Prepared by: EOR

For the City of Madison, Wisconsin

Warner Lagoon Water Quality Analysis

06.19.2019

Cover Image

Warner Lagoon from multi-use trail along eastern shore

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

We wish to thank the stakeholders who gave their time to improve this project, and the City of Madison Engineering Division and Parks Division staff for their helpful information and comments.

1. INTRODUCTION AND BACKGROUND

The City of Madison Engineering Division commissioned this study to evaluate options for improving water quality and fish habitat of Warner Lagoon in Warner Park (Figure 1). The purpose and scope of the study were described in the City's request for proposals dated July 7, 2017. This study was conducted by the Wisconsin office of Emmons & Olivier Resources, Inc. (formerly Montgomery Associates: Resource Solutions, LLC, now MARS-EOR). The project team included former Wisconsin Department of Natural Resources biologists David Marshall and Kurt Welke and LVBrown Studio LLC.

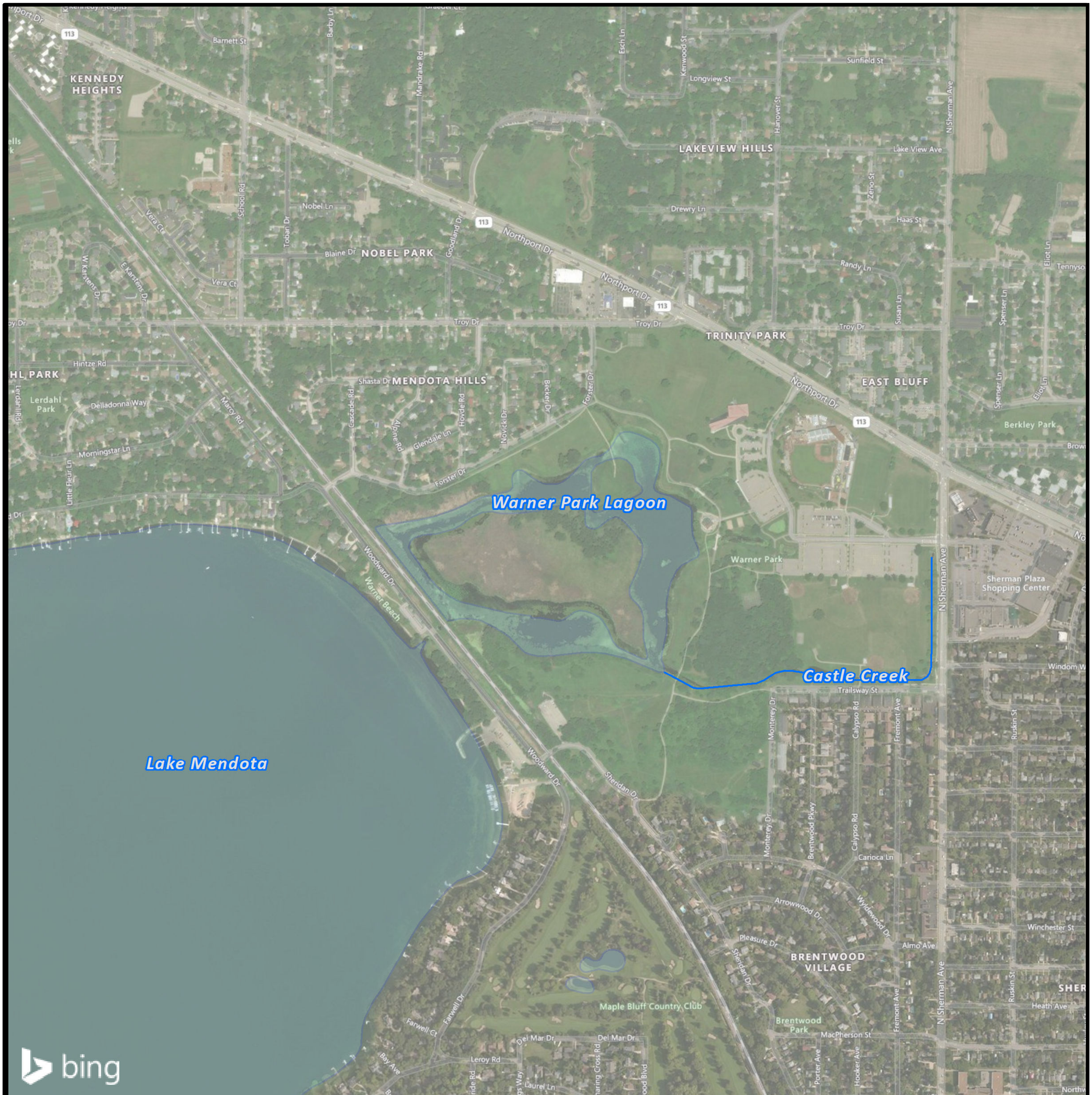
1.1. Water Quality Issues

Warner Lagoon is a pond and wetland system connected to Lake Mendota by culverts under the Wisconsin and Southern Railroad and Woodward Drive. The lagoon was dredged in the 1950s and 1960s for waterfowl habitat and stormwater management. The Lagoon has a surface area of approximately 28 acres with water depths up to approximately 6 ft. The contributing watershed is 1024 acres with primarily urban residential and commercial land uses (Figure 2). Most of the Lagoon is within Warner Park, owned by the City of Madison, and the Wisconsin Department of Natural Resources (DNR) owns the northwest corner of the Lagoon. Public uses of the Lagoon include fishing, wildlife viewing, paddling and ice skating.

Warner Lagoon is hypereutrophic, with high phosphorus concentrations causing highly eutrophic to hypereutrophic conditions (Marshall, 2014). Cyanobacteria blooms are common in hot summer weather. Low dissolved oxygen below winter ice cover leads to frequent fish kills, resulting in a fishery that is dominated by common carp (*Cyprinus carpio*). Carp activity and hypereutrophic conditions lead to turbid water and little rooted aquatic macrophytes in most parts of the lagoon. A notable exception is the northern bay of the Lagoon where lotus plants (*Nelumbo lutea*) established by the Madison Parks Department that now cover approximately 2 acres in the northern arm of the lagoon. These plants provide vegetation diversity, spawning habitat for bluegills, and likely water quality benefits due to filtering of sediment and nutrient uptake.

1.2. Management Objectives

The primary objective of the Engineering Division is to improve the water quality of Warner Lagoon. This includes addressing water quality in the lagoon itself, the benefit the lagoon provides to Lake Mendota, and how the lagoon contributes to the City of Madison's stormwater permit compliance. Improving the fishery, habitat and aesthetics of the lagoon are important secondary objectives.



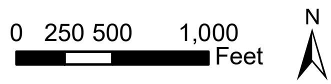


Figure 1 - Regional Location Map

Warner Lagoon Water Quality Analysis

City of Madison

Dane County, WI

City of Madison Engineering Division

MARS-EOR
water-ecology-community

EMMONS & OLIVIER RESOURCES, INC.

119 South Main Street | Cottage Grove, WI 53527

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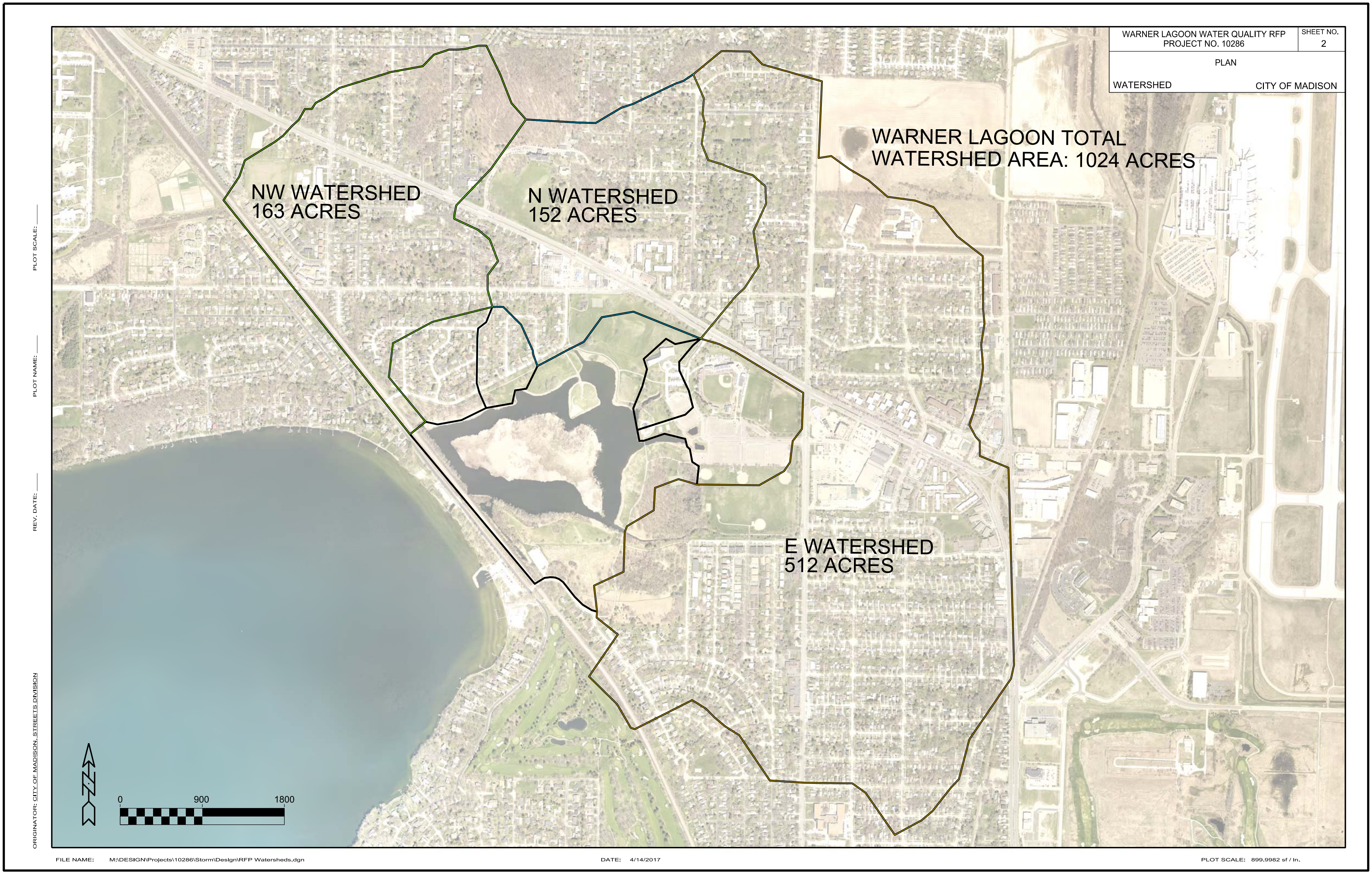

Figure 2. Primary watersheds draining to Warner Lagoon. (From City of Madison.)

2. METHODS

The project team used a variety of methods to conduct this feasibility study, as summarized below.

2.1. Data review

Major data sources reviewed for this project include the following:

- Marshal, DW, 2014. Water resources assessment of Warner Park Lagoon with Management Alternatives. Underwater Habitat Investigations LLC
- Underwater Habitat Investigations LLC and Dane County Land & Water Resources, 2007. Aquatic plant management plan: Jenni and Kyle Preserve Ponds, Tenney Park Lagoon, Vilas Park Lagoon, Warner Park Lagoon, and Verona Quarry.
- City of Madison Engineering Division, 2013. Warner Park: fireworks environmental impact baseline study, 2012.
- City of Madison Parks Division, 2011. Geese management report for Madison Parks Division.
- A 1989 fish survey
- A 2005 water depth and dissolved oxygen survey
- Madison Metropolitan School District, 2012. The Warner Lagoon from 1983 to 2012. Honors Aquatic Biology report.
- The 1970 grading plan for enlargement of the lagoon
- The plans for the original carp barrier
- The proposed plan and permit application for a sediment trap at the northwest watershed outfall off Forester Drive (not constructed)
- City of Madison design calculations for the existing gabion structure at the north outfall
- The 1993 master plan sketch for Warner Park
- Drone photography collected by Edge Consulting Engineers in 2018
- Literature on nutrient loading, stormwater treatment wetlands and carp exclusion

2.2. Site Visits

Project team members visited Warner Park several times to observe conditions and develop ideas for alternatives. Detailed sediment sampling was not part of this scope of work, but limited observations on lagoon sediment characteristics were conducted by wading and probing soft sediment depth with a rod. In addition, a survey of sediment deposits in Castle Creek between the park entrance on Northport Drive and Warner Woods was conducted on June 1, 2018 to help assess the existing sediment trapping efficiency of the channel.

A limited fish survey was conducted by Dave Marshall and Kurt Welke on October 2, 2017 to provide additional baseline data on the fishery. Their report is included in Appendix A. During this survey, water quality data were also collected at locations previously sampled by Marshall (2014).

On January 9, 2018, project team members measured dissolved oxygen in the lagoon near the park shelter through holes drilled through the ice.

2.3. Public Input

Three workshops were conducted to discuss alternatives with stakeholder and City staff on March 12 and June 18, 2018 and March 28, 2019. Stakeholders included Wild Warner, the Yahara Fishing Club, interested citizens, the Wisconsin Department of Natural Resources (DNR), and the City of Madison Parks Division.

2.4. Engineering and Ecological Analysis

The performance of existing and potential future stormwater practices was evaluated using the WinSLAMM computer model, modifying model files developed by the City of Madison for the northwest, north and east watersheds. For existing conditions, we added the existing gabion sediment trap at the north watershed outfall and the retrofit Castle Creek channel constructed in 2014. The north outfall sediment trap was modeled as a wet pond, as were pools along Castle Creek. The remainder of the vegetated Castle Creek channel was modeled as a grass swale.

Although calibration of the WinSLAMM model was beyond the scope of this study, comparison pf predicted sediment trapping with observations of sediment build ups in Castle Creek suggests model results are reasonable. No data on sediment accumulation or clean-out volumes was available for the gabion structure at the north outfall.

Potential future stormwater treatment practices were added to these WinSLAMM models to evaluate additional sediment and phosphorus reductions.

Internal phosphorus loading and lagoon flushing frequency were evaluated using the DNR's Wisconsin Lake Modeling Suite (WiLMS).

Potential flooding due to alterations of Castle Creek were evaluated with a HEC-RAS screening hydraulic model. The model simulates existing conditions from the upstream end of the concrete cunette to the lagoon using typical cross sections and slopes and a simplified representation of the multi-use trail bridge. Two alternatives described below were simulated for comparison. Because no hydrologic model is available to estimate peak discharges from the east watershed, we simulated a range of flows from 50 cfs – 2000 cfs in the hydraulic model.

Carp control options were evaluated based on the experience of team, discussions with DNR fisheries biologists and fisheries biologists at Carp Solutions in Minnesota, and literature review.

The feasibility of dredging was assessed based on the experience of the project team, cost estimates and bids for other dredging projects, and stakeholder input on potential dredging areas, spoils disposal locations, and regulator issues.

3. EXISTING CONDITIONS

3.1. Water Quality

3.1.1. Measurements

On October 2, 2017 the MARS team conducted an updated water quality survey of the lagoon based on sampling sites from the 2014 study (Figure 3). While the 2017 survey was conducted later in the fall compared with the 2014 survey, water temperatures were actually higher in 2017 since the weather was unseasonably cold in 2014. Cold water temperatures can diminish effects of eutrophication. Beyond the observed differences in weather conditions, the lagoon consistently displays highly eutrophic conditions (Figure 4). Total phosphorus measured at Sites 1 and 2 in 2014 and 2017 ranged from 181 ug/L to 398 ug/L (Figure 5). Secchi measurements and Trophic State Index reflect hypereutrophic conditions as well (Figure 6 and Figure 7). The slightly lower TSI for secchi may suggest influence of rooted aquatic plant growth in the lagoon that appeared to increase in 2017. The N:P ratios at Sites 1 and 2 were 5.4:1 and 6.2:1 respectively and indicate nitrogen limitation. Nitrogen limitation is characteristic of hypereutrophic conditions.

The highest water clarity measurements occurred at site 4 that also appeared to coincide with greater rooted aquatic plant growth in 2017, particularly coontail (*Ceratophyllum demersum*). While secchi measurements were not significantly different between 2014 and 2017, turbidity measurements using the Hach Turbidimeter 2100 suggested clearer water at three of four sites in 2017 (Figure 8). These data appeared to reflect an increase of rooted aquatic plants in 2017, primarily coontail. Site 1 consistently displayed to lowest water clarity in both secchi and turbidity measurements.

Figure 3. Water quality and fish sampling sites.

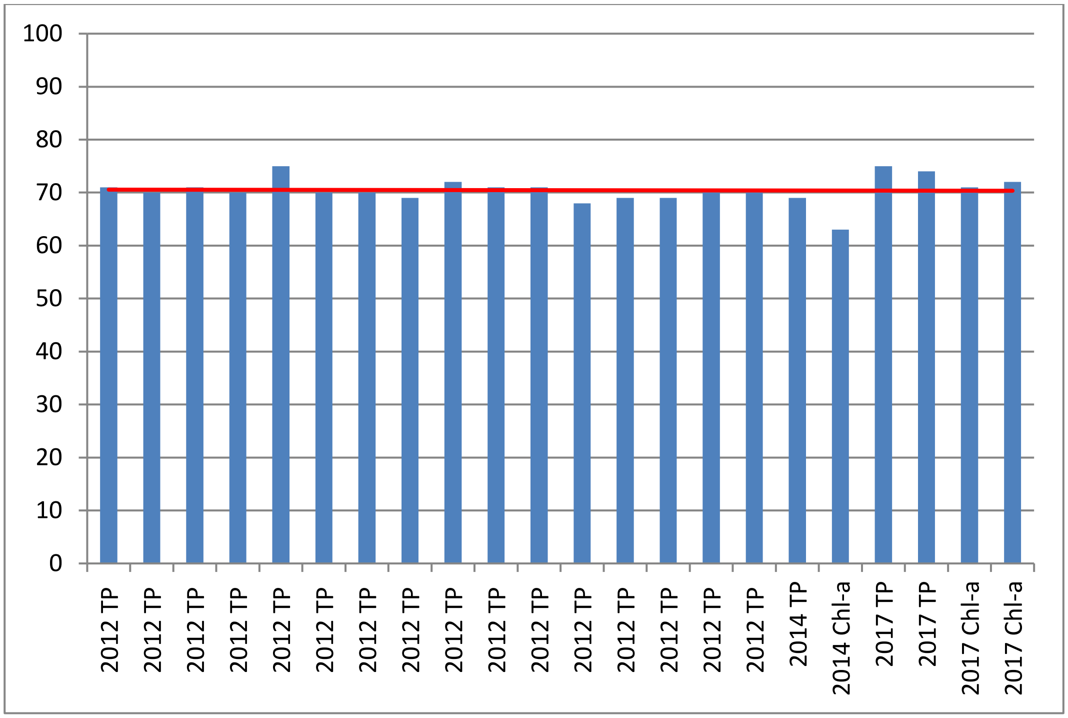

Figure 4. Phosphorus and Chlorophyll a TSI values 2012 - 2017.

(2012 samples collected by City of Madison. 2014 and 2017 samples collected by Marshall.)

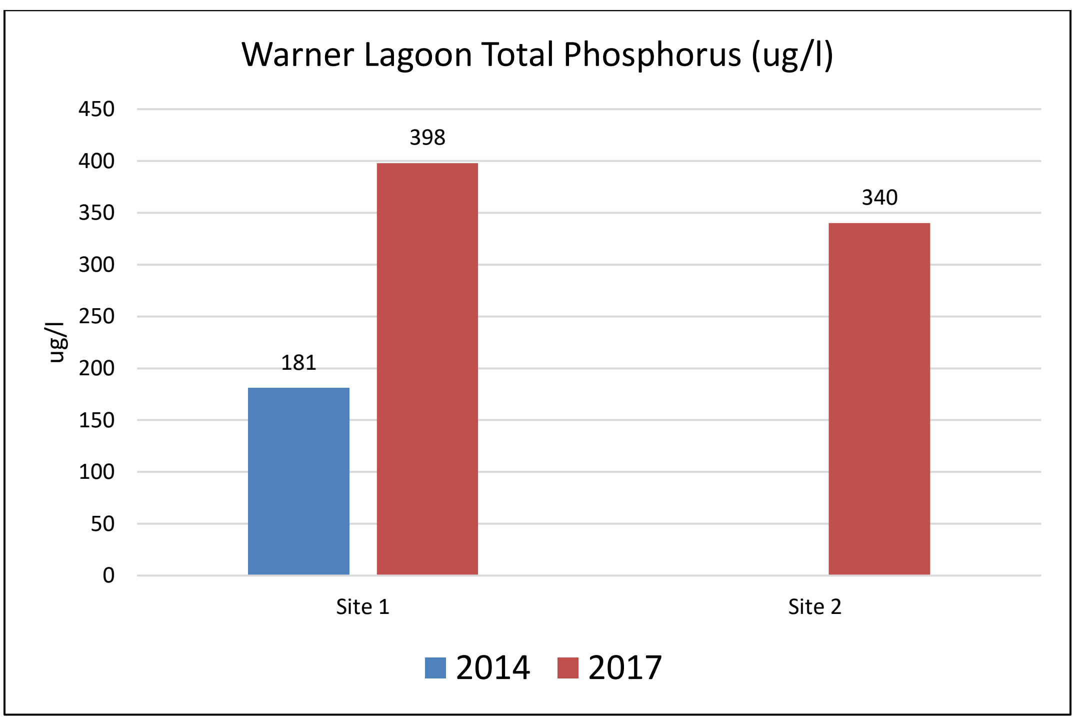

Figure 5. 2014 and 2017 Total Phosphorus Data.

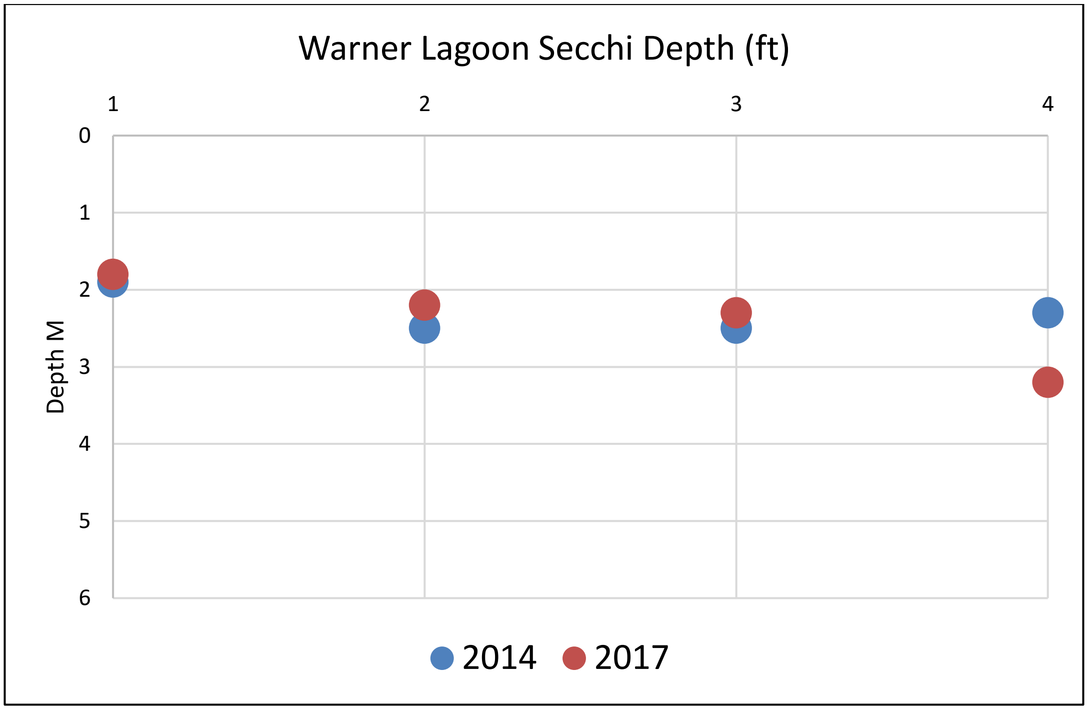

Figure 6. Secchi Measurements 2014 and 2017.

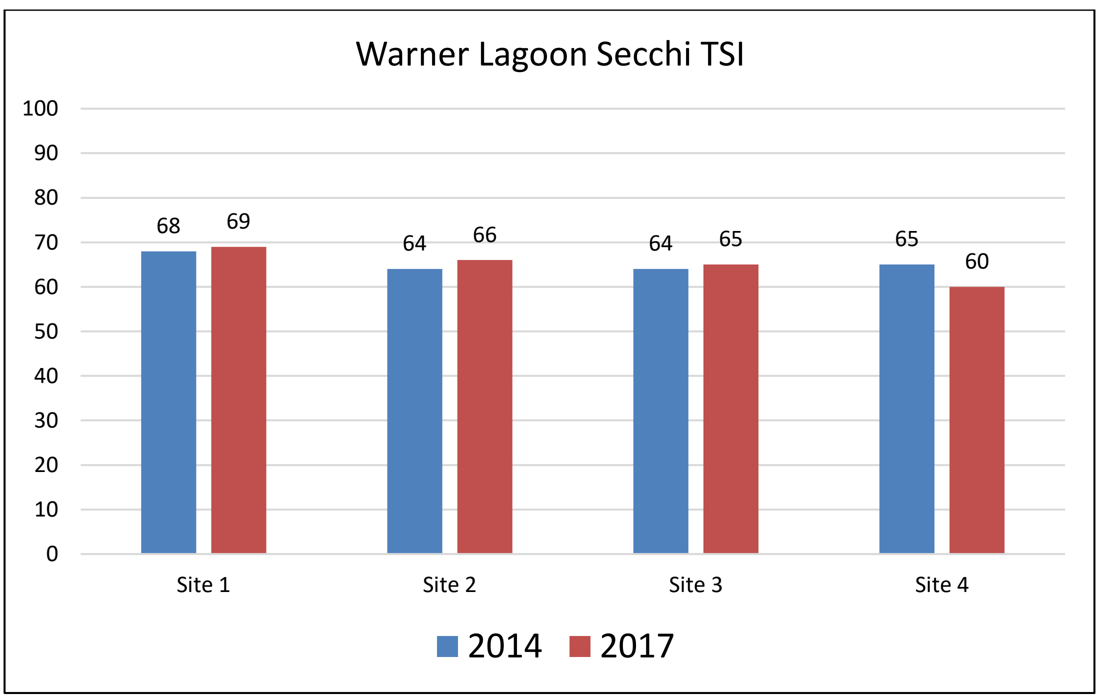

Figure 7. Secchi TSI 2014 and 2017.

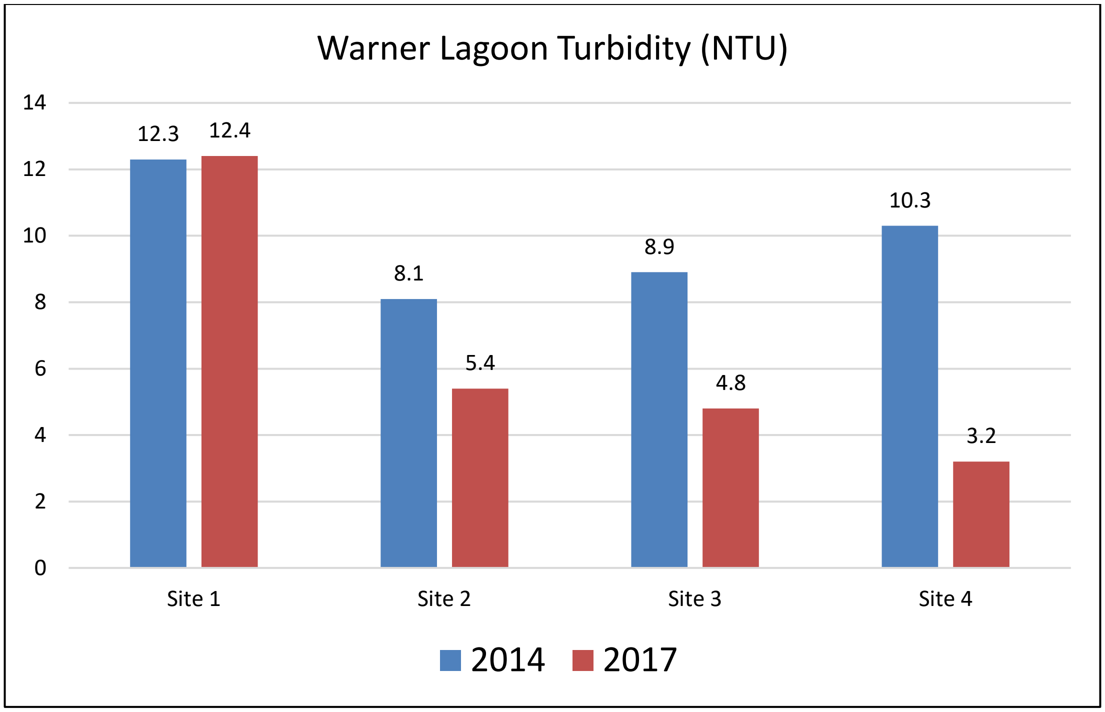

Figure 8. Turbidity Measurements 2014 and 2017.

Chloride concentrations were higher during the 2017 sampling date but the results are based on just a few samples. At Site 1, chloride was 13.5 mg/l in 2014 compared with 29 mg/l in 2017. Even higher chloride was measured at Site 2 in 2017 at 34.7 mg/l. The higher chloride concentration at Site 2 coincided with higher specific conductance at that site (281 uS/cm at Site 1 and 312 uS/cm at Site 2).

The January 9, 2018 dissolved oxygen survey found near anoxia on the north side of the lagoon, where there was thick snow cover but well oxygenated water where snow was plowed for ice skating offshore from the shelter (Table 1). While it would be expected to observe higher dissolved oxygen under snow free ice, where sunlight penetration can support some plant respiration, the magnitude of the difference was surprising.

Table 1. January 9, 2018 dissolved oxygen data.

Location	Depth (m)	Temperature (C)	Dissolve Oxygen (mg/L)
North side (snow covered)	0	0.5	0.6
	0.5	3.7	0.5
	1.0	3.9	0.4
	1.5	4.8	0.4
West of shelter (snow plowed clear)	0	0.7	11.5
	0.5	3.6	12.3

3.1.2. Modeling

Sediment and phosphorus loads simulated by the WinSLAMM model for existing conditions are summarized in Table 2. Existing conditions annual pollutant loads simulated in WinSLAMM. These simulations include the existing gabion structure at the north outfall and the Castle Creek channel retrofit constructed in 2014. Estimated sediment removal efficiencies for these existing features were 28% for the north outfall gabion and 30% for the Castle Creek retrofit.

Table 2. Existing conditions annual pollutant loads simulated in WinSLAMM.

Watershed	Annual Sediment Load (lbs)	Annual Total Phosphorus Load (lbs)
Northwest	44,542	159
North	34,069	124
East	105,860	411

Reconnaissance observations by MARS-EOR on June 1, 2018 of sediment deposited in the retrofit Castle Creek channel were compared with the predicted WinSLAMM trapping efficiency. Sediment thickness was measured in 13 transects between the outfall at the Northport Drive entrance and the start of the concrete cunette through Warner Woods (Figure 9). A thick deposit of course sediment immediately downstream of the outfall was assumed to be road sand. Not counting that deposit, the estimated weight of sediment that accumulated over the 4 years between construction of the retrofit and the survey is approximately 398,000 lbs (Table 3). The majority of the sediment has accumulated in the basin at the downstream end of the channel. The average annual load for those 4 years is 69% of the total watershed sediment load predicted by WinSLAMM. This estimate is very approximate, and conditions in the simulated year (1981) were not the same as in 2014 – 2018. The trapping efficiency of the retrofit channel is almost certainly not as high as 69%, but this comparison illustrates that the channel retrofit has trapped a large volume of sediment and that the sediment removal of 30% calculated by WinSLAMM is plausible.

Table 3. Sediment survey and volume estimate for Castle Creek.

Location	Channel Length (ft)	Width (ft)	Surface Area (sf)	Sediment Thickness (ft)	Void Space in rip rap	Volume (cf)	Weight (lbs)	% of Total
Sediment at outfall - exposed	--	--	120	0.67	NA	80	5990	1%
Sediment at outfall - below water	50	15	750	0.67	NA	503	37627	9%
Transects 1 - 6: central deposit	600	5	0.63	0.13	NA	375	28080	6%
Transects 1 - 6: lateral deposit	600	15	9000	0.13	0.33	371	27799	6%

Location	Channel Length (ft)	Width (ft)	Surface Area (sf)	Sediment Thickness (ft)	Void Space in rip rap	Volume (cf)	Weight (lbs)	% of Total
Transects 6 - 7: central deposit	100	5	0.00	0.00	NA	0	0	0%
Transects 6 - 7: lateral deposit	50	5	250	0.25	0.33	21	1544	0%
Transects 7 - 9	200	15	3000	0.01	0.33	10	772	0%
Transects 9 - 11	500	10	5000	0.33	NA	1650	123552	28%
Transects 12 - 13: basin	250	35	8750	0.33	NA	2888	216216	49%
Total Accumulated:							441581	lbs
Total minus upstream sediment pile (assume road sand):							397964	lbs
Annual Accumulation (over 4 years):							99491	lbs
Winnslam annual load (for 1981):							144364	lbs
Accumulated Sediment as % of WinSLAMM annual load:							69%	

(1) Assumes bulk density of 75 lbs/ft^3 because loose, fine grained sediment commonly has a bulk density slightly higher than that of water.

The WinSLAMM sediment load predictions can be used to estimate an average deposition rate in Warner Lagoon. Summing the annual particulate sediment loads from the northwest, north and east watersheds (Table 2) and applying the average load per acre for those watersheds to the remaining 197 acres of the Warner Lagoon watershed yields a total annual particulate load of approximately 293,000 lbs. Assuming a porosity of 0.4 for the deposited sediment corresponding to a bulk density of approximately 100 lbs/ft^3, the annual volume of sediment deposited would be 2960 ft^3. The equivalent average deposition rate over the 28-acre lagoon is 0.03 in/year. The WinSLAMM results do not include bedload sediment, but monitoring data from Madison indicate that bedload is approximately 5% of total sediment load in storm drainage systems (Pitt and Voorhees, 2007). As stakeholder observations and drone photography indicate, sediment is actually deposited preferentially near stormwater outfalls where accumulation rates are higher than this calculated average.

WiLMS modeling indicates that the volume of runoff flowing into the lagoon annually is much larger than the storage volume of the lagoon, and water in the lagoon flushes into Lake Mendota approximately 4 - 5 times per year. The rate for any given year obviously depends on weather conditions and rainfall volume. Internal phosphorus loading from bottom sediments estimated by WiLMS is approximately 4% of the total load, due to the large stormwater inflows from the watershed compared to the lagoon volume. However, carp activity could lead to higher internal loading due to sediment resuspension.

N.T.S.

Legend

City of Madison Storm Sewer

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Figure 9. Data Collection Map

Warner Lagoon Water Quality Analysis
City of Madison
Dane County, WI
City of Madison Engineering Division

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Drawn by: RSS | 6/18/2019 | Coordinate System: NAD 1983 HARN State Plane WI South

3.2. Fish

A towed DC electroshocking survey was conducted in 2017 to complement the 2014 survey by Marshall. The shocking distance was similar to the 2014 survey but the area shocked was located along the island instead of east shore (Figure 3). Figure 10 compares fish species and numbers caught both years. Similar results were found both years with bluegills the most abundant and only a single young of year common carp found in 2014. More details are included in Appendix A.

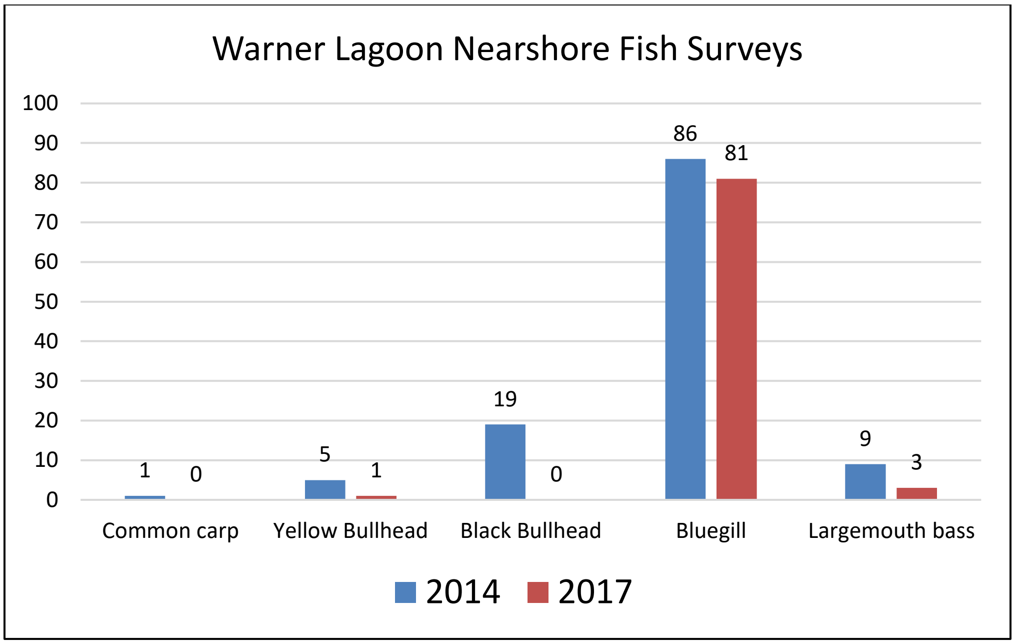


Figure 10. Warner Lagoon Nearshore Fish Electroshocking Survey Results.

No barrier is currently in place between Lake Mendota and Warner Lagoon to block carp migration. A grate-style barrier was placed at the downstream edge of the Woodward Drive box culvert in 2012. Kurt Welke, then with the Wisconsin DNR, provided general construction advice for keeping adult carp out of the lagoon. The City of Madison designed, fabricated and installed the barrier. It has since been removed due to ongoing maintenance problems. The City indicated that it was was very difficult to remove for maintenance and was damaged during routine removal of floating debris blown in from Lake Mendota. Stakeholder feedback suggests the barrier noticeably reduced carp activity in the lagoon.

3.3. Geese

A goose management plan was written by Russ Hefty of the Madison Parks Department in 2011 due to concerns about goose activity including impacts on water quality, vegetation and recreation. Based on that plan and information from City Parks and Engineering staff, current goose control efforts for the lagoon include the following:

- Volunteers with Wild Warner oil the eggs of about 10 nests on the big island annually;

- An annual summer roundup of resident geese typically yields about 30 - 50 birds;
- Additional pairs that show up throughout the summer are harassed away;
- No additional actions are taken during the fall migration due to the large number of birds that pass through the area;
- Parks and Wild Warner are planting tall, native vegetation on “Fire Bird Island” to deter goose activity; and
- Other shorelines are not mowed, except adjacent to the shelter, to deter geese.

Literature on nutrient loading due to goose feces indicates that the solids tend to rapidly sink and become incorporated into bottom sediment, immobilizing much of the phosphorus in the feces (Unckless and Makarewicz, 2007). Thus, the primary pathway for nutrients in goose feces to affect the water column may be internal loading from the bottom sediments.

3.4. Future Trends

If no action is taken to improve conditions at Warner Lagoon, the existing hypereutrophic, turbid water quality and carp-dominated fishery can be expected to persist indefinitely. The increased precipitation and runoff experienced regionally over the last decade may increase sediment and nutrient loading. Although the average sedimentation rate in the lagoon is small, sediment will continue to build up more rapidly below storm sewer outfalls reducing water depths in those locations.

Lowering the water level of Lake Mendota is currently being discussed in the community to alleviate flooding issues and restore shoreline habitat. A lower lake level would also lower the wate level in the lagoon, resulting in shallower water and a potentially worse winter dissolved oxygen problem. It could also reduce connectivity between the lake and lagoon for fish. The possibility of lower lagoon water levels should be considered in future evaluation and implementation of the alternatives described below.

4. ALTERNATIVES

4.1. Overview

Alternatives for improving water quality and habitat in Warner Lagoon were developed to work as an integrated strategy to improve water quality and habitat for fish and wildlife (Figure 11). They are summarized in Table 4 and discussed in more detail in the following sections, including implementation issues and stakeholder input. Appendix B Sheet 1 illustrates how these alternatives could be implemented at Warner Lagoon.

These alternatives present a set of options for the City and community to consider. For some alternatives, no stakeholder consensus was reached. Multiple options are possible for several alternatives, as described in following sections.

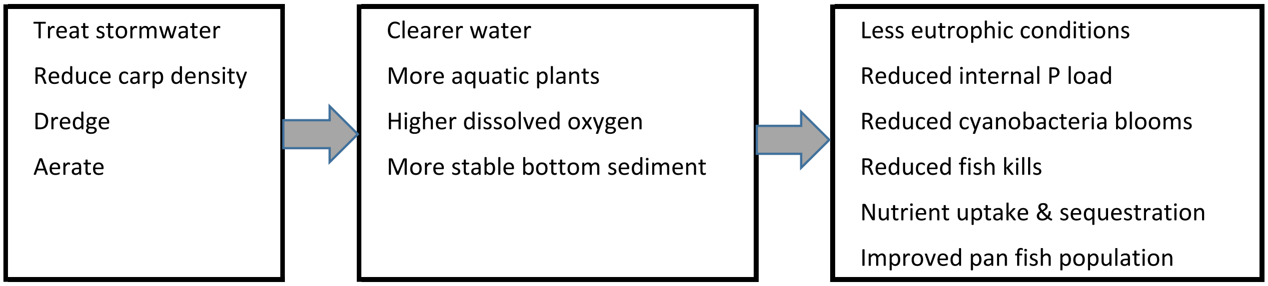


Figure 11. Integrated restoration strategy.

Table 4. Summary of potential alternatives for Warner Lagoon.

Alternative	Benefits	Impacts	Approximate Cost
Construct stormwater treatment wetlands at 3 major storm sewer outfalls.	Could reduce sediment and phosphorus loads by 29 and 23%. Diversify wetland habitat. Remove concrete cunette and naturalize Castle Cr.	Construction would disrupt lagoon use and require equipment traffic in park. Would impact habitat and paddling at outfalls. No stakeholder consensus for Castle Creek outfall.	$140,000 capital.
Remove carp by baited net trapping	Reduce carp biomass to improve water clarity, establish macrophytes and improve panfish population.	Highly visible netting operation would temporarily disrupt aquatic recreation and wildlife.	$20,000
Install carp barrier grate	Reduce adult carp migration into lagoon.	Visible structure would affect aesthetics. Adult gamefish could also be blocked.	$10,000 capital. O&M labor and minor repair costs.
Install aeration system in one or more locations	Maintain DO levels for winter fish survival. Reduce anoxia & internal P release in summer.	Thin ice safety hazard requires fencing. Addition of mechanical equipment to lagoon. No stakeholder consensus.	$5,000 - $10,000 capital. $50-$100/month electrical O&M.
In-lagoon chemical treatment	Could help clarify water to establish macrophytes, if carp control and stormwater treatment are insufficient.	Application requires boat application throughout lagoon. Chemical addition can cause public concern. Discussed with stakeholders as a back-up alternative.	$30,000 per application

Alternative	Benefits	Impacts	Approximate Cost
Dredge deeper fish habitat	Improve diversity of fish habitat & population. Improve fishing, especially if more macrophytes establish. Potentially restore marsh in northwest corner of lagoon.	Upland spoils disposal would negate use of some fields for a season. In-water spoils placement for marsh restoration would impact paddling and change existing habitat. No stakeholder consensus.	$500,000 - $1,300,000 capital.
In-lagoon diversion of runoff away from habitat areas	Reduce sediment and nutrient loads to parts of lagoon.	Would require segmenting lagoon with berms, with impacts to recreation & wildlife.	Not estimated. (Not recommended.)
Tree-drop / other fish structures	Enhance fish and turtle habitat.	Potential for tangling carp trap nets.	$500 capital.

4.2. Stormwater Outfall Treatment

4.2.1. Rationale

Warner Lagoon's water quality is affected by stormwater runoff from its 1024-acre urban watershed, especially sediment and phosphorus loads. Most stormwater outfalls into the lagoon are untreated, and additional treatment is possible at the north and east outfalls. Reducing sediment loads would improve water clarity and vegetation growth, and reducing phosphorus loads would improve upon the lagoon's current hypereutrophic state.

4.2.2. Description

The alternatives in this report focus on the 3 outfalls for the northwest, north and east watersheds because they represent 81% of the upstream watershed. Note that treatment in the upstream watershed is possible but beyond the scope of this study.

Northwest Watershed Outfall

Little upland area is available for stormwater treatment at the outfall of the 163-acre northwest watershed, due to the presence of high quality, mature trees and the adjacent railroad right-of-way. Treatment in the lagoon below the outfall appears to be the only viable option, as proposed previously. The permitting difficulties with that earlier proposal can be lessened by designing a wetland treatment system that is more compatible with the management objectives of Warner Lagoon.

A stormwater treatment wetland concept is shown on Appendix B Sheets 1 and 2. This includes a forebay near the outlet to slow water and concentrate sediment deposition where it can be periodically removed, a marsh basin with emergent vegetation, and a basin outlet formed by a rock-cored berm that can be vegetated and provide maintenance equipment access. Pollutant removal would be through settling of particulates in the forebay and marsh, plus adsorption onto and nutrient uptake by aquatic vegetation. The vegetation would also help slow water, enhancing settling and reducing resuspension.

A rock weir or gabion outlet structure would control discharges from the treatment wetland into the lagoon and create an approximately 6-inch water surface "bounce" during high flow events. This water level rise would increase the detention time in the wetland and enhance settling, but is small enough to be tolerated by native wetland vegetation. Creation of the wetland basin upstream of the berm would not require dredging. The existing water depth is suitable for establishment of emergent macrophytes and deep enough to provide settling treatment.

An alternative design – or one that could be implemented as a first step – is to construct only the forebay across the narrow inlet downstream of the outfall.

Note that this concept is similar to the in-lagoon treatment concept described by Marshall (2014) but focused at the stormwater outfall.

North Watershed Outfall

The concept developed for the north watershed is to supplement the treatment provided by the existing forebay (28% TSS removal and 20% TP removal simulated by WinSLAMM) by augmenting treatment in the lotus-filled bay between the outfall and the main pool near the shelter. This could be accomplished by constructing an outlet structure between the lotus bay and the main part of the lagoon to allow the bay to function as a treatment wetland, as described above for the northwest outfall (Appendix B Sheets 1 and 3), with minimal disturbance to the existing bluegill habitat and water quality functions it provides. The outlet would consist of a gabion across the entrance to the lotus bay with a low-flow notch and earthen berm to tie into higher ground. The outlet would provide a 6-inch water level bounce during runoff events to enhance treatment in the lotus bay.

East Watershed Outfall (Castle Creek)

Concepts developed for Castle Creek include a sediment trap at the upstream end of the vegetated channel retrofitted in 2014 and two options for treatment downstream of that channel in Warner Woods and/or the lagoon (Appendix B Sheet 1). The sediment trap would increase trapping efficiency of the system and reduce sediment removal maintenance requirements in the downstream vegetated channel. The trap would be a wet pond with the stormsewer outfall directed into it and a high-flow bypass to the existing channel (Appendix B Sheet 4).

The first option for additional treatment in and downstream of Warner Woods is to remove the concrete cunette, construct an earthen channel with vegetated banks and a miniature floodplain, plus a treatment wetland cell in Warner Lagoon downstream of the Castle Creek mouth (Appendix B Sheets 1 and 6). Construction of a new channel and floodplain would require earthwork cut and fill but could be kept away from the mature trees in Warner Woods on the north side of the channel. Some tree removal would be necessary on the south side of the channel. Crushed concrete from the cunette and excess soil cut would be used to construct a berm across the narrow lagoon inlet downstream of the Castle Creek mouth to create a treatment wetland cell similar to that described for the northwest outfall.

A second option was developed to address concerns expressed by some stakeholders about the first option. The alternative concept would include removing the concrete cunette, creating a wetland floodplain adjacent to the cunette, with no treatment wetland or other feature in the lagoon downstream of the multi-use path. The extent of the floodplain created would depend on the budget available for the project. It could be narrow (e.g. 5-10 ft wide) as for option 1, but it could be expanded to the south by removing trees and excavating into the existing slope to create a floodplain 20 - 50 ft wide in places (Appendix B Sheet 7). An outlet structure to improve treatment by creating a small water source bounce could be built by re-constructing the existing gabion with a slightly larger footprint.

4.2.3. Benefits and Impacts

Sediment and phosphorus treatment simulated by WinSLAMM for each alternative is summarized in Table 5 The higher performing alternatives for each watershed would each remove approximately 20,000 lbs of sediment and 50 lbs of phosphorus per year. The percent removal for the east watershed is lower than for the northwest and west watersheds, but the east watershed is much larger, and the pounds of pollutant removed is similar to the other watersheds. In combination, these practices could reduce to overall sediment and phosphorus loads to Warner Lagoon by approximately 29% and 23%, respectively (estimating loads for the 192 acres that is not included in the models for these 3 watersheds). Although this phosphorus reduction would be a substantial achievement, measured Total Phosphorus concentrations have been in the range of 200 – 400 ug/L, and the lagoon would likely still be highly eutrophic with the proposed treatment.

For the northwest watershed, the option to install only a forebay would reduce the sediment removal from 50% to 35%, but the cost per pound of pollutant removed would also be lower. The Castle Creek alternative with only floodplain restoration and no downstream wetland basin has a substantially poorer pollutant removal performance than the option with the wetland basin (6% vs. 21% particulate removal).

Observed release of dissolved phosphorus from stormwater ponds is getting considerable attention in the upper midwest.[1] Release appears to be driven by anoxia and internal release from sediment. Seasonal phosphorus release from stormwater wetlands has also been documented, but the wetland treatment literature generally indicates a net phosphorus trapping performance for stormwater treatment wetlands.

[1] http://stormwater.safl.umn.edu/updates-newsletters/updates-april-2018

Table 5. WinSLAMM results for stormwater treatment alternatives.

Proposed BMP	Estimated Cost[1]	Sediment Load (lbs)				Phosphorous Load (lbs)			
		Existing	Proposed	% Reduct.	$ / lb	Existing	Proposed	% Reduct.	$ / lb
Northwest Watershed									
Forebay only	$ 11,367	44,542	28,942	35%	$ 0.73	158.9	120.6	24%	$ 297
Wetland & forebay	$ 30,974	44,542	22,207	50%	$ 1.39	158.9	104.2	34%	$ 566
North Watershed									
New outlet structure	$ 22,183	34,069	13,255	61%	$ 1.07	123.9	74.3	40%	$ 447
East Watershed (Castle Creek)									
Sediment trap, wetland basin & narrow floodplain	$ 80,170	105,860	83,612	21%	$ 3.60	411.4	357.5	13%	$ 1,487
Sediment trap & wider floodplain	NA	105,860	99,721	6%	NA	411.4	397.6	3%	NA

[1] Estimated cost includes permitting and design, plus estimating contingency.

Stakeholder input was favorable for the treatment alternatives for the northwest and north outfalls, and for removing the concrete cunette on Castle Creek (including limited tree removal). No consensus was reached about constructing a wetland treatment basin at the mouth of Castle Creek, due to potential impacts on fishing opportunities and habitat. Although the option to restore a floodplain instead of constructing the wetland basin has lower predicted water quality performance, WinSLAMM is not designed to simulate stream-floodplain interactions and the simulations are therefore highly approximate. Floodplain restoration would have additional aesthetic and habitat benefits.

Flooding impacts of altering Castle Creek were screened with a simple HEC-RAS hydraulic model due to concerns about flooding in the Monterey Drive and Trailsway neighborhood. Simulations of discharges ranging from 50 cfs to 2000 cfs generally predicted slightly lower water surface elevations at the upstream end of the reach with the cunette for both alternatives than for existing conditions (Figure 12 and Figure 13). Although both alternatives include new structures in the downstream part of channel, the proposed floodplain apparently increases channel conveyance enough to compensate for those flow obstructions. If either alternative is pursued, this issue should be evaluated in more detail during permitting and final design.

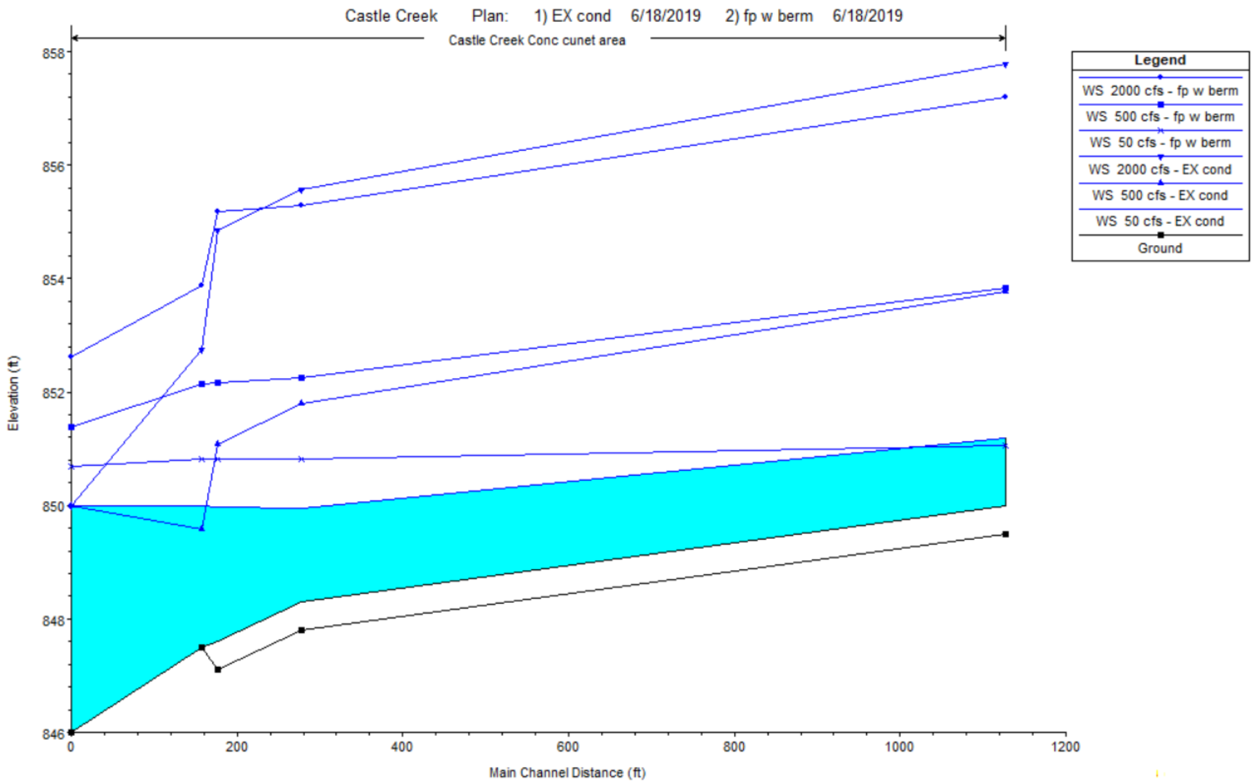


Figure 12. Hydraulic model profiles for existing conditions and treatment wetland alternative for Castle Creek.

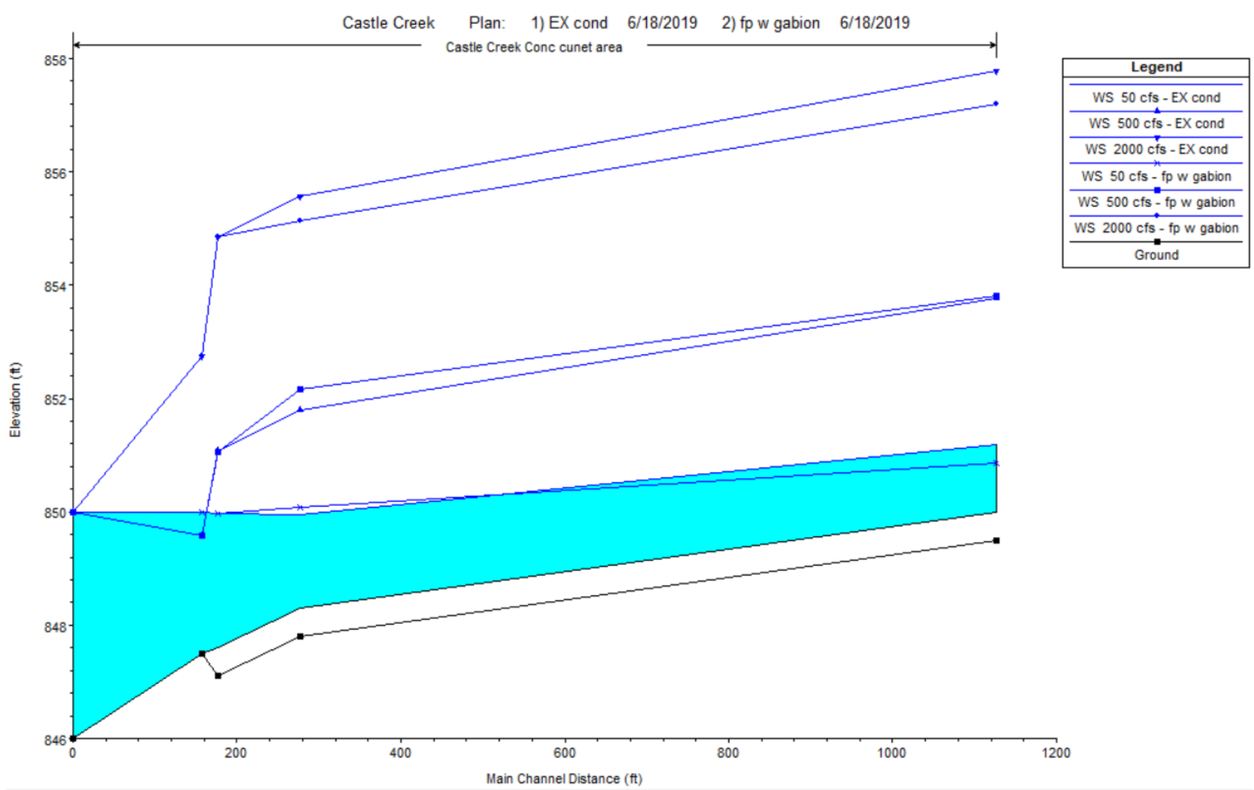


Figure 13. Hydraulic model profiles for existing conditions and floodplain restoration alternative for Castle Creek.

4.2.4. Cost

Estimated construction costs for the treatment wetland at the northwest outfall, the new outlet structure for the north outfall, the Castle Creek sediment trap, and the Castle Creek treatment wetland are $27,000, $18,000, $16,000 and $47,000, respectively (Table 6). Note that these are planning-level costs, and an opinion of probable cost should be developed in a future design phase. The total estimated cost to implement all 3 of these treatment practices is $135,000 including permitting and design and an estimating contingency, for a predicted reduction of 29% for sediment and 23% for phosphorus. Cost per pound of pollutant removed is included in Table 5.

Projects could be implemented separately, but there is some efficiency and synergy for constructing them together. This includes using soil cut from the Castle Creek sediment trap to construct the berm at the north outfall, and recycling crushed concrete from the Castle Creek cunette removal to build the core of berms in the lagoon for treatment wetland cells at one or more outfalls. Some rock import would still be needed if all of the proposed practices are constructed.

Table 6. Planning-level cost estimate for stormwater treatment.

No.	Item	Qty	Unit	Unit Price	Item Price
East Watershed Treatment Wetland & Channel Restoration					
1	Mobilization	1	LS	$ 1,500	$ 1,500
2	Type III trail barricades & signs	4	EA	$ 450	$ 1,800
3	Silt Curtain	100	LF	$ 10	$ 1,000
4	Clearing & grubbing	2.75	AC	$ 5,850	$ 16,088
5	Remove concrete cunette	1500	SY	$ 11	$ 16,575
6	Crush concrete and place rock berm core	60	CY	$ 15	$ 885
7	Excavation & short haul to fill areas/stockpile	712	CY	$ 4	$ 2,848
8	Use cut soil for fill for wetland grading	349	CY	$ 2	$ 698
9	Place soil on rock berm core at outlet	92	CY	$ 4	$ 367
10	Gabion outlet structure	1	EA	$ 4,200	$ 4,200
11	Spread stockpiled soil not used in other locations	86	CY	$ 2	$ 173
12	Fertilizer, seed and mulch on spread soil	518	SY	$ 2	$ 1,036
SUBTOTAL					**$ 47,169**
East Watershed Sediment Trap					
12	Mobilization	1	LS	$ 1,500	$ 1,500
13	Type III trail barricades & signs	2	EA	$ 450	$ 900
14	Erosion control	140	LF	$ 2	$ 280
15	Excavation	535	CY	$ 4	$ 2,140
16	Berm on E & S sides from cut soil	95	CY	$ 2	$ 190
17	Haul excess soil to N & NW outfalls	440	CY	$ 2	$ 880
18	Fertilizer, Seed and Mulch	1400	SY	$ 2	$ 2,800
19	Inlet flow splitter	1	LS	$ 2,000	$ 2,000
20	Inlet pipe (12")	60	LF	$ 45	$ 2,700

No.	Item	Qty	Unit	Unit Price	Item Price
21	Outlet pipe (6")	50	LF	$ 30	$ 1,500
22	Diversion RCP Manhole	1	EA	$ 1,400	$ 1,400
SUBTOTAL					**$ 16,290**
North Watershed Wetland Outlet Structure					
23	Mobilization	1	LS	$ 1,500	$ 1,500
24	Type III trail barricades & signs	3	EA	$ 450	$ 1,350
25	Timber mats	1	EA	$ 1,000	$ 1,000
26	Silt Curtain	175	LF	$ 10	$ 1,750
27	Crush concrete and place rockberm core	115	CY	$ 15	$ 1,696
28	Haul crushed concrete from Castle Cr	115	CY	$ 4	$ 460
29	Haul excess soil from East watershed	245	CY	$ 4	$ 980
30	Build berm with soil from East watershed	245	CY	$ 2	$ 490
31	Vegetate berm	2000	SF	$ 1	$ 2,000
32	Gabion basket outlet structure	1	EA	$ 4,200	$ 4,200
33	Turbidity Barrier	150	LF	$ 10	$ 1,500
34	Restore trail damage	1	LS	$ 500	$ 500
35	Reseed wetland areas at access point	1	LS	$ 500	$ 500
SUBTOTAL					**$ 17,926**
Northwest Watershed Treatment Wetland					
35	Mobilization	1	LS	$ 1,500	$ 1,500
36	Type III trail barricades & signs	2	EA	$ 450	$ 900
37	Timber mats	1	EA	$ 1,000	$ 1,000
38	Gabion outlet structure: 50 ft x 4 ft x 3 ft	22	CY	$ 156	$ 3,467
39	Dredge forebay	100	CY	$ 15	$ 1,500
40	Crush concrete and place rock berm core	182	CY	$ 15	$ 2,732
41	Import & place breaker run berm cores	143	CY	$ 33	$ 4,714
42	Haul excess soil from East watershed	380	CY	$ 4	$ 1,520
43	Import and place soil for berm	380	CY	$ 4	$ 1,520
44	Gabion wetland outlet	1	LS	$ 4,200	$ 4,200
45	Wetland seed / plug install	0.5	AC	$ 1,500	$ 750
46	Turbidity Barrier	300	LF	$ 10	$ 3,000
SUBTOTAL					**$ 26,803**
Combined Construction Cost					$ 108,188
Permitting & Design				10%	$ 10,819
Contingency				15%	$ 16,228
TOTAL ESTIMATED COST					**$ 135,236**

4.2.5. Implementation

Depending on the design of stormwater treatment practices, the Wisconsin DNR General Permit for Wetland Conservation Activities may be appropriate. Otherwise, a waterway Individual Permit may be required. Emphasizing restoration of native wetland communities in the designs would enhance their overall benefit to the lagoon and facilitate permitting.

In designing features, potential carp activity should be considered. It is possible that carp may be motivated to spawn in treatment wetlands. If so, having the ability to place a grate across the outlet structure to keep carp out, or to keep them in for trapping, would be advantageous. The future level of Lake Mendota should also be considered, as should normal seasonal and year-to-year lake level fluctuations. Treatment systems should be designed to be functional at a range of water levels, to the extent practical.

Monitoring dissolved oxygen and phosphorus in treatment practices is recommended to identify if dissolved P is being released from bottom sediments, and to help plan corrective actions.

Although beyond the scope of this study, pursuing watershed treatment opportunities to compliment structural practices in Warner Park makes sense. The City is currently evaluating street leaf collection to reduce dissolved phosphorus loading in fall.

4.3. Carp Removal

4.3.1. Rationale

Reducing the carp population in Warner Lagoon would reduce their disturbance of pond-bed sediment due to their feeding activity. This would produce clearer water and allow more aquatic macrophyte growth due to the clearer water and reduced physical disturbance. More macrophytes would provide better habitat for panfish, and macrophytes can improve water quality through their allelopathic suppression of algae blooms, nutrient uptake and mechanical filtering of sediment. To be effective, carp removal would need to be combined with a measure to reduce the ability of carp to re-enter the lagoon, such as a barrier between the lagoon and Lake Mendota.

4.3.2. Description

Literature suggests a carp biomass threshold of 100 kg/ha or 89 lbs/acre or less to achieve clear water and promote macrophyte establishment. The current carp biomass estimated by our sampling in October 2017 (Appendix A) is approximately 175 – 250 lbs/acre, based on an estimated weight of 6 lbs per carp.

Methods to remove carp include chemical treatment, commercial fishing, baited netting and public fishing. Chemical treatment kills all fish, including panfish and game fish, and it commonly invokes public concerns about toxicity. Commercial harvest has proven unreliable in the experience of the project team, and Warner Lagoon is too small a waterbody to be attractive to commercial fishing operators. Baited trap netting conducted by professionals is likely to be more reliable than commercial fishing. This employs a rectangular net that lies on the bed of the waterbody with sides that can be quickly raised to trap carp that congregate at cracked corn placed as bait (see Appendix

C for more details). Fishing by the public can help control the carp population and may be a viable part of long-term carp control, but it is unlikely to result in the large initial reduction in carp needed to meet the target biomass. Therefore, baited trap netting appears to be the most viable removal method.

4.3.3. Benefits and Impacts

Carp removal in Lake Wingra in the City of Madison in 2008 and 2009 lowered carp biomass by 51%, from 351 kg/ha to 172 kg/ha (Lin and Wu, 2013). Secchi disc measurements of water clarity increased by about half a meter or more after removal (Figure 14), and median Total Phosphorus concentrations dropped from 0.056 mg/L for 1996 - 2007 to 0.033 mg/L for 2008 - 2012 due to reduced blue-green algae and suspended sediment concentrations (Lathrop et al., 2013). This represents a 40% reduction in phosphorus concentrations. The increased water clarity allowed aquatic macrophytes to expand rapidly, primarily invasive Eurasian watermilfoil and native Coontail. This led to efforts to harvest aquatic plants to reduce impacts on sailing and motorized fish trolling. Native aquatic macrophytes other than Coontail have gradually expanded their populations, benefitting fish habitat with little impact on recreation (Lathrop et al., 2013). At Green Lake, macrophytes have re-established in much of the Silver Creek marsh after installation of a carp barrier.[2]

If carp removal from Warner Lagoon were to result in a phosphorus reduction comparable to the 40% reduction in Lake Wingra, that would greatly complement the 29% phosphorus load reduction predicted for the stormwater treatment practices and presumably lead to a notable improvement in the trophic state of the lagoon.

A netting effort would produce a temporary disturbance to wildlife and recreation in the lagoon, and it would be a highly visible operation. This could provide an opportunity to provide public outreach on the relationships between carp, habitat and water quality.

Stakeholders reached a consensus that carp removal is desirable for the fishery and overall lagoon habitat.

[2] Charlie Marks, Green Lake Sanitary District, personal communication, December 2018.

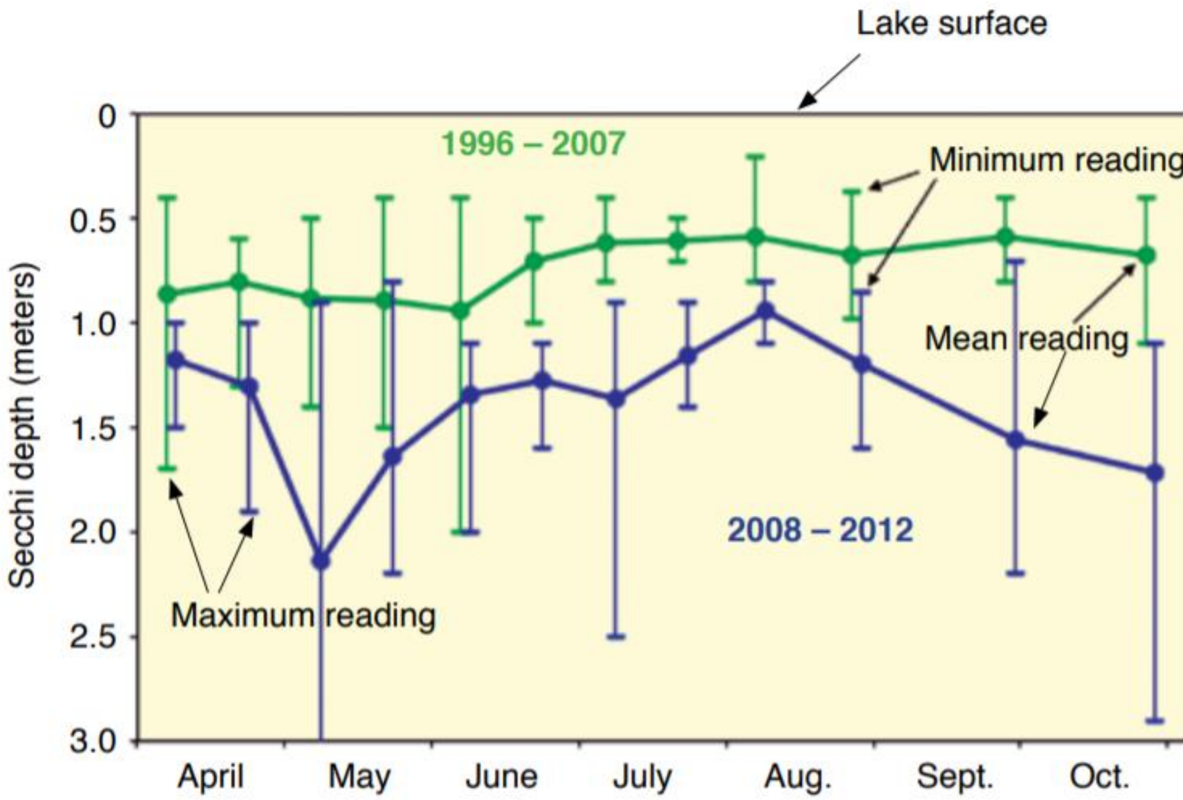


Figure 14. Secchi disc transparency before and after 2008 carp removal.

4.3.4. Cost

The refined carp population and biomass estimate to calculate the number of fish that need to be removed from the lagoon would cost approximately $1500. A proposal for a baited trap netting demonstration project from Carp Solutions (Appendix C) estimates the cost at approximately $13,000 - $20,000. A typical cost for commercial harvest is $5000 for the initial effort, but experience suggests that repeated efforts would be necessary. In addition, the catch would be small enough that commercial operators probably would not be interested in the project. Partnering with Dane County to extend the trap netting to other waterbodies and share costs is recommended.

4.3.5. Implementation

Permitting baited trap netting would require a cooperative agreement between the City of Madison and the Wisconsin Department of Natural Resources to allow a contractor to perform trapping for the City. DNR fisheries biologist Dan Ole has arranged such an agreement with Dane County for carp control at Indian Lake County Park and can provide a template for an agreement. This agreement would apply if the fish that are caught are donated to charity or disposed of but would not apply if the City wishes to recoup a commercial value for the fish. The DNR Water Management

Specialist (currently Wendy Peich) should be consulted to determine if a miscellaneous structure permit is needed or can be waived for temporary placement of traps, depending on the details proposed by the operator.

Additional data collection to better quantify the current carp biomass is recommended to more precisely calculate the number of fish that need to be removed to reach the target of 100 lbs/acre for the lagoon. This would entail netting and marking 250 to 300 carp over one week then recapturing fish by electroshocking to check markings to estimate the number of carp in the lagoon. Measured weights of captured fish would be used to estimate an average weight per carp and compute the number of carp that need to be removed to achieve the target biomass. Contractors can then use this information for cost estimation and planning removal method details.

Some future trapping to maintain the target carp biomass in the lagoon can be expected, given the tendency for carp to learn net avoidance and recruit robustly when densities are reduced. This could be performed by a contractor, but volunteers may also be able to assist with small-scale trapping efforts. For example, using the inlets to the north and south of the park shelter as traps is possible. This occurred in an unplanned incident in the past when a water line for a skating rink was left running in winter, and the fresh water lured a dense concentration of carp into one of the inlets.

4.4. Carp Exclusion

4.4.1. Rationale

Carp exclusion would work in tandem with carp removal described in Section 4.2, to help maintain the target carp biomass after the initial removal effort. The goal would be to keep adult carp out of the lagoon during the spring spawning period during April, May and/or June, depending on weather conditions. It is possible that a barrier may only be needed for a few years, until the panfish population in the lagoon is established enough to effectively prey on young carp.

4.4.2. Description

Barriers to block carp migration but pass flowing water include physical grates, bubble curtains, and electrical barriers. A metal grate was previously in-place but proved difficult to remove and was damaged by debris-removal activities. Bubble curtains use injected air to create a visual and sonic barrier while allowing water, boats and debris to pass. However, bubble curtain effectiveness reported in the literature and at Green Lake is mixed, with a reported effectiveness of approximately 15% - 75% (e.g. Zielinski and Sorensen, 2015 and 2016). In addition, boat passage between Lake Mendota and Warner Lagoon is not an issue because the Woodward Drive culvert blocks watercraft passage. Electrical barriers are still somewhat experimental and very expensive. A simple grate would be the most reliable option if the previous maintenance issues can be addressed.

The previous barrier was located immediately downstream of Woodward Dr. Wind-blown debris from Lake Mendota frequently clogged the barrier, and beavers tended to build dams at the barrier.

Heavy equipment used to clean the barrier damaged the grate, making it virtually impossible to remove regularly. An alternative location is at the downstream end of the outlet channel, at Lake Mendota shoreline which would be less attractive to beavers. A barrier inside the Woodward Drive box culvert would be better protected from damage by debris removal with heavy equipment, but it would be more difficult to access for maintenance and much more expensive to install because it would require cutting into the street and box culvert. Placement between Woodward Drive and the railroad track immediately upstream is not currently an option, because that area is on the railroad right-of-way. The upstream side of the railroad is inaccessible for maintenance, other than by boat, and therefore is not a practical barrier location.

A barrier location near the mouth of the outlet channel close to the Lake Mendota shoreline appears most practical (Appendix B Sheet 1). In addition to being less attractive to beavers, there is more room for debris clearing and other maintenance on both the upstream and downstream sides of the barrier. It would also help to have a barrier that is easier to install and remove for seasonal placement (reducing the time the barrier is in-place and subject to debris clogging) and barrier construction that allows easier disassembly for debris removal and repairs. One option is a grate constructed of PVC pipe on a wooden structure, rather than a metal grate (Figure 15). In addition, a second barrier such as a floating boom designed to collect debris could be placed between the carp barrier and the lake. If grate placement is necessary for the long term and debris clogging is a persistent issue, City staff indicated that re-aligning the channel between Woodward Drive and Lake Mendota could be possible to orient the mouth of the channel such that debris would be less likely to be blown up the channel to the barrier.

A barrier would only need to be in-place to block carp migration during their spring spawning season. Migration into spawning areas typically occurs over a few weeks in April and/or May, triggered by water temperatures in the lake and spawning area. The carp move into the lagoon seeking warmer water, and the lagoon warms up faster than the lake. Barrier placement could use either of the following strategies:

1. *Temperature-Dependent*: Place the barrier when the water temperature in the lagoon is more than 5 degrees higher than the Lake Mendota temperature, and remove it when the difference is less than 5 degrees.
2. *Fixed Schedule*: Place from April 1 –July 4 each year. A standard period is easier for crews to plan and implement. The barrier would be in-place longer than for option 1, but there would be less likelihood of missing the carp migration into the lagoon.

Figure 15. Lightweight carp barrier grate.

(From Carp Solutions)

4.4.3. Benefits and Impacts

A barrier grate would block adult carp passage into the lagoon, which would minimize the disturbance that carp spawning causes in spring. Juvenile carp could still pass through the barrier, but they do not have the same motivation to enter the lagoon as spawning adults do. This strikes a balance between reducing carp use of the lagoon and allowing panfish to continue to migrate between the lake and lagoon. Complete blockage of fish passage would theoretically eliminate carp entry, but it would prevent panfish in Lake Mendota from replenishing the population in the lagoon. In addition, the outlet channel is a popular fishing spot during spring when panfish migrate into the lagoon. Complete blockage would also limit circulation of water from Lake Mendota into the lagoon, which may have some water quality benefit in the western part of the lagoon (Marshall, 2014).

Depending on the barrier placement and construction, it is possible that fish could swim around it at times of very high water. However, even during the extremely high lake stages in 2018, water was confined within the banks of the outlet channel (Figure 16). Thus, it appears feasible to construct a barrier in the outlet channel with minimal risk of being bypassed.

Figure 16. Warner Lagoon outlet channel.

(Photographed on November 5, 2018 at high when Lake Mendota stage.)

A barrier would require maintenance by City staff and/or volunteers. It would need to be placed each spring and removed during the summer. With the lightweight design described above, this could be accomplished without heavy equipment.

Stakeholders noted that the Lake Mendota shoreline is a popular fishing location, and that it would be desirable for the barrier and any debris blocking structure to minimize loss of shore fishing locations.

4.4.4. Cost

A preliminary estimate from Carp Solutions is $10,000 or less for construction and installation of a grate made of PVC pipe on a wooden framework. Annual maintenance would require staff labor to place and remove the barrier and to clear debris as needed during the 2-3 months it was in-place. Minor cost to repair or replace damaged parts of the barrier can also be expected.

4.4.5. Implementation

The experience of DNR fisheries staff at Green Lake has been that a grate opening of 1 $^{7}/_{16}$ inches blocks passage of mature carp, while 2-inch openings allow passage of carp up to 20 inches of both sexes.[3] The original barrier at Warner Lagoon had openings of 2.75 inches, which blocked larger adults.

The barrier should be simple to install and maintain. In addition to the lightweight commercial design in Figure 15, City staff could develop a custom design with a removable section in stoplog-style channels or a gated section that swings open for debris clearing. A tight fit to the streambed using a hard sill, bars embedded into the sediment or a chain-weighted sleeve hung from the bottom of the barrier would be needed to prevent carp from burrowing underneath the barrier.

A waterway permit from the Wisconsin Department of Natural Resources (WDNR) would be required by Ch. 30 of the Wisconsin Statutes to place the barrier structure on the bed of the outlet channel. Based on a discussion with Kathi Kramasz of the WDNR, the permit would likely be an Individual Permit for miscellaneous structures. This permit process typically takes several months or more and requires documentation of the need for the structure and potential alternatives, as well as a public notice period. Given the goals of the project, it is likely that the WDNR would generally be supportive of the project.

Volunteers could assist with barrier management and carp control by observing the barrier regularly to detect problems with debris and notify City staff when maintenance is required.

4.5. Aeration

4.5.1. Rationale

The primary goal for an aeration system would be to maintain enough dissolved oxygen in the lagoon below winter ice cover to allow panfish to survive the winter. Aeration would also have a benefit in summer by reducing anoxic conditions that lead to release of dissolved phosphorus from the lagoon sediment, especially if dredging is implemented to create one or more deep holes.

4.5.2. Description

Aeration options include compressed air diffusers placed on the lagoon bed that bubble air from a blower on the shore, floating aspirators that aerate the water surface, cascade systems that pump water over a series of drops to entrain air, and systems that spray water into the air for aeration.

Many commercial diffuser systems are available and suitable for this application. The diffuser and air lines would be underwater, and the blower would be housed in a small enclosure on the shore. Electrical power could be provided by solar photo-voltaic cells during summer and winter conditions when panels are not snow covered, with a connection to the electrical grid as a backup supply.

A cascade system would need to be placed on the shoreline of the lagoon, where water could be pumped from the lagoon and descend through the cascade back into the lagoon. Although this

[3] Scott Bunde, WDNR, written communication, November 11, 2018.

could be a visually interesting feature, its accessibility would create a greater safety hazard, especially in winter. In addition, it would be less feasible to aerate the deepest water area with a system on the shoreline.

Aspirator and fountain systems can be effective, but their high visibility and water surface disturbance are probably not suitable for the natural setting of Warner Lagoon.

A single aeration location would be sufficient to provide a refuge for fish in low dissolved oxygen conditions. It makes sense to aerate a deep hole to provide the maximum area for fish refuge and to alleviate anoxia-driven phosphorus releases. Multiple aerators may be desirable to reduce internal phosphorus loading if more than one deep hole is dredged.

Operation would be as needed, based on dissolved oxygen measurements. Experience at Indian Lake County Park has been that aeration is not required in all winters, depending on the amount of ice and snow cover.[4]

An important consideration for any aeration system is that it typically creates an ice-free or thin-ice zone due to the disturbance of the water surface. This creates a safety hazard that requires fencing or other protection for public safety. At Indian Lake, snow fencing is placed on the ice around the perimeter of the thin-ice zone at the beginning of each winter, and it has to be retrieved from the water after the ice melts in the spring.

4.5.3. Benefits and Impacts

Mechanical aeration systems present the trade-off of between introducing mechanical equipment into a natural setting and creating a winter thin-ice hazard versus providing insurance that the fishery will be able to survive through the winter. Stakeholders had differing opinions on the merits of aeration. The experience of the fisheries biologists on the project team and with the DNR is that aeration is probably necessary to ensure fish survival, and that an aeration system can serve as an insurance policy on investments in the lagoon habitat. One stakeholder suggested that dredging a deep hole to a depth of 15 ft would be sufficient to maintain dissolved oxygen levels based on experience in other parts of Wisconsin. However, winter dissolved oxygen levels are a function of the oxygen demand of the bottom sediment, the amount of sunlight that can pass through the ice, and flow from surface water or groundwater. Essentially no surface water flows through the lagoon in winter except during melt periods, and there is no indication of enough groundwater discharge into the lagoon to maintain dissolved oxygen – although increasing the water depth and dredging through fine bottom sediment could draw in more groundwater.

Other stakeholders were concerned about the thin-ice safety hazard and potential conflicts with ice skating, as well as the introduction of a mechanical system into this natural area. As noted above, fencing would be needed for public safety. A location away from the park shelter and most heavily used skating area would reduce but not eliminate impacts on skating.

[4] Dick Black, Dane County Parks Department, personal communication, 2018.

As noted above, our measurements found high dissolved oxygen levels below ice that had been plowed of snow for ice skating. This is a common observation on ice-covered lakes. Theoretically, plowing snow from the ice could be a substitute for an aeration system, but some periods of snow cover would have ice too thin to safely plow, and some ice is quite dark and does not pass much sunlight. Thus, any snow plowing for skating may benefit dissolved oxygen levels but would not be a reliable way to maintain consistent dissolved oxygen throughout the winter.

4.5.4. Cost

Based on the experience at Indian Lake County Park and at Lake Belle View in Belleville, Wisconsin, a compressed air system with a diffuser on the lagoon bed supplied by solar cells and an electrical grid backup power supply would have a capital cost of $5,000 - $10,000. Electrical cost when powered by the grid is typically $50-100/month.

4.5.5. Implementation

A waterway Individual Permit for a miscellaneous structure would be required by the Wisconsin Department of Natural Resources (WDNR) under Ch. 30 of the Wisconsin Statutes to place aeration equipment on the bed of the lagoon.

Given the tradeoffs involved in aeration, it makes sense to proceed with caution. If dredging occurs, dissolved oxygen monitoring would help determine if the increased water depth alone is sufficient for winter fish survival and if anoxia that could cause phosphorus releases from sediment occurs in summer. Note that one winter of monitoring may not be enough to determine whether aeration is needed in the long term, since some winters may not experience very low dissolved oxygen. Given the modest cost of an aeration system and the high likelihood that it will be needed, one option is to install a system in case it is needed but to operate it only when dissolved oxygen monitoring indicates it is necessary.

4.6. In-Lagoon Chemical Treatment

4.6.1. Rationale

Waterbodies can be treated with aluminum sulfate (alum) or other coagulant compounds to cause flocculation and settling of sediment and phosphorus. This can at least temporarily improve water quality. For Warner Lagoon where stormwater inflows would require repeated applications, the most feasible use of chemical treatment might be as a short-term measure to enhance water clarity and help establish aquatic macrophytes, if carp control and stormwater outfall treatment are not sufficient to do so.

4.6.2. Description

For lakes, chemicals are commonly applied to the water surface by boat (Figure 17), and improved water clarity can be observed shortly afterward.

In stormwater-driven systems with more rapid throughflow, the benefits of a single treatment can be quickly negated. Automated dosing systems can be constructed to apply chemicals during runoff events, and the City has experimented with such a system at the Marion Dunn Pond on Monroe Street. Such a system requires a large investment in infrastructure, chemicals and labor. WILMS modeling of Warner Lagoon indicates that the water in the lagoon is flushed out 4 - 5 times per year, so repeated chemical dosing would be required.

Figure 17. Coagulant application at Autumn Lake, Madison, WI.

4.6.3. Benefits and Impacts

The City's experience with the Marion Dunn Pond pilot project was that alum caused a rotten egg odor and foam on the water surface, and that water quality improvement was difficult to determine. The real-time dosing system was difficult to operate and maintain. In addition, the sulfate in alum is known to increase methylation of mercury, posing a risk of slightly higher mercury concentrations in fish. Alternative aluminum-based coagulants that contain no sulphates can be used to avoid mercury release from sediments.

Ultra-low dose alum systems are being tested in Minnesota. These systems produce no floc to accumulate on the bed of a waterbody but still require equipment to provide ongoing dosing. These systems are experimental - could prove to be a viable strategy in the future.

Given the complications and expense of chemical treatment, this does not generally appear to be a viable strategy for Warner Lagoon. An exception, as noted above, is a one-time dose to complement carp control and stormwater outfall retrofits to increase water clarity long enough to allow aquatic macrophytes to establish.

4.6.4. Cost

A one-time dose applied to the lagoon by boat would cost an estimated $30,000, based on our experience at Autumn Lake in the City of Madison.

Continuous dosing systems are far more expensive. The Marion Dunn pond dosing system (for a much smaller water body) required constructing a building and about $180,000 of equipment. The cost of City's Starkweather Cr. chemical treatment project is estimated at $5.5 million for construction and $350,000 annual operation and maintenance (Brown and Caldwell, 2016). Note that the watershed area for that system is approximately 5400 ac, about 10 times the watershed area for Warner Lagoon. There are many differences between the Starkweather Creek system and a potential system at Warner Lagoon, but this comparison illustrates the high cost of ongoing chemical treatment.

4.6.5. Implementation

We recommend waiting until after implementation and evaluation of other water quality improvement measures discussed above before proceeding with chemical treatment. If it is needed, a next step would be to consult with a chemical treatment expert to scope a treatment project. This would likely include additional water quality sampling from the lagoon, laboratory jar tests of treatment effectiveness, and setting targets for water quality improvements.

4.7. Dredging

4.7.1. Rationale

The purpose of dredging would be to increase the variety of fish habitat by creating one or more deeper water areas. If the lagoon can successfully be converted to a clear water state with abundant aquatic macrophytes, an area dredged to more than 10 ft would be deeper than rooted plants will grow and provide an open water surface for fishing. The increased depth would also enhance winter survival of fish, at least in combination with an aeration system.

4.7.2. Description

The extent of dredging that could be conducted at Warner Lagoon depends on available funding, the volume of dredge spoils that can be accommodated in different parts of the park, the desire to avoid disturbance of quality habitat and conflicts with ice skating near the park shelter. In addition, limiting the dredged area to maintain abundant aquatic macrophyte beds would also be important for pan fish habitat and water quality benefits. Two different dredging concepts were developed to illustrate possibilities and estimate costs (Appendix B Sheets 1, 6 and 7). Actual dredging extent could be less than or more than either option shown here.

Each concept includes two separate deep holes, based on stakeholder feedback. One area would deepen the area offshore from the park shelter, which currently has the deepest water in the lagoon at about 6 ft. A second area could be dredged immediate west of “Firebird Island”, a popular shore fishing area that could be improved with increased water depth.

In each deep hole, water depth would be increased to 15 feet. Gentle side slopes would be required in dredged areas to reduce sloughing of sediment back into the deep hole. Based on experience with past projects, we assumed 5:1 slopes. Geotechnical data is needed on the nature of the sediment to better predict stable slope angles. Based on stakeholder feedback, the dredge areas shown on Appendix B Sheet 1 maintain a setback of at 30 – 50 ft from the island to avoid impacts to its shoreline habitat, , and at least 100 ft from the shoreline near the shelter to help reduce conflicts between ice skaters and ice fishers, who would be drawn to the deep hole.

Options for spoils disposal have a major impact on how much dredging is feasible. They include upland dewatering and re-use, using dredge spoils to create new wetland habitat within the lagoon, and hauling off-site. The latter option was deemed prohibitively expensive by City staff and the consultant team for all but very small quantities.

Upland spoils placement is possible if contaminants in the sediment meet DNR standards. If contaminants exceed these standards, hauling sediment to a licensed disposal facility would be required. Given the urban land use in the watershed, it is likely that moderate contaminant levels are present in the sediment and that the DNR will require burying the spoils to avoid human contact. This would require cutting existing soil and spreading it over the spoils once they are dewatered. Dewatering would be accomplished in a temporary containment area to control release of water and sediment, either an area surrounded by a constructed berm with a sediment trap outlet or in geotextile bags (for hydraulic dredging). Dewatering commonly takes several months or more. Several upland spoils locations were evaluated and discussed with stakeholders, including various athletic fields, the dog park, and the hill immediately south of the dog park. Parks staff concluded that the only viable location at this time is in the northern part of the park on athletic fields west of the Warner Park Community Center. This area has potential to store 47,000 cubic yards of spoils that would be graded to improve drainage and reduce the steep longitudinal slope of the existing soccer fields (Appendix B Sheet 9). However, much of this area has mapped wetland indicator soils (Figure 18), and the presence of wetlands could limit the amount of spoils that could be placed there.

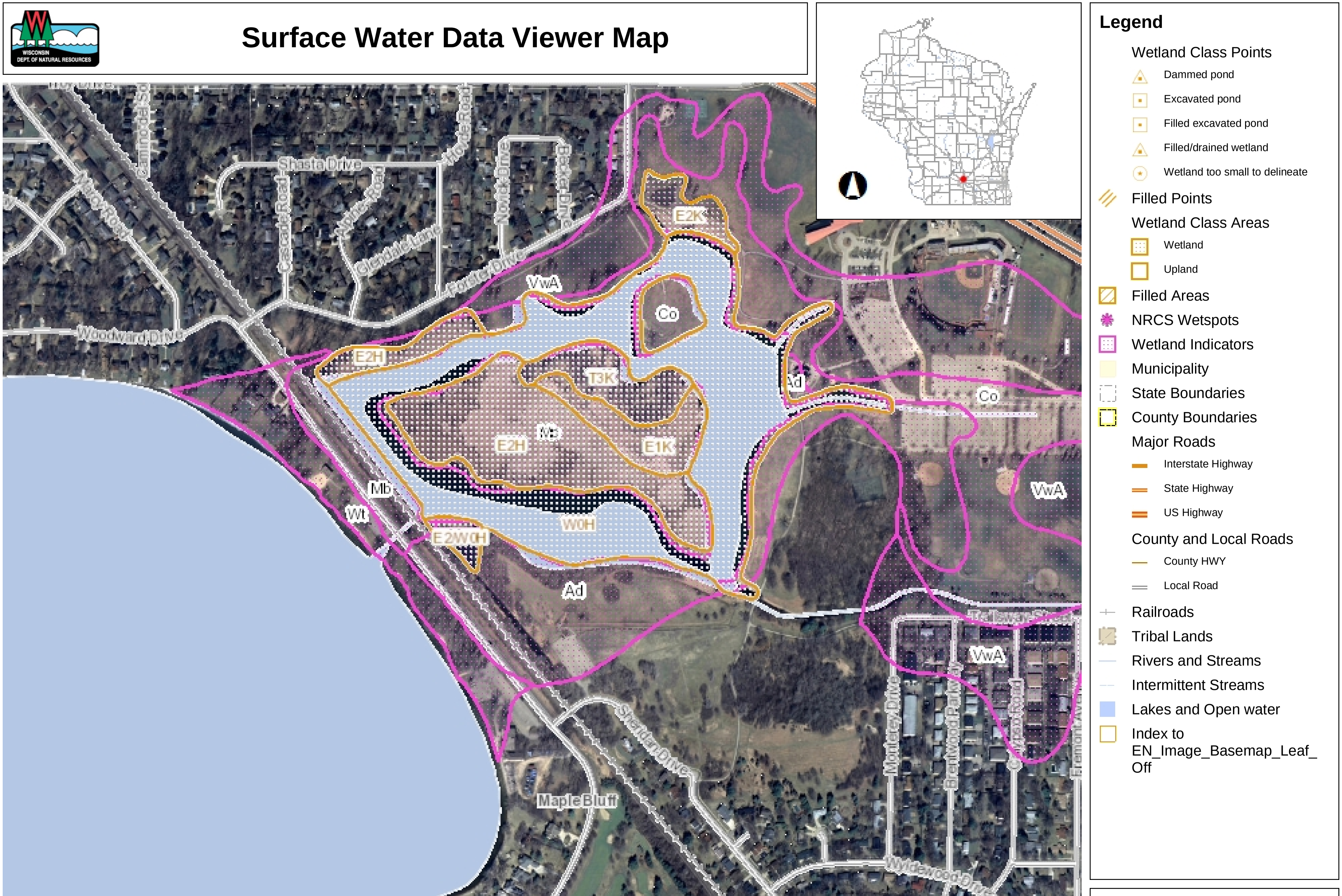
Another option is to use the spoils to create new wetlands in the northwest corner of the lagoon (Appendix B Sheet 1). This would entail using spoils to partially fill a part of the lagoon that currently has water depths of 3-4 ft and little aquatic vegetation (Figure 19). Similar projects have been completed at Lake Belle View in Belleville, Wisconsin (Figure 20) and at Lake Koshkonong. New water depths would be 6-18 inches, and emergent marsh vegetation would be established on the spoils. A practical vegetation establishment plan would be to allow cattails to rapidly colonize most of the spoils to help stabilize them and planting some stands of river bulrush and possibly other native species that can compete with cattails. Over time, cattails can be removed manually to expand the bulrush stands – a project well suited to volunteer labor. In-lagoon placement of spoils would require containment structures at the east and southwest ends of the fill section to prevent the spoils from sloughing away. Rock rip rap has been used for this purpose in other locations, but bio-engineered containment may be more compatible with the habitat of Warner Lagoon, easier to place in areas inaccessible to heavy equipment, and less expensive. This spoils placement option could store approximately 19,000 cubic yards of spoils. Fill placement could impact some existing cattails along the shoreline, and the sedge meadow on western end of the island should be protected from impacts by the fill.

The extent of dredging shown for Option 1 would completely fill the in-lagoon spoils area in the northwest corner of the lagoon. Alternatively, that volume would fill slightly less than half of the upland spoils area shown on Appendix B Sheet 9. The larger dredging Option 2 would completely fill the upland spoils area. Or that volume of spoils could be accommodated in a combination of the two areas if the capacity of the upland area is reduced by wetland constraints.

Either hydraulic or mechanical dredging methods could potentially be used for this project. An advantage of hydraulic dredging is the ability to access the lagoon at one location and move around dredging areas on boats and/or barges. Since the lagoon cannot be drawn down, mechanical excavating equipment would need to work from the shoreline, temporary access roads that were built in the water and removed after the project is completed, or floating platforms.

The location of the spoils disposal area will factor into the relative feasibility of hydraulic and mechanical dredging. For hydraulic dredging, a slurry of sediment and water would be pumped from the lagoon through a temporary pipeline to the disposal area. Hydraulic dredging would be very well suited to the marsh creation option, because the spoils would not require dewatering and the pipeline could discharge into the lagoon with less impact than mechanical equipment. Upland spoils placement would require extensive dewatering of the very wet spoils. Mechanical dredging would entail hauling spoils in dump trucks, resulting in extensive heavy truck traffic between the lagoon and the spoils placement area. However, the spoils would be likely have a lower water content than for hydraulic dredging, somewhat simplifying dewatering.

Surface Water Data Viewer Map



0.3 0 0.13 0.3 Miles

NAD_1983_HARN_Wisconsin_TM

1: 7,920

Figure 18. Wetlands and wetland indicator soils.

Figure 19. Potential spoils fill area for marsh creation.

(Photography by Edge Consulting Engineers, Inc., 2018)

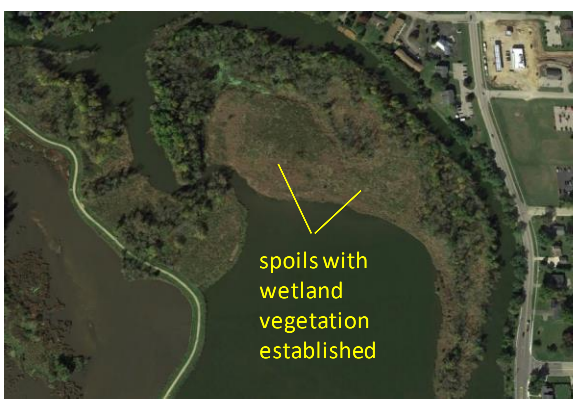


Figure 20. Lake Belle View dredge spoils restoration.

(Top left: Preconstruction ca. 2009. Top right: Post-construction 2011. Bottom: 2018 Google Earth image.)

4.7.3. Benefits and Impacts

Dredging one or more deep holes would improve the diversity of the fishery and enhance recreational fishing opportunities. For in-water spoils placement, creation of new wetland habitat where there is currently open water could also be beneficial: however, stakeholder opinions were very mixed about whether this would be an enhancement to the lagoon or a detrimental impact to existing habitat.

Dredging would cause significant temporary impacts to Warner Park, because it involves a large construction project taking weeks or months to complete. For upland spoils placement, that area would not be usable for normal park activities for a year or more. Geotechnical data on the lagoon sediment is needed to determine if the lagoon sediment would provide the structure and drainage that is desirable for athletic fields, and if contaminant levels are allowable for placement in the park.

4.7.4. Cost

The cost estimates shown below (Tables 7 and 8) provide perspective on potential costs and illustrate the different factors that affect dredging cost. Actual costs will depend on the extent of dredging, location of spoils disposal, contractor bid prices which are typically highly variable, and numerous other factors. The cost estimates for the two dredging options assume different spoils disposal areas and dredging methods to illustrate the different bid items for these different approaches. However, both dredging extents could use either spoils location or dredging method.

The smaller Option 1 assumes dredging 19,000 CY and using spoils to create marsh habitat in the northwest corner of the lagoon. It assumes hydraulic dredging because that is the most likely method to be used for this spoils placement option. Larger dredge Option 2 assumes cutting 44,000 CY and placing spoils on the athletic field west of the Community Center. It assumes mechanical dredging and truck hauling to illustrate different project elements.

The unit price per cubic yard of dredged sediment is the largest factor affecting overall cost, and this line item is about 70% of the cost estimates below. This rate is typically highly variable between different contractor bids, depending on the current marketplace, dredging methods proposed by the contractor, and other factors. Hydraulic and mechanical dredging can have similar costs depending on the details of a particular project. The cost per cubic yard of sediment dredged estimated for the two options is very similar in spite of the different assumptions about methods and spoils locations.

Table 7. Planning-level cost estimate for dredging option 1.

Item	Description	Quantity	Unit	Unit Price	Estimated Cost
1	Mobilization	1	LS	$20,000	$20,000
2	Type III trail barricades and signs	4	EA	$450	$1,800
3	Timber mats for pond access	1	EA	$1,000	$1,000
6	Silt curtain	300	LF	$10	$3,000
7	Clearing trees >4"	0	EA	$20	$0
8	Construct containment area with breaker run rock [1]	300	CY	$39	$11,600
9	Dredge & pump to marsh restoration area	19,100	CY	**$20**	$382,000
10	Spoils restoration: native seed / plugs	3.5	AC	$2,000.00	$7,000
11	Initial growing season maintenance	3.5	AC	$1,000.00	$3,500
12	Restore shoreline trails	1	LS	$1,000.00	$1,000
13	Reseed wetlands impacted by pond access	1	EA	$500.00	$500
Subtotal					$431,400
Permitting & Design				10%	$43,140
Contingency				15%	$64,710
Total Estimated Cost with Contingency					**$539,250**
Cost per cubic yard dredged					$28

[1] Spoils containment could also be constructed with bio-engineered materials, rather than rock.

Table 8. Planning-level cost estimate for dredging option 2.

Item	Description	Quantity	Unit	Unit Price	Estimated Cost
1	Mobilization	1	LS	$20,000	$20,000
2	Type III trail barricades and signs	4	EA	$450	$1,800
3	Timber mats for pond access	1	EA	$1,000	$1,000
4	Perimeter erosion control: install, maintain & remove	500	LF	$2	$1,000
5	Haul road: construction, removal & restoration	1	LS	$11,294	$11,300
6	Silt curtain	500	LF	$10	$5,000
7	Construct containment area: strip 6" top soil, build berm & sediment trap [1]	1,704	CY	$6	$10,200
8	Seed & mulch berm stabilzation	4,856	SY	$1	$4,900
9	Stone weeper	1	EA	$300	$300
10	Dredge and haul to upland spoils area	44,000	CY	**$20**	$880,000
11	Rough grading of dewatering spoils	44,000	CY	$2	$88,000
12	Fine grading of spoils area	23,615	SY	$1	$23,600
13	Place salvaged topsoil	1,704	CY	$3	$5,100
14	Spoils restoration: no mow seed & mulch	25,977	SY	$1	$26,000
15	Restore trails	1	LS	$1,000	$1,000
16	Reseed wetlands impacted by pond access	1	EA	$500	$500
Subtotal					$1,079,700
Permitting & design				10%	
Contingency				15%	
Estimated Cost with 20% Contingency					**$1,295,600**
Cost per cubic yard dredged					$29

[1] If burying spoils is required due to contaminant concentrations, earthwork cost would increase.

4.7.5. Implementation

A WDNR dredging Individual Permit would be required for dredging, plus approval from the U.S. Army Corps of Engineers. Future maintenance dredging in the same area could be eligible for a streamlined general permit. Dredging permits consider the benefits of dredging, environmental impacts of the dredging and equipment access, and the impacts of the proposed spoils disposal. Individual permits have been successfully obtained for many dredging projects, but they typically require months of work and design modifications to satisfy environmental constraints.

Sediment samples will have to be collected from the proposed dredge area and tested for contaminants, based on the WDNR guidance document "Sediment Sampling and Analyses for Dredging Permit Application and Approval". If the spoils qualify as a hazardous waste, disposal in a licensed landfill could be the only option; this is not likely based on the lack of upstream industries and the large watershed area that would dilute potential contaminants but will need to be confirmed. No samples have been tested for this purpose yet. In addition, geotechnical data from sediment samples will help determine if and how spoils can be successfully integrated into athletic fields.

A DNR Interstitial and Carriage Water general permit would also be required for upland spoils dewatering areas. This permit includes requirements for the construction of a containment berm, outlet for drainage of water away from the spoils, and sampling of the drainage water for Total Suspended Solids.

Using the spoils to create new wetlands potentially could be approved as part of the dredging Individual Permit, according to Dane County Water Management Specialist Wendy Peich. Placement of dredge spoils on a the bed of a waterbody would likely require greater permitting effort than for upland disposal, given regulatory concerns over placement of fill in waters of the state. The DNR and the Corps would evaluate the potential benefits of wetland creation, potential environmental impacts, and likelihood of success.

City and community funding sources would be needed to support this project. The DNR has not funded dredging projects for many years, due to the environmental concerns and the typical short life span of projects. Given the benefits to the community and enthusiasm of stakeholders, there is potential to raise substantial funds for a dredging project.

4.8. In-Lagoon Diversion

An idea discussed with stakeholders is diversion of stormwater inflows away from parts of the lagoon to reduce sediment and phosphorus loads to those areas. For example, if deep holes are dredged, stormwater inflows could be diverted away from those areas.

Effective diversion would require physically separating portions of the lagoon to direct stormwater into some areas and away from others using berms or other structures. This is counter to ecological connectivity and recreational uses of the lagoon. In addition, this would reduce the volume of the lagoon through which stormwater would flow, decreasing the amount of settling that would occur before discharge to Lake Mendota. Therefore, sediment and nutrient inputs to Lake Mendota would probably increase. This concept does not appear worth pursuing at Warner Lagoon.

4.9. Additional Habitat Improvements

Improving water quality, reducing the carp population, and allowing aquatic macrophytes to establish would provide substantial benefit to habitat in Warner Lagoon. Simple tree drop structures could be added to provide cover for fish and basking logs for turtles. These features entail placing a fallen tree or log in the water at the shoreline and anchoring it via cables to a live tree. Approval for tree drops is through a DNR general permit. Caution should be exercised in avoiding placing tree drops in areas that could be used in the future for trap netting of carp, since nets can get tangled on branches.

Bluegill spawning habitat could be enhanced by placement of small gravel beds on the bed of the lagoon. Bluegills probably already use sand and gravel deposits below stormwater outfalls now, so this addition may not be necessary. This is an option to consider in the future if lack of spawning habitat appears to limit the panfish population.

5. CONCLUSIONS AND RECOMMENDATIONS

The recommendations described above form an integrated strategy to improve water quality and habitat in Warner Lagoon. Constructing treating practices at stormwater outfalls would reduce sediment and pollutant loads to the lagoon, and the wetland treatment systems described above would enhance habitat in the park. Reducing the carp population would reduce re-suspension of phosphorus-rich sediment and improve water clarity. Clearer water would promote growth of aquatic macrophytes, which benefit pan fish habitat and water quality. More macrophyte growth would improve the function of the proposed stormwater treatment wetlands.

These concepts could be implemented in small steps, for example starting with retrofitting one or more stormwater outfalls and/or trapping carp and installing a barrier between the lagoon and Lake Mendota. Dredging may take more time to implement due to its higher cost and the technical and regulator issues that need to be resolved.

We understand that a next step will be to hold a public meeting to summarize these alternatives and gather input. This should help focus priorities and an action plan.

Finding ways to engage the active volunteer community at Warner Park would make these projects more successful. These could include native vegetation establishment and maintenance, carp control, and monitoring water quality and water depth in the lagoon to help evaluate the effectiveness of actions that are implemented.

6. REFERENCES

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APPENDIX A. OCTOBER 2017 FISH SURVEY

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Fisheries Survey Summary

Warner lagoon

October 2, 2017

Background / Reference

On October 2, 2017, a standard Wisconsin DNR fall electrofishing protocol sample was performed at Warner Lagoon, a 28 acre backwater of Lake Mendota on Madisons' north east side. The seventy four minute (1.2 hr) survey covered the 3 lobes of the lagoon, following the shorelines in a representative and random path. The boat was a standard 1 dipper mini-boom shocker operating at approx. 5 amperes and 200 volts under standard pulse and duty rates of the DC current. All fish were netted, measured and counted.

Summary statistics for bluegill and largemouth bass were calculated. Proportional Stock Density (PSD) values quantify the percentage of quality size fish in a given population. For Bluegill, quality size is 6 inches. Largemouth bass quality size is 12 inches. Typical PSD values in this geographic area range are between 40% - 60% for bluegill and 10% - 30% for bass. Catch per unit effort(CPUE) values are the number of fish captured in 1 hr. Recent bluegill CPUE values from Lake Mendota range from 2 /hr. to 63/hr. and average 22 /hr. Lake Monona, a more panfish dominant lake, has CPUE from 156/hr. to 637/hr. and average 336/hr.

A population and biomass estimate was calculated for carp. Literature suggests biomass thresholds of <150/lbs./acre as the clearwater - macrophtyte steady state.

Results

The survey sample is listed below;

Species	Number Captured	size range	average size
Bluegill	187	2.7 - 7.1	4.6
Largemouth Bass	10	3.2 – 17.6	10.5
Carp	15	18.5 – 30.7	21.3
White Crappie	2		
Black Crappie	1		
Pumpkinseed	1		
Bullheads	6		

Also present: Smallmouth Buffalo, Bowfin, Golden Shiner

Bluegill catch rates were 155/ hr . The bluegill PSD value was 13. Only 15 fish of 118 fish measured exceeded the quality length standard of six inches.

The largemouth bass sample was marginal in terms of number. A more confident characterization would be based on a minimum of 30 observed fish. However, juvenile to adult fish were sampled with a PSD value of 42 and a CPUE of 8.3/hr.

Fifteen carp were sampled. All were adult, with 90% of fish likely to be of the same year cohort based on size. It may be likely these are (were) lagoon originated and resident fish in their second year of growth.

A population estimate based on Bajer and Sorenson (2012) calculated a point estimate of 832 individual carp in the lagoon. Based on an assigned “guess” of 6 to 8 pound weight per fish, biomass estimates are approximately 175-250 lbs. acre.

Discussion

Current limitations to the fishery include winterkill, lack of depth, and lack of desireable vegetation. The current fish community condition (species mix, size distribution, biomass) are a reflection of the recurrent disturbance state the lagoon experiences. When winterkill occurs, the panfish resource is effectively eliminated. In spring, carp quickly re-invade the lagoon. Carp establish dominance through successful spawning and survival (recruitment) that occurs in the absence of competition. Typically, bluegills would limit carp fry survival as panfish are aggressive egg and larval fish predators. As carp numbers and biomass increase, water quality and habitat quality are negatively impacted. This cycle repeats itself regularly when early winters are prevalent.

Warner lagoon is best suited to support a modest panfishery with bluegill as the dominant species. Seasonally, crappie may be managed for but will require more deep water to support a typically pelagic behavior. Largemouth Bass are the dominant gamefish present and actions and features directed toward improving panfish resources will benefit bass numbers and size distribution.

Bluegill catch rates fall within the observed rates commonly sampled in all the Madison lakes (average =127/hr). PSD rates were low and indicative of a population dominated by small individuals below quality (6”) length. PSD rates for Wisconsin waters are typically 40%-60 % for bluegill and panfish. Size structure could be improved with more habitat that includes deeper water and dense submergent and emergent vegetation.

Largemouth bass numbers were modest but show potential as some fish were of the preferred size designation (14 inches) as referenced by Nielson and Johnson (1983). Evidence of recruitment was noted as well. Habitat that benefits bluegill will also improve bass numbers, especially overhead cover in the form of course woody debris such as tree drops.

Carp represent the largest challenge for improving lagoon water quality and habitat. These improvements will likely be based on sechi disk clarity, vegetative diversity, and density. Carp population estimates should be verified by a second method such as mark and recapture based on netting to validate the fall 2017 electrofishing estimate. However, if the fall estimate is “ballpark” accurate, the biomass estimates of 175 lbs./acre - 250 lbs./ acre require reduction.

Actionable items

To address the limitations cited and address the fishery potential in the lagoon, the following draft items are presented.

For carp:

- repeat population estimate to validate density upon which to set reduction targets.
- Installation of adult carp barrier at Woodward drive culvert crossing.
- Define what is necessary and what costs are associated with a “bubble barrier” near the railroad trestle as a redundancy and / or barrier to juvenile immigration.
- Define the logistical, operational, and financial aspects of using baited carp traps (per Bajer) in lagoon to manage adult biomass.
- Explore the contaminant level present in lagoon carp . Harvest can be incentivized by potential relaxation of winter netting regulation if fish meet consumptive advisory.

The key to carp control is to eliminate immigration into the lagoon, reduce adults present in the lagoon, and to provide adequate panfish predatory pressure on eggs and larvae to negate recruitment .

For Panfish and Bass

- Add depth through dredging
- Provide stabile winter oxygen conditions through aeration
- Establish more dense and diverse macrophyte growth
- Provide more coarse woody debris
- Explore field transfer and or stocking to boost the number of quality sized bluegill and bass. These fish are necessary to jump start the desired size structure and relative abundance.
- Set CPUE and PSD value targets based on stakeholder input (consumptive versus recreational fishery)

APPENDIX B. WARNER LAGOON CONCEPTUAL DESIGN PLANS

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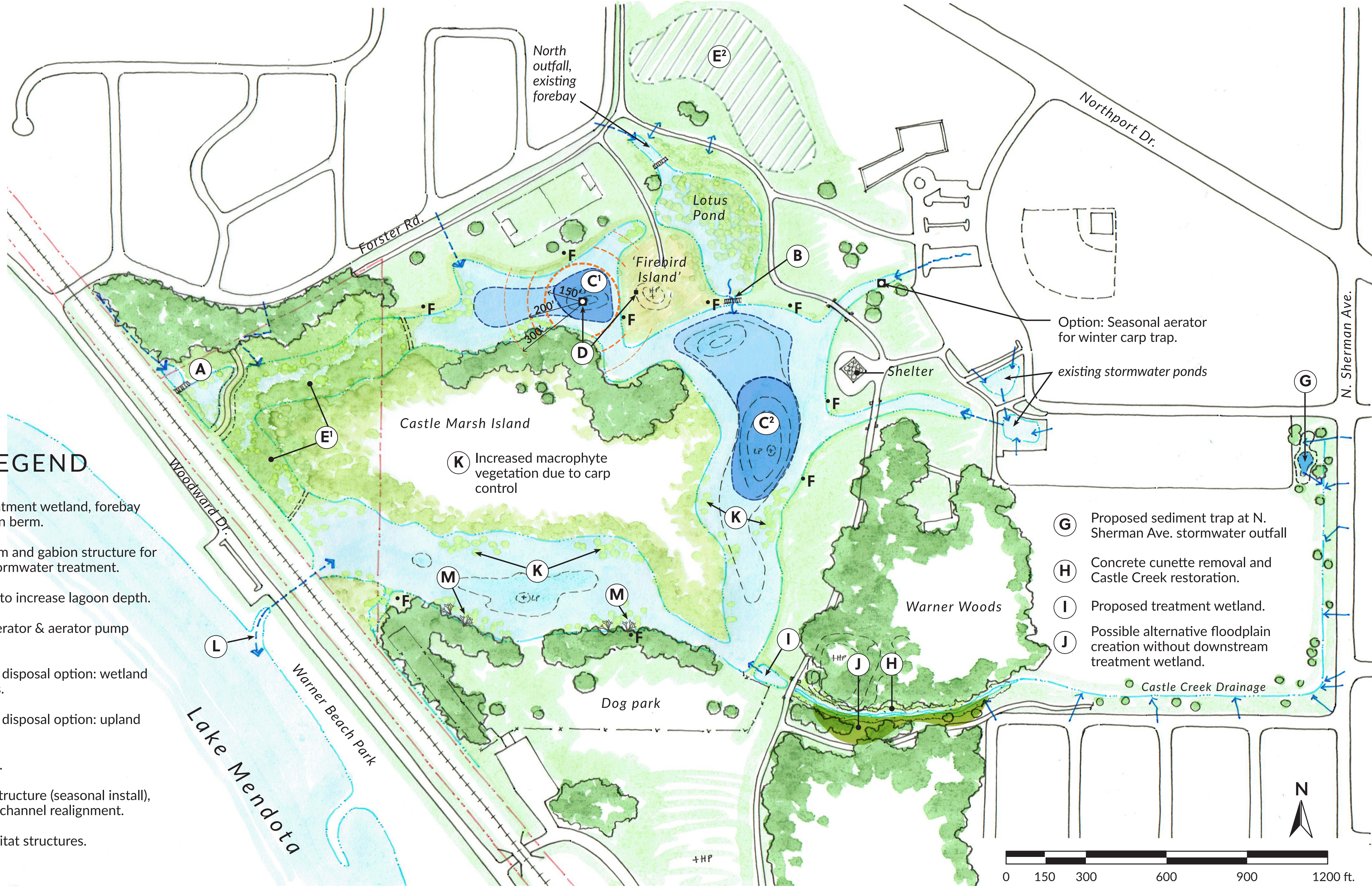


NOTES LEGEND

- **A** Proposed treatment wetland, forebay and separation berm.
- **B** Proposed berm and gabion structure for lotus pond stormwater treatment.
- **C** Dredge areas to increase lagoon depth.
- **D** Submerged aerator & aerator pump house.
- **E1** Dredge spoils disposal option: wetland creation areas.
- **E2** Dredge spoils disposal option: upland area.
- **•F** Fishing nodes.
- **L** Carp barrier structure (seasonal install), and potential channel realignment.
- **M** Tree drop habitat structures.

1 | **WARNER LAGOON** WATER QUALITY

Water Improvement Alternatives Concept Diagram

FINAL OVERVIEW PLAN

June 19, 2019

Montgomery Associates Resource Solutions

Underwater Habitat Investigations, LLC

LVB LVBrown Studio LLC

NOTES:

1. EXISTING CONTOURS FROM 2017 DANE COUNTY LiDAR DATA.
2. EXISTING BATHYMETRIC CONTOURS COMPLETED MAY 2016.
3. BERM CONSISTS OF ROCK CORE AND SPOILS CAP.

NORTH

0 25 50 FEET

LEGEND

	EXISTING BATHYMETRY
855	EXISTING MAJOR CONTOUR
856	EXISTING MINOR CONTOUR
850	PROPOSED MAJOR CONTOUR
849	PROPOSED MINOR CONTOUR
STM STM STM STM	PROPOSED STORM SEWER
	PROPOSED BERM

DRAWN BY GDL

CHECKED BY SJG

DATE

REVISION / ISSUE

NO.

MARS-EOR water · ecology · community

EMMONS & OLIVIER RESOURCES, INC.
119 SOUTH MAIN ST
COTTAGE GROVE, WI 53527
www.eorinc.com

NORTHWEST OUTFALL TREATMENT WETLAND - GRADING PLAN

ALTERNATIVES FOR WARNER LAGOON

WARNER PARK
DANE COUNTY, WI

CITY OF MADISON

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

0 ½ 1

SCALE 1"=50'

PROJECT NO. 1810

DATE 06/18/19

SHEET NO. 2

P:\@GMT-2019.05.20-22.00.49\1810 City of Madison - Warner Lagoon\Drawings\Proposed Wetland Channel revise.dwg

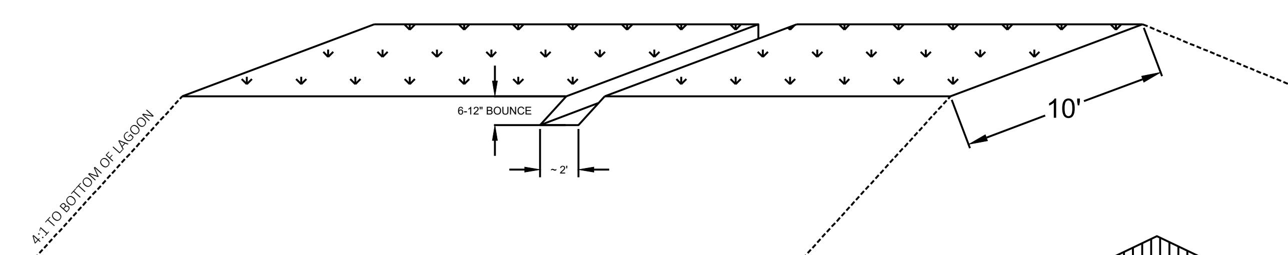
LEGEND

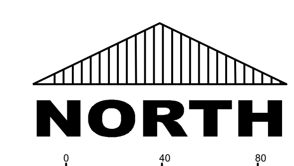
- EXISTING BATHYMETRY
- EXISTING MAJOR CONTOUR
- EXISTING MINOR CONTOUR
- PROPOSED MAJOR CONTOUR
- PROPOSED MINOR CONTOUR
- PROPOSED STORM SEWER
- PROPOSED BERM

NOTES:

1. EXISTING CONTOURS FROM 2017 DANE COUNTY LiDAR DATA.
2. TOP OF BERM: 850.5'
3. OVERFLOW WEIR: 850.0'
4. GABION OUTLET WEIR TO ALLOW FOR 6-12" BOUNCE

BERM SCHEMATIC (N.T.S.)





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GDL	SJG

DATE

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NO.

MARS-EOR
water-ecology-community

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NORTH OUTFALL RETROFIT GRADING PLAN

ALTERNATIVES FOR WARNER LAGOON
WARNER PARK
DANE COUNTY, WI
CITY OF MADISON

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE
0 ½ 1

SCALE
1"=80'

PROJECT NO.	DATE
1810	06/18/19

SHEET NO.
3

WARNER LAGOON
WATER QUALITY

East Sediment Trap Concept Plan

FINAL PLAN

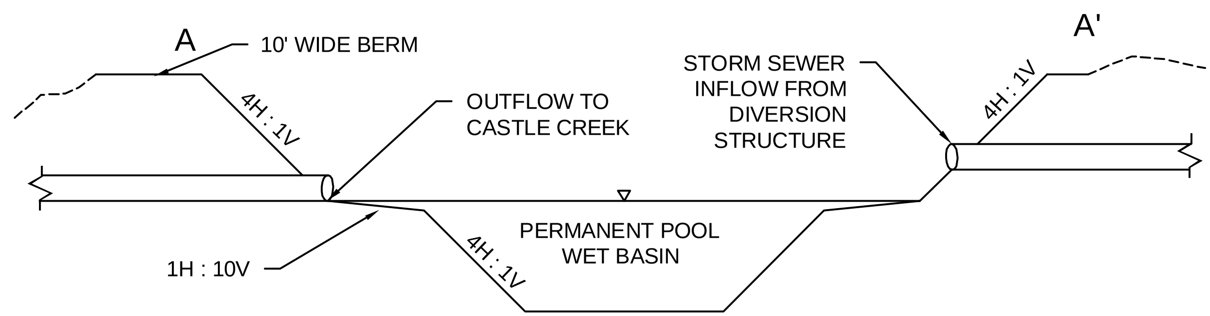
June 19, 2019

Montgomery Associates
Resource Solutions

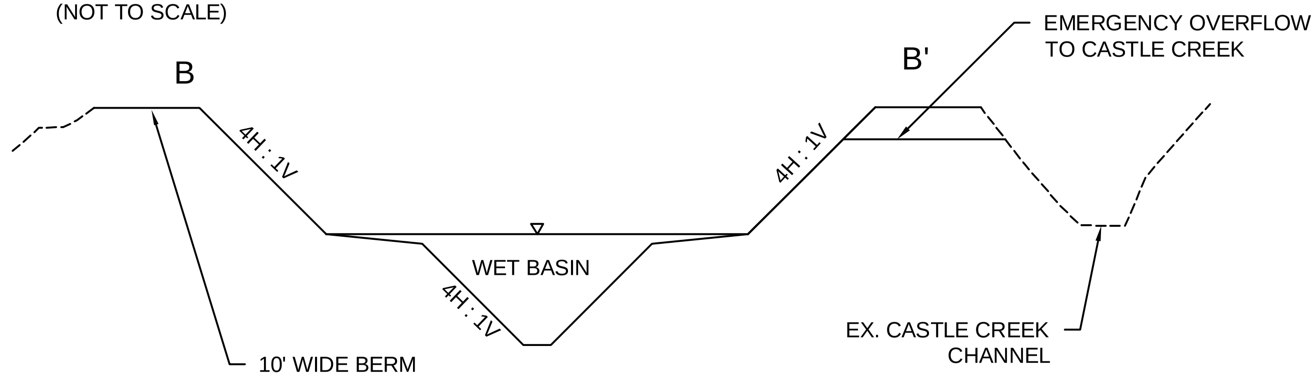
Underwater Habitat Investigations, LLC

LVB LVBrown Studio LLC

SEDIMENT TRAP TYPICAL SECTION A-A'
(NOT TO SCALE)



SEDIMENT TRAP TYPICAL SECTION B-B'
(NOT TO SCALE)



REVISION DATE: 06/18/2019

MARS-EOR water-ecology-community
119 SOUTH MAIN STREET
COTTAGE GROVE, WI 53527 (608) 839.4422

PROJECT: WARNER LAGOON WATER QUALITY ANALYSIS	CLIENT: CITY OF MADISON	TITLE: N. SHERMAN SEDIMENT TRAP CONCEPT	SHEET 5

FILE NAME : P:\1810 CITY OF MADISON - WARNER LAGOON\DRAWINGS\PROPOSED WETLAND CHANNEL.DWG
LAYOUT NAME - SEDIMENT TRAP
PLOT BY : GABE LUJAN PLOT NAME : ________ PLOT SCALE : 1 IN:40 FT_XREF

LEGEND

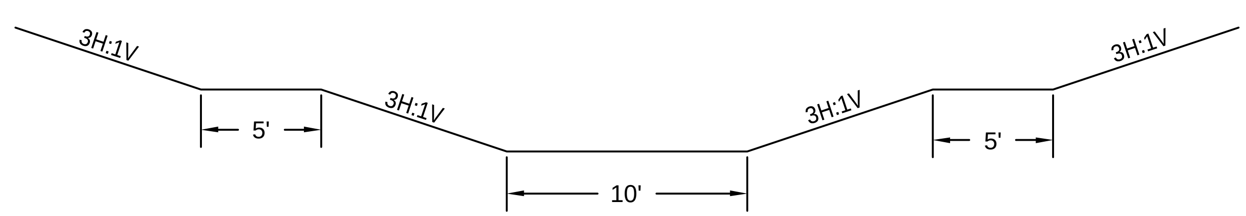
- EXISTING BATHYMETRY
- EXISTING MAJOR CONTOUR
- EXISTING MINOR CONTOUR
- PROPOSED MAJOR CONTOUR
- PROPOSED MINOR CONTOUR
- PROPOSED STORM SEWER
- PROPOSED BERM

LOW MARSH:
ELEVATION ~ 848'
REMOVE CONCRETE CUNETTE

HIGH MARSH (FLOODPLAIN):
ELEVATION ~ 850'
ESTABLISH WETLAND VEGETATION AND TREES

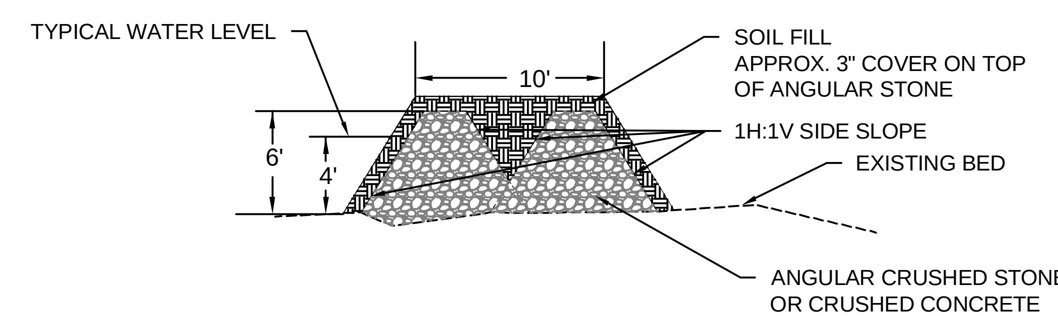
BERM AT MOUTH OF CASTLE CREEK:
ELEVATION ~ 851'
DREDGED AREA BETWEEN BRIDGE AND BERM USE SPOILS FOR BERM COVER
CONSTRUCTED OF CRUSHED CONCRETE FROM CUNETTE
COVERED WITH CUT FROM THE HIGH MARSH AREA

GENERAL WETLAND CHANNEL CROSS SECTION



BERM w/ ROCK CORE TYPICAL SECTION

(NOT TO SCALE)



NORTH

0 40 80 FEET

DRAWN BY	CHECKED BY
GDL	SJG

DATE

REVISION / ISSUE

NO.

MARS-EOR water-ecology-community

EMMONS & OLIVIER RESOURCES, INC.
119 SOUTH MAIN ST
COTTAGE GROVE, WI 53527
www.eorinc.com

CASTLE CR CHANNEL RETROFIT & TREATMENT PLAN GRADING PLAN

ALTERNATIVES FOR WARNER LAGOON
WARNER PARK
DANE COUNTY, WI
CITY OF MADISON

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE
0 ½ 1

SCALE
1"=80'

PROJECT NO.	DATE
1810	6/18/19

SHEET NO.
6

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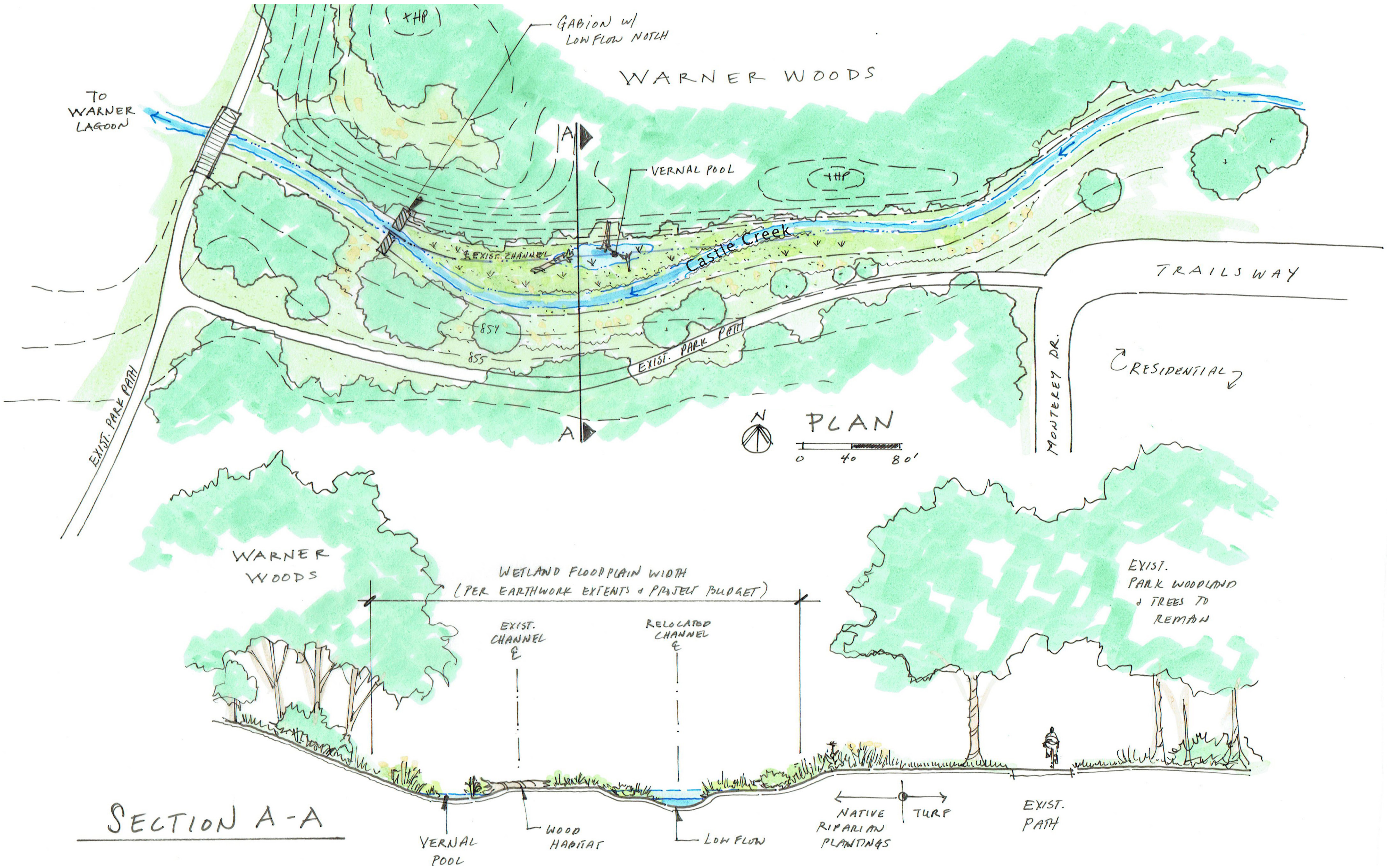

WARNER LAGOON
WATER QUALITY

East Floodplain Alternative Concept Plan

FINAL PLAN

June 19, 2019

Montgomery Associates
Resource Solutions

Underwater Habitat
Investigations, LLC

NOTES:
1. EXISTING CONTOURS FROM 2017 DANE COUNTY LiDAR DATA.
2. EXISTING BATHYMETRIC CONTOURS COMPLETED MAY 2016.
3. BERM CONSISTS OF ROCK CORE AND SPOILS CAP.
4. NORTHERN AND SOUTHERN BERM TO CONTAIN WATER AND SPOILS PLACEMENT.
5. SPOILS PLACED THROUGHOUT CONTAINMENT AREA TO RECREATE MARSH AREA.

NORTH
0 50 100 FEET

LEGEND

	EXISTING BATHYMETRY
855	EXISTING MAJOR CONTOUR
856	EXISTING MINOR CONTOUR
850	PROPOSED MAJOR CONTOUR
849	PROPOSED MINOR CONTOUR
STM STM STM STM	PROPOSED STORM SEWER
	PROPOSED BERM

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DRAWN BY	CHECKED BY
GDL	SJG

DATE

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MARS-EOR water - ecology - community

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MARSH RESTORATION SPOILS PLACEMENT - GRADING PLAN

ALTERNATIVES FOR WARNER LAGOON

WARNER PARK
DANE COUNTY, WI

CITY OF MADISON

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE
0 ½ 1

SCALE
1"=100'

PROJECT NO.	DATE
1810	06/18/19

SHEET NO.
8

NOTES:
1. EXISTING CONTOURS FROM 2017 DANE COUNTY LiDAR DATA.
2. TOP OF SPOILS PLACEMENT AREA: 4.879 ACRES.
3. POTENTIAL VOLUME OF UPLAND SPOILS PLACEMENT: 48,000 CY.
4. SPOILS DEWATERING METHODS TO BE DETERMINED; DEPENDS ON DREDGING METHODS.
5. SOIL CUT BELOW SPOILS AREA TO CREATE DEWATERING CONTAINMENT AREA (IF NECESSARY) COULD BE RE-USED IN OTHER AREAS OF PARK, IF DESIRED.

NORTH

0 50 100 FEET

LEGEND

	EXISTING BATHYMETRY
855	EXISTING MAJOR CONTOUR
856	EXISTING MINOR CONTOUR
850	PROPOSED MAJOR CONTOUR
849	PROPOSED MINOR CONTOUR
STM STM STM STM	PROPOSED STORM SEWER
	PROPOSED BERM

DRAWN BY: GDL
CHECKED BY: SJG

NO.	DATE	REVISION / ISSUE

MARS-EOR water-ecology-community

EMMONS & OLIVIER RESOURCES, INC.
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COTTAGE GROVE, WI 53527
www.eorinc.com

UPLAND SPOILS PLACEMENT GRADING PLAN
ALTERNATIVES FOR WARNER LAGOON
WARNER PARK
DANE COUNTY, WI
CITY OF MADISON

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE
0 ½ 1

SCALE: 1"=100'

PROJECT NO.: 1810
DATE: 06/18/19

SHEET NO.
9

APPENDIX C. BAITED BOX NET TRAPPING PROPOSAL

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April 10, 2018

Removal of common carp from Warner Park using box net traps: Demonstration project

Prepared by: Jordan Wein
Carp Solutions
1380 Pike Lake Court
New Brighton, MN 55112
www.carpsolutionsmn.com

Prepared as a proposal to the City of Madison

Preface

Warner Lagoon is a small (28 acres) and shallow system adjacent to Lake Mendota. The lagoon is inhabited by an abundant population of common carp, as suggested by recent electrofishing surveys conducted by Mr. Kurt Welke. The carp most likely move into Warner Lagoon from Lake Mendota during the spawning season, although it is also possible that the system is inhabited by resident carp.

There is a need to develop a long-term strategy to control carp in Warner Lagoon to improve water quality (Kurt Welke; personal communication). A likely management strategy will include installing a barrier between Lake Mendota and Warner Lagoon and physically removing carp from the lagoon. The carp in Warner Lagoon are unlikely to be removed using conventional methods like commercial seining and the idea of the use of rotenone to euthanize all fish in the lagoon has not been well-received.

Carp Solutions (CS) is company that specializes in assessment of common carp populations and developing long-term, sustainable management strategies for carp. We have also developed a new method of selectively removing carp from lakes, which might be appropriate for controlling carp in Warner Lagoon. This proposal describes a potential demonstration of this method in Warner Lagoon to assess its efficiency and cost effectiveness. This effort could be easily scaled up in the future, potentially be enlisting local volunteer/partners.

Demonstration project: Removal of common carp from Warner Lagoon using baited box nets

We would use a strategy which exploits the fact that carp can be trained to aggregate in areas baited with cracked corn (Bajer et al. 2010). These fish can then be selectively and effectively removed using a "box net" placed at the baited site. A box net is a rectangular net with mesh bottom and mesh sides lined with weighted line around each side causing it to lay flat on the bottom of the lake. While the net normally lies on the bottom of the lake (i.e. it does not cause non-target fish entanglement), its sides can be quickly lifted above the surface of the water to trap the carp that aggregate at the bait. The net is usually lifted at daybreak when most carp aggregate at the bait (Bajer et al. 2010). This net is approximately 30 x 60 feet and is placed near shore in secluded areas (link to a drone video: https://drive.google.com/file/d/1Sz1aZIPJoCVG_5h3D3s598wwK3Mky7Ci/view?usp=sharing). We have been optimizing and testing this method over three years (Table 1).

Table 1: Testing the efficacy of box nets in small lakes in Minnesota.

Lake Name	Owasso	Long	Benton	Typo	Ardmore
Lake Area (ha)	152	70	20.7	121	5.4
Carp abundance in lake	16777	8566	24425	18008	619
Carp biomass (kg/ha)	218.3	260.3	664.9	383.6	378.2
Mean Total Length (mm)	526	540	333.9	578.9	633
Total Carp Removed via Box Nets	1279	3550	5105	2076	494
Biomass Removed (kg)	2530	7551	2877	5351	1630
% Population Removed	8%	41%	21%	12%	56%
# Box Net Sets	5	8	4	15	15

We propose a demonstration project using our box net trap systems to test removal efficiency of carp from the Warner Lagoon. We will install two box nets in Warner Lagoon and we will train volunteers to bait each net with cracked corn for several days (5-10 days) to train the carp to aggregate at the bait. Once the carp are trained, we will return to Madison to conduct the removal. We will conduct one round of removal with an option for adding a second round of baiting and removal if desired. All fish captured while box netting will be counted, checked for marks from DNR electrofishing (2018), measured for length and removed from the lake. We will use marked fish to assess efficiency. **We request a location to dispose of the carp carcasses near Madison. The City of Madison would be responsible for obtaining any permits to conduct this work.**

<u>Cost to City of Madison:</u>

Including installation of 2 traps, setting and springing of traps, removal of carp from traps, disposing of the carp, uninstallation/decontamination, travel time, mileage, per diem and lodging = **$12,846 for one round or $19,302 for two rounds** (broken down in budget table below)

Deliverables: CS will report on the test of box netting to reduce the carp biomass. We will include a size structure and recommendations for the future.

Performance measurements: CS will conduct one or two full rounds of box netting removals by September 30, 2018

Literature cited

Bajer, P. G., H. Lim, M. J. Travaline, B. D. Miller, and P. W. Sorensen. 2010. Cognitive aspects of food searching behavior in free-ranging wild Common Carp. Environmental Biology of Fishes **88**:295-300.

Task Description: Warner Park--City of Madison WI	**Cost per hour/bag/mile**	**Total line item cost**
Installation of 2 box nets (8 hours crew of 2)	$140.00	$1,120
Baiting/setting traps before removal days (crew of 2, 4 hours)	$140.00	$560
Night time net raising, crew of 2: (1 hour)	$140.00	$140
Removing carp from traps, crew of 4 (5 hours)	$240.00	$1,200
Disposal of carp, crew of 4 (3 hours)	$240.00	$1,440
Removal of nets and decontamination, crew of 2 (8 hours)	$140.00	$1,120
Cost of corn bait (~30 bags)	$7.50	$225
3 round trips (534 miles per trip)	$0.55	$881
Travel time for crew of 2 (8 hours round trip X 2 trips)	$140.00	$2,240
Travel time for crew of 4 (8 hours round trip X 1 trip)	$240.00	$1,920
Per diem (meals and incidentals for one net pull, 20 days for all crew)	$64.00	$1,280
Lodging (6 rooms total for one net pull)	$120.00	$720
	Total	**$12,846**
	Cost for 2 pulls	**$19,302**

Our rates

$120 per hour for Ph.D. degree holder
$90 per hour for each M.S. degree holder (crew leader)
$50 additional for each technician on the crew

This means:

$140 per hour for a crew of two people ($90 + $50).
$240 per hour for a crew of four to remove carp from traps ($90+$50+$50+$50).
We use IRS rates for lodging, per diem and mileage for 2018 in Wisconsin

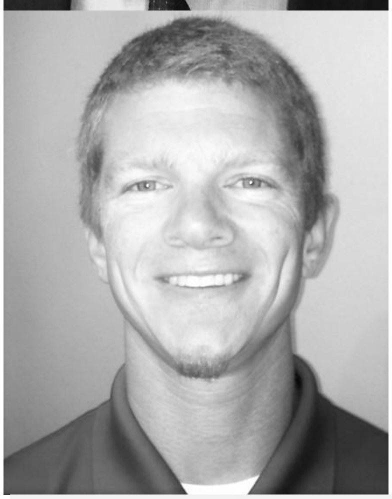
Relevant references and past projects

Name	Organization	Email
Matt Kocian	Rice Creek Watershed District	mkocian@ricecreek.org
Bill Bartodziej	Ramsey Washington Metro Watershed District	bill.bartodziej@rwmwd.org
Brian Vlach	Three Rivers Park District	brian.vlach@threeriversparks.org
Melissa Bokman	Scott County Watershed Management Organization	mbokman@co.scott.us
Jamie Schurbon	Anoka Conservation District	Jamie.schurbon@anokaswcd.org
Andrew Edgcumbe	Carver County Watershed Management Organization	aedgcumbe@co.carver.mn.us

Completed or ongoing projects: **Organization**	**Years of work**
Anoka Conservation District/Martin and Typo Chain	1
Carver County Watershed Management Organization/Benton Lake	1
Nicollet County/Swan and Middle Lake watershed	1
Rice Creek Watershed District/Long Lake Chain	3
Ramsey Washington Metro Watershed District/Phalen Chain	3
Ramsey Washington Metro Watershed District/Owasso Chain	1
Scott County Watershed Management Organization/Cedar Lake	1
Three Rivers Park District/Lake Independence watershed	3
Shell Rock River Watershed District/Fountain and Albert Lea Lakes	1

Key Personnel Bio

Przemek Bajer Ph.D.— Owner: As a faculty member at the University of Minnesota, he has been at the forefront of common carp research and management since 2006. Many of the most referenced scientific publications on carp management in North America have been authored by Dr. Bajer. He has a PhD in fisheries Sciences and is experienced in many aspects of carp management, biology and ecology. He will oversee the entire project, particularly data synthesis, carp ageing, and management recommendations.



Jordan Wein, M.Sc.--Project manager: He has managed all projects for Carp Solutions since June 2015. He has worked previously on closely related projects from 2008-2010 and has a M.S. in Ecology, Evolution and Behavior. His communication and education-based focus establishes lasting relationships with clients and residents on all projects. He will manage all field operations, data collection, and logistics of Carp Solutions staff.

Aaron Claus M.Sc.— Lead Fish Biologist: Previously studying chemical ecology of Bigheaded carps during his graduate academic career, he has broad interests in fish biology, behavior, and management. Starting work for Carp Solutions in 2016, he is an experienced and efficient field operator.
He will conduct field work with seasonal technicians, analyze collected data, and prepare reports.