WRIGHT-PIERCE
Engineering a Better Environment

Memorandum

Date: **October 18, 2022**

Project No.: **20985**

To: **Orleans Wastewater Management Advisory Committee (WMAC)**

From: **Mike Giggey**

Subject: **Orleans Wastewater Management Planning**
Potential Nitrogen Removal Needs in the Watershed of Mill Pond

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At the last two WMAC meetings, there has been discussion of the poor water quality in Mill Pond, and the potential need for reducing nitrogen loads in its watershed. I have prepared this memo to provide the WMAC with background information on Mill Pond, in anticipation of establishing Orleans' nitrogen control needs in the Nauset Harbor system, of which Mill Pond is a sub-watershed.

2012 Massachusetts Estuary Project (MEP) Report

The 2012 MEP report on the Nauset system presents data to support SMAST's assessment of nitrogen-related habitat quality. Table VIII-1 of the MEP report summarizes the data available at that time; see pages 146 and 147 of the MEP report attached to this memo. SMAST rated each of the seven sub-watersheds based on data for five parameters: dissolved oxygen, chlorophyll, macroalgae, eelgrass and infaunal animals. For each parameter, SMAST rated the health of each sub-embayment on a scale ranging from "healthy" to "moderately impaired" to "significantly impaired". The overall rating, considering all five parameters, is "healthy" for Nauset Marsh and Nauset Bay, and "significantly impaired" for the other five sub-watersheds, including Mill Pond.

The MEP report establishes threshold concentrations of nitrogen in the receiving water as follows:

- Primary threshold of 0.45 mg/l to support eelgrass in Town Cove and Salt Pond
- Secondary threshold of 0.50 mg/l to support bottom-dwelling organisms (infauna) in the semi-enclosed sub-watersheds including Mill Pond.

The MEP report goes on to estimate the watershed loads that just meet the threshold concentrations. The "present" loads (based on 2003 and 2004 water use) significantly exceed those threshold loads in Town Cove, Salt Pond and Nauset Stream, indicating that 75% to 100% load reductions are needed in their sub-watersheds. For Mill Pond, the threshold load was set numerically equal to the present load, indicating that no nitrogen removal is needed.

I have been unable to determine why no load removal is needed in the watershed of a sub-embayment that is significantly impaired. This question should be discussed with SMAST.

2022 SMAST Technical Memorandum

On behalf of Orleans and Eastham, SMAST compiled and analyzed water quality data throughout the Nauset Harbor system, and summarized its findings in an August 3, 2022 Technical Memorandum. During the 2001-to-2020

period, nitrogen concentrations have been measured in Mill Pond several times per year at both a shallow station and at the deep hole. The Mill Pond data are presented in Figure 5 of the SMAST Technical Memorandum, which I have appended to this Wright-Pierce memo. I have added the threshold concentration of 0.5 mg/l for clarity. At the shallow station (see the top graph in Figure 5), the 2016-to-2020 concentrations are slightly below the average from 2001 to 2004, with a long period of significantly higher readings between 2004 and 2014. The lower graph in Figure 5 depicts the nitrogen concentration at the deep Mill Pond station, where most of the post-2014 readings are much higher than the 2001-to-2004 period. SMAST notes that the deep samples show low dissolved oxygen and indications of sulfides that would be expected under anoxic (very low oxygen) conditions.

SMAST notes that there have been significant changes in the Nauset system inlet configuration, and those changes, in part, may explain the variability in measured nitrogen concentrations.

The 2022 SMAST Technical Memorandum provides water column nitrogen concentrations that seem to support the concerns raised by the public about poor water quality.

Relative Importance of Mill Pond Loadings

The MEP report of 2012 does not recommend the reduction of nitrogen loads in the watershed to Mill Pond. If these new data (SMAST memo of 2022) were to indicate a load reduction need, that load removal would be entirely the responsibility of Orleans. With no load removal in Mill Pond, my September 15, 2022 memo estimated that Orleans' share of load removal across the entire system could be about 5,000 kg/yr. If this added information results in a 60% removal need in Mill Pond (60% selected merely for illustration), then Orleans' share of system-wide removal needs would increase from about 5,000 kg/yr to about 6,000 kg/yr.

The magnitude of this potential increase in responsibility, and the nature of the water quality data, provide support for the SMAST recommendation that many aspects of the Nauset system should be re-evaluated.

VIII. CRITICAL NUTRIENT THRESHOLD DETERMINATION AND DEVELOPMENT OF WATER QUALITY TARGETS

VIII.1. ASSESSMENT OF NITROGEN RELATED HABITAT QUALITY

The determination of site-specific nitrogen thresholds for an estuary requires integration of key habitat parameters (infauna and eelgrass), sediment characteristics, and nutrient related water quality information (particularly dissolved oxygen and chlorophyll). Additional information on temporal changes within each component sub-basin and its associated watershed nitrogen load further strengthen the analysis. These data were collected to support threshold development for the Nauset Estuary by the MEP and were discussed in Section VII. Nitrogen threshold development builds on this data and links habitat quality to summer water column nitrogen levels from the baseline Orleans Water Quality Monitoring Program.

The Nauset Estuary is a complex estuary composed of 3 types of basins: tidal embayments (open water basins with little associated salt marsh) such as Town Cove, Salt Pond, Wood Cove, and Mill Pond; salt marsh ponds (salt marsh dominated open basins) such as Salt Pond Bay and Nauset Bay; and salt marsh tidal creeks with high tidal velocities and areas of shifting sands (tidal channels through emergent salt marsh) within Nauset Marsh. Each of these 3 basin types has different natural sensitivities to nitrogen enrichment and organic matter loading and each has its own benthic community indicative of an unimpaired or impaired habitat. The MEP evaluation of habitat quality considered the natural structure of each system and the types of infaunal communities and eelgrass coverages that they support under low and high levels of nitrogen enrichment. Currently, the Nauset Estuary is showing differences in nitrogen enrichment and habitat quality among its various component basins (Table VIII-1).

Table VIII-1. Summary of nutrient related habitat quality within the Nauset Estuary within the Towns of Orleans and Eastham, MA, based upon assessments in Section VII. Nauset Marsh is a large shallow salt marsh filled basin, with associated salt marsh open water areas of Nauset Bay and Salt Pond Bay; tributary to the main salt marsh are typical semi-enclosed embayments: Town Cove, Salt Pond, Wood Cove and Mill Pond. Note: WQMP refers to the Orleans Water Quality Monitoring Program.

Health Indicator	Nauset Estuary						
	Nauset Marsh			Town Cove	Salt Pond	Wood Cove	Mill Pond
	Nauset Marsh	Nauset Bay	Salt Pond Bay				
Dissolved Oxygen	H[1]	H[1]	H[1]	SI[2]	SI[3]	MI/SI[4]	MI-SI[5]
Chlorophyll	H[6]	H[6]	H[6]	MI-SI[8]	MI[7]	H[9]	MI-SI[8]
Macroalgae	--[10]	--[10]	MI[11]	MI[11]	--[10]	MI[13]	SI[12]
Eelgrass	H/MI[14]	--[15]	SI[16]	SI[16]	--[15]	--[15]	--[15]
Infaunal Animals	H[17]	H[18]	H[18]	SI[19]	SI[20]	SI[21]	SI[20]
Overall:	H[22]	H[23]	SI[24]	SI[25]	SI[26]	SI[27]	SI[26]
See notes below							

1 - Nauset Marsh: a salt marsh dominated lagoon, oxygen depletion rarely to ≤4 mg/L generally >5mg/L, marsh near inlet
typically >6 mg L-1, WQMP; extensive tidal salt marsh results in natural organic enrichment & natural oxygen depletion
observed oxygen levels are relatively high for a salt marsh and salt marsh dominated open water basins (>5 mg/L),
WQMP, high quality habitat.
2 - main basin: oxygen depletion typically <4 mg/L (55% of record), frequently <3 mg/L (38%), periodic anoxia.
3 - mid-depth: oxygen depletions generally <5 mg/L (61% of record), frequently <4 mg/L (29%), periodic decline to <3 mg/L
(4% of record); deep water: periodic anoxia;
4- oxygen levels depleted to <5 mg/L 20% of record, <4 mg/L 7%, periodically 1 mg L^{-1}, large daily excursions 4-6 mg L^{-1}.
5 - mid-depth: oxygen depletions generally >5 mg/L not declining to 4 mg/L; deep waters periodically anoxic
6 - low summer chlorophyll levels averaging <4 ug/L at all 6 stations, 2001-04, WQMP.
7 - moderate summer chlorophyll levels averaging 6.8 ug/L, blooms >10 ug/L ~20% of record and >20 ug/L ~5%
8 - moderate/high chlorophyll levels, averaging 9-11 ug/L, >10 ug/L >48%-28% of record, blooms >20 ug/L, 8%-3%
9 - low chlorophyll, averaging 4 ug/L over 18 sampling events, 2001-2003 WQMP
10 - drift algae sparse or absent
11 - patchy accumulations of *Ulva*.
12 - dense accumulation of *Ulva*, in innermost basin.
13 - moderate accumulations of filamentous algae.
14 - small bed in channel adjacent Nauset Inlet in 2001 & 2003, moderate loss of coverage post-1951
15 - no evidence this basin is supportive of eelgrass.
16 - MassDEP indicates significant loss of eelgrass coverage, 1951-2001, absence confirmed 2003 MEP.
17 - Infauna: low numbers of species (5) and diversity (H', 1.47), high Evenness (0.7); moderate # of individuals (288),
few stress indicator species, community affected by sediment transport, similar to other high velocity channels.
18 - Infauna: high numbers of individuals (>1000), moderate species (10-12), moderate diversity (2.4-2.8) and high Evenness (0.68-0.83); organic enrichment indicators typical of salt marsh influenced basins, dominated by crustaceans, mollusks & polychaetes, very few stress indicator species.
19 - Infauna: very low numbers of species (2-4) and diversity (H', 0.66-1.45); low number of individuals (36-198), dominated by opportunistic organic enrichment indicators (tubificids) generally >70% of community, indicative of a significantly impaired habitat, consistent with nitrogen enrichment.
20 - Infauna: few species (<2) and individuals (<40), as a result of periodic hypoxia/anoxia.
21 - Infauna: low number of species (6) and diversity (H'= 2.24) moderate numbers of individuals (~300), dominated by organic enrichment indicators (tubificids, Capitella)
22 - Generally high quality, with Moderate Impairment due to the partial loss of eelgrass in the southern reach (MassDEP). The generally low chlorophyll a and lack of significant oxygen depletion and macroalgae are consistent with the productive benthic communities, except near outer Mill Pond.
23 - High Quality salt marsh dominated basin, oxygen depletion, low summer chlorophyll a levels & sparse macroalgae
consistent with productive benthic communities without stress indicators.
24 - Significant Impairment, indicated by eelgrass loss with patchy macroalgal accumulations (*Ulva,* indicative of nitrogen enrichment), but chlorophyll and oxygen are consistent with the generally high quality infauna habitat, except in areas of macroalgal accumulation.
25 - Significant Impairment resulting from significant loss of eelgrass coverage coupled with high chlorophyll levels and loss of benthic animal habitat consistent with measured low dissolved oxygen.
26 - Significant Impairment resulting from loss of benthic animal habitat, periodic hypoxia at mid depths (anoxia at deeper depths) and moderate chlorophyll.
27 - Significant Impairment: benthic animal community with low species and moderate numbers dominated by organic enrichment indicators, moderate accumulations of macroalgae and periodic DO to 1 mg L-1
28 - Significant Impairment: resulting from loss of benthic animal habitat, periodic hypoxia at mid depths (anoxia at deeper depths) with moderate to high chlorophyll levels; dense accumulation of macroalga (*Ulva*) in innermost basin.
H = healthy habitat conditions; MI = Moderate Impairment; SI = Significant Impairment;
SD = Severe Degradation; -- = not applicable to this estuarine reach

At present, eelgrass has nearly disappeared from the Nauset Estuary, with only a small area remaining adjacent Nauset Inlet. The observed loss is consistent with the level of nitrogen enrichment and tidal flows within this system and clearly indicates impairment of this resource. The overall pattern of eelgrass distribution and temporal decline in coverage is fully consistent

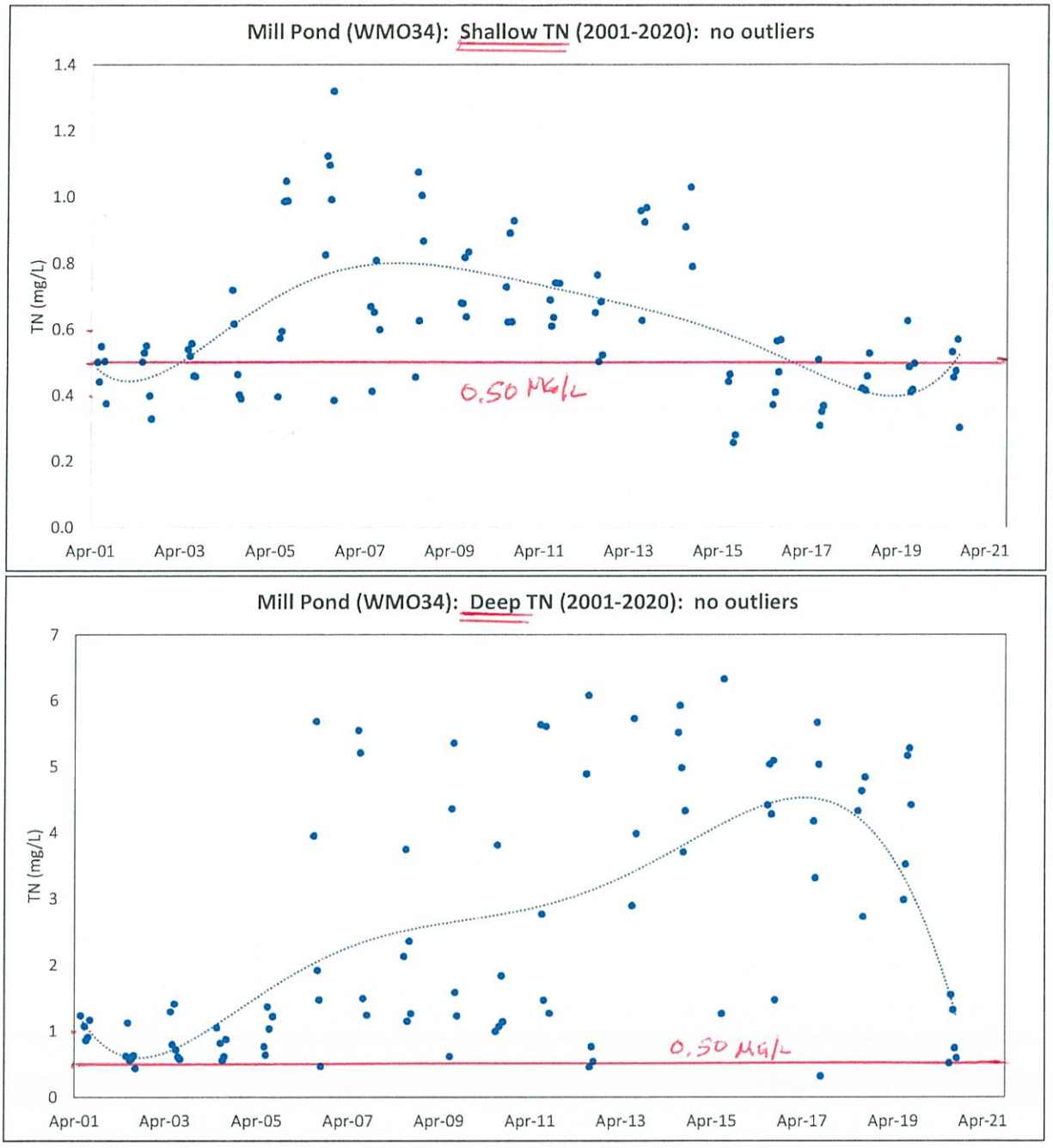

Figure 5. Mill Pond (WMO34) Total Nitrogen Concentrations: Shallow and Deep (2001-2020). Comparison of average shallow TN concentrations in 2001-2004 (MEP) and 2016-2020 showed that the 2016-2020 TN average was lower, but not statistically different from 2001-2004. However, between 2004 and 2016, shallow TN concentrations increased then declined. Deep TN concentration began increasing in 2006, peaked in 2016-2019, and then decreased substantially in 2020. DO readings suggest that deep waters may have been impacted by anoxia. Best fit trendlines have R^2 of 0.36 in the upper figure and 0.41 in the lower figure. The timing of changes in TN concentrations are different than at Town Cove (WMO27) or Salt Pond (WMO38).