2018 Sonar Scan and Water / Sediment Testing Results for Lake Peekskill

Prepared for:
Town of Putnam Valley
265 Oscawana Lake Road
Putnam Valley, NY 10579

Prepared by:
Clean-Flo International LLC
827 Lincoln Avenue
West Chester, PA 19380

Background

Lake Peekskill has been plagued by nuisance toxic blue green algae blooms over the last few years which has restricted the use of the 3 lake beach areas during the summer season.

To solve this problem, the Town of Putnam Valley entered into a contract with Clean-Flo International to implement its proprietary Inversion Oxygenation and Destratification technology along with a bioaugmentation program. The goal of the program is to oxygenate the entire water column while reducing nutrients and organic sediments. Reduced nutrient availability will result in reduced toxic blue green algae blooms in the lake.

Nutrient reduction is achieved in the first few years of operation primarily by the digestion of organic sediments, and this is the key parameter to monitor during the first year.

Implementation

In April 2018 a complete sonar scan was conducted on the lake. The scan was accomplished with a 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 or bathymetry, bottom composition and vegetative biovolume maps.

The data and maps were then used to design the Inversion Oxygenation and Destratification system for the lake. The system design includes a compressor, self-sinking airline and 18 micro-porous ceramic diffusers. The locations of the diffusers were established strategically based on the Biobase contour map by GPS coordinates.

Installation of the system was completed on May 5, 2018. However due to a problem with the installation of permanent power, the system wasn't started until June 20, 2018. This was unfortunate as 6+ weeks additional operation early in the year would have made a considerable difference.

Bioaugmentation

Microbes and enzymes are utilized to help reduce available nutrients and reduce organic sediments. The first application of microbes and enzymes was completed on July 10th. A second application was made on August 23rd.

Water and Sediment Sampling

Water samples were taken 4 times during 2018. These samples were taken on May 5th during system installation, June 20th during system start-up, August 23rd after the system was running about 2 months and October 22nd which was about 4 months after start-up. 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. Sediment samples were taken twice, at system start-up and on October 22nd.

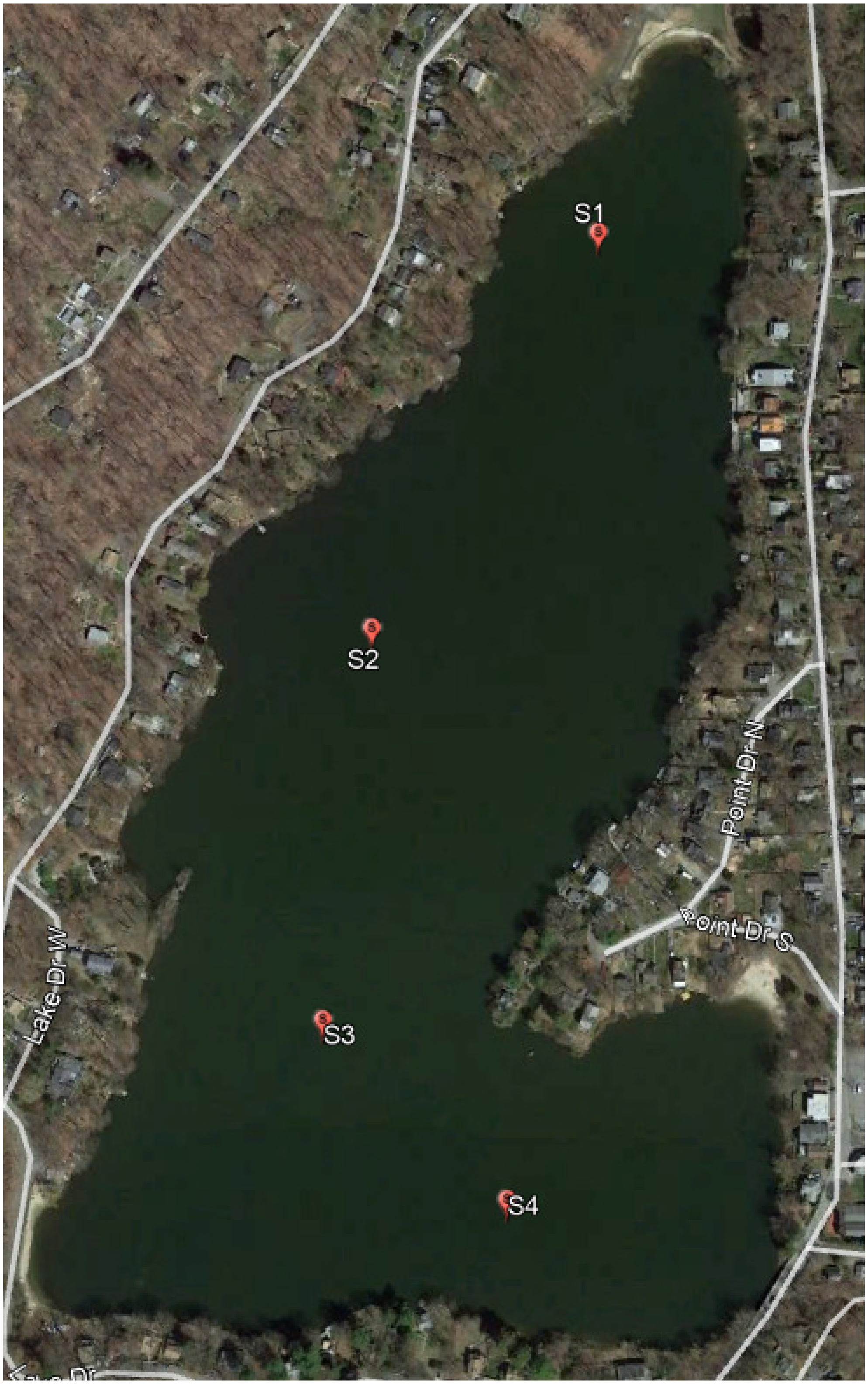


Figure 1 – Sampling locations on Lake Peekskill

The sample results 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 or higher for better overall water quality. DO is generally higher in colder waters. 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.

Date	5/5/18	5/5/18	5/5/18	5/5/18	6/20/18	6/20/18	6/20/18	6/20/18	8/23/18	8/23/18	8/23/18	8/23/18	10/22/18	10/22/18	10/22/18	10/22/18
Location	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Depth																
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		

Table 1 – DO readings in mg/l

Looking at sample S2 on June 20th before the system is started, you can see how the lake runs out of oxygen at the bottom and doesn't have enough DO to support fish below 15 feet. Because the Clean-Flo system fully oxygenates the water column, 2 months after starting the system, 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.

If the power was available to start the system on May 5th, this destratification event would not have occurred and the phosphorus release associated with it also would not have occurred.

Water Samples

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. Typically, phosphorus will be higher at the bottom of the lake than at the surface where algae will use phosphorus for a food source.

Water samples are a snapshot in time and can be greatly affected by rain events and other weather-related activities. Water samples were taken for total phosphorus, ortho phosphorus and algal community and were sent to laboratories for analysis. Total phosphorus levels should generally be 0.02 mg/l or less to avoid nuisance algae growth. As can be observed in the tables below, total P was higher than 0.02 mg/l during all 4 sampling periods. This led to harmful algae blooms that were evident in the August and October samples.

Date	5/5/18	5/5/18	5/5/18	5/5/18	6/20/18	6/20/18	6/20/18	6/20/18
Location	S1	S2	S3	S4	S1	S2	S3	S4
Total P mg/l	0.07	0.09	0.1	0.12	0.06	<0.06	0.07	0.06
Ortho P mg/l	0.04	0.08	0.06	0.09	<0.06	<0.06	<0.06	<0.06
Algal Biovolume								
um^3/ml								
BG	-	-	-		1,890	7,283		6,106
CER	-	-	-		-	-		-
CP	228,743	149,588	140,858		49,584	60,795		66,528
DY	9,474	5,995	8,622		218,345	98,078		123,423
E	-	-	-		28,072	27,262		9,050
G	509,172	447,991	508,687		605,572	844,203		593,200
HAB	-	-	-		4,081	2,185		4,073
M	-	-	-		6,427	5,699		4,698
U	586,904	440,220	538,961		256,457	227,590		213,769
Total Cells	1,334,293	1,043,794	1,197,128	-	1,170,428	1,273,095	-	1,020,847
% HAB	0.00%	0.00%	0.00%	#DIV/0!	0.35%	0.17%	#DIV/0!	0.40%

Table 2 – Water samples analyzed in a laboratory. For algal biovolume guide see below.

Date	8/23/18	8/23/18	8/23/18	8/23/18	10/22/18	10/22/18	10/22/18	10/22/18
Location	S1	S2	S3	S4	S1	S2	S3	S4
Total P mg/l	0.08	0.1	0.09	0.07	0.12	0.1	0.1	0.14
Ortho P mg/l	<0.06	0.07	0.06	<0.06	<0.06	0.07	0.06	0.08
Algal Biovolume								
um^3/ml								
BG	999,078		998,251	1,125,093	380,839	286,439		450,512
CER	-		-	-	-	-		-
CP	38,223		51,444	18,925	114,263	31,215		61,232
DY	683,987		481,150	442,001	166,129	234,636		167,769
E	12,511		-	107,114	6,424	2,652		4,540
G	5,910,793		5,102,084	5,791,879	1,971,839	2,456,519		1,895,108
HAB	2,511,464		1,996,044	1,010,865	20,936	2,529,764		28,856
M	14,641		10,417	25,654	10,167	9,500		8,068
U	4,692,134		3,689,574	3,716,282	824,847	1,344,672		759,447
Total Cells	14,862,831	-	12,328,964	12,237,813	3,495,444	6,895,397	-	3,375,532
% HAB	16.90%	#DIV/0!	16.19%	8.26%	0.60%	36.69%	#DIV/0!	0.85%

Table 3 – Water samples analyzed in a laboratory. For algal biovolume guide see below.

	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.

Table 4 – Guide for algal biovolume analysis.

Sediment Samples

The sediment samples were taken with an Ekman Dredge in all 4 sample locations. These samples were taken right before the system was turned on in June, and again in October.

Date	6/20/18	6/20/18	6/20/18	6/20/18		10/22/18	10/22/18	10/22/18	10/22/18
Location	S1	S2	S3	S4		S1	S2	S3	S4
TOC mg/kg	72200	135000	181000	155000		90300	162000	208000	170000
P mg/kg	1230	1130	1110	775		995	1390	689	692

The total organic carbon (TOC) increased in all 4 samples in October. This will have to be further evaluated in 2019.

The phosphorus (P) in the sediment reduced on average during the first four months from 1,061.25 mg/kg to 942.50 mg/kg. That is over 11% reduction of P in the sediments. Although it is a small sample size and early in the process, the results show a significant reduction of phosphorus in the lake. Additional sampling will be conducted in 2019 and 2020 so further comparisons can be made.

Sonar Scan and Mapping

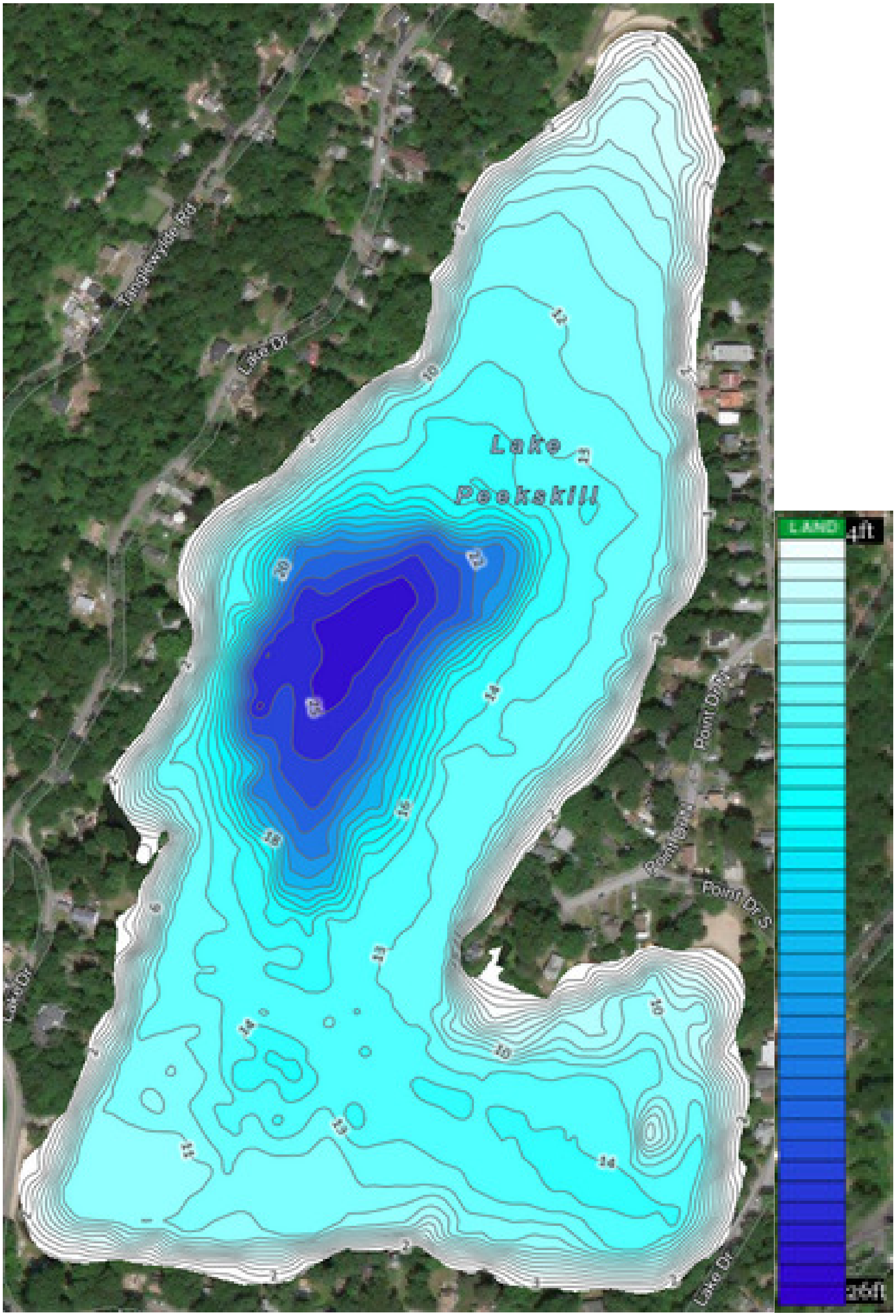
A complete sonar scan of the lake was completed on April 24, 2018 and again on October 22, 2018. The scans were accomplished with our Lowrance HDS7 fish finder/chartplotter with broadband sounder technology, built-in GPS antenna and high-definition mapping. The data obtained was uploaded to Biobase GIS, a cloud-based mapping service, to produce contour, bottom composition and vegetative biovolume maps.

The April scan was utilized for the design location for the Clean-Flo diffusers and will be the baseline condition of the lake for all future scans. 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.

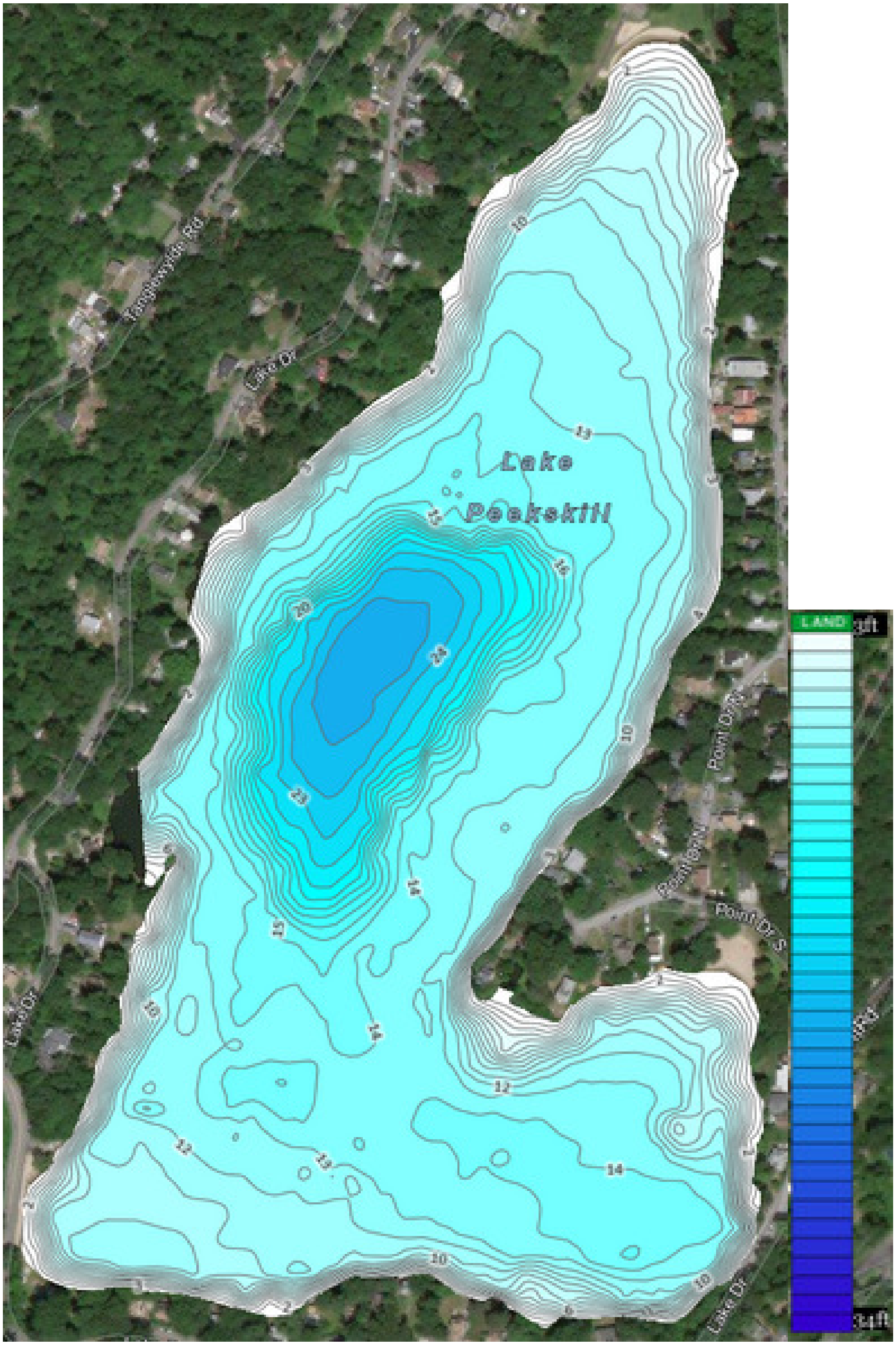
Contour Maps

The contour maps for the lake along with a color-coded scale are shown below. The color scall is a bit different between the 2 scans so you have to look at the contour lines for comparison. The scale goes from light blue (shallowest) to dark blue (deepest). The maps contain some of the depth indications by number and are in 1-foot intervals. The 2018 map shows the lake depth increasing virtually in 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.

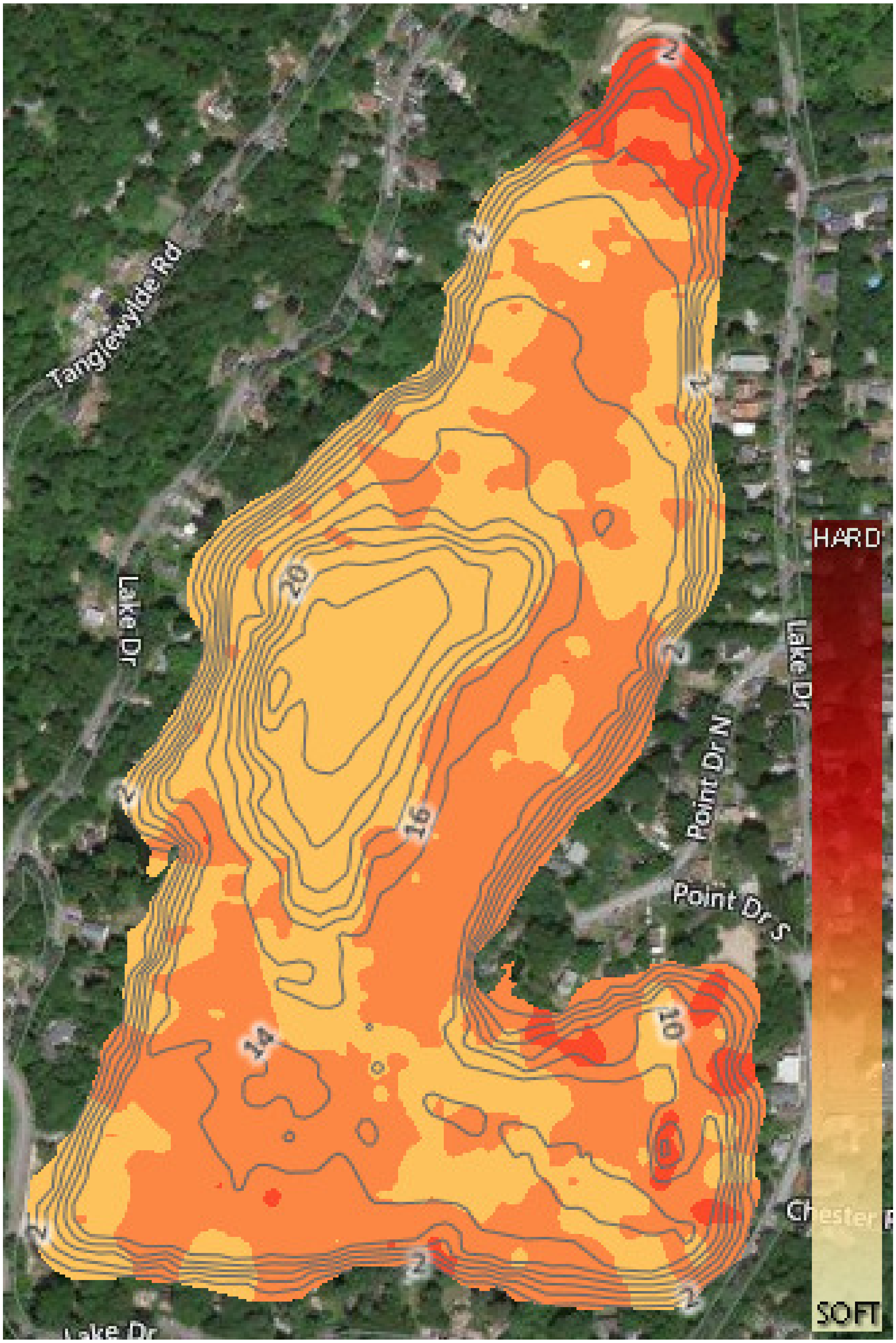
Contour 4/24/18 – The deepest reading obtained in the lake was 26.3 feet. We recorded only a handful of readings over 26 feet and not enough to create a 26-foot contour line. This indicates that the area over 26 feet was very small.



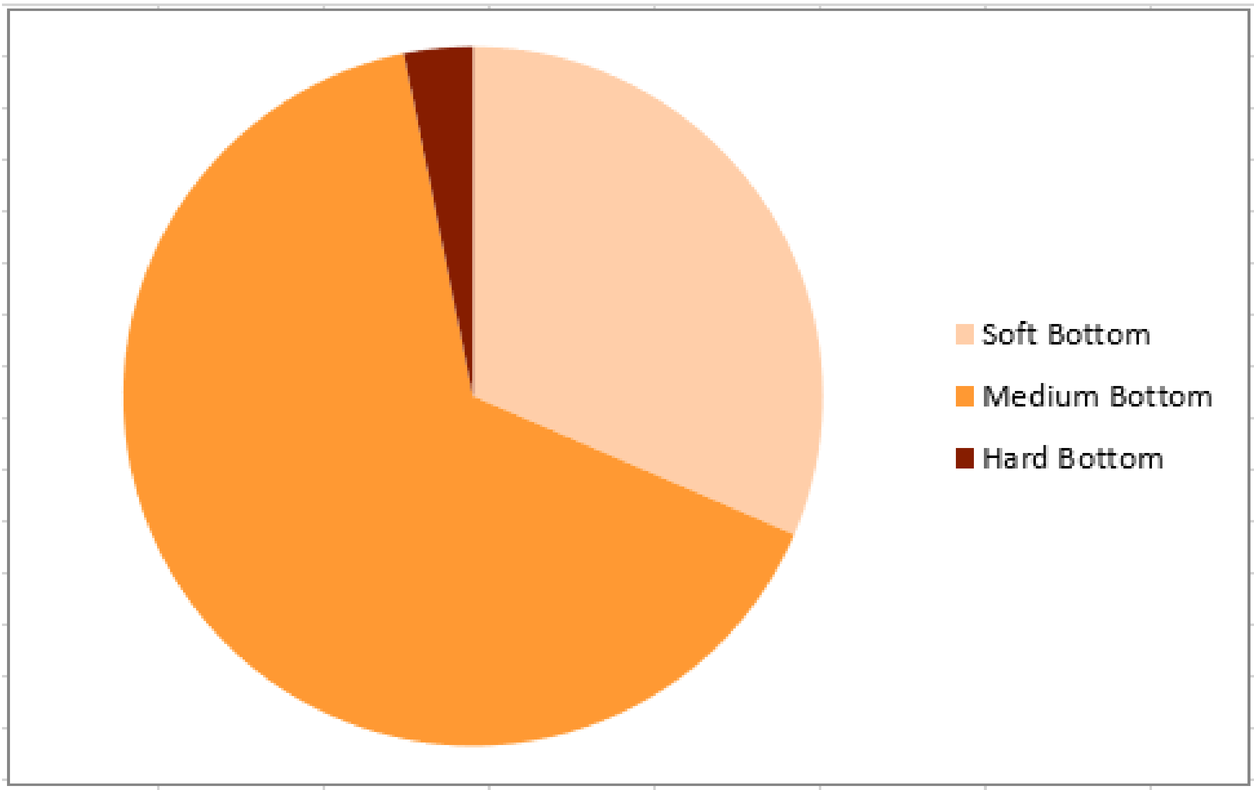
Contour 10/22/18 – Comparing this contour to April 2018, you will see the deep contours have all increased in size. The data shows more readings over 26 feet but still not enough for a new 26-foot contour. This indicates the lake is getting deeper due to organic sediment reduction.



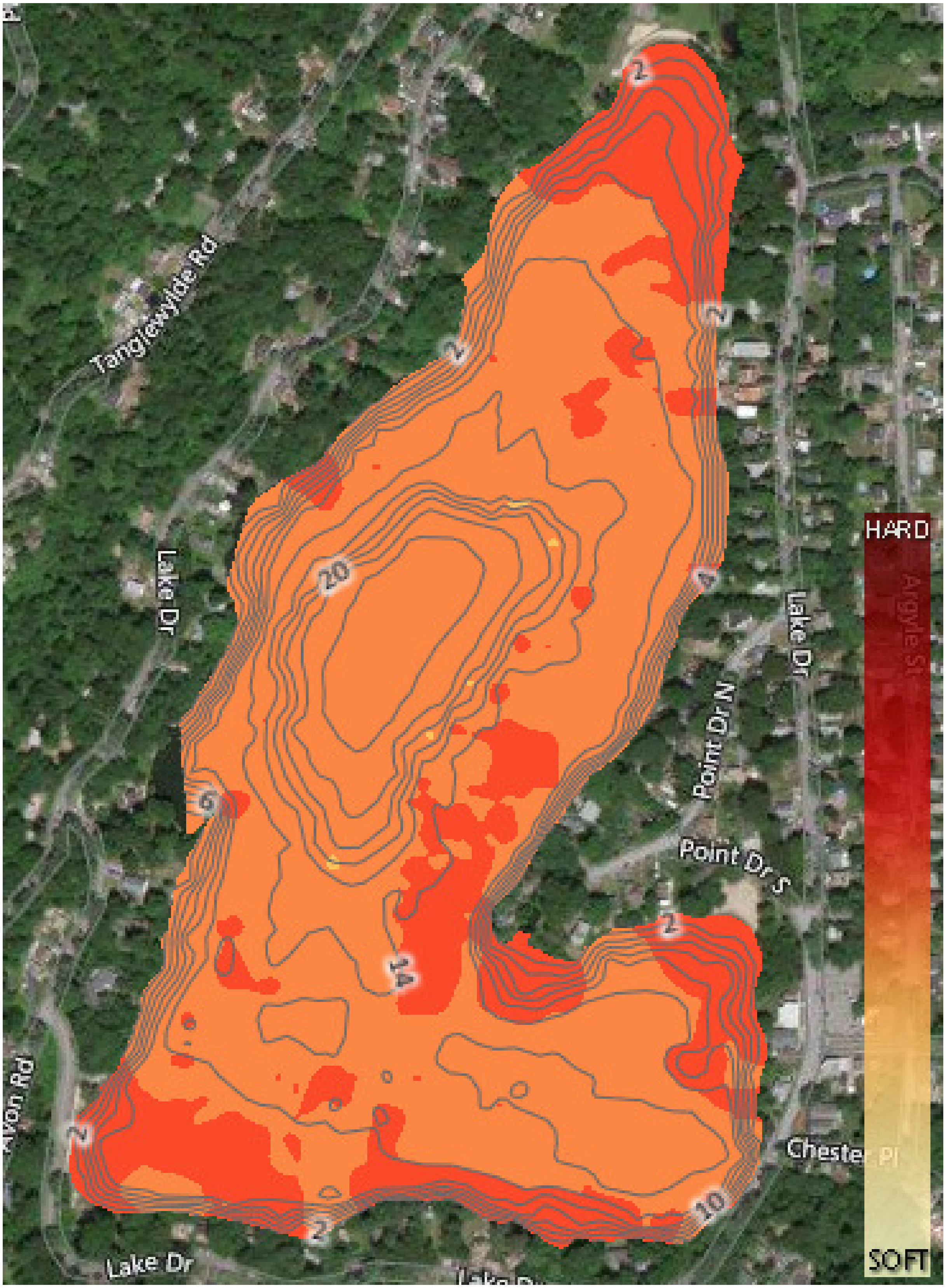
Bottom Composition 4/24/18 – Bottom composition maps are created by the Biobase program to show areas where the bottom sediments are hard and soft. Soft sediments are more indicative of organic components. As you can see on the map below, lighter colors are associated with greater soft sediments and the darker orange and red colors are associated with less soft sediments.



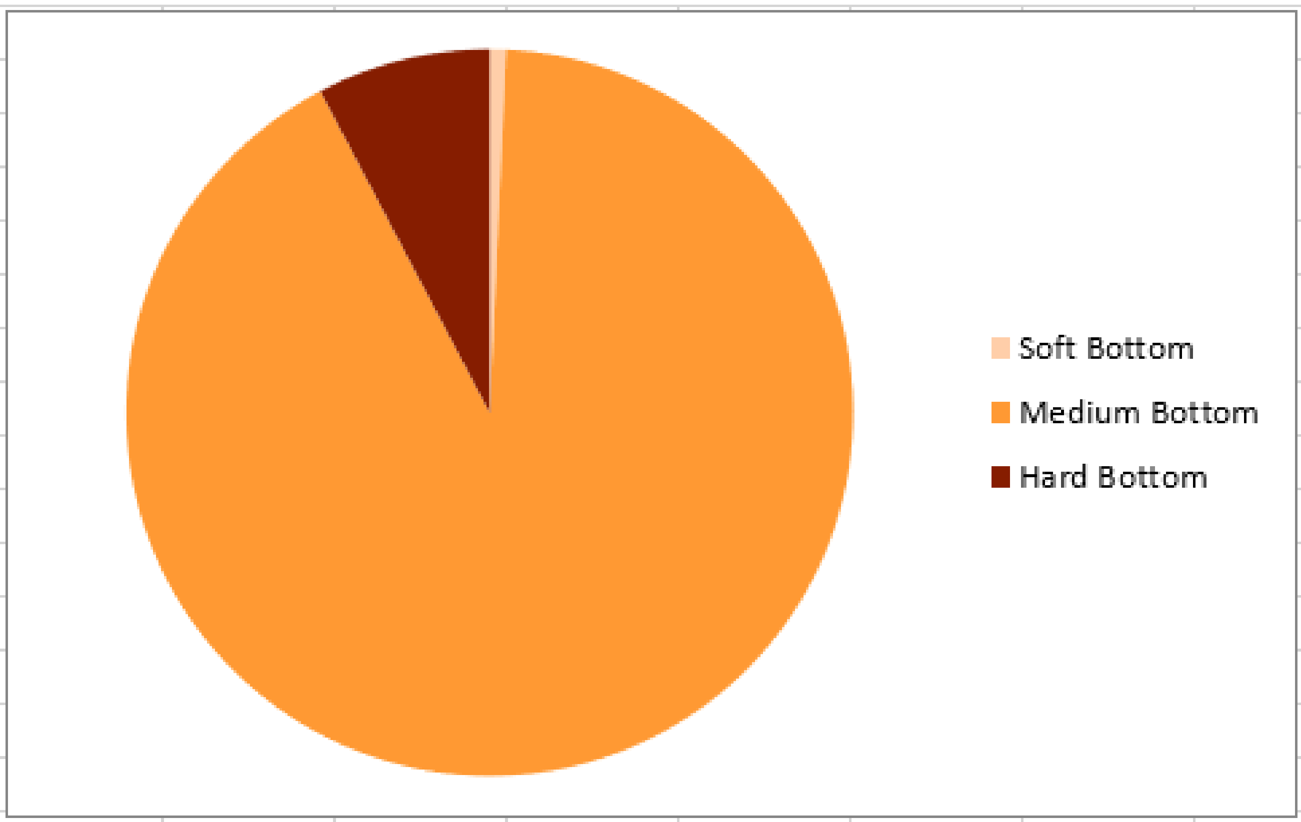
The pie chart below shows the amount of soft, medium and hard bottom sediments in April 2018. As softer sediments decrease, the chart will move toward a higher percentage of red. This chart indicates 31% soft bottom, 65% medium bottom and 3% hard bottom.



Bottom Composition 10/22/18 – Comparing the 2018 map to the 2017 map, there is an obvious change in bottom composition from soft to harder sediments around the entire lake. Almost all of the soft sediments have been reduced.



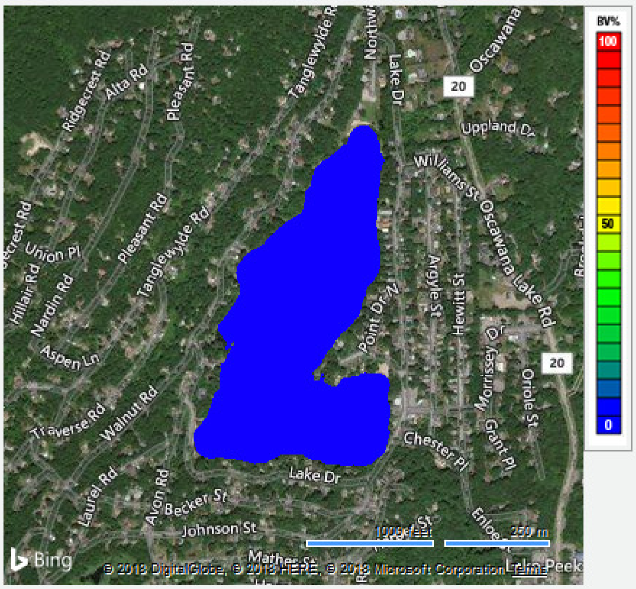
The pie chart below shows the amount of soft, medium and hard bottom sediments in October 2018. This chart indicates 1% soft bottom, 91% medium bottom and 8% hard bottom. A comparison to the scan in April 2018 shows a reduction of almost 100% in the total area of soft sediment, which has resulted in an increase in both the medium and hard bottom areas. The medium bottom areas should continue to get harder as additional organic material is biodegraded.



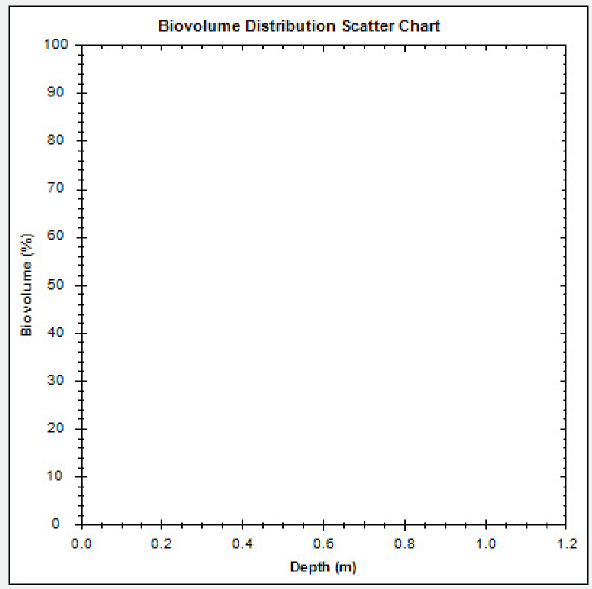
Vegetation Biovolume 4/24/18 – The vegetation biovolume details are shown below. The vegetation biovolume map shows areas of vegetation and density of the vegetation. The measurement scale shows that red is the highest density of biovolume followed by yellow, green and then blue. At the time of the scan 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	0.0%	NaN%	±NaN%	0.0%	±0.0%	3.71 - 27.71 ft	13.80 ft	4.65 miles	2943
	Grid	0.0%	0.0%	±0.0%	0.0%	±0.0%	0.37 - 27.15 ft	12.05 ft	-	0

Vegetation Biovolume Heat Map



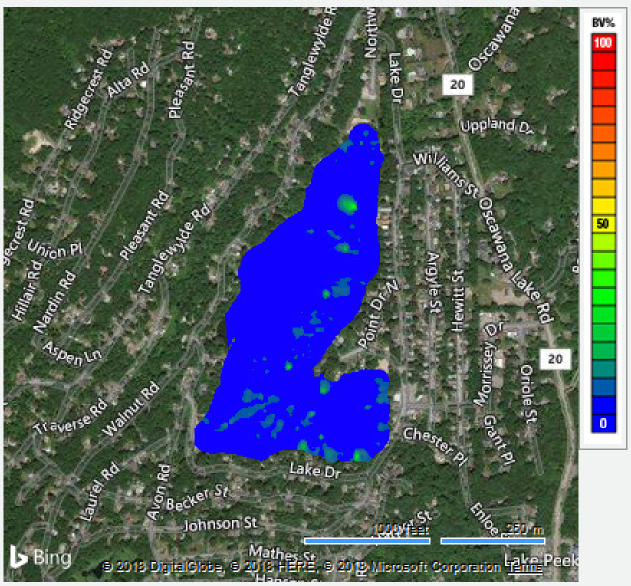
Biovolume Distribution Scatter Chart



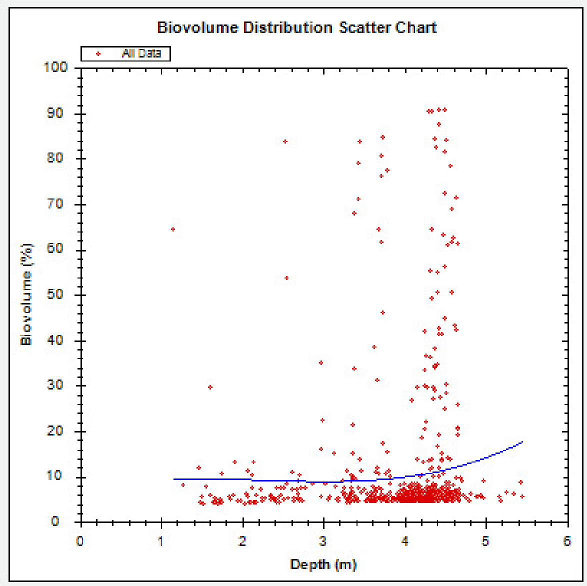
Vegetation Biovolume 10/22/18 – The vegetation biovolume details are shown below. At the time of the scan in October 2018, some vegetation was detected. The majority of vegetation is deeper than 6 feet and will have no impact on recreational activities. Some natural vegetation is beneficial for aquatic 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.

	Type ?	PAC ?	Avg BVp ?	SD BVp ?	Avg BVw ?	SD BVw ?	Depth Range	Avg Depth	Distance	No.Points
Full Survey	Point	14.4%	13.2%	±18.3%	1.9%	±8.2%	2.65 - 34.33 ft	15.30 ft	6.19 miles	7020
	Grid	4.4%	7.7%	±3.9%	0.3%	±1.8%	0.27 - 25.82 ft	12.47 ft	-	388

Vegetation Biovolume Heat Map



Biovolume Distribution Scatter Chart



Scan Details 4/24/18 – Additional details of the scan are shown below. The Clean-Flo process targets the reduction of organic sediments and associated nutrients to reduce nuisance plant and algal growth. Biobase calculates the volume of water at the time of the scan. The volume of water in April 2018 was estimated at 724.23 acre-feet of water. Based on the lake size of 60.11 acres, the average depth was 12.05 feet.

Lake Peekskill, Putnam New York — Generated:

Waterbody Size: 60.11 acres

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: 59.78 acres
Percent: 99.44% of waterbody
Volume: 720.16 acre ft

Est.Waterbody Volume ?
893322.33 cu. m
(724.23 acre ft)

Settings
Track Buffer: 35 m
Grid Cell Size: 7.0 m
Min.BV Detect: 5%
Min.Veg Depth Detect: 0.73 m

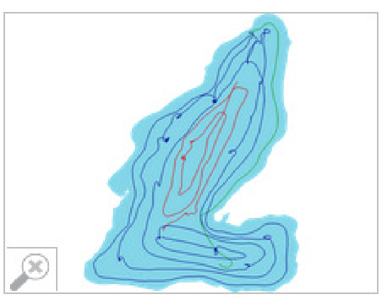
Quality Control
Reviewer: Ian McCormack

Manual Offset
0.333 ft
Transducer depth

Scan Details 10/22/18 – The scan details below show the volume of water in October 2018 is 754.97 acre-feet. That is an increase in water volume of 30.74 acre-feet or 10,016,673 gallons of water. The increase in water volume due to reduction of the organic sediments has increased the average depth from 12.05 feet to 12.56 feet.

Lake Peekskill, Putnam New York — Generated

Waterbody Size: 60.11 acres



Data Collector
Brian Kling

Data Collection Date
10/22/2018 4:16:55 PM (UTC)

Average Water Temperature
57.25° F

Location
Start: 41.33831720, -73.88349257
End: 41.33810064, -73.88335737

Survey Size
Area: 59.60 acres
Percent: 99.15% of waterbody
Volume: 748.55 acre ft

Est.Waterbody Volume ?
931243.43 cu. m
(754.97 acre ft)

Settings
Track Buffer: 35 m
Grid Cell Size: 7.0 m
Min.BV Detect: 5%
Min.Veg Depth Detect: 0.73 m

Manual Offset
0 ft

Conclusion

Lake Peekskill has shown improvement during the time that the Clean-Flo system has been in operation. Although the lake still experienced some harmful algae blooms during the summer season, other important issues showed improvement. Specifically, the entire water column is now oxygenated 24/7 including at the very bottom in the deepest areas. This will reduce the release of phosphorus from the sediments into the water column. The scans have shown a marked reduction of organic soft sediments as a result of high oxygen levels at the bottom throughout the entire lake. In addition, multiple reports seem to indicate that water clarity was much better this year as compared to previous years. Sunlight penetration due to improved water clarity may be the reason for some natural vegetative growth on the bottom of the lake in various areas.

The biological reduction or organic sediments is a tremendous benefit not only short term but long term for the lake. The reduction of 30.74 acre-feet of sediment is equivalent to 49,594 cubic yards (37,917 cubic meters) of sediment. To put this in perspective, a tri-axel dump truck typically holds about 20 yards of topsoil. That equates to over 2,479 dump trucks full of muck driving away from the lake. Not only has the organic sediment issue been improved, but the ecosystem of the lake is also in a much healthier state.

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 weight before the system was started to be 1,000 kg/cubic meter, we end with the following equation:

37,917 m^3 sediment reduced x 1,000 kg/m^3 x 1,000 mg/kg = 37,917,000,000 mg P

37,917,000,000 mg P = 83,592.68 lbs.

This would indicate that over 40 tons of phosphorus have been eliminated from the lake in 2018.

Since the power company did not provide permanent power until June, we got a late start this year. We fully expect to see further improvements next year with the system starting in early spring.

Additional sampling and scan will be conducted during 2019 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.