Santuit Pond

Results of Focused Feasibility Study, Baseline Monitoring, and Nutrient Inactivation Dosing Study Results

Mashpee Select Board Meeting

April 3, 2023

SUPPORTING [DOING] LEADING

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Presentation Overview

- Focus on connection between sediments and water quality
- Internal loading of phosphorus
  - Why is it a problem at Santuit Pond?
  - What drives it?
  - How can it be addressed?
- These questions will be addressed in the context of recent studies of Santuit Pond
  - Focused Feasibility Study (ESS Group 2022)
  - Baseline Monitoring, Sediment Coring, and Nutrient Inactivation Dosing Study (TRC 2022)

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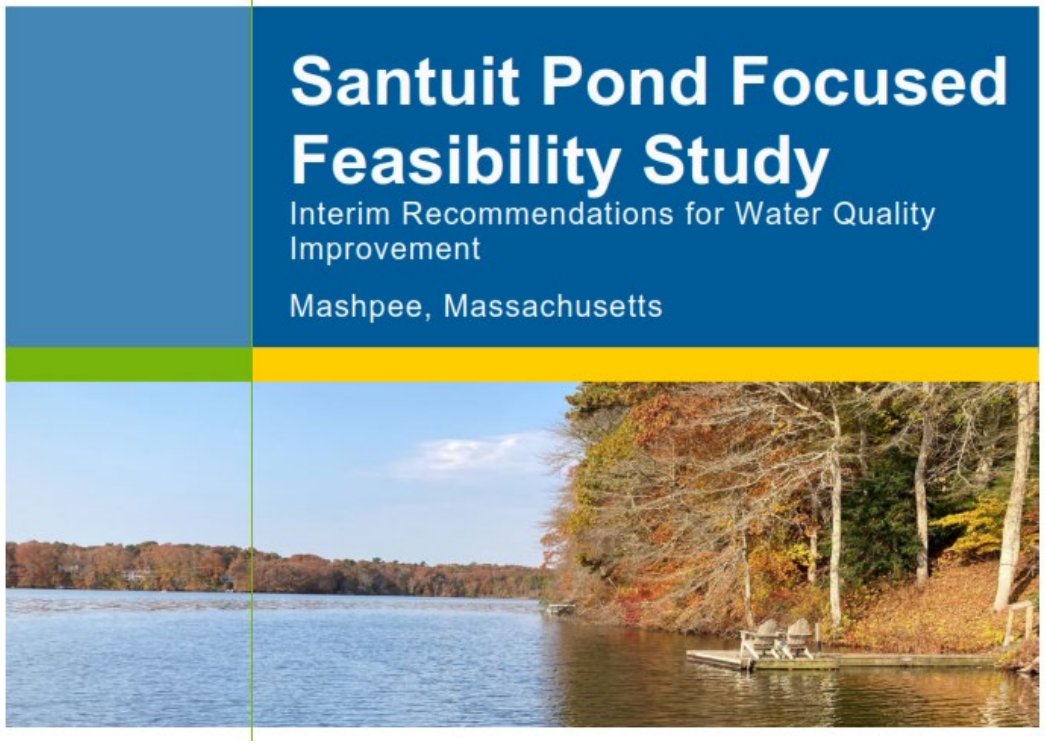
Focused Feasibility Study for Water Quality Improvement

- Completed by ESS Group (2021-2022)
- Conducted site visit in October 2021
- Reviewed existing information
  - AECOM's 2010 Diagnostic Study
  - MassDEP's Integrated List of Waters (2018/2020 Reporting Cycle)
  - USACE 2021 Sediment Sampling and Testing
  - Other sources of recent and historical water quality data
- Identified important environmental resource designations and jurisdictions
- Assessed feasibility of different in-pond management tools that could be used to improve water quality



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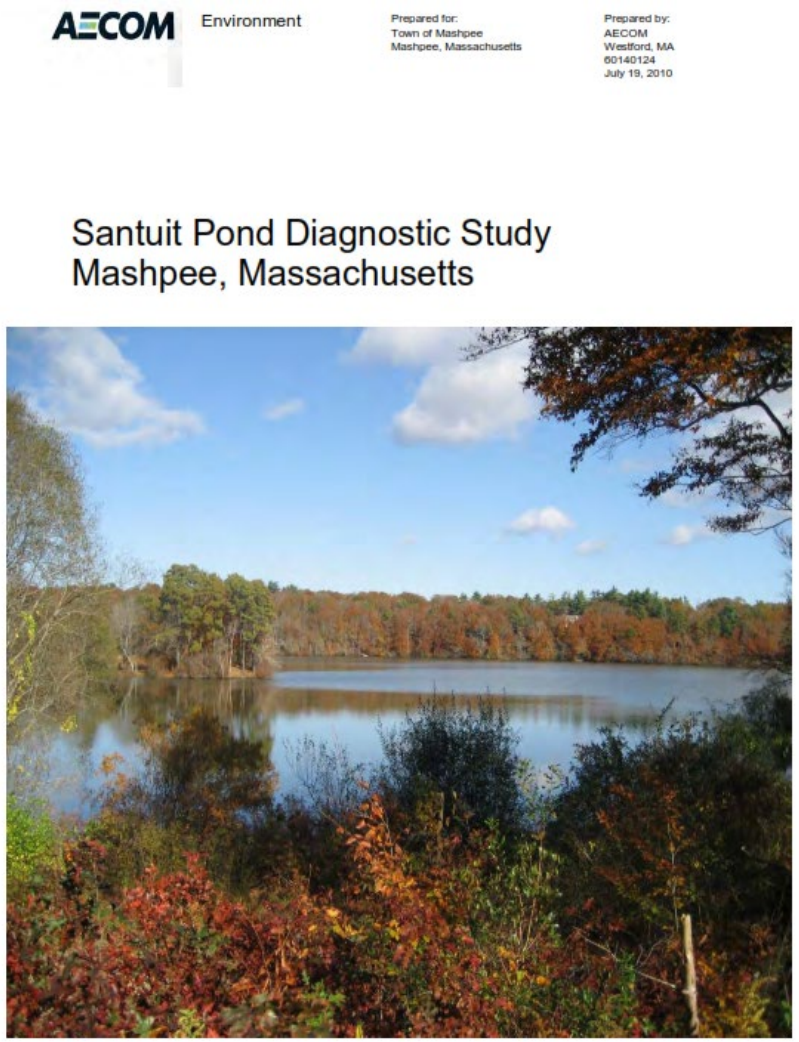
Focused Feasibility Study for Water Quality Improvement

AECOM Diagnostic Study Key Findings

- Pond is highly nutrient-enriched with high phosphorus, low transparency, and high chlorophyll a (algae)
- Dissolved oxygen depletion at pond bottom allows release of iron-bound phosphorus from sediments into the water (internal loading)
- 78% of the annual phosphorus load from internal sources
- Recommended target phosphorus concentration of 15 ppb to avoid recurring algae blooms
- Examined three in-pond restoration options:
  - Dredging – not recommended
  - **Circulation - recommended**
  - **Nutrient inactivation - recommended**



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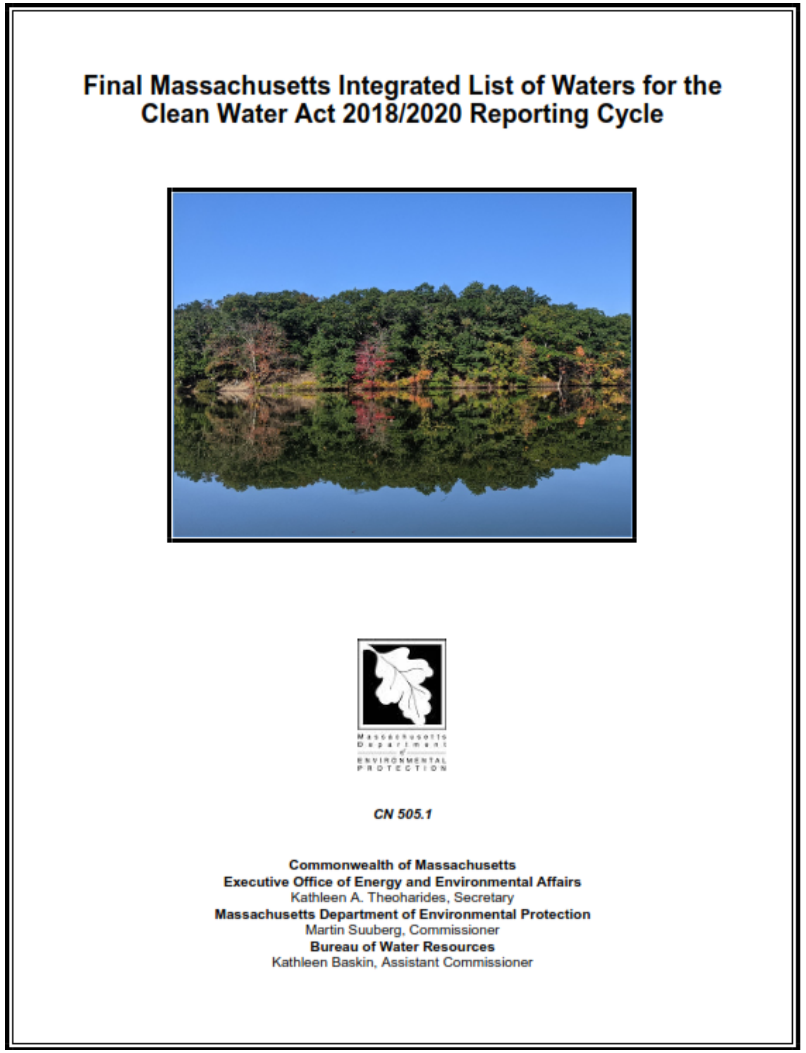
Focused Feasibility Study for Water Quality Improvement

MassDEP's Final Integrated List of Waters

- Santuit Poind still listed for multiple water quality impairments, including:
  - Chlorophyll a
  - Harmful algal blooms
  - Nutrient/eutrophication biological indicators
  - High pH
  - Total phosphorus
  - Transparency/clarity
- These are interrelated impairments and largely echo findings of the AECOM Diagnostic Study



Final Massachusetts Integrated List of Waters for the Clean Water Act 2018/2020 Reporting Cycle

CN 505.1

Commonwealth of Massachusetts
Executive Office of Energy and Environmental Affairs
Kathleen A. Theoharides, Secretary
Massachusetts Department of Environmental Protection
Martin Suuberg, Commissioner
Bureau of Water Resources
Kathleen Baskin, Assistant Commissioner

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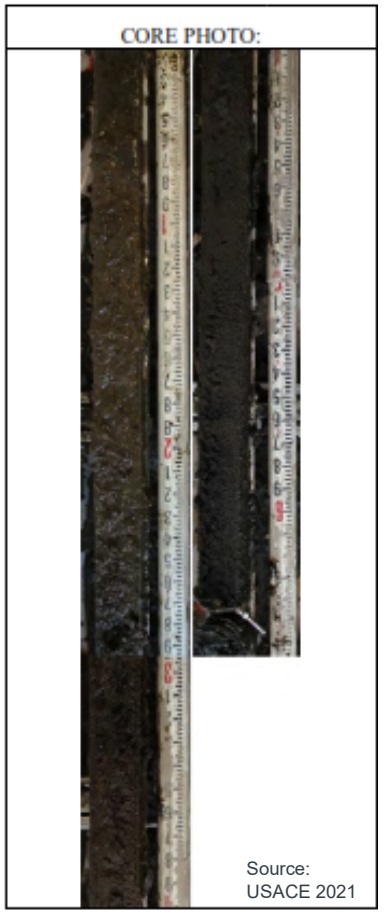
Focused Feasibility Study for Water Quality Improvement

USACE Sediment Sampling and Testing Key Findings

- Fine sediments present over much of the pond, often in excess of eight feet thick
- Some contaminants found at values that may exceed state soil and groundwater standards if sediment were to be placed on land
- Total phosphorus variable by depth of sediment and location in the pond but plentiful
- Average phosphorus in first two feet of sediment was 0.35 mg/g
- Average phosphorus for uppermost portion of all cores (up to 8 ft) was 8.55 mg/g
- Phosphorus not broken into fractions so it is difficult to know from this study alone how much would be available for internal loading



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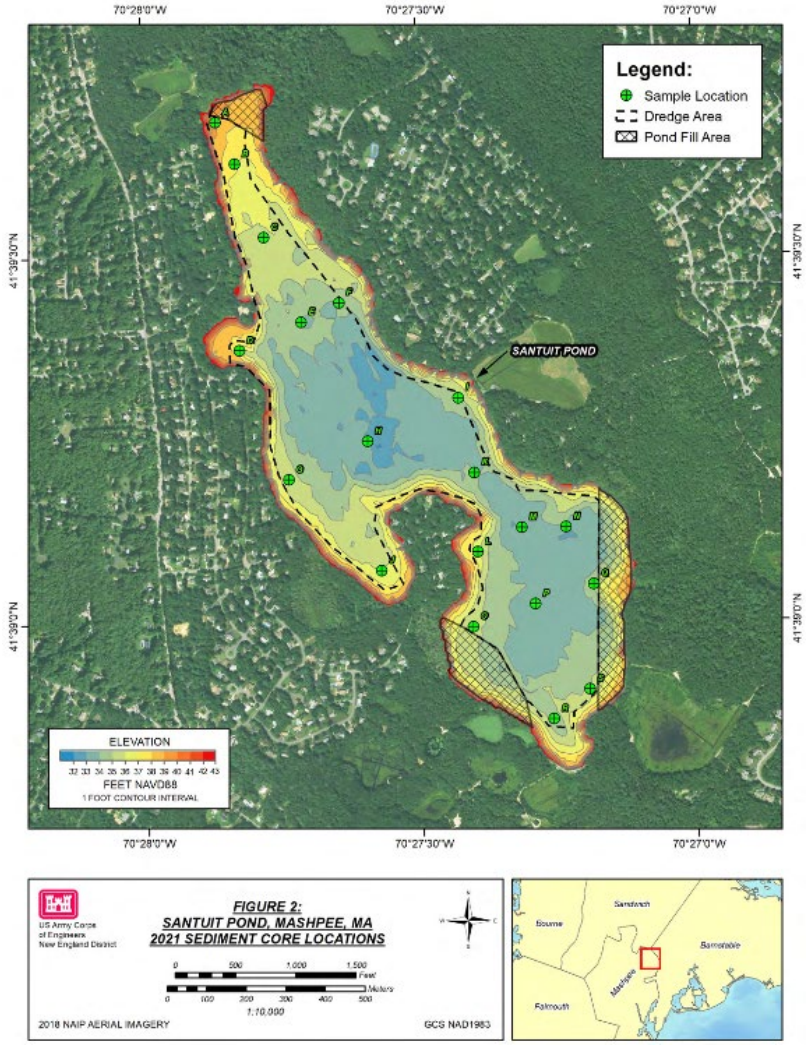
USACE 2021



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Focused Feasibility Study for Water Quality Improvement

Management options reviewed included multiple biological, chemical, and physical approaches

- **Aeration/circulation - recommended**
- **Algaecides - recommended**
- Barley straw – not recommended
- Bioaugmentation – not recommended
- Biochar – not recommended
- Biomanipulation – not recommended
- **Nutrient inactivation - recommended**
- Sonication – not recommended
- Recommended options were most likely to be feasible and effective at the scale needed

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Focused Feasibility Study for Water Quality Improvement

- Circulation: SolarBee circulators already in place and should continue to be used for now
- Algaecides: may be of use to control blooms but will not address the underlying cause
- Nutrient inactivation: could be used to address cause (phosphorus release from sediments) but would require additional study:
  - Provide updated information on concentrations of phosphorus (as fractions) present in sediment
  - Determine depth of the sediment layer that is most actively contributing to internal phosphorus loading
  - Calculate the dosage needed to bind available phosphorus in this active layer

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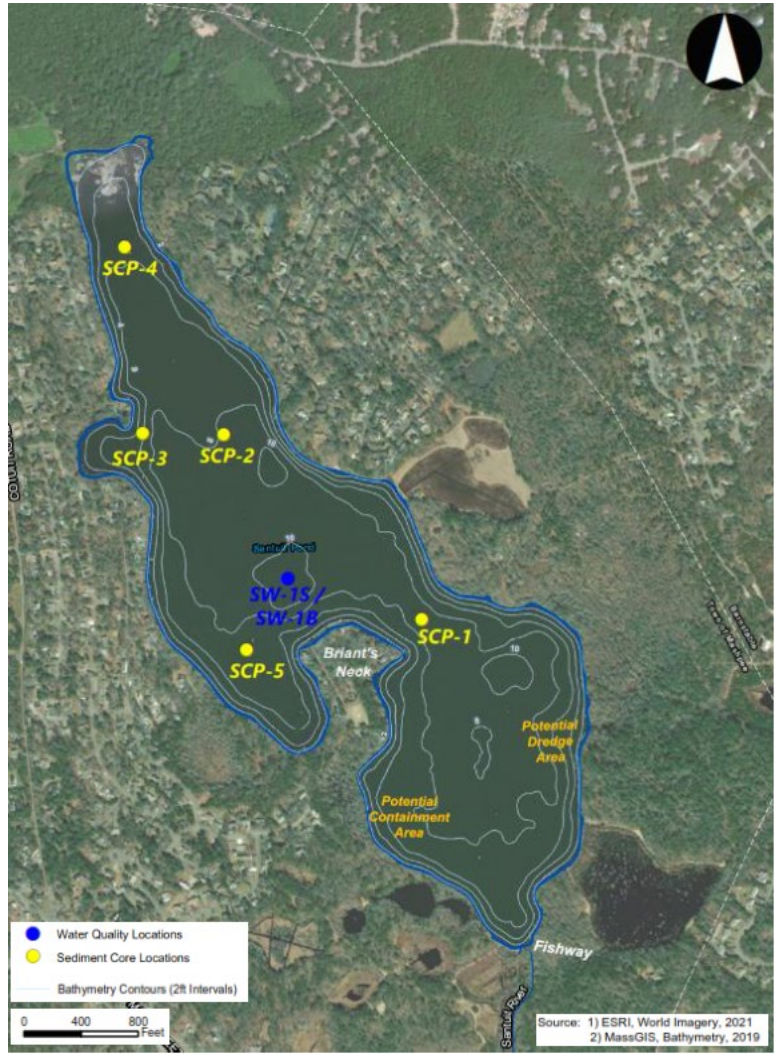
Baseline WQ, Sediment, and Dosing Study

- Completed by TRC (2022)
- Follow-up to the Focused Feasibility Study
- Designed to address outstanding data gaps on internal loading of phosphorus and develop the appropriate dosing for nutrient inactivation
- Included field collection of baseline water quality and sediment cores
- Sampling conducted under EPA-approved Quality Assurance Project Plan



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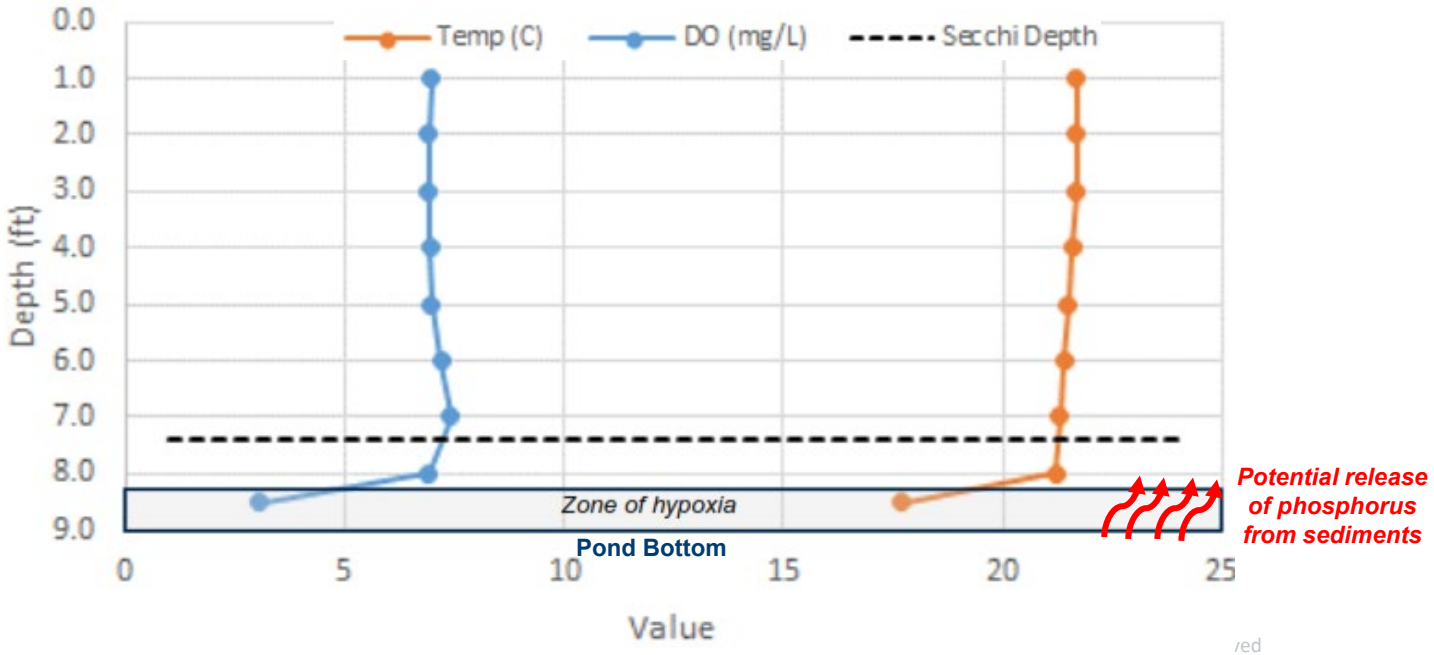
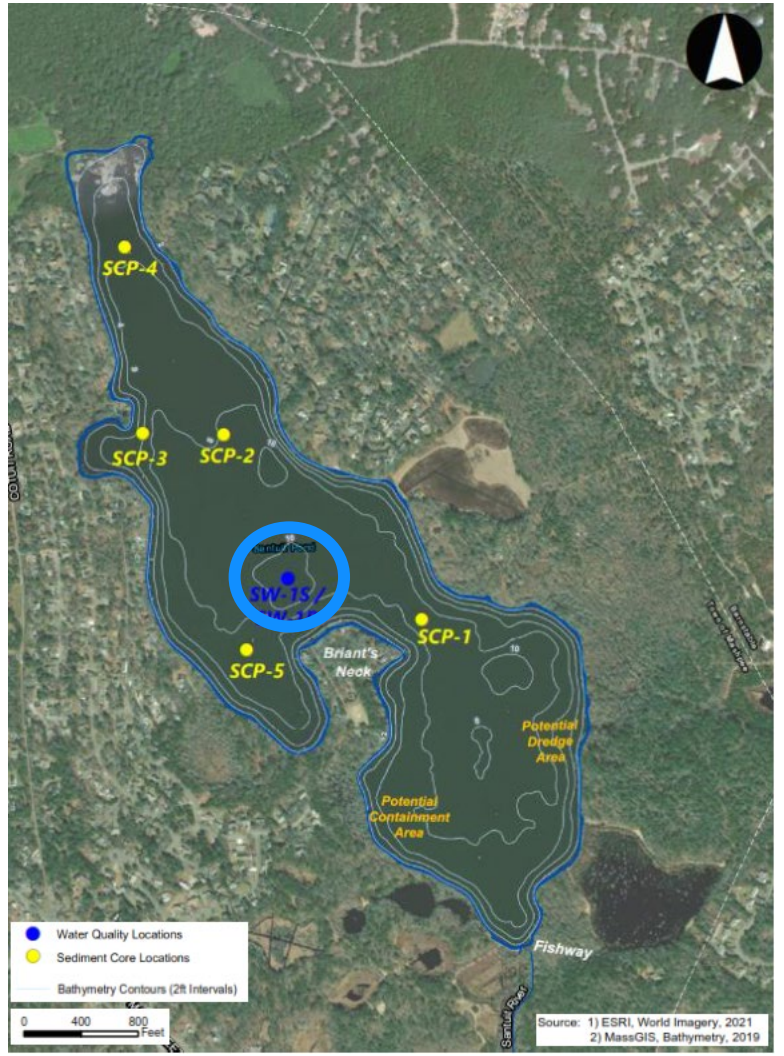
Baseline WQ, Sediment, and Dosing Study

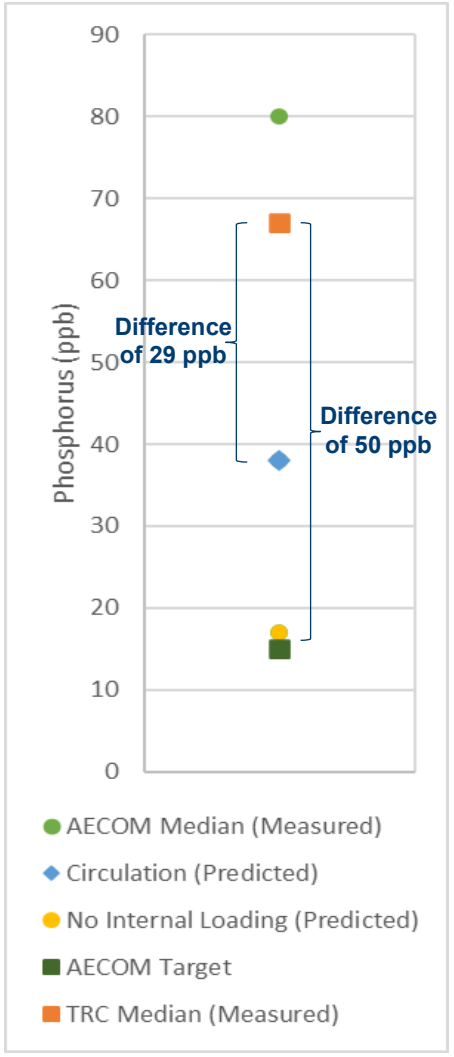
- Evidence of low dissolved oxygen (hypoxia) at bottom of pond
- Represents early June – conditions may worsen in July/August as temperatures rise and respiration rates increase
- Represents mid-day when photosynthesis active – conditions worsen at night when photosynthesis stops

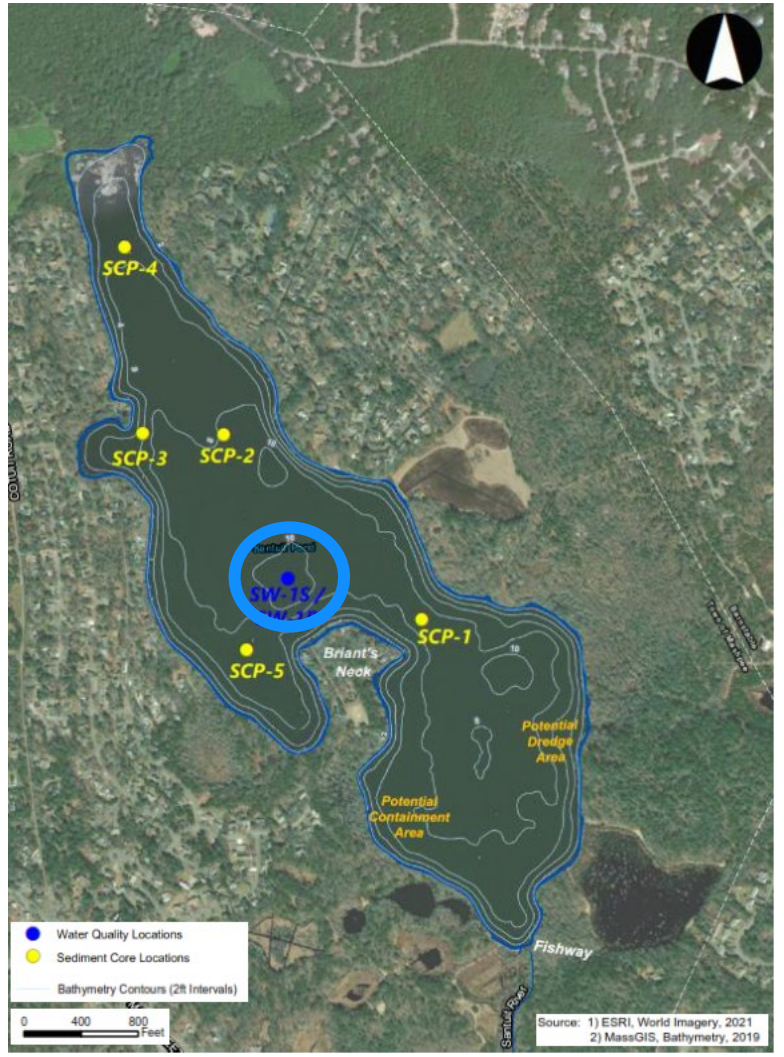




Baseline WQ, Sediment, and Dosing Study

- Total phosphorus remains elevated
  - Median of 67 ppb
- Compare to:
  - AECOM median of 80 ppb in 2010 study
  - AECOM predicted 38 ppb with circulation
  - AECOM predicted 17 ppb with no internal loading
  - AECOM target of 15 ppb





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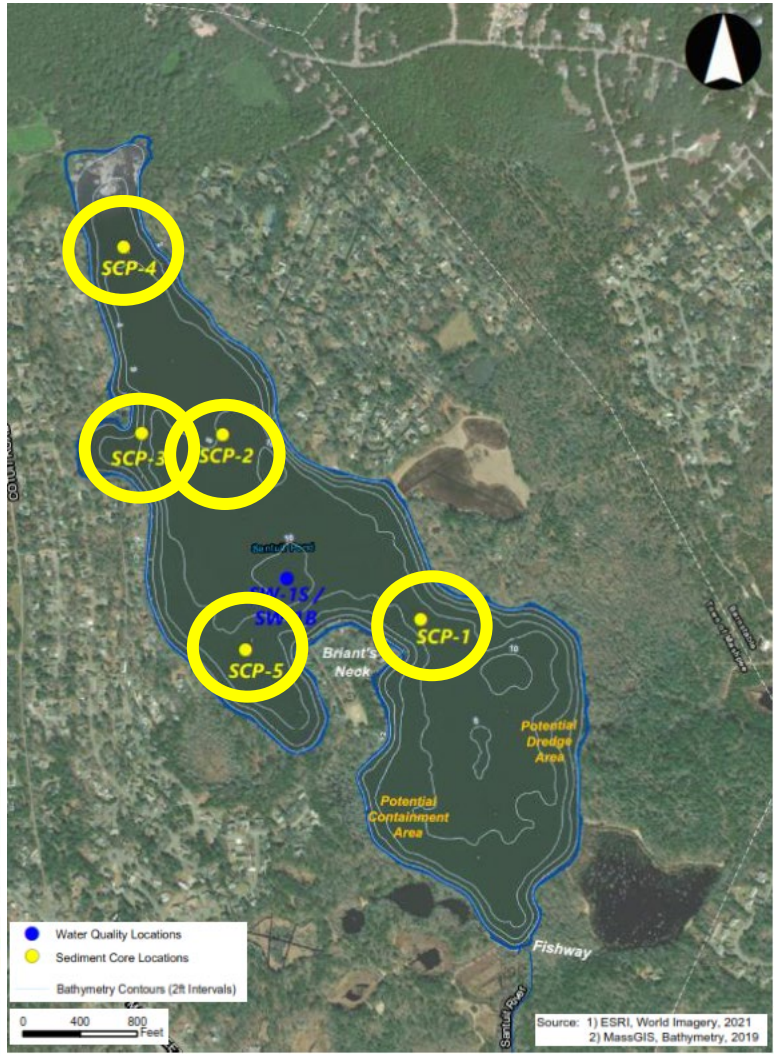
Baseline WQ, Sediment, and Dosing Study

- Reassessment of sediment phosphorus fractions
- Collected five sediment cores, including two from locations previously sampled by AECOM
- Cores collected to at least 20 cm below the sediment surface
- Once on boat, sediment pushed up through top of core liner, where it was sliced into undisturbed 2-cm sections
- Each section was placed into a separate jar
- This collection process allowed for detailed analysis of vertical profile in the sediment



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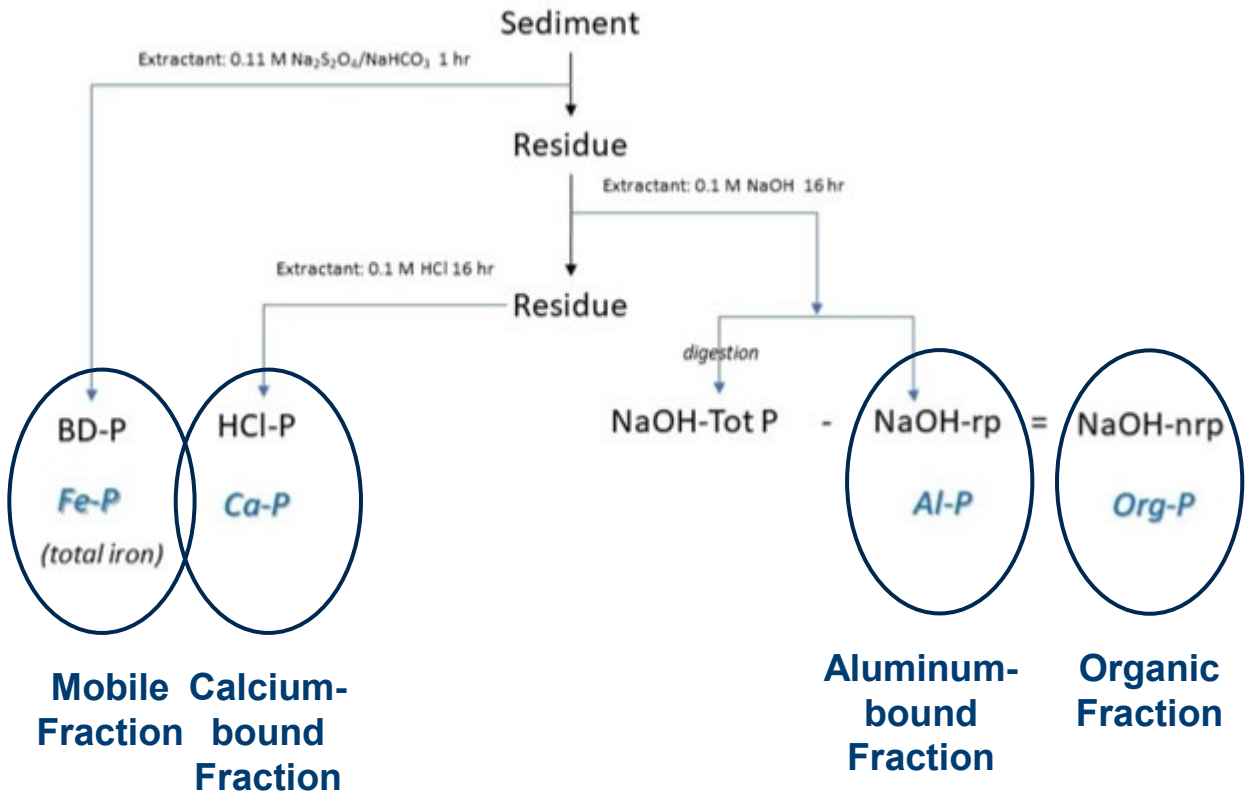
Baseline WQ, Sediment, and Dosing Study

Analyzed each section for the following phosphorus fractions:

- Mobile – includes iron-bound
  - Rapid release into water column when dissolved oxygen is low
- Organic
  - Gradual release into water column as organic matter breaks down
- Calcium-bound phosphorus
  - Stable under typical environmental conditions but may release when pH is low
- Aluminum-bound phosphorus
  - Stable under typical environmental conditions

Simplified Phosphorus Fractionation Analytical Process



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Baseline WQ, Sediment, and Dosing Study

Key Sediment Findings

- Primary phosphorus fractions were organic and iron-bound
- Despite slightly different methodologies, results remarkably in line with those found by AECOM
- Suggests potential for internal loading of phosphorus remains about as high as it was pre-2010

Sediment Core ID	Composition: Avg of Top 4 cm (mg g^{-1} dry sediment)				
	Iron and Loosely Sorbed P (Fe-P)	Organically Bound P (Org-P)	Calcium Bound P (Ca-P)	Aluminum Bound P (Al-P)	Total P
SCP1	0.31	0.52	0.027	0.023	0.88
SCP2	0.29	0.58	0.030	0.025	0.93
SCP3	1.01	0.53	0.041	0.041	1.62
SCP4	0.29	0.69	0.039	0.069	1.09
SCP5	0.29	0.68	0.038	0.038	1.05
Average	**0.44**	**0.60**	**0.035**	**0.039**	**1.11**
AECOM (2010)	**0.37**	**Not Measured**	**Not Measured**	**Not Measured**	**1.20**

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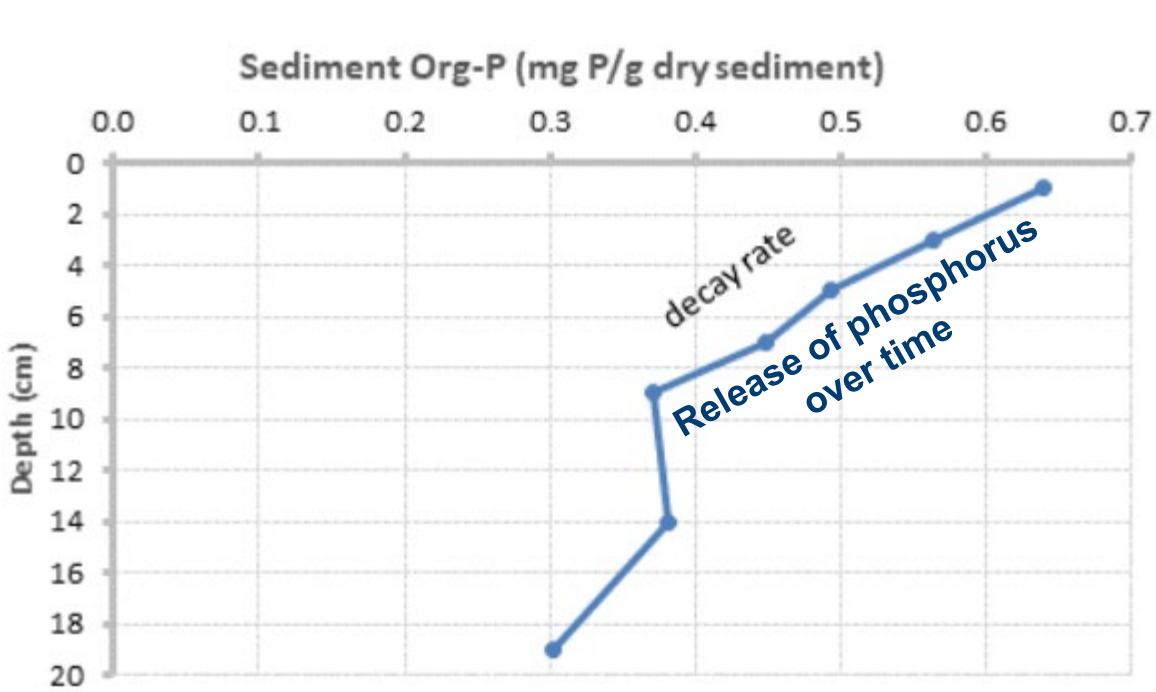
Baseline WQ, Sediment, and Dosing Study

Key Sediment Findings

- Organic phosphorus higher in new sediments than old – slope of graph is decay rate
- Iron is plentiful in sediment – 22 times more iron than organic phosphorus
- As organic phosphorus is released, iron can capture it but only in the presence of dissolved oxygen (DO)
- As oxygen depletes, phosphorus is released into pond water where it is available to algae / cyanobacteria



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Baseline WQ, Sediment, and Dosing Study

Factors that Favor Sediment-Targeted Nutrient Inactivation

- ☑ Excessive phosphorus is driving recurring algae blooms
- ☑ A substantial portion of the phosphorus is due to internal loading
- ☑ The flushing rate of the water body is not excessive
- ☑ A rapid improvement in water quality is desired
- ☑ Cleared space for staging and chemical storage
- ☑ Existing access for treatment vessels
- ☑ Cost-effectiveness is important

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Baseline WQ, Sediment, and Dosing Study

Nutrient Inactivation Recommendations

- Convert oxygen-sensitive iron-bound phosphorus into a more stable form
- Alum (aluminum sulfate) has been used safely for decades in Massachusetts, including Cape ponds
  - Same chemical used in drinking water treatment processes
  - Injected underwater, forms flocculent and sinks to the bottom
  - Switches iron-bound phosphorus to aluminum-bound, forming a stable bond, even where dissolved oxygen is absent
  - Cost per kilogram of phosphorus removed is very low ($100s) compared with most other approaches
  - Works immediately and is effective for extended periods of time, especially if external phosphorus loading is reduced
- Often buffered with liquid sodium aluminate where alkalinity is low, as it is in Santuit Pond

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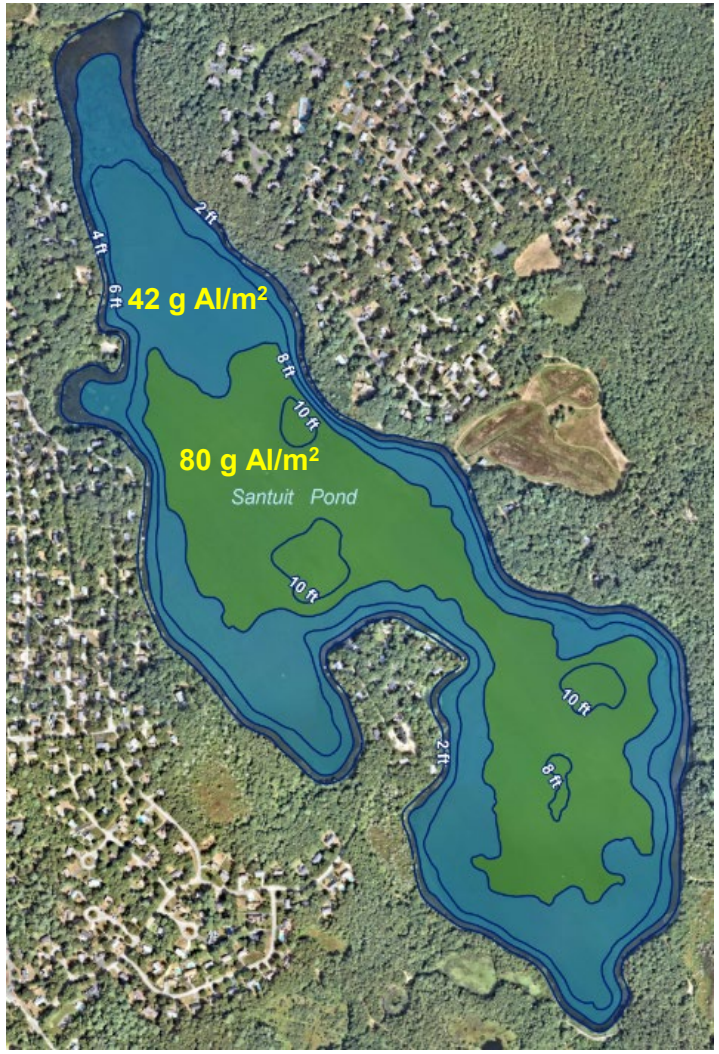
Baseline WQ, Sediment, and Dosing Study

Nutrient Inactivation Recommendations

- Developed dose to capture more than 90% of iron-bound phosphorus in the active layer of sediments
- Would apply below the 4-foot depth contour (~145 acres)
- Recommend a higher rate of application below 8-foot contour (~67 acres) because this is where phosphorus becomes most concentrated
- Could split treatment over two years to enhance effectiveness in a shallow pond like Santuit Pond
- If circulation is also continued, reduction of in-pond phosphorus concentration to less than 20 ppb is possible
- **Reduced phosphorus loading from sediments = cleaner water**



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