PAW PAW LAKE RESTORATION PLAN

Prepared for Paw Paw Joint Lake Project Committee by JFNew and Spicer Group, Inc.

MAY 2010

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I. EXECUTIVE SUMMARY

In August of 2009, the Coloma Charter Township and Watervliet Charter Township contracted with the Joint Lake Project Committee (JLPC), JFNew, Inc. and Spicer Group, Inc. to prepare a long- and short-term lake restoration plan for Paw Paw Lake. The townships formed a Joint Lake Project Committee (JLPC) to work with JFNew and Spicer as a fact-finding committee for the townships. This plan was initiated to assess and balance vegetation management with water quality and to include an evaluation of dredging and watershed improvements (Appendix A).

An initial planning session resulted in a project plan outlining several steps to prepare both a short-term and long-term management plan for the lake. This project plan was developed and the following work items were completed in order to determine a balanced approach to management of the lake:

1. Utilize the background data and bathymetric survey prepared by Spicer Group and presented in the "Paw Paw Lakes and Watershed Management Plan" prepared for the Paw Paw Lake Foundation.
2. An Eckman dredge was used to collect 21 bottom sediment samples throughout the lake. The samples were taken in order to determine the bottom sediment characterization. All of the samples were analyzed for total phosphorus and 7 of the samples were analyzed for heavy metals (Appendix B).
3. Pole samples were taken in areas of the lake which were shallower than 15'. A total of 22 pole samples were taken to determine the bottom characterization in the shallower portions of the lake.
4. The electronic data gathered by the 2007 bathymetric survey was calibrated with the results from the Eckman dredge and pole sampling data to characterize the bottom of the lake into four main bottom characteristics: sand, sand/silt, silty muck, and silty muck over sand.
5. The bottom sediment water quality analysis was evaluated to determine the effectiveness of dredging to limit phosphorus inputs to the lake and to determine any restrictions of the material for land application of dredged materials.
6. A late summer 2009 aquatic vegetation assessment was completed to assess the effectiveness of the 2009 herbicide treatments. This information was utilized to make adjustments to chemical applications for the recommended 2010 Vegetation Control Plan (Appendix C).
7. A meeting was held with the JLPC to review the data that was collected and to review the effectiveness of dredging and other lake management methods on limiting the phosphorus inputs to the lake waters. Since the bottom sediments were found to have extremely high concentrations of phosphorus, it was determined that other alternative methods for managing or controlling phosphorus in the lake other than dredging and chemical treatment of vegetation needed to be evaluated further. Additional methods to be assessed included the use of alum, mechanical harvesting of vegetation, aeration, use of milfoil weevils, and water level management.

8. An evaluation of the costs of different alternatives and their respective effect on removal of phosphorus from the lake was evaluated. This information was prepared and presented to the JLPC to determine the initial recommendation for restoration of the lake.
9. A recommended restoration plan was drafted for review with the JLPC. A review session was conducted to evaluate the cost effectiveness of the alternatives.

The bottom sediments were found to have extremely high concentrations of phosphorus. Spicer Group's 2008 Lakes and Watershed Study also determined there were several drains (inclusive of but not limited to the Branch & Derby Drain) that were contributing phosphorous into the lake. Dr. Wally Fusilier, Consulting Limnologists, Water Quality Investigators found in studies, conducted between 2004-2008, that the bottom of the lake goes anoxic (without oxygen) at various times of the year. Together, these conditions result in the release of phosphorous into the water column and available for plant uptake. Of these various sources of phosphorous, it was determined that the bottom sediments are the main source of phosphorus in the water column and the cause of the excessive weed growth and noxious algal blooms.

As a result of these preliminary findings, it was determined that a balanced approach was needed to address both the phosphorous loading in the lake and the control of nuisance aquatic weeds. Methods that were assessed to address these issues were divided into three categories: (A) Alternatives for removing or binding up phosphorous that is readily available for plant uptake, (B) Alternatives for removing or binding up phosphorous that is not readily available for plant uptake, and (C) Alternatives that do not remove or bind up phosphorous but do control nuisance aquatic weed growth. Each alternatives method was evaluated for use as part of the lake restoration plan, either individually or collectively, and is briefly summarized below:

(A) <u>Removing/Binding of Phosphorous Readily Available for Plant Uptake</u>:

1. <u>Controlling Watershed Inputs</u>: Limiting phosphorous inputs from upstream sources within the contributing watersheds. This was evaluated in Spicer Group's 2008 Lakes and Watershed Study and includes long-term maintenance of the watercourses which convey phosphorous laden sediment to the lake. The annual estimated input of phosphorus from the watershed (e.g. Branch & Derby Drain, Little Paw Paw Lake Drain, etc.) is approximately 1.8 tons.

2. <u>Mechanical Harvesting</u>: Harvesting vegetation results in an immediate removal of phosphorus from the lake. Using harvesting as a part of a long-term management approach could effectively account for 1.3 tons/year of phosphorus removal per year from the lake. However, the amount of phosphorous removed per acre is much less, and there can be measurable losses to fish.

(B) Removing/Binding of Phosphorous Not Readily Available for Plant Uptake:

Binding of phosphorus within the bottom sediments has shown to be a cost effective approach to limiting the available phosphorus for nutrient uptake by the algae and aquatic vegetation. Several alternative methods were evaluated to determine the cost effectiveness of binding phosphorus in the bottom sediments. Three methods were found to be practical approaches:

1. Dredging of Bottom Sediments: Dredging of bottom sediments provides a direct removal of phosphorus that is bound up in the sediments from the lake. As noted earlier, this phosphorous is not readily available until oxygen levels are reduced along the sediment/water interface. Although the cost per ton of phosphorous removed from the lake decreases with the amount being removed, this alternative is the most costly of the alternatives explored. It is estimated to remove nearly 90% of the phosphorous load in the lake, using this alternative may cost upwards of $34 million dollars. These estimates also utilize only the removal of one foot of sediment from the lake and if phosphorous concentrations are found deeper in the sediments, than there would be even greater costs.

2. Alum: The use of alum or aluminum sulfate $Al_2(SO_4)_3$ is a method used to bind up phosphorous within the bottom sediments/substrates of lakes and ponds. It has proven effective in some instances to also remove phosphorous from the water column when used in a liquid form. Effective times for a one-time treatment have varied from 2 years to upwards of 10 years. Additional water quality analysis is needed before long-term effectiveness can be better assessed and before such a program can be implemented.

3. Aeration: Aeration is a method used to counteract the anoxic conditions occurring in Paw Paw Lake and prevents phosphorous from leaving the bottom sediments and being released into the water column. This conditions which typically happens from early summer to mid fall causes the release of phosphorus from the high concentrations in the bottom sediment. Providing aeration during these time periods keeps the phosphorus bound up in the organic matter at the bottom of the lake. Aeration also serves to promote decomposition of organic matter and reduce nuisance weed growth.

(C) Controlling Nuisance Weeds:

1. Herbicides: 1-year, 5-year and 10-year plans are provided for controlling the nuisance growth of undesirable plant species in the lake. These plans are recommended in conjunction with one or more the recommended methods for removing phosphorous of the lake to move towards restoration of the lake and more native plant communities. The use of Fluridone (SONAR) was recommended for attempting to completely eradicate Eurasian water milfoil

(*Myriophyllum spicatum*) in 2010 and then performing spot treatments in subsequent years to control this invasive non-native species.

2. Weevils: The use of biological controls was evaluated and found to be effective in small lakes. However, similar results and data for larger lakes are lacking. We do not have a high level of confidence this method/alternative will effectively work over this large of an area and do not recommend its lake-wide use until further data and results are available for review. However, its use in a small area of the lake is recommended and encouraged.

Recommendations:
The recommended long-term restoration plan is to utilize a multi-faceted approach to both help control nuisance aquatic weed species (specifically Eurasian water milfoil) and restore the lake (by removing and binding up phosphorous which is accelerating eutrophication of the lake).

To eradicate Eurasian water milfoil, Fluridone (a.k.a. SONAR) is recommended to be applied throughout the entire lake in 2011, with spot treatments of 2, 4-D in subsequent years. Applying herbicides other than SONAR and/or in only portions of the lake will not eradicate this species as effectively as SONAR.

To control phosphorous in-loading in the lake two different methods are recommended to be implemented, on a small scale in a portion of the lake (as pilot studies), to evaluate the effectiveness of these methods within Paw Paw Lake – before committing to a lake-wide use of one or more of these methods. The two methods recommended for pilot study, within the northeast portions of the lake, are (1) the use of Alum (aluminum sulfate) to precipitate and bind phosphorous in the water column and bottom sediments and (2) Aeration of the water column and bottom substrates to limit phosphorous release from sediments during anoxic time periods.

These two methods are being recommended as "pilot studies" for upwards of 5 years, less if findings are conclusive sooner, to determine which method better addresses the phosphorous in-loading problem in the lake. Use of these methods on a smaller scale, instead of lake-wide, will help to better evaluate and demonstrate the effectiveness of the treatments.

II. INVESTIGATIVE METHODS

A. Paw Paw Lakes and Watershed Study

In February of 2008 Spicer Group, Inc. completed a report for the Paw Paw Lake Foundation entitled "Paw Paw Lakes and Watershed Study." This report utilized previous studies that were completed of Big Paw Paw Lake, field investigations, surveying, modeling, and inspection of Paw Paw Lake, Little Paw Paw Lake, Lake Stella, and their collective watershed. The intent of the study was to determine the watershed effects on water quality, with an understanding of the sources and fates of pollutants in the watershed. This report and study, in addition to previous work on the lakes and watershed, serve as a basis for recommending Best Management Practices to improve water quality within the lakes.

A hydrographic survey of the lakes was completed using dual frequency sonar equipment in August 2007. Paw Paw Lake Foundation (PPLF) volunteers supplemented this survey with pole soundings of sediment depth in six locations within Paw Paw Lake. Maps showing the bathymetry (i.e. contours) of the lakes, and the distribution of accumulated sediment within the lake were produced (See Drawing A of Appendix D).

A preliminary inspection of the drains tributary to the lakes was completed. The inspection provided an understanding of the hydrology, sedimentation and nutrient contribution for the lake system. This resulted in an appreciation for the holistic approach to managing the lake systems, meaning that the health of the lake system was dependent on the overall health of the contributing watershed. Unless problems and issues identified in the watershed are also addressed, any actions in Paw Paw Lake will not provide long-term solutions for improving the lake water quality.

A study of the water budget and nutrient input into Paw Paw Lake was developed and included information and data related to annual precipitation, inflow, outflow, runoff, evaporation and surface water withdrawals. The residence time for Paw Paw Lake was determined to be 2.3 years. When the Long–Term Hydrologic Impact Assessment (L-THIA) model was developed using soil type and land use information, a nutrient flux from the watershed area was provided for nitrogen, phosphorus and other pollutants as input into Paw Paw Lake. A determination was made that phosphorus was the limiting nutrient for the lake system.

Significant sources of nutrients and sediment in the watershed include residential areas (especially those near the lakes) as well as agricultural areas in the upper watershed. The continued eutrophication problems in the lake are also due in part to internal recycling of nutrients (i.e. nutrient-rich sediment releases phosphorus into the water column during anoxic conditions in the summer months). Between the increasing bottom sediments and the steadily increasing nutrient levels from lands in the watershed, the water quality of Paw Paw Lake continues deteriorating each year. Accelerated weed and algae growth and poor water clarity will continue until nutrient levels are reduced.

Recommendations for lake improvement from the 2008 Spicer Group's Lakes and Watershed Plan are summarized as follows (with specific attention on Paw Paw Lake):

1. **Aquatic Vegetation Management & Habitat Survey-**A detailed aquatic vegetation survey and development of an aquatic vegetation management plan/strategy is important in lake management. The resource value of each vegetative community should be understood before widespread treatment plans are developed.
2. **Continue Water Quality Monitoring Efforts-**Continued monitoring of water quality within the lakes and watershed is recommended. Regular monitoring of water quality provides more information for management decision making and serves to document baseline conditions and improvement within the lakes watershed.
3. **Begin a Watershed Management and Public Education Program-**Establishing a supportive, informed, involved base of citizens will be a critical factor in protection and improvement of the lake.
4. **Establish and Implement Drain Inspection & Maintenance Plan-**Open and tile drains and other tributaries convey water and pollutants to the lake. Maintenance of these drains to reduce the sediment load reaching the lake will provide a direct water quality benefit.
5. **Shoreline Survey-**Complete a detailed survey of shoreline land use and material. Develop demonstration site(s) of shoreline stabilization and management techniques for public education.
6. **Design and Pursue Implementation Funding for Water Quality Retrofits for Immediate Areas-**Develop a conceptual plan for low-impact development retrofits aimed at improving water quality in the "immediate area" watersheds. Pursue funding to implement demonstration site(s) for public education, possibly including rain gardens, drain inlet protection, rain barrels, soil testing and fertilizer alternatives, pervious pavement, etc.
7. **Dredging Assessment and Dredge Plan Development-**Complete a preliminary analysis of dredging plans for Paw Paw Lake and/or Little Paw Paw Lake. Assessment to include focus on areas for dredging, estimates of material to be removed, and disposal options.
8. **Establish Lake Improvement Board and/or Special Assessment District-**Establishment of a funding mechanism for lake improvements is necessary for sustained improvements to Paw Paw Lake.
9. **Review and Revise Township and/or County-wide Ordinances-**Review existing township ordinances that may impact water quality. Propose and pursue implementation or a limit or ban on phosphorus-based fertilizers for residential use in the watershed and encourage low-impact development and proper shoreline management within the watershed. Ordinance review might include zoning, master plans, recreation plans, nuisance weed ordinances, storm water management plans/policies, etc.
10. **Paw Paw Lake Economic Analysis-**Complete a study of riparian property values and water resource quality for the Lakes. This analysis would be a public education tool and aid in demonstrating what level of investment in the lake is appropriate.

B. Aquatic Vegetation Assessments

In order to understand the extent and magnitude of aquatic nuisance plant species in Paw Paw Lake, Aquatic Vegetation Assessment Surveys (AVAS) were conducted both before and following herbicide treatments of the lake. Herbicide treatments were performed in June of 2009 for nuisance exotic plant species, specifically, Eurasian water milfoil. The pre- and post-treatment surveys were conducted on May 24 and August 29, 2009, respectively. The surveys were conducted using the MDEQ (now MDNRE) Procedures for Aquatic Vegetation Surveys. Details on how the surveys were conducted are provided in JFNew's Paw Paw Lake Aquatic Vegetation Report dated November 2009 (Appendix C).

The survey was initiated by mapping out 157 transect lines around the shoreline of the entire lake on 300-foot intervals to fully represent all areas of the lake (Figure 1). The location of these study-transect areas were located using Thales GPS units having sub-meter accuracy. Within each transect area, roughly 30,000 (300 x 100 ft) square feet in size, the aquatic biologists zig-zagged through the area taking two or more rake tosses to a depth of 15 feet and identifying and recording the findings of plant species present and their densities for each rake toss within each area. This enabled a representative sampling and mapping of the entire littoral zone of the lake. Figure 2 shows the littoral zone areas of the lake that were assessed during the May and August 2009 AVAS.

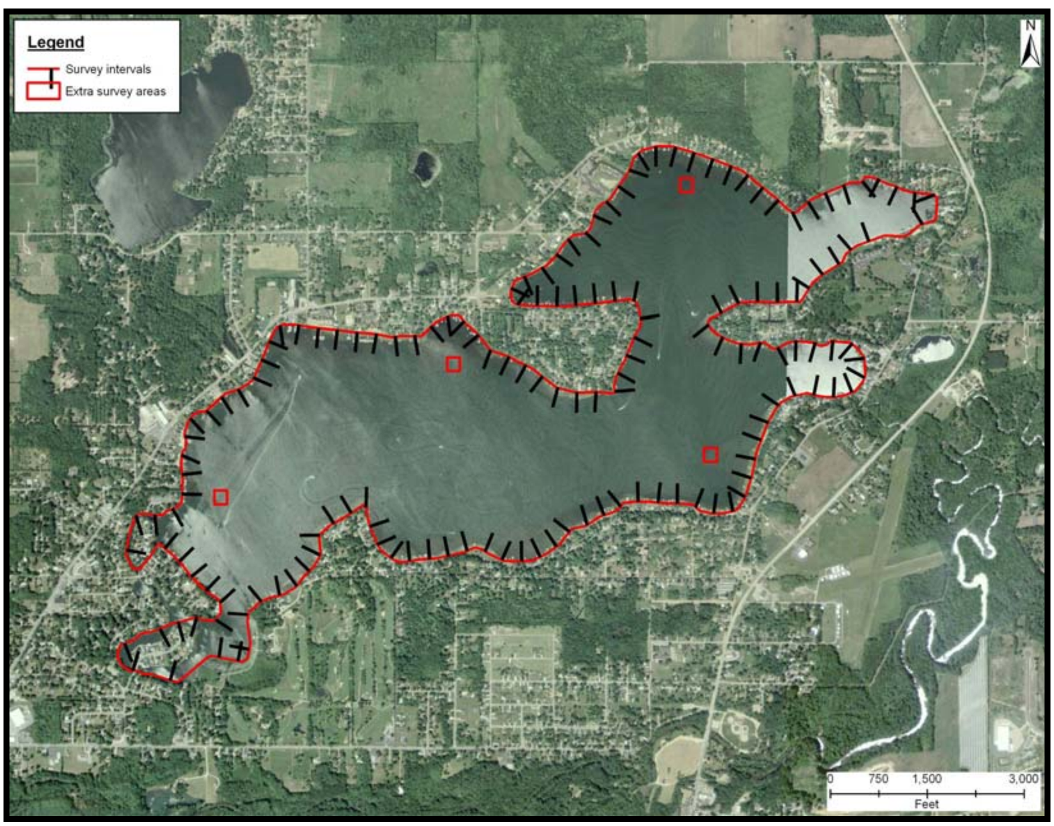

Figure 1. Location of transects surveyed on May 29 and August 24, 2009.

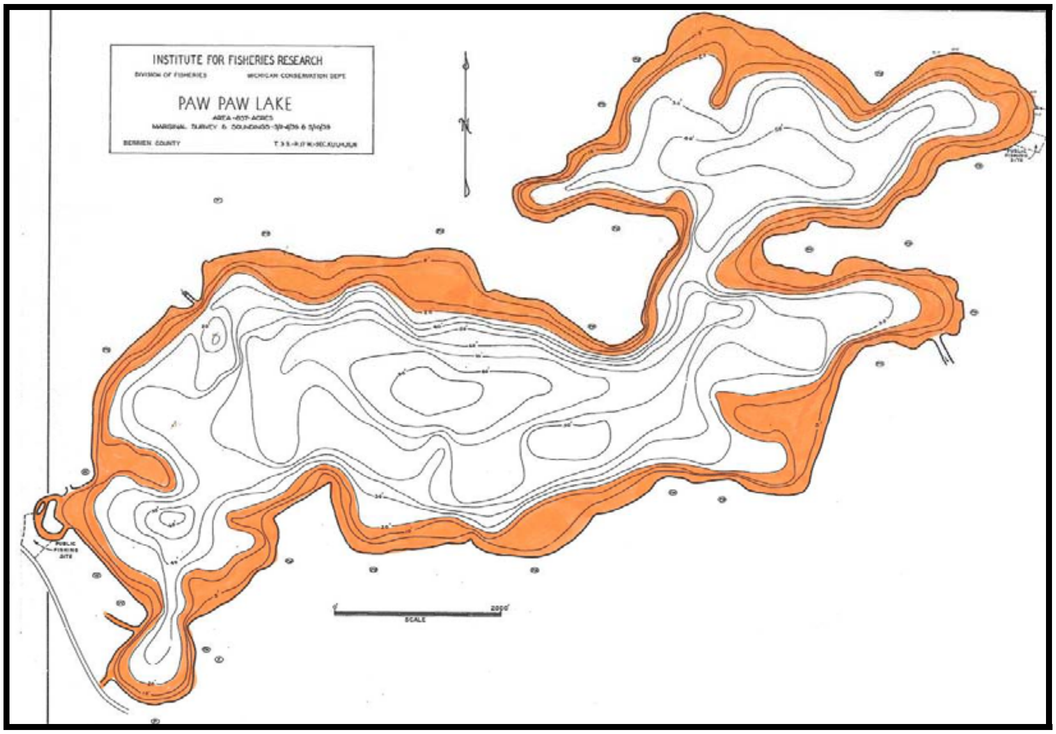

Figure 2. Littoral zone surveyed on May 29 and August 24, 2009 (also provided as Drawing B of Appendix D).

In comparing the pre-treatment and post-treatment locations and densities of Eurasian water milfoil, Drawings C-E of Appendix D, the herbicide treatments did not fully eradicate this species from the lake. Maps of the proposed treated areas were provided but were not included in this report since we can't confirm or deny that they accurately represent the areas of treatment. However, based on these maps, it is our opinion that the proposed treatment areas are poorly spaced and do not provide a good treatment coverage and, therefore, the results seen in the August 2009 data was not overly surprising. To which future treatments that target this plant will recommend complete coverage of the lake.

C. Bottom Substrate Assessments

In May and June 2009, the bottom substrates of the lake were assessed using a small boat and an Eckman dredge to take 21 bottom surface sediment samples throughout the lake. The location of each sample was recorded with a GPS mapping unit with sub-meter accuracy. The bottom substrates at each location were assessed with respect to its consistency and amount of muck, silt, sand or clay that was present. The term "muck" was used to represent the detrital, dead plant, and unconsolidated material that covered a large portion of the lake bottom.

All 21 of the bottom sediment samples were tested for total phosphorous while 7 were tested for heavy metals. The 10 heavy metals that were tested were arsenic, barium, cadmium, chromium, copper, lead, selenium, silver, zinc and mercury (a.k.a. 10 Michigan Metals). Phosphorus has been determined as being the limiting factor for biological growth in the lake so was determined to be the nutrient to be evaluation. Heavy metals were determined on several of the samples in order to understand if there would be concerns as it relates to disposal of dredged materials. Table 1 summarizes the results of the phosphorous and heavy metals analysis of the bottom substrates in the lake.

Table 1. Sediment Analysis of Paw Paw Lake Deep Water Bottom Substrates (highlighted results are above statewide default background levels for the disposal of dredged spoils)

		Michigan Statewide Default Background Levels (parts per million)									
Substrate Sample Location	Phosphorous (ppm)	Arsenic (5.8)	Barium (75)	Cadmium (1.2)	Chromium (18)	Copper (32)	Lead (21)	Selenium (0.41)	Silver (1)	Zinc (47)	Mercury (0.13)
1.00	980	12	230	1.1	20	55	72	1.7	U	180	U
2.00	3000	0	0	0	0	0	0	0	0	0	0
3.00	8600	7.2	170	1.1	18	35	49	0.96	U	180	U
4.00	1400	0	0	0	0	0	0	0	0	0	0
5.00	110	0	0	0	0	0	0	0	0	0	0
6.00	1100	13	210	0.76	17	43	59	1.4	U	150	U
7.00	220	8.5	150	0.98	21	40	79	1.3	0.11	170	U
8.00	23	0	0	0	0	0	0	0	0	0	0
9.00	860	0	0	0	0	0	0	0	0	0	0
10.00	38000	0	0	0	0	0	0	0	0	0	0
11.00	15000	14	190	1	16	47	87	1.9	U	170	U
12.00	52000	0	0	0	0	0	0	0	0	0	0
13.00	99	0	0	0	0	0	0	0	0	0	0
14.00	2000	5.5	94	0.5	9.1	20	30	0.89	U	83	U
15.00	980	0	0	0	0	0	0	0	0	0	0
16.00	1400	0	0	0	0	0	0	0	0	0	0
17.00	230	0	0	0	0	0	0	0	0	0	0
18.00	1000	0	0	0	0	0	0	0	0	0	0
19.00	520	12	210	1.2	18	75	88	2	0.11	190	U
20.00	25	0	0	0	0	0	0	0	0	0	0
21.00	410	0	0	0	0	0	0	0	0	0	0

U = below level of detection

= will require (1) disposal at a licensed landfill or (2) placement of a soil cap and a deed restriction on the property used for disposal

In June 2009, 21 additional bottom substrates in the near shore areas, within water depths of 20 feet, were taken (Drawing B of Appendix D). These substrates were assessed using over 30 feet of PVC pipe to determine the nature of the bottom substrates and probe through them to determine their profile and in many cases the thickness of muck (dead plant material and suspended material) that overlaid the hard pan bottom sediments (comprised of silt, sand, loam and/or clay).

These 21 bottom substrate assessments obtained in 2009 were added to additional bottom substrate assessments obtained by Spicer Group in 2008 and together were analyzed with the echo soundings Spicer Group did of the lake to create a Lake Bottom Characterization Map of the lake (Drawing F of Appendix D).

D. Classification of Sediment with Echo Sounders

Spicer Group completed a bathymetric survey of Paw Paw Lake, Little Paw Paw Lake, and Lake Stella in August of 2007. Spicer Group collected cross sections on the lakes spaced 400 to 600 feet apart using a 200 kHz and 24 kHz dual frequency echo sounder and developed a five foot interval contour map as a final product of the survey.

From the readings obtained with the two different frequency echo sounders a digitalization was made of the bottom characteristic of the lake. Each transducer reports an acoustic energy from the bottom which is converted to an electrical energy. A series of digital signal processing algorithms is applied to the digitized data. These algorithms extract different kinds of information from the data. Each algorithm generates a series of values or features. The features are broken down into three different components; Q1, Q2 and Q3 (Figure 3).

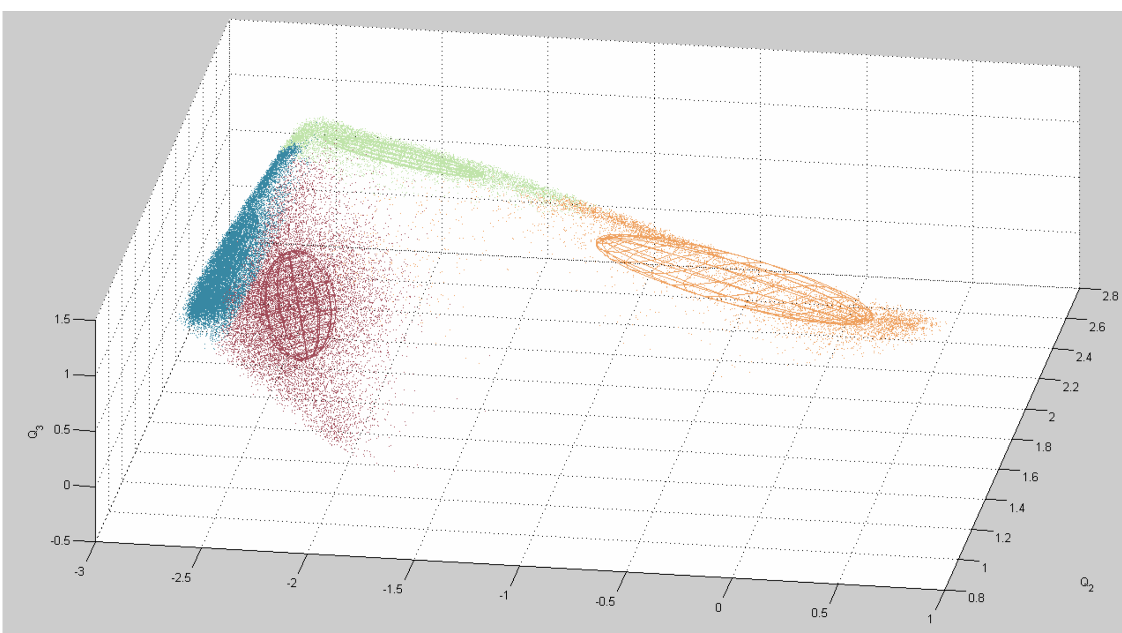

Figure 3. Q1, Q2 and Q3 representations of echo signal.

Spicer Group used the QTC Impact program to mine hundreds of characteristics from raw echo sounder data and summarize the characteristics into three representative parameters Q1, Q2 and Q3 for each collected ping of the echo sounder. The program was then used to create a statistical best fit of the four bottom classes into the cloud of Q parameters.

In November 2009, Spicer Group and JF New teamed together to create a map of the bottom characteristics of Paw Paw Lake. To create the map, Spicer Group used QTC Impact software to statistically categorize the 200 kHz echo sounder data into four classes to provide a direct correlation to Eckman dredge results from JF New. Echo sounder points collected in water shallower than five feet recorded too high of an amplitude to allow for analysis of the echo and, therefore, were excluded from the analysis.

Each collected echo sounding was then assigned its resulting class as shown in Figure 4 below.

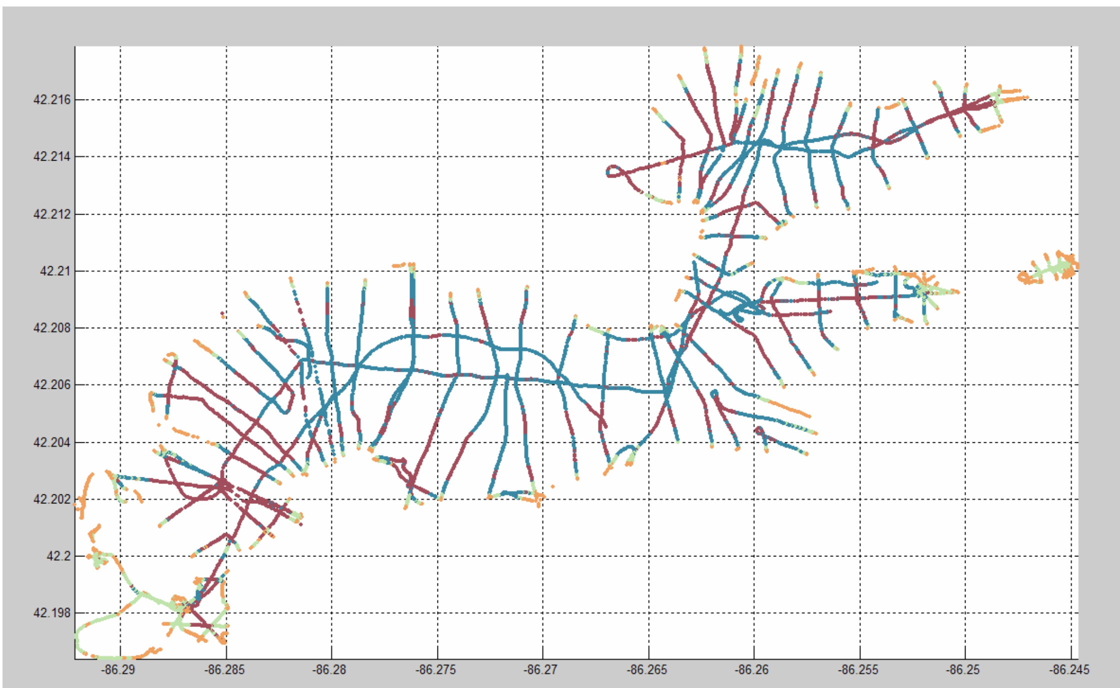

Figure 4. Echo soundings of Paw Paw Lake.

The points were then inserted into ArcGIS and polygons were drawn to represent the collected lines. The Eckman dredge results were summarized into the following four classes of bottom material: Sand, Sand/Silt, Silty Muck, Silty Muck/Sand. These dredge results were overlaid onto the classified polygons. A percentage of each type of bottom material was determined for each bottom class and the percentage majority was then selected as the representative material. Drawing F of Appendix D, and Figure 5 shown below, illustrates the resulting polygons smoothed out across the lake. This map provides a visual representation of the lakebed and material type to be encountered.

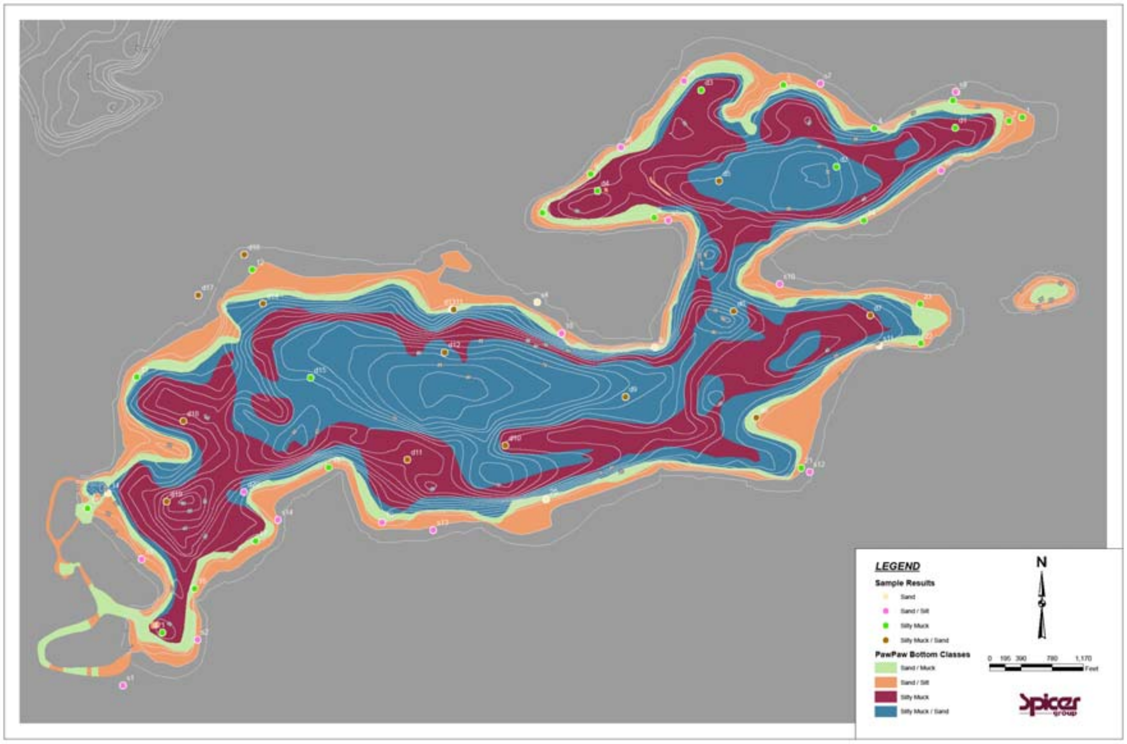

Figure 5. Lake Bottom Characterization Map.

III. RESTORATION ALTERNATIVES

A. Paw Paw Lake Dredging

Sediment is a mixture of inorganic and organic materials either deposited or washed into a lake or surface water body. Typically silt is washed into lakes from surrounding watersheds; the impact of the watershed input was characterized for Paw Paw Lake in the previous study completed by Spicer Group. Other forms of sediment in lakes come from biodegradation of organic matter such as aquatic plants and algae blooms. Based upon the bottom sediments that were analyzed, it can be concluded that a significant input to sedimentation in Paw Paw Lake is from within the lake.

As lakes do fill in, many interesting habitats occur – the process of infill itself is of interest and value and should ideally be allowed to proceed without interference. Sediment in lakes has various valuable attributes. They are as follows:

- a substratum for plants and hence many associated organisms;
- a source of energy for the lake ecosystem;
- a chemical buffering function;
- a source of an archeological record.

However, there are problems associated with sediment. Land use issues, poor watershed management and excessive erosion result in excessive quantities of sediment from contributing watersheds. Bound to sediments are phosphate and nitrate-based nutrients a cause of eutrophication to lakes, poor water quality and algal blooms.

Dredging is a method to remove excessive phosphorus from Paw Paw Lake. A large portion of the phosphorus can be found in the first foot of sediment at the bottom of the lake. Paw Paw Lake encompasses about 880 acres, and dredging the first foot of sediment over the entire lake would result in approximately 1.4 million cubic yards of material. Costs for a dredging project would be between $1 million and $35 million depending on the level of phosphorous removal and Sub Areas being dredged (Table 2).

In an attempt to reduce costs, the lake's sediment has been analyzed to determine what portions of the lake would most benefit from the dredging process. Targeting the dredging at locations with higher phosphorus content provides the best cost benefit ratio. Figure 6, Drawing G of Appendix D, shows the lake broken down by the concentration of phosphorus found in the sediment. If the dredging were to occur strategically, focusing on locations where the sediment is at levels of 750 mg/kg and higher, approximately 99% of the phosphorus could be removed while only dredging about 66% of the lake. Estimated costs to dredge the various portions of the lake are outlined in Table 2 below.

Location	Acre	Cu. Yds.	Dredge Cost	Reported Phosphorous (ppm)	Tons of Sediment	tons of P	$/ton of P-Removed
12	34.5	55714.3	$ 1,392,857.41	52000	36,102,864.00	938.7	$ 1,483.86
10	60.7	97938.52	$ 2,448,462.96	38000	63,464,160.00	1,205.8	$ 2,030.54
11	53.3	86064.48	$ 2,151,612.04	15000	55,769,784.00	418.3	$ 5,144.04
3	43.9	70833.96	$ 1,770,849.07	8600	45,900,408.00	197.4	$ 8,972.16
2	54.6	88069.93	$ 2,201,748.15	3000	57,069,312.00	85.6	$ 25,720.19
14	33.8	54519.74	$ 1,362,993.52	2000	35,328,792.00	35.3	$ 38,580.28
4	34.6	55820.52	$ 1,395,512.96	1400	36,171,696.00	25.3	$ 55,114.68
16	8.1	13024.26	$ 325,606.48	1400	8,439,720.00	5.9	$ 55,114.68
6	50.1	80819.33	$ 2,020,483.33	1100	52,370,928.00	28.8	$ 70,145.96
18	52.5	84650.59	$ 2,116,264.81	1000	54,853,584.00	27.4	$ 77,160.56
1	37.9	61220.74	$ 1,530,518.52	980	39,671,040.00	19.4	$ 78,735.26
15	45.9	74003.3	$ 1,850,082.41	980	47,954,136.00	23.5	$ 78,735.26
9	70.1	113116.8	$ 2,827,919.44	860	73,299,672.00	31.5	$ 89,721.58
19	38.0	61336	$ 1,533,400.00	520	39,745,728.00	10.3	$ 148,385.69
21	32.1	51761.52	$ 1,294,037.96	410	33,541,464.00	6.9	$ 188,196.48
17	2.5	4109.667	$ 102,741.67	230	2,663,064.00	0.3	$ 335,480.68
7	40.2	64878.15	$ 1,621,953.70	220	42,041,040.00	4.6	$ 350,729.80
5	46.4	74841.74	$ 1,871,043.52	110	48,497,448.00	2.7	$ 701,459.61
13	45.1	72740.74	$ 1,818,518.52	99	47,136,000.00	2.3	$ 779,399.56
20	40.4	65132.15	$ 1,628,303.70	25	42,205,632.00	0.5	$3,086,422.27
8	59.1	95296.33	$ 2,382,408.33	23	61,752,024.00	0.7	$3,354,806.82
Totals	**883.8**	**1425893**	**$ 35,647,318.52**		**923,978,496.00**	**3,071**	**$ 11,606.36**

Table 2. Summary of Dredging Costs.

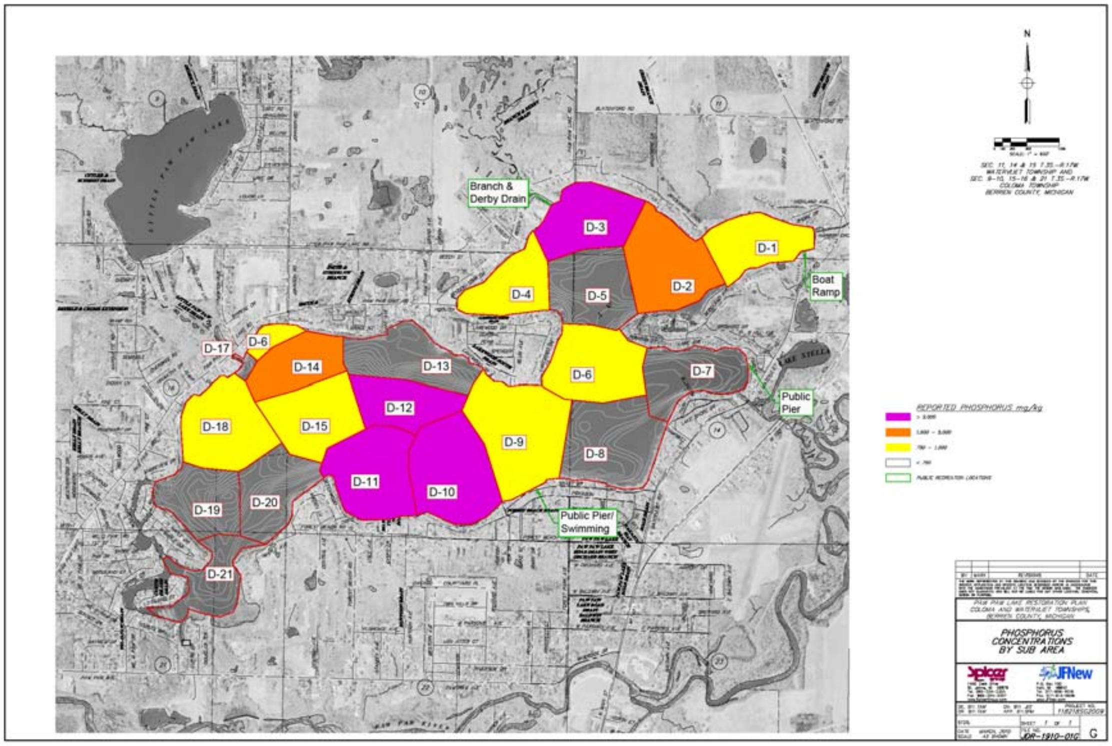

Figure 6. Phosphorous Concentrations by Sub Area.

There are cases where "spot" dredging has helped to control the eutrophication process. However, most studies and management plans point out that dredging of the entire treatment system is necessary to reduce sediment input and siltation within a lake.

Dredging may make the eutrophication process worse by re-suspending and releasing phosphorous, otherwise bound to sediments, into the water column. In the dredging process, a disposal site for the dredged materials must be found. The closer the disposal site is to the lake the less costly the project will become.

Dredging in lakes that are filling in and have less open water area can gain valuable open water acreage. However, that is not an issue at Paw Paw Lake. Dredging lakes is hardly ever desirable on economical and ecological grounds because of the damage that can be caused to the lake, its aquatic resources (e.g. fish, macroinvertebrates) and the surrounding land. Additionally, because of the interest of all the various stages associated with sediment accumulation of lakes, the argument that removing the sediment will remove a source of phosphorous and improve water quality can be made. However, this should not be assumed. Sediment characteristics and chemistry should be investigated first, along with other aspects of sedimentation.

If dredging is carried out, from an ecological point of view it is important to:

- Leave the littoral fringe with marginal vegetation along a significant proportion of the banks;
- Ensure there is a gently graded bank, rather than an abrupt one;

- Leave part of the lake un-dredged so that propagules from aquatic plants can re-colonize quickly;
- Consider the best methods and time of year to do the work.

Recommendation:
At the present time, we do not recommend dredging as a cost-effective alternative especially in comparison to other less costly alternatives (namely Alum and Aeration – to be discussed below). Dredging may be an alternative of further consideration if these other alternatives prove ineffective.

Dredging in isolated areas to provide for navigation and recreation may be considered. Removal of sediments with high phosphorus content will definitely help the overall health of the lake. However, the relative effectiveness is minimal.

B. Aeration

Hypolimnetic aeration is a management strategy to control algae and reduce eutrophic conditions. Aeration of the hypolimnion introduces oxygen into the anoxic zone and creates an oxidizing rather than a reducing environment. The oxidized microzone at the sediment-water interface greatly reduces the transport of phosphorus into the water column by promoting binding/sedimentation of phosphorus (Wetzel 1983; Holdren et al., 2001). Aeration has several advantages and disadvantages that should be considered. Creating oxic conditions improves habitat for fish and invertebrates. However, depending on the specific method of aeration, it may disrupt the thermal layering and break stratification of the lake. Aeration effects are often non-uniform resulting in zones of localized anoxia where phosphorus is still released from the sediment.

In order to keep the hypolimnetic zones from going anoxic aeration is typically done continuously, or if periodically with minimal downtime to maintain oxic conditions at the sediment-water interface. Although infrequently encountered, aeration can cause supersaturation of the water column with nitrogen and expose fish to “gas bubble disease” (Holdren et al., 2001). If aeration is discontinued for a significant length of time the sediment-water interface will turn anoxic and phosphorus will again be released into the water column.

Several lake associations have utilized aeration as a means of reducing phosphorous loading. Discussions were made with members of these lake associations and product providers to further understand and compare the effectiveness of this alternative for controlling phosphorous loading and nuisance weed issues in Paw Paw Lake.

Aeration plans for a lake can be designed to address either specific areas of a lake (e.g. bays, swimming areas) or the entire lake. One lake that was assessed was East Twin Lake, a relatively shallow 900-acre mesotrophic lake in Montmorency County that had aeration units installed in only a portion of the lake. Within that lake approximately 80 acres was identified for aeration. The cost for installing aeration units was approximately $50,000 with an annual maintenance budget of approximately $7,000. The aeration units were installed in 2004, and they are still being used today with good success in limiting weed growth.

Lake Savers, a private engineered aeration company, provided cost estimates for treatment of specific locations within Paw Paw Lake to allow comparison with other methods of weed treatment and reducing phosphorous loading from bottom sediments. A copy of their proposal is available upon request. Costs estimates presented have been based upon the estimates provided adding contingency, evaluation, administrative and engineering costs.

Estimates have been provided for aeration of specific portions of the lake and for full treatment of the lake. The estimates have been provided based on a leasing of the equipment with additional options for purchase and maintenance of the system (Table 3).

Zones	Acres	Costs (5-Yr)	Costs (10-Yr)	lbs of Sediment	tons of Sediment	tons of P	$/ton of P-Contained
D1-D5	217.5	$ 257,000	$ 452,000	227,309,904	113650	350.4	$146.69
D10-D12	148.6	$ 284,000	$ 504,000	155,352,384	77680	2563.0	$110.81
D10-D12 and D1-D5	366.1	$ 541,000	$ 956,000	382,735,584	191370	2893.8	$186.95
Entire Lake	891	$ 877,000	$ 1,562,000	931,487,040	465740	3096.3	$283.24

Table 3. Summary of Aeration Treatment Costs-Leasing.

Recommendation:
We recommend that a pilot project (area) be selected to assess the effectiveness of this alternative within Paw Paw Lake.

At the present time, we recommend leasing aeration equipment for a small area of the lake, such as Areas D-1 and D-2 (northeast portion of the lake) or an even smaller area such as just D-1 (depending on financial resources available), for 3-5 years to assess its effectiveness and applicability to the entire lake. This pilot area is expected to also benefit other areas of the lake given spring turnover and internal flow patterns of water moving oxygenated water into the central and southwestern portions of the lake.

C. Alum

Alum or aluminum sulfate ($Al_2(SO_4)_3$ is a compound that has historically been used for clarifying drinking water, removing phosphorous from wastewater and reducing available phosphorous in the water column and bottom sediments of lakes. This compound is available in both liquid and pellet form. The liquid form is used more commonly with broadcast treatments over large areas and when removal of phosphorous from the water column is desired. The pellet form is used when there needs to be more localized placement of the compound and phosphorous removal/restriction is focused more on the lake bottom-sediment interface. Lime is another compound very similar to alum that has infrequently been used to reduce phosphorous loading. It has been shown to be less effective at binding phosphorous and reducing anoxic rates of release of phosphorous from bottom sediments as compared to alum (James, unpublished).

When alum is added to water it dissociates (i.e. dissolves) forming aluminum ions that hydrate (combine with the lake water), form aluminum hydroxides and then provide adsorption sites for phosphorous to bind to. As phosphorous from the water column continues to bind to the aluminum hydroxide – now an aluminum phosphate compound it grows in size and weight and eventually settles out of the water column and onto the bottom of the lake. Alum has been used to remove phosphorous from the water column of lakes in Michigan and to also create a layer of this coagulated material on the bottom of a lake – suppressing the exchange of phosphorous from the sediments into the water column.

When alum is used in lakes it is typically added to areas below the 10-foot contour of a lake. There can be some level of toxicity to lake organisms including fish if alkalinities are below 75 mg/L as CaCO3. According to Fusilier (2008) alkalinity in the lake has been increasing in the spring (April) sampling periods from 2004 to 2008. Both the April and August 2008 sampling periods showed alkalinity measurements above 80 mg/l. With these measurements, we would not expect adverse impacts to aquatic organisms.

Alum can be an effective means of controlling (reducing by upwards of 80%) internal phosphorous cycling in lakes based on studies conducted by Welsh and Cook (1999) and Steinman and Ogdahl (2008). The ability for alum to remain on the lake bottom is subject to disturbances by fish such as carp (*Cyprinus carpio*) that may disturb bottom sediments and reduce the effectiveness of alum. Dredging activities will also reduce the effectiveness of alum to cover bottom sediments and reduce their ability to release phosphorous into the water column.

Several lakes that have utilized alum as a means of reducing phosphorous loading in the water column, from bottom sediments and for reducing aquatic weed growth were assessed. Discussions were made with members of their lake associations and commercial applicators of these products.

From 2003-2004, the Spring Lake Association, in association with Grand Valley State University, studied the physical and chemical features of their lake, Spring Lake, a 1,100-acre lake in Ottawa County, Michigan. Over the years, Spring Lake experienced algal blooms and dense nuisance weed problems. In 2005, liquid alum was used to treat Spring Lake, which is a drowned river mouth of the Grand River.

To date, Spring Lake has shown a significant drop in Total P in the water column (an approximate 50% reduction), a reduction in algal blooms, a reduction in nuisance weeds and an increase in fishing success (John Nash, 2010 personal communication). The cost for the alum treatment was $1,000,000 with an estimated cost per riparian of $200/year for 20 years. Although Paw Paw Lake is slightly smaller in size than Spring Lake (891 acres vs. 1,100 acres) cost estimates should be fairly comparable when comparing their 2005 costs to the present day with a smaller lake system.

Two more lakes are provided here for further comparison. Lake Pokenpaw, a 500 +/- acre lake in Connecticut utilized alum with a base cost of approximately $250,000 (John Tucci, 2010 personal communication). A summary of various alum treatments in Wisconsin lakes showed the cost for applying alum to range from $280/acre to $700/acre depending on the dosage requirements and the costs to mobilize equipment (Wisconsin Dept. of Natural Resources, 2003).

To use this compound to extract soluble phosphorous from the water column and bind it to bottom sediments, it will require at least a year of chemical analysis from a professional experienced in these matters. Dr. Steinman of Grand Valley State University (GVSU) worked with Spring Lake Association for two years studying the chemical composition and anticipated interactions of an alum treatment on their system.

If the Townships and Association are interested, we will make further contact with GVSU inquiring about their interest in possibly conducting a research study of specific areas of the lake to test the effectiveness of alum. Lake-wide chemical analysis can be costly and time consuming. At the present time, we know of only two private companies that offer this service and costs for alum treatments can vary greatly depending on lake morphology, water chemistry and other physical features. This method has not been used on many larger lakes in Michigan; however, it has been used effectively on smaller waterbodies and other lakes in other States. The cost associated with alum treatments within each of the sub areas is provided in Table 4.

Recommendation:
We recommend that a pilot project (area) be selected to assess the effectiveness of this alternative within one of two areas on the lake. The two locations are (1) D-10, D-11 and D-12 which is the area of highest phosphorous concentrations in the lake and (2) D-2 which is a secluded bay in the northeast corner of the lake. The latter location is highly recommended since it is smaller in size, less expensive to treat, and will provide a good side-comparison to aeration that is being recommended in the eastern portion of this same northeast bay of the lake. We also recommend further water quality analysis and bottom substrate sampling to assess the effectiveness of using alum on a lake-wide basis.

Location	Acre	Alum Cost	Reported Phosphorous (ppm)	tons of sediment	tons of P	$/ton of P- Contained
12	34.5	$ 120,867.79	52000	18,051	938.7	$ 128.76
10	60.7	$ 212,469.93	38000	31,732	1,205.8	$ 176.20
11	53.3	$ 186,710.14	15000	27,885	418.3	$ 446.38
3	43.9	$ 131,716.05	8600	22,950	197.4	$ 667.35
2	54.6	$ 163,766.39	3000	28,535	85.6	$ 1,913.07
14	33.8	$ 101,379.68	2000	17,664	35.3	$ 2,869.61
4	34.6	$ 86,498.74	1400	18,086	25.3	$ 3,416.20
16	8.1	$ 20,182.22	1400	4,220	5.9	$ 3,416.20
6	50.1	$ 100,189.26	1100	26,185	28.8	$ 3,478.31
18	52.5	$ 104,938.75	1000	27,427	27.4	$ 3,826.14
1	37.9	$ 56,920.11	980	19,836	19.4	$ 2,928.17
15	45.9	$ 68,804.72	980	23,977	23.5	$ 2,928.17
9	70.1	$ 70,113.71	860	36,650	31.5	$ 2,224.50
19	38.0	$ 38,018.18	520	19,873	10.3	$ 3,678.98
21	32.1	$ 32,083.59	410	16,771	6.9	$ 4,666.03
17	2.5	$ 2,547.31	230	1,332	0.3	$ 8,317.70
7	40.2	$ 40,213.73	220	21,021	4.6	$ 8,695.78
5	46.4	$ 46,389.51	110	24,249	2.7	$ 17,391.56
13	45.1	$ 45,087.24	99	23,568	2.3	$ 19,323.96
20	40.4	$ 40,371.17	25	21,103	0.5	$ 76,522.87
8	59.1	$ 59,067.98	23	30,876	0.7	$ 83,177.03
Totals	**883.8**	**$ 1,728,336.17**		**461,989**	**3,071**	**$ 562.73**

Table 4. Summary of Alum Treatment Costs.

D. Chemical Herbicide Treatments

The use of herbicides is the most commonly used method for controlling aquatic nuisance plant species and algal blooms. The primary reason for this being that in comparison to other available methods, herbicides can be applied directly to a problem area, you can see immediate results and the costs are comparatively less expensive. However, this method does not address the nutrient load and/or site conditions that create ideal habitats and conditions for these nuisance plant and algal species to persist. Use of herbicides to kill plant species does not result in a measurable amount of phosphorous being removed from the water column. The herbicide treatment removes plant species which serve to extract phosphorous from the sediments and water column leaving more phosphorous for remaining and/or new plant growth to utilize.

The results of the 2009 AVAS and discussions with riparians around the lake indicate that use of herbicides, specifically 2,4-D, was mostly effective in reducing the density of Eurasian water milfoil and opening up areas of the lake for recreational activities. Unfortunately the post-treatment survey also showed that the untreated areas and some of the treated areas still had regenerating and rigorous growths of the species.

The dominant plant species found in Paw Paw Lake include Eurasian water milfoil, coontail, and Cladophora, a filamentous alga (Table 1 of Appendix C), with Eurasian water milfoil being the most dominant and prolific throughout the lake. Eurasian water milfoil was identified at 100% of the AVAS's and at the greatest density 65% of the time. Eurasian water milfoil was common at 27% of the AVAS's, sparse at 6% of the AVAS's, and only one or two plants were found at 1% of the AVAS's. Tables and figures showing the extent of these species in the lake are provided in JFNew's Paw Paw Lake Aquatic Vegetation Report dated November 2009 (Appendix C).

During the pre-treatment survey, Eurasian water milfoil dominated the plant community throughout the littoral zone (0-15 feet; Table 1). Throughout the surveyed littoral zone, Cladophora and coontail were relatively frequent and were found at 91% and 87% (Figure 8) of the sites, respectively (Table 1). Chara, another alga, was also identified at 55% of the sites surveyed in the littoral zone. There were additional native submergent plant species identified during the survey including thin-leaf pondweeds, Illinois pondweed, Large-leaf pondweed, wild celery, submergent arrowhead, native milfoil, najas species, and sago pondweed.

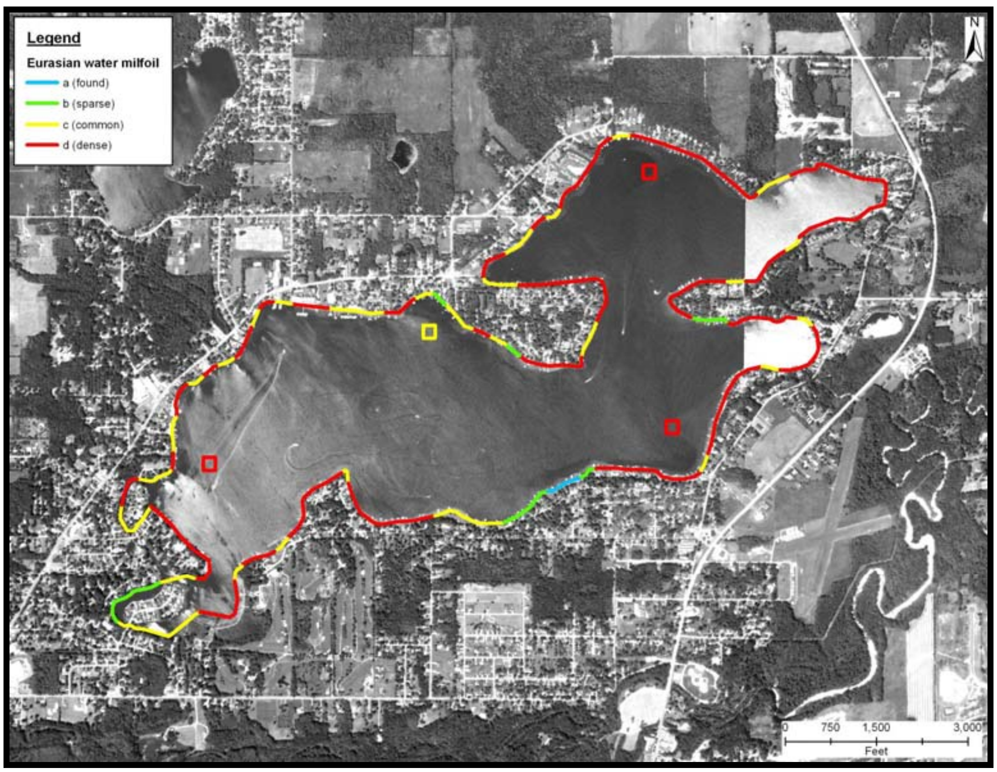

Figure 7. Eurasian water milfoil locations and densities as surveyed May 29, 2009.

During the post-treatment survey, Eurasian water milfoil, coontail, and wild celery were the most dominant species identified in the lake. Eurasian water milfoil was identified at 100% of the AVAS's and at the greatest density 21% of the time. Eurasian water milfoil was common at 29% of the AVAS's, sparse at 32% of the AVAS's, and one or two plants were found at 17% of the AVAS's. During the post-treatment survey, Eurasian water milfoil dominated the plant community throughout the littoral zone (0-15 feet). This species was found at the highest percentage of sites throughout the entire littoral zone (100%). Throughout the surveyed littoral zone, coontail and wild celery were relatively frequent at 83% and 76% of the sites, respectively. Coontail decreased from 87% to 83% of the sites from the spring to summer survey, but wild celery increased from 38% to 76% during the summer survey.

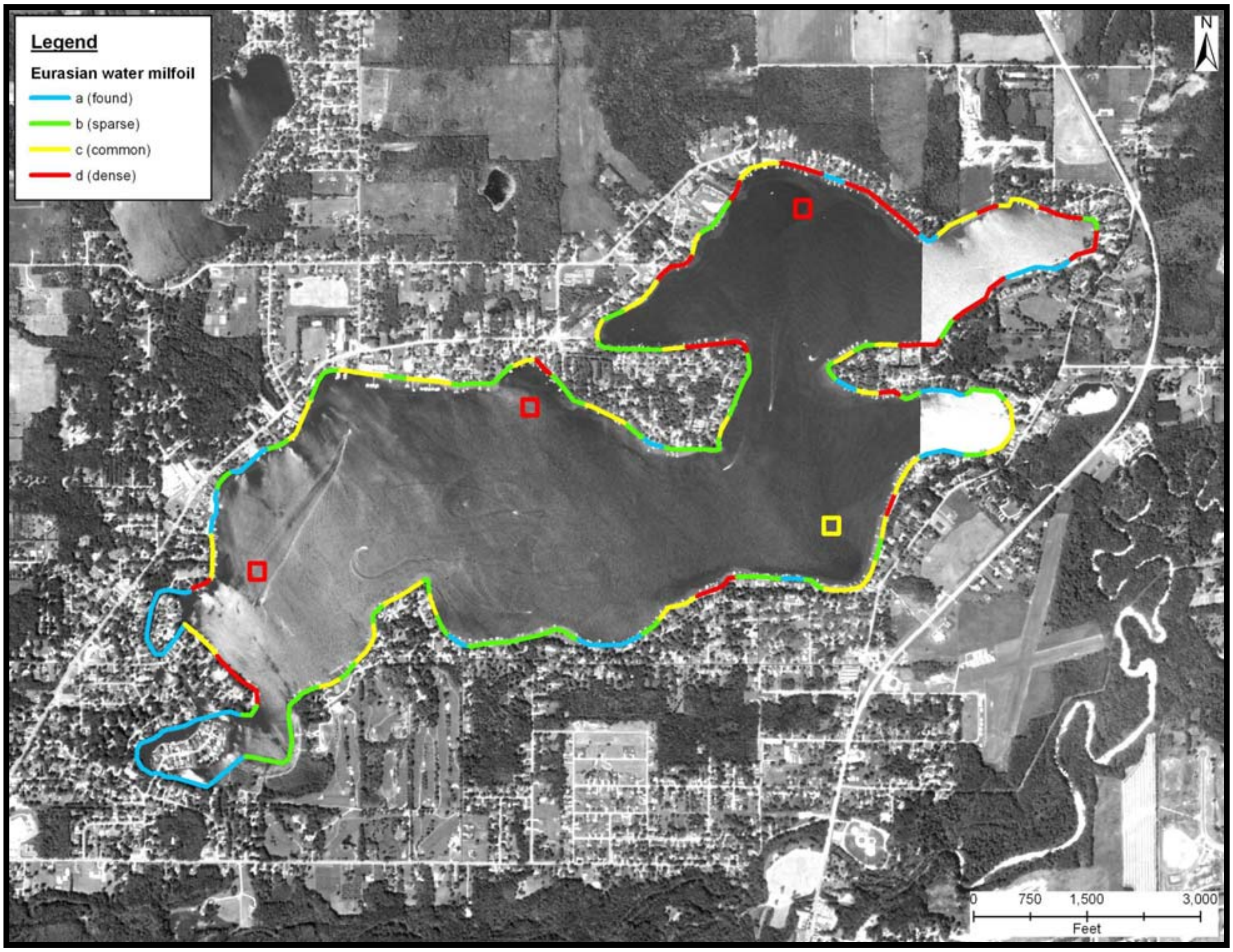

Figure 8. Eurasian water milfoil locations and densities as surveyed August 24, 2009.

As will be discussed in the proposed 1-year plans for the lake, the continued use of 2,4-D and other herbicides can be used to cosmetically enhance the appearance of the lake; however, they do not serve to completely eradicate all nuisance plant species or address the problem of phosphorous loading in the lake.

Although we have not witnessed algal blooms on Paw Paw Lake, we have heard numerous accounts of these blooms and their resulting discoloration of the lake to a lime green color and eventually a noxic smell. These algal blooms appear to be wide-spread throughout the lake and not easily treated for a long-term solution. The application of the basic copper sulfate formulated as crystalline solids can be applied at a rate up to 10 ppm and will be covered in the proceeding sections.

Copper sulfate is only moderately toxic upon acute oral exposure. Copper sulfate can be corrosive to the skin and eyes. It is readily absorbed through the skin and can produce a burning pain, along with the same severe symptoms of poisoning from ingestion. Copper sulfate is very toxic to fish. Its toxicity to fish varies with the species and the physical and chemical characteristics of the water. Even at recommended rates of application, this material may be poisonous to trout and other fish, especially in soft or acid waters. Its toxicity to fish generally decreases as water hardness increases. Fish eggs are more resistant than young fish fry to the toxic effects of copper sulfate. Very small amounts of this material can have damaging effects on fish. Permits are being required in some situations for application of copper sulfate to water bodies. Further field studies have been required by the EPA. Direct application of copper sulfate to water may cause a significant decrease in populations of aquatic invertebrates, plants and fish.

Recommendation:
The use of herbicides will not remove or reduce phosphorous within the lake. Fluridone (SONAR) is recommended to be used in 2011 to eradicate Eurasian water milfoil with spot treatments in subsequent years with 2,4-D to control this species re-emergence and dominance in the lake. The recommended treatments are explained in greater detail in the Recommendations Restoration Plan. These treatments are recommended to be conducted in conjunction with a phosphorous removal or phosphorous binding alternative (e.g. alum and/or aeration) to provide for maximum effectiveness in controlling nuisance weeds.

E. Mechanical Harvesting

Mechanical harvesters are large machines that both cut and collect aquatic plants. The cut plants are removed from the water by a conveyor belt system and stored on the harvester until they can be disposed of on shore. The harvested weeds are disposed of in landfills, used as a composting material or in various land reclamation scenarios. Harvesting is usually done three times during the growing season in Michigan, late spring, mid-summer and early fall when the plants are close to the surface. Depending on plant type, density and storage capacity the harvesters can cut and collect several acres per day. The mechanical harvesters cut plants from 5 to 10 feet below the water surface and in a swath from 6 to 20 feet wide, at this rate they typically can harvest from 0.5 to 1.5 acres per hour depending on the equipment. Because of the machine size and high costs, this method is most efficient in lakes larger than a few acres.

Experienced operators of these mechanical harvesters understand that they can be harvesting more that just the aquatic plants. Small fish, invertebrates, amphibians and turtles can be collected as well. A good operator will make a reasonable effort to return the fish and other aquatic life back into the lake.

Advantages

- Harvesting results in immediate open areas of water.
- Removing plants from the water removes the plant nutrients, such as nitrogen and phosphorus, from the system.
- Harvesting as aquatic plants are dying back for the winter can remove organic material and help slow the sedimentation rate in a waterbody.
- Since the lower part of the plant remains after harvest, habitat for fish and other organisms is not eliminated.
- Harvesting can be targeted to specific locations, protecting designated conservancy areas from treatment.

Disadvantages

- Harvesting is similar to mowing a lawn; the plant grows back and may need to be harvested several times during the growing season.
- There is little or no reduction in plant density with mechanical harvesting.
- Off-loading sites and disposal areas for cut plants must be available. On heavily developed shorelines, suitable off-loading sites may be few and require long trips by the harvester.
- Some large harvesters are not easily maneuverable in shallow water or around docks or other obstructions.
- Significant numbers of small fish, invertebrates, and amphibians are often collected and killed by the harvester.
- Harvesting creates plant fragments which may increase the spread of invasive plant species such as Eurasian water milfoil throughout the waterbody.
- Although harvesters collect plants as they are cut, not all plant fragments or plants may be picked up. These may accumulate and decompose on shore.
- Harvesters are expensive and require routine maintenance.
- Harvesting may not be suitable for lakes with many bottom obstructions (stumps, logs) or for very shallow lakes (3-5 feet of water) with loose organic sediments.
- Harvesters brought into the waterbody from other locations need to be thoroughly cleaned and inspected before being allowed to launch. Otherwise, new exotic species could be introduced to the waterbody.

Other Methods of Mechanical Harvesting

There are numerous other methods for mechanically harvesting aquatic plants. The use of diver-operated suction harvesting (or dredging, as it is often called) is a fairly recent technique. It is termed "harvesting" rather than "dredging" because a specialized small-scale dredge is used in the process. The sediments are not removed from the system; however, the sediments are re-suspended during the operation. This requires the use of turbidity curtain to mitigate these effects of stirring up the lakebed sediments. Divers use this device to remove plants from the sediment. The technique can be very selective;

divers can literally choose the plants to be removed. Removal is efficient and re-growth is limited. The one major drawback is that the method is very slow about 1,100 square feet per person per day. Disposal can be as per other methods; however, a moderate amount of dewatering needs to be completed. However, it is an excellent method for small beds of plants or areas of scattered clumps of plants too large for hand harvesting. Table 5 outlines the advantages and disadvantages of several of these methods.

Management Method	Description	Advantages	Disadvantages	Systems where used effectively	Plant species response
Hand-Cutting / Pulling	Direct hand pulling or use of hand tools	Low-technology, affordable, can be selective	Labor-intensive, cost is labor-based	Most of the undeveloped world, volunteer labor pools	Very effective in very localized areas
Cutting	Cut weeds with mechanical device	More rapid than harvesting	Large mats of cut weeds may become a health and environmental problem, may spread infestation	Heavily-infested systems	Nonselective, short-term
Harvesting (Cut and Remove)	Mechanical cutting with plant removal	Removes plant biomass	Slower and more expensive than cutting; re-suspension of sediments	Widespread use with chronic plant problems	Like cutting, it is cosmetic, non-selective short-term
Grinder or "Juicer" (Cut and Grind)	Mechanical cutting with grinding of plant material and in-lake disposal	Immediate relief of plant nuisance, no disposal	Re-suspension of sediments, decomposition of plants in lake, floating plant material	Useful for chronic plant problems where disposal of plants is problematic	Like cutting and harvesting, it is cosmetic, non-selective short-term
Diver-Operated Suction Harvester	Vacuum lift used to remove plant stems, roots, leaves, sediment left in place	Moderately selective (based on visibility and operator), longer-term	Slow and cost-intensive	Useful for smaller nuisance plant populations in which plant density is moderate	Typically have minimal re-growth for Eurasian water milfoil; not effective for tuber-setting hydrilla
Rotovating	Cultivator on long arm for tilling aquatic sediments	Disrupts Eurasian water milfoil stem bases, intermediate-term results	May spread large numbers of fragments; re-suspension of sediments	Used extensively in the Pacific Northwest and British Columbia, with mixed results	Effective in disrupting Eurasian water milfoil dense stands; not selective and only intermediate-term

Table 5. Characteristics of mechanical management techniques
Source: http://www.aquatics.org/pubs/madsen2.htm

Another major mechanical management technique is rotovating, which is widely used in the Pacific Northwest for management of Eurasian water milfoil. This method uses rotovator heads on submersible arms to till up the bottom sediments and to destroy the root crowns. Rotovating is relatively rapid and can effectively control dense beds of Eurasian water milfoil for up to two years per studies and research completed to date. However, it spreads Eurasian water milfoil fragments, re-suspends large amounts of sediments and nutrients, causes high levels of turbidity, disrupts benthic communities, and is nonselective in the harvesting process.

Hydraulic washing uses a water pump and high pressure nozzles to “wash” plants out of the bottom substrates. This is effective for root removal. At times it is described as a water rake that can be used around piers and for cleaning of beaches. It is very good at root removal where the lake bed is soft or when following a mechanical harvester that has cut the plants and left the roots. It does not address the Eurasian water milfoils very well because of their large root masses.

Mechanical de-rooting methods have been developed to remove or kill plant root crowns; this method was developed to provide for longer-term plant control than conventional harvesting. There are two main approaches; one is with utilization of a rototiller and the other is a cultivator head. Both require two passes to dislodge root systems and dig them up. The passes should be at right angles to one another. The system works best during lake drawdowns or in shallow waters. It may require numerous passes for the best effect. It is a rather slow, tedious method, but it has a good record for root crown removal depending on water depth, substrate type and skill of the operator. The effectiveness can be for up to three or four years.

Nutrient Removal Estimation

Calculating the potential for nutrient removal is moderately straightforward. By knowing the area of the lake covered with aquatic plants (macrophytes) (m^2), the average biomass of the plants in the area (g dry wt / m^2 per year) and the nutrient concentration of the plants (g nutrient / g dry weight of plants) and estimate of the total nutrient available for removal can be calculated. This number is reduced by the percentage of the total area harvested and the efficiency of the harvest. This number is often compared with nutrient loading to the lake to determine the percent of the net annual loading that might have been or was removed by harvesting. Typically, the mean tissue phosphorus concentrations range from 0.15% to 0.39% of dry plant weight. If averaged the phosphorus percentage in dry plant weight is approximately 0.27%, for a ton (dry weight) of macrophytes harvested there will be a removal of about 5.4 lbs of phosphorus (Table 6).

Mechanical Harvesting Costs	
lbs. of Biomass / m2	0.484
lbs. of Biomass / acre	1958.6996
lbs. of Phosphorus / ton of Biomass	5.4
lbs. of Phosphorus / lb of Biomass	0.0027
lbs. of Phosphorus / acre	5.29
Harvesting cost $ / acre	500
Harvesting cost $ / lb of Phosphorus	$ 94.54
Harvesting cost $ / ton of Phosphorus	$189,089.93
Total Acres Observed (May 2009)	160.8
# of Harvesting / Year	3
Total Annual Costs	$241,200.00
Estimated Annual Phosphorus Removed (tons)	1.276

Table 6. Summary of Mechanical Harvesting Costs.

Based on review of current literature, it appears that two or three harvests per year are needed for adequate control and cutting three times per year may also reduce the growth the following season. There is a fair amount of literature in support of mechanical harvesting as being environmentally superior to herbicide use, most of the studies do not seem to consider the impact on macro-invertebrates, semi-aquatic vertebrates, small forage fishes, young game fish sheltering in the weed beds and even adult game fish. The harvester can be viewed as a large non-selective predator in the littoral zone of a lake.

In the past, harvesting was widely touted as a mechanism to remove nutrients from lake systems. However, ecosystem studies indicated that harvesting is not likely to significantly improve the trophic status of a lake. For example in one report, harvesting all available plants in Lake Wingra, Wisconsin removed only 16% of the nitrogen and 37% of the phosphorus net influxes into the lake; these removals were insignificant compared to the lake's internal pools of those nutrients (Carpenter and Adams 1976, 1978). Other studies indicated plant harvesting removed 20% of the annual net phosphorus input. In a more eutrophic system, it has been shown that continuous harvesting of aquatic plants in the littoral zone during summer removed only 1.4% of the total phosphorus input.

Recommendations:
We do not recommend harvesting for the control of nuisance weed control or for a method of reducing phosphorous loading in the lake. Harvesting aquatic plants is not an effective tool for reducing nutrient loads in a lake because it does not address the internal nutrient pool in the sediments. In the best-case scenario, removing all the plants in the lake will only keep pace with the amount of external nitrogen loading and with not quite half of the external phosphorus loading per other studies found. The impact of harvesting on lake system processes could take a long time to develop and the repercussions can be complex, predicting or measuring the harvesting impacts is difficult.

We do not recommend a pilot study using harvesting given the relatively low volume of phosphorous removed using this method and that harvesting fragments and promotes the spreading of such plants as Eurasian water milfoil.

Mechanical harvesting can show an immediate effectiveness for control of weeds in areas where navigation and recreational use are being limited by weed growth.

F. Lake Level Management

Drawing down the water level of a lake (drawdowns) at certain times of the year can be an effective method for controlling aquatic weed growth, specifically nuisance aquatic plants. Drawdowns can be done in the spring or winter months depending on the targeted species. In most instances, the timing of a drawdown can coincide with needed repairs on lake level control structures (e.g. dams and weirs) or preventing ice damage to shoreline structures during winter months.

Lowering the water level in the late fall can be used to dry out the sediments, stressing tubers, rhizomes, turions, and other underground plant parts that require saturated conditions and which are used to store carbohydrates (energy) necessary for plant growth in the spring. The desiccation and freezing action stresses the wintering plant parts so that they are less viable in the spring. Additionally, winter drawdown minimizes negative interaction between water temperature and dissolved oxygen depletion caused by organic matter decomposition because decomposition processes are reduced at cooler temperatures and cold water contains more dissolved oxygen than warmer water.

Some plants, such as Eurasian water milfoil and curly-leaf pondweed are quite susceptible to winter drawdown (Cooke et al., 2005; Hoyer and Canfield, 1997). Cooke et al (2005) present numerous case studies of successful drawdowns for macrophytes control. Other states in which we have done lake management studies, such as Massachusetts and Wisconsin, have state agency policies that facilitate the use of drawdowns as a management tool. A good example on the use and timing of drawdowns in Massachusetts is available on the web at http://www.glenecholake.org/weedcontrol.htm.

Benefits to water quality and fisheries from winter drawdown have been documented on other lakes (Weitkamp, 2004; Cooke et al., 2005). On Lake Spokane (WA), water quality was improved due to the physical flushing of water from the lake and due to sediment consolidation (Weitkamp, 2004). Water level drawdown is an "effective, inexpensive, and widely recognized reservoir fishery management method" (Cooke et al., 2005). Not only are dense, monotypic stands of plants controlled but fish are focused together in a smaller lake volume. This allows greater access of predator fish to abundant, stunted forage fish. Cooke et al. (2005) give numerous case study examples in their text. Drawdown is also a convenient time to add bottom structures that could attract more fish.

Use of drawdowns as a method of weed control is limited to water depths which you can effectively and safely draw lake levels down to (taking into consideration the condition of your existing lake level control structure). The primary outlet control structure for Paw Paw Lake is along Curtis Dr. in the southwest corner of the lake. The structure is currently in need of repair and provides no means for drawing down the lake. The structure consists of a fixed height weir, with extension plates fastened to the top. The function of the extension plates is to lower the lake level from the summer elevation of 621.8 feet to the established winter legal lake level of 621.0 feet. The structure provides no means for lowering the water below the winter lake level. Either modification to this structure would need to be made, or a new structure could be installed. An ideal structure would include a sluice gate installed below the desired winter lake level that would allow for both drawing down the lake and also for maintaining base flows when filling the lake up in the spring. The structure would also need a weir setup that included enough adjustability to set stop logs at the winter lake elevation and the summer lake elevation. A new structure capable of lowering and raising the lake level would likely cost between 200-400 thousand dollars. A drawdown is expected to facilitate the repairs and which time can also assist in controlling aquatic nuisance species in the shallower areas of the lake.

The current legal lake levels at Paw Paw Lake are 621.8 feet in the summer and 621.0 feet in the winter. A temporary drawdown of the lake below these elevations would require a permit from the Michigan Department of Natural Resources and Environment (MDNRE) under Part 307 of Act 451. If the lake were to be drawn down on an annual basis, it would require an amendment to the existing winter legal level through the Circuit Court.

Using the bathymetry maps for Paw Paw Lake we calculated that a 5-foot drawdown would expose 124 acres, or 14% of the lake bottom. This drop in water elevation would dry out and stress those plants located within the 0-5 foot contour of the lake. According to our vegetative plant surveys the majority of nuisance weed species are in water depths greater than 5 feet. A 5-foot drawdown would only expose 66 acres, or 40% of the dense beds as observed on May 29, 2009. Exposing more of the lake bottom, including most of the area that currently supports the growth of aquatic invasive species, specifically Eurasian water milfoil, is not possible due to elevations downstream of the lake outlet.

There can be negative consequences to non-mobile benthic macroinvertebrates when their habitat is exposed during drawdown; mobile macroinvertebrates can move to stay within saturated zones as water levels drop.

When drawing down a lake of this size, the groundwater table will certainly be affected. There will be a localized drop in groundwater levels that close to the lake will match the distance that the lake is lowered. With increasing distance from the lake, this effect will decrease. Wells near the lake that are not more than 5 feet below the current water table would be affected.

Recommendation:
The use of drawdowns can be a safe, inexpensive and effective method to reduce a portion of the nuisance aquatic plants in the shallow water areas of the lake. Larger scale drawdowns can be exponentially beneficial for killing and stressing nuisance weeds but it can also equally kill and stress fish and aquatic macroinvertebrate species.

In the event that the lake is drawn down to repair the outlet structure and/or for any other reason, we recommend that the non-native vegetation that is exposed be removed using available methods (e.g. raking, rotovating).

G. Biological Control

The milfoil weevil (*Euhrychiopsis lecontei*) has been used to control Eurasian water milfoil in several smaller lakes in the Midwest and eastern states with most research being done in Vermont (Creed and Sheldon, 1994; Cofrancesco and Crosson, 1991; Newman et al., 1996). The early larval stages of this weevil feed on the outer meristem tissues of the milfoil plant and older larval stages spend the majority of their time feeding inside the stems on the corticular and vascular tissues of the plant. The adults feed on the leaves of the plant. These activities destroy the plants ability to stay buoyant in the water and to uptake nutrients needed for survival. The plant then dies and sinks to the bottom of the lake. These weevils reproduce on their own and there can up to three generations of weevils produced in a summer.

In controlled laboratory environments, Newman et al. (1996) predicted that between 200-300 weevils per square meter are needed to effectively control EWM. In several Minnesota lakes, Cooke et al. (1993) and Nichols (1991) estimated the cost of using weevils ranged between $150 and $2,000 per acre. Using these sources, the number of weevils that would be needed to effectively control EWM would be over a million and costs could also well exceed $1 million dollars.

Recommendation:
We do not recommend the use of milfoil weevils as a lake-wide method to eradicate Eurasian water milfoil. If riparians on the lake have access to and are willing to plant the weevils in the lake, than we have no objection to these efforts. The location of such treatments should be done in locations where herbicides being applied will not adversely affect these efforts.

IV. RECOMMENDED RESTORATION PLAN

In analyzing and assessing the various alternatives presented in the previous section of this report of Paw Paw Lake, it is important to recognize that some of these alternatives can provide short-term solutions to such issues as nuisance weeds, aesthetic appearances and recreational values while others can provide long-term solutions to such issues as nuisance weeds, nutrient loading, and restoration of the lake's aquatic biota and equilibrium.

In providing recommendations for Board consideration, approval and eventual implementation, we have identified both short- and long-term solutions for restoring the lake to past conditions of having (1) lower densities of nuisance weeds, (2) open water areas for recreational boating, (3) a quality warm water fishery, and (4) good water quality. The short-term solutions focus more on aesthetic appearances and providing increased recreational activities – this is provided through management of vegetative plant communities (specifically, nuisance weeds). The long-term solutions for lake restoration require long-term financial commitments to addressing nutrient loading that has been occurring, both naturally and accelerated by human activities, for hundreds of years. Addressing the source and release of nutrients into the lake is the key factor influencing nuisance weed levels in the lake.

A. Short-Term Recommendations

Vegetative Control

During the spring survey in 2009, we identified 161 acres of dense Eurasian water milfoil beds. Eurasian water milfoil was identified at all 157 survey sites during the pre-treatment survey and the post-treatment survey. Application of this herbicide at the concentrations and sporadic locations applied in past years has not proven effective in controlling, long term, the regrowth and expanse of this plant throughout a lake. Although it has provided a short-term solution for improving the appearance of the lake by knocking down plant densities and giving a more aesthetically looking lake surface for viewing, boating and swimming. The use of herbicides such as 2,4-D to treat Eurasian water milfoil can only be viewed as a band-aid approach to addressing this nuisance weed problem in the lake.

The use of 2,4-D is a cost effective short-term solution to the lake's nuisance weed problem. This type of treatment does not restore the lake to its native broadleaf plant communities that once inhabited the near and offshore areas of the lake. This alternative is being presented as a continued cosmetic approach to keeping the lake looking nice during high recreational use periods of the year at relatively low costs in comparison to the other methods/alternatives explored.

Approximately $50,000 of 2,4-D should treat, knock down the density, of approximately 125 acres of Eurasian water milfoil, to which $75,000 should treat the estimated 2009 estimate of 161 acres of dense Eurasian water milfoil. These treatments, as noted above, and in JFNew's 2009 Vegetative Assessment Report, did not completely eradicate this highly prolific plant. What was apparent was that the untreated milfoil areas continued to grow at rapid rates (upwards of 6 inches a day) and resulted in invasion into the reported treated areas of the lake. Treating only a portion of the lake with 2,4-D will continue to be a cosmetic approach to tackling a lake-wide problem such as the one Paw Paw Lake has with Eurasian water milfoil. Lake-wide participation is needed for this method to be more effective but even with full participation the right herbicides need to be used to ensure complete eradication of Eurasian water milfoil.

To address the seasonal algal blooms that have been known to cover the lake with what has been described as "a thick mass of lime green gelatin," we recommend some of the algae be collected and identified to make sure chemical application is suitable. Pithophora is a specific type of algae that is not affected by copper sulfate. This type of survey and collection can be very cost-effective in the long-run to determine exactly what type of algae is in the lake and how best to treat it. We did not do this during our surveys because we did not see the algal blooms and were not aware at the time that this was an issue. Anyone willing to collect samples for us would be invaluable in helping to save us time and the association money with this effort. If the algae is anything but Pithophora, copper sulfate may be used to treat the problem areas in the lake, but just like with contact herbicides, this method is purely cosmetic and results in no long-term solutions of eradicating the algae. Using money towards reducing phosphorus in the lake will yield better results when trying to control algal blooms.

1-Year Plan (2010)

A yearly assessed plan for controlling nuisance levels of aquatic plants should be done using a three-prong approach, that being: (1) control of invasive, exotic and at times nuisance levels of native species; (2) restoration or preservation of native plant communities; and (3) education of lake users. Based upon the vegetative surveys JFNew conducted in 2009 and the alternatives assessed to date, we recommend the following actions as part of a 1-year plan to reduce the level of invasive and nuisance species in the lake.

This plan does not represent a “Lake Restoration Plan” which we do not believe can be accomplished in the short-term, that is anything less than 10 years, especially when considering the costs of the various alternatives available for restoring Paw Paw Lake. This plan has been put together with the understanding that there is a limited amount of riparian support/funding for this work; the range we were given to work with was between $50,000 and $75,000 for treatments in 2010. In order of importance and progression (depending on funding), here is our recommended 1-year plan for controlling nuisance levels of aquatic plants in Paw Paw Lake:

1. Conduct an Aquatic Vegetative Assessment Survey (AVAS) pre-treatment survey of the lake (May 15 - June 15, and prior to any treatment) [1] to identify and assess the densest locations of Eurasian water milfoil throughout the lake. Using this information create a priority map showing those areas of the lake that should receive treatment prior to other areas, based on density, ability of this plant to fragment and grow into other areas creating further nuisance situations, and where residential

access and use of the property is needed. Provide this map to the Townships for final approval before submitting to the selected herbicide applicator for treatment.

[1] Pre- and post-treatment surveys are to align, wherever possible with previous year surveys to aide in comparison between years.

2. Spot treat the highest priority areas in the lake with 2,4-D to target eradication of Eurasian water milfoil in those areas (May 15-June 1). Areas we recommend as automatic high priority areas are the two boat ramp access sites and the public swimming pier area since these areas if untreated will spread this species through their site activities. Current estimates show that approximately 125 acres of the lake can be treated for $50,000 ($400/acre) by focusing on the narrow shelf where the densest aquatic plant growth occurs. Priority ratings and limited budgets may limit treatments to only those areas where resident access is a priority. Additionally, treatment should be limited to a 50-foot swath in the littoral zone where Eurasian water milfoil is the most dense, if the entire lake is to receive treatment. If priority areas are the only treatment areas, then a wider area in the littoral zone may be covered to kill as much Eurasian water milfoil as possible in these areas.

3. Conduct a post-treatment survey of the lake (July 15-Aug 1)[1] to assess the effectiveness of the herbicide treatments (and locations of those treatments) and the response of native plant communities to those treatments.

4. Summarize AVAS findings into a year-end report, compare with 2009 Vegetative Report prepared by JFNew, assess changes and update 5-year and 10-year plan if and where appropriate.

5. Post signs at all access sites in warning boaters of the potential for invasive plant species introductions from boat trailers. Signs should implore boaters to clean trailers, propellers, and boats of all vegetative fragments when entering and leaving Big Paw Paw Lake. This is especially important given the high density of off-shore users on the lake. Information concerning the potential spread of Eurasian water milfoil should be distributed to all PPLA members and lake users.

6. Establish a “cleaning area” at the two boat ramp access sites which consists of an isolated retention area with running water where boats, motors and trailers can be rinsed before and after boating in the lake to reduce transport of invasive species into and out of the lake.

7. Provide educational materials and hands-on events to educate lake users and riparians on best management practices and encourage them to take part and be part of the cumulative solution. Educational activities should include at a minimum, how to identify and safely remove invasive, non-native and/or exotic species that may be growing along your lakeshore or in your nearshore areas. A few plant species that all riparians need to be aware are: purple loosestrife (*Lythrum salicaria*), reed canary grass *(Phalaris arundinacea*), common reed grass (*Phragmites australis*).

5-Year Plan (2011-2015)

Planning the control of nuisance plant species using a 5-year provides greater opportunity to control the primary nuisance species – Eurasian water milfoil. In this plan, many of the action items in the 1-year plan are used with the exception of using a stronger and more complex herbicide called fluridone, commonly referred to as SONAR. This herbicide has been used very effectively to completely eradicate Eurasian water milfoil from smaller lakes (less than 500 acres in size), but it is relatively expensive and requires a greater degree of expertise by the applicator for its proper application and then continued spot treatments of remaining plants. In comparison to 2,4-D this herbicide treatment system has proven more effective in controlling Eurasian water milfoil and promoting the re-establishment of other native species in comparison to the continued annual use of 2,4-D.

Since the goal is to move towards a restoration of the lake and more native plant communities, we recommend this 5-year plan of using SONAR over that of the 1-year plan that utilizes 2,4-D each year to cosmetically control Eurasian water milfoil. In order of importance and progression (depending on funding), here is our recommended 5-year plan for controlling nuisance levels of aquatic plants in Paw Paw Lake:

1. 2011: Conduct an AVAS pre-treatment survey of the lake (April) [2] to identify and assess the densest locations of Eurasian water milfoil throughout the lake. This will be used by the applicator to identify potential areas where concentrations of SONAR may need to be increased during the initial treatment period. Also identify the location and density of other non-native and native species. This map will also be used for evaluating the effectiveness of SONAR in 2011 and subsequent years. An additional pre-treatment survey should be conducted by the herbicide applicator to take water quality samples to test the water's pH and other levels before treating the lake with fluridone.

2. 2011: Apply SONAR throughout the entire lake in April 2011 (approximate cost for lake-wide treatment $127,000). This includes continual monitoring and additional chemical applications through early May 2011 to maintain required 6 ppb levels of fluridone in the water for a period of 60 days. Monitoring of SONAR concentrations are also called FasTest sampling and is performed on the following day after the lake-wide treatment date: 2, 14, 30 and 60.

3. 2011: Conduct a post-treatment survey of the lake (July)[2] to assess the effectiveness of the SONAR treatments.

4. 2011: Conduct an AVAS post-treatment survey of the lake (August) to allow for comparison of the 2009, 2010 and 2011 herbicide treatments.

5. 2011: Summarize AVAS findings into a year-end report, compare with 2009 and 2010 Vegetative Report prepared by JFNew, assess changes and update 5-year and 10-year plan if and where appropriate.

6. 2011: Post signs at all access sites in warning boaters of the potential for invasive plant species introductions from boat trailers. Signs should implore boaters to clean trailers, propellers, and boats of all vegetative fragments when entering and leaving Big Paw Paw Lake. This is especially important given the high density of off-shore users on the lake. Information concerning the potential spread of Eurasian water milfoil should be distributed to all PPLA members and lake users.

7. 2011: Establish a "cleaning area" at the two boat ramp access sites which consists of an isolated retention area with running water where boats, motors and trailers can be rinsed before and after boating in the lake to reduce transport of invasive species into and out of the lake.

8. 2011: Provide educational materials and hands-on events to educate lake users and riparians on best management practices and encourage them to take part and be part of the cumulative solution. Educational activities should include at a minimum, how to identify and safely remove invasive, non-native and/or exotic species that may be growing along your lakeshore or in your nearshore areas. A few plant species that all riparians need to be aware are: purple loosestrife (*Lythrum salicaria*), reed canary grass (*Phalaris arundinacea*), common reed grass (*Phragmites australis*).

9. 2012: Conduct an AVAS pre-treatment survey of the lake (May 15 – June 15) [1] to identify and assess the location and density of Eurasian water milfoil and other plant species throughout the lake. Map of lake will be used for evaluating the effectiveness of 2010 SONAR treatment and focus of spot treatments for 2012.

10. 2012: Spot treat areas of Eurasian water milfoil with 2,4-D (approximate cost for spot treatment of approximately 60 acres of the lake $24,000).

11. 2012: Conduct a post-treatment AVAS survey of the lake (August) to assess the effectiveness of the SONAR treatments, the response of native plant communities to those treatments, and ability to compare to AVAS surveys from 2009, 2010 and 2011.

12. 2012: Summarize AVAS findings into a year-end report, compare with 2009, 2010 and 2011 Vegetative Report prepared by JFNew, assess changes and update 5-year and 10-year plan if and where appropriate.

13. 2013: Repeat steps 9-12 for remaining years.

10-Year Plan (2011-2020)

A 10-year plan that focuses on controlling Eurasian water milfoil should continue where the 5-year plan leaves off with the benefits of having to only continue the maintenance efforts of properly doing the spot treatments of the lake. According to herbicide specifications and applicators in Indiana the spot treatments with 2,4-D can keep milfoil levels down for years. However, there are mixed results on the long-term effectiveness of SONAR and spot treatments with 2,4-D due to the wide diversity in lakes using these types of treatments. Some reports show having to redo lake-wide treatments after only 3-years and others upwards of 10-years (citing needed) while others report still being able to control their milfoil problems with spot treatments following only one lake-wide treatment (citing needed).

It is our professional opinion that there is not enough scientific data to predict with even a moderate level of confidence the length of time that Paw Paw Lake would need to repeat a full lake-wide treatment. However in assessing Professional Lake Managements July 17, 2009 Vegetative Control proposal to the Paw Paw Lake Association, they estimated a SONAR treatment lasting approximately 4 years before having to redo the SONAR treatment. Of important note, that proposal did not include annual spot treatment of milfoil coming back in with either more SONAR or the less expensive 2,4-D. Their costs for the first SONAR treatment ranged between $83,805 and $126,870 and then the next treatment, if necessary 4 years later, ranged between $86,835 and $131,190.

At the present time, JFNew and SPICER are not comfortable with recommending a 10-year vegetative management plan focusing solely on herbicide treatments especially in light of the other alternatives we propose the Townships for “Restoring the Lake” and which we believe will also address, in part, the nuisance aquatic weed problem.

Pilot Programs

The use of one or more of the previously discussed methods as a test or pilot program in a small portion of the lake before committing to a full scale lake-wide application is recommended. This provides a great opportunity to “test” and “evaluate” these methods at relatively low cost. Given the chemical and nutrient cycle complexities associated with the use of alum and aeration, the ability, and willingness of several of the contractors to offer opportunities, to test these alternatives in a small portion of the lake appears to be an alternative worthy of our presentation as a separate section of this report and recommendations.

A key to their use is to not combine alternative applications where one can negate the effect of another. We understand that efforts were made in previous years to introduce the milfoil weevil to control Eurasian water milfoil but the effort was apparently thwarted since the test area with the beetles was treated with herbicides that killed off this proposed biological control mechanism.

The JLPC needs to evaluate the costs of implementation of each of these alternatives, either as pilot or lake-wide management programs. To aid in this decision making process, the cost estimates for several of the alternatives (i.e. dredging, alum and aeration) have been broken down by cost per sub area (of the lake) and associated with a percent removal of phosphorous for each sub area (Figure 9). Cost estimates for all of the alternatives is provided in Table 7.

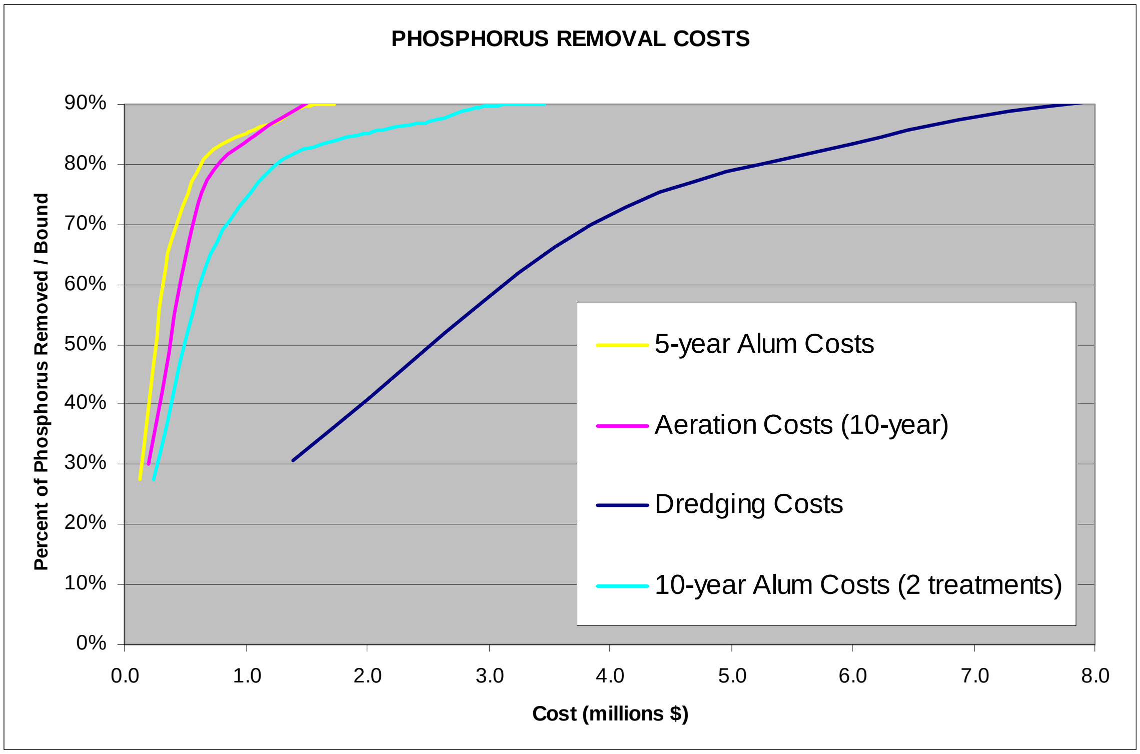

Figure 9. Cost Comparison of Dredging, Alum and Aeration.

Treatment Type	Required Frequency	Total Cost	Annual Cost
Mechanical Harvesting	Tri-Annually	-	$ 250,000.00
Alum Treatment	5 Years (estimated)	$1.7 Million	$ 340,000.00
Aeration	Ongoing	$1.5 Million	$ 150,000.00
Dredging	20-30 Years	$35 Million	$1.4 Million
Lake Level Management	One Time	$300,000	Minimal
Biological Control (Weevils)	One Time	$160,000	Minimal
Herbicide (SONAR)	Annually	$223,000	Year 1 $127,000 Year 2-5 $24,000

Table 7. Summary Cost of Alternatives.

B. Phosphorus Management - Source Reduction

A phosphorus reduction strategy for Paw Paw Lake needs to be developed in the near future and it should include the following steps:

- An agreement on the phosphorus goals for the lake system.
- Identify the point and nonpoint sources of phosphorus entering the lake system.
- Identify external and internal loadings of phosphorus.
- Determine an action plan for each point and nonpoint source.
- Determine an action plan for external and internal loadings of phosphorus.

- Review of the costs of selected BMPs to determine the most cost-effective reduction strategies.
- Implement the strategies / BMPs.

The property owners and watershed stakeholders need to meet and educate themselves on the scope of the phosphorus problem in Paw Paw Lake. When that is completed, a general goal for reduction should be agreed upon for all phosphorus inputs into the lake system. This goal, for example, may be that contributing waters to the lake must have a target goal in the range of 0.05 to 0.1 mg/L of total phosphorus. Another more restrictive strategy would be the development of a Total Maximum Daily Load (TMDL) for the watershed. This would result in a study to determine how much phosphorus can be discharged on a daily basis into the lake and still have the lake meet stringent water quality standards. Once the target load is established, then restrictive action on discharge takes place in the watershed to reduce the daily discharge of phosphorus to meet the prescribed levels. This type of program is hard to enforce and implement in a watershed. It is done under the impaired waters section of the Clean Water Act as it is administered and regulated in the State of Michigan, but at this time it may be a rather drastic action to pursue. It is better to get voluntary compliance through education and change of behaviors than forced regulation for phosphorus reduction. For example, education of property owners in areas close to the lake on the proper types of lawn fertilizers to purchase and the proper application methods can reduce phosphorus loading into the lake.

Identification of point sources and nonpoint sources should be finalized in any strategy. Overview of the watershed will identify point sources. Essentially, the point sources will be inlets into the lake system, failing on-site treatment systems (septic systems), NPDES point source discharge permits, agricultural feed lots, etc.

The non-point sources in some aspects will be a little harder identifying; however, the typical sources are residential lawns, storm water, agricultural runoff, sediment from erosion in the watershed. Looking at the maps produced by the L-THIA model will help identify other land uses that are nonpoint sources of phosphorus loading to the lake system.

Reduction strategies for the external loading can be accomplished through:

- On-site treatment system updates (septic systems) or eliminations.
- Erosion control practices on the tributaries to the lake.
- Lakescaping practices and regulations to address shoreline restoration, rain gardens, and low impact development techniques for urban runoff.
- Education of the public on fertilizer application on tributary waters.
- Creation of a phosphorus application buffer zone around the lake to reduce levels of phosphorus in storm water runoff getting to the lake.
- Education of the agricultural industry to provide for a minimum 10 vegetated buffer along tributary waters. This vegetated buffer will decrease sediment entering into the drains and will act as a deterrent to keep from applying fertilizers or for that matter herbicides to close to the drains.

- Manure and animal feedlot management.
- Aggressive storm water management for water quality results.

Reduction strategies for the internal loading from sediments in the lake can be controlled through:

- Bio-manipulation, can work, but requires extensive study to prepare for implementation of the strategy.
- Wake restrictions in shallow areas of the lake to prevent re-suspension.
- Phosphorus binding or removal treatments, such as alum. Requires extensive study, but can have good results.
- Removal of high concentration phosphorus sediments.
- Harvesting of aquatic plants.

Phosphorous Management Recommendations:

Dredging

We do not recommend dredging of any large areas of the lake given the cost effective analysis of this alternative in comparison to other less costly alternatives. If riparian property owners feel that navigation and recreation will be enhanced by dredging localized areas, removal of sediment in these areas will only minimally help the overall health of the lake.

Aeration

We recommend that a pilot project (area) be selected to assess the effectiveness of this alternative within Paw Paw Lake. One concern is the amount of oxygenation staying in the deeper portions of the lake at the substrate/water column interface to provide sufficient oxygenation and prevention of phosphorous release into the water column.

We recommend leasing aeration equipment for Areas D-1 and D-2 or just D-1 (a secluded bay in the eastern portion of the northeast portion of the lake) for 3-5 years to assess its effectiveness. This pilot area is expected to also benefit other areas of the lake given spring turnover and internal flow patterns of water moving oxygenated water into the central and southwestern portions of the lake.

Alum Recommendations:

We recommend that a pilot project (area) be selected to assess the effectiveness of this alternative within D-4 (a secluded bay in the western portion of the northeast portion of the lake). We also recommend further water quality analysis and bottom substrate sampling to assess the effectiveness of using alum across the entire lake.

Herbicide Recommendations:

Fluridone (SONAR) is recommended to be used in 2011 to eradicate Eurasian water milfoil with spot treatments in subsequent years with 2,4-D to control this species re-emergence and dominance in the lake. The use of this herbicide will not remove or reduce phosphorous within the lake but it will eradicate this nuisance species.

Harvesting Recommendations:
We do not recommend harvesting for the control of nuisance weed control or for a method of reducing phosphorous loading in the lake. Harvesting aquatic plants is not an effective tool for reducing nutrient loads in a lake because it does not address the internal nutrient pool in the sediments. In the best-case scenario, removing all the plants in the lake will only keep pace with the amount of external nitrogen loading and with not quite half of the external phosphorus loading per other studies found. The impact of harvesting on lake system processes could take a long time to develop and the repercussions can be complex, predicting or measuring the harvesting impacts is difficult.

Drawdown Recommendations:
We recommend the removal of non-native vegetation that is exposed during any drawdown of the lake that may occur. Removal of vegetation can utilize any number of methods discussed above, including but not limited to, hand removal, raking and rotovating.

Biological Control Recommendations:
We do not recommend the use of milfoil weevils as a lake-wide method to eradicate Eurasian water milfoil. If riparians on the lake have access to and are willing to plant the weevils in the lake, than we have no objection to these efforts. The location of such treatments should be done in locations where herbicides being applied will not adversely affect these efforts.

C. Grant Sources for Paw Paw Lake

There are numerous federal, state and private grant sources and foundations that may be applicable and/or willing to contribute to the work efforts being recommended for improving the water quality, reducing nutrient loading and improving the overall aquatic resources of Paw Paw Lake. Given the large number of grants that could be listed and the level of detail and instructions each requires we have summarized only a few below and utilized web links to provide a means of finding more detailed level of information on others.

1. GREAT LAKES BASIN PROGRAM for SOIL EROSION & SEDIMENT CONTROL (http://www.glc.org/basin/funding.html)

The purpose of this grant is to protect and improve water quality in the Great Lakes by reducing soil erosion and controlling sedimentation through financial incentives, information and education, and professional assistance.

The objectives for this grant are to (1) minimize off-site damage to harbors, streams, fish and wildlife habitat, recreational facilities, and the basin's public works systems caused by sediment and (2) reduce the on-site damages caused by soil erosion on farms, developments, stream banks and shorelines.

Based on the objectives of this grant and methods outlined below (extracted from the website referenced above), it may be possible to receive a grant under the Great Lakes

Basin Program to reduce sediment (and phosphorous) loading into Paw Paw Lake. Grant amounts for small projects have a maximum of $30,000 while larger projects have a maximum amount of $700,000. Criteria (methods) that would need to be addressed in a grant application include:

- **Recognizing sediment as an important pollutant** and improving the linkage between erosion and sediment control and water quality programs;
- **Maintaining legislative recognition** for the water quality problems associated with soil erosion and sedimentation;
- **Providing dedicated and reliable funding** for soil erosion and sediment control projects in the Great Lakes basin supporting the implementation of urban and rural non-point source pollution management programs;
- **Coordinating efforts, roles and initiatives** between federal, state and local soil and water conservation and pollution control agencies and groups in the Great Lakes basin;
- **Building coalitions and networks** that support the Great Lakes Basin Program;
- **Sharing and obtaining information** on the economic and environmental damage caused by soil erosion and sedimentation.

2. GREAT LAKES RESTORATION INITIATIVE FUNDING

This is the Environmental Protection Agency's initiative to clean up the Great Lakes Region. There is to be funding in excess of $450 million for 5 years starting in 2010. Funding is available for amounts up to $1 million for watershed remediation projects. These projects involve implementing watershed best management practices and measures, demonstration projects, reduction in urban and suburban nonpoint sources of phosphorus, watershed planning, water management design and implementation and watershed modeling.

This funding will also provide a significant amount of funds to program budgets administered by the National Resource Conservation Service (NRCS), Department of Agriculture and the Michigan Department of Natural Resources and Environment (DNRE).

ENVIRONMENTAL PROTECTION AGENCY (EPA)

The EPA usually announces the round of grants in the late summer, early fall, of the year preceding the release of the Requests for Proposals (RFPs). The RFPs are generally released in December to January. The submittal dates vary widely depending on the program. Additional information can be obtained at http://epa.gov/greatlakes/fund/ and http://www.greatlakesdirectory.org/grants.htm.

NATIONAL RESOURCE CONSERVATION SERVICE (NRCS)

National Resource Conservation Service provides limited funding, but is a good source for those individual landowners who want to do small projects in the watershed. The

EQIP and WHIP programs are available to provide small funding sources. Additional information is available at http://www.nrcs.usda.gov/technical/cig/index.html

MICHIGAN DEPARTMENT OF NATURAL RESOURCES & ENVIRONMENT

The Michigan Department of Natural Resources & Environment is always a good source of Non Point Source grants to address watershed problems related to nutrients, bacteria, sediment, and emerging issues. The Nonpoint Source Program follows a two-step process requiring all applicants interested in funding through this request for proposals (RFP) to electronically submit a Notice of Intent (NOI) form for each proposed project. Full proposals will only be accepted from invited entities identified through the NOI process. The deadline for submittal of a NOI is typically in September. The deadline for submittal of full applications is in October.

Grant awards are contingent upon the sale of Clean Michigan Initiative (CMI) general obligation bonds and the enactment of a sufficient funding mechanism in the FY DNRE budget to support this grant program and any other necessary approvals.

The RFP is for water quality grants offered by the Michigan Department of Natural Resources & Environment utilizing funding from Section 319(h) and 205(j)/604(b) of the federal Clean Water Act, and from the Clean Michigan Initiative (CMI) Nonpoint Source Pollution Control Grants. The DNRE will advise what level of funding will be available in a grant cycle. Additional information can be obtained at:

http://michigan.gov/deq/0,1607,7-135-3313_3682_3714---,00.html

The above sites are all public sources of funding through State and Federal programs. It is also beneficial to use a web browser such as GOOGLE, BING, YAHOO, and other search engines to search for grants and funding from the private sector. There are local community foundations, large endowed foundations such as the Kellogg Foundation, Joyce Foundation, Herbert H. and Grace A. Dow Foundation, Coca Cola, and many other private foundations. These foundations can be excellent sources of funding for projects that meet the following criteria:

- have needs which are in areas not normally funded by governmental or public financing
- clearly stated objectives
- strong and purposeful management
- are publicly accountable
- are not hesitant to explore, initiate, volunteer, or execute original ideas or concepts

V. ADDITIONAL RECOMMENDATIONS

Spring/Summer 2010:

- Obtain additional dissolved oxygen profiles at four more locations within the lake, specifically (1) in the west bay of the northeastern embayment (within D-4), (2) in the east bay of the northeastern embayment (within D-1), (3) southeastern embayment (within D-8), and (3) southwestern end (within D-18).
- Obtain sediment samples within the Derby Drain to determine phosphorous loading in sediments entering lake from this point source.
- Obtaining similar sediment samples from outlet of Little Paw Paw Lake.
- Obtaining water quality data for the Derby Drain, outlet of Little Paw Paw Lake.
- Involve riparians with lake surveys, sediment and water quality analyses - make it into a day event.

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