ALUM TREATMENT FINAL REPORT

Lake Kanasatka

Moultonborough, NH

May 2025

Prepared by

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

May 20, 2025

Dear Ms. Smagula,

On behalf of the Lake Kanasatka Watershed Association (LKWA), we submit the following final report summarizing the alum treatment completed for Lake Kanasatka, Moultonborough, NH to reduce the internal phosphorus load and minimize the likelihood of potentially toxic cyanobacteria blooms.

This report satisfies the New Hampshire State Surface Water Discharge Permit No. Lake Kanasatka – 002 authorizing the discharge of aluminum to Lake Kanasatka, Moultonborough, NH in compliance with the provisions of the State of New Hampshire Revised Statutes, Title L Water Management and Protection, Chapter 485-A Water Pollution and Waste Disposal.

As the permittee, LKWA has complied with state water quality standards, visual and ambient water quality monitoring, recordkeeping, and post treatment reporting to NHDES.

Sincerely,

Laura Diemer, CLM
FB Environmental Associates
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603-828-1456

cc: Kirk Meloney, LKWA President

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EXECUTIVE SUMMARY

Lake Kanasatka is a 143-hectare (353-acre) oligotrophic lake in Moultonborough, NH (Figure 1). Lake Kanasatka experienced generally good water quality through the years up until recent persistent whole-lake cyanobacteria blooms that resulted in NHDES posting multiple warnings for extended periods of time each summer from 2020 to 2023. These cyanobacteria blooms were fueled by internal phosphorus loading (representing 20% of the total phosphorus load). Water quality analyses and modeling through planning efforts concluded that a combination of external and internal phosphorus load reduction measures, totaling at least 48 kg/yr of phosphorus, was needed to fully restore Lake Kanasatka.

The project was carried out successfully through close collaboration among several entities. The Lake Kanasatka Watershed Association (LKWA) was the permit applicant and primary financial and administrative entity for hiring and overseeing the professional expertise necessary for the treatment. Laura Diemer, CLM of FB Environmental Associates (FBE) served as the lead consultant to LKWA in planning and executing the treatment. SOLitude Lake Management was hired by LKWA as the applicator to complete the treatment. New Hampshire Department of Environmental Services (NHDES) served as the permitting and funding (via the Cyanobacteria Mitigation Fund) agency and assisted with third-party water quality monitoring on active treatment days. The University of New Hampshire Lakes Lay Monitoring Program (UNH LLMP), along with LKWA volunteers, served a critical role in completing most of the third-party water quality monitoring before, during, and after treatment to evaluate responses in key parameters such as pH, aluminum, and biological observations.

As specified in NHDES Permit No. Lake Kanasatka – 002, the project used a phosphorus inactivation approach to bind phosphorus in surficial sediments through the application of aluminum as aluminum sulfate (alum) and sodium aluminate (aluminate). The proposed treatment dose was 50 g/m^2 of a 2:1 alum:aluminate ratio over 153 acres representing areas 7.5 meters and deeper in Lake Kanasatka. The actual treatment dose was an average 48.9 g/m^2 of an average 2:1 alum:aluminate ratio over 157.8 acres. The actual treatment fell below the limit of application for the maximum total dose of aluminum compounds as set by NHDES in the permit. Of important note, Zones C and B were dosed slightly higher at 51.3 g/m^2 and 52.4 g/m^2, respectively, and Zone A was dosed lower at 42.7 g/m^2. The cost of the treatment was $482,070, not including monitoring or outside consulting assistance. The treatment design and application was modified in several ways to minimize the potential impact to ecological and human health.

The treatment resulted in a 82-89% reduction in the internal phosphorus load in Lake Kanasatka in the first year, falling within the target reduction of 80-90% for internal phosphorus load. As expected, Lake Kanasatka experienced immediate water quality improvement following the alum treatment. The alum floc stripped phosphorus from the water column as it migrated down to the sediment where it bound with mobile phosphorus. Lake Kanasatka experienced record high water clarity and minimal to no cyanobacteria accumulations or blooms from the reduction in available phosphorus. There were a few short-term exceedances of receiving water limits set by the permit for pH and aluminum; however, the criteria are 1) imperfect measures not intended for these types of treatments; 2) wildlife showed no distress linked to the treatment; and 3) zooplankton populations recovered well and followed expected seasonal succession patterns.

It is important to understand that alum treatments are temporary management measures to control internal phosphorus loads that come from legacy external phosphorus loads. Without substantial reductions in the external phosphorus loads, phosphorus will continue to build up in newly deposited sediment and begin to release again as internal phosphorus load. Thus, the expected water quality improvements will deteriorate over time until the internal phosphorus load returns to pre-treatment magnitude. Given Lake Kanasatka's shorter water residence time (higher flushing and dominance of external load), the alum treatment longevity for Lake Kanasatka will likely be shorter than other alum treatments performed on deep stratified lakes in Maine and New Hampshire. Hypervigilance to continually reduce the external phosphorus load to Lake Kanasatka will be critical to maximizing the alum treatment's effective lifespan.

Monthly monitoring of Lake Kanasatka should continue in collaboration between LKWA and UNH LLMP to assess the efficacy of the alum treatment over time. If the efficacy of the alum treatment degrades sooner than expected, then we recommend a second alum treatment be applied at an areal dose of 25 g/m^2 over a treatment area of 153 acres representing 7.5 m and deeper in spring (though additional sediment samples should be collected to confirm the calculated dose for a possible second treatment). The second treatment would treat the labile organic phosphorus fraction not directly targeted in the first treatment. It would also strip the water column of phosphorus for a second time and treat newly settled phosphorus from the external load or newly decayed phosphorus in the sediment since the first treatment.


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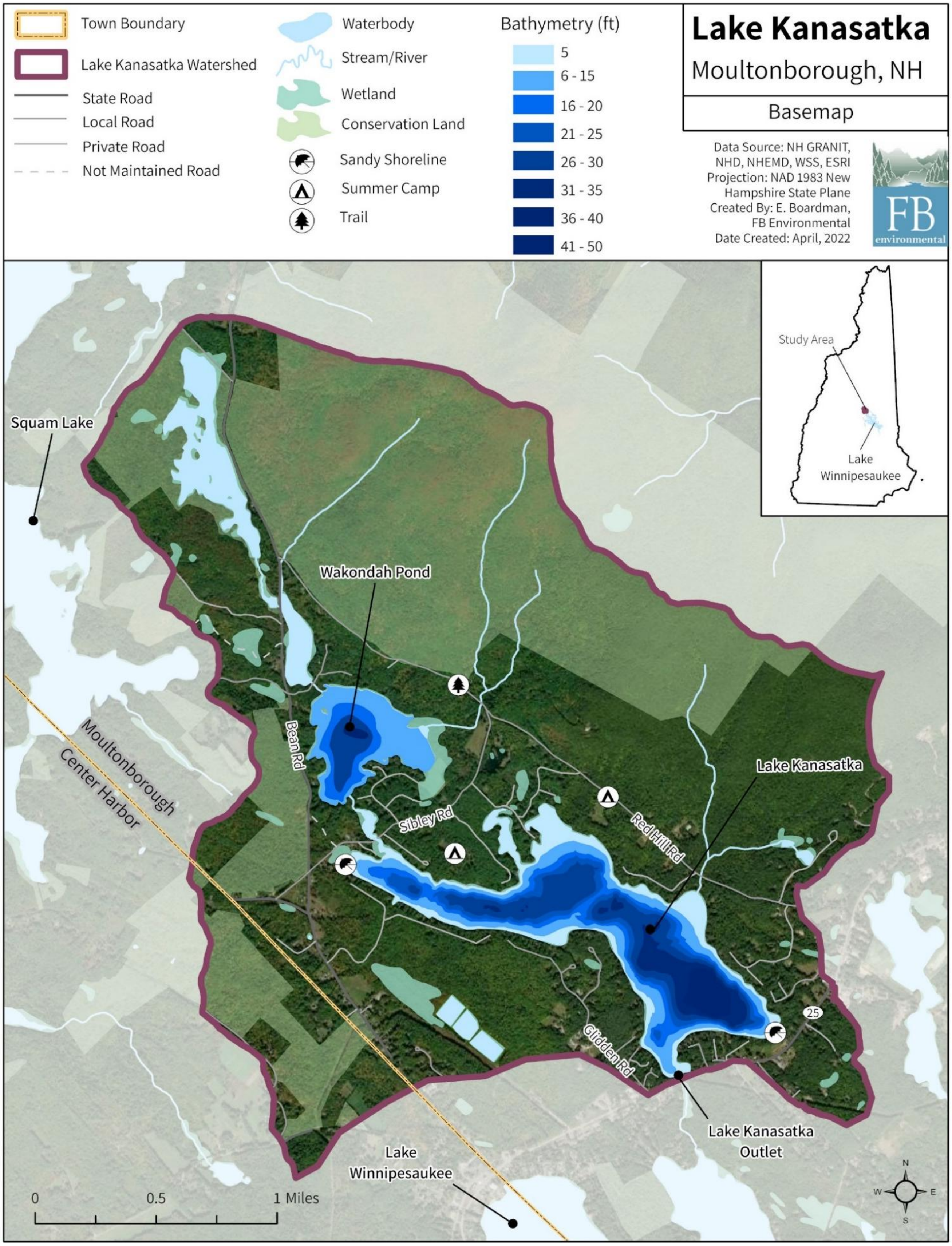


Figure 1. Lake Kanasatka watershed.

INTRODUCTION

Lake & Watershed Characteristics

Lake Kanasatka is a 143-hectare (353-acre) oligotrophic lake with 5.2 miles of shoreline, a maximum depth of 14 meters (46 feet), and a volume of 8,344,010 cubic meters (Figure 1). The areal water load is 5.9 meters/yr (19.4 feet/yr), and the flushing rate is around or just slightly more than once per year. The watershed, not including the lake area, spans 1,690 hectares (4,176 acres) in Moultonborough and Center Harbor, NH (Figure 1). Lake Kanasatka is fed by upstream waterbodies including Wakondah Pond as well as several tributaries such as Kanasatka Brook, Red Hill Stream, and Jennifer's Path Stream. Wakondah Pond is a 38-hectare (94-acre) lake connected to Lake Kanasatka by an unnamed tributary, which flows 268 meters (879 feet) upstream from the Sibley Road crossing at the northwestern end of Lake Kanasatka. From the dammed outlet of Lake Kanasatka at the southern end of the lake, water flows 579 meters (1,869 feet) south via an unnamed tributary[1] near Whittier Highway / NH Route 25 to Blackey Cove of Center Harbor in the economically vital Lake Winnipesaukee, just east of Center Harbor village. The lake has public access near its dam along Route 25 and is surrounded by 164 shorefront homes and one business, an overnight summer camp operating since 1936. Many homeowners rent out their homes, serving as an income source for the residents and tax base for the town and state, contributing $800,000 annually in tax revenues.

Water Quality Problem

Lake Kanasatka experienced persistent whole-lake cyanobacteria blooms that resulted in NHDES posting multiple warnings for extended periods of time each summer from 2020 to 2023 (NHDES, 2023). These cyanobacteria blooms threatened the health and safety of the residents, visitors, pets, and wildlife including the loon population, and reduced safe recreational opportunities, income generation through rentals, and property values.

NHDES issued four cyanobacteria bloom warnings over 2020 and 2021 in late summer (August and September) for periods ranging from seven to 15 days (Table 1). During their routine sampling of Lake Kanasatka, the University of New Hampshire (UNH) Lakes Lay Monitoring Program (LLMP) first alerted NHDES to a possible cyanobacteria bloom in early August 2020. All four bloom periods were lakewide except for the 9/29/20 bloom that was more localized with scum forming along the shorelines. The dominant taxa identified for each bloom in 2021 were determined from 32 samples collected by NHDES from seven areas around the lake, largely along the shoreline or at the Animal Island deep spot.

Lake Kanasatka was placed under two cyanobacteria bloom warnings by NHDES in summer 2022 (Table 1). The first warning lasted 13 days beginning on 7/29/22 for 109,267 cells/mL with *Dolichospermum* as the dominant taxa. NHDES described the bloom as "*appearing as wispy aggregations of light green specks…seen in several locations across the lake*." NHDES also noted that other cyanobacteria (*Dolichospermum*, *Tolypothrix*, and *Calothrix*) were "*present in low densities from shoreline samples" and are "associated with benthic growth and do not form surface blooms but can produce toxins*." The second warning lasted 79 days beginning on 8/29/22 for 1,375,600 cells/mL with *Dolichospermum* and *Aphanizomenon* as the dominant taxa. NHDES described the bloom as "*appearing as bright clouds of material along shorelines…seen in several locations across the lake*." Dr. Amanda McQuaid of UNH LLMP completed a 2020-22 summary report on Lake Kanasatka and Wakondah Pond, reviewing cyanobacteria species and cyanotoxin data (McQuaid & Craycraft, 2023). Cyanotoxins were present in

[1] NHDES Assessment Unit named "Kanasatka Lake Outlet Brook," assessment unit ID NHRIV700020105-05.

concentrations above established thresholds on multiple days during the study period and represented a health risk to humans and wildlife.

In 2023, Lake Kanasatka was under warning from 6/2 to 6/16, 8/7 to 8/31, and 9/22 to 12/14, the latter hitting a record 83 days in duration (Table 1). The June bloom was reported by NHDES as having concentrations of *Dolichospermum* reaching 362,000 cells/mL. The August bloom was reported by NHDES as "*appearing as green clouds, surface streaks and accumulated specks*," with concentrations of *Dolichospermum* reaching 95,400 cells/mL. The bloom occurred "*lakewide throughout the top of the water column, creating low clarity but not necessarily forming surface scums everywhere*." The fall bloom was reported by NHDES as "*appearing as brown and green ribbons of accumulation along some shorelines, and flecks of material accumulating mid-lake. Samples collected and reviewed on 22 September had cyanobacteria (Dolichospermum, Woronichinia and Microcystis) in concentrations up to 608,460 cells/mL in areas of highest observed accumulations. A sample from mid-lake had a density of 16,334 cells/mL (Dolichospermum and Woronichinia). A plankton tow sample taken from 5 meters in the middle of the lake had high densities of Dolichospermum, Woronichinia, the chrysophytes Chrysosphaerella and Synura, and the diatoms Tabellaria and Fragilaria." Samples collected on 10/17/23, 11/5/23, and 11/15/23-11/30/23 showed concentrations of Dolichospermum and Woronichinia as high as 2,242,000 cells/mL, 2,134,000 cells/mL, and >3,000,000 cells/mL, respectively, with "multiple reports of intense lakewide bloom conditions."*

Aerial image of the fall 2023 bloom in Lake Kanasatka (left) and Blackey Cove (right) in Center Harbor, Lake Winnipesaukee.

Table 1. Cyanobacteria warnings issued by NHDES for Lake Kanasatka from 2020-23.

Warning Date	Duration (Days)	Dominant Taxa	Total Cell Concentration (cells/mL)
8/12/2020	14	*Dolichospermum*	78,750
9/29/2020	10	*Microcystis, Aphanizomenon, Woronichinia, Dolichospermum*	393,500
8/4/2021	15	*Dolichospermum*	775,000
9/13/2021	7	*Dolichospermum*	500,000
7/29/2022	13	*Dolichospermum*	109,267
8/29/2022	79	*Dolichospermum*	1,375,600
6/2/2023	14	*Dolichospermum*	362,000
8/7/2023	24	*Dolichospermum*	95,400
9/22/2023	83	*Dolichospermum, Woronichinia and Microcystis*	>3,000,000

In response to the onset of these blooms, the Lake Kanasatka Watershed Association (LKWA) hired environmental consulting firm FB Environmental Associates (FBE) to develop an a-i watershed-based management plan for Lake Kanasatka, which was finalized in August 2022 (FBE, 2022a). Using water quality data collected by LKWA and UNH LLMP since 1983, sources of phosphorus in the watershed impacting the lake's water quality were identified and quantified and included stormwater runoff from developed areas, shoreline erosion, erosion from construction activities or other disturbed ground particularly along roads, excessive fertilizer application, failed or improperly functioning septic systems, unmitigated agricultural activities, and pet, livestock, and wildlife waste. Twenty-two (22) problem sites were identified in the watershed during a field survey conducted by FBE. The main issues identified were unpaved road and ditch erosion, buffer clearing, and untreated stormwater runoff. Additionally, 121 shorefront properties (66% of the total 182 shorefront properties) were identified as having some impact to water quality due to evidence of erosion and lack of vegetated buffer.

As part of the development of the Lake Kanasatka Watershed-Based Management Plan, a Lake Loading Response Model (LLRM) was used to estimate water and phosphorus source loads and predict in-lake water quality for Lake Kanasatka. A complete detailing of the methodology employed for the Lake Kanasatka LLRM is provided in the *Lake Kanasatka Lake Loading Response Model Report* (FBE, 2022b), with updates described in FBE (2023a) based on 2022 data. Per the updated (2022) model, watershed runoff combined with baseflow (61%) was the largest phosphorus loading contribution across all sources to Lake Kanasatka, followed by internal loading at 20% and shorefront septic systems at 10%. Atmospheric deposition (6%) and waterfowl (3%) were relatively minor sources. When considering the time of year when internal phosphorus loading and the risk of cyanobacteria blooms are highest, in this case August, the internal phosphorus load portion of the total load increases to an estimated 46%. The cyanobacteria blooms that Lake Kanasatka experiences are whole lake issues fed by the internal phosphorus load during thermal stratification when waters are warm and calm with minimal mixing.

Thus, internal phosphorus loading was determined to be the primary driver of cyanobacteria blooms in Lake Kanasatka. The lake experiences anoxia (< 2 mg/L dissolved oxygen concentration) in areas of the lake 7.5 meters and deeper and showed a steady increase in hypolimnetic total phosphorus concentration throughout the season, reaching a peak of 200+ µg/L in late summer when thermal stratification peaks. Historic dissolved oxygen and temperature profiles showed that the extent of anoxia in Lake Kanasatka may be worsening, extending historically from 8.5-13 meters from 1977-2015 at 1-Deep to 7.5-13 meters from 2021-22 at 1-Deep. The possible increased prevalence of anoxia in areas of the lake 7.5 meters or deeper represented a significant shift in the potential for phosphorus release from sediment because the bottom surface area exposed to anoxia greatly expanded in areas from 8.5 meters and deeper to 7.5 meters and deeper.

As the second most significant source of phosphorus to the lake, internal phosphorus loading is legacy external phosphorus loading that recycles back into the water column and potentially fuels cyanobacteria growth. There are several modes by which phosphorus is recycled back into the water column[2], with the release of iron bound phosphorus in surficial sediments during anoxic periods being typically the most substantial, particularly in deep stratified lakes such as Lake Kanasatka. As decomposition in the sediment increases with rising temperatures, oxygen demand rapidly depletes available oxygen, then other electron acceptors such as nitrate, manganese oxides, and finally iron oxides, which releases iron bound phosphorus. While oxygen can only decline to a concentration of zero, redox potential can continue to decline below zero, increasing the rate of phosphorus release even after oxygen is depleted.

[2] Other modes include plant cell uptake from sediments and subsequent leakage, organic matter decay, bioturbation from bottom feeding fish or other biota, and mechanical mixing from wind or boat wake action.

Water Quality Goal

The goal of the Lake Kanasatka Watershed-Based Management Plan is to improve the water quality of Lake Kanasatka such that it meets state water quality standards for the protection of Aquatic Life Integrity and substantially reduces the likelihood of harmful cyanobacteria blooms in the lake. This goal will be achieved by reducing the phosphorus load to Lake Kanasatka by 48 kg/yr (revised in 2023) to meet an annual average in-lake total phosphorus concentration of 7.2 ppb.

Addressing identified opportunities for reduction of external sources of phosphorus load was estimated at 43 kg/yr, meeting 90% of the needed reductions to achieve the goal of 48 kg/yr of phosphorus reduced. This would require remediating 22 watershed survey sites (11 kg/yr), treating 121 or 66% of shorefront properties (20 kg/yr), and upgrading 115 shorefront septic systems (12 kg/yr). Because it would be unrealistic to achieve this work within a reasonable timeframe and because more reduction in phosphorus load would still be needed, reducing the internal phosphorus load to Lake Kanasatka was also needed to achieve the goal. Thus, successful restoration of Lake Kanasatka was determined to require addressing both internal and external phosphorus loads.

As part of the alternatives analysis, several management techniques with varying levels of effectiveness, longevity, cost, risk, and effort were evaluated for applicability to Lake Kanasatka in controlling cyanobacteria blooms. For evaluating applicability to Lake Kanasatka, strong preference was given to techniques that reduce phosphorus loading as the primary source of nutrition supporting cyanobacteria growth. Recommended management techniques with the greatest applicability for Lake Kanasatka include:

1) external phosphorus load reduction through nonpoint source controls and pollutant trapping and

2) phosphorus inactivation in surficial sediments.

Reducing the external phosphorus load extends the longevity of a phosphorus inactivation approach and is thus the primary recommendation for sustainable restoration of Lake Kanasatka.

External Load Reduction Efforts

To permit an alum treatment, NHDES required LKWA to document an external phosphorus load reduction of 10 kg/yr (FBE, 2023b). LKWA met that goal by addressing priority sites identified in the Watershed-Based Management Plan. LKWA enlisted the help of 53 volunteers to complete projects such as installing drainage ditches and water razors and stabilizing pathways around the watershed in 2023. Two volunteers donated considerable time using their large tractor/loader/backhoe and small tractor/loader. One volunteer completed 21 consultations for using rubber razors to divert runoff which resulted in 16 installed razors, not including five that were installed on Camp Quinebarge property. Another volunteer completed 18 consultations with property owners and completed 12 projects. Sixteen (16) shorefront properties around Lake Kanasatka have become LakeSmart certified since 2019, with six awarded in 2022 and seven awarded in 2023. At the request of LKWA, the Moultonborough Public Works Director completed grading of Glidden Road and added stone swales to Red Hill Rd in 2023. Due to persistent communication from LKWA, the NHDOT and NHDES Bureau of Dams are in progress to renovate the boat launch/dam area and have ceased dumping/plowing snow at the dam. NHDOT also completed improvements to Route 25 that have reduced sediment loading to the lake. Ten (10) septic system upgrades were documented around the lake between 2021 and 2023, with more planned. LKWA also successfully applied for 319 Watershed Assistance Grant program funding to remediate two BMP sites along Burton Rd as identified during the watershed survey as part of the Watershed-Based Management Plan.

THE PROJECT

Project Partners

LKWA was the permit applicant and primary financial and administrative entity for hiring and overseeing the professional expertise necessary for the treatment. Laura Diemer, CLM of FBE served as the lead consultant to LKWA in planning and executing the treatment. SOLitude Lake Management was hired by LKWA as the applicator to complete the treatment. NHDES served as the permitting and funding (via the Cyanobacteria Mitigation Fund) agency and assisted with third-party water quality monitoring on active treatment days. UNH LLMP, along with LKWA volunteers, served a critical role in completing most of the third-party water quality monitoring before, during, and after treatment as required by the permit and summarized in this report.

Staging & Logistics

Staging and logistics by SOLitude Lake Management is summarized in this section. Full details are provided in the *Alum Treatment Final Completion Report for Lake Kanasatka, Moultonborough, NH* dated September 23, 2024 by SOLitude Lake Management (Appendix A).

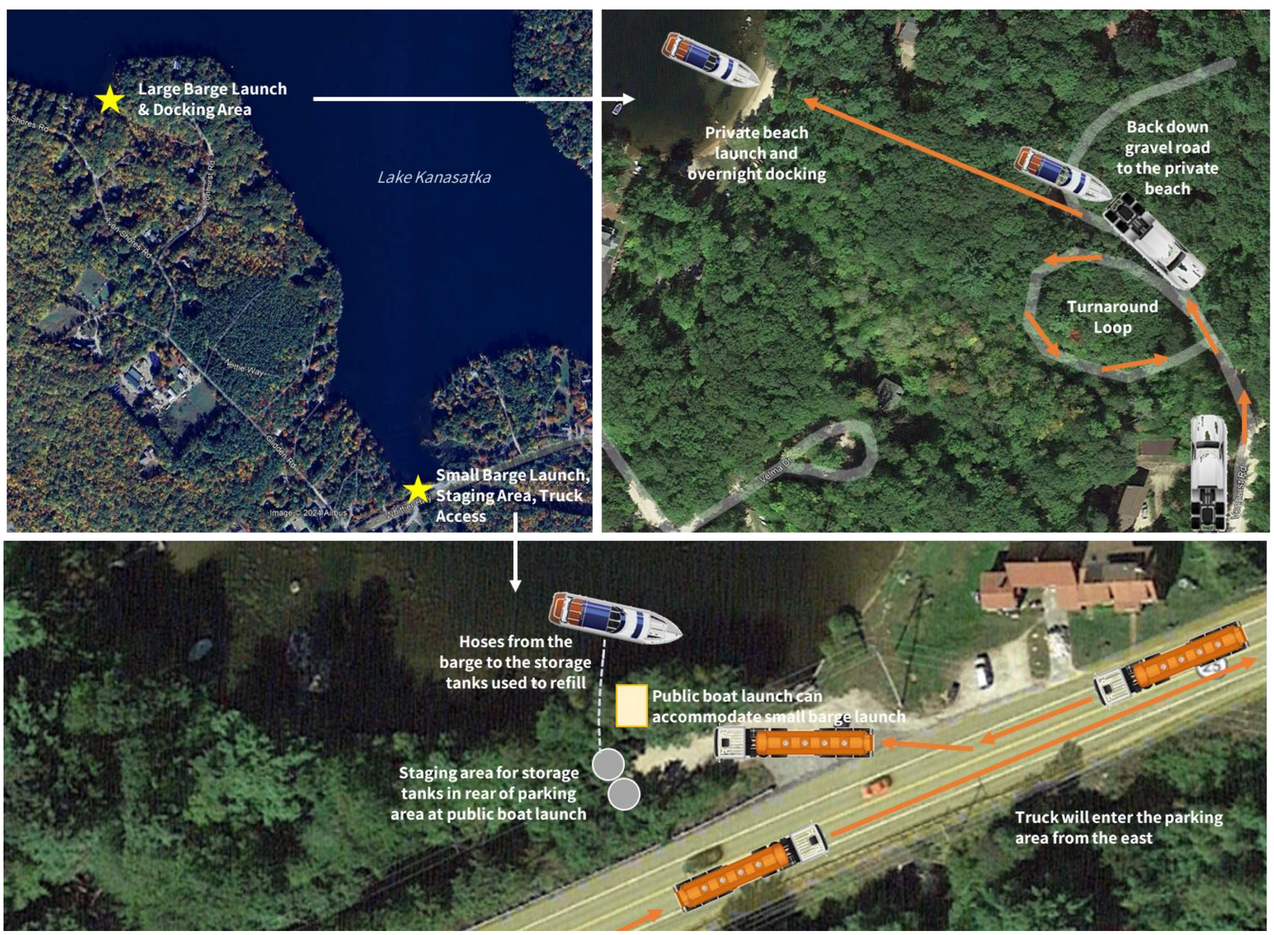
SOLitude Lake Management, hereafter the applicator, mobilized the day prior to the pilot treatment on 4/30/24 (and demobilized on the same day). NHDES requested that a pilot treatment of Lake Kanasatka be completed at least two weeks in advance of the full treatment. The purpose of the pilot treatment was to assess the chemical and biological in-lake response to alum, as well as resolve logistical details associated with access points, staging areas, trucking, and chemical deployment. Because NHDES requested a two-week delay for lab processing between the pilot treatment and full treatment, the applicator was not able to complete a full staging and application test run for the pilot treatment. Instead, the applicator utilized their smaller barge to apply a single pass dose of 25 g/m^2 (supplied by one split tanker) over Zone P during the one-day pilot treatment (Figure 2). The smaller barge was launched and removed from the water at the public boat launch by the dam.

For the full treatment, the applicator mobilized on 5/14/24 with full staging equipment. A larger barge was launched at a private beach off Vonhurst Rd. There is a loop at the end of Vonhurst Rd where the applicator could turn around and back down a gravel road that leads to a private beach. There is no official launch at the beach and because of the shallow water and sandy soils at the private beach, the applicator used a rented telehandler forklift with an extendible arm to launch the barge into the water. The barge was docked overnight at the private beach by beaching the front of the barge partially on the sand and tying off to a stable structure. Two 6,800-gallon upright poly storage tanks (18-20 ft high, 10 ft diameter) with lockable valves and set in a spill guard were staged in the rear of the parking area at the public boat launch by the dam. From the water, the applicator beached the large barge near the launch to refill from the land-based storage tanks. Delivery trucks that came from the west on Route 25 pulled around the gas station to reverse direction and then pull off at the public boat launch on the north side of the road off the main route, safely allowing the trucks to drive down to the storage tanks for refilling. Traffic control was requested and used during deliveries, which was typically two deliveries of alum and one delivery of aluminate per treatment day. The applicator applied a single pass dose of 25 g/m^2 over Zones C, B, and A on 5/15/24 (minus Zone P), 5/16/24, and 5/17/24 during Phase I and on 5/20/24, 5/21/24, and 5/22/24 during Phase II, respectively. Barge demobilization and site breakdown occurred on 5/23/24. In total, 60,794 gallons of aluminum sulfate and 30,392 gallons of sodium aluminate were applied to Lake Kanasatka, as supplied by the Holland Company of Adams, MA. The applicator reported “no major failures, spills, or other incidents during the project,” and all procedures followed the operations and management plan developed by the applicator for the project.

The applicator used a treatment barge with a subsurface injection system that allowed for controlled application and proper mixing of liquid aluminum sulfate and sodium aluminate at variable boat speeds. The barge position on the lake was managed by a global positioning and depth monitoring system that allowed the operator to apply the treatment within the target area. The barge was loaded with aluminum from onshore storage tanks, following procedures and response protocols that minimized environmental impacts from possible spills.

Chemicals were simultaneously distributed at a 2:1 alum:aluminate ratio by means of a dual manifold injection system that resulted in a mixing zone of suitable depth (assumed to be five vertical meters). The applicator applied the aluminum in a pattern that led to relatively even distribution of alum floc on the bottom in the target area with minimum drift outside the target area (refer to the Additional Notes section for further discussion). The application rate was such that the calculated concentration of aluminum in the mixing zone would not exceed 5 mg/L of aluminum, corresponding to a maximum daily dose of 25 g/m^2 and a maximum total dose of 50 g/m^2 (Wagner et al., 2017). The applicator was responsible for real-time ratio adjustment to maintain the pH within the desired range. Refer to the Treatment Execution section for more details.

NHDES closed the public boat launch to the public on active treatment days while personnel were on site. As a precaution and for the safety of personnel, NHDES requested that the public refrain from recreational use of, or water withdrawal from, the lake during and within 24 hours of the completed treatment. Public notification letters were mailed by LKWA to all shorefront property owners around the lake and adjacent to the stream outlet at Blackey Cove. Public notices were also posted by LKWA at the public boat launch and all roads leading to the waterfront. LKWA provided notification information and updates on their Facebook page, website, and via email. The Dam Bureau put up boards before the full treatment to keep the alum floc in the lake during treatment.



Aerial map highlighting logistics of launching, staging, storage, and access. Aerials from Google Earth.

Photos highlighting logistics of launching, staging, storage, and access: (TOP LEFT) Small barge used for pilot treatment. (TOP RIGHT) Large barge used for full treatment. (MIDDLE LEFT) Transport of large barge down Vonhurst Rd. (MIDDLE RIGHT) Launching of large barge from private beach using a telehandler. (BOTTOM LEFT) Storage tanks at the public boat launch during the full treatment. (BOTTOM RIGHT) Large barge refilling from the storage tanks at the public boat launch. Photos from NHDES, LKWA, and FBE.

Treatment Execution

The proposed treatment dose was 50 g/m^2 of a 2:1 ratio of aluminum sulfate and sodium aluminate over 153 acres representing areas 7.5 meters and deeper in Lake Kanasatka (Figure 2). The actual treatment dose was 48.9 g/m^2 of an average 2:1 ratio of aluminum sulfate and sodium aluminate over 157.8 acres (Table 2). The actual treatment fell below the limit of application for the maximum total dose of aluminum compounds as set by NHDES in the permit (Table 3). Of important note, Zones C and B were dosed slightly higher at 51.3 g/m^2 and 52.4 g/m^2, respectively, and Zone A was dosed lower at 42.7 g/m^2 (Table 2). The cost of the treatment was $482,070, not including monitoring or outside consulting assistance. The treatment design and application was modified in several ways to minimize the potential impact to ecological and human health. Aluminum can be toxic to aquatic life in high concentrations, especially at low pH and when the aluminum is first added to the water before it hydrolyzes and forms the floc. Once the floc is formed, it is no longer toxic, but its physical presence can be stressful to fish and can bind with microscopic organisms as it settles.

1) Controlled pH between 6.5 and 8.0[3]. Sodium aluminate, which raises pH, was added in a 2:1 ratio of alum:aluminate (actual range: 1.7-2.4; average: 2.0) to counteract and balance pH within the optimum range of 6.5 to 8.0 to avoid toxic effects (Table 2). The applicator adjusted this ratio in real-time in response to pH changes in the lake as the treatment proceeded (refer to Monitoring Results for pH for details).

2) Optimized conditions conducive to even distribution and proper mixing and settling of the aluminum. The treatment was conducted in spring when water temperatures in the mixing zone (0-5 meters) were around at least 12 degrees Celsius (actual minimum: 11.4 degrees Celsius for pilot and 15.5 degrees Celsius for full) (to allow for faster floc formation, minimizing dissolved aluminum exposure time) and particulates in the water from sediment or cyanobacteria blooms were low (to allow for faster floc setting). Underwater camera evaluations of the alum floc showed good floc formation and settling during the treatment (see photos below). Treatment during non-stratified periods such as in spring when water is cooler and more oxygenated also allows organisms to move more freely around the lake to avoid the treatment area. Treatment proceeded during a time with minimal precipitation (<0.1 inches per day, except for 5/15/24) and wind speeds less than 15 mph for personnel safety and proper distribution of the floc (Table 4). Refer to Additional Notes for further discussion.

3) Allowed for refuge and rest for aquatic organisms. Less than half (45%) of Lake Kanasatka was treated, providing opportunities for mobile aquatic organisms to move out to non-treatment areas. The treatment area was divided into three main treatment zones so that no more than 16% of the lake area was treated on a given day (Table 2). Low doses of 25 g/m^2 (actual range: 20.0-28.4 g/m^2) were applied per zone per day to keep the concentration of aluminum in the mixing zone to 5 mg/L or less[4] (Table 2). Three of the seven treatment days (4/30/24, 5/15/24, and 5/16/24) exceeded the limit of application of 25 g/m^2 for the maximum daily dose of aluminum compounds as set by NHDES in the permit (Tables 2, 3)[5]. The zones were rotated daily during the application period to minimize toxicity potential and allow mobile aquatic organisms to seek refuge away from the treatment area. A pilot treatment treated a portion of Zone C (i.e., Zone P) two weeks before the two-phased full treatment. Zones C, B, and A were treated for three consecutive days in the first phase of the full

[3] Aluminum is toxic to organisms at 0.1 to 0.2 mg/L under acidic conditions (pH < 5.5) when aluminum becomes highly soluble (Freda, 1991).
[4] Recommended for short-term alum treatments even though state/federal acute/chronic criteria for total and dissolved aluminum are much lower.
[5] The alum:aluminate ratio was lowered to 1.7 for Zone B on 5/16/2024 to buffer against low pH fluctuations consistently below the target range. Because more aluminate was added (which has a higher Al content) relative to alum, the Al dose was higher at 28.4 g/m^2 than the target for Zone B on that day. With limited supply of aluminate for Zone A on 5/17/2024, the alum:aluminate ratio was higher at 2.4 and the Al dose was lower at 22.8 g/m^2. Similarly for the second phase of the full treatment, slightly lower alum:aluminate ratios for Zones C and B contributed to a higher ratio (and lower Al dose) for Zone A on the final day when the applicator emptied the storage tanks of remaining solution. Additionally, the Al doses were generally higher than expected given that the percentage of Al in aluminate solution was higher than assumed (10.4-10.6% compared to 10.2%).

treatment, followed by a two-day rest period before Zones C, B, and A were treated again for three consecutive days. Within the treatment zone, every other strip in the zone was treated first before filling in the alternate strips to allow refuge to mobile organisms. The applicator used GPS to navigate and easily track the treated area.

4) Conducted monitoring that evaluates key water quality and biological parameters. Monitoring was completed before, during, and after the treatment to evaluate responses in key parameters such as pH and aluminum, as well as biological observations such as die-offs or fish gill abnormalities. Adjustments were made by the applicator in real-time if concerns by the third-party monitor were identified from continuous pH monitoring behind the barge. Refer to the sections on Monitoring Schedule and Monitoring Results.

Table 2. Volume and ratio of aluminum sulfate (alum) and sodium aluminate (aluminate) and total mass and areal dose of aluminum (Al) added per day per zone in each treatment phase, subtotaled by zone and phase and totaled for the entire treatment.

Date	Alum (gal)[1]	Aluminate (gal)[1]	Acres Treated[1]	Phase	Zone Treated	Alum: Aluminate	Alum (g Al)[2]	Aluminate (g Al)[2]	Total (g Al)	Dose (g Al/m^2)[3]
4/30/24	2,767	1,391	13.8	Pilot	P	2.0	619,447	836,032	1,455,479	26.1
5/15/24	8,329	4,231	39.6	Full Phase I	C (minus P)	2.0	1,835,349	2,472,788	4,308,137	26.9
5/16/24	10,794	6,239	52.5	Full Phase I	B	1.7	2,378,527	3,646,354	6,024,882	28.4
5/17/24	10,279	4,272	51.7	Full Phase I	A	2.4	2,265,044	2,496,750	4,761,794	22.8
5/20/24	10,476	5,438	54.9	Full Phase II	C	1.9	2,308,454	3,178,214	5,486,668	24.7
5/21/24	9,290	4,927	50.7	Full Phase II	B	1.9	2,047,111	2,879,562	4,926,673	24.0
5/22/24	8,860	3,894	52.3	Full Phase II	A	2.3	1,952,358	2,275,830	4,228,188	20.0
Subtotal	21,572	11,060	54.2	Pilot + Full Phase I + II	C	2.0	4,763,250	6,487,033	11,250,283	51.3
Subtotal	20,084	11,166	51.6	Full Phase I + II	B	1.8	4,425,638	6,525,916	10,951,555	52.4
Subtotal	19,139	8,166	52.0	Full Phase I + II	A	2.3	4,217,402	4,772,580	8,989,982	42.7
Subtotal	32,169	16,133	157.6	Pilot + Full Phase I	P, C, B, A	2.0	7,098,367	9,451,925	16,550,291	25.9
Subtotal	28,626	14,259	157.9	Full Phase II	C, B, A	2.0	6,307,923	8,333,606	14,641,529	22.9
Total	**60,795**	**30,392**	**157.8**	**Pilot + Full Phase I + II**	**P, C, B, A**	**2.0**	**13,406,290**	**17,785,530**	**31,191,820**	**48.9**

[1] Gallons of alum and aluminate and acres treated were provided by the applicator in a final completion report (SOLitude Lake Management, 2024).

[2] The mass of Al in the alum and aluminate solutions was determined by multiplying the volume of each solution by the density (i.e., specific gravity in g/L) and percentage of Al (i.e., percentage of Al_2O_3 in solution multiplied by percentage of Al in Al_2O_3 based on atomic weight or 0.5293) in each batch of solution, according to the Certificate of Attributes (COA) submitted by the supplier, Holland Company, Inc. of Adams, MA. The COA information (4.5% Al and 1,330 g/L for alum and 10.6% Al and 1,500 g/L for aluminate) was used to estimate daily dose for the pilot treatment on 4/30/24. The COA information for all other dates during the full treatment was averaged (4.4% Al and 1,328 g/L for alum and 10.4% Al and 1,483 g/L for aluminate) since it is unknown how much of each additional batch mixed with the previous batch as the storage tanks were continually refilled during the full treatment.

[3] The dose (g Al/m^2) was determined by summing the mass of Al in the alum and aluminate solutions (i.e., Total (g Al)) and dividing by the area treated.

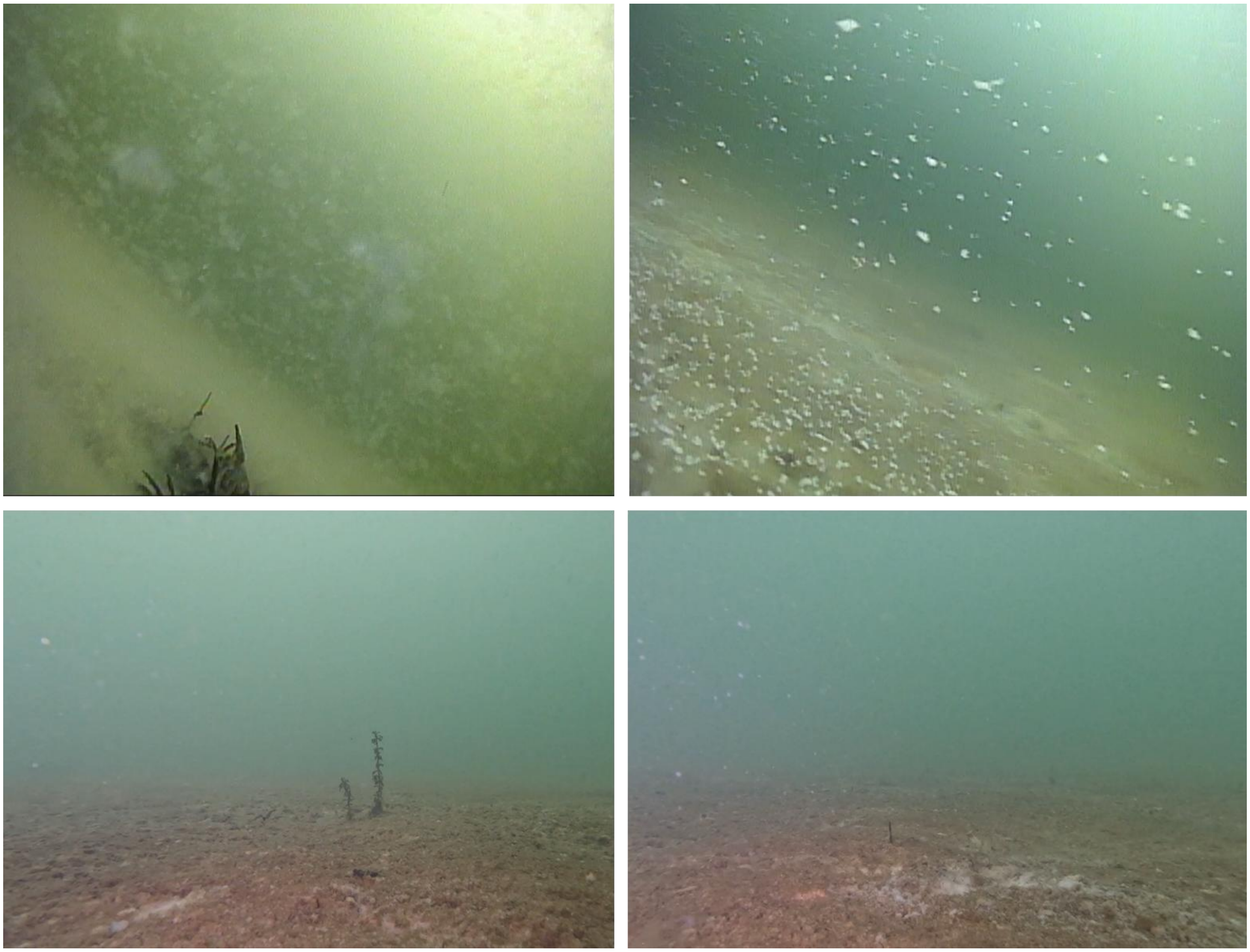
Table 3. Limit of application for aluminum compound additions to Lake Kanasatka.

Chemical Additive	Approx. Ratio of Application	Max daily dose (g Al/m^2)	Max total dose (g Al/m^2)
Aluminum Sulfate ($Al_2(SO_4)_3$) Sodium Aluminate ($NaAlO_2$)	2:1 alum:aluminate	25	50

Table 4. Total precipitation and average wind speed on each treatment day. Weather data obtained from NOAA NCEI online for station LACONIA, NH US WBAN:54736 (ICAO:KLCI).

Date	Total Precip (in)	Avg Wind Speed (mph)
4/30/24	0.12	7.2
5/15/24	0.69	3.0
5/16/24	0.01	4.0
5/17/24	0.00	4.2
5/20/24	0.00	3.6
5/21/24	0.00	5.3
5/22/24	0.00	7.1

Photos highlighting the treatment: (TOP LEFT) NHDES (A. Smagula, D. Neils) and FBE (L. Diemer) on NHDES boat for third-party monitoring on the pilot treatment day. (TOP RIGHT) Plume of aluminum compounds hydrolyzing into alum floc. (MIDDLE LEFT) Aluminum compounds were applied in alternating strips for aquatic life protection. (MIDDLE RIGHT) NHDES (M. Maynard) and FBE (C. Bunyon) on NHDES boat for third-party monitoring during the second phase of the full treatment. (BOTTOM LEFT) Key third-party monitors from UNH LLMP (G. Bunnell, A. McQuaid), LKWA (L. Hutchinson), and FBE (L. Diemer, C. Bunyon). (BOTTOM RIGHT) LKWA (L. Hutchinson) and UNH LLMP (A. McQuaid, G. Bunnell, B. Craycraft) performing baseline monitoring prior to treatment. Photos taken by NHDES, LKWA, UNH, and FBE.



Photos highlighting alum floc evaluation: (TOP) Alum floc settling through the water column and onto bottom sediments during active treatment on 5/17/24 and 5/21/24, using NHDES underwater camera. (BOTTOM) Alum floc settled into bottom sediments post-treatment on 6/20/24 in Zones A and B. Photos taken using FBE underwater camera.

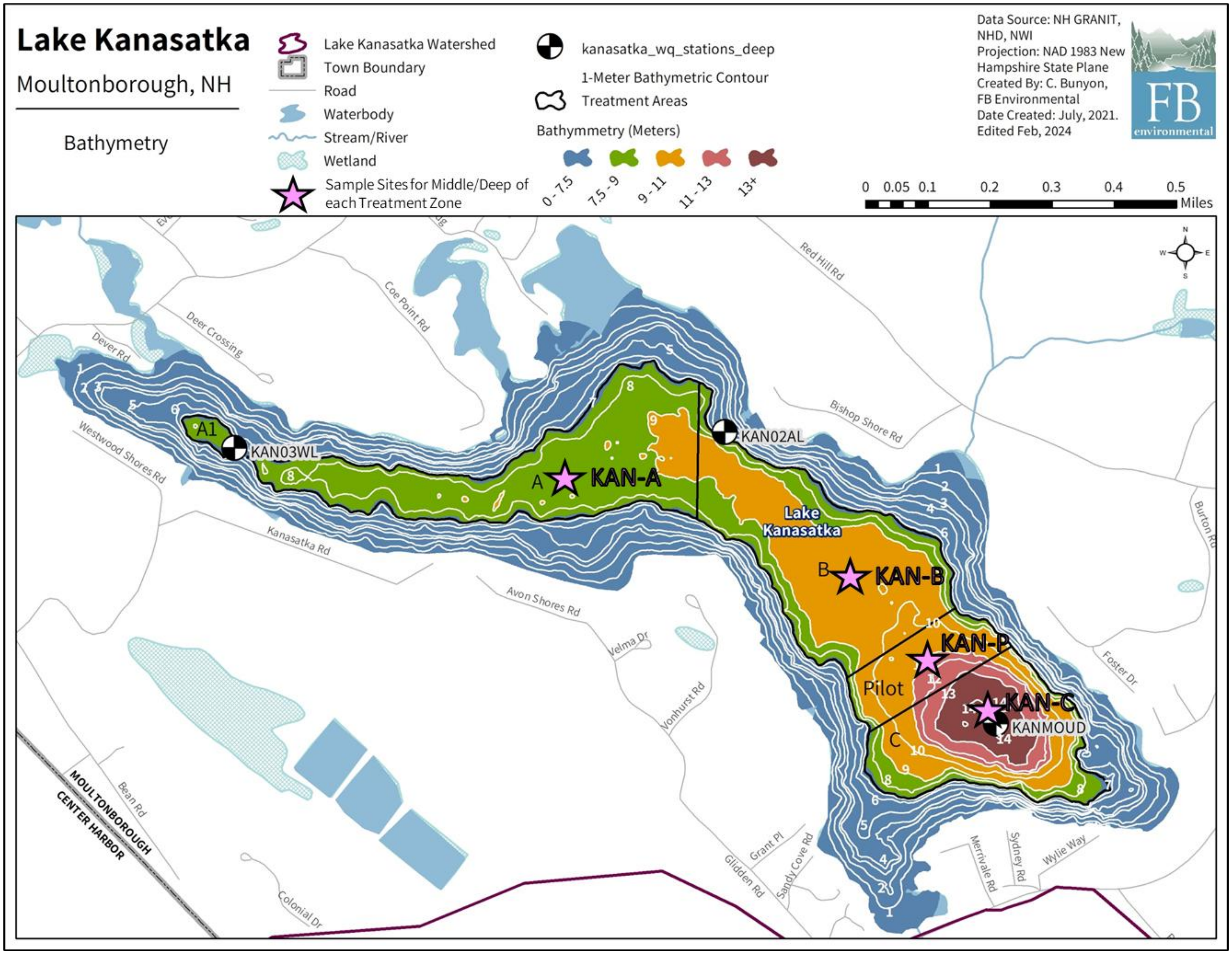


Figure 2. Bathymetric map of Lake Kanasatka showing the three main treatment zones (A, B, and C) and the pilot treatment area (Zone P) as a portion of Zone C, as well as the sample sites for the middle/deep spot of each treatment zone.

Receiving Water Limits

Water quality criteria have been established to minimize the likelihood of impacts on aquatic life. Table 5 includes limits for total and acid soluble aluminum based on criteria established by EPA and NHDES, respectively, for both chronic and acute conditions[6]. Even with careful application, chronic and acute criteria limits for aluminum are often exceeded in the short-term, but the toxicity of applied aluminum is greatly curtailed by maintaining pH between the desired range of 6.5 and 8.0 (refer to limitations discussion below). Turbidity limits are also included as one means of assessing and minimizing the impact of physical alum floc presence on biota.

Current NHDES acute and chronic criteria are 750 µg/L (single sample maximum and volumetric average of all samples after daily treatment) and 87 µg/L (4-day volumetric average of all samples), respectively, for the acid soluble aluminum fraction (NHDES administrative rule Env-Wq 1700). In 2018, EPA published updated aluminum water quality criteria which depend on pH, hardness, and dissolved organic carbon (EPA-822-R-18-001). 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).

Table 5. Limit of receiving water quality criteria for Lake Kanasatka. Adapted from NHDES Permit No. Lake Kanasatka – 002.

Parameter	Daily Event Maximum (Acute)[A]	4-Day Average (Chronic)[B]	End of Permit Term[C]
Acid Soluble Aluminum (µg/L)	750	87	Baseline
Total aluminum (µg/L) *and Acid Soluble Aluminum*[5]	Depends on pH, hardness, DOC	Depends on pH, hardness, and DOC	Baseline
Turbidity	10 NTU above baseline	10 NTU above baseline	Baseline
pH	6.5-8.0	6.5-8.0	Baseline

A. For acid soluble aluminum and turbidity, attainment of acute criteria is determined from the average of all samples collected during each sampling event within the respective treatment zone after a daily treatment has been completed in the respective zone. Average for aluminum and turbidity was interpreted as volumetric average of multiple grab samples collected throughout the water column, if applicable. For pH, attainment of acute criteria is determined from the 1-hour running average of continuous pH measures taken throughout a day's treatment period within the respective daily treatment zone. Average for pH was interpreted as the log-average. The permit also requires a record of single sample maximum aluminum and turbidity and the minimum and maximum 1-hour running average pH for each day of monitoring.

B. For acid soluble aluminum and turbidity, attainment of chronic criteria is determined from the 4-day running average of the daily average of all samples collected within each respective treatment zone. Average for aluminum and turbidity was interpreted as volumetric average of multiple grab samples collected throughout the water column, if applicable, with multiple events per day averaged together. For pH, attainment of chronic criteria is determined from the 4-day running average of pH measures taken in continuous pH measures taken throughout a day's treatment period within the respective treatment zone. Average for pH was interpreted as the log-average.

C. End of permit term is the sampling event for which the volumetric average of acid soluble aluminum is equal to or less than baseline or pre-treatment volumetric average of acid soluble aluminum, plus 20% of the remaining assimilative capacity for aluminum in the lake (calculated as 27 ppb). Total aluminum, turbidity, and pH should also return to baseline or pre-treatment conditions by the last sampling event of the year.

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[6] NHDES currently aligns their acute (1-hour average) and chronic (4-day average) criteria for aluminum with EPA's 1988 guidance, which based the criteria on numerous laboratory studies using 15 species for the acute criterion (cladocerans, midge, snail, fathead minnow, stonefly, amphipod, planarian, and several fish species) and three species for the chronic criterion (two cladocerans and fathead minnow). The final chronic criterion was lowered from 748 µg/L to 87 µg/L to protect brook trout and striped bass under slightly acidic conditions (pH 6.5-6.6). These criteria are conservative and based on studies conducted under certain conditions, such as pH between 6.5 and 9.0. In revised 2018 EPA guidance, acute and chronic criteria for aluminum now use a more flexible, bioavailability-based approach that accounts for pH, dissolved organic carbon, and total hardness. These revised criteria incorporate broader toxicity data from 1989-2017 and employ multiple linear regression models using 22 species (cladocerans were most sensitive) for the acute criterion (LC50 for 96-hour exposure and EC50 for 48-hour exposure) and 12 species for the chronic criterion (EC20 for 6 to 60-day exposures). The acute (and chronic) criteria are "expected to protect 95% of species in a representative aquatic community from acute effects" (p. 41). Both the 1988 and 2018 EPA guidance base the criteria on total recoverable aluminum, though EPA recommends using acid soluble aluminum, and EPA indicated in the 1988 guidance that studies using total recoverable aluminum or acid soluble aluminum were not distinguished and instead combined in analyses for establishing criteria. Using total recoverable aluminum overestimates the bioavailability of aluminum that could be toxic to aquatic life because it includes both soluble and insoluble or particulate (harmless) forms of aluminum in the water. Although NHDES currently uses the 1988 EPA criteria, the 2024 Consolidated Assessment & Listing Methodology indicates that the NHDES criteria are applied to the more bioavailable form of acid soluble aluminum and not total recoverable aluminum. Given this, we applied the 2018 EPA criteria to both acid soluble aluminum and total aluminum, with emphasis on any exceedances for acid soluble aluminum.

There are some important limitations to consider with the continuous pH monitoring approach conducted for this treatment project. pH sensor technology uses a glass membrane electrode (i.e., measurement electrode) that interacts primarily with hydrogen ions in water to generate a voltage difference between the measurement electrode and the reference electrode. The voltage is converted to a pH value and compensated for temperature.

In a stable water environment, it can take 30-60 seconds or more for a pH sensor to stabilize and provide an accurate reading, but most sensors can respond in 10 seconds with 90% of a step change in pH. This becomes different in a dynamic water environment such as during an alum treatment when the addition of aluminum compounds are driving rapid chemical reactions that are instantaneously altering the pH. This is further compounded by moving the sonde through the water at about 3-5 mph behind the barge. At best, the continuous pH measurements can be interpreted as possibly up to 90% step-change of a rolling average of readings every 20-34 ft as the sonde moves through a plume at 3-5 mph and provides readings every 10 seconds. However, these measurements reflect the state of the reactions in water anywhere from 45 seconds to 2 minutes and 30 seconds following injection, rather than the initial impact and recovery of pH at any spatial point following injection. The latter would be more appropriate and applicable to evaluating impact to aquatic life since organisms would theoretically not be following the barge at a constant speed and exposed to those initially-variable pH values continuously. Thus, it is recommended that future plume monitoring be done from static locations as close to initial injection as possible.

While the measurement electrode is ion-specific, meaning it generally only detects hydrogen ions, other ions such as sodium (Na^+) can interfere with readings. If there is significantly more sodium ions compared to hydrogen ions (under neutral to basic pH), then the pH sensor may falsely read a lower (acidic) pH because the sensor interprets the sodium ions as hydrogen ions. Because of the rapid and incomplete reactions as the aluminum compounds hydrolyze and mix throughout the water column, it is difficult to know how much the dissociated sodium ions would interfere with hydrogen ions on the glass electrode membrane at any given time.

Given the short-term nature of these treatments, there are also some important limitations to consider when designing a monitoring protocol and then applying receiving water limits to the parameters identified in Table 5. For example, when and where is it appropriate to monitor for these critical parameters? It is relatively easy to continuously monitor pH (recommend including turbidity in the future) behind the barge to generate a rolling average that smooths out the instantaneous and short-term variability in pH to then be compared to receiving water limits (and likely meet). However, there is a time lag from the moment of injection to when the third-party monitor can catch up to capture the pH dynamics, at which point we are already seeing a dampened effect as the reactions proceed. This may be a limitation that we have to accept without an alternative solution. It is more difficult to discretely monitor aluminum at some seemingly random timepoint following treatment and appropriately apply receiving water limits for acute 1-hour exposure. This study's protocol was to sample aluminum at discrete depths once treatment in a zone was complete for the day. The precise sampling location in the zone may have been last treated hours before but with some influence from all treated areas in the zone through horizontal mixing and currents. Conversely, the precise sampling location in the zone may have been just treated with minimal time for horizontal and vertical mixing and reaction times to reduce the initially high aluminum concentrations that would then continue to decrease over time. The question is whether these examples are representative of "acute 1-hour exposure" limits for aluminum.

Monitoring Schedule

Monitoring of key water quality and biological parameters before, during, and after treatment was completed according to the permit. Table 6 provides a summary of parameters measured, the timing of measurements, and the locations of measurements taken. Refer to Figure 2 for a map of treatment zones and sampling locations.

Pre-Treatment Monitoring

Pre-treatment monitoring included sampling by UNH LLMP at the middle deep spots of the three treatment zones (C, B, A) on the morning of the pilot treatment on 4/30/24. LKWA volunteers completed wildlife surveys. The following sampling was conducted:

- Field measurements of temperature, dissolved oxygen, pH, and specific conductance were collected at 1-meter depth intervals.
- Secchi disk transparency readings were collected.
- At 1-, 3-, 5-, 9-, and 13-meters depth, grab samples were collected and submitted for laboratory analysis of acid soluble aluminum, total aluminum, and total phosphorus.
- Mid-meta cores were collected for analysis of chlorophyll-a, alkalinity, hardness, dissolved organic carbon, and turbidity.
- Mid-meta tows with a 50 μm net size were collected for phytoplankton and zooplankton analysis.
- A shoreline survey by LKWA for any distressed organisms was conducted prior to treatment to set a baseline.

During Active Treatment Monitoring

During active treatment, FBE and NHDES collected water quality and environmental data from a separate vessel. FBE communicated immediately with the applicator if any problems were indicated, including high or low pH, fish kills, or other negative impacts that may have required cessation and/or modification of the treatment protocol.

Prior to treatment on each of the six full treatment days (5/15-17/24, 5/20-22/24), the approximate deepest middle area of each treatment zone (C, B, A) was sampled by UNH LLMP and/or NHDES for the following:

- Field measurements of temperature, dissolved oxygen, pH, and specific conductance were collected at 1-meter depth intervals.
- Secchi disk transparency readings were collected.
- At 1-, 3-, 5-, 9-, and 13-meters depth, grab samples were collected and submitted for laboratory analysis of acid soluble aluminum and total aluminum.
- Mid-meta cores were collected for analysis of chlorophyll-a, alkalinity, hardness, dissolved organic carbon, and turbidity.
- Mid-meta tows with a 50 μm net size were collected for phytoplankton and zooplankton analysis.
- A shoreline survey by LKWA for any distressed organisms was conducted to check for fish, shellfish, snail, amphibian, and bird fatalities or behavioral abnormalities and other signs of potential aluminum or pH toxicity.

During active treatment, FBE and NHDES followed behind the applicator in the plume (100-200 meters) and continuously monitored pH at about 2 meters depth using NHDES' AquaTROLL 500 multiparameter data sonde. Evaluation of floc was completed via a NHDES underwater camera to inspect floc formation and settling, as well as any noticeable distress to visible aquatic organisms. Shortly after treatment completion on each day, the deepest middle area of the treated zone (P, C, B, A) was sampled by FBE and NHDES for the following:

- Field measurements of temperature, dissolved oxygen, pH, and specific conductance were collected at 1-meter depth intervals.
- At 1-, 3-, 5-, 9-, and 13-meters depth, grab samples were collected and submitted for laboratory analysis of acid soluble aluminum and total aluminum.
- Mid-meta cores were collected for analysis of alkalinity, hardness, dissolved organic carbon, and turbidity.

- Mid-meta tows with a 50 µm net size were collected for phytoplankton and zooplankton analysis.
- A shoreline survey by LKWA for any distressed organisms was conducted to check for fish, shellfish, snail, amphibian, and bird fatalities or behavioral abnormalities and other signs of potential aluminum or pH toxicity.

Post-Treatment Monitoring

For post-treatment monitoring, UNH LLMP completed the following monitoring at the approximate deepest middle area of each treatment zone (C, P, B) the day after the pilot treatment (5/1/24) and the week after the pilot treatment (5/7/24); at the approximate deepest middle area of each treatment zone (C, B, A) the day after the first phase of the full treatment was completed (5/18/24), the day after the second phase of the full treatment was completed (5/23/24), and weekly for four weeks after the full treatment was completed (5/31/24, 6/7/24, 6/13/24, 6/20/24); and at the deepest middle area of treatment zone C monthly thereafter for four months (7/22/24, 8/23/24, 9/20/24, 10/18/24), for a total of 12 sampling events:

- Field measurements of temperature, dissolved oxygen, pH, and specific conductance were collected at 1-meter depth intervals.
- Secchi disk transparency readings were collected.
- At 1-, 3-, 5-, 9-, and 13-meters depth, grab samples were collected and submitted for laboratory analysis of acid soluble aluminum, total aluminum, and total phosphorus. Acid soluble aluminum and total aluminum were ceased after the August monthly sampling event because aluminum had returned to baseline or pre-treatment conditions.
- Mid-meta cores were collected for analysis of chlorophyll-a, alkalinity, hardness, dissolved organic carbon, and turbidity. Alkalinity, hardness, dissolved organic carbon, and turbidity were ceased after the August monthly sampling event because aluminum had returned to baseline or pre-treatment conditions.
- Mid-meta tows with a 50 µm net size were collected for phytoplankton and zooplankton analysis.
- A shoreline survey by LKWA for any distressed organisms was conducted to check for fish, shellfish, snail, amphibian, and bird fatalities or behavioral abnormalities and other signs of potential aluminum or pH toxicity. Formal documentation of visual assessments by LKWA were ceased after 6/20/24.
- Floc evaluation by underwater camera was conducted by FBE during one of the weekly sampling events (6/20/24).

Field duplicates were collected for at least 10% of the total number of samples for each laboratory-analyzed parameter: alkalinity, dissolved organic carbon, hardness, chlorophyll-a, acid soluble aluminum, and total aluminum. Total phosphorus needed 13 duplicates for the 130 samples analyzed, but only two duplicates were collected and analyzed; both met the quality control criterion of less than 20% relative percent difference (RPD). All other parameters also met the less than 20% RPD criterion, except for the 5/31/24 KAN-B 0-7-meter integrated core for chlorophyll-a (borderline at 21% and deemed acceptable).

Table 6. Monitoring schedule for Lake Kanasatka. Blue shaded parameters are field measurements; yellow shaded parameters are specific to treatment toxicity assessment; light yellow shaded parameters are nutrients important to tracking changes in internal loading and cycling; green shaded parameters are biological metrics; the grey shaded parameter is related to physical floc evaluation using a camera.

Treatment Phase	**Pre-Treatment**	**During Treatment**			**Post-Treatment**		
Treatment Dates/Times	4/30/24 AM	5/15-17/24, 5/20-22/24 AM	Active treatment	Within 1-2 hours of active treatment	5/1/24, 5/7/24	5/18/24, 5/23/24, 5/31/24, 6/7/24, 6/13/24, 6/20/24	7/22/24, 8/23/24, 9/20/24, 10/18/24
Treatment Zones	Zones C, B, A	Zones C, B, A	In plume**	Zones C, P, B, A	Zones C, P, B	Zones C, B, A	Zone C
Secchi Disk Transparency	•	•			•	•	•
Profile (1-m intervals): DO/Cond/pH/Temp	•	•	•	•	•	•	•
Turbidity (mid-meta core) ^	•	•		•	•	•	•
Alkalinity (mid-meta core) ^	•	•		•	•	•	•
Hardness (mid-meta core) ^	•	•		•	•	•	•
Dissolved Organic Carbon (mid-meta core) ^	•	•		•	•	•	•
Total and acid soluble aluminum (1, 3, 5, 9, 13 m) ^	•	•		•	•	•	•
Total Phosphorus (1, 3, 5, 9, 13 m)	•				•	•	•
Chlorophyll-a (mid-meta core)	•	•			•	•	•
Phytoplankton & Zooplankton (mid-meta tow)	•	•		•	•	•	•
Fish & Aquatic Life [1]	•	•	•	•	•	•	•
Floc evaluation with camera			•			•	

*** continuously ~ 2 meters depth between 100-200 meters behind the barge*
^ collection of aluminum, alkalinity, hardness, dissolved organic carbon, and turbidity samples discontinued once background levels of aluminum are achieved following treatment
[1] surveyors observed shoreline areas for fish, shellfish, snail, amphibian, and bird fatalities, insect hatches, and other signs of potential aluminum or pH toxicity, particular focus on downwind shoreline areas

MONITORING RESULTS

pH

On 4/30/24 during the pilot treatment of Zone P, pH was variable in the morning due to air in the lines causing initial dispersal and mixing issues, according to the applicator (Figure 3). The first run from 9:15-9:30 was not recorded on the sonde, but pH ranged from 5.4 to 8.5. In-between the first few runs, pH continued to be recorded in the plume, after which pH was largely only recorded during active treatments. The run from 10:11 to 10:24 was highly variable, likely due to being closer to the barge. The applicator spread out the remaining few gallons of sodium aluminate in the treatment zone from 13:19 to 13:25 to complete the pilot treatment. Continuous pH behind the barge ranged from 5.5 to 9.3 with a median of 7.4. The one-hour and four-day rolling log-average pH remained within the range of 6.5 and 8.0, meeting state criteria (Tables 7, 8). The applicator's pH measurements behind the barge or elsewhere in the zone collected at 0.25 meters depth ranged from 6.22 to 6.92 (SOLitude Lake Management, 2024).

On 5/15/24 during the first phase of the full treatment of Zone C, pH was relatively stable throughout the day (Figure 4). The third-party monitor maintained a boating distance of 100 to 200 meters behind the barge. The applicator adjusted the sodium aluminate down 3% on two runs from 12:01 to 12:25 and 12:50 to 13:06, the latter of which was a bit acidic but recovered on subsequent runs. The sonde was stopped partway through the final run of the day from 14:18 to 14:44 due to a pH sensor error. Continuous pH behind the barge ranged from 5.7 to 8.9 with a median of 7.2. The one-hour and four-day rolling log-average pH remained within the range of 6.5 and 8.0, meeting state criteria (Tables 7, 8). The applicator's pH measurements behind the barge or elsewhere in the zone collected at 0.25 meters depth ranged from 7.02 to 8.06 (SOLitude Lake Management, 2024).

On 5/16/24 during the first phase of the full treatment of Zone B, pH was highly variable and acidic (Figure 4). During the third run from 9:48 to 10:05, the pH sensor began reading a constant 7.0 without any expected fluctuation despite being in the dynamic plume. The sonde was stopped for troubleshooting and recalibration. The fourth run from 10:40 to 10:53 showed extremely low pH. The pH sensor was determined to be potentially faulty, and the third-party monitor awaited the delivery of a replacement sonde with a new pH sensor in the afternoon beginning with the seventh run from 13:05 to 13:24, during which the sodium aluminate was adjusted up by 3% to buffer the low pH response. Sodium aluminate was adjusted up again during the eighth run from 13:56 to 14:17 and the pH began to respond, though remained slightly acidic for the remaining runs. Continuous pH behind the barge ranged from 4.9 to 8.1 with a median of 6.7. The four-day rolling log-average pH remained within the range of 6.5 and 8.0, meeting state criteria (Table 8). The one-hour rolling log-average pH remained within the range of 6.5 and 8.0, meeting state criteria for 4 of the 7 runs with recorded data (out of the total 11 runs); 30% of continuous pH readings fell below 6.5 (Table 7). The response of Zone B on 5/16/24 seems to be an anomaly, and it is unclear why. It is possible that it was due to a combination of pH sensor errors and unique geochemistry from local spring upwelling suspected in Zone B. The applicator's pH measurements behind the barge or elsewhere in the zone collected at 0.25 meters depth ranged from 6.80 to 7.87 (SOLitude Lake Management, 2024).

On 5/17/24 during the first phase of the full treatment of Zone A, pH was relatively stable throughout the day but became more acidic near the edge of Zone B (Figure 4). The eighth run from 14:46 to 15:02 was very acidic on the first strip so the applicator adjusted the sodium aluminate up and pH stabilized to more neutral. Continuous pH behind the barge ranged from 5.4 to 8.1 with a median of 7.0. The one-hour and four-day rolling log-average pH remained within the range of 6.5 and 8.0, meeting state criteria (Tables 7, 8). The applicator's pH measurements behind the barge or elsewhere in the zone collected at 0.25 meters depth ranged from 6.93 to 7.59 (SOLitude Lake Management, 2024).

On 5/20/24 during the second phase of the full treatment of Zone C, pH was relatively stable throughout the day (Figure 5). The sonde was not recording during the sixth run from 12:23 to 12:47 but ranged from about 6.5 to 7.2 and stabilized to 6.9 after the run was completed. Continuous pH behind the barge ranged from 5.4 to 8.0 with a median of 7.1. The four-day rolling log-average pH remained within the range of 6.5 and 8.0, meeting state criteria (Table 8). The one-hour rolling log-average pH remained within the range of 6.5 and 8.0, meeting state criteria for 7 of 9 runs with recorded data (out of the total 10 runs); 3% of continuous pH readings fell below 6.5 (Table 7). The applicator's pH measurements behind the barge or elsewhere in the zone collected at 0.25 meters depth ranged from 6.82 to 8.52 (SOLitude Lake Management, 2024).

On 5/21/24 during the second phase of the full treatment of Zone B, pH was relatively stable throughout the day (Figure 5). During the fifth run from 11:36 to 11:52, the applicator stopped treatment because a dark gray material was coming out of the sodium aluminate tanks. Upon further investigation back on shore, the storage tanks on land were found to have run out before the next delivery, and the solution at the bottom of the tank had crystalized into a dark gray material. Treatment resumed in the early afternoon after the next delivery to refill the storage tanks was made. While waiting for the next delivery, the third-party monitor recorded pH in previously-treated areas of the treatment zone. The sonde was not recording at the beginning of the eighth run, but pH ranged from 6.9 to 7.4. Continuous pH behind the barge ranged from 5.7 to 7.9 with a median of 7.1. The one-hour and four-day rolling log-average pH remained within the range of 6.5 and 8.0, meeting state criteria (Tables 7, 8). The applicator's pH measurements behind the barge or elsewhere in the zone collected at 0.25 meters depth ranged from 6.55 to 8.63 (SOLitude Lake Management, 2024).

On 5/22/24 during the second phase of the full treatment of Zone A, pH was relatively stable but low throughout most of the day except for the last run (Figure 5). The applicator noted that the sodium aluminate had to be adjusted lower to be sure they could maintain a 2:1 alum:aluminate ratio since no further deliveries were planned. A higher alum:aluminate ratio on this treatment day may account for the lower pH. The last run of the day used a lower alum:aluminate ratio to finish out the last of the reserves for the project. Gaps in continuous pH data during runs were due to the sonde not recording. Continuous pH behind the barge ranged from 5.6 to 8.0 with a median of 6.8. The one-hour rolling log-average pH remained just above 6.5, meeting state criteria, except for a brief time at the beginning of the second run from 8:53 to 9:16; 6% of continuous pH readings fell below 6.5 (Table 7). The four-day rolling log-average pH remained within the range of 6.5 and 8.0, meeting state criteria (Table 8). The applicator's pH measurements behind the barge or elsewhere in the zone collected at 0.25 meters depth ranged from 6.28 to 8.46 (SOLitude Lake Management, 2024).

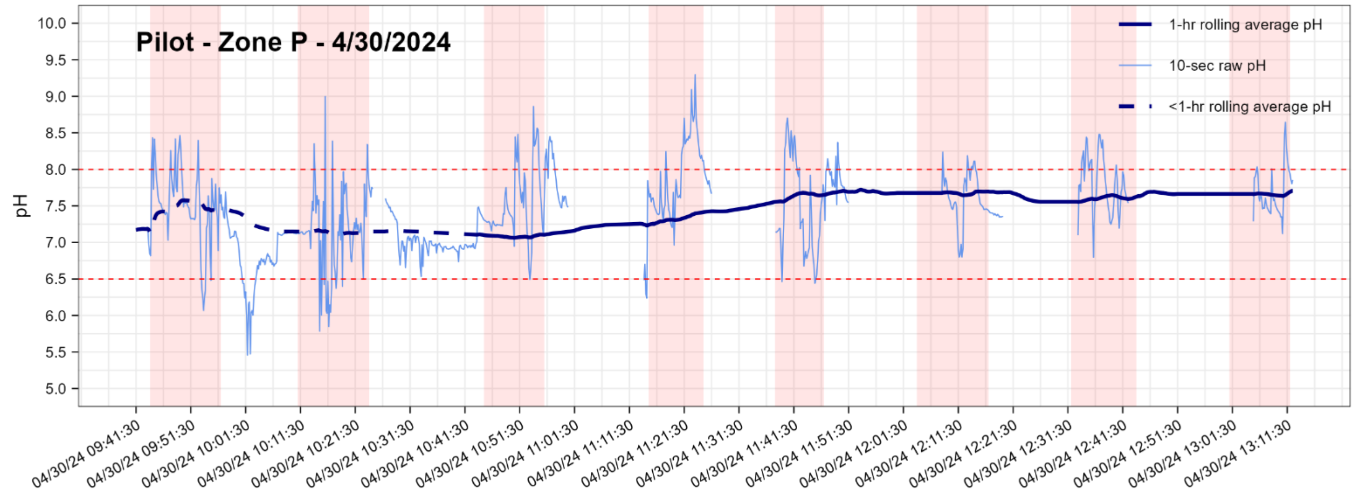

Figure 3. 10-second continuous pH readings (light blue line) measured during the pilot treatment of Zone P on 4/30/24 by a NHDES-owned AquaTROLL 500 deployed in 1-2 meters of water off the side of a NHDES-owned boat, trolling through treated areas approximately 100-200 meters behind the treatment barge. The solid and dotted dark blue line represents the hourly and sub-hourly rolling log-average pH, respectively. The dotted red lines represent the low (6.5) and high (8.0) ends of the acceptable range of pH in freshwater according to state water quality standards. Pink shaded areas represent active treatment times when the barge was dispensing aluminum compounds in the treatment zone.

Table 7. Summary statistics (average, minimum, maximum, count) of 1-hour (acute) rolling log-average pH by date, treatment phase, and zone. Bold, red text highlight pH measurements outside of the 6.5-8.0 acceptable range per state water quality standards and receiving water limits for the permit.

Date	Phase	Zone	Avg pH	Min pH	Max pH	Count Total	Count < 6.5	Count > 8.0	% > 6.5	% < 8.0
4/30/2024	Pilot	P	7.4	7.1	7.7	1,267	0	0	0%	0%
5/15/2024	Full Phase I	C (minus P)	7.2	6.9	7.7	1,959	0	0	0%	0%
5/16/2024	Full Phase I	B	6.7	**5.8**	7.3	3,420	1,015	0	30%	0%
5/17/2024	Full Phase I	A	7.0	6.6	7.2	4,500	0	0	0%	0%
5/20/2024	Full Phase II	C	7.0	**6.1**	7.4	4,161	110	0	3%	0%
5/21/2024	Full Phase II	B	7.1	6.8	7.6	5,279	0	0	0%	0%
5/22/2024	Full Phase II	A	6.7	**6.4**	7.3	4,035	222	0	6%	0%

Table 8. Summary statistics (average, minimum, maximum, count) of 4-day (chronic) rolling log-average pH by date, treatment phase, and zone. Red text highlight pH measurements outside of the 6.5-8.0 acceptable range per state water quality standards and receiving water limits for the permit.

Date	Phase	Zone	Avg pH	Min pH	Max pH	Count Total	Count < 6.5	Count > 8.0	% > 6.5	% < 8.0
4/30/2024	Pilot	P	7.3	7.1	7.6	1,267	0	0	0%	0%
5/15/2024	Full Phase I	C (minus P)	7.4	7.2	7.7	1,959	0	0	0%	0%
5/16/2024	Full Phase I	B	7.1	6.9	7.2	4,212	0	0	0%	0%
5/17/2024	Full Phase I	A	6.9	6.9	7.0	4,500	0	0	0%	0%
5/20/2024	Full Phase II	C	6.9	6.9	7.0	4,431	0	0	0%	0%
5/21/2024	Full Phase II	B	7.1	7.0	7.1	5,279	0	0	0%	0%
5/22/2024	Full Phase II	A	7.1	7.0	7.1	4,287	0	0	0%	0%

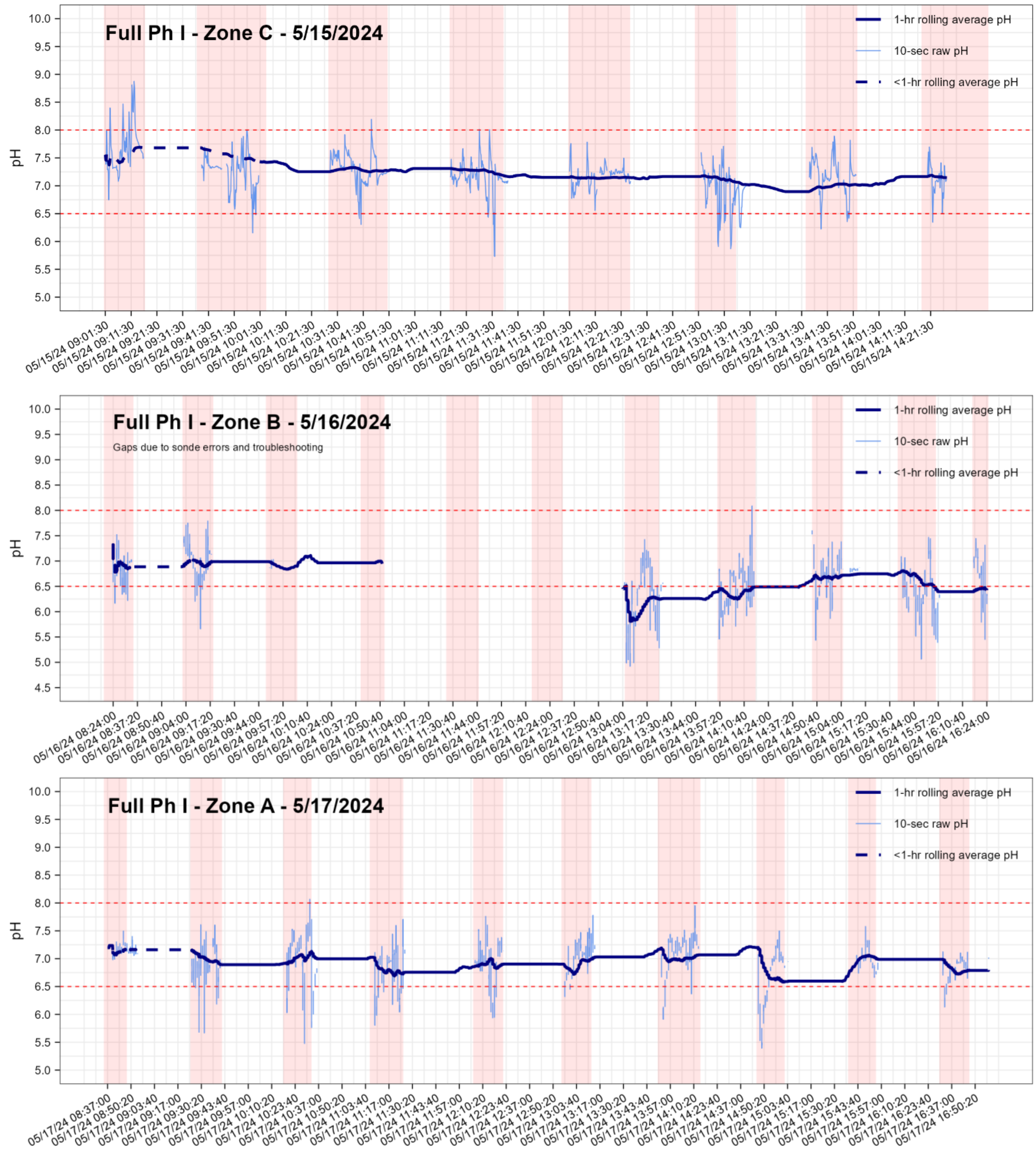

Figure 4. 10-second continuous pH readings (light blue line) measured during the first phase of the full treatment of Zones C, B, and A on 5/15/24, 5/16/24, and 5/17/24, respectively, by a NHDES-owned AquaTROLL 500 deployed in 1-2 meters of water off the side of a NHDES-owned boat, trolling through treated areas approximately 100-200 meters behind the treatment barge. The solid and dotted dark blue line represents the hourly and sub-hourly rolling log-average pH, respectively. The dotted red lines represent the low (6.5) and high (8.0) ends of the acceptable range of pH in freshwater according to state water quality standards. Pink shaded areas represent active treatment times when the barge was dispensing aluminum compounds in the treatment zone.

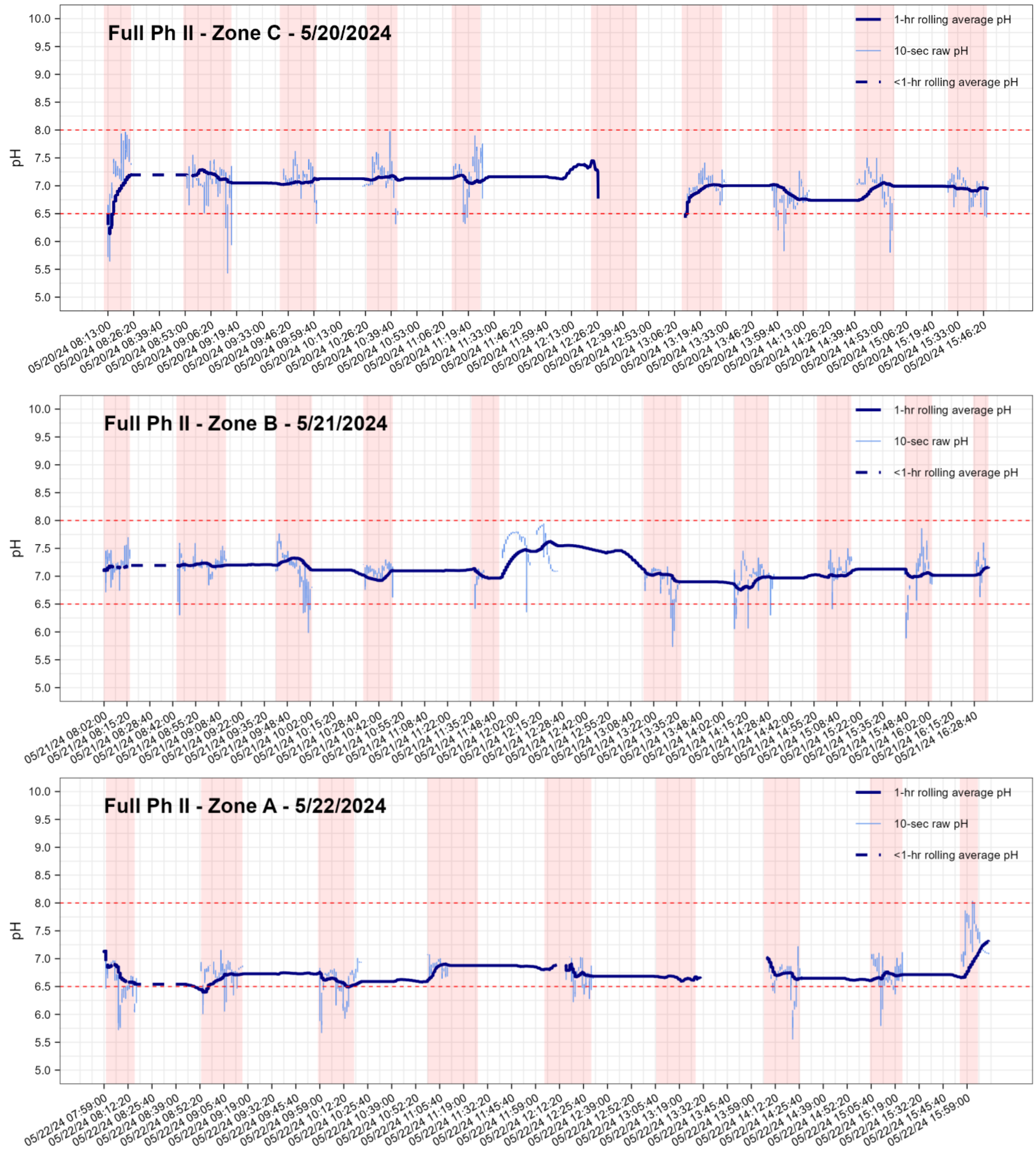

Figure 5. 10-second continuous pH readings (light blue line) measured during the second phase of the full treatment of Zones C, B, and A on 5/20/24, 5/21/24, and 5/22/24, respectively, by a NHDES-owned AquaTROLL 500 deployed in 1-2 meters of water off the side of a NHDES-owned boat, trolling through treated areas approximately 100-200 meters behind the treatment barge. The solid and dotted dark blue line represents the hourly and sub-hourly rolling log-average pH, respectively. The dotted red lines represent the low (6.5) and high (8.0) ends of the acceptable range of pH in freshwater according to state water quality standards. Pink shaded areas represent active treatment times when the barge was dispensing aluminum compounds in the treatment zone.

The continuous pH monitoring directly behind the barge as it is actively dispensing the aluminum compounds tracks the real-time extreme acute exposure risk to aquatic life. As the aluminum compounds hydrolyze into floc, pH fluctuates high or low depending on the baseline geochemistry and the precise alum:aluminate ratio applied during any given run. If applied under the optimal conditions, floc formation and settling occurs rapidly so that pH recovers quickly to baseline or near-baseline within the 6.5 to 8.0 pH range for aquatic life protection within minutes to hours after application. When applying the 6.5 to 8.0 pH criteria range to volumetric log-average pH from 1-meter increment profile measurements for 0-7 meters and whole water column by zone, pH for all zones falls within the 6.5 to 8.0 range, with a depression in pH during the full treatment phases I and II but partial recovery within an hour or the morning after treatment and full recovery to pre-treatment baseline conditions two weeks after treatment (Figure 6). We included a comparison of both volumetric averages for 0-7 meters and whole water column because NHDES typically excludes bottom pH readings in assessments due to the influence of decomposition processes that drive pH naturally lower in bottom waters compared to surface waters.

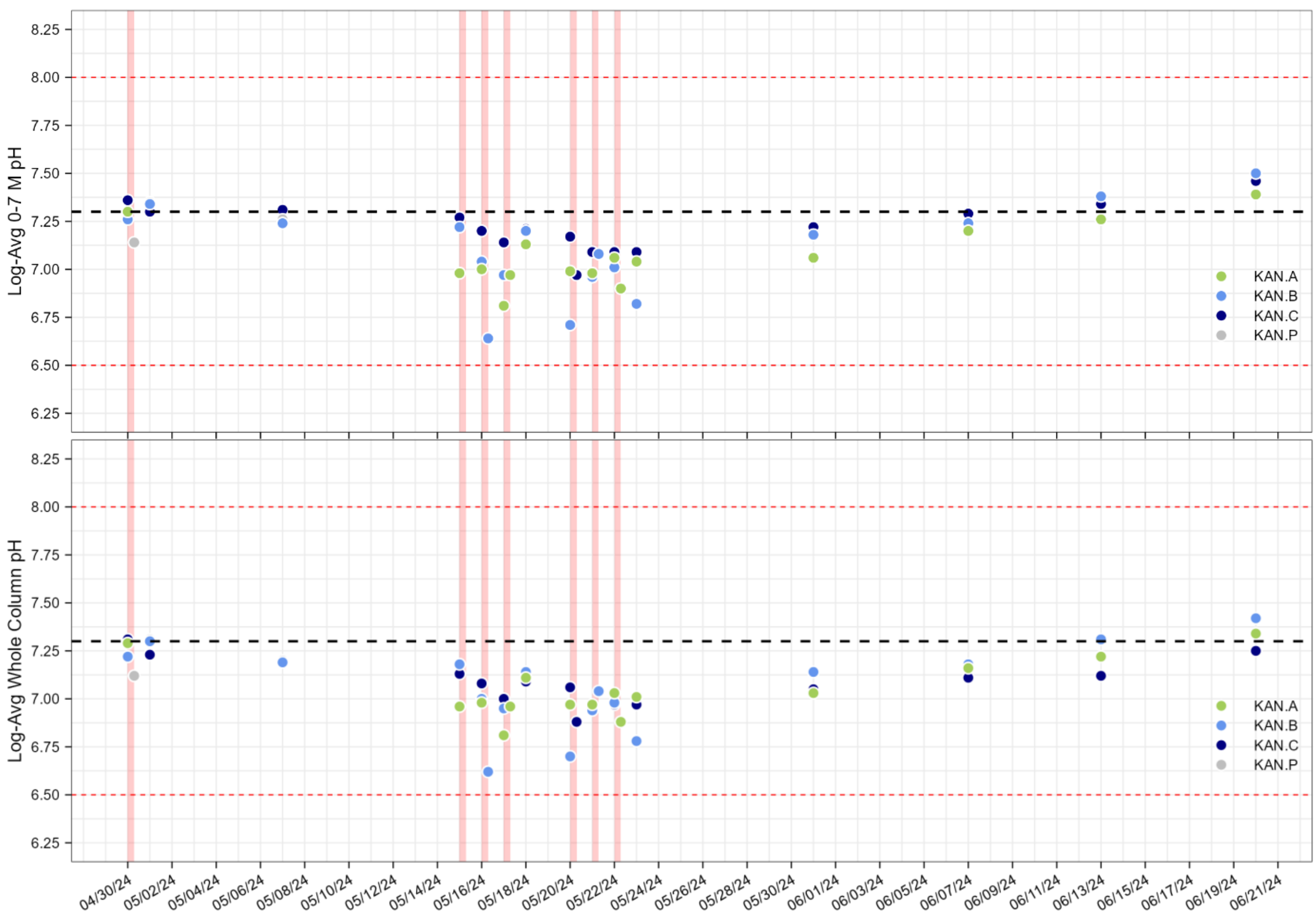

Figure 6. Volumetric log-average pH from 1-meter increment profile measurements for 0-7 meters (TOP) and whole water column (BOTTOM) by zone from 4/30/24 to 6/20/24, after which only KAN-C was monitored. The dotted red lines represent the low (6.5) and high (8.0) ends of the acceptable range of pH in freshwater according to state water quality standards. The dotted black line represents the baseline pH prior to treatment. Pink shaded areas represent active treatment days when the barge was dispensing aluminum compounds in the treatment zone.

Aluminum

Overall, aluminum concentrations spiked immediately after treatment in each treated zone but recovered by 46-75% the next morning and by 82-90% within one week after treatment was completed (Figures 7, 8). Aluminum concentrations met the background concentration target of 27 ppb within two months and measured below pre-treatment concentrations within three months (Figures 7, 8). Volumetric average acid soluble aluminum for whole water column representing discrete grabs collected at 1-, 3-, 5-, 9-, and 13-meters depth by zone and sample event exceeded the DES Criterion Maximum Concentration (CMC) (750 ppb) for acute 1-hour exposure on four occasions (Figure 7; Table 9). Applying EPA CMC criteria for total aluminum to acid soluble aluminum reduces the number of exceedances to three, matching the number of exceedances for total aluminum. Volumetric average total aluminum for the whole water column representing discrete grabs collected at 1-, 3-, 5-, 9-, and 13-meters depth by zone and sample event exceeded the DES Criterion Continuous Concentration (CCC) (87 ppb) for chronic 4-day exposure on 36 occasions (Figure 8; Table 9). Applying EPA CCC criteria for total aluminum to acid soluble aluminum reduces the number of exceedances to 12, one less than the number of exceedances for total aluminum. Single sample maximum aluminum concentrations for each sample day exceeded acute 1-hour exposure criteria 7 out of 17 sample days, representing the treatment days, for both DES CMC (750 ppb) and EPA CMC (variable) (Table 10). No exceedances occurred on non-treatment days, indicating recovery towards background concentrations immediately following treatment.

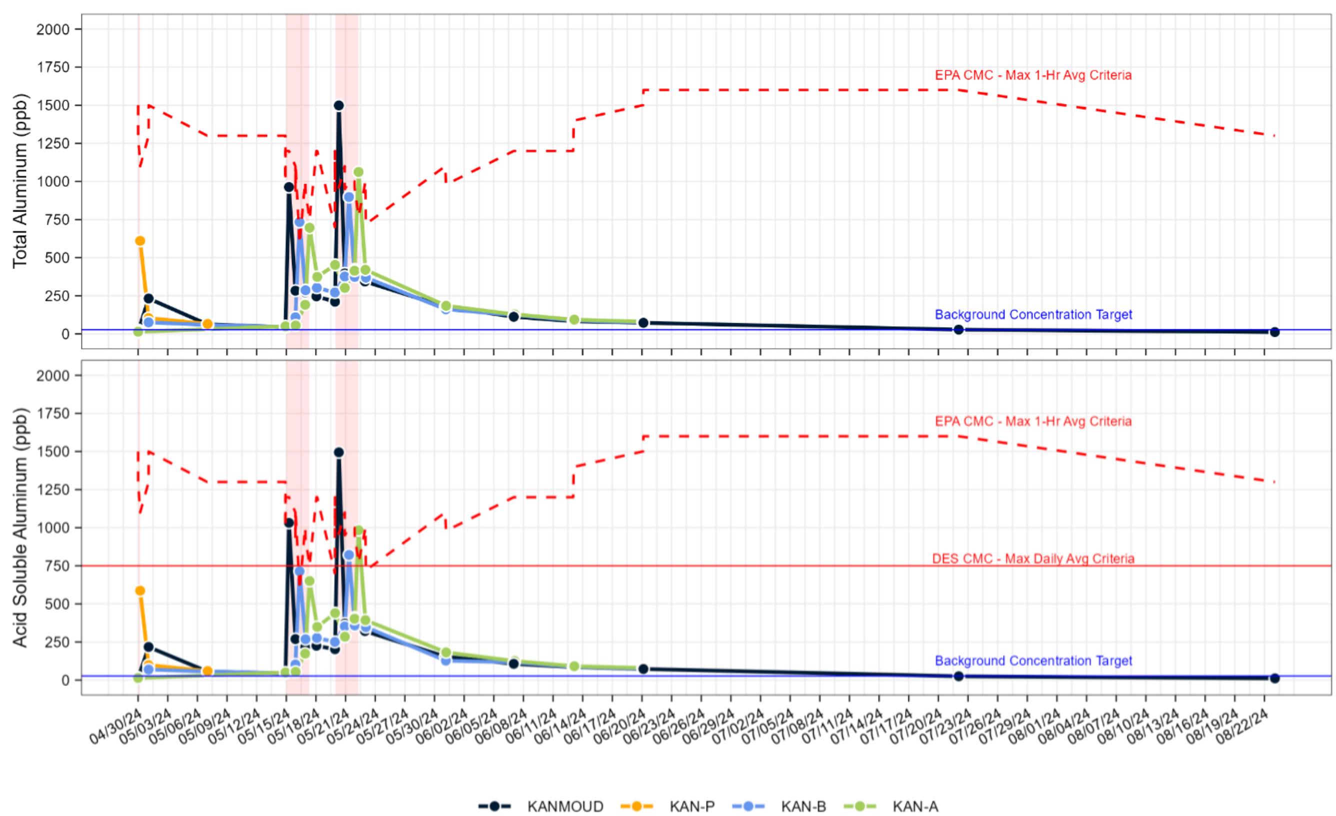

Figure 7. Volumetric average total aluminum (TOP) and acid soluble aluminum (BOTTOM) for whole water column (discrete grabs collected at 1-, 3-, 5-, 9-, and 13-meters depth) by zone and sample event from 4/30/24 to 6/20/24, after which only KAN-C (KANMOUD) was monitored. The dotted red line represents the EPA Criterion Maximum Concentration (CMC) for acute 1-hour exposure for total aluminum (also applied to acid soluble aluminum here), which depends on hardness, pH, and dissolved organic carbon. The solid red line represents the DES CMC at 750 ppb for acute 1-hour exposure for acid soluble aluminum. The blue line represents the target background concentration at 27 ppb. Pink shaded areas represent active treatment days when the barge was dispensing aluminum compounds in the treatment zone.

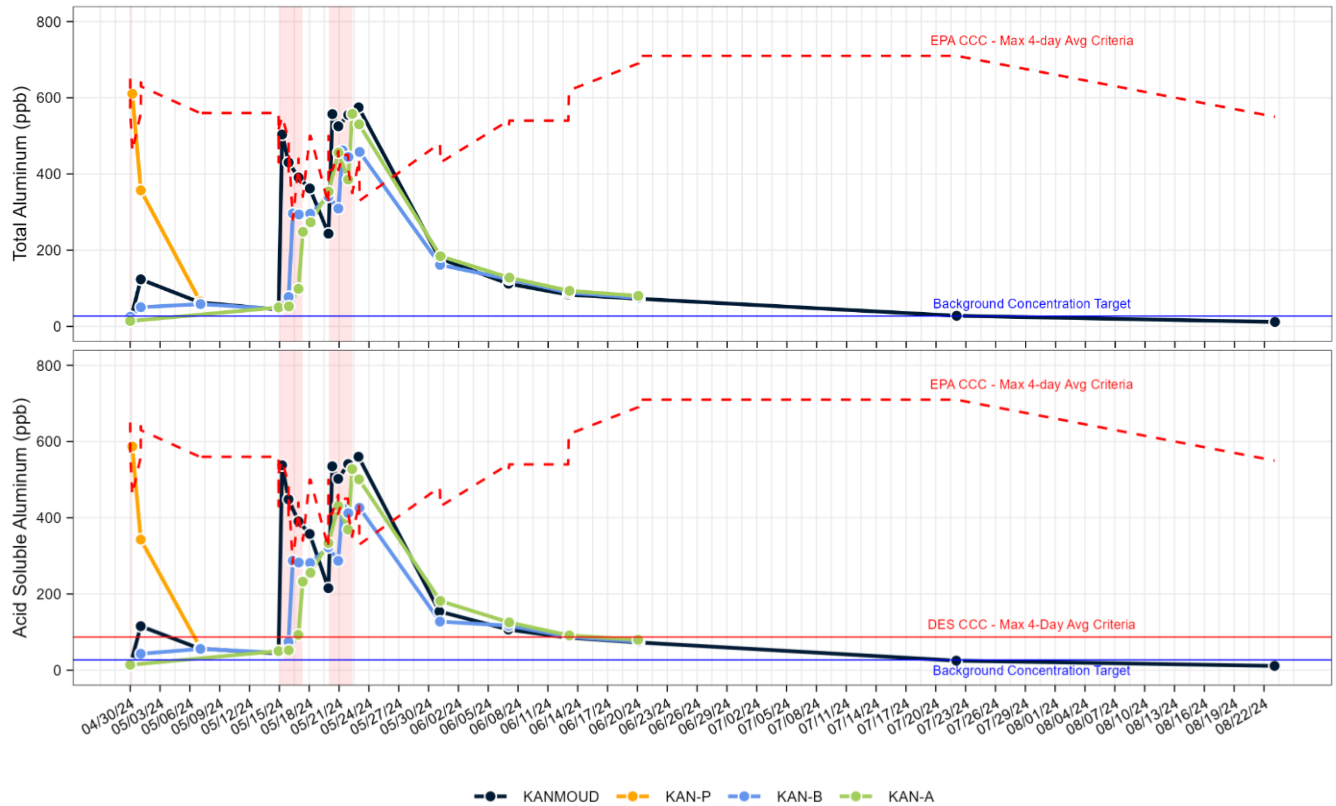

Figure 8. Rolling four-day average of the volumetric average total aluminum (TOP) and acid soluble aluminum (BOTTOM) for whole water column (discrete grabs collected at 1-, 3-, 5-, 9-, and 13-meters depth) by zone and sample event from 4/30/24 to 6/20/24, after which only KAN-C (KANMOUD) was monitored. The dotted red line represents the EPA Criterion Continuous Concentration (CCC) for chronic four-day exposure for total aluminum (also applied to acid soluble aluminum here), which depends on hardness, pH, and dissolved organic carbon. The solid red line represents the DES CCC at 87 ppb for chronic four-day exposure for acid soluble aluminum. The blue line represents the target background concentration at 27 ppb. Pink shaded areas represent active treatment days when the barge was dispensing aluminum compounds in the treatment zone.

Table 9. Count of exceedances of receiving water limits for Lake Kanasatka. Counts represent volumetric average total aluminum and acid soluble aluminum for whole water column (discrete grabs collected at 1-, 3-, 5-, 9-, and 13-meters depth) by zone and sample event. Variable indicates that the criteria are dependent on hardness, pH, and dissolved organic carbon. EPA criteria for total aluminum were also applied to acid soluble aluminum. CMC = Criterion Maximum Concentration for Daily Event Maximum (Acute). CCC = Criterion Continuous Concentration for 4-Day Average (Chronic). Counts are out of 54 total.

Acute or Chronic	Agency	Criteria (ppb)	Acid Soluble Aluminum (count)	Total Aluminum (count)
Daily Event Maximum (Acute) CMC	DES	750	4	NA
Daily Event Maximum (Acute) CMC	EPA	Variable	3	3
4-Day Average (Chronic) CCC	DES	87	36	NA
4-Day Average (Chronic) CCC	EPA	Variable	12	13

Table 10. Single sample daily maximum concentrations of total aluminum (Al) and acid soluble Al, noting site and depth in meters. EPA Criterion Maximum Concentration (CMC) for acute 1-hour exposure for total Al (also applied to acid soluble Al here) depends on hardness, pH, and dissolved organic carbon. DES CMC is set at 750 ppb for acute 1-hour exposure for acid soluble Al. Italicized, red text indicates exceedance of EPA CMC for both total Al and acid soluble Al. Bold text indicates exceedance of DES CMC for acid soluble Al.

Site	Depth (m)	Date	Total Al (ppb)	Acid Soluble Al (ppb)	DES CMC (ppb)	EPA CMC (ppb)
KAN-P	1	4/30/2024	*1,600*	***1,500***	750	1,100
KANMOUD	1	5/1/2024	370	350	750	1,300
KAN-P	5	5/7/2024	100	90	750	1,300
KANMOUD	1	5/15/2024	*1,500*	***1,700***	750	1,200
KAN-B	1	5/16/2024	*1,600*	***1,600***	750	590
KAN-A	1	5/17/2024	*1,200*	***1,100***	750	750
KAN-A	1	5/18/2024	650	580	750	1,200
KANMOUD	1	5/20/2024	*2,800*	***2,700***	750	960
KAN-B	1	5/21/2024	*1,500*	***1,400***	750	1,000
KAN-A	1	5/22/2024	*1,300*	***1,200***	750	770
KAN-A	1	5/23/2024	630	600	750	1,000
KANMOUD	3	5/31/2024	280	200	750	1,100
KAN-B	5	6/7/2024	140	120	750	1,200
KANMOUD	3	6/13/2024	98	97	750	1,200
KAN-A	3	06/20/2024	85	87	750	1,500
KANMOUD	5	7/22/2024	36	32	750	1,600
KANMOUD	13	8/23/2024	13	14	750	1,300

Turbidity

Turbidity measurements read by a portable LaMotte turbidity meter owned by UNH from 5- to 7.5-meter integrated core samples collected in each of the treatment zones never exceeded receiving water limits of 10 NTU above baseline (Table 11). Turbidity averaged 0.46 NTU the morning of the pilot treatment, representing baseline conditions. Turbidity measurements in the treated zones following treatment spiked 35-388% above measurements in the morning before treatment (ranging from peaks of 1.08 to 2.30 NTU) but recovered by 25-80% the next morning (ranging from 0.45 to 1.26 NTU). Turbidity returned to baseline at 0.50 NTU on 7/22/24, though likely earlier given that LaMotte turbidity meter measurements ceased after 5/22/24. Turbidity readings were recorded by a YSI EXO2 data sonde owned by UNH but in units of FNU that are not directly comparable to units of NTU, which are stipulated by the receiving water limits set in the permit. Chronic four-day rolling average turbidity ranged from 0.40 to 2.30 NTU with an average of 0.87 NTU (Table 11).

Table 11. Turbidity measurements read by a portable LaMotte turbidity meter owned by UNH from integrated core samples collected by site and date-time. The four-day rolling average turbidity is calculated by site. Pink shaded rows highlight single sample maximum turbidity measurements on treatment days. Gray shaded rows highlight single sample maximum turbidity measurements on non-treatment days. Exceedance criteria are set at 10 NTU above baseline (0.46 NTU) for both acute 1-hour exposure and chronic 4-day exposure.

Site	Core Depth (m)	Date	Time	Turbidity (NTU)	4-Day Rolling Avg Turbidity (NTU)
KANMOUD	7.0	4/30/2024	7:15	0.47	0.47
KAN-B	7.0	4/30/2024	9:05	0.41	0.41
KAN-A	7.0	4/30/2024	10:15	0.51	0.51
KAN-P	7.0	4/30/2024	13:30	2.30	2.30
KAN-P	7.0	5/1/2024	8:48	0.45	1.38
KANMOUD	7.0	5/1/2024	10:33	0.65	0.56
KAN-B	7.0	5/1/2024	12:31	0.38	0.40
KANMOUD	7.0	5/7/2024	9:06	0.84	0.84
KAN-P	7.0	5/7/2024	9:49	0.55	0.55
KAN-B	7.0	5/7/2024	10:43	0.66	0.66
KAN-A	6.5	5/15/2024	6:44	0.50	0.50
KANMOUD	7.0	5/15/2024	6:50	0.83	0.83
KAN-B	6.5	5/15/2024	7:30	0.93	0.93
KANMOUD	7.0	5/15/2024	15:00	1.68	1.26
KAN-B	7.5	5/16/2024	6:30	1.00	0.97
KANMOUD	7.0	5/16/2024	7:10	1.26	1.26
KAN-A	6.5	5/16/2024	7:11	0.54	0.52
KAN-B	7.5	5/16/2024	16:45	1.38	1.10
KAN-A	7.0	5/17/2024	6:20	0.80	0.61
KAN-B	7.5	5/17/2024	7:25	0.77	1.02
KANMOUD	6.0	5/17/2024	7:28	0.71	1.12
KAN-A	6.5	5/17/2024	17:00	1.08	0.73
KANMOUD	7.0	5/18/2024	10:00	0.85	1.07
KAN-B	6.5	5/18/2024	10:30	0.81	0.98
KAN-A	7.0	5/18/2024	11:35	0.70	0.72
KAN-B	7.5	5/20/2024	6:30	1.14	1.02
KANMOUD	7.0	5/20/2024	6:45	0.63	0.86
KAN-A	6.5	5/20/2024	7:00	0.77	0.78
KANMOUD	7.0	5/20/2024	16:25	1.56	0.94
KANMOUD	7.0	5/21/2024	6:30	0.71	0.85
KAN-B	7.5	5/21/2024	6:30	0.69	0.89
KAN-A	6.5	5/21/2024	6:50	0.78	0.83
KAN-B	7.5	5/21/2024	17:03	1.42	1.02
KAN-A	6.5	5/22/2024	6:30	0.79	0.76
KANMOUD	7.0	5/22/2024	6:37	0.84	0.92
KAN-B	7.5	5/22/2024	6:55	0.81	0.97
KAN-A	6.5	5/22/2024	16:27	1.64	1.00
KANMOUD	5.0	7/22/2024	11:13	0.50	0.50

Wildlife Observations

LKWA provided 18 volunteer shoreline observers for daily visual assessments during and for several weeks after the pilot and full treatment of Lake Kanasatka in 2024. LKWA recorded 27 official assessments on 18 days from 4/30/24 to 6/20/24, with 24 assessments reporting nothing unusual and four assessments reporting an observation (Appendix 1, note that observations on 5/10/24 were recorded on an individual visual form but not recorded on the log sheet). Four assessments found single individual wildlife deceased along the shoreline or in the lake, including a dead frog, dying salamander, and dead smelt along the southwestern shoreline on 5/1/24; a large dead largemouth bass along the southwestern shoreline on 5/10/24; and a large dead white perch floating in the northwestern part of the lake on 5/25/24 and again on 6/14/24 (Appendix 1). These one-off deaths were likely natural and not related to the treatment.

On 5/2/24 following the pilot treatment, volunteers observed black streaks and fragments along the shoreline near Sandy Cove. Sample review by Dr. Amanda McQuaid at UNH found the material to be largely dead plant matter with an estimated scum density of 30,000 cells/mL of cyanobacteria, mostly *Woronichinia* with some *Aphanizomenon* and *Dolichospermum planktonicum*. She noted that these scum appearances were observed by UNH monitors the week prior to the pilot treatment. Similar scum appearances were found around 5/7/24, and sample review by Dr. McQuaid confirmed that the sample consisted of mostly pollen, exoskeletons, and roughly 1,000 cells/mL of the cyanobacteria *Woronichinia*.

During active treatment, third party monitors from NHDES and FBE made a few wildlife observations. A small dead yellow perch (~3 inches long) and a dead terrestrial bird (~5-6 inches long with significant decay and feathers mostly gone) were found floating in Zone A during active treatment on 5/22/24. These one-off deaths were likely natural and not related to the treatment. A pickerel fish was observed swimming in the floc of Zone A on 5/22/24 without any evidence of distress. Loons were observed frequently throughout the entire treatment period swimming in and out of the floc without any evidence of distress. The loons appeared to be curious about the floc and barge.

Additional reports by LKWA were made over several weeks in August related to the co-occurrence of small, mostly yellow perch (~3 inches long or less) and dislodged benthic cyanobacteria that washed up along the southwestern shoreline near Sandy Cove. On 8/7/24, 24 small, mostly yellow perch (~3 inches long or less) were found along the shoreline, with 15 more on 8/15/24 and 36 more on 8/28/24. On 8/27/24, a benthic cyanobacteria, *Oscillatoria*, washed up along the southwestern shoreline and along the sandbar by Maples Stream Inlet. The next day, NHDES issued an alert for Lake Kanasatka. Benthic cyanobacteria are a common occurrence in NH lakes, particularly in higher quality lakes with clearer water. Benthic cyanobacteria have been documented in Lake Kanasatka several times in the past and included taxa such as *Oscillatoria*, *Phormidium*, *Anabaena*, and *Tolypothrix*. Benthic cyanobacteria are slow growing and can surface following decay or disturbance, such as from wind or wave action. Benthic mats can be easily missed if they do not surface or if residents are not actively looking out for them or if they surface but are mixed with a planktonic bloom. One known ecological consequence of alum treatments that was stressed in the treatment plan is more abundant aquatic plant growth, including benthic cyanobacteria, due to clearer waters allowing greater light penetration in the untreated littoral zone of the lake. Small fish die-offs, particularly for species such as yellow perch, are a common occurrence in lakes in summer. NH Fish & Game confirmed that they receive reports of small fish die-offs in July and August each year due to a myriad of factors, including high water temperatures, low oxygen, and disease. In 2024, they saw an increase in ich infections in fish and warned that warmer waters will increase the frequency of these disease-related die-off events in the future. The cause of the small fish die-offs in Lake Kanasatka in August 2024 was inconclusive without further investigation. Toxin exposure from fish grazing of benthic cyanobacteria was considered a slight possibility, but other factors mentioned previously could have been just as, if not more, likely. Without further testing, it was impossible to point to one factor over another.

Photos highlighting visual observations by volunteers in August 2024 of many small dead fish (mostly yellow perch about 3 inches long or less) (TOP) and dislodged benthic cyanobacteria, Oscillatoria *(BOTTOM), that washed up along the shoreline, particularly along the southwestern side of the lake. Photos taken by LKWA.*

Plankton Response

The following summary on plankton community response to the treatment was provided by Dr. Amanda McQuaid, Director of UNH LLMP. Dr. McQuaid and her students completed phytoplankton and zooplankton counting and analysis for 56 samples as required by the permit, plus 25 additional samples for research purposes.

The careful planning and timing of lake treatment is imperative as it relates to aquatic life and plankton populations. General concerns about lake treatment and the potential negative impacts on aquatic life include the effect of pH changes on fish during the active treatment and subsequent food web interference. The purpose of such treatment is to help control the release of internal phosphorus, as it reduces primary productivity by inhibiting nutrient availability which feed algal growth into "blooms".

There are questions about the effects of such treatments on food sources for fish such as zooplankton populations. Phytoplankton (algae and cyanobacteria) and zooplankton (microscopic animals and protozoa) provide a foundation for the aquatic food chain that serves higher trophic levels including fish, birds, and surrounding wildlife. In this section, we summarize the biological parameters monitored through this project with focus on the seasonal succession of the plankton communities and their response to treatment in Lake Kanasatka in 2024.

The following discussion and figures focus on the deep site plankton tows ("KAN-C" (0-11 m) collected before, during, and after treatment) as a consistent site to compare seasonally (daily during treatment, weekly during June, monthly until October in 2024) and annually from 2022 to 2024. A subset of figures comparing among years (2022, 2023, 2024) focus on August, reflecting a time of the year when the lake was well stratified and cyanobacteria typically thrived. Per the permit, additional plankton tows were collected and analyzed for sites "KAN-A" and "KAN-B," which are not included in the following discussion and figures.

Overall, there were seasonal shifts in phytoplankton in 2024 that followed typical successions expected in dimictic, temperate lakes of New Hampshire (i.e., winter/spring are dominated by diatoms and golden-browns, spring/summer by greens (algae) and blue-greens (cyanobacteria), and summer/fall by blue-greens and golden-browns). The major groups (Phyla) of phytoplankton found in Lake Kanasatka in 2024 were diatoms, golden-browns, and cyanobacteria (Figure 9). Zooplankton recovery was evident throughout the treatment phases and followed the typical seasonal succession for the Plankton Ecology Group (PEG) Model for eutrophic lakes, meaning major groups of zooplankton were still in the lake with enough food availability to follow typical seasonal succession patterns following the spring treatment (Figure 9). Seasonal shifts in phytoplankton support zooplankton survival, which in turn controls phytoplankton through grazing. When food sources are limited, zooplankton populations decrease. Zooplankton and phytoplankton succession are a seasonal balancing act of food resources (bottom-up nutrients and productivity) and food web controls (predation and grazing). Of note, we also found the presence of ambush predators, *Chaoborus,* which serve as important links in the food chain because they migrate into the water column to feed on zooplankton and return to the sediments to avoid predation by fish. Several other ambush predators such as *Leptodora* were observed (especially at site "KAN-A"), another good sign for food web and ecosystem balance. It is also noteworthy that there were no Spiny Water Flea observed in this study.

Focusing specifically on the seasonal patterns of cyanobacteria in 2024, *Woronichinia* was the dominant cyanobacteria taxa based on estimated cell count and biovolume (not shown) throughout 2024 (Figure 10). The relative increase in cyanobacteria on 6/13/24, which included *Microcystis* (toxic) and *Aphanocapsa* (picocyanobacteria) (Figure 10)*,* coincided with a decrease in grazers (subsample count of ~0 Cladocerans (i.e., *Daphnia*/mL) from our estimates on 6/13/24, Figure 9). A shift during August and September to deep-dwelling *Planktothrix* also emerged higher in the water column (Figure 10).

Dolichospermum, *Aphanizomenon*, and a variety of other cyanobacteria were observed as dominant taxa in blooms and in plankton samples from prior years (2020-2023 blooms, 2022-2024 plankton tows), but these cyanobacteria taxa were significantly decreased in abundance and diversity during 2024 (Figures 11, 12). Cyanobacteria concentrations ranged up to about 2,000 cells/mL in August 2022 and 2023 compared to less than 200 cells/mL in August 2024 (Figure 12)[7]. These relatively low cyanobacteria concentrations in the water column can rapidly rise and accumulate at the surface where blooms can be observed in the millions. Such levels can vary by the hour and day as they move through the water column. The concentrations of cyanobacteria in plankton tows throughout 2024 were below 1,000 cells/mL or 70x lower than the NHDES threshold (Figure 10) compared to an average abundance from plankton tows in 2022 of 7,000 cells/mL or 10x lower than NHDES threshold (not shown). While there were slightly fewer counts in August 2023 compared to 2022, this event did not account for the deep layers of *Planktothrix* that were observed in 2022 and 2024. Cyanobacteria increased in abundance into September and October in 2023 when surface blooms were observed in record high concentrations. The whole-lake bloom and surface accumulations observed in October 2023 reflected the same taxa found in the August 2023 plankton tow; the breakdown of thermal stratification can bring these cyanobacteria to the surface in mass concentrations, as was observed in fall 2023.

[7] Each cyanobacteria taxa are different in shape, size, toxicity, and ecology. Understanding the shift in cyanobacteria taxa abundance and diversity is important in understanding the shift in nutrient dynamics that have occurred over time and which were altered during treatment. Comparing cyanobacteria cells may be misleading, since cell size and toxicity can vary. However, the NHDES advisory of threshold of 70,000 cells/mL has been used to indicate elevated concentrations of cyanobacteria, which are oftentimes concentrated against a shoreline, the accumulation at which is dynamic and ephemeral. The 70,000 cells/mL threshold is also based on toxic *Microcystis* but is used as a general proxy for high concentrations for all cyanobacteria. In 2020, Lake Kanasatka experienced a whole lake water bloom that exceeded 70,000 cells/mL, which would increase the risk for shoreline accumulations in the millions. It is important to remember that variations between years can also occur naturally and are driven by a variety of bottom-up and top-down factors that cannot be completely assessed in this study. Cyanobacteria populations can prevail in the lake even in low densities. They can also thrive deeper where we do not see (without further monitoring). In NH lakes, the cyanobacteria, *Planktothrix isothrix*, has been identified as a major contributing organism to metalimnetic layers of cyanobacteria and deep layers of cyanobacteria that can oscillate throughout the day and season. We should aim to continue monitoring the full water column to understand these changing populations over time following the first year of treatment in Lake Kanasatka.

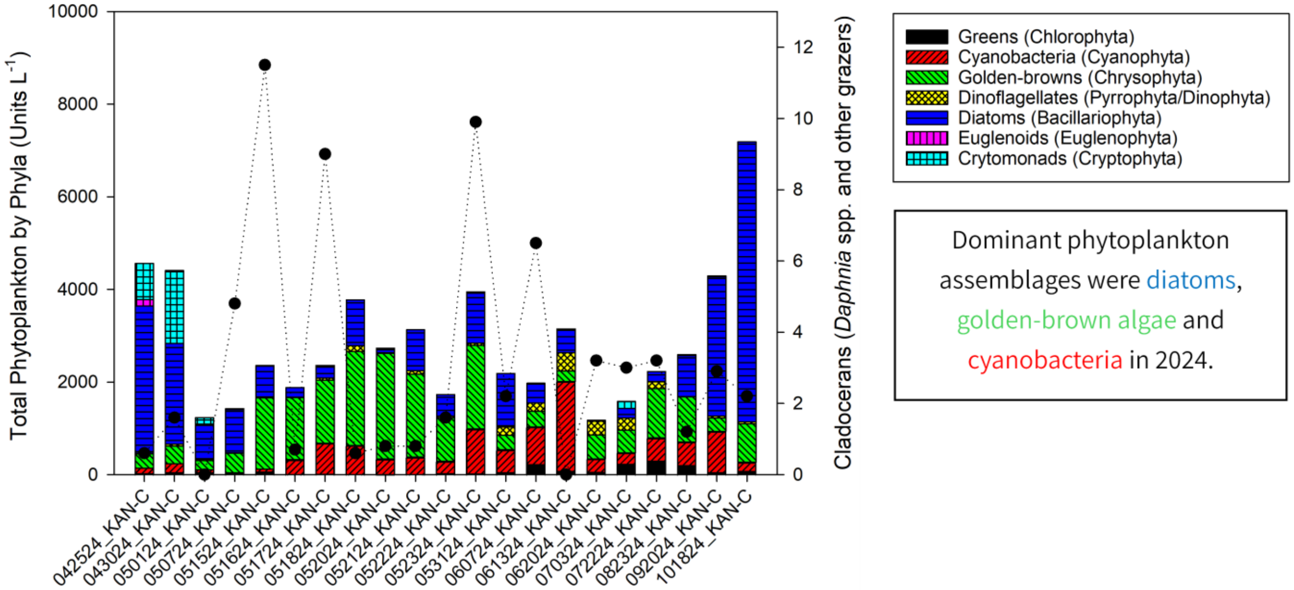

Figure 9. Total phytoplankton (units/L) by Phyla by sampling event at the Deep Site ("KAN-C") of Lake Kanasatka, 4/25/24 to 10/18/24. Treatment occurred on 4/30/24 (Zone P), 5/15-17/24 (Zones C, B, A), and 5/20-22/24 (Zones C, B, A). Two afternoon post-treatment plankton sampling events on 5/15/24 and 5/20/24 are not shown. The dotted line connecting the black dots represents the zooplankton group of Cladocerans (in individuals/L), which includes *Daphnia* and other herbivorous grazers that directly feed on these phytoplankton assemblages.

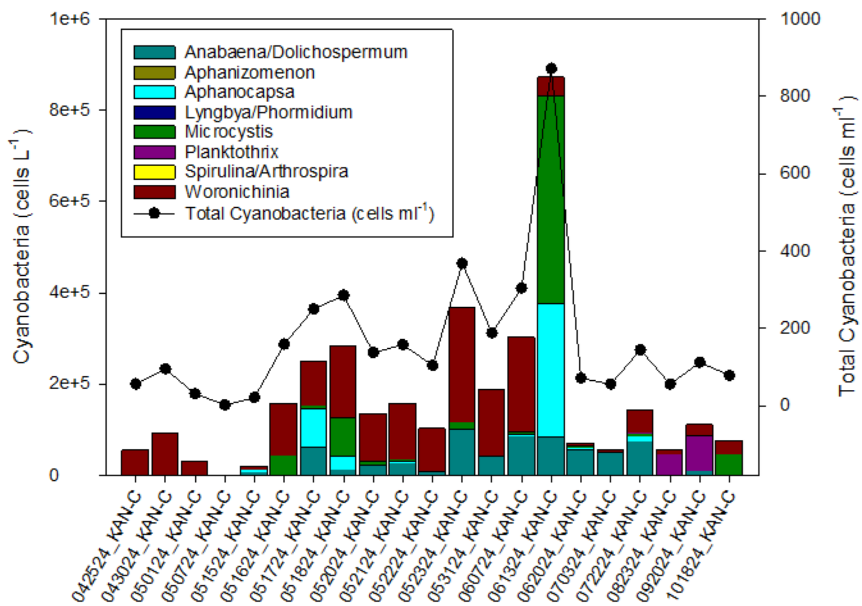

Figure 10. Cyanobacteria concentrations (cells/L and cells/mL) by composition (taxa) and total by sampling event at the Deep Site ("KAN-C") of Lake Kanasatka, 4/25/24 to 10/18/24. Treatment occurred on 4/30/24 (Zone P), 5/15-17/24 (Zones C, B, A), and 5/20-22/24 (Zones C, B, A). Two afternoon post-treatment plankton sampling events on 5/15/24 and 5/20/24 are not shown. Note secondary y axis scale shift for zero baseline.

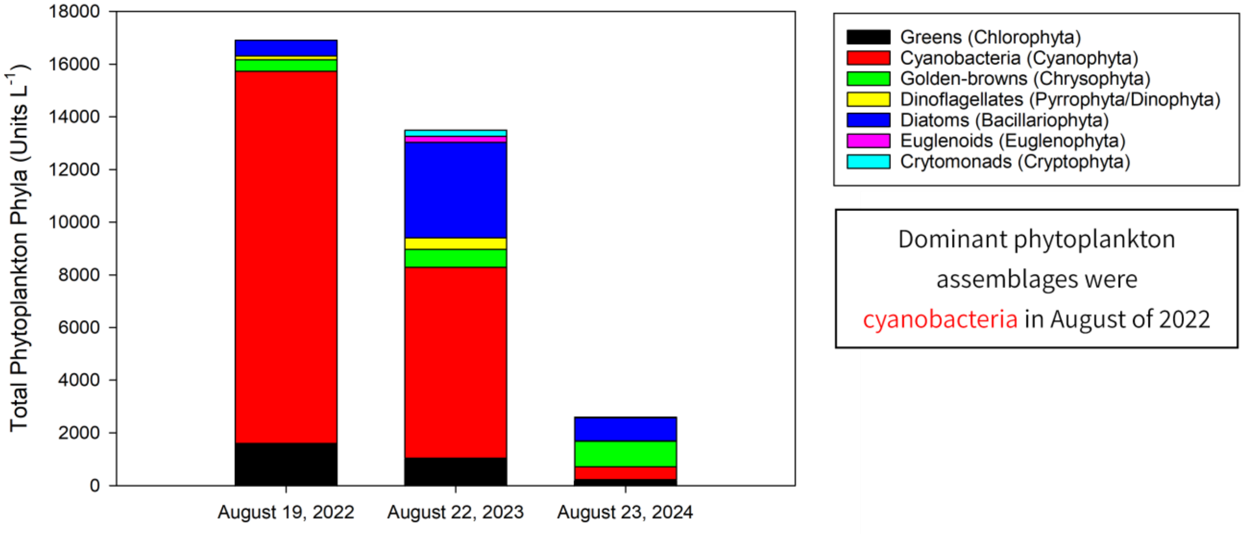

Figure 11. Total phytoplankton (units/L) by Phyla for August sampling events in 2022, 2023, and 2024 at the Deep Site ("KAN-C") of Lake Kanasatka.

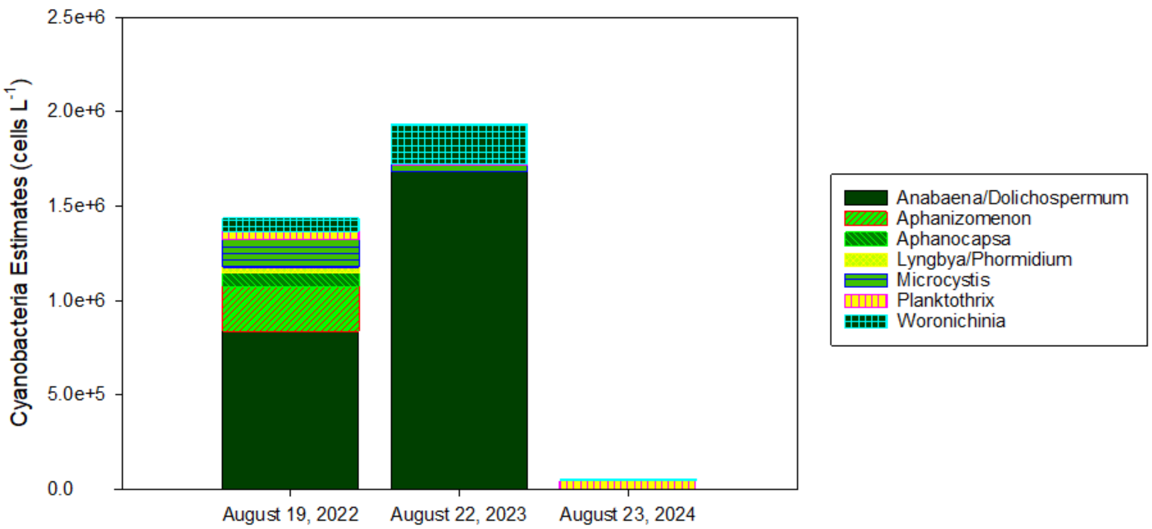

Figure 12. Cyanobacteria concentrations (cells/L) by composition (dominant taxa) for August sampling events in 2022, 2023, and 2024 at the Deep Site ("KAN-C") of Lake Kanasatka (0 to 2 million cells/L equates to 0 to 2,000 cells/mL).

Trophic State Indicators

The alum treatment of Lake Kanasatka in spring 2024 resulted in a 82-89% reduction in the internal phosphorus load in the first year, falling within the target reduction of 80-90% or 7.9-22.1 kg/yr for internal phosphorus load (Table 12, Figure 13). Post-treatment in-lake total phosphorus, chlorophyll-a, and Secchi disk transparency were better than the target and ranged from a 22-82% reduction from pre-treatment in-lake conditions. As expected, Lake Kanasatka experienced record high water clarity at the deep spot, as observed on 7/3/24 with a reading of 9.4 meters. The alum treatment not only treated phosphorus in bottom sediments but also stripped phosphorus from the water column as the floc settled, which is especially apparent in the reduction of summer (i.e., assimilative capacity) total phosphorus concentration from 8.3 ppb pre-treatment to 5.7 ppb post-treatment – surpassing the water quality goal. It was expected that 2024 would be the best water quality year for Lake Kanasatka because of the additional benefit of the one-time stripping of phosphorus from the water column. The relatively high external phosphorus load to Lake Kanasatka will likely increase the summer total phosphorus concentration in 2025 and subsequent years, in combination with a recovery of the internal phosphorus load as the floc ages and is covered by new material. Comparing post-treatment water quality in 2025 to pre-treatment water quality may better evaluate of the effectiveness of the internal phosphorus load reduction, as 2025 will not benefit from another stripping of phosphorus from the water column.

Table 12. The water quality target, pre- and post-treatment water quality condition, and percent reduction achieved for key trophic state indicators for Lake Kanasatka. The target is based on model predictions assuming that the water quality goal of reducing the total phosphorus load of 48 kg/yr has been achieved. Pre-treatment is based on the current (2022) model predictions (calibrated to observed data from 2020-2022). Post-treatment is based on 2024 observed data. Percent reduction is determined as the difference between pre-treatment and post-treatment divided by pre-treatment.

Indicator	Target	Pre-Treatment	Post-Treatment	Percent Reduction
Internal Phosphorus Load (kg/yr)	7.9-22.1*	77.6-122.8	13.6	82-89%
Total Phosphorus (ppb) – Assimilative Capacity	7.2	8.3	5.7	31%
Total Phosphorus (ppb) – Annual Average	8.8	10.4	8.1	22%
Chlorophyll-a (ppb) – Assimilative Capacity	3.0	3.0	1.9	37%
Chlorophyll-a (ppb) – Annual Average	2.7	3.3	2.3	30%
Chlorophyll-a (ppb) – Peak	9.7	12.0	4.4	63%
Secchi Disk Transparency (m) – Annual Average	4.4	3.8	6.9	82%

**Target is based on ± one standard deviation from the average of a 80 or 90% reduction in pre-treatment internal phosphorus loading.*

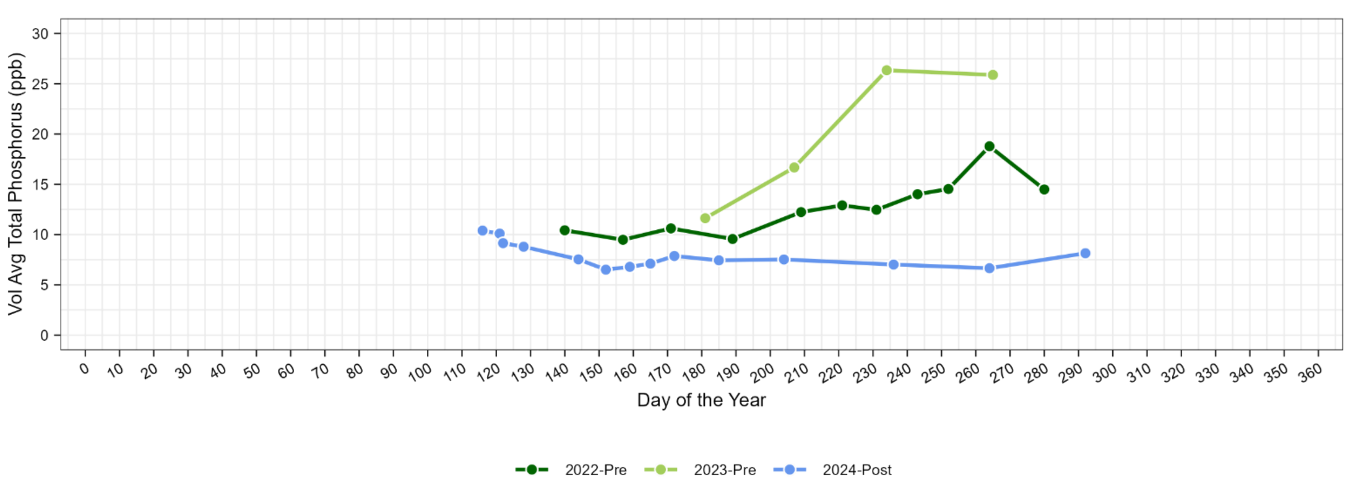

Figure 13. Volumetric average whole water column total phosphorus concentration by day of the year for 2022 (pre-treatment), 2023 (pre-treatment), and 2024 (post-treatment) for Lake Kanasatka.

Additional Notes

There were a couple additional observations to note for this project: 1) evidence of a seiche and 2) evidence of microplastics. During active treatment, profile turbidity data collected by UNH's YSI EXO2 data sonde showed some floc dispersion out of the target area, particularly at deeper depths around 5 meters, which is indicative of a seiche. The pilot treatment occurred on a windy day with moderate currents pushing surface water downstream (south) towards the outlet of the lake, which created a seiche or opposite upstream (north) current at about 5 meters depth. Evidence of floc by higher turbidity readings was noted in adjacent sites for Zones B and C following treatment of Zone P, particularly near the surface for the downstream Zone C and near 5 meters depth for the upstream Zone B. This finding suggests that seiches and other lake current and mixing phenomena due to wind, rain, and water level are important considerations for maximizing the effectiveness of treatment in target areas. Dr. Amanda McQuaid at UNH also noted the presence of microplastics in plankton samples collected on 5/23/24 from Zone A (but not Zones B and C). Microplastics are a growing concern in the environment due to their potential for causing significant health problems in wildlife and humans.

SUMMARY

As expected, Lake Kanasatka experienced immediate water quality improvement following the alum treatment. The alum floc stripped phosphorus from the water column as it migrated down to the sediment where it bound with mobile phosphorus. Lake Kanasatka experienced record high water clarity and minimal to no cyanobacteria accumulations or blooms from the reduction in available phosphorus. There were a few short-term exceedances of receiving water limits set by the permit for pH and aluminum; however, the criteria are imperfect measures not intended for these types of treatments, wildlife showed no distress linked to the treatment, and zooplankton populations recovered well and followed expected seasonal succession patterns.

It is important to understand that alum treatments are temporary management measures to control internal phosphorus loads that come from legacy external phosphorus loads. Without substantial reductions in the external phosphorus loads, phosphorus will continue to build up in newly deposited sediment and begin to release again as internal phosphorus load. Thus, the expected water quality improvements will deteriorate over time until the internal phosphorus load returns to pre-treatment magnitude. Given Lake Kanasatka's shorter water residence time (higher flushing and dominance of external load), the alum treatment longevity for Lake Kanasatka will likely be shorter than other alum treatments performed on deep stratified lakes in Maine and New Hampshire. Hypervigilance to continually reduce the external phosphorus load to Lake Kanasatka will be crucial for maximizing the alum treatment's effective lifespan.

Monthly monitoring of Lake Kanasatka should continue in collaboration between LKWA and UNH LLMP to assess the efficacy of the alum treatment over time. If the efficacy of the alum treatment degrades sooner than expected, then we recommend a second alum treatment be applied at an areal dose of 25 g/m^2 over a treatment area of 153 acres representing 7.5 m and deeper in spring (though additional sediment samples should be collected to confirm the calculated dose for a possible second treatment). The second treatment would treat the labile organic phosphorus fraction not directly targeted in the first treatment. The second treatment would also strip the water column of phosphorus for a second time and treat newly settled phosphorus from the external load or newly decayed phosphorus in the sediment since the first treatment.

REFERENCES

FBE. 2022a. Lake Kanasatka Watershed-Based Management Plan. Prepared by FB Environmental Associates (FBE) for Lake Kanasatka Watershed Association, August 16, 2022.

FBE. 2022b. Lake Kanasatka Lake Loading Response Model Report. Prepared by FB Environmental Associates (FBE) for Lake Kanasatka Watershed Association, July 2022.

FBE. 2023a. Technical Memorandum: Lake Kanasatka Data Review and Model Update. Prepared by FB Environmental Associates (FBE) for Lake Kanasatka Watershed Association, April 10, 2023.

FBE. 2023b. Technical Memorandum: Lake Kanasatka In-Lake Treatment Assistance – External Load Reduction Calculations. Prepared by FB Environmental Associates (FBE) for Lake Kanasatka Watershed Association, December 6, 2023.

McQuaid, A., and Craycraft, B. 2023. Lake Kanasatka and Wakondah Pond 2020-2022 Special Report. Prepared by the University of New Hampshire Extension Lakes Lay Monitoring Program.

NHDES. 2023. Cyanobacteria Bloom History for Lake Kanasatka, Moultonborough, NH. Retrieved from: https://www4.des.state.nh.us/onestoppub/TrophicSurveys/Kanasatka.Moultonboro.Cyano.html

SOLitude Lake Management. (2024). Alum Treatment Final Completion Report: Lake Kanasatka, Moultonborough, New Hampshire. September 23, 2024.

Wagner, K.J., Meringolo, D., Mitchell, D.F., Moran, E., and Smith, S. 2017. Aluminum treatments to control internal phosphorus loading in lakes on Cape Cod, Massachusetts. Lake Reserv Manage., 33:171-186.

APPENDIX 1: VISUAL ASSESSMENT LOGS

VISUAL ASSESSMENTS LOG SHEET					
DAILY SHORELINE SURVEYS TRACKING (BOAT AROUND SHORELINE)					
DATE	TIME START	TIME END	SURVEYOR	GENERAL OBSERVATIONS	FORM (Y/N)
4/30/24	0700	0830	Kevin Kelly	Nothing unusual	N
4/30/24	1600	1730	Kevin Kelly	Nothing unusual	N
5/1/24	0830	1100	Kevin Kelly	Dead frog, dying salamander, dead smelt	Y
5/1/24	1600	1800	Kevin Kelly	Nothing unusual	N
5/8/24	1200	1400	Kevin Kelly	Nothing unusual	N
5/15/24	0630	0730	Kevin Kelly	Nothing unusual	N
5/15/24	1700	1830	Kevin Kelly	Nothing unusual	N
5/16/24	0630	0730	Kevin Kelly	Nothing unusual	N
5/16/24	1800	1900	Kevin Kelly	Nothing unusual	N
5/17/24	0630	0745	Kevin Kelly	Nothing unusual	N
5/17/24	1830	2000	Kevin Kelly	Nothing unusual	N
5/18/24	0630	0730	Kevin Kelly	Nothing unusual	N
5/19/24	0900	1000	Kevin Kelly	Nothing unusual	N
5/20/24	0630	0730	Kevin Kelly	Nothing unusual	N
5/20/24	1800	1900	Kevin Kelly	Nothing unusual	N
5/21/24	0630	0730	Kevin Kelly	Nothing unusual	N
5/21/24	1700	1800	Kevin Kelly	Nothing unusual	N
5/22/24	0630	0730	Kevin Kelly	Nothing unusual	N
5/22/24	1830	2000	Kevin Kelly	Nothing unusual	N
5/23/24	0630	0730	Kevin Kelly	Nothing unusual	N
5/23/24	1830	2000	Kevin Kelly	Nothing unusual	N
5/30/24	0900	1030	Kevin Kelly	Nothing unusual	N
6/6/24	0800	0930	Kevin Kelly	Nothing unusual	N
6/13/24	1530	1630	Kevin Kelly	Nothing unusual	N
6/20/24	0800	1000	Kevin Kelly	Nothing unusual	N
5/25/24	0654	0800	Kevin Kelly	Dead white perch - unusual stomach	Y
6/14/24	0909	1030	Kevin Kelly	Very similar dead white perch	Y

VISUAL ASSESSMENTS FIELD FORM

DISTRESSED WILDLIFE OBSERVATIONS

DATE	May 1, 2024	TIME	9:00 AM	SURVEYOR	Kevin Kelly

LOCATION (GPS COORDINATES) 68 Glidden Road, Moultonborough, NH 03254

LOCATION (DESCRIPTION) Waterfront/ beach area of Lake Kanasatka

OBSERVATIONS (*describe anything unusual such as signs of distressed wildlife in the water; be as specific as possible; include the number and species exhibiting symptoms of distress and probable causes*)

One 3 or 4 inch dead frog floating on surface.

One dying salamander at the water line.

One dead smelt (?) Appeared to be a baitfish with bite marks

PHOTOS (*take several photos of the distressed wildlife*)

VISUAL ASSESSMENTS FIELD FORM

DISTRESSED WILDLIFE OBSERVATIONS

DATE	May 10, 2024	TIME	9:00 AM	SURVEYOR	Kevin Kelly and Scott Apgar
LOCATION (GPS COORDINATES)	60 Glidden Road, Moultonborough, NH 03254				

LOCATION (DESCRIPTION) Waterfront area next to dock

OBSERVATIONS (*describe anything unusual such as signs of distressed wildlife in the water; be as specific as possible; include the number and species exhibiting symptoms of distress and probable causes*)

Approximately 16-18 inch dead largemouth bass. It appeared to have been dead for quite some time.
It was bloated and blanched. No signs of trauma outside or inside mouth.

PHOTOS (*take several photos of the distressed wildlife*)

VISUAL ASSESSMENTS FIELD FORM					
DISTRESSED WILDLIFE OBSERVATIONS					
DATE	May 25, 2024	TIME	10:00 AM	SURVEYOR	Kevin Kelly
LOCATION (GPS COORDINATES)	Middle of Lake Kanasatka at "West Water Quality Monitoring Location."				
LOCATION (DESCRIPTION) Middle of lake at west end near Lisa's house					

OBSERVATIONS (*describe anything unusual such as signs of distressed wildlife in the water; be as specific as possible; include the number and species exhibiting symptoms of distress and probable causes*)

Approximately 6-7 inch dead white perch, floating in 15' of water.
It looked fresh, its stomach appeared swollen, red and purple.

PHOTOS (*take several photos of the distressed wildlife*)

VISUAL ASSESSMENTS FIELD FORM

DISTRESSED WILDLIFE OBSERVATIONS

DATE	June 14, 2024	TIME	11:00 AM	SURVEYOR	Kevin Kelly
LOCATION (GPS COORDINATES)	Middle of Lake Kanasatka at "West Water Quality Monitoring Location."				

LOCATION (DESCRIPTION) Middle of lake at west end. Almost the same spot as May 25th observation near Lisa's house

OBSERVATIONS (*describe anything unusual such as signs of distressed wildlife in the water; be as specific as possible; include the number and species exhibiting symptoms of distress and probable causes*)

Approximately 6-7 inch dead white perch, floating in 15' of water.
It looked fresh, its stomach appeared swollen, red and purple.
Same as May 25, 2024 observation.

PHOTOS (*take several photos of the distressed wildlife*)