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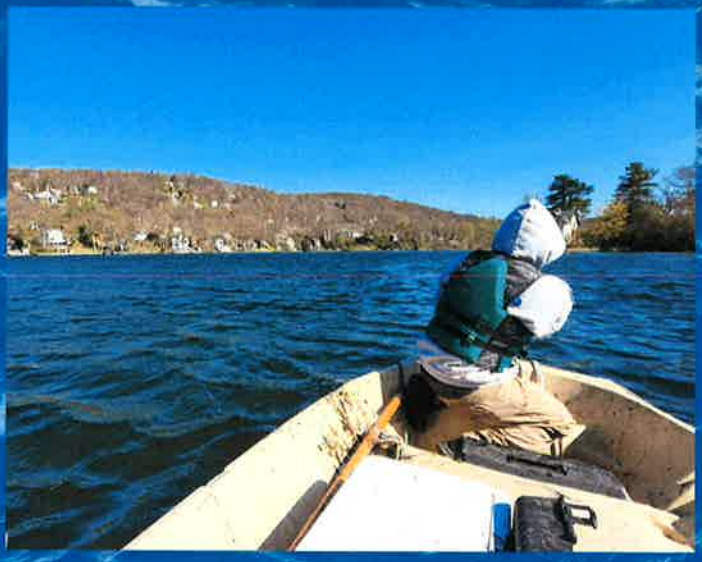
2023

Lake Peekskill Annual Report



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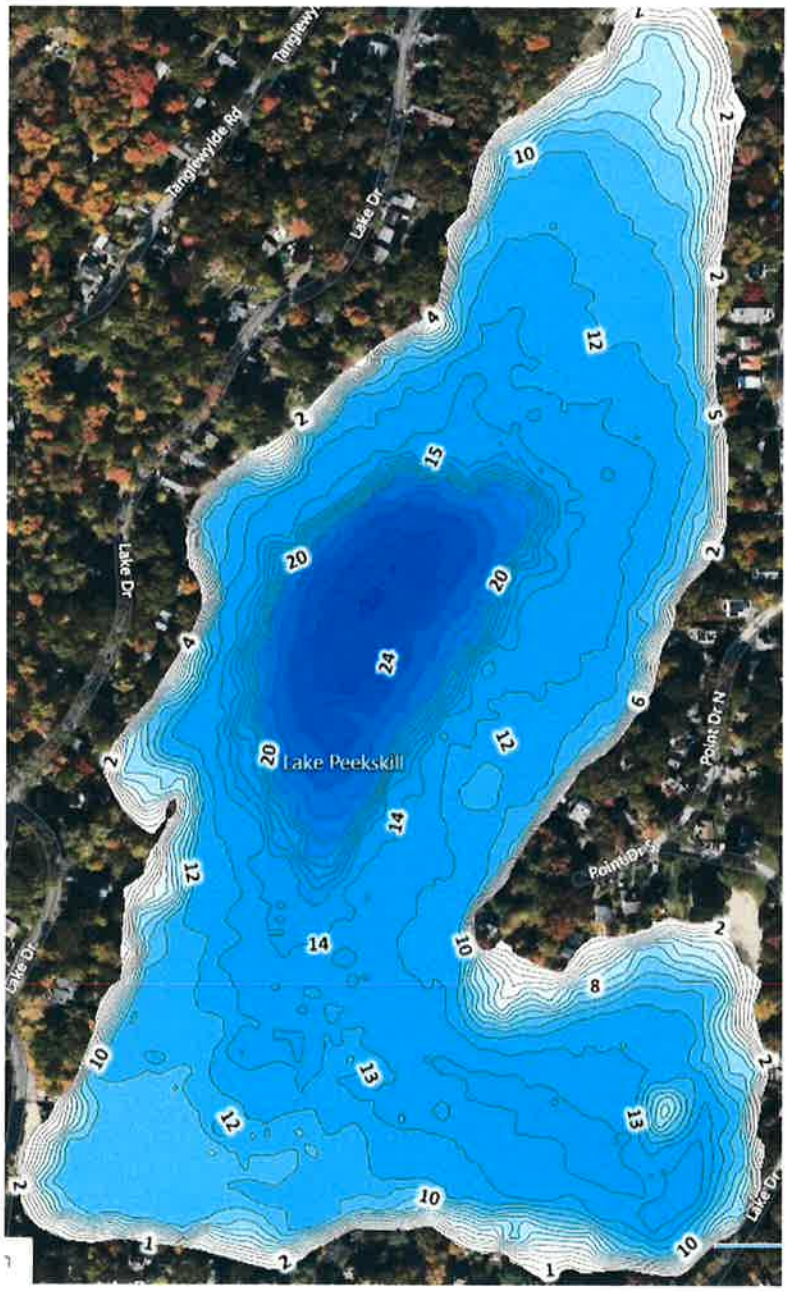
Lake Peekskill 2023 Bathymetric Scan



Town of Putnam Valley
265 Oscawana Lake Road
Putnam Valley, NY 10579

Background

In 2018, Clean-Flo responded to a request for proposal issued by the Town of Putnam Valley for the design, installation, and operation and maintenance of a remediation program to reduce the incidence and severity of harmful algae blooms (HABs). Based on the information provided in the RFP, Clean-Flo designed a RADOR (Rapid Acting Dissolved Oxygen Restoration) system and submitted a proposal for a system and bioaugmentation program. The project was awarded to Clean-Flo, and the system was installed and bioaugmentation began in late June of 2018.

After installation, some improvements were achieved in 2018, but starting in 2019 the full benefits of the program were apparent. Harmful algae blooms were reduced, and the frequency of lake closures was reduced. In 2020 the biological treatment program was disrupted by Covid travel restrictions. The impact of this was detected in algae sampling and testing but did not result in more lake closures.

In June of 2022, the New York State Department of Environmental Conservation (NYSDEC) prohibited further application of biological products. Since then, Clean-Flo has maintained the RADOR system and performed sampling but ceased the bioaugmentation program. The RADOR system has continued to benefit the lake, as described in the results below. However, water quality has deteriorated because of the severity of cyanobacteria harmful algae blooms in the summer of 2023. We believe that the indefinite prohibition of the bioaugmentation program by the NYSDEC has led to this regression.

As part of Clean-Flo's contract, a bathymetric scan of the lake and water quality sampling was performed at the beginning of the program, in late 2018. The scan established baseline conditions for water quality, depth, and vegetation. The most recent scan was performed in October of 2023. The results of the scan, as well as comparison to the 2022 scan, are described in this report.

2023 Scan Summary

On October 3rd, 2023, Clean-Flo performed the annual sonar scan on Lake Peekskill, took water quality readings, laboratory samples, and algae samples. The 2023 scan and sampling show some improved conditions in the lake despite the end of the bioaugmentation program. Algae, water quality, and nutrient sampling data are compiled in the following sections.

The 2022 sampling data and sonar scan show that nutrient levels have increased over the season, especially the latter half of the year. This is to be expected with the cessation of the biological treatment program, which facilitates nutrient management. With the cessation of bioaugmentation in June 2022, cyanobacteria populations increased from previous years but the 2023 levels are consistent with those in 2022. This indicates both the ability of the RADOR system itself to mitigate conditions that favor the complete dominance of cyanobacteria, as well as a lagging benefit of the bioaugmentation program since 2018.

Water Quality and Sampling

Sample locations for water quality readings, nutrient samples, and algae samples are shown below.

Sampling locations on Lake Peekskill

Dissolved Oxygen and Temperature

Dissolved oxygen (DO) readings were obtained with a handheld YSI water quality meter. DO is a measure of the amount of oxygen in the water column available to aquatic organisms. Generally, DO levels should be a minimum of 5 mg/L to sustain a healthy ecosystem. DO at the surface is higher due to the exchange of oxygen between the atmosphere and the surface water, whereas DO is lower at the lake bottom due to decreased contact with the atmosphere and increased consumption of oxygen by decomposing organic matter.

Oxygen data recorded in 2023 is displayed in the table below. In May, DO levels were still well above the 5 mg/L threshold throughout the water column. In June, low oxygen levels were recorded in the bottom four feet of the water column at sample point S2. This situation at the bottom improved in July and August, with the DO

remaining at or slightly below 5.0 mg/L at the bottom at S2. In August, the DO was unusually low at every sample point, even at the surface. These results are anomalous but are due to the massive algae growth that was seen in the late summer and presumed subsequent die-off. Decaying algae are a significant contributor to the depletion of dissolved oxygen.

Dissolved Oxygen (DO) data from 2023

	5/3/2023				6/21/2023				7/14/2023				8/16/2023				9/21/2023			
Depth (ft)	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
2	9.4	9.1	9.4	9.0	9.6	9.6	10.0	10.0	9.2	7.6	9.8	9.4	5.0	4.9	5.4	5.6	9.5	9.1	9.4	8.6
4	9.3	9.1	9.4	9.0	9.6	9.3	10.0	10.0	8.6	7.3	8.5	8.5	4.8	4.7	5.3	5.5	9.7	9.0	9.5	8.7
6	9.3	9.1	9.3	9.0	9.0	9.0	10.1	9.6	8.3	7.3	7.8	8.2	4.7	4.7	5.2	5.3	9.9	8.9	9.4	8.7
8	9.3	9.1	9.1	9.0	9.0	8.7	9.6	9.0	8.3	7.3	7.3	6.8	4.7	4.7	5.1	5.3	9.8	8.5	9.4	8.6
10	9.4	9.0	9.0	8.9	8.7	8.5	8.7	8.5	8.1	7.2	6.4	6.8	4.2	4.6	5.1	5.3	9.0	8.4	9.4	8.5
12	9.4	9.0	8.8	8.9		8.3	8.0	7.0	8.1	7.3	5.2	6.0	4.2	4.6	5.0	5.3	8.6	8.5	8.9	8.3
14		9.0	8.8	9.0		8.0	7.1			7.0	5.1			4.3	4.3	4.4		8.5		
16		8.9				7.3				6.5				4.6				8.5		
18		8.9				6.4				6.2				4.6				8.4		
20		8.9				2.7				5.7				4.6				8.1		
22		8.9				2.0				5.3				4.4				7.9		
24		7.2				0.4				5.0				4.2				7.4		

Laboratory Samples

Water sampling and analysis are used on Lake Peekskill to evaluate nutrient concentrations and algal community in the water column. Total phosphorus (TP) levels should be below 0.02 mg/l to avoid nuisance algae growth. Orthophosphate is the form of phosphorus that is most bioavailable and should be lower than TP, substantially lower than 0.02 mg/L. Algal samples are taken to measure the diversity of the algal population and the prevalence of harmful cyanobacteria, which cause harmful algae blooms (HABs). In general, any harmful cyanobacteria is undesirable. It is critical to keep these species at lower concentrations than those at which they might become toxic and this is possible by stimulating biodiverse algal populations.

Algae water samples were taken at the surface, and the phosphorus and orthophosphate water samples were taken one foot from the bottom with a Van Dorn Beta water sampler. Samples were analyzed for total phosphorus and orthophosphate by Trace Analytical labs. The algae samples were analyzed by Phycotech.

The table below shows phosphorous results for 2023. In July and August TP levels rose to 0.15 mg/L and 0.16 mg/L, respectively. This was seven-to-eight times higher than the 0.02 mg/L maximum recommended TP level. This is attributable to two factors. First is the slightly impaired oxygen in deeper strata in June and August. The second and more important factor is the loss of control of nutrient processing and increase in phytoplankton levels in the absence of bioaugmentation.

Average Total Phosphorus Levels 2023

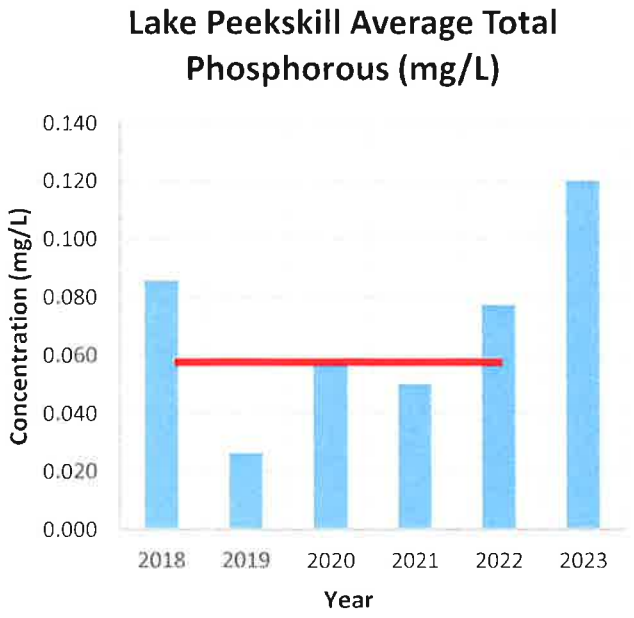
Sampling Date:	5/23/2023	7/14/2023	8/16/2023	9/21/2023
Total Phosphorous (mg/l)	0.04	0.15	0.16	0.13

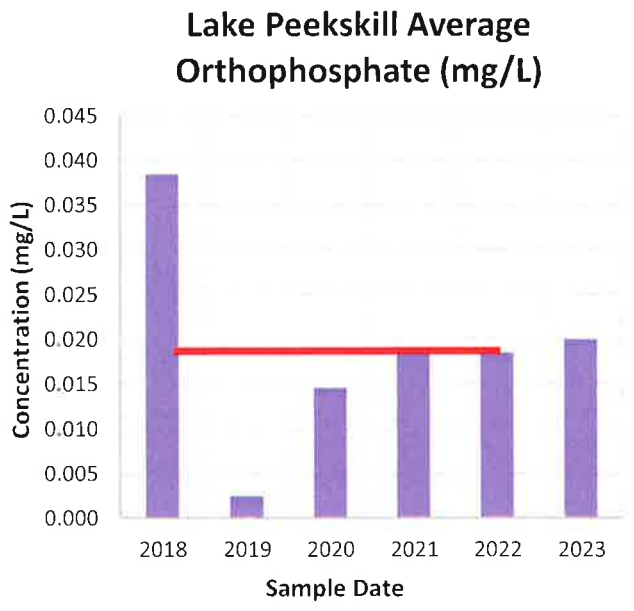
The following table shows orthophosphate levels for 2023. As a component of TP, orthophosphate should typically be far lower in concentration than 0.02 mg/L for algae control. The 0.02 mg/L average orthophosphate concentrations throughout the summer indicate conditions in which algae – in particular cyanobacteria – would be expected to flourish. This is what happened in Lake Peekskill this summer.

Average Orthophosphate Levels 2021-2022

Sampling Date	5/23/2023	7/14/2023	8/16/2023	9/21/2023
Total Orthophosphate (mg/l)	0.02	0.02	0.02	0.02

TP concentrations reflect the fragmented bioaugmentation over the project's lifespan. The year after the project began, the average TP dropped significantly. When bioaugmentation was in full swing, concentrations were lower. Following the end of bioaugmentation, TP has steadily risen. Orthophosphate – the form of phosphorous available to vegetation and algae – followed similar trends. The year after the project began, average orthophosphate concentrations dropped precipitously. They rose in 2020 during the application disruption due to Covid, and again have risen slightly since the bioaugmentation program ended. The charts below illustrate changes in annual average TP and orthophosphate over time. The red lines indicate the period of time when concentrations were lowered and controlled by Clean-Flo's program. Both nutrients are currently higher than desirable and will stimulate algae growth in the coming years.





Algae Samples

Algae samples were analyzed for different species of algae that vary in significance. The following table is a guide for the different groups of algae analyzed and what they indicate about the aquatic environment.

Guide for Algae Analysis

	Functional Group	What does it indicate?
BG	Non-harmful Cyanobacteria	Generally benign and indicative of good water quality.
CER	Ceratium	Often present in tannic/high organic content water bodies. Active migrator in the water column. May cause significant taste and odor at high densities.
CP	Cryptophytes & Dinoflagellates	Often dominate in spring, or in tannic/high organic content water bodies. Generally indicate good water quality.
DY	Chrysophytes, Haptophytes & Diatoms	Generally indicate good water quality. If high densities, can cause significant taste and odor.
E	Euglenophytes	Often present in high organic content water bodies. Co-occurs with Cryptophytes and non-coliform bacteria. High densities can be indicative of poor water quality.
G	Chlorophytes	Generally indicate good water quality. If very high densities, indicates high nitrate concentrations.
TO	Taste and Odor Producers	Algae that often produce taste and odor issues. Diatoms that can produce taste and odor problems, but do so less often, are not included in this group.
HAB	Harmful Cyanobacteria	May produce toxins, but not always producing. Toxins are generally detectable above 5000 cells/mL. Indicative of poor water quality often with high phosphate or low TN:TP ratios.
M	Miscellaneous	All other groups, generally neutral. Includes small Chlorophytes or Cyanobacteria less than 9um in diameter.
U	Unclassified	Images that the classifier cannot confidently identify. Includes small flagellates entrained in detritus, taxa not yet included in the classifier, partial images and images with multiple taxa.

The following table shows a breakdown by group from samples taken in 2022. Despite the small percentages of harmful cyanobacteria in April and May of 2022, over 90% of the algae population consisted of chlorophytes, which indicated that cyanobacteria were outcompeted by the chlorophytes. In July however, after biological treatments were halted, harmful algae rose to 86% of the algal community in shallower sample sites. By August 2022, cyanobacteria – both harmful and non-harmful species – made up the vast majority of all algae.

Algal Community 2022

Algal community 2022 (cells/mL)												
Functional Group	4/29/2022			5/31/2022			7/15/2022			8/18/2022		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
BG (Non-Harmful Cyanobacteria)	0	0	0	34	80	52	905	1,815	3,081	5,996	5,812	6,624
CP (Cryptophytes)	16	0	1	0	2	1	0	0	0	10	7	4
DY (Diatoms, Chrysophytes, etc)	3	14	12	0	17	0	3	6	0	102	34	30
G (Chlorophytes)	397	523	426	870	826	1,212	210	486	70	21	20	30
HAB (Harmful Cyanobacteria)	14	28	0	12	41	71	6,799	921	6,219	1,970	1,471	2,472
M (Miscellaneous)	1	1	1	3	5	3	9	9	9	67	123	34
Total Cells/mL	430	566	440	919	972	1,338	7,927	3,238	9,380	8,166	7,467	9,194
% HAB	3.3%	4.9%	0.0%	1.3%	4.2%	5.3%	85.8%	28.5%	66.3%	24.1%	19.7%	26.9%

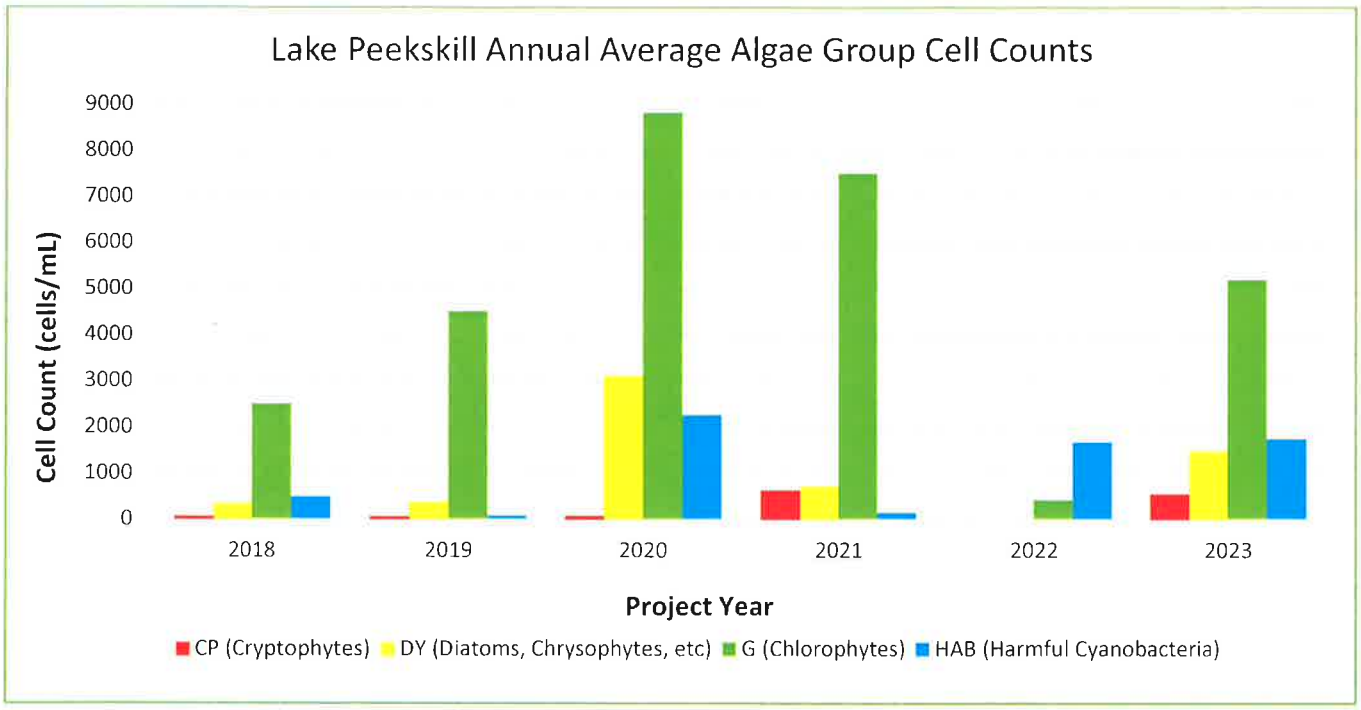
The following table shows a breakdown by group from samples taken in 2023. In the spring and early summer, total algae concentrations were higher than at the same time in 2022 but consisted mostly of beneficial species. This was true through June. The relative concentration of harmful cyanobacteria increased significantly in July and was at levels in August only slightly lower than in 2022. Despite the high concentration of harmful species, *the overall diversity of algal species was higher than in 2022.* This is due to two factors. One, as with cyanobacteria, beneficial algae will capitalize on high nutrient levels, which were present this year. Second, the desirable species have benefited from the biological products added to the lake in 2021 and early 2022. The biodiversity represents a good foundation for resisting cyanobacteria dominance with the operation of the RADOR system in the future.

Algal Community 2023

Algal community 2023 (cells/mL)												
Functional Group	5/4/2023			6/21/2023			8/16/2023			9/21/2023		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
BG (Non-Harmful Cyanobacteria)	6	0	0	53	115	82	95	9	32	116	228	176
CP (Cryptophytes)	1,192	757	1,255	509	958	308	239	368	450	250	165	300
DY (Diatoms, Chrysophytes, etc)	340	362	464	816	4,433	564	191	256	274	2,246	3,002	4,987
G (Chlorophytes)	397	1,708	1,312	15,069	15,964	14,737	1,977	1,716	2,140	2,332	2,809	2,203
HAB (Harmful Cyanobacteria)	14	0	0	306	118	195	9,573	1,868	3,155	1,424	1,370	2,878
M (Miscellaneous)	1	30	37	462	846	342	41	11	10	53	61	21
Total Cells/mL	1,950	2,857	3,068	17,215	22,434	16,228	12,116	4,228	6,061	6,421	7,635	10,565
% HAB	0.7%	0.0%	0.0%	1.8%	0.5%	1.2%	79.0%	44.2%	52.1%	22.2%	17.9%	27.2%

The chart below summarizes annual average algae counts since the project began. Concentrations of harmful cyanobacteria were far lower than green algae and diatoms up to August of 2020. Because of travel restrictions during Covid, bioaugmentation applications were curtailed in 2020, which led to the spike in harmful cyanobacteria. In June 2022, the NYSDEC prohibited further application of bioaugmentation products. The summer of 2022 saw major harmful algae blooms, and the concentration of these species far outweighed that of beneficial species. Similarly, in 2023, although diversity and cell counts for beneficial species were high in May and June, harmful species took over in August (their populations may have risen dramatically in July, but there was no sample event then), and remained relatively high at the time of the last sample event in September. *These results indicate that the lake suffered serious setbacks with the discontinuation of the bioaugmentation program.* This is a summary of the timeline:

- 2018: The project began to combat harmful cyanobacteria, whose populations were at concerning levels
- 2019: Harmful cyanobacteria populations were controlled
- 2020: Covid disruptions curtailed bioaugmentation, harmful cyanobacteria populations increased
- 2021: Full bioaugmentation resumed, harmful cyanobacteria declined significantly, and phycological diversity increased
- 2022: NYSDEC banned bioaugmentation, harmful cyanobacteria increased again
- 2023: No bioaugmentation, late-summer cyanobacteria blooms were especially intense, and green algae (chlorophytes) populations declined.

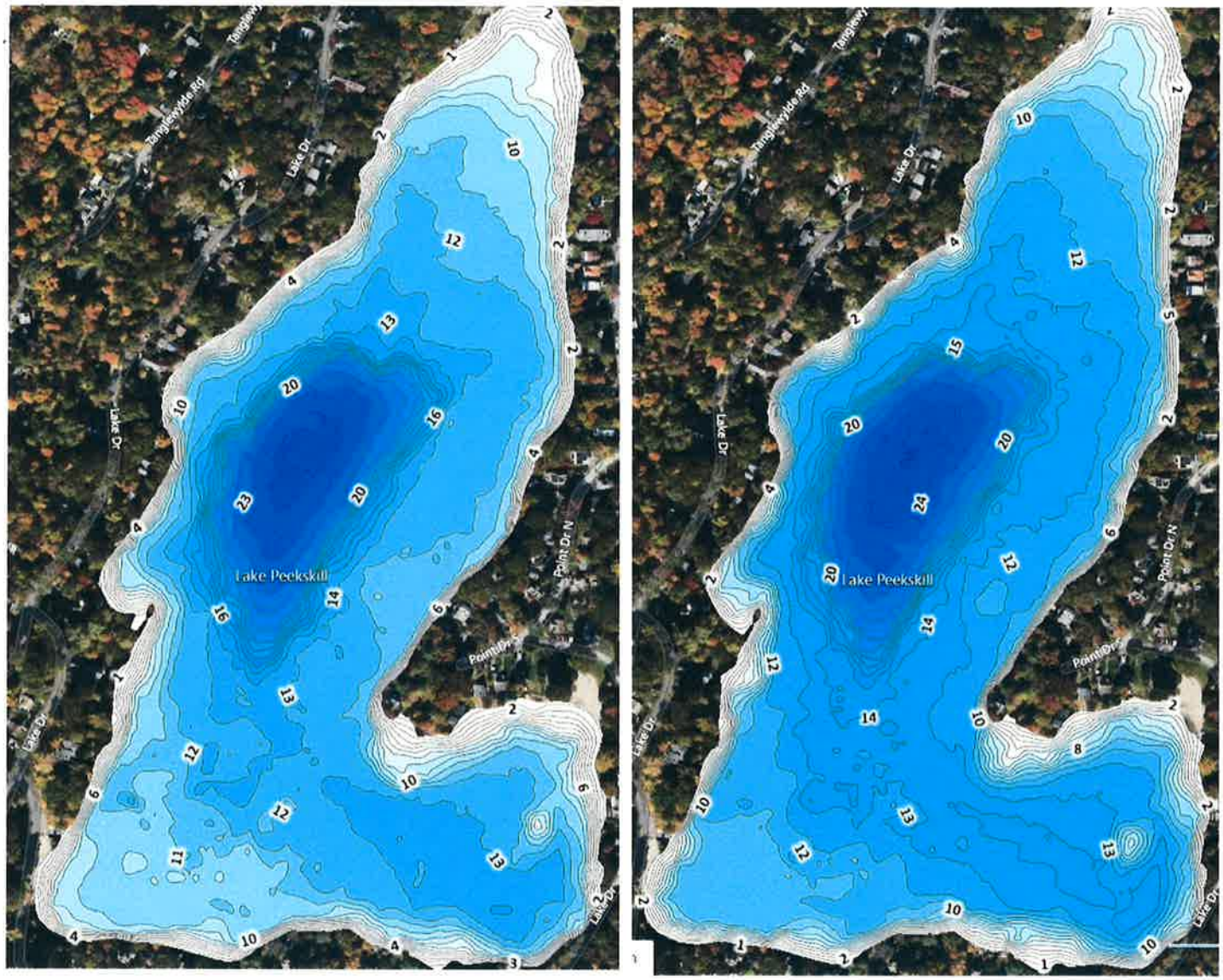


Sonar Scan and Mapping

The sonar scan of the lake was completed on October 3rd, 2023, and is compared to the October 2022 sonar scan. The scans were conducted with a Lowrance Elite-7 Ti^2 scanner with broadband sounder technology, built-in GPS antenna, and high-definition mapping. The data obtained was uploaded to Biobase GIS, a cloud-based mapping service, to produce contour and vegetative biovolume maps, and to analyze vegetation quantitatively.

Bathymetry (Depth) Maps

The contour maps with contours at 1-foot intervals for the lake are shown in the figure below. From 2022 to 2023, the lake has increased in depth and volume. The increase has taken place primarily within the 20-foot contour and deeper. In 2022, the average depth was 11.9 feet, the maximum depth was 24.8 feet, and the volume was 716.4 acre-feet (233.4 million gallons). In 2023, the average depth is 12.3 feet, the maximum depth is 25.2 feet, and the volume is 739.2 acre-ft (240.9 million gallons). This represents gains of 0.4 feet (5.2 inches) in average depth, 0.4 feet (5.2 inches) in maximum depth, and 22.8 acre-ft (7.4 million gallons) in volume.

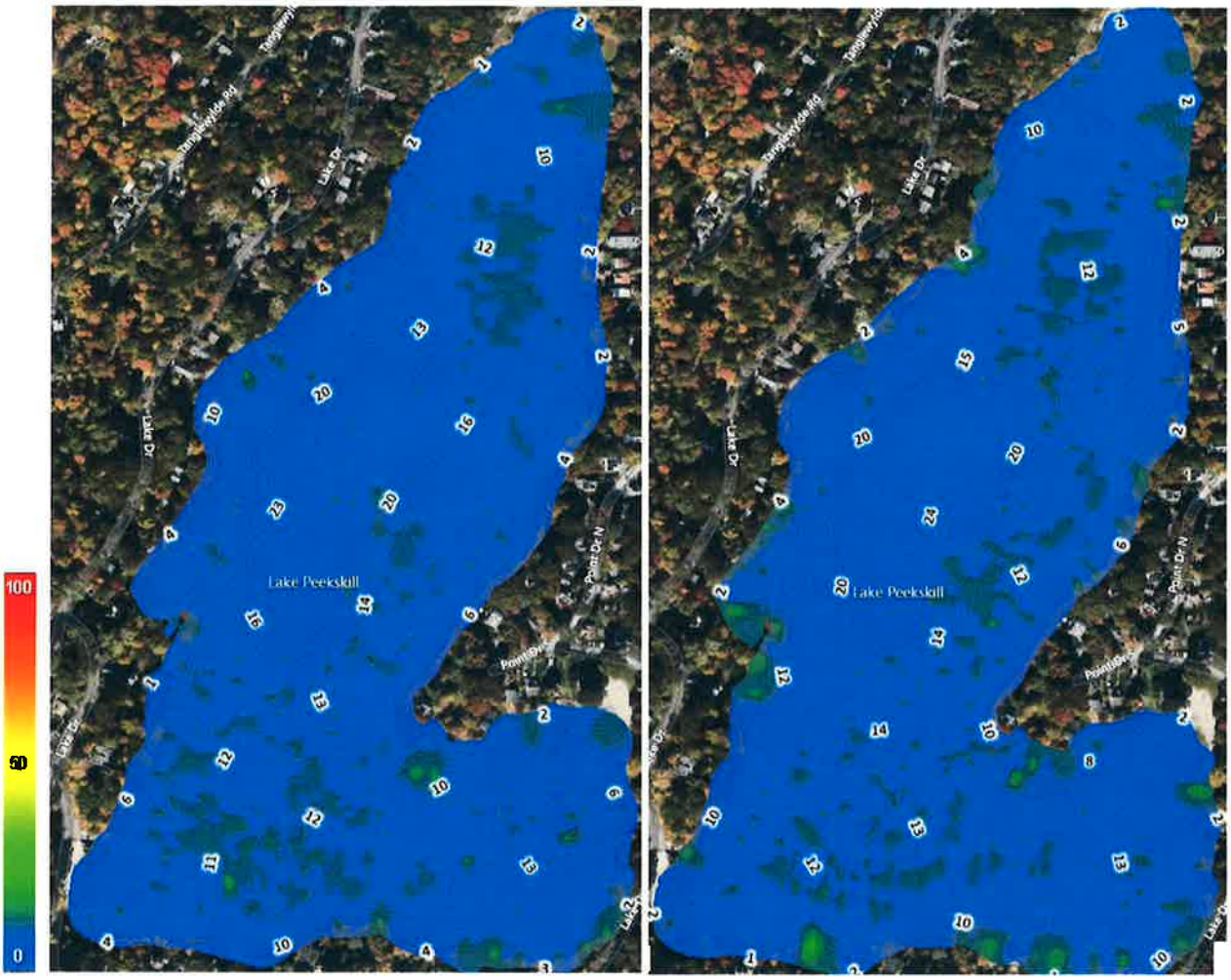


Bathymetric Maps 2022 (left) and 2023 (right)

Vegetative Biovolume

Biovolume maps display the locations of vegetative growth, the percentage of vegetative biovolume of those areas. The dark blue regions in the maps are devoid of vegetation growth, while the light green-to-red regions have low to high biovolume, respectively. The Survey Summaries represent statistics generated from data obtained by the scans.

The figures below illustrate vegetative biovolume in Lake Peekskill in 2022 and 2023. The distribution of vegetation between years is similar. In 2023 there was a slight decrease in vegetation coverage in the southwest quarter of the lake. There were slight increases in density in small spots along the southern and eastern shoreline.



Vegetative Biovolume map of Lake Peekskill from the 2022 scan (left) and 2023 (right).

The tables below quantify the coverage and biovolume of vegetation in 2022 and 2023. The amount of the lake's area covered by vegetation (PAC) was 5.0% in 2022 and increased to 8.9% in 2023. The average percentage of the lake water column occupied by vegetation (BVw), a measure of vegetative density, was 0.3%. This increased to 0.7% in 2023. Increases in coverage and density are due to the high nutrient concentrations and discontinuation of the bioaugmentation program.

Vegetation Coverage and Density 2022

2022 Vegetation Survey Summary						
PAC	Avg. BVp	SD BVp	Avg BVw	SD BVw	Depth Range	Depth Avg
5.00%	6.40%	± 1.8%	0.30%	± 1.5%	0.56 - 24.81 ft	11.92 ft

Vegetation Coverage and Density 2023

2023 Vegetation Survey Summary						
PAC	Avg. BVp	SD BVp	Avg BVw	SD BVw	Depth Range	Depth Avg
8.90%	7.40%	± 2.7%	0.70%	± 2.2%	0.36 - 25.24 ft	12.30 ft

Conclusions

There are four principal findings of this year's sampling and scan.

1) Dissolved oxygen was maintained at healthy levels through most of the season except at depths below 20 feet during several sampling events, and across the board in August. The results in August were very unusual and may be a consequence of the high levels of algae – both beneficial and HABS – observed in the lake during that part of the summer.
2) Nutrient levels were higher this season than last. Both total phosphorous and orthophosphate were well above thresholds at which they become major drivers of algae and vegetation growth. The increase in nutrient concentrations has been facilitated in many respects by the cessation of bioaugmentation.
3) Algae concentrations were higher during the 2023 season. The diversity of the algal population was *far higher* than in previous years – a good thing – and HAB concentrations were about the same or slightly lower than in 2022. However, the trend of harmful cyanobacteria growth seen since the bioaugmentation stopped indicates that without this type of intervention, HABs will be difficult to control.
4) The lake increased in depth and volume in 2023. This indicates continued digestion – and effective removal – of organic sediment on the bottom. In the long run this will have the effect of reducing nutrients in the water column. However, in the absence of a bioaugmentation program which uses enzymes to accelerate this process, increases in depth and volume will be marginal.

Recommendations

The Town of Putnam Valley is not renewing its contract with Clean-Flo after 2023. In spite of this, we strongly recommend continued operation and maintenance of the RADOR system. Successful management of cyanobacteria is dependent upon the synergistic effects of both oxygenation and a biological treatment program that accelerates the digestion of nutrient-rich muck and provides essential nutrients to beneficial algae. If the NYSDEC relaxes its restrictions on bioaugmentation in the future, we recommend that a program similar to ours be implemented again.

The conditions in Lake Peekskill warrant strong intervention. Without it, the process by which HABs became entrenched in the first place will continue to worsen and reduce the usefulness to and enjoyment of the lake by the town's residents.

Finally, we recommend that the town evaluate its watershed to evaluate nutrient inputs. Sources could include stormwater that carries organic matter and fertilizer runoff and leaking or failing septic systems. Given the increasing nutrient levels seen over the years, it is probable that there are external sources.