LOWER FOX RIVER

WATERSHED RECOVERY PLAN

SHARED MEASUREMENT

FOR TRACKING PROGRESS & REPORTING SUCCESS

TECHNICAL REPORT

Draft Version March 31, 2023

KEEPERS OF THE FOX — FROM THE VALLEY TO THE BAY

FOX-WOLF WATERSHED ALLIANCE

WISCONSIN DEPT. OF NATURAL RESOURCES

ALLIANCE for the GREAT LAKES

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THE NEED FOR COLLABORATION

In early 2021, the Fox-Wolf Watershed Alliance (Fox-Wolf), Alliance for the Great Lakes, and Wisconsin Department of Natural Resources (WDNR) established a Shared Measurement Workgroup to assist in the development of the Lower Fox River Watershed Recovery Plan (Plan) under the Keepers of the Fox program coordinated through the Fox-Wolf. The concept of Shared Measurement recognizes that a variety of land and water monitoring is being done across the basin by a broad range of stakeholders and looks to develop mechanisms to centralize data reporting and analysis. While long term monitoring data exists, data collection is done independently without opportunity for sharing and collaboration with other data collectors, which does not provide easy access for conservation partners and no mechanism exists for the collection, storage, reporting, and analysis across organizations. Implementation practitioners, natural resource professionals, and academics alike recognize that water quality is often slow to respond to on-land activity, and limited data access further obscures the ability to see incremental progress. Data collection has not been considered as intersectional with implementation efforts, so by combining data collected by all stakeholders and analyzing as a whole rather than in isolation, we can see the impact of implementation efforts more readily and leverage progress for continued support.

Through the shared measurement framework, the workgroup formalized relationships between existing data collection and analysis agencies to establish a process for evaluating progress towards basin-wide water quality goals as well as the ecological and social impact of that progress. Additionally, the group considered how water quality monitoring and associated metrics could be used to effectively communicate to a non-scientific audience the changes that are measured in the water. By creating a pathway to translate scientific data in a simple, easy to understand way, stakeholders will be able to engage a public audience and garner buy-in for the need for future support.

SHARED MEASUREMENT WORK TO DATE

The Shared Measurement Workgroup consists of three discrete subgroups cross-collaborating to establish a process for evaluating Plan implementation progress and impacts on the short- and long-term water quality goals identified in the Recovery Plan as well as and the social and ecological impact of achieving these goals. These groups and relative purpose include:

Land Conservation Metrics Subgroup

1. Work with implementers to agree upon a suite of metrics that can be used to evaluate the progress of implementation on the landscape, focusing on key best management practices (BMPs) across the watershed

2. Establish methods of estimating the annual load reduction resulting from BMP implementation in each of the basins by HUC12 watershed
3. Recommend a reporting framework that speaks to technical and non-technical audiences
4. Begin development of a standardized and repeatable evaluation protocol for implementation metric that will populate short- and long-term progress reports

Water and Ecological Metrics Subgroup

1. Work with natural resource and academic professionals to agree upon a suite of indicators and metrics focused on tributary, Fox River, and lower Green Bay water quality improvement and ecological response resulting from implementation of BMPs in the basin
2. Recommend a reporting framework that speaks to technical and non-technical audiences and that considers realistic short- and long-term achievability of water quality improvement and ecological response goals
3. Begin development of a standardized and repeatable evaluation protocol for each water quality and ecological response indicator/metric that will populate short- and long-term progress reports

Socioeconomic Metrics Subgroup:

1. Consult with social scientists at the University of Wisconsin - Madison Division of Extension and University of Wisconsin-Whitewater to develop a framework for socioeconomic metric development.
2. Recommend a process for identifying socioeconomic metrics which may identify causal relationships between Plan implementation and changes in the lives of citizens in the basin, users of the water resources, economies of the basin's municipalities and businesses, and the cultural perspective of the water resource by residents of the state and users of the resource alike.
3. Assess the degree to which socioeconomic metrics can best illuminate the impacts of Recovery Plan implementation over time without excessive influence from outside factors and influencers.

OUTCOMES AND DELIVERABLES

Shared Measurement Workgroup key outcomes and deliverables include:

1. Establish a shared measurement workgroup and associated subgroups, leveraging subject experts in plan development and building a framework for future cooperation
2. Inventory current monitoring efforts and recommend monitoring strategy going forward, including the continuation of existing efforts and establishment of new metrics

3. Recommend a framework to track and report annually on land based implementation, setbacks, successes, and challenges to communicate progress and build support for continued work
4. Recommend a framework to track and report on a five year cycle on metrics that communicate progress toward implementation, water quality goals and water response, ecological response, and social and economic impacts
5. Explore existing online data visualization platforms for public facing reporting
6. Recommend a system for stakeholder data coordination, collection, storage, reporting, and analysis.

THE VALUE OF COMMUNICATION

EVALUATING PUBLIC CONCERN

A scoping effort was led by Fox-Wolf Watershed Alliance in early 2021 to identify an initial framework and data reporting mechanism through a "Brand and Public Survey" distributed to volunteers, partner agencies, and through social media that resulted in over 400 responses from individuals who live or work in the Lower Fox River Watershed (Lower Fox River). The survey evaluated respondents level of concern across six major categories (Lack of water access, Algae blooms in the water, Loss of fish and wildlife habitat or populations, Contaminated fish and wildlife, Visible pollution, and Phosphorus or sediment runoff in the water) on a 1 – 10 scale, with 1 being a low level of concern and 10 being the highest level of concern. The results of the survey were averaged and found that the greatest average level of concern was indicated for "Algae blooms in the water" and "Loss of fish and wildlife habitat or population", while "Phosphorus or sediment runoff in the water" and "Lack of Water Access" were indicated as those with the lowest average level of concern (Figure 1).

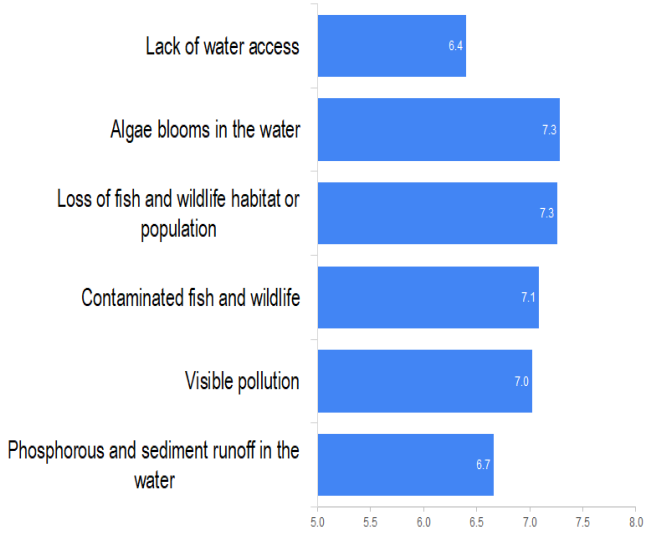

Figure 1. Fox-Wolf Watershed Alliance Brand and Public Survey Results

The survey results provide an important, albeit unsurprising, perspective and set the stage for Shared Measurement Workgroup members to consider evaluating additional metrics beyond TMDL goals to garner and strengthen support for accelerated implementation of water quality protection practices in the Lower Fox River. The survey illuminated the public's disconnect between phosphorus and sediment concentrations in the Lower Fox River with algae bloom development and loss of fish populations, indicating future outreach and education efforts should focus on helping the public understand the impactful role of phosphorus in causing surface water quality problems. Presentation of the survey results and subsequent discussions with project partners and County Executives confirmed the need to develop a suite of implementation, water quality response, ecological and socioeconomic metrics and establish consistent reporting mechanisms to share progress with as broad an audience as possible. To that end, the Shared Measurement Workgroup developed a meaningful, achievable, and realistic framework for Annual and Five Year reporting cycles for the Keepers of the Fox to assess progress toward our shared and diverse goals. This report structure is laid out in detail below in the Tracking & Reporting Strategy portion of the document.

REPORTING AS A MECHANISM

The technical and scientific aspects of the work being done can be difficult to understand by an audience of non-conservation professionals, and data isn't easily analyzed by the public. To garner support of elected officials, funders, agricultural producers, business and industry, and the general public, reports will be highly graphic, easy to understand and developed for a general audience. The metrics chosen by the Shared Measurement group target the varied interests and investments that are most meaningful to a broad range of audiences from elected officials to recreational users to outdoor enthusiasts to hunter/fishers and beyond. Communicating in a clear, easy to understand way is key in engaging a broader audience in advocating for recovery work and to show value in the work to potential funders.

SHARED MEASUREMENT STRATEGY

A FRAMEWORK TO TRACK AND REPORT

Throughout the process, Shared Measurement workgroups determined how to adequately capture the reduction of pollutants in the watershed that results from the implementation of land best management practices (BMPs). The land subgroup developed metrics to track the progress of BMP implementation on an annual basis. The water subgroups selected metrics to be reported on a five year cycle that illustrate the slower change seen in water, incorporating metrics that reach a broader audience such as socioeconomics.

The following is a summary of the purpose and metrics that will be highlighted in both reporting cycles. More detailed data collection and evaluation methods and funding and capacity needs for each metric will be documented in a Keepers of the Fox Data Management and Delivery Plan still in development.

ANNUAL IMPLEMENTATION REPORT

Annual Reporting will provide data on the extent of BMP implementation, funding acquired for implementation across the Lower Fox River, and any annually available data related to the socioeconomic metrics chosen for review. The report will be geared toward an audience who are supportive of conservation implementation but are not involved in the day to day work. From this comprehensive annual reporting, smaller-scale reports at the HUC12, County, or Municipal levels will be generated that provide a "funding snapshot" that includes a comparison of funding targeted, acquired, and needed, describe key successes and challenges, and concise calls to action for resource staff and decision makers to track progress and plan for future work at multiple scales.

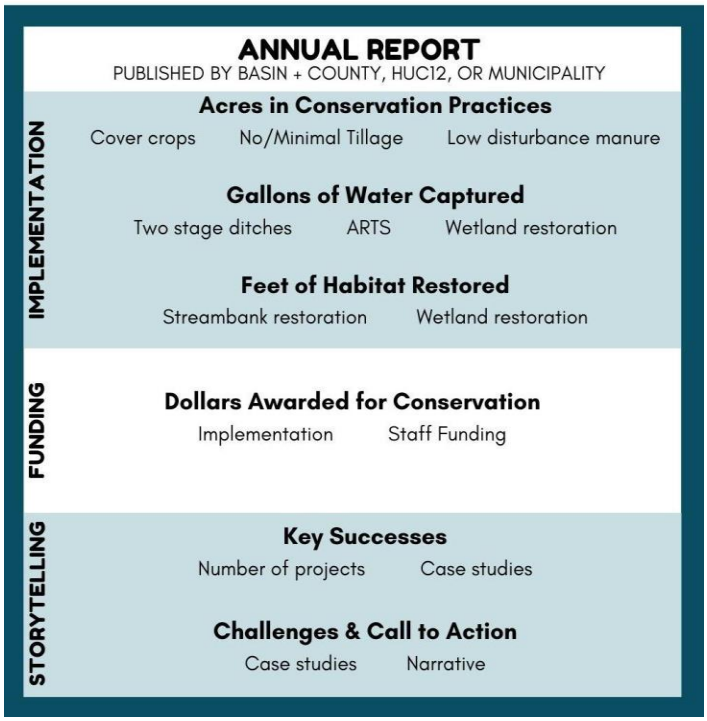

Figure 2. Annual Report Metrics

KEY METRIC: IMPLEMENTATION

While all conservation practices utilized in the basin (those currently known and those that will be developed, designed, or created in the future) will be considered throughout the implementation period, this plan focuses on three main practice types - Continuous Cover (cover crops, no/low tillage, low disturbance manure application), Structural Water Storage (soil health practices, two-stage ditches, agricultural runoff treatment systems), and Streambank Restoration (streambank, riparian, wetland restoration). Details on the reasoning behind selection of these practices, descriptions of these practices, and their co-benefits can be found in the Implementation Action Plan.

ACRES IN CONSERVATION PRACTICES

Background

Continuous cover practices continue to be a primary conservation practice implemented in the Lower Fox watershed and adoption of these practices is

anticipated to grow over time. As the key to continuous cover is maintaining cover on soil year round and a detailed count of the number fields adopting these practices is difficult to calculated and subject to change, using a measurement that approximates the total acres of land covered in organic matter and a given time is an appropriate substitution to individual field verification. Organic coverage on fields from growing or dormant cover crops, crop residue, or the stems and stalks remaining from the harvested crop, provide a very important cover for the soil during the fallow time of year, shielding soil particles from heavy rainfalls and erosion until crops can produce a protective canopy. Crop residue provides a stabilizing structure to soil, decreasing erodibility and runoff.

Justification

Measurement of land cover is determined through an index called NDTI, or Normalized Difference Tillage Index. Satellites capture images of crop fields and provide an estimation of how much of the soil is covered by vegetation and how much is bare. Through the use of Google Earth Engine and ArcGIS, the NDTI team is able to take these satellite images, overlay the farm fields, and by utilizing an algorithm, determine a value for each field. A lower NDTI value means that there is less soil cover on the field, higher NDTI values mean that there is more cover. Because satellite images can be skewed by cloud cover or standing water, field verification has been conducted to ground truth the satellite imagery. NDTI is an invaluable tool to give an accurate picture of the number of acres utilizing continuous cover practices as reporting from implementation partners cannot account for acres of voluntary adoption. NDTI scores will be calculated chosen from the best available image captured fall harvest and snow cover. Calculated NDTI scores will be aggregated by field acreage to report total acres covered in the report area (HUC12, county, or watershed scale).

Recommendation

The final Shared Measurement work group recommendation is to report the percent land covered in the report area.

GALLONS OF WATER CAPTURED

Background & Justification

Historical land use change from woodlands and oak savannah to agriculture, urbanization, and the conversion of wetlands have led to the loss of the associated water storage capacity services. These wetlands historically provided, leading to an increase in sediment and nutrient runoff, the flashiness of streams, and streambank erosion. In 2019, WDNR partnered with Outagamie County to better refine where structural practices were most needed to restore water storage capacity by analyzing the needs for 17 of 20 subwatersheds across the Lower Fox River. This

analysis identified that 2/3 of historically present wetlands in the basin have been converted to urban or agricultural land uses. An estimated 1.6 billion gallons of water storage capacity based on the MSE4 2-year rainfall event has been lost in the analyzed areas due to land use changes and loss of wetlands.

The Outagamie County report *Non-Point Source Runoff Storage Capacity Opportunities for Sediment & Nutrient Reduction in the Lower Fox River Basin* quantifies the amount of water storage capacity needed to return to pre-settlement land use runoff conditions. Data will guide the selection, siting, and implementation of conservation practices that will permanently restore water storage capacity while trapping sediment and phosphorus.

Practices such as two stage ditches and agricultural runoff treatment systems are engineered practices that utilize modeling software to determine reductions achieved. These BMPs installed through County Land Conservation Departments, other conservation partners committed to participating in watershed recovery and through funding secured by Keepers of the Fox efforts will be reported for annual reporting. Gallons stored and phosphorus trapped will be determined by engineered design of practice.

Recommendation

The final Shared Measurement work group recommendation is to report the gallons of water stored in the report area.

FEET OF HABITAT RESTORED

Background & Justification: Streambank

Loss of water storage via naturally occurring wetlands also impact streambank conditions. Decades of traditional farming and the loss of wetland areas have created a landscape that does not have capacity to store or assimilate water and nutrients, leading to flashy storm events and increased runoff. Low-lying areas can flood during snowmelt and rainfall and rapidly moving water has eroded and degraded streams and created growing channels across the land. Upstream, increased tile and ditch drainage as well as urbanization have caused excess runoff to tributaries and streams. The Plum Creek Sediment Fingerprinting authored by U.S. Geological Survey (USGS) have shown that streambank erosion is a significant source of total phosphorus and total suspended solids in Plum Creek (Fitzpatrick et al. 2019)[1], indicating that a combination of practices that increase water holding

[1] Fitzpatrick et al, "Stream corridor sources of suspended sediment and phosphorus from an agricultural tributary to the Great Lakes," 2019 *Proceedings of SEDHYD 2019* Page 189 http://www.sedhyd.org/2019/proceedings/SEDHYD_Proceedings_2019_Volume4.pdf

capacity and streambank stabilization are necessary in the Lower Fox River to realize meaningful improvements in water quality. By identifying and stabilizing streambank sections that have severely eroded, the remaining stretches of streambank will protected from high water velocity and will be allowed to return to their natural, healthy state.

Background & Justification: Wetland

Wetlands provide several important ecosystem services, including water storage, trapping sediments and nutrients, and providing critical fish and wildlife habitat. As described previously, over 1.6 billion gallons of water storage has been lost in the Lower Fox River as a result of wetland conversion to other land uses through drainage or filling (i.e., agricultural fields, urban areas, residential areas, etc.). As a result, restoring wetlands can provide some of the lost water storage and nutrient reduction services needed in the Lower Fox River.

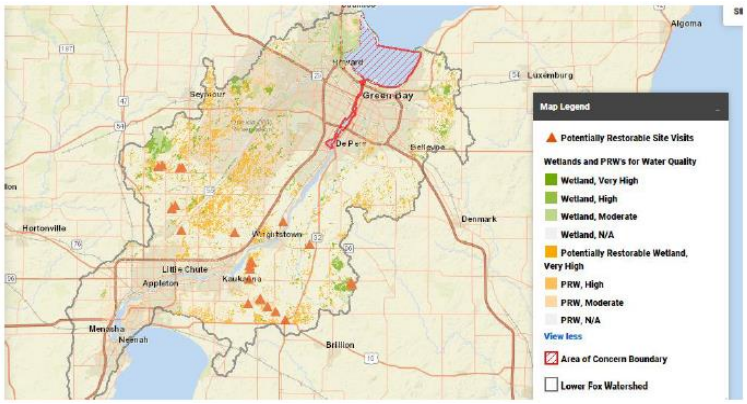

Figure 3. Screenshot of Explorer tool, illustrating results of Lower Fox Watershed Assessment

In 2018, The Nature Conservancy (TNC) published a report in partnership with WDNR Office of Great Waters and UW-Green Bay Cofrin Center for Biodiversity that provided the results of an ArcGIS evaluation of potentially restorable wetlands (PRWs) where re-establishment opportunities exist in the Lower Fox River. Of those opportunities, TNC ranked PRWs as “Very High”, “High”, and “Moderate” based on the likelihood that the site would retain sediment and phosphorus, if tile drain was present, and soil test phosphorus levels from NMP data. This data is visualized through TNC’s Wetlands and Watersheds Explorer[2].

Using this information, a group of stakeholders estimated the total acres of opportunity for re-establishing wetlands or installing ARTS by considering only the sites in the “Very High” or “High” PRW rankings, removing those that are known to have buildings or other features that would preclude restoration, and estimated that only 15-25% of the remaining acres would actually be restorable.

[2] The Nature Conservancy ArcGIS tool, Wetlands and Watersheds Explorer, https://maps.freshwaternetwork.org/wisconsin/#

The group found that between 5,745 – 9,575 acres of PRWs likely exist within the LFR. However, phosphorus retention in natural wetlands can range between 0 – 100% and is dependent on several factors, including upland management[3]. This suggests that while natural wetlands do provide several ecosystem services, it should be used as a tertiary nutrient and sediment reduction treatment downstream of a system of other conservation practices.

These streambank and wetland BMPs installed through County Land Conservation Departments, other conservation partners committed to participating in watershed recovery and through funding secured by Keepers of the Fox efforts will be reported for annual reporting. Gallons stored and phosphorus trapped will be determined by engineered design of practice.

Recommendation

The final Shared Measurement work group recommendation is to report the feet of streambank and acres and wetland restored in the reported area.

KEY METRIC: FUNDING

Background & Justification

The anticipated financial investment in recovery efforts is large, nearly $600M over the course of a 20 year implementation timeline. The Keepers of the Fox has developed a Funding Strategy (see Funding Strategy for Watershed Recovery technical document) to meet the needs of dollars for implementation as well as support staff to be the "boots on the ground." Annual accounting for the magnitude of investment in BMPs is key to communicating to existing and potential funders the progress made as well as the work yet to be completed. Funding secured by Keepers of the Fox efforts, including grants awarded to county land conservation departments, and utilized for implementation of BMPs and conservation staff will be reported for annual reporting.

Recommendation

The final Shared Measurement work group recommendation is to report the total dollar amount invested in conservation in the reported area.

[3] Maximizing the Water Quality Benefits of Wetlands in Croplands. https://www.nrcs.usda.gov/sites/default/files/2023-01/CEAP-Wetlands-2023-ConservationInsight-WetlandsWaterQuality.pdf.

KEY METRIC: STORYTELLING

Background & Justification

Measureable change in water quality is slow, and many metrics utilized to monitor progress are highly scientific or outside the scope of non-conservation staff. While there are meaningful indicators of change that are easily communicated, these are best reported on a five year cycle (see Five Year Report below) rather than annually.

The need to tell the story of water recovery cannot be understated. Translating scientific data into common language narratives is key to connecting and engaging with a broad audience, and this audience provides the public support necessary to continue to progress in recovery efforts. Annual report storytelling provides the opportunity to connect a specific report audience (basin, HUC12 municipal, or county level audience) and provide meaningful and tangible actions. The opportunity to celebrate successes while pointing out challenges on an annual basis provides context to recovery work and motivates funders, decision makers, and the general public to continue to support implementation.

Through the Keepers of the Fox Council (see Shared Decision Making technical document), the Technical Analysis & Reporting workgroup will review annual and five year reports and provide the necessary translation and storytelling to be used for non-scientific communication. In partnership with the Community Engagement workgroup, narratives will be developed to tell the story of conservation.

Recommendation

The final Shared Measurement work group recommendation is to provide a narrative story of the successes and challenges of work completed during the year in the reported area.

FIVE YEAR REPORT

The Five Year Report will be comprised of two main portions, the first being a "Watershed Health Report" to provide localized progress and response metrics, and the second being a "Basin, Fox River, and Lower Bay Response" report to provide a holistic, systems lens of resulting water quality, ecological, and socioeconomic impacts/improvements resulting from implementation progress (Figure xx). While delayed tributary water quality response is an outcome LFR partners should be prepared for, documenting and reporting the multi-facteted implementation, ecosystem response, and socioeconomic metrics represents an integrated and holistic approach to defining success in TMDL implementation and associated outcomes. It is anticipated that the Five Year Report cycle will begin in 2025.

Figure 4. Five Year Report Metrics

KEY METRIC: IMPLEMENTATION SUMMARY

Background and Justification

Per USDA NRCS 590[4], ATCP 50[5], and NR 151[6] regulations, all farms in Wisconsin should have a nutrient management plan (NMP)[7]. NMPs ensure that nutrients such as manure and/or fertilizers that are applied to agricultural fields are at rates that support healthy crop yields but do not exceed the rate that plants can take up nutrients. When nutrients such as phosphorus and nitrogen are applied at rates too great for crop uptake, they can runoff into surface or groundwater resources and result in contamination to humans and the environment. NMPs require testing both soil and manure to understand what the nutrient content is and how/when these nutrients should be applied to agricultural fields, which also benefits Wisconsin farmers by reducing input costs.

[4] USDA NRCS Conservation Practice Standard 590, https://datcp.wi.gov/Documents/NM590Standard2015.pdf
[5] DATCP Chapter 50 Soil and Water Resource Program, https://docs.legis.wisconsin.gov/code/admin_code/atcp/020/50
[6] WDNR Chapter NR151, Runoff Management, https://docs.legis.wisconsin.gov/code/admin_code/nr/100/151
[7] DATCP Nutrient Management Plans, https://datcp.wi.gov/Pages/Programs_Services/NutrientManagement.aspx

To keep NMPs up to date, producers sample agricultural soils every 4 years, collecting one sample for every 5 acres and reporting the average total phosphorus concentrations at field scale. This information is collected, retained, and mapped by county land conservation districts and UW-Madison Division of Extension. From this information, the percent of fields in various STP interpretation categories listed in UW Extension Publication A2809 (Very Low, Low, Optimum, High, Excessively High) across the Lower Fox River Basin and by HUC12 subwatershed basin can be determined on a five-year rolling average.

In the Lower Fox River, most forage crops grown fall within "Demand Level 1 and 2", which means that there is very little probability that yields will increase with additional P applications once the STP reaches ~30 ppm or greater.[8] Fields that have a STP greater than 35 ppm STP are considered "excessively high", fields with STP observed between 50 – 100 ppm should reduce manure applications, and any fields above 100 ppm STP should cease P applications (from both manure and/or commercial fertilizers) until STP levels are drawn down.

Approximately every 18 lbs of phosphorus removal will result in a reduction of STP of 1 ppm. Crop phosphorus removal levels are summarized in Table 4.2 of the UWEX A2809 report and show that crops in Demand Level 1 and 2 (corn, soybean, alfalfa, hay, etc.) range from approximately 1 – 13 lbs/unit yield total phosphorus removal annually. This means that in fields with STP levels categorized as "Excessively High", a reduction of nearly 1 ppm per year and up to 5 ppm every 5 years may be achieved if P applications cease (including fertilizer and manure application).

<u>Recommendation</u>

The final Shared Measurement work group recommendation is to summarize and report the median concentration of fields in each of the STP interpretation categories in all agricultural priority HUC12s every five years. Additionally, this summary would include a comparison of the percent of fields with STP in "excessively high" interpretation categories across reporting years to determine if a downward trend is observed.

[8] UW Extension Resource A2809, Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin, https://cdn.shopify.com/s/files/1/0145/8808/4272/files/A2809.pdf

KEY METRIC: WATER QUALITY MEASUREMENT & RESPONSE

HUC12 TRIBUTARY RESPONSE MONITORING: NUTRIENT CONCENTRATIONS

Background and Justification

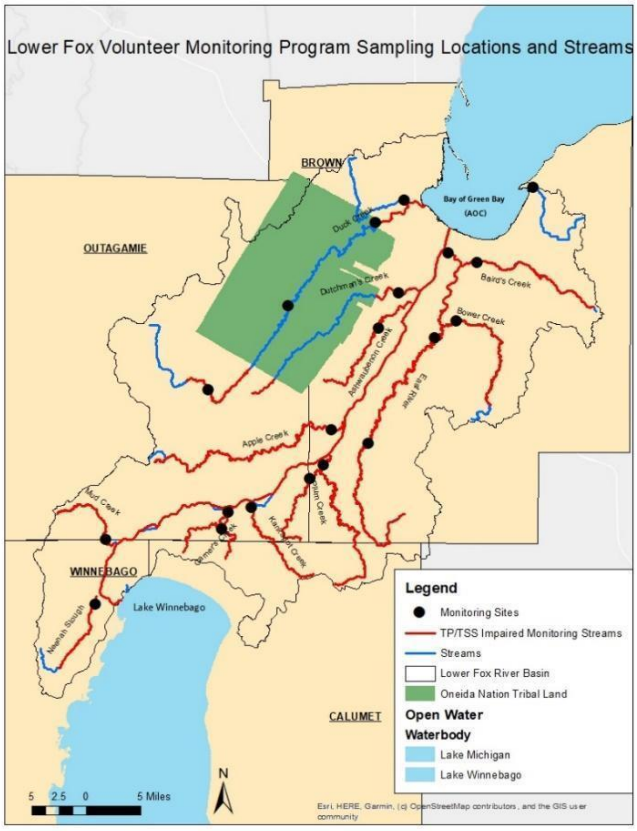

Figure 5. Map of the Lower Fox River Volunteer Monitoring Program Sampling Locations and Tributaries

Tributaries in the Lower Fox River have numeric water quality criteria established in NR Wis. Adm. Code 102.06(1) and 102.06(3), which state that surface waters considered streams generally exhibiting unidirectional flow are required to meet a summer median total phosphorus (TP) concentration of 0.075 mg/L. Numeric water quality targets for total suspended solids (TSS) were not developed for Lower Fox River tributaries as attainment of the TP water quality criteria is believed to result in sufficient reductions to TSS[9]. Tracking TP and TSS in Lower Fox River tributaries is an ongoing effort through the Lower Fox Volunteer Tributary Monitoring Program[10], a citizen-science program that began in 2015 with support from Great Lakes Restoration Initiative (GLRI) funding through 2020 and is currently supported through WDNR funding. A total of 20 sampling locations across 16 tributaries are evaluated once per month from May to October (Figure 5) following guidance outlined in "Guidelines for Monitoring Watershed Restoration Effectiveness" (WDNR EGAD #3200-2020-26)[11].

A primary goal of the program is to collect data to assess long-term water quality trends/success, with a focus on annual concentrations of Total Phosphorus (TP), Dissolved Reactive Phosphorus (DRP), Total Suspended Solids (TSS), and Total Nitrogen (TN). This program is also key in WDNR decision-making on potential

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[9] TMDL and Watershed Management Plan for TP and TSS in the Lower Fox River Basin and Lower Green Bay, https://dnr.wi.gov/water/wsSWIMSDocument.ashx?documentSeqNo=62246254

[10] Lower Fox River Volunteer Tributary Monitoring Program, https://dnr.wisconsin.gov/topic/TMDLs/LowerFox/VolunteerMonitoring.html#:~:text=The%20program%20relies%20on%20volunteers,in%20the%20right%20time%20frame.

[11] Guidelines for Monitoring Watershed Restoration Effectiveness, https://www.researchgate.net/publication/351846938_Guidelines_for_Monitoring_for_Watershed_Restoration_Effectiveness

changes to tributary classifications included in the Water Condition Lists (Impaired Waters, Restoration Waters, and Healthy Waters) submitted by WDNR to EPA as part of the Clean Water Act (CWA) Section 305(b) Integrated Reporting requirements. At present, 14 of the 16 streams monitored under the Lower Fox Volunteer Tributary Monitoring Program are listed as impaired (Restoration Water category) for high TP and/or TSS concentrations. Tracking and reporting the results of the Lower Fox River Volunteer Tributary Monitoring Program and subsequent changes to water quality impairments is the key long-term metric in determining how successful implementation of the TMDL is on a watershed scale, and therefore is a well-justified metric to include in the 5-year reporting cycle. It should be noted, however, that significant changes in tributary water quality is not anticipated to occur until TMDL implementation is approaching completion. Additionally, many tributaries may require a response time beyond completion of TMDL reductions given additional stressors not addressed by implementation of traditional BMPs to address annual nutrient and sediment losses, such as the legacy of land use in the Lower Fox River promoting elevated STP levels that will take many years to draw down, availability of legacy P beyond the edge of field in fluvial sediments and other potential P hotspots, the impact of dissolved P on tributary water quality, changes in nutrient cycling resulting from invasion by exotic species, etc. (Jarvie et al., 2013; Dupouey et al., 2022; Zedler, 2007; Suding, 2011).

Recommendation

The final Shared Measurement work group recommendation is to summarize and report TP, DRP, TSS, and TN concentrations and rolling trends observed at all 20 sampling locations evaluated through the Lower Fox River Tributary Volunteer Monitoring program.

HUC12 TRIBUTARY RESPONSE MONITORING: NUTRIENT LOADING

Background and Justification

While the Lower Fox Tributary Volunteer Monitoring program was designed to provide enough statistical power to assess changes in TP and TSS concentrations following a 60% reduction in TP as outlined in the Lower Fox River TMDL and provides an important outreach/education service, it wasn't designed to detect small, short-term or incremental reductions statistically significantly.

The results of Meyers, 2022[12] confirmed that while the Lower Fox River Volunteer Monitoring Program is designed to detect large changes in TP concentrations (>50%) over long periods (>10 year trend analysis or pre and post time periods of 3-5 years) for the majority of sites. However, this study also found that detecting smaller TP reductions (<30%) within a shorter time period (<3-5 years) is not likely under the

[12] Meyers, 2002. Power Analysis, https://drive.google.com/file/d/1v5qg9uLN-80XFB2KifFRylU3glDJ61CT/view?usp=share_link

current monitoring program. As a result, a clear recommendation to explore alternative metrics for assessing short-term progress was made by the Shared Measurement work group. To start, the Water Metrics work group revisited WDNR's Guidelines for Monitoring Watershed Restoration Effectiveness guidance, which includes the following:

"As the monitoring goal of some restoration projects will be to document total loads being delivered to downstream waterbodies, solely measuring GSM TP concentrations may not adequately characterize project effectiveness. A monitoring plan that does not capture the expected changes where or when they may occur only leads to confusion surrounding the actual benefits of the restoration. BMPs may be installed that are expected to improve water quality by reducing peak concentrations during runoff events, decreasing stream flow spikes (e.g. increase infiltration), reducing runoff outside the growing season (e.g. winter cover crops), among others. To capture these improvements flow monitoring and developing a continuous record of discharge is likely the best method for detecting change. However, the cost and staff time required for loading monitoring is increased."

Concentration	Flux (Load)
Usually median of fixed interval samples	Total annual or seasonal
More relevant to stream responses	More relevant to downstream lake responses
More indicative of baseflow conditions (likely to respond more slowly to BMPs)	More indicative of storm flow conditions (likely to respond more quickly to BMPs)
Does not require discharge and fewer samples (less expensive to monitor)	Requires discharge and more samples to fit a discharge-concentration model (more expensive to monitor)

Figure 6. Comparison of Relative Role of Concentration Versus Load Monitoring in Watershed Restoration Projects

To help provide information necessary for further development and implementation of the recommended water quality assessment framework and five year reporting, UW-Green Bay led a study to evaluate historical load monitoring in the Lower Fox River Basin and documented watershed characteristics to describe similarities/differences statistically through a cluster analysis. This information generated a recommended continuous load monitoring strategy at "Representative Subwatersheds" in the Lower Fox River Basin[13]. Drainage area characteristics, watershed cluster, flow-weighted period mean concentrations (FWC) of flow, TSS, TP and DP at intensively monitored streams in the LFRB, and historical monitoring period are summarized in Figure 7.

[13] UWB Lower Fox Monitoring Plan Report, https://drive.google.com/file/d/1YpavsYIISXRDVDijqhfrfvc34eRGYg53/view?usp=share_link

Stream	% LFB Area	%Ag	%Urban	Watershed Cluster	Period Flow-weighted (mg/L) TSS	TP	DP	DP%	Period Water Years		USGS #	Primary Funding
Plum	3.3	82	5.9	1	547	0.99	0.27	27%	11	2011-21	04084911	GLRI/USGS
Plum West	1.5	89	6.6	1	286	0.86	0.42	50%	8	2014-21	04084927	
Bower	2.2	93	1.7	1	256	0.80			3	2007-09	04085119	
Ash-Creamery	2.9	86	8.2	1	198	0.69	0.34	50%	3	2004-06	04085068	
East ZZ	7.1	81	3.5	2	173	0.59	0.27	47%	10	2012-21	04085108	GLRI/USGS
Apple	7.1	66	27.0	2	206	0.51	0.20	40%	3	2004-06	04085046	DNR/GLRI/AOC?
Baird	3.2	78	8.8	2	92	0.44	0.22	51%	11	2004-14	040851325	
Ash-Grant	3.9	80	12.3	2	104	0.41	0.26	63%	3	2019-21	040850684	NEW Water
East River	22.2	67	19.5	2	95	0.38	0.16	42%	4	2004-07	040851378	GLRI/USGS/DNR
Dutch-Hansen	4	64	24.1	2	82	0.32	0.21	64%	3	2019-21	04085078	NEW Water
Duck_CTHFF	15.8	72	7.6	4	70	0.32	0.17	52%	5	2004-08	04072150	Oneida/USGS
Wequiock	1.8	70	8.0	4	66	0.29			3	2019-21	UWGB	tbd
Silver	0.8	69	10.1	4	22	0.20	0.13	66%	8	2014-21	04072076	NEW Water?
Mahon	0.4	38	33.8	3	62	0.19			6	2011-16	UWGB	tbd

Figure 7. Watershed Characteristics and Monitoring History for Subwatersheds in the Lower Fox River

The recommendations were considered by the Shared Measurement work group along with other important considerations (e.g. infrastructure costs, leveraging existing program and upcoming project funds, value of continuous data in adapting management methods, and value of data to track hydroclimate drivers), and resulted in the following recommended tiered approach to prioritizing continuous monitoring stations (Table 1):

- Tier 1 – Critical Priority Subwatersheds/USGS Stations for Continuous Monitoring
- Tier 2 – High Priority Subwatersheds/USGS Stations for Continuous Monitoring
- Tier 3 – Medium Priority Subwatersheds/USGS Stations for Continuous Monitoring

Subwatershed/Station Name	Continue, Restart, or New	Tier	% Lower Fox Area
Plum Creek @ D	Continue	1	3%
East River @ ZZ	Continue	1	7%
Ashwaubenon Creek @ Grant	Continue	1	4%
Dutchman Creek @ Hansen	Continue	1	4%
Duck Creek @ FF	Restart	2	16%
East River @ Monroe	New	2	22%
Apple Creek	Restart	2	7%
Wequiock Creek	Continue	3	2%
Mahon Creek	Continue	3	0.4%
Silver Creek	Continue	3	1%

Table 1. Recommended Continuous Monitoring Locations in the Lower Fox River

Tier 1 stations represent those with existing infrastructure/monitoring effort, have secured funding, cover a broad area of the basin and representative land uses, and have current targeted implementation efforts. Tier 2 stations represent those that cover large portions of the watershed, are approaching targeted implementation

efforts, and have unique land use and/or watershed characteristics not reflected in the Tier 1 stations (e.g. differences in soil compositions in Duck Creek, urbanization and CAFO density in Apple Creek, etc.). Tier 3 stations represent those that have experienced less degradation and have unique land use and/or watershed characteristics (e.g. higher quality tributary resources, urbanization, previous targeted implementation efforts, etc.).

Monitoring Tier 1 and Tier 2 stations would cover approximately 60% of the Lower Fox River and reflects Nine Key Element subwatersheds that are all in various stages of active agricultural implementation, unique subwatershed characteristics, leverage past and ongoing monitoring, and provides a robust platform to track the impacts of changing management and hydroclimate drivers (Fermanich et al., 2022). These findings and recommendations align with the "Guidelines for Monitoring Watershed Restoration Effectiveness" WDNR guidance, are anticipated to describe successes in TMDL implementation in the short term, and will provide timely information on subwatershed management to support any necessary adaptive management measures as 9KE plans are implemented at the subwatershed level.

Recommendation

The final Shared Measurement work group recommendation is to summarize and report the Lower Fox Volunteer Tributary Monitoring trends for TP, TSS, DRP, and TN, provide any updates on changes to TP/TSS impairment classifications in the most recent WDNR Integrated Reports submitted every two years to EPA, and to report loads/trend analysis for TP, TSS, DP, TN in Tier 1 continuous monitoring stations in the 2025 report, and report loads/trend analysis for TP, TSS, DP, TN in Tier 1 and Tier 2 continuous monitoring stations in the 2030 report.

LOWER FOX RIVER AND BAY RESPONSE: NUTRIENT CONCENTRATIONS

Background and Justification

While tracking tributary nutrient and sediment concentrations and loading is a key recommendation of the Shared Measurement work group, additional focus on monitoring the Lower Fox River and Bay of Green Bay response is necessary, given the regulatory numeric and narrative goals established in the TMDL for these waterbodies. Per NR Wis. Adm. Code 102.06(1) and 102.06(3), a TP criteria of 0.1 mg/L and TSS criteria of 18 mg/L is established for the Lower Fox River, and NR Wis. Adm. Code 102.06(5) specifies that water clarity and other phosphorus-related conditions must be suitable to support a diverse biological community, resulting in a narrative criteria of 0.06 mg/L TP and 15 mg/L TSS for Green Bay.

Several water quality parameters, including TP, DP, and TSS, are collected through WDNR's Long Term Trends (LTT) Rivers monitoring program, which is designed to

evaluate long-term patterns in Wisconsin's largest watersheds. Two LTT sites are coupled with USGS stream flow gauges on the Lower Fox River (Fox River @ Neenah, Fox River @ De Pere), with field sampling for nutrients and other parameters occurring on a monthly basis throughout the year. TP, DP, TSS, TN, and other LTT data and trends from 1988 to present for the Lower Fox River station can be viewed at WDNRs LTT Monitoring Shiny App[14], as well as trend descriptions (Figure 8).

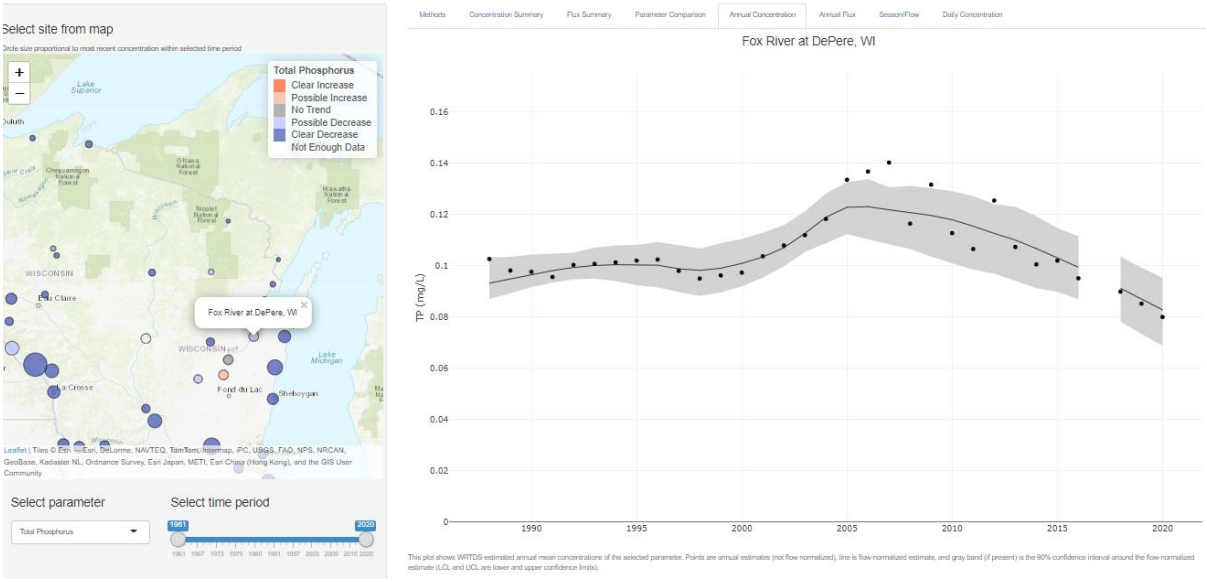

Figure 8. WDNR Shiny App Annual Concentration Trend of Fox River at DePere

Additionally, NEW Water's Aquatic Monitoring Program (AMP) was developed in 1986 to understand the water quality of the Lower Fox River and Green Bay to better inform the calculations of WPDES permit limits and better direct treatment decisions. These data can be used in the WPDEs permit process, which includes ambient water quality information to calculate the Water Quality Based Effluent Limits. Without definitive data, the WDNR applies various safety factors based on their estimate of existing water quality impairment which may exist in the receiving waters. This long-term database allows NEW Water staff to negotiate with a strong knowledge base during the overall permitting process. NEW Water AMP sample locations are located in the lower Fox River, lower East River, and extend along the eutrophication gradient from the mouth of Green Bay north to Little Sturgeon Bay (Figure 9). However, for the purposes of this planning effort, nutrient concentration data will only be

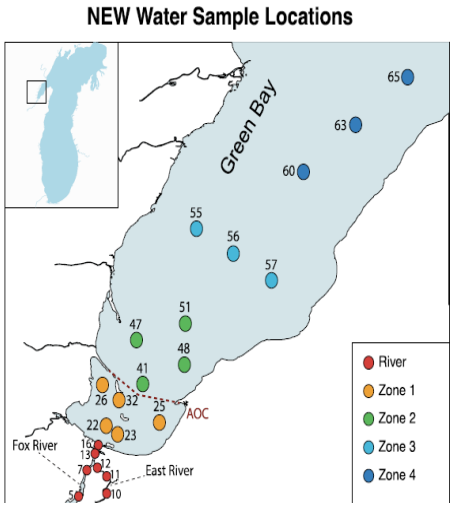

Figure 9. NEW Water AMP Sampling Locations

[14] WNDR Long-Term River Water Quality Trends in Wisconsin, https://wisconsindnr.shinyapps.io/riverwq/

considered at the lower Fox and East stations, and Zone 1 of the bay of Green Bay. At each location, the phosphorus series, TSS, nitrogen series are evaluated through weekly grab samples from May to October, providing a robust dataset and baseline for nutrient trends in the Fox River and lower Bay of Green Bay. Given the numeric and narrative requirements in NR Wis. Adm. Code and described in the Lower Fox River TMDL, collection and reporting of this data is justified.

Recommendation

The final Shared Measurement work group recommendation is to summarize and report the concentration trends for TP, TSS, DRP, and TN for the Fox River and lower Bay of Green Bay collected through the WDNR LTT and NEW Water AMP monitoring programs.

LOWER RIVER AND BAY RESPONSE: NUTRIENT LOADING

Background & Justification

In 2020, Fox-Wolf, in partnership with NEW Water, commissioned Dale Robertson at USGS to conduct a load and trend analysis of the Lower Fox River, using long term data collected by WDNR, NEW Water, and USGS[15]. Utilizing WRTD, a weighted regressions on time, discharge, and season modeling approach, USGS estimated concentrations and loads of TP, dissolved phosphorus (DP), and TSS at the Lake Winnebago Outlet, DePere, and mouth of the Fox River from water year 1989 to 2021; described changes in concentrations and loads during this period; and compared the concentrations and loads for the 2017-2021 timeframe with the WDNR criteria and goals set in the TMDL.

Water quality criteria in the Fox River, as established in the TMDL, is median concentrations of 0.10 mg/L for TP and 20 mg/L for TSS between May and October. The study found mean TP concentrations ranged from 0.089 mg/L at the Winnebago Outlet to 0.128 mg/L at the mouth of the Fox River. DP represented about 28 percent of the P at all three sites over the entire period, an increase from about 13 percent to 31 percent at the Winnebago Outlet, and from about 21 percent to about 31 percent of at DePere and the mouth of the Fox River. Mean TSS concentrations have decreased in recent years, with the most recent median summer TSS concentrations below the 20-mg/L WDNR criterion at all three sites. While TP and TSS concentrations decreased, total streamflow and TP, DP, and TSS loads gradually increased from the Winnebago Outlet to DePere to the mouth of the Fox River.

[15] Robertson, et al. Changes in Phosphorus and Sediment Loading in the Fox River, Northeastern Wisconsin, 1989–2021 DRAFT REPORT, https://docs.google.com/document/d/15QVsMdH_VkoSjRAIS2YyQGJWOzdo69lS/edit?usp=share_link&ouid=116508353952020696689&rtpof=true&sd=true

Although there was a significant decrease in TP and TSS concentrations at DePere and the mouth of the Fox River, there was little change in the actual loading because of the 41-48% increase in flow in recent years.

Overall, results showed a decrease in flow-normalized TP and TSS loads at DePere and the mouth of the Fox River, the cause of which his unclear. Implementation of agricultural conservation management practices in the watershed, reductions in industrial and municipal point-source discharges in the watershed, and deposition of sediment and P into the areas of the Lower Fox River that were recently dredged as part of a PCB cleanup activities between 2004 and 2020 may all have played a part. Additional studies are needed to determine the relative importance of each of these actions and whether the observed decrease in concentrations and flow-normalized TP and TSS loads will continue to be observed in the downstream reaches of the Fox River.

While the study is still in draft form, it provides valuable insight into the general water quality condition of the Lower Fox River. By repeating a load and trend analysis every five years, the Keepers of the Fox will be equipped to track long term, river scale trends with a statistically significant confidence.

Recommendation

The final Shared Measurement work group recommendation is to complete a load and trend analysis every 5 years for TP, TSS, DRP, and TN at the mouth of the Fox River and Lake Winnebago outlet.

LOWER FOX RIVER AND BAY RESPONSE: ALGAE

Background & Justification

While the Lower Fox River TMDL did not specify a numeric or narrative target for Chlorophyll *a* concentrations, it is well established that phosphorus loading plays a critical role in the proliferation of algae. Increases in P have been documented in causing shifts from a clear water, macrophyte dominated system to a turbid-water phytoplankton dominated system in aquatic systems worldwide (Scheffer et al., 1993; Schindler, 2006). Not only does a shift to an algal-dominated water resource result in ecological impacts, but spans social and economic impacts through a reduction in aesthetic value and potential human health impacts. For this reason, the Lower Green Bay & Fox River Area of Concern 2011 Remedial Action Plan established a Chlorophyll *a* target between 13-32 ug/L, though current targets for

the Eutrophication or Undesirable Alae and Beach Closings impairments reflect updated targets[16].

NEW Water has collected chlorophyll-a data as part of their routine AMP since 1986. While median Chlorophyll *a* concentrations appear to be decreasing, average concentrations still indicate highly eutrophic conditions in the Lower Fox River and Bay of Green Bay. Furthermore, several recent instances of extremely high concentrations were observed and suggest that a surface cyanobacterial bloom was present at the time of collection (Figure 10).

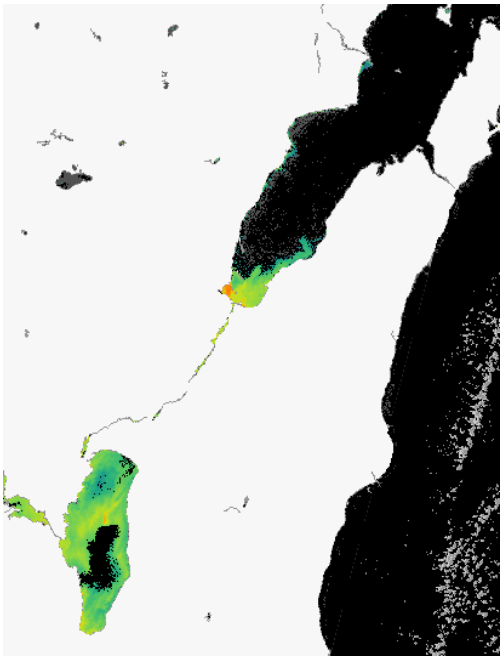

Figure 10. Satellite observed CHAB on August 25, 2022 in Lake Winnebago and the Bay of Green Bay

Additionally, a 2016 - 2020 Cyanobacterial Harmful Algal Blooms (CHABs) study was completed for the lower bay portion of the AOC using a combination of grab samples and buoy data to characterize the frequency and severity of CHABs. Results of this study align with NEW Water's trends, with average Chlorophyll *a* concentrations at selected sampling locations in Green Bay observed at 62 ug/L, and TP and chlorophyll concentrations significantly linearly correlated ($R = 0.6$, $P<0.0001$). Phycocyanin is a blue pigment produced by cyanobacteria, and is often used as an indicator for the presence of a cyanobacterial algae bloom. The results of this study found increases in laboratory measurements of phycocyanin in water grab samples occurred one to two times per year, with over 90% of blooms occurring between July and August. Microcystin was the most abundant cyanotoxin observed and was significantly correlated with phycocyanin concentrations ($R = 0.62$, $p<0.001$ after removing outliers) which suggests that the presence of the microcystin toxin trends with total cyanobacterial abundance. However, Chlorophyll *a* concentrations were not significantly correlated with microcystin concentrations ($R = 0.19$, $p = 0.2$), suggesting that Chlorophyll *a* may not be an appropriate metric to describe or predict cyanobacterial impact to public health though it remains an appropriate metric for describing water quality.

These data provide important baseline information into bloom dynamics and confirm associated aesthetic, public health, and ecological impacts in the Fox River

[16] WDNR 2020-2021 Remedial Action Plan Update, https://widnr.widen.net/s/cxq9ddw7qr/gw_lgb_rap2020-2021

and bay of Green Bay. While the active monitoring of the CHABs study was completed in 2020, UW-Milwaukee, NEW Water, UW-Green Bay, and WDNR continue to collaborate in the deployment and data collection of buoys that collect continuous Chlorophyll-*a* and phycocyanin concentrations via fluorometers. One issue with the in-situ fluorometer measured phycocyanin concentrations is that they were not well correlated with laboratory measured phycocyanin concentrations in any year of the CHABs study, and more work is needed to develop buoy data to accurately estimate phycocyanin/cyanobacteria biomass.

Another method of evaluating CHABs is through National Oceanic and Atmospheric Administration (NOAA) satellite observations in Lake Winnebago and Green Bay, which provides daily map products online that are important for assessing the frequency and severity of blooms and considering the impact of bloom formation and transport in Lake Winnebago to the Lower Fox and bay of Green Bay. A caveat to this is that satellite data can be obscured by clouds and doesn't assess bloom presence in the Fox River, which may make it difficult to compare bloom extent and severity across multiple years.

Another important tool that can fill these gaps is through citizen science-based bloom reporting. EPA manages the "bloomWatch[17] online dashboard that crowdsources to find and report blooms nationwide (Figure xx). Citizens can report important information about the bloom and upload photo documentation through the bloomWatch app, offering a unique opportunity to capture additional information on where algae blooms are being observed in smaller basin tributaries and the lower Fox River.

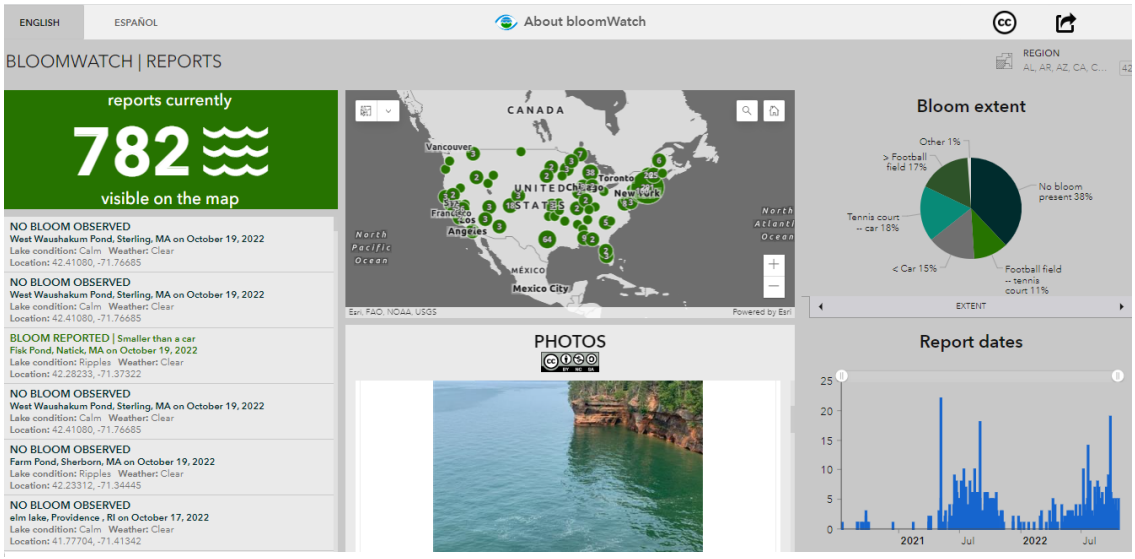

Figure 11. EPA's bloomWatch Online Dashboard

[17] EPA bloomWatch, https://experience.arcgis.com/experience/471ac77822b34303ba3c4170ccf11a2f

While algal dynamics are admittedly complex and there is still much to learn in terms of monitoring and understanding stressors beyond nutrients, the combination of quantitative and qualitative data currently being collected (and potential to be collected) provide a strong foundation in which to describe trends in the frequency and severity of algae blooms.

Recommendation

The final Shared Measurement workgroup recommendation is to summarize and report annual concentrations and rolling trends for Chlorophyll-a through the NEW Water AMP program, to continue evaluating the potential to collect real-time in-situ phycocyanin/cyanobacterial biomass buoy data, to qualitatively describe the frequency, duration, and severity of CHABs observed through NOAA satellite imagery, and to establish citizen-based monitoring and reporting of blooms on the EPA bloomWatch dashboard.

LOWER FOX RIVER AND BAY RESPONSE: WATER CLARITY

Background and Justification

Water clarity is closely associated with turbidity from sediment runoff and algal bloom presence and has clear ecological, aesthetic, and recreational implications. Measuring water clarity to assess lake trophic status is often completed using a black and white Secchi disk that is lowered into the water until no longer visible and is recorded as the "Secchi depth". Higher Secchi depth values therefore indicate clearer water conditions as compared to lower values (Figure 12).

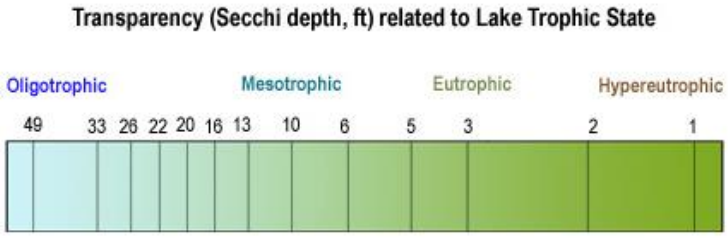

Figure 12. A general relationship between observed Secchi depth values and lake trophic status. Higher Secchi depth values indicate clearer-water conditions with less suspended sediment particles and algae, whereas lower Secchi depth values indicate a more turbid water and algal-dominated lake trophic status.

Numeric targets for TP and TSS were developed for tributaries and the main stem of the Fox River by considering light penetration levels in Zone 1 and 2 of Green Bay sufficient for growth of submerged aquatic vegetation. The 0.1 mg/L TP and 18 mg/L TSS criteria are modeled to result in a Secchi depth of 1.14 m, which would in turn increase water clarity by 63% from the 1993 - 2005 baseline median Secchi depth of 0.70 m reported in the TMDL.

NEW Water has collected water clarity data through Secchi depth measurements as part of their routine AMP since 1993. Secchi depth measurements are collected at the majority of their long term water sampling sites.

Secchi depth trends were presented in the 2013 State of the Bay report (UW Sea Grant, 2013) using a combination of data from UW-Green Bay researcher Paul Sager and NEW Water collected from 1970 through 2011. Since 1986, the long term Secchi depth averages presented in the State of the Bay report are 0.51 m for Zone 1, 1.42 m for Zone 2, and 2.4 m for Zone 3 of Green Bay (Figure 13).

More recent data collected as part of the 2016 - 2020 CHABs project reported an average 0.80 m Secchi depth for Zone 1 of Green Bay (Miller et al., 2022), suggesting a slight improvement in water clarity conditions in the Zone 1 of the bay when compared to the median baseline value of 0.70 m reported in the TMDL and 1986 - 2011 long term average of 0.51 m reported in the State of the Bay report.

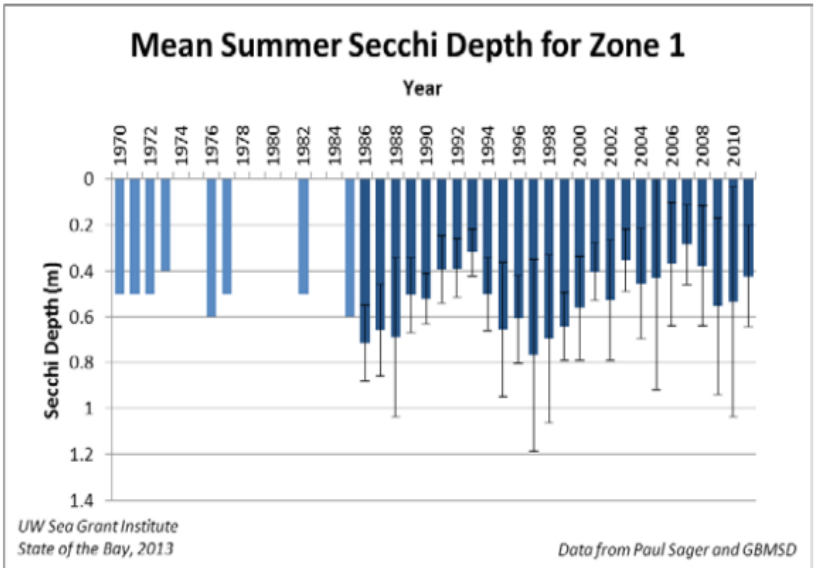

Figure 13. Lower Green Bay Mean Secchi Depths for 1970 - 2011

Increases in water clarity resulting from reduced nutrient and sediment loading is expected to increase the depth and extent at which submerged vegetation can currently colonize (see following "Habitat" section for more detailed description), and an increase in submerged vegetation is also expected to provide reduced wind and wave driven resuspension of sediments (Jeppesen et al., 1997; Barko and James, 1998). Given the efforts to reduce nutrient and sediment loading coupled with significant efforts to restore riparian and coastal wetland habitat in the Lower Green Bay & Fox River AOC, an increase in water clarity over the next decade is expected, making the tracking and reporting of this metric well-justified.

Recommendation

The final Shared Measurement work group recommendation is to summarize and report the median Secchi depth observed in Zones 1 and 2 of Green Bay as a rolling average using NEW Water AMP program data.

LOWER FOX RIVER AND BAY RESPONSE: HABITAT

Background and Justification

Historic accounts describe the Fox River and Green Bay Estuary as a verdant water body, with hundreds of acres of submergent and emergent riparian and coastal wetland habitat that supported an abundant aquatic community (A.E. Jenks, 1901). Jenks' (1901) research on wild rice gatherers in the Great Lakes region described the bay of Green Bay as having "thousands of acres of wild rice in the shallows of its waters" south of the Menominee River to the head of the Lower Bay. An early habitat survey conducted in 1943 confirmed this account, documenting a prolific and diverse coastal wetland community in the southernmost portion of the bay of Green Bay, known today as the Duck Creek Delta (DCD) (Zimmerman, 1953).

However, more contemporary surveys have documented significant loss of habitat extent and species diversity in the DCD (Flood, 2015, Houghton et al., 2017, Kupsky and Dornbush, 2018). The loss of habitat in the DCD is a result of water quality degradation from excess nutrient and sediment runoff, direct habitat conversion, and invasion by exotic species. Additionally, a series of natural sandbar islands known as the Cat Island Chain once buffered the DCD from the extensive wind and wave fetch and ice scour characteristic of the bay of Green Bay, but a combination of high water levels, strong storms and shoreline hardening ultimately resulted in the nearly complete loss of the Cat Island Chain in the 1970s (Frieswyk and Zedler, 2007). These natural and anthropogenically-induced stressors resulted in the loss of nearly 90% of the coastal wetland habitat extent and associated diversity/habitat quality in the DCD between 1834 and 1975 (Bosley, 1978) (Figure 14).

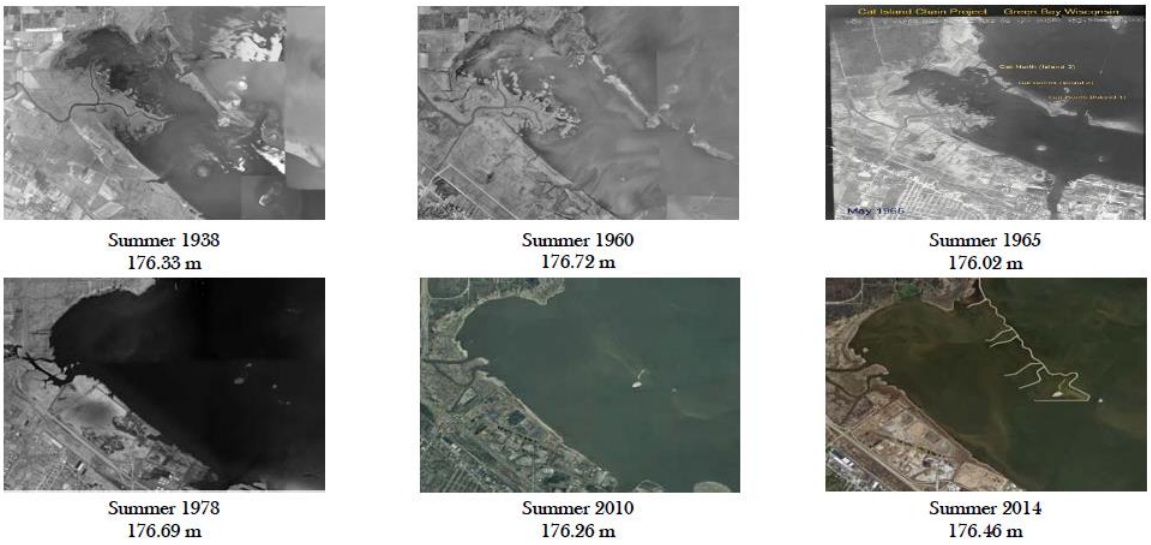

Figure 14. Aerial Images Showing the Progression of Habitat Loss in the DCD from 1938 to 2014. Captions Show the Year Each Photo Was Taken as Well as the Mean Surface Water Elevation in July that Year

Restoration of the Cat Island Chain wave spine was completed in 2013 with support from the Great Lakes Restoration Initiative, with a short-term purpose of housing dredge material from the Port of Green Bay shipping channel and longer-term goal of restoring approximately 250 acres of sandbar island habitat in lower Green Bay. An additional goal is for the wave spine and sandbar habitat to restore protection from wind and wave fetch to the leeward Duck Creek Delta coastal wetland.

In 2010, a point-intercept monitoring protocol was developed by WDNR to evaluate aquatic vegetation colonization extent, abundance and diversity at ~207 points in the Duck Creek Delta (DCD) a prior to implementation of the Cat Island Chain wave spine and dredge material placement efforts. This protocol was also developed to evaluate the same parameters at ~288 points in Dead Horse Bay (DHB), a coastal wetland on the leeward side of the Longtail Point, which remains as a natural sandbar wave barrier. At each point, vegetation is sampled via rake pole with rake rullness, species observed, water depth, and substrate hardness recorded. Additional bathymetric and predicted sediment hardness maps were developed by UWGB in 2017 and updated in 2019 using sidescan sonar technology for both survey locations.

The point intercept surveys at DCD and Deadhorse Bay were conducted in 2010 by WDNR, 2013, 2014, 2016, and 2018 by UWGB. More recently, the WDNR Aquatic Invasive Species (AIS) program housed under the Office of Great Waters completed the survey in the DCD in 2021 and 2022 as part of the European Frogbit Early Detection effort. From these data, UWGB and Ducks Unlimited have developed heat maps showing predicted submerged aquatic vegetation extent and abundance based on observations of common species (Sago Pondweed - *Stuckenia pectinata* and Coontail - *Ceratophyllum desmersum*) for each survey year (Figure 15).

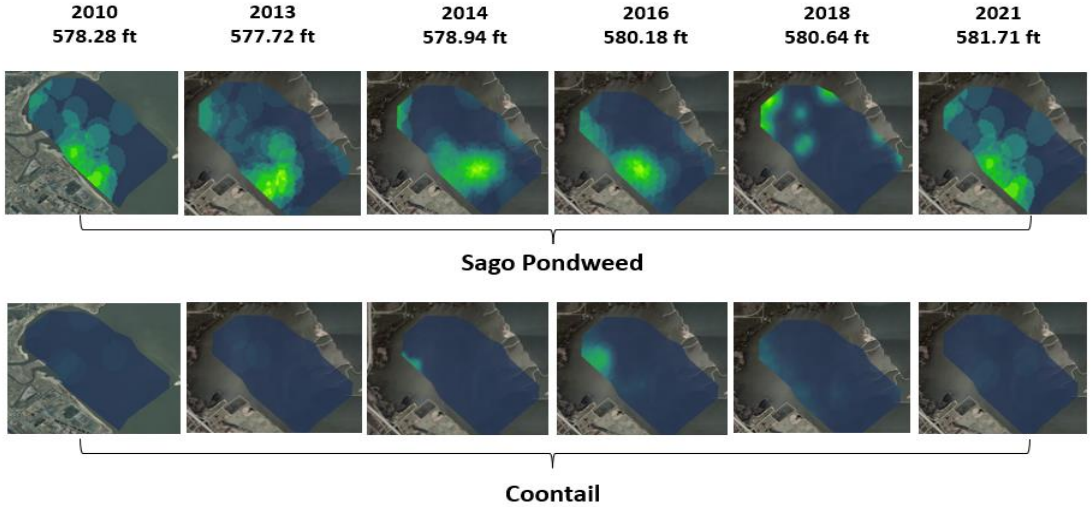

Figure 15. Heat Maps Shows the Predicted Extent of Sago Pondweed and Coontail Based on Observation of These Species During Point-Intercept Surveys in Each Survey Year.

In addition to these point intercept surveys, the UWGB Cofrin Center for Biodiversity completed several habitat surveys from 2014 - 2017 and compared the results of these surveys with historical habitat information to help guide actions to address the Loss of Fish and Wildlife Habitat and Degradation of Fish and Wildlife Populations beneficial use impairments (BUIs) for the Lower Green Bay & Fox River AOC. The result of this work confirmed the significant loss of several habitat types, including riparian and coastal wetland habitat throughout the AOC (Figure 16).

Using this information, 12 habitat restoration projects were conceptualized by the Lower Green Bay & Fox River AOC Fish and Wildlife Technical Advisory Committee from 2018 to 2022. Completion of these restoration projects is anticipated to occur by 2030, at which point a Verification Monitoring Program will be implemented across the AOC to evaluate improvements to the quantity and quality of AOC priority habitat types impacted by degraded water quality among other previously described stressors. Priority habitats most impacted (historically and contemporarily) by degraded water quality include Riparian Emergent Marsh, Submergent Marsh, Coastal High Energy Marsh, Fox River Open Water, Tributary Open Water, and Green Bay Open Water. Changes to these habitat types following implementation of the AOC restoration projects will be communicated in the reporting year 2030.

Figure 16. Map Of Observed Locations Throughout The Lower Green Bay & Fox River AOC Where Submerged Aquatic Vegetation Was Observed In 2017. The Extent, Abundance, And Diversity Of This Vegetation Has Decreased Significantly When Compared To Historical Data

<u>Recommendation</u>

The final Shared Measurement work group recommendation is to continue the DCD and DHB point-intercept surveys to evaluate submerged aquatic vegetation extent, abundance, and richness on an annual basis and at least once in the growing season and led by WDNR OGW. Results of these surveys should be submitted to Ducks Unlimited and updated in the Cat Island Mapping Tool. While this GIS tool does not currently extend along the entire west shore of the AOC portion of Green Bay, DNR OGW will continue to work with Ducks Unlimited to extend the area of interest that

the mapping tool currently covers. Additionally, the Shared Measurement workgroup recommends that changes to the quantity and quality of priority habitats impacted by poor water quality (i.e. Riparian Emergent Marsh, Submergent Marsh, Coastal High Energy Marsh, Fox River Open Water, Tributary Open Water, and Green Bay Open Water) following implementation of all AOC restoration projects should be communicated in the 5 year reporting cycle, beginning in the reporting year 2030.

LOWER FOX RIVER AND BAY RESPONSE: MACROINVERTEBRATES

Background and Justification

Macroinvertebrates make up an important component of the aquatic food web and are frequently used as a criterion for assessing the health of lakes, rivers, and streams. The composition of aquatic macroinvertebrate assemblages can provide information on the ecological condition of streams that may be otherwise difficult to quantify. As most aquatic invertebrates have limited mobility, they can be good indicators of local water quality, integrating local and upstream watershed stressors. Additionally, most aquatic macroinvertebrates live from months to years in streams, integrating the effects of multiple environmental stressors over time. Instead of measuring the multitude of possible stressors over different spatial and temporal scales, measuring macroinvertebrate assemblages allows the direct examination of how stressors are impacting biologic integrity.

WDNR, following WisCALM guidance, routinely collects macroinvertebrate data for stream and river condition assessments. These assessments determine if water quality conditions support *Aquatic Life* designated use as part of the CWA 303(d) and 305(b) of the Integrated Report to the EPA. As part of the Biological Large River LTT program, macroinvertebrates were sampled at stations starting in 2017 and will be re-evaluated every 5 years. Macroinvertebrate data is also collected as part of WDNR's Targeted Watershed Assessment (TWA) program on an as needed basis. Another avenue for collecting this data WDNR staff are currently discussing ties within the Lower Fox Volunteer Tributary Monitoring program, where macroinvertebrate and habitat surveys could be implemented on a 5-year basis at the 20 sample locations evaluated under this program. Additionally, several other partners collect macroinvertebrate data throughout the Lower Fox River, including NEW Water as part of the Adaptive Management program assessment in the Ashwaubenon and Dutchman Creek subwatersheds.

Recommendation

The final Shared Measurement work group recommendation is to summarize and report WDNR and other partner data to determine macroinvertebrate indices in areas of targeted implementation (wadeable and non-wadeable Index of Biotic Integrity) and to include macroinvertebrate sampling on a 5-year basis at all 20

sampling locations to generate a dataset reflecting pre, during, and post-implementation in the Lower Fox River subwatersheds into the Lower Fox Volunteer Tributary Monitoring Program goals.

LOWER FOX RIVER AND BAY RESPONSE: FISH POPULATIONS

Background and Justification

There are numerous environmental stressors that have potential effects on the biologic communities, and the overall health of stream ecosystems. Many of these stressors vary considerably in space and time, and it may be difficult to unravel the interacting effect of many stressors present ephemerally, or only present at low levels. By directly assessing the composition of fish in a waterbody we can directly observe the overall effects of many stressors on aquatic life, by directly examining changes in the structure or composition. Fish are good indicators of environmental quality as they are long lived, so the composition of the assemblage reflects the cumulative environmental quality over a longer time period. Additionally, fish community composition is largely influenced by stream size and temperature combinations so that accurate expectations for a healthy fish community can be used to develop benchmarks.

The Wisconsin Department of Natural Resources uses the collection of fish in wadeable streams and non-wadeable rivers for the calculation of one of the WDNR's fish Index of Biotic Integrity (fIBI). The fIBI is used as an indicator of aquatic ecosystem health and to assess against appropriate aquatic life benchmarks. The fIBI was built to reflect structural changes in fish assemblages in response to local and watershed-level disturbance, riparian condition, and local habitat quality. As such, the fIBI reflects the response of the fish assemblage to multiple types, and multiple scales, of environmental disturbance.

WDNR, following WisCALM guidance, routinely conducts fish and habitat surveys to collect data for stream and river condition assessments using the fIBI. These assessments determine if water quality conditions support *Aquatic Life* designated use as part of the CWA 303(d) and 305(b) of the Integrated Report to the EPA. As part of the Large River biological LTT program starting in 2017, non-wadeable fish surveys are sampled annually at a trend site on the Fox River and every five years at multiple locations in the Lower Fox River. Wadeable fish and habitat surveys are also collected as part of WDNR's Targeted Watershed Assessment (TWA) program on an as needed basis. Between the years of 2015-2107, targeted watershed assessments, including fish and habitat surveys, were conducted throughout all the sub-watersheds of the Lower Fox River. Future wadeable fish and habitat surveys through a TWA's will be conducted on an as needed basis.

Recommendation

The final Shared Measurement work group recommendation is to request WDNR to continue with the annual LTT non-wadeable fish surveys and 5-year rotation fish surveys on the Lower Fox River. Additionally, the Shared Measurement work group recommendation is to request WDNR to conduct fish and habitat surveys through a targeted watershed assessment when implementation targets are approached in any sub-watershed. Observed improvements in other measured metrics may also initiate the planning for conducting a targeted watershed assessment reflecting pre, during, and post-implementation in the LFR Basin subwatersheds.

KEY METRIC: SOCIOECONOMICS

RECREATIONAL USE, QUALITY OF LIFE, COMMUNITY ENGAGEMENT

Background & Justification

UW-Madison's Division of Extension was contracted to assist the Shared Measurements team in developing metrics that could show the impact that improvements to water quality could have on local economies and communities at large. Due to the difficulty in determining what data sources exist and are readily available for use, no final recommendations have been made for the specific metrics to measure Recreational Use, Quality of Life, and Community Engagement. Alliance for the Great Lakes is pursuing advancing this work and look to develop final recommendations will continue into 2023. Decisions on the final socioeconomic metrics chosen will take into consideration the influence of other factors in play (i.e. the water quality of a basin

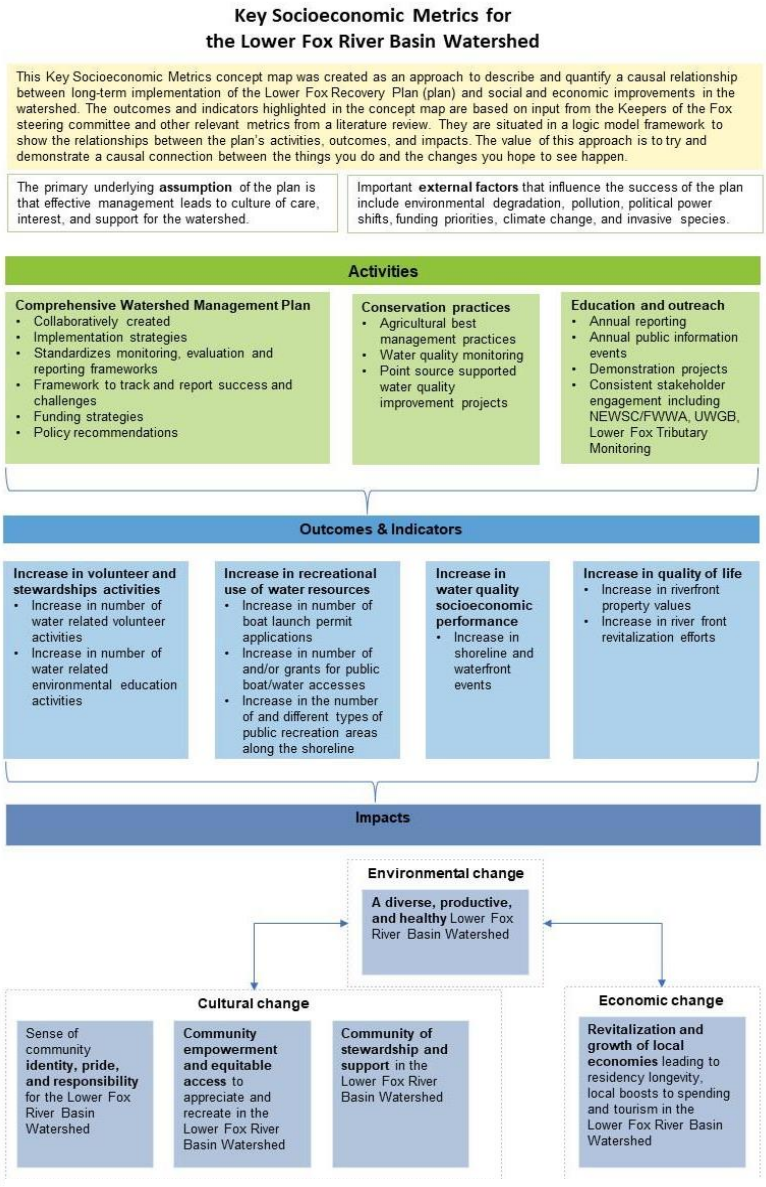

Figure 17. University of Wisconsin Extension Theory of Change

tributary is only one factor impacting the real estate values for homes adjacent to that water resources, and is most often overshadowed by other regional or national housing value influencers such as interest rates and inflation). A theory of change concept map of metrics and their impact on watershed recovery has been developed and will be used to further consider data selection (Figure 17).

Recommendation

Continued work will be done to determine socioeconomic metrics that are meaningful and measureable. The final Shared Measurement work group will work with the Keepers of the Fox Council workgroups to choose data that resonates most meaningful with the intended non-scientific audience.

KEY METRIC: STORYTELLING

Background & Justification

The need to tell the story of water recovery cannot be understated. Translating scientific data into common language narratives is key to connecting and engaging with a broad audience, and this audience provides the public support necessary to continue to progress in recovery efforts.

Through the framework of the Keepers of the Fox council, implementers, data collectors, technical experts, and skilled communicators will gather ahead of the report finalization and publication. At this time, the compiled data analysis will be presented and the team will parse out a narrative that paints the picture of the last five years' change. This provides an opportunity to not only celebrate successes but point out challenges to continued progress. Storytelling also allows for the extraneous variables such as weather, commodity prices, land use change, and many more to be considered and explained as impacting water quality.

Recommendation

The final Shared Measurement work group recommendation is to provide a narrative story of the successes and challenges of work completed during the year in the reported area.

ACKNOWLEDGING THE INVESTMENT NEEDED

The success of ongoing monitoring efforts hinge on securing long term investment of staff capacity and funding. The Shared Measurement workgroup will continue to capture the anticipated magnitude of investment and secured and potential sources of funding. These details will be included in the KOF Data Management and Delivery Plan, a phase two effort of this overarching recovery plan initiative.

REPORT DEVELOPMENT

The combination of the Annual and Five Year Reporting framework provides a mechanism to garner additional support and buy in for implementation. Annual reports provide County staff and other implementers to track progress and develop near-term plans, and the Five Year reports allow basin partners to summarize and celebrate implementation progress, track progress toward overall basin goals, and ultimately tell the story of watershed recovery through lenses that speak to multiple audiences on topics that they care about.

We anticipate the first Annual Report and Keepers of the Fox Data Management and Delivery Plan being compiled in 2023, and the first Five Year Report available in 2025. The 2030 and 2040 scheduled Five Year Reports will also include a summary of relative progress toward the 30% and 60% reduction in TP goals established under the Keepers of the Fox program, and identify what needs remain if these benchmarks are not being achieved.

Going forward, continuity for shared measurement data collection, analysis, and reporting will continue under the framework of the Keepers of the Council. UWGB and DNR will co-coordinate the Metrics & Data Coordination committee in the development of the Keepers of the Fox Data Management and Delivery Plan, tracking monitoring progress, and addressing funding/capacity needs to implement the monitoring plan. Fox-Wolf will lead coordination of the Technical Analysis & Reporting committee in deriving clear and consistent messaging from monitoring results to include in the Annual and Five Year reports.

EVALUATION AND ADOPTION OF REPORTING TOOLS

Over the course of our Shared Measurement work, various data visualization dashboard vendors were approached to evaluate for potential use in the Lower Fox reporting structure. Conversations with Great Lakes Commission (Blue Accounting), Great Lakes Observing System (Seagull), and Michigan State University (GLWMS) showed potential as data visualization mechanisms. However, the cost of each option exceeds currently available funding. As the work of the Keepers of the Fox Council progresses and additional funding becomes available, opportunities to develop an online dashboard for metrics will be pursued.

In the meantime, reports will be graphic visualizations created by Keepers of the Fox program director and hosted on the Keepers of the Fox website and via single data visualization sheets. As capacity and funding are available, work to automate data collection and reporting using tools will be conducted.

FUTURE VISION

SUSTAINED PROGRESS THROUGH THE KEEPERS OF THE FOX COUNCIL

The work of the Shared Measurement groups does not end with the development of metrics through this planning process; work will continue as part of the Keepers of the Fox Council. Representative members of each of the Shared Measurement Subgroups will participate regularly on the Metrics & Data Collection and Technical Analysis & Reporting sub-committees (Figure xx). Key representatives from data collecting agencies will evaluate data and data collection methods, metrics, and reporting frameworks and continue to serve as an adaptive measurement and data management team. A parallel technical team will provide additional analysis of data, make correlations to implementation on the landscape, as well as assist in developing narrative explanations for a non-scientific audience. More details on the function of the Keepers of the Fox and its subgroups are available in the Shared Decision Making & Community Engagement in Recovery portion of the plan.

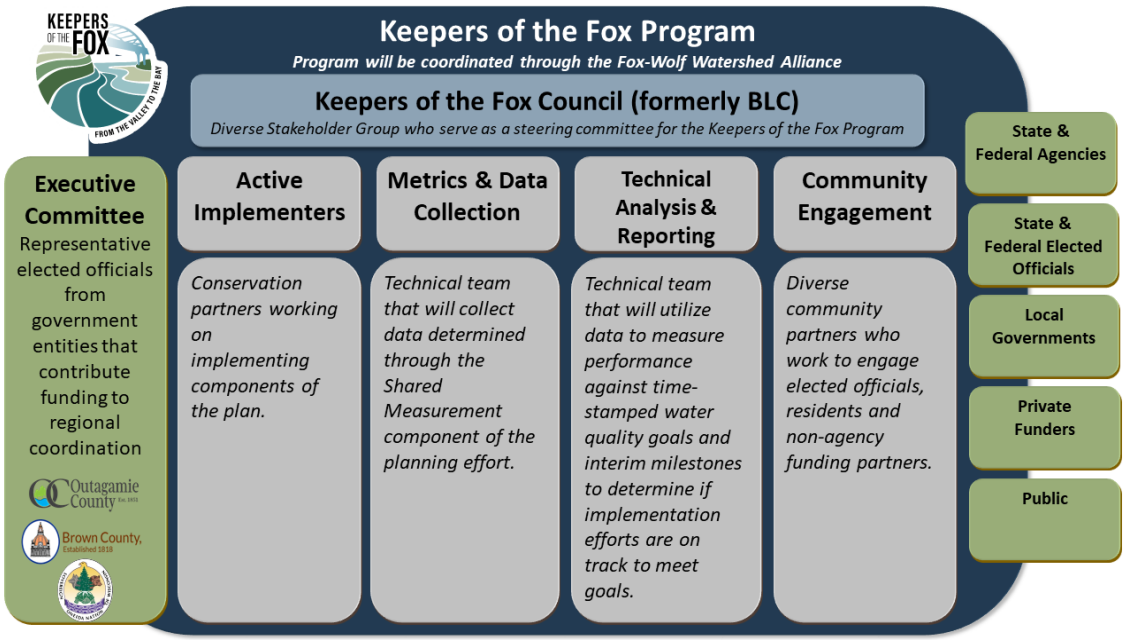

Figure 18. The Keepers of the Fox Council and Associated Workgroups

DATA MANAGEMENT AND DELIVERY PLAN

The Data Management and Delivery Plan will serve the dual purpose as the quality assurance plan for data collection and management and capture the level of investment needed to maintain the level of measurement recommended in the Recovery Action Plan. At its core, it will provide policies and procedures to ensure data is accurate, relevant, complete, and timely and detail from who, in what format, to whom, and at what frequency data is to be delivered. The Data Management and

Delivery Plan is anticipated to be the next phase of Shared Measurement work and will be complete ahead of the first reporting cycle.