Evaluation Summary – Scientific Data and Analysis for Aeration and Bioaugmentation
Lake Harmony
10/01/17

The following information is a summary of the scientific analysis concerning the composition and location of organic vs. inorganic materials found at the bottom of Lake Harmony. The purpose of this summary is to determine if aeration and Bioaugmentation processes would be a viable option to increase the depth and health of Lake Harmony. The data presented in this document is a compilation of data found in the Hanover Report dated November 15th 2015 initiated by the Lake Harmony Watershed Preservation Group and core samples taken by Brian Rafferty. This document will also explore possible additional analysis that may be required prior to taking affirmative action concerning the aeration and Bioaugmentation process.

The Hanover Report indicates that there was 1.3 million cubic yards of unconsolidated sediment in the lake. It also indicated that the unconsolidated sediment was slightly greater than one half of the lake's original water volume. This unconsolidated sediment is a mixture or organic and inorganic material as well as water. This is the type of material (muck) that you step into and sink, and many times smells with hydrogen sulfide. It also contains a massive amount of nutrients to fuel weed and algae growth. Getting rid of this muck is the main focus.

Typically organic muck contains roughly 20-60% organic or more, 20-40% water and 20-40% inorganic. 1.3 million cubic yards is equal to 35,100,000 cubic feet. At 118 acres, the lake covers 5,140,080 square feet, so if the sediment was evenly distributed throughout the entire lake, the bottom would be covered in 6.83 feet of unconsolidated sediment throughout.

The Hanover report has a sonar scan which was done by Nature Works in 2013 showing areas of hard and soft bottom. This will provide an idea of where there is more or less muck. The scale used for measurement is that darker areas have less muck. If we move forward, we will also be doing a scan of the entire lake prior to installing the system to establish the baseline as it stands currently.

Hanover Report References.

Page 17 – second paragraph, total unconsolidated sediment is 1,438,986 cubic yards. Softer top sediments (think muck) comprise about 1,216,991 cubic yards.

Page 19 conclusions – 1.3 million cubic yards of unconsolidated sediment. Flushing rate is very low and retention time is very high. (Ideal for aeration and Bioaugmentation)

Appendix B – FX Browne report shows color coded sediment map with 0-2 feet of sediment around the shorelines of the lake. Large accumulations of sediment down the center of the lake.

Appendix D – Nature Works did mapping with Biobase in 2013. If you look at the 3rd page in the appendix you will see a map that has a red to almost white scale on the left side. You can't read it but the top (red) is hard and the bottom (white) is soft. This doesn't show a lot of hard bottom but there is some around where Joe and Kathi's houses are. The entire center portion of the lake is soft or very soft indicative of muck accumulation.

Appendix E – Hanover did bathymetry and cores. On the second page you will see Section 4 that intersects close to Joe Arking's property. If you look at the details of that section in the chart below the map you will see little to no muck on the right side of that section. That is Joe's side of the lake.

When you look through all the maps and charts, it is not surprising that there was no muck at Joe's dock. Muck in a lake can also shift from time to time based on wind and wave action, as well as boat traffic.

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Further, the "top" sediments may be suitable for fill material in areas that will not be carrying any load, such as parks, golf courses, farmland (as topsoil amendment), etc. The "bottom" sediments may be suitable for use in constructing berms for ponds and detention/retention basins. This material, however, functions as an impermeable lining for the lake bed and should be left in place.

A **rough calculation** of the total amount of unconsolidated sediment within Lake Harmony yielded a total volume of 1,438,986 cubic yards. The softer, "top" sediments comprised approximately 1,216,991 cubic yards of this total volume. These estimates were based on severely limited data, and therefore contain considerable error. A more detailed bathymetric study must be performed in order to obtain a more realistic volume of unconsolidated sediment in the lake.

For rough planning purposes, a rough cost estimate for dredging the 1,216,991 cubic yards of softer, "top" sediments would likely range between $25,000,000 to $30,000,000. This cost range is based on an estimated unit cost of $20 to $25 per cubic yard of removed material.

A partial dredging project may be sufficient to improve lake water quality conditions by removing sediments with the highest nutrient composition, and may help to meet budgetary constraints. Additional sediment surveying and sampling is required to determine the potential effectiveness of partial lake dredging and associated costs.

2012 Natureworks "Fish Population Survey Report"

This report indicated that water quality was good and the fish were healthy, although included recommendations for reducing nutrient inputs and improving structure which is commonly lacking in glacial lakes with soft bottoms. The report did not include any recommendations for dredging of unconsolidated bottom sediments to expose underlying structure in shallower areas where there has been more recent sediment deposition associated with urban runoff to the lake.

2013 Natureworks Bathymetric Survey

The 2013 Natureworks Bathymetric Survey did not include detailed reporting or recommendations for sediment removal. Rather, the products of this survey were maps for current water depth, sediment thickness, and aquatic vegetation coverage. Mapping was conducted using sonar calibrated against physical measurements at several locations with steel rods which were pushed through the unconsolidated sediments to a point of refusal. The total sediment volume in the lake was calculated to be approximately 1.3 million cubic yards. The data and mapping from this survey are included as Appendix D of this report.

Based our review of the above listed documents and input from LHWPG, Hanover Engineering and Benesch Engineering have identified data gaps which are critical to future lake and watershed management. These data gaps are discussed in greater detail in the following section of this report. Conclusions and recommendations in this report are based on past data, limited research conducted by both firms, and input from LHWPG and other stakeholders.

Hanover Report Page 19

entire Lake Harmony Watershed. A proposal to complete this work using funds allocated for such work by the Township was prepared and submitted to the Township for review and consideration.

VI. CONCLUSIONS

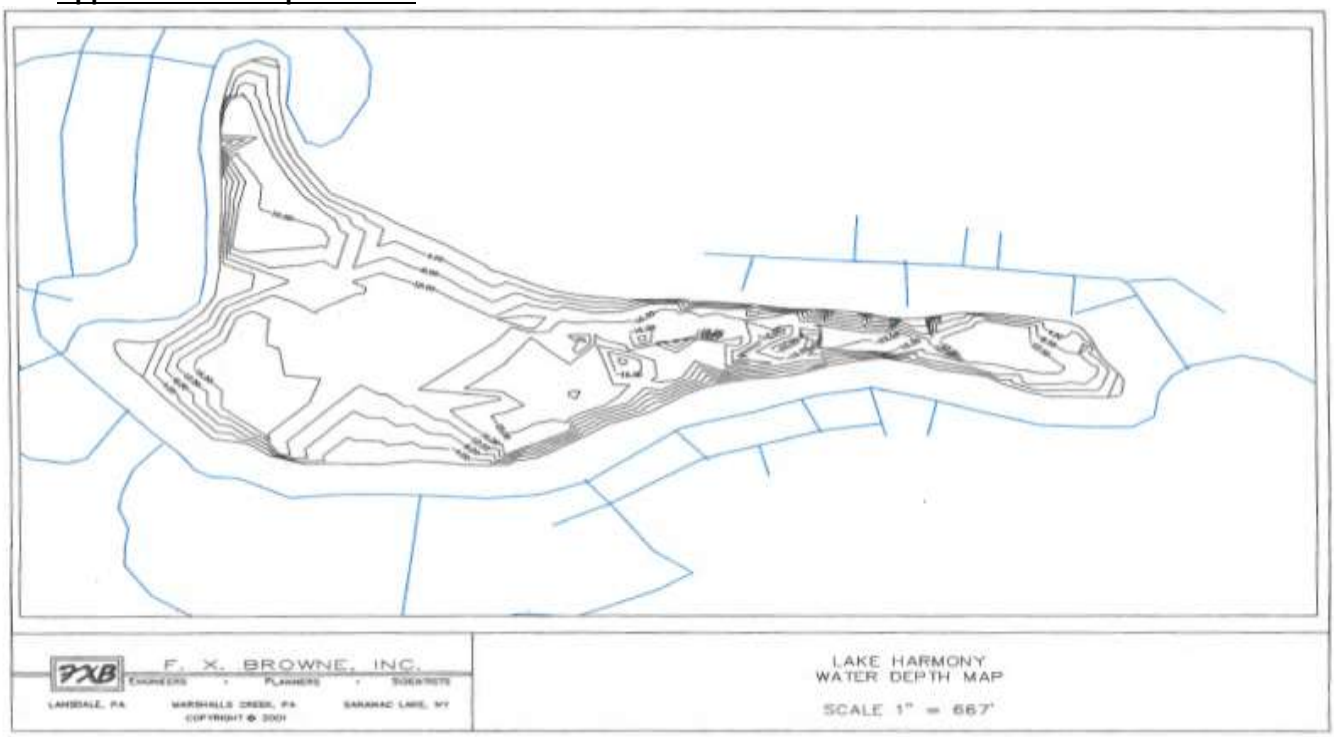
Based on our review of past reports and associated materials completed for Lake Harmony and its watershed, as well as discussions with Kidder Township, LHWPG members, and other stakeholders, we have concluded that Lake Harmony has been and continues to be impacted by sediments and nutrients from the lake's watershed. The lake contains nearly 1.3 million cubic yards of unconsolidated sediment, which is slightly greater than one-half of the lake's original water volume at normal pool elevation. The sediments and associated nutrients impact the recreational uses, aesthetics, water quality, and aquatic habitat associated with Lake Harmony. In recent years, algae blooms on the lake have been increasing in frequency and severity, including cyanobacteria (aka bluegreen algae) which are known to potentially release dangerous algal toxins that can cause maladies and can even be fatal for humans, pets, and livestock. Rocky shoreline and littoral zone areas have become laden with sediment, smothering valuable aquatic habitat for smaller aquatic organisms and impacting fish spawning. There has also been a notable increase in nuisance aquatic vegetation in areas which are becoming shallower and contain soft rich sediments. Dock and beach areas require spot dredging to deepen water for recreational use by swimmers and boaters. Lastly, water leaving the lake is warmer and more turbid, and contains elevated quantities of nutrients, sediments, and algae (potentially including dangerous algal toxins) which are discharged into downstream waterways.

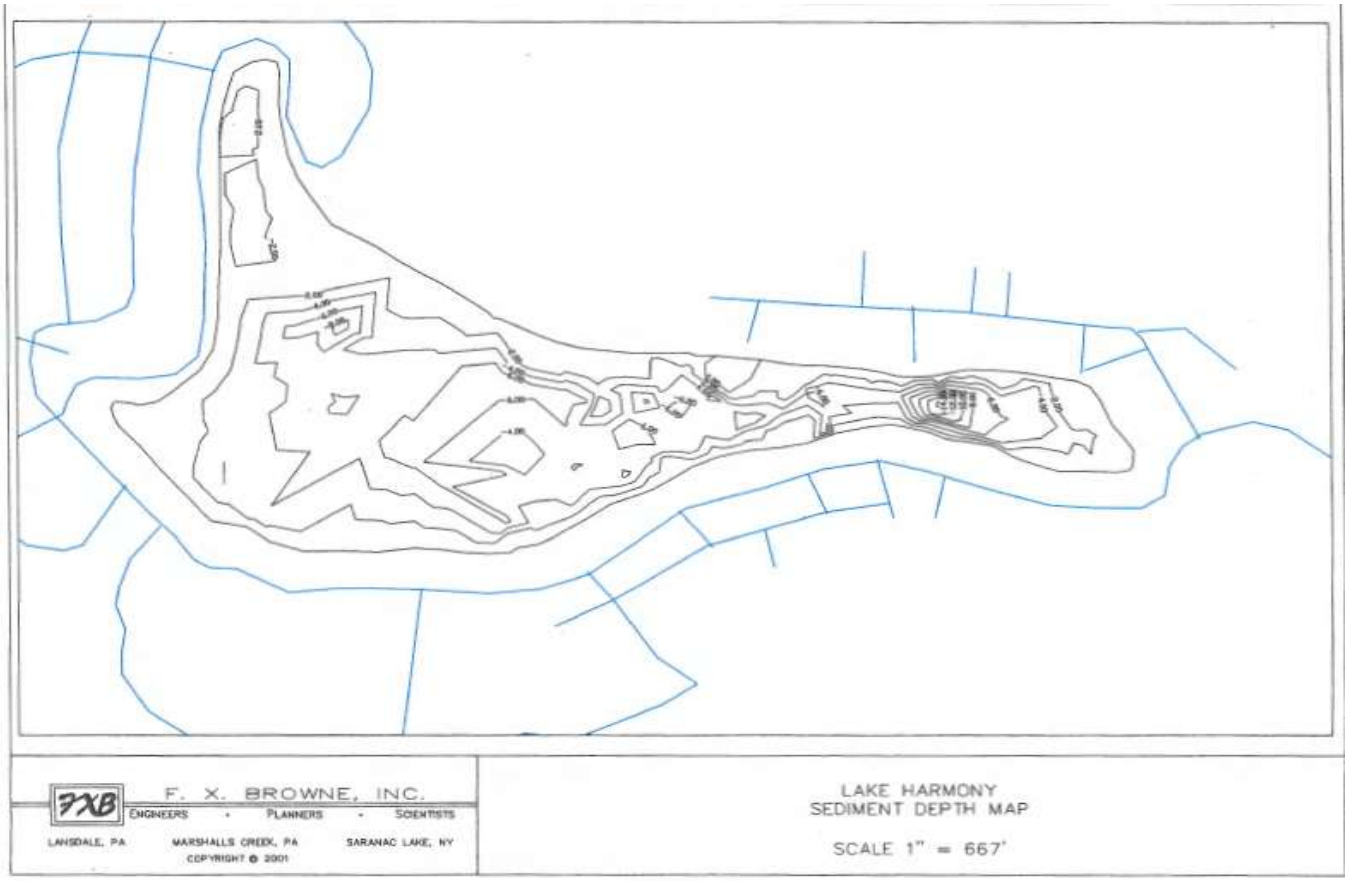
The primary source of the sediments is from uncontrolled stormwater within the lake's watershed, and particularly from dirt and gravel roads and areas with no or insufficient stormwater management controls. Steep slopes on both sides of the lake have been developed with homes, lawns, and roadways, with little or no consideration for stormwater runoff which goes directly into the lake, carrying land-based pollutants such as roadway materials, eroded soils, organic matter, lawn fertilizers, pesticides, animal wastes, and other materials.

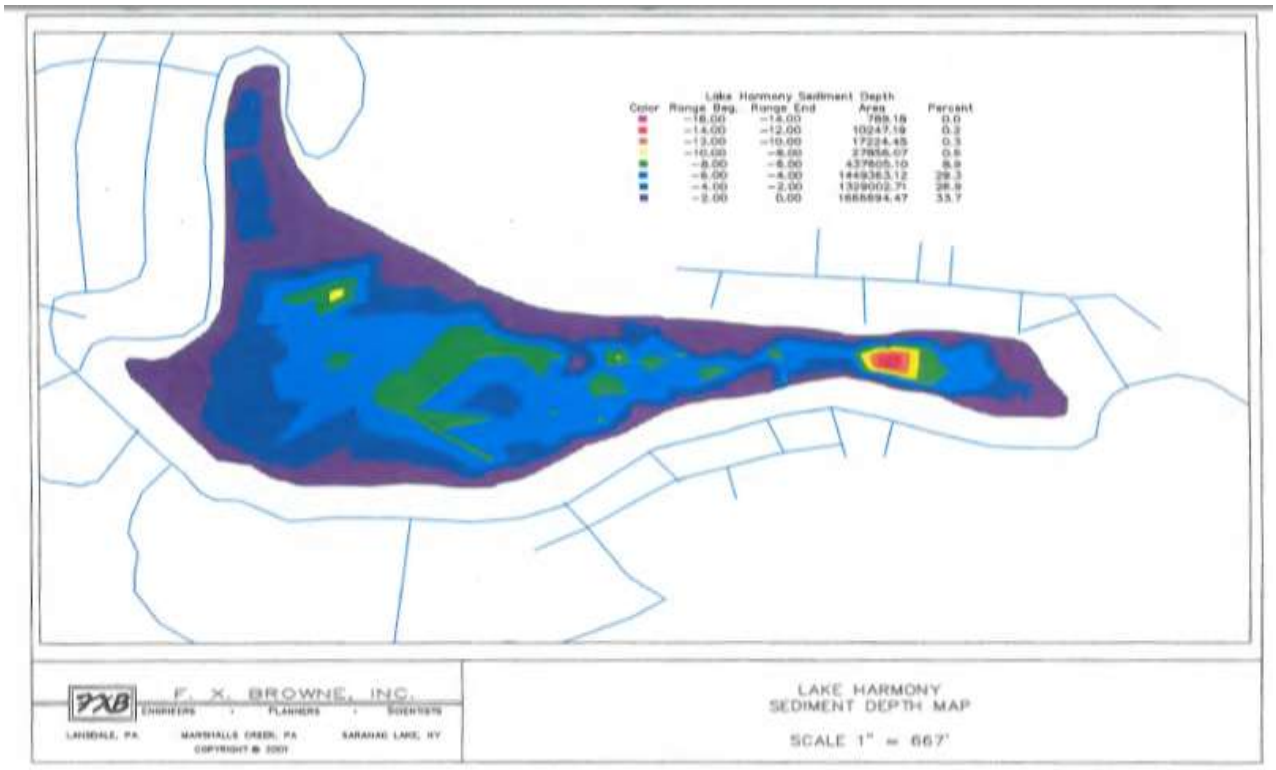
Lake Harmony is a natural glacial lake which has a very low watershed to lake basin ratio, with no significant streams contributing flow. The hydrology of the lake is supported primarily by rainfall runoff and springs within the lake bed. As such, the flushing rate is very low; or conversely, the hydraulic retention time is very high. Therefore, materials which enter the lake and settle to the bottom, and particularly the nutrients, may increase in concentration within the water column and support excessive growth of algae and aquatic plants.

Preventing erosion and sedimentation through proper stormwater management within the Lake Harmony watershed is critical to protecting the lake from impacts including deteriorated water quality; excessive algae and plant growth; high turbidity from wind

Appendix B - 5 maps 3 charts



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-12.00 -10.00 17224.45 0.3
-10.00 -8.00 27856.07 0.5
-8.00 -6.00 437805.10 8.9
-6.00 -4.00 1449363.12 29.3
-4.00 -2.00 1329002.71 26.9
-2.00 0.00 1886894.47 33.7
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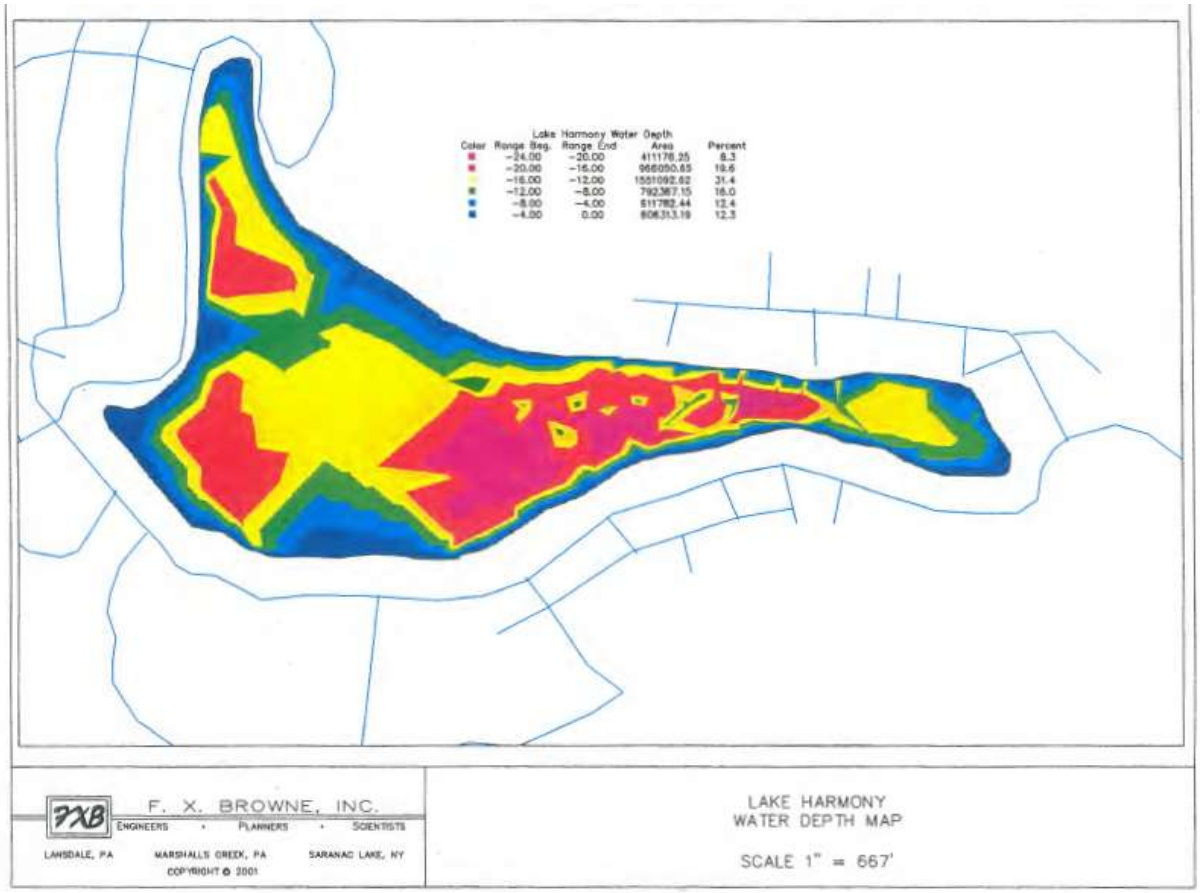
LAKE HARMONY
SEDIMENT DEPTH MAP
SCALE 1" = 667'


Lake Harmony Water Depth
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-8.00 -4.00 611782.44 12.4
-4.00 0.00 606313.19 12.3
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LAKE HARMONY
WATER DEPTH MAP
SCALE 1" = 667'

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Lake Harmony
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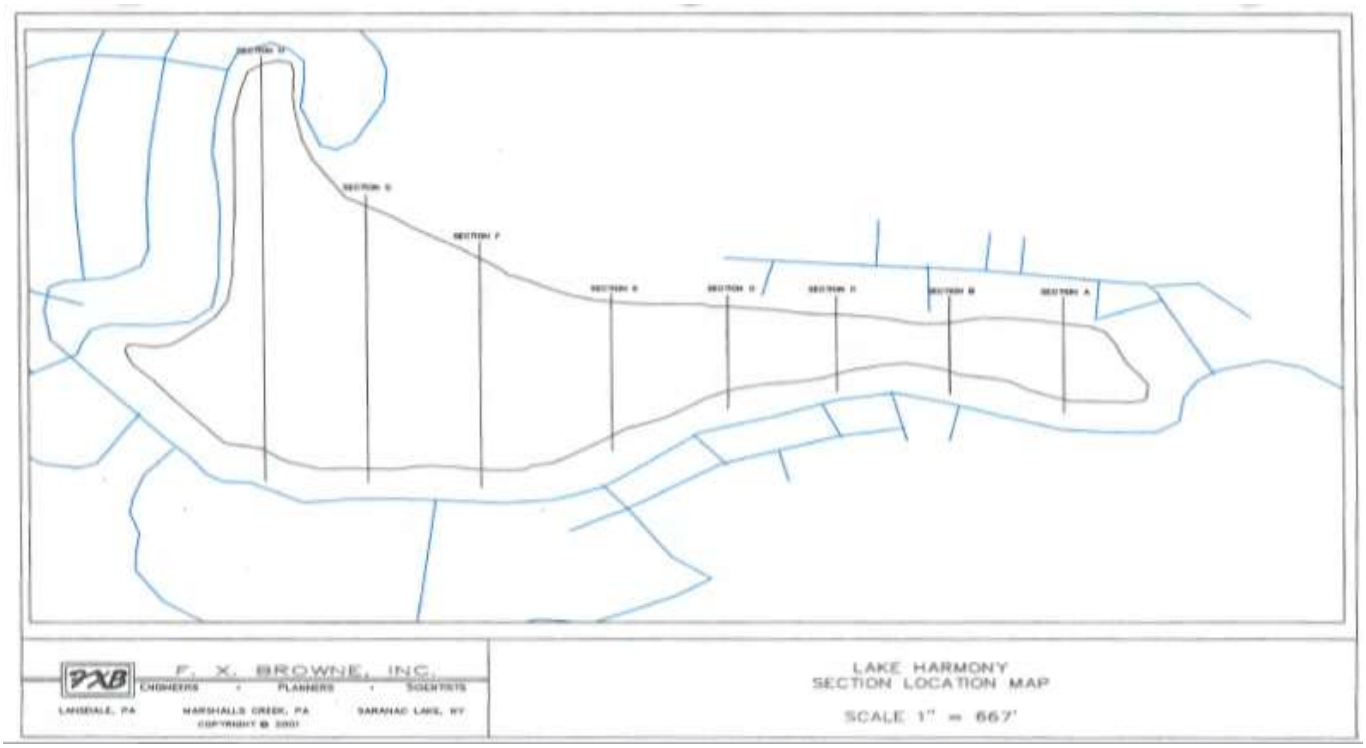

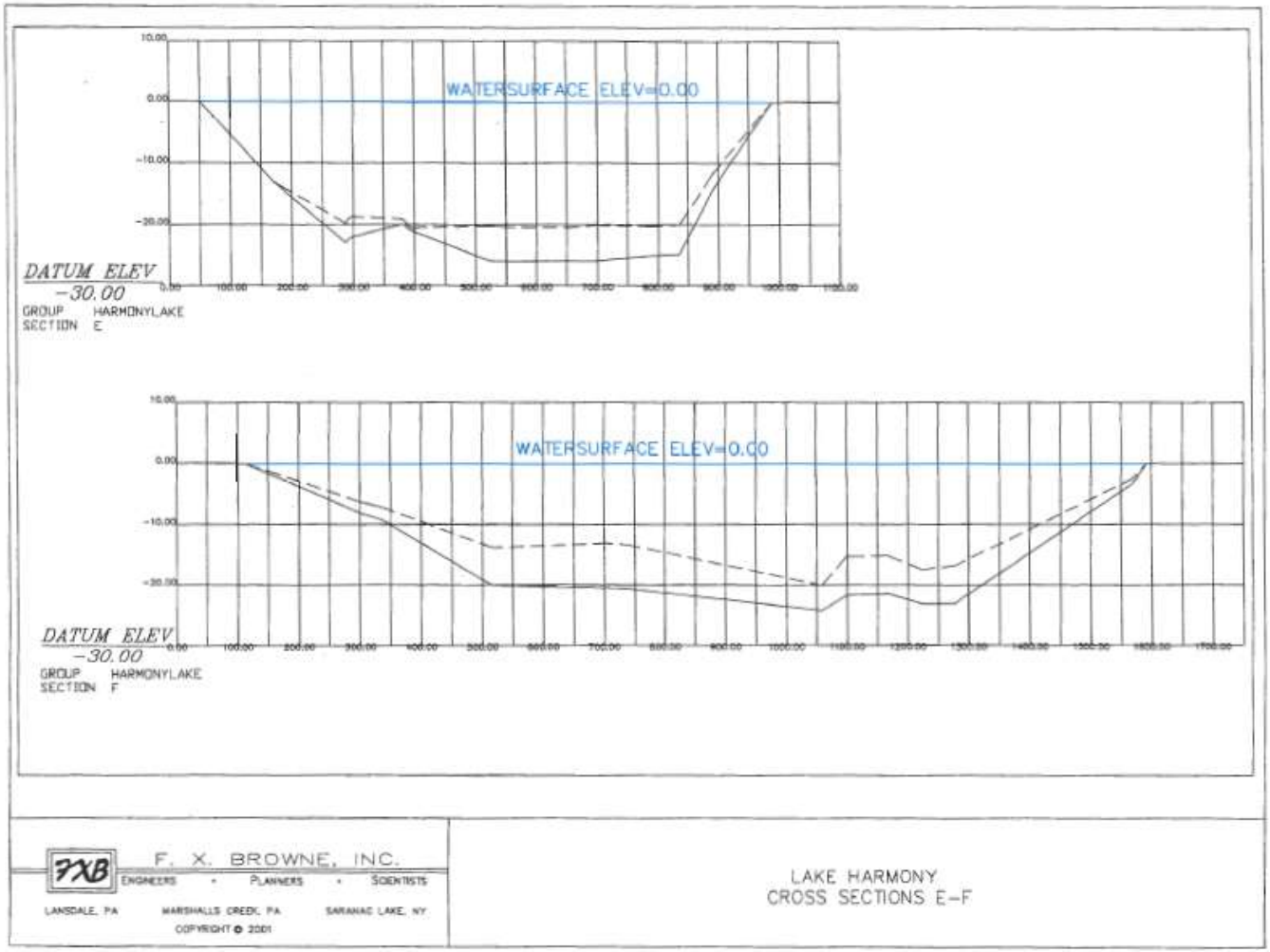

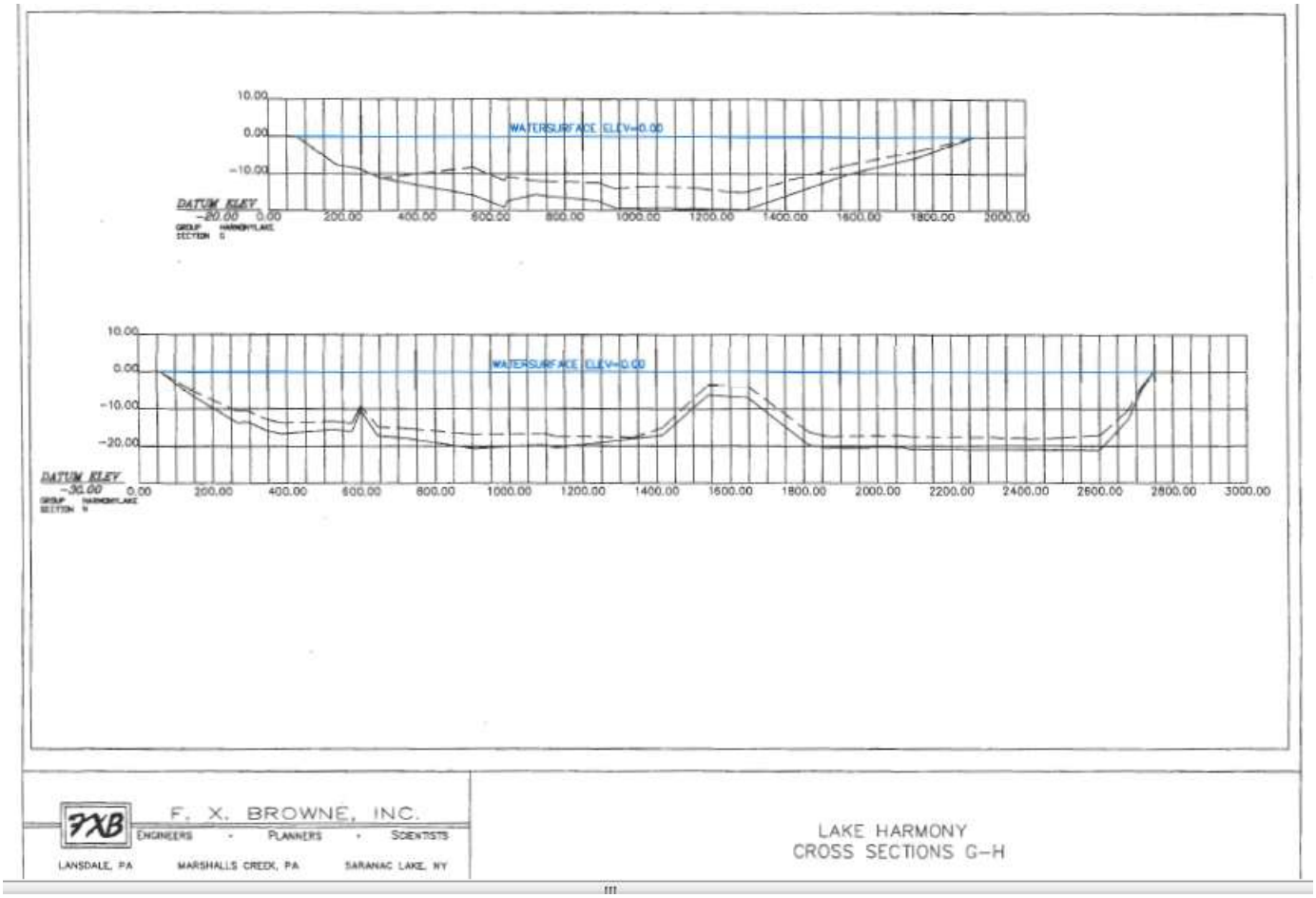
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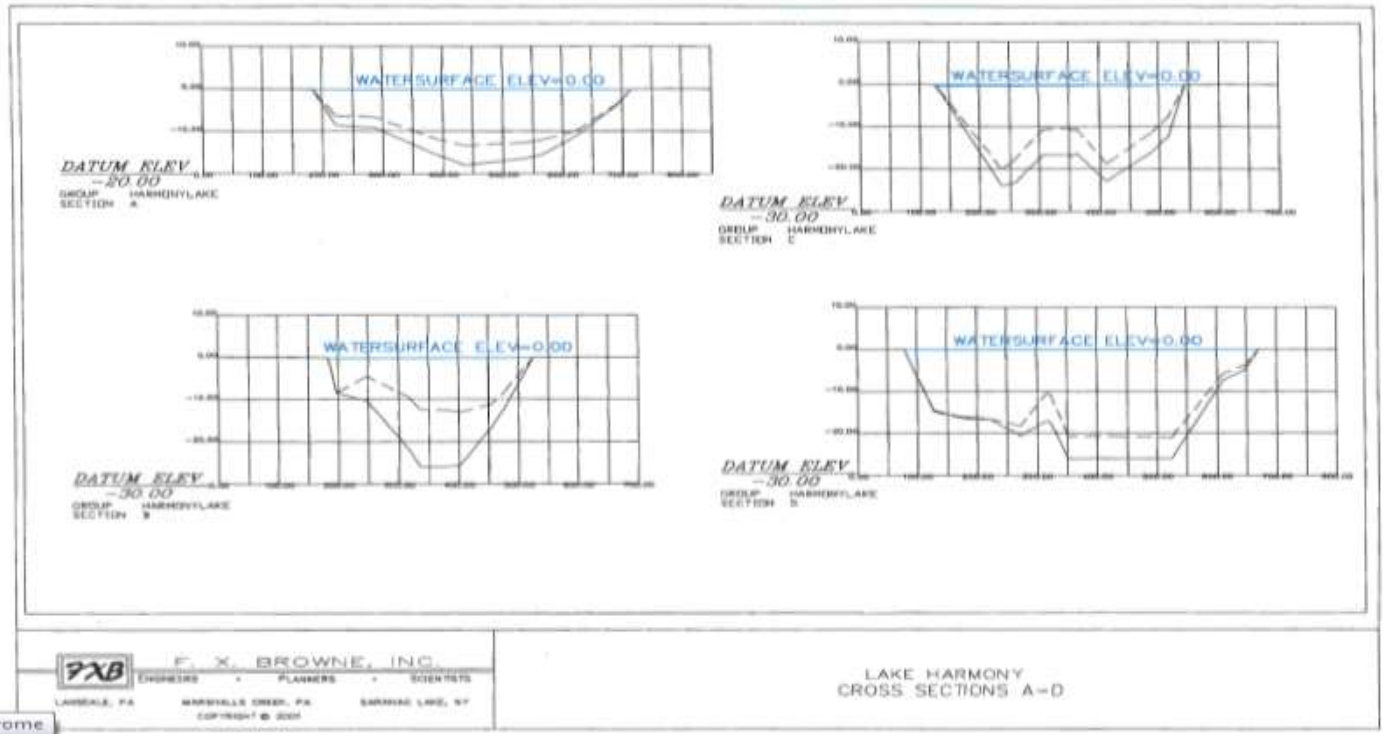
LAKE HARMONY
CROSS SECTIONS G–H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LAKE HARMONY
CROSS SECTIONS A–D

Appendix C

Lake Harmony Sediment Analyses Report
Sample Date: September 19, 2007
Collected By: Jason E. Smith, Senior Scientist – Hanover Engineering Associates, Inc.
Assistance By: Marvin Raphaelson – Lake Harmony Concerned Citizens
Sample Method/Equipment: Lake sediment (unconsolidated material) samples were collected using a 4 ft Ogeechee Sand Corer at three random locations within Lake Harmony and were composited respectively as either "top" or "bottom" sediment samples based on physical characteristics. The top sediments were composed of mucky unconsolidated material and the bottom sediments were composed of early clay/mineral deposits.
Purpose: The primary purpose for conducting this sampling was to determine the basic composition of the unconsolidated sediments in the bottom of Lake Harmony, primarily as an effort to determine disposal and reuse potential if dredged from the Lake.

Laboratory Results (by Wilkes University – Environmental Quality Laboratory):
General Description:

Laboratory Results (by Wilkes University – Environmental Quality Laboratory):

General Description:

Source	Final Soil Description	Soil Type	Estimated Thickness/ Volume	Extractable mg P/ g dry wt*
Lake Harmony – Top	mucky sandy loam	mineral soil	7.54 ft. 1,216,991 c.y.	0.056
Lake Harmony – Bottom	sandy clay loam	mineral soil	1.72 ft. 221,995 c.y.	0.205

*Phosphate extracted by converting the soil to anaerobic/ anoxic environment with a pH of less than 2.

Grain Size Analysis:

Source	Sand Percentage	Silt Percentage	Clay Percentage	Organic Percentage
Lake Harmony – Top	55.56	27.78	16.67	6.89
Lake Harmony – Bottom	64.10	15.38	20.51	3.66

Solids Analysis:

Source	Total Mass, g	Water Mass, g	Solid Mass, g	Organic Mass, g
Lake Harmony – Top	75.2865	53.475	21.8115	1.5038
Lake Harmony – Bottom	77.94671	35.6983	42.24841	1.5457

Recommendations: The materials in both the "top" and "bottom" layers of sediment sampled from Lake Harmony contained relatively low amounts of organic materials in comparison with peat or humus which is commonly found in many natural lakes and kettle formations in the Pocono Region. The majority of the material (top) may be suitable as topsoil or a topsoil amendment, but not as a highly saleable material such as peat or humus.

Further, the "top" sediments may be suitable for fill material in areas that will not be carrying any load, such as parks, golf courses, farmland (as topsoil amendment), etc. The "bottom" sediments may be suitable for use in constructing berms for ponds and detention/retention basins. This material, however, functions as an impermeable lining for the lake bed and should be left in place.

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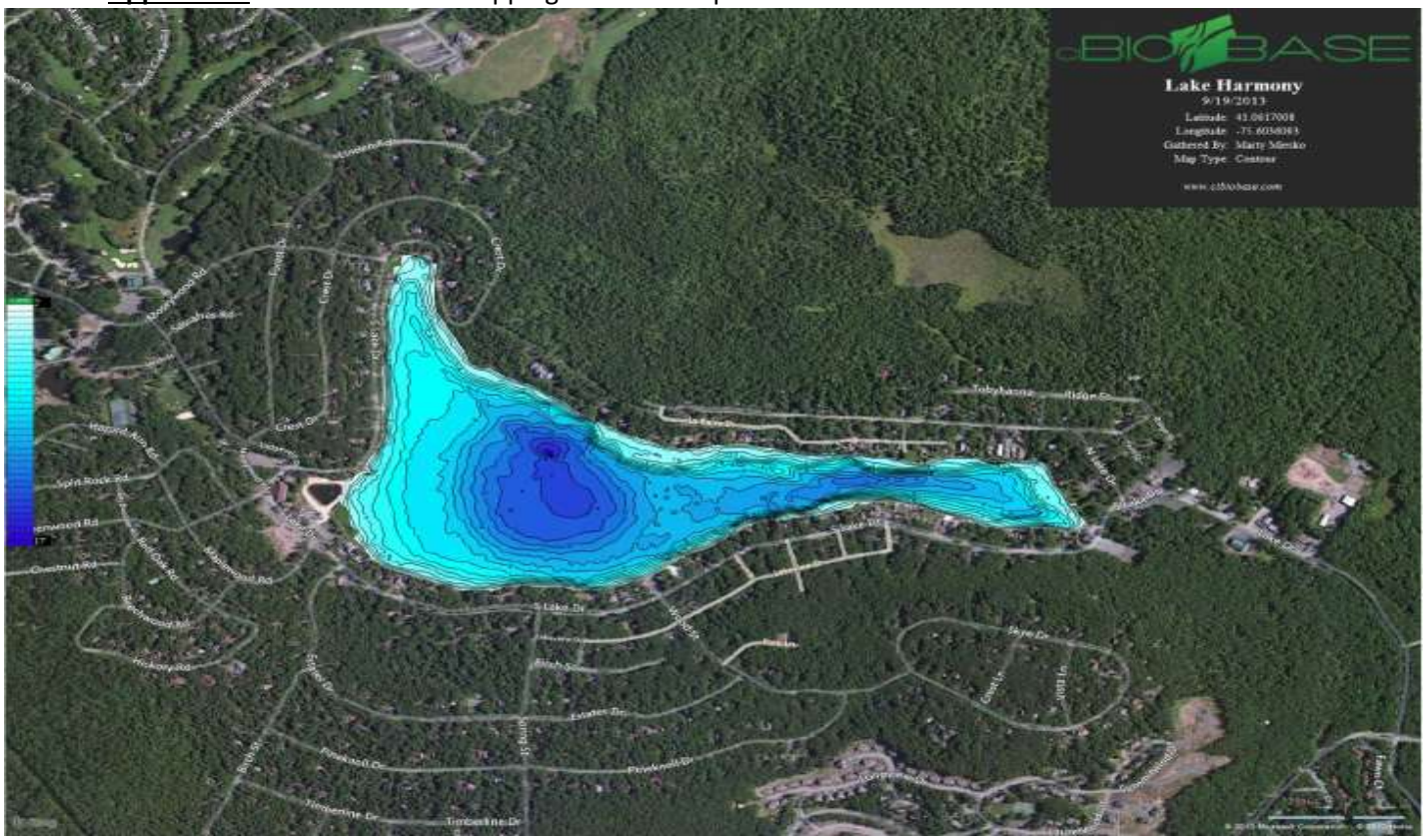
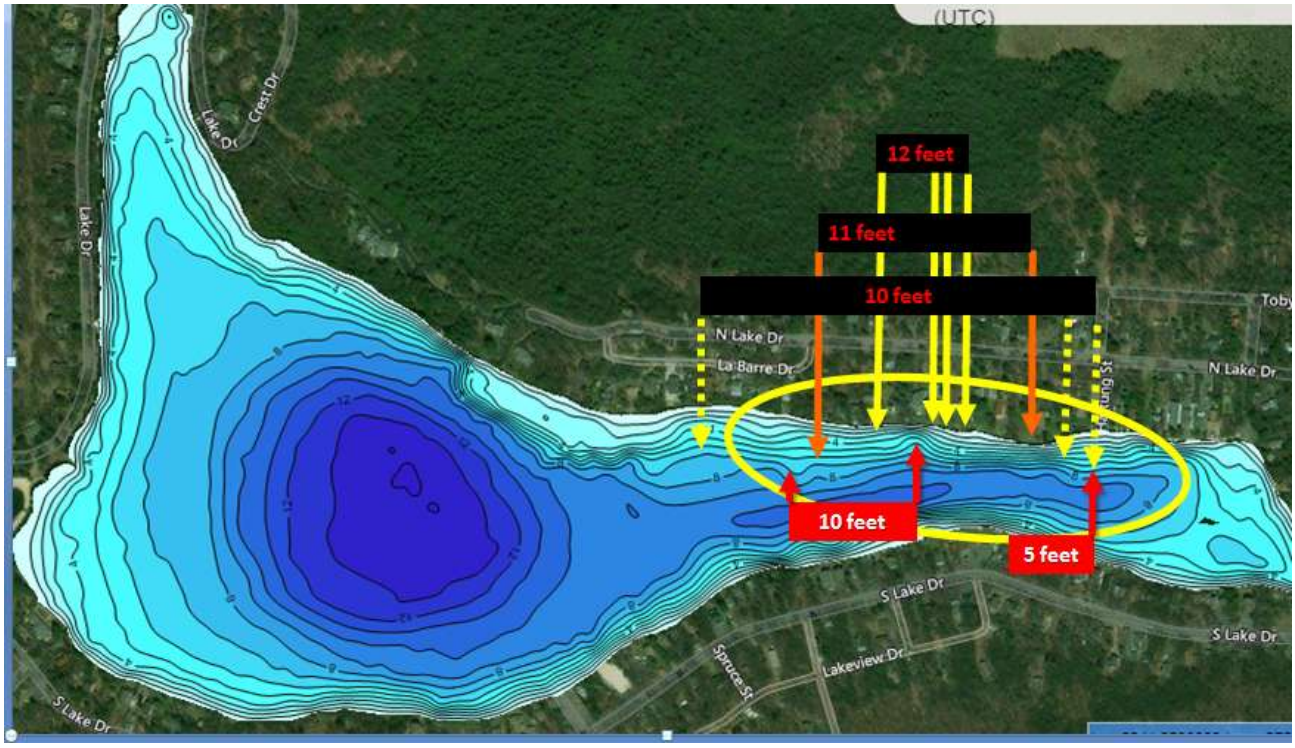
Appendix D 2013 Site Mapping- Hanover Report



Map that has a red to almost white scale on the left side. Red is hard and the bottom (white) is soft. Perimeter of the lake bed is hard inorganic sediment. The entire center portion of the lake is soft or very soft indicative of muck accumulation.

2017 BioBase Site Sonar Scan Mapping vs Site Mapping 2013

Recent Scan shows a depth reduction over a 4 year period----2013 depths in black/2017 in red



Summary

From the scientific data above it seems that the Aeration system could reduce over half of the inorganic materials at specific locations primarily located in the center of the lake. There would be an average of 3.4 foot increase in water column throughout the lake. Now we know that the sediment is not evenly distributed and some areas have much more sediment than others, so in those high sediment areas, we would likely see more than the 3+ feet of increase in water column, which is a significant reduction.

The process because once it is reduced, plant life reduces, odors disappear and water quality gets much better. Our process will only have an effect on the organic and water portions of the muck, not the inorganic. The organic portion keeps the inorganic suspended in the muck, but once the organic is reduced by our process, the inorganic drops out of the water column to the bottom.

Other additional options

- Do nothing
- Spot Dredge perimeter of lake with or without aeration
- Use Biologic additives only

Restorative Lakes Sciences

Jennifer L. Jermalowicz-Jones, PhD Water Resources Director Restorative Lake Sciences Spring Lake, MI 49456 616.843.5636 jenniferj@restorativelakesciences.com

Restorative Lakes Sciences is a consulting firm (owned by Jennifer) who apply scientific analysis on lake health and various methods to clean and restore lakes. They have worked on many projects with Clean Flo on when and how to apply the aeration operation to maximize efficiencies of the system. First and foremost Restorative Lake Science scientific analyses methods to restore water bodies then recommends the various options to the lake proprietors to achieve the best results. They can perform the following services :

1. Set up a whole lake analysis
2. Determine the percentage of organic vs. inorganic materials in the lake. We should have 40% plus organic vs. inorganic to get maximum results.
3. Lake Water Quality Monitoring and Assessments
4. Lake Sediment Reduction S and Management Programs
5. Aquatic Vegetation Assessments and Reduction Programs
6. Rare and Endangered Species Assessments and Preservation Programs
7. Biological Control Research and Implementation Programs
8. Algal Analyses and Toxic Algal Bloom Reduction Plans
9. Lake Fishery Assessment Studies and Habitat Analyses
10. Shoreline Buffer Implementation and Soft Shoreline Programs
11. Aquatic Toxin and Pollutant Modeling and Programs for Reduction

Restorative Lakes Sciences - Results

The LHWPG Board contacted Restorative Lake Sciences (RLS) in July of 2017 to conduct a sediment study of the lake in order to determine the possible feasibility of the lake as a candidate for laminar flow aeration (also referred to as inversion oxygenation or LFA). On July 21, 2017, scientists from RLS collected 10 sediment samples from the bottom of Lake Harmony in various locations to represent the lake surface area. Sediments were collected by hand with an Ekman hand dredge (9" x 9") sampler. Sediments were placed on ice and transported to an EPA-NELAC certified laboratory for analysis (see attached data report to this report for lab analysis data, procedures, etc.). Sediments were tested for percentage of organic matter (carbon) which is the parameter of greatest interest for muck reduction with the use of an aeration system. The sediment sample data revealed that the sediments in Lake Harmony were overall moderate in organic faction with a mean of 25% organic carbon, and a range of 15%-38%. The majority of sampling sites exhibited moderate quantities of organic matter values. Reportedly, the lake exhibits a decline in dissolved oxygen concentration with depth and occasional cyanobacterial (blue-green algae) blooms and thus would benefit from LFA for additional improvements aside from just muck reduction.

CONCLUSIONS AND RECOMMENDATIONS

Overall, Lake Harmony contains a moderate amount of organic matter in the lake sediments. This means that there is also a faction of mineral content in the sediments rather than organic content. Aeration is designed to reduce organic matter and also reduce associated sediment

nutrients. The LFA would likely reduce some organic muck but would also yield additional benefits such as increased dissolved oxygen concentrations throughout the entire water column and as a result, reduce release of phosphorus that is fueling cyanobacteria (blue-green algae) growth. The water clarity of the lake should increase over time and the amount of algae should decline.

References

Lake St Catherine Conservation fund David Emmons cell 802-236-2566 dave7vt@gmail.com 4/18/17

Lake Saint Catherine is an 852-acre body of water located in Rutland County, Vermont in the towns of Wells and Poultney.
Lake St. Catherine State Park is located along its eastern shore. Dave has the Clean Flo system in for about 5 years in a small area of the lake. He uses about 40 diffusers for about 9 months out of the year. April till about Nov. They do not use it in the winter due to ice fishing and other activities on the lake. They also do not use the winter enzymes. He does a calculation of organic materials to non organic materials to evaluate the efficiency of the system along with the depth increase per year. He indicated that that they were about 60% to 80% of organic material (Muck) in the lake and has reduced to about 20%. Parts of the lake were only 5ft.He indicated that he increases the depth of the lake where the diffusers are form 6" to 12" per year. He is in the process of expanding to other parts of lake since the State of Vermont has seen such improvement in lake quality and depth increase in the areas he has the diffusers. The electric cost to run the system is about $ 500.00 per year. Very quiet and easy to maintain. As a follow-up I would like Brian Rafferty to talk with him about how to do some organic material measurements in Lake Harmony. Dave is also willing to share his data with our group. I will pass it on once he sends it to me or Brian.

Additional comments from Pete Ginopolas– Visit to St Catherine May 2017

Advantages of Aeration

- Simple alternative to dredging
- Restores and maintains aerobic conditions by removing toxic gases and carbon dioxide
- Oxygenates entire water column and into the sediment pore water
- Prevents release of nutrients from anoxic sediments – reducing/eliminating internal loading.
- Reestablishes the aerobic environment required to accelerate biological breakdown of organic nutrients.
- Improve water quality / clarity for recreation
- Reduce phosphorus, nitrogen, hydrogen sulfide
- Organic muck reduction
- Algae control – shift to diatoms, reduce chance of toxic blue green algae blooms
- Weed control
- Reduce pathogenic bacteria
- Eliminate odor
- Reduce fish kills / improve overall fishery
- Reduce iron, manganese and other metals
- Compliance with discharge standards
- Pond aeration is the simple, yet effective, process of increasing oxygen levels in a pond and can not only greatly enhance the aesthetic beauty of a pond, but can also improve the

natural systems taking place beneath the water's surface. Aeration creates destratification of the water column, as lakes and ponds typically consist of stratified layers separated mainly by different temperature and oxygen levels. Natural resource and environmental managers are often challenged by problems caused by lake and pond stratification. The main purpose of aeration is to increase and stabilize the amount of dissolved oxygen in the entire water column and this has a widespread effect on many different aspects of pond and lake health.

Disadvantages of Aeration

- Will not reduce inorganic sediment around the perimeter of the lake
- Liability to run system in winter
- Initial Funding

Alternative comments against aeration

1. Will not work for this lake.
2. Waste of money
3. Was pulled out in a nearby lake
4. Others can do it less expensive
5. Will not increase depth

Note : Most of these comments are related to individuals from Hanover and Nature Works that would lose business if Lake Harmony adopts an aeration system.

Email from Clean Flo concerning comments from NatureWorks of equipment being pulled out of two lakes

Just to provide some background, Clean-Flo (CF) was formed in 1970 by an engineer, Bob Laing. Bob ran the business from then until February of 2005 when a partner and I bought the business. Since we bought the business, we have made a number of technology changes to improve cost and efficiency, while maintaining the core principles of laminar flow. A project implemented 10 or 20 years ago would look much different today. In fact the bioaugmentation process used today is totally different than in 1985 when Congress lake was installed and in 2006 when Deerfield lake was installed.

Congress Lake was installed in 1985, however we have a file of papers that provide a paper trail and details on the project. It started due to a problem with oxygen depletion, nutrient overloading, fishery impacts and bacteria problems in the lake. I was also asked to visit Congress Lake in 2014 and actually met with the general manager, Paul Showalter to discuss implementing a new system in the lake because the original CF system had not been maintained. At that time I also talked with Bob Laing to get as much background on the lake and the original system design as I could. Parts of the original system were still operating at that time but there wasn't enough oxygenation. After the project was installed in 1985, CF performed the system maintenance for a period of 3 years. Testing performed over those first 3 years showed improvements in water quality and clarity, bacteria levels reduced as well as organic sediment reductions. Nutrient levels were also much lower than before the system was installed. After the initial 3 years, Congress Lake decided to hire a local lake company to do it because it was less expensive. The local company recommended that they start to turn the system off during the winter to reduce operating cost and also raise the diffusers 6 feet of the bottom because they felt that was necessary to reduce turbulence.

Oxygen levels can only be increase to the point of the lowest diffuser so once the diffusers were raised, oxygen levels at the bottom plummeted and the bottom turned anaerobic.

As far as we are aware, they continued to run the system like this and may have applied chemicals to the lake over the past 30 years. When I was at the lake in early 2014 the lake looked good but we were told they did have seasonal algae and weeds issues and were looking for a way to reduce chemical usage. To give you an idea of the changes in a design from 1985 to today, the original design in Congress lake used 80 diffusers, whereas our design in 2014 only required 33 diffusers.

Your second site is The Hideout. I assume they are talking about Deerfield Lake which was installed in 2006. This project was implemented through a distributor at the time, Ecoscientific Solutions out of Scranton. Ecoscientific had the Hideout as a customer for lake management services and asked us to put together a design for aeration of Deerfield. We did which they then sold to the Hideout. We shipped the equipment to them and they installed it in March of 2006. We provided them with the initial bioaugmentation program and proposed a budget for future years. Ecoscientific was responsible for doing the maintenance and product applications. Due to a change in personnel at the Hideout, the bioaugmentation program as designed by us was not implemented during the following years due to budget. They applied some product but much less than originally recommended. However even with the reduced program, my understanding was that they were getting results on reduced plant growth which is what they initially wanted. Since we didn't communicate with the Hideout directly over the past 10 years, my understanding is that they decided to replace the system this year because they were having problems with the header pipe that was installed to service the diffusers. We were contacted by the Hideout last year to submit a proposal to install a new system, but I believe they decided to pursue a lesser cost alternative. We had actually proposed a system that would use less horsepower than the original system as well as less cost than the original system.

We have made substantial design improvements since both of these projects were implemented. What we are doing today and the types of projects we are completing versus 10 years ago is drastic. In both cases these customers invited us back in to prepare proposals for replacement systems and in both cases we provided more efficient programs at less cost than the originals. At Congress Lake I don't think they have done anything but continue to run the original system from 1985, and in the case of the Hideout, I think they have implemented a lesser cost system. If these projects were failures, would they even invite us back to submit proposals?

Thanks for the opportunity to explain these 2 projects. We can talk further by phone if needed.

Brian Kling, PE
CLEAN-FLO International
610-431-1934 Ext. 101
www.clean-flo.com
Cleaning Water Biologically

Final Proposal – Clean Flo

Based on using Chestnut and Henning for compressors, The additional cost of the airline, fittings and extra installation time increases the total cost to $123,417. Our offer of a 5% discount on the total cost would make the final total $117,246 plus PA sales tax. Optional location calculation for Summit instead of Chestnut. Summit requires more air line and the total cost would increase by $1,517.

Shed Cost and Installation (2 required) : $ 2000.00

Biological Additives - first year included in base cost (depending on the timing of installation, there may be unused additives in the first year that can get used in 2018.

Electric Installation $ TBD

Total Project Cost: $ 140,00.00

Yearly Maintenance $ 1,600

Yearly Electric Cost $ 600.00

Yearly Biological Additives $10,000 budget – not mandatory but improves results

Yearly Biobase Mapping $1,000 (would be done at the same time every year)