Immediate Watershed & Within-Basin **Management for Inland Lakes**

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When an integrated approach is necessary

Introduction: Our inland lakes as a "commons"

Garrett Hardin first warned us in 1968 of the inherent dangers of a commons without proper management. He defined a commons as a resource that is not owned and is therefore available to all who exploit it. He showed the world that if a resource was not properly governed or managed and population growth was increasingly uncontrolled then the resource stocks (supplies) would plummet to a number that could no longer sustain the population.

Today, we see continuous evidence that we have ignored many of those warnings and find ourselves with complex problems and no sustainable solutions. Our inland water resources are one of the commons. Inland waters such as lakes provide multiple benefits to both riparian communities and local municipalities through a variety of ecosystem services. Inland lakes also provide economic and aesthetic values to riparian waterfront property owners with increased residential lot values and scenic views. We have allowed our inland lakes to be subject to invasive species, our watersheds to become inundated with nutrients and pollutants that flow into fragile water bodies, and our public drinking water supplies to require repeated chemical and mechanical treatments due to metals, contaminants, pharmaceuticals, and pathogens. Yet, we desire to live on inland lakes as they increase property values, provide useful ecosystem resources, and contribute economic capital to the local tax base. We build within our watersheds with little regard to the impacts of the development on local or distant connected waterways.

Non-point source pollution and its consequences

Lakes, especially those with heavy shoreline development, are under continuous stress and vulnerable to water quality degradation from the surrounding development and land use activities. A major source of this stress includes the anthropogenic contributions of nutrients, sediments, and pathogens to the lake water from the surrounding landscape (Carpenter et al., 1998).

Nonpoint source (NPS) pollution is the pollution caused when climatic events carry pollutants off of the land and into lakes, streams, wetlands, and other water bodies. Unlike point source pollution which is derived from distinctive discharge pipes, NPS pollution is often diffuse in nature. This creates challenges in determining the location of pollution sources which makes mitigation (treatments) a difficult and sometimes impossible task. NPS pollution is regulated and includes categories such as agricultural source runoff (Figure 1) and confined animal feed operations (CAFOs), small urban runoff (populations with < 100,000 residents), urban storm water runoff from unsewered areas, septic tanks, runoff from abandoned mines, land disturbing activities, and atmospheric deposition. The NPS pollutants of greatest concern to local waterways include

Figure 1. NPS pollution is regulated and includes categories such as agricultural source runoff.

nutrients such as nitrogen and phosphorus, sediment, toxic compounds, and pathogens (*E. coli*, among many others). The National Water Quality Inventory (1994) ranked the leading sources of water quality impairment to lakes as agriculture, municipal point sources, and urban runoff. Additionally, watersheds generally export more non-point source loads relative to point source loads as a result of the reductions of point source pollution required by the Clean Water Act of 1972 (Nizeyimana et al. 1997).

Nutrients have caused critical water quality issues such as the inundation of lakes with dense, filamentous green algae, or worse, toxic blue-green algae (Figure 2). Submersed aquatic vegetation also increases with high levels of phosphorus and leads to impedance of navigation and recreational activities, as well as decreases in water clarity and dissolved oxygen that lead to widespread fish kills. Major sources of phosphorus for inland waterways include fertilizers from riparian lawns, septic drain fields, and non-point source transport from agricultural activities in the vicinity of a water body.

The need to define critical source areas for pollutant reduction

A specific area within a watershed that contributes any NPS pollutant is referred to as a critical source area (CSA). Critical source areas can contribute high loads of nutrients and sediments to inland waterways and often escape detection during lake management programs. These pollutants often enter lakes after a climatic event such as heavy rainfall or snowmelt. The surrounding landscape is critical for the determination of CSA's as some areas contain high slopes which increase the probability of erosion, while others contain soils that pond and contribute pollutants to the lake via runoff from the land. This information is critical to include in a watershed management program since management programs should be site-specific and address the pollutant loads at the site-level. Many management programs will follow recommendations from low impact development, which aims to reduce the amount of impervious areas in developed areas. Since so many lake shorelines are already developed or are being further developed, the use of low impact development practices will help reduce runoff and protect water quality. An example of a low impact development practice would be the installation of vegetation buffers along lake shorelines, especially in front of recently constructed homes with impervious surfaces. Following this protocol will allow for improvements to water quality at the regional scale.

Figure 2. Nutrients have caused critical water quality issues such as the inundation of lakes with dense, filamentous green algae, or worse, toxic blue-green algae.

Indian Lake, Cass County, Michigan: A case study

Indian Lake is located in Sections 30 and 31 of Silver Creek Township (T.5S, R.16W) in Cass County, Michigan. The lake surface area is approximately 499 acres (Michigan Department of Natural Resources; www.michigan.gov/dnr). This lake was recently re-classified as mesotrophic by the Michigan Department of Natural Resources, and improvement from a eutrophic rating determined during a 2009 lake management plan study that was requested by the Indian Lake Improvement Association (ILIA). This reclassification is likely due to the decline in primary production from a whole-lake laminar flow aeration system. Indian Lake has two deep basins (north and south) and a moderate-sized littoral zone. In 2014, Indian Lake had a maximum depth of 30.0 feet, but by 2016, a maximum depth of 31 feet was recorded in the deepest basin through depth contour mapping. The lake bottom consists primarily of sandy substrate, along with marl and organic matter deposits. Indian Lake has a lake perimeter of approximately 4.65 miles.

The purpose of this plan was to recommend management options for improving the lake water quality and reducing invasive species such as hybrid Eurasian watermilfoil and nuisance blue-green algal blooms in Indian Lake. Two of the management recommendations were to increase dissolved oxygen in the lake and possibly reduce water column nutrients such as phosphorus through implementation of a whole-lake laminar flow aeration (LFA) system.

Continued evaluation on the efficacy of the LFA system on various water quality parameters demonstrated the lake water quality continued to improve through increased water clarity, reduced nutrients in the water column and sediment, reduction of soft bottom throughout the lake basin, and reduction of dense aquatic vegetation biovolume.

However, strong observations were made regarding the dominance of blue-green algal blooms that appeared after heavy rainfall. This led to further recommendations on protecting the lake water quality through the determination of critical source areas (CSAs) present in the immediate watershed of Indian Lake that could contribute nutrients and solids to the lake. One of these CSAs was noted to be the Indian Lake inlet at the north end of the lake (aka the Mann Drain). It was determined that the mean nutrient concentrations of phosphorus (P), total kjeldahl nitrogen (TKN), and total suspended solids (TSS) were much higher in the waters coming in from the inlet than the ambient mean concentrations of all three parameters in the Indian Lake basins. As a result of this determination, it was recommended that a reduction strategy of these parameters be pursued through the installation of innovative biologically-activated filters in the inlet to reduce these nutrient loads. Three filters were placed along the drain watercourse and spanned the width of the drain beginning in 2012. A significant concern was that the measured nutrient reduction in the lake itself as a result of the LFA system could be compromised by continued inputs of excessive nutrients and solids from the inlet. The mean concentrations from 2012-2017 are summarized below in Table 1.

The aforementioned mean concentrations of nutrients and solids in the inlet were compared to the means of the same parameters in Indian Lake. In 2017, for example, the mean TP concentration was 0.023 mg/L which is higher than in previous years but still below the eutrophic threshold. This mean TP concentration is substantially lower than that in the inlet for all of the years measured. The inlet is acting as a source of nutrients to Indian Lake which will continue to impair water quality with time. The mean TSS in the lake was also < 10 mg/L with the exception of a single sample measured in 2015 which was 16 mg/L. Record rainfall occurred in 2015, and the filters were challenged under these intense high-flow conditions, which contributed record nutrient and solid loads to Indian Lake. A loading rate of approximately 0.35 kg/L/day of phosphorus was estimated based on a mean flow rate of approximately 2.0 cfs from the inlet during the sampling dates and the mean of the phosphorus prior to implementation of the buffer.

Thus, the filter in the inlet is reducing these loads to Indian Lake during normal flow conditions as can be realized by looking at the mean TSS concentrations in the inlet.

The ILIA installed these filters with the support of the Cass County Drain Commissioner since he was aware of the water quality impairments from the inlet to the lake. Additionally, most lake associations in Michigan consist of volunteers and a limited budget through Special Assessment Districts (SADs). This means that improvement methods have to be both economically feasible as well as environmentally feasible. This is why the filters were selected over the creation of a detention or settling basin. Such engineered designs are costly and according to many licensed professional engineers, will not filter all solids and most nutrients from the water in inlets or drains. The ILIA has a primary goal of protecting their unique aquatic resource, and is amongst the most progressive lake community to date with educated and motivated residents that want to protect this lake for all generations.

It was recommended that ongoing reduction of the nutrients and solids entering Indian Lake from the inlet continue to protect the water quality of the lake. Over time, these nutrients can settle to the bottom of the lake, accumulating in lake sediments and further supporting accelerated aquatic plant and algae over-growth which the ILIA had spent hundreds of thousands of dollars on over the previous two decades. The improvements within Indian Lake to date have been quite positive with the lake now classified as mesotrophic. It was possible to reduce the trophic status of the lake only as long as both in situ (within-basin) and external (immediate watershed) improvements were made to reduce nutrient and solid loads to the lake. This integrated program put forth by the ILIA is an important contribution to the state regulatory mission of making inland lakes "swimmable, boatable, and fishable" for lake residents and visitors alike.

Concluding Remarks

The overall health of an inland lake depends on both the implementation of within-basin improvement methods along with immediate watershed best management practices (BMPs). When only the former are introduced and lake

Table 1. Annual Mean Concentrations in TKN, TP, and TSS in the Indian Lake Inlet Waters (Data Collected by Restorative Lake Sciences).

Year	Total Kjeldahl Nitrogen (mg/l)	Total Phosphorus (mg/l)	Total Suspended Solids (mg/l)
2012	2.0	0.072	46.3
2013	1.3	0.061	28.7
2014	1.7	0.045	11.7
2015	4.4	1.5	293
2016	0.8	0.046	26.5
2017	0.5	0.061	<10

improvements are either not long-lasting or appear compromised, then watershed influences of nutrients and sediments should be suspected. Although implementation of immediate watershed BMPs adds considerable cost to a lake improvement program, it will inevitably result in the reduced need for future restorative efforts that would be much higher in cost. Once a lake shifts beyond a favorable stable state, it is challenging and sometimes impossible to bring it into balance. Lastly, since most public lakes are a "commons" it is even more critical to have a plan in place to protect the lake from overuse which will continue as our population increases with time. This is especially important since most watershed externalities cannot be managed entirely within a given watershed and so each lake should be evaluated on an individual basis but with regard to CSAs that can be affordably addressed.

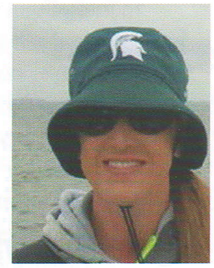
References

Carpenter, S.R., N.F. Caraco, D.L. Correll, R.W. Howarth, A.N. Sharpley and V.H. Smith. 1998. Nonpoint pollution of surface waters with phosphors and nitrogen. *Ecological Applications*, 8(3): 559-568.

Michigan Department of Natural Resources (www.michigan.gov/dnr).

National Water Quality Inventory, 1994. *The Quality of our Nation's Water: 1994. Executive summary of the National Water Quality Inventory: 1994 Report to Congress*. United States Environmental Protection Agency Office of Water, Washington D.C., EPA 841-S-94-002. December 1995.

Nizeyimana, E., B. Evans, M. Anderson, G. Peterson., D. DeWalle, W. Sharpe, J. Hamlett and B. Swistock. 1997. *Quantification of NPS Loads within Pennsylvania Watershed.* Final report to the Pennsylvania Department of Environmental Protection, Environmental Resources Research Institute, The Pennsylvania State University, University Park, Pennsylvania.



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