WRIGHT-PIERCE
Engineering a Better Environment

Memorandum

Date: October 2, 2025 (Revised October 20, 2025)

Project No.: 20985

To: George Meservey

From: Mike Giggey

Subject: Orleans Nitrogen Management in Mill Pond Sub-Watershed
Mill Pond Aeration and Sediment Removal

In considering ways to improve water quality in Mill Pond, ten options have been identified for review. Eight of those options have been evaluated according to 13 criteria in Wright-Pierce and AECOM memos dated between August 21 and September 22, 2025. Seven of those eight alternatives are all focused on reducing the nitrogen load from the Mill Pond sub-watershed, and one (shellfish aquaculture) would remove nitrogen directly from the water column in Mill Pond. The last two alternatives to be evaluated are somewhat different in that they focus on improving water quality in the Pond, either through aeration of the water column or by removing some of the sediments in the Pond that are impacting the water quality. These options do not reduce watershed nitrogen load, but could improve water quality that has degraded over time due, at least in part, to prior nitrogen loads. These two options are described and evaluated in this memo.

Description

These options include actions to improve water quality in Mill Pond. Pond aeration involves the installation of air or oxygen diffusion systems in the deepest part of the Pond and supported by equipment on shore to pressurize the air or to generate and pressurize the oxygen to feed the diffusers. Aeration would both directly provide oxygen to deep pond waters and help to overcome stratification that inhibits mixing of deep waters with well-aerated surface waters. As a separate or supplemental action, sediment could be removed to reduce the immediate source of the water quality degradation addressed by the aeration system. Sediment removal could be accomplished by the aeration system to avoid traditional dredging. These two options could be implemented separately or together. They do not address the nitrogen sources in the watershed, but instead seek to mitigate the impacts of historic nitrogen loading.

The Orleans Pond Coalition (OPC) implemented in 2019, and continues to operate today, a pilot pond aeration system in Sarah's Pond as a phosphorus control measure. The goal there is phosphorus control; phosphorus migration from the pond sediments can be reduced or prevented by creating aerobic conditions (presence of oxygen) in the overlying water column. That pilot project showed that this approach can be effective for that goal, and it identified equipment problems that initially hampered project success. Nonetheless, the Sarah's Pond project is a local illustration of the concept of oxygenation of pond waters with bottom-placed diffusers and on-shore blowers or compressors. See the OPC website for more information.

In Mill Pond, water quality degradation is suspected to be related to significant bottom deposits of dead phytoplankton, whose breakdown releases nitrogen and consumes oxygen, creating anoxic (absence of oxygen) conditions in the overlying water. The absence of oxygen can lead to biochemical conversion of

compounds like sulfur which is benign when combined with oxygen (sulfate—SO_4) but odorous when combined with hydrogen (sulfide—H_2S). Reversing the anoxic conditions will promote natural aerobic processes that generally improve water quality, in terms of both specific constituents and water clarity, and improve the habitat of bottom-dwelling organisms.

The Massachusetts Estuary Project (MEP) routinely characterized the nitrogen loads to coastal embayments in three categories: watershed load (generally reaching the pond through the groundwater), atmospheric load from rain and snow, and benthic loads of nitrogen released by bottom sediments. While nitrogen removal goals are typically expressed as percentages of the watershed load from septic systems, the TMDLs consider all three nitrogen sources. In the 2012 MEP report for the Nauset system, numerous measurements of benthic load were made. In Mill Pond, benthic loads were estimated from core samples taken from the pond bottom at three locations, including at its deepest point. Across all Nauset sub-embayments, benthic loads comprised 65% of the total load, but in Mill Pond, only 35% of the total nitrogen load was from benthic release. In the Pleasant Bay systems, benthic loads reported in 2006 ranged from none to 82% of the total load (average 46%), with embayments like Arey's Pond and Namequoit River having the highest percentages (80% to 82%). Collectively, these data do not point toward excessive benthic loads as paramount in Mill Pond water quality, compared to other impaired embayments in Orleans, at the time of the MEP data collection and analysis.

A water quality update undertaken by SMAST in 2022 has allowed the comparison of recent water quality data with those analyzed in the MEP work. No sediment cores were collected in that 2022 update, but significant declines in deep water quality were demonstrated that reflect stratification and sediment accumulation. Other studies have shown how changes in the mouth of the Nauset system have resulted in a decreased tidal volume, which could lead to reduced flushing and stratification.

It is likely that there are sufficient organic deposits in Mill Pond, particularly in the deep basin, to create anoxic conditions over a significant portion of the year. Aerating the water column above those sediments will reduce the nitrogen flux from the sediments, at least under some conditions. While oxygenation of deep waters will reduce benthic nitrogen fluxes, the primary intent of aeration would be to create more aerobic conditions and accordingly improve the general water quality. If the aeration rate is enough to also reduce stratification, further benefits result.

If control measures are put in place for Mill Pond watershed loads, the reduction in watershed load will be paralleled over time by a proportionate reduction in benthic loads. One way to accelerate that gradual natural reduction in benthic load is the physical removal of sediments and the benthic nitrogen load they create. While a "brute force" approach of mechanical dredging would accomplish that end, it has not been considered in detail here due to the expected overwhelming public and regulatory opposition. An alternative approach could be coupled with pond aeration, if one were to increase the aeration rate during ebb tides enough to suspend some of the sediments so they can be removed from the immediate system and conveyed downstream. This approach to managing the pond water quality though sediment removal is not well understood or widely used, so its feasibility is uncertain. Without ongoing projects to learn from, it is difficult to predict potential negative impacts, such as sediment deposition elsewhere or temporary reduction in water clarity. To implement these options, significantly more information is needed on the areal extent of the anoxic bottom layer, the length of time that anoxic conditions exist, and the specific constituents of the deep and shallow layers.

Ownership and Control

Pond aeration would be a Town project. The design, installation, operation and maintenance of in-pond diffusers and the on-shore blowers/compressors would be Town responsibilities.

Performance and Extent

Aeration of water is a widely used technique for improving water quality in multiple environmental settings. It would be a straightforward matter to design a system for transferring a certain amount of air or pure oxygen into the Pond. The more difficult job is to determine the amounts or air or oxygen needed to effect the desired improvement in water quality, and to measure the changes. This uncertainty would necessitate a pilot project to determine full-scale parameters. Even more uncertain is use of an aeration system to suspend sediments, and the ability of tidal forces to move sediments out of the Pond.

Costs

The costs of pond aeration would be much less than the traditional septic load reductions techniques like public sewering, both in first cost and likely for long-term operation and maintenance. The most significant operational expense would be for electricity.

Speed in Water Quality Improvement

Improvements in water quality could be expected to begin as soon as a pond aeration system becomes operational. If an aeration system were designed to also suspend sediments, those benefits might not occur as rapidly, but improvements related to them should occur faster than most watershed load reduction approaches, assuming those sediments are effectively transported out of the Pond.

Predictability of Performance

These options are sufficiently unproven that their implementation would be preceded with an initial pilot testing phase.

Reliability

Once in place, a pond aeration system should be mechanically reliable project. It would be designed to allow adjustment of aeration rates and locations to reflect the variable and changing conditions in the Pond. While the basic equipment is reliable; it is the impact on water quality that is difficult to judge.

Need for Large Town Capital Expenditure

Town costs would be moderate for these options compared to public sewering. However, it must be recognized that watershed load reduction is needed anyway, even if these two alternatives are effective, and the amount of needed watershed load reduction would not be reduced by these options.

Regulatory Acceptability

The improvement of water quality through aeration is straightforward, and an aeration project might not encounter significant regulatory hurdles . Expanding this option to include an aeration system to suspend sediment for transport downstream raises many other potential concerns, so the expanded option is not likely to be readily permitted. In either case, precedents are not available to judge the nature and degree of regulatory support or opposition.

Public Acceptability

If there were widespread understanding of the nature and goals of pond aeration, the public might be supportive. However, the inability to point to successful local programs and the difficult-to-quantify benefits and impacts should be viewed as impediments to public acceptability. The location of on-shore equipment is likely to be a significant issue to the public.

Flexibility in Face of Unknown TMDL and Applicability to a Phased Approach

These option are very amenable to a phased multi-pronged approach. They provide a means to improve water quality while options to reduce watershed nitrogen loads are being implemented. It should be recognized that these options are unlikely to reduce costs for watershed load reduction.

Environmental Impacts

The environmental impacts of pond aeration should be largely positive, but lack of widespread use in the coastal environment prevents an easy definitive assessment. Operationally, there might be local noise impacts related to blower/compressor stations on the shore, or sulfide odors during system start-up. Prior red tide episodes in the Nauset Harbor system should be reviewed to determine if sediment disturbance in Mill Pond might exacerbate this risk.

Impact on the Orleans WWTF

These options would have no impact on the capacity of the WWTF.

Ease of Implementation

Given the need for significant additional study and pilot testing, and lack of precedent in permitting, these alternatives could not be quickly implemented. The Town Harbormaster or the Public Works Department are logical candidates to implement and operate these options.

Summary of Advantages and Disadvantages

Pond aeration has these principal benefits:

- This is a moderate-cost option.
- Its benefits would be seen relatively quickly

- It is easily combined with other alternatives.

The principal drawbacks include:

- Actual water quality benefits are difficult to predict definitively
- The regulatory acceptability is uncertain, particularly if sediment removal is included
- Significant additional study is needed, along with pilot testing.

The October 2, 2025 draft of this memo was reviewed by the WMAC at its October 11, 2025 meeting. This updated memo reflects comments made by the WMAC and Town staff at that meeting.