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Technical Memorandum

To: George Meservey, Director of Planning & Community Development, Town of Orleans
Nate Sears, Natural Resources Manager, Town of Orleans

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Date: October 14, 2025

RE: Cedar Pond Adaptive Management Monitoring Program: 2025 Semi-Annual Report
(Status of field activities between January 2025 and August 2025)

This Technical Memorandum, 2025 Semi-Annual Cedar Pond Report, on the status of water quality monitoring is required under the 2017 Certificate of the Secretary of Energy and Environmental Affairs, the Massachusetts Department of Environmental Protection (MassDEP) Superseding Order of Conditions, and the Massachusetts Division of Marine Fisheries (MassDMF) Fishway Operations and Maintenance Plan. A 2025 Annual Report will be prepared following completion of 2025 calendar year monitoring. The 2025 Annual Report will include: a) a more refined assessment of all 2025 data, including data collected during the last three months of 2025, b) a comparison of 2025 data to 2018-2024 monitoring data, c) discussion of past adaptive management actions, and d) a review of potential modifications of management activities for consideration for implementation in 2026.

I. Background

Cedar Pond is a heavily manipulated kettle pond located at the headwaters of a tidal creek that discharges to the innermost portions of the Rock Harbor estuary (**Figure 1**). Through water quality monitoring conducted for the 2008 Massachusetts Estuaries Project (MEP) ecosystem assessment of Rock Harbor[1] and regular monitoring by town volunteers,[2] the impaired water quality of Cedar Pond had been well documented.[3] Although it was impaired, 2002/2003 stream measurements for the Rock Harbor MEP assessment showed that the pond was removing 58% of the watershed nitrogen flowing through it and, therefore, was preventing it from reaching the estuarine basin of Rock Harbor. The MEP assessment also determined that the Rock Harbor estuary was impaired by nitrogen enrichment and in need of nitrogen reduction to restore its impaired resources.

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[1] Howes B.L., S.W. Kelley, J. S. Ramsey, R.I. Samimy, D.R. Schlezinger, E.M. Eichner. 2008. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Rock Harbor Embayment System, Orleans, MA. SMAST/DEP Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 132 pp.

[2] Eichner, E. 2007. Review and Interpretation of Orleans Freshwater Ponds Volunteer Monitoring Data. Cape Cod Commission. Barnstable, MA. 80 pp.

[3] *e.g.*, failing to meet state surface water regulatory standards, regular low or anoxic dissolved oxygen concentrations, high nitrogen, phosphorus, and chlorophyll concentrations.

Portions of the Cedar Pond system have been subject to various management actions over the past 150 years, mostly without comprehensive assessments of potential impacts. These actions have included: a) filling a portion of the pond for the construction of Route 6, b) siting regional power lines over the pond that were subsequently used by a large summer cormorant population for roosting, and c) changes to the stream channel connecting the pond to Rock Harbor. The significant changes to the stream channel in 2007 were the most recent action and occurred after the completion of the MEP stream monitoring. The stream changes increased tidal saltwater inflows to the pond and gradually increased salinity in the pond. The pond ecosystem was altered from a brackish, slightly salty condition with surface salinity of 6.9 parts per thousand (ppt) to a coastal salt pond with 21.8 ppt surface water salinity. This shift in pond ecology also eliminated the watershed nitrogen attenuation the pond provided for Rock Harbor. Subsequent monitoring showed that, during at least one summer, the pond became a net nitrogen source, adding to the nitrogen exported to Rock Harbor and increasing the overall export beyond the load added solely by the watershed. The significant increase in salinity magnified nutrient-related water quality impairments within the pond, degraded the potential pond herring habitat, and threatened the adjacent Atlantic White Cedar wetland.

In 2011-2012, the Town asked the Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth (CSP/SMAST) to develop a management plan for Cedar Pond with three goals: 1) restore water quality, 2) restore the historic herring run, and 3) protect the adjacent Atlantic White Cedar wetland.[4] The 2013 Management Plan was reviewed and approved by appropriate Town Committees, the Board of Selectmen and the Conservation Commission. However, the Conservation Commission approval was appealed by some Orleans citizens, and the Town was then required to complete a Massachusetts Environmental Policy Act (MEPA) filing for the project. Subsequently, MEPA approved the Plan in 2017 and added a condition to develop a Fishway Operations and Maintenance Plan (Fishway Plan). The Fishway Plan was developed in coordination with MassDMF with the goal to provide potential herring/alewife passage into the pond for spawning and out of the pond for the young of the year.

The Cedar Pond Management Plan included an adaptive management approach, where regular review of monitoring data would be used to guide adjustments in plan implementation. State regulatory approvals confirmed and formalized a requirement to have regular reporting of monitoring results. Monitoring results are to be reviewed annually in two reports: 1) a Semi-Annual Report focused on the status of data collection efforts from January to July and 2) an Annual Report reviewing a whole year of data results. The Annual Report will have recommendations for any management changes to better achieve the Management Plan goals.

This Technical Memorandum is the 2025 Semi-Annual Report and focuses on 2025 dissolved oxygen (DO) and temperature profile data collected from March 2025 through September 2025. Laboratory assay results for water column samples collected during this period are still being compiled. The 2025 Annual Report will complete an in-depth review and presentation of all 2025 data, along with comparison to previous monitoring results. It is anticipated that the 2025 Annual Report will be completed during the first quarter of 2026.

[4] Eichner, E., B. Howes, and D. Schlezinger. 2013. Cedar Pond Water Quality Management Plan. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 54 pp.

II. Management Plan Implementation: Historical Water Quality Improvements (2018-2024)

One of the adaptive strategies in the Management Plan has been to gradually return Cedar Pond to its historically lower salinity/brackish conditions by reinstalling the tidal boards in the pond outlet. The boards would only allow the highest tides into the pond, while also allowing freshwater from natural watershed groundwater inputs to gradually return the pond to lower salinities. Based on historical data at the time, it was expected that this return back to brackish conditions would improve the impaired 2011-2012 water quality conditions that had developed due to removal of the boards and the changes in the stream between Rock Harbor and Cedar Pond. CSP/SMAST developed an initial board elevation in 2014 based on previously collected data[5] and the elevation was adjusted as more data was collected.

The initial board elevation was adjusted during the development of the Fishway Plan by Town, MassDMF, and CSP/SMAST staff. The goal of the Plan was to balance tidal inflows, water quality goals, pond water levels, and fish passage. Board elevations at the outlet were to be adjusted throughout the year to allow spawning fish to enter in the spring and juvenile fish to leave in the summer and fall. The spring elevation (March 15 to June 30) was set to allow at least 6 inches (0.15 m) of water depth to flow over the top of the board. This elevation was thought to facilitate entry into the pond by river herring migrating upstream from Cape Cod Bay/Rock Harbor for spawning within the pond. On July 1, when water levels have historically decreased, the board elevation would be adjusted to allow at least 2 inches (0.05 m) of outflowing water over the top board. This adjustment would last until November 15 and would be designed to allow juvenile herring (spawn of the year) to leave the pond. The Plan also had a commitment from all staff to identify any fish noted during visits to the pond for monitoring or board adjustment.

In order to provide understanding of water levels and board elevations, CSP/SMAST initially installed shallow and deep sondes with multiple sensors in the center of the pond. These sondes collected readings every 10 to 15 minutes. This monitoring was accompanied by approximately monthly water column samples and dissolved oxygen and temperature profiles at the deep basin and streamflow readings and water quality samples. These mid-pond sondes have been collecting continuous readings since November 2017.

During the first annual review of monitoring results, it was noted that the pond water quality improved, but salinity increased after the boards were lowered. Based on the data review, Town, DMF, and CSP/SMAST staff discussed options to better attain the Management Plan goal of reduced salinity while also addressing Fishway Plan goals. As a result of the discussions, it was agreed that board elevations would be maintained in 2019, but the opening in the boards would be limited to a 6 inch notch. The goals of this configuration would allow fish passage, but reduce the cross-sectional area exposed to tidal water inputs. It was hoped that this change in the board configuration would help to retain the lower salinity concentrations of winter/early spring throughout the summer. CSP/SMAST also added another water level recorder, deployed at the pond outlet, in order to better understand localized water levels at the boards.

[5] Howes, B., E. Eichner, R. Samimy, J. Ramsey, and S. Kelley. 2014. CSP/SMAST Technical Memorandum: Board Height Recommendation for Cedar Pond Outlet. To: Town of Orleans (George Meservey, Director of Planning & Community Development and Carolyn Kennedy, Chair, Marine and Fresh Water Quality Task Force). Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 13 pp.

Review of the annual data in 2019, 2020, and 2021 showed shallow salinity was low in March/April, but typically increased during the summer at the same rate as measured in 2018 once the board notch was added. In 2019, winter and early-spring salinity in the pond was significantly reduced and the pond began March (the beginning of Fishway Plan board lowering) at a low salinity just above (~6 ppt) the 1 to 4 ppt range targeted in the Management Plan.[6] Salinity levels throughout 2019 were lower than 2018, because initial 2019 salinity levels were low. In 2020, the elevation of the bottom of the notch was increased slightly following staff review of water level monitoring results.[7] Following this change, water quality improved incrementally, but salinity rates again increased at approximately the same rate as in 2018 and 2019 once the notch was added. In 2021, spring salinity levels were slightly lower than 2020, but increased at approximately the same rate as previous years once the board notch was added. In 2022, the rate of salinity increase was lower, largely because spring salinity concentrations were higher, but the late summer peak salinity was similar to 2019-2022 levels. In 2023, salinity levels were lower than 2022. Shallow salinities were relatively low throughout 2023 (average = 7.3 ppt; peak = 8.6 ppt) and deep readings were higher, but relatively stable (average = 13.1 ppt; peak = 14.9 ppt).[8] Review of some of the 2023 data suggested that there were lower tidal inputs to Cedar Pond.

Water quality during 2019-2024 improved each year with higher shallow DO levels, lower nitrogen and phosphorus concentrations, and less nitrogen and phosphorus transferred from the pond to Rock Harbor. These improvements were initially measured in 2019 compared to 2011-2012 conditions with 2020 conditions showing an even greater proportion of the pond water column achieving the MassDEP minimum dissolved oxygen concentrations, further decreases in TN and TP water column concentrations, and lower pond export of TN and TP to Rock Harbor.[9] Water quality conditions in 2021 were again incrementally better with: 1) all shallow DO profile concentration readings above the MassDEP minimum for the first time and 2) shallow TN concentrations were approximately the same as 2020, but shallow TP concentrations were the lowest measured 2018-2021. Water column dissolved oxygen (DO) concentrations in 2022 were incrementally better than 2021 with acceptable DO concentrations throughout a greater portion of the water column than in any of the previous monitoring years.[10] Deep conditions continued to be impaired, but stronger salinity stratification in the water column generally reduced their impact on shallower waters. In 2023, DO improvements were sustained, TN and TP export was the lowest among the six years of monitoring, and TN export from the pond was lower than it had been during

[6] Eichner, E., B. Howes, and D. Schlezinger. 2020. Cedar Pond Adaptive Management Monitoring Program: Annual Technical Report, January 2019 to December 2019. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 38 pp.

[7] CSP/SMAST Technical Memorandum: Cedar Pond Board Adjustment. October 21, 2020. From: E. Eichner, Howes, B., and D. Schlezinger. To: G. Meservey, Director of Planning & Community Development and N. Sears, Natural Resources Manager, Town of Orleans. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 6 pp.

[8] Eichner, E., D. Schlezinger, and R. Samimy. 2023. Cedar Pond Adaptive Management Monitoring Program: Annual Technical Report, January 2023 to December 2023. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 52 pp.

[9] Eichner, E., B. Howes, and D. Schlezinger. 2021. Cedar Pond Adaptive Management Monitoring Program: Annual Technical Report, January 2020 to December 2020. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 44 pp.

[10] Eichner, E., D. Schlezinger, and R. Samimy. 2023. Cedar Pond Adaptive Management Monitoring Program: Annual Technical Report, January 2022 to December 2022. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 58 pp.

the MEP assessment (2002/2003 monitoring). 2024 readings showed that improvements were sustained, but changes were minimal.

In addition to the water quality improvements, the improved ecosystem conditions in Cedar Pond have encouraged herring to return to the pond. Prior to 2022, no fish were observed entering or leaving Cedar Pond during more than four years of Management Plan monitoring and over 80 visits to the pond outlet and Cedar Pond Creek by Town, CSP/SMAST, and MassDMF staff. Through management discussions among these staff, MassDMF assisted the Town with installing fyke nets in Cedar Pond Creek during the primary alewife/herring spawning period to see if any herring were returning. During this deployment (March/April 2022), 30 alewives were trapped and released. This monitoring was not repeated in 2023 or 2024, but their presence was an additional encouraging sign about improved water quality and ecosystem conditions in Cedar Pond and provides some hope that future alewife visits will increase due to fish returning to the stream were they were born.

III. Status of 2025 Cedar Pond Water Quality Data Collection

In order to assist the Town in continuing to meet the terms of the MassDEP regulatory approval of the Cedar Pond Management Plan, CSP/SMAST staff are again collecting the water quality data in 2025, including:

1) water column profile measurements and water quality samples at selected depths approximately monthly at the deepest location in the pond,
2) deployed continuous monitoring devices at shallow (~1.3 m) and deep (~3.7 m) depths at the deep sampling location (measuring DO, temperature, chlorophyll, and depth every 15 minutes),
3) deployed a continuous water level recorder at the pond outlet to record elevations relative to the board/notch height, and
4) collected stream water quality samples, streamflow readings, and deployed a continuous water level recorder in Cedar Pond Creek at the same location used since 2002/2003.

Water column sampling and profile data has been collected on nine dates so far in 2025: March 5, March 20, March 27, April 16, May 20, June 17, July 17, August 14, and September 15. Additional future sampling dates are planned for October, November, and December. Streamflow and water quality sample collection has occurred on 18 dates through mid-September (approximately every two weeks).

Sampling is continuing throughout 2025, but early water column profile data generally is consistent with recent monitoring, but with some year-to-year variations. The data collected to date shows that the pond had shallow temperatures of 6 to 10°C in March and April and then warmed rapidly to approximately 28°C in July and began to slowly cool in August (26°C) and September (21°C) (**Figure 2**). The water column had developed strong stratification at 2.5 m by May 20. This is slightly different than in 2023 and 2024, but within year-to-year variation, when strong stratification was initially measured on June 15 and April 15, respectively. Strong temperature stratification was sustained through the July measurements, but was not present in August and September. Individual salinity profiles also showed variations between dates, but tended to show similar levels in the upper 1.5 m and more elevated levels (3 to 4 ppt higher) in

deeper samples. These patterns were similar to past years, but the salinity concentrations appeared to be a bit higher, perhaps due to the 2024 drought and lower groundwater inputs than usual. The 2025 Annual Report will evaluate the whole measurement record and look at the continuous recordings as well to evaluate the interplay between temperature and salinity stratification.

DO readings to date showed that shallow conditions continue to be acceptable, but deep readings tend to be anoxic and less than the MassDEP minimum (5 mg/L) (**Figure 3**). Some of the profiles show either deep impacts on shallow levels (typically with reduced stratification strength) or indications of phytoplankton DO additions (*e.g.*, DO saturation levels greater than 110%). The variability of DO readings, sustained acceptable shallow conditions, and deep anoxia generally were consistent with past historical conditions, but more refined and complete year review may note some differences that should be discussed.

Further review of all factors impacting water quality in Cedar Pond, including precipitation, groundwater levels, tides, DO saturation levels, etc., and results for continuous readings at the mid-pond and outlet monitoring locations will be reviewed in the 2025 Annual Report. The 2025 Annual Report will be completed during the first quarter of 2026.

Figure 1. Cedar Pond Locus and Sampling Locations. Cedar Pond is located in northern Orleans, south of Route 6 and west of Town Cove. A stream outlet from Cedar Pond flows under Route 6 and discharges into the Rock Harbor estuary. Water quality samples are collected at the: a) Deep sampling location (multiple depths, green circle) and b) the Creek Stream Gauge (yellow triangle). Autonomous recording devices were also installed at shallow and deep depths at the deep sampling location, the creek stream gauge location and the inlet (orange diamond). Modified from Figure 1 in Cedar Pond Management Plan (2013).

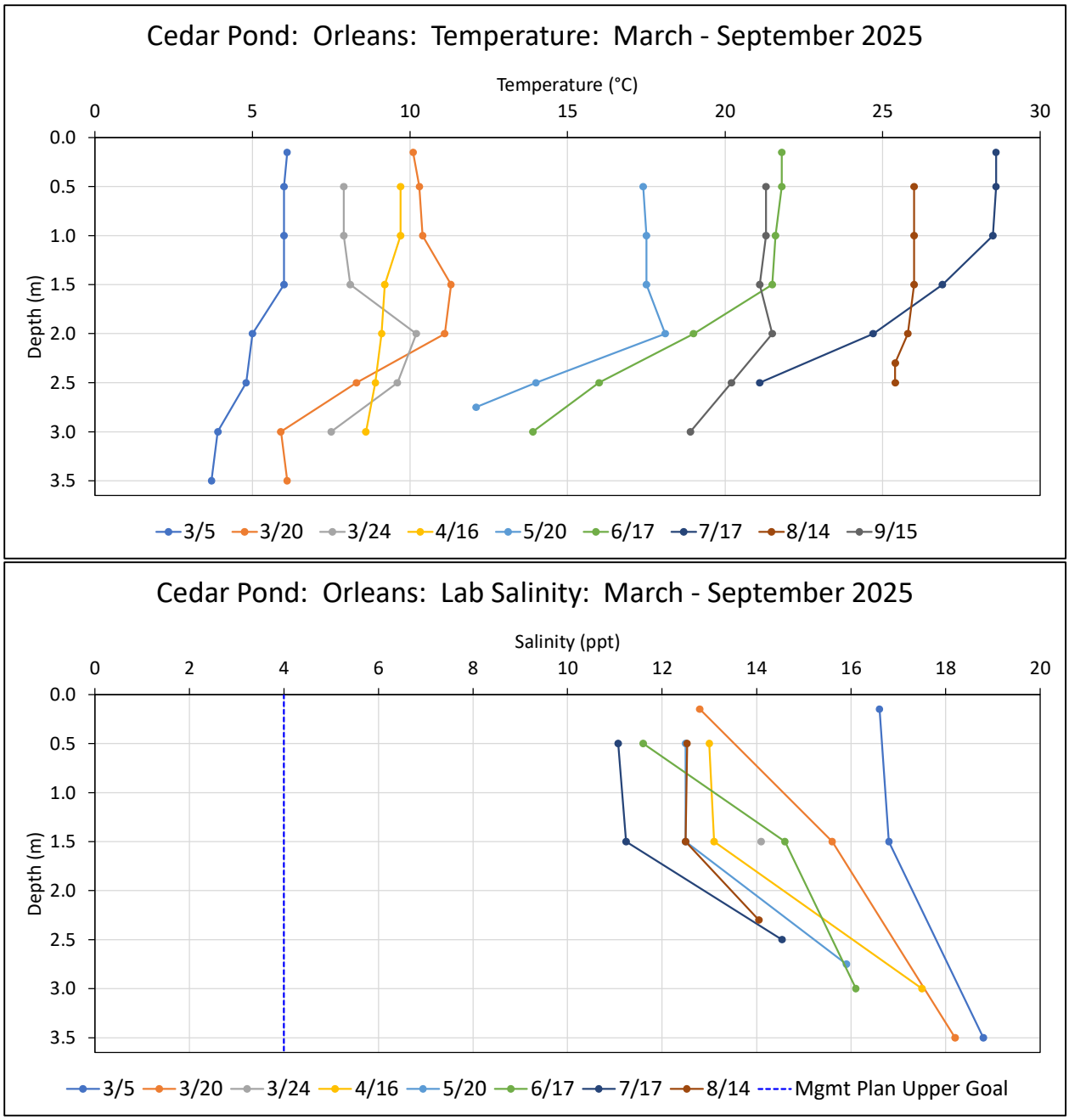

Figure 2. Cedar Pond March to September 2025 Temperature and Salinity Profile Readings. To date, water column profile data has been collected on nine dates in 2025: March 5, March 20, March 27, April 16, May 20, June 17, July 17, August 14, and September 15. Temperature readings show increasing shallow temperatures until July (28°C) followed by incrementally lower temperatures in August (26°C) and September (21°C). Deep temperatures were typically lower, although temperature stratification only occurred in May, June, and July profiles. Salinity profiles generally showed similar readings at 0.5 m and 1.5 m depths with higher levels at deeper depths. All 2025 salinity readings to date were greater than the upper limit of the 1 to 4 ppt target range in the Cedar Pond Management Plan.

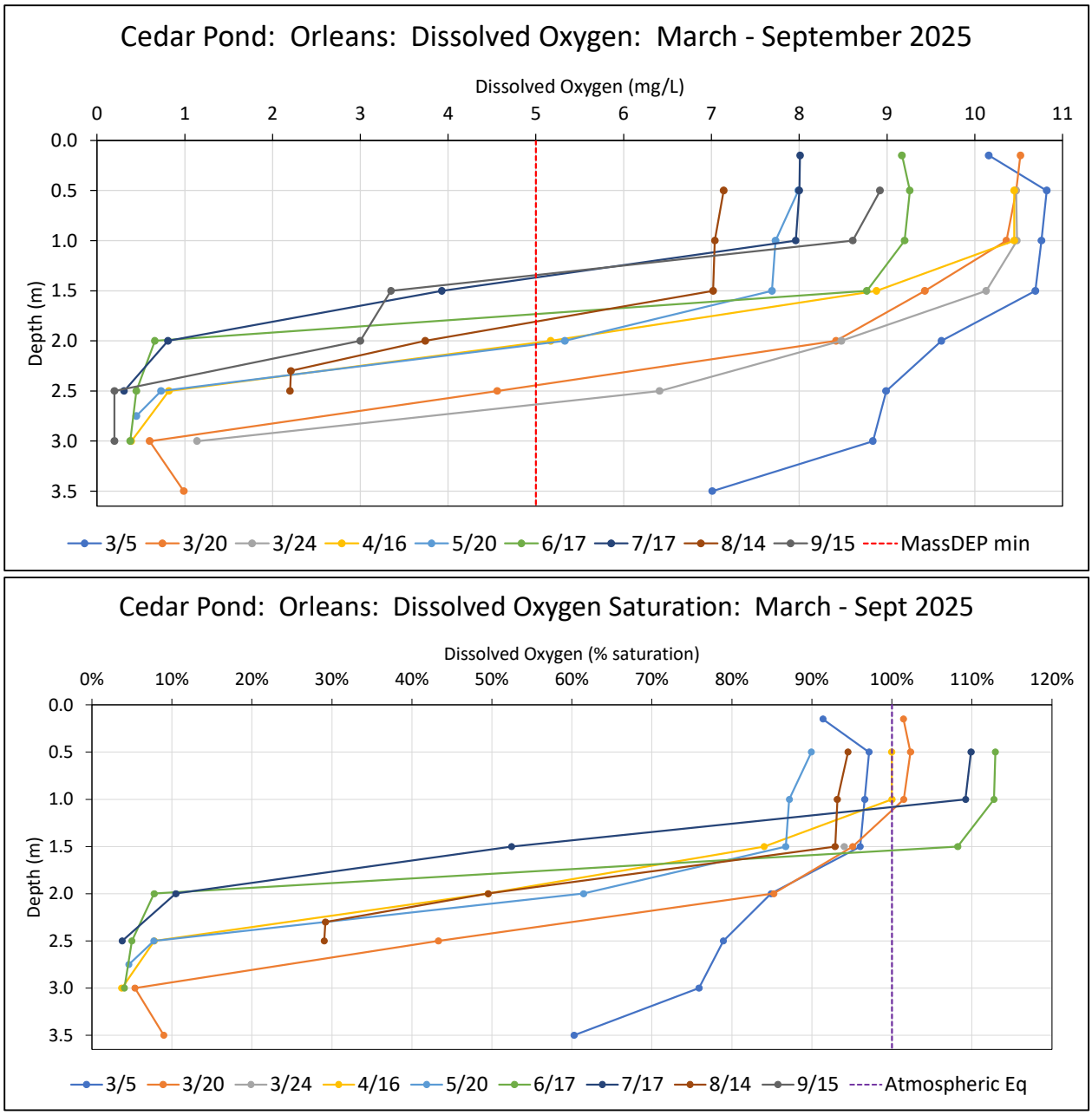

Figure 3. Cedar Pond March to September 2025 Dissolved Oxygen Profile Readings. DO concentrations in shallow waters (0-1 m) were greater than the MassDEP minimum (5 mg/L) in all 2025 profiles to date. Water at 1.5 m was mostly greater than the minimum, but was less than the minimum in July and September profiles. Waters deeper than 2.5 m were anoxic in all profiles after the March profiles with the anoxia generally rising to 2 m depth in June and July, but some recovery in August and September.