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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: November 21, 2025

RE: 2025 Pilgrim Lake: Water Quality Changes Post-Alum Treatment: YR2, 6 month 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 2017 assessment-specific data, 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. The assessment portion of the Management Plan 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 watershed septic systems were the primary source (51% to 56%) of phosphorus measured in the Pilgrim Lake water column (**Figure 1**).

The Management Plan also reviewed water quality management options that were specific to the

[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.

identified 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 of the alum treatment [*i.e.*, Order of Conditions (OOC)] were requirements for pre-alum application water quality monitoring followed by monthly post-alum application water quality monitoring from March through October. Monitoring results were required to be reported in two reports during each of the years: a six month report and a one year report.

The Town hired CSP/SMAST to complete the water quality sampling, laboratory assays of the samples, and the results reporting required in the OOC. The initial six month report was submitted to the Town on November 22, 2024[3] and contained the pre-alum and initial post-alum monitoring results. The Year 1 Technical Memorandum was submitted to the Town on October 14, 2025.[4] This current Technical Memorandum is the Pilgrim Lake Year 2 six month report.

II. Pilgrim Lake Alum Treatment and Follow-up Monitoring

The Pilgrim Lake alum treatment OOC required monthly water quality monitoring from March through October of "aluminum levels, temperature, oxygen, pH, alkalinity, conductivity, total and dissolved phosphorus, nitrogen, and secchi (sic) transparency."[5] This monthly monitoring was to occur for two years with six month and annual reports in each year.

In order to be consistent with the OOC, 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 2025 dates: March 18, April 16, May 2, June 2, July 1, August 1, September 3, and October 2. 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.[6]

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[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] CSP/SMAST Technical Memorandum. October 14, 2025. 2024 Pilgrim Lake: Water Quality Changes Post-Alum Treatment: One Year Report. From: E. Eichner, TMDL Solutions and M. Labrie, CSP/SMAST. To: G. Meservey, Director of Planning & Community Development, Town of Orleans. 13 pp.

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

[6] 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.

Temperature profiles showed that 2025 water column conditions were similar to 2024, but had differences in timing. Temperature profiles in March and April 2025 were isothermic with similar temperatures throughout the water column (**Figure 3**). Shallow temperatures measured in May were warmer than deep readings, but the differences were insufficient for stable stratification. In May 2024, stratification was measured in the May 16 profile. In June 2025, the initial stratification was measured with the upper, warm, well-mixed layer (*i.e.*, the epilimnion) extending to 3 m depth, the same depth measured in June 2024. The rest of the June 2025 profile showed decreasing temperatures with each measurement increment; similar profile patterns albeit with higher epilimnion temperatures were measured in July, August, and September. The epilimnion extended to 3 m again in July 2025, then 4 m in August, and 5 m in September. This pattern was the same as in 2024. The peak 2025 temperature was 26°C measured at multiple depths in the August 1 profile, while the peak 2024 temperature was 27.8°C measured at 0.5 m on July 15. The October 2025 temperature profile showed isothermic readings to 6.3 m, which again was similar to 2024, although the 10/2/25 temperatures were mostly 19.5°C and the 10/22/24 temperatures were between 14 and 16°C.

DO profiles in 2025 generally showed acceptable DO concentrations in the epilimnion except for August and reduced levels and hypoxia/anoxia in the deeper readings (**Figure 4**). As with the temperature profiles, the March and April 2025 DO profiles have similar readings throughout the water column, which would be consistent with well-mixed conditions. The conditions during these months were more well-mixed than in 2024, where there was some weak stratification at 4 m in April and decreasing DO levels at deeper depths. In May 2025, DO levels began to decrease at depths deeper than 4 m with readings at deeper than 7 m less than the MassDEP minimum of 5 mg/L. In May 2024, DO levels were similar to 5 m and then began to decrease. In June 2025 with the initial temperature stratification, DO levels decreased at 4 m and deeper and anoxia was measured at 7.7 m and deeper. In July 2025, DO levels began to decrease between 4 m and 5 m, but the anoxia remained at approximately the same depth (7.5 m). July 2025 DO saturation levels (~110%) suggested, however, that sediment nutrients were being added to the epilimnion. Some of these nutrients may have been because of the warming of the shallow sediments (*e.g.*, shallow temperatures increased by ~5°C between June and July) and accompanying aerobic digestion of organic matter. The July 2025 profile was similar to July 2024 profile, though the July 2024 profile had higher shallow saturation levels. The August 1, 2025 profile had acceptable, but low DO in the epilimnion (*e.g.*, DO saturation levels mostly at ~80%) and a 3.1 mg/L DO concentration 5 m depth at the deep edge of the epilimnion. This profile suggest that deep hypoxia was mixing into the epilimnion and causing decreased levels throughout the layer. Similar deep conditions existed in the September 2025 profile, but epilimnion DO levels had returned to near atmospheric equilibrium (~100% saturation), which is consistent with well-mixed conditions. In the October 2025 DO profile, the whole water column was mixed and DO levels suggest that the deep hypoxia/anoxia was still having impacts (e.g., DO saturation levels were between 82% and 92%). These 2025 profiles readings were variations on those measured in 2024, as well as in 2017 when the Management Plan readings were collected: deep anoxia, hypoxia occasionally reaching the bottom of the epilimnion, impacts of deep hypoxia impacting the epilimnion, etc. These reinforce the need for phosphorus reductions to manage water quality in Pilgrim Lake.

Shallow total phosphorus (TP) concentrations in 2025 tended to be similar to most 2024 months (~20 µg/L), but deep TP concentrations tended to be slightly lower than in 2024 (**Figure 5**). In 2024, shallow TP concentrations were generally between 19 µg/L and 22 µg/L except for higher

readings in the April and May (*i.e.*, right after the March alum treatment) and an August 15 µg/L reading. In 2025, this pattern was similar with TP levels in most months between 17 µg/L and 22 µg/L, higher levels in May and October, and a low level in September (12 µg/L). Deep TP concentrations in 2025 were generally lower than 2024 with levels between 20 µg/L and 30 µg/L and with one high reading (86 µg/L) on September 3. In 2024, deep readings were generally between 29 µg/L and 47 µg/L with one high reading (75 µg/L) on August 21. The average deep TP level in 2024 was 39 µg/L, while it was 33 µg/L in 2025. All TP concentrations measured in 2024 and 2025 were greater than the 10 µg/L Ecoregion Threshold.[7]

The reduced TP levels slightly reduced chlorophyll concentrations in 2025 (**Figure 6**). Average chlorophyll levels in 2024 from 0.5 m, 3 m, and deep samples were 8 µg/L, 11 µg/L and 23 µg/L, respectively. Average chlorophyll levels at the same depths in 2025 were 8 µg/L, 7 µg/L and 16 µg/L, respectively. Highest shallow chlorophyll concentrations occurred in the spring, likely due to warming of shallow sediments and accompanying aerobic release of phosphorus. All 2024 and 2025 CHL concentrations were greater than the 1.7 µg/L Ecoregion Threshold.[8] As would be expected from reduced TP levels, Secchi clarity also improved slightly in 2025 compared to 2024 (**Figure 7**).

Since nitrogen was not addressed by the alum treatment, total nitrogen (TN) concentrations in 2024 and 2025 were similar. Average shallow, 3 m, and deep TN levels in 2024 were 0.58 mg/L, 0.59 mg/L, and 0.73 mg/L, respectively. In 2025, the respective averages at the same depths were 0.63 mg/L, 0.61 mg/L, and 0.71 mg/L (**Figure 8**). These levels during both years were higher than the average shallow TN concentrations in 2017 (0.44 mg/L),[9] which would be consistent with gradual greater TN additions based on additional development within the Pilgrim Lake watershed and groundwater travel times.[10]

In addition to the usual nutrient-related, water quality measures, the ConComm also required regular monthly assays of total aluminum and dissolved aluminum levels throughout 2024 and 2025. Total aluminum and dissolved aluminum readings in 2024 showed a return to background levels within two months after the alum treatment, while 2025 had even lower concentrations throughout the sampling period (**Figures 9, 10**). 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 2024 were greater than the USEPA estimated acute Aquatic Life Criteria concentrations based on Pilgrim Lake pH and alkalinity.[12]

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 in 2024 and 2025 show that the treatment met this goal. The 2024 and 2025 monitoring data showed that Pilgrim Lake

[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] *Ibid*.

[9] Eichner, E., B. Howes, and D. Schlezinger. 2019. Pilgrim Lake Management Plan and Diagnostic Assessment.

[10] Pleasant Bay MEP assessment (2006) projected a 25% increase in Pilgrim Lake watershed nitrogen loads based on 2002/2003 watershed development.

[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).

continues to have temperature stratification during the summer, just as it did in 2017 during monitoring for the Management Plan. This stratification isolates the deeper portions of the water column and allows sediment oxygen demand to create anoxic conditions that often spread throughout the deep layer and occasionally impact the shallow, epilimnion layer. The alum treatment reduced the amount of phosphorus released from the sediments during these anoxic periods and, in turn, reduced the phosphorus added to the water column from the sediments. Reduced phosphorus levels reduced the levels of chlorophyll, a proxy measurement for phytoplankton levels, and slightly improved summer Secchi clarity readings.

Aside from preventing algal blooms, the alum treatment had moderate impacts on reducing water column phosphorus levels. This extent of this outcome was somewhat expected given that the Management Plan found that watershed septic system TP additions were a much larger portion of the phosphorus in the water column than the sediment inputs. Watershed wastewater inputs were 51% to 56% of water column phosphorus inputs to Pilgrim Lake. In comparison, sediment phosphorus additions were 12% to 26% of the water column inputs with the higher end of the range occurring late in the summer when anoxia was most extensive (**see Figure 1**). The primary water quality management control for Pilgrim Lake remains the planned CWMP sewering and more significant and sustainable improvements in the water quality will occur when the sewering is implemented.

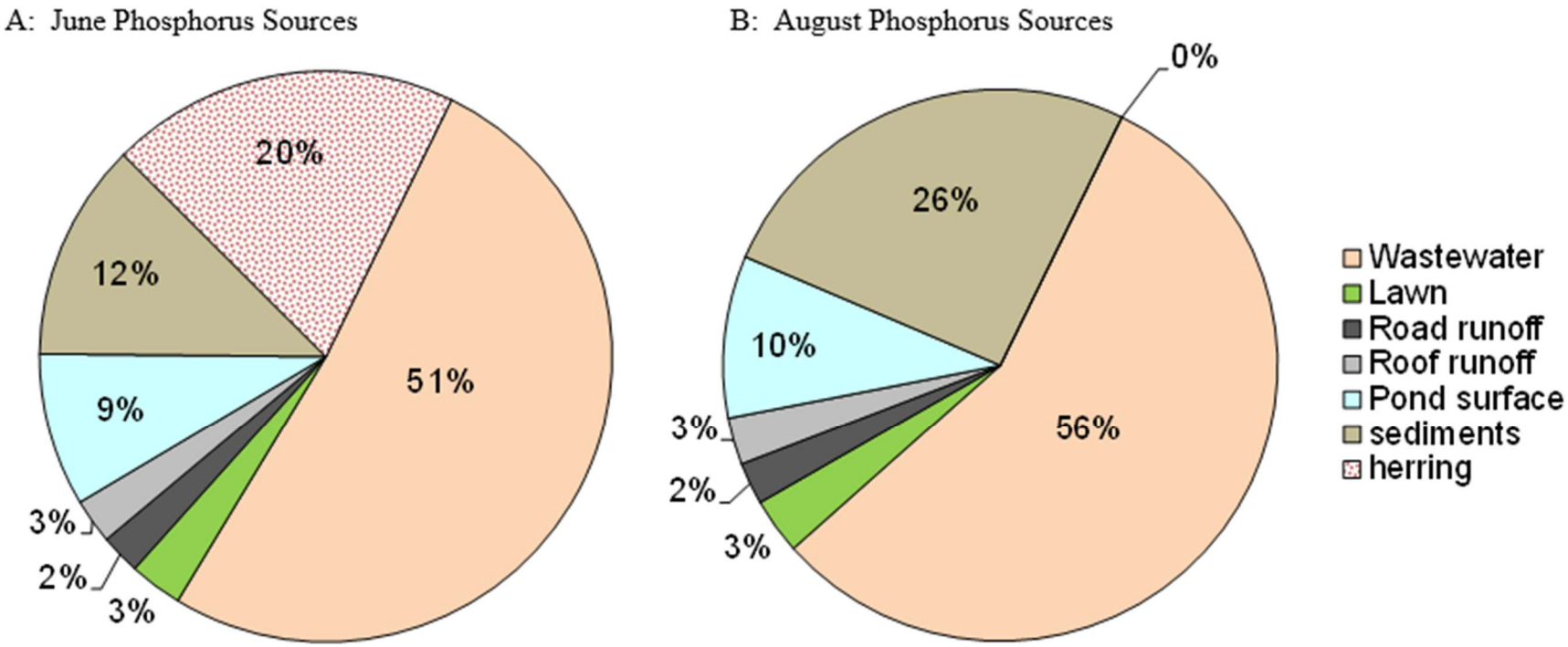

Figure I. 2017 Seasonal Phosphorus Loading Sources to Pilgrim Lake Water Column. Based on review of the watershed and measurements of road runoff and pond sediment regeneration rates, CSP/SMAST staff developed phosphorus budgets to determine the relative inputs of phosphorus to the water column of Pilgrim 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.

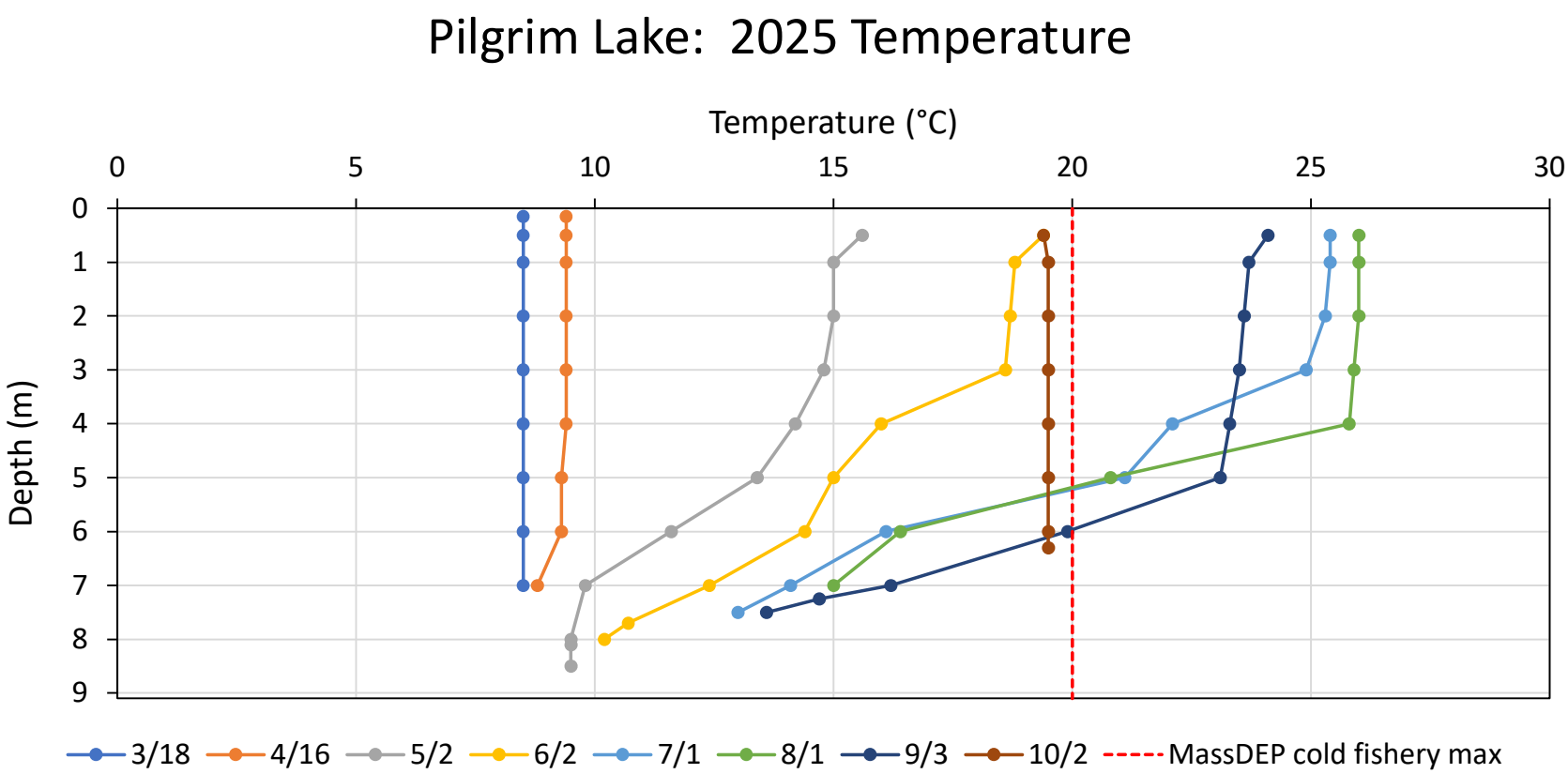

Figure 3. Pilgrim Lake: 2025 Water Column Temperature Profiles. Profiles were collected monthly between March and October at the long term sampling point. The lake thermally stratified beginning in June and was stratified through September. March, April, and October profiles had isothermic, well-mixed conditions. Once stratification occurred, the epilimnion (*i.e.*, the well-mixed, shallow portion of the water column) extended to 3 m depth in June and July, 4 m in August, and 5 m in September. 2025 readings were similar to 2024 readings.

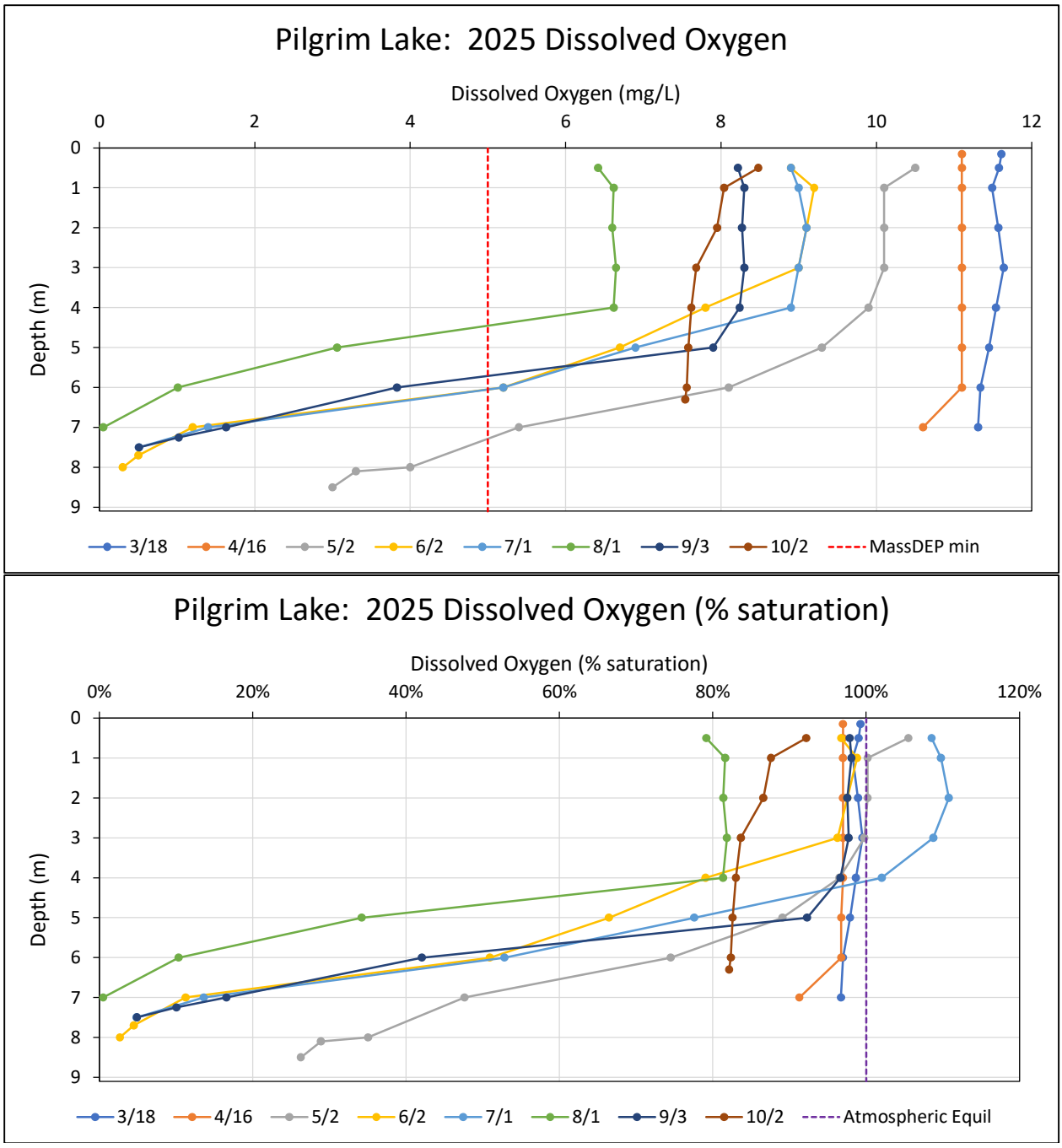

Figure 4. Pilgrim Lake: 2025 Water Column Dissolved Oxygen Profiles. Profiles were collected monthly between March and October at the long term sampling point. The lake thermally stratified beginning in June and was stratified through September. Once stratification isolated the deeper portions of the water column, sediment oxygen demand caused hypoxia/anoxia in the deeper portions. DO levels with less than the MassDEP minimum (5 mg/L; 314 CMR 4) generally at depths greater than 5 m, although the August 1 profile had a level <5 mg/L at 5 m depth. Shallow DO levels were generally near atmospheric equilibrium (~100% saturation), but the August profile levels near 80% saturation suggested that deep hypoxia was impacting the shallow water column. When temperature stratification was not present (*i.e.*, March, April, and October), DO concentrations throughout the water column were greater than the MassDEP minimum.

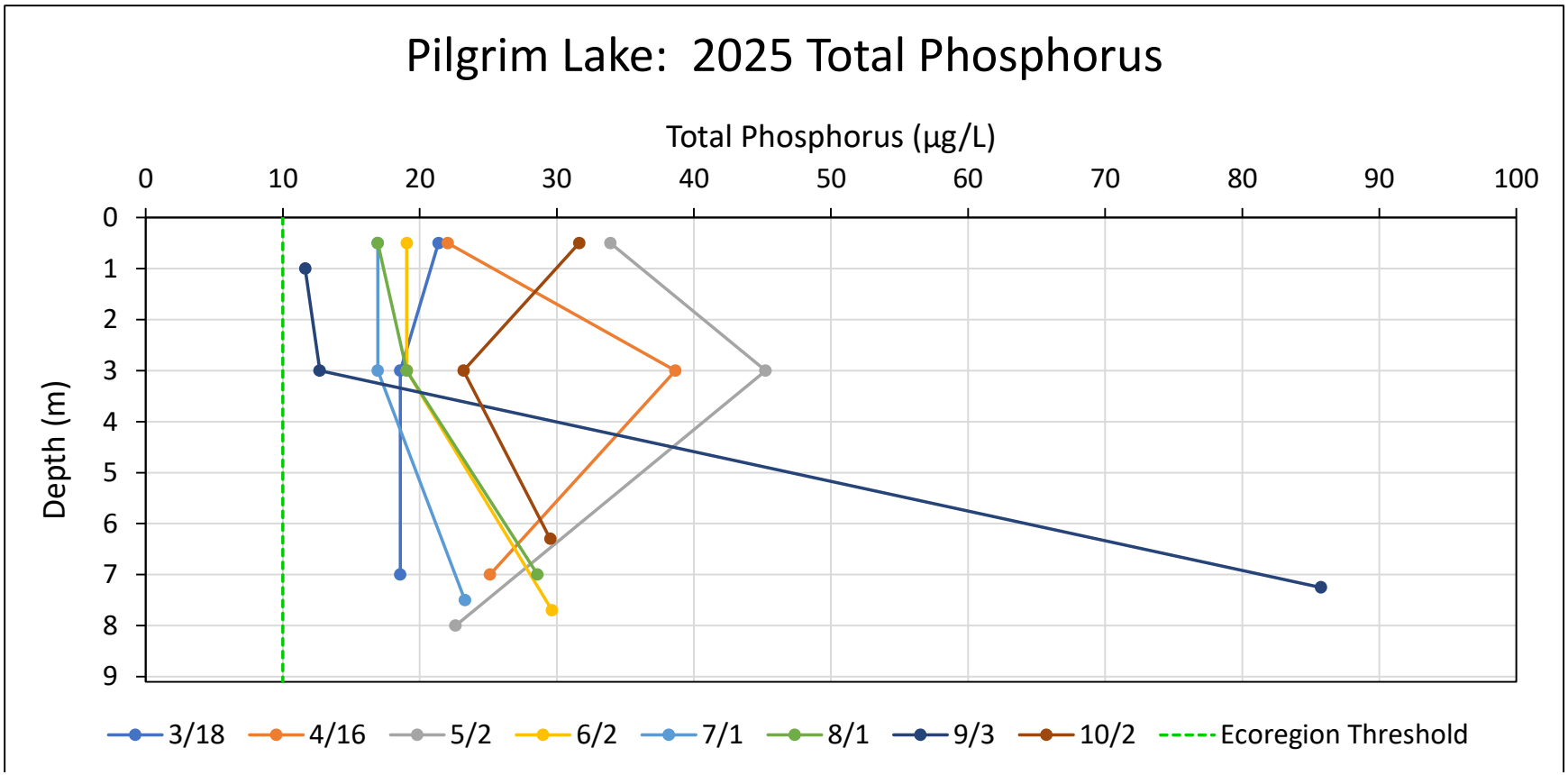

Figure 5. Pilgrim Lake: 2025 Water Column Total Phosphorus Profiles. Shallow total phosphorus (TP) concentrations in 2025 tended to be within the same range as during 2024, but deep TP levels tended to be within a lower range than 2024. In 2025, shallow TP levels in most months were between 17 µg/L and 22 µg/L with higher levels in May and October, and a low level in September (12 µg/L). The shallow TP range in 2024 after the alum treatment tended to be between 19 µg/L and 22 µg/L. In 2025, deep TP levels in most months were between 20 µg/L and 30 µg/L with one high reading (86 µg/L) on September 3. In 2024, deep TP levels tended to be higher (29 µg/L to 47 µg/L range), but also had one high reading (75 µg/L) on August 15. The average deep TP level in 2024 was 39 µg/L, while it was 33 µg/L in 2025. All TP concentrations measured in 2024 and 2025 were greater than the 10 µg/L Ecoregion Threshold.

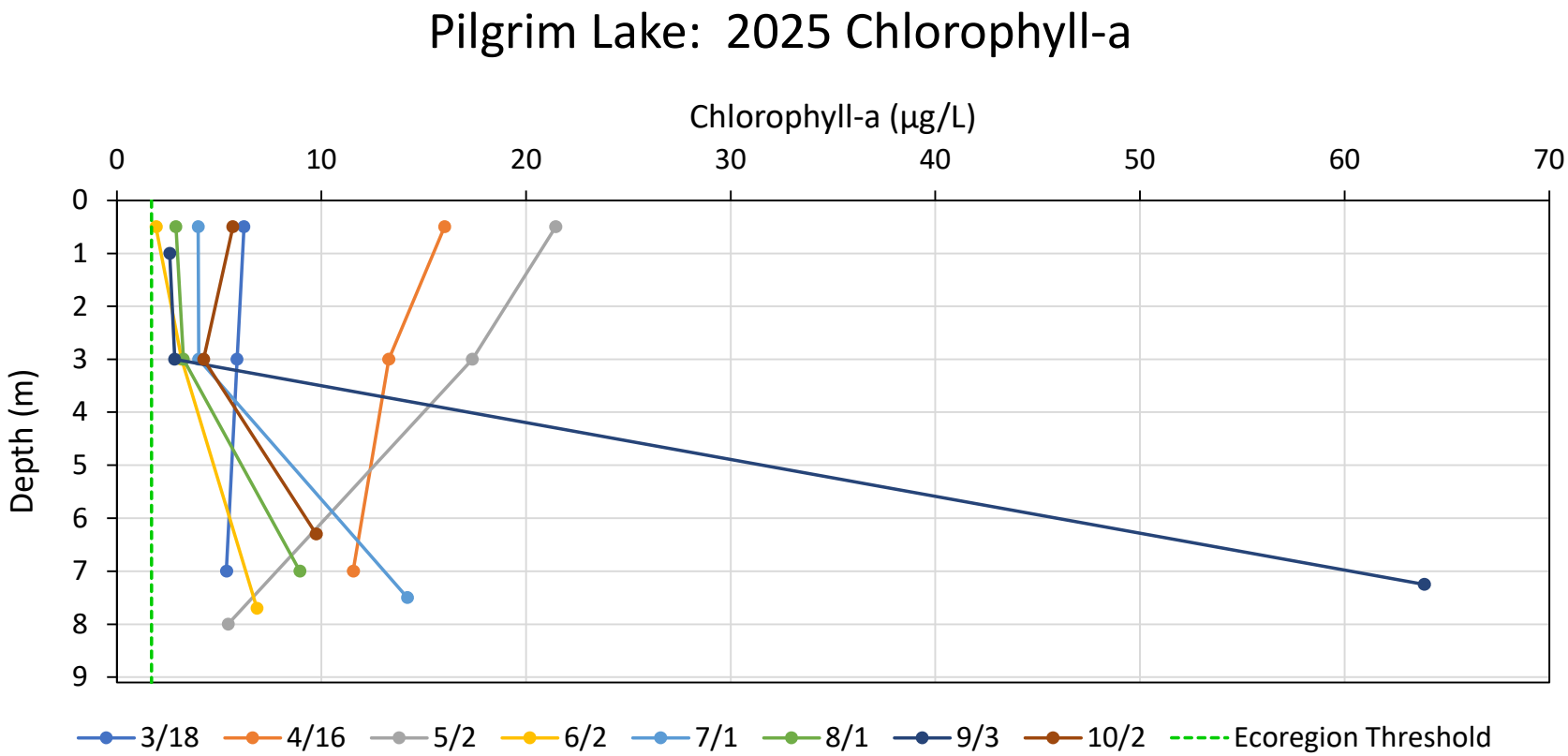

Figure 6. Pilgrim Lake: 2025 Water Column Chlorophyll-a Profiles. Water column chlorophyll concentrations in 2025 were slightly less than in 2024. Average 2025 chlorophyll levels in 0.5 m, 3 m, and deep samples were 8 µg/L, 7 µg/L and 16 µg/L, respectively, while average 2024 chlorophyll levels at the same depths were 8 µg/L, 11 µg/L and 23 µg/L, respectively. Highest shallow chlorophyll concentrations occurred in the spring, likely due to warming of shallow sediments and accompanying aerobic release of phosphorus. The high level in the deep sample on September 3 was similar to high levels measured in deep samples in 2024 in August 21 and September 18 samples. All 2024 and 2025 CHL concentrations were greater than the 1.7 µg/L Ecoregion Threshold.

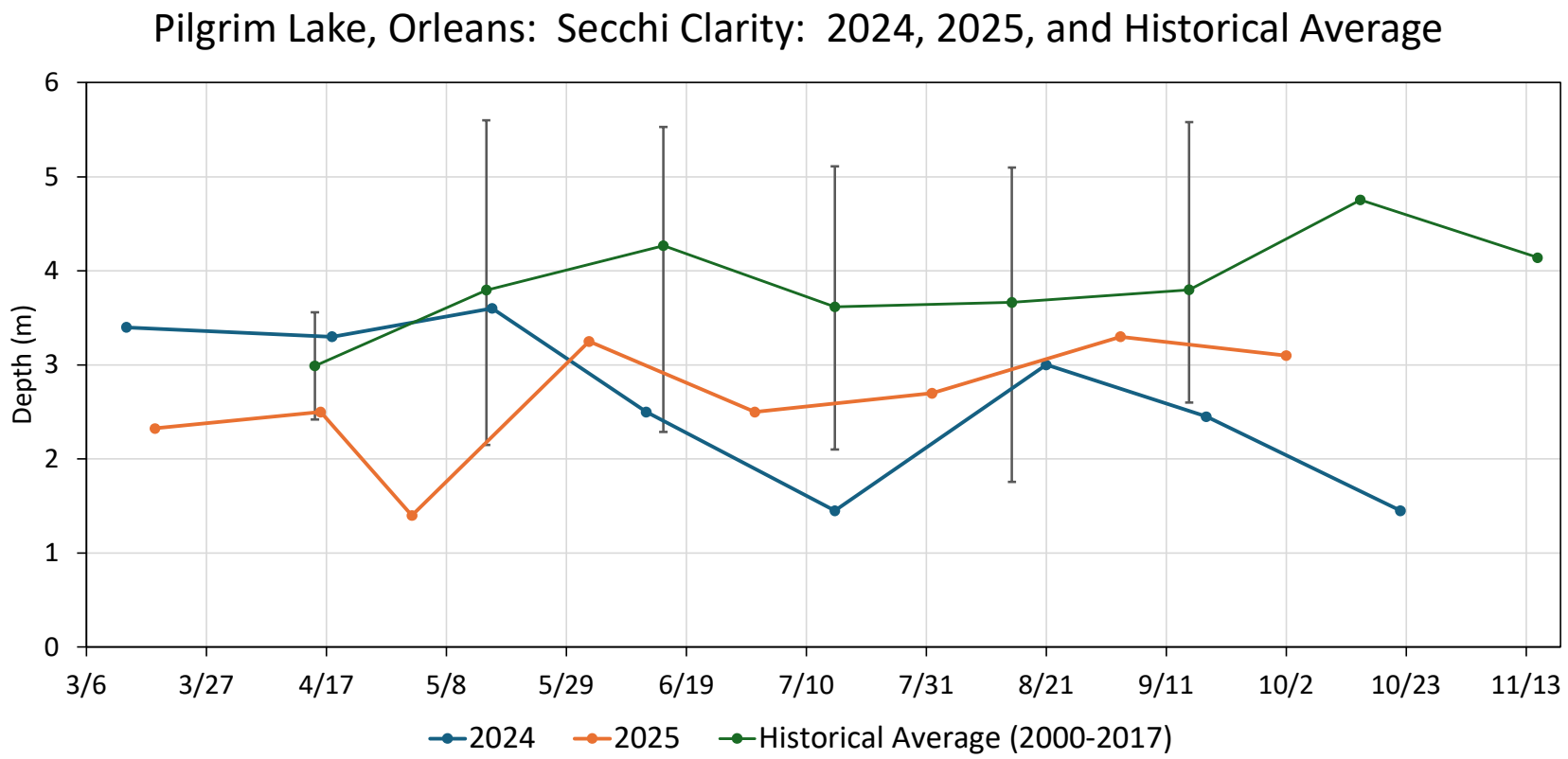

Figure 7. Pilgrim Lake: Water Column Secchi Clarity: 2024, 2025, and Historical Ranges (2000-2017). Secchi clarity levels in 2025 were greater than 2024 levels during June through October, but were less than 2024 levels in March and April. Both 2024 and 2025 clarity levels throughout the years were at the low end of the monthly historical average based on data collected between 2000 and 2017. The slightly greater clarity in 2025 was consistent with slightly lower 2025 TP concentrations compared to those in 2024.

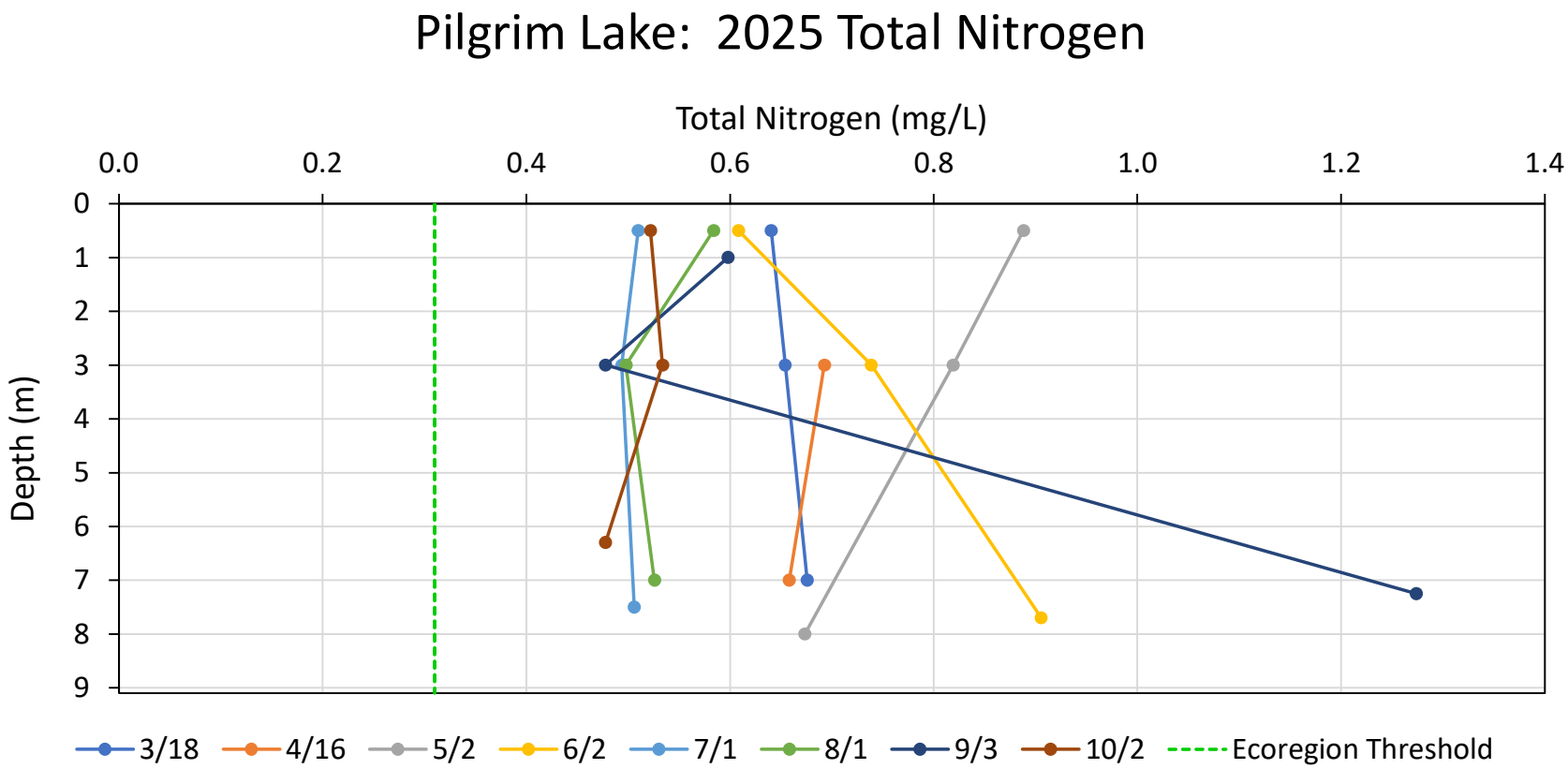

Figure 8. Pilgrim Lake: 2025 Water Column Total Nitrogen Profiles. Water column TN concentrations in 2024 and 2025 were similar. In 2025, shallow, 3 m, and deep average TN levels were 0.63 mg/L, 0.61 mg/L, and 0.71 mg/L, respectively, while 2024 averages at the same depths were 0.58 mg/L, 0.59 mg/L, and 0.73 mg/L, respectively. Given that nitrogen is not addressed by alum treatments, it was reasonable to expect that 2024 and 2025 TN levels would be similar. However, shallow concentrations were notably higher than 2017 levels (0.44 mg/L TN). A gradual increase in TN levels would be consistent with gradually greater watershed TN additions as more of the watershed is developed. All TN water column concentrations in both 2024 and 2025 were greater than the Cape Cod Ecoregion Threshold of 0.31 mg/L TN.

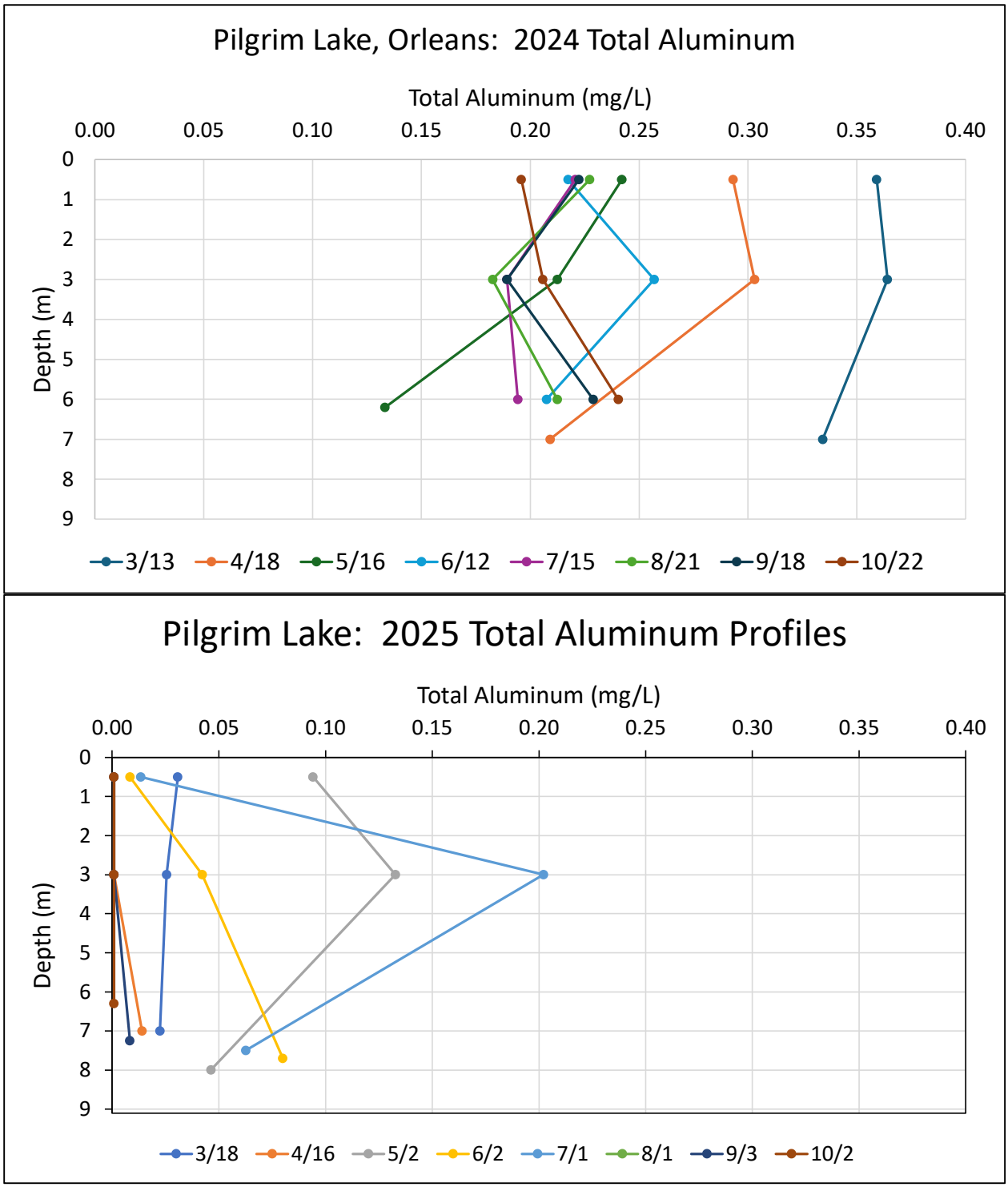

Figure 9. Pilgrim Lake: 2024 and 2025 Total Aluminum Water Column Profiles. Total aluminum concentrations were elevated during the initial post-alum treatment water column sampling on March 13, 2024, but the concentrations decreased significantly in the April 18 samples and were within the 2024 background range by the May 16 sampling. 2025 levels were even lower than those in 2024; the maximum 2025 concentration (0.20 mg/L) was within the range of 2024 levels, but the rest of the levels were less than those in 2024. None of the concentrations, including those in March 2024, were greater than estimated USEPA acute Aquatic Life Criteria concentrations based on Pilgrim Lake pH and alkalinity.

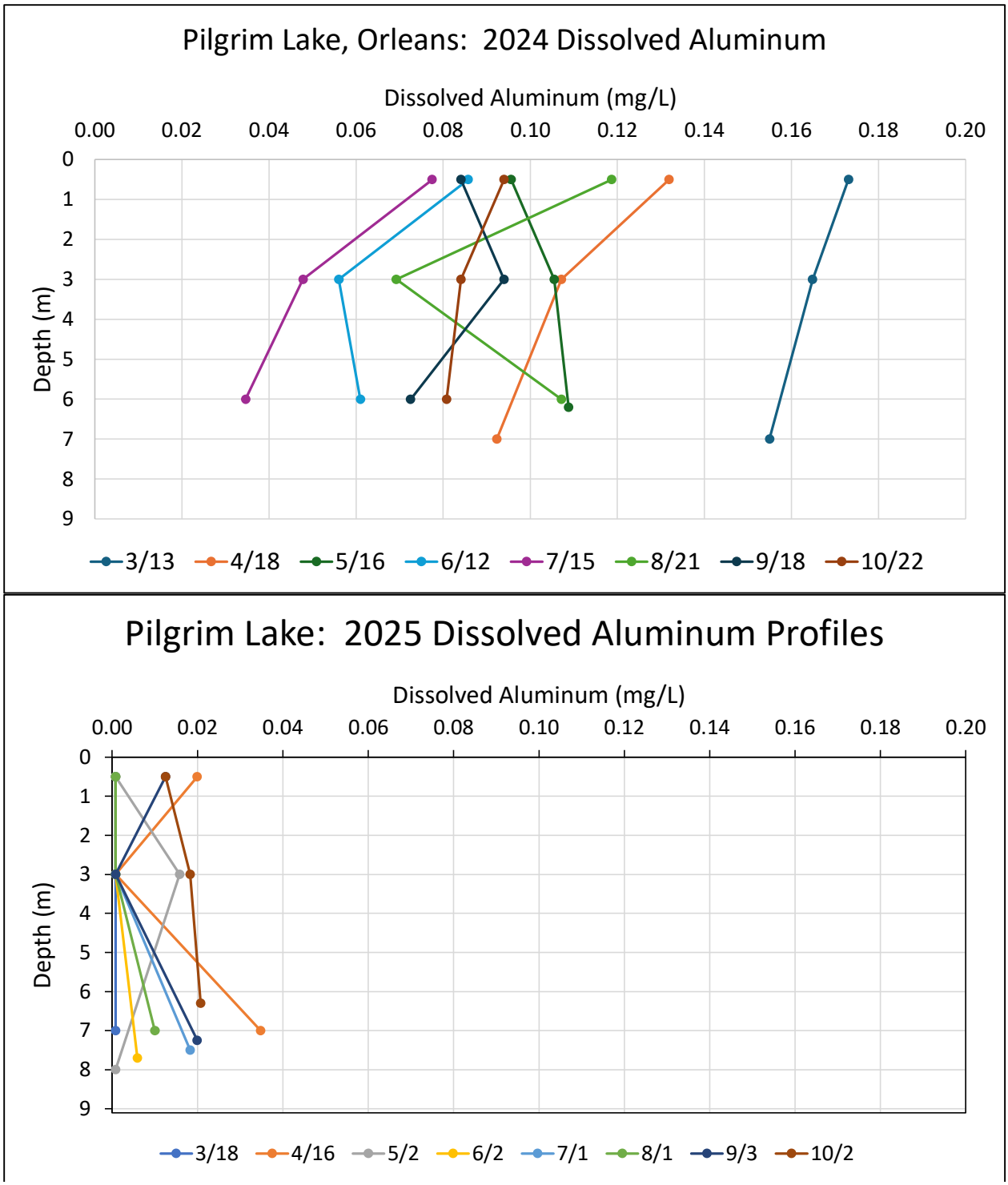

Figure 10. Pilgrim Lake: 2024 and 2025 Dissolved Aluminum Profiles. Dissolved aluminum concentrations were elevated during the initial post-alum treatment water column sampling on March 13, 2024, but the concentrations decreased significantly in the April 18 samples and were within the background range by the May 16 sampling. 2025 levels were even lower than those in 2024; the maximum 2025 concentration (0.035 mg/L) was less than the minimum 2024 concentration. None of the concentrations, including those in March 2024, were greater than estimated USEPA acute Aquatic Life Criteria concentrations based on Pilgrim Lake pH and alkalinity.