Notes from Restorative Lake Sciences (Dr. Jennifer Jermalowicz-Jones) evaluation study and restoration plan of Swan Lake in Allegan, Michigan from Sylvia Aukeman

Swan lake is located in Cheshire township in Allegan County, Michigan. It is categorized as a drainage lake since it has three prominent inlets as well as an outlet at the southwest section of the lake which enters Swan Creek and eventually empties into the Kalamazoo River and Lake Michigan. The lake basin is comprised of 214 acres and has 3 significant areas of water influx; one at the north, east, and southwest regions of the lake. One drain outlet at the north end of the lake was not flowing during either sampling period. The north inlet could be a significant source of nutrients during heavy rain events due to the wetlands. The saturated soil in the wetland may contribute to nutrient overflow although wetlands filter out nutrients and sediments during dryer periods. The south inlet had the highest flow and is likely the largest contributor of nutrients too.

Lakes are classified according to trophic status which means it is classified according to the amount of nutrients (Phosphorus, Chloraphyll-a, nitrogen) in the lake and the transparency of lake (how far you can clearly see beneath the surface of the water).

- Oligotrophic classification has low phosphorus levels, low chloraphyll-a levels and a high Secchi transparency of >15 feet which equals good water quality.
- Mesotrophic classification has a phosphorus levels of 0.10-0.25 mg $^{L-1}$ and Chlorophyll-a level of 2.2-6.0 micrograms per liter and Secchi Transparency of 7.5-15.0 feet which equals fair water quality.
- Eutrophic classification has >0.025 mg L^{-1} Phosphorus levels and Chlorophyll-a >6.0 micrograms per liter level and Secchi Transparency of <7.5 feet which equals poor water quality.

  Swan lake is considered hyper-eutrophic due to the very high nutrients and low Secchi transparency, and elevated chlorophyll-a and marked dissolved oxygen depletion with depth which creates a perfect environment for algae blooms. If the algal biomass in the lake reaches too high a concentration massive fish die-offs may occur as decomposing biomass deoxygenates the water. NOTE: more water in the lake will not change the amount of Phosphorus and Chlorophyll-a in the lake basin.

Swan Lake is facing significant issues that degrade water quality over time, including inputs of nutrients and sediments from surrounding drains, and leaking septic tanks and drain fields which lead to a decline in lake health. The lake fishery is becoming impaired by the addition of sediments to the lake. Increased biochemical oxygen demand (BOD) is resulting in a decline in dissolved oxygen with depth throughout Swan Lake. BOD represents the amount of oxygen consumed by bacteria and other microorganisms while they decompose organic matter under aerobic (oxygen is present) conditions at a specified temperature. Lakes or streams should contain some oxygen in the form of dissolved oxygen. It is critical to maintain aquatic life and aesthetic quality of streams and lakes by decreasing nutrients and increasing oxygen in the basins of Swan Lake.

The immediate watershed which is the area directly draining into the lake, is approximately 16,389.7 acres. This a about 77 times the size of the lake, which is VERY large. In general, larger watersheds possess more opportunities for pollutants to enter the ecosystem, altering the water quality and ecological communities.

The blue-green algae, *Microcystis species* was the most prevalent algae in the lake which is an indicator of poor water quality. About 30% of lakes have *Microcystin* which is produced by the blue-green algae *Microcystis*.

Water quality sampling locations were obtained within the 2 deepest basins of the lake on November 8, 2023 (a non-stratified period) and July 1 (a stratified period). The stratification of lakes refers to a change in the temperature at different depths in the lake, and is due to the density of water varying with temperature. The 2 deepest basins of the lake were monitored for physical water quality parameters such as water temperature, dissolved oxygen, pH, specific conductivity, total dissolved solids (TDS), turbidity (cloudiness or haziness), and Secchi transparency. Chemical water quality parameters were also measured including total Kjeldahl nitrogen (amount of nitrogen contained in organic form), total inorganic nitrogen (ammonia, nitrate, and nitrite), chlorophyll-a, total phosphorus, and ortho phosphorus, and water clarity.

The pH of Swan Lake indicates it is a neutral lake with moderate alkalinity. The inlets had a mean total phosphorus concentration above the eutrophic threshold and moderate nitrogen concentrations. The total suspended solids were low, which was favorable. Therefore, turbidity in Swan Lake is likely high due to the algae dispersed throughout the water.

The Total Phosphorus concentration in Swan Lake basins was well over the eutrophic threshold. Additionally, the bioavailable Total Phosphorus is quickly available for aquatic biota (plant and animal life) including algae and lowers the amount of dissolved oxygen needed for this biota.

Conductivity is a measure of the ability of water to pass an electrical current. Organic compounds do not conduct current very well. It is a useful general measure of water quality Significant changes in conductivity could be an indicator that a discharge or some other source of pollution as entered the lake. The mean conductivity of Swan Lake was moderate and indicative of a large agricultural watershed. Agricultural watersheds create substantial challenges for lakes. Lakes that lie within an agricultural watershed may experience acute and chronic influx of sediments, nutrients, and bacteria among other pollutants. In many areas, however, the watershed reduction approach is limited, and therefore restorative measures must begin within the lake basin. Intense monitoring of agricultural non-point pollutant loads (pollution from land runoff which can include precipitation, drainage, and seepage from manure, pesticides, fertilizers, herbicides, oil, grease, etc.) is expensive and transaction costs associated with regulation policies would likely be high. Therefore, accurate information on farm runoff of phosphorus is not measured and unknown. Faulty septic systems are another source of nonpoint pollution and is one we can measure and fix. Since riparians (lake property owners) have little control over local pollutant loading from agriculture to inland lakes, the maintenance of septic systems is critical for water quality protection.

The mean water clarity (Secchia transparency test ranged from 4.4 feet to 4.8 feet with the lowest values in November and this preceded a marked algae bloom (*Microcystis species*). The Mean chlorophyll-a, which is the measure of algal pigment, was elevated quite high and indicative of hyper-eutrophic waters. Dissolved oxygen depletion was prevalent in the basin with depth in July but was uniform and elevated in November which is normal during periods of non-stratification. Sediments samples were excessively high in total phosphorus and elevated nitrogen with lower organic carbon.

It is noted that the Allegan Conservation District is working on a watershed improvement plan. Control of nutrients from surrounding watershed or catchment to any lake is a proven necessity for long-term nutrient reduction.

In addition, many lakes in Michigan contain soils that are not suitable septic systems. With ideal soil types microbes in the soil are able to decompose nutrients and reduce the probability of groundwater contamination. However, soils that are not ideal for septic systems are not very permeable, prone to saturation or ponding, and have muck. Swan Lake property has loamy sand, silt loam, ponded and muck soil with old septic systems which probably contributes to lake water quality issues since it is not suitable for septic systems.

Based on the study, Swan Lake contains invasive aquatic plant species which includes the submersed hybrid Eurasian Watermilfoil (EWM), Curly-leaf Pondweed (CLP), and the emergent Purple Loosestrife and Phragmites. Eurasian Water milfoil is a major threat to the ecological balance of an aquatic ecosystem through causation of significant declines in favorable native vegetation with lakes in that it forms dense canopies and may limit light from reaching native aquatic ecosystems within lakes. Eurasian Watermilfoil was found to occupy 21.7 acres of surface area in Swan Lake during the July 1 visit (out of a total of 214 acres which Swan Lake occupies). Native aquatic plants may grow to nuisance levels in lakes with abundant nutrients such as phosphorus, and in sites with high water transparency. Continued survey for invasive aquatic plant species is needed to ensure that additional invasives do not enter Swan Lake. Aquatic herbicide treatments are recommended on a spot-treatment basis to effectively reduce the invasives over time. Algaecides should ONLY be used on green algal blooms since many treatments can exacerbate blue-green blooms. The blue-green algae, Microcystis species was the most prevalent algae in the lake which is an indicator of poor water quality.

Multiple techniques are often needed to bring a marked balance back to the lake ecosystem. In other words, one solution may not be enough to accomplish restoration. Swan Lake improvement strategies to reduce external loading of Phosphorus and Nitrogen to the lake, increase dissolved oxygen with depth, reduce cyanobacteria blooms (blue green algae - Microcystis species), and improve water clarity and quality are urgently needed.

It is recommended that Swan Lake begin a spot herbicidal treatment program for Eurasian Watermilfoil (EWM) otherwise these weeds will spread and be very expensive to control. These weeds a major threat to the ecological balance of our aquatic ecosystem. A hypolimnetic oxygenation system be deployed to the lake bottom in the near future (after final approval post testing). This will increase and hold constant dissolved oxygen concentrations while reducing the release of phosphorus on the lake bottom. This technology would operate May-November. This technology is patented and utilizes pure oxygen that is pumped into the bottom of the lake through direct hoses that deliver the oxygen to the hypolimnion to avoid destratification of the water column. This reduces the release of phosphorus from lake sediments which reduces the nutrients in the upper water layers and thus reduces the presence of blue-green algae blooms. It has 96% oxygen transfer efficiency. As a result, the oxygen rich environment will accelerate the natural breakdown of organic matter while creating and preserving an odor free environment. It must be combined with reducing external nutrient loads from the immediate watershed. An innovative and natural charcoal technology product called TimberChar Biochar has been used with measurable reductions in nutrients and solids from stormwater. It filtrates nutrients and pollutants that may enter inland waters such as Swan Lake. It is a multi-filament polypropylene sock placed in front of the lake drains and has a life expectancy of up to 3 years. Drain influxes of nutrients are the largest threat to water quality of Swan Lake, along with the use of septic systems and drain fields. A boat cleaning station should be installed at all public boat launches. Environmental Canine Service septic can be used to detect poor septic systems. The Allegan Health Department also has tablets which can be used in the septic system to detect leakage of sewage from the drain field. Finally, a professional service such as Restorative Lake Sciences needs to have oversight and management of lake with EGLE compliance and education.

The next two pages are pictures of the plan to restore Swan Lake with the approximate cost. All of the steps should be completed but we can start by having Restorative Lake Science do the spot weed treatment, Biochar filter on inlets, and assess our septic systems. The cost for their oversite/services is on the bottom. This can be accomplished through a Special Assessment District (SAD) process which would eventually divide the cost by the number of lake owners and add to their taxes. This SAD process is rather long since there has to be at least 2 public hearings. The actual restoration would not be able to begin until probably summer of 2026.

Table 25. List of Swan Lake proposed restoration methods with primary and secondary goals and locations for implementation.

Proposed Improvement Method	Primary Goal	Secondary Goal	Where to Implement
Systemic herbicide spot-treatments for invasives	Reduce invasives in lake	Reduce long-term use of herbicides in lake	Entire lake where invasives present
Hypolimnetic Oxygenation	Increase DO, reduce blue-green algae, increase water clarity	Reduce nutrients in the water column and sediments	Deepest Basin(s) N=2
Timberchar® Biochar Drain Filters	To reduce incoming nutrient loads	To reduce algal blooms associated with incoming nutrients	All 3 drains
Septic System Maintenance Program	To reduce nutrient loads to the water table and lake	To reduce associated algal blooms	Each property for annual inspections and consideration of SludgeHammer® units (individually funded)
Bi-annual water quality monitoring of lake and drains (CSA's)	Monitor efficacy of BMP's implemented, including any oxygenation, drain filters, etc.	Compare baseline water quality and drain data to modern data to view trends for data-driven management	Both the lake and all major drains (CSA's)
Annual lake surveys pre and post-treatment	To determine efficacy of herbicide treatments on invasives	To determine ability of native aquatic vegetation biodiversity to recover post-management implementation	Entire lake
Riparian/Community Education	To raise awareness of lake/drain issues and empower all to participate in lake protection	Long-term sustainability requires ongoing awareness and action	Entire lake community and those who frequent the lake; may also include relevant stakeholders

Table 26. Swan Lake proposed lake restoration program costs. NOTE: Items with asterisks are estimates only and are likely to change based on acquisition of formal quotes from qualified vendors.

Proposed Swan Lake Improvement Item	Year 1 Costs	Years 2-5 (Annual) Costs[4]
Systemic herbicides [1] for EWM treatment	$19,500	$15,500
PrO2 System[2] (includes annual lease cost and electrical for each year as well as maintenance)	$55,000*	$55,000*
Drain filters[3] for drains Note: maintenance for future years	$10,000**	$10,000**
Environmental Canine Services[4] septic leachate detection	$12,000	$0
Professional services (limnologist management of lake, oversight, EGLE compliance, education)[5]	$25,000	$25,500
Contingency[6]	$12,150	$10,600
Total Annual Estimated Cost	$133,650	$116,600

[1] Herbicide treatment scope may change annually due to changes in the distribution and/or abundance of aquatic plants.
[2] Oxygenation system is an estimate and will likely change with vendor proposals/costs. This is a rough number based on experiences with similar lakes.
[3] Drain filters include individual, retrofitted biologically activated filters for nutrient and solid reductions. In future years, maintenance of the filters will be required.
[4] Environmental Canine Services cost based on similar project size. Updated quote needed.