Biomanipulation is a Water Quality Improvement Technique

What is the problem with the lakes in our watershed?

Eutrophication from Phosphate is the problem

Biomanipulation can lower phosphate

Chlorophyll is reduced because cyanobacteria is grazed

Water clarity improves because cyanobacteria are decreased and large aquatic plants increased

Table 1: Trophic classification based on chlorophyll, water clarity measurements, and total phosphorus values. (Carlson and Simpson, 1996)

Trophic class	Total Phosphorus (μg/L)	Chlorophyll (μg/L)	Secchi Depth (m)
Oligotrophic	< 12	< 2.6	> 4
Mesotrophic	12-24	2.6-7.3	2-4
Eutrophic	> 24	> 7.3	< 2

Tainter Lake	**1990**	**TMDL Goals**
Total phosphorus (μg/L)	150	59
Chlorophyll-a (μg/L)	87	25
Secchi depth (m)	0.8	1.6
Percent time >30μg/L Chl-a	92	28
Lake Menomin	**1990**	**TMDL Goals**
Total phosphorus (μg/L)	108	57
Chlorophyll-a (μg/L)	40	25
Secchi depth (m)	1.3	2.0
Percent time >30μg/L Chl-a	54	28

What is the definition of biomanipulation?

Biomanipulation refers here to the deliberate reduction of zooplanktivory, which is followed by an increase in the abundance and size of zooplankton (predominantly large Daphnia species) and results in increased grazing pressure on phytoplankton and ultimately clearer water of lakes. The desired reduction of planktivory may be achieved either by removing zooplanktivorous fish manually or by promoting an abundant piscivorous fish community by stocking and protection measures to increase predation pressure on the planktivorous fish.

Biomanipulation Concerns Three Aspects of Aquatic Life

Zooplankton and other animals that eat cyanobacteria

Aquatic plants that compete for nutrients and inhibit cyanobacteria growth

Benthivorous and zooplanktivorous fish that recycle nutrients, destroy aquatic plants and eat zooplankton

Relationship Between Fish And Cyanobacteria

Rough fish feed on the bottom where they stir up the sediment cycling nutrients such as nitrogen and phosphorus back into the water column.

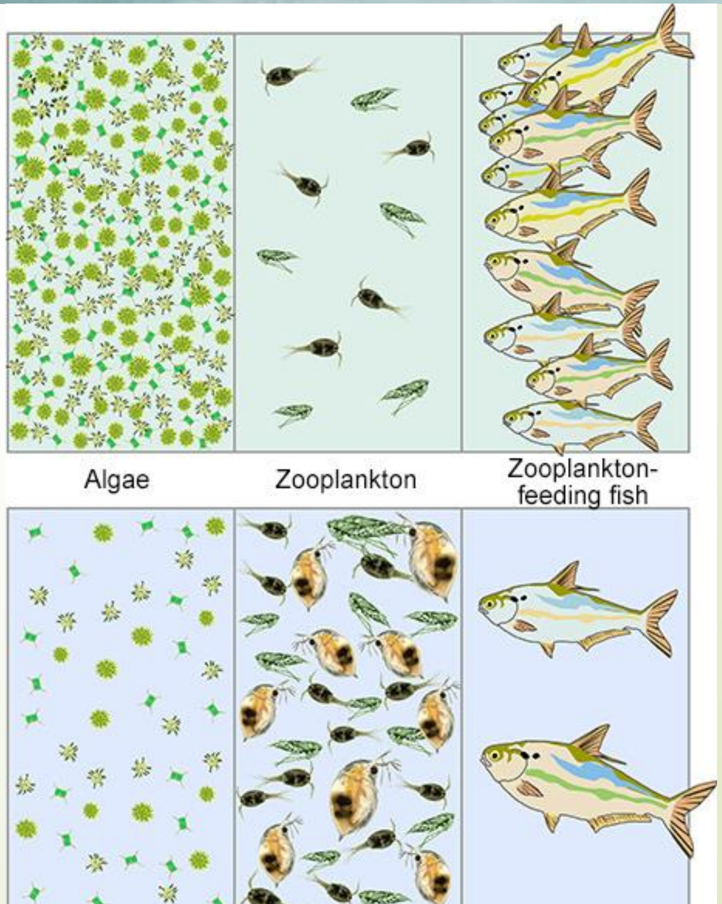
Feeding habits also tear out aquatic plants destroying fish habitat. In addition eliminating the competition for nutrients leaving more for the cyanobacteria.

Bottom fish are prolific and their young eat the zooplankton that eat cyanobacteria.

The scientific literature has shown removal of bottom fish can improve water clarity.

The management of rough or bottom fish in Tainter lake has happened every decade since 1946.

However there has not been a removal since 1986 and our lake is definitely overdue.



Fish Biomass removal reduces Phosphate the nutrient that allows cyanobacteria to get out of control

Is the annual mean concentration of TP in the lake higher than 250 ug/ L for shallow lakes with mean depths 3–5 meters?

Fish biomass = 9.42 $TP^{0.62}$; valid for shallow lakes, <5 meters in average depth, like Lake Tainter.

Remove biomass of zooplanktivorous fish to below 50 kg per ha, and/or biomass of benthivorous fish to below 25 kg per ha, within 1–2 seasons. This would be equivalent to 45 lbs. per acre and 22 lbs. per acre respectively.

If the fish biomass can be estimated with total phosphate, the algebraic equation can be used to calculate phosphate removed with the fish biomass.

The fish biomass is in kilograms per hectare, TP, total phosphate is in micrograms/liter (Jeppesen & Sammalkorpi 2004).

Most important message is that fish removal equals a reduction in phosphate and nitrogen which will reduce the available nutrients to cyanobacteria.

This is why the friends of the red cedar basin started fish removals again after a long gap.

The study attempted to obtain biomass estimates of common carp but the DNR did not allow gathering of information on other rough fish species

Date (2018)	Water Temp (°F)	Transect / Time (hour)	Time per transect (hour)	# Carp Captured	CPUE estimate (lbs/ac)	CPUE estimate (lbs/ac) By Date	2018 CPUE estimate (lbs/ac)
9/21	72	1	.37	6	405.2	143.0	**79.8 ± 63.2**
		2	.37	1	133.7		
		3	.33	0	16.8		
		4	.82	0	16.8		
10/2	Uknown	1	.50	0	16.8	16.8	
		2	.36	0	16.8		
		3	.37	0	16.8		
		4	.37	0	16.8		
10/17	47	1	.50	0	16.8	16.8	
		2	.33	0	16.8		
		3	.33	0	16.8		
		4	.33	0	16.8		

Table 3: Electrofishing CPUE survey data by transect. In Tainter Lake, the seven (7) fish captured as a part of fall CPUE surveys were marked with a left pelvic fin clip and released back to the basin. These marks will be included in the total number of carp marked this project period and can be used as part of a mark-recapture estimate in the event of a large scale capture event.

An estimate range was established but with a high standard error. Too high to be accurate.

The largest estimate was 650,000 pounds of carp in Lake Tainter. We need additional data to more accurately predict the pounds of common carp. It is important to remember, this is only one kind of bottom fish that we have in Lake Tainter, others exist.

Redhorse and sucker appear to be numerous In Lake Tainter. However, more data would be needed to have an accurate estimate. The DNR did not allow us to tag or remove this type of rough fish during the pilot study.

Date	Transect	# of Sucker/redhorse sp.	# of Carp
10/2/2018	1	1	0
	2	50	0
	3	30	0
	4	40	0
	Average	30.25	0
10/17/2018	1	10	0
	2	5	0
	3	37	0
	4	10	0
	Average	15.5	0
2018 Average		22.88	0

Table 7. Sucker/Redhorse index values (CPUE)

- There is some data to show that redhorse are numerous in Lake Tainter. All bottom fish can be a similar problem. This fish is important because redhorse also feed on zooplankton. Benthivorous fish need to be reduced in biomanipulation and redhorse are a bottom dwelling fish (**Jeppesen & Sammalkorpi, 2002**). Most of the redhorse surveyed by the project appear to be shorthead and silver redhorse species. This is consistent with the DNR surveys I have seen. These species are considered rough fish that are not rare or endangered and could be removed under act 180 assembly bill 377.

What Type of fish are considered rough?

The second category, ***rough fish***, is not precisely defined, but s. 29.001 (74), Stats., specifies that the term ***includes*** "suckers, not listed as endangered or threatened under s. 29.604 (3), common carp, goldfish, freshwater drum, burbot, bowfin, garfish, sea lamprey, alewife, gizzard shad, rainbow smelt and mooneye." In general, there is neither a closed season nor a bag limit for the taking of rough fish. Rough fish may be taken by hook and line, by hand, by dip net, and by spear, which includes bow and arrow (Act 180, Assembly Bill 377).

State of Wisconsin
Department of Natural Resources
dnr.wi.gov

Rough or Detrimental Fish Removal Contract
Form 3600-005 (R 2/11) Page 1 of 5

☐ Original Contract
☐ Renewal No. ________

THIS CONTRACT is made and entered into pursuant to sections 29.417, 29.421 or 29.424, Wisconsin Statutes, by and between the State of Wisconsin Department of Natural Resources (the Department), and the Contractor,

WSB and Associates, 178 East 9th Street , Suite 200, St. Paul, MN 55101 – (651) 286-8473; Tim Adams, 1024 4th St W, Wabasha, MN 55981- (651) 380-9398

Jeff Riedemann, 2953 320th Ave NW, Cambridge, MN - 55008- (763) 244-4122

FOR AND IN CONSIDERATION of the terms and conditions contained in this contract, the above-named parties agree:

1. SPECIES AND WATERS. The Contractor shall remove (listall):

Carp, Buffalo and Freshwater Drum.

from the following waters:

Tainter Lake, Dunn County, WI.

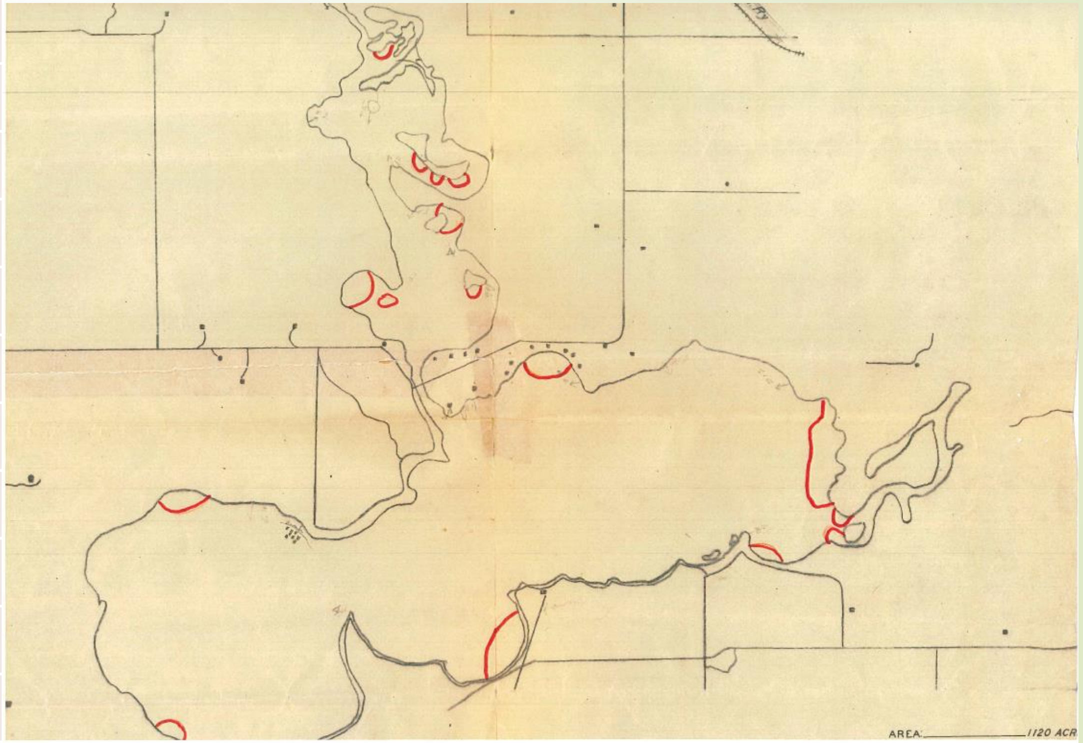
2. TERM; RENEWALS. Performance under this contract shall be completed to the satisfaction of the Department during the period from **4-01-18** through **12-31-18**, for time is of the essence.

3. DEFINITIONS. In this contract, unless the context clearly indicates otherwise, the terms "Department" and "Contractor" include their respective

Historical Rough Fish Removal Data

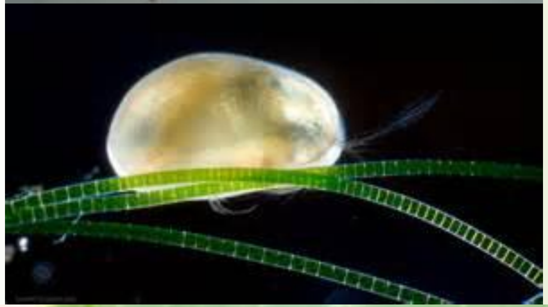
Species of fish	Year	Pounds	Recorded	Removed	Month
Common Carp	1951	89,515	yes	yes	NA
Dogfish	1951	76	yes	yes	NA
Common Carp	1952	110,836	yes	yes	NA
Dogfish	1952	10	yes	yes	NA
Common Carp	1953	13,047	yes	yes	NA
Dogfish	1953	30	yes	yes	NA
Common Carp	1954	3,609	yes	yes	NA
Common Carp	1972	5,480	yes	yes	Aug.
Common Carp	1974	50,000	yes	yes	Apr. May
Sucker not specific	1974	1,650	yes	yes	Apr.May
Common Carp	1980	17,500	yes	yes	Unknown
Common Carp	1981	16,592	yes	yes	Unknown
Common Carp	1986	7,910	yes	yes	Sept.Oct
Sucker not specific	1986	50	yes	yes	Sept.Oct

Seine Net Locations



Zooplankton Feed on Cyanobacteria and Algae

- Daphnia feed within the water column reducing cyanobacteria
- Copepods feed within the water column and the bottom sediment
- Seed shrimp eat filaments of cyanobacteria on plants and the lake bottom
- Native mussels filter the cyanobacteria clarifying the water



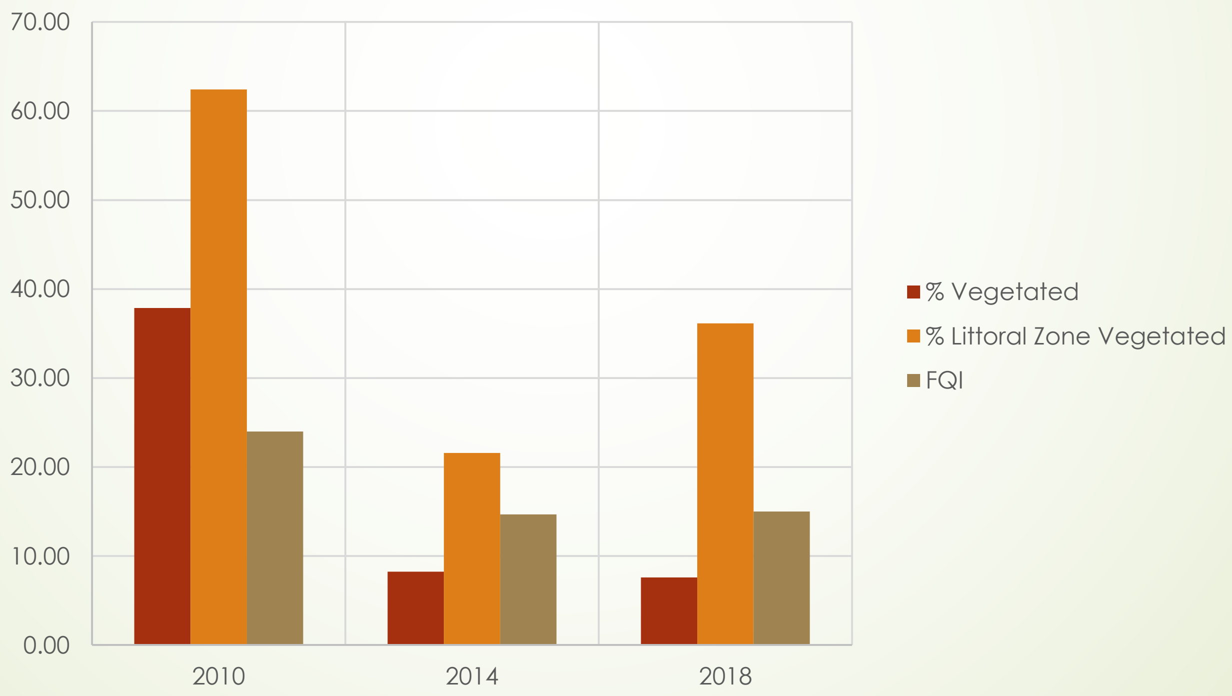
We need to increase the plant coverage in Lake Tainter.

Aquatic plants have a range in the amount of phosphate they can take out of the water.

The range is between .05 and .29 mg/m^2/day (Ecological Engineering T.A. DeBusk, J.E. Peterson and K. R. Reddy).

Therefore 100 acres of increased plant cover has the potential to remove 4148.6 to 24,061 pounds of phosphate during the summer growing season.

Tainter plant coverage is declining.



Turbidity Curtains Protect Plants

- Plants compete with cyanobacteria for nutrients
- Stabilize sediment
- Produce chemicals that inhibit algae and cyanobacteria growth
- Provide habitat for zooplankton

What are the benefits for doing biomanipulation?

BENEFITS

- Water-quality improvements include increased transparency, decreased turbidity, decreased chlorophyll-*a*, total phosphorus (TP) and total nitrogen (TN) concentration.
- Generally, method is inexpensive.
- Does not require complex infrastructure.
- Does not require potentially toxic chemicals; however, chemicals such as rotenone have been applied.
- The introduction of piscivorous fish may enhance recreational fishing.

Biomanipulation coupled with phosphorus reduction:

1. Jeppesen, E., et al. 2007. "Restoration of Shallow Lakes By Nutrient Control and Biomanipulation: The Successful Strategy Varies With Lake Size and Climate". *Hydrobiologia*. 581 (1): 269-285.

2. Jeppesen, E., et al. 2007. "Shallow lake restoration by nutrient loading reduction—some recent findings and challenges ahead." *Hydrobiologia*. 584 (1): 239-252. http://www.springerlink.com/content/g176v2123187mh12/

How well does biomanipulation work?

Lake Finjasjön was Biomanipulated

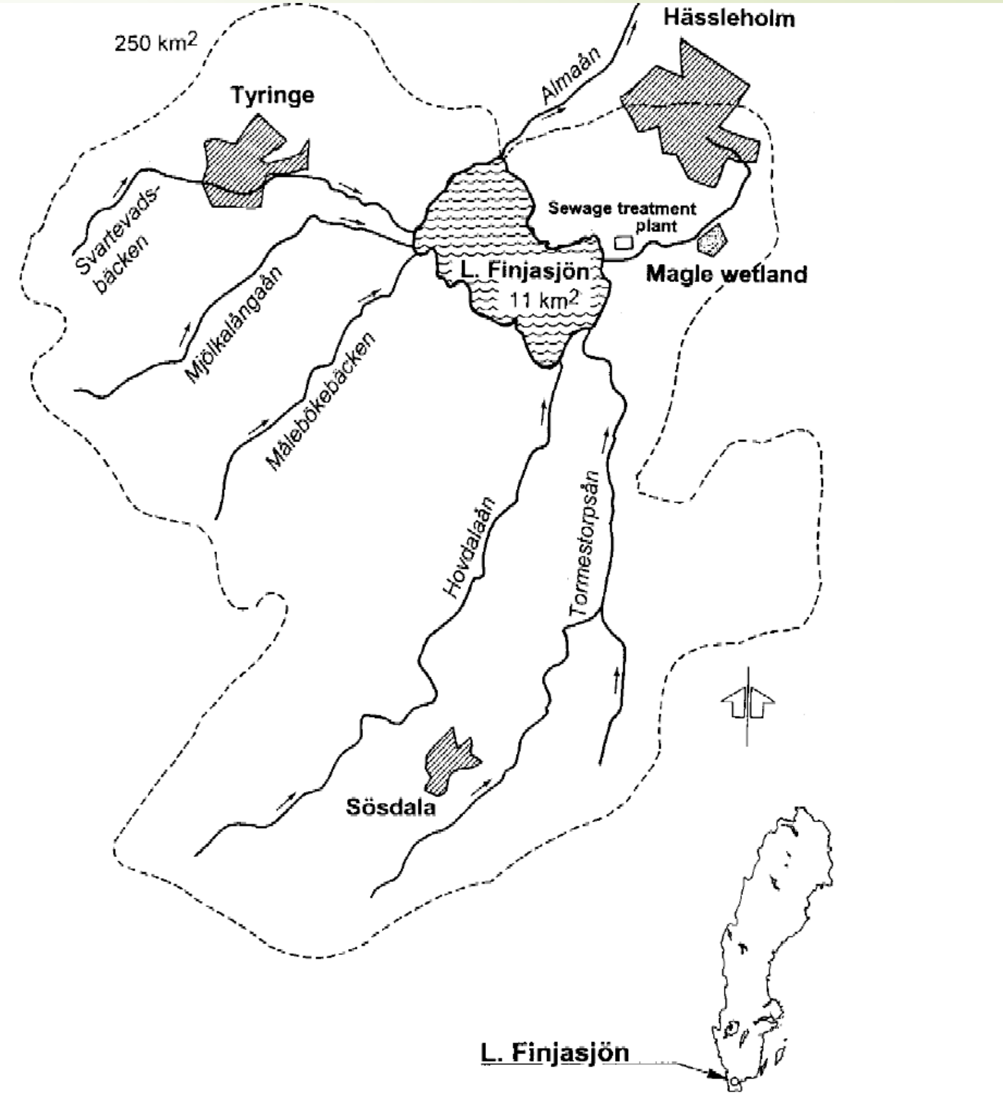
Average depth 9 feet Maximum depth 36 feet

Hydrologically connected fed by five tributary rivers

Dredging was tried but unsuccessful

Similar phosphate levels to Tainter Lake

The fish removal was successful with an excellent result



In Wisconsin Lake Wingra was Biomanipulated

- Benthivorous and planktivorous fish were removed
- Aquatic plants increased
- Zooplankton number and size increased
- Grazing on cyanobacteria increased and their number decreased
- Consequently water clarity increased

Figure 1: The Yahara River lake system includes four large lakes connected via the Yahara River.

Lake Wingra

This bit of good news is so rare you might not really believe it at first. One of Madison's lakes is actually cleaner this summer than it has been in years.

Limnologists with UW-Madison say recent tests have shown that Lake Wingra is cleaner than it has been during the past 12 years or more.

But it doesn't take a scientist to see the difference. All you have to do is stand hip-deep in the lake and look through the clear water to the sandy bottom where native aquatic plants make it look like you're wading around in an aquarium.

The reason for this turnaround? Carp. Or, more precisely, the lack of carp.

Limnologist Dick Lathrop said the removal of more than half of the carp in the lake over the last two winters has resulted in less silt being churned up by the muck-loving fish. Not only is the water clearer, according to Lathrop, but native plants are doing better and outbreaks of blue-green algae have been minimal. The popular beach on the lake has not been closed once this year due to water quality.

Richard Friday has lived on Lake Wingra since the mid-1970s and in all those years, he has never seen the water in the lake so clear.

Carp exclosure experiment showing the much clearer water and luxuriant aquatic macrophytes growing in deeper water inside the 1-ha vinyl-wall exclosure as compared to the surrounding water in Lake Wingra. (Photo: Mike DeVries, July 2007)

Figure 4.02-3 Algae Bloom on Lake Wingra

Section 319
NONPOINT SOURCE PROGRAM SUCCESS STORY
Iowa

Removing Carp Restored the Big Wall Lake Ecosystem

Waterbody Improved Common carp, a nuisance species, entered Iowa's Big Wall Lake during the early 1990s. The fishes' feeding behavior continuously stirred up bottom sediment and eliminated much of the lake's beneficial aquatic vegetation. The resulting water turbidity blocked light and prevented the growth of new aquatic plants. As a result, the Iowa Department of Natural Resources (DNR) added Big Wall Lake to the 2002 Clean Water Act (CWA) section 303(d) list due to degraded aquatic habitat caused by the presence of common carp. To address the problem, local and state partners installed a new outlet structure to draw down the lake's water level, and then treated the lake with rotenone. This eliminated the carp population and allowed preferred types of submersed and emergent aquatic vegetation to become re-established, which led to an overall improvement in water quality. After the renovation, DNR re-assessed the lake and found that it fully supported its overall designated use. As a result, DNR removed Big Wall Lake from the state's list of impaired waters in 2012.

Problem

Big Wall Lake is a 978-acre shallow glacial lake in southeastern Wright County, in north-central Iowa (Figure 1). At its deepest, the lake is only about 6 feet deep, with an average depth of less than 2 feet. Surrounding the lake is a nearly level, 1,205-acre agricultural watershed.

In 1974 the lake level was raised 6 inches by an agreement between the DNR, the Wright County Board of Supervisors and private landowners. The goal was to maintain an artificially high water level that would provide additional surface area and a deeper pool for boaters. However, the agreement hindered the ability of the DNR to lower the water level as part of proper shallow lake management.

In 1993 a large population of common carp moved into the lake during high-water events. When feeding, the carp uprooted and eliminated the lake's existing submerged aquatic vegetation (SAV) and continuously stirred up bottom sediment, which caused turbidity that blocked light and prevented the growth of new plants on the lake bed. Because the loss of SAV can degrade habitat and allow undesirable aquatic species to dominate the

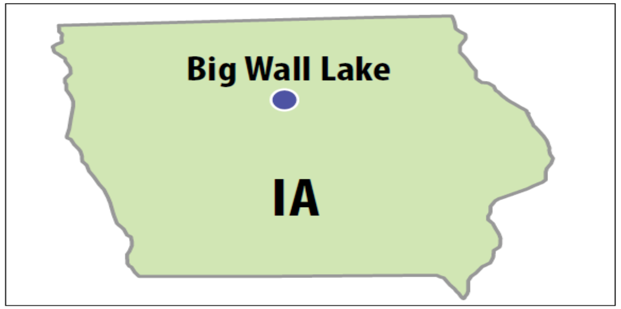


Figure 1. Big Wall Lake is in north-central Iowa.

Agency (EPA) Region VII showed that the lake was impaired by the damage caused by the common carp. As a result, DNR added the lake (segment IA 02-IOW-00860-L _ 0) to the state's list of impaired waters in 2002.

Once introduced into Big Wall Lake, the carp population thrived because the lake level was maintained at a higher and more stable water level, based on the 1974 agreement. The local DNR wildlife biologist recommended that, to restore the lake's water

The World is using these methods and we should too.

Lake Name	Average Depth & Area	Community	Country	Article Author
Lake Finjasjon	7ft.; 2741 acres	Hassleholm	Sweden	Annadotter et. al.
Lake Kraenepoel	5ft.; 54 acres	Aalter	Belgium	Louette et. al.
18 different lakes	All lakes average depth 8ft.; lakes ranged 3 to > 5000 acres	18 different communities	Netherlands	Meijer et. al.
70 lakes	Average lake area 590 acres in Denmark and 286 acres in Netherlands	Netherlands and Demark communities	Denmark and Netherlands	Sondergard et. al.

A Comprehensive Approach is Needed

Studies show that multiple techniques can be successful

Many remediation projects involve doing only phosphate reduction through Land Use Management reporting a lack of progress

We can learn from the mistakes of others and include multiple techniques

Erratum: "*Microcystis* Rising: Why Phosphorus Reduction Isn't Enough to Stop CyanoHABs"

Sharon Levy

Environ Health Perspect 125(2):A34–A39 (2017), http://dx.doi.org/10.1289/ehp.125-A34

One of the researchers quoted in this article was not fully identified. Timothy Davis is a research scientist at the Great Lakes Environmental Research Laboratory of the National Oceanic and Atmospheric Administration.

EHP regrets the error.

Fully understanding how similar ecosystems are affected by alum will help determine if lake alum treatments alone can consistently combat algal toxins and other symptoms of eutrophication. Overall, the alum treatment effectively controlled nutrient levels, however, if restoration goals are more biological, adding biomanipulation as a dual treatment may enhance lake restoration success.

Webber, Christa M., "Combating Eutrophication: An Ecosystem Scale Analysis of Aluminum Sulfate (Alum) Effectiveness among lakes, with comparison to Alum and Biomanipulation Dual Treatment" (2014). *Dissertations & Theses in Natural Resources*. 103..

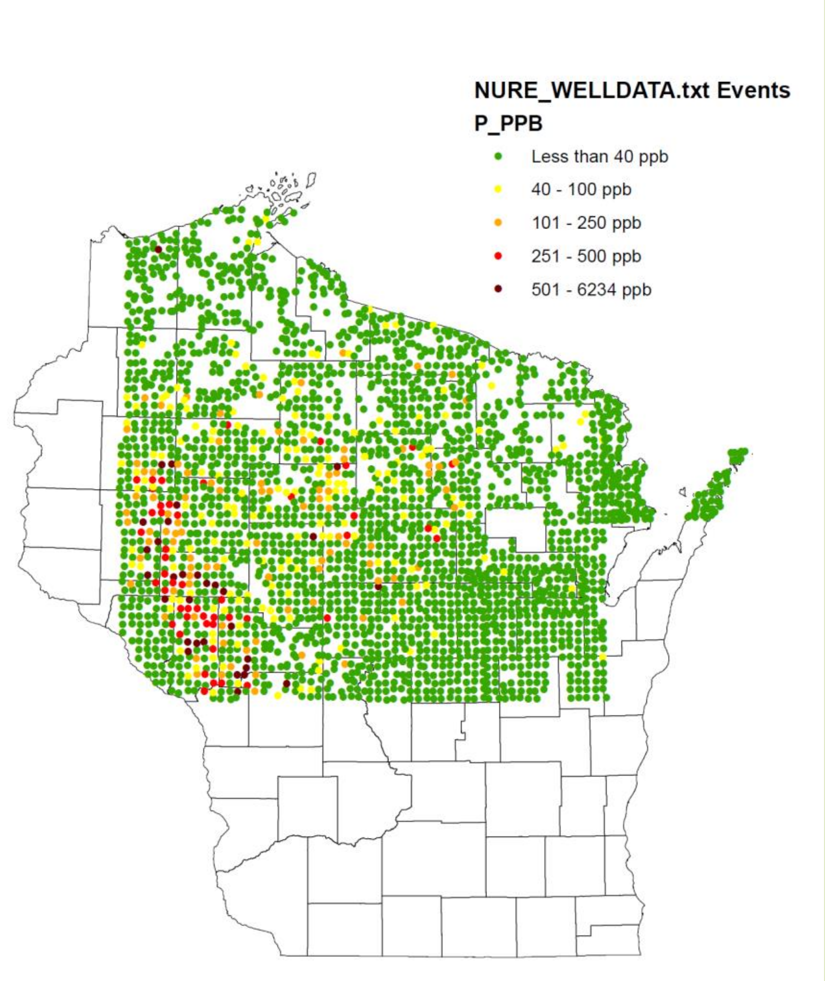
However, eutrophication-control policies based solely on
P are coming under increasing scrutiny as evidence to
support
ecological improvements with P-based mitigation is proving
elusive, especially regarding costly measures to reduce P
loads
from agriculture. Over the past four decades, many
watershed
nonpoint source projects have reported little or, in some
cases,
no net improvement in P loss reduction, even after extensive

Phosphate In Groundwater

My measurements of phosphate in wells

TOTAL PHOSPHORUS MG/L IN WELL WATER IN THE RED CEDAR WATERSHED					
WELL TYPE	OWNER	WELL DEPTH	STOUT	ICP-RAL	SPEC-RAL
P	KA	30	0.02		
M	WHEELER	350	0.48	0.39	
P	RL	150	0.64		
P	AR	120	0.19		
P	WO	40	0.03		<0.02
M	DALLAS		0.13		
M	RIDGELAND		0.17	>0.37	0.04
P	NK	280	0.08	>0.37	0.04
P	GB	80			0.07
P	KG	43			0.03
M	BIRCHWOOD			0.62	
P	BA	180	0.28	>0.37	0.28
M	CHETECK		0.6	0.34	0.24
M	RICE LAKE			>0.37	0.13
M	BARRON		0.09	>0.37	
P	SAND CREEK		0.56	0.38	0.18
M	BOYCEVILLE		0.43		
M	PRARIE FARM		0.04		
P	V&M		0.14		
M	COLFAX		1.4	0.93	

USGS measurements of Phosphate in well water



What are all the water quality improvement techniques?

Techniques Explored in the 2009 Document:

1. Best Management Practices
2. Water Level Drawdown
3. Lake Sediment Removal
4. Recruit/Plant Rooted Plants
5. Modify Lake Footprint
6. Dilution and Flushing
7. Biomanipulation
8. Phosphorus Inactivation
9. Algaecides
10. Algaestats
11. Artificial Circulation
12. Mechanical Removal
13. Shading

New Techniques included here:

14. Water Level Management
15. Floating Wetlands