Lake Susan, City of Chanhassen, Carver County, Minnesota (Google Earth)

Lake Soil Fertility Evaluation for Lake Susan, City of Chanhassen, MN

Lake Sediment Samples Collected:
May 9, 2013 (25 samples)

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Lake Soil Fertility Evaluation for Lake Susan, City of Chanhassen, MN

Summary

A total of 25 Lake Susan sediment samples were collected on May 9, 2013 throughout the 88 acre lake to characterize lake sediment fertility (Figure S1). The lake "soils" were analyzed for 15 parameters including phosphorus, nitrogen, potassium, iron, and pH.

One objective of the lake sediment survey was to estimate the phosphorus release potential of the lake sediments. Results indicated that deep lake sediments have a low potential for phosphorus release and shallow sediments have a somewhat greater potential based on iron to phosphorus ratios.

Another objective of the sediment survey was to determine where curlyleaf and milfoil would have the potential to produce heavy growth (where heavy growth is defined as plants matting at the surface) in Lake Susan. Based on lake sediment sample results, it is predicted the lake sediments have a potential to produce mostly light to moderate curlyleaf growth. Other sediment parameters indicate there is a potential for sediments to produce light to moderate milfoil growth conditions in the growing zone of Lake Susan.

Maps showing areas of predicted phosphorus release, curlyleaf, and milfoil growth are shown on the next three pages (Figures S2, S3, and S4).

Figure S1. Lake Susan sediments in the growing zone varies from a mucky sediment to a silty-sand mixture. This picture shows a silty-sand sediment in Lake Susan.

Sediment Phosphorus Release Potential

A variety of factors contribute to internal phosphorus loading in lakes. Research by Jensen et al (1992) found when a total iron to total phosphorus ratio was greater than 15 to 1, phosphorus release from lake sediments was minor. That benchmark has been used to characterize the potential of Lake Susan sediments to release phosphorus. Results show several of the sediment sites in deep water (17, 18, 19) have a low Fe:P ratio and that phosphorus release from Lake Susan sediments in deep water would appear to be high. Phosphorus release potential is also high in several areas in shallower depths (Figure S2).

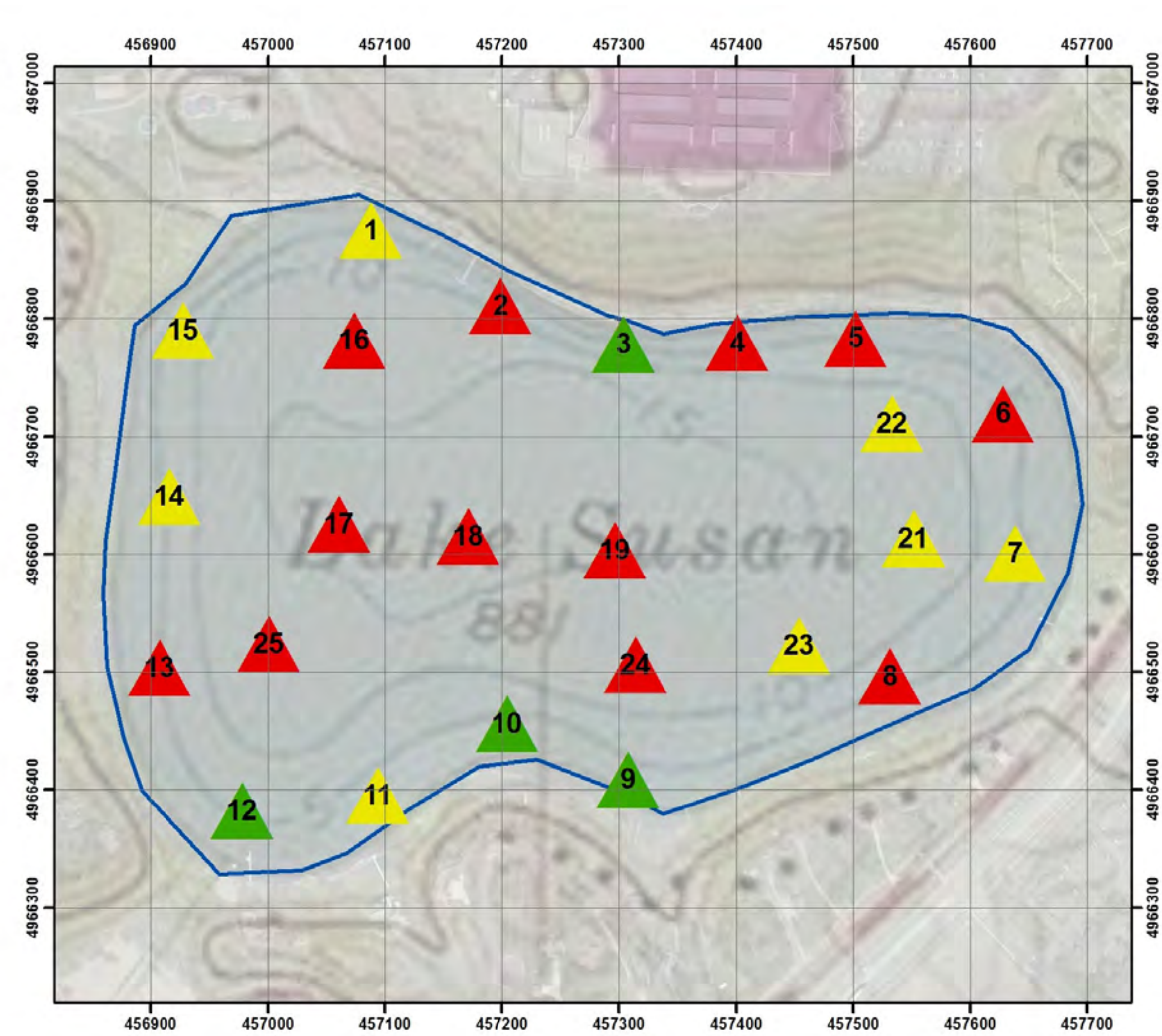


Figure S2. Lake sediment phosphorus release potential at each sample site is shown with colored triangles. Green = low potential, yellow = moderate potential, and red = high potential.

Curlyleaf Pondweed Growth Potential Based on Lake Sediments

Lake sediment sampling results from 2013 have been used to predict lake bottom areas that have the potential to support heavy curlyleaf pondweed plant growth. Based on the key sediment parameters of pH, sediment bulk density, organic matter, and the Fe:Mn ratio (McComas, unpublished), the predicted growth characteristics of curlyleaf pondweed are shown in Figure S3. Based on sediment characteristics, curlyleaf pondweed is predicted to have mostly light to moderate growth in Lake Susan.

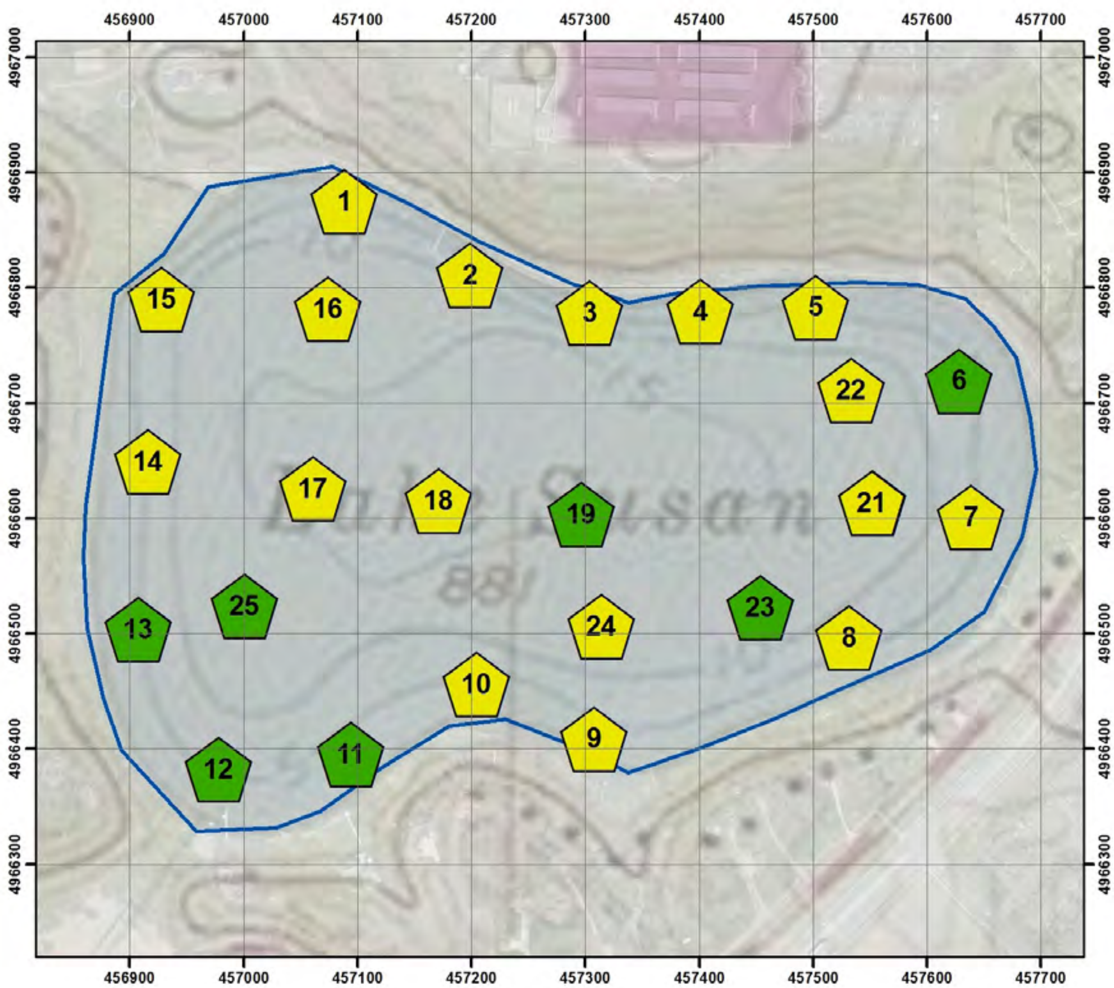
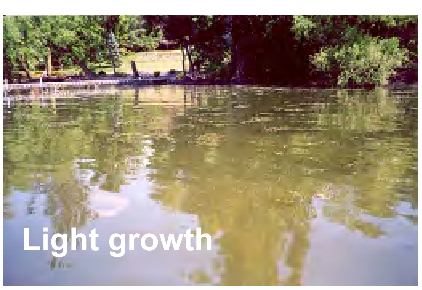
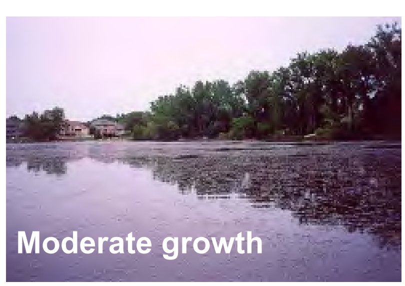
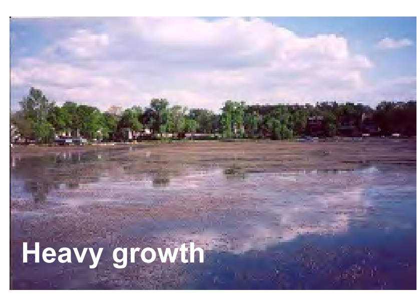


Figure S3. Curlyleaf Pondweed: Areas of predicted growth are shown with pentagons. Green = light growth and yellow = moderate growth.







Eurasian Watermilfoil Growth Potential Based on Lake Sediments

Lake sediment sampling results from 2013 have been used to predict lake bottom areas that have the potential to support EWM growth. Eurasian watermilfoil has been in Lake Susan for a number of years. Based on the key sediment parameters of NH_4 and organic matter (McComas, unpublished), a map was prepared that predicts what type of growth could be expected for milfoil growth in Lake Susan (Figure S4). In shallow water, lake sediment results predict mostly light to moderate growth. In water depths of 13 feet to 15 feet, heavier milfoil growth is predicted.

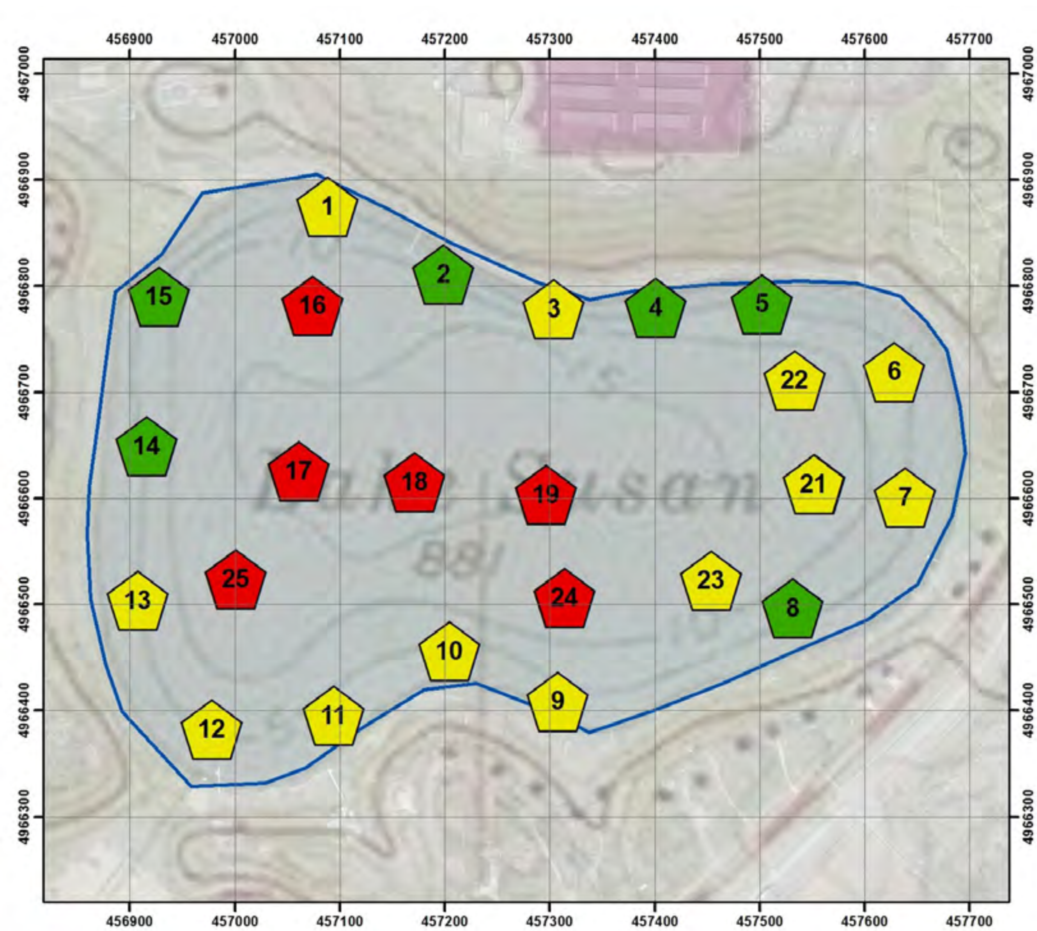


Figure S4. Eurasian Watermilfoil: Areas of predicted growth are shown with pentagons. Green = light growth, yellow = moderate growth, and red = heavy growth.

Lake Soil Fertility Evaluation for Lake Susan, City of Chanhassen, Minnesota

Introduction

Lake Susan is a moderately fertile, 88 acre lake located within the City of Chanhassen (Carver County), Minnesota. The lake is a recreational lake with a public landing and a fishing pier, and is eutrophic.

The objectives of this lake soil fertility survey were to characterize the lake soils around Lake Susan to assess potential for sediment phosphorus release and to use lake soil data to predict where areas of heavy growth of curlyleaf and milfoil growth could occur in the future.

Methods

Lake Soil Survey: A total of 25 samples were collected from depths ranging from 5 to 16 feet. Location of sample sites is shown in Figure 1. Samples in shallow water were collected using a modified soil auger, 5.2 inches in diameter. Samples in deeper water (12 - 16 feet) were sampled using a ponar dredge. Soils were sampled to a sediment depth of 6 inches. The lake soil from the sampler was transferred to 1-gallon zip-lock bags and sent to the University of Minnesota Soil Testing and Research Analytical Laboratory.

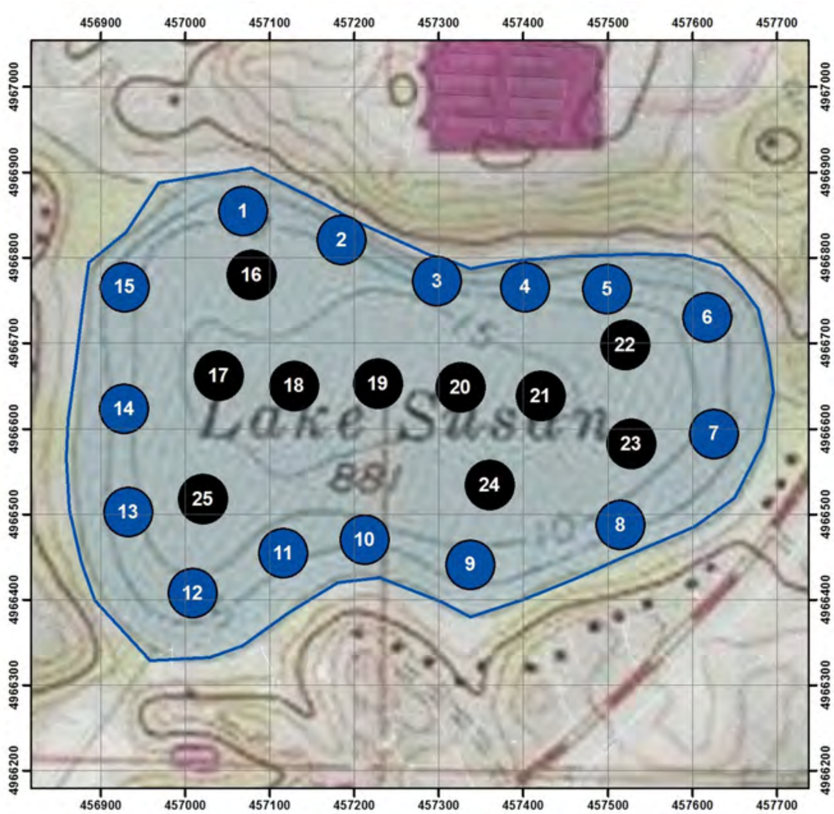


Figure 1. Location map of the lake sediment collection sites.

Lake Soil Analysis Using Standard Soil Tests: At the lab, sediment samples were air dried at room temperature, crushed and sieved through a 2 mm mesh sieve. Sediment samples were analyzed using standard agricultural soil testing methods. Fifteen parameters were tested for each soil sample. A summary of extractants and procedures is shown in Table 1. Routine soil test results are given on a weight per volume basis.

Table 1. Soil testing extractants used by University of Minnesota Soil Testing and Research Analytical Laboratory. These are standard extractants used for routine soil tests by most Midwestern soil testing laboratories (reference: Western States Laboratory Proficiency Testing Program: Soil and Plant Analytical Methods, 1996-Version 3).

Parameter	**Extractant**
P-Bray	0.025M HCL in 0.03M NH_4F
P-Olsen	0.5M $NaHCO_3$
NH_4-N	2N KCL
K, Ca, Mg	1N NH_4OA_c (ammonium acetate)
Fe, Mn, Zn, Cu	DTPA (diethylenetriamine pentaacetic acid)
B	Hot water
SO_4-S	$Ca(H_2PO_4)_2$
pH	water
Organic matter	Loss on ignition at 360^oC

Figure 2a. Soil auger used to collect lake sediments in water depths to 7 feet.

Figure 2b. Ponar dredge used to collect lake sediments in deeper water.

The Adjustment Factor for Reporting Results as Volume/Weight: There has been discussion for a long time on how to express analytical results from soil sampling. Lake sediment research results are often expressed as grams of a substance per kilogram of lake sediment, commonly referred to as a weight basis (mg/kg). However, in the terrestrial sector, to relate plant production and potential fertilizer applications to better crop yields, soil results typically are expressed as grams of a substance per cubic foot of soil, commonly referred to as a weight per volume basis. Because plants grow in a volume of soil and not a weight of soil, farmers and producers typically work with results on a weight per volume basis.

That is the approach used here for lake sediment results: they are reported on a weight per volume basis or $\mu g/cm^3$.

A bulk density adjustment was applied to lake sediment results as well. For agricultural purposes, in order to standardize soil test results throughout the Midwest, a standard scoop volume of soil has been used. The standard scoop is approximately a 10-gram soil sample. Assuming an average bulk density for an agricultural soil, a standard volume of a scoop has been a quick way to prepare soils for analysis, which is convenient when a farmer is waiting for results to prepare for a fertilizer program. It is assumed a typical silt loam and clay texture soil has a bulk density of 1.18 grams per cm^3. Therefore a scoop size of 8.51 cm^3 has been used to generate a 10-gram sample. It is assumed a sandy soil has a bulk density of 1.25 grams per cm^3 and therefore a 8.00 cm^3 scoop has been used to generate a 10-gram sample. Using this type of standard weight-volume measurement, the lab can use standard volumes of extractants and results are reported in ppm which is close to $\mu g/cm^3$. For all sediment results reported here, a scoop volume of 8.51 cm^3 was used.

Although lake sediment bulk density has wide variations, a scoop volume of 8.51 cm^3 was used for all lake sediment samples in this report. This would not necessarily produce a consistent 10-gram sample. Therefore, for our reporting, we have used adjusted weight-volume measurements and results have been adjusted based on the actual lake sediment bulk density. We used a standard scoop volume of 8.51 cm^3, but sediment samples were weighed. Because test results are based on the premise of a 10 gram sample, if our sediment sample was less than 10 grams, then the reported concentrations were adjusted down to account for the less dense bulk density. If a scoop volume weighed greater than 10.0 grams than the reported concentrations were adjusted up. For example, if a 10-gram scoop of lake sediment weighed 4.0 grams, then the correction factor is 4.00 g/ 10.00 g = 0.40. If the analytical result was 10 ppm based on 10 grams, then it should be 0.40 x 10 ppm = 4 ppm based on 4 grams. The results could be written as 4 ppm or 4 $\mu g/cm^3$. Likewise, if a 10-gram scoop of lake sediment weighed 12 grams, then the correction factor is 12.00 g / 10.00 g = 1.20. If the analytical result was 10 ppm based on a 10 gram scoop, then it should be 1.20 x 10 ppm = 12 ppm based on 12 grams. The result could be written as 12 ppm or 12 $\mu g/cm^3$. These are all dry weight determinations.

This correction factor is important for evaluating the ammonium-nitrogen raw data. There appears to be a threshold nitrogen concentration at 10 ppm. If nitrogen is greater than 10 ppm, heavy milfoil growth can occur. If the correction factor is not applied, light, fluffy sediments may produce a high nitrogen reading, but would not support heavy milfoil growth. When the correction factor is applied, and if the nitrogen concentration falls below 10 ppm, light or moderate growth of milfoil is predicted rather than heavy growth.

Lake Soil Analysis Using Microwave Heating with Nitric Acid Digestion (EPA Method 3051): Of the 25 collected samples, seven Lake Susan sediment samples were subsampled and analyzed with a more rigorous digestion method following the methodology of EPA Method 3051. A lake sediment sample of up to 0.5 g was digested in 10 ml of concentrated nitric acid for 10 minutes using microwave heating. Although this is a rigorous digestion it is not intended to accomplish total decomposition of the sample and therefore concentrations may not reflect the total content in the sample, however, it is close to a total content. Results are reported two ways, first as a weight/weight, as µg/g and then, because the bulk density of the sample was known, results are also adjusted to be reported as $\mu g/cm^3$-dry weight using an adjustment factor.

Lake Soil Survey Results

Standard Soil Tests: A total of 25 lake sediment sites were sampled around Lake Susan in water depths from 5 to it's deepest point up to 16 feet. Lake soil sampling results are shown in Table 2. Unadjusted lake sediment data are found in the Appendix.

Previous research (Jensen et al 1992) has shown that a high iron to phosphorus ratio is correlated with a low sediment phosphorus release potential.

Soil fertility conditions were also evaluated to determine if lake sediments could potentially support heavy growth conditions in Lake Susan for curlyleaf pondweed or for Eurasian watermilfoil. For curlyleaf pondweed, the critical sediment parameters have been found to be sediment pH, bulk density, organic matter, and the iron to manganese ratio. For Eurasian watermilfoil, we have used a sediment nitrogen concentration of over 10 parts per million (ppm) as an indicator of potential heavy growth. In other studies there is a correlation to nuisance milfoil growth when exchangeable ammonium is over 10 ppm in lake sediments. It turns out organic matter content over 20% can limit heavy milfoil growth.

Table 2. Lake soil data with adjusted values based on standard soil testing methods. Samples were collected on May 9, 2013. Soil chemistry results are reported as ppm (µg/cm^3) except for organic matter (%), and pH (standard units).

Standard Soil Tests (adjusted values)																		
Site	Depth (ft)	Bulk Density (g/cm^3)	Water pH	Bray-P (ppm)	Olsen-P (ppm)	Potassium (ppm)	Organic Matter (%)	Zinc (ppm)	Iron (ppm)	Copper (ppm)	Manganese (ppm)	Calcium (ppm)	Magnesium (ppm)	Boron (ppm)	Ammonium (ppm)	Sulfate (ppm)	Fe/Mn	Fe/P
1	6	1.25	7.7	1.6	10.1	45.6	1.7	2.0	77.0	1.5	17.7	3159.6	192.1	0.313	4.4	89.7	4.3	7.6
2	7	1.28	7.6	1.1	8.7	25.1	1.5	1.1	63.8	0.9	26.0	3118.5	170.8	0.364	2.4	78.5	2.4	7.3
3	7	1.03	7.6	4.4	2.6	157.4	2.6	5.6	82.5	5.3	43.9	3306.6	458.1	0.278	9.3	87.1	1.9	18.8
4	6	1.35	7.7	6.9	6.9	26.5	0.9	0.9	39.0	1.2	15.7	2540.1	124.1	0.180	2.8	61.0	2.5	5.7
5	5	1.38	7.8	1.2	10.6	29.4	0.7	1.0	37.7	1.1	22.4	3624.1	131.3	0.185	2.6	58.9	1.7	3.6
6	7	1.24	7.5	21.1	10.6	34.9	1.2	2.8	39.3	2.6	12.1	2066.3	123.9	0.285	4.2	124.7	3.3	1.9
7	7	0.96	7.6	0.8	5.7	56.6	4.2	1.7	72.0	2.2	20.7	2695.4	178.3	0.405	4.9	39.4	3.5	12.6
8	7	1.37	7.7	5.8	5.8	24.5	0.7	1.5	31.5	1.5	15.5	2890.6	160.5	0.220	3.1	95.5	2.0	5.4
9	7	0.81	7.8	0.7	4.2	54.0	9.5	1.5	80.9	2.2	27.0	2496.8	192.2	0.277	3.7	12.5	3.0	19.3
10	7	1.02	7.6	0.9	4.4	62.7	3.1	4.1	66.5	1.5	25.8	3023.8	222.6	0.411	3.4	67.9	2.6	15..1
11	7	0.77	7.7	0.7	5.9	41.4	12.2	1.6	82.7	1.9	18.2	2365.1	165.6	0.405	3.4	27.6	4.6	14.0
12	6	0.74	7.3	3.8	3.2	42.3	14.9	2.4	87.7	1.5	19.1	2170.7	187.1	0.349	3.8	63.2	4.6	23.1
13	7	0.73	7.5	0.6	11.1	35.8	11.6	1.7	82.0	1.6	18.4	2321.9	173.5	0.671	3.4	80.3	4.5	7.4
14	7	1.21	7.7	2.1	6.2	32.9	1.7	1.4	46.6	1.7	14.8	2785.7	145.7	0.357	2.6	51.3	3.1	7.5
15	7	0.92	7.8	1.6	4.7	36.0	4.1	0.9	43.6	1.0	7.4	2391.0	125.1	0.288	3.3	21.1	5.9	9.3
16	13	0.74	7.6	0.6	23.3	90.1	7.2	3.5	150.3	4.2	16.8	2702.7	273.5	0.458	15.5	62.4	9.0	6.5
17	15	0.73	7.5	0.6	43.0	115.4	8.7	3.3	215.3	5.3	29.5	2990.3	308.8	0.594	20.7	77.3	7.3	5.0
18	16	0.73	7.5	0.6	39.6	109.6	9.0	3.2	222.4	5.0	34.1	3040.6	330.1	0.619	19.6	89.8	6.5	5.6
19	15	0.71	7.4	0.6	36.0	112.3	9.1	2.5	239.4	4.3	42.7	2786.1	285.6	0.582	11.5	99.7	5.6	6.7
20	15	0.65	7.5	0.6	14.3	56.8	10.3	3.1	116.3	4.7	14.3	2334.4	212.6	0.480	5.3	72.8	8.1	8.1
21	13	0.67	7.6	0.6	14.7	60.6	9.8	2.8	122.0	3.5	12.8	2421.5	207.6	0.433	8.1	65.7	9.5	8.3
22	13	0.65	7.5	0.6	13.3	52.2	8.8	2.5	107.7	3.5	14.9	2393.7	207.0	0.405	5.8	81.6	7.2	8.1
23	13	0.69	7.4	0.6	17.9	73.0	10.5	2.5	156.3	3.7	21.2	2651.4	268.5	0.571	8.4	114.7	7.4	8.8
24	14	0.71	7.5	0.6	27.2	95.3	11.1	3.1	192.2	4.7	27.6	2956.0	308.4	0.652	14.6	77.2	7.0	7.1
25	15	0.73	7.4	0.6	34.0	97.7	10.1	2.5	244.9	4.8	39.5	3158.9	310.9	0.649	18.2	96.5	6.2	7.2

EPA Method 3051 Digestion: Sediment samples from seven sites were spilt and analyzed using a fairly rigorous digestion using EPA method 3051. Results are shown on a weight/weight basis (µg/g)(Table 3) and on a weight/volume basis (Table 4). Samples 17, 19, and 20 had lower bulk densities then the shallower samples and parameter concentrations are lower on weight per volume basis compared to the weight per weight basis.

Table 3. Microwave heating with HNO3 digestion and ICP analysis (EPA method 3051). Values are shown on a weight/weight basis.

EPA Method 3051 (values in µg/g)															
Site	Depth (ft)	Al	B	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	P	Pb	Zn
S - 3R	7	9505.8	14.872	34504	0.743	17.925	28.179	15851	2044.5	16972	780.12	362.08	24.996	414.78	11.649	93.961
S - 3R DUP	7	10733	18.067	34861	0.787	20.386	27.498	16995	2125.5	17375	776.91	378.96	26.896	443.34	13.575	95.504
S - 7R	7	3275.5	5.924	37331	0.417	4.180	15.726	5539.5	662.13	5007.3	374.91	194.25	8.835	472.89	4.472	27.659
S - 9R	7	3794.1	6.939	66534	0.307	6.676	24.653	8093.6	827.54	6102.9	1135.9	327.97	11.086	653.63	3.052	38.341
S - 14R	7	1884.0	3.386	31168	0.168	1.102	8.605	3163.7	367.27	3933.5	285.47	136.57	5.474	465.76	0.863	13.415
S - 17R	15	16195	20.521	90424	0.866	19.985	69.578	23643	2445.3	9889.2	1793.0	1021.0	23.599	1319.6	17.108	107.35
S - 19R	15	17045	22.032	98399	1.037	20.795	72.494	24098	2556.6	9656.6	1876.2	1318.6	23.276	1292.0	18.597	106.32
S - 20R	15	12139	18.238	72813	1.297	17.293	65.988	18037	1910.0	10313	1192.9	563.75	23.625	905.80	22.388	91.355

Table 4. Microwave heating with HNO3 digestion and ICP analysis (EPA method 3051). Values are shown on a weight/volume basis.

EPA Method 3051 - Adjusted Values (values in µg/cm³-dry weight)																
Site	Depth (ft)	Al *adjusted*	B *adjusted*	Ca *adjusted*	Cd *adjusted*	Cr *adjusted*	Cu *adjusted*	Fe *adjusted*	K *adjusted*	Mg *adjusted*	Mn *adjusted*	Na *adjusted*	Ni *adjusted*	P *adjusted*	Pb *adjusted*	Zn *adjusted*
S - 3R	7	8365	13.1	30364	0.65	15.8	24.8	13949	1799	14935	687	319	22.0	365	10.3	82.7
S-3R DUP	7	9445	15.9	30678	0.69	17.9	24.2	14956	1870	15290	684	333	23.7	390	11.9	84.0
S - 7R	7	2686	4.9	30611	0.34	3.4	12.9	4542	543	4106	307	159	7.2	388	3.7	22.7
S - 9R	7	2618	4.8	45908	0.21	4.6	17.0	5585	571	4211	784	226	7.6	451	2.1	26.5
S - 14R	7	1941	3.5	32103	0.17	1.1	8.9	3259	378	4052	294	141	5.6	480	0.9	13.8
S - 17R	15	10041	12.7	56063	0.54	12.4	43.1	14659	1516	6131	1112	633	14.6	818	10.6	66.6
S - 19R	15	10227	13.2	59039	0.62	12.5	43.5	14459	1534	5794	1126	791	14.0	775	11.2	63.8
S - 20R	15	6676	10.0	40047	0.71	9.5	36.3	9920	1051	5672	656	310	13.0	498	12.3	50.2

The soil method extraction represents available metals and nutrients and EPA method 3051 more closely represents a total content. It is clear, based on the ratios, that not all the metal or nutrient content is available and their concentrations are less. For example, for phosphorus total phosphorus is much higher than the available phosphorus and the ratio of total phosphorus to available phosphorus varies from 19 to 107 (Table 5).

Table 5. Comparing the ratios of a vigorous digestion (EPA method 3051) to a mild extraction (Soil methods) for nine parameters.

Values for 3051 and Soils Tests are in µg/cm³																											
Site	Boron			Calcium			Copper			Iron			Potassium			Mg			Mn			Phosphorus			Zn		
	3051	Soil	Ratio	3051	Soil	Ratio	3051	Soil	Ratio	3051	Soil	Ratio	3051	Soil	Ratio	3051	Soil	Ratio	3051	Soil	Ratio	3051	Soil	Ratio	3051	Soil	Ratio
S - 3R	14.5	0.28	51.8	30,521	3,307	9.2	24.5	5.3	4.6	14453	82.5	175.2	1835	157.4	11.7	15113	458.1	33.0	686	43.9	15.6	378	4.4	85.9	83.4	5.6	14.9
S - 7R	4.9	0.41	12.0	30611	2695	11.4	12.9	2.2	5.9	4542	72.0	63.1	543	56.6	9.6	4106	178.3	23.0	307	20.7	14.8	388	5.7	68.1	22.7	1.7	13.4
S - 9R	4.8	0.28	17.1	45908	2497	18.4	17.0	2.2	7.7	5585	80.9	69.0	571	54.0	10.6	4211	192.2	21.9	784	27	29.0	451	4.2	107.4	26.5	1.5	17.7
S - 14R	3.5	0.36	9.7	32103	2786	11.5	8.9	1.7	5.2	3259	46.6	69.9	378	32.9	11.5	4052	145.7	27.8	294	14.8	19.9	480	6.2	77.4	13.8	1.4	9.9
S - 17R	12.7	0.59	21.5	56063	2990	18.8	43.1	4.3	10.0	14659	215.3	68.1	1516	115.4	13.1	6131	308.8	19.9	1112	29.5	37.7	818	43.0	19.0	66.6	3.3	20.2
S - 19R	13.2	0.58	22.8	59039	2786	21.2	43.5	4.3	10.1	14459	239.4	60.4	1534	112.3	13.7	5794	285.6	20.3	1126	42.7	26.4	775	36.0	21.5	63.8	2.5	25.5
S - 20R	10.0	0.48	20.8	40047	2334	17.2	36.3	4.7	7.7	9920	116.3	85.3	1051	56.8	18.5	5672	212.6	26.7	656	14.3	45.9	498	14.3	34.8	50.2	3.1	16.2

Sediment Phosphorus Release Potential Based on Fe:P Ratios

A variety of factors contribute to internal phosphorus loading in lakes. Research by Jensen et al (1992) found when a total iron to total phosphorus ratio was greater than 15 to 1, phosphorus release from lake sediments was minor. We have used the ratio for the soil test results as well. That benchmark of 15:1 has been used to characterize the potential of Lake Susan sediments to release phosphorus. If the Fe:P ratio is greater than 15:1, p-release was considered to be light. If the Fe:P ratio was 7.5 to 15 p-release was considered to be moderate and if the Fe:P ratio was less than 7.5, p-release was considered to be high. Results show several of the sediment sites have a low Fe:P ratio in deep water and that phosphorus release from Lake Susan sediments would appear to be high. In shallower water, sediment phosphorus release appears to be light to high (Table 6 and Figure 3). Several deep water sites have high sediment phosphorus, but also have a high iron content as well.

Table 6. Lake sediment data for iron and phosphorus and the calculated Fe to P ratio. Samples were collected on May 9, 2013.

STANDARD SOIL TESTS					
Site	Depth (ft)	Iron (ppm)	Bray-P (ppm)	Olsen-P (ppm)	Fe/P
1	6	77.0	1.6	10.1	7.6
2	7	63.8	1.1	8.7	7.3
3	7	82.5	4.4	2.6	18.8
4	6	39.0	6.9	6.9	5.7
5	5	37.7	1.2	10.6	3.6
6	7	39.3	21.1	10.6	1.9
7	7	72.0	0.8	5.7	12.6
8	7	31.5	5.8	5.8	5.4
9	7	80.9	0.7	4.2	19.3
10	7	66.5	0.9	4.4	15.1
11	7	82.7	0.7	5.9	14.0
12	6	87.7	3.8	3.2	23.1
13	7	82.0	0.6	11.1	7.4
14	7	46.6	2.1	6.2	7.5
15	7	43.6	1.6	4.7	9.3
16	13	150.3	0.6	23.3	6.5
17	15	215.3	0.6	43.0	5.0
18	16	222.4	0.6	39.6	5.6
19	15	239.4	0.6	36.0	6.7
20	15	116.3	0.6	14.3	8.1
21	13	122.0	0.6	14.7	8.3
22	13	107.7	0.6	13.3	8.1
23	13	156.3	0.6	17.9	8.8
24	14	192.2	0.6	27.2	7.1
25	15	244.9	0.6	34.0	7.2

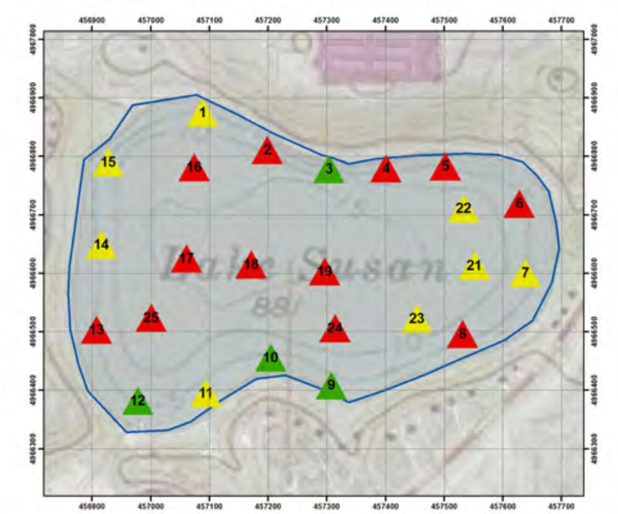


Figure 3. Lake sediment phosphorus release potential at each sample site is shown with colored triangles. Green = low potential, yellow = moderate potential, and red = high potential.

Phosphorus release results are slightly different when using EPA Method 3051 data compared to soil test methods with the major difference found in the deeper sediments (Table 7). EPA Method 3051 resulted in high iron concentrations producing high Fe:P ratios resulting in a low p-release potential (Table 7). However, a strong correlation was found between the available phosphorus (Olsen soil test) and total phosphorus (EPA Method 3051)(Table 8 and Figure 4), whereas there was not as strong of a correlation between available iron and total iron (Figure 4). Because total iron may not control phosphorus as well as available iron, the Fe:P ratios found in Figure 3 are considered to be more representative of p-release potential.

Table 7. Microwave heating with HNO3 digestion and ICP Analysis. Data are shown in µg/g except for the last column.

Site	Depth (ft)	Al (µg/g)	Fe (µg/g)	P (µg/g)	Al/Fe	Al/P	Fe/P (µg/g)	Fe/P (µg/cm³)
S - 3R	7	9506	15851	415	0.6	22.9	38.2	18.8
S-3R DUP	7	10733	16995	443	0.6	24.2	38.3	--
S - 7R	7	3276	5539.5	473	0.6	6.9	11.7	12.6
S - 9R	7	3794	8093.6	654	0.5	5.8	12.4	19.3
S - 14R	7	1884	3163.7	466	0.6	4.0	6.8	7.5
S - 17R	15	16195	23643	1320	0.7	12.3	17.9	5.0
S - 19R	15	17045	24098	1292	0.7	13.2	18.7	6.7
S - 20R	15	12139	18037	906	0.7	13.4	19.9	8.1

Table 8. Phosphorus results for seven samples using EPA Method 3051 and a standard soil test, in this case, the Olsen-P method.

Site	SOIL TEST PHOSPHORUS (Olsen-P)		EPA METHOD 3051	
	Olsen-P (ppm) uncorrected	Olsen-P (ppm) adjusted	P (µg/g)	P (µg/cm³)
S3	5 (Bray)	4.4 (Bray)	415	365
S4	6	6.9	443	390
S7	7	5.7	473	388
S9	6	4.2	654	451
S14	6	6.2	466	480
S17	69	43.0	1,320	818
S19	60	36.0	1,292	775
S20	26	14.3	906	498

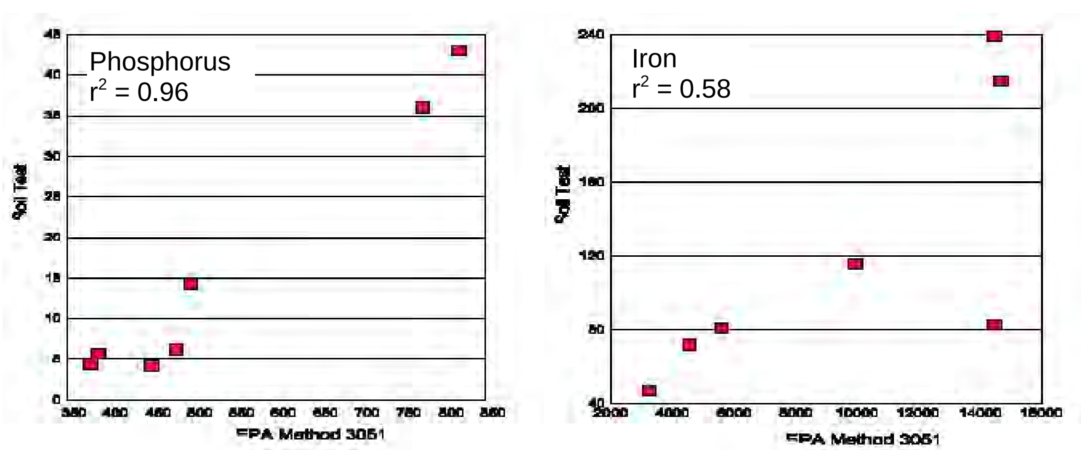


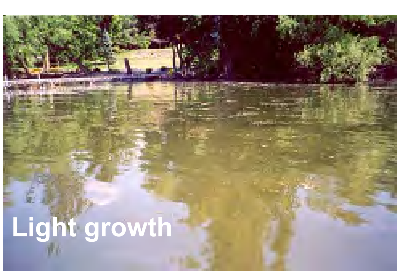
Figure 4. Correlation of phosphorus (left) and iron (right) comparing EPA Method 3051 with standard soil test.

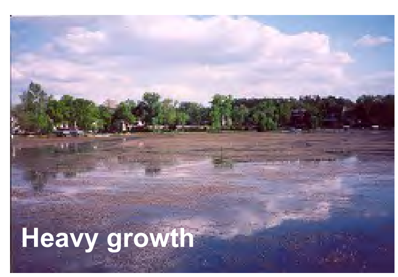
Curlyleaf Pondweed Growth Potential

Lake sediment sampling results from 2013 have been used to predict lake bottom areas that have the potential to support nuisance curlyleaf pondweed plant growth. Based on the key sediment parameters of pH, sediment bulk density, organic matter, and the Fe:Mn ratio (McComas, unpublished), the predicted growth characteristics of curlyleaf pondweed are shown in Table 9 and Figure 5.

Table 9. Lake Susan sediment data and ratings for potential heavy curlyleaf pondweed growth.

Site	Depth (ft)	pH (su)	Bulk Density (g/cm^3 dry)	Organic Matter (%)	Fe:Mn Ratio	Potential for Curlyleaf Pondweed Growth
Light Growth		**<7.4**	**1.04**	**0.1-5**	**>4.5**	**Light (green)**
Moderate Growth		**7.4-7.7**	**0.52-1.03**	**6-20**	**1.6-4.5**	**Moderate (yellow)**
Heavy growth		**>7.7**	**<0.51**	**>20**	**<1.6**	**Heavy (red)**
1	6	7.7	1.25	1.7	4.3	Moderate
2	7	7.6	1.28	1.5	2.4	Moderate
3	7	7.6	1.03	2.6	1.9	Moderate
4	6	7.7	1.35	0.9	2.5	Moderate
5	5	7.8	1.38	0.7	1.7	Moderate
6	7	7.5	1.24	1.2	3.3	Light
7	7	7.6	0.96	4.2	3.5	Moderate
8	7	7.7	1.37	0.7	2.0	Moderate
9	7	7.8	0.81	9.5	3.0	Moderate
10	7	7.6	1.02	3.1	2.6	Moderate
11	7	7.7	0.77	12.2	4.6	Light
12	6	7.3	0.74	14.9	4.6	Light
13	7	7.5	0.73	11.6	4.5	Light
14	7	7.7	1.21	1.7	3.1	Moderate
15	7	7.8	0.92	4.1	5.9	Moderate
16	13	7.6	0.74	7.2	9.0	Moderate
17	15	7.5	0.73	8.7	7.3	Moderate
18	16	7.5	0.73	9.0	6.5	Moderate
19	15	7.4	0.71	9.1	5.6	Light
20	15	7.5	0.65	10.3	8.1	Moderate
21	13	7.6	0.67	9.8	9.5	Moderate
22	13	7.5	0.65	8.8	7.2	Moderate
23	13	7.4	0.69	10.5	7.4	Light
24	14	7.5	0.71	11.1	7.0	Moderate
25	15	7.4	0.73	10.1	6.2	Light





Curlyleaf Pondweed Growth Potential Based on Lake Sediments

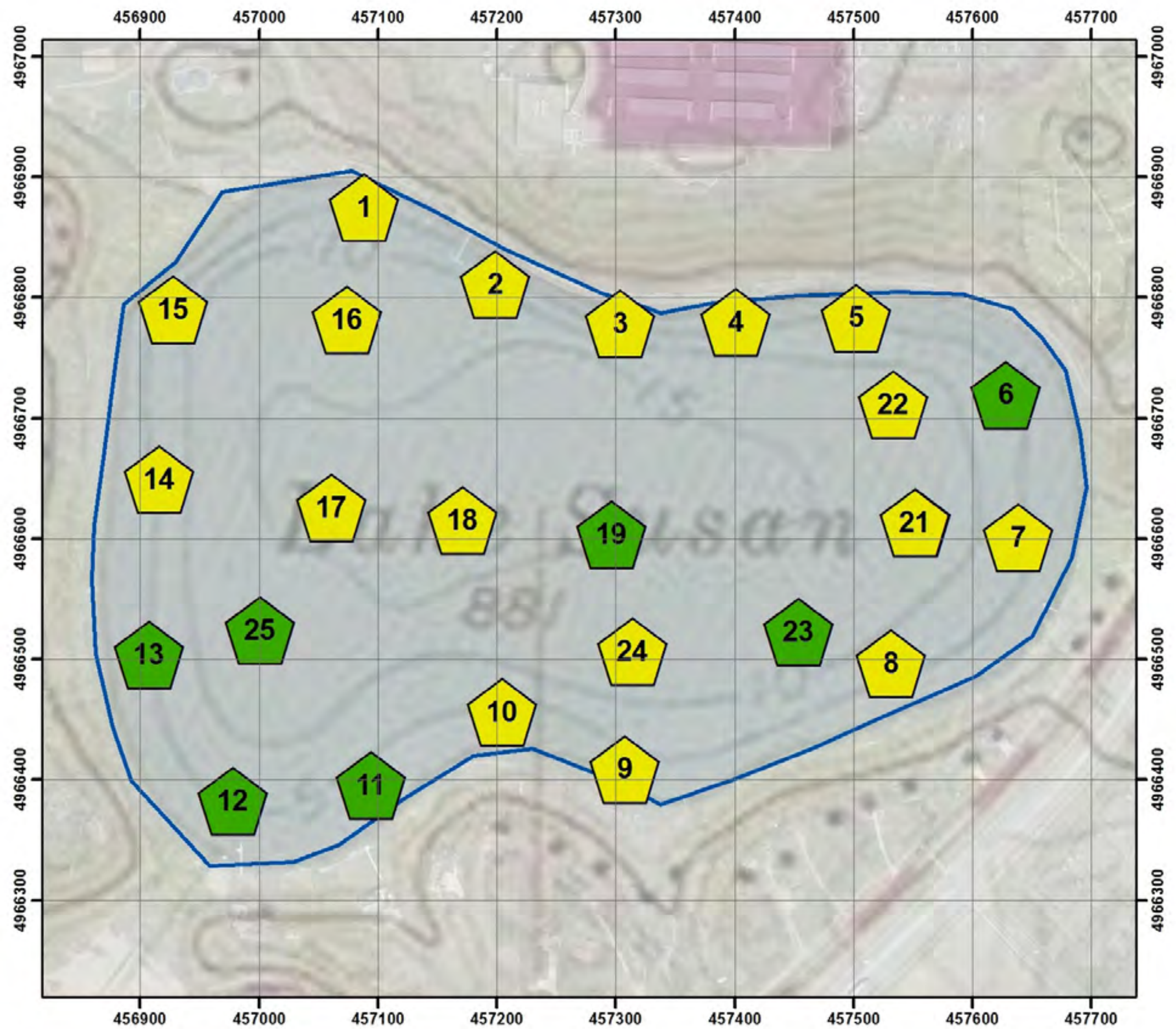


Figure 5. Curlyleaf Pondweed: Areas of predicted growth are shown with pentagons. Green = light growth, yellow = moderate growth, and red = heavy growth.

Curlyleaf Growth Predictions and 2013 Conditions

Based on lake sediment analyses, results indicate curlyleaf pondweed has the potential for mostly light to moderate growth in Lake Susan (Figure 6a). This type of future growth pattern would be expected to occur based on lake sediment characteristics.

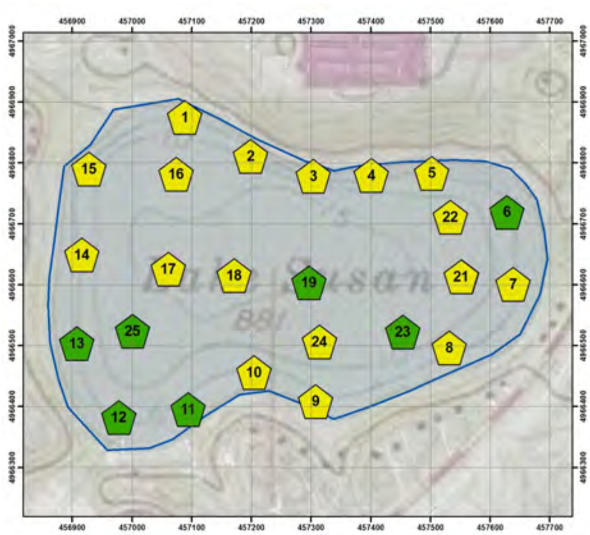


Figure 6a. Predicted curlyleaf pondweed growth characteristics based on 2013 lake sediment survey. Green shading = light growth, yellow shading = moderate growth, and red shading = heavy growth.

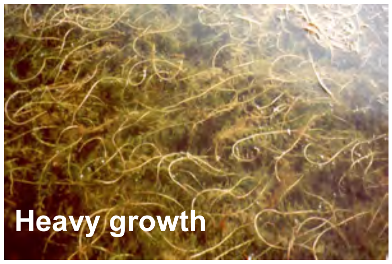
Figure 6b. Curlyleaf pondweed growth was fairly widespread in Lake Susan on May 9, 2013, but it was early in the growing season. Significant areas of curlyleaf had been treated.

Eurasian Watermilfoil Growth Potential

Lake sediment sampling results from 2013 have been used to predict lake bottom areas that have the potential to support EWM growth. Eurasian watermilfoil has been observed in Lake Susan in the past. Based on the key sediment parameters of NH_4 and organic matter (McComas, unpublished), a table and map were prepared that predict what type of milfoil growth could be expected in Lake Susan (Table 10 and Figure 7).

Table 10. Lake Susan sediment data and ratings for potential EWM growth.

Site	Depth (ft)	NH_4 Conc (ppm)	Organic Matter (%)	Potential for Eurasian Watermilfoil Growth
Light Growth		**<4**	**<0.5 or>20**	**Light (green)**
Moderate Growth		**4-10**	**0.6-2 and 18-20**	**Moderate (yellow)**
Heavy Growth		**>10**	**3-17**	**Heavy (red)**
1	6	4.4	1.7	Moderate
2	7	2.4	1.5	Light
3	7	9.3	2.6	Moderate
4	6	2.8	0.9	Light
5	5	2.6	0.7	Light
6	7	4.2	1.2	Moderate
7	7	4.9	4.2	Moderate
8	7	3.1	0.7	Light
9	7	3.7	9.5	Moderate
10	7	3.4	3.1	Moderate
11	7	3.4	12.2	Moderate
12	6	3.8	14.9	Moderate
13	7	3.4	11.6	Moderate
14	7	2.6	1.7	Light
15	7	3.3	4.1	Light
16	13	15.5	7.2	Heavy
17	15	20.7	8.7	Heavy
18	16	19.6	9.0	Heavy
19	15	11.5	9.1	Heavy
20	15	5.3	10.3	Moderate
21	13	8.1	9.8	Moderate
22	13	5.8	8.8	Moderate
23	13	8.4	10.5	Moderate
24	14	14.6	11.1	Heavy
25	15	18.2	10.1	Heavy



Eurasian Watermilfoil Growth Potential Based on Lake Sediments

In Lake Susan, in shallow water, lake sediment results predict mostly light to moderate growth. Currently, there is no plant growth in water depths out to 16 feet. However, if water clarity improves and aquatic plant growth would grow to deeper depths, it is predicted that there would be moderate to heavy milfoil growth in water depths of 13 to 15 feet (Figure 7).

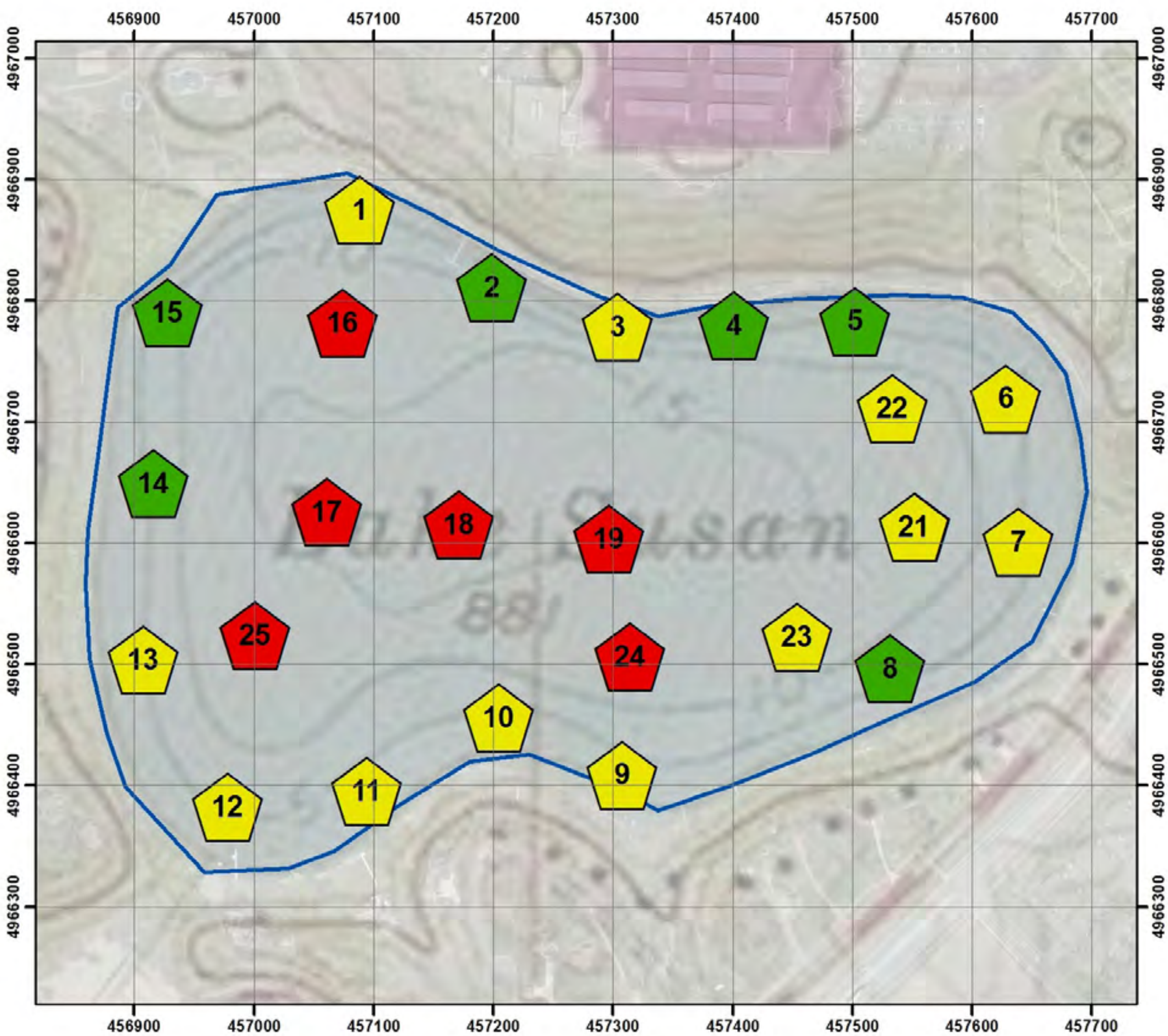


Figure 7. Eurasian Watermilfoil: Areas of predicted growth is shown with pentagons. Green = light growth, yellow = moderate growth, and red = heavy growth.

Overview of Role of Soil Nutrients for Plant Growth

The fertility of lake sediments may influence the type of aquatic plant growth in lakes. The role of sediment nutrients in mineral nutrition of land plants is shown in the box below. Aquatic plants have the same basic requirements as land plants .

Role of Soil Nutrients for the Mineral Nutrition in Plants **(from** Gardner, F.P., R.B. Pearce, and R.L. Mitchell. 1985. Physiology of Crop Plants and Foth, H.D. and B.G. Ellis. 1997. Soil Fertility 2nd Edition.)

N: Nitrogen is a constituent in amino acids, amides, proteins and nucleoprotein. It is essential to cell division, expansion and growth. Nitrogen is generally the most limiting nutrient in crop production (except for legumes).

P: Phosphorus is essential as a component of the energy transfer compound - ATP, for genetic information system (DNR & RNA), for cell membranes and phosphoprotein. Phosphorus is generally second to nitrogen as the most limiting nutrient for plant growth. Some phosphorus deficiency symptoms include dark green to blue-green leaves, and stunted plants. Phosphorus in soil solutions is usually present in low concentrations.

K: Potassium is essential to plants because it acts as enzyme activators for certain enzymes is aids in the maintenance of osmotic potential and water uptake. Most soils are buffered for potassium so yearly fluctuations are minor

Ca: Calcium is a component of the cell wall and is essential for cell division and elongation.

Mg: Magnesium is the center of the chlorophyll molecule. Magnesium also binds with ADP, ATP, and organic acids and therefore is essential for hundreds of enzymatic reactions. Magnesium is a cofactor for many enzymes. Nitrogen metabolism and protein synthesis are also dependent on the presence of Mg.

Fe: Iron is a constituent of the electron transport enzymes. Although Fe is not a part of the chlorophyll molecule, it affects chlorophyll levels because it must be present for chloroplast ultrastructure formation. Iron deficiencies can reduce the number and size of chloroplast.

Mn: Manganese is an activator of several enzymes, especially those involved in fatty acid and nucleotide synthesis and is essential in respiration and photosynthesis.

S: Sulfur is a constituent of the amino acids eystine, cysteine, and methionine. It also activities certain proteolytic enzymes and is a constituent of coenzyme A, glutathione, and certain vitamins. Sulfur deficiency can cause stunting and general plant yellowing: stems are thin. Sulfur is primarily absorbed as the SO_4 ion.

Zn: Zinc is essential for the enzymes in the synthesis of tryptophan. Zinc levels are positively correlated with increasing organic matter and negatively correlated with increasing pH.

B: Boron may influence cell development by controlling sugar transport and polysaccharide formation. Requirements for B and Ca often go hand in hand in hand; this has suggested that B, may be needed for cell wall formation and for metabolism of pectic compounds.

Cu: Copper is part of the chloroplast enzyme plastocyanin in the electron transport system between photoslystmes I and II. It is present as an exchange ion on soil particles and minutely in the soil solution. Copper may become toxic in soils with a use of copper sprays.

Na: Sodium is the most soluble of the salts. It may be a micronutrient, but generally is so abundant, is rarely limiting. It is leachable and its concentration gradually decreases over time.

CEC: Cation exchange capacity is the sum of exchangeable cations that a soil or other material can adsorb at a specific pH. CEC is determined at a pH of 7.0.

pH: pH has little or no direct effect on plant growth, however indirect effects are numerous and potent. In optimum pH is somewhere between 6.0 and 7.5.

Organic matter: Organic matter exerts a profound influence on almost every facet of the nature of soil. Most A horizons contain about 1 to 6 percent organic matter. A soil with greater than 20% organic matter is an organic soil and is classified as either peat or muck.

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Iron:phosphorus ratio in surface sediment as an indicator of phosphate release from aerobic sediments in shallow lakes

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Key words: Lakes, sediments, iron, phosphorus, phosphate release

Abstract

Analysis of Danish lakes showed that both mean winter and mean summer concentrations of lake water total phosphorus in the trophogenic zone correlated negatively with the total iron to total phosphorus ratio (Fe:P) in surface sediments. No correlation was found between the water total phosphorus concentration and either the sediment phosphorus concentration alone or with sediment calcium concentration. The increase in total phosphorus from winter to summer, which is partly a function of net internal P-loading, was lowest in lakes with high Fe:P ratios in the surface sediment.

A study of aerobic sediments from fifteen lakes, selected as representative of Danish lakes with respect to the sediment Fe and phosphorus content, showed that the release of soluble reactive phosphorus was negatively correlated with the surface sediment Fe:P ratio. Analysis of phosphate adsorption properties of surface sediment from 12 lakes revealed that the capability of aerobic sediments to buffer phosphate concentration correlated with the Fe:P ratio while the maximum adsorption capacity correlated with total iron. Thus, the Fe:P ratio may provide a measure of free sorption sites for orthophosphate ions on iron hydroxyoxide surfaces.

The results indicate that provided the Fe:P ratio is above 15 (by weight) it may be possible to control internal P-loading by keeping the surface sediment oxidized. Since the Fe:P ratio is easy to measure, it may be a useful tool in the management of shallow lakes.

APPENDIX

Lake Susan unadjusted lake sediment data based on Standard Soil Test methods, 2013.

Site	Bray-P (ppm)	Olsen-P (ppm)	NH_4OAc-K (ppm)	LOI OM (%)	Water pH	DTPA -Zn (ppm)	DTPA -Fe (ppm)	DTPA -Cu (ppm)	DTPA -Mn (ppm)	NH_4OAc-Ca (ppm)	NH_4OAc-Mg (ppm)	Boron (ppm)	NH_4-N (ppm)	SO_4-S (ppm)
S1	2 // 1	9 // 10	42 // 44	1.6 // 1.7	7.7 // 7.7	1.909 // 1.932	70.480 // 74.535	1.391 // 1.426	16.089 // 17.346	2977.0	181.03	0.270 // 0.320	4.5 // 3.7	90 // 79
S2	<1	8	23	1.5	7.6	0.976	58.498	0.853	23.895	2856.5 // 2865.5	139.47 // 173.88	0.334	2.2	72
S3	5	3	179	2.6	7.6	6.331	93.824	6.031	49.889	3760.3	521.00	0.316	10.5	99
S4	6	6	23	0.9	7.7	0.812	33.882	1.027	13.681	2207.5	107.88	0.156	2.5	53
S5	<1	9	25	0.7	7.8	0.873	32.011	0.932	19.057	3079.1	111.52	0.157	2.2	50
S6	20	10	33	1.2	7.5	2.645	37.235	2.504	11.411	1955.5	117.24	0.270	4.0	118
S7	<1	7	69	4.2	7.6	2.034	87.793	2.675	25.236	3287.1	217.39	0.494	6.0	48
S8	5	5	21	0.7	7.7	1.264	27.033	1.310	13.297	2481.2	137.77	0.189	2.7	82
S9	<1	6	78	9.5	7.8	2.193	116.90	3.238	39.039	3609.9	277.81	0.400	5.4	18
S10	<1	5	72	3.1	7.6	4.665	76.403	1.679	29.616	3473.0	255.69	0.472	3.9	78
S11	<1	9	63	12.2	7.7	2.471	125.87	2.882	27.652	3599.9	252.08	0.617	5.2	42
S12	6	5	67	14.9	7.3	3.763	138.72	2.350	30.202	3434.7	296.10	0.552	6.1	100
S13	<1	18	58	11.6	7.5	2.677	132.86	2.618	29.840	3761.2	281.06	1.087	5.6	130
S14	2	6	32	1.7	7.7	1.357	45.378	1.633	14.440	2713.3	141.95	0.348	2.6	50
S15	2	6	46	4.1	7.8	1.179	55.714	1.332	9.523	3057.5	160.00	0.368	4.2	27
S16	<1	37	143	7.2	7.6	5.494	238.42	6.679	26.602	4287.7	433.92	0.726	24.6	99
S17	<1	69	185	8.7	7.5	5.344	345.24	8.549	47.262	4794.7	495.16	0.952	33.1	124
S18	<1	64	177	9.0	7.5	5.231	359.34	8.116	55.031	4912.1	533.31	1.000	31.7	145
S19	<1	60	187	9.1	7.4	4.171	398.83	7.178	71.136	4640.9	475.74	0.970	19.1	166
S20	<1	26	103	10.3	7.5	5.551	211.00	8.482	25.962	4234.1	385.61	0.870	9.9 // 9.4	147 // 117
S21	<1	26	107	9.8	7.6	5.076 // 4.912	214.75 // 216.20	6.225 // 6.164	22.316 // 22.835	4275.7	366.54	0.840 // 0.690	14.4	116
S22	<1	24	94	8.8	7.5	4.472	193.97	6.285	26.818	4313.0	372.94	0.730	10.4	147
S23	<1 // <1	30 // 31	125 // 123	10.6 // 10.4	7.4 // 7.3	4.276	265.63	6.357	36.028	4506.6	456.29	0.970	14.2	195
S24	<1	45	158	11.1	7.5	5.078	318.49	7.793	45.726	4899.4	511.21	1.080	24.2	128
S25	<1	55	158	10.1	7.4	3.969	396.10	7.700	63.901	5108.8	502.84	1.050	29.4	156