

BMPs for Protecting or Restoring Phosphorus-Impaired Lakes

Dick Osgood, Certified Lake Manager

Watershed management for restoring phosphorus (P)-impaired lakes using best management practices (BMPs) has not panned out. Previously, I made the case that watershed management is “unlikely to work” for mitigating eutrophication and “may work” for preventing eutrophication (Osgood 2015). Here, I present three case studies illustrating a range of situations where watershed management (a) has worked, (b) has not worked sufficiently and (c) has worked using enhanced technologies. Critical lessons learned from these cases support guidelines for more effective lake management.

The problem is this: Large-scale land clearing alterations in watersheds result in irreversible changes to their hydrology, leading to and sustaining eutrophic (or P-impaired) lakes. Restoring eutrophic lakes requires substantial (>80 percent) reductions in watershed P loading (Uttormark 1979) or internal P loading or both. If caught soon enough, lakes retain their resilience and eutrophication can be reversed (e.g., Deer Lake). If not, watershed management using passive controls, such as BMPs, are insufficient, even after decades and millions of dollars (e.g., Yahara Lakes). In these cases, watershed management using chemical or engineering approaches can be effective (e.g., Central Florida Lakes).

Case Studies

Deer Lake, Wisconsin

Tenacity, focus, resolve, doggedness: These traits have paid off for Deer Lake.

The Deer Lake Conservancy (DLC) was fortunate that the Deer Lake watershed is small and manageable and that Deer Lake’s water quality had not yet changed irreversibly. The DLC foresaw

the problem, attacked the problem systematically and strategically, stuck with a disciplined, long-term strategy, and told their story.

Deer Lake today has markedly improved water quality as a result. According to the DLC, Deer Lake is the first lake in Wisconsin to have been restored from eutrophic to mesotrophic.

Deer Lake in western Wisconsin is a popular destination for anglers and others. The 812-acre lake has a tributary area that is predominantly agricultural, except for the seasonal and permanent homes on its shore. The watershed is small – 6,800 acres, which is only eight times the lake’s surface area.

Problems were first noted in the late 1960s with complaints about poor water quality, notably algae blooms. Algae “spraying” (using copper sulfate) occurred throughout the 1970s and 1980s. The state identified agricultural runoff as the biggest threat to Deer Lake.

The Deer Lake Improvement Association (DLIA) enrolled in Wisconsin’s Volunteer Monitoring Program in 1987. Awakened members then realized that something needed to be done with polluted runoff.

A large rainstorm in 1993 washed huge amounts of sediment into the lake along with hundreds of tires (22 trucks full), which had been dumped upstream. With this undeniable signal, you might say, the DLIA became “tired” of this pollution.

Lake leaders, now motivated, commissioned several studies to frame what actions were required to get a handle on mitigating upstream pollution sources. They realized they needed to act. They also recognized the DLIA was not the right organization to effect the required changes.

The DLC was formed in 1995 to “prevent pollution, protect and improve water quality of the lake and surrounding environment and to prevent the intrusion of pollutants into the lake.”

The DLC got off on a strong foundation. They sought board members with specific talents and skills, such as marketing, legal, accounting, and real estate. According to Jim Miller, “this was one of the two most important initial steps that we made.” The DLC also recognized its lacked scientific lake management expertise and retained Harmony Environmental. The DLC’s nonprofit status facilitated fundraising.

By 1997, all the pieces were in place. The DLC developed a long-term strategy, identified its first project and raised sufficient funds to start.

This first project was key. Rather than tackling the biggest project first, they selected a more manageable and achievable project – one that could be done relatively quickly and with a high likelihood for success.

This project involved improving a degraded ravine in a 145-acre subwatershed. The DLC purchased a 17-acre easement and built a 600-foot wing dam along the ravine to create a sedimentation basin. This project was highly visible, mitigated a significant source of P and sediments entering the lake and set the stage for future work.

The DLC has completed 33 projects involving the control of 167 acres (purchased) and 30 acres (easement). Projects include 12 sedimentation basins, 3 control dams, 7 wetland restorations, 3 gravel pit restorations, 6 prairie restorations, and 1 creek restoration. Dozens of additional small projects, such as rain gardens, rock infiltration areas, and native plantings were installed to capture

runoff from waterfront property. The total expenditures have been about \$1,200,000.

The DLC's working principles include:

- Seeking permanent solutions.
- Acquiring property if possible, acquiring easements otherwise.
- Aiming for 90 percent reductions in P from each project area.
- Educating the lakeshore residents and others.
- Projects designed to high technical and engineering standards.
- Maintenance is planned and provided.
- Monitoring is conducted to verify and validate P reductions.

And, it has worked!

P loads from the Deer Lake watershed have been reduced by more than 50 percent and Deer Lake has improved.

Although the DLC may not have fully realized it at the time, Deer Lake was on the cusp of irreversible impairment.

Lake monitoring in 1993 demonstrated that dissolved oxygen had not become fully depleted below the thermocline – an early indicator of problems. Hypolimnetic (near bottom) P concentrations were measured at 989 parts per billion (ppb), another indicator that internal P cycling had become initiated.

Modeling I have performed indicated that the lake's surface P concentrations could be reduced from 28 ppb to 16 ppb with a 50-percent reduction in P inputs. But, was it too late?

The DLIA has participated in WI DNR Citizen's Lake Monitoring since 1987, including P analysis since 1992. These results clearly show the lake has improved concomitant with the DLCs project results.

Years	P*	Clarity**
Pre-Project (1992-1996)	22 ppb	10 feet
1 st 10 years (1997-2006)	20 ppb	10 feet
Most recent (2007-2013)	16.5 ppb	20 feet

* Surface total phosphorus, June-September, averages

** July-August, averages

For the first ten years following project implementation, Deer Lake's quality showed minimal change. More

recently, water quality has improved in accordance with modeling analysis.

According to Jim Miller of the DLC, project visibility has been key to its success. In Jim's words:

"As the DLC began, our focus was the installation of projects that would slow runoff and capture P, especially from agricultural sources. The DLC has tried to identify a parcel of land in each of the largest watersheds draining into the lake, which would allow us to control P (and other pollutants).

"What has been accomplished with this watershed protection program is the protection of arteries that feed this lake. Without the ability to control the inflow from these watersheds, we cannot control the water quality of the lake itself. What we have is unique among lakes in Wisconsin, we have secured for future generations the ability to protect Deer Lake.

"Projects tended to be at the upstream ends of the drainage ravines that flowed into Deer Lake, and as such, had not been cleared for agricultural or residential development, therefore making them somewhat difficult to access. To be able to bring the DLC members and the Department of Natural Resources staff into these locations to see the projects, we developed a trail system. We did not realize at the time that this largely educational function was also a recreational opportunity. As many lake residents, whose lots were one acre or smaller, found they could hike in a natural area instead of on a county road. The project visibility grew and resulted in a doubling of DLC membership."

Project partners have included Harmony Environmental, National Park Service, Natural Resources Conservation Service, United States Geological Service, and the University of Wisconsin Extension.

Lessons learned and best practices as demonstrated in this case study:

- The watershed must be small (<ten times the lake surface area) and manageable (for the first project) to demonstrate success and establish credibility.

- The lake must have retained its resilience.
- An effective lead organization is required.
- Nonprofit status facilitates fundraising.
- Pollution sources must be identified and prioritized.
- Access to project sites is critical.
- Performance monitoring is required.
- Conservation areas have changed the use of surrounding land by replacing row crops with uses that generate less runoff.
- Land values adjacent to conservation areas increase.
- Achieving positive, observable results takes time (decades).
- Achieving positive, observable results takes money (\$1.2 million in this case).
- Achieving positive, observable results requires discipline.

Yahara Lakes, Madison, Wisconsin *In a Nutshell*

The work in the Yahara watershed has taken many years, much money, highly competent scientific leadership, and the dedication of many people. This is one of few cases where the community has stuck to the effort and has not given up.

Despite this, there has been no progress toward the 50 percent P reduction goal.

The latest program, begun in 2012, appears to have realistically assessed the scope and magnitude of the effort needed – we will have to give it time to play out to see. The bottom line is that hardwired hydrological changes to watersheds are not easily or readily reversed.

History

The Yahara Chain of Lakes consists of Lakes Mendota, Monona, Waubesa, and Kegonsa. Lake Mendota is one of the most studied lakes in the world with the University of Wisconsin-Madison (UW) campus being on the lake shoreline (great views with outdoor seating and bratwurst in the summer at the Student Union).

By the mid-1800s, Madison was becoming urbanized and the areas surrounding the lakes were being

developed for agriculture. By the late-1800s, the City of Madison began discharging sewage into Lake Monona and the first notice of algae blooms occurred.

Due to deteriorating conditions in Lake Monona, wastewater effluent was diverted into Waubesa in 1936, then finally downstream of the lakes in 1958.

For Mendota, its deterioration started by the mid-1940s with algae blooms becoming “severe” by the 1960s (Lathrop 2007). This deterioration was due to an increase in sewage pollution from upstream communities discharging to two of Mendota’s inflowing tributaries after the end of WWII until the sewage was diverted out of the lake in 1971. After WWII, the use of agricultural fertilizers also began to increase along with the intensification of agriculture including both milk production (i.e., more manure) and the growing of corn (more bare soil subject to erosion).

Management

Management of the algae blooms (algae treatments), then their ultimate source, watershed P loading, has occurred during three sequential time periods:

- Copper sulfate was used to treat nuisance algae conditions from 1925 until 1954 in the lower three lakes when they were receiving Madison’s inadequately treated sewage effluents.
- Watershed management with state cost-share programs was first implemented in the 1970s and 1980s to control nonpoint pollution from agricultural and urban runoff.
- The “Lake Mendota Priority Watershed Management Project” was initiated in 1994 with watershed project implementation from 1998 through 2008.
- “Yahara CLEAN Strategic Plan,” initiated through the “Clean Lakes Alliance” was developed in 2012 with a 20-year implementation phase anticipated.

Status of the Yahara Lakes and Phosphorus Loading

There is clear consensus and numerous scientific research publications supporting these conclusions:

- The Yahara Lakes were originally (pre-1800s) unimpaired.
- Land development (mostly agriculture) and sewage inputs increased P loading and polluted the lakes.
- The community was well aware of pollution impacts (algae blooms) in the early-1900s. The first treatments (copper sulfate) of the lower three lakes began in 1925.
- Sewage was diverted from Monona first, then ultimately downstream of the lakes by 1958. The lakes have remained impaired.
- Excess P loading is a result of agricultural and urban runoff, which is highly variable from year-to-year, but has not shown any declining trends from 1976 through 2012.
- The eutrophic condition of the Yahara Lakes has also not shown any improving trends.
- P loading to the Yahara Lakes is excessive, about double what is desirable.

Scope and Magnitude of Watershed Management Efforts

The Yahara Lakes’ quality is driven primarily by external P loads (Lathrop and Carpenter 2013). This might be considered fortuitous because the lakes’ recovery would not be retarded by internal P recycling.

There have been three major programmatic initiatives dating back to the 1970s to reduce phosphorus inputs to the lakes, yet P loading and lake quality have not changed, despite considerable efforts to mitigate eutrophication (Lathrop 2007).

It is instructive to review these initiatives because they mirror the path taken by many lake communities have attempted.

- *First program (1970s and 1980s)* – A loose affiliation of federal, state, and local programs encouraged BMPs through cost-share funding opportunities relying on voluntary implementation. A strategic plan with goals and performance criteria was lacking.

- *Lake Mendota Priority Watershed Project (1994-2008)* – This program had a clear goal to reduce P loading by 50 percent. Final project reports (Genskow and Betz, 2012) enumerate many project accomplishments, but only one that estimated a P load reduction – an estimated reduction of 8,923 pounds per year from reduced barnyard runoff. This represents about 12 percent of the required overall reduction, but increases in P loading in other areas may have offset this. The project invested \$2.3 million spanning about ten years.

- *Yahara CLEAN Strategic Action Plan for P Reduction (plan adopted in 2012)* – A more focused, strategic approach with a lead organization assuming responsibility. The plan calls for a 50 percent reduction in P loading to be implemented over 20 years at an estimated cost of \$128 million. While it is too soon to tell whether this will prove effective, they appear to be off to a slow start with on the ground projects and funding. The Clean Lakes Alliance’s 2013 financial statements show they have assets of about \$1 million, but 85 percent of those are “promised” cash or in-kind services. Their 2013 expenditures of about \$1 million contained only 16 percent for watershed programs (it is unclear whether these included on the ground implementation actions).

Lessons Learned

- For eutrophic lakes where external P reductions can lead to recovery, even enormous watershed management efforts were not successful at achieving the P reduction goals, despite:
 - A strong, local organization dedicated solely to the cause.
 - A detailed and credible strategic plan.
 - A long time.
 - Faith.
- The current watershed program is more realistic and ambitious, and will require:
 - Ongoing monitoring and maintenance to assure their benefits are maintained and sustained.
 - Ongoing management and administration will require an active and sufficiently funded organization to persist.

- Only time will tell if this will be sufficient.

Stormwater Management in Central Florida (Orlando) Lakes

(see also Harper 2013)

The central Florida landscape is dotted with hundreds of lakes, which range in size from a few acres to more than 30,000 acres. Central Florida has few natural streams or channels, and runoff discharges naturally to the nearest lake. Prior to 1960, most of central Florida was sparsely developed with agriculture – water quality in the central Florida lakes was good during this period with many of the lakes used for potable water.

With the development of Walt Disney World, urbanization exploded in central Florida. Residential, commercial, and highway construction replaced much of the previous agricultural areas. The loss of the citrus orchards was significant because citrus is fertilized with nitrogen, while the lakes tend to be P-limited. New development discharged runoff to the nearest lake.

Untreated urban runoff increased P loadings. Water quality deteriorated rapidly with significant reductions in water clarity and increased algal blooms. The poorest water quality for most lakes occurred during the 1980s.

Requirements for treating runoff from new developments in Florida were implemented in 1982, and all developments were required to construct either dry or wet treatment systems. Many of the initial projects were pilot projects or were undersized and did not result in significant water quality improvements.

Implementation of stormwater retrofit projects increased during the 1990s, particularly in urban residential areas. By this time, most of the available watershed area had been developed, particularly areas near the lake where stormwater treatment projects would be most beneficial. The lack of available space limited the ability to implement stormwater treatment systems capable of providing sufficient water quality improvements.

Construction of underground exfiltration systems became popular since these systems could be constructed beneath pavement areas. Unfortunately, these systems were expensive to

implement and long term clogging and maintenance was problematic.

During the early 1990s, alum stormwater treatment systems began to be installed on some of the more visible urban lakes. These systems inject alum into the storm sewer lines on a flow-proportional basis, forming precipitates of aluminum $\text{Al}(\text{OH})_3$ and $\text{Al}(\text{PO}_4)$, which bind with P, suspended solids (TSS), metals, bacteria, and algae, and settles the pollutants into the bottom. The controls for the injection systems are contained in small buildings with underground piping extending to each point of alum addition and flow measurement.

The alum treatment systems exhibit typical removal efficiencies of 90 percent for total P, 95 percent for TSS, 40-50 percent for total N, and 60-90 percent for metals. Due to the high removal efficiencies and the minimal space requirements, alum treatment systems have removal costs, which are substantially lower (20 to 200 times less per pound of P removed) than costs associated with wet or dry ponds.

Alum stormwater treatment systems resulted in substantial improvements in water quality in the treated lakes.

During the 1990s and early-2000s, Florida state agencies were focused on treatment of external loadings to lakes and would only provide funding and TMDL credits for stormwater treatment projects. Internal nutrient recycling was not included in any TMDL reports and allocations conducted at the time. This approach led to a gross overestimation of the impacts of runoff on water quality and a narrowly focused emphasis on stormwater treatment.

The emphasis on stormwater treatment slowly changed during the mid-2000s, and funding gradually became available for projects targeting internal recycling, but only after all external sources had been treated. Over the past few years, TMDL reports have begun to include loading estimates from internal recycling. Grant funding can currently be obtained for mitigating internal loadings, but stormwater management projects still receive top priority. The most successful water quality improvement projects have resulted from providing treatment for both external and internal loadings.

Lessons learned and best practices as demonstrated in this case study:

- Significant, sufficient P loading reductions are possible with chemical or engineering approaches, which are often cheaper and quicker than BMPs.

Summary

Watershed management requires a long-term, organized effort supported by good science; an active, effective organization and significant investments. With luck, such as a small tributary area (<ten times the lake surface area) and the timely recognition of developing problems, eutrophication can be arrested and reversed. When watersheds are larger or when runoff pollution overwhelms the lake, watershed management has not proven to be effective owing to the scope of the problem, the loss of resilience in the lake, or (commonly) both. In these cases, chemical or engineering workarounds have been shown to be effective as well as cheaper and quicker.

Our lake and watershed policies and practices should be amended to recognize these shortcomings and take advantage to implement innovative approaches that have been demonstrated to work.

Thanks to Cheryl Clemmens, Harmony Environmental, Harvey Harper, Environmental Research & Design, Inc., Dick Lathrop, University of Wisconsin and Jim Miller, and Deer Lake Conservancy for assisting with these cases.

References

- Genskow, K. and C.R. Betz. 2012. Farm Practices in the Lake Mendota Watershed: A Comparative Analysis of 1996 and 2011. University of Wisconsin-Extension Environmental Resources Center for the Dane County Land and Water Resources Department.
- Harper, H. 2013. Control of watershed loadings using chemical treatment. *LakeLine*, 33:19-22.
- Lathrop, R.C. 2007. Perspectives on the eutrophication of the Yahara lakes. *Lake Res Manage*, 23:345-365.
- Lathrop, R.C. and S.R. Carpenter. 2013. Water quality implications from three decades of phosphorus loads and trophic dynamics in the Yahara chain of lakes. *Inland Waters*, 4: 1-14.

(OSGOOD, continued on p. 18 . . .)



I'm There When You Need Me

I can access almost everything from my smartphone, so why not my monitoring data? With In-Situ's new Aqua TROLL® 600 Multiparameter Sonde featuring **wireless Bluetooth® connection** to Android™ devices, now I can! Slick, app-based control of configuration, calibration, and data transfer and analysis, make it a simple and cost-effective solution. Plus, with a 9+ month battery life, fast-responding sensors, and a flexible handheld platform, it's perfect for continuous monitoring and lake profiling. It keeps me fast, mobile, and efficient – just the way I like it.

Available for purchase or rent. Learn more at in-situ.com/lakeline



The New **Aqua TROLL 600 Multiparameter Sonde**

IN-SITU.COM/LAKELINE



Be Mobile. | Be Smart. | Be In-Situ.

Get **BUSY** at **NALMS**

PROGRAMS

- Inland HAB Program
- Lakes Appreciation Month
- Professional Certification
- Student Awards
- Student Programs

COMMITTEES

- Articles of Incorporation and Bylaws
- Financial Advisory
- Grants, Marketing, and Fundraising
- Nominating
- Policy
- Publications
- Outreach and Education

GET MORE INFORMATION ONLINE AT WWW.NALMS.ORG
OR CONTACT [SARA SPEEL@WABASHRIVER.NET](mailto:SARA.SPEEL@WABASHRIVER.NET)