1 Selected Experience

1.1 Grand Lake St. Mary's, OH

Grand Lake St. Mary's, a 13,500-acre drinking water reservoir located in west central Ohio, was the site of the two world's largest alum treatments. Due to funding constraints, the lake was planned to be treated over multiple years to deliver the full buffered alum dose. HAB Aquatic Solutions applied over 2.6 million gallons of alum and sodium aluminate in 29 days during the first year of the project (June 2011) to a 4,900-acre portion of the lake. In April 2012 (year 2), HAB applied over 2.7 million gallons of alum and sodium aluminate to the same section of the lake in 29 days.

Figure 1. One of HAB's Large Application Barges

Although only 27% of the total aluminum dose has been applied to date, internal P loading was reduced by 43% and water column P decreased by 30-43%. A team of third party scientists from Tetra Tech analyzed sediment samples throughout the lake and confirmed that HAB's GPS guided application process resulted in an even distribution of the target aluminum dose, despite high algal concentrations present at the time of application.

1.2 Green Lake, WA

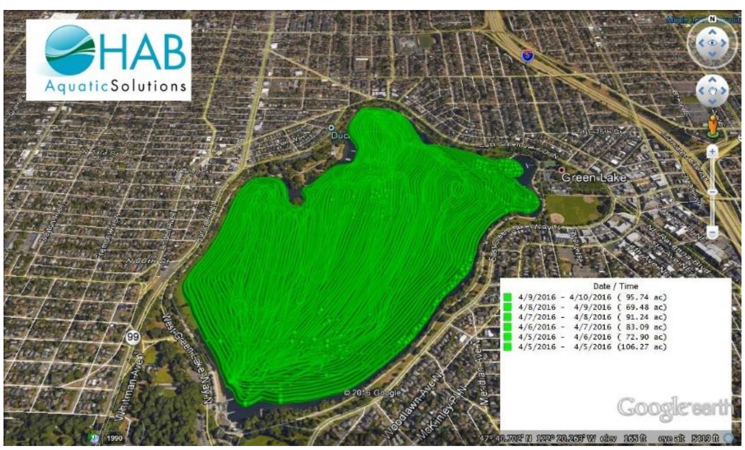


Figure 2. Final Green Lake Coverage Map

Green Lake is 259-acre, poorly buffered lake (total alkalinity of below 25 mg $CaCO_3$/L) located in Seattle, WA. This urban lake has an average depth of 13 feet, a maximum depth of 30 feet and has had a long history of cyanobacteria blooms dating back to at least 1916. The City of Seattle contracted with HAB to successfully apply 81,744 gallons of alum and 40,905 gallons of sodium aluminate over a six-day period in April 2016. The buffered alum application increased water clarity from 9 to 19 feet and had no effect on lake pH or dissolved oxygen concentrations. The image above shows the Green Lake Coverage Map, with each individual application path represented by a single green line. HAB provides a coverage map to their clients on all projects.

1.3 Lake Wapato, WA

Wapato Lake is a shallow, 34-acre urban lake located in the City of Tacoma, WA. The poorly buffered lake (total alkalinity of below 25 mg $CaCO_3$/L) has a long history of poor water quality with the first closure to recreational use occurring in 1942. Problems at the lake have ranged from swimmers getting rashes, to bad odors, to heavy algae blooms, and to the toxic algae blooms that have been common in recent years. Excessive amounts of the nutrient phosphorus was the main cause of the toxic algal blooms. Internal phosphorus loading (leaching from the lakebed sediments) is significant in the lake and phosphorus is high in the sediments and available to be released into the overlying water column. HAB Aquatic Solutions successfully conducted a buffered alum application (15,932 gallons of alum and 9,470 gallons of sodium aluminate) over a three-day period in May 2017. The application produced a "floc" that settled to the bottom of the lake. The floc has sites where phosphorus in the sediments become chemically bound as it leaches from the bottom. The floc effectively intercepts and binds the phosphorus, which makes it unavailable for the algae to use for growth. The goals of the project were to dramatically reduce the internal loading of phosphorus from the sediments, lower the amount of phosphorus available to algae in the water, reduce the amount of algae and associated toxins and remove any recreational restrictions at the lake. For more information visit HAB's project website at www.wapatoalum.com.

Figure 3. Application Barge Preparing to Fill

1.4 Pinto Lake, CA

Figure 4. Educational Opportunity at Pinto Lake

Pinto Lake is a 120-acre recreational lake in Watsonville, CA. The lake developed massive algal blooms every late summer and fall and algal toxin levels typically exceeded the State health criteria. As a result, the lake was classified as "impaired" and was closed for contact recreation during the bloom periods. Of particular interest, the death of 31 endangered southern sea otters have been traced to algal toxins which have accumulated in shellfish eaten by the otters. Pinto Lake is the likely source of the toxins in the shellfish and the cause of the otter deaths. An excessive amount of the nutrient phosphorus was the main cause of the toxic algal blooms. Internal phosphorus loading (leaching from the lakebed sediments) and watershed runoff both contribute phosphorus to Pinto, but a study in 2011 showed that the majority (85%) was coming from the lakebed.

Samples from the bottom of the lake confirmed that phosphorus was very high in the sediments and available to be released into the overlying water column. HAB Aquatic Solutions conducting a buffered alum application (79,000 gallons of alum and 39,500 gallons of sodium aluminate) over a ten-day period in April 2017. The application was highly successful with a dramatic reduction in water column phosphorus and algal biomass, an elimination of algal toxins and the lifting of recreational use restrictions. For more information visit HAB's project website at www.pintolakealum.com.

Figure 5. Alum and Sodium Aluminate Being Applied at Pinto Lake

1.5 Lake Wister, OK

Figure 6. Water Chemistry Testing

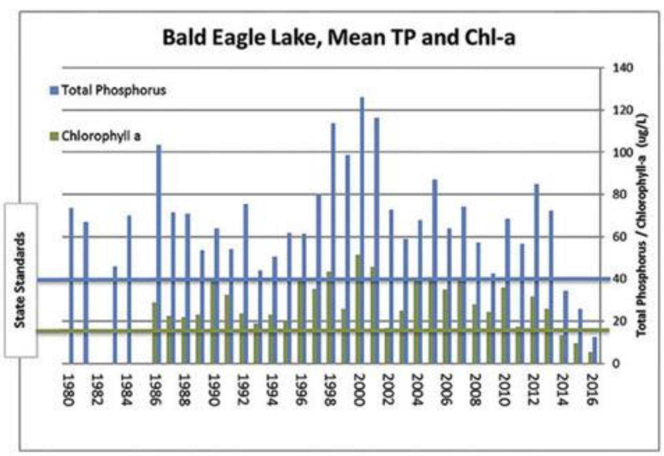
Lake Wister is a 7,300-acre, USACE flood control reservoir located near Poteau, OK. The reservoir also serves as the drinking water source for communities near the waterbody. The drinking water intake is in an isolated 100-acre bay and HAB conducted a two-day buffered alum application (15,828 gallons of alum and 7,914 gallons of sodium aluminate) in August 2014. The application occurred in the bay containing the water intake and effectively reduced algal biomass and turbidity in the reservoir, which reduced treatment requirements in the water plant. HAB conducts jar tests on all of their projects to confirm that the planned alum dose will not have any adverse environmental effects.

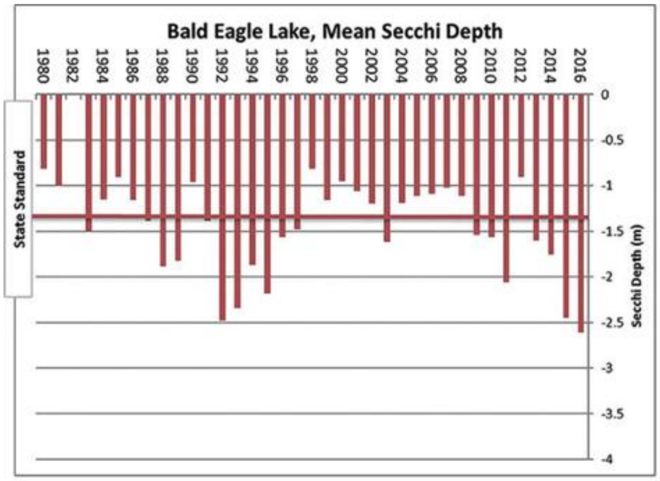
1.6 Bald Eagle Lake, MN

Bald Eagle Lake is 1071 acres in size and is located just north of the Twin Cities near the town of White Bear Lake, MN. The Rice Creek Watershed District partnered with Wenck Engineering to complete a Total Maximum Daily Load (TMDL) study and determined Bald Eagle Lake was impaired/threatened by an excess of phosphorus. The watershed district contracted with HAB Aquatic Solutions to conduct two liquid alum applications. In April 2014, half of the required dose was applied (248,000 gallons) in 8 days. The remaining dose (248,000 gallons) was applied in April 2016.

Figure 7. Subsurface Formation of Floc

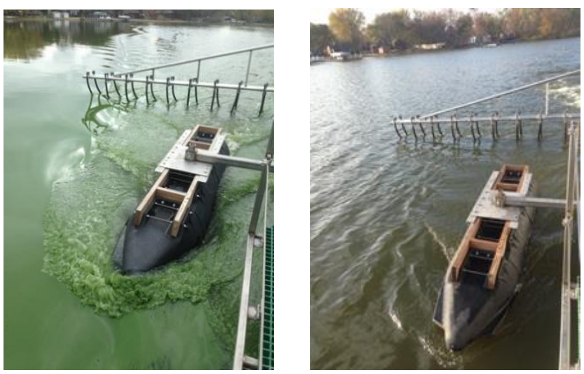
Prior to HAB's aluminum sulfate application, the 30-year water clarity summer average was 3.9 feet at Bald Eagle Lake. Post alum lake treatment, water quality has been averaging 8.2 feet. The current quality of Bald Eagle Lake is the best it has been in the 30-year sampling record and is now greatly exceeding the project goals for total phosphorus, chlorophyll (a measure of the amount of algae in the lake) and water clarity (Secchi disk depth). The graphs below show the changes in total phosphorus, chlorophyll and water clarity and how the current conditions related to the project goals.





1.7 Spring Lake, MN

Spring Lake is 600 acres in size, located in central Minnesota near the town of Prior Lake. In 2011 the Prior Lake-Spring Lake Watershed District completed a Total Maximum Daily Load (TMDL) study and determined Spring Lake was impaired/threatened by an excess of phosphorus. The watershed district contracted with HAB Aquatic Solutions to apply 292,000 gallons of liquid aluminum sulfate in 11 days in the fall of 2013.

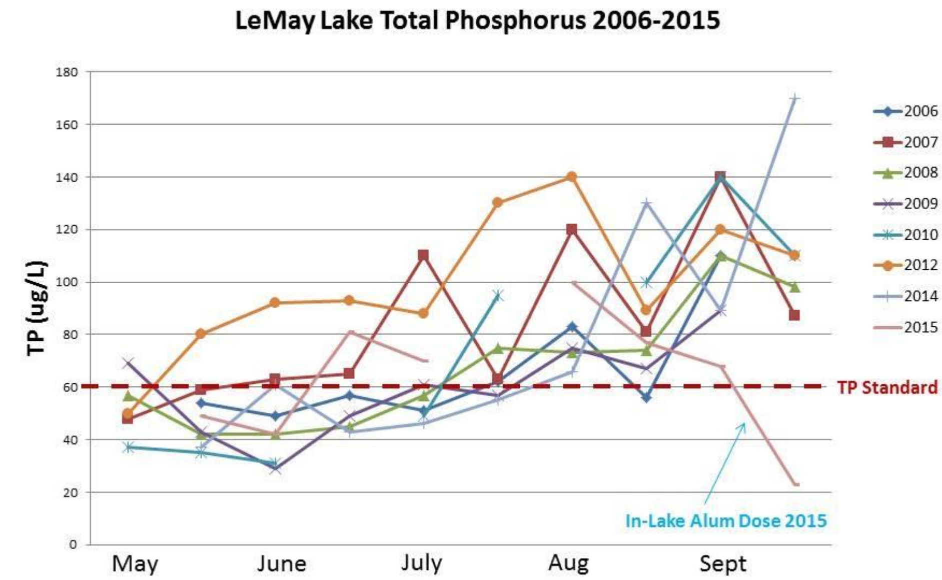


Prior to the aluminum sulfate treatment Barr Engineering recorded 220 ppb phosphorus and 45 ppb chlorophyll *a* (algae density). Following the alum treatment Barr Engineering measured 59 ppb phosphorus and 4 ppb chlorophyll *a*.

Figure 8. Spring Lake Before (left) & After (right) Application

1.8 LeMay Lake, MN

LeMay Lake is a 32-acre lake located in central Minnesota in the town of Eagan. Wenck Engineering conducted a water quality study and found the lake was degraded by high rates of internal phosphorus loading. The City of Eagan contracted with HAB Aquatic Solutions to apply 9,853 gallons of liquid aluminum sulfate and 4,927 gallons of sodium aluminate over a day in the fall of 2015. Prior to the application, water column total phosphorus in the late summer/early fall averaged near 120 ppb, but was reduced by over 80% to 23 ppb after the application (see graph below).



1.9 Cedar Lake, WI

Cedar Lake is a 1,118-acre recreational lake near Star Prairie, WI with a maximum depth of 34 feet. Cedar Lake has been on the Wisconsin list of impaired waters since 1998 because of high total phosphorus levels. The lake is eutrophic to hypereutrophic with summer algae blooms that result in odors and unsightly build-up of algae along the shorelines. The lake is phosphorus limited: it is the concentration of phosphorus which controls the level of algae growth. Impairment of recreation uses was added to the list of water quality concerns for Cedar Lake because of excess algae growth in 2012. Cedar Lake algae blooms have been documented since the 1930s. Copper sulfate was used on the lake since the 1940s to provide short term relief of nuisance blooms.

There has been an increase in phosphorus in the lakebed sediments over the years and they release phosphorus when oxygen levels decrease at the lake bottom. The water column of Cedar Lake periodically mixes during high summer winds and cool conditions, bringing phosphorus-rich water to the surface for algal uptake and growth. In addition to this internal loading of phosphorus, phosphorus input to the lake comes from the watershed and direct rainfall, along with minor inputs from groundwater.

Samples from the bottom of the lake confirmed that phosphorus was very high in the sediments and available to be released into the overlying water column. HAB Aquatic Solutions conducted the first of five planned alum applications over a sixteen-day period in June 2017. In 2017, approximately 20% (287,813 gallons of alum) of the total dose (1,437,325 gallons of alum) was applied and the remaining dose will be applied over multiple future years. The application produces a “floc” that settles to the bottom of the lake. The floc has sites where phosphorus in the sediments become chemically bound as it leaches from the bottom. The floc effectively intercepts and binds the phosphorus, which makes it unavailable for the algae to use for growth. The goals of the project are to dramatically reduce the internal loading of phosphorus from the sediments, lower the amount of phosphorus available to algae in the water, reduce the amount of algae and potential toxins and improve the recreational opportunities for lake users.

2 Project References

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