2019 Sonar Scan and Water / Sediment Testing

Results for Lake Peekskill

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On October 8th 2019, the most recent sonar scan was conducted on the lake, while water samples and sediments were collected from sampling sites in the lake. Dissolved Oxygen and temperature readings were also taken at each of the sampling sites. The purpose of the scan and sampling was to provide this progress report of the system and treatment of the lake.

Water and Sediment Sampling

Water samples were taken on April 12th, July 1st, July 29th and October 8th, 2019. These samples were analyzed for dissolved oxygen, total phosphorus, ortho phosphorus and algal community. All samples were taken in 4 locations with the exception of algal community which was only taken in 3 locations per the contract. DO samples could not be taken on July 1st due to equipment malfunction. Sediment samples were also taken at the same 4 locations to analyze for total organic carbon, organic percentage, and phosphorus levels in the sediment.

Figure 1. Sampling locations on Lake Peekskill

The sample analysis results and other data are shown below.

Dissolved Oxygen

Dissolved oxygen (DO) readings were obtained with a YSI water quality meter. DO is a measure of the amount of oxygen that exists in the water column. Generally, DO levels should be greater than 5 mg/L to sustain a healthy warm-water fishery for better overall water quality. DO at the surface is generally higher due to the exchange of oxygen from the atmosphere with the lake surface, whereas DO is lower at the lake bottom due to decreased contact with the atmosphere and increase biochemical oxygen demand (BOD) from microbial activity.

Below, DO data from 2018 and 2019 are displayed in Tables 1 and 2 respectively. In May 2018, DO levels are higher than normal due to the colder water temperature from spring lake turnover. By June 20th, the date the solution was commissioned, the water was anaerobic below 13 feet. By August the stratification had been reversed and reoxygenation achieved throughout the water column.

Table 1- DO data from 2018. DO expressed in mg/L

Date	5/5/18				6/20/18				8/23/18				10/22/18			
Location	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Depth (ft)																
1	10.46	10.01	11.15	10.7	9.3	9.13	9.14	9.31	8.53	7.63	8.72	8.77	9.92	9.65	9.48	9.62
3	10.71	10.06	10.96	10.64	9.11	9.24	9.18	9.05	8.31	7.42	8.65	8.74	9.9	9.62	9.53	9.64
5	11.48	10.09	10.67	10.57	9.12	9.11	9	9.12	7.5	7.24	8.2	9.01	9.54	9.55	9.51	9.65
7	11.6	11.76	10.7	10.19	9.2	9.69	9.71	9.27	8.09	7.26	8.07	8.73	9.54	9.47	9.4	9.45
9	11.1	11.4	11.66	11.43	8.85	9.34	9.06	9.02	8.05	6.87	8.1	8.65	9.5	9.34	9.6	9.55
11		11.1	10.89	11.12		9.49	9.01	9		6.92	7.62	8.53		8.94	9.17	9.43
13		10.05				9.52	7.08			6.6	7.67			9.19		
15		9.55				3.91				6.62				9.14		
17		9.45				0.53				6.76				9.28		
19		8.81				0.08				6.68				9.28		
21		8.64				0.01				6.33				8.97		
23		3.1								5.41				8.9		

Throughout 2019 destratification and complete reoxygenation to maintain an aerobic water column was maintained. Overall, the data suggests thorough mixing and oxygenation.

Table 2 – DO Data from 2019. DO expressed in mg/L

Date	4/12/19				7/29/19				10/8/2019			
Location	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Depth (ft)												
1	11.8	11.79	11.7	11.61	7.5	7.93	7.6	8.05	8.57	8.27	8.9	8.57
3	11.25	11.57	11.51	11.48	7.7	7.37	7.41	8.06	8.52	8.05	8.45	8.34
5	11.16	11.42	11.45	11.4	7.64	7.18	7.2	7.9	8.32	8.07	8.19	8.22
7	10.9	11.33	11.33	11.48	7.45	7.02	7.15	7.45	8.04	7.82	8.05	8.09
9	11.05	11.4	11.3	11.44	7.47	6.82	7.04	6.78		8.07	8.4	8.2
11		11.33	11.23	11.08		6.44	6.78	5.8		8.21		
13		11.31				6.64				7.67		
15		11.31				6.51				8.23		
17		11.4				6.28				8.14		
19		11.42				5.42				8.22		
21		11.35				3.27						

Because the system fully oxygenates and mixes the water column, the lake is fully oxygenated above 5 mg/l. This allows aquatic life to access all areas of the lake and will result in a healthier and more robust aquatic community. DO is also needed for the decomposition of organic matter.

<u>Water Samples</u>

The algae water samples were taken at the surface and the phosphorus water samples were taken 1 foot from the bottom with a Van Dorn Beta water sampler. Water samples were analyzed by Eurofins Scientific. Typically, phosphorus will be higher at the bottom of the lake than at the surface where algae are able to use phosphorus for a food source. Unlike algae, cyanobacteria can descend to the bottom to access nutrients there. Hence the significance of analyzing phosphorus levels at the bottom.

Water samples are a snapshot in time and can be greatly affected by rain events and other weather-related activities. Water samples were analyzed for total phosphorus, ortho phosphorus and algal community by independent laboratories. Total phosphorus levels should generally be 0.02 mg/l or less to avoid nuisance algae growth. As can be observed in table 3 below, total P was higher than 0.02 mg/l for 3 of the 4 samples. Orthophosphate is the form that is bioavailable. There has been a significant downward trend in phosphorus levels in 2019 compared to 2018, and even more so in orthophosphate levels, which is shown in Figure 2.

Table 3 – Average phosphorus levels for 2019 in Lake Peekskill. ND stands for None Detected

Sampling Date	**4/12/19**	**7/1/19**	**7/29/19**	**10/8/19**
Total P mg/l	0.0195	0.02775	0.03175	0.02625
Ortho P mg/l	0.001667	0.0045	0.001	ND

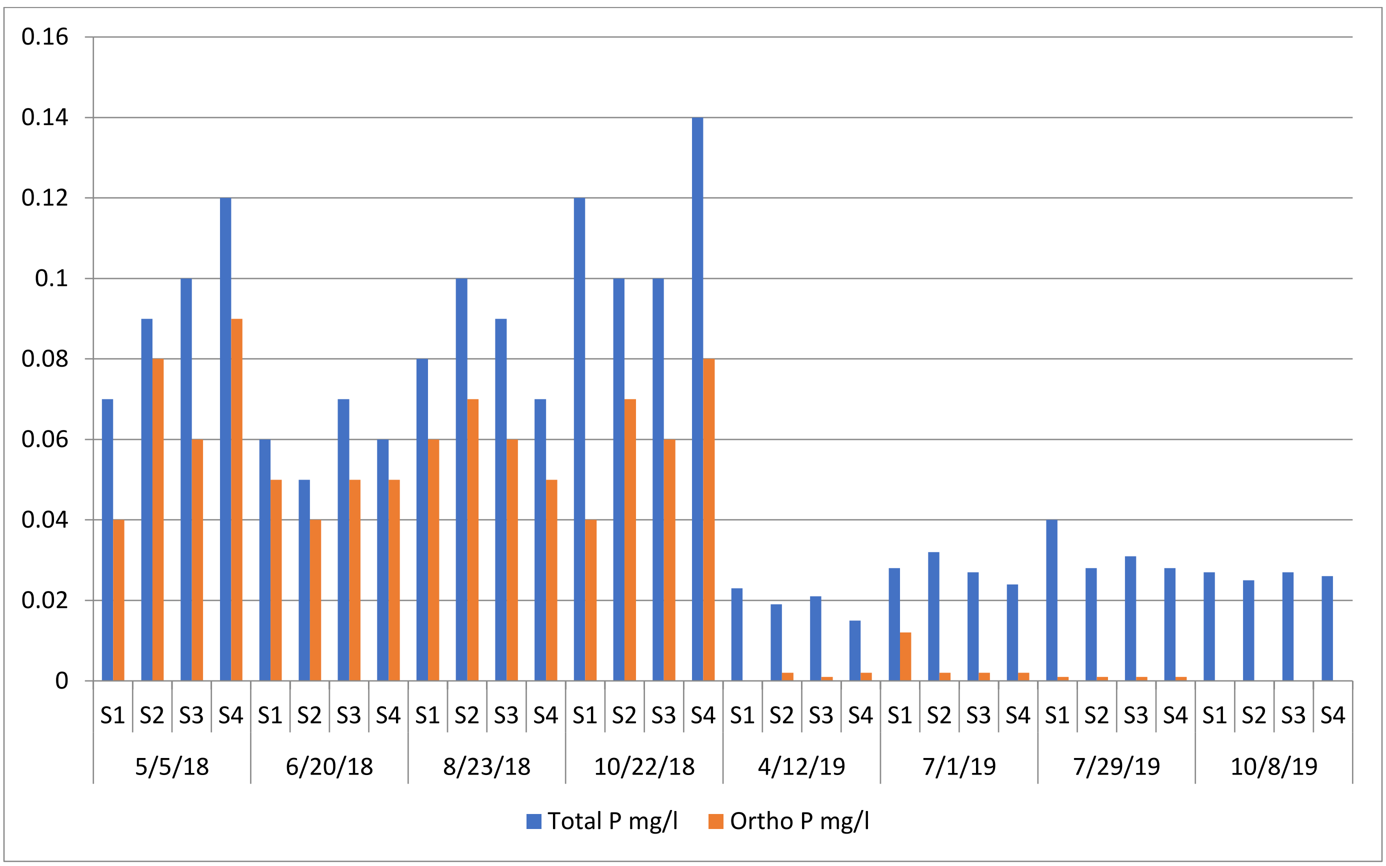


Figure 2. Historical water sample data for Peekskill Lake. S1-S4 are the sample sites. The orange columns are ortho-phosphorus levels while the blue columns are the total phosphorus levels.

The algal samples were analyzed for several different species of algae that vary in significance. Table 3 gives a guide of the different groups of algae screened for and what they indicate about the water environment.

Table 3. Guide for algal 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.
HAB	Harmful Cyanobacteria	May produce toxins, tastes, or odors. 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.

Below is a compilation of the algae data from water samples taken in 2018. This data expresses the algae cell count per volume of water (cells per milliliter) which is a measure of concentration. In May, no HABs were detected. In June HABs were present and the lake had already been shut to the public. Algae populations experienced a boom after that, growing roughly by a factor of 10 (compare Total Cells from 6/20 to 8/23). In August and October, high HABs levels were also measured.

Table 4. Algal community data from 2018.

Algal Biovolume	5/5/18			6/20/2018			8/23/2018			10/22/2018		
cells/ml	S1	S2	S3	S1	S2	S4	S1	S3	S4	S1	S2	S4
BG				10	37	29	5,712	5,047	5,978	1,361	1,256	943
CP	163	90	76	40	54	65	54	40	23	162	37	98
DY	11	10	14	161	66	105	1,103	776	808	383	466	378
E				11	7	4	4	7,845	13	1	1	1
G	648	586	637	1,588	1,458	1,283	7,434	2,443	7,015	2,152	2,620	2,199
HAB				51	31	10	2,593	90	1,362	314	1,116	329
M				81	69	50	115	1,196	196	72	73	49
U	564	423	491	289	297	272	1,550	10,417	1,517	399	403	279
Total Cells	1,385	1,109	1,218	2,232	2,019	1,818	18,566	27,855	16,911	4,845	5,972	4,276
% HAB	0.00%	0.00%	0.00%	2.30%	1.54%	0.57%	13.97%	0.32%	8.05%	6.48%	18.68%	7.69%

The compilation of algae data from 2019 can be found in Table 5 below. Based on the data, the percentage of HABs present in the water has not exceeded 5.52% and has mostly been near or at 0% across all the samples taken. This is a significant change from previous samples taken in 2018 that registered HABs being up to 18.68% of the algae population. Compared to 2018, total algae population levels from 2019 are lower across the board as well.

Table 5. Algal community data from 2019.

Algal Biovolume	4/12/19			7/1/2019			7/29/2019			10/8/19		
cells/ml	S1	S2	S3	S1	S3	S4	S1	S2	S3	S2	S3	S4
BG	5	25	-	30	29	22	752	736	715	214.45	82.09	130.29
CP	50	30	25	305	168	192	5	78	63	7.26	1.23	6.20
DY	211	314	356	245	573	841	514	653	553	98.81	117.89	157.31
E	2	3	1	11	9	-	9	21	41	5.28	1.23	1.86
G	247	241	294	10,213	12,537	11,789	4,971	5,462	5,105	1,066.96	932.39	1,271.86
HAB			44			11	270	166	292	7.96	0.00	0
M	1	4	3	305	301	239	370	738	513	27.05	30.24	21.71
U	67	172	73	1,656	1,613	1,361	665	1,120	978	387.33	342.56	212.18
Total Cells	582	789	796	12,766	15,230	14,454	7,556	8,974	8,261	1,815	1,508	1,801
% HAB	0.00%	0.00%	5.52%	0.00%	0.00%	0.08%	3.58%	1.85%	3.54%	0.44%	0.00%	0.00%

Below is a graph of all the algal population data organized by sample site and date sampled. Across the board, HABs were almost invisible and green algae species that indicate good water quality were the largest part of the overall algae population. Based on this data, the HABs have been reduced to almost 0% while the overall algae levels (Total Cells) have also decreased significantly from 2018 to 2019. The drop in population of other algae species has resulted in green algae, which are indicative of good water quality, filling the population void left by the other algae.

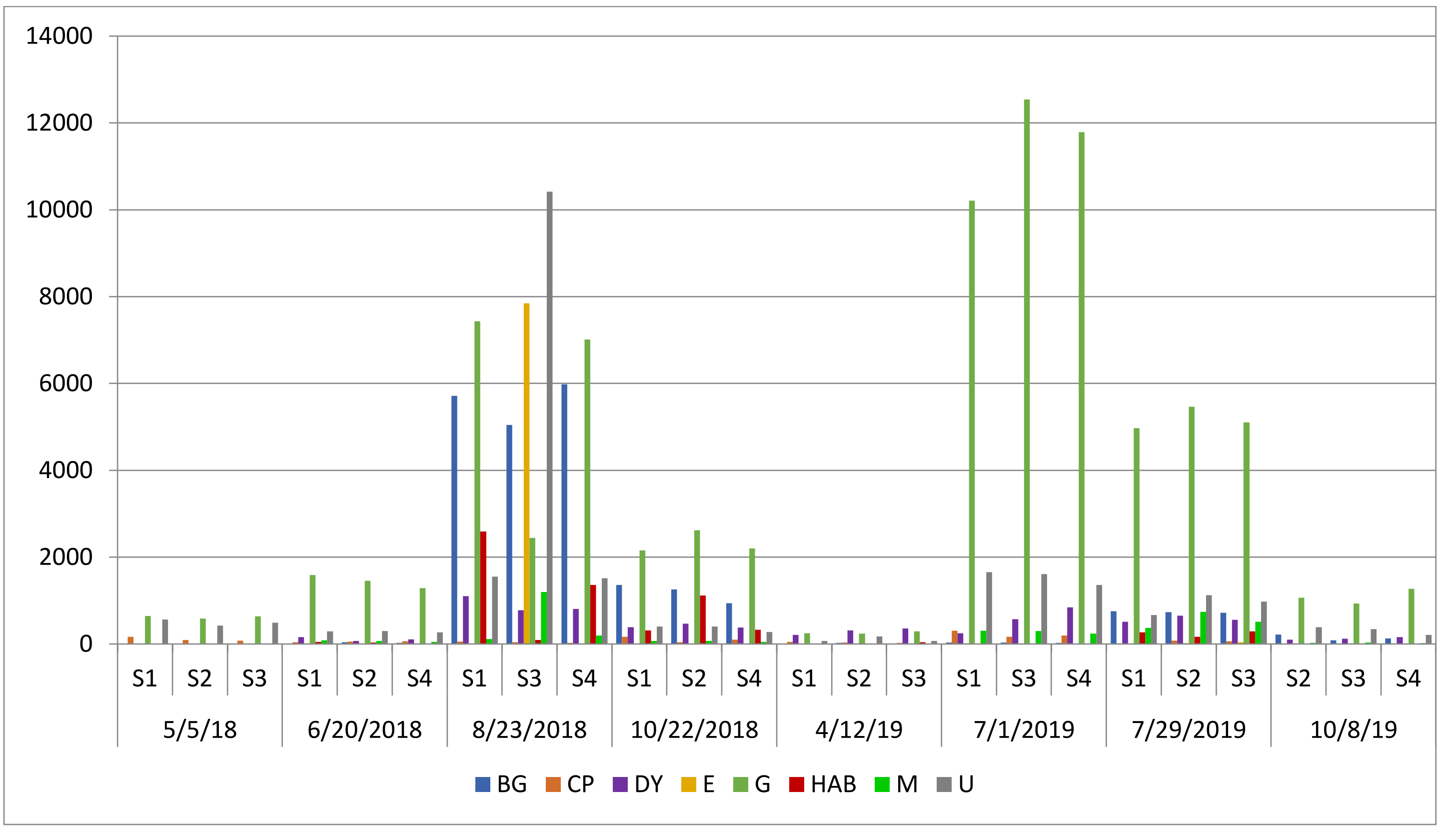


Figure 3. Total Algae biovolume data from 2018 to 2019. Vertical axis is in cells per milliliter.

For a more simple analysis, a graph displaying only the HABs and the Chlorophyte (green) algae levels (figure 4) can be found below. HABs levels have consistently dropped from 2018 to 2019 and green algae levels have increased.

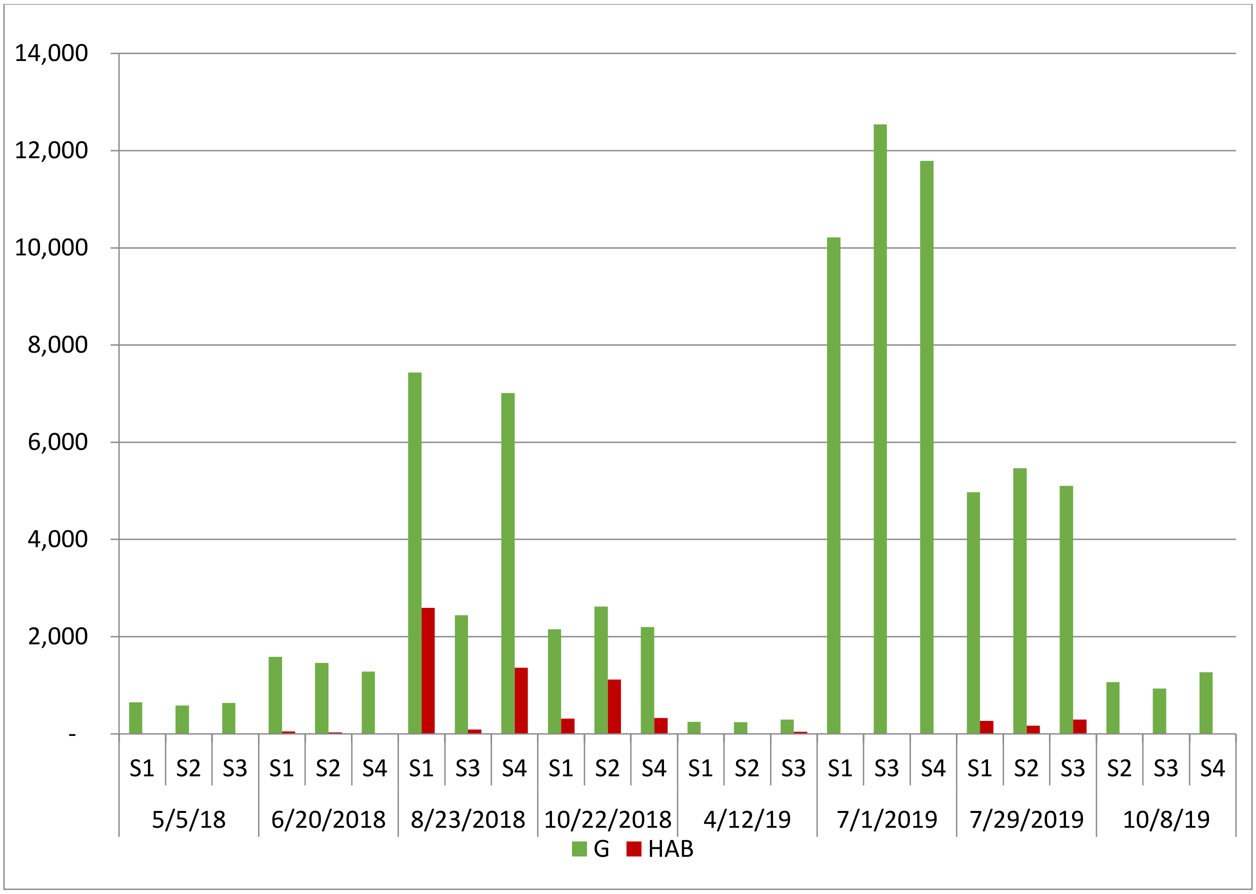


Figure 4. Harmful cyanobacteria and chlorophyte (green algae) level comparison.

<u>Sediment Samples</u>

The sediment samples were taken with an Ekman Dredge in all 4 sample locations and sent to Eurofins Scientific for analysis.

Based on the analysis of the sediment samples displayed in Table 6, the phosphorus (P) in the sediment has a consistent downward trend and has ultimately dropped below 1000 mg/kg. This means that phosphorus is being used up more by the ecosystem than previously. This is an indication of increased nutrient uptake and metabolism by organisms in the lake. Overall, the data demonstrates that the ecosystem is processing the nutrients more quickly, and consistently reducing muck. Figure 5 gives a big-picture view of phosphorus levels in the lake sediments since 2018. There is a consistent downward trend in the concentration of phosphorus across the 2 years the Clean-Flo / SIS.bio system has been in operation.

Table 6. Analysis averages across sites from 2019.

Sampling Date	**4/12/19**	**7/1/19**	**7/29/19**	**10/8/19**
TOC mg/kg	180000	119750	152725	182000
P mg/kg	1198.75	1061.5	242	490.25

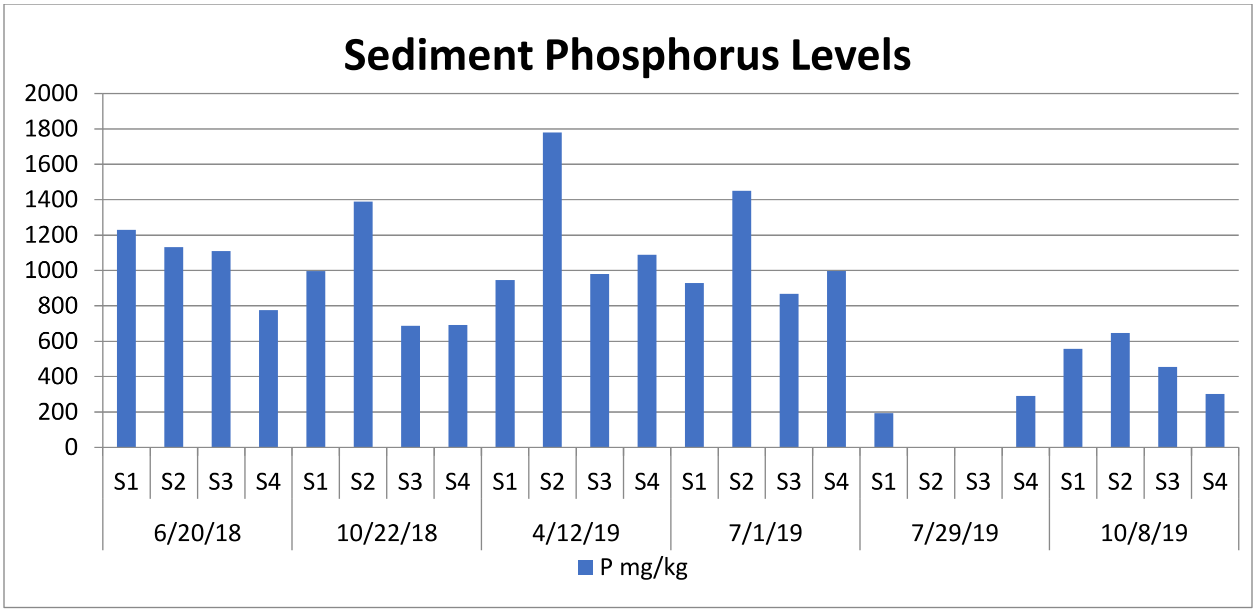


Figure 5. Historical comparison of phosphorus levels in Peekskill Lake sediments. (S2 and S3 are blank for 7/29/19 because samples were ND)

The TOC data indicates that there is plenty of potential for further sediment digestion in the future.

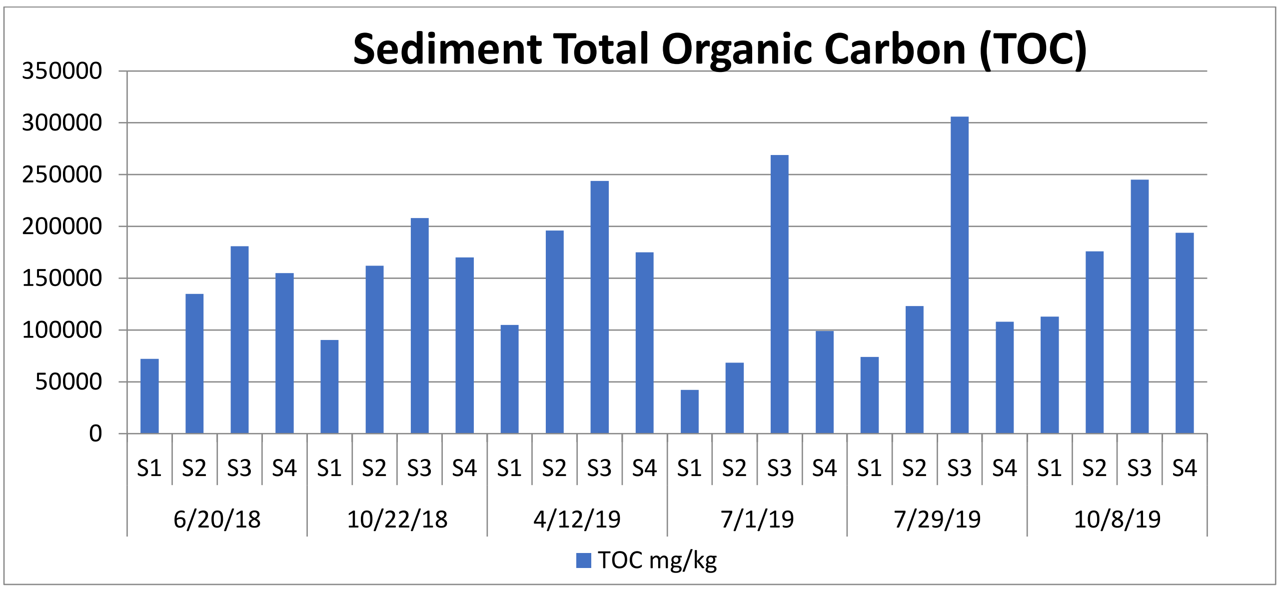


Figure 6. Sediment Total Organic Carbon (TOC) levels from 2018 through 2019.

Sonar Scan and Mapping

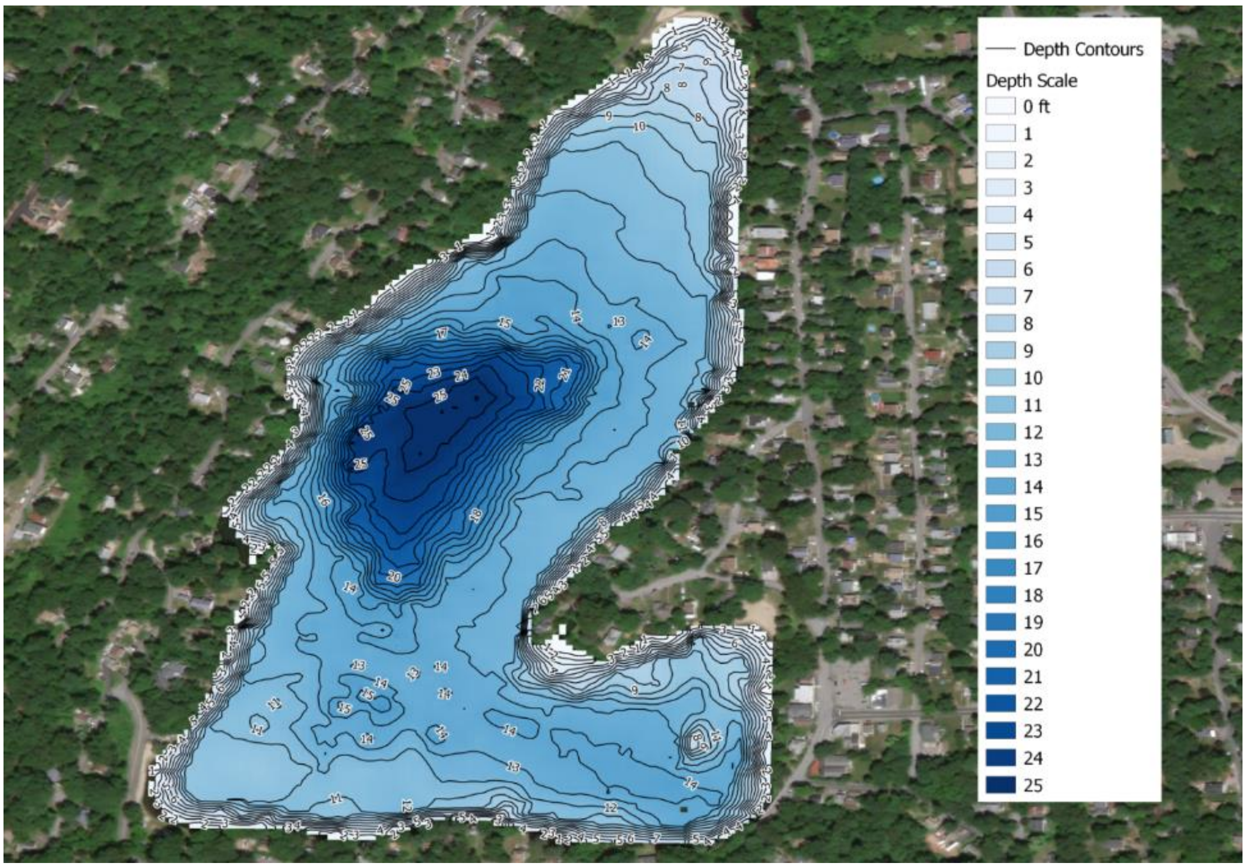
A complete sonar scan of the lake was completed on October 8th, 2019 and will be compared with the sonar scan taken in early 2018. The scans were conducted with our Lowrance HDS7 fish finder/chartplotter with broadband sounder technology, built-in GPS antenna and high-definition mapping. The data obtained was uploaded to Biobase GIS, a cloud-based mapping service, to produce contour, bottom composition and vegetative biovolume maps.

These scans are an excellent way to help understand water body characteristics, compare changes over time and measure the progress of any restoration or improvement project. The information is generated based on thousands of data points, so it allows you to objectively determine how the lake changes over time under the surface where it matters most, without the potential for human error from manual measurements.

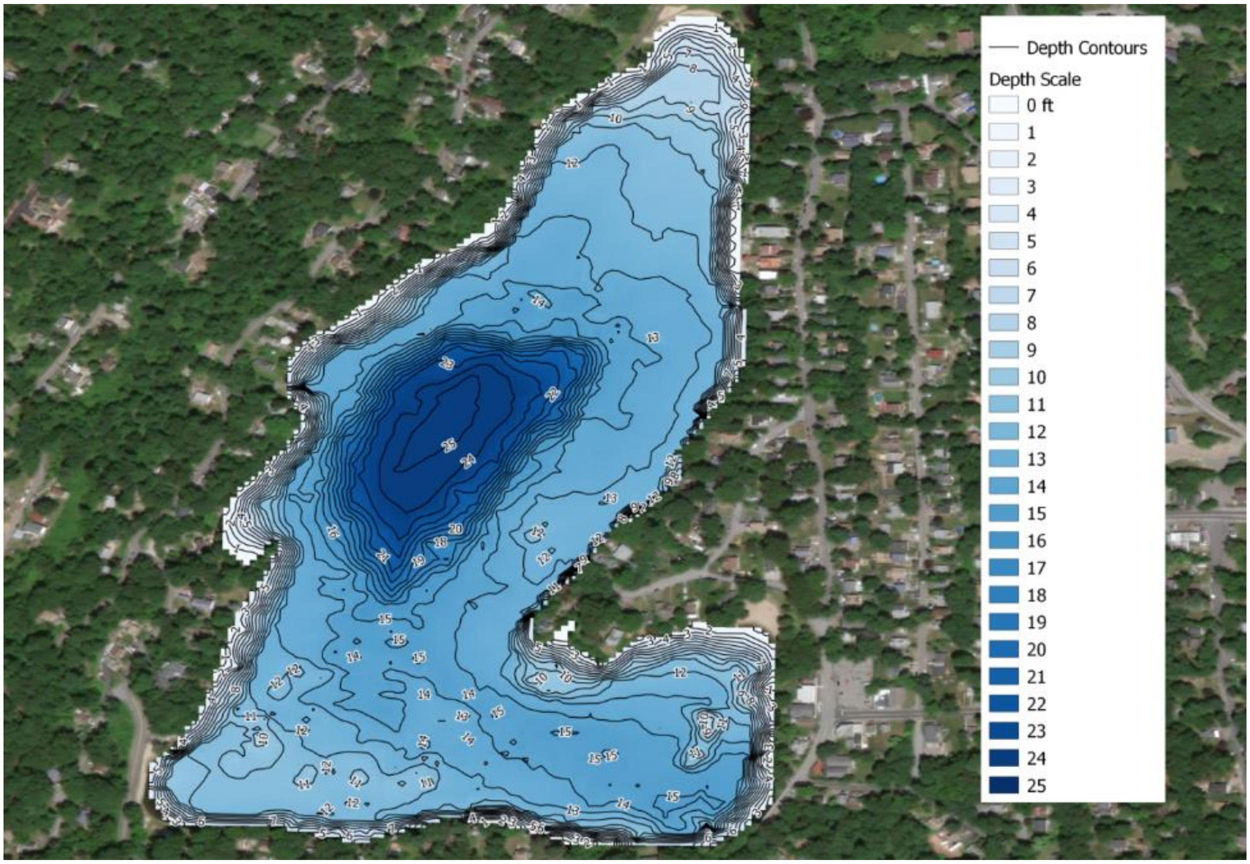
The sonar signal can get distorted in water less than 2.5 feet deep and the accuracy of the composition and vegetation/biovolume maps can be diminished in those areas.

<u>Contour Maps</u>

The contour maps for the lake along with a color-coded scale are shown below. The 2018 map shows the lake depth increasing in virtually all areas of the lake, meaning the soft organic sediments are being biodegraded. This organic sediment is likely years of dead and decaying weed and algal growth that contains a lot of nutrients to fuel future growth. By reducing the organic sediments, nutrients are also being reduced and converted into food for aquatic insects and fish.



Contour Map (4/24/18) – The deepest reading obtained in the lake was 26.3 feet. We recorded only a handful of readings over 26 feet. This indicates that the area over 26 feet was very small.



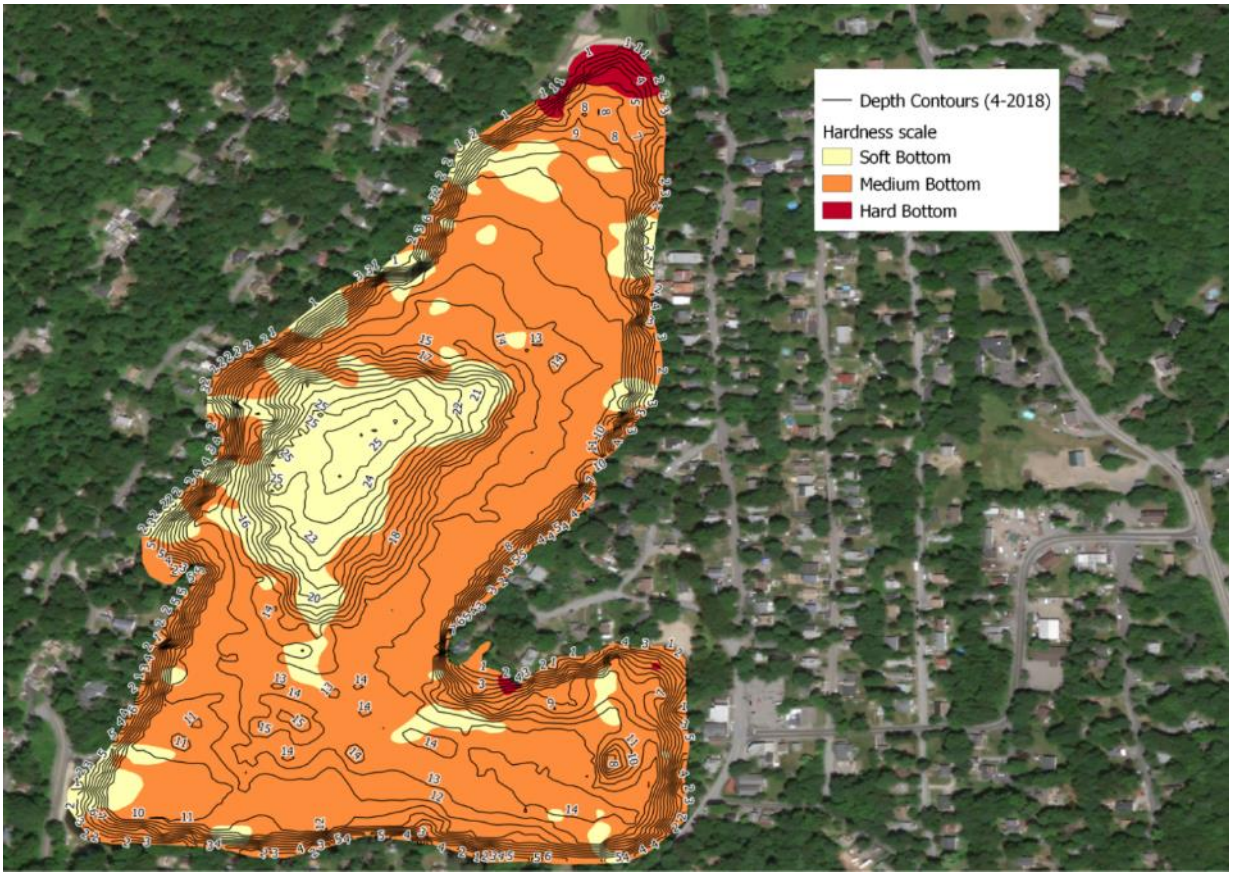
Contour Map (10/8/19) – Comparing this contour to April 2018, you will see the deep contours have all increased in size. This indicates the lake is getting deeper due to organic sediment reduction.

The contour that has seen the most notable growth is the 14 foot contour. The figure below (figure 7) shows the comparison of the 14-foot contour from April 2018 and from the most recent scan. The light blue line represents the contour in 2018 while the yellow line represents the contour from 2019. The contour grew from encompassing a 14-acre area to an 18-acre area.

Figure 7. Comparison of 14-foot contour from 2018 and 2019. The light blue contour is from 2018 and the yellow contour is from 2019.

Bottom Composition

The bottom composition maps for the lake, along with a color-coded scale, are shown in the maps below. The scale goes from light tan (softest) to red (hard bottom). The softest areas contain large amounts of loose organic sediment. In areas where there is less organic sediment, the color changes to orange and ultimately red if there is no soft organic sediment.



Bottom Composition Map 4/24/18 –As you can see on the map above, lighter colors are associated with greater soft sediments and the darker orange and red colors are associated with less soft sediments.

The pie chart below shows the amount of soft, medium and hard bottom sediments in April 2018. This chart indicates 22% soft bottom, 76% medium bottom and 2% hard bottom.

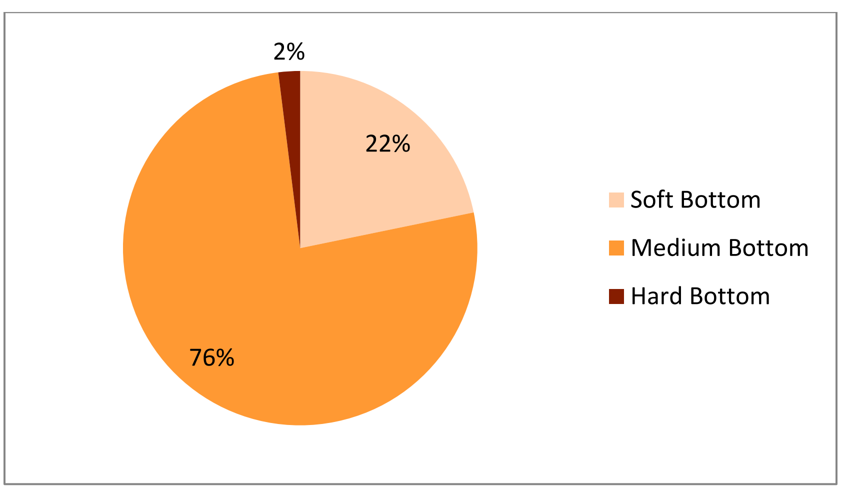
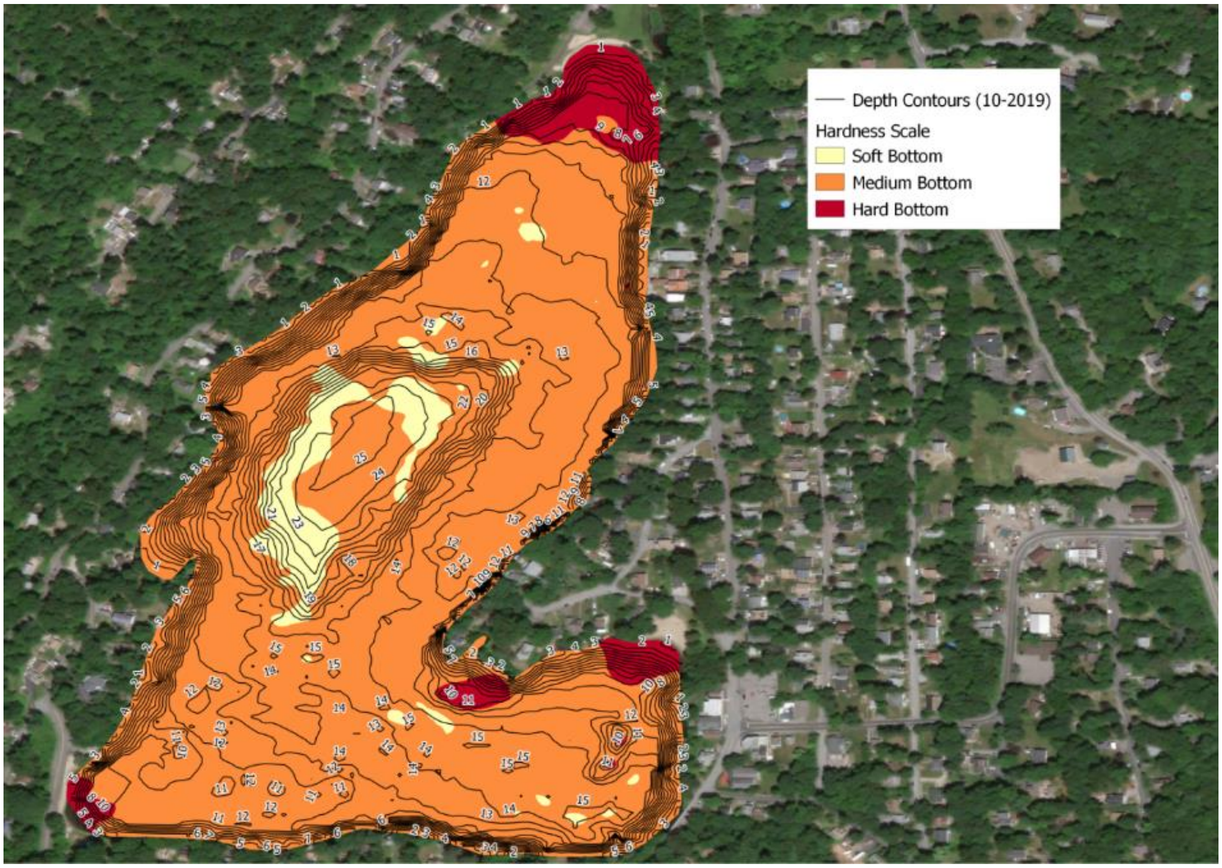


Figure 8. Bottom composition percentages based on 2018 scan



Bottom Composition Map 10/8/19 – Comparing the 2019 map to the 2018 map, there is an obvious change in bottom composition from soft to harder sediments around the entire lake.

The pie chart below shows the amount of soft, medium and hard bottom sediments in October 2019. This chart indicates 6% soft bottom, 87% medium bottom and 7% hard bottom. The key parameter is the increase in red, or hard bottom since this means that organic sediments have been completely digested. The red hard bottom has increased from 2% to 7%. A comparison to the scan in April 2018 shows a 16% reduction in soft sediments. The medium bottom areas have increased due to the soft sediments reducing to medium hardness because of the system & treatments. The ratio of soft to medium is not critical as long as hard bottom gradually increases.

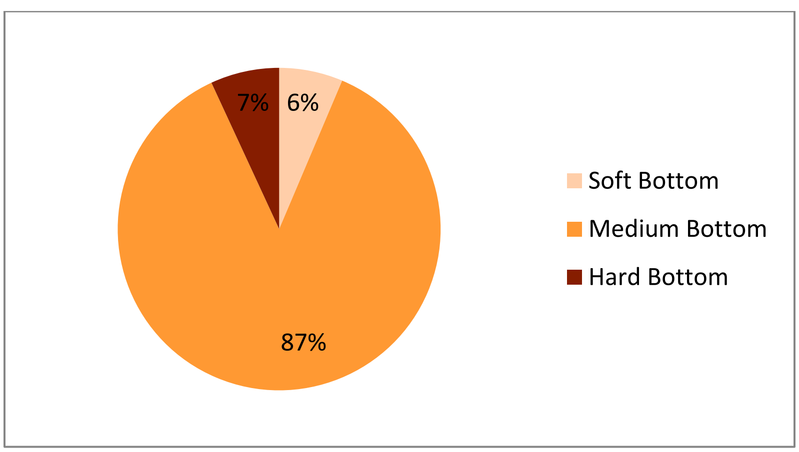
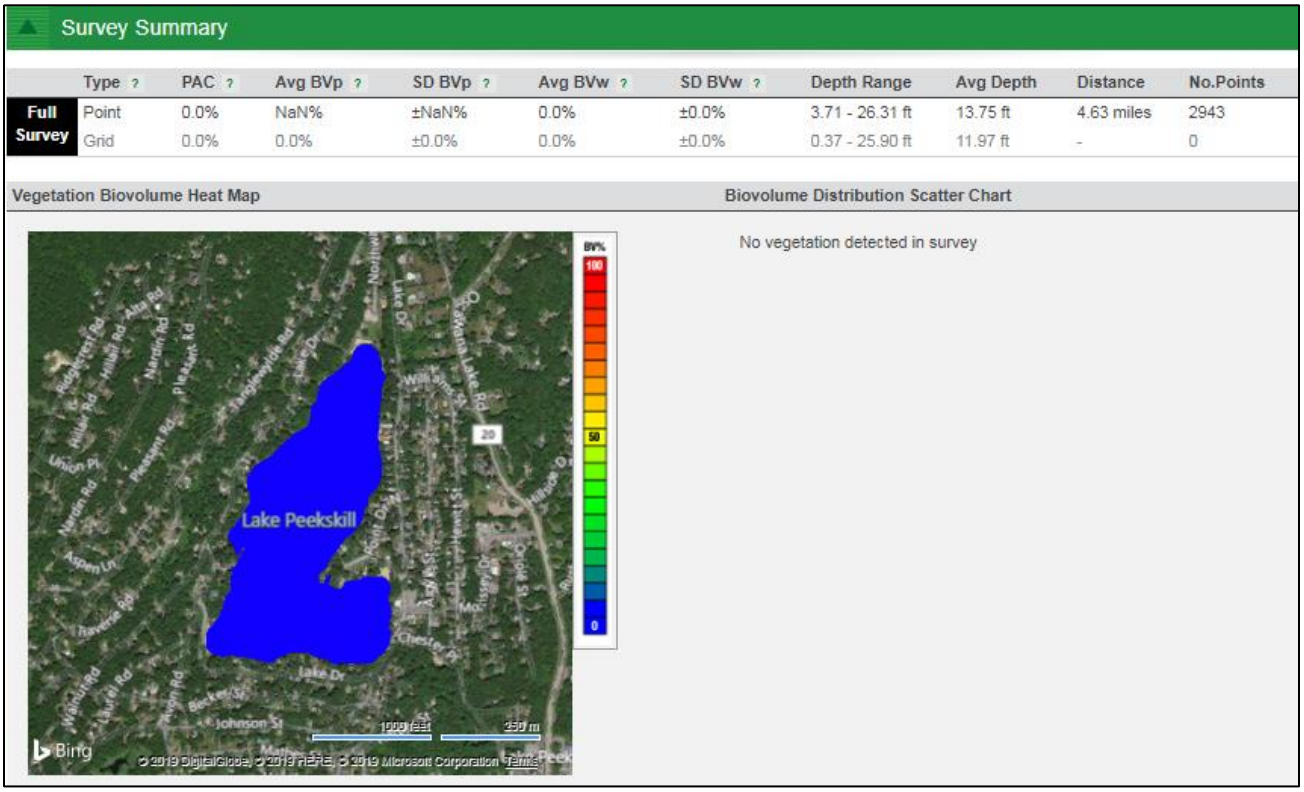


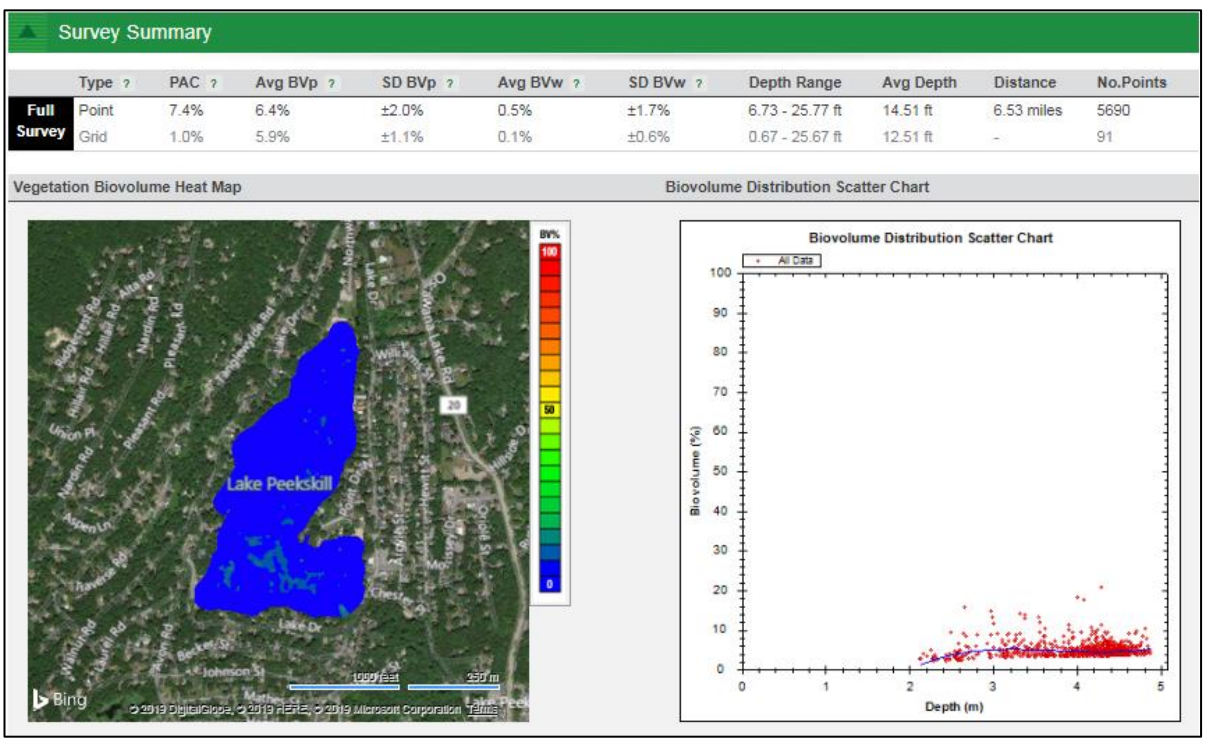
Figure 9. Bottom composition percentages based on 2019 scan

<u>Biovolume Maps</u>



	Type	PAC	Avg BVp	SD BVp	Avg BVw	SD BVw	Depth Range	Avg Depth	Distance	No.Points
Full Survey	Point	0.0%	NaN%	±NaN%	0.0%	±0.0%	3.71 - 26.31 ft	13.75 ft	4.63 miles	2943
	Grid	0.0%	0.0%	±0.0%	0.0%	±0.0%	0.37 - 25.90 ft	11.97 ft	-	0

Vegetation Biovolume 4/24/18 – The vegetation biovolume details above shows areas of vegetation and density of the vegetation. The measurement scale shows that red is the highest density of biovolume followed by yellow, green and then blue. At the time of the scan in April 2018 there was no vegetation detected in the lake.



	Type	PAC	Avg BVp	SD BVp	Avg BVw	SD BVw	Depth Range	Avg Depth	Distance	No.Points
Full Survey	Point	7.4%	6.4%	±2.0%	0.5%	±1.7%	6.73 - 25.77 ft	14.51 ft	6.53 miles	5690
	Grid	1.0%	5.9%	±1.1%	0.1%	±0.6%	0.67 - 25.67 ft	12.51 ft	-	91

Vegetation Biovolume 10/8/19 – The vegetation biovolume details are shown above. At the time of the scan, some vegetation was detected.

Comparing these reports shows that minimal vegetation has grown over the time the system has been in operation. Some natural vegetation is beneficial for aquatic life and provides habitat for fish. Natural vegetation will also utilize nutrients that would otherwise be utilized by algae. The progression of aquatic plant growth will be monitored with future scans.

<u>General Scan Data</u>

Lake Peekskill, Putnam New York — Generated: 10/16/2019 8:01:06 PM (UTC)

Waterbody Size: 60.11 acres — report link

Data Collector
Brian Kling

Data Collection Date
4/24/2018 3:05:21 PM (UTC)

Average Water Temperature
54.97° F

Location
Start: 41.34400837, -73.88078856
End: 41.34317604, -73.88088770

Survey Size
Area: 60.00 acres
Percent: 99.82% of waterbody
Volume: 718.34 acre ft

Est.Waterbody Volume ?
887667.53 cu. m
(719.64 acre ft)

Settings
Track Buffer: 40 m
Grid Cell Size: 8.0 m
Min.BV Detect: 5%
Min.Veg Depth Detect: 0.73 m

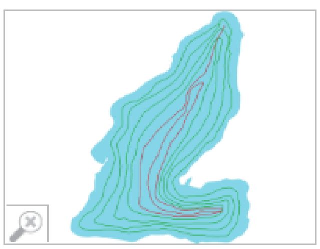
Quality Control
Reviewer: Ian McCormack
Comments: We have reviewed this trip. Please use the "ASK THE EXPERTS" button for this trip if you have any questions.

Offset Information
See Below

Scan Details 4/24/18 – Additional details of the April 2018 scan are shown above. The water body was 718.34 acre-feet in volume with an average depth of 11.95 feet.

Lake Peekskill, Putnam New York — Generated: 10/15/2019 7:37:02 PM (UTC)

Waterbody Size: 60.11 acres — report link



Data Collector
Brian Kling

Data Collection Date
10/8/2019 5:15:34 PM (UTC)

Average Water Temperature
65.43° F

Location
Start: 41.34375799, -73.88064434
End: 41.34316927, -73.88088770

Survey Size
Area: 60.11 acres
Percent: 100.00% of waterbody
Volume: 751.91 acre ft

Est.Waterbody Volume ?
927462.05 cu. m
(751.91 acre ft)

Settings
Track Buffer: 100 m
Grid Cell Size: 7.0 m
Min.BV Detect: 5%
Min.Veg Depth Detect: 0.73 m

Offset Information
See Below

Scan Details 10/8/19 – The scan details above show the volume of water in October 2019 is 751.91 acre-feet with an average depth of 12.5 feet.

Based on the scans, the lake has gained 33.57 acre-feet due to digestion and elimination or organic sediments. This amount is equal to 54,159.6 cubic yards.

NB: It should be noted that the water level of the lake was 42 inches below the spillway in 2019 but at the level of the spillway in 2018. This difference is an input into software algorithm so that the water volume calculations are all computed back to the same equivalent water level in order to ensure that they are comparable.

Conclusion

Lake Peekskill has shown improvement during the time that the Clean-Flo / SIS.bio biotechnology solution program has been in operation. Thorough destratification and reoxygenation has been consistently observed based on the DO readings in Table 1.

The sonar scans have shown a marked increase in hard sediments (see bottom composition maps) as a result of high oxygen levels at the bottom and bio-augmentation throughout the entire lake. This reduction amounts to 33.57 acre-feet, which is equivalent to 54,159.6 cubic yards (41,440 cubic meters) of sediment. To put this in perspective, a tri-axel dump truck typically holds about 20 cubic yards of topsoil. That equates to over 2,707 dump trucks full of muck being "removed" from the lake over the two years the system has been operating.

Based on the sediment sampling, there was over 1,000 mg/kg of phosphorus in the sediment when the system was started. If we assume the sediment density to be 1,000 kg/cubic meter, we end with the following equation:

41,440 m^3 sediment reduced x 1,000 kg/m^3 x 1,000 mg/kg = 41,440,000,000 mg P

This would indicate that over 41.4 metric tons of phosphorus have been eliminated from the lake over 2018 and 2019.

(*NB. This is an estimate based on the assumptions stated above. It should be noted that sediment is denser than water and therefore estimating sediment density to be 1,000kg/cubic meter is a conservative estimate. Conversely, the effect of the remediation program has been to reduce phosphorus levels in the remaining sediment, so still assuming phosphorus concentrations to be 1,000mg/kg is no longer conservative.*)

This converts to 91,277.53 lbs. or 45.6 US tons of Phosphorus that has been removed from the in-lake sediment stockpile.

Effective nutrient management has resulted in

- the digestion and elimination of 54,159.6 cubic yards of sediment
- the consequent elimination of an estimated 45 tons of phosphorus contained in that sediment
- the virtual elimination of toxin producing HAB species

The net effect of these improvements is the fact that despite the lake only being open to the public for 3 days in 2018 due to toxic CyanoHABs, not a single confirmed toxic CyanoHAB event occurred in 2019.

Since the elimination of toxic CyanoHAB events and closure of the lake to the public because of the associated health risks was the ultimate objective of the biotechnology solution program, it has been a success.

Additional sampling and bathymetric analysis will be conducted during 2020 to continue monitoring the progress of the lake. The system has to be shut down during the winter season for safety issues and that will reduce benefits during a few months, but once turned on again in early spring, the improvements to the lake should begin anew.