
Open water (tributary)	Data gap

Site Descriptions for Sites of the East River Corridor



Map also shown in Appendix G.

Site 1: Van Beaver Park Wetland 1

Location and Ownership

This site is located wholly within Van Beaver Park, city of Green Bay, and .24 miles upstream of the East Mason Street Bridge on the east side of the river; (center of site: Lat: 44.4962, Long: -87.9976). The open water of the Fox River is 2.5 river miles from the wetland and the site is 1.2 miles from the open water of the Fox River by air.

Physiography and Vegetation

Van Beaver Park Wetland 1 site is a longitudinally isolated riparian wetland complex comprising a central emergent marsh grading into shrub carr and lowland hardwood vegetation on its fringe. The site is laterally connected to the main stem of the East River via a single large (7-foot width, 40 feet long) culvert under the shoreline walking trail. The culvert is located at Lat. 44.4961, Long. -87.9983.

Historic photos indicate fill was added to the northern portion of the site sometime in the late 1950's and the shoreline separating the wetland from the main flow of the river is lined with blocks of concrete rip-rap.

Non-native vegetation dominates the upland and wetland soils of the site. Phragmites and reed canary grass dominate the core of the emergent wetland, though the condition of the Phragmites has been severely degraded by a fall 2016 herbicide treatment. Historic photos indicate a central U-shaped body of open water will form during periods of high water. The shrub carr habitat is confined to small patches and comprises mostly sand-bar willow. The lowland hardwood forest comprises scattered, large cottonwoods with green ash to form a canopy over box elder, buckthorn (*Rhamnus cathartica*), and hawthorn. Bow elder and black willow, mix with the hawthorn, buckthorn, non-native honeysuckle, and black locust along the edge of the site.

Non-native herbaceous vegetation (e.g., dame's rocket, sweet white clover, motherwort, hound's tongue, garlic mustard) form the dominant ground cover on the upland areas of the site.

Habitats and Acreage for Site 1: Van Beaver Park Wetland

Van Beaver Park Wetland East River		
Habitat Type	**Acres**	**Patches**
Open water	14.9	1
Hardwood swamp	8.9	3
Emergent marsh inland	8.7	1
Shrub carr	3.2	3
Surrogate grassland (old field)	1.4	1
TOTALS	37.1	9

Ecological Functions

- Migratory and breeding habitat for urban waterfowl
- Minor migratory feeding habitat for land birds
- Fish spawning site for wetland spawning fish (e.g. northern pike)
- Urban storm water sediment and nutrient capture
- River water nutrient and sediment capture and transformation
- Flood storage capacity

Value of Site to Support BUI removal

See **Table 17** for information on the recommended actions for this site, those priority species and habitats that would be positively impacted by those actions and the relevant AOC objectives served by those actions.

Site 2: China Plate Wetland

Location and Ownership

This site is also located just south of Van Beaver Park, city of Green Bay, approximately .25 miles upstream of site #1 on the east side of the river; (center of site: Lat: 44.4919, Long: -87.9941). The open water of the Fox River is 2.75 river miles from this site and the site is 1.4 miles from the open water of the Fox River by air.

Physiography and Vegetation

This site is a longitudinally isolated riparian wetland comprised almost entirely of an emergent marsh recently dominated by Phragmites and reed canary grass. The site is laterally connected to the main stem of the East River along its entire length (about 1.7 miles) and no rip-rap fill was noted at the site. An urban storm water drain enters the site from the northeast through a shrub thicket lined channel, and a minor intermittent flow path drains the middle portion of the wetland. Historic photos indicate the site was used in times of low water for agriculture (hay meadow) but no evidence of fill was noted.

Phragmites and reed canary grass dominate the core of the emergent wetland, though, as in Site #1, the condition of the Phragmites has been severely degraded by a fall 2016 herbicide treatment.

The site is called "China Plate" wetland because of the number of broken china plates and other household garbage removed from the site when the city took ownership.

Habitats and Acreage for Site 2: China Plate Wetland

China Plate Wetland East River		
Habitat Type	**Acres**	**Patches**
Emergent marsh inland	15.1	1
Open water	16.9	1
TOTALS	32.0	2

Ecological Functions

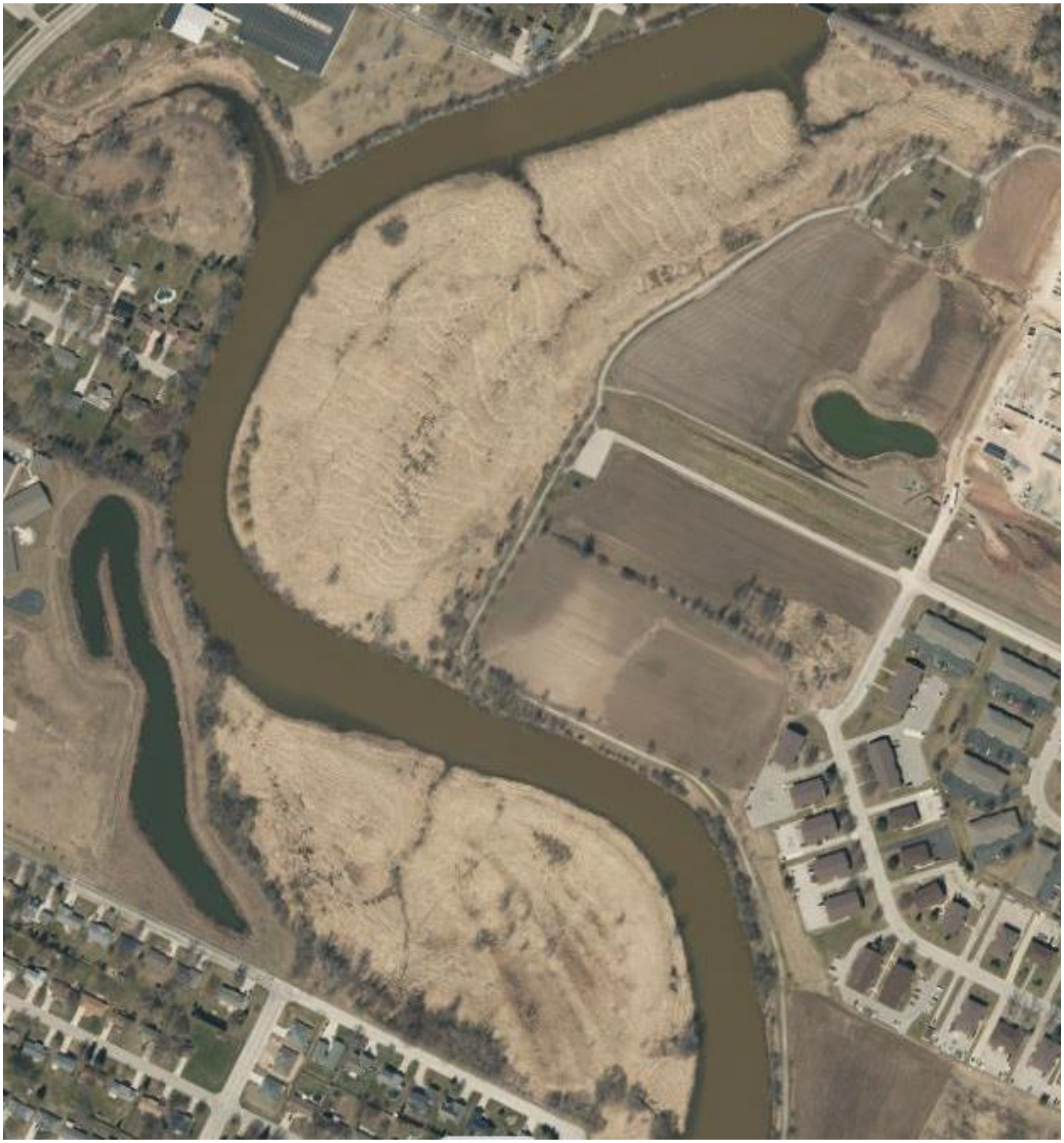
- Migratory and breeding habitat for urban waterfowl
- Fish spawning site for wetland spawning fish (e.g. northern pike)

- Sediment and nutrient capture from main flow of the East River
- Urban storm water sediment and nutrient capture
- Flood storage capacity

Value of Site to Support BUI removal

See **Table 17** for information on the recommended actions for this site, those priority species and habitats that would be positively impacted by those actions and the relevant AOC objectives served by those actions.

Site 3: Railroad Track Wetlands



Location and Ownership

The habitats comprising this site lie on both sides of the river approximately .6 miles upstream of Site #2 (center of site: Lat: 44.484, Long: -88.0066) and is owned by two municipalities (Village of Allouez and Village of Bellevue) and a private owner (Krueger International). The open water of the Fox River is about 3.33 river miles from this site and the site is just under a mile from the open water of the Fox River by air.

Physiography and Vegetation

This site comprises 2 patches of riparian emergent marsh, and the corridor and open water of a small lateral tributary to the East River which enters the site from the west. The riparian emergent wetlands of this site are partially disconnected from the main stem of the East river by banks of rip-rap, but long stretches of the wetland are clear of rip-rap and river water inundates these wetlands during high water periods. Several flow paths drain the interior of the wetlands. Historic photos indicate the wetlands were under agricultural use (pasture / marsh hay) in the late 1930s but the area has been under natural cover since the late 1970s.

Non-native vegetation dominates the wetland soils of the site with Phragmites and reed canary grass being the primary cover in emergent wetland area. However, as in sites 1 and 2 the stand of Phragmites has been severely degraded by a fall 2016 herbicide treatment.

Remnant patches of sedge meadow were found scattered along the fringes of the wetland and the site may have potential to restore this habitat type.

Habitats and Acreage for Site 3: Railroad Track Wetlands

SITE 3 East River		
Habitat Type	**Acres**	**Patches**
Emergent marsh inland	62.6	5
Open water	41.6	1
Southern sedge meadow	28.3	4
Surrogate grassland (old field)	2.6	1
TOTALS	135.1	11

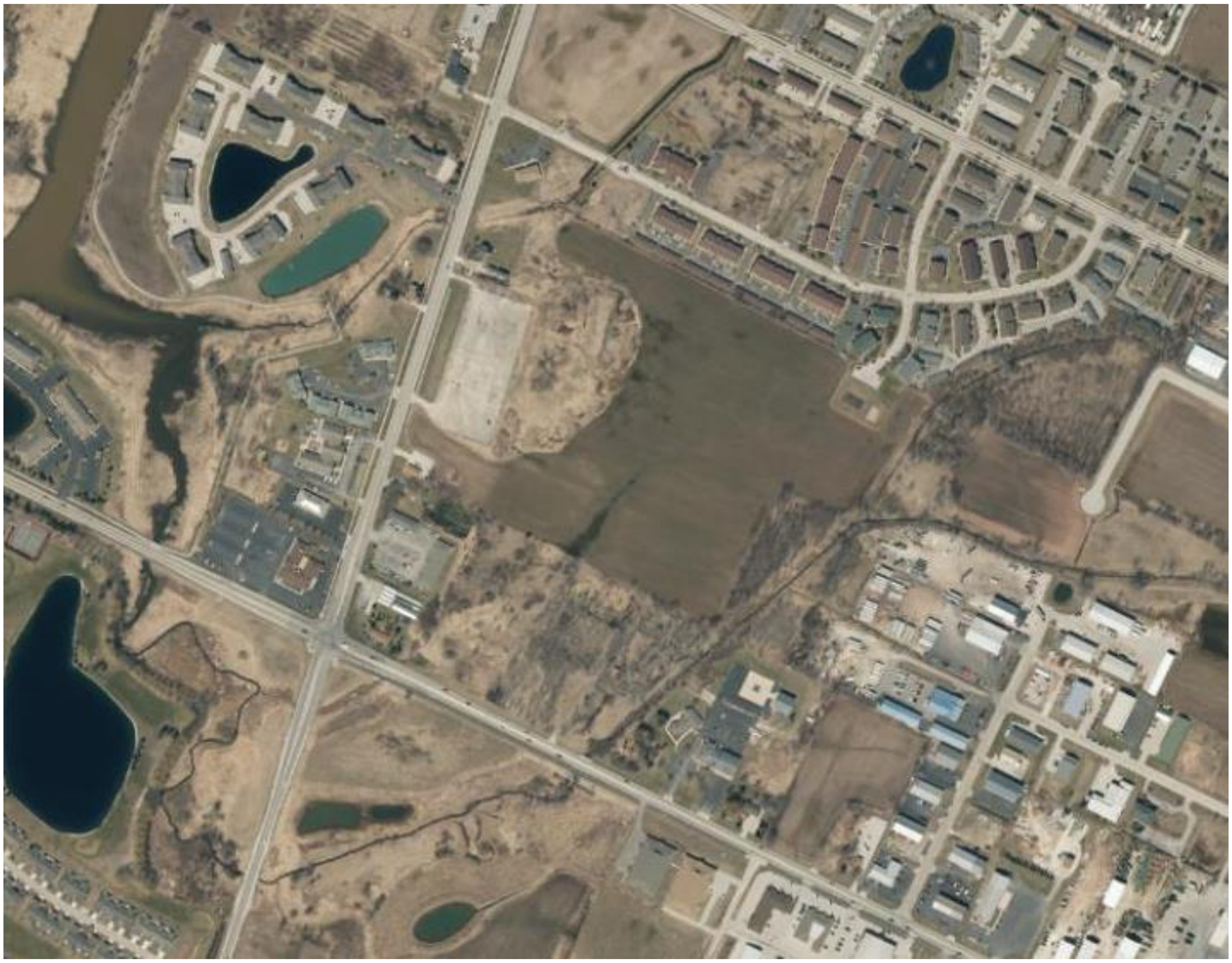
Ecological Functions

- Migratory and breeding habitat for urban waterfowl
- Habitat for keystone marsh mammals; i.e., muskrat
- Fish spawning site for wetland spawning fish (e.g. northern pike)
- Sediment and nutrient capture from main flow of the East River
- Suburban storm water sediment and nutrient capture
- Sheltered feeding and resting habitat for migrating diving and puddle ducks
- Flood storage capacity

Value of Site to Support BUI removal

See **Table 17** for information on the recommended actions for this site, those priority species and habitats that would be positively impacted by those actions and the relevant AOC objectives served by those actions.

Site 4: Willow Creek Complex



Location and Ownership

This site threads through a large area at the junction of Bellevue Street and Allouez Avenue (Lat: 44.4719; Long: -88.0009). The site lies about .28 miles upstream of Site 3; about 3.61 miles upstream of the Fox River and about 1.4 miles from the Fox River by air. Multiple land owners are present in this site.

Physiography and Vegetation

Willow Creek is a second order stream that collects water from a series of small perennial and intermittent flows and enters the East River at this site after passing through a large floodplain fragmented by roads and commercial and residential development. While the upper portions of Willow Creek and its tributaries have retained some of their natural morphology and riparian habitat, many of the streams draining this watershed show signs of ditching and straightening as they cross the East River floodplain before coalescing at the mouth of the creek. Much of the remnant natural vegetation (emergent marsh, shrub carr and hardwood swamp) of this site resides as riparian habitat along these stream and flow paths. The riparian emergent wetland habitat of the site fringes the mouth of Willow Creek and is dominated by Phragmites and narrow-leaved cattail.

Habitats and Acreage for Site 4: Willow Creek Complex

Willow Creek Complex East River		
Habitat Type	**Acres**	**Patches**
Emergent marsh inland	50.6	5
Hardwood swamp	29.2	3
Open water	12.4	1
Open water inland	4.9	3
Shrub carr	6.3	1
Surrogate grassland (old field)	115.9	11
TOTALS	219.3	24

Historic photos indicate much of the floodplain portions of the site were under agricultural use (row cropping and pasture) in the 1930s and some of the meanders of Willow Creek above Bellevue Street can be seen in the old aerial photos. Currently much of the floodplain is typed as "Potentially Restorable Wetlands" and present opportunities for enhancing or restoring fish spawning and wildlife habitat.

Ecological Functions

- Spawning site for wetland spawning fish (e.g. northern pike)
- Migratory and breeding habitat for urban waterfowl
- Migratory habitat for shorebirds
- Minor migratory feeding habitat for land birds
- Urban and suburban sediment and nutrient capture from main Willow Creek watershed
- River water nutrient and sediment capture and transformation
- Flood storage capacity

Value of Site to Support BUI removal

See **Table 17** for information on the recommended actions for this site, those priority species and habitats that would be positively impacted by those actions and the relevant AOC objectives served by those actions.

Site 5: Green Isle Park Complex

Location and Ownership:

The Green Isle Park Complex stretches from Allouez Avenue at the downstream end of the site to Highway 172 on the upstream end, with the approximate center of the site at Latitude 44.4686, Longitude -88.0111. There are multiple landowners of this site, both public and private with the major public lands being owned by the Village of Allouez and the Village of Bellevue as parkland. The open water of the Fox River is approximately 4.38 miles downstream of the center of the site and the Fox river is about 1.2 miles from the site by air.

Physiography and Vegetation

The entire site lies within the Flood Zone AE and its Floodway of the East river and holds a diverse mix of wetland and upland habitat types in the riparian zone of both sides of the East River.

The riparian emergent wetland bordering the east bank of the East River at the downstream end of the site is not rip-rapped and open to flooding by the river. This wetland holds remnant sedge meadow patches scattered through the dominant growth of reed canary grass and cattail. Phragmites stands growing along the open water edge of the wetland have been treated in 2016. The other significant riparian emergent wetland occurs just upstream of the canoe / kayak launch on the east side of the river. This wetland grades into the river in a slack water, silty area and is also open to inundation during high water periods. From the open water, the gently sloping grade holds a natural transition gradient from river emergent marsh through shrub carr to lowland forest.

This site is the first site to have significant patches of upland forest along the river above the city of Green Bay. Historic (1938) aerial photographs show several patches of remnant forest in the northern and eastern sections of Green Isle Park. While the northern stand has been thinned to a stand of scattered large diameter red oaks in a park like setting, the eastern stand in the park has maintained a solid canopy condition.

Habitats and Acreage for Site 5: Green Isle Park Complex

Green Isle Park Complex East River		
Habitat Type	**Acres**	**Patches**
Emergent marsh inland	64.1	6
Hardwood swamp	31.4	5
Open water	39.7	1
Other forest	2.3	2
Southern dry mesic forest	24.6	2
Southern sedge meadow	15.3	4
Surrogate grassland (old field)	18.0	7
Other*	80.7	2
TOTALS	276.1	29

*Note the term "Other" was used in this project to designate areas of high development embedded in a site and not targeted for habitat restoration or enhancement projects. It is used here as the term for areas mapped as non-target habitat in this project.

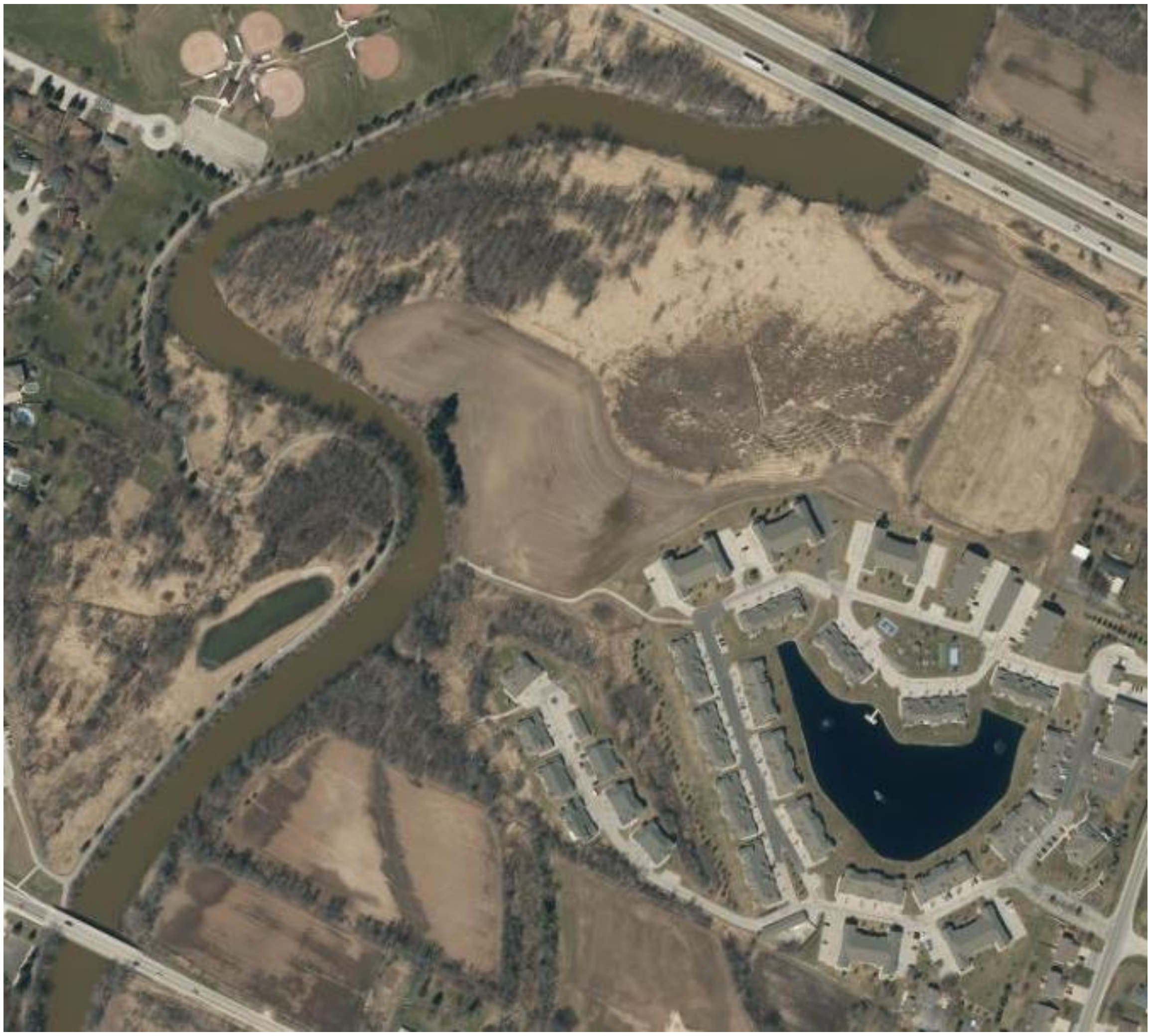
Ecological Functions

- Spawning site for wetland spawning fish (e.g. northern pike)
- Migratory and breeding habitat for urban waterfowl
- Migratory habitat for shorebirds
- Migratory feeding habitat for land birds
- Suburban storm water sediment and nutrient capture
- River water nutrient and sediment capture and transformation
- Flood storage capacity

Value of Site to Support BUI removal

See **Table 17** for information on the recommended actions for this site, those priority species and habitats that would be positively impacted by those actions and the relevant AOC objectives served by those actions.

Site 6: Riparian Parkland



Location and Ownership

This site comprises the riparian lands between Highway 172 at its downstream end to East Hoffman Road (County XX) at the upstream end. Center of the site is approximately Lat. 44.4610 and Long. -88.0157. The Villages of Bellevue and Allouez own considerable acreage in this site as parkland. Private land was also included in the assessed area for this site; primarily on the east side of the river.

Physiography and Vegetation

The site lies entirely within the Environmentally Sensitive Area and Flood Zone Area of the East River corridor. A large complex comprising emergent marsh and lowland hardwood forest dominates the east shore of the site just upstream of Highway 172. This lowland forest occupies a point bar of the river with several meander scars, or natural levees, present forming a gentle ridge and swale pattern across the low river terrace. Pole size basswood, green ash, elm grow beneath larger cottonwoods in the core of the stand, as box elders and black willows arch out over the river at the forest edge. The vegetation on the west shore of the site is a mix of lowland hardwoods, shrub car and small, high quality sedge meadow patches. Rip-rap, up to 8' above present water line, armors the river banks on the outside bends of the river, and is overgrown with shrubs (e.g., ninebark, red-twig dogwood, sumac, non-native honeysuckle, nannyberry) and wild grape.

The biking / hiking trail on the west side of the river swings around a high-quality patch of sedge meadow about .17 miles south of the parking lot at the end of Broadview Drive. This sedge meadow borders an intermittent flow path that drains a shrub carr / lowland forest patch to the south.

A small lowland forest patch adjacent to the storm water pond / prairie restoration at the south end of the site comprises pole size green ash, basswood, and box elder over a thick understory of buckthorn (*Rhamnus cathartica*) and scattered red-twig dogwood.

Patches of submerged aquatic vegetation, which began to appear just downstream of the Highway 172 bridge are more obvious here in the nearshore areas of the river. Common species included coontail, long-leaf pondweed, sago pondweed.

Habitats and Acreage for Site 6: Riparian Parkland

Riparian Parkland Site East River		
Habitat Type	**Acres**	**Patches**
Active Rowcrop Ag	27.0	1
Emergent marsh inland	27.4	6
Hardwood swamp	29.3	4
Open water	19.8	1
Open water inland	1.1	1
Shrub carr	3.7	1
Southern sedge meadow	2.5	2
Surrogate grassland (old field)	8.7	3
Surrogate grassland restored	2.4	1
TOTALS	121.9	20

Ecological Functions

- Breeding habitat for anurans, bats, marsh breeding birds, muskrat, stream macroinvertebrates, turtles, and wooded wetland birds.
- Good migratory stopover feeding and refuge habitat for waterfowl, shorebirds and land birds
- Potential spawning habitat for wetland spawning fish (e.g. northern pike)
- Sediment and nutrient capture from main flow of the East River
- Suburban storm water sediment and nutrient capture
- River water nutrient and sediment capture and transformation
- Flood storage capacity

Value of Site to Support BUI removal

See **Table 17** for information on the recommended actions for this site, those priority species and habitats that would be positively impacted by those actions and the relevant AOC objectives served by those actions.

Site 7: East Hoffman Road Site

Location and Ownership

This site lies just upstream from East Hoffman Road with its center at approximately Lat. 44.4534 and Long. -880193. The site center is about 6.76 miles from the confluence of the East and Fox Rivers by river miles and 1.8 miles by air east of the Fox River. The Village of Allouez owns the land on the west side of the river and several private lands were included in the site on the east side of the river.

Physiography and Vegetation

This small site holds a mix of lowland hardwood forest, open old field grasslands, shrub carr, small emergent wetland patches and a prairie restoration surrounding a storm water pond. The small patch of natural habitat on the west side of the river just upstream of Hoffman Road holds lowland forest, emergent mash and shrub carr habitat. The forest comprises pole sized green ash, basswood and cottonwood over a dense *Rhamnus cathartica* understory. The emergent wetland is fringed by patches of Phragmites but dominated by cattail, and the shrub carr comprises a mix of willows, scattered green ash over reed canary grass and sedges.

Habitats and Acreage for Site 7

East Hoffman Road Site East River		
Habitat Type	**Acres**	**Patches**
Emergent marsh inland	5.4	2
Hardwood swamp	11.3	1
Open water	6.9	2
Open water inland	1.5	1
Other forest	1.5	1
Shrub carr	2.4	1

Surrogate grassland (old field)	13.0	3
Surrogate grassland restored	2.4	1
TOTALS	44.4	12

Ecological Functions

- Breeding habitat anurans, bats, stream macroinvertebrates, turtles, and wooded wetland birds.
- Fair migratory stopover feeding and refuge habitat for land birds
- Suburban storm water sediment and nutrient capture
- River water nutrient and sediment capture and transformation
- Flood storage capacity

Value of Site to Support BUI removal

See **Table 17** for information on the recommended actions for this site, those priority species and habitats that would be positively impacted by those actions and the relevant AOC objectives served by those actions.

Site 8: East River / Bower Creek Oxbows Conservation Area

Location and Ownership

This large natural habitat complex is located at the confluence of Bower Creek and the East River; Lat. 44.4468, and Long. -88.0124. The center of the site is about 7.43 miles from the confluence of the East and Fox Rivers and approximately 2.3 miles by air from the Fox River to the west. The site lies entirely within the East River Flood Zone and a majority of the site lies with the mapped ESA for the East River.

There are multiple landowners within the site, including private, public (Villages of Allouez and Bellevue and the City of De Pere) and a non-profit conservation organization (Izaak Walton League).

Physiography and Vegetation

The landscape at the confluence of Bower Creek and the East River comprises meandering perennial and intermittent stream channels, oxbow wetlands and riparian wetlands adjacent to uplands holding old-growth hardwood stands, young forest, old field grasslands and agricultural fields. East of County Road GV the floodplain which drains to this site holds a large acreage of existing and potentially restorable wetlands connected to the main stem of the East River by a network of intermittent or perennial flow paths and wetlands.

Habitats present include emergent marsh (riparian), hardwood swamp, upland dry-mesic forest, sedge meadow, restored grasslands, and shrub carr with transitional ecotones present between these habitats throughout the site.

One of the most prominent hydrogeologic features of this landscape are the multiple intact oxbow wetlands in the floodplain at the junction of Bower Creek and the East River. These oxbow wetlands hold sedge meadow habitat in varying degrees of quality, in part dependent on the river water levels, hydroperiod of the wetland, and degree of connectivity with the main flow of the East River and Bower Creek.

Above the confluence of Bower Creek and the East River, the East River narrows considerably and large oaks and basswoods begin to over arch the river, in some cases with branches that reach across the width of the stream. As a consequence, the river becomes shadier above this point and exposed mud flats and stream banks begin to appear along the edge of the river. Coarse woody debris remains scattered and of small diameter as further downstream, but the potential for branches and boles of these large river bank trees to fall and add material to the stream bed is high.

The west side of the river holds several high quality, though small, patches of sedge meadow and a large open water / emergent marsh complex that drains clear water to the river via two outlets. These floodplain wetlands present good opportunities for fish and wildlife enhancement projects.

Habitats and Acreage for Site 8: East River / Bower Creek Oxbows Conservation Area

East River/Bower Creek Oxbows Conservation Area		
Habitat Type	**Acres**	**Patches**
Active Rowcrop Ag	377.6	5
Emergent marsh inland	110.5	9
Floodplain Forest	80.6	4
Hardwood swamp	208.4	29
Open water	39.8	3
Open water inland	35.9	16
Other forest	5.8	1
Shrub carr	56.2	9
Southern dry mesic forest	137.2	17
Southern sedge meadow	24.8	5
Surrogate grassland (old field)	1240.9	38
Surrogate grassland restored	36.9	2
Other	26.3	2
TOTALS	2380.9	140

This site offers neighboring municipalities an opportunity to develop nature based recreational activities in a natural setting adjacent to a large urban area. The East River walking and biking trail on the west side of the river and the Osprey Point Conservation Area on the east side of the river are already established points of entry for people into this area.

Ecological Functions

- Breeding habitat for waterfowl, anurans, bats, Fox River fish, marsh breeding birds, muskrat, stream macroinvertebrates, tributary fish, turtles, and wooded wetland birds.
- Good migratory stopover feeding and refuge habitat for waterfowl, shorebirds and land birds
- Spawning habitat for wetland spawning fish (e.g. northern pike)
- Sediment and nutrient capture from main flow of the East River
- Suburban storm water sediment and nutrient capture
- River water nutrient and sediment capture and transformation
- Flood storage capacity

Value of Site to Support BUI removal

See **Table 17** for information on the recommended actions for this site, those priority species and habitats that would be positively impacted by those actions and the relevant AOC objectives served by those actions.

Results of Field Survey of Duck Creek Corridor

General Description

The stretch of the Duck Creek riparian corridor considered for this assessment extends from the Highway 29 crossing (44.545922 / -88.094851) downstream approximately 5.15 km (3.2 miles) to a point just upstream of the Highway 41/141 bridge near the mouth of the stream (44.564005 / -88.055234) in the city of Green Bay. Through this stretch Duck Creek flows slowly as a sinuous warm water stream influenced, as the East River, both by the hydrology and water quality of the upstream watershed and the periodic upstream flow of water from Green Bay during high water and / or seiche events. The riparian cover varies from sections with small homes set near the river above rip-rapped low banks often with a small dock, to scattered patches of riparian forest, both upland and floodplain; small patches of sedge meadow or emergent marsh bordering the main stem of the river; and scattered lands dedicated to public uses such as recreation and storm water management. A few commercial buildings occur near the Velp Avenue bridge and adjacent to the Village of Howard's Memorial Park. For long stretches the banks of the river are concealed by thickets of young box elder (Acer negundo), non-native honeysuckle, saplings and sprouts of basswood (*Tilia americana*), sumac (*Thyphina spp*), non-native *Rhamnus* spp., ninebark (*Physiocarpus oppulifolius*), nanny berry (*Viburnum lentago*), choke cherry (*Prunus virginiana*), and other shrub species, all often overgrown with wild grape (*Vitis riparia*).

The assessed area lies entirely within mapped Environmentally Sensitive Areas (ESAs) and Shoreline Zones for Brown County. The ESAs for Brown County include floodways and their 35 foot buffers, wetlands with a 35-foot buffer, navigable and non-navigable streams with 75 and 35 foot buffers respectively and several other natural features. The assessed area lies entirely within the mapped Flood Hazard Areas (Zones A and AE: the 100-year floodplain, i.e., areas subject to inundation by the 1 percent annual chance flood event) of the East River.

Geology and landform

The assessed section of Duck Creek flows through the "Howard Ridges" and "Green Bay Plain" land type associations within the Central Lake Michigan Coastal Ecological Landscape of Wisconsin. The Howard Ridge association covers the upper portion of the area grading into the Green Bay Plain association near the Highway 41/141 bridge. The Howard Ridge association, as expressed in the Duck Creek riparian corridor, comprises a mix of rolling ridge and plain landforms of predominantly well drained silty clay or sandy loams (e.g., Yahara, Manawa, Sisson and Shawano soils) and wet to dry alluvial soils in the floodplain along the stream. The Green Bay Plains association near the mouth of the creek lies in the nearly level silty sediment of the Nipissing Lake plain with scattered low dunes and a series of low natural levees on the point bars where the stream has migrated laterally across its floodplain (see Figure 9). Soils are predominantly mucks, alluvial wet soils and nearly level loamy fine sands. Common habitat types include lowland hardwood stands, shrub carr, sedge meadow and emergent marsh vegetation in the wettest swales or near the stream.

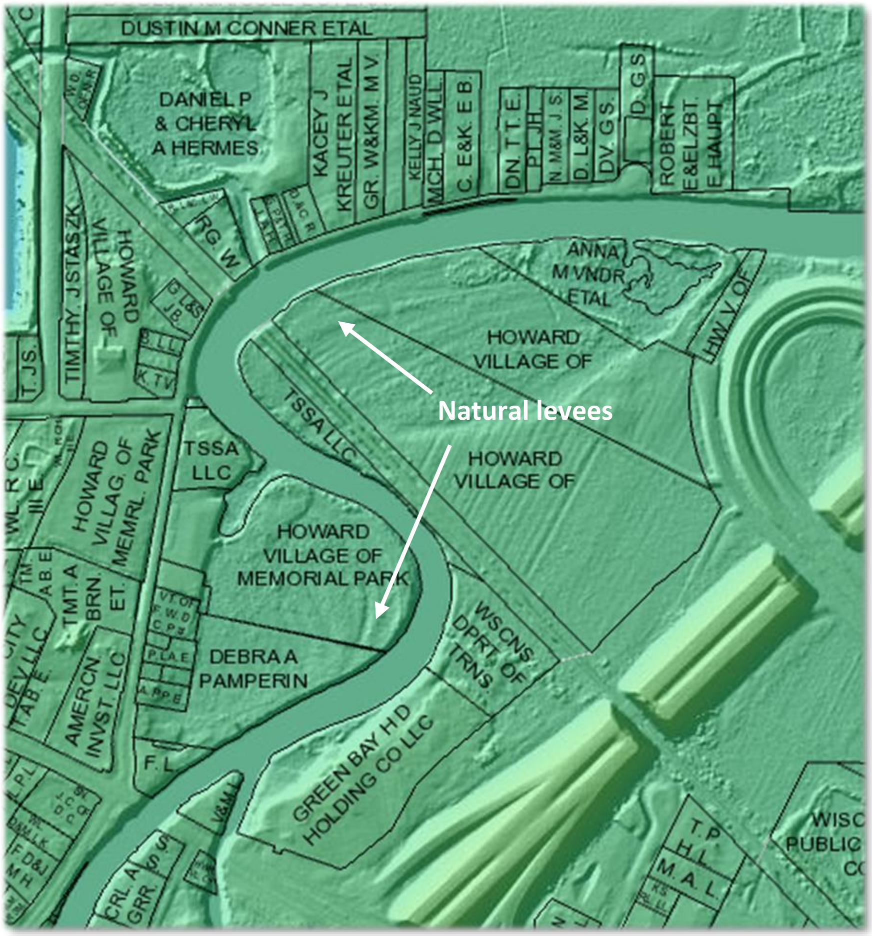


Figure 9. Landform image of lower Duck Creek showing a sequence of natural levees laid down as Duck Creek has migrated across its floodplain. *http://maps.gis.co.brown.wi.us/geoprime/#xmin=87179.20650153181;ymax=585147.4962615446;ymin=584326.6629282114;xmax=88512.53983486515. Accessed 12/17/17.*

Hydrology

In total, Duck Creek drains an 87,260 acre surface watershed dominated (56%) by agricultural land use. Natural cover (e.g., forest and wetlands) represents the second highest percentage of land use / cover in the watershed (19.5%). Lancaster Brook is the only tributary of significance that joins the stream through a highly modified ditch and diked wetland complex adjacent to the assessed area. A few storm water retention ponds, storm water drains and several laterally connected wetlands which fringe the main stem of the river provide additional sources of surface water to the stream. Ground water input in this stretch of the Duck Creek is unknown. This stretch of Duck Creek is also under the influence of periodic flows of water from Green Bay and the Fox River during storm or high water seiche events originating on the bay. High water levels of the bay can affect water levels in Duck Creek upstream to the Highway 29 bridge.

Duck Creek, like the East River, is classified as impaired by phosphorus and sediment under section 303(d) of the Clean Water Act, with impairments negatively impacting in-stream habitat, and creating high turbidity and elevated temperatures in the river's water. According to the Upper Duck Creek Nonpoint Source Watershed Implementation Plan (Outagamie County Land Conservation Department, 2016) agriculture is the dominant land use in the watershed and is responsible for 94 % of the sediment and 91% of the phosphorus loading in the watershed. According to the Total Maximum Daily Load plan for the Lower Fox River Basin and Lower Green Bay, Duck Creek is a major contributor of total phosphorus (11.5%) and total suspended solids (17.9%) to Green Bay.

General habitat notes

Although the Duck Creek landscape was already impacted by early timber harvest and settlement by European immigrants in the early to middle 1800's, land surveyor records of the 1830's indicated a landscape comprising forests of red, bur and white oak, on drier sites with sugar maple, basswood, hemlock, yellow birch and red and white pine on more mesic sites. These survey notes indicated the mouth of Duck Creek flowing through extensive marsh, wet prairies and sedge meadows near Green Bay. Like the history of the East River corridor, extensive clearing of these forests for agriculture and, over time, the growth of the city of Green Bay, left only small patches of isolated forest along Duck Creek by the 1940s. The aerial photographs of the area in the late 1930s show a landscape of multiple small agricultural fields with pockets of residential buildings lining the stream banks. Since the mid-1930s small to modest homes have become common along the stream, though significant patches of remnant forest and wetlands are still present. The undeveloped lands in the assessed area are, for the most part, recreational parks or parkways and lands set aside for management of urban storm water. However, there are still several tracts of land with good ecological condition in private ownership that could, if protected for public use, provide multiple public benefits, including protection of habitat for fish and wildlife targeted for recovery in the AOC.

Special Features

The Duck Creek corridor contains several ecological features that are significant to fish and wildlife and habitats targeted for recovery in the AOC. These include:

- Several patches of current to recoverable sedge meadow habitat. In general, these patches hold intact sedge dominated cores edged by scattered *Cornus stolonifera, Salix spp*., and lowland hardwood stands. *Phragmites, Typha angustifolia and Phalaris,* if present, are usually present as adjacent monotypic stands*.* The rate of invasion by these non-native species is unknown. All but one of the sedge meadow patches occur on lands in public ownership.
- The open water of the main stem of Duck Creek is accessible to fish from Green Bay and Duck Creek is known to hold many of the fish common to lower Green Bay.
- Aquatic plants both floating and submerged were common in the assessed stretch of Duck Creek. Both *Nuphar variegate* and *Nymphaea odorata* are present in the lower parts of the assessment area, with *Nuphar* being the more common often forming long patches along the shoreline of Duck Creek. Submerged species induced *Ceratophyllum demersum, Potamogeton crispus, P. foliosus, P. amplifolius, P. nodosus, Elodea nuttallii* and *Myriophyllum spicatum*.
- Riparian forests in both upland and lowland settings. Most lowland forests held low tree diversity with *Populus deltoides, Acer negundo*, and *Fraxinus pennsylvanica* being the most common co-dominant trees in many stands. These lowland forest stands are often heavily infested with non-native species particularly *Rhamnus catartica* as an understory species and in more open stands *Phalaris* often dominates the sites. In contrast the riparian stands on higher ground often had rich understories of native herbaceous ground cover and shrub layer species.

General Habitat / Natural Community / Species Comments

As along the East River edge habitat and small habitat patches dominate the Duck Creek riparian corridor, with the average habitat patch size being about 7.62 acres. (Table 12). Residential and commercial development line the banks of the creek in some areas fragmenting the linear stretches of shoreline habitat. This condition provides favorable habitat for those species able to survive the suburban / natural area edge. Similar to the East River, the ecotones of the assessed area are softened by a mix of diverse shrub species, native and non-native, and young native trees and the prevalence of this situation is reflected in the high number of edge bird species recorded during the assessment (Appendix I). Please refer to the UWGB website for descriptions of the habitat types identified in this report.

Table 12. Duck Creek habitats and acres

DUCK CREEK	
Habitats	**Acres**
Emergent marsh inland	7.4
Floodplain Forest	57.2
Hardwood swamp	36.5
Open water	61.7
Open water inland	2.0
Other forest	4.9
Southern dry mesic forest	61.5
Southern sedge meadow	11.6
Surrogate grassland (old field)	67.5
Other	3.5
TOTAL	**313.8**

Table 13. Summary Field Assessment Notes on Priority Species or Species Group

Priority Species or Species Group	Comments on Presence in Duck Creek Assessed Area
Anurans	Green frogs and gray treefrogs are common representative species.
Bats	No information
Coastal birds (breeding season)	n/a
Coastal wetland aquatic macroinvertebrates	n/a
Coastal wetland mustelids	No wetland mustelids were observed along Duck Creek in 2017, though no concentrated effort was made to locate this group.
Colonial water birds (breeding season)	No colonial water birds were observed nesting along the Duck Creek during 2017. Cormorants and red-breasted mergansers are seen resting or feeding on the river through the summer.
Fox River fish	n/a
Freshwater Unionid mussels	The stretch of Duck Creek assessed has not been surveyed for native unionid mussels, however recent surveys of Duck

	Creek above this stretch has found several species of mussel of state concern
Land birds (migratory)	Many species of warblers, flycatchers, finches and other species of land birds were encountered in May utilizing the forested areas along Duck Creek. The site likely contributes to the overall attractiveness of the lower Green Bay area for migratory land birds.
Marsh breeding birds	Green, great blue, and black-crowned night herons, great egrets, mallards, and Canada geese are the most common species found throughout the summer in the fringing wetlands or on the open water of Duck Creek.
Nearshore invertebrates	n/a
Shorebirds (migratory)	Site was not surveyed during the peak shorebird migration periods. During the assessment spotted sandpipers were commonly seen along the river utilizing the coarse woody debris and mud floats which occasionally edge the river.
Shoreline fish	n/a
Stream macroinvertebrates	Macroinvertebrates (e.g., caddis fly larvae, Grammaridae, Asellidae) were abundant and commonly found in submerged aquatic vegetation. Other invertebrates (e.g., Odonates) were commonly observed over the stream during the summer.
Tributary fish	Based on several Duck Creek fish surveys dating from the 1990s; 58 species of fish have been recorded from Duck Creek (Kohler, 1997), (USFW, 1992). These surveys were conducted throughout the Duck Creek system so not all these species would likely occur in the lower reaches of the stream considered in this assessment. Based on these surveys, several species targeted for recovery in the AOC are present in Duck Creek, including yellow perch, smallmouth and largemouth bass, northern pike, muskellunge, and walleye. It should be noted that on one day of the assessment (7/9/17) 18 people were observed fishing in the stretch between the Velp Avenue bridge and the Highway 29 bridge. They were mostly catching yellow perch and rock bass.
Turtles	Painted turtles and snapping turtles seem on main stem of river and in riparian wetlands.
Wetland terns	None observed
Wooded wetland birds (breeding season)	10-minute breeding bird surveys conducted in lowland hardwood stands along Duck Creek in June of 2017 found many species highly associated with lowland hardwood forests in Wisconsin. These included warbling vireo, black-capped chickadee, great crested flycatcher, Baltimore oriole, American redstart, blue-gray gnatcatcher, eastern wood-pewee, rose-breasted grosbeak, and wood duck.

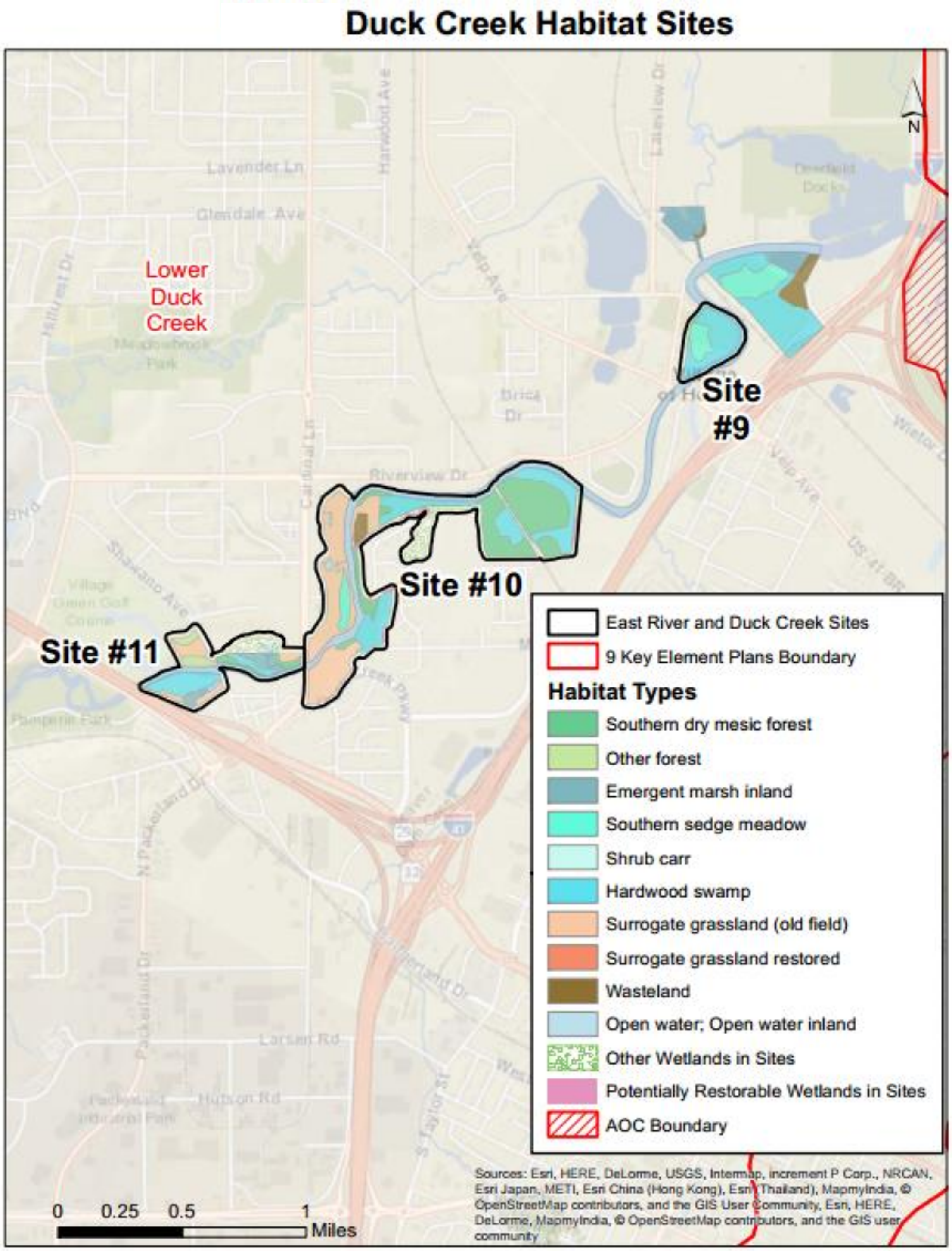
Significant Invasive Species and Management Issues

The corridor of Duck Creek holds many plant species considered not native to the area and in some habitats these non-native invasive species represented important natural community components throughout the assessed areas. Emergent marsh and lowland forest habitats were particularly infested with several non-native species, whereas sedge meadow and upland forest communities were degraded to a lesser extent. For example, the small riparian emergent marshes along assessed stretch of Duck Creek are now heavily infested with Phragmites spp.; *Phalaris arundinacea*, (reed canary grass) and *Typha angustifolia* (narrow-leaved cattail). Damp soil sites supporting sedge meadow and shrub carr habitats, also supported patches of or scattered individuals of *Rhamnus frangula (*alder buckthorn*) and Phalaris arundinacea.* On drier upland forest or field edge habitats Rhamnus *cathartica* (common buckthorn*)* and *Lonicera tatarica (*honeysuckle*),* or other non-native species of the *Lonicera* genus were commonly encountered*.* These species have become naturalized into this landscape and it is unrealistic to assume or expect that control or management measures needed to remove them from the landscape will be possible. The best approach may be to accept their presence and impact in the landscape and apply any control management efforts to the remnant habitat patches of highest (i.e., least invaded) quality; incorporate easily sustained ecological and hydrological processes into restoration projects that discourage invasion by target non-native species; and monitor the habitats or sites of highest interest to detect new species at the earliest moment.

Table 14. Notes on non-native invasive plant species encountered during the assessment of the Duck Creek corridor.

Habitat Types	Invasive Species Encountered
Hardwood swamp	Common buckthorn *Rhamnus cathartica*, was regularly encountered, but in varying densities, in the lowland forests along Duck Creek as well as in drier sites.
Surrogate grassland (old field)	Generally dominated by non-native grasses (e.g., *Bromus inermis, Phalaris arundinacea*) and non-native herbs (e.g., *Cirsium arvense, Daucus carota, Melilotus alba, Coronilla varia*)
S. dry mesic forest	
Emergent marsh inland	Phragmites (though treated in 2016 and most stands showed major dieback), Phalaris, Typha angustifolia, *Iris pseudacorus*
S. sedge meadow	Phragmites (though treated in 2016 and most stands showed major dieback), Phalaris
Open water inland	Duck Creek has varyingly diverse beds of submerged aquatic vegetation throughout this stretch providing fish spawning and feeding habitat, macroinvertebrate habitat, and water quality (e.g., sediment load capture) benefits. The extent of threat posed by non-native completive plant species (e.g., Myriophyllum spicatum, Najas minor, and Potamogeton crispus) is not certain.

Site Descriptions for Sites of the Duck Creek Corridor



Map also available in Appendix H.

Duck Creek Site 9: River's Bend Sedge Meadow

Location and Ownership

This site is located approximately 1.5 upstream from the mouth of Duck Creek just upstream from the River's bend Supper Club on the west side of the stream (Lat. 44.5604; Long. -88.0612). The site has both public (Village of Howard) and private ownership.

Physiography and Vegetation

This point bar in the alluvial plain of Duck Creek holds several low meander scars on the leading edge of the point and embays an emergent marsh / sedge meadow wetland. A hardwood stand of super canopy cottonwood over pole green ash and box elder comprise the forest type on the site. Red-twig dogwood and willow edge the forest and advance into the sedge meadow on slightly higher ground.

Habitats and Acreage for Site 9: River's Bend Sedge Meadow Site

River's Bend Sedge Meadow Site: Duck Creek		
Habitat Type	**Acres**	**Patches**
Floodplain Forest	18.5	1
Open water	14.6	1
Southern sedge meadow	6.4	1
TOTALS	39.5	3

Ecological Functions

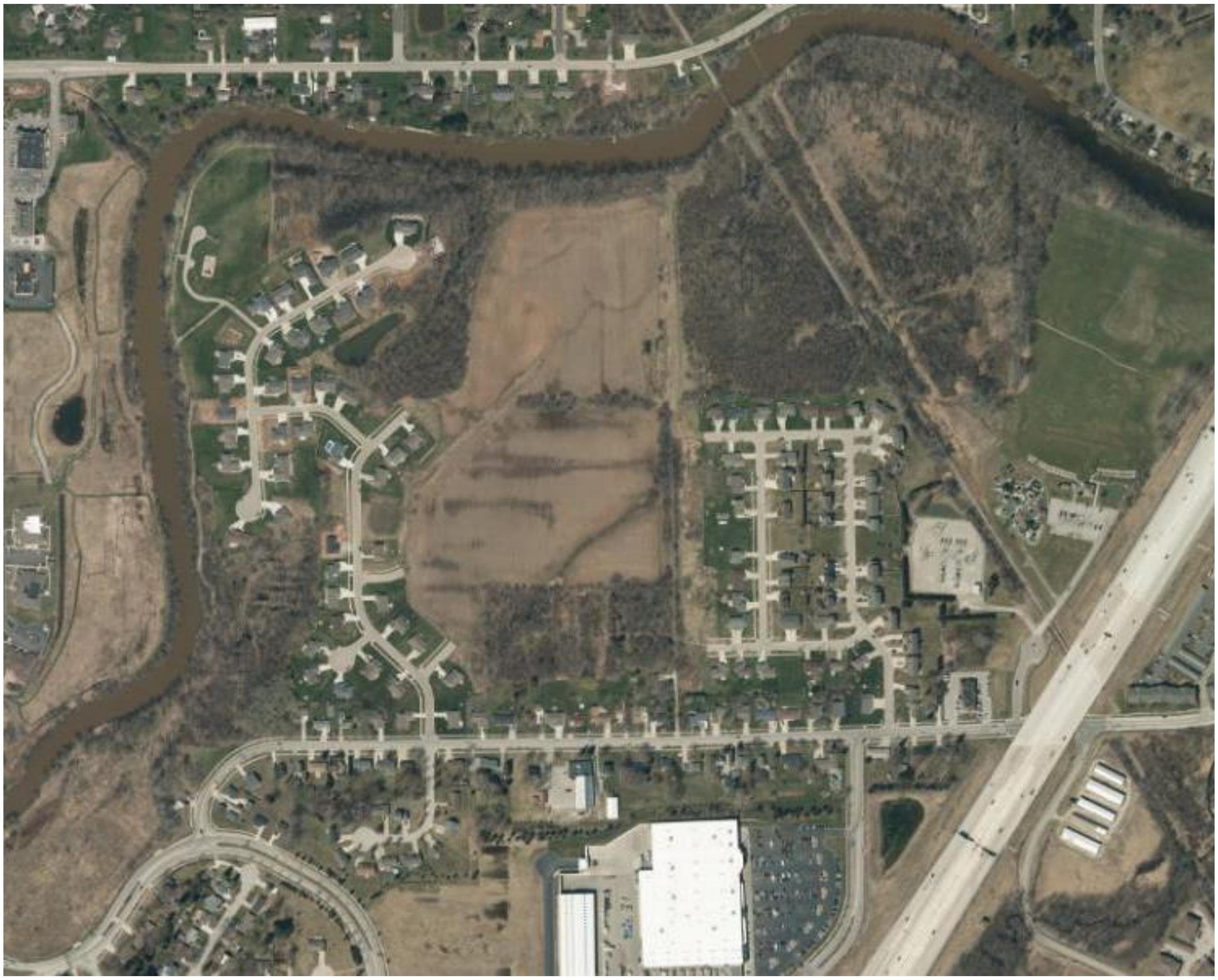
- Breeding habitat for anurans, bats, marsh breeding birds, turtles, and wooded wetland birds.

- Good migratory stopover feeding and refuge habitat for land birds
- Potential spawning habitat for wetland spawning fish (e.g. northern pike)
- Sediment and nutrient capture from main flow of Duck Creek
- Urban storm water and overland flow sediment and nutrient capture
- Flood storage capacity

Value of Site to Support BUI removal

See **Table 17** for information on the recommended actions for this site, those priority species and habitats that would be positively impacted by those actions and the relevant AOC objectives served by those actions.

Duck Creek Site 10



Location and Ownership

This large riparian corridor site has multiple land owners, both public (Village of Howard) and private. The center of the site is Lat. 44.5514, and Long. -88.0822 and is about 3.12 river miles from the mouth of Duck Creek. Except for a significant block of upland forest at the east end of the site, the site lies entirely within the mapped Environmentally Sensitive Area and Flood Zone of Duck Creek.

Physiography and Vegetation

The riparian corridor through this site is characterized by large patches of upland and lowland forest, open grassy fields, agricultural land and residential and commercial development. The stream itself is broadly meandering with few riparian wetlands. The stream banks rise quickly into upland settings and are armored with rip-rap for considerable lengths of the section. Multiple storm water drains empty into Duck Creek through this stretch and large storm water management ponds occur along the west side of the stream downstream of the Cardinal Lane bridge. Floating and submerged aquatic macrophyte beds occur throughout despite the turbidity of the water.

The several of the upland forest patches hold diverse and high quality native understory and ground cover vegetation, though non-native shrubs such as non-native honeysuckle and buckthorn are present in the landscape.

Habitats and Acreage for Site 10.

Site 10 Duck Creek		
Habitat Type	**Acres**	**Patches**
Floodplain Forest	17.1	1
Hardwood swamp	36.5	3
Open water	36.7	1
Open water inland	1.4	3
Southern dry mesic forest	57.2	7
Southern sedge meadow	5.1	1
Surrogate grassland (old field)	57.9	3
Other	3.5	1
TOTALS	215.4	20

Ecological Functions

- Breeding habitat for anurans, bats, stream macroinvertebrates, turtles, and wooded wetland birds.
- Good migratory stopover feeding and refuge habitat for waterfowl and land birds
- Sediment and nutrient capture from main flow of the Duck Creek
- Suburban storm water sediment and nutrient capture

Value of Site to Support BUI removal

See **Table 17** for information on the recommended actions for this site, those priority species and habitats that would be positively impacted by those actions and the relevant AOC objectives served by those actions.

Duck Creek Site 11: Lower Park Corridor

Location and Ownership

This site lies between the bridges over Highway 29 and Cardinal Lane (County Trunk EB). The center of this site is approximately 44.5464; Long. -88.0903. Land ownership is a mix of public (Brown County Pamperin Park) and several private land owners.

Physiography and Vegetation

Natural cover of riparian emergent wetland, lowland forest and riparian thicket of small trees and non-native shrubs and herbs line this stretch of Duck Creek. A small tributary enters the stream just above the Cardinal Lane bridge flowing through a stand of Phragmites and lowland hardwoods.

A significant wetland comprising an open water pond and an emergent wetland of cattail empties into Duck Creek just upstream of the abandoned Shawano Street bridge. The water from this wetland drains through a single culvert to Duck Creek and appears to be no barrier for fish passage. The lowland hardwood forest bordering the stream on the east side between Highway 29 and the abandoned Shawano Street bridge as a mix of native and non-native herbaceous species below a canopy of cottonwood, basswood and green ash. Box elders edge this forest stand along Duck Creek and the side pond.

On the opposite (west) side of Duck Creek young green ash, buckthorn, black walnut, chokecherry and non-native honeysuckle have grown in below the sprawling limbs of previously open grown box elder. Dames rocket and other non-native herbaceous species form the ground layer.

Habitats and Acreage for Site 11: Lower Park Corridor

Lower Park Corridor Site Duck Creek		
Habitat Type	**Acres**	**Patches**
Emergent marsh inland	7.4	2
Floodplain Forest	21.7	2
Open water	10.4	1
Open water inland	0.6	1
Other forest	4.9	2
Southern dry mesic forest	4.3	2
Surrogate grassland (old field)	9.6	4
TOTALS	58.9	14

Ecological Functions

- Breeding habitat for anurans, bats, marsh breeding birds, muskrat, stream macroinvertebrates, turtles, and wooded wetland birds.
- Good migratory stopover feeding and refuge habitat for waterfowl and land birds
- Potential spawning habitat for wetland spawning fish (e.g. northern pike)
- Sediment and nutrient capture from main flow of Duck Creek
- Suburban overland flow sediment and nutrient capture
- Flood storage capacity

Value of Site to Support BUI removal

See **Table 17** for information on the recommended actions for this site, those priority species and habitats that would be positively impacted by those actions and the relevant AOC objectives served by those actions.

4) AOC Explorer online mapping tool

Overview

The Wildlife Recovery: Lower Green Bay & Fox River AOC Explorer (AOC Explorer) visually displays the results of this report in a format that is easy to access and use. The Wildlife Recovery: Lower Green Bay & Fox River AOC Explorer (AOC Explorer) is an online decision support tool, one of several tools accessible at this web address: maps.freshwaternetwork.org/wisconsin/. In addition to the data layers for the components discussed here, there is also a layer for AOC habitat types assessed by UW-Green Bay with a link to their report for this joint project. In combination, this information can be used to consider AOC projects that can benefit fish, wildlife and water quality.

Methods

The AOC Explorer is an online decision support system. It is hosted by The Nature Conservancy and is created within a custom web framework. The functionality of the mapping service is built using the ESRI API. Data is stored, managed, and served using ESRI products.

The tool is populated with the spatial data described in the previous sections of the report. Other data that indicate local boundaries are also included. These data include county and watershed boundaries, the Oneida Nation boundary, and the boundaries that delineate the Nine Key Element Plans in the watershed.

All of the data was collected into ESRI for data management and to be published into the map service.

Results

The AOC Explorer includes a layer with Lower Fox River watershed wetlands and potentially restorable wetlands that were assessed for the benefit they can have to improve downstream AOC habitats and decrease eutrophication by improving water quality. A second layer with fish barriers and fish habitat can be explored to plan projects to improve aquatic habitat and access for migratory fish. The third layer showcases the East River and Duck Creek corridors as additional AOC project opportunities to improve priority AOC populations and habitats. AOC habitat types assessed by UWGB are also included with a link to their report for this joint project. In combination, this information can be used to consider AOC projects that can benefit fish, wildlife and water quality.

Discussion Specific to AOC Explorer

The purpose of the AOC Explorer is to provide an intuitive, spatial tool in which to consider protection and restoration opportunities in the Lower Fox River Watershed. The ability to see impediments to fish passage, wetlands and potentially restorable wetlands together on the landscape can spark innovative integrated projects that provide an array of benefits to the AOC.

The Explorer allows users to turn on any combination of layers in the tool, and to adjust the transparency of solid polygon layers as needed. It also allows the option of activating one of several layers so that you can click on the activated layer and see the attribute for the selected polygon or point. Print Map and Measure functions are also available.

Features of the AOC Explorer include the “Bookmark and Share” tool which provides the ability to create a link that you can share with partners that will allow them to zoom exactly where you are on the landscape with the same items visible and the same selection(s) you have made. There is also a data download feature which allows you to download the data for the Watershed Assessment Layers, the Fish Barrier Assessment, and the East River and Duck Creek sites and habitats.

The AOC Explorer is one of several decision support systems (DSS) available at the Wisconsin's Waters, Wetlands, and Watersheds website. A DSS for Wetlands by Design (WbD) is also available at this site. While these DSS's have some similarities in approaches and methods, and their results overlap in the Lower Fox Basin, the data within them are intended for different audiences and applications. The AOC Explorer should be used by those seeking to improve water quality and wildlife habitat conditions in the AOC. Assessments of the phosphorus and sediment reduction potential of sites utilize data and methods unique to the Lower Fox; therefore, results in the AOC Explorer are superior for these water quality services. WbD data should be consulted by users working in other watersheds, by users who aim to protect and restore wetlands for non-water-quality-related goals, and by those seeking a more regional or statewide perspective on wetland habitat and ecosystem service provision. WbD results include assessments of a broader array of services than are available in the AOC Explorer including nitrogen reduction, flood abatement, carbon storage, surface water supply (aka stream baseflow maintenance), shoreline protection, and floristic integrity. Note that the 'fish and aquatic habitat' results in both the AOC and WbD decision support tools are the same. A forthcoming tool, to be served alongside the AOC and WbD tools, will support decisions in the Mukwonago River Watershed around balancing groundwater withdrawals for human use with the needs of groundwater-dependent habitats such as fens.

DISCUSSION

Protection, management, restoration, or rehabilitation of altered river systems like the watershed of the Lower Fox River and Green Bay requires attention be given to processes and patterns at both site level habitat scale and the watershed scale. This project assessed opportunities to protect, manage, or restore habitat for species of concern for the Lower Green Bay and Fox River Area of Concern at both a site level (riparian corridors of the East River and Duck Creek), and at watershed scales (watershed assessment, fish barrier analysis). It was necessary to look at both site and watershed scales as the fish and wildlife habitat quality of the AOC and lower reaches of Duck Creek and the East River is highly affected and perhaps most dependent on the quality of the water received from the upper watershed. Thus, the goal of maximizing habitat quality at small scales in the riparian zone of lower Duck Creek, the East River and the core AOC must be accompanied by addressing the larger landscape scale issues that affect water quality, particularly sediment and nutrient loading. Fortunately, in the case of the Lower Fox River and Green Bay numerous conservation partners are working in the watershed on these larger landscape issues to improve water quality downstream. Site specific habitat projects work in the riparian corridors of the lower East River and Duck Creek will benefit from these landscape scale efforts.

For this project, the development of specific project or management recommendations to benefit priority AOC habitats, species groups and species was guided by a set of project objectives developed by the University of Wisconsin – Green Bay. Table 15 lists these restoration objectives. The report by the University of Wisconsin – Green Bay contains more details on these objectives.

Table 15. Lower Fox River and Green Bay AOC Recovery Objectives.

1. Manage and protect AOC islands
2. Expand and improve Great Lakes beach habitat
3. Restore and enhance southern sedge meadow habitat
4. Improve habitat quality of small AOC tributaries (enhance fish passage, restore natural stream substrates, and protect riparian vegetation)
5. Improve open water nearshore fish habitat in lower Green Bay
6. Expand and improve quality of emergent marsh (high energy) complexes
7. Expand and improve quality of submerged aquatic vegetation
8. Protect strategic coastal landscapes through land acquisition or conservation easement
9. Protect large areas of quality wooded wetlands along AOC coast
10. Re-establish freshwater mussel populations
11. Improve water quality in Green Bay, Fox River, and smaller tributaries
12. Designate and protect contiguous wetland habitat gradients at select AOC coastal sites
13. Enhance backwater habitats along Fox River for larval fish and invertebrates
14. Restore rocky and gravel substrates in open Fox River channel at suitable locations
15. Control invasive species and improve shoreline habitat at inland wetlands near Green Bay and Fox river shoreline
16. Improve or restore floodplain deltas near river mouths at AOC tributaries

General Recommendations

Based on the identified restoration objectives, the following general management recommendations will provide population support to AOC priority species and protect habitat essential to AOC recovery:

- For the highest benefit to priority AOC species, focus habitat protection and restoration work on projects that benefit those habitats favored by highly mobile priority species; e.g., fish, bats, and birds. Species with high mobility can more reasonably be expected to be supported by dispersed favored habitats over a wider geography. However, look for habitat protection or restoration opportunities in any project to incorporate benefits for other priority AOC species of lower landscape mobility (e.g., turtles and other herps);
- Table 5 above illustrates the importance of the aquatic and wetland habitats of the East River to priority species and species groups of the AOC. The tributary water and riparian emergent marsh habitats hold most of the life history relationships with the priority species and species groups of the AOC. The other wetland habitats; i.e., sedge meadow, shrub carr and hardwood swamp, also hold a considerable number of relationships to the life history requirements for the priority species groups. Habitat protection, restoration, improvement or re-creation of these habitats would benefit the largest number of priority AOC species and species groups.
- Table 5 also shows that some priority species groups utilize only a limited number of habitats. For example, freshwater unionid mussels have a life history relationship with only one habitat type, the tributary open water habitat. Wooded wetland breeding birds, stream macroinvertebrates and Fox River fish have only 2 habitat relationships within the East River and Duck Creek corridors. Those habitats that supply life history needs to a species group that is supported in few other habitats should be considered important for protection, restoration or improvement.
- Target sedge meadow restoration (maintain high quality sites by removal of encroaching invasive plants, maintain, restore or recreate sustaining hydrologic processes) particularly in oxbow settings and small intermittent lateral flows;
- Target shrub carr restoration (maintain high quality sites by removal of encroaching invasive plants, maintain, restore or recreate sustaining hydrologic processes) in conjunction with sedge meadow restoration;
- Protect existing good to high quality riparian upland and lowland forest habitat through cooperation with municipal land owners or willing private land owners;
- Look for opportunities in the riparian and delineated flood zone areas along the East River and Duck Creek to restore wetlands that had been converted to agriculture or artificially drained or ditched;
- Look for opportunities to restore or create wetlands for both fish and wildlife habitat and water quality benefits at the headwaters of small intermittent, first and second order tributaries on the East River in particular;
- Replace highest ranked fish passages barriers in the AOC tributary network, targeting those high ranked barriers that are embedded in larger blocks of natural riparian cover; are on streams with good mussel habitat; or high-water quality;
- Restore floodplain reconnection through targeted removal of stream bank rip-rap;

- Look for opportunities to create sand seepage wetlands in lower order side tributaries to increase ground water infiltration, capture sediment and nutrients and restore fish and wildlife habitat;
- Improve habitat quality on lower quality lowland and upland forest habitat patches through targeted, judicious control of non-native invasive plants (particularly common buckthorn), and support of white tailed deer harvest / control efforts where possible;
- Restore forest habitat on select riparian old field and abandoned agricultural land (especially if these lands were prior wetlands) to increase the patch size of existing forest, connect existing forest patches and provide water quality benefits;
- Look for opportunities to increase coarse woody debris in the stream through tree drops, however balance the goal of increasing woody debris with the positive benefits of canopy shading on stream temperature (also maintain passable conditions for non-motorized craft). For example, removing trees on a south facing bank of the channel may remove less canopy cover from the open water of the stream and expose more stream bank facilitating establishment of emergent vegetation than removing tree cover on a north facing bank of the stream;
- Work with the relevant municipal governments to examine storm water management practices and look for opportunities to install systems to protect the water quality of the stream. Installation of possible upland projects including bioretention areas, dry ponds, or step pond storm conveyance systems, or storm water infiltration systems to reduce runoff and pollutants entering the East River or Duck Creek; and
- Seek non-motorized boat ordinances on the section upstream of the kayak / boat launch across from Green Isle Park on the East River, and provide additional access points for non-motorized water craft downstream of this launch.

RECOMMENDED PROJECTS

Tables 16 and 17 below summarize and relate the Lower Fox River and Green Bay AOC Recovery Objectives (Table 15) to the AOC Objectives, Potential project sites and AOC priority species and habitats that would benefit from implementing recommendations at the sites.

Table 16 organizes the management recommendations *by the AOC Objectives* in Table 15; Table 17 lists the management recommendations *by geography*--either the project site along the East River or Duck Creek; the watershed of the Lower Fox River or the tributary network that drains to the AOC.

Table 16. Management and Restoration Recommended Actions for the East River and Duck Creek Corridors, Lower Fox River Watershed, and AOC Tributary Network in relationship to the Overall AOC Objectives

Overall AOC Objectives	Recommended Actions for the East River and Duck Creek Corridors, Lower Fox River Watershed, and AOC Tributary Network	Duck Creek, East River, AOC Tributary Network or Watershed Sites to employ Actions	*Habitats* + Populations Positively Impacted
1. Manage and protect AOC islands.	None		
2. Expand and improve Great Lakes beach habitat.	None		
3. Restore and enhance southern sedge meadow habitat.	Protect existing southern sedge meadow remnants on public land and on private land in cooperation with willing landowners. Conduct a hydrologic analysis of the sites to determine viability of the community and whether hydrologic restoration or alterations are necessary. Conduct an inventory of invasive plant species to determine control measures. Create restoration and protection plan identifying sites, objectives, methods, and monitoring metrics.	Duck Creek: 9, 10 East River: All sites	*Southern sedge meadow* *Shrub carr* Anurans, bats, coastal birds (breeding season), coastal wetland mustelids, landbirds (migratory), marsh breeding birds, and wetland terns

4. Improve habitat quality of small AOC tributaries (enhance fish passage, create riparian fish spawning habitat, restore natural stream substrates, and protect riparian vegetation)	Riparian habitat quality could be improved with a mixture of projects including dropping coarse woody material into the channel, opening the canopy and removing concrete rubble and rip-rap material in select stretches to increase riparian emergent and stream bank vegetation, and rehabilitating substrate and riparian habitat in small side tributaries that enter the East River and Duck Creek in the assessed reaches of these streams. Planting of native emergent plants in protected pockets along the riparian banks of the stream should be considered. Emergent marsh or ephemeral wetland fish spawning habitat should be pursued on passable tributaries to the AOC and the rivers flowing to the AOC. Much potentially restorable wetland habitat is available in the floodplain of the East river, particularly in the Willow Creek and Bower Creek area. Opportunities to restore wetland habitat and create fish spawning and wetland wildlife habitat in these floodplains should be sought. Such projects could also contribute to water quality goals. Fish passage improvement projects that open access to existing or done in conjunction with newly created spawning habitat should be pursued. (Watershed efforts to reduce the magnitude of stream flashiness and the nutrient load must complement local instream habitat improvement projects to enhance and sustain any benefits gained by these local riparian and instream projects).	Duck Creek: 9, 10, 11 East River: All sites AOC Tributary Network	*Emergent marsh (riparian)* *Tributary open water* Anurans, coastal wetland mustelids, fox river fish, freshwater unionid mussels, muskrat, tributary fish, stream invertebrates, and turtles
5. Improve open water and nearshore fish habitat in lower Green Bay.	N/A		
6. Expand and improve quality of emergent marsh	N/A		

(high energy) complexes.			
7. Expand and improve quality of submerged aquatic vegetation.	Submerged aquatic vegetation was noted throughout the length of Duck Creek and above the Highway 172 bridge in the East River. The extent, diversity and viability of native and aggressive non-native submergent marsh in these rivers however is uncertain. Once determined, efforts to protect, maintain, and expand the best submergent marsh biodiversity hotspots should be undertaken. One approach might be to determine the substrate needs for target plant species and then enhance and restore substrate condition. However, watershed efforts to reduce the magnitude of stream flashiness and the sediment load must be successful to enhance and sustain any benefits gained by these local instream efforts.	Duck Creek: 10, 11 East River: 3, 6, 7, 8	<u>*Tributary open water*</u> Anurans, coastal birds (breeding season), coastal wetland mustelids, marsh breeding birds, muskrat, nearshore invertebrates, shoreline fish, turtles, waterfowl (migratory), and wetland terns
8. Protect strategic coastal landscapes through land acquisition or conservation easement.	Opportunities exist for protection of riparian emergent marsh, southern sedge meadow, lowland hardwood, upland southern dry-mesic forest and surrogate grassland habitats along both the East River and Duck Creek corridors. These tracts hold high quality habitat, provide lateral and linear riparian connectivity to the open water, and could support additional benefits including storm and flood water management, water quality protection, and recreational opportunities. Protection by acquisition or conservation easement from willing landowners through a partnership effort of public and non-profit conservation organizations should be explored.	Duck Creek: 9, 10, 11 East River: 3, 5, 6, 7, 8	*Southern sedge meadow* *Shrub carr* *Emergent marsh (riparian)* *Hardwood swamp* *Southern dry-mesic forest* *Northern mesic forest* Anurans, bats, coastal wetland mustelids, landbirds

			(migratory), marsh breeding birds, muskrat, stream invertebrates, tributary fish, turtles, waterfowl (migratory), wooded wetland birds (breeding season)
9. Protect large areas of quality wooded wetlands along AOC coast.	It is recommended that the protection through acquisition of fee title or conservation easement of blocks of wooded wetland from willing landowners along the East River and Duck Creek be explored. Management of existing wooded wetlands should include targeted invasive species control, possible canopy thinning with underplanting of native herbaceous and woody species.	Duck Creek: 10, 11 East River: 5, 6, 7, 8	
10. Re-establish freshwater mussel populations.	As noted in the report, surveys upstream of the assessed section of Duck Creek contain significant populations of several mussel species. It is recommended to build upon this survey work to conduct an inventory for remnant freshwater mussel beds in the assessed stretch of the river and translocate/reintroduce populations if favorable conditions exist. Several small tributaries to the East River (Osprey Point tributary, and small flows from the riparian wetlands at site 8) may have water quality, substrate attributes and host fish species needed for native mussel populations.	Duck Creek: 11 East River: 3, 8 AOC Tributary network	*Tributary open water* Freshwater unionid mussels, coastal wetland mustelids, and waterfowl (migratory)

11. Improve water quality in Green Bay, Fox River, and smaller tributaries.	Promote best management practices and innovative nutrient management measures in Fox River watershed. Numerous older storm water drains were encountered emptying directly into Duck Creek and the East River along the assessed sections of these streams. Efforts should be made to manage these flows to reduce the load of toxins, nutrients, and sediments from these urban/suburban storm water discharge pipes.	Duck Creek: 10, 11 East River: All sites Multiple PRW restoration possibilities occur in the Lower Fox River Watershed	Nearly all fish and wildlife habitats and populations would benefit from improved water quality, especially submerged aquatic vegetation, anurans, fox river fish, freshwater unionid mussels, nearshore invertebrates, shoreline fish, stream invertebrates, and tributary fish, waterfowl (migratory)
12. Designate and protect contiguous wetland habitat gradients at select AOC coastal sites.	N/A		
13. Enhance backwater habitats along Fox River for larval fish and invertebrates	N/A		

14. Restore rocky and gravel substrates in open Fox River channel at suitable locations.	N/A		
15. Control invasive species and improve shoreline habitat at inland wetlands near Green Bay and Fox River shoreline.	Establish native plants and construct or restore (if necessary) shallow topographic gradient at edges of small wetlands in AOC project area (within 1 km of shoreline) or along Duck Creek, East River, and other tributaries. Work with local public works departments to improve habitat value of retention ponds and other artificial habitats in urban environment.	Duck Creek: 9, 11 East River: All sites	*Emergent marsh (inland)* *Shrub carr* *Open water (inland)* Anurans, coastal birds (breeding season), marsh breeding birds, waterfowl (migratory), landbirds (migratory), coastal wetland aquatic macroinvertebrates, shoreline fish
16. Improve or restore floodplain deltas near river mouths at AOC tributaries	The Duck Creek assessment area abuts the AOC at its mouth. Efforts to protect the Duck Creek delta should be coordinated with efforts to protect riparian habitats upstream of the delta.	Duck Creek: 9	*Tributary open water* *Emergent marsh (riparian)* Coastal wetland mustelids,

			freshwater unionid mussels, stream invertebrates, tributary fish, anurans, marsh breeding birds, coastal birds (breeding season), waterfowl (migratory)

Table 17. Recommended actions by geography.

Sites	Habitats Present in Site	Relevant Objectives	Recommended Actions	AOC Priority Species and Habitats positively impacted by recommended actions at these sites.
Duck Creek 9	Southern sedge meadow Shrub carr Emergent marsh (riparian) Hardwood swamp, Tributary open water	3, 8, 15, 16	Protect parcels with sedge meadow habitat through work with willing landowners, manage sedge meadow habitat through invasive species control and restoration or management of hydrologic regime.	Anurans, bats, coastal birds (breeding season), coastal wetland mustelids, landbirds (migratory), marsh breeding birds, and wetland terns
Duck Creek 10	Southern sedge meadow Shrub carr Hardwood swamp Southern dry mesic forest Surrogate grassland (old field)	3, 4, 7, 8, 9, 11	Restore sedge meadow habitat through work with public land managers; protect and expand riparian forest habitat through protection and restoration work with willing landowners; work with local public works departments to improve habitat value of retention ponds and other artificial habitats in the riparian / urban corridor. Numerous older storm water drains were encountered emptying directly into Duck Creek	Anurans, bats, coastal birds (breeding season), coastal wetland mustelids, landbirds (migratory), marsh breeding birds, and wetland terns

	Tributary open water		along the assessed section and efforts should be made to manage these flows to reduce the load of toxins, nutrients, and sediments from these urban/suburban storm water discharge pipes.	
Duck Creek 11	Hardwood swamp Emergent marsh (riparian) Southern dry mesic forest Tributary open water Other forest	4, 7, 8, 9, 11, 15	Protect and expand riparian forest habitat through protection and restoration work with willing landowners; work with local public works departments to improve habitat value of retention ponds and other artificial habitats in the riparian / urban corridor; riparian habitat quality could be improved with a mixture of projects to include dropping coarse woody material into the channel, opening the canopy and removal of concrete rubble and rip-rap material in select stretches to increase riparian emergent and stream bank vegetation; planting of native emergent plants in sunlit protected pockets along the stream bank should be considered.	
East River 1	Emergent marsh (riparian) Shrub carr Hardwood swamp Tributary open water	3, 4, 11, 15	This site has potential for sedge meadow and riparian emergent wetland habitat restoration as well as creation of riparian fish (especially northern pike) spawning habitat. As the site is heavily infested with non-native vegetation, control of non-native invasive species beyond that needed for sedge meadow and emergent wetland restoration would probably not be cost effective or sustainable. Control for *Phragmites* was conducted on the site in 2016 and provides benefits for restoration efforts. Any habitat restoration should also consider management actions for water quality benefits.	Anurans, bats, coastal birds (breeding season), coastal wetland mustelids, landbirds (migratory), marsh breeding birds, tributary fish, Fox River fish, shorebirds (migratory), and wetland terns
East River 2	Emergent marsh (riparian) Tributary open water	3, 4, 11, 15	This site holds a patch of riparian wetland that presents an opportunity to restore emergent march and sedge meadow, and possibly small patches of shrub carr, and	Anurans, bats, coastal birds (breeding season), coastal

			lowland forest habitat. Control for *Phragmites* was conducted on the site in 2016 and provides some benefit for restoration efforts. As the site is open to river flows its entire length, this site should be examined for opportunities to create fish spawning and marsh bird habitat as well as projects that would provide water quality benefits. A storm water drain enters the site adjacent to the marsh from the northeast carrying street litter and likely impaired water quality. The possibility of a constructed treatment basin should be explored.	wetland mustelids, Fox River fish, landbirds (migratory), marsh breeding birds, shorebirds (migratory), and wetland terns
East River 3	Southern sedge meadow Emergent marsh (riparian) Shrub carr Tributary open water	3, 4, 7, 8, 11, 15	The two large contiguous riparian wetland offers an opportunity to restore a large emergent wetland, sedge meadow and shrub car complex with potential to restore habitat for fish spawning. The wetland is publicly owned and recently treated for Phragmites control.	Anurans, bats, coastal wetland mustelids, landbirds (migratory), marsh breeding birds, shorebirds (migratory), turtles, and wetland terns
East River 4	Emergent marsh (riparian) Shrub carr Tributary open water Surrogate grassland (old field)	3, 4, 11, 15	This large site has many opportunities for habitat improvement to benefit multiple species. Large areas of potentially restorable wetlands exist upstream of County Rd XX and Allouez Avenue. These PRWs could be restored to enlarge and connect existing wetland habitat as fish spawning and bird breeding habitat as well as sedge meadow habitat. Land protection and restoration work with willing private landowners would be necessary in some areas. Information on the AOC Tributary Open Water fish barrier tool indicates an impassable culvert at County XX, this should be examined and remedied for fish passage. Control for *Phragmites* was conducted on the site near the East River in 2016 and provides some benefit for restoration efforts.	Anurans, bats, coastal wetland mustelids, landbirds (migratory), marsh breeding birds, shorebirds (migratory), turtles, stream macroinvertebrates, unionid mussels, muskrat, and wetland terns
East River 5	Southern sedge	3, 4, 8, 9,	The Green Isle Park and opposite shore wetlands offer	Anurans, bats, coastal birds

	meadow Emergent marsh (riparian) Tributary open water Southern dry mesic forest Surrogate grassland (old field) Hardwood swamp	11, 15	opportunities to expand riparian protection through land acquisition from willing landowners, restoration of lowland and upland forest communities through invasive species control, planting forest cover on acquired riparian lands, and sedge meadow / shrub carr, lowland forest restoration in a large wet soil block across the river from Green Isle park.	(breeding season), coastal wetland mustelids, landbirds (migratory), shorebirds (migratory), marsh breeding birds, and wetland terns, turtles,
East River 6	Southern sedge meadow Emergent marsh (riparian) Hardwood swamp Surrogate grassland (old field) Tributary open water Southern dry mesic forest	3, 4, 7, 8, 9, 11, 15	The site holds small patches of good quality sedge meadow / shrub carr / lowland forest habitat on the west side of the river and potential for improvement and restoration of a significant block of lowland riparian forest on the east side. Targeted removal of rip-rap material in this site should be explored to reconnect the river with the flood plain and provide natural river bank habitat. Vanden Heuvel Park in the Village of Bellevue may be suitable for creation of fish spawning wetlands as well and provide interest for recreational users of the park.	Anurans, bats, coastal birds (breeding season), coastal wetland mustelids, landbirds (migratory), shorebirds (migratory), turtles, marsh breeding birds, and wetland terns
East River 7	Hardwood swamp Emergent marsh (riparian) Shrub carr Southern sedge meadow Surrogate grassland (restored) Tributary open water	3, 4, 7, 8, 9, 11, 15	This small site may hold opportunities to restore riparian forest cover through work with willing landowners on the east side of the river. Opportunities to protect and improve habitat conditions on a small emergent wetland, lowland forest, ephemeral stream complex on the west side of the river through management of invasive species by the Village of Allouez and work with willing adjoining landowners.	Anurans, bats, coastal birds (breeding season), coastal wetland mustelids, landbirds (migratory), tributary fish, turtles, waterfowl (migratory), wooded wetland birds (breeding season), muskrat, marsh breeding birds, and wetland terns
East River 8	Hardwood swamp Southern dry mesic	3, 4, 7, 8, 9, 11, 15	This large site holds multiple opportunities to work with lands under municipal ownership or willing private	Anurans, bats, coastal birds (breeding season), coastal

	forest Other forest Tributary open water Emergent marsh (riparian) Southern sedge meadow Shrub carr Surrogate grassland (old field) Surrogate grassland (restored)		landowners to protect and restore habitat beneficial to priority AOC species and habitats. Work with willing landowners of current agricultural lands which lay in the floodplain between County Road GV and the river should be emphasized. These lands have potential for restoration to fish and wildlife wetland habitat, lowland and upland forest restoration, water quality improvement projects and compatible public recreational benefits. Large acreage of potentially restorable wetlands connected by small streams to the East River exist on the east side of County Road GV. Protection and restoration of these wetlands for fish, wildlife and water quality benefits should be pursued. This site also contains several intact oxbow wetlands which should be protected as unique hydrogeologic features of the landscape. These oxbows contain sedge meadow habitat in varying degrees of quality, and restoration should be pursued on these habitats. The east side of the river also contains a patch of old growth riparian forest which should be protected through work with the landowner and neighboring conservation group. The west side of the river holds several good, though small, patches of sedge meadow worthy of protection and appropriate management. The natural gradient of sedge meadow thru shrub carr to lowland forest is present throughout the site and should be protected and maintained. The large open water / emergent marsh complex on the west of the river presents perhaps the best opportunity for fish and wildlife enhancement projects. Fish passage should be examined at all culverts within the site (e.g, bike trail, County Road GV and access drives). Lastly, suitable conditions may exist in some of the	wetland mustelids, landbirds (migratory), unionid mussels, stream macroinvertebrates, tributary fish, shorebirds (migratory), turtles, waterfowl (migratory), wooded wetland birds (breeding season), muskrat, marsh breeding birds, and wetland terns

			smaller lateral tributaries of the East River (e.g., small tributary that flows through the Izaak Walton parcel) to consider the reintroduction of native mussel species. However, the presence of host fish species should be considered. Specific Actions: • Develop a multi-partner site conservation plan that seeks to promote the conservation and social benefits of the site; • Initiate land acquisition of targeted parcels from willing landowners, (parcels targeted fall within the mapped Flood Hazard Areas; Zones A and AE: the 100-year floodplain, i.e., areas subject to inundation by the 1 percent annual chance flood event, of the East River); • Restore acquired lands to appropriate priority habitat types, and/or management of the existing habitat on those lands to maintain or improve habitat conditions; • Manage lands currently under public ownership to support the ecological values present or possible (in most cases continuing with current management actions); • Restore degraded priority habitats on lands under public ownership; • Establish adequate fish passage through all the culverts or other barriers that exist in the site; • Accommodate and develop public use and water quality improvement opportunities in this site. • Restore riparian conditions: e.g., rip-rap removal, targeted shoreline canopy opening, shoreline emergent planting establishment, addition of coarse woody material to stream	

AOC Tributary Network	Tributary open water	4, 10	• Replace highest ranked fish passages barriers in the AOC tributary network, targeting those high ranked barriers that are embedded in larger blocks of natural riparian cover; are on streams with good mussel habitat; or high-water quality	Tributary fish, freshwater unionid mussels, stream macroinvertebrates, Fox River fish
Lower Fox River Watershed	Emergent marsh (inland) Tributary open water Other wetland types	11	• Use results from the Watershed Assessment (GIS and field-based results) to restore highest ranked wetlands	Anurans, bats, marsh breeding birds, tributary fish, in addition all species associated with the open water of the Lower Fox River, Green Bay, the East River and Duck will be positively impacted by improvements to the water clarity and quality resulting from water quality work in the watershed.

Note on Land Protection:

As listed in the above table of recommended management actions there are several riparian parcels in designated flood zones or environmentally sensitive areas along the East river and Duck Creek which hold habitats of priority for the AOC. In some cases, the parcels hold existing high-quality habitat and in other cases the lands offer good opportunities to restore high priority habitats. Through working with willing landowners, those parcels should be targeted for acquisition that are 1) riparian (designated flood zone), 2) abutting existing habitat, 3) connecting existing habitat, 4) hold restorable wetlands, and 5) of a size that indicates significant benefits to one or more AOC priority species groups if restored. These parcels offer opportunities to expand acreage for riparian emergent marsh, southern sedge meadow, lowland hardwood, and upland mesic and southern dry-mesic forest habitats and supply habitat for multiple AOC priority species.

APPENDICES

Appendix A: Priorities for Barrier Removal to Improve Access to Northern Pike Spawning Habitat in Green Bay Tributaries

Priorities for Barrier Removal to Improve Access to Northern Pike Spawning Habitat in Green Bay Tributaries

April 2013

Introduction

Many Great Lakes fishes migrate into tributary streams to spawn. Northern pike are a top predator in Green Bay of Lake Michigan, and they spawn in tributary streams and wetlands. Recruitment of juvenile northern pike in Green Bay has been reduced by loss of spawning habitat, through both habitat degradation and reduced access. Access to spawning habitat is blocked by barriers including dams and poorly functioning road crossings. Reconstruction of road crossings to facilitate fish passage has the potential to be one of the most efficient ways of increasing northern pike recruitment because management action at a very small scale – the width of a road – can lead to access to very large extents of suitable habitat. However, because there are thousands of crossings whose improvement could potentially benefit pike, methods are needed to prioritize restoration efforts.

The objectives of this project were to:

1. Conduct an intensive field survey to identify barriers to fish passage on all tributaries to Green Bay.
2. Identify factors that influence northern pike spawning habitat suitability.
3. Estimate the cost of replacing each fish passage barrier.
4. Prioritize barrier removals that will open up the most high-quality habitat for the least cost.

The results of this project will provide practical information for road managers and groups interested in fish passage. Efforts are underway to restore aquatic ecosystem connectivity across the Great Lakes Basin, and the methods developed through this project will contribute to this broader goal.

Methods

This section provides a concise overview the methods used in this project. Details of each step are provided in appendices referenced in this section. All project data are stored in a geodatabase (at The Nature Conservancy's Wisconsin office), which is compatible with both ArcGIS and Microsoft Access. The content and/or function of each object in the database is described in Appendix A. Metadata on original data sources, processing steps, and attribute definitions for each feature class are included in the database.

The project area was defined as all tributaries to Green Bay up to either the first major dam on a mainstem river (DePere dam on the Fox River, Stiles dam on the Oconto River, Peshtigo dam on the Peshtigo River, Marinette dam on the Menominee River, Boney Falls dam on the Escanaba

River) or to a distance (10-25 km) that was judged to limit the potential use of further upstream areas by northern pike (Sturgeon River, Whitefish River, Rapid River, Days River, Ford River, Cedar River).

Potential locations of fish passage barriers were identified from several datasets in a Geographic Information System (GIS), including intersections of roads, railroads, and streams at the 1:24,000 scale, dams in a database compiled by Januchowski-Hartley et al. (2013), and structures visible in high resolution aerial photographs (see detailed methods in Appendix B). A two-phase survey protocol was used to evaluate each structure. Phase 1 was conducted in April 2012, and was used to determine whether the stream at each structure had enough water to allow passage by adult northern pike, and if so, whether it was clearly passable by fish or needed further evaluation in phase 2 (see detailed protocol in Appendix C). Phase 2 was conducted from May-September 2012, and was used to measure detailed attributes of that subset of structures identified in phase 1 as presenting some impediment to fish passage (see detailed protocol in Appendix D). Structures that had not been identified through the GIS analyses, but were discovered during field surveys were also assessed. Several hundred small streams and ditches that had enough water for passage by northern pike, but were not represented in the 1:24,000-scale streams layer, were added to the streams layer by digitizing their paths from the same high resolution aerial photographs used to identify potential barriers (Appendix E).

Passability by adult northern pike was estimated for all structures that were assessed with phase two surveys. Passability is a number between 0 and 1 that represents the percentage of northern pike that can pass upstream through the structure during typical April stream flow conditions, and is primarily based on water velocity through the structure and whether the structure has an outlet drop (see detailed methods in Appendix F).

The value of spawning habitat (expressed as change in quality-weighted area; ΔH) that would be made accessible by removal of each barrier was estimated by multiplying the area of wetlands and streams upstream of that barrier by the modeled probability of there being enough water in that stream for passage by adult northern pike and the modeled probability of observing young-of-year northern pike in that stream (see detailed methods in Appendix G).

The cost to replace each impassable or partially passable crossing structure with a fully passable structure was estimated from measurements collected during the field survey. The width of the new structure was set equal to the bankfull width of the stream, which allows the channel dimensions, substrate, and flow characteristics in the crossing to resemble those of a natural channel. We specified a round or bottomless culvert for bankfull widths < 12 ft and a free span bridge for bankfull widths of 12-25 ft. The primary determinants of project cost are the structure's dimensions, excavation and fill volume, and road surface type. Unit costs were based on the experience of project cooperators carrying out road crossing replacement projects in Wisconsin and Michigan in 2009 (see detailed methods in Appendix H).

A custom program (written in VBA as a module called OptimizeDS) was created in the database used to house all project data that prioritizes barrier removal projects based on the cost per acre of quality-weighted spawning habitat that would be made accessible. The program evaluates ΔH for each barrier, removes the barrier with the highest ΔH per cost, then re-evaluates ΔH for the remaining barriers, removes the next barrier with the highest ΔH per cost, and so on until all barriers have been removed. The cost and ΔH of removing a barrier *a* that is upstream of other barriers (e.g., *b* and *c*) is evaluated by considering barriers *a*, *b*, and *c* together. The resulting sequence of projects can be used to create a prioritized list of projects for road managers in the watershed.

Results

A total of 7,066 structures were surveyed by Wisconsin Department of Natural Resources staff in 2012. We added to this dataset 1,100 structures from the Duck-Pensaukee watershed, which were surveyed by the University of Wisconsin-Madison and The Nature Conservancy using similar methods in 2011, and 255 structures from the east side of the Door Peninsula, which were surveyed in 2012 by the volunteers for the Ridges Conservancy, for a total of 8,421 structures. More than half of these structures turned out to not be relevant for fish passage (Table 1).

Table 1. Reasons for excluding structures from connectivity analysis (see Appendix C for detailed descriptions of these outcomes).

Survey Outcome	**Number of Sites**
Not enough water	2,327
Upstream of high gradient reach	1,700
No crossing	459
No access	396
Clearly not connected to a blue line	117
Secondary connection to wetland	113

Of the 3,309 structures that were relevant for fish passage, 72% were fully passable by fish. The average passability did not vary significantly by structure ownership (Figure 1). It is notable that 16% of these structures are privately owned, which means that connectivity analyses that only focus on publicly-owned structures may provide an incomplete picture of the issue. The presence of an outlet drop was the most common reason that structures were classified as barriers (see detailed criteria in Appendix F). Figure 2 displays a map of the structures included in the connectivity analysis.

Table 2. Methods for classifying passability of structures.

Passability Method	**Number of Sites**
Passable	2,168
Outlet drop	254
Velocity > 2 ft/s	119
Depth < 0.3 ft	109
Constriction ratio < 0.5	100
Obstruction	22
Length > 100 ft	17
See note	105
Structure type (bridge or dam)	161
No access	254

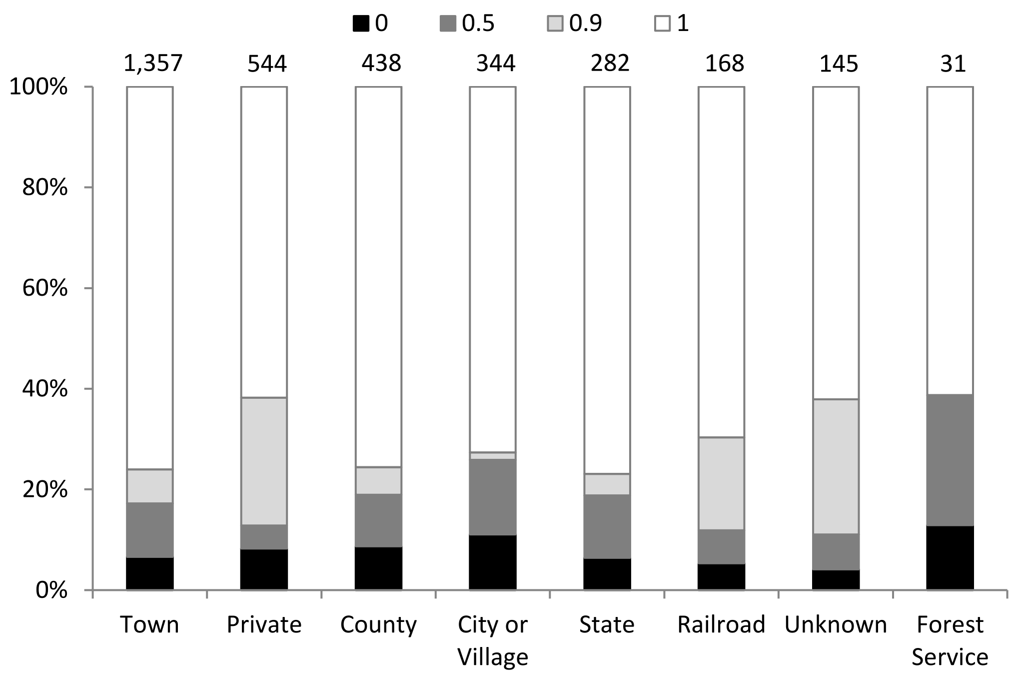
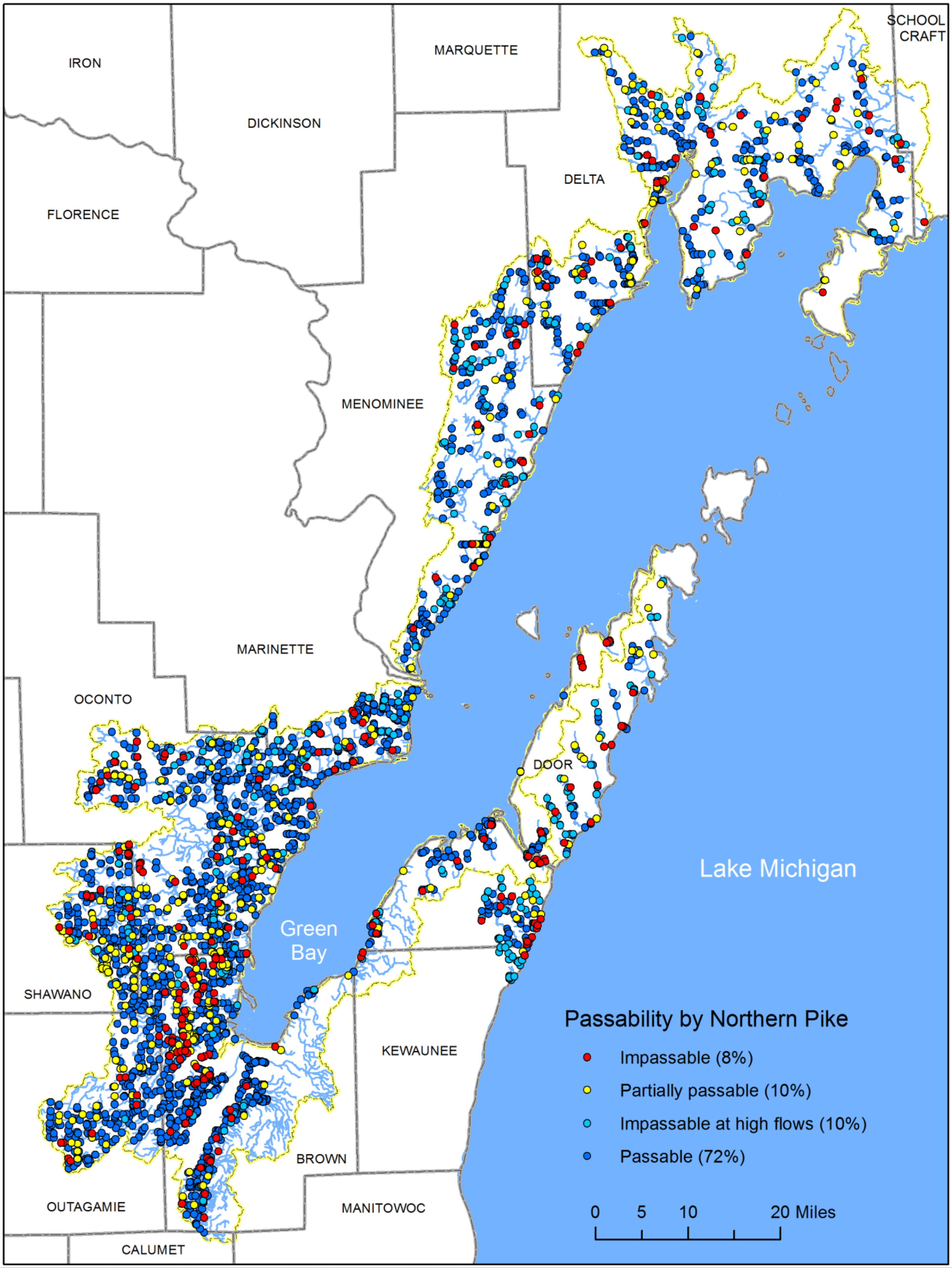


Figure 1. Percent of structures in each passability class by ownership category. Labels above each bar are the number of structures in that category.

The probability of catching young-of-year (YOY) pike in traps at over 300 sites from 1994-2011 was positively related to the percentage of wetland and forest upstream of the trap and the passability of structures between the trap and the bay, and negatively related to distance from the bay. Contrary to our expectations, the drainage area of the stream was not a significant predictor of YOY pike catch. However, in 2012 many small streams were dry, and there was a strong relationship between drainage area and lack of flow, so the probability of flow was included as a measure of habitat quality that influenced the value of removing barriers.

The total estimated cost to remove (i.e., replace with passable structure or install fishway) the 917 structures that are at least partial barriers to fish is $49.8 million. The result of this expenditure would be to restore access for northern pike to 26,800 quality-weighted acres of wetland habitat. The cost per acre of habitat gain (ΔH) varies dramatically among these potential projects, from $125 per acre for the most efficient project to well over $100,000 per acre for dozens of structures that block negligible amounts of habitat. Consequently, if barriers are selected for removal based on the prioritized list, half of the total potential habitat gain could be achieved for $4.2 million, and 90% of the habitat gain could be achieved for $15.5 million (Figure 3).

As barrier removal projects are completed, the attributes of the affected barriers should be updated and OptimizeDS should be rerun. An alternative prioritization method is to use the APASS model included with this report to select one or more barriers for removal to match a specified project budget. Exporting the APASS_input query as a text file will create the input to APASS.


IRON
MARQUETTE
SCHOOL CRAFT
DICKINSON
DELTA
FLORENCE
MENOMINEE
MARINETTE
OCONTO
DOOR
Lake Michigan
Green Bay
SHAWANO
KEWAUNEE
BROWN
OUTAGAMIE
MANITOWOC
CALUMET
Passability by Northern Pike
Impassable (8%)
Partially passable (10%)
Impassable at high flows (10%)
Passable (72%)
0 5 10 20 Miles

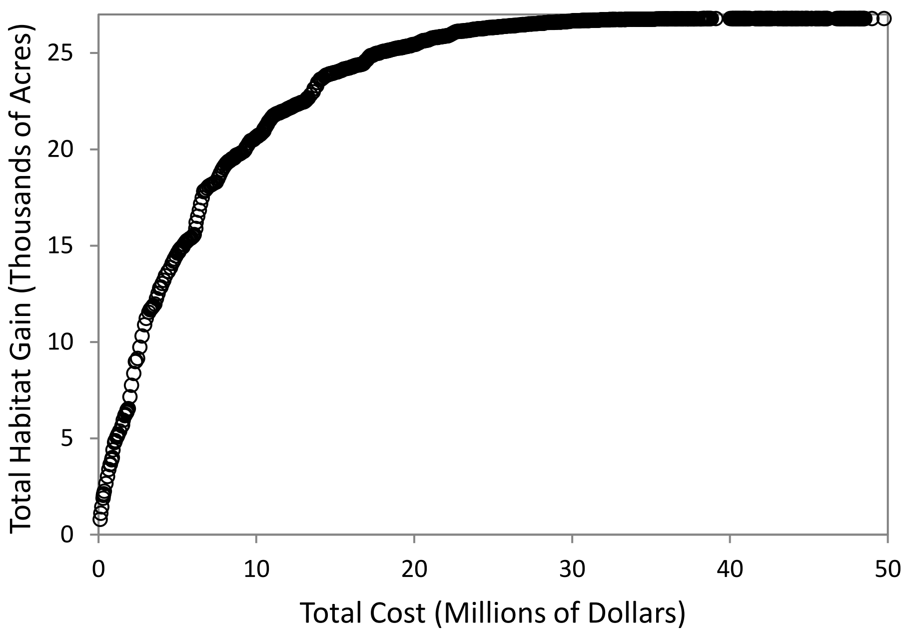


Figure 3. Gain in quality-weighted wetland habitat that would be made accessible as a function of cost to remove barriers.

Discussion

The results of the barrier removal prioritization should not be taken as precise measures, so site-specific knowledge should take precedence when a project is being considered for implementation. For example, our experience in the field suggests that wetlands vary substantially in their hydrologic and vegetation characteristics, which determine whether a wetland is suitable for northern pike spawning and larval development. However, the wetland datasets that were available at the scale of the entire project area did not include attributes that adequately distinguished suitable from unsuitable wetlands. Additional fieldwork or GIS analyses using high resolution topographic data such as LIDAR could help create a fish-spawning-based wetland classification. In addition, the barrier removal cost estimates are very rough, and should be refined where possible with site-specific engineering plans. Despite these shortcomings, the wide range in cost per acre of habitat gain among potential projects suggests that project ranks should be relatively reliable.

Over 250 structures on network streams were not surveyed because they were on private property and the owners could not be contacted. If a project is being considered in a tributary system that includes an unsurveyed structure, efforts should be made to survey it and the passability updated from the default value (0.9) to its true value. The barrier database should be updated as removals are completed, both to keep track of progress toward restoring connectivity and to ensure that future project plans account for the changing barrier “landscape”.

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References

Januchowski-Hartley SR, McIntyre PB, Diebel MW, Doran PJ, Infante DM, Joseph C, and Allan JD. 2013. Restoring aquatic ecosystem connectivity requires expanding inventories of both dams and road crossings. Frontiers in Ecology and the Environment.

Appendix A. Description of objects in GreenBay geodatabase.

Name	Description
barriers	Attribute table for barriers feature class (all structures on stream network including passable structures; see metadata for more information)
barriers_non_network	Attribute table for barriers_non_network feature class (all structures on not on stream network; see metadata for more information)
barriers_non_network_Shape_Index	Location information for feature class
barriers_Shape_Index	Location information for feature class
boundary	Attribute table for study area boundary (dissolved HUC12 boundaries)
boundary_Shape_Index	Location information for feature class
catchments	Attribute table for catchment (watershed) boundaries (see metadata for more information)
catchments_Shape_Index	Location information for feature class
CostTable	Table generated by OptimizeDS
domain_cross_type	Coded value attribute domain for Report_Query
domain_fieldcheck	Coded value attribute domain for Report_Query
domain_material	Coded value attribute domain for Report_Query
domain_obstruct	Coded value attribute domain for Report_Query
domain_out_type	Coded value attribute domain for Report_Query
domain_pass_methd	Coded value attribute domain for Report_Query
domain_road_surf	Coded value attribute domain for Report_Query
domain_shape	Coded value attribute domain for Report_Query
domain_struc_cond	Coded value attribute domain for Report_Query
domain_type	Coded value attribute domain for Report_Query
domains	All attribute domains in geodatabase
GDB_ColumnInfo	Geodatabase table
GDB_DatabaseLocks	Geodatabase table
GDB_GeomColumns	Geodatabase table
GDB_ItemRelationships	Geodatabase table
GDB_ItemRelationshipTypes	Geodatabase table
GDB_Items	Geodatabase table
GDB_Items_Shape_Index	Geodatabase table
GDB_ItemTypes	Geodatabase table
GDB_ReplicaLog	Geodatabase table
GDB_SpatialRefs	Geodatabase table
HUC12	Attribute table for HUC12 boundaries in study area (see metadata for more information)
HUC12_Shape_Index	Location information for feature class
railroads	Attribute table for 1:24,000-scale railroads (see metadata for more information)
railroads_Shape_Index	Location information for feature class
Results	Table generated by OptimizeDS

roads	Attribute table for TIGER roads (see metadata for more information)
roads_Shape_Index	Location information for feature class
SelectedObjects	Geodatabase table
Selections	Geodatabase table
streams	Attribute table for streams feature class (see metadata for more information)
streams_Shape_Index	Location information for feature class
temp	Table generated by OptimizeDS
ToFrom	Barrier topology table
wetlands	Attribute table for wetlands feature class (see metadata for more information)
wetlands_riparian	Attribute table for riparian wetlands feature class (see metadata for more information)
wetlands_riparian_Shape_Index	Location information for feature class
wetlands_Shape_Index	Location information for feature class
APASS_input	Query for exporting APASS input file.
Cost1	Cost query 1
Cost2	Cost query 2
Cost3	Cost query 3
Cost4	Cost query 4
Cost5	Cost query 5
Cost6	Cost query 6
Log	Query used to calculate HAB_VALUE
Outlets1	Unique watershed outlets
Report_Query	Query used to format information for Barrier_report
RSX1	Query used to calculate HAB_VALUE
RSX2	Query used to calculate HAB_VALUE
RSX3	Query used to calculate HAB_VALUE
Barrier_form	Form for barrier data entry and editing
Barrier_report	Report for exporting formatted barrier information
Export Table Properties	Module for exporting all fields and descriptions
modHandleReport	Module that assists with photo rendering in Barrier_report
OptimizeDS	Module that runs barrier removal prioritization

Appendix B. Data sources for mapping locations of potential barriers.

- Roads
  - U.S. Census Bureau TIGER 2000 roads (http://www.census.gov/geo/maps-data/data/tiger-line.html)
- Railroads
  - 1:24,000 railroads for Wisconsin and Upper Peninsula Michigan (available upon request from WDNR, http://dnr.wi.gov/maps/gis/)
- Streams
  - Wisconsin Department of Natural Resources 1:24,000-scale flowlines (http://dnr.wi.gov/maps/gis/datahydro.html)
  - National Hydrography Dataset, high resolution, 1:24,000-scale, used for Michigan only (http://nhd.usgs.gov/data.html)
- Dams
  - Great Lake Basin Dam Database (described in detail in Januchowski-Hartley et al. 2013, available from the authors)
- Aerial photographs
  - Wisconsin Regional Orthophotography Consortium, 6-12" resolution color photographs, acquired April 2010
  - Bing Maps, used for Michigan only

Appendix C. Phase 1 barrier survey protocol.

The **goals** of this inventory are to:

1. Assess whether mapped and unmapped streams and wetlands have enough water depth and flow to allow access by adult northern pike.
2. Determine the type of follow-up survey to be conducted on potential barriers to fish passage, including road and railroad crossings and dams.
3. Verify spatial connections between mapped and unmapped streams and wetlands.

Methods: At each mapped point, choose the appropriate **FieldCheck**. Measurements should be estimated visually, rather than measured, to save time.

No access: Structure is on private property or not easily accessible by road. If the structure can be seen from the road, try to complete assessment below. Note any impressions on likelihood of permission to survey by landowner.

No crossing: Stream and road do not actually cross here.

Clearly not connected to blue line: Even if there is definitely or possibly enough water, the feature is clearly not connected to a mapped stream.

Secondary connection to wetland: The crossing provides access to a wetland that is more easily accessed through another flow path.

Definitely enough water: If standing water, average water depth > 6 inches. If flowing water, average water depth > 3 inches. Water depth is measured to sediment surface, even when vegetation is present.

Possibly enough water: If standing water, average water depth > 3 inches. If flowing water, average water depth > 1 inch.

Not enough water: If standing water, average water depth < 3 inches. If flowing water, average water depth < 1 inch.

Passable: Structure does not appear to limit passage of adult northern pike; no further assessment needed. A structure is passable if either of the following is true:

1. Structure has an open bottom and appears to be at least 50% as wide as the stream.
2. Water surface is flat through entire length of structure, and for streams, the structure appears to be at least 75% as wide as the stream, at least 50% of bottom of the structure is covered with stream substrate, and there is no scour pool downstream of the structure.

Survey 1: Water surface is flat through entire length of structure or current velocity appears less than or equal to the stream.

Survey 2: Water velocity appears greater than the stream and/or the structure has an outlet drop.

Some examples of FieldNotes:

- rock weir under bridge
- rough channel recently excavated in upstream wetlands
- stream stays on east side of road
- blue line actually crosses here
- debris dam

Appendix D. Phase 2 Barrier Survey Protocol

Equipment Check List

- ☐ Trimble Yuma electronic data recorder
- ☐ Tape measure (100 ft)
- ☐ Survey level and tripod
- ☐ Survey rod (16 ft telescoping)
- ☐ Current meter
- ☐ Waders, hip boots, or wading shoes
- ☐ Safety vests

Safety

Streams can be hazardous places to work, so take a moment to evaluate risks before you begin to survey stream crossings. These surveys will work best with two people to make measurements easier, but also to provide help if needed. Crews should be aware of road and traffic safety when parking their vehicles and crossing over the road for measurements. Take measurements carefully and estimate if necessary. Avoid wading into even small streams at high flows, pools of unknown depths, or scaling steep and rocky embankments. There are usually ways to make effective estimates of structure dimensions without risking harm, such as measuring culvert lengths over the top of the roadway instead of through the structure.

Clean Your Equipment

The following simple precautions will help prevent the spread of invasive species among survey sites. Follow this protocol between every site, but be particularly careful when moving among watersheds.

1. Inspect your equipment and remove any aquatic plants, animals, and mud.
2. Using a jug of clean tap water, rinse all equipment that was in contact with stream water, including flow meters, tape measures, and waders.
3. Drain water from all equipment.
4. At the end of the day, store all equipment where it will dry thoroughly before the next field trip.

Measurements

All length measurements should be made in feet and recorded to the nearest 0.1 foot. Do not record inches, even for measurements that are less than one foot. For example, record 0.5 feet instead of 6 inches. Measurements longer than 20 feet may be rounded to the nearest foot if you are not confident in the precision of the measurement (e.g., when you have to lay the tape over the road when measuring the length of a culvert).

General

Site ID: Do not change this ID for existing features. Leave blank for new features.

Road: Confirm or record the name of the road. If the road does not have a name, use "Unnamed" or describe the road, like "Connor's Driveway" or "Dirt road off Hwy 23".

Stream: Record the name of the stream for new features.

Type: Record the appropriate type for new features.

Date: Check the box next to the date to record the current date.

Crew: Record initials or last names of survey crew.

Notes: Record information about the site not included in other fields, such as name and contact information of adjacent landowners.

Streamflow: Choose the term which best describes the stream flow conditions during the survey. Flow is relative to the channel volume – even small streams can have high flow.

Hydro type: Record the type of hydrologic feature at the crossing. Ditches may look like streams, but are straightened. Streams generally have a meandering pattern. Wetlands do not have a defined channel except sometimes near the crossing. Bankfull width should only be recorded for streams.

Bankfull: Measure the bankfull width of a riffle (see below) in the stream, perpendicular to the direction of flow, to the nearest 0.1 foot. Bankfull width is the channel width at the point where water has filled the principal stream channel and just begins to flow onto the active floodplain. Most streams only fill their bankfull channels about once per year. The point that defines the edge of the bankfull channel is typically defined by a sharp transition from a vertical or sloping bank to a horizontal floodplain. Woody vegetation rarely grows in the bankfull channel, although tree roots may be exposed below the bankfull elevation. Bankfull width should only be recorded for streams, not ditches or wetlands.

Riffles are sections of natural stream channels that have relatively shallow and fast flowing water compared to other sections of the stream. In most streams, the substrate in a riffle is composed of larger particles (e.g., gravel or cobbles) than other sections of the stream. Measurements of stream channel and flow characteristics at a "reference riffle" are used to describe the most challenging conditions that fish face in natural reaches of the stream. While the channel width in riffles can range from narrow to wide, you should choose a narrow riffle for this assessment. The bankfull (defined below) channel width in a narrow riffle is used as a standard for evaluating whether the crossing structure is wide enough to carry high stream flows without creating unnaturally high water velocities.

Choose a reference riffle that is far enough from the crossing that its characteristics are not affected by the crossing. This may be as little as 50 feet from the crossing on a very small stream or as much as several hundred feet on a large stream or river. You may select a reference riffle that is upstream or downstream of the crossing. Some streams have relatively constant depths and velocities, and do not have any distinct riffle sections. In this type of stream, focus on selecting a narrow reference reach.

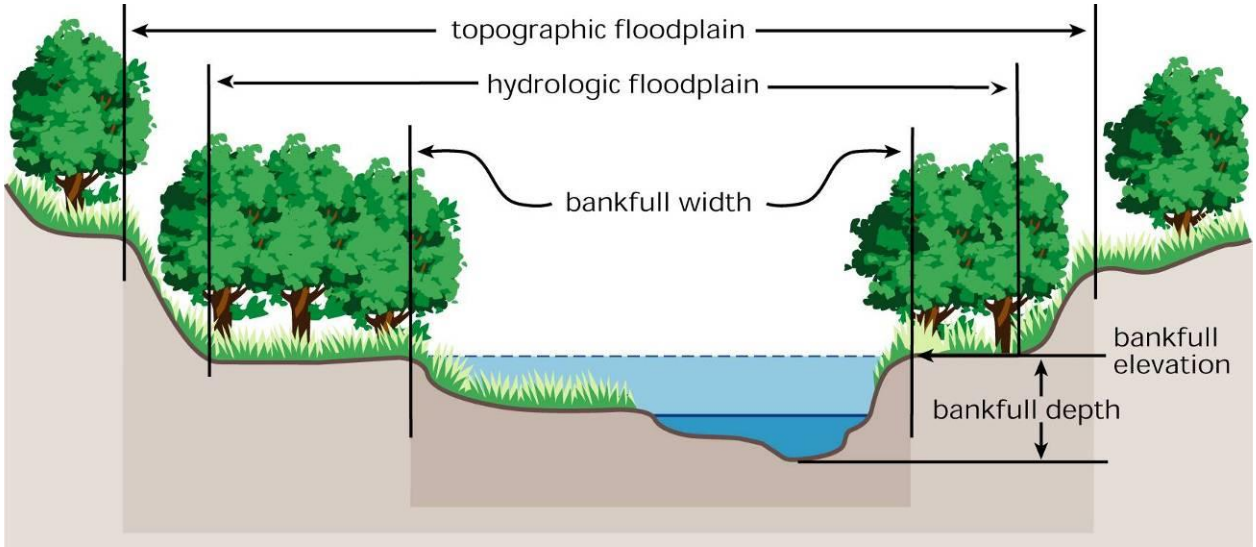
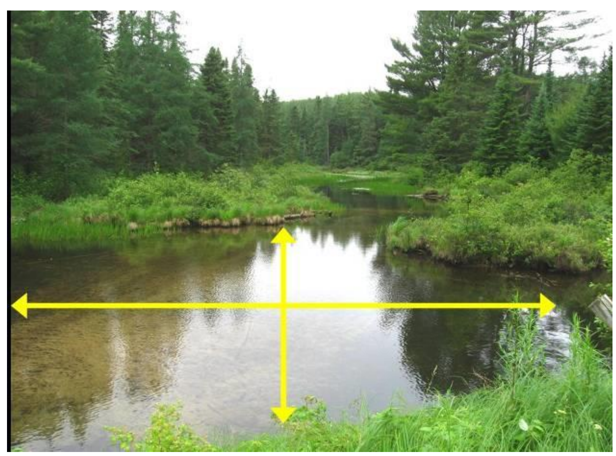


Image credit: Stream Corridor Restoration: Principles, Processes, and Practices, 10/98, by the Federal Interagency Stream Restoration Working Group (FISRWG).

Scour Pool: If the stream channel is noticeably wider and deeper directly below the crossing than in other sections of the stream, this is a scour pool that is created by high velocity water during high flow events.

Upstream Pond: If the stream channel is noticeably wider directly above the crossing than in other sections of the stream, this is a pond that is created by a crossing structure that is too small or set at a higher elevation than the natural stream bed.



Road surface: Note the road surface type: paved (blacktop or cement), gravel (rotten granite or crushed rock), sand or dirt (native soil without any additions other than sand).

Road width: Measure the width of the road at the crossing to the nearest foot. Measure the road width from the outside edge of one road shoulder to the outside edge of the other shoulder. The road shoulder ends, and the ditch (or crossing embankment) begins, when the surface starts to slope away from the road.

Fill depth: Measure or estimate the depth of road fill above the crossing (i.e. from the top of the culvert to the surface of the road) to the nearest foot.

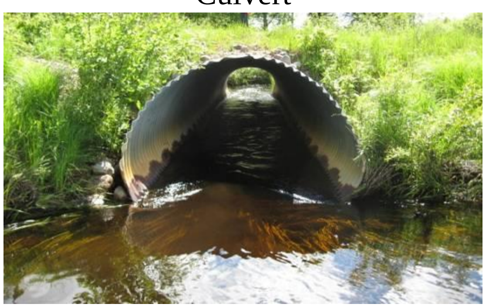
Embankment Slope: Visually estimate the slope of the embankments. A slope ratio of 1:2 means 1 foot of vertical drop for every 2 feet of horizontal distance.

Erosion: Note the overall extent of erosion on the road, embankments, and ditches near the crossing.

Survey 1

Crossing design: Record whether the structure is one or more culverts or a bridge. Both types of structures may be constructed from any material. Culverts have a closed bottom (which may be buried under stream substrate); bridges have an open bottom. For crossings that have more than one culvert, measure the dimensions, substrate, and flow depth and velocity of the culvert that carries the most flow.

Culvert



Bridge

Structure condition: Is the structure in new, good, fair, or poor condition?

Structure material: Is the structure made out of metal, concrete, plastic, or wood?

Structure interior: Record whether the interior of the crossing is smooth or corrugated.

Structure length: Measure the structure length to the nearest foot. If a culvert has mitered ends, measure the length at the bottom. The structure length can be measured by stretching the tape across the road surface.

Structure width: Measure the structure width to the nearest 0.1 foot. If there is more than one culvert, measure the one that carries the most flow. If the crossing is too wide to measure at the inlet or outlet, or if it is too dangerous, estimate the width from the top of the crossing.

Structure height: Measure the structure height to the nearest 0.1 foot. For bottomless structures, height is measured from the streambed to the ceiling of the structure. For structures with bottoms, height is measured from the floor to the ceiling, including the depth of substrate, if present.

Survey 2

Substrate type: If the bottom of the culvert is covered with stream bed substrate, record the type:

- Cobble – baseball-sized or larger rocks
- Gravel – rocks between the size of a pinhead and a baseball
- Sand – particles are smaller than a pinhead and feel gritty between fingers
- Silt – very fine particles that don't stick together
- Clay – very fine particles that stick together
- Bedrock – solid slabs of rock
- Rip-rap – cobble-sized or larger pieces of rock placed during construction

Substrate width: Measure the width of the bottom of the culvert covered by streambed substrate to the nearest 0.1 foot.

Water depth and velocity can either be measured using a current meter or modeled using a culvert elevation profile. Use measured velocity/depth if the stream has at least moderate flow at the time of survey. Use a combination of inlet/upstream bed and outlet/tailwater control when the stream has less than moderate flow. Choose the upstream and downstream measurement points that appear to control the water surface slope through the structure at moderate to high flows.

Structure water depth: Measure the water depth in structure to the nearest 0.1 foot as follows. If the water depth varies in the section of the structure you can reach at each end, find the structure cross section with the shallowest maximum depth and record the deepest point at this cross section. If you can walk through the structure safely, find the structure cross section from the entire length that has the shallowest maximum depth and record the deepest point at this cross section. The depth at this point is the limiting depth for fish passage. If the water is too deep to wade, use a survey rod to measure from the top of the crossing.

Structure water velocity: If you have a current meter, measure the water velocity at the same point that you measured water depth. If the maximum water depth is less than 0.4 feet, measure the velocity at the midpoint of the water depth at the deepest point. If the maximum water depth is greater than 0.4 feet, measure the velocity at 0.2 feet above the substrate at a few points that are deeper than 0.4 feet and record the lowest velocity.

If you do not have a current meter, drop an orange, bobber, or other floating object into the water at the inlet of the crossing and time how long it takes to float through the structure. Calculate the velocity by dividing the length of the structure by the time it took the item to float through the structure.

% culvert length: Based on a visual estimate, what percentage of the culvert length has a flow velocity similar to the one you measured with the current meter. This will determine how long a fish would have to swim against the maximum velocity in the culvert.

Tailwater control elevation: Using the survey level and rod, measure the elevation of the highest point on the stream bed downstream of the crossing to the nearest 0.01 foot. Also measure the distance from the structure outlet to the tailwater control (**Tailwater distance**).

Upstream bed elevation: Using the survey level and rod, measure the elevation of the point on the stream bed upstream of the crossing that controls the water surface slope through the crossing to the nearest 0.01 foot. Also measure the distance from the structure outlet to the upstream control (**Upstream bed distance**).

Inlet and outlet elevation: Using the survey level and rod, record the elevation of the bottom of the culvert at the inlet and outlet to the nearest 0.01 foot. If there is sediment in the culvert, measure the elevation on top of the sediment.

Obstruction: If an obstruction may impede fish passage, note the type:

- Crushed: the culvert is crushed enough to constrict flow.
- Debris: tree branches or other debris is blocking the culvert.
- Vegetation: dense rooted vegetation, such as Phragmites, blocks passage through the culvert.
- Rocks: piles of rip-rap or rock weirs create an obstruction to fish passage.

Outlet drop: If the outlet of the structure is elevated above downstream water surface, measure the vertical distance from the downstream water surface to the bottom of the stream crossing structure to the nearest 0.1 foot interval.

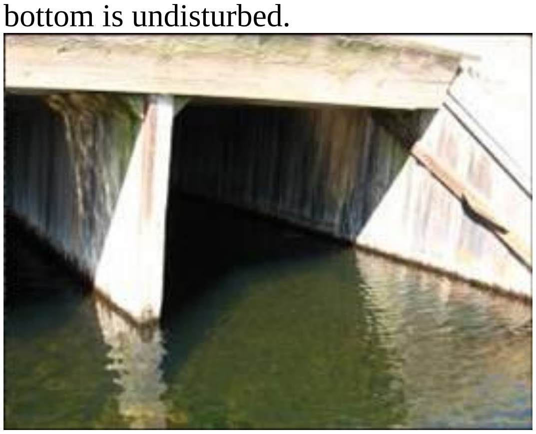
Limiting factor: In your opinion, which aspect of the crossing design presents the greatest challenge to fish passage. In general, outlet drops are the most difficult to pass, followed by high velocity (>2 ft/sec), and shallow depth (<0.2 ft). Long culverts exacerbate problems caused by velocity and depth. Culverts that are narrow relative to the stream can be a barrier during high flow events.

Structure Shape: Choose the term that best describes the shape of the structure.

Round

Square/Rectangle – typically concrete, with floor (may be covered with natural stream substrate).

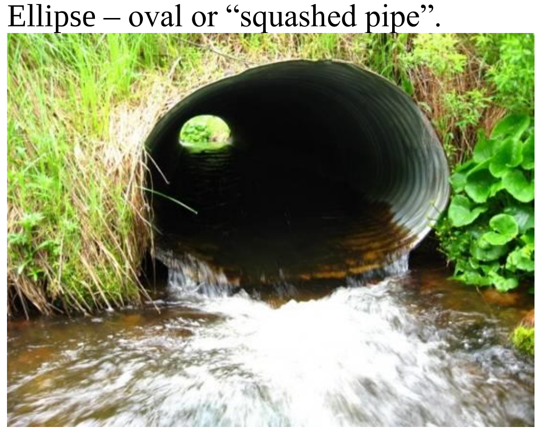
Open Bottom Square/Rectangle – the walls of the crossing are buried and the stream bottom is undisturbed.



Pipe Arch – similar to a round pipe, but bottom is flattened.

Open Bottom Arch – the walls of the crossing are buried and the stream bottom is undisturbed.

Ellipse – oval or “squashed pipe”.



Inlet Type: Circle the term(s) that best describe the inlet (upstream end) of the crossing structure.

Projecting – end of culvert protrudes from embankment.

Apron – extension of culvert floor beyond end of pipe.

Mitered – end of culvert cut at an angle, usually sloping back toward road

Wingwall – concrete, gabion, masonry, or timber walls that are built out at angles from the inlet.

Headwall – concrete, gabion (wire mesh filled with rocks), masonry, or timber wall built around inlet.

Trash Rack – mesh cover or gate over inlet to prevent floating debris from entering culvert.

Outlet Type: Select the term(s) that best describe the outlet (downstream end) of the crossing structure.

At Grade – bottom of culvert is at the elevation of the stream bed.

Cascade

Embedded – the bottom of the culvert is buried below the stream bed.

Freefall into Pool

Photos

Take photos of the inlet, outlet, and views up and downstream. Select the picture you are about to take from the drop down menu on the Picture tab. Then click the camera icon to activate the camera. Push the red button on the right side of the Yuma to take a picture.

Inlet

Outlet

Upstream

Downstream

Appendix E. Stream digitizing protocol (see streams metadata in geodatabase for more details).

The goal of this protocol was to map streams that were observed in the field to have enough water for passage of adult northern pike, but were not included in the standard hydrography datasets (see Appendix B).

Streams were digitized in ArcGIS using the 'stream mode' editing option, and digitizing was conducted in the direction of stream flow (i.e., upstream to downstream). All streams were digitized at a consistent map scale within ArcGIS (1:2,500). The downstream node of all digitized stream features was snapped to the upstream node of another stream feature or to Green Bay. Streams were not digitized in areas with barriers/structures labeled as 'secondary wetland connections' or 'upstream of high gradient reach'. New stream features were not created solely to represent flow between isolated wetlands that did not appear to have a surface connection to Green Bay.

Appendix F. Methods for determining passability of road crossings by northern pike.

0. No drop, depth and velocity OK, 1
1. Outlet drop
    a. Drop > 0.3 ft, 0
    b. Drop < 0.3 ft, 0.5
    c. Outlet type = cascade or freefall, but no drop recorded, 0.5
2. Velocity
    a. Measured velocity > 3 ft/s, 0
    b. Measured velocity > 2 ft/s and flow is moderate or high, 0.5
    c. Measured velocity > 2 ft/s and flow is low, 0
    d. Modeled April velocity > 3 ft/s, 0
    e. Modeled April velocity > 2 ft/s, 0.5
3. Depth
    a. Modeled April depth < 0.3 ft and culvert slope > 1%, 0.5
4. See note
    a. Case-by-case evaluation consistent with other criteria
5. Not enough info
    a. 0.9 (average of all surveyed crossings)
6. No access
    a. 0.9 (average of all surveyed crossings)
7. Structure type
    a. Dam, 0
    b. Open bottom culvert or bridge, 1
8. Pike upstream
    a. If pike observed upstream, but default PASS = 0, 0.5
9. Obstruction
    a. 0.5, unless notes indicate that it is clearly complete barrier
10. Constriction (structure width / bankfull width)
    a. Constriction ratio (structure width/bankfull width) < 0.5 and WSA > 1 mi^2, 0.9
11. Length
    a. Length > 100 ft, 0.5

Appendix G. Methods for estimating the amount of spawning habitat that would be made accessible by removal of fish passage barriers (HAB_VALUE).

Watershed Delineation

1. Split the streams layer at the location of each barrier.
2. Delineate the watershed for each segment in the split streams layer using the 10 m resolution National Elevation Dataset, and tools in ArcGIS.

Stream Area

3. Regress bankfull width on watershed area: log10(BANKFULL) = 0.0131*log10(WSAMI2)^3 + 0.1088*log10(WSAMI2)^2 + 0.2768*log10(WSAMI2) + 0.7394
4. Use regression in step 3 to predict bankfull width for all streams (BFPRED).
5. BFCOMB = If(BANKFULL Is Null, BFPRED, BANKFULL)
6. STREAM_AREA = BFCOMB*ShapeLength

Wetland Area

1. Identify all wetlands in the Wisconsin Wetlands Inventory (in WI) and National Wetlands Inventory (in MI) that are adjacent to a stream line (i.e., riparian) or that are contiguous with a riparian wetland.
2. Intersect the riparian wetlands with the watershed boundaries in ArcGIS to determine the area of wetland in each watershed (WET_AREA).

Flow Weighting:

1. WATOBS = WATER expressed as probability that a stream segment will have enough flow for adult pike (definitely enough = 1, possibly enough = 0.5, not enough = 0).
2. WATUPDN = WATOBS values of 0 extended upstream and 1 extended downstream
3. WATPRED ~ logistic regression of WATUPDN on log(ShedArea) and ForestWetland (ShedArea was deleted accidentally, but could be recreated if needed).
4. WATCAT = 0 if above high gradient reach or above large dam, otherwise 1
5. WATCOMB = (WATUPDN + WATPRED) / 2) * WATCAT
6. WET_AREA_W = WET_AREA * WAT_COMB
7. STREAM_AREA_W = STREAM_AREA * WAT_COMB

Habitat Area

1. Group stream segments into “subnetworks” that are bounded by barriers. Each subnetwork is assigned the ID of the barrier at its downstream end.
2. Sum(WET_AREA_W + STREAM_AREA_W) for each subnetwork as HAB_AREA.

Habitat Value:

1. Use all young-of-year (YOY) northern pike trap data from 1994 to 2011 to fit logistic regression for YOY presence/absence (includes random effect of year to account for variable water conditions): YOY_PROB = 1/(1+Exp(-(-3.047+0.9242*[ALLPASS]-0.00002167*[OUTDIST] +0.4126*Sqr([WETLAND])+0.1739*Sqr([FOREST])))) where:
    a. YOY_PROB is the probability of catching 1 or more YOY pike in a trap

   b. ALLPASS is the product of the passabilities of all structures between the trap and Green Bay
   c. OUTDIST is the distance in meters through the stream network from the trap to Green Bay
   d. WETLAND and FOREST are the percentages of wetland and forest cover in the total upstream watershed of the trap.
2. HAB_VALUE = YOY_PROB * HAB_AREA

Appendix I. Methods for estimating replacement cost for culverts and dams.

Dams: Multiply the height of the dam by $36,600, which was the average cost per foot in 2007 dollars of 10 “nature-like” fishways installed in the northeastern US (J. Turek, NOAA Restoration Center, Narragansett, RI, unpublished data).

Road crossings: The cost to replace each impassable or partially passable crossing structure with a fully passable structure was estimated from measurements collected during the field survey. The width of the new structure was set equal to the bankfull width of the stream, which allows the channel dimensions, substrate, and flow characteristics in the crossing to resemble those of a natural channel. We specified a round or bottomless culvert for bankfull widths < 12 ft and a free span bridge for bankfull widths of 12-25 ft. The primary determinants of project cost are the structure’s dimensions, excavation and fill volume, and road surface type. Unit costs were based on the experience of project cooperators carrying out road crossing replacement projects in Wisconsin and Michigan in 2009. The following queries were used in Access to calculate costs.

Bankfull rounded: Round([barriers]![BFCOMB],0)

Fill depth: IIf([barriers]![FILL_DEPTH] Is Null,(([barriers]![OUT_INVERT]+[barriers]![IN_INVERT])/2)-[barriers]![INST_HEIGT],[barriers]![FILL_DEPTH])

Total fill depth: IIf([barriers]![S1_HEIGHT] Is Null,[barriers]![S1_WIDTH],[barriers]![S1_HEIGHT])+[Fill depth]+2

Fill volume: ((([barriers]![ROAD_WIDTH]*[Total fill depth]*([barriers]![BFCOMB]+6))+(((([barriers]![S1_LENGTH]-[barriers]![ROAD_WIDTH])*[Total Fill Depth])*([barriers]![BFCOMB]+6))/2)))

Side slope fill volume: ([Total Fill Depth]^2*(barriers!BFCOMB+6))*2

Prism volume: ([Fill volume]+[Side slope fill volume])/27

Excavation cost: [Prism volume]*12

Cost/Foot: IIf(barriers!BFCOMB<2.5,34.85,IIf(barriers!BFCOMB<3.5,65.55,IIf(barriers!BFCOMB<4,74.7,IIf(barriers!BFCOMB<4.5,83.8,IIf(barriers!BFCOMB<5,115.6,IIf(barriers!BFCOMB<6,138.5,IIf(barriers!BFCOMB<7,125.77,IIf(barriers!BFCOMB<8,155.85,IIf(barriers!BFCOMB<9,214.61,IIf(barriers!BFCOMB<10,294.26,IIf(barriers!BFCOMB<11.1,297.46,0)))))))))))

Culvert Length: 4*[Total fill depth]+barriers!ROAD_WIDTH

Total pipe cost: [Culvert Length]*[Cost/Foot]

Pipe end area:
IIf(barriers!BFCOMB<2.5,4.9,IIf(barriers!BFCOMB<3.5,9.62,IIf(barriers!BFCOMB<4,12.57,IIf(barriers!BFCOMB<4.5,15.9,IIf(barriers!BFCOMB<5,19.63,IIf(barriers!BFCOMB<6,28.27,IIf(barriers!BFCOMB<7,38.48,IIf(barriers!BFCOMB<8,50.27,IIf(barriers!BFCOMB<9,63.62,IIf(barriers!BFCOMB<10,78.54,IIf(barriers!BFCOMB<11.1,95.03,0)))))))))))

Culvert volume: ([Culvert Length]*[Pipe end area])/27

Reconstruction cost: ([Prism volume]-[Culvert volume])*8

Bedding cost: (([Culvert Length]*(barriers!BFCOMB+6)*0.5)/27)*16

Surfacing cost: IIf(barriers!ROAD_SURF="1",10000,800)

Pipe disposal:
IIf([barriers]![CROSS_TYPE]="1",100,IIf([barriers]![CROSS_TYPE]="2",200,IIf([barriers]![CROSS_TYPE]="3",300,IIf([barriers]![CROSS_TYPE]="4",400,0))))

Unsuitable haulaway: IIf([barriers]![BFCOMB]<8,200,400)

Riprap: IIf(barriers!BFCOMB<8,750,1500)

Dewatering: IIf(barriers!BFCOMB<8,500,2000)

Bevel: 1000

Polymer coating: 0.25*[Total pipe cost]

New culvert HEIGHT:
IIf(barriers!BFCOMB<2.5,2,IIf(barriers!BFCOMB<3.5,2.75,IIf(barriers!BFCOMB<4,3.16,IIf(barriers!BFCOMB<4.5,3.58,IIf(barriers!BFCOMB<5,3.92,IIf(barriers!BFCOMB<6,4.75,IIf(barriers!BFCOMB<7,5.58,IIf(barriers!BFCOMB<8,6.25,IIf(barriers!BFCOMB<9,6.91,IIf(barriers!BFCOMB<10,7.58,IIf(barriers!BFCOMB<11.1,8.2,Null)))))))))))

Depth zero slope: [Total fill depth]-1

Arch pipe plus fill: IIf([New culvert HEIGHT]=0,0,([New culvert HEIGHT]+(IIf([New culvert HEIGHT]<6.25,1.5,2))))

Road elevation change: IIf(([Depth zero slope]-([New culvert HEIGHT]+(IIf([New culvert HEIGHT]<6.25,1.5,2))))>0,Null,([Depth zero slope]-([New culvert HEIGHT]+(IIf([New culvert HEIGHT]<6.25,1.5,2))))*(-1))

Crown fill: ([Road elevation change]^2*barriers!ROAD_WIDTH*100)/27

Total crown volume: (([Arch pipe plus fill]^3*200)/27)-((([Depth zero slope]^3*200)/27)+[Crown fill]

Crowning cost: IIf([Total crown volume]>0,[Total crown volume]*6,0)

Crown pipe cost: IIf([Road elevation change]>0,(([Road elevation change]*4)*[Cost/Foot])*1.25,0)

Concrete pipe add: IIf(([Depth zero slope]-[Arch pipe plus fill]-(IIf([BFCOMB]>8,2,1.5)))>8,[Total pipe cost]*0.2,0)

Total Cost: IIf([barriers]![CROSS_TYPE]="8",Null,IIf([BFCOMB]<11.1,([Excavation cost]+[Total pipe cost]+[Reconstruction cost]+[Bedding cost]+[Surfacing cost]+[Pipe disposal]+[Unsuitable haulaway]+[Riprap]+[Dewatering]+[Bevel]+[Polymer coating]+[Crowning cost]+[Crown pipe cost]+[Concrete pipe add])*1.2,IIf([BFCOMB]<24,100000,IIf([BFCOMB] Is Null,Null,150000))))

Appendix B: Watershed Approach and Field Level GIS Assessment Datasets

Appendix B. Watershed Assessment GIS Datasets	
Layer Name / Data Source	**Description**
Wisconsin Wetland Inventory (WWI) Wisconsin DNR http://dnr.wi.gov/topic/wetlands/inventory.html	Wetlands digitized from base maps of 1:24000 or greater. Mapping scale and date vary by county.
Potentially Restorable Wetlands (PRW) Wisconsin DNR http://dnr.wi.gov/topic/surfacewater/datasets/PRW/	Former wetland areas where the current land use can be converted, e.g. agricultural land (2016)
WDNR 24K Hydrography Geodatabase Wisconsin DNR http://dnr.wi.gov/maps/gis/datahydro.html	Statewide hydrography dataset
Hydrography 24K Value Added Wisconsin DNR ftp://dnrftp01.wi.gov/geodata/hydro_va_24k/	This project attributed channel, riparian, and watershed level data for streams in the 24K hydrogeodatabase (24KGDB) with a variety of geologic, land cover, and other base data.
Watershed Boundary Dataset (WBD) USDA-USGS https://www.nrcs.usda.gov/wps/portal/nrcs/detail/ national/water/watersheds/dataset/?cid=nrcs143_021616	Watersheds delineated using USGS topo maps of 1:24000 or greater; accessed 2015. Edited to be used in this assessment. Table M4.
WI Healthy Watershed Assessment Wisconsin DNR http://dnr.wi.gov/topic/watersheds/hwa.html	This assessment ranks each watershed based on many aspects of watershed condition, including water quality, hydrology, habitat, and biological condition. The assessment results are a modeled prediction of both overall watershed health and vulnerability.
Wiscland 2 Wisconsin DNR http://dnr.wi.gov/maps/gis/datalandcover.html	30m raster of Wisconsin landcover 2016
Digital Elevation Model USGS - 3D Elevation Program https://nationalmap.gov/3DEP/	10m Digital Elevation Model
Active River Area (ARA) TNC	Estimates the floodplain area using cost(slope)-distance analysis. Calculated from 24k Hydrography and 3DEP – 10m
SSURGO Soil Surveys Natural Resources Conservation Service http://www.arcgis.com/home/item.html?id= 4dbfecc52f1442eeb368c435251591ec http://datagateway.nrcs.usda.gov/	Digitized from 1:24000 base maps; accessed through ArcGIS Online and NRCS data gateway
TIGER Roads US Census Bureau https://www.census.gov/geo/maps-data/data/tiger- line.html	2015 dataset
Minor Civil Divisions State Cartographers Office http://www.sco.wisc.edu/find-data/mcd.html	Cities, Towns and Villages jurisdictions
303d Impaired Waters List Wisconsin DNR http://dnr.wi.gov/topic/impairedwaters/2016ir_iwlist.html	Section 303(d) of the Clean Water Act 2016 required list of all waters that are not meeting water quality standards.
WPDES Permits Database/CAFO Permit database Wisconsin DNR http://dnr.wi.gov/topic/wastewater/PermitLists.html http://dnr.wi.gov/topic/AgBusiness/CAFO/StatsMap.html	Permitted surface water discharges of pollutants to waters of the state with monitoring requirements, special reports, and compliance schedules appropriate to the facility in question.
Lower Fox River Basin Phosphorus and Drain Tile Mapping Project Outagamie County Land Conservation Department See Appendix C	Report was used to identify high soil phosphorus fields and fields that may be tiled

Appendix C: Lower Fox River Basin Phosphorus and Drain Tile Mapping Project

Lower Fox River Basin Phosphorus and Drain Tile Mapping Project

Technical Report For: The Nature Conservancy

Prepared by:
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1/5/2016

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Contents

1.0 Introduction

The goal of the project was to map publicly available soil phosphorus and drain tile data on a per field basis in the Lower Fox River Basin. The Lower Fox River Basin is located in northeastern Wisconsin and encompasses Brown, Calumet, Winnebago, and Outagamie Counties (Figure 1). The Lower Fox River Basin is 403,657 acres and flows northeast to the Bay of Green Bay. Approximately 50% of the basin consists of agricultural land.

The basin can be further divided into 19 HUC 12 subwatersheds (Figure 2). Drain tile was mapped for all agriculture acres by analyzing multiple years of aerial imagery for drain tile signatures in fields. Phosphorus data was obtained from available nutrient management plans (NMP) from farms that were in the watershed area. For each available NMP, phosphorus data in parts per million (ppm) and soil test year, when available, were attributed to each agricultural field along with the producer name and field name to help with identification of potential focus areas. Maps were created to summarize the results in the Lower Fox Basin. All maps referenced in report are available in full resolution in the Appendix. The following sections detail the steps taken in mapping the drain tile and phosphorus data.

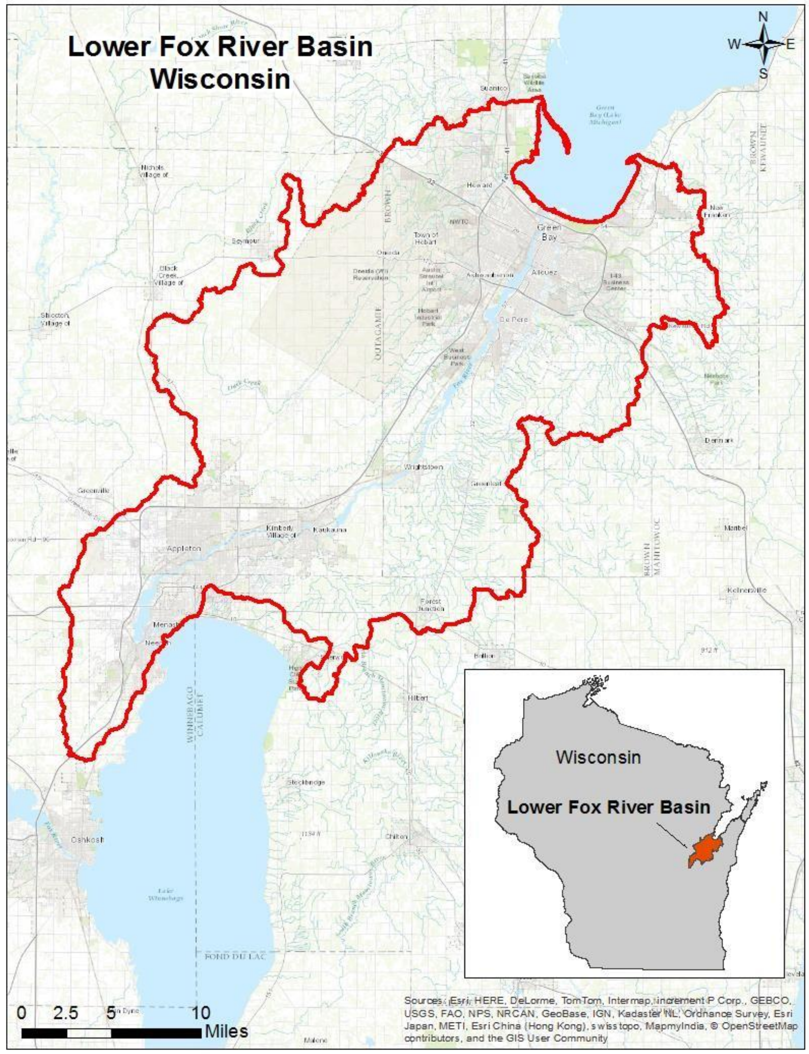


Figure 1. Lower Fox River Basin.

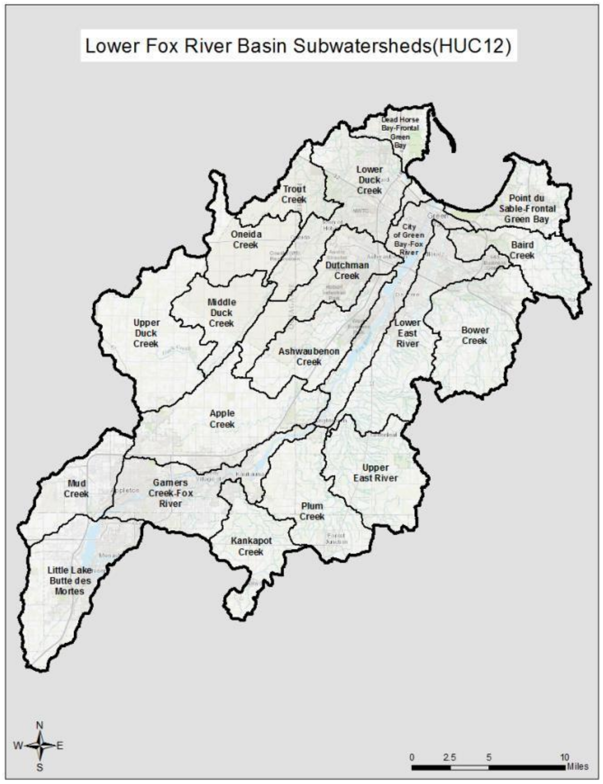


Figure 2. Lower Fox River Basin Subwatersheds.

1.1 Drain tile Mapping

1. The first step in drain tile mapping was to find aerial imagery that showed drain tile line signatures (Figure 3). Imagery used for this process included: 2010 County (Brown, Calumet, Outagamie) Orthoimagery, 2014 County (Brown, Calumet, Outagamie) Orthoimagery, Imagery©2015 Google, NAIP (National Agriculture Imagery Program) 2013, NAIP 2015, and ESRI basemap imagery.

Figure 3. Drain tile signatures in a crop field. (Imagery©2015Google)

2. Next a GIS polygon feature class was created to map tile drained fields. Existing field polygon shapefiles for each county and existing drain tile mapping data from previous projects in the watershed were combined to create one field polygon feature class that covered the Lower Fox River Basin. Figure 4 below shows the agriculture fields feature class for the Lower Fox River Basin.

3. Field boundaries were then digitized to 2015 NAIP imagery. The data attributed was the presence of drain tile line signatures and imagery that showed the features.

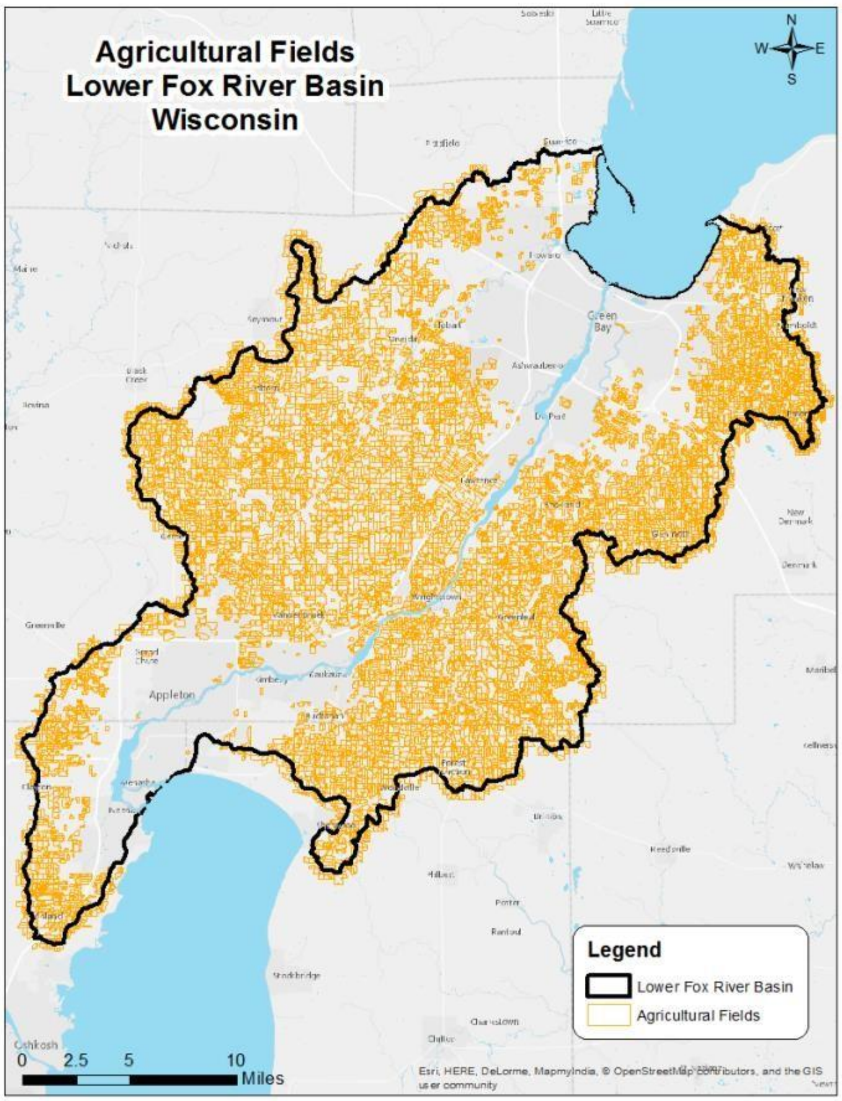


Figure 4. Agriculture fields in Lower Fox River Basin.

4. Several remote sensing image analysis methods were also tried to detect drain tile line features from imagery. While there shows some effectiveness, the methods tried did not produce adequate results in the time allowed for the project. See Appendix 3.2 for more detail.

5. A final map and report were put together to summarize the data and findings and to display data mapped.

1.2 Phosphorus Mapping

This phosphorus mapping project builds off two existing phosphorus mapping databases for Brown and Outagamie County. Documentation on the phosphorus mapping process for Outagamie County's existing database can be found in Appendix 3.2.

1. The first step in the phosphorus mapping process was to gather all the existing data that was available. Phosphorus mapping GIS data for Concentrated Animal Feeding Operations (CAFO) in the Lower Fox River Basin was obtained from the Wisconsin DNR. Available nutrient management plans (NMP) were obtained for Calumet and Outagamie County.

2. Existing P mapping and field GIS data from adjacent counties were combined with the existing 2013 Outagamie County Phosphorus mapping GIS data layer. The combined layer was then clipped to the Lower Fox River Watershed area.

3. Additional attributes were added to the new 2015 Lower Fox Phosphorus Mapping GIS Layer to track soil test year and multiple farms using the same field.

4. DNR CAFO data was joined to the watershed wide phosphorus mapping layer and updated available soil phosphorus data was entered into the layer. Field boundaries were edited to match most recent NMP available.

More detailed description of phosphorus mapping procedures used see Appendix 3.2.

5. A final map and report were put together to summarize the data and findings and to display data mapped.

2.0 Results and Findings

After all the data was entered it was analyzed to see general trends and statistics. The following section describes results and findings of phosphorus and drain tile mapping.

2.1 Drain Tile Mapping

A total 2,418 of 11,805 fields in the Lower Fox River Basin showed drain tile drainage signatures equaling 69,730 acres of drain tiled farm fields. Mapped tile drained fields are shown in Figure 5.

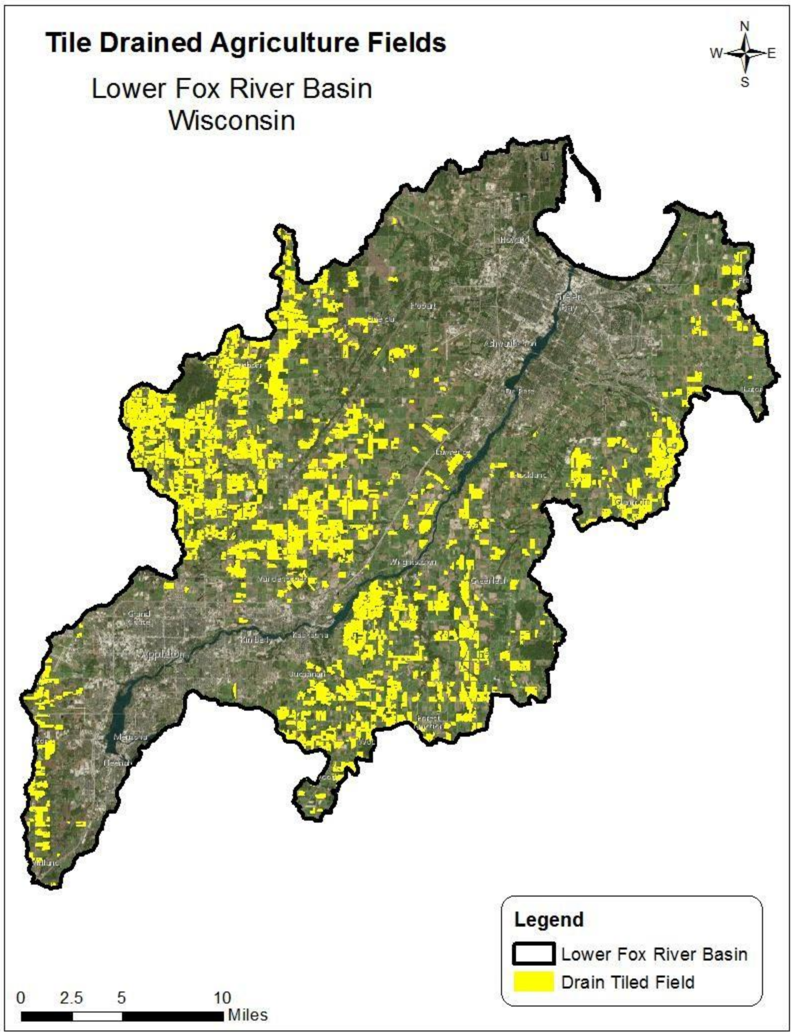


Figure 5. Tile drained agriculture fields.

The number of drain tiled fields, drain tiled field acres, and percent of total field acres tiled per subwatershed in the basin are shown in Table 1. Upper Duck Creek subwatershed has the highest percentage of tile drained agriculture fields, total tile drainage acreage, and number of tile drained fields in comparison to all the subwatersheds. Calculating the percent of total agricultural fields with drain tile by subwatershed is a better representation of the data, since the land use and size of the subwatersheds varies. Kankapot, Oneida Creek, Plum Creek, and Apple Creek also ranked high with over 40% of their total fields being tile drained.

Table 1. Drain tile mapped per subwatershed (HUC 12) in the Lower Fox River Basin.

Watershed (HUC12)	**# Tiled Fields**	**Tiled Field Acres**	**% of Total Field Acres Tiled**
Apple Creek	200	8,094	43
Ashwaubenon Creek	72	2,791	25
Baird Creek	47	885	11
Bower Creek	249	5,976	34
Dead Horse Bay	0	0	0
Dutchman Creek	40	1,356	18
Fox River	14	805	27
Garners Creek	39	1,122	25
Kankapot Creek	195	5,863	49
Little Lake Butte des Mortes	86	2,455	33
Lower Duck Creek	4	346	6
Lower East River	30	1,416	12
Middle Duck Creek	81	3,332	33
Mud Creek	53	1,160	21
Oneida Creek	135	4,697	47
Plum Creek	288	7,483	47
Point du Sable	45	793	13
Trout Creek	21	959	16
Upper Duck Creek	717	15,988	77
Upper East River	102	4,208	27
Total	2,418	69,729	NA

2.1.1 Challenges

There were several setbacks and challenges to getting drain tile data mapped. The first challenge was the Common Land Unit (CLU) layer used for mapping the fields. The CLU layers used were obtained in 2007 from the USDA Farm Service Agency when it was made available for the first time to the public. The current CLU layers have never been available to the public since then. Therefore the base data was outdated and had to be updated. In addition to the data being old, the CLU data was created with legacy topology issues that skewed the actual number of fields and acreage. For example in many areas several of the same shapes were "stacked" on top of one another and 1,000 acre multipart features existed. Another challenge was identifying drain tile signatures in different images. Drain tile signatures show up differently depending on the crop in the field and time the imagery was taken. In some images drain tile lines are darker and greener than the surrounding field and in other images drain tile lines are lighter than the surrounding field. Distinguishing drain tile lines from other similar features such as cropping and natural drainage patterns was difficult, especially since tile drains often follow natural drainages.

2.2 Phosphorus Mapping

A total of 4,455 fields were mapped with phosphorus in ppm data from a total of 269 farms. A table of all the farms mapped can be found in Appendix 3.1. The 4,455 farm fields added up to 114,480 acres of land. A total of 4,611 farm fields were mapped but 156 of those fields were missing phosphorus data. Figure 6 shows a small version of the Phosphorus Soil Test Values map with ranges of 25 ppm.

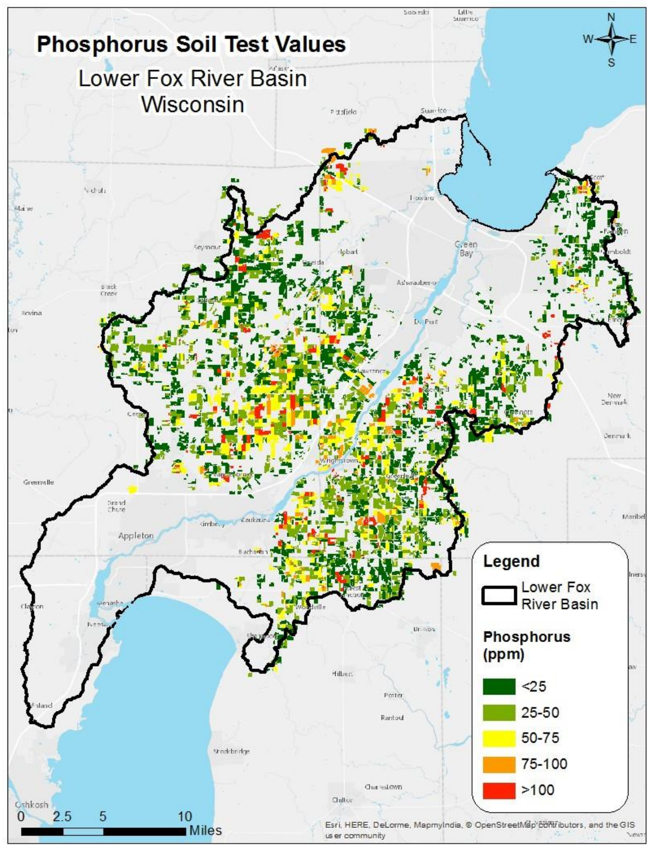


Figure 6. Phosphorus soil test values.

Table 2 below shows the total number of farm fields along with total acres for five different ranges of phosphorus values. The majority of farm fields mapped (over 75%) in the Lower Fox River Basin had soil test values 50 ppm or below.

Table 2. Phosphorus range data**.**

Phosphorus Values (ppm)	Total # of Farm Fields	Total Acres
<25	2,198	53,003
25-50	1,235	32,957
50-75	569	17,480
75-100	179	4,797
>100	274	6,228
Total	4,455	114,465

In order to observe phosphorus trends over time, phosphorus data for fields was mapped based on the soil test year if the data was available. Total number of fields mapped along with acres per soil sample year is shown in Table 3 below.

Table 3. Fields mapped by soil sample year.

Soil Sample Year	# fields	Acres
2008	217	6,598
2009	183	6,250
2010	280	8,739
2011	418	13,207
2012	423	12,252
2013	386	10,850
2014	408	11,028
2015	157	3,477

The total numbers of fields mapped were summarized by watershed as well as the minimum, maximum, and average phosphorus soil test values (Table 4). The three watersheds with the most mapped fields were Apple Creek, Lower East River, and Bower Creek. Average phosphorus values per subwatershed excluding subwatersheds with less than 100 fields mapped ranged from 25 ppm to 46 ppm.

Table 4. Fields mapped by subwatershed (HUC12).

Watershed (HUC12)	# Mapped Fields	Acres	P minimum (ppm)	P maximum (ppm)	P average (ppm)
Apple Creek	378	12,249	3	188	46
Ashwaubenon	261	9,312	3	125	36
Baird Creek	202	3,457	4	155	31
Bower Creek	327	8,210	3	214	29
Dead Horse Bay	3	83	53	101	80
Dutchman Creek	187	5,036	4	346	38
Fox River	90	2,586	2	266	40
Garners Creek	46	1,138	6	150	56
Kankapot Creek	194	4,602	7	166	40
Lower Duck Creek	130	3,136	4	118	38
Lower East River	355	8,535	3	188	36
Middle Duck Creek	206	5,682	4	334	40
Mud Creek	1	133	64	64	64
Oneida Creek	204	6,575	3	126	29
Plum Creek	460	10,952	4	403	42
Point du Sable	167	3,177	1	175	25
Trout Creek	89	3,003	6	233	54
Upper Duck Creek	429	9,942	3	334	32
Upper East River	515	12,382	4	304	39

2.2.1 Challenges

As with the drain tile mapping there were also challenges to getting phosphorus data mapped. Not all agriculture land is under a NMP or if it is we don’t always have a record. Another challenge was that there was no temporal data associated with the CAFO phosphorus mapping data obtained from the Wisconsin Department of Natural Resources. Therefore, some of the CAFO data that was added may be several years outdated and was added to a separate attribute field in the data table. In addition several nutrient management plans that were obtained were missing soil test data and maps for some fields, or only had soil test data and no maps or vice versa.

3.0 Appendices

3.1 Summary of Soil Test Phosphorus Data per Farm

Phosphorus Data Mapped by Farm

3.2 Documentation

GIS Procedure for Per Field Phosphorus Data by Watershed

GIS Procedure for Per Field Tile Mapping

Image Analysis Methods tried for Remote Sensing of Drain Tile

3.3 Maps

Figure 1. Lower Fox River Basin

Figure 2. Lower Fox River Basin Subwatersheds Map

Figure 3. Agricultural Fields Map

Figure 4. Tile Drained Agriculture Fields Map

Figure 5. Phosphorus Soil Test Values Map

3.1 Summary of Soil Test Phosphorus Data per Farm

Table 5. Phosphorus data mapped by farm.

Producer Name	# Fields Mapped	Acres	Minimum Soil Test Phosphorus (ppm)	Max Soil Test Phosphorus (ppm)	Average Soil Test Phosphorus (ppm)	# Fields missing P (ppm) data	# Acres missing
No Name	2	58	9	31	20		
Al Schmidt	10	200	28	86	62		
Al Timm	8	208	13	22	19		
Allan Zahn	9	127	11	150	42	1	17
Ambrosius Farms	14	242	14	301	59		
Ashman, Randy	14	188	4	47	20		
Baehman, Bruce	20	143	8	114	37	2	31
Bernie Lasee	17	200	28	60	41		
Biese Family Farm	20	222	5	107	22		
Bill Derouin	8	163	22	52	37		
Birlings Bovines	17	538	17	71	35		
Bob Zeamer	12	146	10	33	20		
Bowers Dairy	2	73	22	51	37		
Brickstead Dairy	47	1,374	9	142	35	4	130
Bruce VanDeHey	5	90	21	206	77	1	13
Budzban Dairy	20	212	5	114	23		
Burns, Jim	6	111	8	74	30		
C&N	2	31	18	101	60		
Calf Source (Milk Source)	12	294	11	101	87		
Carl Jordan	1	18	16	16	16		
Carl Petersen	1	12	23	23	23		
Christensen, Bob	11	112	21	109	59		

Producer Name	# Fields Mapped	Acres	Minimum Soil Test Phosphorus (ppm)	Max Soil Test Phosphorus (ppm)	Average Soil Test Phosphorus (ppm)	# Fields missing P (ppm) data	# Acres missing
Clem Siporski	2	28	26	45	36		
Clint Bodart	1	108	12	12	12		
Collins Dairy	2	103	45	50	48		
Conard Farms	14	281	5	165	37		
Conrad Liebergen, Brightside Dairy	42	884	16	101	41	2	9
Conrad Meetz	7	50	11	25	18		
Country Aire	90	2,694	4	147	42		
Dairyland Farm (Larry Dufek)	88	3,056	3	142	23	5	181
Daivid Beining	1	21	19	19	19		
Dale Haese	19	422	6	59	26		
Dale Marx	13	230	9	71	29		
Dan DeGrave	3	41	5	12	7		
Dan Hoelzel	16	184	6	327	86	1	2
Dave Bougie	6	152	8	17	11		
Dave Lewis	12	260	26	192	101		
Dave Zeamer	16	188	11	67	26		
De Coster, Mike	8	90	4	55	26		
DenMar Acres	8	429	10	26	17		
Dennis Bastian	5	90	15	60	31		
Detrie Farms	36	568	4	61	21		
Dick Koltz	7	79	5	26	12		

Producer Name	# Fields Mapped	Acres	Minimum Soil Test Phosphorus (ppm)	Max Soil Test Phosphorus (ppm)	Average Soil Test Phosphorus (ppm)	# Fields missing P (ppm) data	# Acres missing
Diederich Dairy	18	425	5	64	24		
Donald Welch	2	13	101	101	101	1	7
Doug Verbeten (DCV)	15	114	15	88	42	1	10
Eggert Dairy	15	184	9	69	24		
Emerald Acres	19	589	11	94	47		
Erdmann Farms	11	235	28	94	62		
Everlea Heifers	2	139	35	125	80		
Feldkamp, Dennis	6	63	16	54	33		
Fox Farms	4	67	3	26	15		
Fox Ridge Dairy	25	689	14	72	41		
Garvey, Rick	3	186	19	76	40		
Gary Huss	20	322	5	50	26		
Gerald Seidl	20	308	7	37	20		
Gerald Stahl	46	1,215	4	155	29	5	90
Glenn Geurts	10	84	13	38	19		
Goffard Brothers	12	247	18	79	47		
Golden Rail Dairy	18	431	16	65	32		
Gonnering, Gary	3	39	17	24	22		
Gorges, Duane	1	14	16	16	16		
Grand View Dairy	28	945	8	87	31	1	10
Green Valley Dairy	31	1,269	4	190	36		
Greenleaf Ledge Dairy	31	495	12	138	39	1	12
Greg Schaumberg	11	135	51	101	96		

Producer Name	# Fields Mapped	Acres	Minimum Soil Test Phosphorus (ppm)	Max Soil Test Phosphorus (ppm)	Average Soil Test Phosphorus (ppm)	# Fields missing P (ppm) data	# Acres missing
Hein Dairy	10	125	11	39	19		
Herman Bros	8	236	24	65	38		
Hermus, Lee	14	335	22	63	33		
Herzog, Hans	8	93	7	253	54		
Hoelzel Dairy	30	524	24	403	70	1	15
Hofacker, Nick	15	264	0	0	0	15	264
Holsum Dairies	5	59	13	35	22		
Hopfensperger, Bruce	3	38	24	192	103		
Hornstead Dairy	15	586	13	78	54	10	418
Huebner Farms	24	507	9	132	54		
Idlewild Farms	14	349	5	41	21		
J Spring Dairy	15	230	7	27	15		
J&T Vanasten	3	99	41	90	72		
Jack Nett	5	84	12	21	16		
Jake Wickesberg	1	39	101	101	101		
Jamie Gajewske	2	19	8	15	12		
Jeff Mencheski	1	7	10	10	10		
Jeff Ronsman	23	254	1	26	10		
Jens Dairy	19	223	6	93	21		
Jerry Sorenson	12	500	16	161	76		
Jim Dobberpuhl	20	325	8	159	23		
Jim Healy	8	80	7	23	13		
Jim Kroll	67	1,302	3	138	29	6	94

Producer Name	# Fields Mapped	Acres	Minimum Soil Test Phosphorus (ppm)	Max Soil Test Phosphorus (ppm)	Average Soil Test Phosphorus (ppm)	# Fields missing P (ppm) data	# Acres missing
Jim Kropp	7	323	6	99	33		
Jim VanGheem	7	342	24	78	46		
Joe Capelle	10	157	9	20	14		
Joe Daul	7	74	4	24	13	1	8
Joe DeCleene	21	316	13	67	32		
Joe Kersten	10	66	12	130	49		
John Burkel	10	254	13	147	59		
John Koltz	5	71	9	25	16		
John Levash	1	27	11	11	11		
John Van Deurzen	23	315	12	61	27		
John Wiegert	17	130	10	60	28		
John Zeamer	5	67	7	16	10		
Kaczmarek Genetics LLC (Paul Kaczmarek)	9	215	32	130	72		
Karweick, Vernon	4	55	13	32	20		
Keith Gonnering	1	66	18	18	18		
Keith Haldiman	15	250	10	231	61		
Keith VanDerLinden	12	390	11	101	40	1	21
Kempen Dairy	10	175	17	37	24		
Ken Boylan	8	23	3	26	11		
Kent Petersen	2	70	36	51	44		
Kesler Farms	30	749	7	58	25		
Keune Farms	5	254	8	101	48		

Producer Name	# Fields Mapped	Acres	Minimum Soil Test Phosphorus (ppm)	Max Soil Test Phosphorus (ppm)	Average Soil Test Phosphorus (ppm)	# Fields missing P (ppm) data	# Acres missing
Keune, Bob and Paul	8	220	12	34	24		
Klug Dairy	1	72	61	61	61		
Klugs	1	89	20	20	20		
Kortz, Gary	4	113	49	101	88		
Krause Dairy	19	422	6	70	28	2	6
Kropp, Dale	2	73	0	0	0	2	73
Krueger Farms	8	221	11	68	33		
Kurey Farms	47	1,336	3	65	23		
Kurt Jordan	3	96	28	86	50		
Land L Farms	35	1,079	6	126	45		
Lardinois Farms	1	19	16	16	16		
Larrand Dairy	33	841	10	346	62		
Ledgeview Dairy	103	2,085	3	71	24	1	2
Lee Gossen	9	191	12	26	17		
Lemke Farms	30	442	9	53	27		
Lewis Krueger	19	661	14	103	27		
Maass, Mike	7	500	3	101	26		
Maple Grove Dairy	51	675	11	166	44		
Mark Stanelle	11	198	9	20	13		
Mathes Dairy	9	250	36	58	49		
Matthew Stumpf	9	156	20	81	46		
Max Ots	2	19	13	21	17		
McKallister Farms	7	237	38	108	63		

Producer Name	# Fields Mapped	Acres	Minimum Soil Test Phosphorus (ppm)	Max Soil Test Phosphorus (ppm)	Average Soil Test Phosphorus (ppm)	# Fields missing P (ppm) data	# Acres missing
Meadow View Dairy	5	189	26	233	83		
Meadowlark	91	2,287	14	266	42	1	5
Michael Geiger	2	35	5	36	21		
Micke Dairy	4	121	6	35	16		
Micke, Don	10	137	18	89	44		
Mike Ambrosius	15	143	4	20	9		
Mike and Deb Schneider	8	127	18	79	41		
Mike Bodart	1	23	96	96	96		
Mike Geiger	4	64	14	76	33		
Mike Kavanaugh	3	53	59	110	78		
Mike Mader	23	535	9	88	42		
Mike Stephani	4	86	5	25	15	2	33
Mike Van De Walle	13	147	4	35	15		
Milky Way Farms	1	15	30	30	30		
Mooren, Jim	13	89	14	48	30	2	7
Morgan Long	13	213	17	165	52		
Mueller Dairy	18	549	8	65	28	3	26
Muenster, Ben	31	402	14	230	43		
Munchies Farms	7	55	9	183	36		
Nathan Sprangers	13	243	18	94	49	3	65
Neighborhood Dairy	37	1,105	12	113	37		
Nettekoven, Greg	13	650	13	60	27		
New Horizons Dairy	57	1,958	7	237	46		

Producer Name	# Fields Mapped	Acres	Minimum Soil Test Phosphorus (ppm)	Max Soil Test Phosphorus (ppm)	Average Soil Test Phosphorus (ppm)	# Fields missing P (ppm) data	# Acres missing
Nic Buhr	1	4	9	9	9		
Nick Van Gheem Farm LLC	14	309	22	116	42		
Norbert Vanderlinden	12	159	23	90	45		
Olson, J&G	10	478	12	40	24		
Oneida Farm	15	873	9	75	35		
Oneida Nations Farms	95	4,192	5	161	32		
Parkview Feeders	25	622	14	83	40		
Pat VandeHey	13	340	11	34	23		
Peter Grosse	8	205	16	66	36		
Peter Hoelzel	17	236	16	81	40		
Petersen Dairy	22	310	9	152	51		
Phillipsland Farms	1	18	0	0	0	1	18
Plum Pride Holsteins	27	412	10	100	37		
R and E Farms	21	1,014	12	61	37		
Ralph Bohrtz	6	107	12	25	17		
Randy Vandehei	12	184	10	67	28		
Ranovael Dairy	32	1,449	4	145	40		
Ray Vande Voort	8	91	3	177	44		
Renn-Way	9	107	20	43	30		
Reynders Dairy	31	481	6	188	28	1	19
Richard Mahnke	13	168	8	67	26		
Richardson, Jim	8	438	7	73	29		

Producer Name	# Fields Mapped	Acres	Minimum Soil Test Phosphorus (ppm)	Max Soil Test Phosphorus (ppm)	Average Soil Test Phosphorus (ppm)	# Fields missing P (ppm) data	# Acres missing
Rick Loppnow	3	43	6	6	6		
Rob Juneau	13	119	11	110	30		
Robert Gerrits	6	138	24	66	38		
Robert Zeamer	1	37	15	15	15		
Robertson Bros Farms	75	1,267	6	118	29		
Rodney Huth	8	268	20	100	55		
Roger Maternoski	21	274	8	53	26		
Rohm, Keith	8	410	15	38	23		
Rohm, Merlin	1	37	16	16	16		
Rolling Creeks Farm	1	95	56	56	56		
Romenesko Farms	6	99	13	92	40		
Rueden Beef	1	48	37	37	37		
Russ Allen	4	150	7	50	20		
Salter, Mike E.	6	106	0	0	0	6	106
Salter, Mike G	21	89	13	43	23		
San Ric Holsteins	14	280	20	92	40		
Schlimm, Bob	14	203	8	101	32		
Schneekloth, Dwayne	10	239	11	49	21		
Schuh View Dairy	46	2,422	9	103	41		
Schuh, Robert	10	162	29	87	61		
Schwalbach Dairy	11	202	18	116	49		
Scott Mullen	1	22	19	19	19		
Scott Schaumberg	12	469	7	59	30		

Producer Name	# Fields Mapped	Acres	Minimum Soil Test Phosphorus (ppm)	Max Soil Test Phosphorus (ppm)	Average Soil Test Phosphorus (ppm)	# Fields missing P (ppm) data	# Acres missing
Seitz, Roger	5	37	19	54	43		
Seven Oaks Dairy	30	946	7	84	31		
Shiloh Dairy	1	68	0	0	0	1	68
Siebrand Miedema	7	376	10	63	32		
Simon, Jim	10	205	8	227	61		
Sky Hy Acres	13	214	29	166	73		
Sprangers Family Dairy	10	224	17	144	56		
Steffens Dairy Farm	12	210	13	142	52		
Stencil Dairy Farms	42	1,797	23	62	43	32	1,219
Steve Etienne	14	241	13	43	24		
Stingle, Darrin	29	842	15	65	27		
Strebel Farms	69	1,084	6	175	40	1	17
Sunnyside Farms	5	63	15	181	61		
Thompson's Gold Dust Dairy	191	5,043	5	127	34	11	134
Tidy View Dairy	76	4,949	4	164	45		
Tim Hendricks	13	180	3	214	23		
Tim Krueger	22	271	16	56	30		
Tim Mader	2	58	48	79	64		
TineDale Farms	35	1,948	2	101	34		
Tom Bernhardt	7	129	14	84	50		
Tom Boylan	15	160	12	70	24		
Tom Halbach	1	7	37	37	37		

Producer Name	# Fields Mapped	Acres	Minimum Soil Test Phosphorus (ppm)	Max Soil Test Phosphorus (ppm)	Average Soil Test Phosphorus (ppm)	# Fields missing P (ppm) data	# Acres missing
Tom Perock	13	435	8	21	13		
Tom Phillips	28	306	10	134	40		
Tony & Bill Rueden	14	239	8	118	48	2	15
Treml, Keith	7	158	27	72	39	2	25
Tri County Farms	29	1,058	9	70	29	1	11
Uitenbroeck, Mark	12	167	56	162	88		
Ullmer Acres LLC (Phil Ullmer)	3	82	32	85	57		
United Meadows Dairy	45	703	3	122	44	1	11
Van Asten Dairy	3	56	5	17	9		
Van Asten, Jeff	7	112	14	38	22		
Van Asten, Marvin	1	6	166	166	166		
Van Boxtel, Steve	9	96	15	121	37		
Van Camp, Floyd	2	261	33	56	45		
Van Camp, Jim	2	58	23	24	24		
Van Camp, Wayne	15	391	19	101	90		
Van De Hei, Dennis	10	179	22	114	61		
Van De Loo Farms	62	1,820	5	136	37		
Van DeHei, Al	11	213	13	62	31	2	37
Van Gheem, Jack	7	118	13	39	24		
Van Gheem, John	2	68	21	46	34	1	2
Van Gheem, Paul	25	653	7	52	25	1	11
Van Groll, Brian	3	196	25	94	53		

Producer Name	# Fields Mapped	Acres	Minimum Soil Test Phosphorus (ppm)	Max Soil Test Phosphorus (ppm)	Average Soil Test Phosphorus (ppm)	# Fields missing P (ppm) data	# Acres missing
Van Handel Farms	8	225	14	30	23		
Van Handel, Greg	21	415	7	188	57		
Van Lanen, Pat	21	497	10	126	32		
Van Rossum Dairy	31	741	12	126	49		
Van Wychen Farms	56	2,232	4	101	30		
Vande Hey, Bruce	8	258	31	36	33	3	24
Vande Vroot, Pat	2	35	19	21	20		
Vande Walle, Dennis	40	876	5	204	30	4	36
Vanden Huevel, Tony	2	39	13	26	20		
VandeWettering Brothers	31	587	9	140	46		
Verhasselt Farms	115	4,224	4	334	46		
Vosters Dairy	11	232	12	53	29		
Wall Dairy	13	185	16	95	45		
Warren Allen	24	238	5	81	35		
Wayne Staeven	9	141	32	51	41		
WaysideDairy/Geiger	5	115	15	44	24		
Wichman Farms	31	640	7	70	21		
Wickesberg, Dennis	8	181	10	82	45		
Wiese Brothers	139	5,333	5	304	41	7	185
Wil-Shar Holsteins	12	167	4	74	30	4	49
Witterholt's Family Farm	12	209	11	64	26		
Woldt	1	24	54	54	54		
Woldt Farms	34	1,063	7	163	59		

Producer Name	# Fields Mapped	Acres	Minimum Soil Test Phosphorus (ppm)	Max Soil Test Phosphorus (ppm)	Average Soil Test Phosphorus (ppm)	# Fields missing P (ppm) data	# Acres missing
Wrobleski, Bill	1	11	9	9	9		
Zirbel Dairy	13	732	9	61	32		

3.2 Documentation

GIS Procedure for Phosphorus Mapping

Outagamie County GIS Procedure for Per Field Phosphorus Data by Watershed (2013 phosphorus data)

From the NMP parcel layer, query a list of relevant Farms to the watershed being looked at to use as a reference. In alphabetical order, number each farm starting with 1.

Starting with the most current, sort through Nutrient Management Plans (NMP) to gather all relevant plans needed.

Sort through relevant plans to check for maps showing individual farm fields and phosphorus data in ppm and P Index.

Email agronomists to acquire any data needed that is not currently available.

Create a new folder in ArcCatalog to store all information and layers needed for the project.

Within this folder create a new file geodatabase and feature dataset to store all layers needed for the project. Define the feature dataset in NAD_1983_HARN_WISCRS_Outagamie_County_Feet.

Import the Farm Service Agency's Cropland Unit feature class into the file geodatabase for editing and attributing. The name was then changed to OC_P_CLU2013.

Obtain all appropriate reference layers (aerial image, roads layer, PLSS layer, NMP Parcel layer) needed to find given farms and farm fields. Export all layers into the feature dataset to define all layers to the same coordinate system.

Create a new ArcMap session using the necessary reference layers to work on the project. Save the session as a template to work from each day.

Start Editing.

In alphabetical order, starting with the most recent plans, attribute the P (ppm) and PI data to the corresponding farm fields. Where needed split, merge, or digitize any fields to match the layer you are creating with the maps provided in the NMP. Use the aerial image to help in editing each farm field polygon.

To find the corresponding farm fields for each farm, either query by farm to highlight the farm fields in the NMP Parcel layer or query by name to highlight roads in the roads layer.

After all farm fields are edited for each farm, use the Field Calculator to populate the Farm Name and File Number fields. Farm names are entered by farm name or by farmer's last name, first.

The file number is based on the year (2013) and number (001) given to each farm (13001). Use Calculate Geometry to populate the Acres field.

Save edits and the ArcMap session after each farm to prevent the loss of progress.

Symbolize by giving each farm a unique color to distinguish between edited farm fields and non edited farm fields.

When finished editing all NMP symbolize farm fields by P_ppm to show phosphorus levels on a per field basis. Use bright orange and red colors for extremely high levels of phosphorus.

Add metadata to the created layer.

Calculate average for Polenske sample points.

Using the saved python script *FileNameInsert_Arc10_1.py*, add a new field to each shapefile called File Name that is populated with its feature class name.

Using the saved python script "*import_point_FC_fromSubFolders_Arc10_1.py"*

pull all point shapefiles from the main Polenske folder, export and merge them into the current workspace, the "MappingData" feature dataset in your "P Mapping" geodatabase.

Add the newly created point shapefile into your current work map. Join this layer to the field layer by "join data from another layer based on spatial location" Use the point shapefile as the layer to join, summarize attributes by average, and specify the output of the new feature class into the "MappingData" feature dataset.

Select all records from the newly created layer that do not have null as the average P value. Export this data to the current feature dataset to create a layer of only the necessary fields with calculated average P values.

Using the ObjectID field, join this newly created layer to the main field layer to allow for the calculation of the "P_ppm field" from the "average p" values in the joined table. Use field calculator to calculate these values as "P – ppm field" = "average P"

Remove the join, it is now no longer needed.

2015 Phosphorus Mapping GIS Update Procedure

Add existing phosphorus mapping layers from Outagamie County and Brown County to map. Add field layers (CLU) for Calumet and Winnebago County.

Create 1280 ft buffer of the Lower Fox Basin.

Select CLU/Fields by location in the Lower Fox and export selected portions of each layer.

Merge Outagamie, Brown, Calumet, and Winnebago data into one feature class.

Add field attributes P_ppm2009, P_ppm2010, P_ppm2011, P_ppm2012, P_ppm2013, P_ppm2014, P_ppm2015, TNC_ppm 2015, TNC_ppm2013, Operator 2, P_ppm2015Update, HUC12, County.

Start editing.

Going by alphabetical order of County, then CAFO name, edit all CLU/fields to match DNR CAFO shapefile data.

Use a spatial join to join the data to the LowerFoxPmapping layer. Spatial joins will create a new shapefile. Rename the shapefile to most recent join. Ex. BricksteadJoin.

After spatial join, use field calculator to edit Producer Name, Field Name, and correct P_ppm attribute.

Repeat this process for all DNR CAFO shapefiles.

Obtain available nutrient management plans for Lower Fox Basin and update layer based on the most recent available nutrient management plan data.

Where needed split, merge, or digitize any fields to match the layer you are creating with the maps provided in the NMP. Use the aerial imagery to help in editing each farm field polygon.

<u>GIS Procedure for Drain tile Mapping</u>

Drain tile mapping layers already available for Upper East, Plum Creek, Kankapot Creek, and Upper Duck Creek Watersheds.

Merge existing mapped watersheds with field polygons (CLU) from the rest of the Lower Fox Basin.

Added attributes Ortho_2014, Ortho_2010, NAIP2013, NAIP2015, ESRI_Base. Google 2015 Imagery was not added as an attribute since Google imagery cannot be brought into ArcMap.

If drain tile signatures are present in field enter yes in Drain tile_photo attribute and enter Yes in the imagery attribute that drain tile signatures were seen. (Note: Existing drain tile mapped fields (Upper East, Plum Creek, Kankapot, and Upper Duck Watersheds) did not have Imagery attributes, imagery data was entered as time allowed but was not finished due to time constraints.)

Join Drain Tile Mapping field layer data with Soil P Mapping data using spatial join. Resulting layer called *LowerFoxTNCFinal.*

Edit any spatial joins that don't match correctly.

Create metadata for *LowerFoxTNCFinal* shapefile (Figure 7).

LowerFoxTNCFinal

File Geodatabase Feature Class

Thumbnail Not Available

Tags

agriculture fields/land cover, phosphorus, drain tile

Summary

This agricultural fields layer was created to map phosphorus and agricultural drain tile in the Lower Fox River Basin for The Nature Conservancy.

Description

2015 data layer created to map phosphorus and tile drainage data in the Lower Fox River Basin in Wisconsin, USA.

Attribute Descriptions:

ProducerN = Producer Name

Operator2 = A name indicates the field was also included in that producer's Nutrient Management Plan

P_ppm2015Update = Most recent soil test P value available, updated in December 2015

TNCP_ppm2015 = Data entered in 2015 from WDNR CAFO P mapping data

TNCP_ppm2013 = 2013 P mapping data from Outagamie County and Brown County

Tile_Photo = Yes indicates field is tiled

TNCP_index2013 = 2013 soil P index data from Outagamie County and Brown County

P_ppm2008, P_ppm2009, P_ppm2009, P_ppm2010, P_ppm2010, P_ppm2011, P_ppm2012, P_ppm2013, P_ppm2014, P_ppm2014, P_ppm2015 = Soil test P data from Nutrient Management Plans correspoding to the soil test year

Ortho_2014, Ortho_2010, NAIP2013, NAIP2015, ESRI_Base = Y indicates tile is seen in the imagery

Credits

Outagamie County Land Conservation Department 920-832-5073

Figure 7. LowerFoxTNCFinal metadata.

Remote Sensing of Drain tiles

Several methods were used to try to extract drain tile features from aerial imagery. A major challenge to the image analysis methods was the amount of time and computer processing that it took to process just a small subset of a much larger image. The average time to process just a clip of an image that only showed one field was a half hour to an hour. Methods tried and results are described and shown below.

Hough Transformation:

Using IDL©by Exelis image analysis software, a Hough Transformation was performed on small subsection of 2014 Orthoimagery (Figure 8). A Hough transform is a technique used for the detection of regular curves such as lines, circles, ellipses, etc. Even though the Hough transform showed drain tile lines well in the resulting photo (Figure 8), the resulting image was difficult to classify and therefore feature extraction could not be performed. The Hough transformation leaves artifacts of light pixels in dark areas and vice versa. Image classification is done on the intensity of pixel values, which varied too much to classify certain pixel values to drain tile line/non drain tile line. The Hough transformation also left a spiral pattern in the resulting image which also made classification difficult.

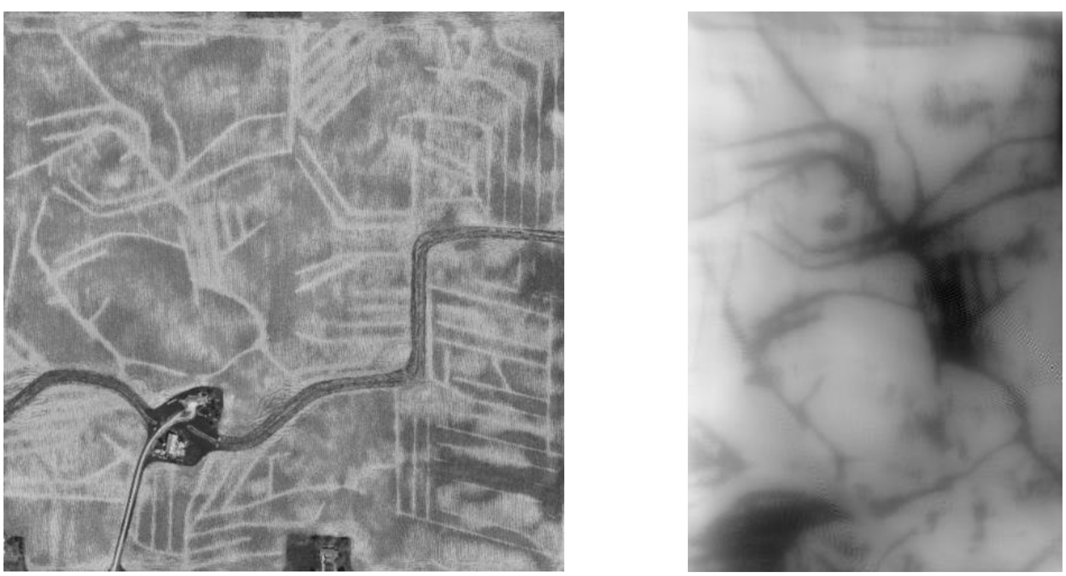


Figure 8. Black and white image used for Hough Transformation (left) and resulting Hough transformed image (right).

Canny Edge Detector:

The Canny Edge Detection method was applied to 2014 Color Orthoimagery transformed to black and white. The Canny Edge detector is an algorithm used to detect edges in images. The canny edge detection method picked out the edges of the drain tile but also picked up other edges (crop patterns and other noise in the image) (Figure 9).

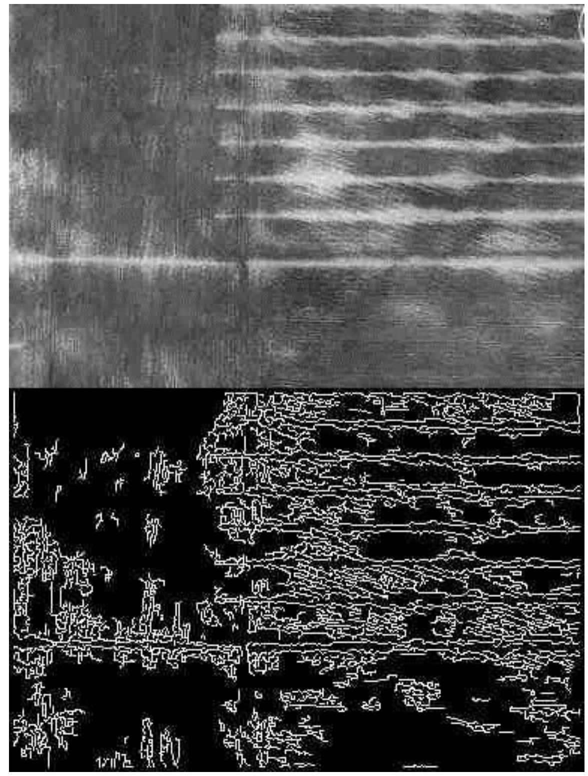


Figure 9. Black and white image used for Canny Edge Detection method (top) and Canny Edge Detection Results (bottom).

Feature Extraction/Classification of Orthoimagery using ENVI by Exelis:

There are Classification and Feature Extraction processes available in ENVI Image Analysis software that were also used on the Orthoimagery. The classification workflow categorizes pixels in an image into many classes using different methods. Feature extraction workflow identifies objects from imagery based on spatial, spectral, and texture characteristics then classifies the objects into known feature types using one of the following work flows:

- Rule Based: Define features by building rules based on object attributes such as area, elongation, spectral mean, texture, etc.
- Example Based: Select training data (samples of known identity) to assign objects of unknown identity to known features.
- Segment Only: Extract segments only without performing rule-based or example-example based classification.

The basic workflow for both processes:

1. Select input file (image) and select mask to use (optional). First step in classification and feature extraction workflows shown in Figure 10 below.

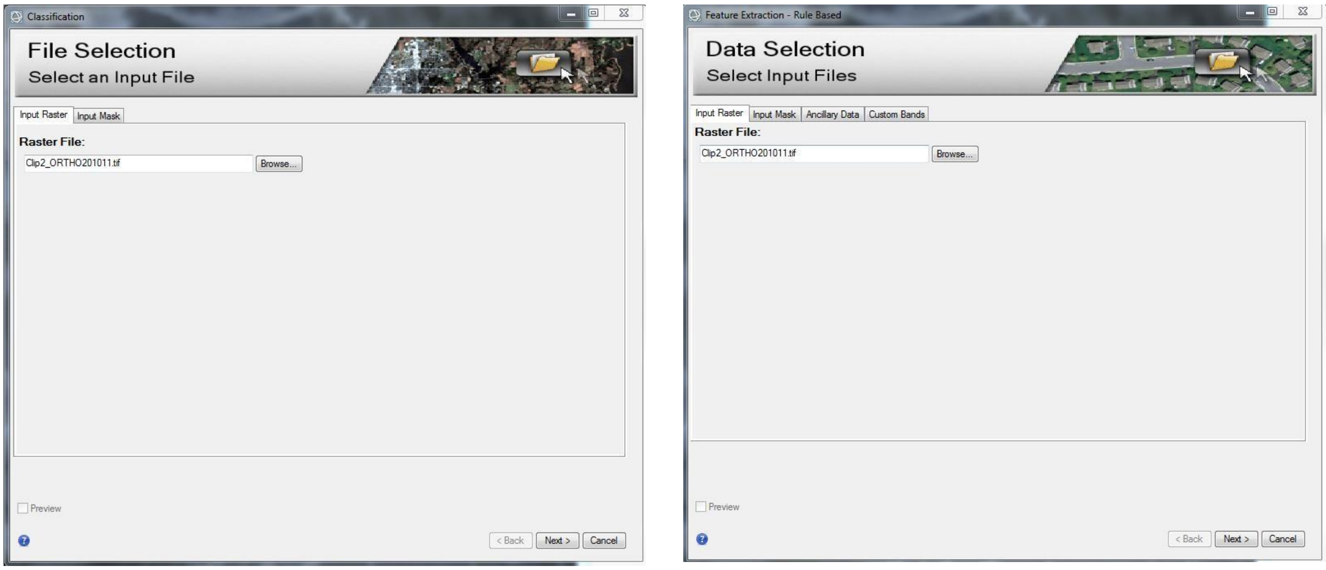


Figure 10. ENVI classification and feature extraction first step in workflow.

2. Choose classification/feature extraction settings (Figure 11).

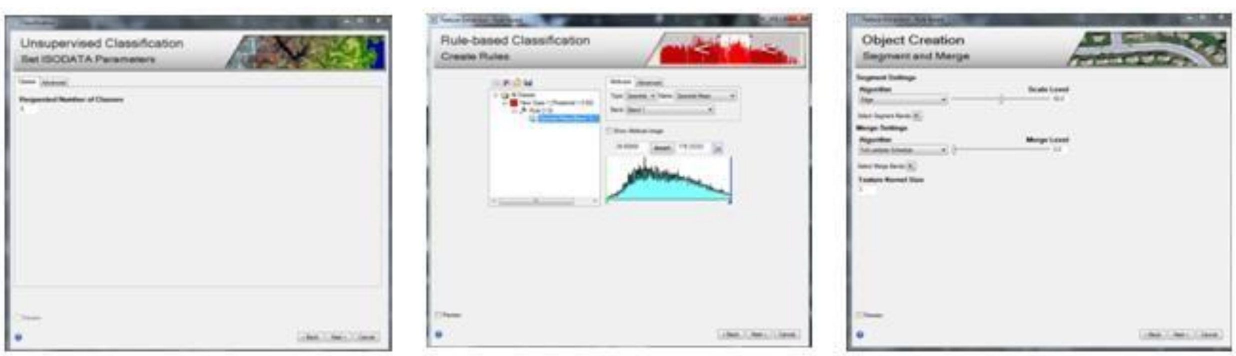


Figure 11. Step 2 in Classification workflow and Steps 2 & 3 in Feature Extraction workflow.

3. Clean up data (classification) (Figure 12).

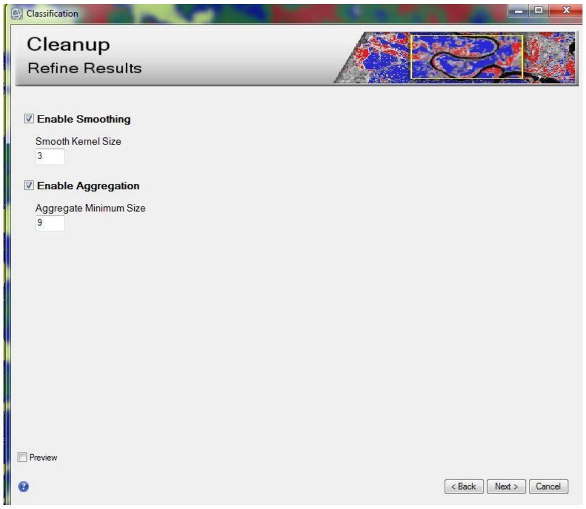


Figure 12. Step 3 in classification workflow.

4. Export data as either raster or vector or both (Figure 13).

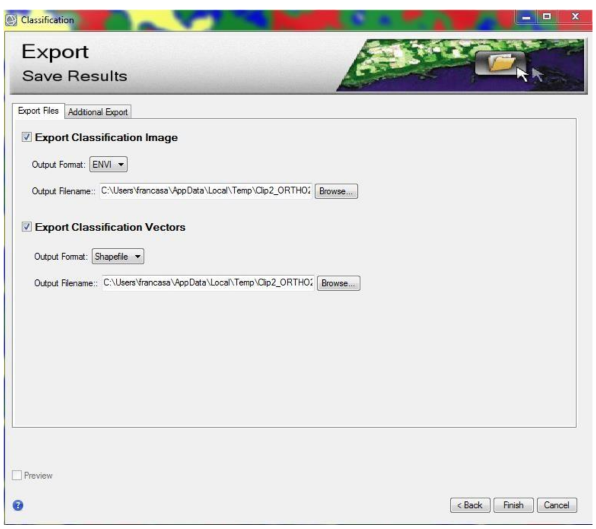


Figure 13. Final step in Feature Extraction and Classification process.

Feature Extraction/Classification Inputs and Results (Figure 14):

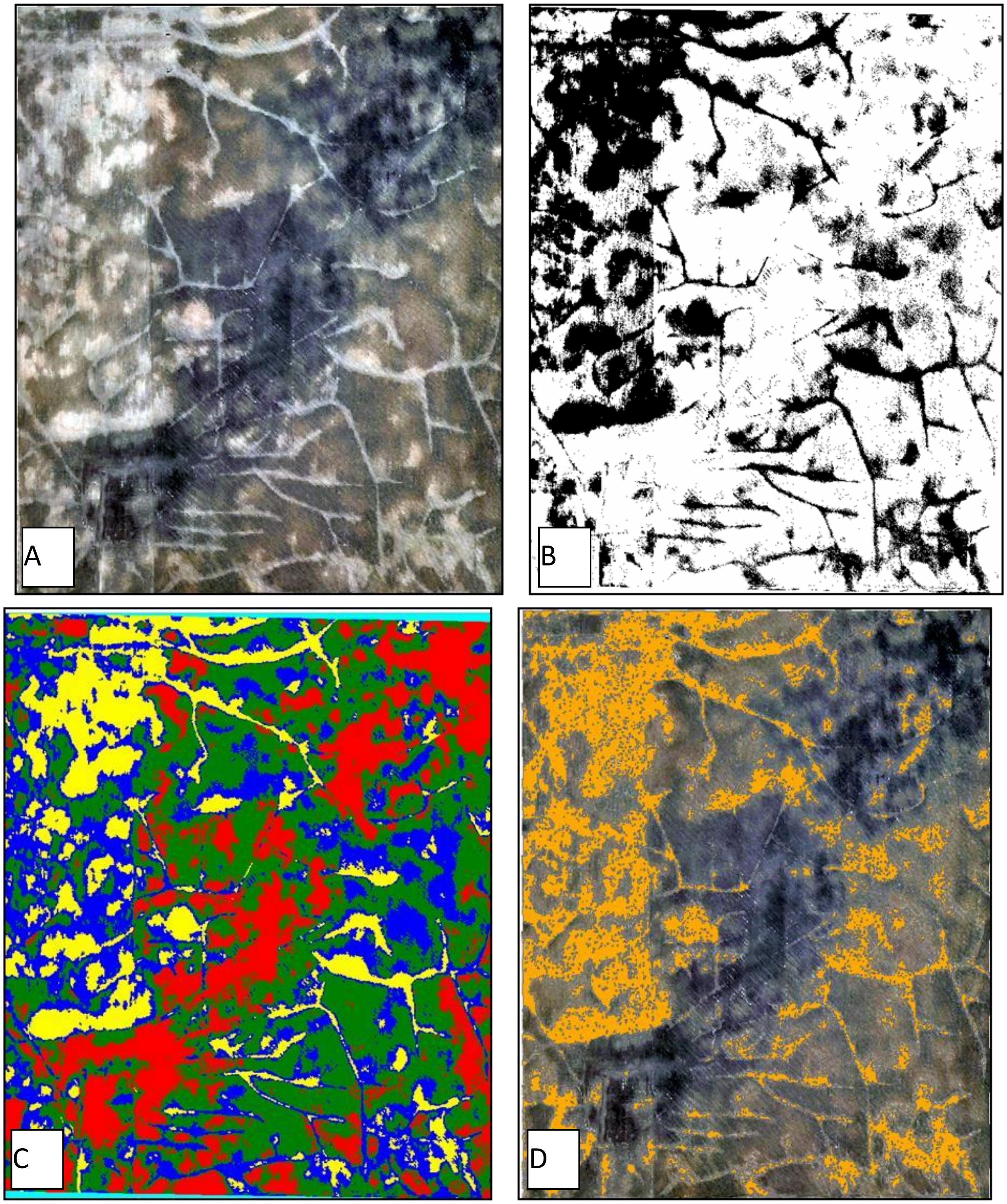
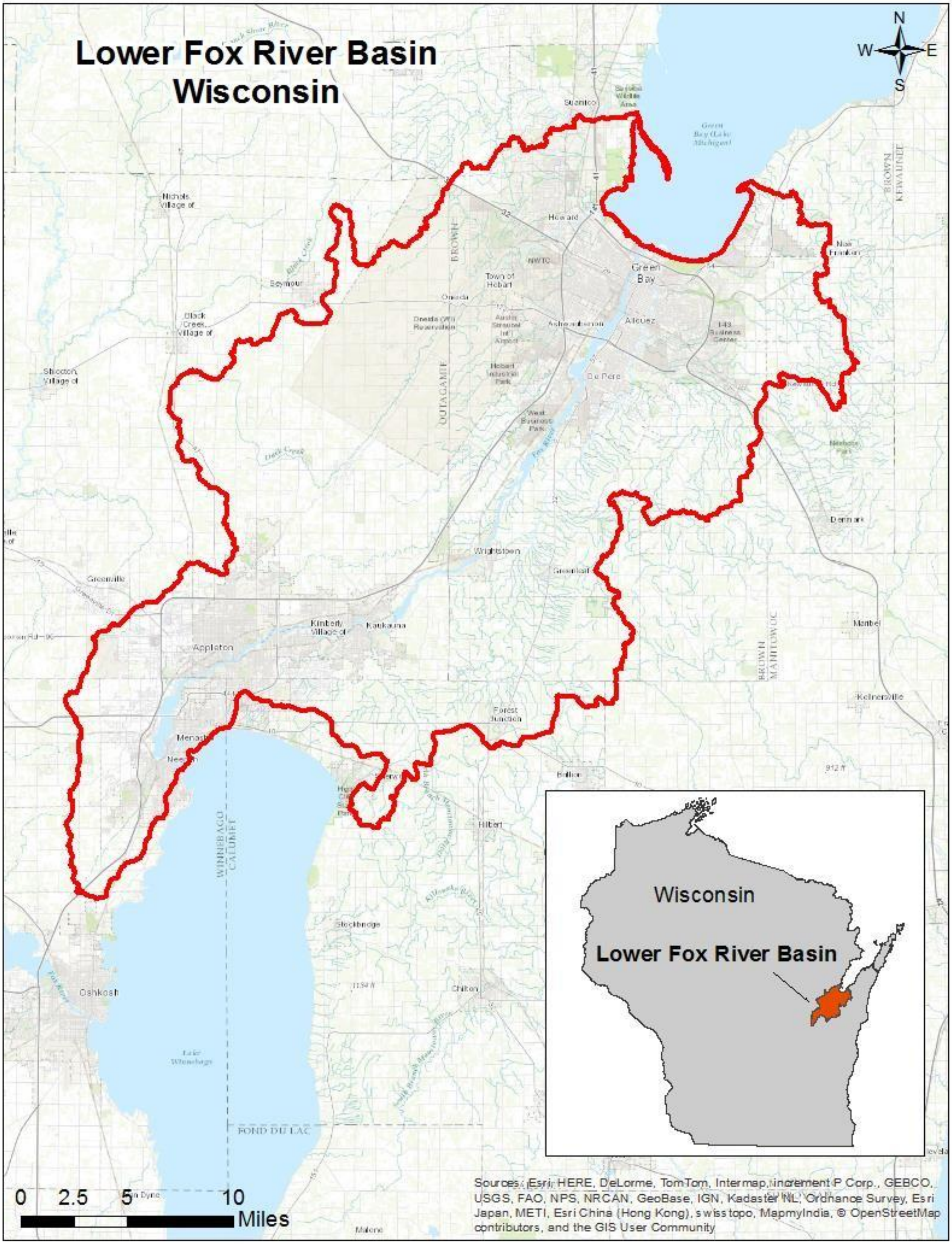
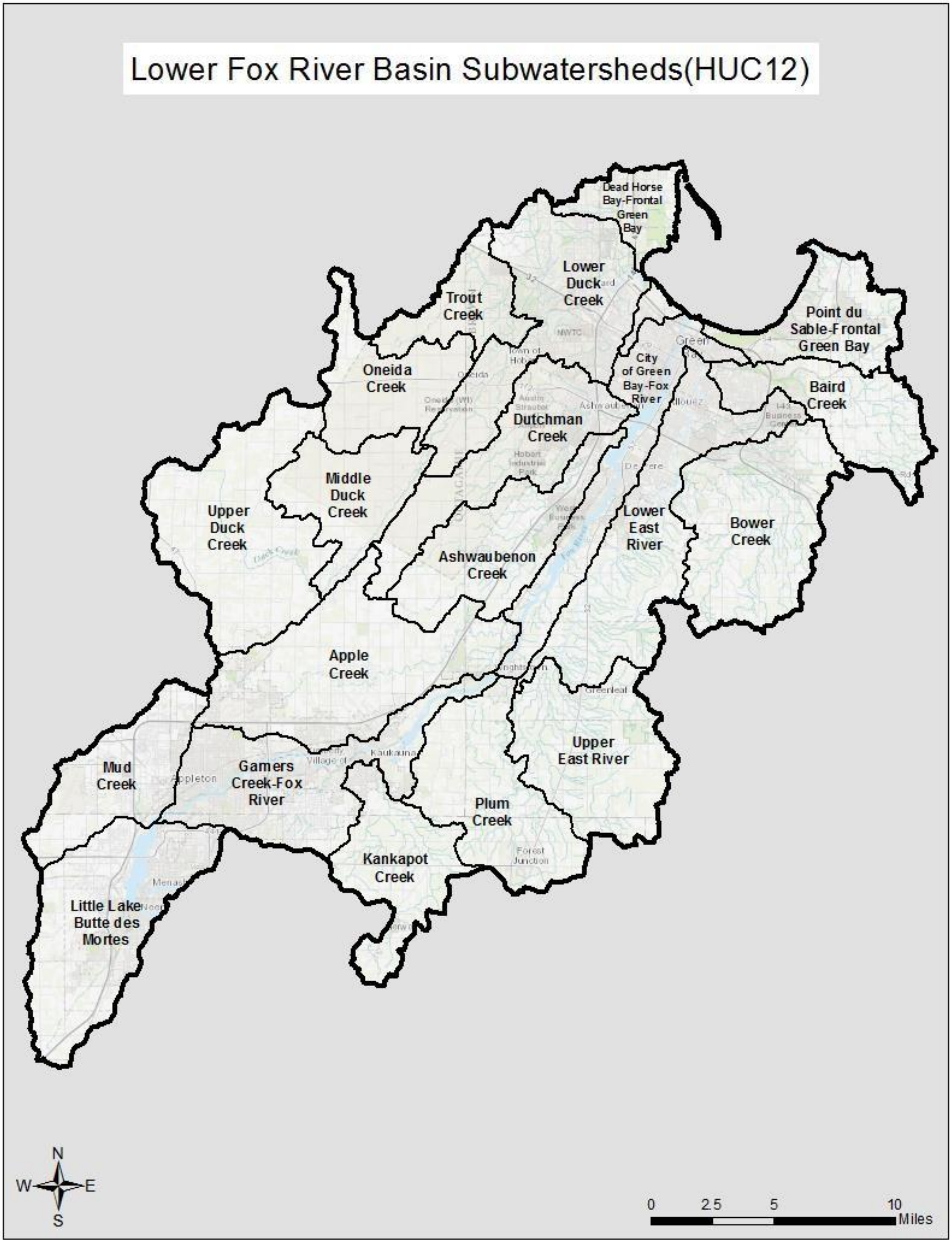


Figure 14. Input image (a), mask image (b), classification workflow output raster (c), and feature extraction workflow output overlain on input image (d).

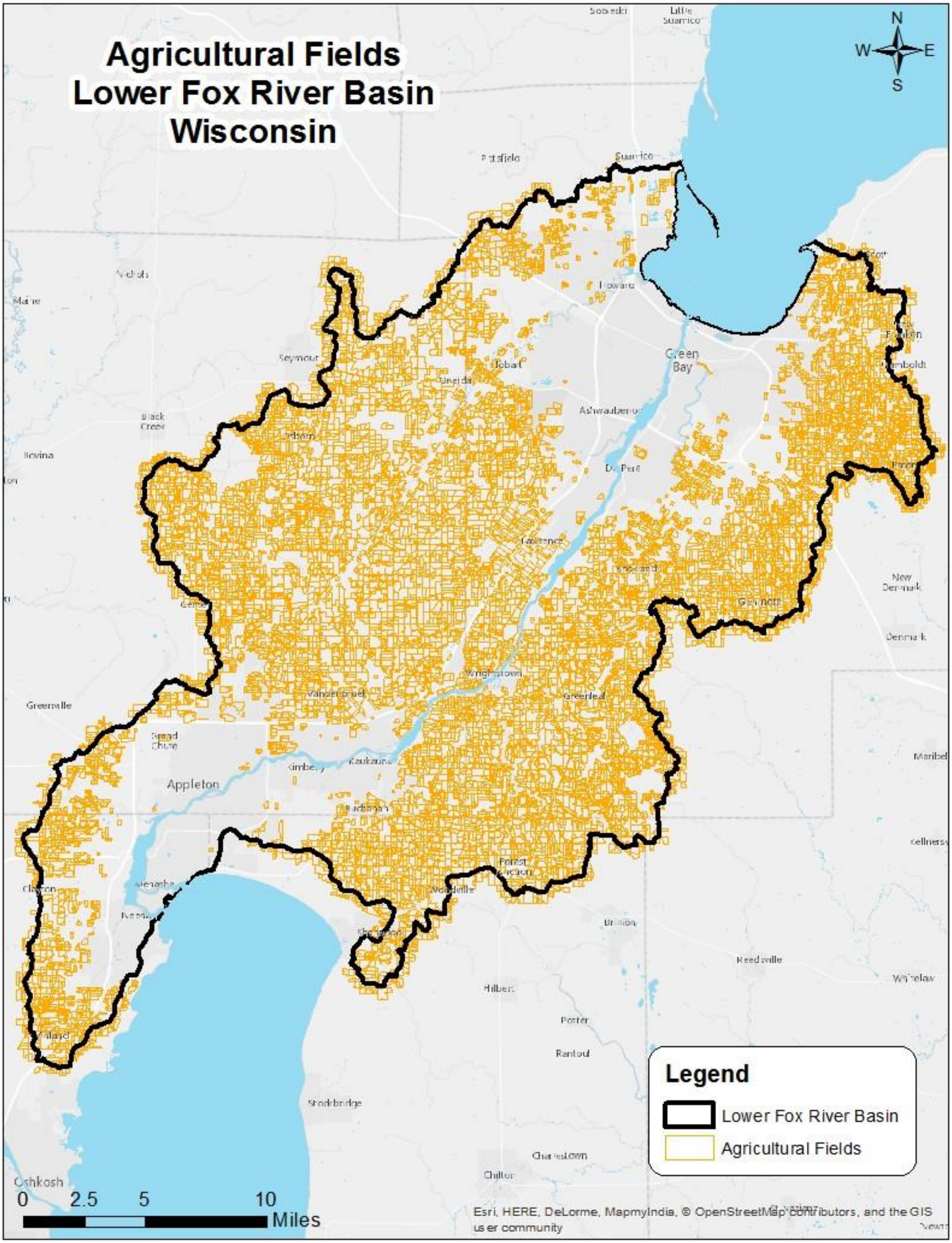
3.3 Maps

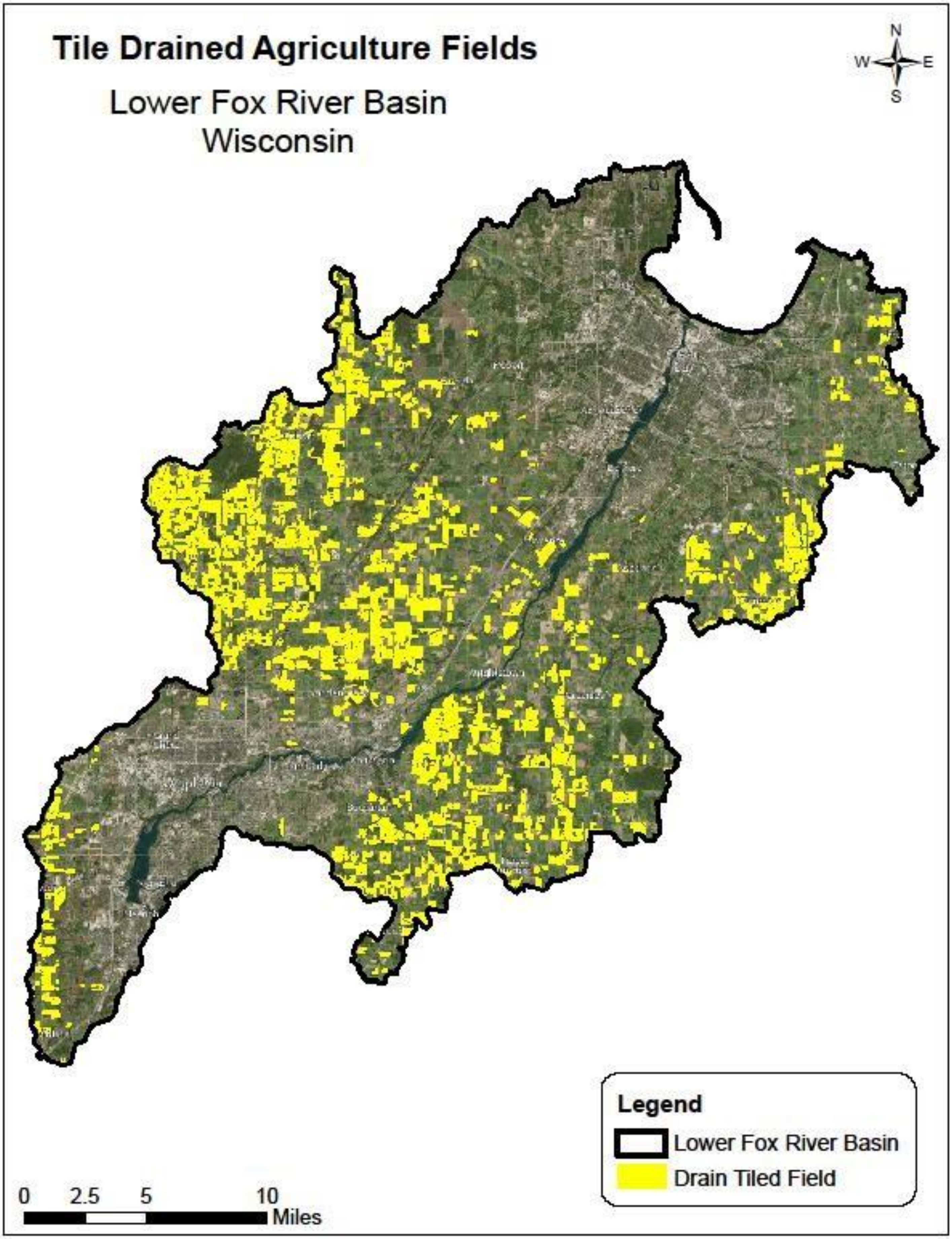


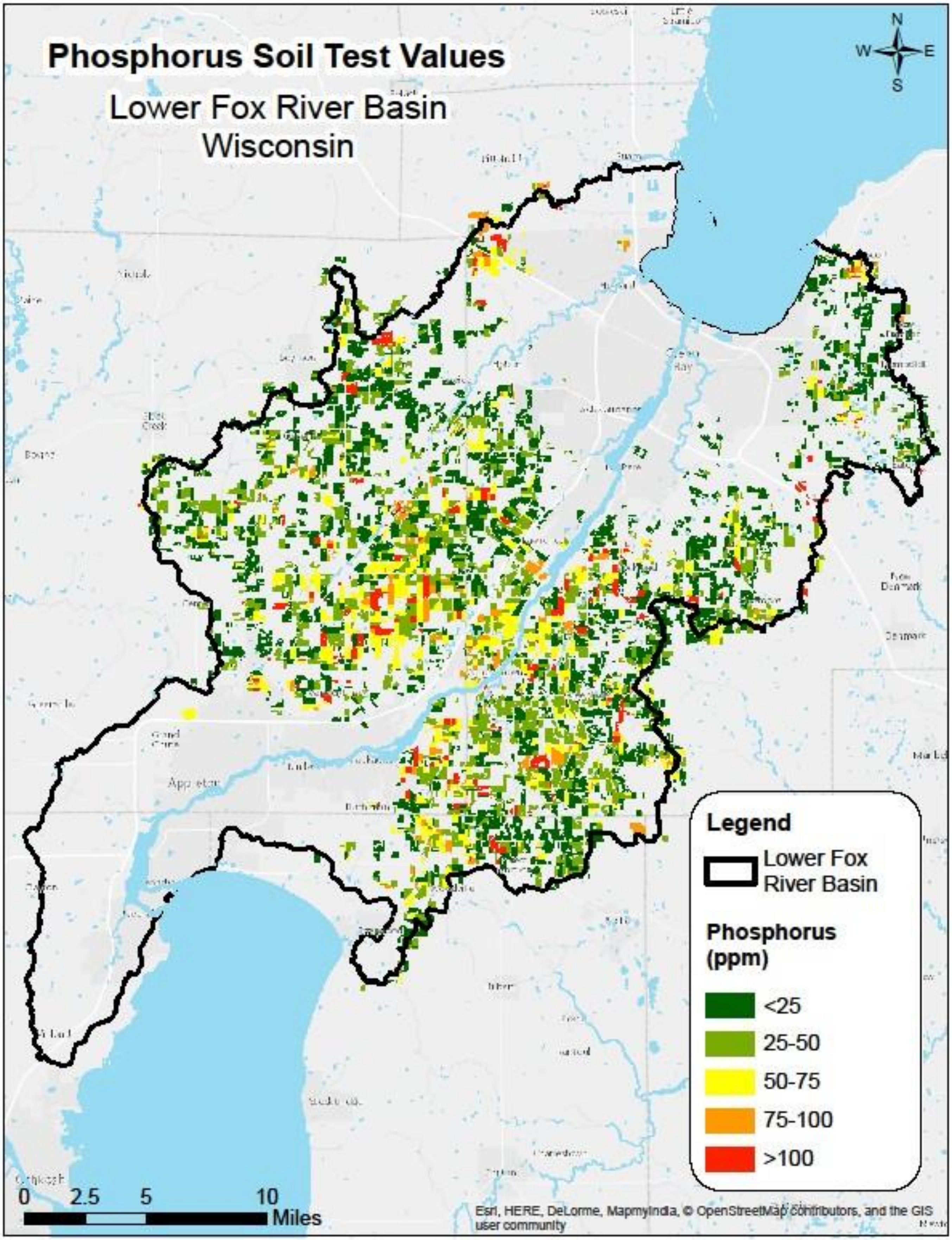
Lower Fox River Basin
Wisconsin
Wisconsin
Lower Fox River Basin
Green Bay
Howard
De Pere
Appleton
Kaukauna
Wrightstown
Greenleaf
Seymour
Oshkosh
Neenah
Menasha
Denmark
Stockbridge
Chilton
Hilbert
Greenville
0 2.5 5 10
Miles
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community



Lower Fox River Basin Subwatersheds(HUC12)
Dead Horse Bay-Frontal Green Bay
Lower Duck Creek
Trout Creek
Point du Sable-Frontal Green Bay
Oneida Creek
City of Green Bay-Fox River
Baird Creek
Dutchman Creek
Middle Duck Creek
Upper Duck Creek
Lower East River
Bower Creek
Ashwaubenon Creek
Apple Creek
Upper East River
Mud Creek
Garners Creek-Fox River
Plum Creek
Kankapot Creek
Little Lake Butte des Mortes
N
W
E
S
0
2.5
5
10
Miles


Agricultural Fields
Lower Fox River Basin
Wisconsin
N
W
E
S
Legend
Lower Fox River Basin
Agricultural Fields
0
2.5
5
10
Miles
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community
Green Bay
Appleton
Kaukauna
Wrightstown
Greenleaf
De Pere
Ashwaubenon
Seymour
Oneida
Greenville
Oshkosh
Brillion
Reedsville
Denmark
New Denmark
Hilbert
Potter
Rantoul
Stockbridge
Chilton
Charlestown
Howard
Suamico
Pittsfield
Kimberly
Woodville
Bovina
Black Creek
Nichols
Maine
Maribel
Whitelaw


Tile Drained Agriculture Fields
Lower Fox River Basin
Wisconsin
N
W
E
S
Legend
Lower Fox River Basin
Drain Tiled Field
0
2.5
5
10
Miles


Phosphorus Soil Test Values
Lower Fox River Basin
Wisconsin
N
W
E
S
Legend
Lower Fox River Basin
Phosphorus (ppm)
<25
25-50
50-75
75-100
>100
0
2.5
5
10
Miles
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

Appendix D: Methods to Assess Current and Potentially Restorable Wetlands for Ecosystem Service Potential

Phosphorus Retention (PR)

Code	Criterion	Rationale	Assessment Resource		Unit of Analysis			Datasets	GIS-based Criterion
			Wetland	PRW	Polygon	Complex	Catchment		
PR_O1	Site is connected to a surface water directly or through an existing wetland. **This criterion is necessary to the service.**	Wetlands connected to surface water have a greater ability to affect water quality.	X	X	X			WWI/PRW Plus	LLWW Functional Significance is High or Moderate = YES
PR_O2	Lack of vegetated buffer around site.	Wetland buffers in natural cover serve as filters for overland flow before it enters wetlands; wetlands lacking such buffers play a larger role in protecting water quality.	X	X	WWI, only	PRW, only			Less that 50% of the landcover within 60 m of a site is natural vegetation = YES; Same as SS_O2
PR_O4	Stream total phosphorus concentration is high.	Higher phosphorus concentrations in surface waters increases P loading of downstream wetlands.	X	X		X		Healthy Watershed Assessment, WDNR 24K Hydrography Value Added	Concentration in the complex (area-weighted average of catchment values) exceeds the median concentration for the WHUC 12 = YES
PR_O5	High animal unit density.	Crop fields near livestock concentrations receive phosphorous as a result of manure spreading.	X	X		X		CAFO permits, Wiscland 2	Site is adjacent to dairy rotation fields that are within 10 miles of a permitted CAFO = YES
PR_O6	Site receives nutrients from a point source.	Sites downstream of pollution sources have a greater opportunity to affect water quality than those upstream	X	X		X		WWI, PRW, WDNR 24K Value Added, Wisconsin Pollutant Discharge Elimination System (WPDES), CAFO permits	Site is on a flowline within a catchment that is downstream of a catchment with a point source = YES
PR_E2	Dominant vegetation of site is dense and persistent.	Dense vegetation slows the flow of water, which increases settling of suspended sediment. During the growing season, dense vegetation also uses dissolved phosphorous for plant growth.	X		X			WWI	Forest, scrub-shrub and persistent emergent marsh wetland types, with modified wetlands (f, g, v and x) excluded = YES; Same as FA_E2
PR_E3	Soil at the site has the capacity to absorb phosphorous.	Fine textured and organic soil types retain more phosphorous than course, sandy soils.	X	X	X			SSURGO Soils	Soil textures of Clay, Clay loam, Sandy clay, Silt, Silt loam, Silty clay, or Silty clay loam within the A or O are prevalent at the site = YES
PR_E4	Site does not have anaerobic conditions.	Aerobic conditions increase phosphorous retention in the sediment and the uptake of phosphorus by vegetation.	X		X			WWI, SSURGO Soils	Based on the WWI Hydrologic Modifier. Wetland has wet soil (K), or wetland has prolonged standing water (H), but is not formed over organic soil = YES
PR_E5	Site has shallow slope.	The lower the slope of a site, the longer it retains water.	X	X		X		USGS - 3D Elevation Program, 10m DEM.	Slope of site is less than the median slope of sites in the WHUC 10 =YES
PR_E6	Ratio of catchment area to site area.	The largest sites, less likely to overflow after a storm, are more effective in retaining stormwater runoff, and removing phosphorous either by allowing sediment to settle, or by plant uptake.	X	X		X		WWI, WDNR 24K Hydrography Value Added	Wet units that intersect stream/river network used to create the upstream area measures were compared to the area of the catchments above them, wetunits not directly connected to the network were compared to their immediate catchment area. Sites whose ratio is in the most favorable 1/3 of ratios for the WHUC10 = YES
PR_E8	Site occurs in topographical depression.	Depression wetlands retain water longer that sloped or flat wetlands. Longer retention time increases settling of suspended solids and phosphorous uptake.	X	X	X			WWI/PRW Plus	LLWW Landform is BA = YES

Sediment Retention (SS)

Code	Criterion	Rationale	Assessment Resource		Unit of Analysis			Datasets	GIS-based Criterion
			Wetland	PRW	Polygon	Complex	Catchment		
SS_O1	Site is connected to a surface water directly or through an existing wetland. **This criterion is necessary to the service.**	Wetlands connected to surface water have more opportunity to influence water quality.	X	X		X		WWI/PRW Plus	LLWW Functional Significance is High or Moderate = YES
SS_O2	Lack of vegetated buffer around site.	Wetland buffers in natural cover serve as filters for overland flow before it enters wetlands; wetlands lacking such buffers play a larger role in protecting water quality.	X	X	PRW only	WWI only		Wiscland 2	Less that 50% of the landcover within 60 m of a site is natural vegetation = YES
SS_O3	Proximity of roadway sediment source to site.	Crossing of road right of way over sites and streams; Sediment found on roadways will be washed off during rain events and flow downstream where wetlands are typically located.	X	X		X		WWI/PRW Plus, TIGER Roads (2015)	Wetunit and road within a buffered selection = YES
SS_O4	Predicted Total suspended sediment concentration is high.	Higher runoff volume and velocity is capable of dislodging more sediment as it travels across the landscape resulting in more sediment transport downslope.	X	X		X		Healthy Watershed Assessment, WDNR 24K Hydrography Value Added	Concentration in the complex (area-weighted average of catchment values) exceeds the median concentration for the WHUC 12 = YES
SS_E1	Internal flow path distance within site.	The longer the hydrologic path length, the greater the friction provided and this the more effective a wetland is at slowing flow and settling sediment particles. Don't include artificial through flow from NWI + The longer the flow path within the site, the greater the friction that will slow the movement of water and increase its settling ability.	X	X		X		WWI/PRW Plus, WDNR 24K Hydrography Geodatabase	Length of a site's shoreline interface exceeds the WHUC10 non-zero median interface length, with entrenched and artificial waterways excluded = YES (Same as FA_E4)
SS_E2	Dominant vegetation of site is dense and persistent.	Dense wetland vegetation impedes water flow, causing suspended sediment to settle, even outside of the growing season.	X		X			WWI	Forest, scrub-shrub and persistent emergent marsh wetland types, with modified wetlands (f, g, v and x) excluded = YES (Same as FA_E2)
SS_E3	Site occurs in a topographic depression.	Depression wetlands retain water which allows suspended particles to settle.	X	X	X			WWI/PRW Plus	Landform is BA = YES
SS_E4	Ratio of catchment area to site area.	Larger wetlands, less likely to overflow, can trap more sediment.	X	X		X		WWI, WDNR 24K Hydrography Value Added	Wet units that intersect stream/river network used to create the upstream area measures were compared to the area of the catchments above them, wetunits not directly connected to the network were compared to their immediate catchment area. Sites whose ratio is in the most favorable 1/3 of ratios for the WHUC10 = YES (Same as FA_E5)
SS_E5	Bank or shoreline upstream or in site is subject to erosion; Stream Power Index (SPI) measures the erosive power of overland flow as a function of local slope and upstream drainage area.	Wetlands or wetlands restored mitigate erosion due to moving water.	X	X	X			USGS - 3D Elevation Program, 10m DEM.	The complex contains an area of SPI(>7) that is greater than the median area of SPI for the WHUC10 = YES

Fish & Aquatic Habitat (FAH)

Code	Criterion	Rationale	Assessment Resource		Unit of Analysis			Datasets	GIS-based Criterion
			Wetland	PRW	Polygon	Complex	Catchment		
FAH_O1	Site is connected to a perennial stream or lake. **This criterion is necessary to the service.**	Wetlands connected to perennial surface water have the opportunity to provide fish & aquatic habitat.	X	X		X		WWI/PRW Plus	Site is not isolated or entrenched = YES
FAH_E1	Site is inundated in spring.	Wetlands flooded in spring provide habitat for reproduction and food chain support.	X	X		X		WWI/PRW Plus; Active River Area	Site Landform is BA, FR, FF, or FP and within ARA = YES
FAH_E2	Site is not associated with a waterbody impaired for fish & aquatic life.	Viable populations require clean water.	X	X		X		Impaired Waters, Clean Water Act 303(d) List	Site is on a waterway not impaired for fish and aquatic life factors (e.g. mercury), or is upstream of an impaired waterway = YES
FAH_E3	Site is associated with a waterbody bordered by natural landcover.	Natural shorelines increase available habitat for fish & aquatic life.	X	X		X		Wiscland 2; WDNR 24K Hydrography Geodatabase	Site is adjacent to a waterway whose percent natural cover within 60 meters exceeds the median for the WHUC 12 = YES
FAH_E4	Catchment supports a healthy macroinvertebrate community.	Wetlands support the presence of healthy aquatic macroinvertebrates communities.	X	X			X	WI Healthy Watershed Assessment	Catchment Macroinvertebrate Index of Biological Integrity (IBI) exceeds the median for the WHUC 12 = YES
FAH_E5	Site is connected to a waterbody with few barriers to fish passage.	Wetlands associated with barrier-free waterways are more likely to support complete and sustainable populations.	X	X		X		WI Healthy Watershed Assessment	Wetunit associated with waterbody whose Stream Patch Size is greater than the median Stream Patch Size of the WHUC 10 = YES
FAH_S1*	Site is associated with a waterbody accessible for public fishing.	Wetlands associated with waterways accessible to anglers are more likely to benefit the fishing public.	X	X		X		WI DNR Lakes/reservoir waterbody dataset	Wetunit is associated with a waterbody that has a public boat landing = YES

*This is a bonus criteria. First the total number of O and E criteria that a site met is divided by the total possible number of O and E criteria for a value between zero and one. Scores are then increased by 0.1 if S criterion for that site is met. S criteria only used for Fish & Aquatic Habitat, not PR or SS.

Appendix E: Field Assessment Datasheet for Potentially Restorable Wetlands

Field Form: Assessment of PRWs for Water Quality in Lower Fox Watershed

Site Number:_____________________________ **Date:**______________________

Does the PRW span more than one site? (Yes / No) [if yes, list other site numbers. ________________

☐ On the field map, delineate the estimated approximate boundaries of the PRW and indicate direction of surface flow (best guess).

Is the site <u>actually</u> a restorable wetland? (Yes / No) [if no, describe reasoning and end survey]________

____

1. Restorability (re-establishment)

a. Is the PRW in cropland? (All, Some, None) [if some or none, give % of non-crop land acres and describe use & vegetation]. ____

b. Is ditching present that impacts hydrology of the PRW? (Yes / No / Unsure) [f yes, could ditching be filled or plugged? Describe. ____

____

c. Is tile present that could be removed or broken? (Yes / No / Unsure). Describe evidence & location. ____

____

Is tile functioning? H=functioning ___ M=compromised ____ L=significantly failing _____

d. Are there other means by which hydrology could be restored to the site (Yes / No). Explain.

____

e. Would restoration of this PRW cause changes in hydrology that would cause flooding of nearby properties or structures? (Yes / No / Maybe / Unsure) If 'yes' or 'maybe,' describe and explain if there are workarounds. ____

f. If restored, what is the likelihood the PRW would have sufficient hydrologic inputs to maintain wetland hydrology & vegetation, given condition of surrounding landscape, current land uses, connection to wetlands or waterbodies, evidence of groundwater discharge, and other?

High ____ Medium ____ Low ____ Explain.____

____

2. Feasibility

a. What is your estimate of the relative cost of restoring this PRW?

More than $100K _____ $10K-100K_____ Less than $10K____ Describe rationale & factors considered. ____

b. Is the site on which the PRW occurs currently for sale? (Yes / No)

c. How physically accessible is the site for restoration (consider proximity to roads; need to cross water, wetlands, or other barriers; etc.) (High / Medium / Low)

d. How many landowners would be directly affected by the restoration ______________________

e. Are there other landowners that would be indirectly affected by the restoration (e.g., through providing access across their property, through flooding of their property, etc.) ______________

____

f. If you interacted with the landowner, note anything of interest. __________________________

____

3. **Validation/Verification** (purpose of this section is to collect field data to validate and/or improve on data assessed via GIS)

a. What is the potential to maintain or restore hydrologic connectivity of the PRW to a flowing water course (ditch, stream, or river)? (High / Medium / Low)

b. Is the PRW tiled, does it currently receive nutrient inputs from tile, or does it have the potential to be restored in a way that would intercept flow from tile? (Yes / No / Unable to ascertain)

c. What % of the PRW's perimeter <u>has</u> vegetated buffer (upland and wetland)? ______________%
What % of the PRW's perimeter <u>could potentially have</u> vegetated upland buffer, given optimal restoration? ________%

d. Based on proximity to roads & road outfalls, is PRW likely to receive sediments from winter road sanding? (Yes / No)

e. Does the PRW occur in a topographic depression, slope, and/or other? Please describe.

____

f. Is the PRW connected to: Surface water directly? _____ Through an existing wetland? _____

g. Is there evidence of point source nutrient loading to the PRW from:

i. runoff/channelized flow from a barnyard? (Yes / No)
ii. piped effluent from source other than tile, (Yes / No)
iii. other/specify ____

h. Does the PRW have a constricted outlet, whether natural or human-made? (Yes / No)

<u>For each PRW, provide a preliminary opinion on potential for wetland restoration:</u>

Rank and provide a brief explanation.
H=high feasibility/restorability M=moderate feasibility/restorability L=low feasibility/restorability)

____

____

____

____

Appendix F: AOC Habitat Types Used for 2015 Habitat Mapping Effort

Habitat types and descriptions originated from the Wisconsin Wildlife Action Plan (WAP; 2015); however, two habitats (emergent marsh and surrogate grassland) were subdivided into more detailed categories[1], several habitats or subdivisions were added for the field work that were not included in the original WAP[2], others were added after the field work[3], and some descriptions were modified to better describe each type within this AOC. Scientific names of each common name provided below as a table footnote ‡.

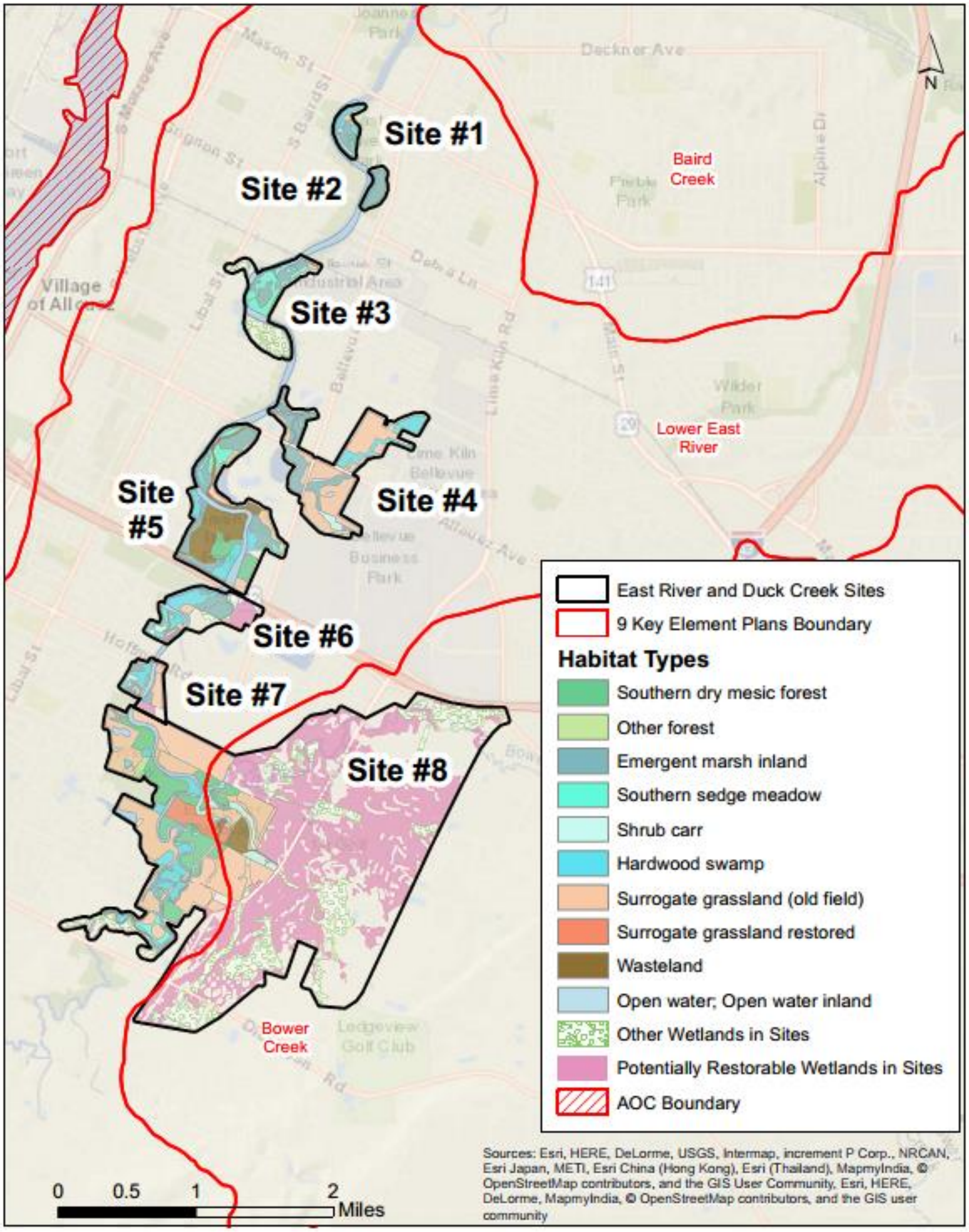
Habitat (Plant Community Type)	Habitat Code	Description
Emergent Marsh[1,2] (High Energy Coastal)	EMHE	Open wetland with standing water in some part of area, dominated by emergent macrophytes. Dominants include cattails, bulrushes, bur-reeds, arrowheads, spikerush, etc.; often invaded by *Phragmites* or reed canary grass.
Emergent Marsh[1,2] (Inland)	EMIN	
Emergent Marsh[1,2] (Riparian)	EMRI	
Emergent Marsh[1,2,3] (Roadside)	EMRS	
Fox River Open Water[2,3]	FOXR	Open water of the Fox River.
Great Lakes Beach	GLBE	Shoreline habitat at interface of land and water along the margins of Lakes Michigan. Includes sand, shells, mud, cobble, rip-rap, vegetation.
Hardwood Swamp	HASW	Wet forest dominated by green or black ash, sometimes with red maple, yellow birch, cottonwood, swamp white oak, and elm. Very common in AOC.
Northern Mesic Forest	NMFO	Widespread forest type dominated or co- dominated by sugar maple, eastern hemlock, white pine, and American beech can be a co-dominant. Other important tree species include yellow birch, American basswood, and white/green ash. Fairly common in AOC.
Open Water Inland[2,3]	OWIN	Inland open water bodies (e.g., retention pond, small lake). Common in AOC.
Green Bay Open Water[2,3]	GBAY	Open water of the Bay of Green Bay (i.e., pelagic zone).
Other Forest[2]	OTFO	Broad category meant to capture forest types that don't fit into other communities. Early successional forests dominated by aspen, box elder, cottonwood, sumac, and young trees of mixed composition. Pine plantations. Very common in AOC.

Submergent Marsh	SUMA	Herbaceous community of aquatic macrophytes in lakes, ponds, and rivers. Dominants include pondweeds along with waterweed, eel-grass, and species of water-milfoil and bladderworts. Somewhat common in AOC.
Shrub Carr	SHCA	Transitional habitat between open wetlands and forested wetlands. Dominated by tall shrubs such as red-osier dogwood, silky dogwood, meadowsweet, and various willows. Canada blue- joint grass is often very common. Common in AOC.
Southern Dry Mesic Forest	SDMF	Forest dominated by red oak, white oak, basswood, sugar and red maple; white ash and shagbark hickory often also present. Relatively uncommon in AOC.
Southern Sedge Meadow	SSME	Open wetland community most typically dominated by tussock sedge and Canada blue-joint grass. Not common in AOC.
Surrogate Grassland[1] (Old Field)	SGOF	Variety of open, non-forested habitats dominated by grasses or upland shrubs. Very common in AOC.
Surrogate Grassland (Restored)[1,2]	SGRE	Variety of open non-forested habitats dominated by native grasses or shrubs. Uncommon in AOC.
Surrogate Grassland (Roadside)[1,2,3]	SGRS	Variety of open non-forested habitats dominated by grasses or shrubs found along roadsides. Very common in AOC.
Tributary Open Water[2,3]	TRIB	Open water of a tributary (e.g., Duck Creek, East River, Mahon Creek).
Wasteland[2]	WAST	Highly disturbed industrial lands dominated by non-native grasses and forbs (e.g., *Phragmites australis*), including the occasional tree/shrub. Common in AOC.

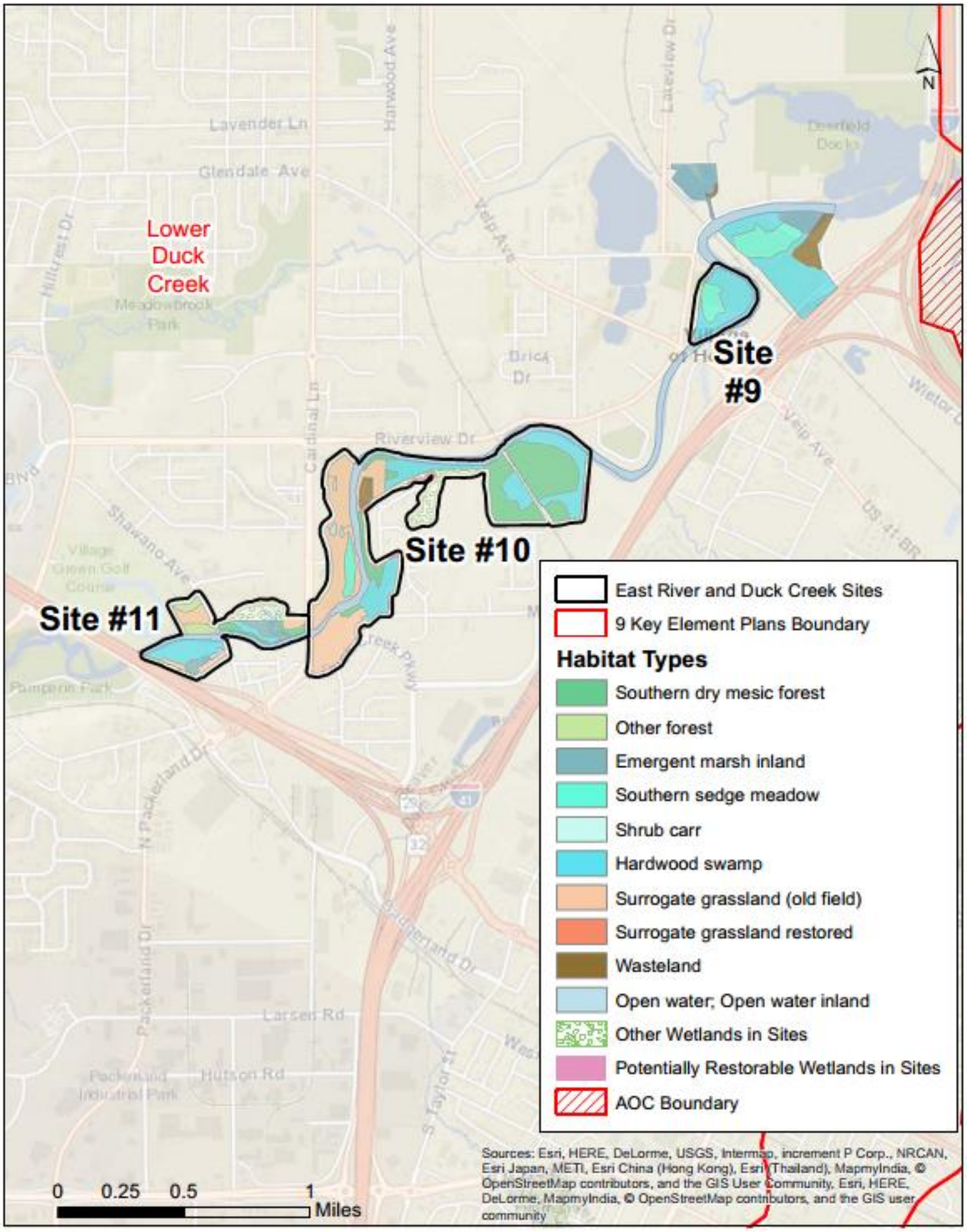
‡ Scientific names of common names listed in table above are provided alphabetically as follows: American basswood (*Tilia americana* L), American beech (*Fagus grandifolia* Ehrh.), balsam fir (*Abies balsamea* [L.] Mill.), black ash (*Fraxinus nigra* Marshall), bladderworts (*Utricularia* spp.), bur oak (*Quercus macrocarpa* Michx.), Canada blue-joint grass (*Calamagrostis canadensis* [Michx.] P. Beauv.), eastern hemlock (*Tsuga canadensis* [L.] Carrière), eel-grass (*Vallisneria americana* Michx.), elm (*Ulmus* spp.), meadowsweet (*Spiraea alba* Du Roi), northern white cedar (*Thuja occidentalis* L.), pondweeds (*Potamogeton* spp.), red maple (*Acer rubrum* L.), red oak (*Quercus rubra* L.), red-osier dogwood (*Cornus sericea* L.), shagbark hickory (*Carya ovata* [Mill.] K. Koch), silky dogwood (*Cornus amomum* Mill.), spruces (*Picea* spp.), sugar maple (*Acer saccharum* Marshall), sumac (*Rhus* spp.), tussock sedge (*Carex aquatilis* Wahlenb.), water-milfoil (*Myriophyllum spicatum* L.), waterweed (*Elodea canadensis* Michx.), white ash (*Fraxinus americana* L.), white oak (*Quercus alba* L.), white pine (*Pinus strobus* L.), willows (*Salix* spp.), and yellow birch (*Betula alleghaniensis* Britton)

For descriptions and more information on the habitat types utilized in this report please refer to the University of Wisconsin's "Green Bay Area of Concern" website's Habitat page: http://www.uwgb.edu/green-bay-area-of-concern/fish-wildlife-habitats/habitats/

Appendix G: Map of Lower East River Habitat Sites



Appendix H: Map of Lower Duck Creek Habitat Sites



Appendix I: Biological Notes From East River and Duck Creek Habitat Assessment

East River Species

Mammals (based on 2017 field assessment)

Information on mammals presented here was gathered through incidental observations taken during the assessment period. No efforts were made towards a thorough inventory.

Common Name	Scientific Name	Comments
White-tailed deer	*Odocoileus virginianus*	Encountered throughout the riparian corridor from Green Bay to De Pere
Gray squirrel	*Sciurus carolinensis*	Common in the wooded patches
Muskrat	*Ondatra zibethicus*	Houses seen in the larger riparian emergent wetland patches
Opossum	*Didelphus virginianus*	Woodlots and wetland edges

Fish (from literature)

Fish recorded from Bower Creek. From: https://cida.usgs.gov/wdnr_fishmap/map/ . Data accessed 1/3/18.

Common Name	*Scientific Name*
GIZZARD SHAD	*Dorosoma cepedianum*
WHITE CRAPPIE	*Pomoxis annularis*
BLACK BULLHEAD	*Ameiurus melas*
GREEN SUNFISH	*Lepomis cyanellus*
PUMPKINSEED	*Lepomis gibbosus*
YELLOW PERCH	*Perca flavescens*
BLACK CRAPPIE	*Pomoxis nigromaculatus*
JOHNNY DARTER	*Etheostoma nigrum*
GREEN SUNFISH X PUMPKINSEED	*Lepomis cyanellus x Lepomis gibbosus*
WHITE SUCKER	*Catostomus commersonii*
NORTHERN PIKE	*Esox lucius*
WHITE BASS	*Morone chrysops*

Fish recorded from the East River. From: https://cida.usgs.gov/wdnr_fishmap/map/ . Data accessed 1/3/18.

Common Name	*Scientific Name*
BLACK BULLHEAD	*Ameiurus melas*
YELLOW BULLHEAD	*Ameiurus natalis*
FRESHWATER DRUM	*Aplodinotus grunniens*
WHITE SUCKER	*Catostomus commersonii*
COMMON CARP	*Cyprinus carpio*
NORTHERN PIKE	*Esox lucius*

JOHNNY DARTER	*Etheostoma nigrum*
GREEN SUNFISH	*Lepomis cyanellus*
BLUEGILL	*Lepomis macrochirus*
COMMON SHINER	*Luxilus cornutus*
PEARL DACE	*Margariscus margarita*
LARGEMOUTH BASS	*Micropterus salmoides*
WHITE BASS	*Morone chrysops*
GREATER REDHORSE	*Moxostoma valenciennesi*
HORNYHEAD CHUB	*Nocomis biguttatus*
GOLDEN SHINER	*Notemigonus crysoleucas*
EMERALD SHINER	*Notropis atherinoides*
CHINOOK SALMON	*Oncorhynchus tshawytscha*
YELLOW PERCH	*Perca flavescens*
BLACKSIDE DARTER	*Percina maculata*
NORTHERN REDBELLY DACE	*Phoxinus eos*
SOUTHERN REDBELLY DACE	*Phoxinus erythrogaster*
BLUNTNOSE MINNOW	*Pimephales Notatus*
FATHEAD MINNOW	*Pimephales promelas*
BLACK CRAPPIE	*Pomoxis nigromaculatus*
WESTERN BLACKNOSE DACE	*Rhinichthys obtusus*
CREEK CHUB	*Semotilus atromaculatus*
CENTRAL MUDMINNOW	*Umbra limi*

Fish recorded from surveys in the assessed reach of the East River; (Quinlan, 1989).

Fish recorded from East River reach included in this assessment (From: Quinlan, 1989)	
Common Name	***Scientific Name***
Black bullhead	*Ameiurus melas*
Freshwater drum	*Aplodinotus grunniens*
White sucker	*Catostomus commersonii*
Common carp	*Cyprinus carpio*
Northern pike	*Esox lucius*
Bluegill	*Lepomis macrochirus*
Common shiner	*Luxilus cornutus*
White bass	*Morone chrysops*
Emerald shiner	*Notropis atherinoides*
Yellow perch	*Perca flavescens*
Bluntnose minnow	*Pimephales Notatus*
Fathead minnow	*Pimephales promelas*
Black crappie	*Pomoxis nigromaculatus*
Channel catfish	*Ictalurus punctatus*
Tadpole madtom	*Noturus gyrinus*
Gizzard shad	*Dorosoma cepedianus*
Spottail shiner	*Notropis hudsonius*

Herps (based on field assessment)

Snapping turtle (*Chelydra serpentine*) – main stem of the East River
Eastern gray treefrog (*Hyla versicolor*) – heard occasionally from the lowland forest patches
Green frog (*Rana clamitans melanota*)– a common species seen and heard in the wetlands especially in the upper reaches

Odonates (based on field assessment)

Odonates (adults) Encountered During the Assessment		
Common name	***Scientific name***	
Big green darner	*Anx junius*	*Intermittently encountered, emergent marsh settings.*
Canada darner	*Aeshna canadensis*	*Uncommon throughout, most often associated with oxbow wetlands*
Lance-tipped darner	*A. constricta*	*Uncommon throughout, most often associated with oxbow wetlands*
Common white tail	*Plathemis lydia*	*Common over open water especially upstream of Green Isle Park*
Twelve-spot skimmer	*Libellula pulchella*	*Common over open water especially upstream of Green Isle Park*
Black saddlebags	*Tramea lacerata*	*One seen associated with Allouez storm water ponds*
White-faced meadow hawk	*Sympetrum obstrusum*	*Common over interior wetlands*
Ruby meadow hawk	*S. rubicundulum*	*Common over interior wetlands*
Baskettails	*Epitheca spp.*	*Uncommon; only over open water*
Ebony jewelwings	*Calopteryx maculata*	*Common, shady wetlands*
Spreadwings	*Lestes spp.*	*Common*
Bluets	*Enallagma spp.*	*Common*

Birds (based on field assessment)

Information on birds was gathered through a series of 10-minute point counts conducted during the month of June and incidental observations taken during the assessment period.

BIRDS ENCOUNTERED DURING ASSESSMENT		Season of Encounter		
Common name	***Scientific name***	**Migration**	**Breeding**	**Characteristic of the Riparian Corridor**
Canada Goose	*Branta canadensis*	X	C	X
Mallard	*Anas platyrhynchos*	X	C	X
Mourning Dove	*Zenaida macroura*		C	X
Great Blue Heron	*Ardea herodias*		C	X

Green Heron	*Butorides virescens*	X	C	X
Belted Kingfisher	*Megaceryle alcyon*		C	X
Red-bellied Woodpecker	*Melanerpes carolinus*	X	C	X
Hairy Woodpecker	*Picoides villosus*		O	X
Northern Flicker	*Colaptes auratus*		O	X
Great Crested Flycatcher	*Myiarchus crinitus*	X	O	X
Eastern Kingbird	*Tyrannus tyrannus*		C	X
Warbling Vireo	*Vireo gilvus*	X	C	X
Blue Jay	*Cyanocitta cristata*		C	X
Barn Swallow	*Hirundo rustica*	X	C	X
Black-capped Chickadee	*Poecile atricapillus*	X	C	X
White-breasted Nuthatch	*Sitta carolinensis*		C	X
House Wren	*Troglodytes aedon*	X	C	X
Blue-gray Gnatcatcher	*Polioptila caerulea*	X	O	X
American Robin	*Turdus migratorius*	X	C	X
Gray Catbird	*Dumetella carolinensis*	X	C	X
Cedar Waxwing	*Bombycilla cedrorum*	X	O	X
Common Yellowthroat	*Geothlypis trichas*	X	C	X
Yellow Warbler	*Setophaga petechia*	X	C	X
Song Sparrow	*Melospiza melodia*	X	C	X
Northern Cardinal	*Cardinalis cardinalis*	X	O	X
Red-winged Blackbird	*Agelaius phoeniceus*	X	C	X
Common Grackle	*Quiscalus quiscula*	X	O	X
Baltimore Oriole	*Icterus galbula*	X	O	X
Wood Duck	*Aix sponsa*		O	X
Red-breasted Merganser	*Mergus serrator*	X		
Sandhill Crane	*Antigone canadensis*		O	
Killdeer	*Charadrius vociferus*		C	
Spotted Sandpiper	*Actitis macularius*	X		
Ring-billed Gull	*Larus delawarensis*	X	C	X
Herring Gull	*Larus argentatus*	X	O	
Double-crested Cormorant	*Phalacrocorax auritus*	X	O	
Great Egret	*Ardea alba*	X	O	
Black-crowned Night-Heron	*Nycticorax nycticorax*		O	
Osprey	*Pandion haliaetus*		R	
Bald Eagle	*Haliaeetus leucocephalus*	X		
Cooper's Hawk	*Accipiter cooperii*	X		

Red-tailed Hawk	*Buteo jamaicensis*		O	
Yellow-bellied Sapsucker	*Sphyrapicus varius*	X	O	
Downy Woodpecker	*Picoides pubescens*	X		
Least Flycatcher	*Empidonax minimus*	X		
Red-eyed Vireo	*Vireo olivaceus*	X		
American Crow	*Corvus brachyrhynchos*	X	O	
Tree Swallow	*Tachycineta bicolor*		C	
N. Rough-winged Swallow	*Stelgidopteryx serripennis*	X	C	
Red-breasted Nuthatch	*Sitta canadensis*		O	
Wood Thrush	*Hylocichla mustelina*		R	
European Starling	*Sturnus vulgaris*		R	
House Finch	*Haemorhous mexicanus*	X	O	
American Goldfinch	*Spinus tristis*	X	C	
Ovenbird	*Seiurus aurocapilla*		O	
American Redstart	*Setophaga ruticilla*		C	
Magnolia Warbler	*Setophaga magnolia*	X		
Bay-breasted Warbler	*Setophaga castanea*	X		
Chestnut-sided Warbler	*Setophaga pensylvanica*	X	O	
Yellow-rumped Warbler	*Setophaga coronata*	X		
Wilson's Warbler	*Cardellina pusilla*	X		
Chipping Sparrow	*Spizella passerina*	X	O	
Savannah Sparrow	*Passerculus sandwichensis*		U	
Dark-eyed Junco	*Junco hyemalis*	X		
Rose-breasted Grosbeak			O	
Indigo Bunting	*Passerina cyanea*		C	
Brown-headed Cowbird	*Molothrus ater*		O	

Characteristic = these species were commonly encountered throughout the assessment area and were considered representative of the habitat conditions of the riparian corridor of the East River.

x = observed

R = rarely encountered

U = uncommonly encountered

O = occasional

C = commonly encountered

Duck Creek Species

Mammals (based on 2017 field assessment)

Information on mammals presented here was gathered through incidental observations taken during the assessment period.

Common Name	Scientific Name	Comments
White-tailed deer	*Odocoileus virginianus*	Forest patches
Woodchuck	*Marmota monax*	Open fields along the river
Gray squirrel	*Sciurus carolinensis*	Wooded sites
Eastern Chipmunk	*Tamias striatus*	Forest edges and wooded sites
Raccoon	*Procyon lotor*	Stream banks, wooded patches
Eastern cottontail rabbit	*Sylvilagus floridanus*	Forest edges
Muskrat	*Ondatra zibethicus*	Riparian emergent marshes

Fish (from literature)

Fish recorded from Duck Creek 1961 through 2002. From: https://cida.usgs.gov/wdnr_fishmap/map/ . Database accessed 1/3/18.

COMMON NAME	SCIENTIFIC NAME
ALEWIFE	Alosa pseudoharengus
ROCK BASS	Ambloplites rupestris
BLACK BULLHEAD	Ameiurus melas
YELLOW BULLHEAD	Ameiurus natalis
BROWN BULLHEAD	Ameiurus nebulosus
FRESHWATER DRUM	Aplodinotus grunniens
CENTRAL STONEROLLER	Campostoma anomalum
STONEROLLERS	Campostoma spp.
GOLDFISH	Carassius auratus
GOLDFISH	Carassius auratus
CARPSUCKER	Carpiodes carpio or Carpiodes velifer
WHITE SUCKER	Catostomus commersonii
BROOK STICKLEBACK	Culaea inconstans
SPOTFIN SHINER	Cyprinella spiloptera
COMMON CARP	Cyprinus carpio
GIZZARD SHAD	Dorosoma cepedianum
NORTHERN PIKE	Esox lucius
MUSKELLUNGE	Esox masquinongy
FANTAIL DARTER	Etheostoma flabellare
JOHNNY DARTER	Etheostoma nigrum
BANDED KILLIFISH	Fundulus diaphanus

BANDED KILLIFISH	Fundulus diaphanus
GREEN SUNFISH	Lepomis cyanellus
PUMPKINSEED	Lepomis gibbosus
BLUEGILL	Lepomis macrochirus
BURBOT	Lota lota
COMMON SHINER	Luxilus cornutus
PEARL DACE	Margariscus margarita
SMALLMOUTH BASS	Micropterus dolomieu
LARGEMOUTH BASS	Micropterus salmoides
WHITE PERCH	Morone americana
WHITE BASS	Morone chrysops
RIVER REDHORSE	Moxostoma carinatum
SHORTHEAD REDHORSE	Moxostoma macrolepidotum
REDHORSES	Moxostoma spp.
HORNYHEAD CHUB	Nocomis biguttatus
GOLDEN SHINER	Notemigonus crysoleucas
EMERALD SHINER	Notropis atherinoides
SPOTTAIL SHINER	Notropis hudsonius
TADPOLE MADTOM	Noturus gyrinus
PINK SALMON	Oncorhynchus gorbuscha
COHO SALMON	Oncorhynchus kisutch
RAINBOW TROUT	Oncorhynchus mykiss
CHINOOK SALMON	Oncorhynchus tshawytscha
RAINBOW SMELT	Osmerus mordax
YELLOW PERCH	Perca flavescens
LOGPERCH	Percina caprodes
BLACKSIDE DARTER	Percina maculata
SOUTHERN REDBELLY DACE	Phoxinus erythrogaster
BLUNTNOSE MINNOW	Pimephales Notatus
FATHEAD MINNOW	Pimephales promelas
BLACK CRAPPIE	Pomoxis nigromaculatus
LONGNOSE DACE	Rhinichthys cataractae
WESTERN BLACKNOSE DACE	Rhinichthys obtusus
BROWN TROUT	Salmo trutta
WALLEYE	Sander vitreus
CREEK CHUB	Semotilus atromaculatus
CENTRAL MUDMINNOW	Umbra limi

Birds (based on field assessment)

Information on birds was gathered through a series of 10-minute point counts conducted during the month of June and incidental observations taken during the assessment period,

BIRDS ENCOUNTERED DURING ASSESSMENT		Season of Encounter		
Common name	*Scientific name*	Migration	Breeding	Characteristic of the Riparian Corridor
Canada Goose	*Branta canadensis*	X	C	X
Mallard	*Anas platyrhynchos*	X	C	X
Mourning Dove	*Zenaida macroura*		C	X
Green Heron	*Butorides virescens*	X	C	X
Belted Kingfisher	*Megaceryle alcyon*		C	X
Red-bellied Woodpecker	*Melanerpes carolinus*	X	C	X
Northern Flicker	*Colaptes auratus*		O	X
Great Crested Flycatcher	*Myiarchus crinitus*	X	O	X
Eastern wood pewee				X
Warbling Vireo	*Vireo gilvus*	X	C	X
Blue Jay	*Cyanocitta cristata*		C	X
Black-capped Chickadee	*Poecile atricapillus*	X	C	X
White-breasted Nuthatch	*Sitta carolinensis*		C	X
House Wren	*Troglodytes aedon*	X	C	X
Blue-gray Gnatcatcher	*Polioptila caerulea*	X	O	X
American Robin	*Turdus migratorius*	X	C	X
Gray Catbird	*Dumetella carolinensis*	X	C	X
Cedar Waxwing	*Bombycilla cedrorum*	X	O	X
Common Yellowthroat	*Geothlypis trichas*	X	C	X
American Redstart	*Setophaga ruticilla*		C	X
Yellow Warbler	*Setophaga petechia*	X	C	X
Song Sparrow	*Melospiza melodia*	X	C	X
Northern Cardinal	*Cardinalis cardinalis*	X	O	X
American Goldfinch	*Spinus tristis*	X	C	X
Rose-breasted Grosbeak			O	X
Red-winged Blackbird	*Agelaius phoeniceus*	X	C	X
Common Grackle	*Quiscalus quiscula*	X	O	X
Baltimore Oriole	*Icterus galbula*	X	O	X
Great Blue Heron	*Ardea herodias*		C	
White pelican			U	
Double-crested cormorant			O	
Spotted sandpiper				
Killdeer	*Charadrius vociferus*		C	
Herring Gull	*Larus argentatus*	X	O	

Wild turkey			O	
Cooper's Hawk	*Accipiter cooperii*	X	U	
Downy Woodpecker	*Picoides pubescens*	X	O	
Hairy Woodpecker	*Picoides villosus*		O	
Eastern phoebe			O	
Willow flycatcher			O	
Least Flycatcher	*Empidonax minimus*	X	O	
Eastern Kingbird	*Tyrannus tyrannus*		C	
American Crow	*Corvus brachyrhynchos*	X	O	
Brown thrasher		X		
Tree Swallow	*Tachycineta bicolor*	X	C	
Ovenbird	*Seiurus aurocapilla*		O	
Chestnut-sided warbler	*Setophaga pensylvanica*	X	O	
Nashville warbler		X		
Black-throated green warbler		X		
Northern waterthrush		X		
White-crowned sparrow		X		
Swamp sparrow			U	
White-throated sparrow		X		
Indigo Bunting	*Passerina cyanea*		C	
Brown-headed Cowbird	*Molothrus ater*		O	

Characteristic = these species were commonly encountered throughout the assessment area and were considered representative of the habitat conditions of the riparian corridor of the East River.

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Mussels (based on literature)

12 mussel species were found in Duck Creek above Highway 29 in field surveys conducted in 2014 and 2015; from: *Weinzinger, 2017*.

Abundance totals for freshwater mussels from Duck Creek, 2014 - 2015. (Weinzinger, 2017).		
Scientific Name	**Common Name**	**Number**
Actinoaias ligamentina	Mucket	14
Alasmidonata viridis	Slippershell	123
Amblema plicata	Deertoe	2
Anodontoides ferussaciaanus	Cylindrical papershell	9
Elliptio dilatata	Spike	188
Fusconaia flava	Wabash pigtoe	2
Lampsilis siliquoidea	Fatmucket	97
Lasmigana complanata	White heelsplitter	8
Lasmigana compressa	Creek heelsplitter	5
Pyganodon grandis	Giant floater	115
Quadrula quadrula	Mapleleaf	3
Strophitus undulatus	Creeper	30

Odonates (based on field assessment)

Odonates Encountered During the Assessment	
Common name	***Scientific name***
Big green darner	*Anx junius*
Common white tail	*Plathemis lydia*
Beavertails spp	*Epitheca spp.*
Dot-tailed whiteface	*Leucorrhinia intacta*

Notes

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[i] Wisconsin Department of Natural Resources. 1988. Lower Green Bay Remedial Action Plan. PUBL-WR-175-87 REV 88.

[ii] The Cadmus Group, Inc., March 2012. Total Maximum Daily Load and Watershed Management Plan for Total Phosphorus and Total Suspended Solids in the Lower Fox River Basin and Lower Green Bay Report.

[iii] National Research Council (NRC). 2001. *Compensating for wetland losses under the Clean Water Act*. National Academy Press. Washington, DC.

[iv] Zedler, J. B. 2003. Wetlands at your service: Reducing impacts of agriculture at the watershed scale. *Frontiers in Ecology and Environment* 1:65-72.

[v] Zedler, J.B., J.M. Doherty & N.A. Miller. 2012. Shifting restoration policy to address landscape change, novel ecosystems, and monitoring. *Ecology and Society* 17(4).

[vi] Miller, N., J. Kline, T. Bernthal, J. Wagner, C. Smith, M. Axler, M. Matrise, M. Kille, M. Silveira, P. Moran, S. Gallagher Jarosz, and J. Brown. 2017. Wetlands by Design: A Watershed Approach for Wisconsin. Wisconsin Department of Natural Resources and The Nature Conservancy. Madison, WI.

[vii] Wisconsin Department of Natural Resources, *Wisconsin Wetland Inventory*, http://dnr.wi.gov/topic/wetlands/inventory.html

[viii] Kline, J., T. Bernthal, M. Burzynski, K. Barrett. 2006. Milwaukee River Basin wetland assessment project: Developing decision support tools for effective planning. Final Report to U.S. EPA, Region V. Wisconsin Department of Natural Resources, Madison, Wisconsin.

[ix] Koosmann, Angelena A, & Forsythe, Patrick S. (n.d.). *Small Tributaries of Upper and Lower Green Bay, Lake Michigan : A Case for Understanding Their Role in Shaping the Population Dynamics and Structure of Resident and Transient Native and Exotic Fish Communities.,* University of Wisconsin-Green Bay.

[x] Brown County and Oconto County Land Conservation Departments. Personal communication. 2017