Nippo Lake Supplementary Materials

Photo courtesy of Nippo Lake Association

Prepared by: New Hampshire Department of Environmental Services

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Contents

Nippo Lake Internal Loading Treatment Plan; Barrington, NH

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WRS

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Contents

Cover letter

December 23, 2020

New Hampshire Department of Environmental Services
Watershed Management Bureau
29 Hazen Drive; PO Box 95
Concord, NH 03302-0095

Dear Bureau Members:

This submission covers the request for a water quality certification for an aluminum treatment in Nippo Lake with the goal of preventing cyanobacteria (blue-green algae) blooms. The past and ongoing approach involves watershed management techniques to alleviate blooms, however, both observations and modeling have demonstrated that this approach alone is insufficient to reduce future blooms. An aluminum treatment is a preventive management approach that addresses the cause of algae blooms rather than treating the bloom itself. In the case of Nippo Lake, a major factor influencing blooms is internal phosphorus loading from surficial bottom sediments exposed to anoxia. Alternative approaches are possible but inactivation of phosphorus is an appropriate approach in terms of effectiveness and cost over a 1-2 decade timeframe.

We are recommending treatment of surficial sediments with aluminum over an approximately 56 acre area below a water depth of 4.6 m (15 feet). The recommended dose is up to 53 g/m^2. This dose was determined by detailed sediment and in-laboratory jar testing and is just slightly higher than the average dose applied in other lakes in New England. Such a treatment could be conducted at almost any time when there is open water but is optimal as a spring treatment. The recommended dose need not be applied all at once but could be spread over several applications. The duration of benefits is expected to be 15 to 20 years, possibly longer given efforts toward watershed management conducted over the last decades.

The 2019 sediment memorandum, the technique screening memorandum and the watershed-based plan for Nippo Lake provides considerable additional detail, including lake testing locations, past water quality monitoring results, restoration plans and alternative management options. This narrative provides a summary of findings as relates to the proposed treatment and addresses specific regulatory concerns. It should be adequate for understanding the lake and project, but feel free to review the supporting documents. Please contact me with any questions.

Sincerely yours,

Don Kretchmer, CLM
dkretchmer@metrocast.net

Background

Nippo Lake is 85 acres in size with a maximum depth of 52 feet and a mean depth of 20 feet (Figure 1). Land use in the watershed is primarily forested but also includes diffuse residential development and roadways (Figure 2). NHDES completed trophic surveys of Nippo Lake in 1982 and 2004 categorizing it as mesotrophic on both occasions. In the ten years from 2010-2019, Nippo Lake experienced documented cyanobacteria blooms that impaired recreational uses of the lake in eight years (Table 1). The quantity of algae and cyanobacteria in Nippo Lake is directly related to the concentration of the nutrient in shortest supply, phosphorus (P). The watershed-based plan for Nippo Lake provides the basis for this conclusion and a plan to address both external and internal loads of phosphorus to the lake (NHDES 2020). The Nippo Lake watershed-based plan documents that the internal load represents 34% of the total phosphorus load to Nippo Lake (Table 3). As that load is focused in the growing season, it is disproportionately more important in fostering algal blooms than sources that are more evenly spread over the year. External phosphorus sources, natural and unnatural, account for 44% of the load to the lake (Table 3). A plan to reduce the external load by approximately 30% (5kg per year) has already been executed. These activities include upgraded stormwater systems adjacent to roadways and associated with private homes. These external load reductions, realized and expected, represent the extent of unnatural phosphorus load removal. As part of the watershed-based plan, a modeled in-lake phosphorus concentration target of 7.2 ug/L was established. Phosphorus at this level would result in a much-reduced likelihood of cyanobacteria bloom conditions. To meet the target, the internal load of phosphorus must be reduced by an additional 10 kg per year.

An alternatives assessment was conducted (DKWRC-WRS 2020) to evaluate a wide variety of phosphorus control options (Appendix A). The assessment identified sediment phosphorus inactivation as the most rapid and effective method for reducing the internal load of phosphorus in Nippo Lake. Phosphorus inactivation will bind phosphorus in the surficial bottom sediment retarding its release under low oxygen conditions. Phosphorus inactivation, is less expensive than other options and is typically needed only once every 10-20 years to meet user expectations. Phosphorus inactivation will minimize the risk of cyanobacteria blooms, promote a more balanced and adaptive biological community in the lake, and improve recreational uses such as swimming, fishing, and wildlife viewing.

The estimated treatment area is 56 acres (66% of total lake area) (Figure 3). As proposed, sediment phosphorus inactivation would be accomplished through the addition of aluminum-based compounds (aluminum sulfate and sodium aluminate) and could be completed in less than a month once funding and approval is in place. While this is a common technique nationally and even regionally, it is a relatively unique technique to New Hampshire with only one project being conducted in 1984 (Kezar Lake, Sutton). Because of the uniqueness of this technique to New Hampshire, the proposed project includes a small 10-acre pilot program prior to full project execution is recommended.

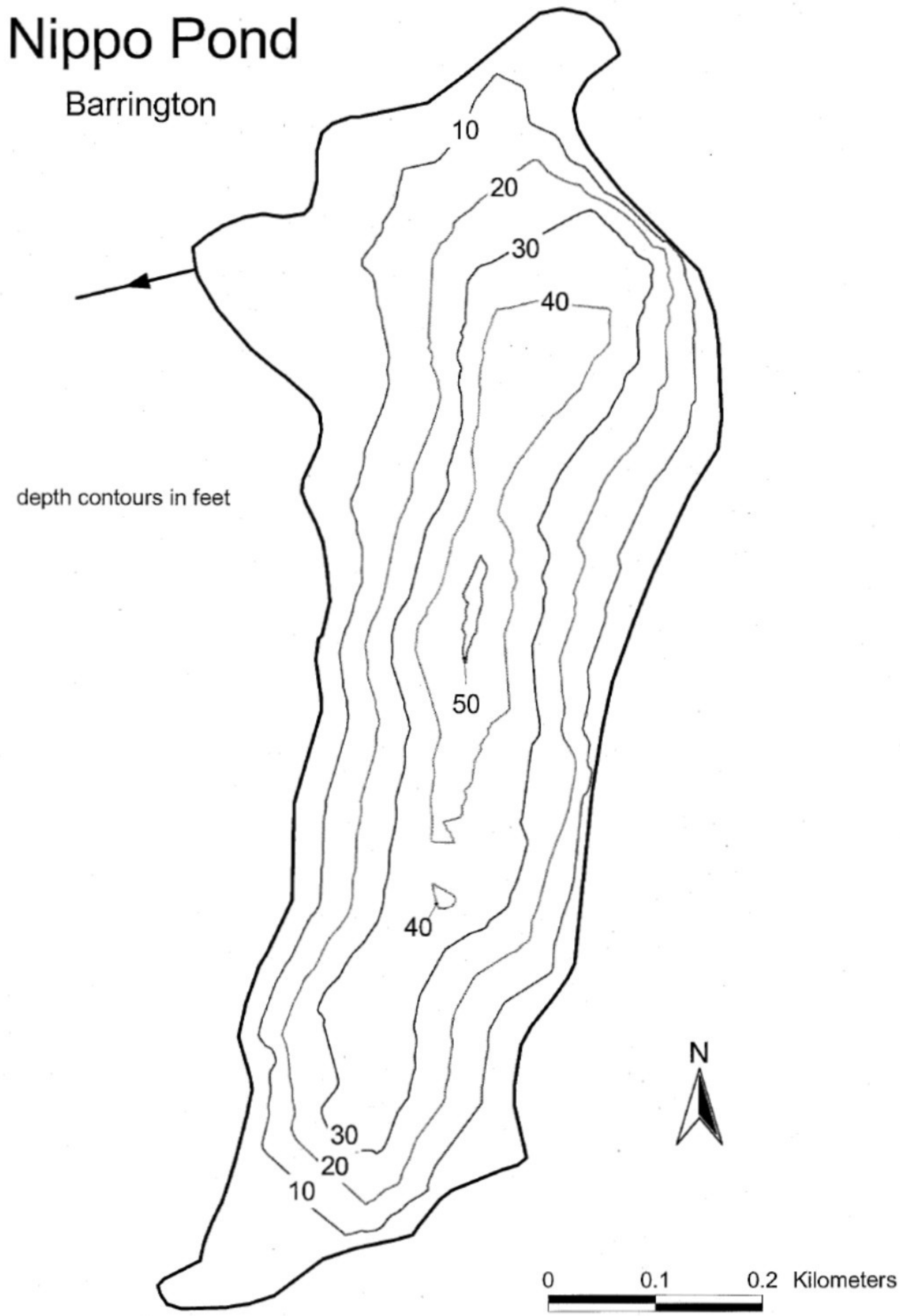

Figure 1. Nippo Lake Bathymetry

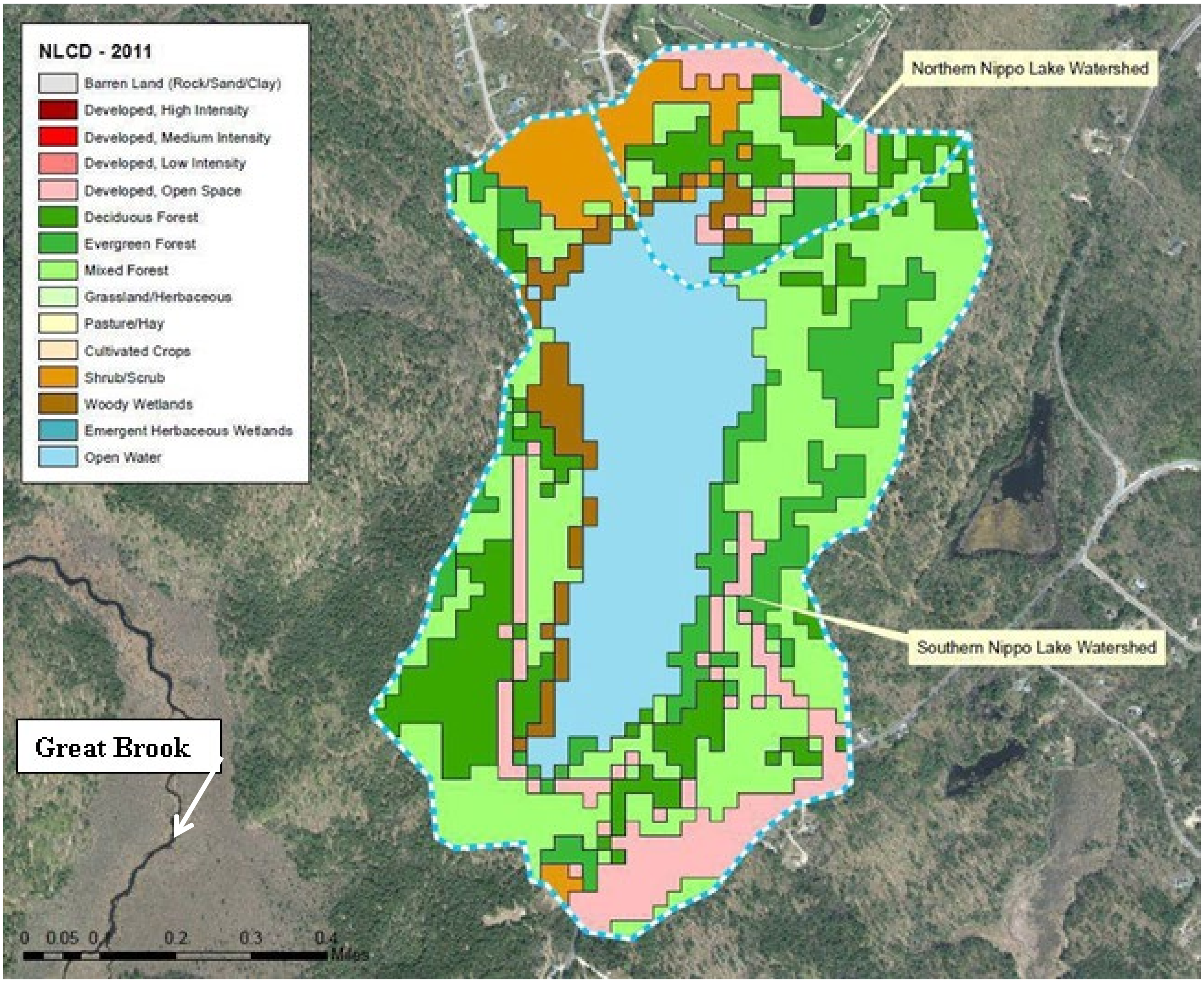

Figure 2. Nippo Lake Watershed with Land Cover

Table 1. Reported cyanobacteria blooms in Nippo Lake between 2010 and 2019 (sources: NHDES and UNH Center for Freshwater Biology).

Reported Bloom	***Sample Collected***	***Genera***	***Cell Count***	***Comments***
June 17, 2010	Yes	Anabaena	86,500 cells/mL	Advisory issued; in effect until 9/24/2010 microcystins < recommended maximum levels
July 11, 2011	Estimate	Anabaena	80,000 cells/mL	Bloom had receded by 6/22/2011
July 30, 2013	No	Oscillatoria and Anabaena	N/A	
September 30, 2013	No	Anabaena	N/A	Surface film
August 19, 2014	Yes	Anabaena	Phycocyanin concentrations exceeded 100,000 cells/mL	
August 5, 2015	Yes	Unknown picoplankton	170,000 cells/mL	
August 18,2015	Yes	Small cyanobacteria	300,000 cells/mL	
June 3, 2016	Yes	Anabaena	50,000 cells/mL	
July 28, 2016	Yes	Picocyanobacteria	230,000 cells/mL	Advisory issued
May 29, 2018	Yes	Anabaena	N/A	Sampled after bloom conditions
June 7, 2018	Yes	Anabaena	100 cells/mL	Microcystin levels < detectable limits
July 23, 2018	Yes	Anabaena	750 cells/mL	Microcystin levels < detectable limits
August 26, 2019	Yes	Picocyanobacteria	200,000 cells/mL	Advisory issued; in effect until 9/23/2019

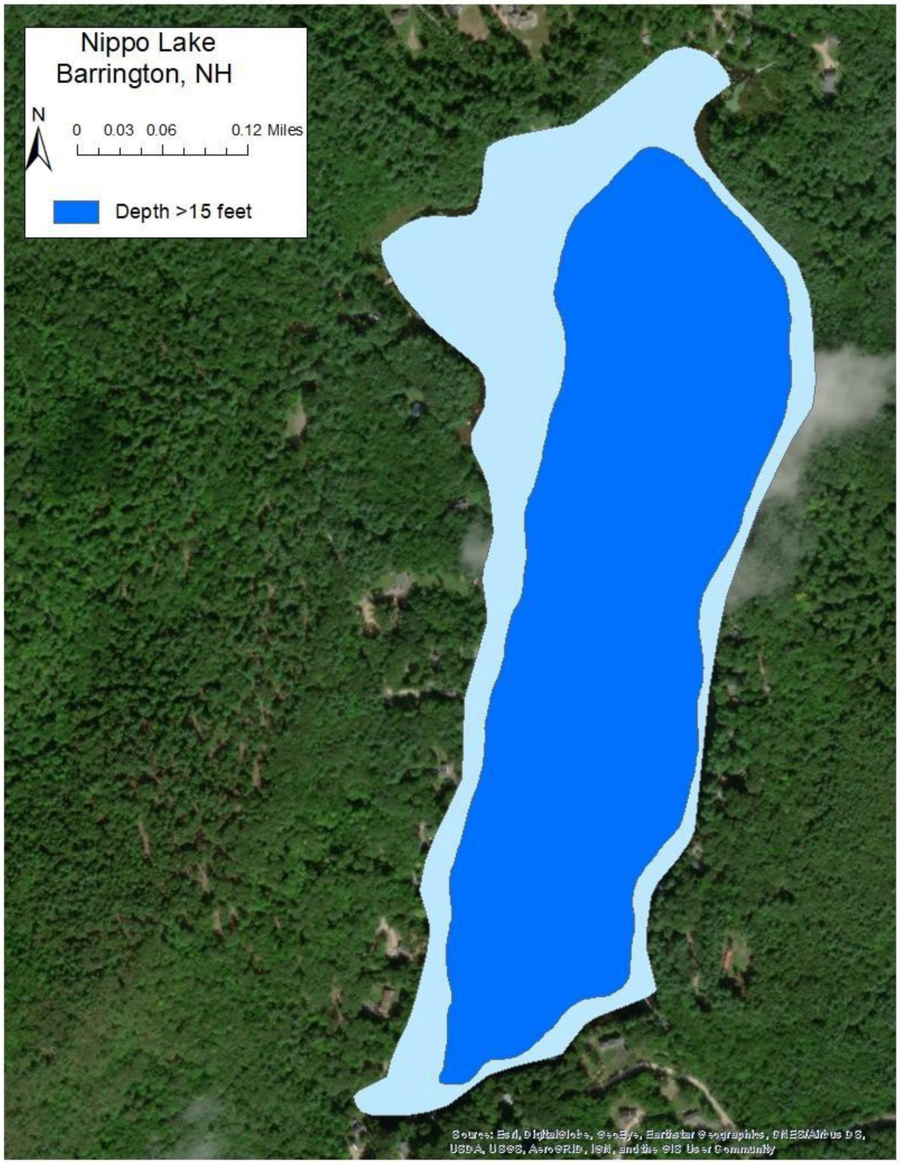

Figure 3. Nippo Lake and proposed treatment area (depth >15ft)

Benefits of Proposed Project

In-Lake Water Quality and Algae

A monitoring program has been conducted over the past ten years, largely carried out by volunteer lake monitors under direction of the Lay Lakes Monitoring Program (LLMP) at the University of New Hampshire. Prior to 2010, data were only collected in some years by NHDES.

Temperature, dissolved oxygen, alkalinity, pH, conductivity, color, chlorophyll-a and Secchi disc transparency have been measured in the field. Algae and zooplankton have been sampled and analyzed. Sediment samples have been tested for key features relating to the release of phosphorus under low oxygen conditions. The results were discussed in a technical memorandum by DK Water Resource Consulting LLC (Appendix B). This narrative provides the key physical and chemical information necessary to treat bottom sediments to reduce phosphorus availability and minimize algae blooms.

Total phosphorus concentrations in the upper layer (epilimnion) in 1980's were between 4 and 7 µg/L (Figure 4) in the surface water of Nippo Lake, well below the desirable threshold of 8 µg/L that defines an oligotrophic lake in NH. The watershed plan prepared by NHDES (2020) includes an average annual phosphorus concentration goal of 7.2 µg/l in Nippo Lake which is below the oligotrophic threshold and similar to Nippo Lake concentrations observed in the 1980's. This goal was developed in response to observed epilimnetic phosphorus concentrations that have increased over the past 10 years to 10 to 16 µg/L in the surface waters. These concentrations have contributed to regular cyanobacteria blooms in Nippo Lake. More importantly, hypolimnetic (deep water) concentrations in 2016 averaged 95 µg/L, roughly ten times the surface concentrations and peaked over 180 µg/L by the end of the stratification period in October (Figure 5, Table 2). These data document the disproportionate accumulation of phosphorus in the deep water consistent with the release from anoxic sediment. Some of the deep-water phosphorus is undoubtedly mixed into surface waters over the course of the summer as the epilimnion increases in depth and the remainder of the water column is mixed during fall turnover. The more important implication is that cyanobacteria growth is likely best supported near the thermocline during stratification where cyanobacteria can "harvest" phosphorus from the hyplimnion and migrate upwards in the water column by using buoyancy regulating gas vacuoles in order to capture light for photosynthesis. Eventually, this phenomenon leads to cyanobacteria dominance in the phytoplankton community and lake-wide blooms.

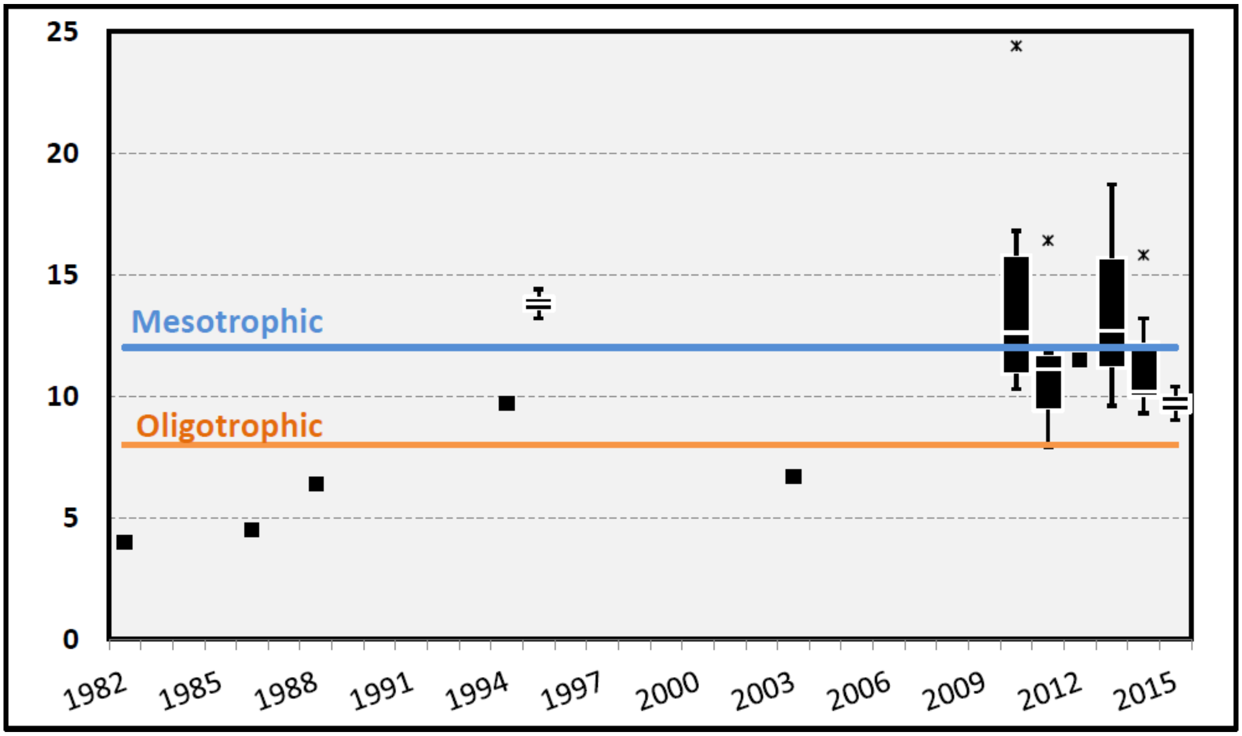

Figure 4: Total phosphorus concentration from the epilimnion of Nippo Lake.

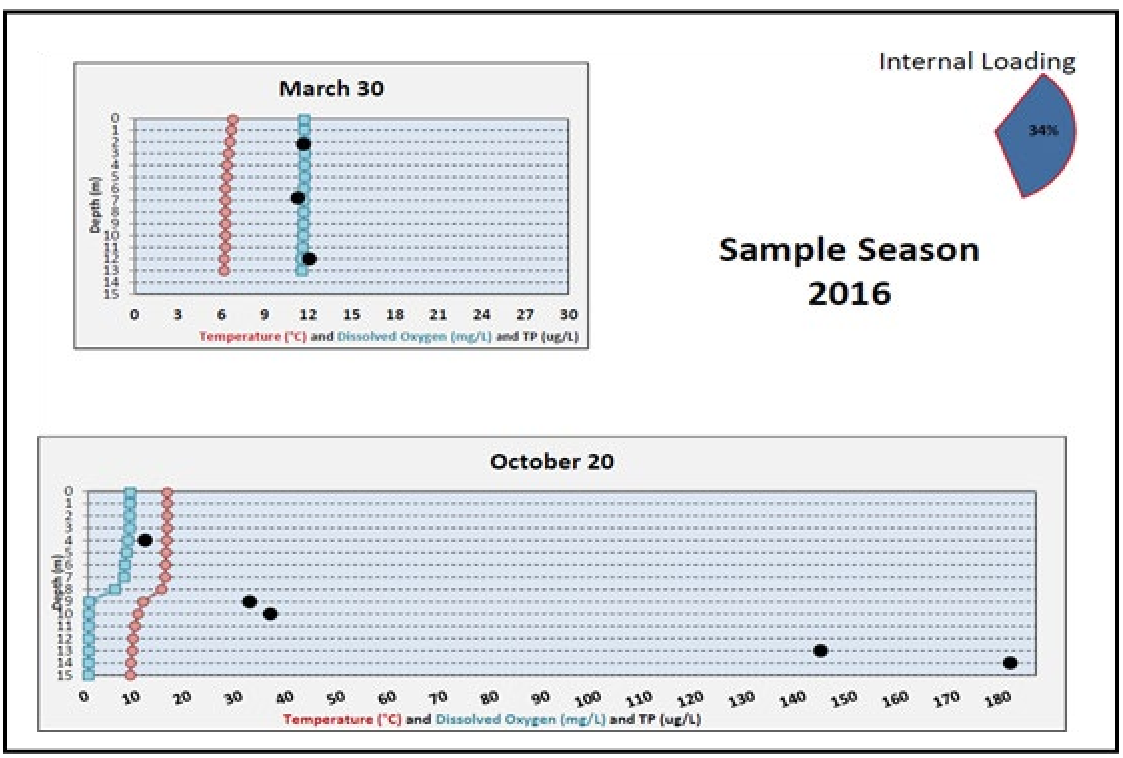

Figure 5. 2016 Total phosphorus, temperature and dissolved oxygen results for Nippo Lake.

Table 2. 2016 average epilimnetic and hypolimnetic total phosphorus concentrations in Nippo Lake.

Nippo Lake
Sample Season 2016
TP (µg/L)

Layer	Average	Median	St. Dev.
Epilimnion	9.8	9.6	1.4
Hypolimnion	95.0	100.5	58.0

The driving force behind internal release of phosphorus from surficial sediments is exposure to anoxia in the overlying water, as low oxygen promotes chemical and biochemical reactions to occur that allow phosphorus to be released from the sediment into the overlying water. The oxygen profiles for Nippo Lake during 2016 (Figure 5) are indicative of the low oxygen problem during summer. Oxygen is reduced below 7 m (21 feet) and <1 mg/L at depths >9 m (30 feet) for much of August and September. This creates a large contributory sediment zone during summer from which phosphorus is released. It is also possible that sediments at depths shallower than 7 m may be anoxic below the overlying water interface and contribute to the internal phosphorus load. The blooms and clarity experienced by Nippo Lake are consistent with the availability of phosphorus from internal sources in the lake. It is appropriate to address these sources of nutrients, especially phosphorus, to limit algae production overall.

Watershed Inputs

Sources of nutrients to Nippo Lake have been estimated as a part of the watershed management plan. A summary of phosphorus sources is presented in Table 2.

Table 3. Current phosphorus budget for Nippo Lake (NHDES 2020).

TP Inputs to Lake	Phosphorus Load (kg/yr)	Percent of Total
Atmospheric	3.8	10
Internal	12.9	34
Waterfowl	1.7	5
Septic Systems	2.8	7
Watershed	16.4	44
Total Load to Lake	**37.5**	**100**

A central finding of the watershed plan is that both external (watershed) loads of phosphorus and internal loads of phosphorus must be reduced to reduce the potential for cyanobacteria blooms. Several measures to reduce the external load of phosphorus have been implemented and others are planned (Table 4). Overall, the intention is to reduce the external load of phosphorus to Nippo Lake by 5kg / year (30%). The external load reductions coupled with 80-90% reduction in internal load as detailed below are expected to produce acceptable water quality in Nippo Lake for the future and meet a target annual concentration of 7.2 ug/L of phosphorus as established in the watershed management plan (NHDES 2020).

Table 4. Phosphorus load reduction estimates to Nippo Lake.

Management Category	Location	Description	Year of install	Est. P reduction (kg/yr)
Roads	Golf Course Way	Road paving and drainage BMPs	2019	3.8
	Flower Drive	Drainage BMPs for gravel road	2021	0.6
Residential	Golf Course Way	Raingarden	2018	0.0
	Sarah Lane	Water diversion	2019	0.2
	Nippo Court	Infiltration trench	2019	0.0
	Flower Drive	Water diversion	2019	0.1
	Flower Drive	Water diversion	2019	0.0
	Nippo Court	Water diversion	2020	0.1
	Sarah Lane	Infiltration trench and water diversion	2020	0.0
Septic systems	Nippo Court	Septic system upgrade	2018	0.5
		Watershed Load Reduction Total		**5.3**
Internal	Lake sediments	In-lake phosphorus inactivation	2021	10.0
			Projected load reduction end of 2021	**15.3**

Available Phosphorus in Sediment

Given the sediment release of phosphorus to be a substantial source in Nippo Lake, surficial sediment samples were collected in 2018 and analyzed. The results of this analysis were discussed in detailed in a technical memorandum prepared in January 2019 (DKWRC 2019, Appendix B). Fractions of phosphorus by form and depth in Nippo Lake are presented in Figure 6.

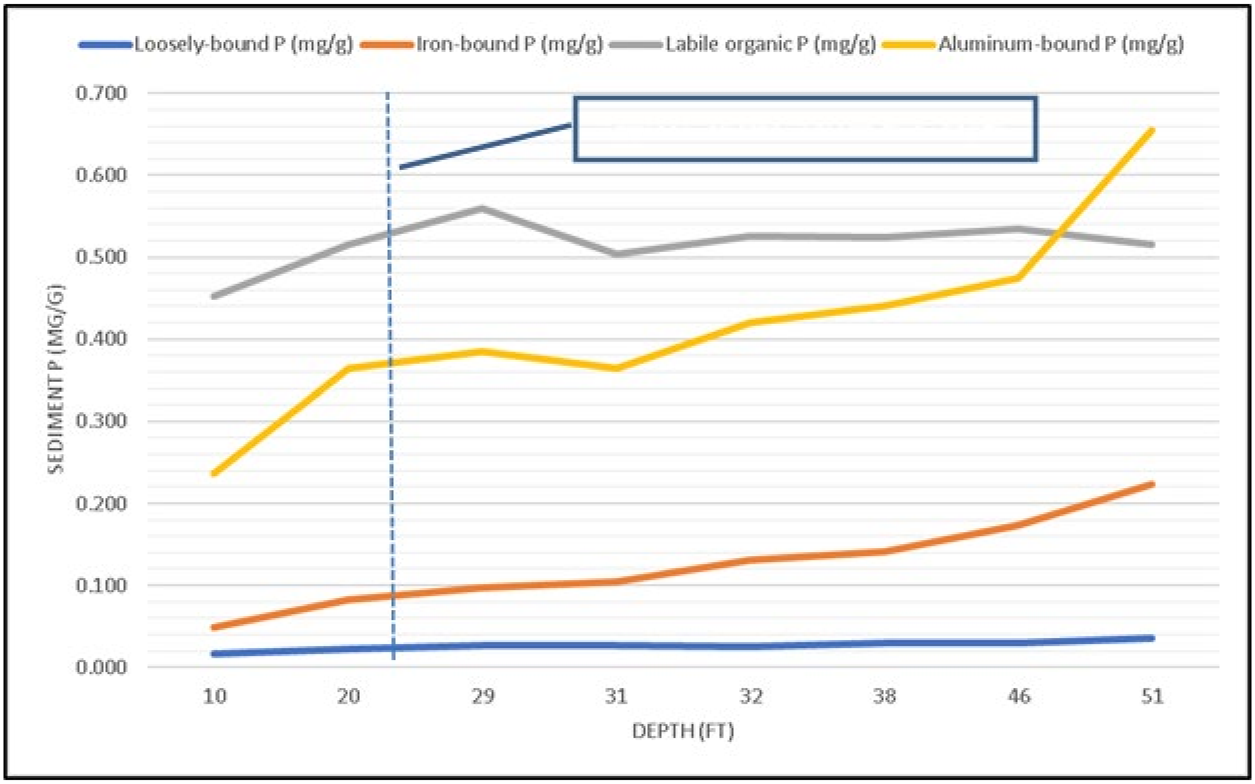

Figure 6. Forms of phosphorus by water depth in Nippo Lake Barrington, NH. Samples collected in 2018.

Total phosphorus in the sediment are less important than the concentrations of available fractions, as much of the P may not be accessible to algae. The aluminum-bound fraction does not get released under oxic or anoxic conditions and is typically unavailable to algae. The loosely-bound and iron-bound phosphorus fraction is the most readily available, although not even all of this portion is quickly released when oxygen is depleted. Biogenic (labile) phosphorus is another potentially available fraction, representing the most easily released organically bound phosphorus. The release of the biogenic portion is dependent, in part, on microbial degradation of the organic matter prior to anoxic facilitated release to the water column so this fraction is somewhat less available than loosely-bound and iron bound P but can still contribute substantially to the internal load. Observed available sediment P concentrations are considered moderate when compared to other lakes where internal loading is significant but are clearly sufficient to result in substantial anoxic release of P to the hypolimnion (Table 2). Phosphorus concentrations in Nippo Lake sediments increase with water depth as is typical in lakes as sediments migrate towards the deepest sections.

The concentration of iron-bound, loosely-bound and biogenic (labile) phosphorus must be converted to a mass with consideration of % solids and specific gravity to fully understand its potential impact. For the 2018 samples, iron-bound and loosely-bound phosphorus averaged approximately 1.4 g/m2 in Nippo Lake. Including biogenic (labile) phosphorus with the iron-bound phosphorus and loosely-bound phosphorus, yielded a higher available phosphorus mass of 5.8 g/m2 in Nippo Lake. Inactivation of all forms of phosphorus with the potential for release is advisable for Nippo Lake to offer the greatest level of protection from future cyanobacteria blooms. This would require an aluminum dose of 53 g/m^2 over the proposed treatment area of 56 acres. This represents an approximate 10:1 ratio of aluminum to available phosphorus based on many recent aluminum treatments (James and Bischoff 2015, Reitzel et al 2005, Ryydin et al 2000 and Rydin and Welch 1999). In calculating the dose, loosely-bound and iron-bound P is treated at a 15:1 Al:P ratio while biogenic (labile) P is treated at 7.5:1 ratio. Details on the calculation of the dose are presented in Table 5.

Table 5. Calculation of aluminum dose from sediment data using an aluminum sulfate to sodium aluminate ratio of 1.8.

N/A	Loosely Sorbed and Fe-P only	Biogenic (labile) P only	Total of all available forms[1]
Treatment area for scenario	15+ Feet (4.5m)	15+ Feet (4.5m)	15+ Feet (4.5m)
Per acre cost			
Mean Available Sediment P (mg/kg DW)	158	520	678
Target Depth of Sediment to be Treated (cm)	10	10	
Volume of Sediment to be Treated per m2 (m3)	0.100	0.100	
Specific Gravity of Sediment	1.03	1.03	
Percent Solids (as a fraction)	0.082	0.082	
Mass of Sediment to be Treated (kg/m2)	8.4	8.4	
Mass of P to be Treated (g/m2)	1.33	4.39	5.73
Target Area (ac)	1	1	1
Target Area (m2)	4032	4032	4032
Aluminum sulfate (alum) @ 11.1 lb/gal and 4.4% aluminum (lb/gal)	0.4884	0.4884	0.4884
Sodium aluminate (aluminate) @ 12.1 lb/gal and 10.38% aluminum (lb/gal)	1.256	1.256	1
Stoich. Ratio (ratio of Al to P in treatment)	15	7.5	
Resulting areal dose (g Al/m2)	20	33	53
Ratio of alum to aluminate during treatment (volumetric)	1.80	1.80	1.80
Aluminum Load			
Dose (kg/area)	81	133	214
Dose (lb/area)	178	292	470
Dose (gal alum) with Alum only	364	598	962
Application (gal/ac) for alum	364	598	962
Dose (gal alum) @ specified ratio of Alum to Aluminate	150	246	396
Dose (gal aluminate) @ specified ratio of Alum to Aluminate	83	137	220
Application (gal/ac) for Alum in Alum+Aluminate Trtmt	150	246	396
Application (gal/ac) for Aluminate in Alum+Aluminate Trtmt	83	137	220
Acreage to be treated (ac)	56.00	56.00	56.00
Acreage to be treated (ha)	22.68	22.68	22.68
Total mass of P to be inactivated (kg)	302.66	996.09	1298.74

[1]Note that rows that are not additive are not displayed

Proposed Project

The proposed project is an aluminum treatment of Nippo Lake with the goal of reducing phosphorus released from sediment that fuels cyanobacteria blooms. Based on the documented condition of Nippo Lake the most important action that can be taken to improve the lake is the reduction of internal loading of phosphorus from sediments exposed to anoxia. With an aluminum application as planned, the lake is expected to have decreases in internal loading ranging from 80-90%.

By reducing the available phosphorus for algal uptake Nippo Lake will experience ecological benefits related to water quality. Water clarity will increase, resulting in average summer water clarity >5.0 m (16 feet), total algal biomass will decrease and algae composition will favor more desirable species conducive to more efficient energy flow through the food web. Oxygen improvements are also an expected benefit of phosphorus inactivation. The reduction in algae production will translate to less oxygen-demanding organic matter settling into deeper water, but the ongoing oxygen demand of the existing organic sediments will not be appreciably reduced by the treatment. Thus while the zone of anoxia is expected to be thinner, it is unlikely to be eliminated. Improvements in the dissolved oxygen conditions will provide additional habitat for fish species, zooplankton, and benthic invertebrates.

For Nippo Lake, treatment of an area of about 56 acres is expected to minimize internal loading and control algae blooms for 10-20 years. This area represents the sediments below 15 feet in water depth or all the sediments with a high potential to release phosphorus to the water column (Figure 3).

Aluminum has been the sediment phosphorus inactivation additive of choice in New England for the last 30 years. It is not a new approach and has been used to successfully manage lakes since the 1970s (Welch and Cooke 1999). Aluminum sulfate (alum) can be applied by itself where lake water alkalinity is high, but in most cases sodium aluminate is applied with the aluminum sulfate to keep the pH stable. Alkalinity in Nippo Lake is low and ranges from 6 to 12 mg/L with an average of 7mg/L (NHDES EMD; 13 samples, 2016-2020) in Nippo Lake. As such buffering will be needed at the recommended doses in order to minimize environmental risks (see below).

Application of aluminum for phosphorus inactivation is completed from the surface using vessels specifically designed for that purpose, and chemicals are metered to provide precise ratios of aluminum sulfate to sodium aluminate and tight pH control as well as accurate dose amounts (Figure 6). Barges traverse GPS guided paths for accurate delivery of aluminum to target areas. Dose determination is made from sediment analyses and confirmed with laboratory assays. A review of treated lakes (e.g., Huser et al. 2016, Wagner et al. 2017) indicates improved conditions in virtually all lakes, but varying lengths of time for water quality benefits. Sediment features not yet fully understood appear to affect results, but cyanobacterial dominance has been reduced in nearly all cases. Water clarity is typically 5-7 m the summer after treatment and has remained higher than 3 m in most lakes for more than a decade, often two decades.

Figure 6. One Current Approach to Application of Aluminum

Successful aluminum treatment is a function of supplying an adequate dose to the appropriate treatment area. It is generally acknowledged that the targeted treatment area should be at least the area of sediment that can experience anoxia, which facilitates the release of phosphorus bound by iron (Fe-P) as well as loosely bound phosphorus which is typically a much smaller fraction than Fe-P. In addition, labile organic phosphorus can be broken down by microbes to become available so it is often advisable to treat that fraction as well. Treating a slightly larger area where algae may grow on the surficial sediment then float upward in response to change in light and/or temperature is also advisable. The necessary dose is a matter of both the Fe-P concentration and other sediment constituents that may compete with Fe-P for binding sites on the applied aluminum compounds.

The aluminum to phosphorus ratio (Al:P) necessary for effective inactivation varies inversely with Fe-P concentration, as lower Fe-P levels mean that other constituents are abundant and compete for binding sites (James and Bischoff 2015). When Fe-P is high more Al is needed, but the ratio of Al to P will be lower than for a sample with less Fe-P since the Al will encounter more Fe-P than other possible binding compounds in the situation with higher Fe-P. Binding of Fe-P with Al is more efficient at higher Fe-P. The range of Al:P ratios for successful treatments tends to range from 10 to 150, and the range of aluminum doses have been 10 to about 200 g/m2, although treatments at >100 g/m2 have generally not been needed and most Al:P ratios have been near the low end of the known range.

The upper 10 cm (4 inches) of sediment is what can typically interact with the overlying water (Welch et al 2017) although it can be a somewhat thinner or thicker layer in some circumstances. The mass of phosphorus per square meter to a depth of 10 cm is therefore the target of inactivation. Details on the dose calculation are presented in Table 5. The target mass of phosphorus in Nippo Lake at the 10 cm sediment depth is therefore 5.7 g/m2. The aluminum dose should be between 10 and 20 times the Fe-P and loosely bound phosphorus mass and 5-10 times the labile organic phosphorus mass. Using an Al:P ratio of 15:1 for the Fe-P and the loosely bound P and a ratio of 7.5 for labile organic-P, the recommended areal aluminum dose would be 53 g/m2 for Nippo Lake.

For treatment of Nippo Lake, a 1.8:1 volumetric ratio of alum (aluminum sulfate) to aluminate (sodium aluminate) is recommended during the application to stabilize pH. This ratio may be adjusted as the treatment progresses in response to field measurements of pH to keep the pH in the desired range. The alum and aluminate solutions are expected to be 4.4% and 10.2% aluminum, respectively. At the recommended ratio and dose this equates to additions of 22,176 gallons of alum and 12,320 gallons of aluminate to Nippo Lake. The cost of this treatment is estimated at between $175,000 and $200,000. An additional $25,000 may be required if a pilot application precedes application of the full dose.

Timing and sequencing of aluminum application

Aluminum application to Nippo Lake is proposed to occur in 3 phases. Since aluminum has not been used as method to inactivate sediment phosphorus in New Hampshire lakes since the 1980s, the first phase will include an aluminum application in a 10-acre pilot plot at dose of 26.5 g/m2 in the target treatment area. The pilot phase is designed to evaluate environmental conditions and make necessary adjustments to the application dose rate and alum:aluminate ratio in order to minimize risks to aquatic organisms (see below). The first application will occur over the remaining 46 acres that were not treated initially. The second application will occur over the entire 56 acres. For both applications, a dose of 26.5 g/m2 will be applied in all locations exceeding 15 feet deep. When the mass of aluminum from all three applications are combined, the total dose will be equivalent to 53 g/m2.

The pilot phase is scheduled for April 2021 and will be completed in a single day. The remaining applications will be scheduled 2-3 weeks after the pilot. For the first and second applications, a maximum of one-quarter (25%) of the total area scheduled to be included in the respective application will be treated in a single day (12 acres/day for application 1 and 14 acres/day for application 2). The purpose of limiting the daily application area to 25% of the total area is to provide refuge from the treatment area for mobile aquatic organisms. The goal would be for each application to occur over four consecutive days. Following completion of the first application, environmental conditions will be evaluated to determine if the second application could proceed the following day or if a period of time is needed to protect aquatic life. One approach utilized in other treatments has been to complete the first dose on a Friday, monitor through the weekend, and resume treatment on Monday.

Ecological and Human Health Considerations

The impacts of aluminum treatments have been studied and documented over a long period of time. The potential negative impacts are temporary and long-term beneficial impacts have been known to last up to 20 years. In the states surrounding New Hampshire, aluminum has been the phosphorus binder of choice for the past 25 years. It is not a new approach for New Hampshire either, as Kezar Lake was treated in 1984. In Massachusetts a dozen ponds have been treated on Cape Cod since 2000 with no adverse impacts and lasting improvement, although not all responded to the same degree (Wagner et al. 2017). In the last two years, Lake Attitash in MA on the NH border and Lake Congamond in MA were treated and responded well. Over in VT, Ticklenaked Pond was treated in 2016 and was recently removed from the impaired waters list as a result of documented improvement. Maine has 4 lakes that were treated in the 1980s, 3 of which showed 20 years of improvement. In the last 2 years 4 lakes have been treated in Maine, all with desirable results. One Maine lake, Cochnewagon within the Cobbosee Watershed Management District, was treated in 1986 and again in 2019. Along with Hamblin Pond in Barnstable on Cape Cod in MA, these are the only two lakes in New England to have been successfully treated, gone back to an unacceptable condition after about 2 decades, and been treated again. The longevity of benefits from the Huser et al. (2016) study for stratified lakes has averaged 21 years, so these treatments represent lasting but not permanent rehabilitation. A summary of the potential risks associated with aluminum treatment in Nippo Lake are included below.

Human Health

Aluminum is regularly added in public water treatment systems as a mechanism to bind solids and clarify finished water. It has a secondary maximum contaminant level of 0.05 – 0.2 mg/L as recommended by the US Environmental Protection Agency for public drinking water systems. NHDES has also adopted these secondary criteria. The greatest risk related to ingestion of excessive concentrations of aluminum are to dialysis patients (2013 Water Quality Association technical factsheet).

Nippo Lake does not serve as a public water supply, but some unknown number of lakeside residents may draw water directly from the lake for residential use. NHDES discourages the consumption of untreated lake water. Aluminum application to the Nippo Lake will occur only in offshore areas (approximately >50 feet from shore) in excess of waters greater than 15 feet deep. Taken collectively, there is there is little to no risk to human health through the addition of alum or aluminate to manage internal phosphorus loads. Public notice will occur one week prior to treatment and remain in place at least one week post treatment pending analytical results from the monitoring program. Last, with respect to groundwater, there is no risk for well contamination as the dose was planned specifically such that the aluminum would become bound to bottom sediments.

Aquatic life

High aluminum concentrations and pH (high or low) are the water quality parameters of greatest concern relative to potential impacts to aquatic life associated with the proposed project. The impacts of aluminum at high concentrations are well known and most significant for fish and invertebrates whereas risks to aquatic plants, including algae, are not as well understood, but as currently studied, appear to be less significant (Gensemer and Playle, 1999).

Water quality criteria have been established to minimize the likelihood of impacts to aquatic life. Current NHDES acute criteria are 750 ug/L or 0.750 mg/l (1-hour average) and the chronic criteria are 87 ug/L or 0.087 mg/l (4-day average) (NHDES administrative rule Env – Wq 1700). These criteria are based on the acid soluble aluminum fraction which is typically about 70% of the total aluminum concentration but can range from 39 – 93% (T. Walsh, 2016 NEAEB presentation). In 2018 EPA published updated aluminum water quality criteria which depend on pH, hardness, and dissolved organic carbon (DOC) (EPA-822-R-18-001). Based on a November 2019 Nippo Lake sample from the epilimnion, the total aluminum criteria under the

EPA criteria would change to 430 ug/L and 230 ug/L for the acute and chronic values, respectively (pH=6.56; hardness 12.1 mg/L, DOC=2.9 mg/L). In developing the new aluminum criteria, EPA reviewed previous studies and documented that the genera most sensitive to acute aluminum toxicity were two zooplankter taxa (Ceriodaphnia sp., Daphnia sp.) and two fish genera (Micropterus sp. and Oncorhynchus sp.). For chronic toxicity, a mussel (Lampsilis sp.), a zooplankter (Daphnia sp.), and two fish genera (Salvalinus sp., Salmo sp.) were most sensitive. The criteria are conservative in nature and are based on minimizing impacts to 95% of aquatic organisms and events that occur once per year (EPA-822-R-18-001).

The New Hampshire Fish and Game Department reports that Nippo Pond is a warmwater fishery with a typical community of warmwater fish species including smallmouth bass, yellow perch, sunfish, and brown bullhead (horned pout) (Jason Smith, personal communication). No formal fish surveys of the lake have been completed since the 1950s. The zooplankton community reported by NHDES in the 1982 and 2004 lake trophic reports were comprised of Vorticella sp. (protist), unidentified copepod larvae (reported as Nauplius), Holopedium sp. (water flea), and Keratella sp. (rotifer). In the same reports, the phytoplankton community were documented as including Tabellaria sp. (diatom), Asterionella sp. (diatom), Anabaena sp. / Dolichospermum sp. (cyanobacteria), and Dinobryon sp. (golden brown).

The addition of aluminum sulfate (alum) to water, by itself, will increase the water's acidity and lower the pH temporarily. These effects are most dramatic in waters with low buffering capacity (ie. alkalinity). As noted above, to remedy this outcome, sodium aluminate (aluminate) is added at specific ratios to alum in order to balance the pH. Managing the pH balance of the water is critically important during aluminum applications as pH that is either too high or too low will negatively impact the aquatic community. In particular, while there are many forms of aluminum, the most toxic forms occur at pH values below 6.0 and above 8.0 (EPA-822-R-18-001; Gensmer and Playle 1999).

Nippo Lake is a class B water as identified by NHDES. NHDES water quality criteria for pH in class B waters are 6.5 and 8.0. Nippo Lake is listed as impaired (category 4A-P) for pH on the NHDES 2020 303(d) impaired waters list. Data used in the assessment of pH ranged from 5.23 to 9.62, with an average pH of 6.5. Water samples collected from March through June from 2010 – 2020 had and average pH of 5.9. Data (n=6) from fall 2020 (n=6) which was not included in the 2020 assessment was similar with an average pH of 6.49 and a range of 6.16 – 6.94. The 2020 samples were collected at depths ranging from 3 – 13 m.

In fall 2020, NHDES completed laboratory tests in an effort to evaluate aluminum concentrations and pH of water collected from Nippo Lake following the addition of alum and aluminate at the various doses and ratios. Known as "jar tests", the first lab experiment by NHDES was used to measure aluminum concentrations and pH levels in 1-liter Erlenmeyer flasks. For the recommended maximum one-day dose (27g/m^2) and ratio of alum to aluminate (1.8:1) acid soluble aluminum concentrations ranged from 0.57 to 2.77 mg/L (Table 6). For the experiment, two doses of aluminum were added two days apart (day 0 and day 2). For the 27 g/m^2 treatment, the acid soluble aluminum concentration was 0.94 mg/L 24-hours and 0.57 mg/L 48-hours after the first dose, respectively. In the same experiment, pH levels for the 27 g/m^2 treatment were 5.23 and 5.39 at 24 and 48-hours after the first dose, respectively (Table 6).

A second experiment was conducted using a 1-liter graduated cylinder which was approximately 8-10" taller than the Erlenmeyer flasks. The results from this experiment yielded acid soluble aluminum concentrations that ranged from 0.21 – 1.39 mg/L with the lowest concentration occurring 48-hours after the first dose of 27 g/m^2 (Table 6). The pH ranged 4.74 to 6.26 with the highest pH reading also occurring 48-hours after the first dose. Results from the second experiment were assumed to be slightly more realistic to natural conditions as there was more distance (depth) between the sample point (top of graduated cylinder) and the bottom (base of graduated cylinder). However, neither of the experiments included lake bottom sediment which presumably would have bound more of the added aluminum and provided additional pH buffering capacity to the overlying water.

Table 6. Acid soluble aluminum concentrations (mg/L) in Erlenmeyer flask jar tests. A 27 g/m^2 dose is recommended for the project.

Ratio aluminum sulfate:sodium aluminate = 1.8:1	-	-	-	-	-
Dose (g/m^2)	Day 0	Day 1	Day 2	Day 3	Day 4
13.5	0.008*	0.102*	1.137*	1.427*	1.783
18	0.008*	0.248*	1.807*	2.127	1.403
25	0.008*	0.529	0.484*	2.450	1.207
27	**0.008***	**0.944**	**0.571***	**2.773**	**1.383**
Control (lake water only)	0.008	0.008	0.010	0.013	0.016

*Indicates day dose was added. Concentrations on day 0 are prior to any aluminum additions. Concentrations on days 1 -4 are reflective of dose from previous days.

Table 7. pH in Erlenmeyer flask jar tests. A 27 g/m^2 dose is recommended for the project.

Ratio aluminum sulfate:sodium aluminate = 1.8:1					
Dose (g/m^2)	Day 0	Day 1	Day 2	Day 3	Day 4
13.5	6.87*	6.08*	5.31*	4.89*	4.80
18	6.87*	6.73*	4.90*	4.80	4.83
25	6.87*	5.32	5.49*	4.82	4.87
27	**6.87***	**5.23**	**5.39***	**4.81**	**4.77**
Control	6.87*	6.69	6.94	6.87	6.83

*Indicates day dose was added. pH levels on day 0 are prior to any aluminum additions. pH levels on days 1 -4 are reflective of dose from previous days.

Table 8. pH levels and acid soluble aluminum concentrations (mg/L) in graduated cylinder jar tests. Aluminum dose = 25 g/m^2. Ratio of aluminum sulfate:sodium aluminate = 1.8:1.

Day	Hours	pH	Acid soluble Al
0*	0	6.94	0.008
0	1	5.25	1.070
0	4	5.63	0.600
1	24	6.00	0.419
2*	48	6.26	0.209
3	72	4.74	1.390
4	96	4.99	0.648
7	168	5.47	No sample
11	264	5.50	No sample

*Indicates day dose added. Day 0 results are prior to any aluminum additions. Data other than hour 0 are reflective of prior dose(s).

Kezar Lake in Sutton, NH was treated with aluminum in June 1984. Laboratory jar tests were performed prior to a lake-wide treatment. The concentration of residual dissolved aluminum in vessels treated with 25 g/m^2 (ratio 1.6:1 alum:aluminate) were 1.25 mg/L and 0.78 mg/L after six and 24-hours, respectively. The pH of water in the same vessels was 5.15 and 5.26 after six and 24-hours, respectively. Higher doses of aluminum and/or lower ratios of alum to aluminate yielded higher aluminum concentrations and lower pH levels. Ultimately, 100 acres of Kezar Lake was treated at an aluminum dose of 40 g/m^2 at a ratio of 2:1, alum to aluminate. Residual dissolved aluminum concentrations increased from 0.14 mg/l before to 0.17 mg/L after treatment and the pH dropped from 6.1 to 5.5 one month after treatment. Aluminum and pH returned to normal two months after treatment (NHDES staff report 142, February 1985).

Visual observations during the treatment documented that "although a few stressed fish were observed during the treatment, no fish kill was observed".

A summary of aluminum concentrations in other New England lakes where aluminum has been applied indicated total aluminum concentrations ranged from 0.1 to 0.5 mg/L immediately after application (K. Wagner, personal communication). Lake Cochnewagon in Monmouth, Maine is approximately 400 acres. In 2019, approximately 225 acres (56%) was treated with 39 g/m^2 of aluminum and total aluminum concentrations ranged from 0.23-0.50 mg/L immediately after treatment. Total aluminum concentrations had decreased to 0.12 and 0.09 mg/L 3-weeks and 5-weeks, respectively, post-treatment.

In summary, it is expected that acid soluble aluminum concentrations in Nippo Lake within 1-hour of treatment will be near or exceed the current (NHDES, 0.75 mg/L) acute criteria and they are likely to exceed the proposed [EPA, ~0.43 mg/L (based on Nippo Lake pH, hardness, and DOC)] acute aluminum concentrations. Based on the second lab experiment acid soluble aluminum concentrations could approach up to 1 mg/L in the immediate treatment area 1-hour after treatment but that concentrations would likely decrease to less than 0.6 mg/L after 4-hours, and less than 0.21 2-days after treatment (Table 8). Based on these results, it is also possible that the current chronic aluminum criteria used by NHDES of 0.087 mg/L and possibly the EPA proposed criteria (0.23 mg/L based on Nippo Lake pH, hardness, and DOC) could be exceeded.

The detection of acid soluble aluminum concentrations that exceeded current and proposed aluminum water quality criteria under laboratory conditions were likely a result of low pH water. However, unlike the lab experiments, during the application of aluminum to Nippo Lake, the pH will be maintained within a range of 6.0-8.0 through the addition of controlled volumes of aluminum sulfate and sodium aluminate. If pH levels deviate from this range, aluminum application will be temporarily discontinued in order to minimize potential impacts to the aquatic community and the ratio of aluminum sulfate to sodium aluminate will be adjusted to result in a lake pH within the acceptable range. The pilot application phase will provide an initial opportunity to assess potential impacts prior to the full treatment. Additional protection from potential aquatic life impacts will be provided by the requirement to treat no more than 25% of the proposed treatment area on a given day allowing for areas of refuge for mobile aquatic organisms. Last, based on the prior experience in Kezar Lake, laboratory results offer a worst-case scenario of dissolved aluminum concentrations and pH levels. Outcomes of aluminum applications in other New England lakes, such as Lake Cochnewagon, in-lake aluminum concentrations were near or below water quality criteria immediately after treatment and well below criteria within 3-weeks following the treatment.

Taken together, the risks to aquatic organism in Nippo Lake will be minimal. The greatest impact would be to immobile or low mobility aquatic organisms such as freshwater mussels, zooplankton, or phytoplankton in areas greater than 15’ where the treatment is planned to occur. Mussels typically inhabit shallower water (<10’), and therefore, potential impacts would be largely avoided since most would be expected to occur outside the treatment zone and not exposed to the aluminum floc. Zooplankton and phytoplankton are expected to be temporarily impacted to a limited extent, however, their populations are expected to rebound to a typical community by mid-summer. Plankton densities are likely to be lower, however, not because of impacts associated with aluminum toxicity, but rather, because less phosphorus will be available for primary production and subsequent zooplankton production. With respect to fish, it is assumed they will be able to avoid impacts through movement around the lake.

Currently, the deep-water locations experience low oxygen and increased phosphorus release leading to cyanobacteria blooms. The low oxygen and blooms do not provide quality habitat for aquatic biota. In the long run, however, zooplankton will benefit from an increase in preferred food sources, such as easier to eat algae species. The benthic invertebrate habitat will also improve with expected increases in oxygen. With improved fish food resources, the fishery is likely to benefit as well. Aluminum treatments are essentially a bottom-up approach to management. By altering nutrient levels and shifting algae composition at the bottom of the food web, an improved energy flow up the food web will occur (Wagner et al. 2017).

Operations and Management Plan

Details of operations are partly a function of the selected application contractor equipment and approach, but the few companies that perform aluminum treatments follow the same general process. A site for access, typically a boat launch, is selected and prepped as needed. At Nippo, the most appropriate site for access and staging appears to be at the North end of the lake at the end of Golf Course Way (Figure 7).

A site for chemical delivery and vessel loading (i.e., the staging area) is also needed at Nippo Lake and will likely be near the access point. Although interference from boaters during treatment is to be avoided, it will not be necessary to close the lake to all boat access. The staging site is where aluminum products are delivered and/or stored and where the treatment vessel is repeatedly loaded. A small, temporary dock at a shoreline point accessible to the treatment vessel is all that is needed in the water.

Figure 7: Potential staging area for phosphorus inactivation project at end of Golf Course Way.

Landward, the staging area must provide access for tanker trucks that deliver the aluminum products; hoses can run up to 200 feet but runs of less than 50 feet in a downhill direction are preferred. Road condition to support heavy tanker trucks and turn around capacity will need to be considered for the proposed staging area at Nippo Lake. For larger treatments, storage tanks are set up with secondary containment and tanker trucks deliver aluminum sulfate to one tank and sodium aluminate to a second tank. The proposed Nippo Lake project is small enough that it could be accomplished either directly from tanker trucks or with holding tanks depending on the selected contractor's preference. The treatment crew then transfers the aluminum products to containers on the treatment vessel. For smaller projects, the tanker truck can be a split system with both aluminum products on the same truck or two tankers can be present and remain on site until emptied by repeated loading of the treatment vessel. With the smallest treatment vessel typically used, 10-15 acres can be treated at 27 g/m^2 per day and would require only a single split truck and likely no on-site storage. It is estimated, based on current dosing recommendations described above that several tanker truck deliveries would be required per day over the application period. The contractor will clean up the staging site and remove the barge via the access site at the conclusion of treatment. A third party will certify that the staging and access sites have been returned to a desirable condition at that point.

If the project is approved as proposed, a final operations and management plant will be provided to NHDES a least 1-month prior to the beginning of the application for review and to ensure environmental safety. The operations and management plan will be developed in conjunction the selected application contractor so that plan conforms to the equipment they plan on using to deliver and apply the aluminum solutions. The plan will specifically include, but not be limited to, the following:

1) Details on the access and staging areas including a basic site map;
2) The method of chemical delivery, transfer, and on-site storage as well as the length of time chemicals will be stored at the site and plans for securing chemicals during storage.
3) Safety measures for minimizing chemical spillage, leakage, and containment.
4) The names and contact information for the persons responsible for chemical management as well as emergency contact information.
5) Details for cleaning up at the access and chemical transfer points following application.

Monitoring plan

Water quality will be extensively monitored before, during and after the treatment in order to document important water quality parameters and the extent of stratification in order to maximize aluminum treatment efficacy and minimize potential impacts to aquatic life. The narrative below describes a proposed monitoring plan which is summarized in Appendix C. The monitoring plan will be finalized once a contractor has been selected and with input from NHDES.

Pre-treatment monitoring will include sampling at three points along the centerline of the lake no more three weeks prior to the pilot treatment. Two of the sample points will be approximately 10 meters deep and one approximately 15 meters deep. At each location field measures of temperature, dissolved oxygen, pH, and specific conductance will be measured at 1m meter depth intervals. Additionally, at approximately 1/3, 1/2, and 2/3 of the total depth grab samples will be collected and submitted for laboratory analysis of alkalinity, hardness, dissolved organic carbon, acid soluble aluminum, total aluminum, total phosphorus and chlorophyll a. Secchi disc transparency readings will also be collected at each location. The data must be made available for review prior to any planned treatment.

Two additional pre-treatment monitoring events will be completed no more that 2-days in advance of each of the first and second scheduled treatments, respectively. Monitoring will occur at the deep spot of the lake in a location that is approximately 15 meters deep. These monitoring events will include field measurements of temperature, dissolved oxygen, pH, and specific conductance measured at 1m meter depth intervals. from the deep spot of the lake. At approximately 1/3, 1/2, and 2/3 of the total depth grab samples will be collected and submitted for laboratory analysis of alkalinity, hardness, dissolved organic carbon, acid soluble aluminum, total aluminum, total phosphorus and chlorophyll a. Additionally, Secchi depth transparency, as well as phytoplankton and zooplankton samples will be collected the same location. The depth of sample collection will be approximately 7 meters or more. These data are not expected to be available prior to treatment but will be used to inform future treatments. Last, at least 10 additional field measures of pH or a continuous tow of a sonde will be completed around the perimeter of the lake. It is recommended that of these be nearshore (<3 meters depth) and collected in approximately 0.5 meters of depth. Underwater video transects from shore to deep water will be checked to document the presence and condition of mussels, plants and other sessile organisms. A shoreline survey for any distressed fish will also be conducted prior to treatment. The survey results will be used to facilitate discussions of findings and possible issues (e.g., underwater obstructions, pH variance that may require adjustment of the alum:aluminate ratio) prior to the start of treatment.

Monitoring during the treatment will consist of continuous visual assessments for distressed aquatic organisms, a focus on field measures of pH, and samples collected for laboratory analysis of total and acid soluble aluminum. One station in each established treatment sector (25% of total treatment area) will be assessed by means of top (~1/3 total depth) and bottom (~2/3 total depth) of field water quality measures prior to the start of treatment, mid-day, and at the end of daily treatment. Field measures of pH, specific conductance, water temperature, dissolved oxygen, and turbidity will be collected with a multi-probe sonde. Secchi disc transparency will also be measured. At end of each day of treatment, samples from the top and bottom depths will be collected for laboratory analysis of alkalinity, hardness, dissolved organic carbon, and total and acid soluble aluminum, and chlorophyll a. At the conclusion of the day’s work or before treatment the next day (the latter may be more insightful and light may be limiting at the end of treatment each day) the floc zone and portion of the lake downwind of the treatment area will be inspected for any distressed organisms. The monitoring crew will coordinate with the treatment crew to keep them informed of any issues and make any necessary adjustments to improve treatment effectiveness and avoid adverse impacts. Daily monitoring plans may be altered depending on conditions and contractor preference, equipment, and past experiences.

One week after all treatments have been completed and then monthly through September 2021 a monitoring program will be completed that mimics the plan proposed to be conducted 2-days prior to treatment. An identical monitoring event will be completed immediately after ice-out, August, and October of 2022. An interim report of all available data will be provided within 4-months of treatment that includes the water quality data and details of the treatment.

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Appendix A

Review of methods to control internal loading of phosphorus and associated cyanobacterial blooms in Nippo Lake.

To	NHDES
CC	Nippo Lake Association
Subject	Review of methods to control internal loading of phosphorus and associated cyanobacterial blooms in Nippo Lake
From	Don Kretchmer, DK Water Resource Consulting LLC and Ken Wagner, Water Resource Services
Date	April 3, 2020

In recent years, Nippo Lake has experienced frequent cyanobacteria blooms that have impaired recreational uses of the lake. The quantity of algae and cyanobacteria in Nippo Lake is directly related to the concentration of the nutrient in shortest supply, phosphorus. The watershed-based plan for Nippo Lake provides the basis for this conclusion and a plan to address both external and internal loads of phosphorus to the lake. The Nippo Lake watershed-based plan documents that the internal load represents 34% of the total phosphorus load to Nippo Lake. A plan to reduce the external load is detailed in the watershed-based plan. Even if external loading (44% of the total load) were decreased substantially, the internal load would need to be substantially reduced as well to reduce in-lake phosphorus concentrations to a level that would preclude most cyanobacteria blooms.

This review is being prepared to assess management alternatives suitable to address cyanobacteria blooms in Nippo Lake caused by phosphorus loading. The factors that control the abundance of cyanobacteria form the basis for attempts to manage and limit them. Light and nutrients are the primary needs for cyanobacterial growth. Algae management techniques such as dyes, artificial circulation and selective plantings seek to establish light limitation, while methods such as oxygenation, dilution and flushing, drawdown, dredging, phosphorus inactivation, and selective withdrawal are used to reduce nutrient availability.

Table 1 provides a listing of the algal (cyanobacterial) management techniques in current use in lakes with techniques most applicable for use at this time in Nippo Lake listed in the first column and those deemed not applicable to Nippo Lake in the second column. Appendix Table 1 lists key considerations for all techniques evaluated for possible use to enhance Nippo Lake. Strong preference is given to those techniques that address loading of phosphorus and particularly internal loading of phosphorus, but the table does convey a range of options that could be considered for control of cyanobacteria in Nippo Lake. These techniques take advantage of algal ecology and supplement or counteract the forces involved in algal and cyanobacterial losses or growth, respectively. Given the above caveats, the specific circumstances in Nippo Lake, and a focus on internal phosphorus load as a key factor in continued cyanobacteria blooms, many of the techniques applied to lakes with cyanobacteria bloom issues warrant no further consideration.

Table 1: Range of options for control of cyanobacteria in lakes and suitability to address current conditions in Nippo Lake (recommended options are shaded).

Options potentially applicable	Options deemed not applicable.
Nonpoint source control of phosphorus (watershed-based plan)	Point source control of phosphorus
Pollutant trapping (watershed-based plan)	Dilution and flushing
Circulation and destratification	Drawdown
Hydraulic dredging	Dry excavation of sediment after drawdown
Hypolimnetic oxygenation	Wet excavation of sediment from shore

Algaecides	Light limiting dyes
Phosphorus inactivation	Surface covers
Settling agents	Selective withdrawal of water
Sediment oxidation	Sonication
Mechanical removal/treatment on shore	Selective nutrient addition
Enhanced grazing through food chain interactions	Addition of herbivorous fish
	Bottom feeding fish removal
	Microbial competition
	Addition of pathogens
	Plantings of macrophytes for nutrient utilization
	Plantings of macrophytes for shade

Among the applicable techniques for reducing phosphorus concentration and enhancing the condition of Nippo Lake, watershed management (Nonpoint source control- Alternative 1b, Appendix Table 1 and Nonpoint pollutant trapping-Alternative 1c, Appendix Table 1) is highly desirable and can protect any investment made in techniques applied directly to the lake, but is unlikely to be sufficient by itself to solve the problem and will take years to realize improvement in the lake at a meaningful level. The most rapid and effective method for reducing phosphorus concentrations is phosphorus inactivation), which will both clear the water column of algae and associated particulate phosphorus (Settling agent-Alternative 14, Appendix Table 1) and bind the phosphorus in the surficial sediment that is being released under low oxygen conditions (Phosphorus Inactivation-Alternative 12, Appendix Table 1). This option is less expensive than other options and will be needed only once every 10-20 years to meet user expectations, possibly less frequently if watershed management is fully implemented. Maintaining a balanced biological community in the lake also provides a buffer against algae blooms and enhances uses such as fishing and wildlife viewing and is worthwhile as a supplemental in-lake technique (Enhanced grazing-Alternative 16b, Appendix Table 1).

Recommendations

Based on the screening analysis conducted, the following techniques are recommended for Nippo Lake.

- Nonpoint source controls and nonpoint source pollutant trapping BMP's. These techniques have been described in the watershed-based plan for Nippo Lake and will primarily deal with the watershed portion of the load.
- Phosphorus inactivation with aluminum and use of aluminum as a settling agent. The addition of aluminum to the water column (and sediments after settling) will remove phosphorus from the water column and sequester phosphorus in the sediments making it unavailable for release under anoxic conditions in the deep areas of the lake.
- Enhanced grazing through food chain interactions. A healthy aquatic community with a balance of piscivores (fish which eat smaller fish), planktivores (fish which eat zooplankton) and grazing zooplankton (free floating crustaceans) which eat algae) will increase the likelihood that Nippo Lake will exhibit the best possible water quality for a given amount of phosphorus in the lake.

Appendix A.

Table 1. Nippo Lake algae management options review (shaded techniques are recommended)

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO NIPPO LAKE
1) Management for nutrient input reduction	♦ Includes wide range of watershed and lake edge activities intended to eliminate nutrient sources or reduce delivery to lake ♦ Essential component of algal control strategy where internal recycling is not the dominant nutrient source, and desired even where internal recycling is important	♦ Acts against the original source of algal nutrition ♦ Creates sustainable limitation on algal growth ♦ May control delivery of other unwanted pollutants to lake ♦ Facilitates ecosystem management approach which considers more than just algal control	♦ May involve considerable lag time before improvement observed ♦ May not be sufficient to achieve goals without some form of in-lake management ♦ Reduction of overall system fertility may impact fisheries ♦ May cause shift in nutrient ratios which favor less desirable algae	♦ Applicable (see below for evaluation of input management alternatives)
1a) Point source controls	♦ More stringent discharge requirements ♦ May involve diversion ♦ May involve technological or operational adjustments ♦ May involve pollution prevention plans	♦ Often provides major input reduction ♦ Highly efficient approach in most cases ♦ Success easily monitored	♦ May be very expensive in terms of capital and operational costs ♦ May transfer problems to another watershed ♦ Variability in results may be high in some cases	♦ Not applicable – no point sources

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO NIPPO LAKE
1b) Nonpoint source controls	♦ Reduction of sources of nutrients ♦ May involve elimination of land uses or activities that release nutrients ♦ May involve alternative product use, such as no phosphate fertilizer	♦ Removes source ♦ Limited ongoing costs	♦ May require purchase of land or remedial action on private property ♦ May be viewed as limitation of "quality of life" ♦ Usually requires education and gradual implementation	♦ High applicability ♦ Essential to control both external and internal sources to reduce probability of algal blooms ♦ Control of external sources may increase longevity of any phosphorus inactivation program for internal loading ♦ Watershed-based plan details source reduction options
1c) Nonpoint source pollutant trapping	♦ Capture of pollutants between source and lake ♦ May involve drainage system alteration ♦ Often involves wetland treatments (det./infiltration) ♦ May involve stormwater collection and treatment as with point sources	♦ Minimizes interference with land uses and activities ♦ Allows diffuse and phased implementation throughout watershed ♦ Highly flexible approach ♦ Tends to address wide range of pollutant loads	♦ Does not address actual sources ♦ May be expensive on necessary scale ♦ May require substantial maintenance	♦ Somewhat applicable ♦ Mitigation of runoff on Golf Course Way has been completed with some pollutant trapping features ♦ Few locations where trapping could be employed around watershed which is relatively steep

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO NIPPO LAKE
2) Circulation and destratification	♦ Use of water or air to keep water in motion ♦ Intended to prevent or break stratification ♦ Generally driven by mechanical or pneumatic force	♦ Reduces surface build-up of algal scums ♦ May disrupt growth of cyanobacteria ♦ Counteraction of anoxia improves habitat for fish/invertebrates ♦ Can eliminate localized problems without obvious impact on whole lake	♦ May spread localized impacts ♦ May lower oxygen levels in shallow water ♦ May promote downstream impacts	♦ Somewhat applicable ♦ May reduce internal phosphorus release but may increase photic zone phosphorus concentrations by moving high phosphorus water upward in water column ♦ Will require continual growing season use for foreseeable future ♦ Will likely require shore-based infrastructure ♦ Will require considerable ongoing operational costs to move sufficient water to possibly suppress cyanobacteria
3) Dilution and flushing	♦ Addition of water of better quality can dilute nutrients ♦ Addition of water of similar or poorer quality flushes system to minimize algal build-up ♦ May have continuous or periodic additions	♦ Dilution reduces nutrient concentrations without altering load ♦ Flushing minimizes detention; response to pollutants may be reduced	♦ Diverts water from other uses ♦ Flushing may wash desirable zooplankton from lake ♦ Use of poorer quality water increases loads ♦ Possible downstream impacts	♦ Not applicable ♦ No large source of dilution water available

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO NIPPO LAKE
4) Drawdown	♦ Lowering of water over autumn period allows oxidation, desiccation and compaction of sediments ♦ Duration of exposure and degree of dewatering of exposed areas are important ♦ Algae are affected mainly by reduction in available nutrients.	♦ May reduce available nutrients or nutrient ratios, affecting algal biomass and composition ♦ Opportunity for shoreline clean-up/structure repair ♦ Flood control utility ♦ May provide rooted plant control as well	♦ Possible impacts on non-target resources ♦ Possible impairment of water supply (nearshore wells or downstream resources) ♦ Alteration of downstream flows and winter water level ♦ May result in greater nutrient availability if flushing inadequate	♦ Not applicable ♦ Will not address internal loading issue
5) Dredging	♦ Sediment is physically removed by wet or dry excavation, with deposition in a containment area for dewatering ♦ Dredging can be applied on a limited basis, but is most often a major restructuring of a severely impacted system ♦ Nutrient reserves are removed and algal growth can be limited by nutrient availability	♦ Can control algae if internal recycling is main nutrient source ♦ Increases water depth ♦ Can reduce pollutant reserves ♦ Can reduce sediment oxygen demand ♦ Can improve spawning habitat for many fish species ♦ Allows complete renovation of aquatic ecosystem	♦ Temporarily reduces benthic invertebrate populations ♦ May create turbidity ♦ May eliminate fish community (complete dry dredging only) ♦ Possible impacts from containment area discharge ♦ Possible impacts from dredged material disposal ♦ Interference with recreation or other uses during dredging	♦ Somewhat applicable (see below for evaluation of specific dredging methods)

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO NIPPO LAKE
5a) "Dry" excavation	♦ Lake drained or lowered to maximum extent practical ♦ Target material dried to maximum extent possible ♦ Conventional excavation equipment used to remove sediments	♦ Tends to facilitate a very thorough effort ♦ May allow drying of sediments prior to removal ♦ Allows use of less specialized equipment	♦ Eliminates most aquatic biota unless a portion left undrained ♦ Eliminates lake use during dredging	♦ Not applicable ♦ Lake cannot be drained
5b) "Wet" excavation	♦ Lake level may be lowered, but sediments not substantially exposed ♦ Draglines, bucket dredges, or long-reach backhoes used to remove sediment	♦ Requires least preparation time or effort, tends to be least cost dredging approach ♦ May allow use of easily acquired equipment ♦ May preserve aquatic biota	♦ Usually creates extreme turbidity ♦ Normally requires intermediate containment area to dry sediments prior to hauling ♦ May disrupt ecological function ♦ Use disruption	♦ Not applicable ♦ Large drawdown not possible ♦ Lake is too large to manage with shore-based equipment ♦ No staging area near shore
5c) Hydraulic removal	♦ Lake level not reduced ♦ Suction or cutterhead dredges create slurry which is hydraulically pumped to containment area ♦ Slurry is dewatered; sediment retained, water discharged	♦ Creates minimal turbidity and impact on biota ♦ Can allow some lake uses during dredging ♦ Allows removal with limited access or shoreline disturbance	♦ Often leaves some sediment behind ♦ Cannot handle coarse or debris-laden materials ♦ Requires sophisticated and more expensive containment area	♦ Somewhat applicable ♦ No large staging area near shore ♦ Pumping hydraulically dredged sediments uphill to a potential staging area would be a challenge ♦ Would be expensive ♦ Quality of sediments for disposal is unknown
6) Light-limiting dyes and surface covers	♦ Creates light limitation	♦ Creates light limit on algal growth without high turbidity or great depth ♦ May achieve some control of rooted plants as well	♦ May cause thermal stratification in shallow ponds ♦ May facilitate anoxia at sediment interface with water	♦ Not applicable

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO NIPPO LAKE
6.a) Dyes	♦ Water-soluble dye is mixed with lake water, thereby limiting light penetration and inhibiting algal growth ♦ Dyes remain in solution until washed out of system.	♦ Produces appealing color ♦ Creates illusion of greater depth	♦ May not control surface bloom-forming species ♦ May not control growth of shallow water algal mats ♦ Altered thermal regime	♦ Not applicable ♦ Lake is too large ♦ Artificial color would be objectionable
6.b) Surface covers	♦ Opaque sheet material applied to water surface	♦ Minimizes atmospheric and wildlife pollutant inputs	♦ Minimizes atmospheric gas exchange ♦ Limits recreation	♦ Not applicable ♦ Lake is too large ♦ Cover would eliminate recreation opportunities
7) Mechanical removal	♦ Filtering of pumped water for water supply purposes ♦ Collection of floating scums or mats with booms, nets, or other devices ♦ Continuous or multiple applications per year usually needed	♦ Algae and associated nutrients can be removed from system ♦ Surface collection can be applied as needed ♦ May remove floating debris ♦ Collected algae dry to minimal volume	♦ Filtration requires high backwash and sludge handling capability ♦ Labor and/or capital intensive ♦ Variable collection efficiency ♦ Possible impacts on non-target aquatic life	♦ Not applicable ♦ Photic zone volume is too large and algal populations grow too rapidly to effectively treat. ♦ Would require complete treatment of photic zone every week or two. ♦ Would need municipal scale physical plant on shore of lake to begin to be effective
8) Selective withdrawal	♦ Discharge of bottom water which may contain (or be susceptible to) low oxygen and higher nutrient levels ♦ May be pumped or utilize passive head differential	♦ Removes targeted water from lake efficiently ♦ May prevent anoxia and phosphorus build up in bottom water ♦ May remove initial phase of algal blooms which start in deep water ♦ May create coldwater conditions downstream	♦ Possible downstream impacts of poor water quality ♦ May promote mixing of remaining poor quality bottom water with surface waters ♦ May cause unintended drawdown if inflows do not match withdrawal	♦ Not applicable ♦ Would likely not be able to deplete hypolimnion without drawing down the lake substantially in the summer. ♦ No mechanical way to do this with existing dam, would require a siphon tube.

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO NIPPO LAKE
9) Sonication	♦ Sound waves disrupt algal cells	♦ Supposedly affects only algae (new technique) ♦ Applicable in localized areas	♦ Unknown effects on non-target organisms ♦ May release cellular toxins or other undesirable contents into water column	♦ Not applicable ♦ Scale of lake is too large for this to be effective

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO NIPPO LAKE
10) Hypolimnetic aeration or oxygenation	♦ Addition of air or oxygen provides oxic conditions ♦ Maintains stratification ♦ Can also withdraw water, oxygenate, then replace	♦ Oxic conditions reduce phosphorus availability ♦ Oxygen improves habitat ♦ Oxygen reduces build-up of reduced compounds	♦ May disrupt thermal layers important to fish community ♦ Theoretically promotes supersaturation with gases harmful to fish	♦ Possibly applicable ♦ If sized properly would reduce volume of anoxic water ♦ Would require continuous operation during stratification period ♦ Has shore power and infrastructure needs ♦ Lake recovery from power outages or equipment malfunctions during stratification may not be possible during one season
11) Algaecides	♦ Liquid or pelletized algaecides applied to target area ♦ Algae killed by direct toxicity or metabolic interference ♦ Typically requires application at least once/yr, often more frequently ♦	♦ Rapid elimination of algae from water column , normally with increased water clarity ♦ May result in net movement of nutrients to bottom of lake	♦ Possible toxicity to non-target species ♦ Restrictions on water use for varying time after treatment ♦ Increased oxygen demand and possible toxicity ♦ Possible recycling of nutrients	♦ Somewhat applicable (see below for discussion of specific algaecides)

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO NIPPO LAKE
11a) Forms of copper	♦ Cellular toxicant, disruption of membrane transport ♦ Applied as wide variety of liquid or granular formulations	♦ Effective and rapid control of many algae species ♦ Approved for use in most water supplies	♦ Possible toxicity to aquatic fauna ♦ Accumulation of copper in system ♦ Resistence by certain green and blue-green nuisance species ♦ Lysing of cells releases nutrients and toxins	♦ Somewhat applicable ♦ Will reduce or eliminate an existing bloom ♦ Won't appreciably change conditions that caused bloom so bloom conditions may re-occur in same season ♦ Will require application permit
11b) Peroxides	♦ Disrupts most cellular functions, tends to attack membranes ♦ Applied as a liquid or solid. ♦ Typically requires application at least once/yr, often more frequently	♦ Rapid action ♦ Oxidizes cell contents, may limit oxygen demand and toxicity	♦ Much more expensive than copper ♦ Limited track record ♦ Possible recycling of nutrients	♦ Somewhat applicable. ♦ May work to reduce or eliminate an existing bloom but at high cost. ♦ Won't appreciably change conditions that caused bloom so bloom conditions may re-occur in same season ♦ May require an application permit
11c) Synthetic organic algaecides	♦ Absorbed or membrane-active chemicals which disrupt metabolism ♦ Causes structural deterioration	♦ Used where copper is ineffective ♦ Limited toxicity to fish at recommended dosages ♦ Rapid action	♦ Non-selective in treated area ♦ Toxic to aquatic fauna (varying degrees by formulation) ♦ Time delays on water use	♦ Somewhat applicable ♦ Will reduce or eliminate an existing bloom ♦ Won't appreciably change conditions that caused bloom so bloom conditions may re-occur in same season ♦ Will require permit ♦ May have waterbody use restrictions

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO NIPPO LAKE
12) Phosphorus inactivation	♦ Typically salts of aluminum, iron or calcium are added to the lake, as liquid or powder ♦ Phosphorus in the treated water column is complexed and settled to the bottom of the lake ♦ Phosphorus in upper sediment layer is complexed, reducing release from sediment ♦ Permanence of binding varies by binder in relation to redox potential and pH	♦ Can provide rapid, major decrease in phosphorus concentration in water column ♦ Can minimize release of phosphorus from sediment ♦ May remove other nutrients and contaminants as well as phosphorus ♦ Flexible with regard to depth of application and speed of improvement	♦ Possible toxicity to fish and invertebrates, especially by aluminum at low pH ♦ Possible release of phosphorus under anoxia or extreme pH ♦ May cause fluctuations in water chemistry, especially pH, during treatment ♦ Possible resuspension of floc in shallow areas ♦ Adds to bottom sediment, but typically an insignificant amount	♦ Applicable ♦ Hypolimnetic anoxia and pH suggest that aluminum would be the most appropriate compound to inactivate phosphorus ♦ Data shows substantial iron and organic bound phosphorus in surface sediments that would be inactivated by aluminum ♦ Water column phosphorus would be stripped during application ♦ Watershed management activities and small size of watershed suggest that treatment lifespan would be relatively long
13) Sediment oxidation	♦ Addition of oxidants, binders and pH adjustors to oxidize sediment ♦ Binding of phosphorus is enhanced ♦ Denitrification is stimulated	♦ Can reduce phosphorus supply to algae ♦ Can alter nitrogen to phosphorus ratios in water column ♦ May decrease sediment oxygen demand	♦ Possible impacts on benthic biota ♦ Longevity of effects not well known ♦ Possible source of nitrogen for cyanobacteria	♦ Possibly applicable ♦ Effects are not well understood and there are insufficient case studies to predict effectiveness with any degree of confidence

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO NIPPO LAKE
14) Settling agents	♦ Closely aligned with phosphorus inactivation, but can be used to reduce algae directly too ♦ Lime, alum or polymers applied, usually as a liquid or slurry ♦ Creates a floc with algae and other suspended particles ♦ Floc settles to bottom of lake ♦ Re-application typically necessary at least once/yr	♦ Removes algae and increases water clarity without lysing most cells ♦ Reduces nutrient recycling if floc sufficient ♦ Removes non-algal particles as well as algae ♦ May reduce dissolved phosphorus levels at the same time	♦ Possible impacts on aquatic fauna ♦ Possible fluctuations in water chemistry during treatment ♦ Resuspension of floc possible in shallow, well-mixed waters ♦ Promotes increased sediment accumulation	♦ See # 12 above. ♦ Technique refers to the water column phosphorus stripping that would occur during sediment treatment. ♦ Will typically require re-treatment every year.
15) Selective nutrient addition	♦ Ratio of nutrients changed by additions of selected nutrients ♦ Addition of non-limiting nutrients can change composition of algal community ♦ Processes such as settling and grazing can then reduce algal biomass	♦ Can reduce algal levels where control of limiting nutrient not feasible ♦ Can promote non-nuisance forms of algae ♦ Can improve productivity of system without increased standing crop of algae	♦ May result in greater algal abundance through uncertain biological response ♦ May require frequent application to maintain desired ratios ♦ Possible downstream effects	♦ Not applicable ♦ Likely would involve adding nitrogen to favor species other than cyanobacteria. ♦ Contrary to principles of watershed management, particularly with respect to nitrogen limited estuarine resources downstream of Nippo Lake. ♦ Nitrogen addition may result in additional algal growth of non-cyanobacteria species

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO NIPPO LAKE
16) Enhanced grazing	♦ Manipulation of biological components of system to achieve grazing control over algae ♦ Typically involves alteration of fish community to promote growth of grazing zooplankton	♦ May increase water clarity by changes in algal biomass or cell size without reduction of nutrient levels ♦ Can convert unwanted algae into fish ♦ Harnesses natural processes	♦ May involve introduction of exotic species ♦ Effects may not be controllable or lasting ♦ May foster shifts in algal composition to even less desirable forms	♦ Somewhat applicable ♦ (see below for specific alternatives to support enhanced grazing)
16a) Herbivorous fish	♦ Stocking of fish that eat algae	♦ Converts algae directly into potentially harvestable fish ♦ Grazing pressure can be adjusted through stocking rate	♦ Typically requires introduction of non-native species ♦ Difficult to control over long term ♦ Smaller algal forms may be benefited and bloom	♦ Not applicable ♦ Not permitted in NH
16b) Enhanced grazing through food chain interactions	♦ Reduction in planktivorous fish to promote grazing pressure by zooplankton ♦ May involve stocking piscivores or removing planktivores ♦ May also involve stocking zooplankton or establishing refugia	♦ May increase water clarity by changes in algal biomass or cell size without reduction of nutrient levels ♦ Converts algae indirectly into harvestable fish ♦ Zooplankton response to increasing algae can be rapid ♦ May be accomplished without introduction of non-native species ♦ Generally compatible with most fishery management goals	♦ May involve introduction of exotic species ♦ Effects may not be controllable or lasting ♦ May foster shifts in algal composition to even less desirable forms ♦ Highly variable response expected; temporal and spatial variability may be high ♦ Requires careful monitoring and management action on 1-5 yr basis ♦ Larger or toxic algal forms may be benefitted and bloom	♦ Somewhat applicable ♦ A balanced and stable fish and invertebrate community is generally supportive of good water quality. ♦ Nuisance cyanobacterial species are generally not preferred by grazers.

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO NIPPO LAKE
17) Bottom-feeding fish removal	♦ Removes fish that browse among bottom deposits, releasing nutrients to the water column by physical agitation and excretion	♦ Reduces turbidity and nutrient additions from this source ♦ May restructure fish community in more desirable manner	♦ Targeted fish species are difficult to control ♦ Reduction in fish populations valued by some lake users (human/non-human)	♦ Not applicable ♦ No documented occurrence of such fish in Nippo Lake
18) Microbial competition	♦ Addition of microbes, often with oxygenation, can tie up nutrients and limit algal growth ♦ Tends to control nitrogen more than phosphorus	♦ Shifts nutrient use to organisms that do not form scums or impair uses to same extent as algae ♦ Harnesses natural processes ♦ May decrease sediment	♦ Minimal scientific evaluation ♦ Nitrogen control may still favor cyanobacteria ♦ May need aeration system to get acceptable results	♦ Not applicable ♦ Favorable results for phosphorus control have not been documented.
19) Pathogens	♦ Addition of inoculum to initiate attack on algal cells ♦ May involve fungi, bacteria or viruses	♦ May create lakewide “epidemic” and reduction of algal biomass ♦ May provide sustained control through cycles ♦ Can be highly specific to algal group or genera	♦ Largely experimental approach at this time ♦ May promote resistant nuisance forms ♦ May cause high oxygen demand or release of toxins by lysed algal cells ♦ Effects on non-target organisms uncertain	♦ Not applicable ♦ Experimental

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO NIPPO LAKE
20) Competition and allelopathy by plants	♦ Plants may tie up sufficient nutrients to limit algal growth ♦ Plants may create a light limitation on algal growth ♦ Chemical inhibition of algae may occur through substances released by other organisms	♦ Harnesses power of natural biological interactions ♦ May provide responsive and prolonged control	♦ Some algal forms appear resistant ♦ Use of plants may lead to problems with vascular plants ♦ Use of plant material may cause depression of oxygen levels	♦ Not applicable ♦ (see below for discussion of alternatives)
20a) Plantings for nutrient control	♦ Plant growths of sufficient density may limit algal access to nutrients ♦ Plants can exude allelopathic substances which inhibit algal growth ♦ Portable plant "pods" , floating islands, or other structures can be installed	♦ Productivity and associated habitat value can remain high without algal blooms ♦ Can be managed to limit interference with recreation and provide habitat ♦ Wetland cells in or adjacent to the lake can minimize nutrient inputs	♦ Vascular plants may achieve nuisance densities ♦ Vascular plant senescence may release nutrients and cause algal blooms ♦ The switch from algae to vascular plant domination of a lake may cause unexpected or undesirable changes	♦ Not applicable ♦ Much of Nippo Lake is too deep to support vascular plants. ♦ No logical spot for wetlands or floating islands ♦ May result in vascular plant increase lakewide.
20b) Plantings for light control	♦ Plant species with floating leaves can shade out many algal growths at elevated densities	♦ Vascular plants can be more easily harvested than most algae ♦ Many floating species provide waterfowl food	♦ Floating plants can be a recreational nuisance ♦ Low surface mixing and atmospheric contact promote anoxia	♦ Not applicable ♦ Lake too deep Plants would interfere with recreational activities

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO NIPPO LAKE
20c) Addition of barley straw	♦ Input of barley straw can set off a series of chemical reactions which limit algal growth ♦ Release of allelopathic chemicals can kill algae ♦ Release of humic substances can bind phosphorus	♦ Materials and application are relatively inexpensive ♦ Decline in algal abundance is more gradual than with algaecides, limiting oxygen demand and the release of cell contents	♦ Success appears linked to uncertain and potentially uncontrollable water chemistry factors ♦ Depression of oxygen levels may result ♦ Water chemistry may be altered in other ways unsuitable for non-target organisms	♦ Not applicable ♦ Experimental technique with unpredictable results.

Appendix B

Nippo Lake Sediment Analysis

DK Water Resource Consulting LLC

January 2019

Nippo Lake Sediment Analysis

Technical Memorandum

Prepared By: Don Kretchmer, DK Water Resource Consulting LLC

Contents

1.0 Background

Nippo Lake in Barrington, NH suffers from algal blooms and related water quality impairments. The lake is approximately 15.5 meters deep at the deepest hole (51 ft), and has a mean depth of 7 meters (23 ft). The lake area is 35.5 ha (85 acres). The lake volume is approximately 2.4 M m^3 (1,962 acre-ft) with a watershed of 119 hectares (294 acres). Water quality data have been collected by volunteers, staff from the New Hampshire Department of Environmental Services (NHDES) and the University of New Hampshire (UNH) Cooperative extension for more than 30 years. These data allow a look at changes in lake water quality over time as well as a comprehensive look at current water quality. In response to summer cyanobacteria blooms in recent years, a watershed plan is being prepared by the NHDES in cooperation with the Nippo Lake Association (NLA). Central to the plan is a watershed and lake modeling effort that includes estimation of both external and internal nutrient loads. The modeling results indicate that both external (watershed) loading of nutrients and internal (release from sediments) loading of nutrients are contributing to nutrient enrichment of Nippo Lake. A phosphorus budget for Nippo Lake generated from the modeling effort is presented in Table 1.

Table 1. Current phosphorus budget for Nippo Lake.

TP Inputs to Lake	Phosphorus Load (kg/yr)	Percent of Total
Atmospheric	3.8	10
Internal	12.9	34
Waterfowl	1.7	5
Septic Systems	2.8	7
Watershed	16.4	44
Total Load to Lake	**37.5**	**100**

Phosphorus loading of this magnitude to Nippo Lake has resulted in the current condition which is characterized by frequent summer cyanobacteria blooms. Reduction in both internal loads and external loads of phosphorus are necessary to reduce in-lake phosphorus concentrations to a level that substantially reduces the likelihood that blooms will occur. Details on the modeling and the evaluation of lake response under a variety of management scenarios will be discussed in the upcoming watershed management plan for Nippo Lake (NHDES 2019).

As the first phase of implementation of the watershed plan, several watershed phosphorus control projects have been initiated. These projects center on non Point sources of phosphorus and have been implemented over the past several years. Several additional projects are expected to be implemented soon.

This document characterizes the phosphorus content of the surficial sediments of Nippo Lake (upper 10 cm). This characterization will be used to evaluate options to reduce the internal phosphorus (P) load to the lake to supplement reductions in the external phosphorus load. Most promising of those options is the use of aluminum to strip phosphorus from the water column and inactivate sediment phosphorus. This document represents a summary of the sediment data that will be used to fully evaluate options for reduction of the internal load of phosphorus to Nippo Lake.

1.1 Approach

There are several central questions that drive the sediment assessment presented in this summary:

1. How much phosphorus is in the sediments of Nippo Lake?
2. How much of this phosphorus (internal load) could be released under low oxygen conditions?
3. How much of this phosphorus is essentially permanently bound in the sediments?
4. Is sediment phosphorus inactivation (likely through addition of aluminum) technically feasible to counteract the internal P load?

These questions can be answered with the sediment data however, permitting considerations, costs and possible funding sources are to be addressed in future phases of the Nippo Lake watershed planning project.

1.2 Field Program.

The sediment sampling program was developed through collaboration among NHDES, DK Water Resource Consulting LLC and the Nippo Lake Association. The monitoring program is described in detail in the sediment sampling Quality Assurance Project Plan (QAPP) prepared specifically for this project (NHDES 2018).

Sediment sampling was conducted on July 31, 2018. Field personnel included staff members from NHDES, DK Water Resource Consulting LLC and volunteers from the Nippo Lake Association. Eight samples were collected along with one replicate sample as specified in the QAPP. Actual sampling locations are depicted in Figure 1. Coordinates for these stations are presented in Table 2. All sampling stations were located as close as practicable to stations identified in the QAPP. Stations were chosen to provide a representation of sediment conditions at all depths throughout the lake.

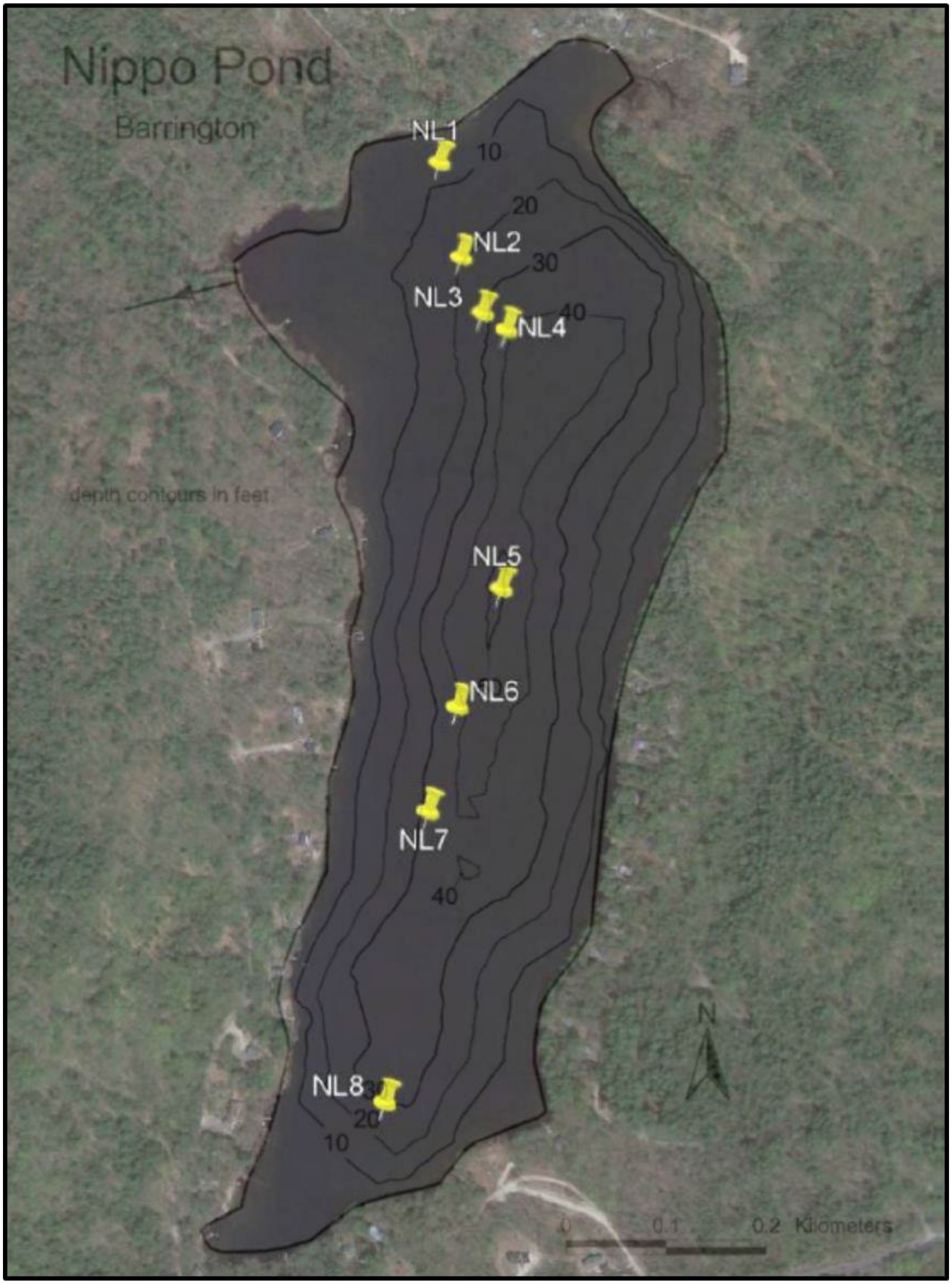

Figure 1: Sampling locations, Nippo Lake Sediment Monitoring, July 31, 2018.

Table 2. Sampling Coordinates, Nippo Lake Sediment Monitoring, July 31, 2018.

Sample Station	Time of Sample	Latitude	Longitude
NL 1	10:20	43.226521	71.082931
NL 2	10:40	43.225616	71.082664
NL 3	10:50	43.225091	71.082401
NL 3 duplicate	10:59	43.225091	71.082401
NL 4	11:35	43.224933	71.082103
NL 5	11:43	43.222544	71.082195
NL 6	11:54	43.221481	71.082745
NL 7	12:00	43.220553	71.083106
NL 8	12:11	43.218033	71.083640

1.3 Sampling Results

Phosphorus (P) in sediment originates from historic loading and, to a lesser degree, the native soils beneath a lake. The sediment P in samples is split into fractions by sequential lab extractions and is reported in four categories depending on how tightly the P is bound in the sediments and under what conditions P might be released back to the water column. Loosely bound P is the most readily available fraction for uptake by algae. Iron bound P can be released from sediments under low oxygen conditions and be available to algae. Labile organic P is bound in organic matter and is released as the organic matter decays and is then available for uptake by algae. Aluminum bound P is more or less permanently bound to aluminum and generally remains in the sediments regardless of the oxygen status of the overlying water. In addition to aluminum bound P there are other forms of permanently bound P including calcium bound mineral P and organic P that are resistant to bacterial breakdown. These other forms are included in sediment total P but are generally not considered mobile.

Nippo Lake typically experiences anoxia in the summer. As a result of the anoxia, a portion of the loosely bound, iron bound, and, to a lesser extent, labile organic P is released to the water column in the deep layers of the lake (hypolimnion). This P is transported to the epilimnion through diffusion, wind mixing and deepening of the epilimnion where it can be taken up by algae. The amount of sediment derived P released annually is the internal load referenced in Table 1.

Sediment samples collected on July 31, 2018 were stored, shipped and analyzed at University of Wisconsin-Stout according to procedures in the approved QAPP document (NHDES 2018). Results of the analysis are presented in Table 3. Quality control data are presented in Appendix A. All quality control results fell well within the performance criteria (<20% relative percent difference) set in the QAPP (NHDES 2018).

In Nippo Lake sediments, concentrations of loosely bound P are relatively low at all depths (Table 3, Figure 2). Iron bound phosphorus is relatively low at shallow stations and becomes progressively higher at deeper stations. Labile organic P is relatively consistent across stations. Aluminum bound P is also higher at deeper stations than shallow stations. As a result of the uneven distribution of both iron and aluminum bound P with depth, total phosphorus in the sediment is lowest in shallow water and highest in deep water. This is to be expected as sediments tend to redistribute deeper in a lake over time along the slope of the bottom.

Table 3: Sediment Monitoring Results for Nippo Lake, July 31, 2018 (sorted by water depth).

	Depth of Sample	Depth of Sample	Moisture content	Solids fraction	LOI	Wet bulk density	Dry bulk density	Loosely-bound P	Iron-bound P	Labile organic P	Aluminum-bound P	Total P	Sum of mobile[2]
	feet	meters	(%)	N/A	(%)	(g/cm^3)	(g/cm^3)	(mg/g)	(mg/g)	(mg/g)	(mg/g)	(mg/g)	mg/g or g/kg
NL 1	10	3.048	90.4	0.096	40.0	1.037	0.102	0.017	0.049	0.452	0.237	0.969	0.518
NL 2	20	6.096	91.7	0.083	35.0	1.034	0.087	0.023	0.083	0.515	0.364	1.071	0.621
NL 3 Mean[1]	29	8.839	91.8	0.082	34.2	1.034	0.086	0.027	0.097	0.559	0.386	1.131	0.683
NL 8	31	9.449	91.5	0.085	34.0	1.036	0.089	0.027	0.104	0.504	0.364	1.154	0.635
NL 7	32	9.754	92.2	0.078	36.6	1.031	0.081	0.025	0.131	0.526	0.420	1.225	0.682
NL 6 Mean[1]	38	11.582	91.9	0.081	37.0	1.032	0.085	0.030	0.141	0.524	0.441	1.246	0.696
NL 4	46	14.021	93.3	0.067	36.9	1.027	0.070	0.030	0.174	0.535	0.474	1.328	0.739
NL 5	51	15.545	91.1	0.089	35.0	1.037	0.093	0.035	0.223	0.515	0.655	1.458	0.773

[1]Values are the mean of duplicates and split samples.

[2]Sum of mobile P includes loosely-bound P, iron-bound-P and labile organic P

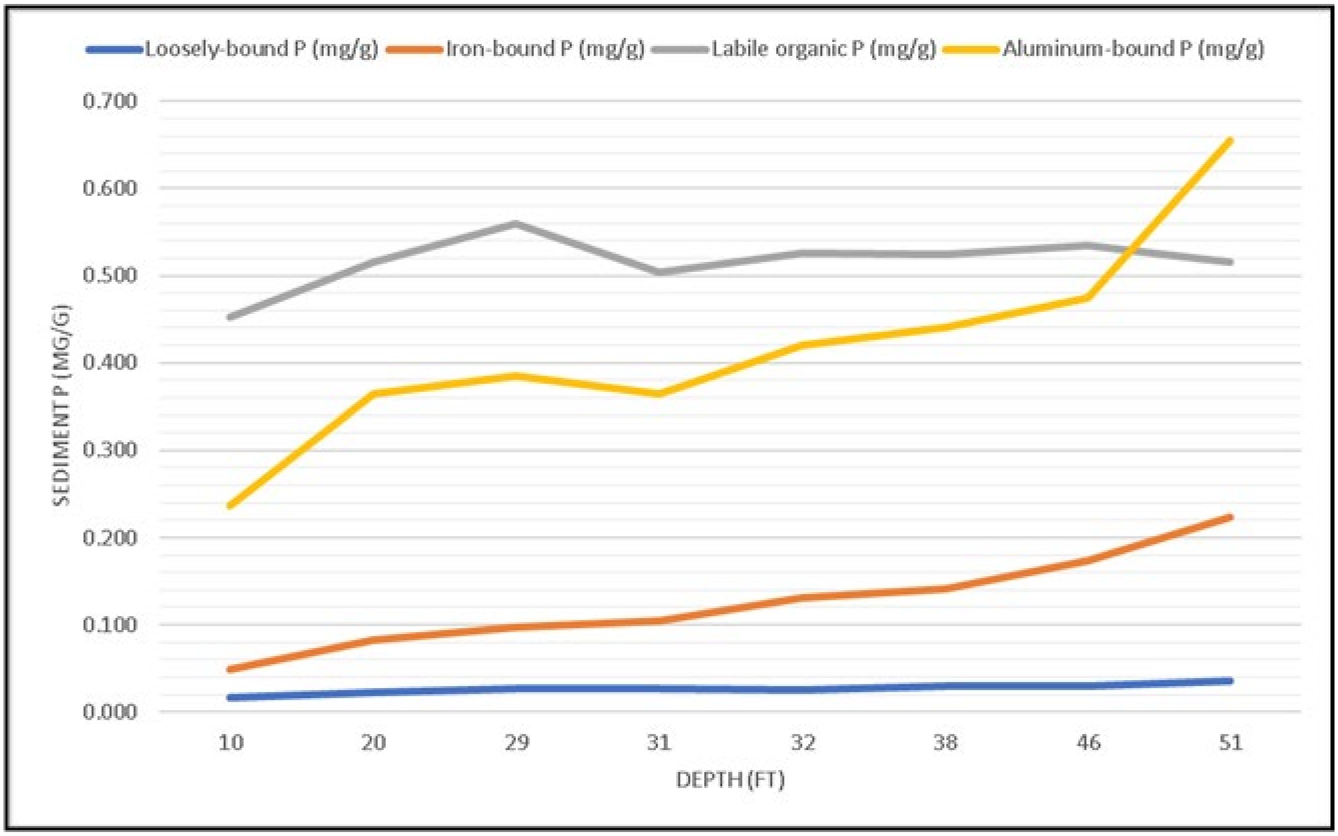

Figure 2: Fractions of sediment phosphorus by water depth. Nippo Lake, July 31, 2018.

The results of the sediment testing are translated into an internal P reserve through several assumptions:

1. Over the entire lake, the average available sediment P concentration was 0.152 mg/g for the loosely bound P and iron bound P combined. The average available sediment P concentration including labile organic P over the entire lake is 0.668 mg/g. While the loosely bound P and the iron bound P are the likely major drivers of current internal loading, it is likely that labile organic P also contributes and will continue to do so in the future. Therefore, it may be advantageous to include all three potentially mobile fractions in management strategies. This is a common strategy in lake management in recent years.
2. The depth of sediment participating in P release is 10 cm. This value is usually set at 4 to 10 cm. We have estimated on the high end of the expected range to be sure we represent all of the phosphorus potentially contributing to the internal load.

3. The percent of solid material reflected as 100% minus the percent moisture as measured in the samples.
4. The specific gravity of the sediment, in dry form, was calculated to be 1.39.

The estimated mass of sediment P is presented in Table 4. Based on one year of field work conducted in 2016, anoxia is typically observed below 9 meters in Nippo Lake. The estimate of internal load used in the water quality model (NHDES 2019) was generated by estimating accumulation of phosphorus in the hypolimnetic volume below 9 meters and assuming that 75% of that gross internal load would be available for algal growth by the following growing season or 12.9 kg. The gross internal load estimate was 17.2 kg/yr.

The modeling estimate of internal P loading can be cross checked by evaluating potential release from measured sediment reserves below 9 meters (30 feet). Because the iron bound P and loosely bound P are the most readily available, they are appropriate to use in this assessment. Not all of the 224 kg of available sediment P below 9 meters area will be released in any year. The portion of available sediment P that is released and makes it into the epilimnion where it becomes part of the effective P load to a lake is normally between 10 and 30%, with most values between 10 and 20% (Mattson et al 2004, BEC 1993, ENSR 2001, ENSR 2008, AECOM 2009) particularly among stratified lakes. In shallow lakes, a larger percentage may become available by virtue of mixing, if anoxia is strong enough to allow release, but for stratified systems lower effective releases prevail. Under the circumstances in Nippo Lake it would be reasonable to estimate a low effective release due to the low potential for substantial wind mixing due to the steep watershed and the depth of the lake relative to its size. Using a potential transfer rate of 10% per year equates to an internal load of 22.4 kg/yr, slightly higher than the gross estimate (17.2) made from hypolimnetic accumulation calculation but probably within the range of year to year variability. It is also possible that the entire 10cm of sediment depth does not contribute equally to the internal load resulting in an overestimate of release from the sediment data.

The data suggest that there are considerable available P reserves in areas where the water does not become anoxic, leaving open the possibility that the contributory area is, at times, greater than the area below 9 meters (30 feet). Release of that sediment P is greatly depressed by the presence of oxygen (which keeps P bound to iron and insoluble), so the contribution of the additional areas is likely to be low as long as oxygen is present. A change in the depth of anoxia would change this situation so consideration should be given to treating some areas above 30 feet as a buffer. Likewise, the pool of labile organic P may not be contributing much to the phosphorus release now but may in the future as the organic matter decays. Phosphorus currently bound in organic matter may also bind with aluminum or other inactivation compounds introduced to bind other forms of P so it may be advantageous to include labile organic P as a component of the sediment phosphorus to be inactivated. This will increase treatment costs but may increase the likelihood of acceptable results from a phosphorus inactivation project.

Table 4: Estimated mass of phosphorus in sediments below selected water depths in Nippo Lake, July 31, 2018.

Water Depth (m)	Water Depth (ft)	Area (acres)	Area (hectares)	Loosely Bound P + Iron Bound P in upper 10 cm of sediments (kg)	Loosely Bound P + Iron Bound P + Labile Organic P in upper 10 cm of sediments (kg)
9	30	27	11	224	857
7	23	42	17	326	1314
3	10	65	26	462	2029
0	0	85	35	606	2663

It is generally believed that only the P in the upper 4 to 10 cm of sediment interacts with the water column (Cooke et al. 2005). There can be upward mobilization of P, but studies and field work have indicated that inactivating a mass of P equal to that calculated for the upper 10 cm of sediment is adequate to get maximum reduction in internal loading (Cooke et al 1993, Rydin and Welch 1998, Welch and Cooke 1999).

1.4 Next Steps

The information obtained from the sediment sampling program confirms the presence of sufficient mobile sediment phosphorus to support substantial internal loading in Nippo Lake. It also provides estimates of the mass of phosphorus that would need to be inactivated in order to reduce the internal load. These data can be used to develop appropriate strategies for treatment of the internal load and develop cost estimates for these treatment strategies. The success and longevity of any internal load treatment is highly dependent on the actions currently being undertaken to reduce the external watershed load. It is also dependent on control of future sources of phosphorus from the watershed. The next phase of the watershed planning project addresses these elements and is critical to moving Nippo Lake towards restoration.

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Appendix Table 1. Quality Control Data for Nippo Lake sediment sampling program July 31, 2018.

Quality Control Data, Nippo Lake Sediment - July 31, 2018

	Duplicates[1]	Split[2]	Moisture content (%)	Solids %	LOI (%)	Wet bulk density (g/cm^3)	Dry bulk density (g/cm^3)	Loosely-bound P (mg/g)	Iron-bound P (mg/g)	Labile organic P (mg/g)	Aluminum-bound P (mg/g)	Total P (mg/g)
Field Replicate												
NL 3	1	1	91.672	0.083	33.333	1.035	0.087	0.027	0.104	0.526	0.384	1.150
NL 3DUP	1	1	91.932	0.081	35.036	1.033	0.085	0.026	0.090	0.592	0.387	1.113
Relative Percent Difference			0.284	3.123	5.109	0.198	3.300	3.704	13.462	12.548	0.781	3.169
Station 3 Mean			**91.802**	**0.082**	**34.185**	**1.034**	**0.086**	**0.027**	**0.097**	**0.559**	**0.386**	**1.131**
Laboratory Duplicates and Splits												
NL 6-1-1	1	1	91.826	0.082	37.500	1.032	0.086	0.030	0.144	0.510	0.447	1.249
NL 6-1-2	1	2						0.030	0.144	0.538	0.425	1.249
NL 6-2	2	1	91.967	0.080	36.552	1.032	0.084	0.031	0.135	0.525	0.451	1.241
Relative Percent Difference			0.153	1.757	2.594	0.008	1.824	3.226	6.667	5.204	5.765	0.646
Station 6 Mean			**91.896**	**0.081**	**37.026**	**1.032**	**0.085**	**0.030**	**0.141**	**0.524**	**0.441**	**1.246**

[1]Duplicates represent two separate alliquots withdrawn from original sample and analyzed

[2]Splits represent one alliquot withdrawn and split prior to analysis

DK Water Resource Consulting LLC

WRS

Appendix C

Proposed Nippo Lake phosphorus inactivation project monitoring plan

Treatment Phase	Approximate date(s) of Monitoring	Type of Monitoring	Frequency	Location(s) and Depth(s)	Parameters Monitored	Comments
Pre-treatment 1	March/April 2021; no more than 3-weeks prior to pilot treatment	Water quality monitoring	Single sample event	3 locations (2@~10m deep, 1@~14m deep) along the north-south centerline of the lake. Sample depth is 1m increments for field measures and 1/3,1/2, and 2/3 of total depth for grab samples	Field measurements: temperature, pH, dissolved oxygen, specific conductance, Secchi disc transparency. Grab samples: alkalinity, hardness, dissolved organic carbon, acid soluble aluminum, total aluminum, total phosphorus, chlorophyll a.	Results must be made available for review prior to any treatments.
Pre-treatment 2	May 2021; no more than 2-days prior to treatments 1 and 2.	Shoreline survey of aquatic organism distress and underwater video. Water quality monitoring.	Prior initiation of the first and second treatments (2 events total);	Field measures: Deep spot (>14m) at 1m intervals. Grab samples at 1/3,1/2, and 2/3 of total depth; Additional 10 pH field measures at 0.5m depth from various locations around lake at locations with depth <5m.	Field measurements: temperature, pH, dissolved oxygen, specific conductance, Secchi disc transparency. Grab samples: alkalinity, hardness, dissolved organic carbon, acid soluble aluminum, total aluminum, total phosphorus, chlorophyll a. Zooplankton and phytoplankton samples from deep spot.	Field measured data will be reviewed prior to treatment; grab sample data will not be available prior to treatment
During Treatment	–May 2021	Shoreline survey of	Field measurement	One sample location in each of 4 treatment “sectors”. Field	Field measured: temperature, pH, dissolved	Field measured data

		aquatic organism distress and underwater video. Water quality monitoring	s: beginning, middle, end of each treatment day (8 treatment days proposed). Grab samples: end of treatment day. Visual observations: Continuous throughout day.	measurements and grab samples at 1/3 and 2/3 of total depth. Additional 10 pH field measurements at 0.5m at various locations around lake at locations with depth <5m.	oxygen, specific conductance, Secchi disc transparency. Grab samples: alkalinity, hardness, dissolved organic carbon, acid soluble aluminum, total aluminum, total phosphorus, chlorophyll a. Phytoplankton and zooplankton samples at end of day.	will be reviewed prior to and after treatment; Grab sample data will not be available for up to 2-3 weeks after sample collection
Post-Treatment	May 2021 – October 2022	Water quality monitoring.	2021: 1-week post second treatment, monthly June – September 2021. 2022: Ice-out, August, and October.	Field measurements from deep spot at 1m intervals. Grab samples at 1/3,1/2, and 2/3 of total depth. Zooplankton and phytoplankton samples	Field measurements: temperature, pH, dissolved oxygen, specific conductance, Secchi disc transparency. Grab samples: alkalinity, hardness, dissolved organic carbon, acid soluble aluminum, total aluminum, total phosphorus, chlorophyll a. Phytoplankton and zooplankton samples.	Monitoring should mimic pre-treatment 2 monitoring.

To: File
From: Kirsten Nelson, NHDES

Date: December 22, 2015

RE: Deep spot data summary document of Nippo Lake, Barrington, NH

Background

Nippo Lake is a deep, 85-acre, natural lake located in Barrington, NH. New Hampshire Department of Environmental Services (NHDES) has performed two lake trophic surveys as part of their Lake Trophic Survey Program (LTSP) in 1982 and 2004. Based on a rating system that considers bottom dissolved oxygen concentration, Secchi depth, vascular plant abundance, and epilimnetic chlorophyll-*a* concentration, Nippo Lake was classified as mesotrophic for both LTSP surveys. Since 1986, Nippo Lake has been monitored yearly by the Nippo Lake Association (NLA) volunteers in association with the University of New Hampshire's volunteer Lakes Lay Monitoring Program (UNH LLMP). Additional sampling has been conducted by UNH's Center for Freshwater Biology (CFB) scientists. Using a differing set of criteria to establish trophic status, UNH originally classified Nippo Lake as oligotrophic based on chlorophyll-*a*, total phosphorus, and nitrogen concentration as well as Secchi depth. Concerns about stormwater input and the occurrence of multiple cyanobacteria blooms since 2010 has led to increased need to summarize the available data as a preliminary step towards understanding past and current waterbody conditions. This document aggregates NHDES and UNH data to better understand the status and trends of the most commonly collected water quality parameters.

Methods

Total phosphorus, chlorophyll-*a* concentration, Secchi depth, and specific conductance were aggregated and examined for trends using non-parametric one-sided Mann-Kendall trend tests for datasets that had ≥ 10 individual years of data. An exception was made for specific conductance, which had nine individual years of data available. The Mann-Kendall tests investigated whether a significantly increasing or decreasing trend was present, depending on the parameter in question. Significance was declared at $p \leq 0.05$. Annual median values were used for statistical analyses instead of averages to dampen outlier influence. To maintain consistency with the methodology outlined in a 2009 NHDES report (R-WD-09-29) titled "Assessment of Chlorophyll-*a* and Phosphorus in New Hampshire Lakes for Nutrient Criteria Development" only samples from June, July, August, and September were selected for analyses and inclusion in this report. Total phosphorus data from May sampling events were plotted separately.

Only data for the Nippo Lake deep spot were investigated to maintain consistency and reflect overall lake conditions. Additional historical sampling locations are present on this lake; however, their data were not included in this report. Thermal layers were determined by examining six available temperature versus depth profiles, determining at what depth temperature changed by more than 1° C, and averaging the break points. Thermal layers varied by year and month; however, a thermal profile was collected on only a handful of sample dates. For the sake of analysis, general dividing points were necessary to categorize all data by thermal layer. The epilimnion was considered to be 0 – 4 meters, the metalimnion from 4.5 – 7.5 meters, and the hypolimnion > 7.5 meters. However, if, for example, a composite sample ranged from 0 – 4.5 meters, the sample was considered an epilimnetic sample.

Total Phosphorus

One hundred fifteen total phosphorus samples in 13 individual years were available spanning from 1982 to 2015. After removing samples outside of the June – September range, 99 total phosphorus samples were available, with 40 epilimnion, 23 metalimnion, and 36 hypolimnion samples. Total phosphorus data was collected by the NHDES LTSP (epilimnion [n = 2], metalimnion [n = 2], hypolimnion [n = 2]), UNH CFB (epilimnion [n = 17], metalimnion [n = 21], hypolimnion [n = 34]), and UNH LLMP (epilimnion [n=19], metalimnion [n = 0], hypolimnion [n = 0]). On some sample days, multiple samples were taken within a thermal layer. Multiple total phosphorus values were averaged within each thermal layer on individual sampling events. This resulted in 66 total phosphorus measurements, with 37 in the epilimnion, 14 in the metalimnion, and 15 in the hypolimnion.

According to the 2014 New Hampshire Consolidated Assessment and Listing Methodology (CALM), the epilimnetic total phosphorus thresholds by trophic class are < 8 ug/L for oligotrophic lakes, ≤ 12 ug/L for mesotrophic lakes, and ≤ 28 ug/L for eutrophic lakes. Thresholds have not been established for metalimnion or hypolimnion total phosphorus samples.

Chlorophyll-a

Three hundred thirty-nine chlorophyll-*a* samples were available spanning from 1982 to 2015. Only samples from June, July, August, and September were selected. Due to small sample size, three hypolimnetic samples were combined with their corresponding mesotrophic samples to capture the range of chlorophyll-*a* concentration, resulting in a total of 316 chlorophyll-*a* samples for analyses, with 297 epilimnion and 19 metalimnion/hypolimnion samples. Chlorophyll-*a* samples were collected by NHDES LTSP (n=2), UNH CFB (n=39), and UNH LLMP (n=272). On some sample days, multiple samples were taken within a thermal layer. Multiple chlorophyll-*a* samples in a thermal layer taken on the same day were averaged, for a total of 285 individual data points, with 285 epilimnion and 13 metalimnion/hypolimnion samples.

There is a slight difference in the NHDES and UNH methods for collecting a composite sample in thermally stratified lakes. NHDES composite samples include the epilimnion and half of the metalimnion, while UNH composite samples include only water from the epilimnion. Often algae will accumulate at the thermocline in the metalimnion so a composite sample collected using the NHDES methods will generally have the higher chlorophyll-*a* value than if the UNH methods had been used. However, UNH did take separate chlorophyll-*a* samples into the metalimnion and/or the hypolimnion starting in 2011.

The CALM describes chlorophyll-*a* thresholds as < 3.3 ug/L for oligotrophic lakes, ≤ 5.0 ug/L for mesotrophic lakes, and ≤ 11 ug/L for eutrophic lakes. Thresholds have not been established for hypolimnion samples.

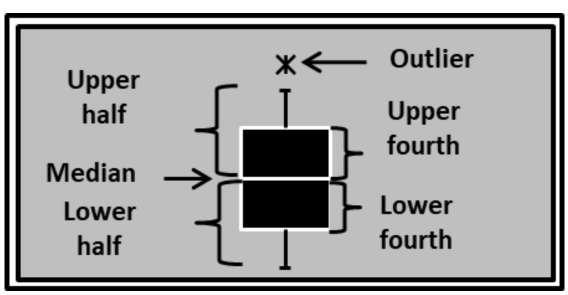
Secchi Depth
Three hundred thirteen Secchi depth measurements from 30 individual years were available spanning from 1982 to 2015. Only samples from June, July, August, and September were selected for analyses, resulting in a total of 295 Secchi depth measurements. Secchi Depth readings were collected by the NHDES LTSP (n=2), UNH CFB (n=13), and UNH LLMP (n=280).

In general, a Secchi depth greater than 4.5 meters indicates oligotrophic conditions, while a Secchi depth of less than 2 meters is indicative of eutrophic conditions. The median Secchi depth for New Hampshire lakes is 3.2 meters.

Specific conductance
One hundred eighty-three specific conductance measurements were taken between 1982 and 2015. After removing samples from outside June - September, 176 measurements remained over 9 individual years, with 59 in the epilimnion, 44 in the metalimnion, and 73 in the hypolimnion. Readings were collected by NHDES LTSP (n=6) and the UNH CFB (n=170). On some sample days, multiple samples were taken within a thermal layer. Multiple specific conductance measurements within a thermal layer taken on the same day were averaged. This resulted in 35 readings, with 12 in the epilimnion, 11 in the metalimnion, and 12 in the hypolimnion.

Specific conductance is the numerical expression of water's ability to carry an electrical current. It is determined primarily by the number of ionic particles present. The soft waters of New Hampshire traditionally have low conductivity values, generally less than 50.0 uS/cm. However, specific categories of good and bad levels cannot be constructed for conductivity because variations in watershed geology can result in natural fluctuations. Values in New Hampshire lakes exceeding 100 uS/cm can indicate cultural, meaning human, disturbances. An increasing conductivity trend typically indicates the presence of pollution sources in the watershed.

Box and whisker plots
Box and whisker plots provide a graphical representation of the spread, variance, and skewedness of a dataset. They are centered around the median of a dataset, with 50% of the data above and 50% of the data below. The box itself contains 50% of the data, which is the upper and lower 25% of the dataset. Outliers are data points that are 1.5 times greater or lesser than the length of the box. For years when a single sample event occurred, a solid black square was utilized.



Results

Total Phosphorus

An upward Mann-Kendall trend test found that epilimnetic total phosphorus increased significantly at the deep spot from 1982 – 2015 ($z = 3.069$; $p = 0.001$; Table 1; Figure 1). Metalimnetic total phosphorus also increased ($z = 2.154$; $p = 0.016$; Table 1; Figure 2). Hypolimnetic total phosphorus was examined through the entire column as well as samples taken at less than 10 meters to examine total phosphorus loading in part of the hypolimnetic area. While the total hypolimnetic column approached significance over time ($z = 1.41$; $p = 0.079$; Table 1; Figure 3), below 10 meters total phosphorus increased significantly ($z = 2.712$; p = =0.003; Table 1; Figure 4).

Total phosphorus sampling was also conducted by UNH CFB in the spring to capture fully mixed conditions in 2014 and 2015 (Figure 5). Before a lake stratifies in the summer, total phosphorus values are similar throughout the water column. As thermal stratification occurs, individual thermal layers may have differing total phosphorus amounts, depending on influences like internal total phosphorus loading, hypolimnetic anoxic conditions, external total phosphorus inputs, etc. While the 2014 and 2015 sought to target fully mixed conditions, the results suggest thermal stratification was already occurring, due to the differing total phosphorus levels throughout the water column (Figure 5).

Table 1. Total phosphorus median (ug/L) and number of samples of each thermal layer per year of deep spot sampling from 1982 to 2015 at Nippo Lake, Barrington, NH.

Year	Epilimnion		Metalimnion		Hypolimnion		Hypolimnion (> 10 m)	
	Median	n	Median	n	Median	n	Median	n
1982	4	1	13	1	22	1	22	1
1983								
1984								
1985								
1986	4.9	1						
1987								
1988	6.4	1	6.4	1	47.4	1	47.4	1
1989								
1990								
1991								
1992								
1993								
1994	9.7	1	16	1	69.9	1	69.9	1
1995	13.8	2	15.1	2	32.1	2	32.1	2
1996								
1997								
1998								
1999								
2000								
2001								

Year	Epilimnion		Metalimnion		Hypolimnion		Hypolimnion (> 10 m)	
	Median	n	Median	n	Median	n	Median	n
2002								
2003	6.7	1	6.6	1	28.7	1	40.6	1
2004	5	1	18	1	64	1	64	1
2005								
2006								
2007								
2008								
2009								
2010	12.6	9			43	1	43	1
2011	11.1	6	14.7	1	35.2	1	42.4	1
2012	11.5	1	8.6	1	15	1	15	1
2013	12.7	3	15.2	1	108.9	1	108.9	1
2014	10.2	8	15.1	4	62	4	95.4	4
2015	9.7	2						

Figure 1. Epilimnetic total phosphorus (≤ 4 m; ug/L) at the deep spot at Nippo Lake, Barrington, NH, from 1982 – 2015. The total phosphorus threshold for oligotrophic lakes is 8 ug/L and 12 ug/L for mesotrophic lakes (2014 CALM). A significant upward trend (p = 0.001) was present.

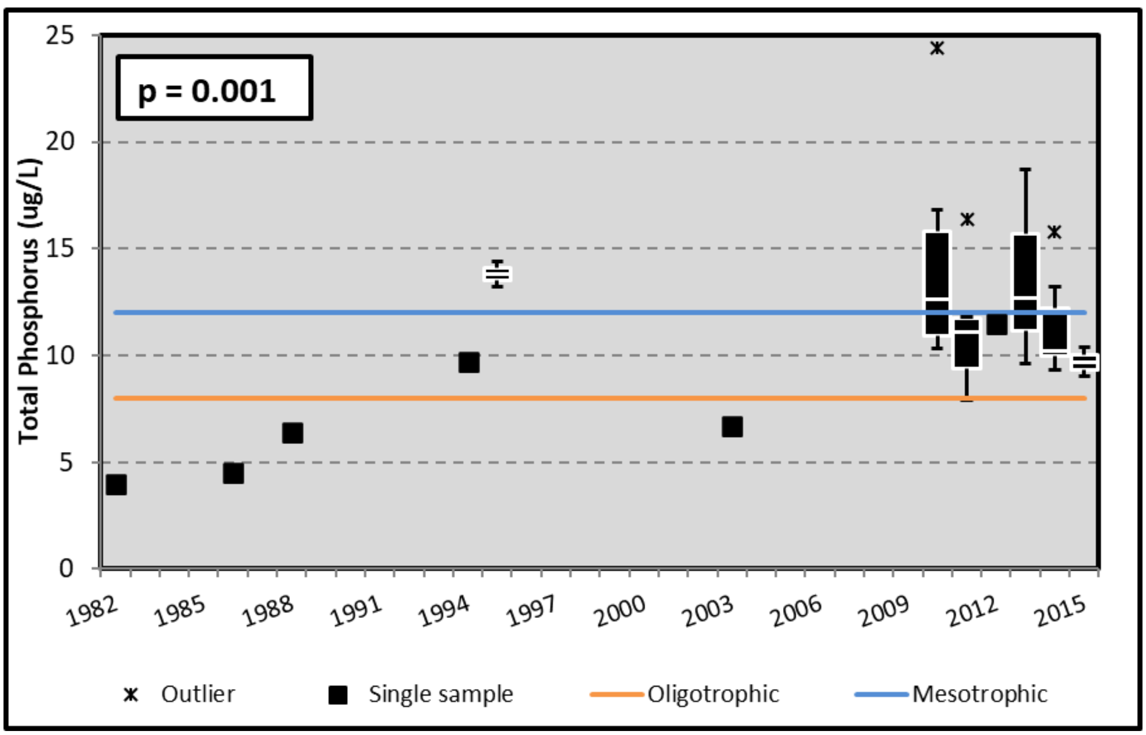


Figure 2. Metalimnion total phosphorus (4.5 – 7.5 m; ug/L) at the deep spot at Nippo Lake, Barrington, NH from 1982 – 2015. A significant upward trend (p = 0.016) was present.

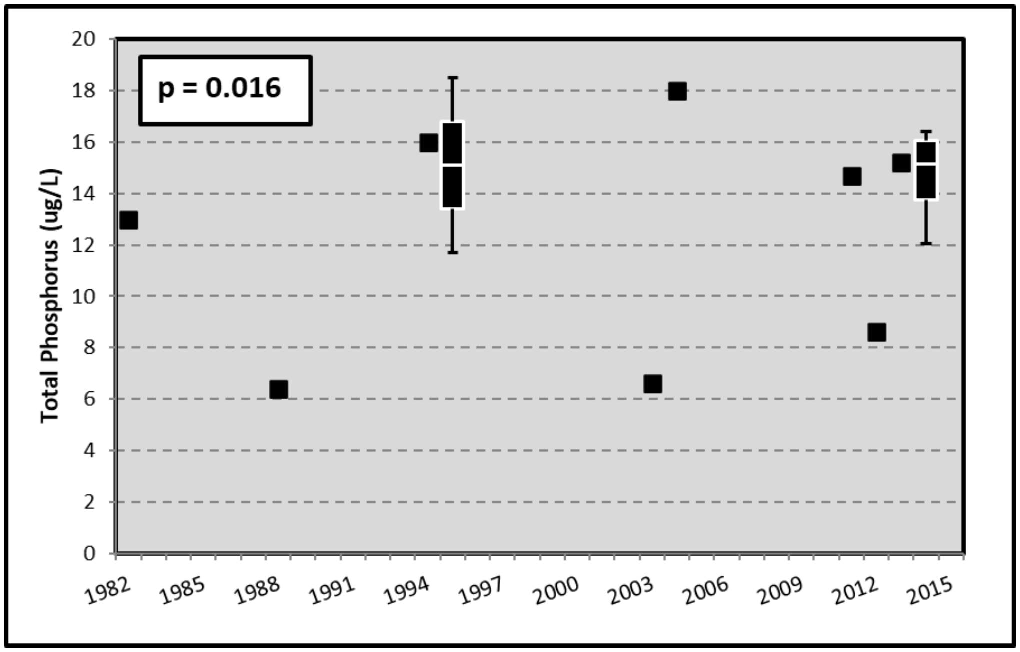


Figure 3. Hypolimnion total phosphorus (> 7.5 m; ug/L) at the deep spot at Nippo Lake, Barrington, NH from 1982 – 2015. No significant trend (p = 0.079) was present.

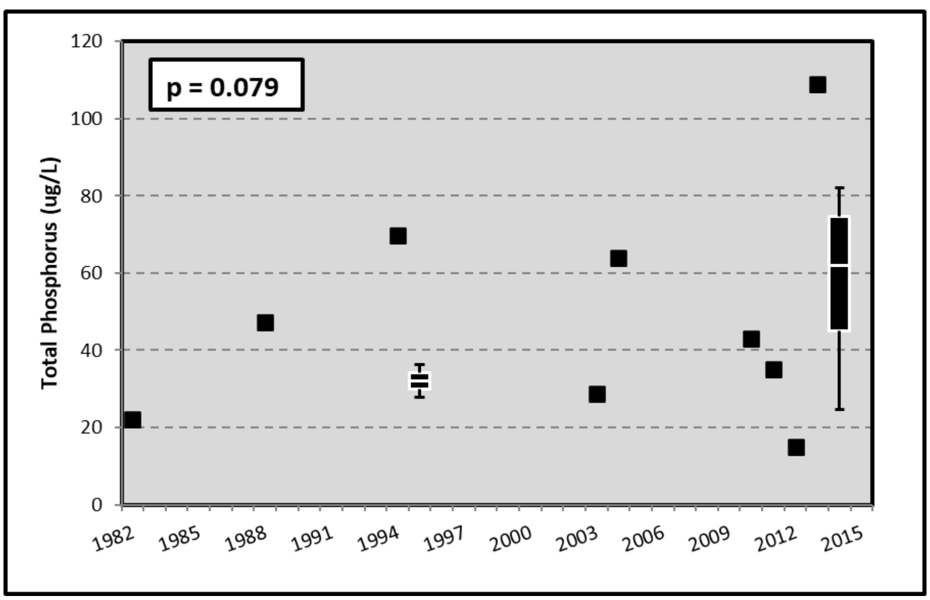


Figure 4. Hypolimnion total phosphorus (>10 m; ug/L) at the deep spot at Nippo Lake, Barrington, NH from 1982 – 2015. A significant upward trend (p = 0.003) was present.

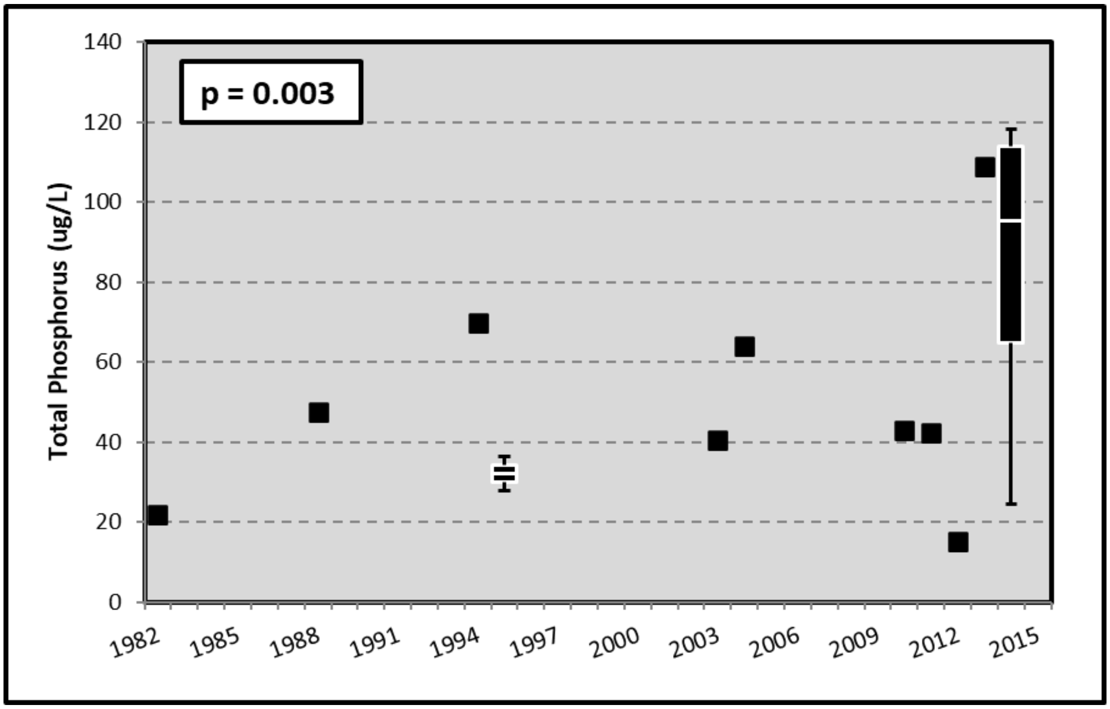
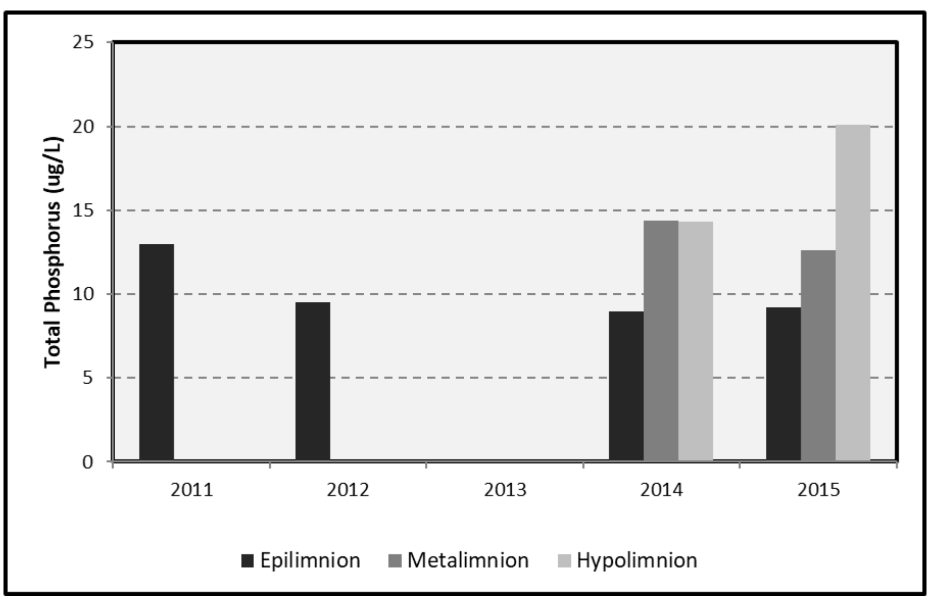


Figure 5. Total phosphorus sampling (ug/L) in May, before fully stratified conditions, by thermal layer in Nippo Lake, Barrington, NH.



Chlorophyll-a

An upward Mann-Kendall trend test found that epilimnetic chlorophyll-*a* concentration did not significantly increase from 1986 to 2015 ($z = 0.589$; $p = 0.278$; Table 2; Figure 6). A Mann-Kendall trend test was not performed on the combined metalimnetic and hypolimnetic chlorophyll-*a* because fewer than 10 ($n = 8$) individual years of data were available (Table 2, Figure 7).

Table 2. Median and number of chlorophyll-*a* samples (ug/L) by year and thermal layer at the deep spot in Nippo Lake, Barrington, NH from 1982 – 2015.

Year	Epilimnion		Metalimnion	
	Median	n	Median	n
1982			3.35	1
1983				
1984				
1985				
1986	1.20	8		
1987	1.25	10		
1988	3.00	12		
1989	2.90	10		
1990	3.25	10		
1991	6.10	10		
1992	3.15	10		
1993	1.85	8		
1994	3.25	10	7.21	1
1995	1.89	10	5.93	3
1996	1.40	6		
1997	2.70	6		
1998				
1999	2.40	7		
2000	2.80	6		
2001	1.95	10		
2002	2.00	7		
2003	1.10	6	1.86	1
2004			1.80	1
2005	1.57	13		
2006	2.30	10		
2007	1.55	10		
2008	2.60	1		

		5		
2009	3.05	1 4		
2010	2.20	1 3		
2011	3.60	1 3	15.21	1
2012	2.10	1 2		
2013	3.10	1 3	15.28	1
2014	3.35	1 2	16.05	4
2015	2.71	1 3		

Figure 6. Epilimnetic chlorophyll-*a* concentration (ug/L) at the deep spot of Nippo Lake, Barrington, NH from 1986 to 2015. The threshold for oligotrophic lakes is 3.3 ug/L and 5 ug/L for mesotrophic lakes (2014 CALM). No significant trend (p = 0.278) was present.

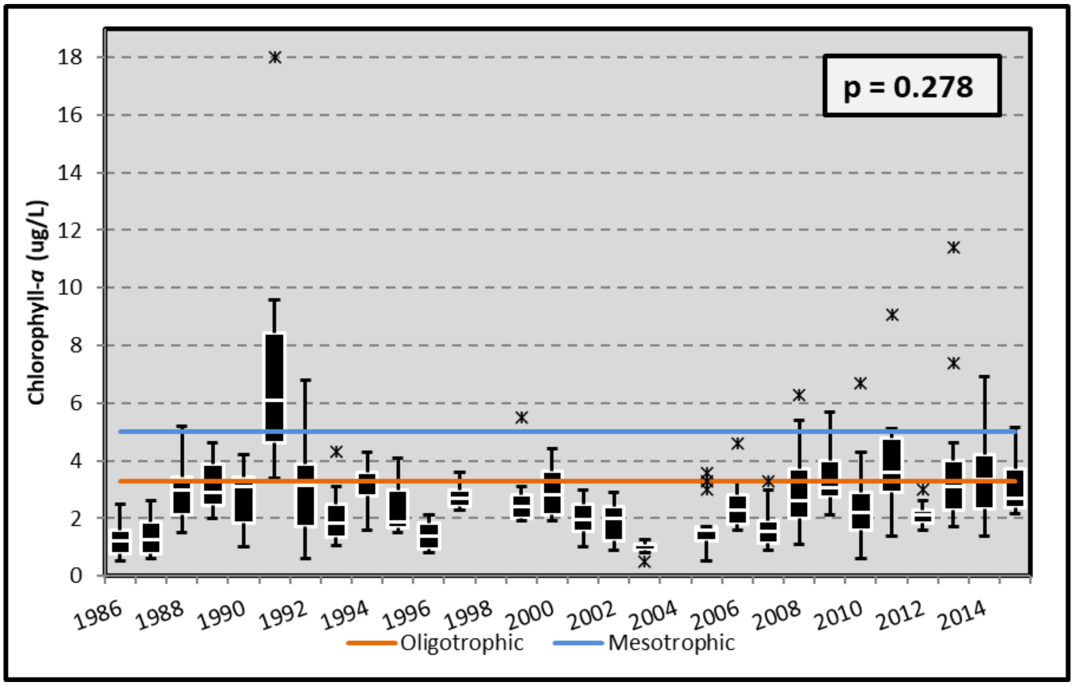
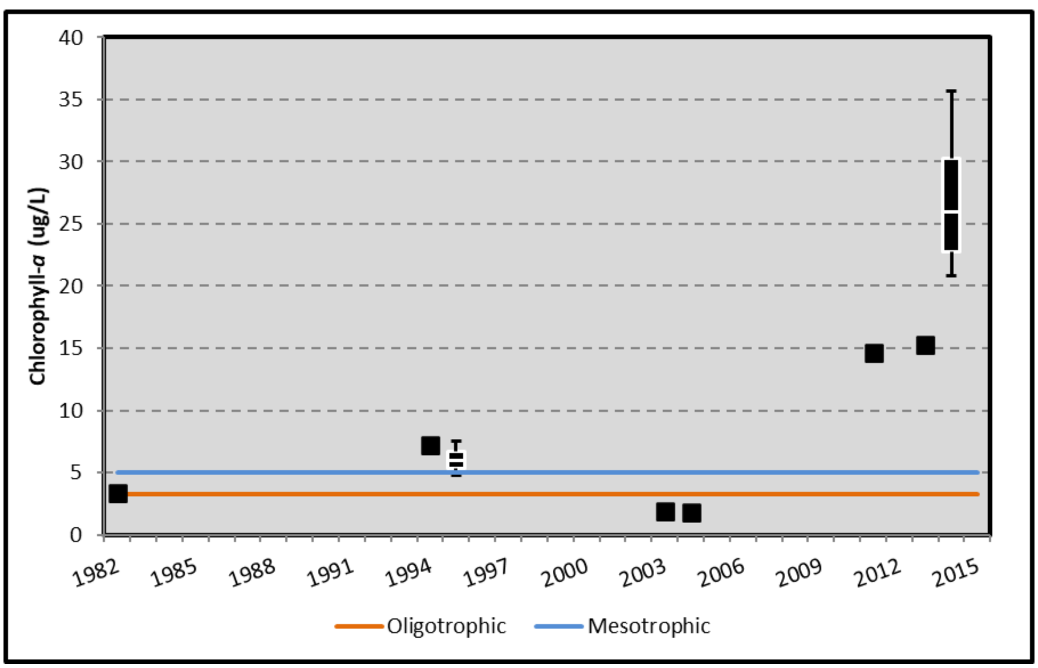


Figure 7. Combined metalimnetic and hypolimnetic chlorophyll-a concentrations (ug/L) at the deep spot of Nippo Lake, Barrington, NH from 1982 to 2015. The threshold for oligotrophic lakes is 3.3 ug/L and 5 ug/L for mesotrophic lakes (2014 CALM).



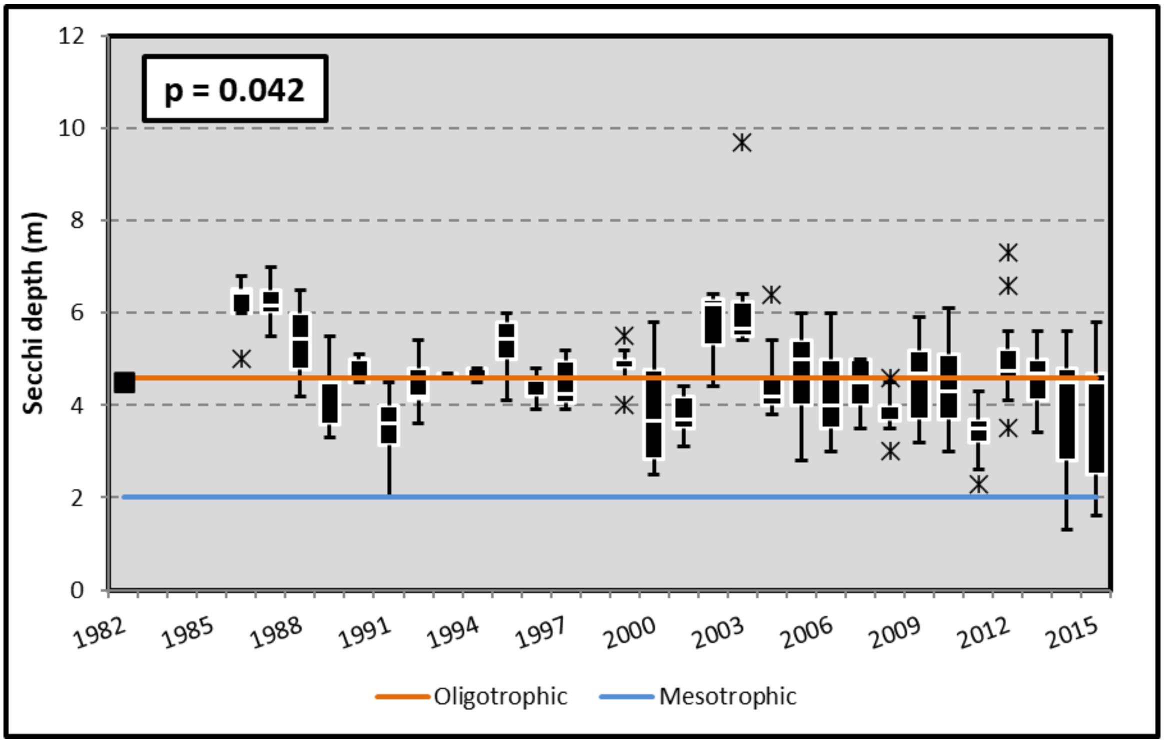
Secchi Depth

A downward Mann-Kendall trend test found that median Secchi depth significantly decreased from 1982 to 2015 ($z = -1.726$; $p = 0.042$; Table 3; Figure 8).

Table 3. Median and number of samples of Secchi disk readings (m) at Nippo Lake, Barrington, NH from 1982 – 2015.

Year	Secchi Depth	
	Median	n
1982	4.50	1
1983		
1984		
1985		
1986	6.40	9
1987	6.15	10
1988	5.45	12
1989	4.50	10
1990	4.50	11
1991	3.60	10
1992	4.20	10
1993	4.65	2
1994	4.60	8
1995	5.45	8
1996	4.55	7
1997	4.25	6
1998		
1999	5.00	9
2000	3.65	6
2001	3.70	10
2002	6.20	7
2003	5.65	7
2004	4.20	10
2005	5.00	16
2006	4.00	11
2007	4.50	10
2008	4.00	15
2009	4.70	16
2010	4.30	13
2011	3.50	14
2012	4.75	15
2013	4.70	14
2014	4.50	19
2015	4.50	17

Figure 8. Deep spot Secchi depth measurements (m) at Nippo Lake, Barrington, NH from 1982 to 2015. A significant downward trend (p = 0.042) was present. Generally, Secchi depth values >4.5 m are considered oligotrophic, 4.5 – 2.0 m are mesotrophic, and <2 m are eutrophic.



Specific Conductance

Upward Mann-Kendall tests found that median specific conductance significantly increased in the epilimnion (z = 2.897, p = 0.002), the metalimnion (z = 2.897, p = 0.002), and the hypolimnion (z = 5.377, p < 0.0001) from 1982 to 2015 in Nippo Lake, with the largest increase in the hypolimnion (Table 5; Figure 9). Nine individual years of sampling were available for analysis; however, Mann-Kendall trend tests are more reliable with a minimum of ten samples. Therefore, this trend analysis is preliminary.

Table 5. Median and number of samples of specific conductance (uS/cm) for each thermal layer from 1982 – 2015 in Nippo Lake, Barrington, NH.

Year	Epilimnion		Metalimnion		Hypolimnion	
	Median	n	Median	n	Median	n
1982	68.40	1	66.40	1	70.90	1
1983						
1984						
1985						
1986						
1987						
1988	80.70	1	79.00	1	80.40	1
1989						

Year	Epilimnion		Metalimnion		Hypolimnion	
	Median	n	Median	n	Median	n
1990						
1991						
1992						
1993						
1994	66.87	1	64.10	1	76.00	1
1995	78.08	2	75.35	2	82.75	2
1996						
1997						
1998						
1999						
2000						
2001						
2002						
2003						
2004	96.73	1	95.40	1	107.70	1
2005						
2006						
2007						
2008						
2009	81.55	1			88.40	1
2010	78.42	1	76.69	1	89.85	1
2011	72.37	1	71.96	1	82.22	1
2012						
2013						
2014	82.96	3	80.43	3	96.12	3
2015						

Figure 9. Epilimnetic specific conductance values (uS/cm) in Nippo Lake, Barrington, NH from 1982 - 2015. A significant upward trend ($p = 0.002$) was present; however, fewer than 10 data points were used in analysis.

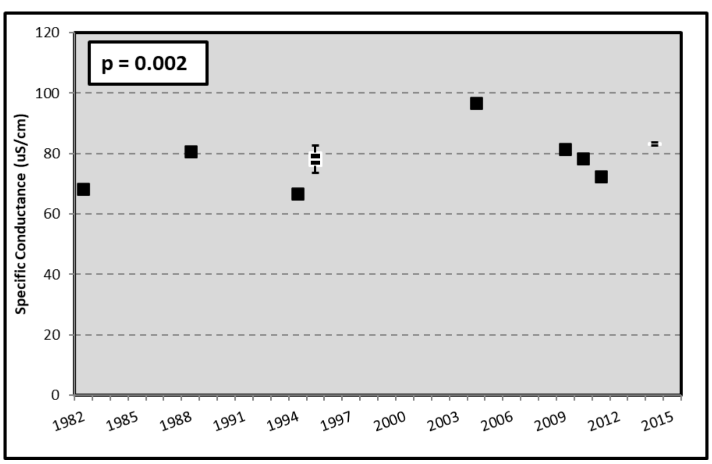


Figure 10. Metalimnetic specific conductance (uS/cm) in Nippo Lake, Barrington, from 1982 to 2015. A significant upward trend (p = 0.002) was present; however, fewer than 10 data point were used in analysis.

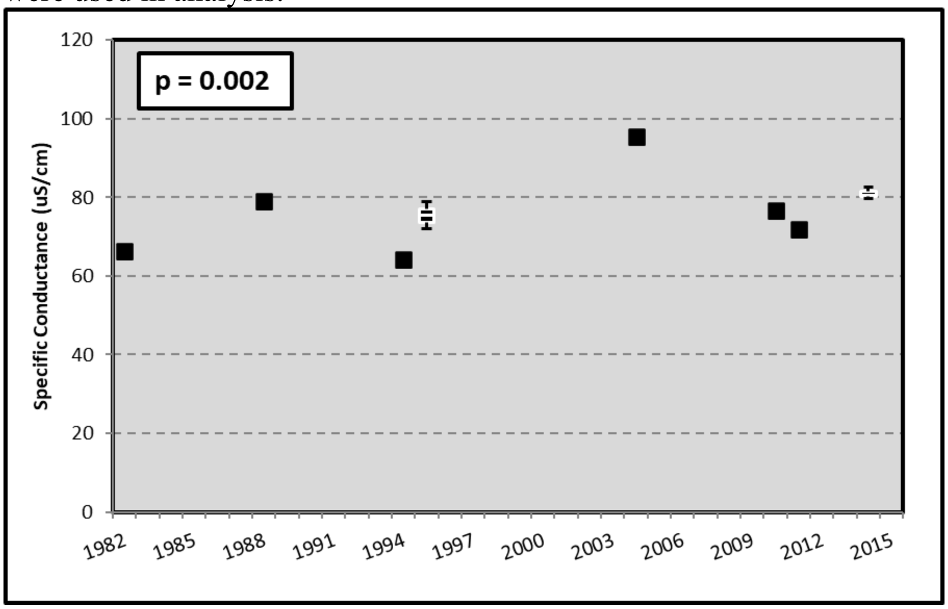
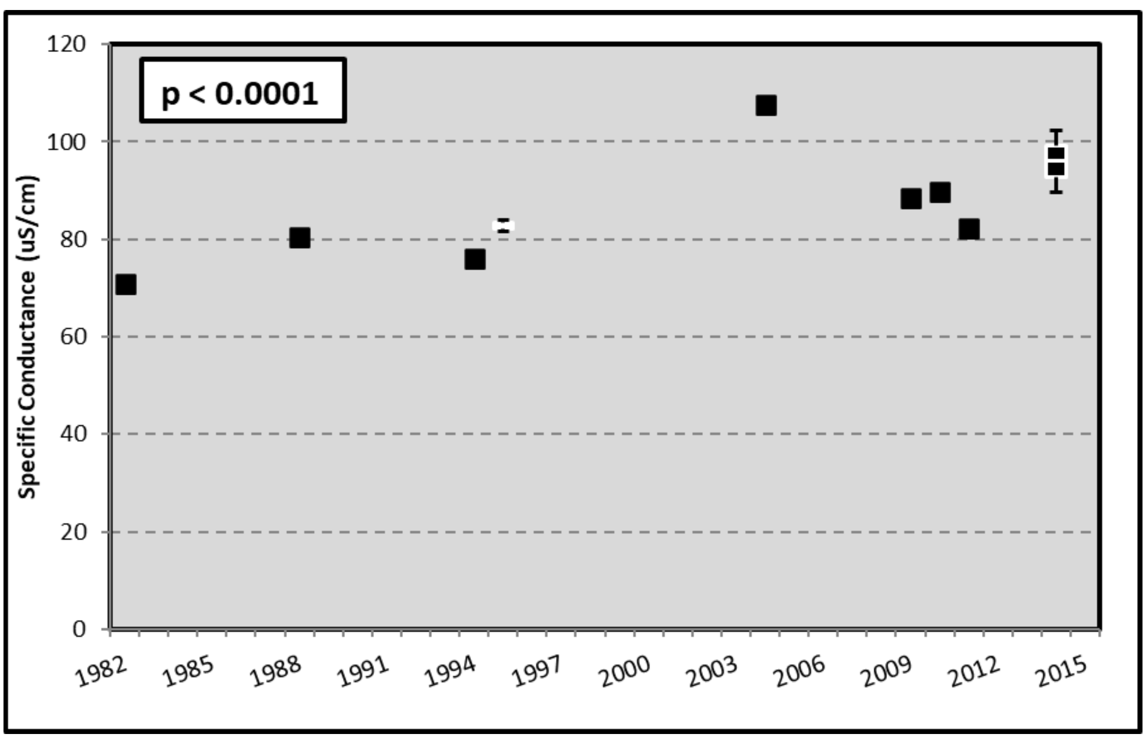


Figure 11. Hypolimnetic specific conductance (uS/cm) in Nippo Lake, Barrinton, from 1982 to 2015. A significant upward trend (p < 0.0001) was present; however, fewer than 10 data point were used in analysis.



Summary

From 1982 to 2015, Nippo Lake has undergone some statistically significant changes, which has implications for overall water quality and trophic status. Total phosphorus has significantly increased in the epilimnion, metalimnion, and hypolimnion at depths greater than 10 meters. NHDES epilimnetic total phosphorus thresholds are < 8 ug/L for oligotrophic lakes and ≤ 12 ug/L for mesotrophic lakes (2014 CALM). While Nippo Lake is classified as mesotrophic, epilimnetic total phosphorus values falling into the eutrophic category occur as early as 1995, and are found regularly when sampling efforts increased in 2010. However, epilimnetic chlorophyll-*a* concentration has not significantly changed in this same time period and the majority of samples fall comfortably below the 2014 CALM chlorophyll-*a* mesotrophic threshold of 5 ug/L. The decoupling of total phosphorus level from chlorophyll-*a* concentration could be due to sampling methodology, as epilimnetic sampling for chlorophyll-*a* through LLMP or UNH CFB only includes epilimnetic water and algal concentrations are higher in the metalimnion. Metalimnetic sampling revealed chlorophyll-*a* concentrations in the eutrophic category as early as 1994 (5 ug/L < chlorophyll-*a* ≤ 11 ug/L), and targeted metalimnetic chlorophyll-*a* sampling in 2013 and 2014 indicating hypereutrophic conditions (chlorophyll-*a* > 11 ug/L).

Lastly, Secchi depth readings decreased significantly while specific conductance levels increased significantly in each thermal layer from 1982 to 2015. Overall, Nippo Lake water quality appears to have declined in the 1982 to 2015 time period, suggesting better watershed management practices are necessary to prevent further declines.

Future Monitoring Suggestions

Long term datasets are invaluable for determining trends in water quality parameters. While the data presented in this report are helpful for preliminary investigations, additional data collection will be necessary to better quantify anthropogenic influences on Nippo Lake. A list of possible additional sampling actions is listed below:

1. Early spring total phosphorus sampling of the deep spot water column to better quantify fully mixed conditions. This sampling should occur immediately after ice out to avoid partial stratification.
2. Weekly deep spot sampling to quantify changes in total phosphorus levels at each thermal layer through the summer and bi-weekly until turnover. Along with suggestion #1, this will help better understand internal phosphorus loading.
3. Utilize NHDES chlorophyll-*a* concentration sampling methodology alongside the epilimnetic chlorophyll-*a* sampling. While it is important to continue the current (epilimnetic) chlorophyll-*a* sampling protocol for long term trend analysis, a better understanding of metalimnetic chlorophyll-*a* concentration is also necessary.
4. Collect additional specific conductance measurements at each thermal layer in the June – September time range to improve statistical analysis.
5. Phycocyanin and chlorophyll-*a* florescence samples should be collected for analysis with water quality samples. Samples can be analyzed at DES or UNH via the EPA cyanobacteria program.

January 2019

Nippo Lake Sediment Analysis

Technical Memorandum

Prepared By: Don Kretchmer, DK Water Resource Consulting LLC

Contents

1.0 Background

Nippo Lake in Barrington, NH suffers from algal blooms and related water quality impairments. The lake is approximately 15.5 meters deep at the deepest hole (51 ft), and has a mean depth of 7 meters (23 ft). The lake area is 35.5 ha (85 acres). The lake volume is approximately 2.4 M m^3 (1,962 acre-ft) with a watershed of 119 hectares (294 acres). Water quality data have been collected by volunteers, staff from the New Hampshire Department of Environmental Services (NHDES) and the University of New Hampshire (UNH) Cooperative extension for more than 30 years. These data allow a look at changes in lake water quality over time as well as a comprehensive look at current water quality. In response to summer cyanobacteria blooms in recent years, a watershed plan is being prepared by the NHDES in cooperation with the Nippo Lake Association (NLA). Central to the plan is a watershed and lake modeling effort that includes estimation of both external and internal nutrient loads. The modeling results indicate that both external (watershed) loading of nutrients and internal (release from sediments) loading of nutrients are contributing to nutrient enrichment of Nippo Lake. A phosphorus budget for Nippo Lake generated from the modeling effort is presented in Table 1.

Table 1. Current phosphorus budget for Nippo Lake.

TP Inputs to Lake	Phosphorus Load (kg/yr)	Percent of Total
Atmospheric	3.8	10
Internal	12.9	34
Waterfowl	1.7	5
Septic Systems	2.8	7
Watershed	16.4	44
Total Load to Lake	**37.5**	**100**

Phosphorus loading of this magnitude to Nippo Lake has resulted in the current condition which is characterized by frequent summer cyanobacteria blooms. Reduction in both internal loads and external loads of phosphorus are necessary to reduce in-lake phosphorus concentrations to a level that substantially reduces the likelihood that blooms will occur. Details on the modeling and the evaluation of lake response under a variety of management scenarios will be discussed in the upcoming watershed management plan for Nippo Lake (NHDES 2019).

As the first phase of implementation of the watershed plan, several watershed phosphorus control projects have been initiated. These projects center on non Point sources of phosphorus and have been implemented over the past several years. Several additional projects are expected to be implemented soon.

This document characterizes the phosphorus content of the surficial sediments of Nippo Lake (upper 10 cm). This characterization will be used to evaluate options to reduce the internal phosphorus (P) load to the lake to supplement reductions in the external phosphorus load. Most promising of those options is the use of aluminum to strip phosphorus from the water column and inactivate sediment phosphorus. This document represents a summary of the sediment data that will be used to fully evaluate options for reduction of the internal load of phosphorus to Nippo Lake.

1.1 Approach

There are several central questions that drive the sediment assessment presented in this summary:

1. How much phosphorus is in the sediments of Nippo Lake?
2. How much of this phosphorus (internal load) could be released under low oxygen conditions?
3. How much of this phosphorus is essentially permanently bound in the sediments?
4. Is sediment phosphorus inactivation (likely through addition of aluminum) technically feasible to counteract the internal P load?

These questions can be answered with the sediment data however, permitting considerations, costs and possible funding sources are to be addressed in future phases of the Nippo Lake watershed planning project.

1.2 Field Program

The sediment sampling program was developed through collaboration among NHDES, DK Water Resource Consulting LLC and the Nippo Lake Association. The monitoring program is described in detail in the sediment sampling Quality Assurance Project Plan (QAPP) prepared specifically for this project (NHDES 2018).

Sediment sampling was conducted on July 31, 2018. Field personnel included staff members from NHDES, DK Water Resource Consulting LLC and volunteers from the Nippo Lake Association. Eight samples were collected along with one replicate sample as specified in the QAPP. Actual sampling locations are depicted in Figure 1. Coordinates for these stations are presented in Table 2. All sampling stations were located as close as practicable to stations identified in the QAPP. Stations were chosen to provide a representation of sediment conditions at all depths throughout the lake.

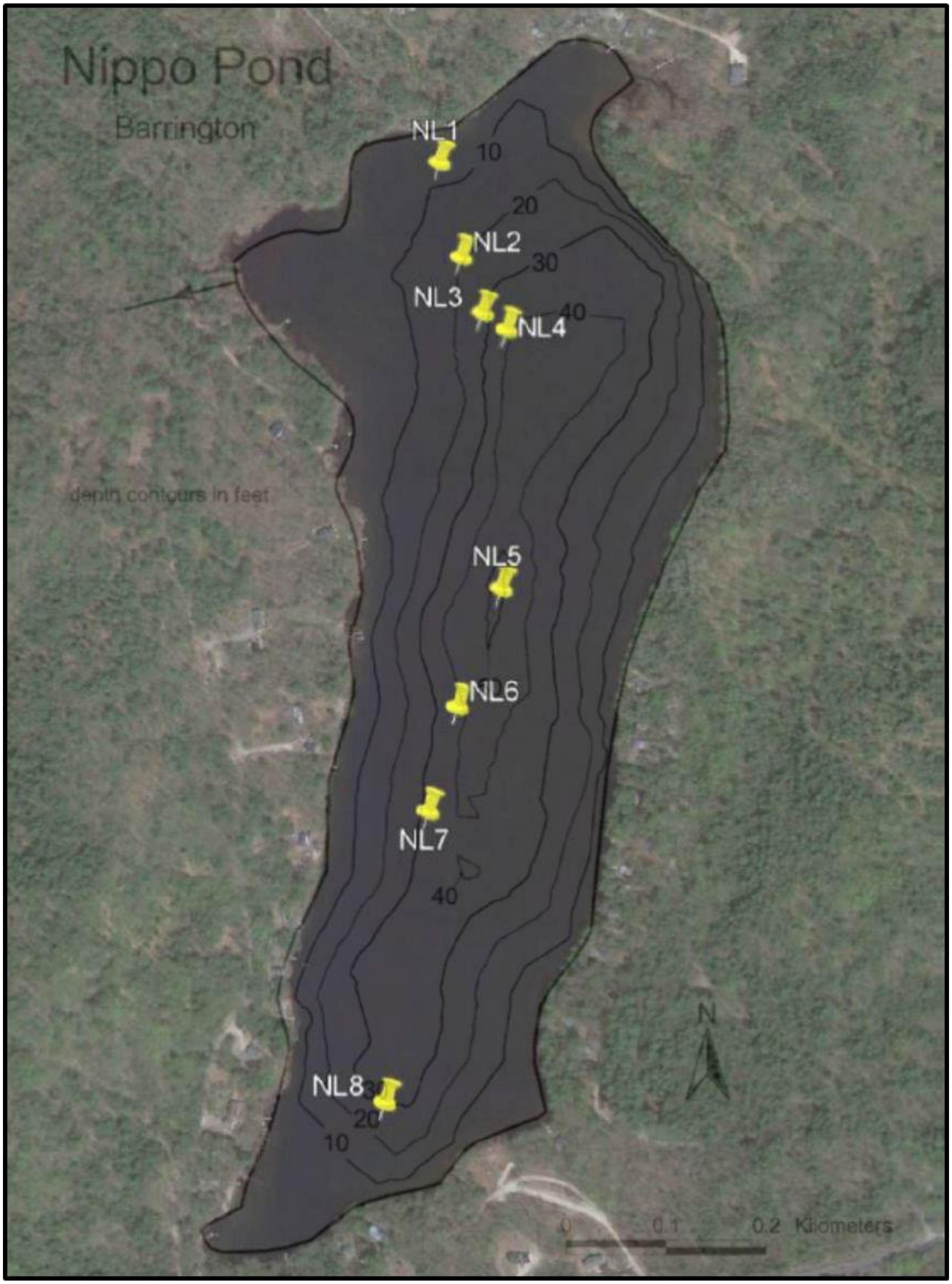


Figure 1: Sampling locations, Nippo Lake Sediment Monitoring, July 31, 2018.

Table 2. Sampling Coordinates, Nippo Lake Sediment Monitoring, July 31, 2018.

Sample Station	Time of Sample	Latitude	Longitude
NL 1	10:20	43.226521	71.082931
NL 2	10:40	43.225616	71.082664
NL 3	10:50	43.225091	71.082401
NL 3 duplicate	10:59	43.225091	71.082401
NL 4	11:35	43.224933	71.082103
NL 5	11:43	43.222544	71.082195
NL 6	11:54	43.221481	71.082745
NL 7	12:00	43.220553	71.083106
NL 8	12:11	43.218033	71.083640

1.3 Sampling Results

Phosphorus (P) in sediment originates from historic loading and, to a lesser degree, the native soils beneath a lake. The sediment P in samples is split into fractions by sequential lab extractions and is reported in four categories depending on how tightly the P is bound in the sediments and under what conditions P might be released back to the water column. Loosely bound P is the most readily available fraction for uptake by algae. Iron bound P can be released from sediments under low oxygen conditions and be available to algae. Labile organic P is bound in organic matter and is released as the organic matter decays and is then available for uptake by algae. Aluminum bound P is more or less permanently bound to aluminum and generally remains in the sediments regardless of the oxygen status of the overlying water. In addition to aluminum bound P there are other forms of permanently bound P including calcium bound mineral P and organic P that are resistant to bacterial breakdown. These other forms are included in sediment total P but are generally not considered mobile.

Nippo Lake typically experiences anoxia in the summer. As a result of the anoxia, a portion of the loosely bound, iron bound, and, to a lesser extent, labile organic P is released to the water column in the deep layers of the lake (hypolimnion). This P is transported to the epilimnion through diffusion, wind mixing and deepening of the epilimnion where it can be taken up by algae. The amount of sediment derived P released annually is the internal load referenced in Table 1.

Sediment samples collected on July 31, 2018 were stored, shipped and analyzed at University of Wisconsin-Stout according to procedures in the approved QAPP document (NHDES 2018). Results of the analysis are presented in Table 3. Quality control data are presented in Appendix A. All quality control results fell well within the performance criteria (<20% relative percent difference) set in the QAPP (NHDES 2018).

In Nippo Lake sediments, concentrations of loosely bound P are relatively low at all depths (Table 3, Figure 2). Iron bound phosphorus is relatively low at shallow stations and becomes progressively higher at deeper stations. Labile organic P is relatively consistent across stations. Aluminum bound P is also higher at deeper stations than shallow stations. As a result of the uneven distribution of both iron and aluminum bound P with depth, total phosphorus in the sediment is lowest in shallow water and highest in deep water. This is to be expected as sediments tend to redistribute deeper in a lake over time along the slope of the bottom.

Table 3: Sediment Monitoring Results for Nippo Lake, July 31, 2018 (sorted by water depth).

Nippo Lake Sediment Data - July 31, 2018													
	Depth of Sample	Depth of Sample	Moisture content	Solids fraction	LOI	Wet bulk density	Dry bulk density	Loosely-bound P	Iron-bound P	Labile organic P	Aluminum-bound P	Total P	Sum of mobile[2]
	feet	meters	(%)		(%)	(g/cm^3)	(g/cm^3)	(mg/g)	(mg/g)	(mg/g)	(mg/g)	(mg/g)	mg/g or g/kg
NL 1	10	3.048	90.4	0.096	40.0	1.037	0.102	0.017	0.049	0.452	0.237	0.969	0.518
NL 2	20	6.096	91.7	0.083	35.0	1.034	0.087	0.023	0.083	0.515	0.364	1.071	0.621
NL 3 Mean[1]	29	8.839	91.8	0.082	34.2	1.034	0.086	0.027	0.097	0.559	0.386	1.131	0.683
NL 8	31	9.449	91.5	0.085	34.0	1.036	0.089	0.027	0.104	0.504	0.364	1.154	0.635
NL 7	32	9.754	92.2	0.078	36.6	1.031	0.081	0.025	0.131	0.526	0.420	1.225	0.682
NL 6 Mean[1]	38	11.582	91.9	0.081	37.0	1.032	0.085	0.030	0.141	0.524	0.441	1.246	0.696
NL 4	46	14.021	93.3	0.067	36.9	1.027	0.070	0.030	0.174	0.535	0.474	1.328	0.739
NL 5	51	15.545	91.1	0.089	35.0	1.037	0.093	0.035	0.223	0.515	0.655	1.458	0.773

[1]Values are the mean of duplicates and split samples.

[2]Sum of mobile P includes loosely-bound P, iron-bound-P and labile organic P

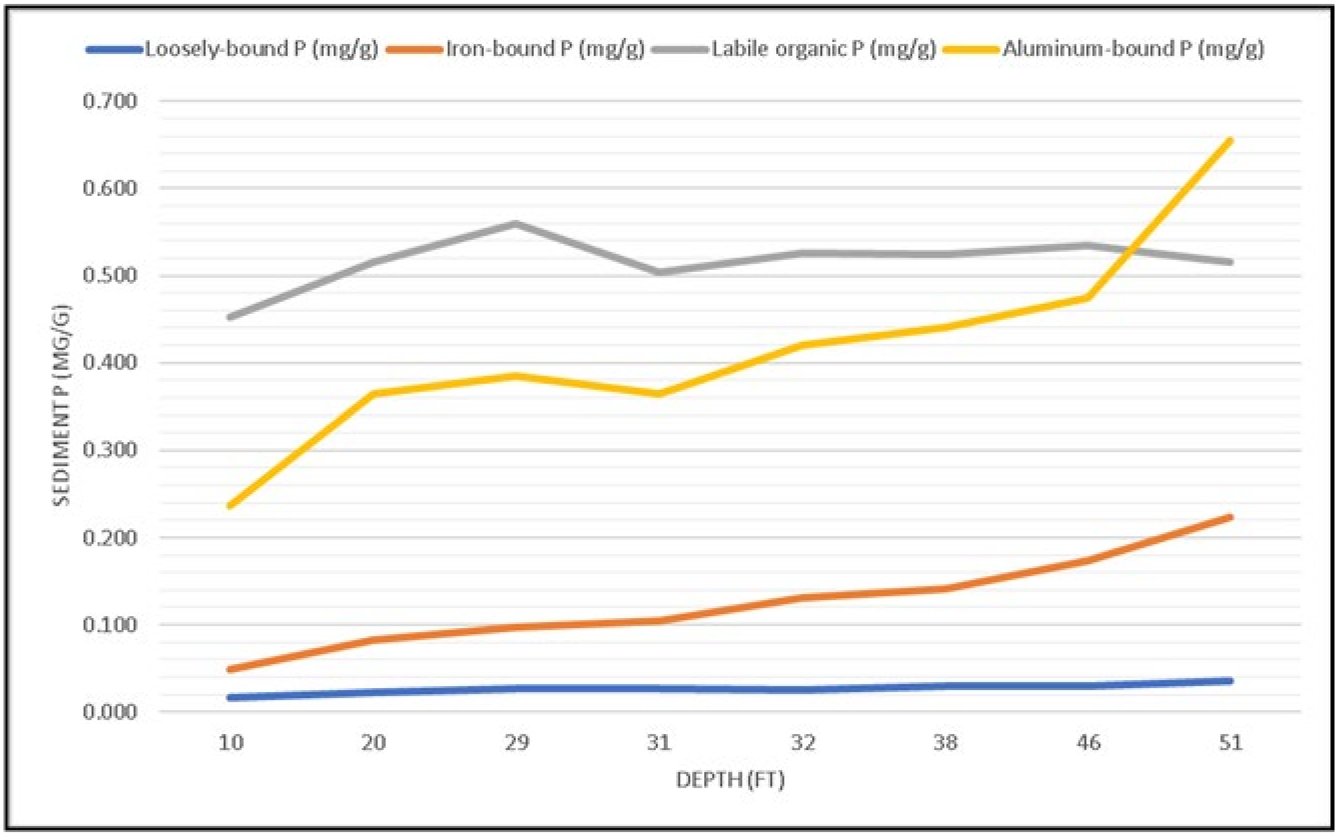

Loosely-bound P (mg/g)
Iron-bound P (mg/g)
Labile organic P (mg/g)
Aluminum-bound P (mg/g)
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
SEDIMENT P (MG/G)
10
20
29
31
32
38
46
51
DEPTH (FT)

Figure 2: Fractions of sediment phosphorus by water depth. Nippo Lake, July 31, 2018.

The results of the sediment testing are translated into an internal P reserve through several assumptions:

1. Over the entire lake, the average available sediment P concentration was 0.152 mg/g for the loosely bound P and iron bound P combined. The average available sediment P concentration including labile organic P over the entire lake is 0.668 mg/g. While the loosely bound P and the iron bound P are the likely major drivers of current internal loading, it is likely that labile organic P also contributes and will continue to do so in the future. Therefore, it may be advantageous to include all three potentially mobile fractions in management strategies. This is a common strategy in lake management in recent years.
2. The depth of sediment participating in P release is 10 cm. This value is usually set at 4 to 10 cm. We have estimated on the high end of the expected range to be sure we represent all of the phosphorus potentially contributing to the internal load.

3. The percent of solid material reflected as 100% minus the percent moisture as measured in the samples.
4. The specific gravity of the sediment, in dry form, was calculated to be 1.39.

The estimated mass of sediment P is presented in Table 4. Based on one year of field work conducted in 2016, anoxia is typically observed below 9 meters in Nippo Lake. The estimate of internal load used in the water quality model (NHDES 2019) was generated by estimating accumulation of phosphorus in the hypolimnetic volume below 9 meters and assuming that 75% of that gross internal load would be available for algal growth by the following growing season or 12.9 kg. The gross internal load estimate was 17.2 kg/yr.

The modeling estimate of internal P loading can be cross checked by evaluating potential release from measured sediment reserves below 9 meters (30 feet). Because the iron bound P and loosely bound P are the most readily available, they are appropriate to use in this assessment. Not all of the 224 kg of available sediment P below 9 meters area will be released in any year. The portion of available sediment P that is released and makes it into the epilimnion where it becomes part of the effective P load to a lake is normally between 10 and 30%, with most values between 10 and 20% (Mattson et al 2004, BEC 1993, ENSR 2001, ENSR 2008, AECOM 2009) particularly among stratified lakes. In shallow lakes, a larger percentage may become available by virtue of mixing, if anoxia is strong enough to allow release, but for stratified systems lower effective releases prevail. Under the circumstances in Nippo Lake it would be reasonable to estimate a low effective release due to the low potential for substantial wind mixing due to the steep watershed and the depth of the lake relative to its size. Using a potential transfer rate of 10% per year equates to an internal load of 22.4 kg/yr, slightly higher than the gross estimate (17.2) made from hypolimnetic accumulation calculation but probably within the range of year to year variability. It is also possible that the entire 10cm of sediment depth does not contribute equally to the internal load resulting in an overestimate of release from the sediment data.

The data suggest that there are considerable available P reserves in areas where the water does not become anoxic, leaving open the possibility that the contributory area is, at times, greater than the area below 9 meters (30 feet). Release of that sediment P is greatly depressed by the presence of oxygen (which keeps P bound to iron and insoluble), so the contribution of the additional areas is likely to be low as long as oxygen is present. A change in the depth of anoxia would change this situation so consideration should be given to treating some areas above 30 feet as a buffer. Likewise, the pool of labile organic P may not be contributing much to the phosphorus release now but may in the future as the organic matter decays. Phosphorus currently bound in organic matter may also bind with aluminum or other inactivation compounds introduced to bind other forms of P so it may be advantageous to include labile organic P as a component of the sediment phosphorus to be inactivated. This will increase treatment costs but may increase the likelihood of acceptable results from a phosphorus inactivation project.

Table 4: Estimated mass of phosphorus in sediments below selected water depths in Nippo Lake, July 31, 2018.

Water Depth (m)	Water Depth (ft)	Area (acres)	Area (hectares)	Loosely Bound P + Iron Bound P in upper 10 cm of sediments (kg)	Loosely Bound P + Iron Bound P + Labile Organic P in upper 10 cm of sediments (kg)
9	30	27	11	224	857
7	23	42	17	326	1314
3	10	65	26	462	2029
0	0	85	35	606	2663

It is generally believed that only the P in the upper 4 to 10 cm of sediment interacts with the water column (Cooke et al. 2005). There can be upward mobilization of P, but studies and field work have indicated that inactivating a mass of P equal to that calculated for the upper 10 cm of sediment is adequate to get maximum reduction in internal loading (Cooke et al 1993, Rydin and Welch 1998, Welch and Cooke 1999).

1.4 Next Steps

The information obtained from the sediment sampling program confirms the presence of sufficient mobile sediment phosphorus to support substantial internal loading in Nippo Lake. It also provides estimates of the mass of phosphorus that would need to be inactivated in order to reduce the internal load. These data can be used to develop appropriate strategies for treatment of the internal load and develop cost estimates for these treatment strategies. The success and longevity of any internal load treatment is highly dependent on the actions currently being undertaken to reduce the external watershed load. It is also dependent on control of future sources of phosphorus from the watershed. The next phase of the watershed planning project addresses these elements and is critical to moving Nippo Lake towards restoration.

2.0 References

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Appendix Table 1. Quality Control Data for Nippo Lake sediment sampling program July 31, 2018.

Quality Control Data, Nippo Lake Sediment - July 31, 2018													
	Duplicates[1]	Split[2]	Moisture content	Solids %	LOI	Wet bulk density	Dry bulk density	Loosely-bound P	Iron-bound P	Labile organic P	Aluminum-bound P	Total P
			(%)		(%)	(g/cm^3)	(g/cm^3)	(mg/g)	(mg/g)	(mg/g)	(mg/g)	(mg/g)
Field Replicate												
NL 3	1	1	91.672	0.083	33.333	1.035	0.087	0.027	0.104	0.526	0.384	1.150
NL 3DUP	1	1	91.932	0.081	35.036	1.033	0.085	0.026	0.090	0.592	0.387	1.113
Relative Percent Difference			0.284	3.123	5.109	0.198	3.300	3.704	13.462	12.548	0.781	3.169
Station 3 Mean			**91.802**	**0.082**	**34.185**	**1.034**	**0.086**	**0.027**	**0.097**	**0.559**	**0.386**	**1.131**
Laboratory Duplicates and Splits												
NL 6-1-1	1	1	91.826	0.082	37.500	1.032	0.086	0.030	0.144	0.510	0.447	1.249
NL 6-1-2	1	2						0.030	0.144	0.538	0.425	1.249
NL 6-2	2	1	91.967	0.080	36.552	1.032	0.084	0.031	0.135	0.525	0.451	1.241
Relative Percent Difference			0.153	1.757	2.594	0.008	1.824	3.226	6.667	5.204	5.765	0.646
Station 6 Mean			**91.896**	**0.081**	**37.026**	**1.032**	**0.085**	**0.030**	**0.141**	**0.524**	**0.441**	**1.246**

[1]Duplicates represent two separate alliquots withdrawn from original sample and analyzed

[2]Splits represent one alliquot withdrawn and split prior to analysis

AUTHORIZATION TO DISCHARGE UNDER
THE NEW HAMPSHIRE STATE SURFACE WATER DISCHARGE PERMIT

In compliance with the provisions of the State of New Hampshire Revised Statues, Title L Water Management and Protection, Chapter 485-A Water Pollution and Waste Disposal,

Nippo Lake Association, Inc., P.O. Box 313, Barrington, NH 03825

is authorized to apply, as a demonstration:

Aluminum

to receiving water named

Nippo Lake in Barrington, New Hampshire

in accordance with effluent limitations, monitoring requirements and other conditions set forth herein.

This permit shall become effective on the date of signature.

This permit extends until the treatment and monitoring requirements specified herein have been satisfied or if the treatment is determined to be harmful to the aquatic life or human health.

Effective Date: May 10, 2021

Expiration Date: May 10, 2026

Signed this 10 of May, 2021.

____
Thomas O'Donovan, P.E.
Director, Water Division
New Hampshire Department of Environmental Services

PART I. PROJECT OVERVIEW

1. Project Description

The project, as permitted below, allows for the application of aluminum to Nippo Lake in Barrington, NH to control the frequency and severity of cyanobacteria blooms. The project serves as demonstration of the use of aluminum for lake restoration purposes in New Hampshire. Aluminum will be introduced by the addition of aluminum sulfate [$Al_2(SO_4)_3$] and sodium aluminate [$NaAlO_2$] from a vessel outfitted with holding tanks, pumps, hoses, and meters for delivery of the chemicals. Chemicals will be added, as permitted below, at a ratio of the volume of aluminum sulfate to sodium aluminate equal to the prescribed dose of aluminum per area. A majority of the aluminum added will precipitate as floc on the lake bottom in the approximate area of application. The aluminum floc will bind with internal phosphorus in the benthic sediments and significantly reduce the amount of phosphorus that is available to fuel cyanobacteria blooms and result in a net benefit for lake condition.

2. Purpose, justification, and benefit

The purpose of the project is to restore the recreational use and ecological health of Nippo Lake. In eight of the ten years from 2010 – 2019, Nippo Lake has experienced cyanobacteria blooms that have interfered with recreation and had ecological impacts for a significant portion of the summer season and stretching into fall. An evaluation of lake conditions and development of a lake loading model identified that 34% of the annual phosphorus load is contributed by lake bottom sediments. Data collected from Nippo Lake documented that at depths below 8 meters there is little to no dissolved oxygen. The condition, known as anoxia, results in the release phosphorus from the sediments into the overlying water which is then available for uptake by cyanobacteria. Data from a typical year in 2016 indicated that concentrations of phosphorus at depths of 13 - 15 meters were between 140 to 180 ug/L while concentrations near the surface were around 10 ug/L.

The goal of the demonstration treatment is to reduce the phosphorus load to Nippo Lake as released from benthic sediments by 80-90% over current conditions in order to meet a target in-lake annual phosphorus concentration of 7.2 ug/L. By reducing the phosphorus load, the risk of cyanobacteria blooms in Nippo Lake will be minimized to the extent possible for a period expected to extend 10 – 20 years, provided additional nutrient sources are controlled. Aluminum application as a demonstration in Nippo Lake was chosen as the best alternative as compared to other internal nutrient management options such as aeration, oxygenation, or dredging for achieving the desired outcome of the project as it best targets the source of nutrients, is proven as a successful additive to control the release of phosphorus from the sediments, and is most cost effective as compared with other options. The demonstration project will improve the overall condition of Nippo Lake by reducing the frequency and extent of cyanobacteria blooms and, in turn, the length of time when the waterbody is a potential risk to human, pet, and livestock health and increasing the length of time it is suitable for recreation. Secondarily, by reducing the dominance of cyanobacteria, a more balanced and adaptive plankton community is expected to proliferate. Lastly, a reduction in nutrient availability is expected to increase water clarity and dissolved oxygen concentrations during the summer months.

PART II. CHEMICAL ADDITIVES AND RECEIVING WATER LIMITS

1. Chemical additives - During the period beginning on the effective date and lasting through the expiration date, the permittee is authorized to apply aluminum sulfate (alum) and sodium aluminate (aluminate) to Nippo Lake in order control the growth of algae in the lake by inactivating iron-bound phosphorus in surficial bottom sediments. The active ingredient in both of these additives is aluminum. The application shall be limited as specified below in Table 1.

Table 1. Limits of chemical addition to Nippo Lake, Barrington, NH.

Chemical Additive	Limit of Application[1]		
	Approximate Ratio of Application[2]	**Maximum Daily Dose[3]** (grams of aluminum / m^2)	**Permit Dose Maximum[4]** (grams of aluminum / m^2)
Aluminum Sulfate, $Al_2(SO_4)_3$; ~4.4% aluminum by volume	1.8 parts aluminum sulfate : 1 part sodium aluminate by volume	27	54
Sodium Aluminate, $NaAlO_2$; ~10.2% aluminum by volume			
pH[5]	None such that the receiving water limits are exceeded.		

2. Receiving water limits - The receiving water is defined as Nippo Lake, Barrington, New Hampshire. Chemical additives, as defined above, shall be added to the receiving water in 3 distinct phases; pilot, application 1 and application 2. Each phase will be broken into daily events that occur in one of five zones. The limits of receiving water quality criteria are specified in Table 2. Attainment of receiving water limitations shall be evaluated as the average of the of the measurements from all zones during the respective application phase. In the case of pH, supplemental measures outside of the zones, as described in the monitoring plan, shall also be included in evaluating the attainment of receiving water limitations.

Table 2. Limit of receiving water criteria in Nippo Lake Barrington, NH.

Receiving Water Characteristics	**Receiving Water Limitation**[6]		
	Daily Event Maximum[7]	**Weekly Average**[8]	**End of Permit Term**[9]
Acid Soluble Aluminum[10], ug/L	750	87	Pre-alum application ambient concentration[11]
Turbidity[12]	10 NTUs above conditions prior to treatment		
pH[13]	6.5 - 8.0 S.U.		

Footnotes:

1. Adherence to the limit of application shall be estimated and reported by the permittee to NHDES based on the known mass of aluminum in the chemical compounds, the percentage of aluminum in the solutions applied, and measured as the volumes of solutions applied.

2. The ratio of alum to aluminate may be adjusted during any application in order to control pH within a target range of 6.0 – 8.0 units within a treatment zone to minimize risks to aquatic life. Adjustments to the ratio of alum to aluminate must be accounted for in the limits of the maximum daily dose and the permit dose maximum.

3. The maximum daily dose applies to the zone planned for treatment during each respective phase.

4. The permit dose maximum applies to areas equal to or greater than 15 feet in depth (approximately 56 acres in total) and represents the cumulative total of daily treatments applied within the zones.

5. Given that the chemical addition permitted herein is temporary in nature and does not represent a continuous discharge of effluent pollutants from a fixed location, the concept of “end of pipe” limits as required in Env-Wq 301.17, is not directly applicable to this permit. The aluminum product sinks through the water column adsorbing phosphorus as it falls and binding with phosphorus in the sediment. The critical point of measure is not an end of pipe but rather the final receiving water outside the application zone during the treatment. Therefore, the end of pipe pH criteria, as defined in Env-Wq 301.17, does not apply, except that the receiving water limits must be met.

6. The receiving water limits are defined as the average of the concentrations or measurements from Nippo Lake.

7. Attainment of the daily event maxima limitation is defined as the average of all samples collected at the end of the treatment day as specified in PART VI. MONITORING.

8. Attainment of the weekly average limitation is defined as the average of all samples collected at the end the day for each phase of treatment ending 7-days after the beginning of each phase of treatment as specified in PART VI. MONITORING. If a treatment phase extends beyond 7-days, the permittee shall contact NHDES to discuss how to address weekly average limitations.

9. The end of permit term limitation shall be the average of samples collected during the last month of sampling in the year in which the treatment occurs as specified in PART VI. MONITORING.

10. Acid soluble aluminum concentration shall be determined using EPA method 200.7 with a laboratory quantitation limit of at least 15 ug/L.

11. Pre-alum application ambient concentration is defined as the pre-alum application ambient sampled concentration, plus 20% of the remaining assimilative capacity for aluminum within the lake.

12. Turbidity shall be estimated using Standard Method 2130 B by way of a suitable field or laboratory meter that measures to the nearest 0.1 NTU.

13. pH shall be estimated using Standard Method 4500-H+B by way of a suitable field or laboratory meter that measures to the nearest 0.01 standard units.

Part III. ADHERENCE TO WATER QUALITY STANDARDS

1. The addition of the aluminum sulfate and sodium aluminate as provided herein shall not cause a violation of the water quality criteria of the receiving water defined in Table 2.

2. The discharge shall be free from substances in kind or quantity that settle to form harmful benthic deposits; float as foam, debris, scum or other visible substances; produce odor, color, taste or turbidity that is not naturally occurring and would render the surface water unsuitable for its designated uses; result in the dominance of nuisance species; or interfere with recreational activities except as occurs for the explicit purpose of this permit.

3. The discharge shall not result in toxic substances or chemical constituents in concentrations or combinations in the receiving water that injure or are inimical to plants, animals, humans or aquatic life; or persist in the environment or accumulate in aquatic organisms to levels that result in harmful concentrations in edible portions of fish, shellfish, other aquatic life, or wildlife that might consume aquatic life.

4. The permittee shall not at any time, either alone or in conjunction with any other person(s), cause directly or indirectly the discharge of any chemicals into receiving waters except chemicals that have been applied in accordance with the permit limits in such a manner as to not lower the applicable class water quality, interfere with the existing uses or designated uses assigned to waters by the legislature, or violate any of the conditions listed in the permit.

5. The permittee shall conduct monitoring in accordance with the conditions specified in the permit (PART VI), using analyses performed in accordance to those prescribed or referred to herein. If the permittee monitors any pollutant more frequently than required by the permit using similar procedures as conditioned in this permit, the results of such monitoring shall be included in the calculation and reporting of the data so long as the additional samples do not bias the results for the purpose of meeting the permit limitations.

6. The chemical additive and receiving water limitations contained in the permit and the classification of waters requirements as provided by RSA 485-A:8 shall be met and maintained at all times. Whenever it is demonstrated that the limitations are not adequate to maintain said classification requirements, the permittee shall be required to cease chemical additions until such time as the classification requirements are met.

7. The department maintains the authority to suspend or revoke this permit at any time following the criteria and procedures set forth in Env-Wq 301.10.

PART IV. UNAUTHORIZED DISCHARGES

1. This permit authorizes the application of aluminum sulfate and sodium aluminate in quantities defined in Table 1 to specific areas of Nippo Lake as a demonstration. Controlled application or release of these chemicals from any other sources or locations into Nippo Lake or its tributaries are not authorized by this permit.

2. The Permittee shall report any noncompliance which may endanger health or the environment including but not limited to receiving water permit limit violations, chemical spills, change of volume or type of pollutant and adverse incident as defined in the permit. Information shall be provided verbally within 24-hours from the time the Permittee becomes aware of the circumstances. A written report shall also be provided within 5-days of the time the Permittee becomes aware of the circumstances. The written report shall contain a description of the noncompliance and its cause; the period of noncompliance, including exact dates and times, and if the noncompliance has not been corrected, the anticipated time it is expected to continue; and steps taken or planned to reduce, eliminate, and prevent reoccurrence of the noncompliance.

PART V. SPECIAL CONDITIONS

1. A mixing zone as defined in Env-Wq 1707.02 is designated as the surface area of Nippo Lake treated on any given day as specified in this permit. Mixing zone water quality criteria must be met at all times within the specified treatment zone on the day(s) of treatment.

2. The permittee shall request termination of the permit when the monitoring specified herein has been completed. NHDES shall respond to the termination request in writing.

3. The permittee is responsible for ensuring that the entity applying the chemicals allowed by this permit controls the amount applied as necessary to meet applicable state water quality criteria standards as defined in PART III of this permit with compliance required upon initiation of the application and ending upon permit termination.

4. If the permittee or the entity applying the chemicals allowed by this permit becomes aware (e.g., through self-monitoring or by notification from the state or third party), or the State determines that the chemicals cause or contribute to an excursion of any applicable water quality standard, the permittee is responsible for ensuring that the entity applying the chemicals takes appropriate corrective action(s) up to and including ceasing the discharge.

5. An Operations and Management Plan must be submitted to NHDES by the permittee prior to the addition of chemicals included in this permit. The Operations and Management Plan shall be reviewed and approved by NHDES prior to application of the chemicals to Nippo Lake. The NHDES approved Operations and Management Plan, along with all supporting maps and documents, must be retained at the address provided in the application for this permit. The Operations and Management Plan and all supporting documents must be readily available, upon request, and copies of any of these documents provided, upon request, to the State, federal, or local agencies governing chemical applications within their respective jurisdictions. The Operations and Management Plan shall contain no less than:

    a) A clear statement that this is a demonstration project.
    b) Details on the access and staging areas including a basic site map.
    c) The method of chemical delivery, transfer, and on-site storage as well as the length of time chemicals will be stored at the site and plans for securing chemicals during storage.
    d) Safety measures for minimizing chemical spillage or leakage and chemical spillage containment measures.
    e) The names and contact information for the persons responsible for chemical management as well as emergency contact information.
    f) Details for cleaning up at the access and chemical transfer points following application.

6. Notice by the permittee of the planned chemical application shall be given to all abutters of Nippo Lake via mail or email at least 3-days prior to treatment. Notice of chemical application shall also be posted every 200 feet along shoreline at least 3-days prior to the chemical application and maintained in place for at least 30 days following the last date of application.

7. The permittee shall provide NHDES a description of the vessel to be used for the application of chemicals including the pumps, hoses, holding tanks, meters, and onboard spillage containment measures along with the vessel's size, engine type and horsepower prior to any application of chemicals to Nippo Lake. The vessel shall track the volumes of each chemical added and the course of application on each given day.

8. Chemical applications shall occur in three phases as follows:

    a) Pilot phase – 10 acres of Nippo Lake in an area >15 feet deep at a rate of 27g of aluminum / m^2.
    b) Phase 1 – 46 acres of Nippo Lake contiguous to the Pilot phase in an area >15 feet deep at a rate of 27g of aluminum / m^2.
    c) Phase 2 – 56 acres of Nippo Lake in an area >15 feet deep at a rate of 27g of aluminum / m^2.

9. The timing and duration of the three phase shall be as follows:
    a) Pilot phase –a one to two-day application duration.
    b) Phase 1 – at least two weeks and not more one month following the Pilot phase with a four to five-day application duration. No more than 12 acres shall be treated on any one day.
    c) Phase 2 – at least two days following Phase 1 and upon evaluation of pH conditions in Nippo Lake as described below with a four to five-day application duration. No more than 15 acres shall be treated on any one day.

10. A change to the timing and duration of the demonstration project authorized by this permit may be requested by the permittee provided good cause is submitted in writing and approved by NHDES. Changes in the timing and duration of the demonstration project must not extend the project initiation beyond the end of May 2022.

11. The permittee shall provide NHDES with a map depicting a minimum of 5 application zones at least 14 days prior to commencing any chemical applications. The application zones shall be labeled: PILOT; ZONE 1; ZONE 2; ZONE 3; ZONE 4. No chemical shall be added by the permittee prior to receiving approval, in writing or email, of the application zones by NHDES. The application zones shall correspond to phases as follows:
    a) PILOT ZONE (~10 acres) – Pilot phase and phase 2.
    b) ZONE 1 (~11.5 acres) – Phase 1 and 2.

c) ZONE 2 (~11.5 acres) – Phase 1 and 2.
d) ZONE 3 (~11.5 acres) – Phase 1 and 2.
e) ZONE 4 (~11.5 acres) – Phase 1 and 2.

12. The permittee is responsible for applying for and securing any additional permits that may be required to carry out this project. The issuance of this permit does not relieve the permittee from obtaining any other permits or approvals required by law.

13. All unauthorized activities on, in, or from the waterbody are prohibited during all periods of chemical application associated with this permit. Further, swimming in and water withdrawal from Nippo Lake are prohibited for 24-hours following each day of chemical addition.

14. Given that waterbody and weather conditions are dynamic, NHDES maintains the authority to require minor changes, where reasonable, in the monitoring requirements described in Part VI. The purpose of any required changes would be limited to those that allow for a better evaluation of compliance with the receiving water limits, minimization of harm to aquatic life, and insurance of public safety.

PART VI. MONITORING

The permittee is responsible for monitoring Nippo Lake prior to, during, and after chemical application as described below.

1. Baseline Monitoring – A single event completed two to three weeks prior to the Pilot Phase at two locations approximately 10-meters deep and one location approximately 14-meters deep. Field measures of temperature and dissolved oxygen concentration and percent saturation shall be collected at 1 meter intervals from the surface to the bottom at both the 10 and 14-meter deep spots. At each site, samples shall be collected at 1/3, 1/2, and 2/3 total depth or, if stratified, the midpoint of the epilimnion, metalimnion, and hypolimnion and analyzed for specific conductance, turbidity, pH, alkalinity, hardness, dissolved organic carbon, acid soluble aluminum, total aluminum, total phosphorus, and chlorophyll a. A Secchi disc transparency estimate shall be collected at each sample location. Zooplankton and phytoplankton samples shall be collected to a depth of 2/3 the total depth at each location. All results, except the plankton sample, must be made available to NHDES for review at least 3 days prior to any application of chemicals.

2. Application Monitoring – During the pilot phase, phase 1, and phase 2 of the chemical treatment, monitoring shall occur approximately 1-hour prior to treatment, mid-treatment, and approximately 1-hour after the daily treatment has occurred. Monitoring 1-hour prior to each treatment shall consist of a dissolved oxygen / temperature profile in 1m increments and a plankton sample, as a vertical haul of 2/3 of

the water column, at one location approximately 14-meters deep on each day of treatment. At two locations approximately 10-meters deep and one location approximately 14-meters deep approximately 1-hour prior each treatment pH and turbidity measures shall be collected at 1/3, 1/2, or 2/3 total depth or the mid-epilimnion, mid-metalimnion, and mid-hypolimnion, if stratified. Additionally, on each day of treatment and during each time period, 10 supplemental pH field measures shall be taken at locations that are between 3 and 4 meters deep around the perimeter of the lake. Supplemental pH field measures shall be collected at a depth of approximately 0.5 meters. During the approximate mid-point of each daily treatment, turbidity and pH samples shall be collected consistent with the monitoring 1-hour prior to treatment. Monitoring 1-hour after on each day of treatment shall include discrete grab samples for specific conductance, pH, turbidity, acid soluble aluminum, and total aluminum at 1/3, 1/2, or 2/3 total depth or the mid-epilimnion, mid-metalimnion, and mid-hypolimnion, if stratified, at the two 10-meter deep locations and the 14-meter deep location. Alkalinity need only be collected at the 14-meter deep location at the same three depths described above 1-hour after treatment. Additionally, on the day of the pilot treatment and the last day of treatment during phase 1 and 2, dissolved organic carbon, hardness, total phosphorus, and chlorophyll *a* shall be sampled at the same locations and depths as the post 1-hour monitoring samples outlined above. At all times during treatment, pH must be continuously monitored and recorded within the active application zone. Continuous observations must be made within and nearby the active application zone for distressed aquatic organisms and chemical application shall immediately cease if any are observed.

3. Post-application Monitoring – After all chemical applications are completed, a weekly monitoring event shall be completed during the first four weeks immediately following the completion of chemical applications, then a monthly monitoring event shall be conducted for the next three months, and three additional sampling events shall be conducted as directed by NHDES within one year of the completion of the chemical application. All post-application monitoring events shall be completed at a single location that is approximately 14-meters deep and include measures of dissolved oxygen and temperature at 1-meter intervals. Grab samples collected at 1/3, 1/2, and 2/3 of total depth or the midpoints of the epilimnion, metalimnion, and hypolimnion if Nippo Lake is stratified and shall be analyzed for pH, turbidity, alkalinity, hardness, dissolved organic carbon, acid soluble aluminum, total aluminum, total phosphorus, chlorophyll a, and turbidity. A Secchi disc transparency estimate shall be collected. Zooplankton and phytoplankton samples shall be collected to a depth of 2/3 the total depth as a vertical haul. A visual survey for dead or distressed aquatic organisms shall be completed during each sampling event completed within the first four months following application.

PART VII. REPORTING AND RECORDKEEPING REQUIREMENTS

1. The permittee shall submit records of the chemicals applied and the following information:

    a) The name, chemical formula, and percent aluminum by volume, and the supplier of the chemicals applied to Nippo Lake.
    b) A daily account of the volume of each chemical applied, combined mass of aluminum per area (dose), location (zone), estimated area, and geo-referenced vessel track of chemical application as well as copies of the field records supporting the daily account.
    c) A map showing the application zones, ranges of dates during which chemicals were applied within each respective zone.
    d) A record of the approximate average ratio by volume of sodium aluminate to aluminum sulfate applied on each application day including periods during the application when the ratio was intentionally modified from the requirements specified in this permit in order to meet the pH range as specified in Table 1, footnote 2.
    e) An electronic record of pH readings taken within the application zone on each respective day chemicals are applied to that application zone during the application.
    f) Notes of any equipment failures or deviations from the Operations and Management Plan as required herein.

2. The permittee shall submit monitoring results as full laboratory results (including Chain of Custody) and all records of data collected in the field electronically, as applicable, no later than 14-days following each monitoring period, except as may be necessary for baseline monitoring, whereby all monitoring results must be made available to NHDES for review at least 7-days prior to initiating any chemical application to Nippo Lake.

3. The permittee shall retain records of all monitoring information, including all calibration and maintenance records, copies of all reports required by this permit, and records of all data required by this permit, for a period of at least 3-years from the date of the last monitoring event.

4. A report that summarizes all components of this project shall be submitted to NHDES for review no more than 18 months after the date of final chemical treatment. NHDES shall be afforded an opportunity to comment and request revision to the report. A final report shall be submitted to NHDES no more than 18 months after the date of final chemical treatment.

5. Submittal of requests and reports to NHDES

    a. The following requests, reports, and information required as a condition of this permit shall be submitted to New Hampshire Department of Environmental Services, Water Division (NHDES-WD):

1) Notification of chemical application at least three (3) days prior to the commencement of the application;
2) Notification of any substantial change (realized or anticipated) in the volume or character of pollutants being introduced into the receiving water;
3) Notification of chemical spills;
4) Notification of spillage or leakage of permitted chemicals and containment or lack of containment as defined in the operations and management plan and changes to safety measures to prevent future incidents;

b. These reports, information, and requests shall be submitted to NHDES-WD electronically at david.neils@des.nh.gov .

6. Verbal Reports and Verbal Notifications

a. Any verbal reports or verbal notifications, if required as a condition of this permit, shall be made to NHDES. This includes verbal reports and notifications which require reporting within 24-hours.

b. Verbal reports and verbal notifications shall be made to:
NHDES Contact: **603-271-8865**

PART VIII. APPEAL, MODIFICATION, AND TRANSFER OF PERMIT

1. Appeal - Any person aggrieved by the decision may file an appeal with the N.H. Water Council (“Council”) that meets the requirements specified in RSA 21-O:14 and the Water Council’s procedural rules Env-WC 100 *et seq*. The appeal must be filed directly with the Council within 30-days of the date of permit issuance.

2. Permit Modification – Modifications to this permit by the permittee shall follow the process and procedures set forth in Env-Wq 301.13

3. Permit transfer - The permit shall not be transferable.

Nippo Lake Alum Treatment OPERATIONS & MANAGEMENT PLAN

1.0 Introduction

SOLitude Lake Management (SLM) has been selected by the Nippo Lake Association to complete a buffered alum treatment to inactivate phosphorus in the surficial sediment of Nippo Lake. Previous studies of the lake served to determine the need and approach for this action, stating significant internal loading of phosphorus supporting nuisance cyanobacteria blooms. The goal of the project, to eliminate this internal loading of phosphorus to the most practical extent possible, was deemed best achieved by conducting a treatment with buffered alum. Specifically, the recommendation was to treat all areas >15 feet, totaling 56 acres, with a dose of 53 g/m^2 of aluminum.

The following sections describe the work plan and individual project elements in more detail.

2.0 General Project Description

The goal of alum treatment is to strip/inactivate the phosphorus in the water column and bottom sediments. This is accomplished by applying an aluminum salt to the pond (aluminum sulfate) which reacts with the water to form an insoluble aluminum hydroxide solid (floc). This floc settles through the water column removing phosphorus and then settles to the bottom forming a "blanket," which effectively inactivates phosphorus in the sediment.

Once applied, the reaction of alum and water (especially soft water lakes) causes the water to become acidic (low pH). To counter this effect, a buffer solution of sodium aluminate is applied along with the alum. Per the project specifications, the volumetric ratio of 1.8 parts alum to 1 part sodium aluminate will be employed. This ratio differs slightly from the typical 2:1 ratio, but previous testing showed the change is needed to maintain stable pH based on ambient water quality in the lake. In any case, pH during the application will be maintained between 6 and 8 SU, with a preferred range of 6.5 - 7.5 SU. The use of sodium aluminate is preferred over other buffer solutions because it also contributes to the aluminum dose. In some cases, based on natural water quality conditions of the lake, the ratio may be adjusted slightly to maintain desirable pH levels. Any adjustments would be instituted immediately upon observation of need based on monitoring results. In our experience, on-site jar tests prior to treatment are often unreliable and may falsely indicate the need for a different application ratio. Water quality shifts of this nature are typically subtle and only slight adjustments to the ratio are needed and can be appropriately done in the field without significant downtime.

2.1 Mobilization and Staging Area Set Up

Launching of the treatment vessel and the staging of operations will occur at the end of Golf Course Way along the north side of the lake.

Due to the limited daily quantities of product needed for this treatment, storage tanks will not be utilized for this project. Instead, the daily amount of products will be delivered in a split tanker and transferred directly to the treatment vessel. SOLitude will coordinate timely delivery and transfer of the aluminum sulfate and sodium aluminate to insure efficient operation of the lake application. All piping and fittings will be appropriate to the materials being transferred, corrosion resistant, with proper joint seals, and free of observable defects. All tanks, pipes, hoses, couplings and connectors for aluminum compounds will meet appropriate standards.

Chemical Delivery & Loading

The chemical products for this treatment will be provided by the Holland Company of North Adams, MA. Liquid Aluminum sulfate (4.4 % aluminum) and liquid sodium aluminate (10.38% aluminum) will be used and specification & SDS sheets are attached. All products are NSF certified and Certificates of Analysis will be provided for all deliveries. Trucks will back down Golf Course Way from Stagecoach Road. One split tanker delivery of alum and sodium aluminate will occur daily for each of the anticipated 9 days of application required.

Chemical from trucks is conveyed to the treatment vessel tanks by lengths of 2" reinforced hose, rated to handle these types of materials. There are shut-off valves at each hose connection and there is an emergency shutoff valve at the tanker. Hoses for each chemical are clearly marked to avoid confusion and misconnection. Since the treatment vessel cannot move all the way to shore given its increased draft after filling, we may need to install up to 30 feet of temporary floating dock out into the lake for accessing and loading the treatment vessel.

2.2 Equipment Specifications

Due to the small quantity of product and the proposed waiting period before starting full scale application, the pilot treatment will be conducted with our 24-foot Carolina Skiff, We have used this smaller setup successfully on multiple projects including the 2020 treatment of Congamond Lake and the 2018 treatment of East Pond in Maine as well as several treatments of smaller waterbodies.

There is concern that the end of the lake near the staging area may be too shallow to allow the launching and effective use of our larger treatment barge (see inset picture) for this project. Further assessment will be conducted, but if use of the barge is not possible, the Phase 1 and 2 treatments will also be conducted with the Carolina Skiff. If used, the barge has rough dimensions of 30 feet long by 10 feet wide. It is powered by twin outboard engines. The barge is extremely stable in the water and maneuvering/ steering is excellent.

Both treatment vessels will be equipped with a fathometer and GPS –based speedometer. These systems enable us to adjust chemical delivery (gal.) versus vessel speed (mph) which will insure even distribution of the alum and sodium aluminate. In-line flowmeters that measure chemical delivery rates are also utilized.

Our treatment barge is equipped with a compartmented, translucent, polyethylene tank with a combined capacity of 2,250 gallons. This tank is also calibrated on the outside, which allows our operators to visually monitor chemical delivery to insure the desired volumetric ratio is met. For the Carolina Skiff, the combined tank capacity is 300 gallons.

Since the two chemicals cannot be tank-mixed prior to application, there are separate pumping systems for each product including individual spray booms and nozzles. Hydraulically driven, centrifugal, pumps are used on the treatment barge and gasoline powered pumps are utilized on the skiff. The boom is mounted off the stern of the barge/skiff so the actual discharge of product will occur subsurface. Along the entire length of both booms, nozzles are evenly spaced at prescribed distance intervals. The nozzles along the two booms are positioned in opposite pairs angled towards one another. With the nozzles evenly dispersing chemical forward of the horizontal boom, excellent floc is formed as the chemicals pass/mix around the boom's turbulent waters. The boom on the alum barge can be lowered to a variable depth, up to 10 feet below the surface while the skiff boom is fixed at approximately 2-feet below the surface.

Support Equipment

SOLitude will provide on-site support equipment throughout the duration of the treatment. This equipment is invaluable for maintaining the treatment vessel/systems and expediting unforeseen mechanical repairs. A reasonable assortment of tools and spare parts for the vessel and chemical delivery system are also stored and maintained on site.

2.3 Treatment Operations

As specified in the RFB, approximately 56 acres of Nippo Lake will be subject to treatment, corresponding to an anoxic zone of >15 feet in depth. Per the RFB, this treatment area has been further broken down into 4 areas and a pilot area. As specified in the RFB, the applied aluminum dose will be 53 g/m^2 and the total quantity of products to be applied at this dose is approximately 22,176 gallons of alum and 12,320 gallons of sodium aluminate.

The treatment area/sectors will be delineated and installed into the GIS system on-board the treatment vessel and the treatment will be guided with an integrated GPS Navigation System. The guidance system screen will show the pond and treatment area/sector boundary with a grid overlay. While assisting the operator in maintaining accurate passes/transects, the system logs the path of the treatment vessel with an accuracy of ± 1 meter. Each and every load of chemical applied is logged and monitored; chemical volumes applied to each sector are pre-determined and checked for accuracy daily.

Based on the dosing and specifications in the RFP, the treatment will progress in a deliberate manner based on the following table. Note: we believe there is an error in the table where the acreages of each area in "Application 1" should be 11.5 acres.

Approximate Treatment area	**Pilot treatment** (May 2021)	**Application 1** (2-3 weeks after Pilot)	**Application 2** (2-3 days after Treatment 1)
Pilot Area (acres)	10		
Day/Area 1 (acres)		12	14
Day/Area 2 (acres)		12	14
Day/Area 3 (acres)		12	14
Day/Area 4 (acres)		12	14

This process will split the dose over two applications of 26.5 g/m2 and allow for no more than 25% of the total treatment area to be subject to treatment in any one day. This process requires more time, but provides a further safeguard against adverse effects to the fish population and meets the requirements of the NH DES permit.

Records will be maintained throughout the treatment and will include 1) hours of application, 2) application rate & quantity of liquid aluminum sulfate and sodium aluminate applied, 3) approximate acreage treated, 4) approximate location (on map) of area treated, 4) summary of chemical deliveries, 5) any environmental or weather conditions that delayed treatment and documentation of any monitoring conducted by the contractor. Actual application paths are recorded with the onboard GPS system and will be used to produce accurate maps of the treatment areas.

Treatment Timing/Duration

It is expected that the application process will take approximately 9 days to complete based on the proposed application phasing in the RFB. While it could be possible to conduct the treatment more quickly, we understand this process is needed to ensure an effective treatment and to limit the potential for any adverse effects as well as provide a level of comfort to the regulators.

2.4 Staffing & Safety

Safety on the job is of paramount importance at SOLitude. Experienced and specially trained staff will be assigned to this project. Our staff has received instruction in the proper and safe handling of the chemicals. Protective eye equipment and clothing is naturally provided for all employees. A spill containment kit is maintained on shore in the unlikely event of leakage during chemical transfer from the tank-truck to the treatment vessel. Experienced biologists/engineers will be conducting all testing and monitoring during the project.

A company Health & Safety Plan and a Spill Response Plan are attached as Appendix A.

With application below the surface, winds and surface currents will have a minimal effect on most of the alum floc, however treatment will cease when sustained winds are greater than 20 mph or if thunder/lightning are present. The SOLitude Crew Leader may also cease operations under any other conditions deemed unsafe.

If any adverse incidents are observed or reported (including fish/wildlife mortality), treatment operations will cease immediately until all parties agree that it is safe to continue operations. Credible adverse incidents will be reported to all regulatory agencies immediately.

All staff will maintain a high level of professionalism at all times. As large alum projects can attract attention, this will be important to avoid negative publicity but more importantly to reflect positively on the project and project partners.

The following staff are anticipated to be involved in the Nippo Lake alum treatment project.

Staff	Contact Information	Responsibilities
Dominic Meringolo, Senior Environmental Engineer / Project Manager	Mobile – 508-373-4526	Project Manager/Senior Applicator
Marc Bellaud, President / Aquatic Biologist	Mobile – 508-954-8577	Oversight, Senior Applicator
Keith Gazaille, District Manager / Aquatic Biologist	Mobile – 508-954-8567	Oversight, Senior Applicator
Kara Sliwoski, Project Manager/Aquatic Biologist	Mobile – 508-523-1024	Applicator
Peter Beisler Scientist/Applicator	Mobile – 774-249-4988	Environmental Scientist, Applicator
Krista Michniewicz, GIS Specialist	Office – 908.798.6959	GIS/GPS Support
Robert Wheaton, Applicator/Operation Manager	Mobile – 508-864-0119	Oversight, Equipment, Applicator
Additional Biologists, field technicians and laborers will be used to assist as required		

2.5 Notifications

At least 3-days prior to the start of the alum application, the Nippo Lake Association will deliver a treatment notice to all abutters via mail or email as well as post such notice every 200-feet along the shoreline. The posted notices will be maintained for at least 30 days following the final day of alum application. The form of the notice will be as follows.

NOTICE

NIPPO LAKE
TREATMENT AND CLOSURE SCHEDULE

The Nippo Lake Association, through its contractor, SOLitude Lake Management, will begin treatment of Nippo Lake on Tuesday, May 25th. SOLitude will be applying a solution of aluminum sulfate and sodium aluminate. Aluminum from the products binds with phosphorous, one of the key nutrients that helps algae to thrive. By making the phosphorous unavailable as a nutrient, algae growth is reduced. This is being done to improve the water quality of Nippo Lake.

The Association asks that the lake not be used, including for boating, swimming, or fishing, on days that treatment is being conducted. The tentative dates of treatment are as follows

Pilot Treatment - May 25th
Phase 1 Treatment - June 7th-10th
Phase 2 Treatment - June 14th-17th

Recreational use of Nippo Lake while being treated may reduce the efficiency of the treatment and may interfere with the treatment process. Regular recreational use of the lake can occur between treatment periods and once the treatment has concluded.

Anyone needing additional information should contact the Nippo Lake Association at 603-315-8026

2.6 Monitoring

We understand that monitoring will be performed by another consultant and SOLitude will work closely with the consultant to review data throughout the project.

2.7 Reporting

At the conclusion of the project, a final written report will be developed that outlines the treatment tasks performed. The report will provide a narrative of the treatment process, GIS-based maps of the treatment areas and daily treatment sectors/tracks as well as logs of the product application rates/volumes and other pertinent treatment data. Photographs will be included. Any deviations from the treatment plan will be noted.

APPENDIX A

Health & Safety PlanSpill Response Plan

HEALTH AND SAFETY PLAN

PREPARED FOR

Nippo Lake Association
Barrington, NH
Nippo Lake Alum Treatment

PREPARED BY

SOLITUDE LAKE MANAGEMENT, LLC
590 Lake Street
Shrewsbury, MA 01545
508-865-1000

Table of Contents

SECTION 1: INTRODUCTION

The goal of this Health and Safety Plan (HASP) is to provide SOLitude Lake Management (SOLITUDE LAKE MANAGEMENT) personnel with proper safety information and precautions that should be followed to insure worker health and safety.

Human exposure to treatment products may occur occupationally, usually involving dermal and inhalation exposure routes. Exposures may occur in workers who refill product containers and/or apply products and in workers involved in post-application activities, such as equipment cleaning. Because of these potential exposures, it is prudent to implement safety procedures and protocols to minimize exposure and protect worker safety. These protocols include training of all applicators in equipment use, safety, and use of Personal Protective Equipment (PPE) in full compliance with all OSHA, PESH, and USEPA regulatory requirements.

SECTION 2: GENERAL INFORMATION

2.1 Personnel

Primary Contacts	*Phone Number*
Project Manager: Dominic Meringolo	(508) 373-4526
District Manager: Rob Meyers	(631) 897-0442
Compliance Manager: Brandon Peoples	(508) 865-1000
Safety Officer: Robert Wheaton	(508) 865-1000

The responsibilities of the aforementioned individuals include, but are not limited to, the following:

- Supervise field staff in the performance of aquatic application activities and ensure compliance with Health and Safety Protocols.
- Ensure that all personnel are qualified and trained according to city, state and federal laws and standards to apply treatment products.
  - Ensure that applicators are Certified Applicators, Certified Technicians or Apprentices, as described by local State Regulations.
  - Ensure that certified applicators carry proof of certification or license on their person and have in their custody a complete label of every product being applied.
  - Ensure that applicators receive continuing education credits required for re-certification.

- Ensure that all staff receive Health and Safety training to minimize potential exposure to treatment products and are thoroughly trained in the correct operation of all equipment.

2.2 Health and Safety Training

2.3.1 Curriculum Development: Training materials will be developed to comply with US Occupational Safety and Health Administration and Local Public Employee Health & Safety regulations and standards:

- To teach staff how to prevent and/or minimize exposure when applying treatment products.

2.2.2 Training. All staff will receive Health and Safety training from SOLITUDE LAKE MANAGEMENT to minimize potential exposure to treatment products, as well as training on the proper use of vehicles and equipment. This training will include:

- Worker Right to Know requirements
- Use of Personal Protective Equipment
- Application protocols and methods
- Spill cleanup procedures
- Equipment clean up protocols
- Potential adverse effects that can occur with exposure to treatment products that may be used for aquatic and terrestrial applications.
- Basic first aid

2.2.3 Daily safety meetings will be held with all staff on site prior to the start of work.

2.3 Personal Protective Equipment. The need for personal protective equipment (PPE) is dependent on the type of treatment products being used. Specific PPE Requirements are printed on product labels.

2.3.1 Life jackets - USCG approved Type 1 Inflatable Personal floatation devices (PFD) will be worn by all staff while on the treatment vessel. A type IV floatation device will also be equipped and readily accessible on the vessel.

2.3.2 Gloves. Elbow length chemical-resistant gloves are required when handling all products. Elbow length gloves protect wrists and prevent products from running down sleeves into gloves. Glove materials should include nitrile, butyl or neoprene as they offer good protection for both dry and liquid products. Cotton or leather gloves should never be used as they absorb and hold product close to skin for long periods of time.

2.3.3 Coveralls. Cloth coveralls and/or Tyvek suits are required to be worn by product applicators at all times during product loading and filling, application and equipment clean up.

2.3.4 Apron. A chemical resistant apron is required when repairing or cleaning spray equipment and when mixing and loading liquid products. Aprons offer excellent protection against spills and splashes of liquid products and can be easily worn over other protective equipment. Nitrile, butyl and neoprene aprons are recommended.

2.3.5 Boots. Unlined chemical resistant boots that cover the ankles. Nitrile and butyl boots are required during loading and filling operations or equipment cleaning.

2.3.6 Eye Protection. Goggles or a face shield are recommended whenever there is the possibility of product getting into eyes and are required when pouring or mixing products. Contact lenses should not be worn during any of these activities.

2.3.7 Respirators. Product labels indicate if a respirator is required.

2.3.7.1 Fit Test. All applicators required to use respirators should be fit-tested for proper fit of respirators and appropriate respirators will be provided to applicators. Respirator should be worn tightly enough to form a seal around the applicator's face. Facial hair must be groomed such that a proper seal between the face and respirator is made.

2.3.7.2 Respirator Cartridges**.** Respirator cartridges designed to filter out products from the air must be used. Having the wrong cartridge may expose the applicator to toxic levels of products. The filter should be checked often and replaced when it becomes dirty or when breathing becomes difficult. If applicator notices a product odor, he/she must first ensure that the respirator has a proper seal. If odor persists, then cartridge must immediately be discarded.

2.4 Other Safety Equipment

2.4.2 Other Safety Equipment will be provided in the event of accidental exposure:

- Standard First Aid Kit
- Emergency Shower
- Emergency eye wash station
- Bottled water with squirt top to flush exposed skin.
- Fire extinguisher
- Flashlight

2.5 Storage. Products shall be stored in a secure but accessible location in accordance with manufacturer's recommendations.

2.6 Loading and Filling Operations**.** Because applicators are most likely to be exposed to products when handling the products during loading and/or filling, it is important that applicators strictly adhere to safety guidelines and protocols.

- Always wear adequate protective clothing and equipment.
- Use chemical resistant gloves, aprons, and coveralls (as appropriate) and eye protection.
- Use respirator with appropriate cartridge when indicated on label or when handling products indoors.
- To prevent spills, close containers after each use
- If accident occurs, attend to it immediately (see below).
- Remove and dispose of any contaminated clothing and wash thoroughly with soap and water.
- A Reportable Occurrence Form must be completed and submitted to Contract Supervisor.

2.7 Product Spill Cleanup

2.7.1 Reportable Spill Defined. Any spill inside a structure of any product of more than one (1) gallon liquid of any combination of product and/or solvent, or dry formulations containing one (1) pound or more of active ingredient or any spill outside a structure of any product containing one (1) pound or more of active ingredient.

2.7.2 Employee Exposure (pre or post spray.) If employee inhales, ingests or is otherwise exposed to significant amounts of product, s/he must immediately contact the Contract Supervisor who will contact 911 for medical assistance.

2.7.3 Employee Exposure (during application.) If exposure occurs during product application, the employee must immediately contact 911 (via cellular phone) for medical assistance. If possible, the employee must then notify the Contract Supervisor. Copy of SDS and label (available on every vehicle) should be presented to emergency personnel and/or physician.

2.7.3.1 Employee exposure procedures include the following:

- If eyes are exposed, employee should gently flush eyes with eyewash as instructed, generally 15 minutes.
- All exposed clothing should be removed and exposed skin should be thoroughly flushed with water; if shower is available, employee should cleanse skin and hair thoroughly with soap and water.
- Thoroughly ventilate area and remove all personnel from area until spill is cleaned.

- A Reportable Occurrence Form must be completed and submitted to Contract Supervisor.

2.7.4 Spill Containment and Clean Up Procedures**.** All spills should be isolated to the smallest possible area. The following procedures are recommended:

2.7.4.1 Spill Containment Supplies

- 100 lbs absorbent material (e.g., vermiculite).
- Absorbent product spill rags
- Absorbent pads, pillows and barriers
- 55-gallon open head drums
- Dustpan
- Shop brush
- Square point handle shovel

2.7.4.2 Small Spills**.** Shut off ignition sources. Small spills that do not contaminate ground water should be managed in house using the following procedures:

- Wear protective clothing indicated on the product label during the entire cleaning process.
- Isolate contaminated area. Keep people away from the spill.
- Soak up the spill. Spread an absorbent material (e.g., vermiculite) over the entire spill.
- Collect contaminated materials and place into labeled heavy-duty hazardous materials bags for disposal.
- Clean area with water and detergent and remove residue with additional absorbent material. Place in labeled hazardous materials bags.
- Decontaminate area using chemical wipes and place wipes in labeled hazardous materials bags.
- Clean up contaminated vehicles and equipment.
- Dispose of all contaminated materials in labeled hazardous materials bags.

2.7.4.3 Major Spills**.** Shut off ignition sources. For major spills or spills that contaminate ground water:

- Contact 911 to notify Hazmat Unit.
- Contact SOLITUDE LAKE MANAGEMENT President or Safety Officer at (508)865-1000.
- Wear protective clothing indicated on the product label.
- Isolate contaminated area—keep people away.
- Use caution to isolate and/or soak up the spill.
- Wait for Hazmat Unit to arrive.

2.8 Equipment/Vehicle Cleaning

2.8.1 Clean Up Materials.

- Chemical wipes
- Hazardous materials bags with labels
- Water hose
- Liquid detergent
- Bucket
- Brush with long handle

2.8.2 Clean Up Protocol.

- Chemical wipes will be provided for the cleanup of aprons, boots, goggles, and respirators.
- Contaminated clothes should be placed in sealed plastic bags for washing; all contaminated clothing should be washed and properly laundered, dried and stored at the end of each day.
- Equipment Clean Up:
    - Wear appropriate personal protective equipment, such as Tyvek coveralls, chemical resistant gloves, etc.
    - The exterior of the spray equipment should be wiped down with a chemical wipe and disposed on in labeled hazardous waste bags.
    - Chemical resistant gloves (nitrile, butyl, or neoprene) must be worn during equipment wipe down.
- Personnel Clean Up:
    - Personnel are requested to wash hands and other parts of the skin that may have been exposed to products during application or equipment clean up. To facilitate this clean up, sinks will be provided for all personnel involved in application.
    - Emergency showers and eye wash equipment will be provided near the loading area in the event of accidental exposure.
    - Tyvek coveralls should be removed and discarded in hazardous materials bags. All work clothing should be removed prior to ending the work day.

2.9 Disposal. Empty noncombustible product container should be returned to manufacturer, whenever possible. If this is not possible, containers must be cleaned before disposal, using the triple-rinse technique or other methods approved by local agencies. The triple rinse technique is as follows:

- Fill container one quarter full with proper diluent.
- Plug opening of the container.
- Rotate container, making sure to rinse all surfaces.
- Turn container upside down.
- Allow rinse to drain.
- Repeat procedure twice more.

- Puncture top and bottom of container to prevent reuse
- Crush container, if possible.
- Deposit container in licensed sanitary landfill or recycling facility.

2.10 Biological Hazards

2.10.1 General: In addition to the hazards described in this document, product applicators may encounter biological hazards that include endemic hazards such as animals, insects, and poisonous plants. An integral part of protection against these types of hazards is understanding the local flora and fauna. As these species vary from site to site, so does their likelihood of causing a harmful or hazardous condition.

2.10.2 Animals: Animals represent hazards because of their poisons or venoms, size and aggressiveness, diseases transmitted and/or the insects (vectors) that they may carry. Encounters with poisonous snakes, common in some areas of the United States, may be caused by moving containers, reaching into holes, or walking through high grass, swampy areas or rocks. A snake bite warrants medical attention after administration of proper first aid procedures. Rabies is a viral infection most often transmitted by bites of animals infected with the virus. These animals include dogs, bats, skunks, foxes and raccoons, but any warm blooded animal can become infected. Examples of rapid signs include observing a raccoon in the daytime, a live bat on the ground or any other unusual, aggressive, or passive behavior. Employees should make every effort to avoid contact with any animals while in the field. Spray vehicles (trucks and ATVs) should be maneuvered away from any potential contact and the Contract Supervisor notified immediately. In the unlikely event the employee is bitten or scratched by an animal in the field, the employee must immediately contact 911 for medical assistance. The location and description of the animal should be retained and reported to the Contract Supervisor and physician.

2.10.3 Other Insects: Other than the vector potential of mosquitoes transmitting West Nile virus, St. Louis Encephalitis virus or other mosquito-borne viruses; another vector-borne disease in some areas is Lyme Disease, which is a bacterial infection transmitted by the bite of a tick. Prevention and protection techniques include wearing of light colored, tight knit clothing, long pants, long sleeved shirts, tucking pant legs into shoes or boots, wearing a hat, using insect repellents and checking oneself daily for ticks after being in grassy, wooded areas.

2.10.4 Poisonous Plants: Workers should know how to identify and avoid direct contact with poisonous plants such as poison ivy, poison oak and poison sumac. The usual effect is dermatitis or skin inflammation. Preventive and protective measures are similar as those for Lyme Disease. Risk can be reduced by cleaning the skin thoroughly with soap and water after individuals either come into contact with such plants or suspect that they have contacted these plants.

2.11 Heat Stress

2.11.1 General: Heat stress may occur when work is performed at high temperatures or in high humidity and may resemble the symptoms of product exposure. The Contract Supervisor will monitor employees for signs of heat stress. In addition, field personnel should take care to note signs of heat stress in themselves as well as in fellow employees. To make this possible, each individual must be able to recognize the symptoms of heat stress, and to know how best to prevent such stress from occurring.

2.11.2 Heat Exhaustion

- What happens to the body: headaches, dizziness/light-headedness, weakness, mood changes (irritable or confused/can’t think straight), feeling sick to your stomach, vomiting, decreased and dark colored urine, fainting and pale clammy skin.

- What should be done:
    - Move the person to a cool shaded area to rest. Don’t leave the person alone. If the person is dizzy or light headed, lay them on their back and raise their legs about 6-8 inches. If the person is sick to their stomach lay them on their side.
    - Loosen and remove any heavy clothing.
    - Have the person drink some cool water (a small cup every 15 minutes) if they are not feeling sick to their stomach.
    - Try to cool the person by fanning them. Cool the skin with a cool spray mist of water or wet cloth.
    - Contact 911 (via cellular phone) for medical assistance.

2.11.3 Heat Stroke

- What happens to the body: dry pale skin (no sweating), hot red skin (looks like a sunburn), mood changes (irritable, confused/ not making any sense), seizures, collapse/ passed out (will not respond.)

- What should be done:
    - Contact 911 (via cellular phone) for medical assistance. Notify Contract Supervisor.

- Move the person to a cool shaded area. Don't leave the person alone. Lay them on their back and if the person is having seizures/ fits remove any objects close to them so they won't strike against them. If the person is sick to their stomach lay them on their side.
- Remove any heavy and outer clothing.
- Have the person drink some cool water (a small cup every 15 minutes) if they are alert enough to drink anything and not feeling sick to their stomach.
- Try to cool the person by fanning them. Cool the skin with a cool spray mist of water or wet cloth.
- If ice is available, place ice packs under the arm pits and groin area.

2.11.4 Heat Stress Prevention: To prevent heat stress from occurring, workers should hydrate themselves before the workday begins. Fluid intake should be increased to equal the amount to sweat produced (water is the best choice and should be served cool but not cold (i.e., approximately 50-60 degrees Fahrenheit). Utilizing the coolest part of the day (i.e., evening and nighttime working hours) should alleviate the risk of heat stress.

2.12 Lightning: Under no circumstances should product applicators work in the immediate vicinity of thunderstorms. Crews should seek shelter immediately. Standing under a tree in a thunderstorm increases the danger since trees do not constitute shelter; in fact standing under a tree during a thunderstorm will greatly increase the danger of being struck by lightning. If absolutely no shelter is available, workers should seek out a low spot in the topography and remaining as low to the ground as possible.

2.13 Notification of an Accident

Upon observing or being made aware of an Accident, the following information will be immediately noted and reported:

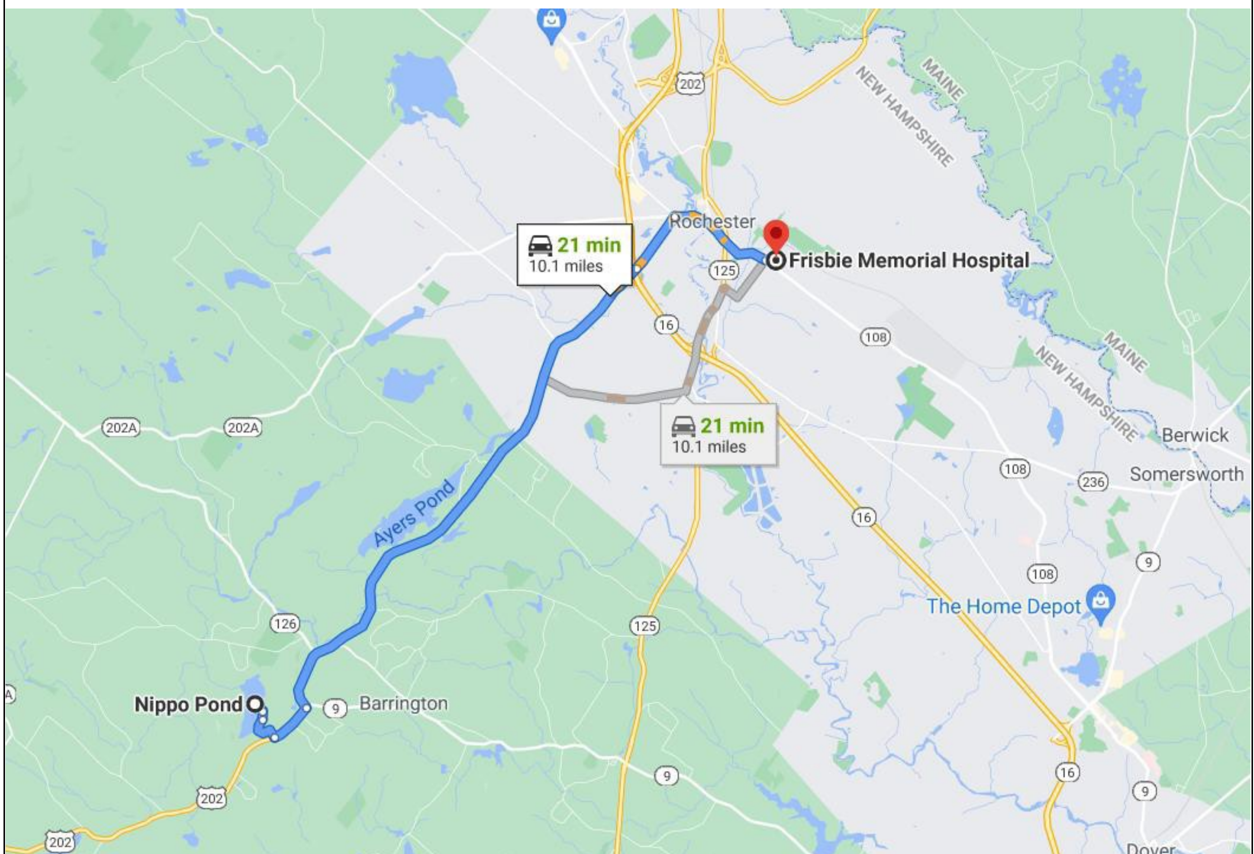
- The caller's name and telephone number.
- The name and telephone number of a contact person.
- How and when you became aware of the Accident.
- Description of the Accident identified and the location.
- Description of any steps taken or to be taken to remedy or otherwise address any adverse effects.

Accident Contact List:

1. Internal Decision-maker:

Company or Organization Name: SOLitude Lake Management, LLC Name: Rob Meyer, District Manager & Brandon Peoples, Asset and Compliance Manager
Address: 590 Lake Street
City, State, Zip Code: Shrewsbury, MA 01545
Telephone Number: 508-865-1000
Email address: rob.meyer@solitudelake.com; bpeoples@solitudelake.com
Fax number: 508-865-1220
2. Permitting Agency:
Company or Organization Name: New Hampshire Department of Environmental Services
Address: 29 Hazen Drive
City, State, Zip Code: Concord, NH 03302
Telephone Number: (603) 271-8865
3. Primary Contractor:
Company or Organization Name: SOLitude Lake Management
Name: Dominic Meringolo, Project Manager
Address: 590 Lake Street
City, State, Zip Code: Shrewsbury, MA 01545
Telephone Number: 508-373-4526
2.14 Emergency Medical Facility
Company or Organization Name: Frisbie Memorial Hospital Name:
Address: 11 Whitehall Rd
City, State, Zip Code: Rochester, NH 03867
Telephone Number: (603) 332-5211

Directions:


21 min
10.1 miles
Rochester
Frisbie Memorial Hospital
21 min
10.1 miles
Ayers Pond
Nippo Pond
Barrington
NEW HAMPSHIRE
MAINE
Berwick
Somersworth
The Home Depot
Dover

SECTION 3: SIGNATURE REQUIREMENTS

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the application of products, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Name:	Dominic Meringolo	Title:	Project Manager, SOLitude Lake Management
Signature:	Dominic Meringolo	Date:	05/11/2021

APPENDIX A – ACTIVITY HAZARDS ANALYSIS

Nippo Lake Alum Treatment
Spill Prevention and Response Plan

Name of Applicator: **SOLitude Lake Management**

Address **Nippo Lake (Barrington, NH) – Golf Course Way Staging Area**

Facility Phone (508) 373-4526 (Dominic Meringolo, Project Manager's Mobile Phone #)

Types of Work or Hazardous Substances Used:

Liquid Aluminum Sulfate
Liquid Sodium Aluminate

Spill Prevention

- Ensure all hazardous substances are properly labeled.
- Store, dispense, and/or use hazardous substances in a way that prevents releases.
- Provide secondary containment when storing hazardous substances in bulk quantities (~55 g).
- Maintain good housekeeping practices for all chemical materials at the facility.
- Routine/Daily checks in the hazardous substance storage area to be performed by Project Manager and documented using the inspection form in Appendix A.

Extreme care will be taken to avoid spills during transfer of treatment chemicals into and from the storage tanks to the tanks on the application vessel, from fuels, or hydraulic oils in the staging area or in the pond itself. Aluminum sulfate is acidic and sodium aluminate is caustic but the two compounds are not mixed together before injection at depth into the pond. They are kept isolated from each other at the staging area and will be transferred from storage tanks or tanker to separate on-board containers by two-inch reinforced hoses, rated to handle these materials.

Spill Containment

The general spill response procedure at this facility is to stop the source of the spill, contain any spilled material and clean up the spill in a timely manner to prevent accidental injury or other damage.
Small spills will be contained by site personnel if they are able to do so without risking injury. Spill kits will be kept on site. The type of absorbent material will be dependent on which product is spilled. If both are spilled, standard "speedy-dry" absorbent will be used. Both products neutralize each other and no further action is needed. Absorbent will be kept on site for leaks or minor spills. If the spill is just alum, crushed limestone will be used. If the spill is just sodium aluminate, vinegar will be used to neutralize the base and speedy dry will be used to absorb liquids. Any spills will be documented on the Spill Log (Appendix B)

Nippo Lake Alum Treatment
Spill Prevention and Response Plan

Emergency Procedures:

- Immediately call **911** in the event of injury, fire or potential fire, or spill of a hazardous substance that gives rise to an emergency situation.
- If a spill has occurred, contact the following persons immediately:

Dominic Meringolo	(Primary)	(508) 373-4526
Kevin Fitzgerald	(Secondary)	(603) 315-8026

- **In the event of a large spill, a properly trained employee should**:
  - Assess the area for any immediate dangers to health or safety. If any dangers are present, move away from the area, **call 911**.
  - Notify the primary and/or secondary contact from the list above and then continue your spill response. The primary contact should assess additional notification requirements.
  - Retrieve the spill kit from the closest location.
  - Assess the size of the leak and any immediate threat of the spill reaching sensitive resources. If there is an immediate threat and there are no safety concerns, then attempt to block the spill from coming in contact with the sensitive resources.
  - If the spill can be contained with absorbent booms, deploy them around the spill. Use the booms to direct the spill away from any immediate hazards or sensitive resource areas.
  - If there is no immediate threat to sensitive resource areas, or after controlling the spill, try to plug or stop the leak, if possible. If applicable, put on protective gear (gloves, goggles, protective clothing, etc.) and plug the leak.

Spill Reporting

If a hazardous substance spill exceeds 25 gallons or if any amount has been released to soil, surface water, or storm drains, notify the following agencies:

National Response Center (NRC)	(800) 424-8802
NH DES Spill Response	(603) 271-3899
Town of Barrington Fire Department	(603) 664-2241

Nippo Lake Alum Treatment
Spill Prevention and Response Plan

Plan Management

The primary contact or designee shall administer this plan and will be responsible for updating and including any required documentation.

Training

All personnel who may respond to any spill, need to be trained on the contents and procedures in this plan. Trained personnel will add their names and dates of training to the Training Log (see Appendix C). Only persons trained on this plan shall respond to a spill. If you are not trained and witness a spill, call or notify the primary and secondary contacts listed on Page 2 of this plan.

Appendix A - Inspection Form

Acceptable Unacceptable

❒ ❒ **Tanks, Fitting, Valves, Labels?**
Are all tanks, fitting, valves secure and in proper working order? Are tools available to adjust or repair serviceable elements of the application equipment in the event of a malfunction? Do all the containers still have labels?

❒ ❒ **Evidence of Spills?**
Is there any indication that a spill might have occurred? If so, was the spill properly cleaned up? Was there any spill kit materials used? Was the Spill Log filled out for that incident? Any housekeeping issues?

❒ ❒ **Spill Kit Complete?**
Have any items been used from the spill kit? If items are missing, is there an associated entry in the Spill Log? Are there any items missing that are currently on order? Is the spill kit stored where it is supposed to be stored? Is there a sufficient supply of daily cleanup materials?

❒ ❒ **Items Fixed?**
Have all deficiencies previously noted been fixed or made acceptable?

List any issues, deficiencies, or failures in detail:

Appendix B – Spill Log

Date of Spill	Location of Spill	Size of Spill (~ gal)	Prevention Measures Taken?	Spill Kit Materials Reordered ?	Was the Spill Kit Adequate? (List any deficiencies, i.e. missing equipment, etc.)

Appendix C – Training Log

Employee's Printed Name	Signature	Date Completed

ACTIVITY HAZARD ANALYSIS

Activity: *Application of Alum at Nippo Lake*	**Date:** May 11, 2021
	Project: Application of Alum to Nippo Lake
Description of the work: This project involves equipment mobilization/demobilization and application of aluminum sulfate and sodium aluminate to a portion of Nippo Lake	**Site Supervisor:** DOMINIC MERINGOLO **Site Safety Officer: SAME** **Review for latest use:** **Before the job is performed.**

Section 1

Work Activity Sequence **(Identify the principal steps involved and the sequence of work activities)**	**Potential Health and Safety Hazards** **(Analyze each principal step for potential hazards)**	**Hazard Controls** **(Develop specific controls for each potential hazard)**
Equipment Mobilization/Demobilization	1) Slipping/Falling hazard while assembling and working on treatment vessel. 2) Injury hazard from falling components 3) Backing trailer/barge or skiff into water	1) Safety meeting and hazard communication to promote awareness, use of proper footwear. 2) Awareness, signaling while hoisting and moving components. 3) Spotters will be used to guide the driver backing into the lake along the pave boat ramp. Spotters will also watch for potential hazards and keep other people out of the way. 4) Minimum PPE while working on equipment mobilization and launching will consist of steel-toed boots
Pilot and Full Scale Treatment	1) Exposure from loading and applying alum and sodium aluminate 2) Spill hazard while transferring chemical from tank truck to treatment vessel 3) Slipping/falling hazard while working on the treatment vessel on the lake. 4) Drowning hazard while on-board the treatment vessel.	1) Safety meeting and hazard communication on proper handling of chemicals and proper safety equipment including eyewear and gloves. Minimum PPE when handling alum/sodium aluminate will be safety glasses & chemical resistant gloves. 2) Briefing on chemical transfer protocol. Chemical will be transferred by pump through 2” flexible hose rated for products. Adequate spill material on-site, smal containment berm around transfer point, multiple shut-off valves and frequent checking of hose fittings and connections. Appropriate tools for adjusting application operations or responding to leaks and spills will be onboard the application boat. See Work Plan for additional details. 3) Staging area for chemical transfer will be posted with warning signs and yellow caution tape.

		4) Safety meeting and hazard communication to promote awareness proper footwear. 5) Personal floatation devices.
2. Review emergency procedures	1) Delays/Inadequate response to emergency situations	Review HSP.
3. Mobilizing boat(s) (and demobilizing)	1) Drowning, man overboard, vessel sinking, collision 2) Muscle strain (particularly, but not limited to) back and neck. 3) Slips, trips, and falls	All personnel will wear USCG-approved life jackets (PFDs) Type II or work vests that are inspected daily before and after each use for wear and buoyancy. Defective equipment will not be used. A throwable ring buoy with a minimum of 90 feet of rope will be within 200 feet of boat crew at all times to be thrown to man overboard or to float with in case of vessel sinking. Audible and visual signals will be readily available on the boat. At least one operational air horn or loud sound signaling device will be onboard. Visual distress signals shall be onboard such as flares,,distress flag, distress light. Proper lifting procedures will be used when lifting sample material or sampling equipment. Lifting of heavy loads will be alternated among field crew members to allow for muscle rest. Whenever possible, the lifting and moving of heavy loads by a single person will be avoided. Safe means of boarding or leaving the boat will be established to prevent slipping and falling. Look before disembarking and hold onto something sturdy to steady yourself when boarding or disembarking vessels. Watch carefully as you move around on the dock or in the vessel Controls include the use of proper footwear; avoidance of high hazard areas, securing of loose equipment and supplies; immediate cleanup of spilled materials; work on level ground; etc. Personnel should not run on-site.

	4) Head injuries	An OSHA-approved hardhat will be donned whenever there is an overhead hazard. In the event of a head injury, emergency procedures as outlined in the SSHP will be followed. Emergency contact information and a map to the hospital are included in the SSHP and will accompany the field crew at all times.
	5) Crushed and pinched fingers, hands, and toes	If necessary, work gloves and steel-toed boots will be worn by the field crew. In addition, a first aid kit will accompany the field crew.
	6) Catching or snagging of fingers, loose clothing, straps, etc. by field sampling equipment	Excessively loose clothing will be avoided by the field crew. Any loose straps associated with clothing or PPE will be secured or tucked in.
	7) Fire on boat	An easily accessible fire extinguisher will be on the boat. Personnel will be familiar with the use of the extinguisher and how to summon for emergency assistance.
	8) Inclement Weather	Any “observable” lightning or thunder – stop work and return to shore. Team leader must monitor appropriate sources to track developing potential for lightning, high winds, tornados, etc. Tornado warnings in the general area will require work to stop and return to shore.
4. Boat use	See above	Complete the Boating Self-Assessment Checklist prior to commencing with sampling activities
	2) Struck-by hazard, run into equipment or debris	All operations will be directed by a USCG qualified, licensed and experienced Captain as the team leader. All vessels will be properly licensed and identified in accordance with MA state or other regional or government regulations. Captain has full authority for the boat and safety of crew on the boat and response to environmental conditions. If captain deems conditions are unsafe, he/she has full authority to postpone or cease operations. Aware of proper boat operation (right-of-ways), drive defensively, keep wide berth from other boats/equipment, Bow man watch out for floating debris, etc. Observe and comply with safety markers
	3) Fire from sparks from engine	Boat must be operated in accordance with U.S. Coast Guard regulations for: speed, lighting, right-of-way, etc. All gasoline engines, except outboards, installed in the vessels must have an approved backfire flame arrestor fitted to the carburetor.
	4) Vessel operation in inclement weather or at night.	Work will not take place in inclement weather (determined by Captain) or at night. In conditions of low or limited visibility vessels shall be equipped with proper lighting (both navigation and anchor).
	5) Refueling of sampling equipment	Engine will be shut off and there will be no smoking when refueling equipment.

	6) Rope entanglement 7) Low water temperature 8) Refueling – fire 9) Biological Hazards 10) Heat Stress	When sampling using a rope the engine shall be in neutral or shut off so as not to get rope tangled in the propeller. Rope loose on the deck shall be kept to a minimum and shall not be looped or wrapped around any part of sampling personnel. If water temperature drops below 40 degrees F, cold water survival suits shall be worn. Allow equipment to cool a bit before refueling. If ticks are a hazard in the area, wear light colored long sleeved shirt at pants, tuck pant legs into socks, check for ticks at least daily, Use insect repellant Follow the heat stress precautions in the HSP. In general: Wear sun screen and hydrate properly Read and follow heat stress precautions specified in the HSP. Be familiar with signs and symptoms of heat stress. Acclimatize to hot weather work Be conscious of your individual tolerance to work in hot weather and monitor yourself and co-workers for signs and symptoms of heat stress Take breaks as necessary in shady or cool areas and drink plenty of liquids
5. Protection of wetlands, endangered species.	Damage to wetlands and disturbance of endangered species activities.	Be aware when working around marshy areas and cause as little disturbance as possible. Be aware of all wildlife, in particular, endangered species, if possible. Be careful with all activities whether sampling, traveling, or refueling (avoid spillage).

Section 2

Equipment to be used (List equipment to be used in the work activity)	Inspection Requirements (List inspection requirements for the work activity)	Training Requirements (List training requirements including hazard communication)
Treatment Vessel	Barge/skiff integrity is inspected prior to mobilization and periodically while on site. All systems are checked prior to mobilization.	Hazard communication during pre-treatment safety meeting and again with any new crew members added to the program.
Chemical Tanks, Hosing, Pumps and Valves	All fittings, hoses, valves, etc. are inspected regularly and tightened/replaced/repaired as necessary.	Hazard communication during pre-treatment safety meeting and again with any new crew members added to the program.
Support Boats (12 & 16-foot) Jon Boats with outboard motors	All trailers are inspected per MA procedures. Boats are visually checked for leaks and integrity of the hull.	Hazard communication during pre-treatment safety meeting and again with any new crew members added to the program.

Holland Company
LIQUID ALUMINUM SULFATE

Aluminum Sulfate Hydrate – Basic

Safety Data Sheet

SECTION 1. PRODUCT AND COMPANY IDENTIFICATION

Product Identifier
Product Name: Liquid Aluminum Sulfate Hydrate (Basic)
Other means of Identification: SDS ID Liquid Aluminum Sulfate
Recommended use of chemical and restrictions on use: Water treatment and industrial applications

Company Information:
Holland Company, Inc.
153 Howland Avenue
Adams, MA 01220 U.S.A.
Phone: 413-743-1292

Emergency Phone:

Holland Company	1-800-639-9602
Chemtrac (USA)	1-800-424-9300
CANTUTEC (Canada)	1-613-996-6666

SECTION 2. HAZARDS IDENTIFICATION

WARNING
IRRITANT AVOID CONTACT

WARNING
MAY BE CORROSIVE TO SOME METALS

Hazard Statements
Irritating to eyes. Category 2
Skin contact may result in mild irritation.
Do not ingest May be harmful if swallowed. Category 5
May be corrosive to some metals. Category 1

Precautionary Statements
Avoid direct contact.
Use protective equipment if direct contact is possible.
Wash hands and any exposed skin thoroughly after contact.
Store and transfer using equipment of appropriate corrosion resistant materials of construction.

SECTION 3. COMPOSITION / INFORMATION ON INGREDIENTS

Substance
Chemical name: Aluminum Sulfate (liquid)
Name: Liquid Aluminum Sulfate Hydrate - Basic
CAS#: 17927-65-0
Impurities: NA. No impurities or additives which are themselves classified and which contribute to the classification of this substance.

SECTION 4. FIRST AID MEASURES

Eye contact: Acute irritation.
Immediately rinse eyes with water for an extended period.
If irritation persists, get medical attention.

Skin contact: Possible acute irritation.
Remove contaminated clothing - footwear and wash skin with water.
If irritation develops get medical attention.

Ingestion: Possible acute discomfort.
In case of ingestion. Drink large amounts of water. Do not induce vomiting.
Get immediate medical advice.

Inhalation of mist: Possible acute irritation.
Remove from continued exposure.
If irritation or breathing difficulty occurs get immediate medical attention.

Most important symptoms/effects:
Serious eye irritation. Irritation to gastrointestinal tract.

Indication of immediate attention and special treatment needed:
If after direct contact, you feel unwell seek medical advice. Notes to physician treat symptomatically.

SECTION 5. FIRE FIGHTING MEASURES

Suitable extinguishing media:
Product is not flammable and will not burn. Use water to cool and maintain integrity of containers.

Unsuitable extinguishing media:
None identified.

Specific hazards from chemical:
Negligible fire hazard.
Hazardous combustion products from a fire may be oxides of sulfur.

Protective equipment:
As in any fire, appropriate firefighting protective gear and self-contained breathing apparatus (MSHA/NIOSH approved or equivalent) should be used.

SECTION 6. ACCIDENTIAL RELEASE MEASURES

General:
Site specific procedures to address accidental spills are necessary as dictated by facility design, location, staffing, containment structures, and regulatory requirements.

Personal protection, protective equipment, and emergency services:
In the event of a spill clear unnecessary staff from spill area, isolate area and restrict entry.
Avoid eye and skin contact with spilled material. If direct contact with spilled material is likely use protective equipment to prevent contact with eyes and skin. Do not release into sewers or waterways.

Methods and materials for containment and clean up:
Prevent further leakage or spillage if safe to do so. Manage spilled liquid using containment structures or inert materials to collect for reuse. Product not reused can be neutralized and converted to aluminum hydroxide using a mild alkali such as soda ash, or calcium carbonate (agricultural lime). Neutralized residue can be swept up or rinsed down with water and captured using absorbent materials for disposal in accordance with local, state, province, and federal regulations.

Caution: When neutralizing large spills CO_2 will be created and can be a breathing hazard.
Take steps to provide adequate ventilation.

SECTION 7. HANDLING AND STORAGE

Incompatible Chemicals and Materials:
Avoid contact with sodium hypochlorite (bleach), chlorites, sulfites, strong bases, aqua ammonia.
Avoid contact with common metals which may result in corrosion over time.

Containment:
Storage tanks should have a dedicated liquid tight secondary containment system to minimize the possibility of a release into the environment and to prevent contact with incompatible chemicals.

General hygiene:
Do not eat, drink, take medication or smoke when direct contact is possible.
Always thoroughly wash hands after leaving a work area where contact is possible or has occurred.

Storage and transfer:
Store in covered containers in a secure location. To minimize the possibility of a release into the environment or contact with incompatible materials, storage tanks should have a dedicated liquid tight secondary containment system. Have storage tanks, containers, and transfer systems properly labeled for contents. Annually empty storage tanks to inspect and clean. Perform regular maintenance cleaning of the transfer system. For accepting deliveries have procedures for determining product quantity in storage tanks. Use tanks, containers, and transfer systems, pumps, valves, and process control instrumentation of appropriate materials of construction. Some materials commonly used are FRP, PVC, CPVC, Teflon®, and stainless steel. Over time, common metals such as steel, iron, copper, and aluminum may experience corrosion and their use should be avoided.

Temperature for storage:
Preferred storage temperature range is 5˚C-38˚C (40˚F-100˚F).
Outside of these temperature ranges product handling and shelf life may be affected.

Ventilation:
No special requirements.

Personal protection:
If direct contact with material is likely use appropriate protective equipment.

SECTION 8. EXPOSURE CONTROL / PERSONNAL PROTECTION

Exposure guidelines:
No exposure limits noted for this substance.

Appropriate engineering controls:
Eyewash stations. Showers. Local passive ventilation is typically used. Under normal conditions respiratory protective equipment is not needed.

Individual protection measures, such as personal protective equipment:
Wear appropriate protective googles or protect eyeglasses. Wear clothing that will prevent skin contact. Seek professional advice when selecting respiratory protection equipment.
Wash any contaminated clothes before reusing. Do not eat, drink, take medication, apply cosmetics, or smoke where direct contact is possible. Always thoroughly wash hands after leaving a work area.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance: Liquid clear to slight haze. Colorless to amber or green tint.
Odor: Negligible.
Odor threshold: Not determined.
pH: > 2.0 @ 25°C (77°F) Typical: 2.2 - 2.6.
Freeze point approx.: -13°C (8°F)
Boiling point-range: Not determined.
Flash point: NA.
Evaporation rate: Similar to water.
Flammability (solid, gas): Not flammable.
Upper/lower flammability or explosive limits: NA
Vapor pressure: Similar to water.
Vapor density: Similar to water.
Relative Density (specific gravity): 1.29 - 1.34 @ 21°C (70°F)
Water Solubility: Complete.
Partial coefficient: n-octanol/water: NA, inorganic compound column 2 of REACH Annex VII.
Auto ignition: Not flammable.
Decomposition temperature: Not determined.
Viscosity: No data.

SECTION 10. STABILITY AND REACTIVITY

Reactivity: Not reactive under normal conditions.

Chemical stability: Stable under recommended conditions of storage.

Possible hazardous reactions: Contact with strong alkalis such as sodium hydroxide, ammonia, hypochlorite (bleach) may generate heat, splattering and hazardous vapors.

Hazardous polymerization: Does not occur.

Conditions to avoid: Unaffected by static discharge, shock, or vibration.

Incompatible Materials: Chlorite, hypochlorite (bleach), sulfites, strong bases, common metals.

Hazardous decomposition products: None expected under normal conditions of use and storage.

SECTION 11. TOXICOLOGY INFORMATION

Information on likely routes of exposure:

Eye, Skin, Ingestion, inhalation (of liquid mists).

Reported Oral LD50 (Rat) > 5,000 mg/kg Dermal: No information Inhalation: No information

Symptoms and immediate (Acute) effects:

Eye contact: Contact causes serious eye irritation.

Skin contact: Repeated contact may cause irritation.

Inhalation: Avoid breathing liquid mists. May cause irritation.

Ingestion: Do not taste or swallow. May be harmful if swallowed.

Symptoms and delayed (Chronic) effects: NA

Numerical measures of toxicity: Not determined.

Carcinogenicity listing: NTP Not listed. IARC Not listed. OSHA Not listed.

Reproductive toxicity, germ cell mutagenic, or teratogenic effects: Not classified.

SECTION 12. ECOLOGICAL INFORMATION

Ecotoxicity: An environmental hazard cannot be excluded in the event of incorrect or unprofessional handling, or disposal of unused material.

Aquatic: Reported fish LC50 static 1460-1500 mg/L 48h Leuciscus idus melanotuss.

Persistence and degradability: Not determined

Bioaccumulation potential: Not determined

Mobility in Soil: Not determined

Other adverse effects: Not determined

SECTION 13. DISPOSAL CONSIDERATIONS

RCRA Hazardous waste: Unused material is not listed as a hazardous waste.

Disposal of Waste: Dispose of waste and unused material in accordance with applicable local, regional, and national laws and regulations.

Contaminated packaging: Dispose of waste and unused material in accordance with applicable local, regional, and national laws and regulations

SECTION 14. TRANSPORTATION INFORMATION

Note: Please see current shipping documents for up the most to date information.

Land (DOT), Sea (IMDG), Air (ICAO/IATA)

UN number: UN3082

Shipping name: Environmentally hazardous substance inorganic (aluminum sulfate solution) N.O.S.

Hazard class: 9

Packing group: III

Marine pollutant: No

Special precautions: None known

SECTION 15. REGULATORY INFORMATION

RCRA Hazardous waste: Not Listed
CERCLA Hazardous substance: Not listed CWA, Sec.311 (b) (4)

CERCLA Reportable Quantity (RQ): 5,000lbs as $Al_2(SO_4)_3$ - anhydrous, containing 29.8% Al_2O_3 which is approximate equivalent to 1,600 gallons of liquid Aluminum Sulfate Hydrate (8.3% Al_2O_3).
RCRA Hazardous waste: Not Listed

CWA (Clean Water Act): Not determined

SARA 311/312 Hazard Categories:

Acute (immediate) health effects: Yes **Chronic (delayed) health effects:** No

Fire Hazard: No

Sudden release of pressure hazard: No **Reactivity hazard:** No

SARA 313 Toxic Chemical listing: Not listed **SARA Extremely hazardous substance (EHS):** Not listed

OSHA Air (table Z-1, Z-1A): Not listed **OSHA Special Regulated Substance:** Not listed

TSCA Section Inventory Status: Product exempt or listed on the TSCA Inventory.

Canadian Domestic Substances List (DSL): Not determined
State - Province regulations: Not determined

SECTION 16. OTHER INFORMATION

NSF International Certified: As meeting NSF/ANSI/CAN Standard 60 for Water Treatment Chemicals Maximum use 150mg/L.

AWWA: Meets AWWA Product Standard ANSI/AWWA B403-16 or as amended.

NFPA: Health 1 Flammability 0 Instability 0 Special Hazards Not determined
HMIS: Health 1 Flammability 0 Physical hazard 0 Personal protection Not determined

Preparatory statement: The information in this Safety Data Sheet (SDS) is correct to the best of our knowledge, information, and belief as of the publication date. The information only relates to the specific material designated and may not be valid when this material is used in combination with any other materials or in any process unless specified in the text. The information is designed solely as guidance for safe handling, storage, transportation, release, and disposal and should not be considered a product warranty or quality specification.

Date Sources for the SDS:
Literature, direct manufacturing experience, databases, practice, publications, own tests, regulations

Revision: July 21, 2020 replaces all earlier **SDS ID:** Liquid aluminum sulfate hydrate - basic

Holland Company, Inc.
153 Howland Avenue
Adams, Massachusetts 01220 U.S.A.
800-639-9602

Holland Company

LIQUID SODIUM ALUMINATE

Safety Data Sheet

SECTION 1. PRODUCT AND COMPANY IDENTIFICATION

Product/Chemical Name: Liquid Sodium Aluminate
Chemical Family: Inorganic aluminum salt
General use: Water treatment and manufacturing applications

Company Information:
Holland Company, Inc.
153 Howland Avenue
Adams, MA 01220 U.S.A.
Phone: 413-743-1292 FAX: 413-743-1298

Emergency Phone:
1-800-424-9300 Chemtrac (USA)
1-613-996-6666 or Cell *666 CANTUTEC (Canada)

SECTION 2. HAZARDS IDENTIFICATION

DANGER - CORROSION
AVOID CONTACT

Hazard Statements
Chemical burns to eyes and skin can result from contact.
Serious eye damage/eye irritation - Category 1
Skin corrosion/irritation - Category 1, Sub-category C
Harmful if ingested.

Precautionary Statements
Avoid direct contact.
Use protective equipment if direct contact is possible.
Wash face, hands and any exposed skin thoroughly after contact.
Store in closed containers in a secure area.

SECTION 3. COMPOSITION / INFORMATION ON INGREDIENTS

Substance
Chemical name: Aluminum soluble salts (liquid)
Name: Liquid Sodium Aluminate
CAS#: 11138-49-1
Impurities: NA. No impurities or additives which are themselves classified and which contribute to the classification of the substance.

SECTION 4. FIRST AID MEASURES

Eye contact:
Immediately rinse eyes with water for an extended period.
Get immediate medical attention.

Skin contact:
Remove contaminated clothing - footwear.
Wash skin for extended period until no evidence of chemical remains.
After washing affected areas thoroughly if irritation develops get medical attention.

Inhalation of mist or liquid:
Remove from continued exposure.
Get immediate medical attention.

Ingestion:
Do not actively induce vomiting.
Rinse mouth and drink water.
Get immediate medical attention.

SECTION 5. FIRE FIGHTING MEASURES

Flammability:
Product is not flammable and will not burn.
Controls:
To maintain the integrity of storage containers use water to keep containers cool.
If possible remove portable containers from areas under fire threat.
Hazards:
In a fire dried product can decompose at elevated temperatures and may release toxic fumes Exposure to products of decomposition during a fire may be hazardous.
Special equipment:
In case of possible exposure to products of decomposition use appropriate self-contained or other approved respiratory protection. Consult engineers if necessary.
Mechanical impact:
Not sensitive.
Static discharge:
Not sensitive**.**

SECTION 6. ACCIDENTIAL RELEASE MEASURES

General:
Site specific procedures to address accidental spills are necessary as dictated by facility design, location, staffing, containment structures, and regulatory requirements. Consult engineers if needed.

Personal protection:
In the event of a spill clear unnecessary staff from spill area.
If direct contact with spilled material is likely use protective equipment.

Spills:
Manage spill using containment structures or inert materials and collect for reuse.
Product not reused can be neutralized and converted to aluminum hydroxide using a mild / diluted acid. Neutralized residue can be swept up or rinsed down with water and captured using absorbent materials for disposal in accordance with local, state, province, and federal regulations. Caution: When neutralizing chemicals take steps to provide adequate ventilation. Consult engineers if needed.

SECTION 7. HANDLING AND STORAGE

Incompatible Chemicals:
Avoid contact with acids and acidic (low pH) materials.

Containment:
To minimize the possibility of a release into the environment and contact with other incompatible chemicals, storage tanks and containers should have a dedicated liquid tight secondary containment system. Consult engineers if needed.

General hygiene:
Do not eat, drink, take medication or smoke when direct contact is possible.
Always thoroughly wash exposed skin after leaving a work area where contact is possible or has occurred.

Storage: Store in closed container in a secure area.
Keep tanks closed and contents protected from dust, dirt, and moisture.
Clean storage tanks on a regular schedule based on inspection and experience.
Have storage tanks, containers, and transfer systems properly labeled for contents.
Have procedures for determining product quantity in storage tanks and for accepting deliveries.
Use tanks, transfer lines, pumps valves and process instrumentation designed for this material using approved materials of construction. Some materials commonly used are mild steel, stainless steel, plastic, and FRP. Nonferrous metals will be damaged by corrosion. To maintain product stability it is important to: Avoid adding water to product. Do not agitate or recirculate material in storage tanks. Do not bubble air into material in storage tanks. Consult engineers if needed.

Temperature for storage: Preferred storage temperature range is 16˚C-43˚C (60˚F-110˚F).
Outside of these temperature ranges optimal product stability and shelf life may be affected.

Ventilation: No special requirements.

Personal protection: If direct contact with material is likely use protective equipment.

SECTION 8. EXPOSURE CONTROL / PERSONNAL PROTECTION

Exposure Limits

Ingredient: aluminum soluble salts

OSHA PEL		ACGIH TLV		NIOSH
TWA	STEL	TWA	STEL	IDLH
2mg/m^3 as Al	none est.	2mg/m^3 as Al	none est.	none est.

Respiratory - Ventilation: Local passive ventilation is typically used. Under normal conditions respiratory protective equipment is not needed. If work requires direct exposure to product mist use appropriate, approved respiratory protection. Consult engineers if necessary.
Eye - Skin wash: Have appropriate eye wash and safety shower stations available in the work area.
Eyes: Use protective eye glasses-goggles and face shield protection to prevent direct contact.
Skin: Use impervious gloves and foot covering. Wear long sleeve shirts and full length trousers.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance: Liquid, clear to slight haze, off white to light amber tint.
Odor: Not significant. Free from organic or solvent odors.
Odor Threshold: NA
pH: >12.5 @ 25C (77F) as is basis.
Melting/Freeze point: -10˚C (15˚F) approximate
Boiling point-range: >110˚C (230˚F)
Flash point: NA
Evaporation rate: NA
Flammability: Not flammable.
Upper/lower flammability limits: NA
Vapor pressure/density: NA
Density: 1.4-1.6 S.G. @ 21˚C (70˚F)
Water Solubility: Complete.
Partial coefficient: n-octanol/water; NA, inorganic compound column 2 of REACH Annex VII.
Auto ignition: NA
Decomposition temperature: Not determined
Viscosity: 500-800cps @ 25˚C (77˚F)

SECTION 10. STABILITY AND REACTIVITY

Chemical stability:
Product is chemically stable under normal ambient temperature and conditions while stored or used.

Conditions to avoid:
None known.

Materials to avoid:
Acids and Acidic materials, Aldehydes, non-ferrous metals. Consult engineers if necessary.

Decomposition products:
None known.

SECTION 11. TOXICOLOGY INFORMATION

Toxicity: Numerical measures of toxicity not determined.

Effects of exposure:
Eyes: Causes chemical burns. Severe damage to the eye.

Skin: Can cause chemical burns and irritation.

Respiratory: Inhalation of liquid or mist can cause chemical burns and coughing.

Mucous membranes: Causes chemical burns.

Ingestion: Can cause vomiting, pain and discomfort to mouth, throat, and stomach.

Sensitization: Not sensitizing

Carcinogenicity: NTP Not listed. IARC Not listed. OSHA Not listed.

Reproductive Toxicity, Mutagenic or teratogenic effects:
No known reproductive toxicity, mutagenic or teratogenic effects in animal experiments are known.

SECTION 12. ECOLOGICAL INFORMATION

Aquatic toxicity:
With preapproval; Federal, State, Provincial, and EU regulators allow the direct application of aluminum salts into surface waters such as lakes, ponds, and streams for beneficial uses such as:
Phosphorus inactivation.
Toxic Cyanobacteria (Blue-Green Algae) control.
Turbidity reduction for improved water clarity.
It is reported that at the environmentally relevant pH range of 5.5-8.8 the solubility of aluminum is low. Aluminum salts dissociate with water resulting in rapid formation and precipitation of aluminum hydroxides. Aluminum salts must not be introduced into surface waters in an uncontrolled way. In aquatic environments at a pH <5.5 and >8.8 the direct addition of aluminum salts may result in soluble aluminum, and until a pH range of 5.5-8.8 is reached could demonstrate toxicity and be harmful to aquatic organisms.

LC50 96hrs:
>110 mg/l mosquito fish.

Toxicity to other organisms:
No data available.

Bioaccumulation potential:
This product is not expected to bioaccumulate.

Octanol-water coefficient:
NA, inorganic compound.

Biodegradability:
Not applicable to inorganic substances.

Chemical degradability:
In water at pH range of 5.5-8.8 precipitates of aluminum hydroxide are formed.

Mobility in Soil:
No data available.

SECTION 13. DISPOSAL CONSIDERATIONS

RCRA Hazardous waste: Not listed. Unused product that has not been neutralized ≥ 12.0pH is corrosive and a Characteristic waste (D002). Consult engineers if necessary.

Neutralization:

Product can be neutralized and converted to aluminum hydroxide using a mild / dilute acid. Neutralized residue can be swept up or rinsed down with water and captured using absorbent materials for reuse or disposal in accordance with local, state, province, and federal regulations. Consult engineers if necessary.

Special precautions:

None known

Container reuse:

Packaging and storage containers that cannot be thoroughly cleaned must be disposed of in accordance with local, state, province, and federal regulations. Consult engineers if necessary.

SECTION 14. TRANSPORTATION INFORMATION

DOT, IATA, IMDG, TDG

UN number: UN1819

Shipping name: Liquid Sodium Aluminate (sodium aluminate solution)

Hazard class: 8

Packing group: II

Environmental hazards: Not a marine pollutant

Special precautions: None known

SECTION 15. REGULATORY INFORMATION

RCRA Hazardous waste: Not Listed.

Unused, un-neutralized product may be a Characteristic Waste (D002). Consult engineers if necessary.

CERCLA Hazardous substance: Not listed CWA, Sec.311 (b) (4)

CERCLA Reportable Quantity (RQ): NA

SARA 311/312 Categories:

Acute (immediate) health effects: Yes

Chronic (delayed) health effects: No

Sudden release of pressure hazard: No

Reactivity hazard: No

SARA 313 Toxic Chemical listing: Not listed

SARA Extremely hazardous substance (EHS): Not listed

OSHA Air (29CFR 1910.10000, table Z-1, Z-1A): Not listed

OSHA Special Regulated Substance (29CFR 1910): Not listed

California prop 65 chemical: No

WHMIS: E corrosive

United States TSCA Section Inventory Status: Listed

Canada DSL/NDSL: Listed

State - Province regulations: State and Province specific regulations have not been determined by the Holland Company. Consult engineers if necessary.

Inventories (additional) listed: Philippines (PICCS), Japanese (ENCS), European (EINECS)

SECTION 16. OTHER INFORMATION

NSF International - NSF/ANSI Standard 60 Drinking Water Treatment Chemicals:
Maximum use (MUL): 40mg/L

HMIS Rating:
Health: 3
Flammability: 0
Reactivity: 0
NFPA Rating:
Health: 3
Fire: 0
Reactivity: 0
Special: NA

Preparatory statement:
The information in this Safety Data Sheet (SDS) is correct to the best of our knowledge, information we have available, and belief as of the publication date. The information is designed solely as guidance for handling, storage, transportation, release, and disposal and is not to be considered a warranty or quality specification.

Date Sources for the SDS:
Manufacturing experience, literature, databases, practice, publications, own tests, regulations

Revision:
Jan 2017 replaces all earlier
SDS ID: Liquid Sodium Aluminate

Holland Company, Inc.
153 Howland Avenue
Adams, Massachusetts 01220
U.S.A.
800-639-9602

Deep-water water quality monitoring sites and supplemental pH measurement sites.

Station	Latitude (N)	Longitude (W)	Station type
NIPBARD	43.2226	-71.0818	Deep-water
NIPALUMN	43.2260	-71.0817	Deep-water
NIPALUMS	43.2184	-71.0838	Deep-water
Nippo_10_1	43.2273	-71.0817	Supplemental
Nippo_10_2	43.2257	-71.0834	Supplemental
Nippo_10_3	43.2235	-71.0835	Supplemental
Nippo_10_4	43.2213	-71.0839	Supplemental
Nippo_10_5	43.2192	-71.0846	Supplemental
Nippo_10_6	43.2176	-71.0834	Supplemental
Nippo_10_7	43.2194	-71.0819	Supplemental
Nippo_10_8	43.2214	-71.0808	Supplemental
Nippo_10_9	43.2236	-71.0803	Supplemental
Nippo_10_10	43.2257	-71.0797	Supplemental

Current NHDES and EPA proposed aluminum water quality criteria.

Phase	Day/Week/Month	Date	Current NHDES water quality criteria (ug/L)*		pH (units)	DOC (mg/L)	Hardness (mg/L)	EPA Proposed water quality criteria (ug/L)**	
			Acute WQ Criterion	Chronic WQ Criterion				Acute WQ Criterion	Chronic WQ Criterion
Baseline	Day 1	5/4/2021	750	87	6.42	2.90	12.42	330	180
Pilot	Day 1	5/25/2021	750	87	6.46	2.93	12.88	350	190
Phase 1	Day 1	6/8/2021	750	87	6.47	use value from 6/11	use value from 6/11	400	210
Phase 1	Day 2	6/9/2021	750	87	6.48	use value from 6/11	use value from 6/11	380	210
Phase 1	Day 3	6/10/2021	750	87	6.46	use value from 6/11	use value from 6/11	380	200
Phase 1	Day 4	6/11/2021	750	87	6.47	2.63	13.04	340	190
Phase 2	Day 1	6/14/2021	750	87	6.48	use value from 6/17	use value from 6/17	330	180
Phase 2	Day 2	6/15/2021	750	87	6.43	use value from 6/17	use value from 6/17	320	180
Phase 2	Day 3	6/16/2021	750	87	6.43	use value from 6/17	use value from 6/17	320	180
Phase 2	Day 4	6/17/2021	750	87	6.42	2.36	13.20	320	180
Post-application	Week 1	6/23/2021	750	87	6.23	2.33	13.23	370	200
Post-application	Week 2	6/30/2021	750	87	6.32	2.43	13.23	340	190
Post-application	Week 3	7/7/2021	750	87	5.96	2.37	13.57	130	90
Post-application	Week 4	7/15/2021	750	87	5.74	2.37	13.63	79	49
Post-application	August	8/25/2021	750	87	5.66	2.07	13.73	64	40
Post-application	September	9/21/2021	750	87	5.95	2.33	13.73	130	88
Post-application	October	10/21/2021	750	87	6.59	2.60	14.70	470	240

* Current NHDES criteria are based on acid-soluble aluminum concentrations

** EPA proposed criteria are based on total aluminum concentrations and depend on pH, dissolved organic carbon (DOC), and hardness

EPA aluminum criteria calculator: https://www.epa.gov/wqc/aquatic-life-criteria-aluminum