Analysis of Water Quality Data Collected at Bucks Pond and John Joseph Pond, 1999-2021

Water is collected on the GSLA ponds from June to August annually. Tests and reports come from three sources that measure different elements of water quality:

- Barnstable County reports on E.Coli for Bucks and John Joseph Ponds (1999-2021)

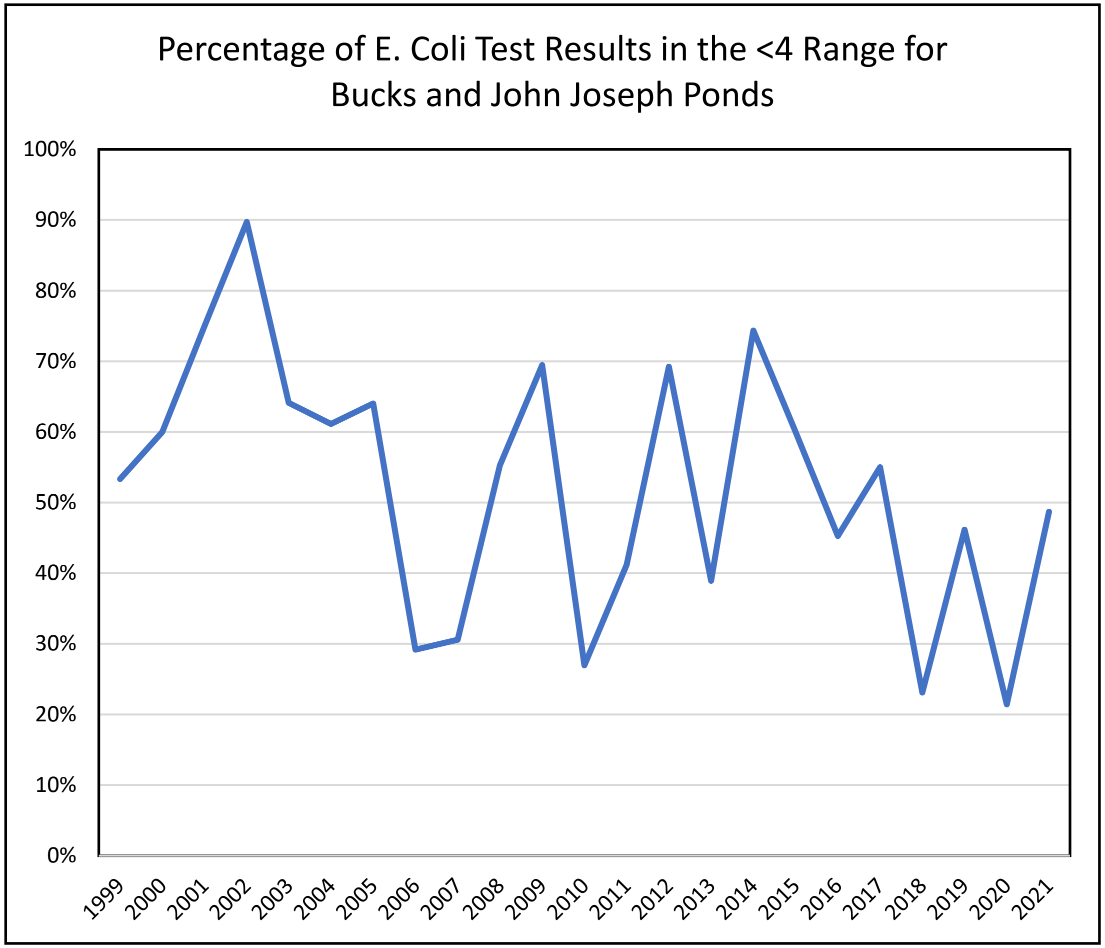
- UMass Dartmouth School for Marine Science & Technology (**SMAST**) for Bucks Pond (2006-2020) reports on
  - Temperature at Incremental Depths from 0.5 m to 9 m
  - Dissolved Oxygen at Incremental Depths from 0.5 to 9 m
  - Secchi Depth (Indicates How Clear the Water Is)
  - pH Levels (Acidity vs Alkalinity)
  - Calcium Carbonate (Hardness of the Water, Provides Resistance to pH Changes)
  - Total Phosphorus at Incremental Depths from 0.5 m to 9 m
  - Total Nitrogen at Incremental Depths from 0.5 m to 9 m
  - Chlorophyll *a* (molecule in all green plants including algae)
  - Phaeophytin (molecule formed when Chlorophyll *a* breaks down - loses Mg)

- Association to Preserve Cape Cod (APCC) reports on concentrations of Phycocyanin, the blue pigment in cyanobacteria, for Bucks and John Joseph Ponds (2019, 2021)

- Both E. Coli and Cyanobacteria Pose Serious Concerns for Human Health

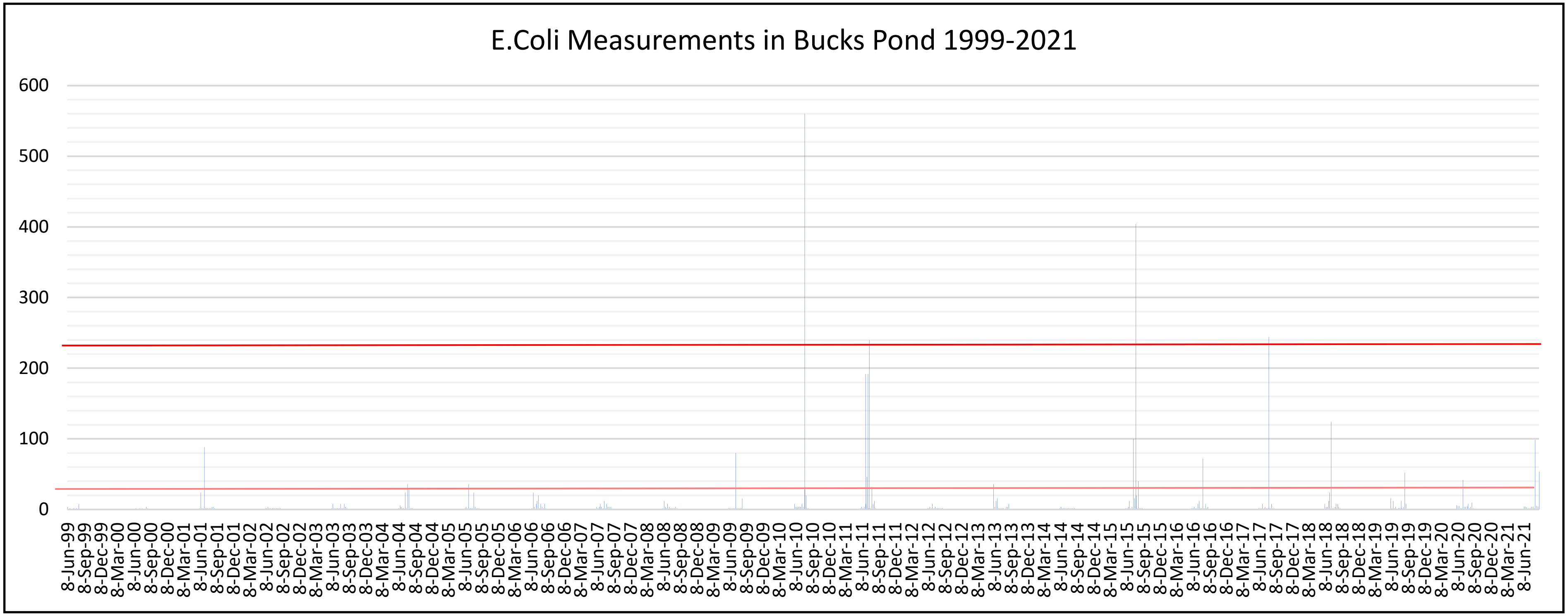
Baseline Water Quality in Bucks and John Josephs Ponds Shows a Declining Trend Due to an Increase in E. Coli Contamination

- E. Coli (*Escherichia coli*) is a common species of bacteria found in human sewage and used as an indicator for fecal contamination. E. Coli was tested in GSLA ponds from 1999-2021 except 2011.
- *Enterococci* are a different species of fecal bacteria with the ability to survive in saltwater. *Enterococci* was tested in GSLA ponds in 2011.
- A normal E. Coli test result for GSLA beaches (median and mode) is less than 4 units per 100 mL. The number of test results coming back within that range shows an overall declining trend.



Source: Barnstable County E. Coli Test Results, 1999-2021

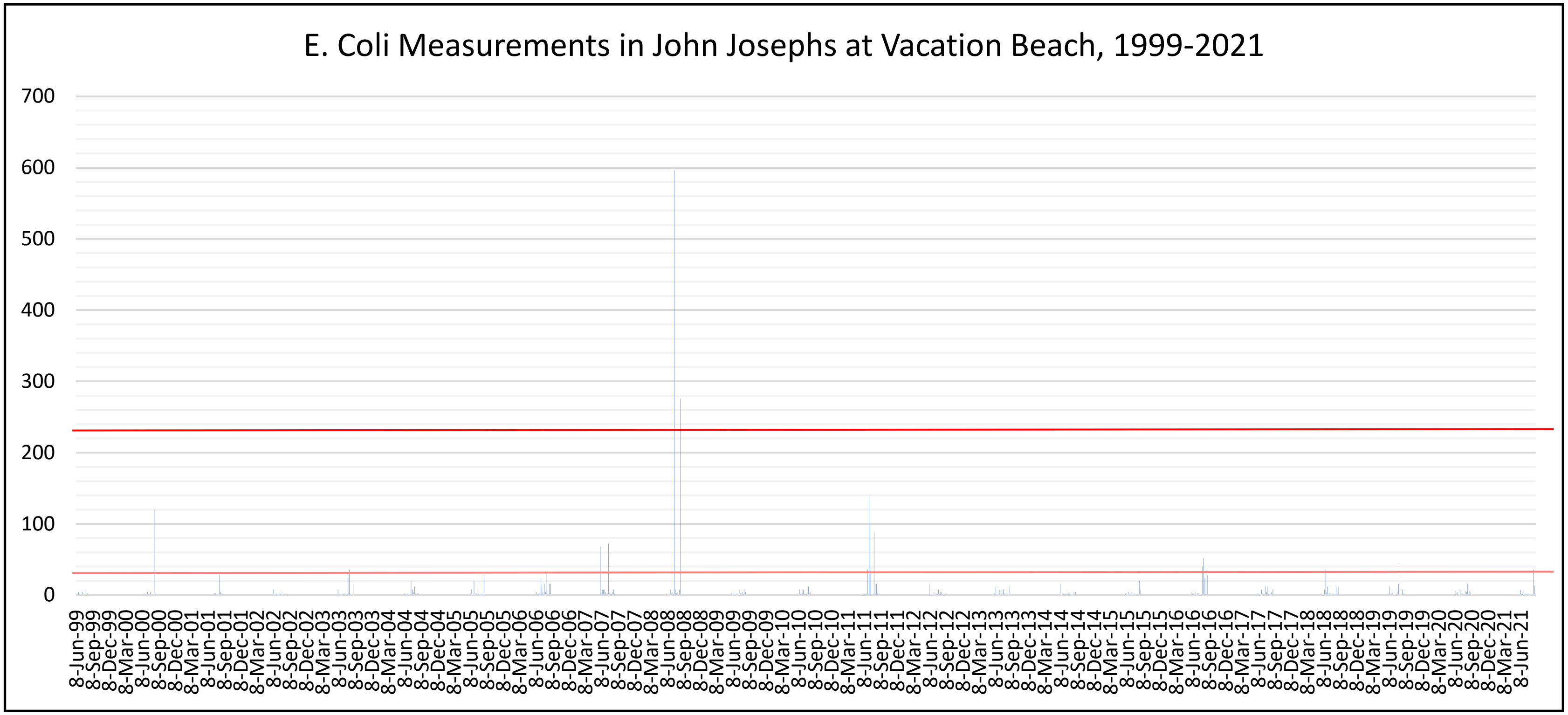
Bucks Pond Has Experienced Intermittent E. Coli Measurements that Exceed Acceptable Health Standards but Did not Trigger a Beach Closure



Source: Barnstable County E. Coli Test Results, 1999-2021

- The potential for human illness from swimming starts at 30 units of E. Coli per 100 mL and 35 units of *Enterococci* per 100 mL (as per EPA OFFICE OF WATER 820-F-12-058).
- EPA and Massachusetts set a limit of 235 units of E. Coli per 100 mL for all beaches with no distinction between swimming beaches and "other recreational uses."
- Test results on Clearwater Beach that exceeded 235 units per 100 mL occurred in 2010, 2011 2015 and 2017.
- Beaches were not closed because next-day tests showed readings in the acceptable range.

John Josephs Pond Has Experienced Intermittent E. Coli Measurements that Exceed Acceptable Health Standards but Did not Trigger a Beach Closure

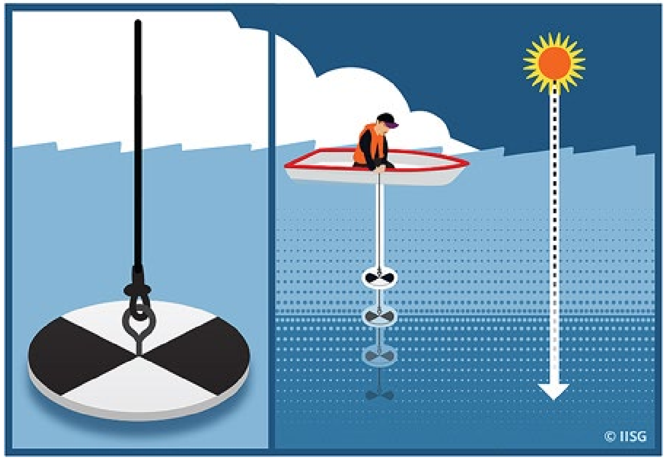


Source: Barnstable County E. Coli Test Results, 1999-2021

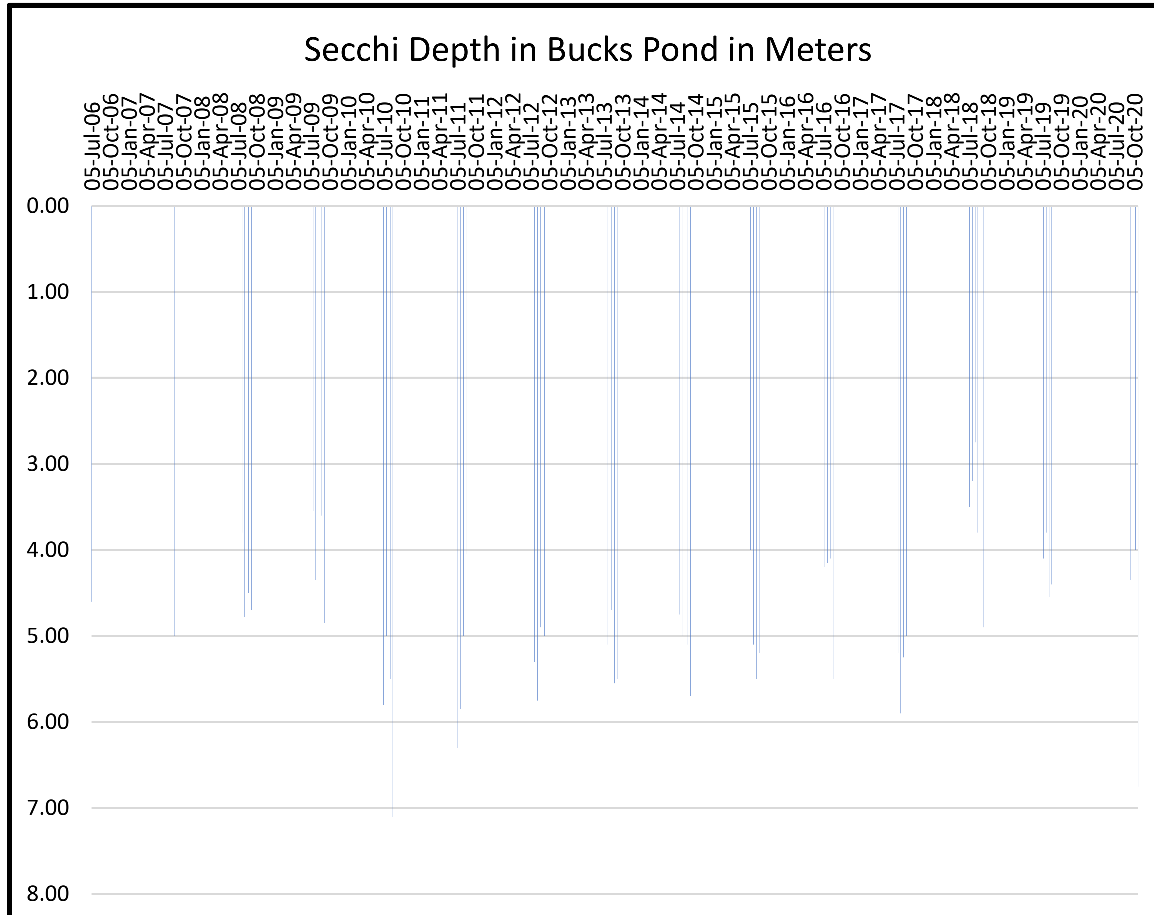
- The potential for human illness from swimming starts at 30 units of E. Coli per 100 mL and 35 units of *Enterococci* per 100 mL (as per EPA OFFICE OF WATER 820-F-12-058).
- EPA and Massachusetts set a limit of 235 units of E. Coli per 100 mL for all beaches with no distinction between swimming beaches and “other recreational uses.”
- Test results exceeding 235 units per 100 mL occurred on Vacation Beach in 2008.
- The beach was not closed because next-day tests showed readings in the acceptable range.

Data from SMAST Indicate That the Water in Bucks Pond Looks Relatively Clear

Secchi Disk

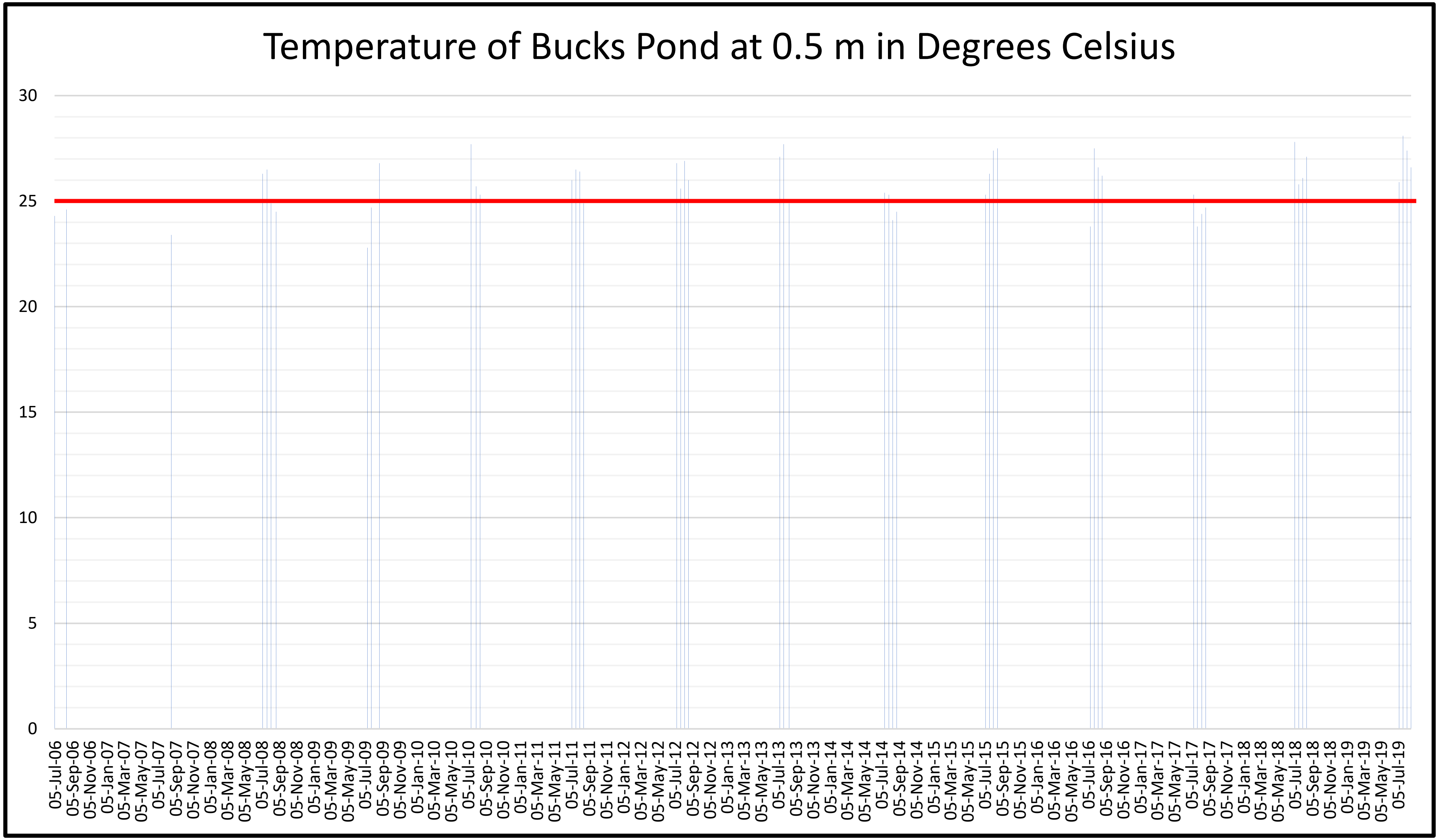


- The higher number, the deeper the Secchi disk is visible, which means clear water.
- A typical range in Secchi depth for a freshwater pond is 2 to 10 meters.
- 2010, 2011 and 2017 had the clearest water.



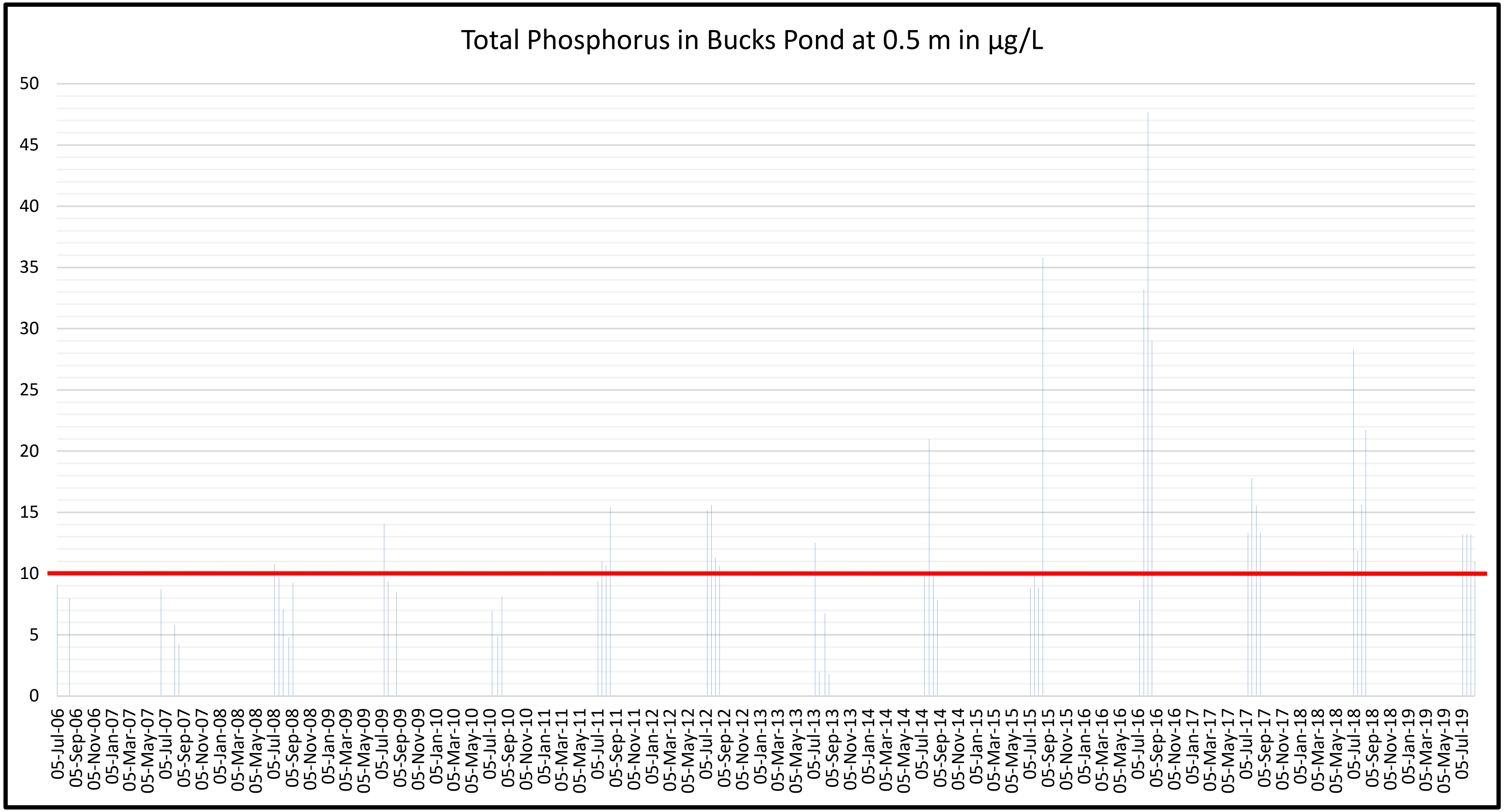
Source: SMAST Spreadsheet, 2006-2019

Water Temperatures are a Potential Contributor to Health Hazards: Temperatures above 25 Degrees Celsius Encourage Cyanobacteria Growth



Source: SMAST Spreadsheet, 2006-2019

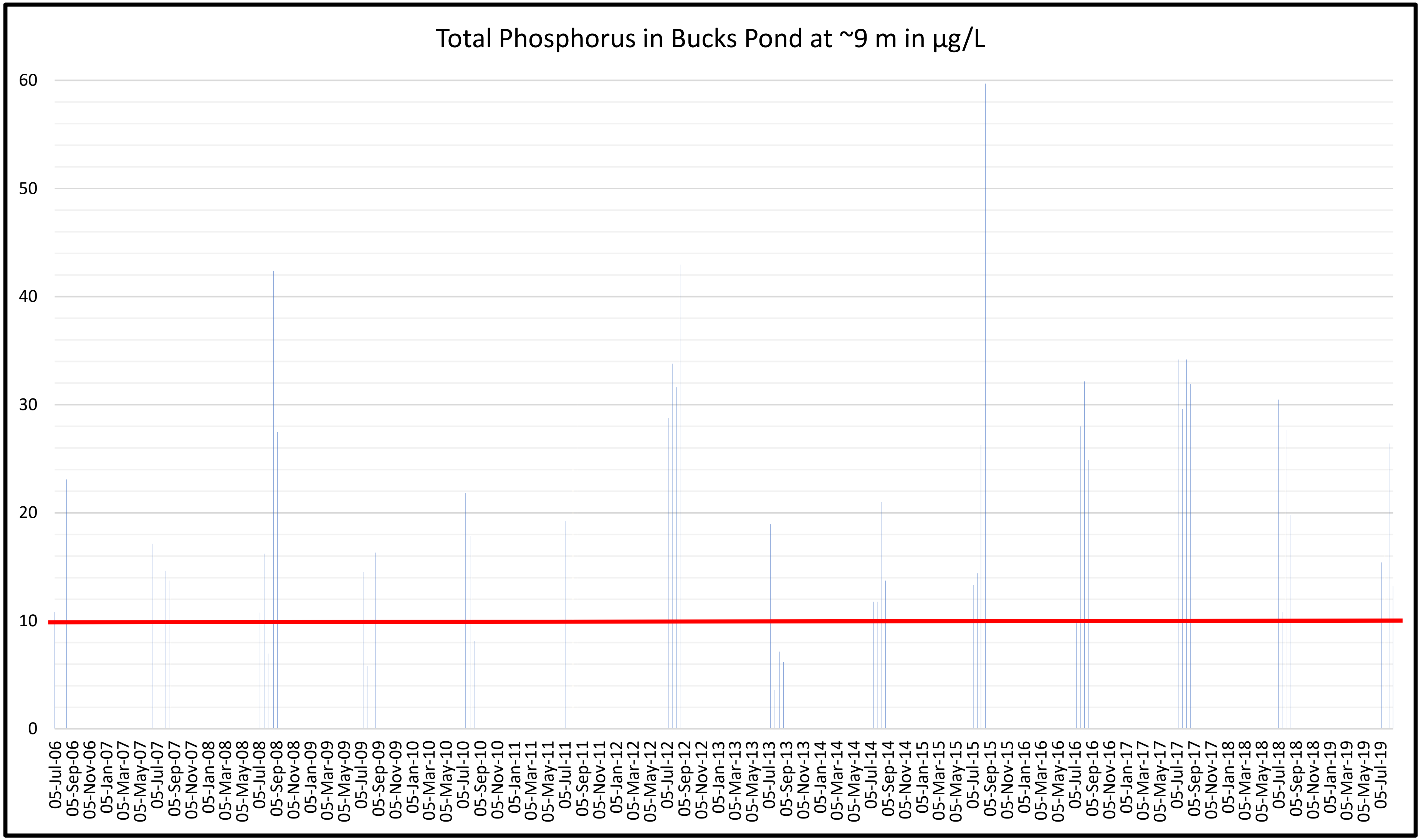
Phosphorus Levels Above 10 µg/L Promote Cyanobacteria Growth



Source: SMAST Spreadsheet, 2006-2019

- EPA-predicted range for Cyanobacteria Growth starts at 10 µg/L of Total Phosphorus (https://www.epa.gov/sites/default/files/2018-10/documents/nutrient-criteria-manual-lakes-resevoirs.pdf)

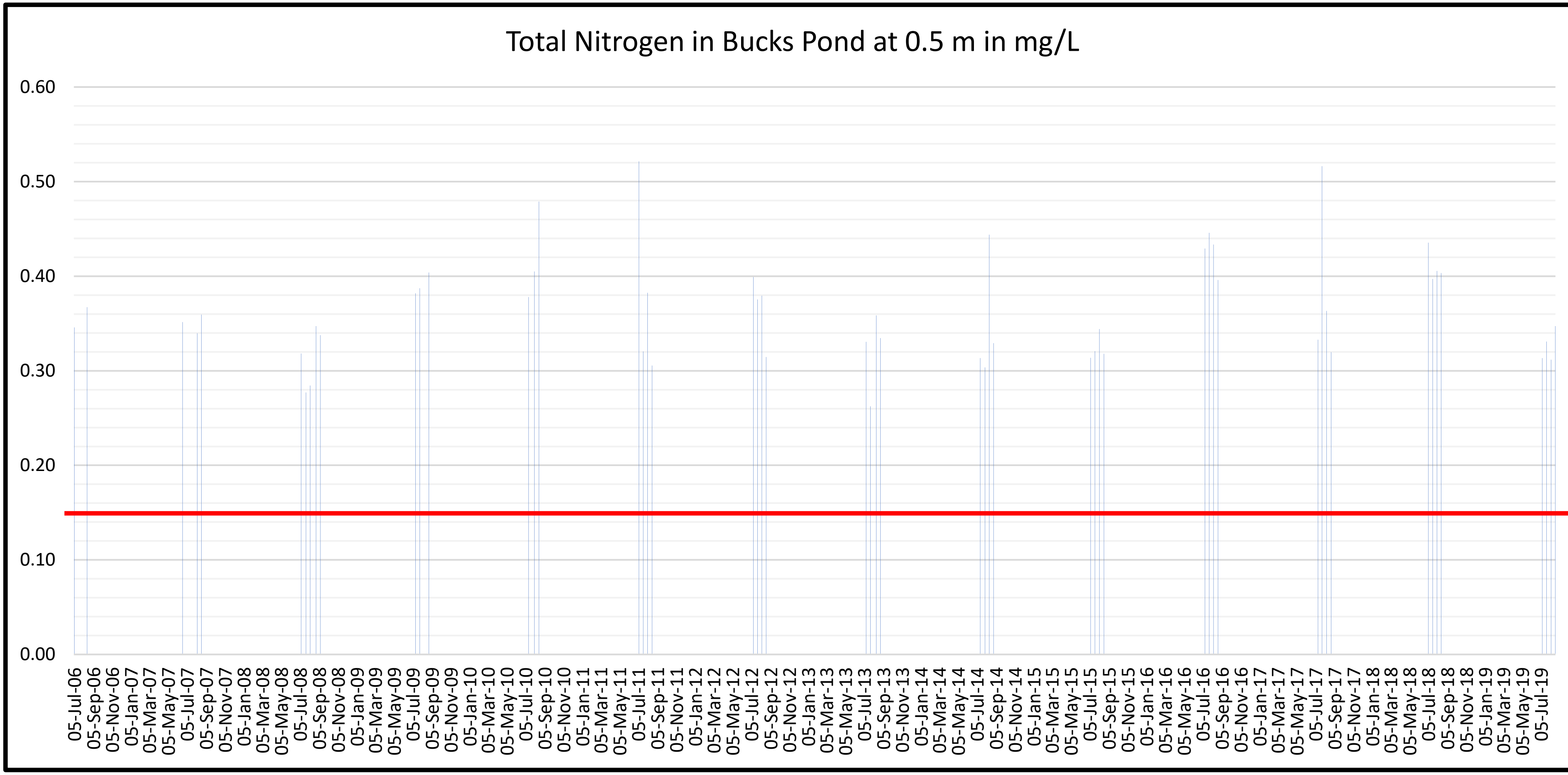
There is Even Greater Fluctuation in Phosphorus Levels at Lower Depths



Source: SMAST Spreadsheet, 2006-2019

- EPA-predicted range for Cyanobacteria Growth starts at 10 µg/L of Total Phosphorus (https://www.epa.gov/sites/default/files/2018-10/documents/nutrient-criteria-manual-lakes-resevoirs.pdf)

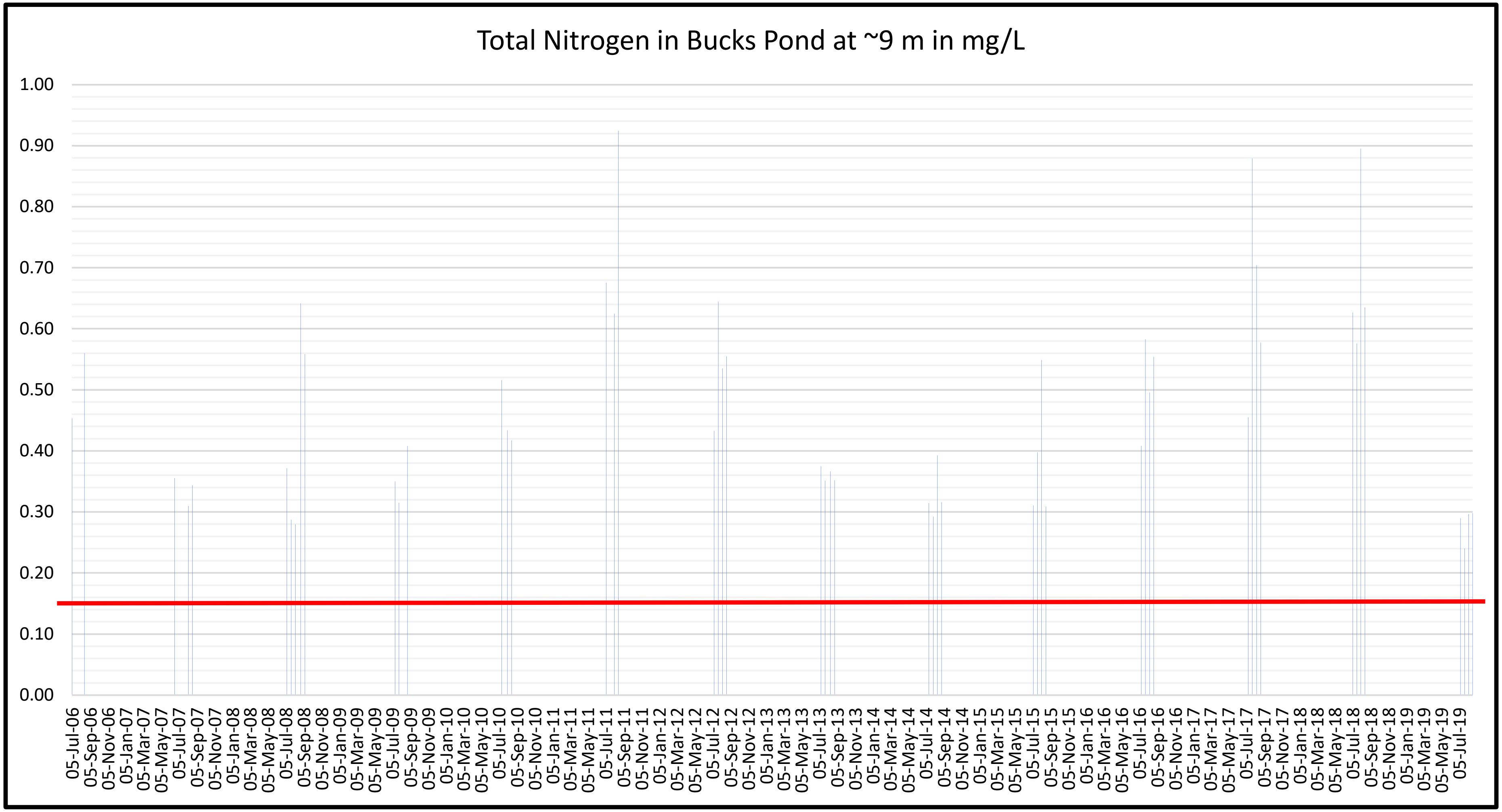
Nitrogen Levels Above .15 mg/L Promote Cyanobacteria Growth: Cyanobacteria Need both Phosphorus and Nitrogen to Thrive



Source: SMAST Spreadsheet, 2006-2019

- EPA-predicted range for Cyanobacteria Growth starts at .15 mg/L of Total Nitrogen (https://www.epa.gov/sites/default/files/2018-10/documents/nutrient-criteria-manual-lakes-resevoirs.pdf)

There is Greater Fluctuation in Nitrogen Content at Lower Depths: The Ratio of Nitrogen to Phosphorus Favorable to Cyanobacteria is Unknown



Source: SMAST Spreadsheet, 2006-2019

- EPA-predicted range for Cyanobacteria Growth starts at .15 mg/L of Total Nitrogen (https://www.epa.gov/sites/default/files/2018-10/documents/nutrient-criteria-manual-lakes-resevoirs.pdf)

Cyanobacteria and Potential Health Hazards

At low concentrations, cyanobacteria is not problematic for human health. When cyanobacteria proliferate, however, toxins are released at levels that can cause illnesses including upper respiratory infections, gastrointestinal distress, neurological damage, liver damage and even death.

When cyanobacteria proliferate, they can form "harmful cyanobacteria blooms" (HCBs) that give a visual indication of unsafe conditions. APCC tests for phycocyanin (blue-green algae pigment) that can indicate a proliferation before a cyanobacteria mat takes form.

Conditions favorable to cyanobacteria include:

- Temperatures above 25 Degrees Celsius
- Phosphorus and Nitrogen in Combinations that are not yet Clearly Understood
- Stable Water (Low Turbidity)

Table 1. Cyanotoxins on the Contaminant Candidate List (CCL)

Cyanotoxin	Number of Known Variants or Analogues	Primary Organ Affected	Health Effects[1]	Most Common Cyanobacteria Producing Toxin[2]
Microcystin-LR	80~90	Liver	Abdominal pain Vomiting and diarrhea Liver inflammation and hemorrhage Acute pneumonia Acute dermatitis Kidney damage Potential tumor growth promotion	*Microcystis* *Anabaena* *Planktothrix* *Anabaenopsis* *Aphanizomenon*
Cylindrospermopsin	3	Liver		*Cylindrospermopsis* *Aphanizomenon* *Anabaena* *Lyngbya* *Rhaphidiopsis* *Umezakia*
Anatoxin-a group[3]	2-6	Nervous System	Tingling, burning, numbness, drowsiness, incoherent speech, salivation, respiratory paralysis leading to death	*Anabaena* *Planktothrix* *Aphanizomenon* *Cylindrospermopsis* *Oscillatoria*

[1]Source: *Harmful Algal Research and Response National Environmental Science Strategy (HARRNESS)*
[2]Not all species of the listed genera produce toxin; in addition, listed genera are not equally as important in producing cyanotoxins.
[3]The anatoxin-a group does not include the organophosphate toxin anatoxin-a(S) as it is a separate group. In the US, the most common member is thought to be anatoxin-a, and thus this toxin is listed specifically.

APCC Data on Phycocyanin (Blue-Green Algae Pigment) Showed High Levels of Cyanobacteria in Bucks Pond in October 2019

2019 Cyanobacteria Monitoring Data			WLW			BFC				Dominance%		BFC PC to MC Regressions			WLW PC to MC Regressions			Notes:	Map Cyano Status	Other notes
Sample Date	Fluor Date	Pond Temp (F)	PC (ug/L)	CHLA (ug/L)	Ratio	PC (ug/L)	CHLA (ug/L)	Ratio	Microcystis	Dolichospermum	Other	100% MC	Mixed	100% DS	100% MC	Mixed	100% DS			
7/18/19	7/19/19	79.5	0.17	0.01	13	53.66	0.3	180.88	96	1	3	1.96	0.1438	0.0243	0.01	0.0003	0.0008		Low	
7/30/19	7/30/19	79.4	16.08	0	0	386.86	0.86	449.84	62	35	3	14.11	1.1737	0.077	0.59	0.0399	0.012		Low	
8/6/19	8/6/19	80.3	2.02	0	0	120.63	0.24	495.73	69	23	8	4.41	0.3401	0.039	0.07	0.0044	0.0036		Low	
8/14/19	8/15/19	75.3	33.98	0.01	0	326.81	0.63	521.51	48	48	4	11.92	0.9811	0.0698	1.24	0.0884	0.0186		Low	
8/20/19	8/20/19	80.8	15.56	0	0	329.49	0.93	355.56	76	21	3	12.02	0.9896	0.0701	0.57	0.0386	0.0118		Low	
9/25/19	9/26/19	65.4	3.26	0.09	34.96	771.17	2.84	271.54	100	0	0	28.08	2.4437	0.1153	0.12	0.0073	0.0047	High due to est Microcystin in BFC sample above 14ppb	High	Contacted town to give warning of concerning findings
9/30/19	10/1/19	65.4	2.46	0.11	23.03	490.84	2.36	207.98	100	0	0	17.89	1.5117	0.0886	0.09	0.0054	0.004	High due to est Microcystin in BFC sample above 14ppb	High	Updated town that levels were still high.
10/7/19	10/8/19	73.2	2.53	0.16	16.32	57.15	0.45	127.95	100	0	0	2.09	0.1537	0.0252	0.09	0.0056	0.0041	High due to less than two weeks with elevated Microcystin	High	
10/17/19	10/18/19	59.8	3.78	0.12	31.47	96.43	0.38	251.56	100	0	0	3.53	0.2681	0.0342	0.14	0.0086	0.0051		Low	Updated town of Low concern

Source: APCC 2019 Cyanobacteria Monitoring Report

In 2021, APCC Data on Phycocyanin (Blue-Green Algae Pigment) Showed Two Weeks of High Concentrations of Cyanobacteria in John Joseph Pond

Sampling Date	APCC Map Warning Tier	Dominant Genus	Bloom Forming Colonies Phycocyanin (ug/L)	Estimated Microcystin Concentrations in Bloom Forming Colonies (ug/L)	Cyanobacteria Bloom Material Presence
6/10/2021	Low	Mixed	28.3	0.07	No
6/25/2021	Low	*Microcystis* spp.	1.7	0.06	No
7/2/2021	Low	*Microcystis* spp.	12.0	0.44	No
7/16/2021	High	*Microcystis* spp.	311.6	11.37	No
7/21/2021	High	*Microcystis* spp.	261.5	9.54	No
7/30/2021	High	*Microcystis* spp.	107.7	3.94	No
8/6/2021	Low	*Dolichospermum* spp.	95.9	0.03	No
8/13/2021	Low	*Microcystis* spp.	38.7	1.42	No
8/27/2021	Low	Mixed	31.2	0.08	No

Table 2. Summary Cyanobacteria monitoring results for John Josephs Pond in Harwich, MA

Source: APCC 2021 Cyanobacteria Monitoring Report for Bucks, John Josephs, Skinequit Ponds and West Reservoir

The Cyanobacteria Levels Exceeded Health Department Recommendations and Beach Closure Was Recommended

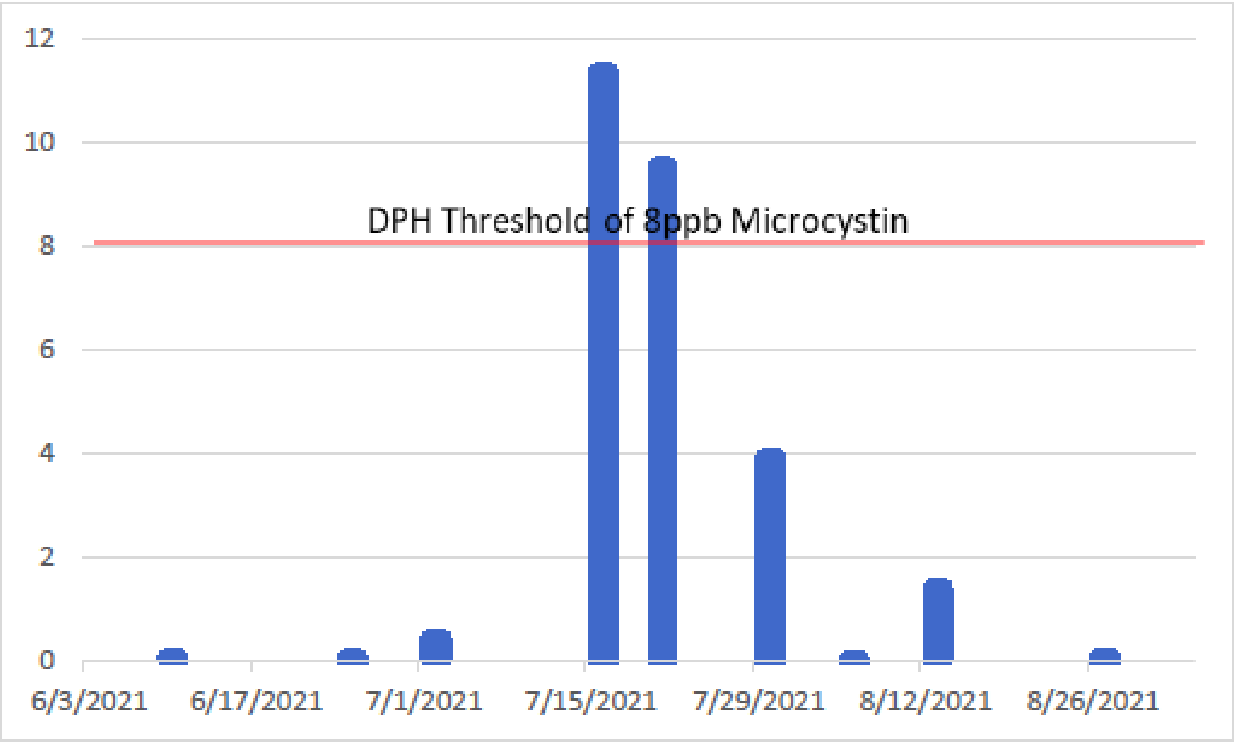


Figure 3. Estimated Microcystin (ug/L) in Bloom Forming Colonies in John Josephs Pond. The X-axis contains sampling dates and the Y-axis contains the estimated microcystin concentrations for each sampling event in parts per billion (ppb). If cyanobacteria bloom material was discovered at a sampling event, it is denoted by a green arrow.

Source: APCC 2021 Cyanobacteria Monitoring Report for Bucks, John Josephs, Skinequit Ponds and West Reservoir

APCC Data Indicated Low Levels of Cyanobacteria in Bucks Pond from June to August of 2021

Sampling Date	APCC Map Warning Tier	Dominant Genus	Bloom Forming Colonies Phycocyanin (ug/L)	Estimated Microcystin Concentrations in Bloom Forming Colonies (ug/L)	Cyanobacteria Bloom Material Presence
6/10/2021	Low	*Dolichospermum* spp.	189.1	0.05	No
6/25/2021	Low	Mixed	111.4	0.31	No
7/2/2021	Low	Mixed	202.1	0.59	No
7/16/2021	Low	*Microcystis* spp.	40.6	1.49	No
7/30/2021	Low	Mixed	16.3	0.04	No
8/13/2021	Low	*Microcystis* spp.	26.4	0.97	No
8/27/2021	Low	*Microcystis* spp.	64.8	2.37	No

Table 1: Summary Cyanobacteria monitoring results for Bucks Pond in Harwich, MA

Source: APCC 2021 Cyanobacteria Monitoring Report for Bucks, John Josephs, Skinequit Ponds and West Reservoir

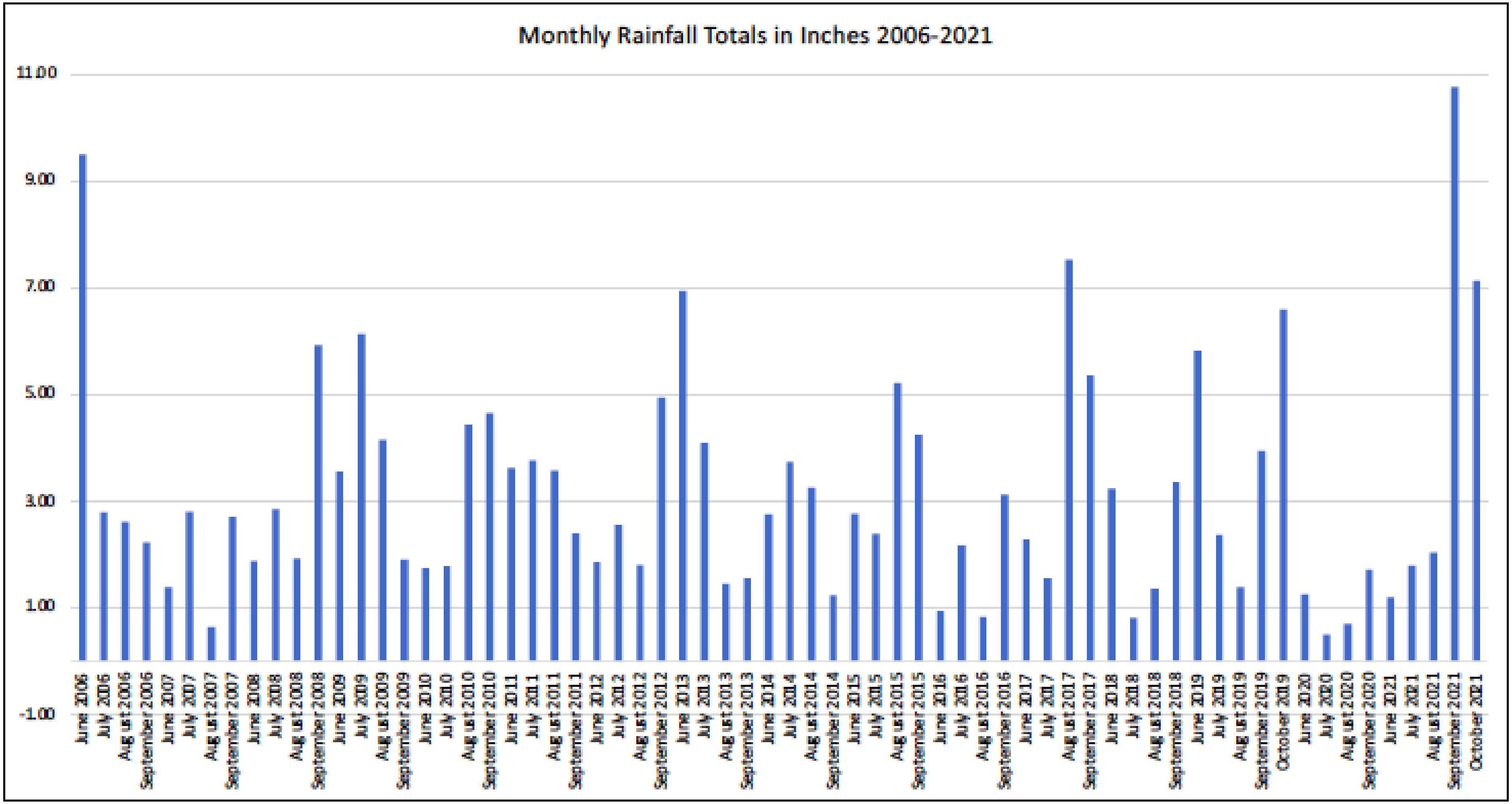
Trends in the Data Raise New Questions

- If Bucks Pond had low levels of cyanobacteria from June to August 2021, why did it have a bloom in the fall of 2021? What changed in the environment? Shift in phosphorus to nitrogen content? Stillness of the water in the off-season? Rainfall?

- What is causing the spikes in nutrient content in the ponds overall? Is high ground water causing septic systems to leach? Are low ground water levels increasing the concentration of nutrients? Are rains washing fertilizers from lawns into the ponds? Are underground water sources introducing nutrients from outside the GSLA neighborhood? Is the introduction of new beach sand introducing nutrients into the ponds?

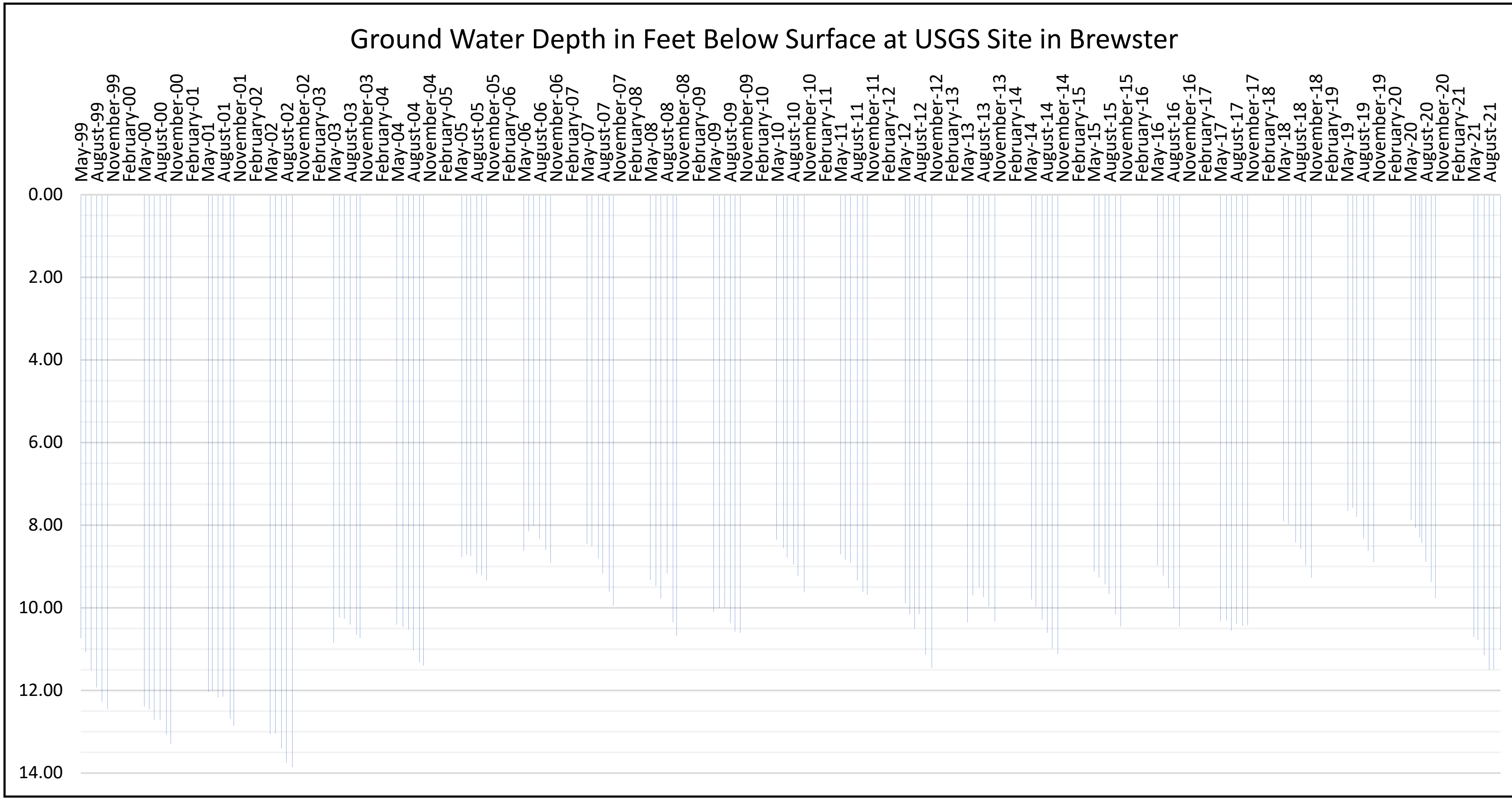
- What source(s) are releasing E. Coli contaminated water into the ponds? Outdated septic systems within the GSLA neighborhood? Ground water sources from outside the GSLA neighborhood?

Did High Rainfall in Fall 2021 Trigger a Cyanobacteria Bloom in Bucks Pond?



Source: NOAA Rainfall Data from Chatham Weather Station, 2006-2021

Ground Water Levels Do Not Seem to Correlate with Excess Nutrients or E. Coli



- High nutrient measurements occurred in 2014, 2015, 2016 and 2018.
- High E. Coli measurements occurred in 2008, 2010, 2011, 2015, 2017 and 2018.
- Low water years were 1999, 2000, 2001, 2002, 2021.
- High water years were 2005, 2006, 2010, 2011, 2018, 2019, 2020.

Next Steps

- Advocate for additional research and testing to occur throughout the year;
- Investigate GSLA septic systems as a potential cause of high nutrients and E. Coli;
- Approach Harwich Water Department about expediting sewer construction;
- Investigate when landscapers are applying fertilizer to lawns to seek correlations with spikes in the nutrient content of the ponds;
- Advocate for a ban on lawn fertilizers with phosphorus;
- Investigate potential correlations between beach sand replenishment and increase in nutrients in the ponds;
- Encourage GSLA property owners to:
    - Manage septic systems to prevent leaching into the ponds;
    - Use landscaping techniques that do not pollute the ponds;
    - Plant native plants, barrier gardens, and rain gardens to enable storm water run-off to filtrate before it reaches the ponds;
    - Use detergents and dish soaps that do not contain phosphorus.

Human Health and Property Values are being Compromised by Inaction

In 2007, the Cape Cod Pond and Lake Stewardship Program (PALS) published a report that provided the following summary for Bucks Pond:

> "The Great Sand Lake pond system was extensively studied in June 2007 as part of the Evaluation of Wastewater Management Options for Freshwater Ponds for the Town of Harwich (GSL Report). Detailed phosphorus loads were evaluated and specific recommendations for phosphorus reduction included educational materials to reduce private phosphorus inputs, management of waterfowl, and design enhancements to septic systems. As a potential long-term option to address future phosphorus loading to the watershed, the implementation of a wastewater collection and treatment system was discussed. In order to protect this pond system from degradation, action towards phosphorus reduction must be taken."

And for John Joseph Pond concluded:

> "This entire Great Sand Lake system is surrounded by medium-to-high density residential development with a network of minor roads. As mentioned above regarding Bucks Pond, John Joseph Pond was also studied in detail in June 2007 and identified as an area requiring phosphorus load reduction to improve water quality."