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Technical Memorandum

To: George Meservey, Director of Planning & Community Development, Town of Orleans

From: Ed Eichner, Principal, TMDL Solutions
Micheline Labrie, Director, Coastal Systems Program, SMAST, UMassD

Date: October 14, 2025

RE: 2024 Pilgrim Lake: Water Quality Changes Post-Alum Treatment: One Year Report

I. Introduction and Background

The Town of Orleans Comprehensive Wastewater Management Plan (CWMP) includes a strategy to integrate management of coastal and freshwater water quality. As part of that strategy, the Town of Orleans, working through the Marine and Fresh Water Quality Committee (OMFWQC), began a process of developing management plans for the Town's larger freshwater ponds. The Town began working with the Coastal Systems Program from the School for Marine Science and Technology at UMass-Dartmouth (CSP/SMAST) to collect and review available pond water quality data[1] and then reviewed this data and other details about the ponds (*e.g.*, municipal beaches, quality of access, size, etc.) to prioritize the completion of individual pond and lake management plans. To date, plans have been completed for Uncle Harvey's Pond, Pilgrim Lake, Crystal Lake, and Bakers Pond. Each pond management plan included a diagnostic assessment of the pond to determine a reasonable understanding of pond ecosystem functions, water and habitat quality, and a review of applicable water quality management options.

The Pilgrim Lake Management Plan was completed in 2019 and included synthesis of all available historical water column data and complementary assessment-specific data collected in 2017, such as measurement of sediment nutrient inputs, identification of phytoplankton species, and continuous water column measurements.[2] These in-pond data were combined with watershed information (*e.g.*, septic system evaluations and measurement of stormwater runoff inputs) to provide a comprehensive understanding of both external and internal nutrient sources and their role in causing the water quality conditions in Pilgrim Lake. This assessment found that: a) Pilgrim Lake water quality was impaired (*i.e.*, low dissolved oxygen, algal blooms, clarity loss), b) phosphorus was the key to managing water quality in Pilgrim Lake, and c) that

[1] Eichner, E and B. Howes. 2017. Town of Orleans Freshwater Ponds, Water Quality Monitoring Database: Development and Review. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 217 pp.

[2] Eichner, E., B. Howes, and D. Schlezinger. 2019. Pilgrim Lake Management Plan and Diagnostic Assessment. Town of Orleans, Massachusetts. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 114 pp.

watershed septic systems were the primary source (51% to 56%) of phosphorus measured in the Pilgrim Lake water column (**Figure 1**).

After these ecosystem functions were reasonably understood, the Management Plan then reviewed water quality management options that were specific to the impairments in Pilgrim Lake. After several OMFWQC public meetings to discuss potential management options, the OMFWQC voted to pursue a multi-tiered management strategy of: 1) asking the Select Board to prioritize sewering of the watershed areas contributing wastewater phosphorus to Pilgrim Lake (19 properties adding phosphorus to the lake in 2017) and 2) implementing an alum treatment to try to prevent algal blooms while waiting for the completion of the sewer installation.

In early August 2023, Pilgrim Lake experienced a significant algal bloom (**Figure 2**). The Town submitted an alum treatment proposal to the Conservation Commission (ConComm) in November 2023 and received approval in December 2023. The alum treatment was completed in March 2024. Included in the ConComm's approval (*i.e.*, Order of Conditions) were requirements for post-alum application water quality monitoring from March through October and two required reports for two years: a six month report and a one year report. The six month report was submitted to the Town on November 22, 2024.[3] This Technical Memorandum is the required Pilgrim Lake Year 1 report.

II. Pilgrim Lake Alum Treatment and Follow-up Monitoring

The Pilgrim Lake alum treatment Order of Conditions required monthly monitoring from March through October of "aluminum levels, temperature, oxygen, pH, alkalinity, conductivity, total and dissolved phosphorus, nitrogen, and secchi (sic) transparency."[4] This monthly monitoring was to occur for two years with six month and annual reports in each year.

In order to support the Town, CSP/SMAST staff measured dissolved oxygen (DO) and temperature profiles, Secchi clarity readings, and collected water quality samples at surface (0.5 m depth), 3 m, and deep (1 m off the bottom) at the long-term sampling station on eight 2024 dates: March 13, April 18, May 16, June 12, July 15, August 21, September 18, and October 22. Samples were transported to the CSP Analytical Facility on the same day samples were collected and assayed for: pH, alkalinity, ortho-phosphorus (*i.e.*, dissolved phosphorus), total phosphorus, total nitrogen, chlorophyll-a, pheophytin, dissolved aluminum, and total aluminum. The assays used for pH, alkalinity, total phosphorus, total nitrogen, chlorophyll-a, and pheophytin were the same assays utilized for Pond and Lake Stewards (PALS) samples. These assays and the sampling procedures are included in the Town's current Ponds and Lakes Monitoring Program Quality Assurance Project Plan (QAPP), which was approved by the Massachusetts Department of Environmental Protection.[5] Water quality measurements and sample results were discussed and submitted to the Town in the November 22, 2024 technical memorandum and are briefly summarized below. Additional monitoring was not required in 2024 after the October sampling.

[3] CSP/SMAST Technical Memorandum. November 22, 2024. 2024 Pilgrim Lake: Water Quality Changes 6 Months Post-Alum Treatment. From: E. Eichner, TMDL Solutions and M. Labrie, CSP/SMAST. To: G. Meservey, Director of Planning & Community Development, Town of Orleans. 14 pp.

[4] Special Conditions in the Town of Orleans Conservation Commission Order of Conditions (DEP#054-26240).

[5] Town of Orleans Ponds and Lakes Monitoring Program Quality Assurance Project Plan 2024-2027. Prepared by Town of Orleans Marine and Fresh Water Quality Committee and Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. Approved by MassDEP, June 2024. 51 pp.

DO and temperature profiles showed the pond water column warming and cooling between March and October, along with persistent anoxia in the deepest portions of the water column (**Figure 3**). Secchi clarity in 2024 was generally slightly lower (-0.3 m average) than 2023 readings, but was higher in August (+0.65 m) and September (+0.32 m) (**Figure 4**). 2024 shallow temperatures were similar to those measured in 2023,[6] but the depth of anoxia in 2024 tended to be at a deeper depth than in 2023, which suggest the alum treatment likely suppressed the sediment oxygen demand slightly even though that is not a primary function of alum treatments.

Shallow total phosphorus (TP) concentrations tended to be similar in most 2024 months (~20 µg/L) except for the spring reading, while deep TP concentrations were generally slightly elevated above shallow levels (**Figure 5**). In April and May, though, shallow TP concentrations were higher than the rest of the year (33 to 35 µg/L). These shallow April/May 2024 concentrations were also much higher than the historical average shallow TP concentration of 11.6 µg/L (n=10; 2001-2017). These elevated spring concentrations were likely a combination of the reworking of the sediment phosphorus balance by the August phytoplankton bloom (*i.e.*, deep sediment phosphorus deposited around the shallow margin of the pond) and the impact of herring entering the pond to spawn. All TP concentrations measured in 2024 were greater than the 10 µg/L Ecoregion Threshold.[7]

On June 12, some filamentous algae were noted along the shoreline near the town beach. Regular monthly samples were also collected on this date and the shallow and 3 m TP concentrations were 20.9 µg/L, which was within the usual shallow TP concentration range for Pilgrim Lake and no more excessive than usual. The water column was stratified with unimpaired DO concentrations within the transition zone, so no deep sediment TP impacts could have been experienced in shallow waters. At the sampling site, samplers noted clear water and no signs of a bloom. Collectively, this suggests that the 2024 bloom was a shallow, local occurrence near the beach, perhaps due to sediment warming and resuspension of the August 2023 bloom nutrients deposited in this area. Filamentous algae growth has been associated with higher nutrient groundwater inputs in clearer lakes,[8] something that occurs year-round in Pilgrim Lake. It is also possible that the August 2023 bloom has shifted the overall pond ecosystem into a wider range of potential responses that includes early season blooms.

Total nitrogen (TN) concentrations in 2024 were generally similar throughout the water column on each sampling date except for a notably higher deep level in August due to prolonged anoxia (**Figure 6**). The shallow readings tend to be slightly higher than the long term average August/September shallow concentration of 0.45 mg/L (n=24) that was determined in 2017. The slightly higher 2024 shallow TN concentrations suggest that there are additional nitrogen sources being added to the water column since 2017.

Chlorophyll (CHL) concentrations in 2024 were generally elevated, but grouped in a relatively consistent range except for readings in July, October, and deep readings in August and September. Shallow and 3 m CHL levels in March through June, August, and September were generally between 3.3 and 7.2 µg/L (**Figure 7**). These concentrations were elevated and largely

[6] APCC Cape Cod Regional Pond Monitoring Program data courtesy of OMFWQC

[7] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas. Cape Cod Commission. Barnstable, MA.

[8] Page, M.; Goldhammer, T.; Hilt, S.; Tolentino, S.; Brothers, S. Filamentous Algae Blooms in a Large, Clear-Water Lake: Potential Drivers and Reduced Benthic Primary Production. Water 2022, 14, 2136. https://doi.org/10.3390/w14132136

consistent with historical, impaired, long-term summer averages. The high July and October levels were throughout the water column suggesting some sort of bloom. The elevated deep August and September readings were consistent with a July bloom and settling of the bloom remnants to the deeper portions of the water column. The October bloom would have been consistent with mixing of the entire water column (something seen in the relatively isothermic October temperature profile) and redistribution of the elevated deep September TP concentrations throughout the entire water column. It was notable that neither of the July and October blooms were concentrated enough to cause observations of surface scums or any notes of APCC advisories in nearshore cyanobacteria monitoring.[9] All 2024 CHL concentrations were greater than the 1.7 µg/L Ecoregion Threshold.[10]

In addition to the usual nutrient-related, water quality measures, the ConComm also required regular monthly assays of aluminum levels following the alum treatment. CSP assayed collected water samples for total aluminum and dissolved aluminum, and these readings showed a return to background levels within two months after the alum treatment (**Figure 8**). Background dissolved aluminum concentrations were consistent with levels measured in Uncle Harvey's Pond in 2021[11] and none of the highest levels in March were greater than the USEPA estimated acute Aquatic Life Criteria concentrations based on Pilgrim Lake pH and alkalinity.[12]

Alkalinity and pH readings showed no notable impact from the 2024 alum treatment. 2024 shallow alkalinity concentrations varied between 20 and 24 mg $CaCO_3$/L (**Figure 9**). 2024 pH readings were acidic, as is natural for Cape Cod ponds, with shallow readings varied between 6.0 and 6.7 (**see Figure 9**).

III. Conclusions/Discussion

The goal of the Pilgrim Lake alum treatment was to try to prevent an algal bloom similar to the August 2023 bloom (see **Figure 2**) and monitoring and observations show that the treatment met this goal. The 2024 monitoring data showed that the deep DO concentrations increased slightly, which is not a goal of alum treatments, but is often a byproduct (*e.g.*, it was also noted in follow-up monitoring after the Uncle Harvey's Pond alum treatment). This DO increase seems to have prevented extensive deep TP from reaching the shallow portions of the water column (noted in the August 2023 bloom). Shallow TP and chlorophyll concentrations continued to show impaired conditions, which would be expected given that the sediments were determined in the Management Plan to be 12% of spring water column TP and 26% of August water column TP (see **Figure 1**). Addressing the watershed septic system TP additions (51% to 56% of water column inputs) remains the primary management goal to restore acceptable water quality in Pilgrim Lake.

[9] https://www.orleanspondcoalition.org/cyanobacteria-monitoring/ (accessed 10/9/25).

[10] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas. Cape Cod Commission. Barnstable, MA.

[11] CSP/SMAST Technical Memorandum. 2021 Uncle Harvey's Pond: Water Quality Changes 6 Months Post-Alum Treatment. November 30, 2021. From: B. Howes and E. Eichner. To: G. Meservey, Director of Planning & Community Development, Town of Orleans. 14 pp.

[12] https://www.epa.gov/wqc/2018-final-aquatic-life-criteria-aluminum-freshwater (accessed 10/9/25).

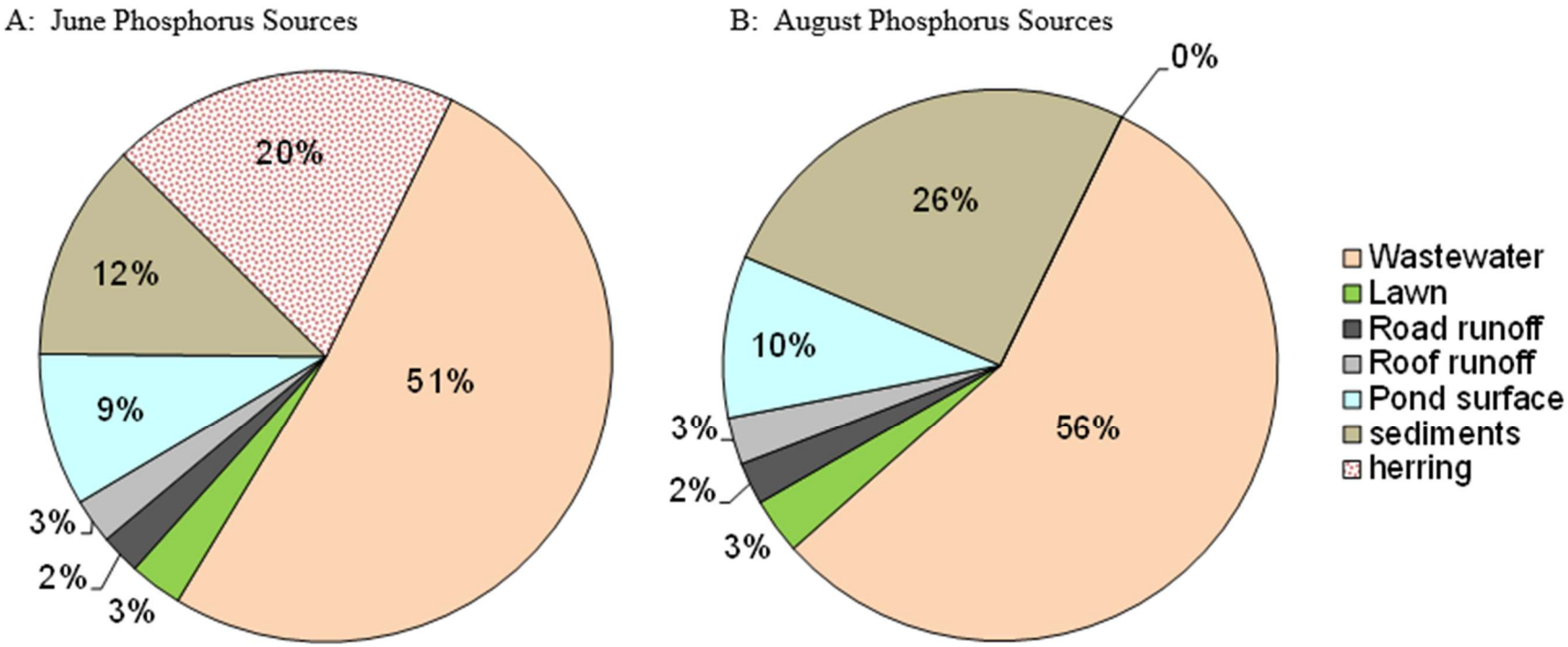


Figure I. 2017 Seasonal Phosphorus Loading Sources to Pilgrim Lake Water Column. Based on review of the watershed and measurements of road runoff and pond sediment regeneration rates, CSP/SMAST staff developed phosphorus budgets to determine the relative inputs of phosphorus to the water column of Pilgrim Lake. This assessment, which is described in the Pilgrim Lake Management Plan (Eichner, Howes and Schlezinger, 2019), showed that the relative size of the sources varied by month, but that wastewater from septic systems near the pond was the primary source of phosphorus in all months. In June, wastewater was 51% of the overall Pilgrim Lake phosphorus budget, while in August, it was 56%. Sediment regeneration of phosphorus based on measurements of sediment cores and review of water column dissolved oxygen levels was 12% of the overall Pilgrim Lake phosphorus budget in June and 26% of the budget in August. From Figure IV-27 in the Pilgrim Lake Management Plan.

Figure 2. Pilgrim Lake Algal Bloom. On August 6, 2023, Pilgrim Lake experienced a significant phytoplankton bloom. A review of data collected a few days after the bloom suggested that anoxic conditions in the deep layer expanded through the temperature transition zone between the deep and shallow layers. This expansion allowed the elevated TP levels in the deep layer (3X to 4X greater than surface TP levels) to mix into the warm, shallow layer. This new nutrient input combined with appropriate levels of light, other nutrients, and temperatures created optimal conditions for rapid growth of cyanobacteria. Photo courtesy of G. Meservey.

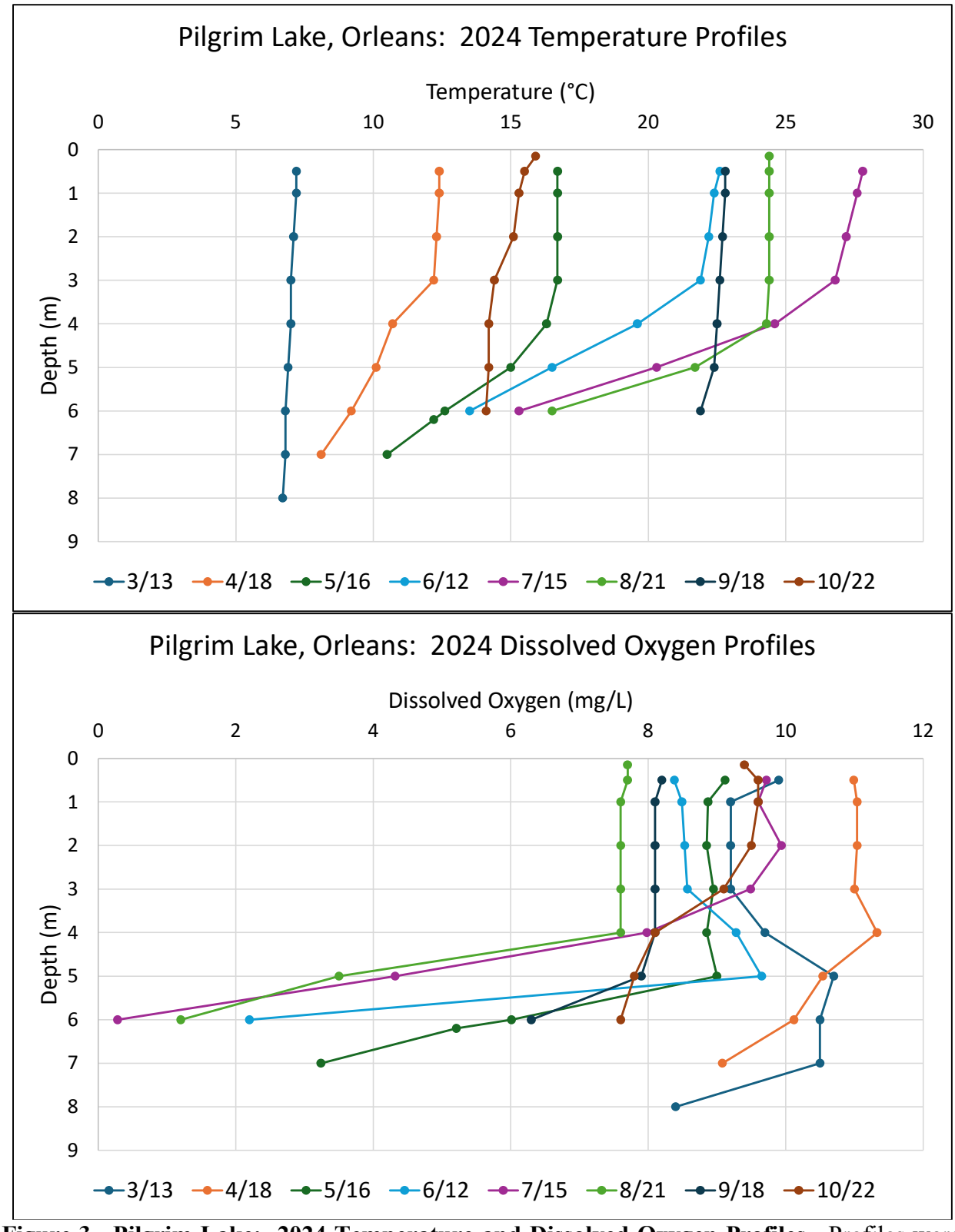


Figure 3. Pilgrim Lake: 2024 Temperature and Dissolved Oxygen Profiles. Profiles were collected monthly between March and October at the long term sampling point. The lake thermally stratified in May and was stratified through September. Once stratification occurred the deep layer began to show the pronounced impacts of sediment oxygen demand.

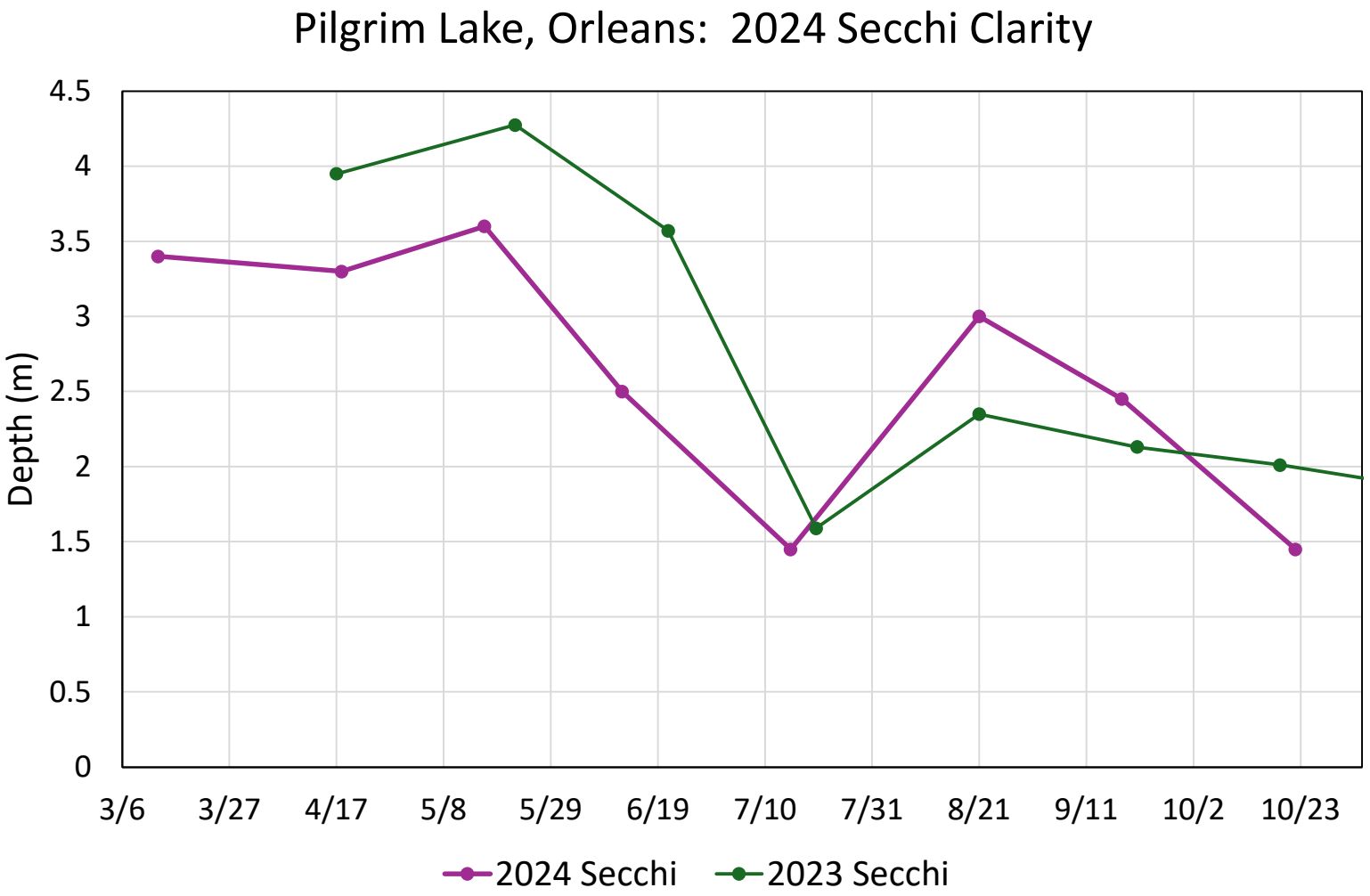


Figure 4. Pilgrim Lake: 2023 and 2024 Secchi Clarity. 2024 Secchi clarity was less than 2023 readings from March through July, but greater than 2023 in August and September. The average difference between the two years was 0.3 m, but ranged from -1.07 to +0.65 m. June through October readings in both years were less than the long-term averages for those months. July readings in both years were~2 m less than the long-term July average. 2023 data collected by APCC (courtesy of the OMFWQC).

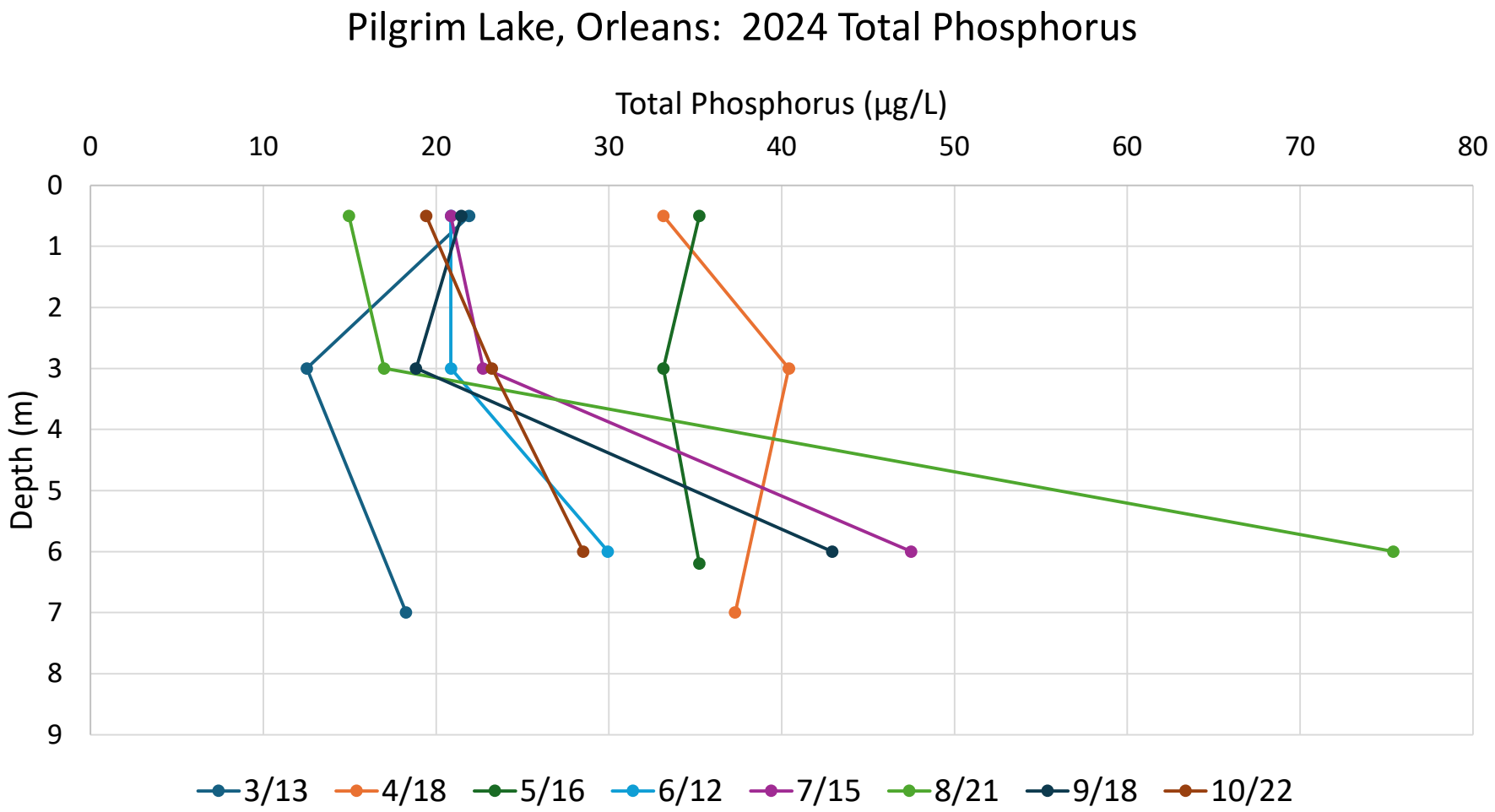


Figure 5. Pilgrim Lake: 2024 Total Phosphorus Profiles. Total phosphorus (TP) levels throughout the water column (except for July and August deep levels) were greater in April and May than in the rest of 2024. The higher April and May levels were likely due to a combination of the reworking of the sediment phosphorus balance by the August 2023 phytoplankton bloom and the impact of herring entering the pond to spawn in 2024. These April/May levels were lower, however, than 2023 April results. The higher deep levels in July and August were consistent with deep, low DO closest to the sediments in July and August. Deep TP concentrations from April through September were on average consistent with 2017 levels except for the 2024 August reading, which was 34% higher. All 2024 TP concentrations were greater than the 10 µg/L Ecoregion Threshold.

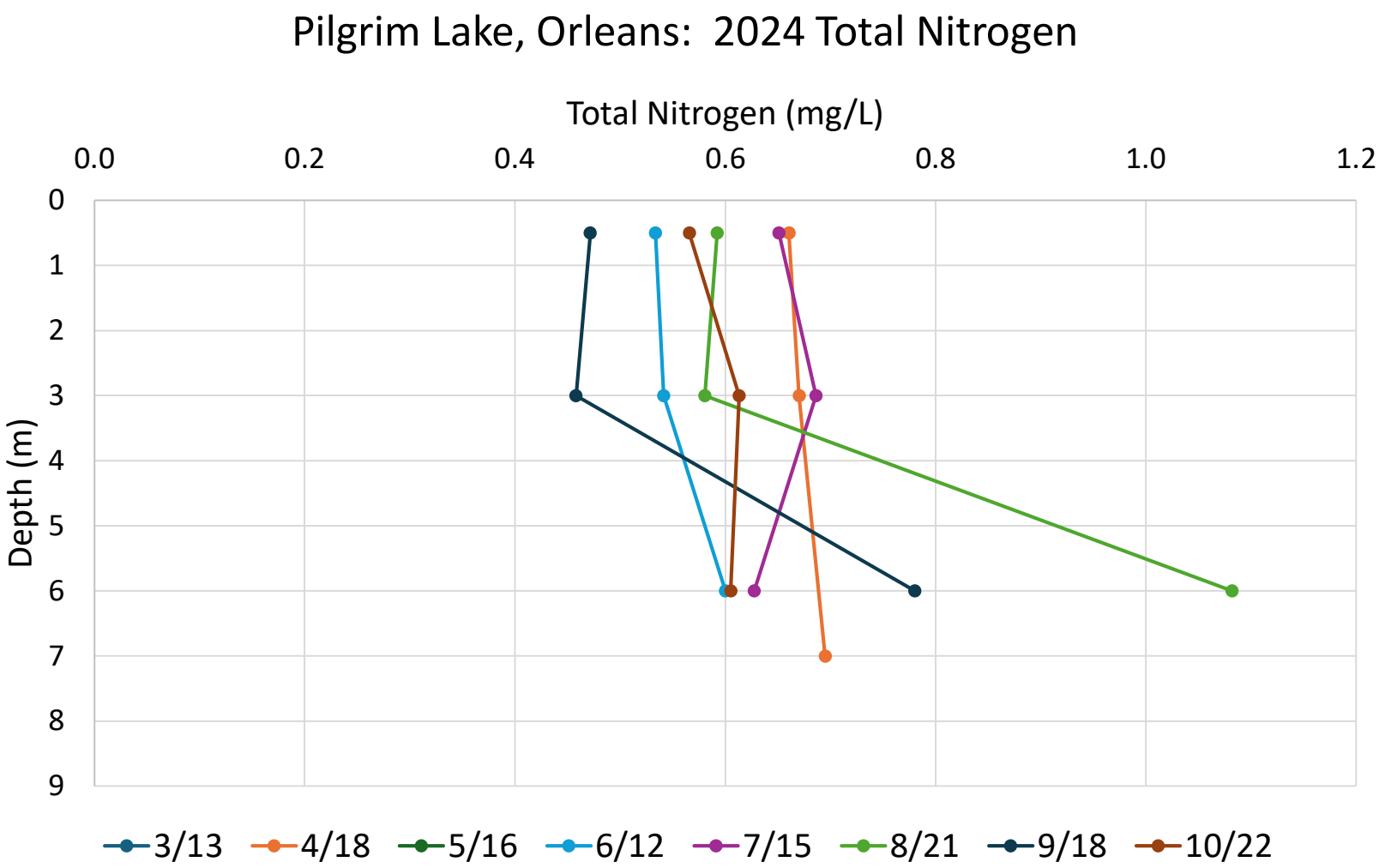


Figure 6. Pilgrim Lake: 2024 Total Nitrogen Profiles. Shallow total nitrogen (TN) concentrations tended to be clustered between 0.47 and 0.66 mg/L, while deep readings in August and September were notably higher due to sediment release to the water column. The August deep reading (1.08 mg/L TN) was consistent with the long term average August/September deep TN concentration (1.12 mg/L, n=21).

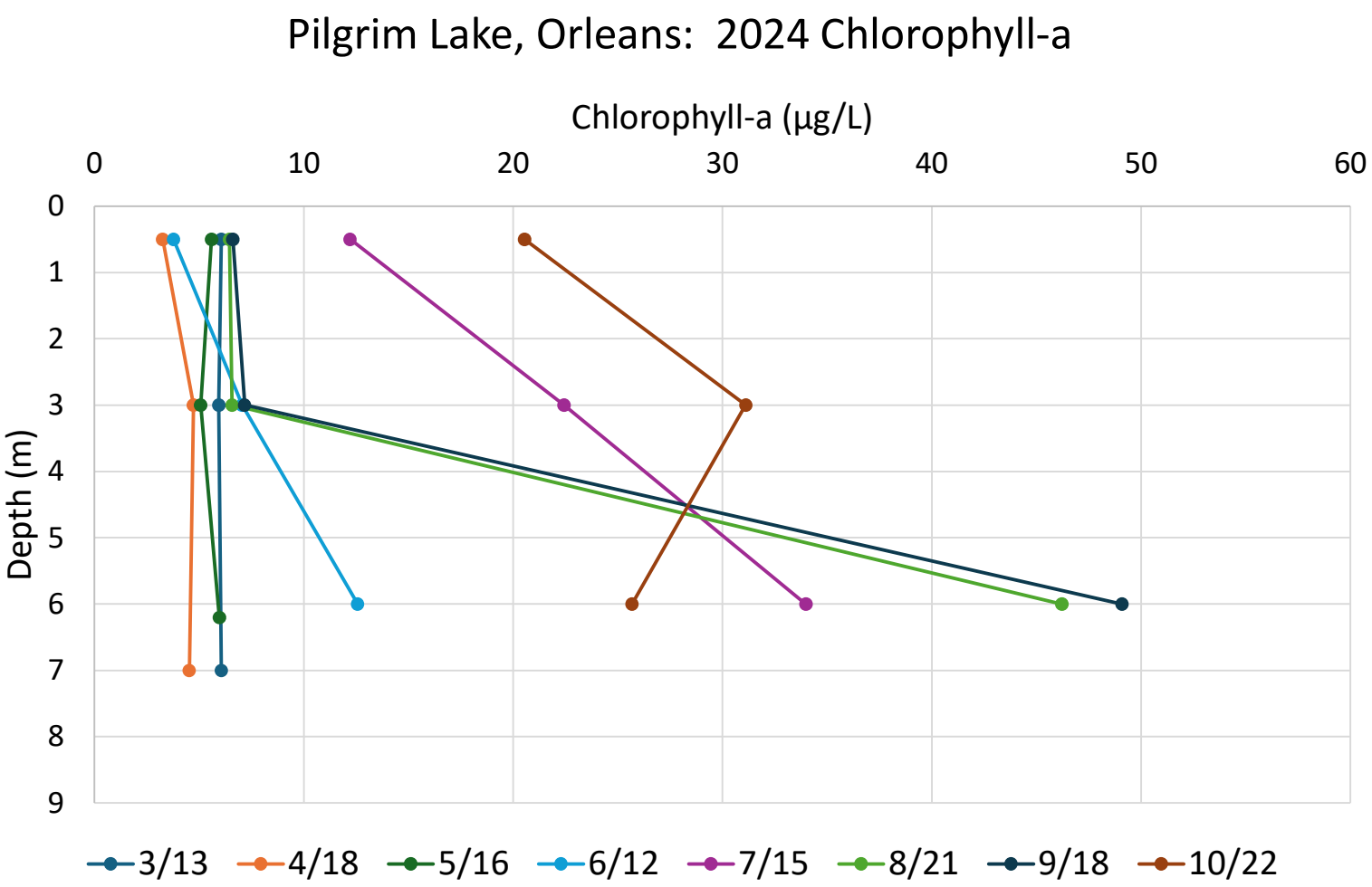
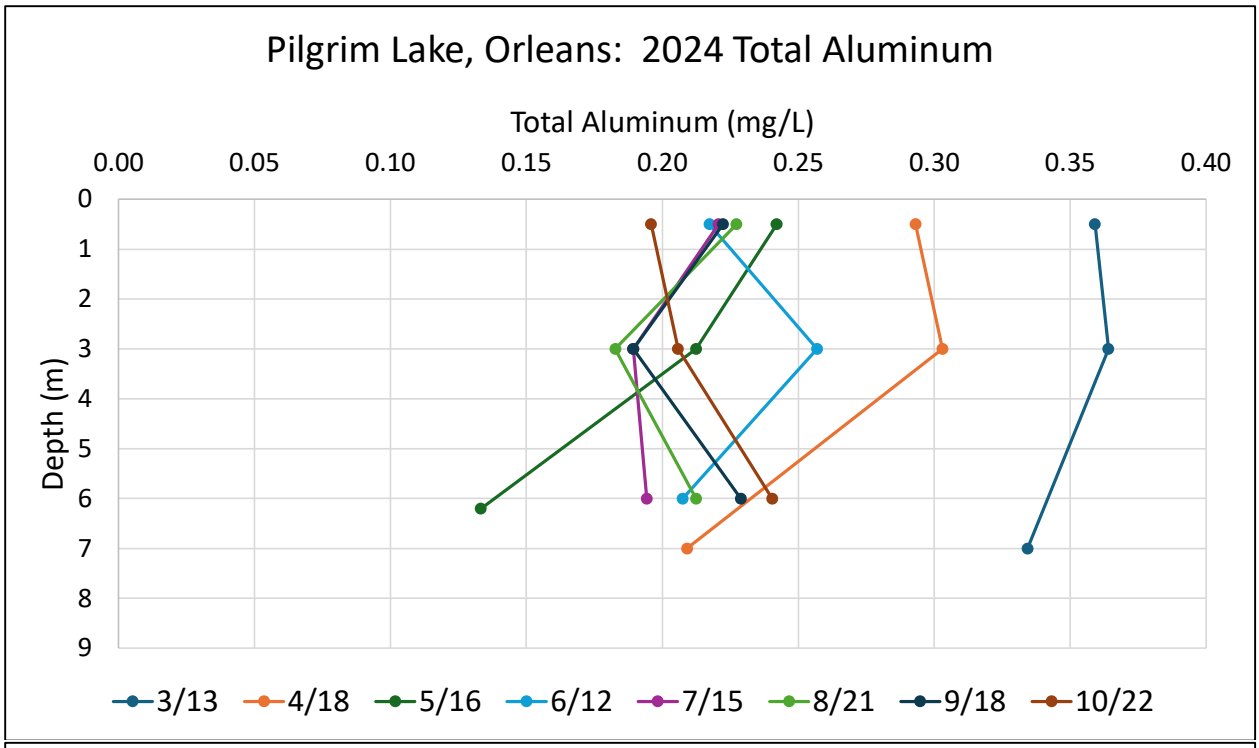


Figure 7. Pilgrim Lake: 2024 Chlorophyll Profiles. Chlorophyll (CHL) concentrations in 2024 were generally elevated, but grouped in a relatively consistent range except for readings in July, October, and deep readings in August and September. Shallow and 3 m CHL levels in March through June, August, and September were generally between 3.3 and 7.2 µg/L. These concentrations were elevated, but largely consistent with historical, impaired, long-term summer averages. The high July and October levels were throughout the water column suggesting some sort of bloom. The elevated deep August and September readings were consistent with a July bloom and an average particle settling rate from 3 m. The October bloom would have been consistent with mixing of the entire water column and redistribution of the elevated deep September TP concentrations throughout the entire water column. It was notable that neither of the July and October blooms were concentrated enough to cause observations of surface scums



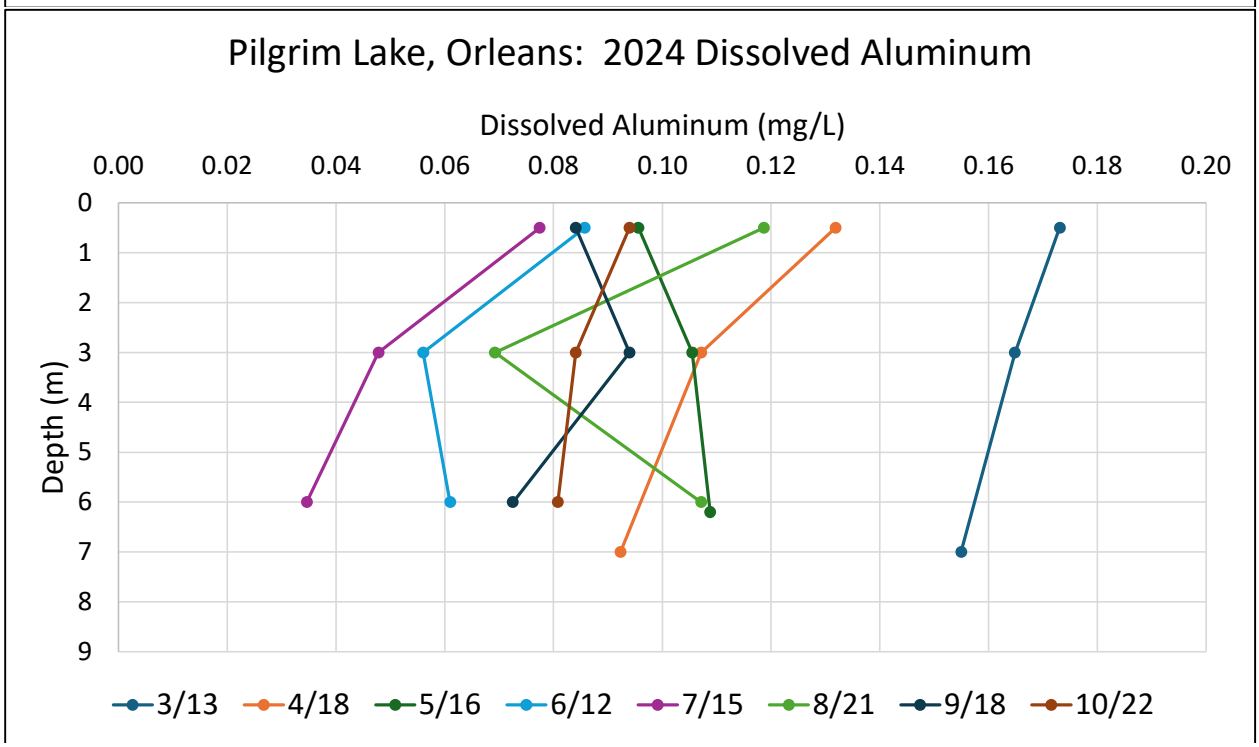


Figure 8. Pilgrim Lake: 2024 Total Aluminum and Dissolved Aluminum Profiles. Both total and dissolved aluminum concentrations were elevated during the initial post-alum treatment water column sampling on March 13, 2024, but the concentrations decreased significantly in the April 18 samples and were within the background range by the May 16 sampling. Background dissolved aluminum concentrations were consistent with levels measured in Uncle Harvey's Pond in 2021 (CSP/SMAST Technical Memorandum; 11/30/21) and none of the highest levels in March were greater than estimated USEPA acute Aquatic Life Criteria concentrations based on Pilgrim Lake pH and alkalinity.

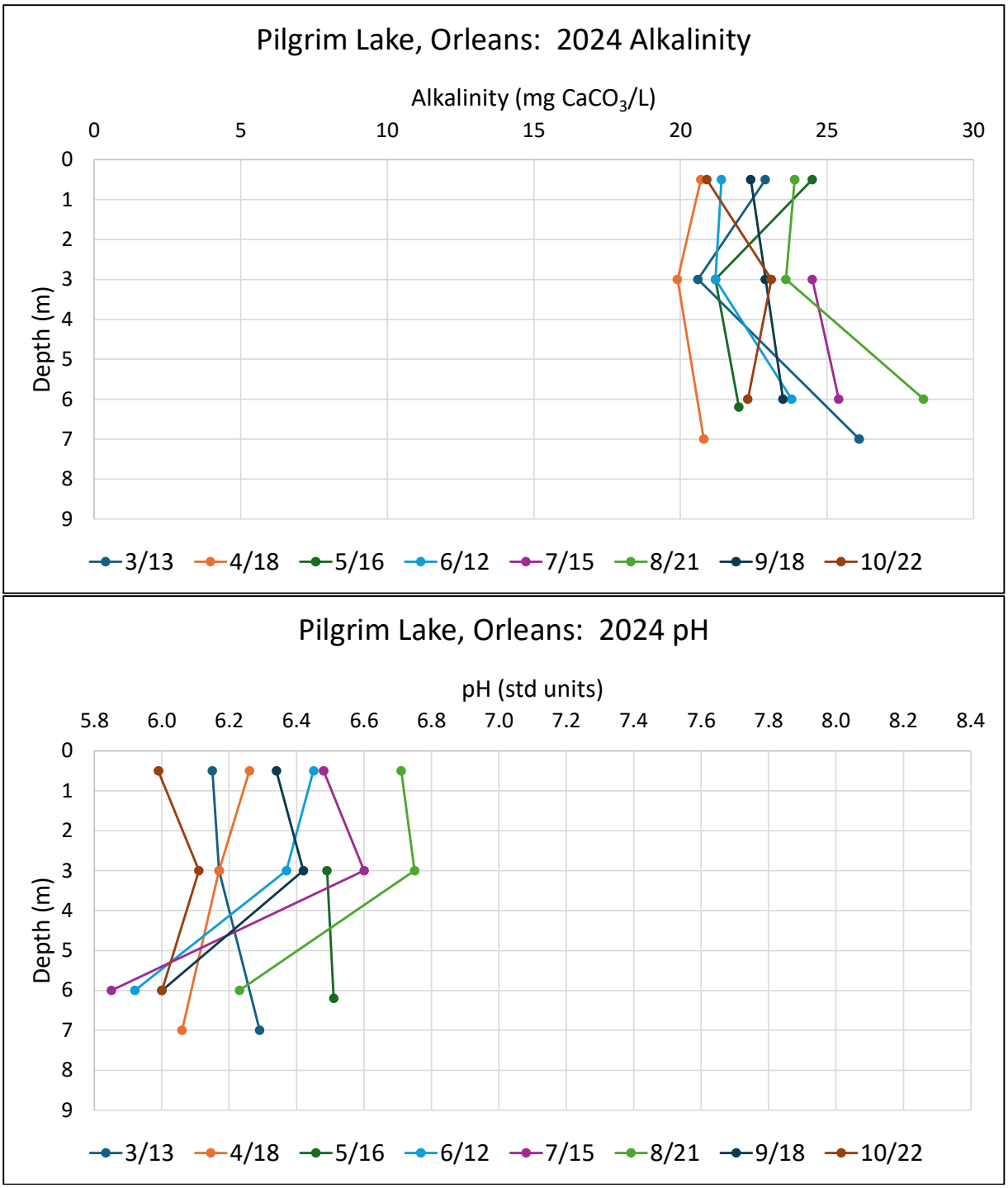


Figure 9. Pilgrim Lake: 2024 Alkalinity and pH Profiles. Alkalinity and pH readings showed no notable impact from the 2024 alum treatment. 2024 shallow alkalinity levels varied between 20 and 24 mg $CaCO_3$/L with the August 2024 reading at the upper end of the range. The August reading was slightly higher than the long-term PALS average (18 mg $CaCO_3$/L, n=19), but within the historical range of shallow August/September levels. 2024 pH readings were acidic, as is natural for Cape Cod ponds, with shallow readings varied between 6.0 and 6.7. The August 2024 shallow pH reading was 6.7, which was slightly lower than the long-term PALS average (6.9, n=20). The initial pH readings after the alum treatment (March 13) were lower than August 2024, but were also within the long-term PALS range and were greater than the pH readings in October.