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2014 Lower Long Lake Water Quality Review

Introduction

The goals of this testing protocol were to monitor various water quality parameters of the lake, compare results to historical data, and identify any potential risks to the health of Lower Long Lake. Water samples were taken at four different locations and tested for 14 parameters. Tests were conducted on a monthly basis from April through August. Tests were conducted with a Hanna Multiparameter Water Quality Meter or LaMotte SMART2 Colorimeter.

Test results were compared to historical data from the report "2013 Lower Long Lake Water Quality Review" by LakePro, Inc.

In this report, we added historical data from Water Quality Investigators. Their report provided annual averages for many of the parameters from 2002 to 2009. Including this data allows us to see more accurate trends in the water quality data. In order to make the analysis easier, we added annual averages for our data and trendlines on the graphs. The blue trend lines allows us to quickly see the direction each water quality parameter is moving.

Results

Parameter	2014 Season Average	Target Range	Status
Temperature	67.3 ˚F	Less Than 75 ˚F	● Healthy
Dissolved Oxygen	8.4 mg/L	4.0 – 12.0 mg/L	● Healthy
Total Phosphorus	52 ppb	0 – 100 ppb	● Healthy
Phosphate	28 ppb	0 – 100 ppb	● Healthy
Nitrate	548 ppb	0 – 1,000 ppb	● Healthy
Chlorophyll-a	4.2 ppb	0 – 7.3 ppb	● Healthy
Transparency	15.4 feet	More than 6.5 feet	● Healthy
pH	7.9 S.U.	7.0 – 9.0 S.U.	● Healthy
Total Dissolved Solids	381 ppm	0 – 1,000 ppm	● Healthy
Conductivity	763 ppm	0 – 1,500 ppm	● Healthy
Alkalinity	115 ppm	100 – 250 ppm	● Healthy
Sulfate	13.0 ppm	3 – 30 ppm	● Healthy
Fluoride	0.05 ppm	0.01 – 0.30 ppm	● Healthy
Chloride	176 ppm	0 – 230 ppm	● Healthy

Year-End Discussion

Lower Long Lake's water quality is very good. The season average for every parameter was within its target range, showing there are no immediate concerns with the water.

Temperature and Dissolved Oxygen

The surface water temperatures in 2014 were cooler than previous years. The previous winter was extremely cold and most Michigan lakes had above average ice and snow cover. This led to cooler water temperatures in the spring. Furthermore, the early summer of 2014 brought below average temperatures, further slowing the warm-

up of the lake. As a result, the water temperatures later in the summer were not as high (i.e. into the 80's) as usual.

There is a limit on how much dissolved oxygen can be in the water and that limit depends upon water temperature. Because water temperatures were lower this summer, the water was able to hold more dissolved oxygen. In 2014, Lower Long Lake had the highest concentrations of dissolved oxygen since LakePro began testing in 2011. Dissolved oxygen is vital for a healthy aquatic ecosystem, so this year's concentrations were a positive for lake.

Nutrients, Plant Production, and Transparency

Nutrients in the water are the fuel for plant growth. Monitoring the nutrient concentrations reveals the potential for nuisance plant growth. Phosphorus is one of main nutrients necessary for aquatic plant growth, so it is important that this nutrient remains low in the lake. The total phosphorus remained within the target range all year. Phosphate, which is the form of phosphorus usable to plants, was also within the target range for all of 2014.

Nitrate is another major nutrient for aquatic plant growth. In 2014, the nitrate concentrations remained within their target range. It is important that residents fertilize and use their land in ways that prevents additional nutrients from entering the lake.

We also measure Chlorophyll concentrations because it is the most direct indicator of plant production. The target for chlorophyll is below 7.2 parts per billion, but for Lower Long Lake, we expect the concentrations to be much lower. For all tests in 2014, the chlorophyll concentrations remained below the target level. These results showed that the plants did not grow to excess levels, despite the availability of nutrients.

One of the most important effects of plant growth on the lake is the reduction of water clarity. Before algae forms the green mats of "scum" on the surface, it is suspended in the water column. Algae floating in the water can decrease water clarity, even before you see a tint of green. This year, the water clarity averaged a depth of 15 feet, which is very good for a developed lake.

In order to better understand the relationship between nutrients, plant production, and clarity, limnologists use Trophic State Indices (TSI) to score each category and examine the relationship between them. In general, lower scores indicate a less productive lake. In 2014, the TSIs for Lower Long Lake were:

Category	Water Quality Parameter	Trophic State Index (season average)	Classifciation
Nutrients	Total Phosphorus	61	Eutrophic
Plant Production	Chlorophyll	45	Mesotrophic
Clarity	Transparency	38	Oligotrophic

The TSI for Total Phosphorus classified the lake as Eutrophic, or highly productive. This is based on the high availability of nutrients to fuel high plant productivity. The TSI for Chlorophyll, however, is lower than the nutrient score. This shows that despite the availability of nutrients, the plants did not grow to the levels supported by the nutrients. This could have been due to another limiting factor, poor growing conditions, or plant management activities. Finally, the TSI for Transparency is lower than both previous scores. This score confirms that plant growth did not match nutrient availability and, furthermore, the plant production did not decrease the transparency to the predicted level. This is a result of excellent water clarity and very few clarity factors other than plant production.

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Water Chemistry Parameters

It is important to monitor the basic water chemistry of the lake water. Shifts in these parameters indicate major changes to the lake that may need to be further investigated.

The pH of the lake remained within the target range for the entire year. This shows that despite changes in dissolved oxygen, alkalinity, and rainfall, the pH did not fluctuate to a point of concern.

The Total Dissolved Solids (TDS) showed there were low amounts of dissolved substances in the water. This parameter includes nutrients, salts, and other substances, so it is a positive that this parameter has remained low in the lake.

Conductivity, which measures ionic molecules in the water, usually follows the TDS. This parameter measures the ability of molecules in the water that conduct electricity. Thus, it is particularly sensitive to salts, which are excellent conductors. In 2014, the Conductivity was in the middle of the target range, indicating a normal amount of ionic molecules in the lake and no immediate concern of salts.

Alkalinity measures the concentration of one salt, Calcium Carbonate, which is beneficial to the aquatic ecosystem. The carbonate ions are able to accept protons from acids, making it a natural buffer. This means that as acidic substances enter the lake, the carbonate is able to buffer against severe changes in pH that could pose a threat to the ecosystem. In 2014, the Alkalinity was at a healthy level for all tests.

Pollutants

Finally, the lake is tested for Fluoride, Sulfate, and Chloride as indicators of pollution. These molecules should be present in the water naturally, but elevevated levels can indicate pollution from within the watershed and may pose a risk to the ecosystem. All three parameters were within their target ranges for all of 2014.

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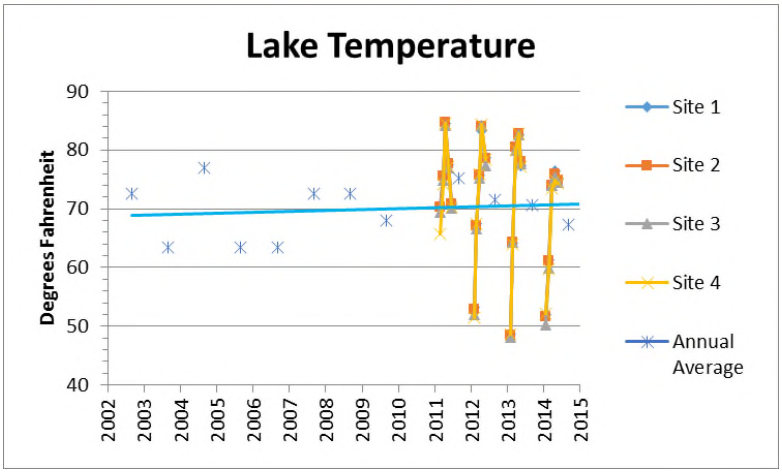
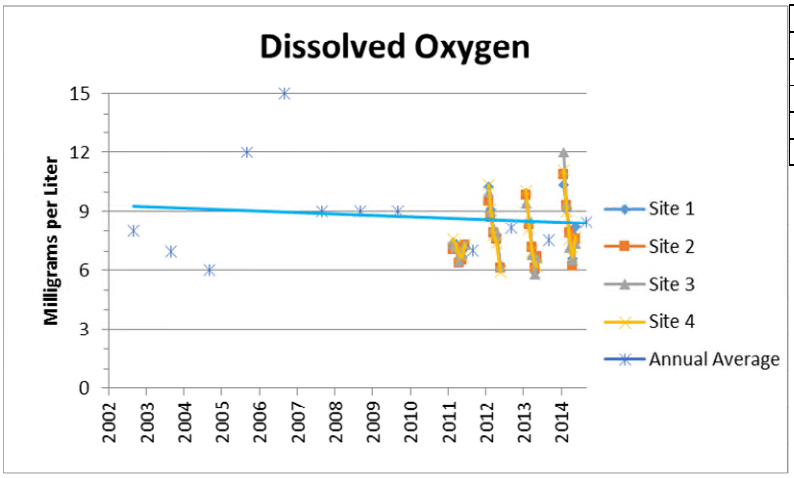


Lake Temperature (°F)					
	April	May	June	July	August
Site 1	52.0	61.3	74.3	76.4	75.0
Site 2	51.6	61.2	74.0	76.0	74.8
Site 3	50.2	59.9	74.0	75.4	74.5
Site 4	52.2	59.8	73.5	74.9	74.4
			Season Average		67.3

Discussion

The long term trend for water temperature is slightly upward. The 2014 season average was below the trend and, therefore, helped to flatten it. Water temperature is dependent upon air temperatures and the dates selected for testing. For that reason, LakePro tries to select similar dates for testing each year. The main concern with increasing water temperatures is the reduction in dissolved oxygen solubility.



Dissolved Oxygen (mg/L)					
	April	May	June	July	August
Site 1	10.4	9.1	7.8	6.6	8.2
Site 2	10.9	9.3	7.9	6.2	7.6
Site 3	12.0	9.4	7.2	6.5	7.4
Site 4	11.1	9.0	7.6	6.7	7.7
			Season Average		8.4

Discussion

As temperatures slowly rose, the dissolved oxygen solubility decreased. Correspondingly, the season average dissolved oxygen concentrations show a slightly downward trend. While the dissolved oxygen remains at healthy levels, it is important to monitor this parameter into the future to see if the trend continues and to possibly prepare for dissolved oxygen below critical levels.

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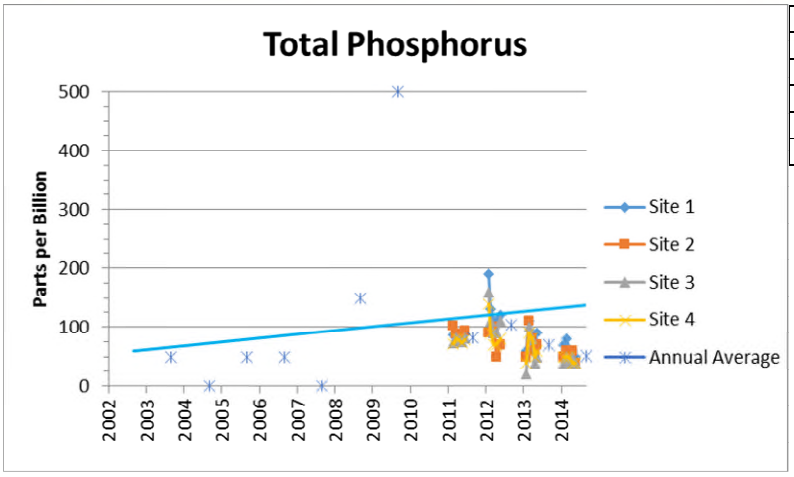
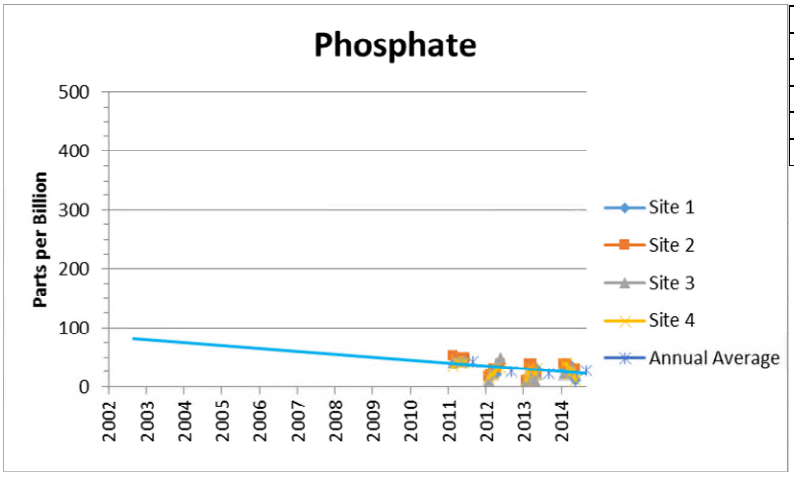


Total Phosphorus (ppb)					
	April	May	June	July	August
Site 1	70	80	60	60	50
Site 2	50	60	60	60	40
Site 3	40	50	40	50	40
Site 4	50	50	50	40	40
			Season Average		52
			Trophic State Index		61

Discussion

In general, a lake's watershed inputs are much more significant than their outflow. Consequently, lakes tend to accumulate the substances that flow into it. The trend for Total Phosphorus shows a steady increase since testing began in 2003 as a result of accumulating this nutrient. There are ways to rid a lake of phosphorus, such as mechanical harvesting and heavy rain events that create excess flow. However, it is much easier to prevent excess nutrients from entering the lake. For this reason, it is vital that residents around the lake fertilize and use their land responsibly so as to prevent phosphorus from reaching the lake.



Phosphate (ppb)					
	April	May	June	July	August
Site 1	30	30	40	20	10
Site 2	40	40	30	30	30
Site 3	20	20	30	30	20
Site 4	40	40	20	30	10
			Season Average		28

Discussion

As more total phosphorus accumulates in the lake, so too will the phosphates. There is no historical data available for phosphates, so the trendline reflects the changes during the four years of LakePro's testing. The trend is downward, showing that mechanical harvesting, abundant rain, or responsible land management has had a positive impact on the nutrient concentrations in the lake.

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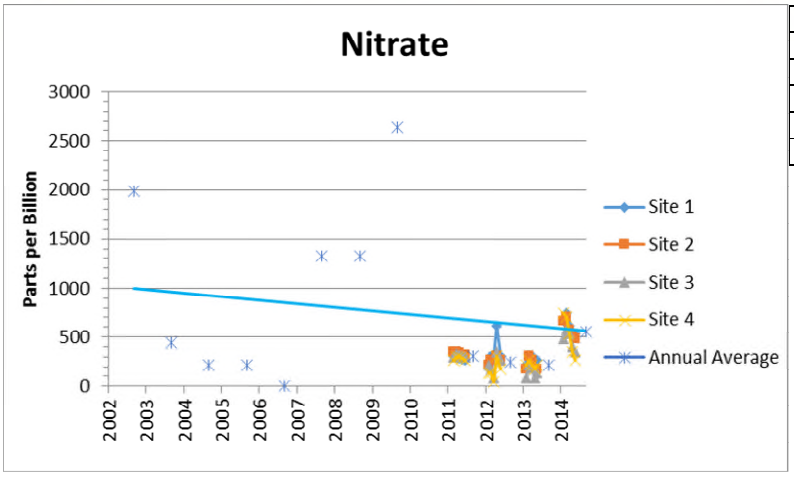
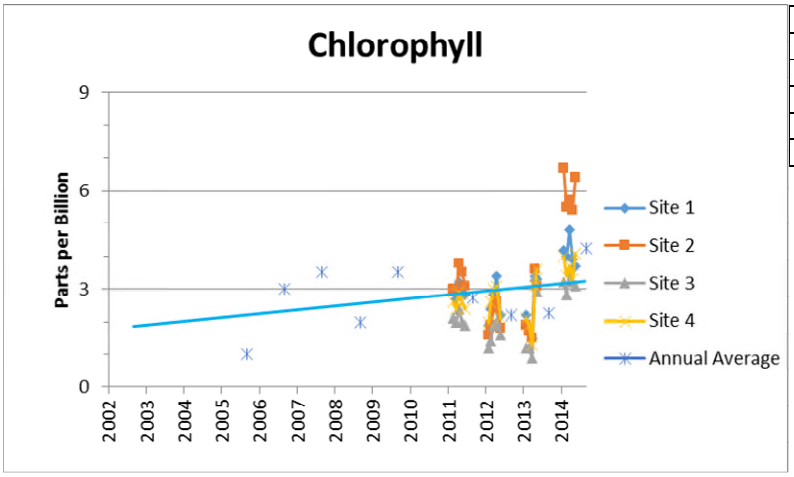


Nitrate (ppb)					
	April	May	June	July	August
Site 1	660	748	616	528	528
Site 2	660	704	572	528	484
Site 3	484	572	528	396	352
Site 4	748	704	528	352	264
			Season Average		548

Discussion

Similar to phosphorus, lakes generally accumulate more nitrate. The historical trend for nitrate is downward, due mostly to extremely high values in 2002 and 2007 through 2009. The past four years show the concentration of nitrate well within the target range, with a slight upward trend due to a higher value in 2014. It is important that residents around the lake fertilize and use their land responsibly so as to prevent nitrate from reaching the lake.



Chlorophyll (ppb)					
	April	May	June	July	August
Site 1	4.2	4.0	4.8	3.9	3.7
Site 2	6.7	5.5	5.7	5.4	6.4
Site 3	3.2	2.8	3.6	3.2	3.1
Site 4	4.0	3.4	3.7	3.3	4.1
			Season Average		4.2
			Trophic State Index		45

Discussion

Similar to the total phosphorus, chlorophyll shows an upward trend over the testing history. This supports that as the lake accumulates more nutrients, specifically phosphorus, the plant growth worsen in the lake. The chlorophyll remains within the target range, but slowly or reversing the upward trend should be a goal for the lake management. Continuing to mechanically harvest will remove plant biomass and the nutrients within it. Responsible land management by residents around the lake will help stifle the source of excess nutrients, preventing further worsening of the plant growth.

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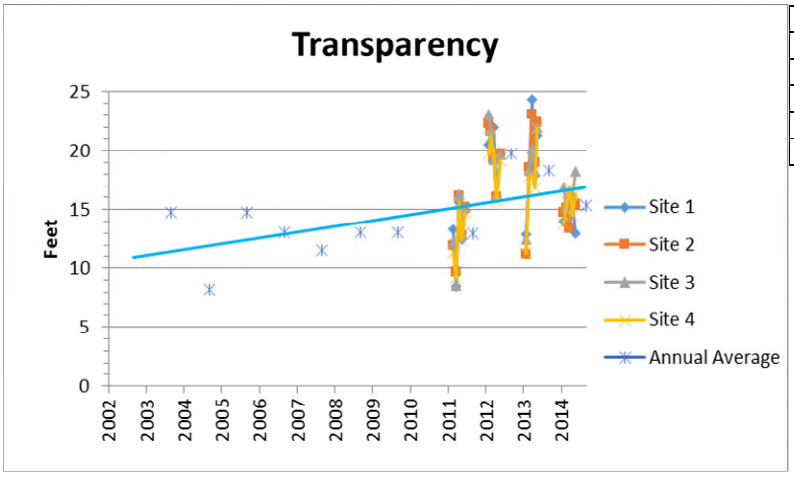
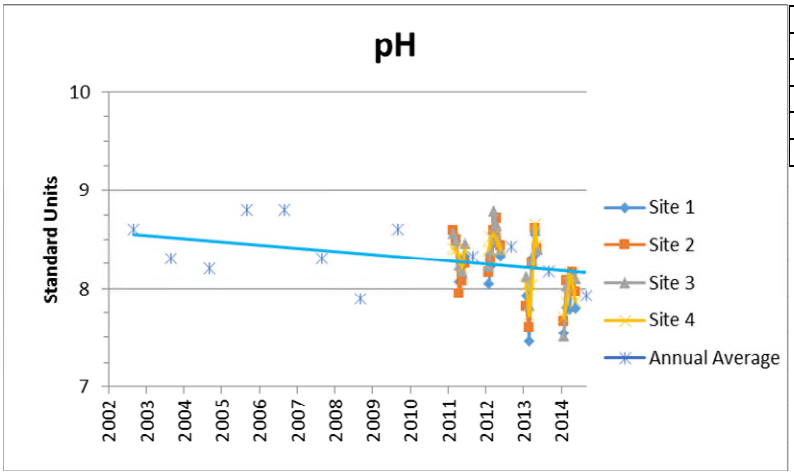


Transparency (feet)					
	April	May	June	July	August
Site 1	14.0	15.4	15.3	15.4	13.0
Site 2	14.8	15.1	13.4	15.8	15.4
Site 3	16.9	15.2	16.4	16.2	18.2
Site 4	13.8	15.6	16.9	14.5	16.3
			Season Average		15.4
			Trophic State Index		38

Discussion

More chlorophyll usually indicates higher amounts of algae in the water column, which clouds the water and reduces transparency. Despite the upward trend of chlorophyll, the transparency has also trended upward. The improvement in water clarity could be due to better weather, fewer dissolved solids, or fewer suspended solids (e.g. sediment). The increasing transparency is positive for the appearance of the lake. However, more sunlight reaching deeper depths and higher nutrient levels may lead to worsening of the nuisance plant growth in the lake.



pH (Standard Units)					
	April	May	June	July	August
Site 1	7.54	7.81	7.79	8.16	7.80
Site 2	7.66	8.08	8.01	8.16	7.97
Site 3	7.51	8.03	8.14	8.14	8.10
Site 4	7.70	7.86	8.15	8.05	7.87
			Season Average		7.9

Discussion

The pH has declined over the testing history. The shift has moved annual values away from 9 and closer to 8, the middle of the target range. This change has not had a major impact on the lake, but it is important to look for this trend to level off. If the pH continues to decrease toward 7 or below, it may indicate a problem with pollution or the oxygen production of the lake.

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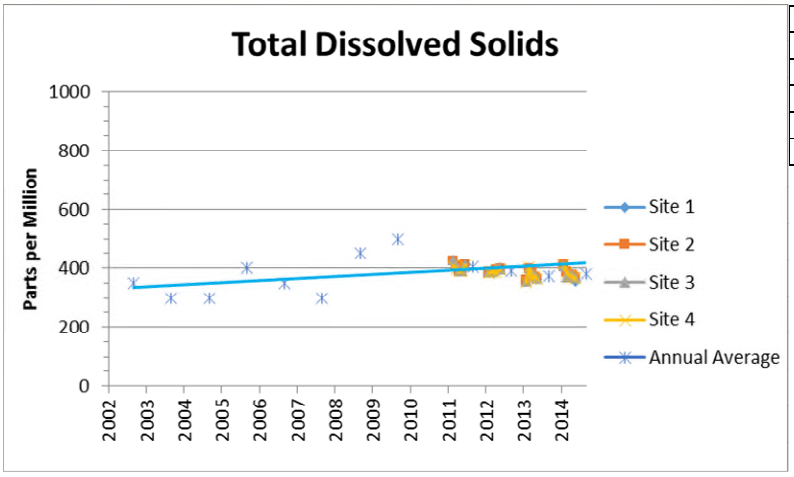
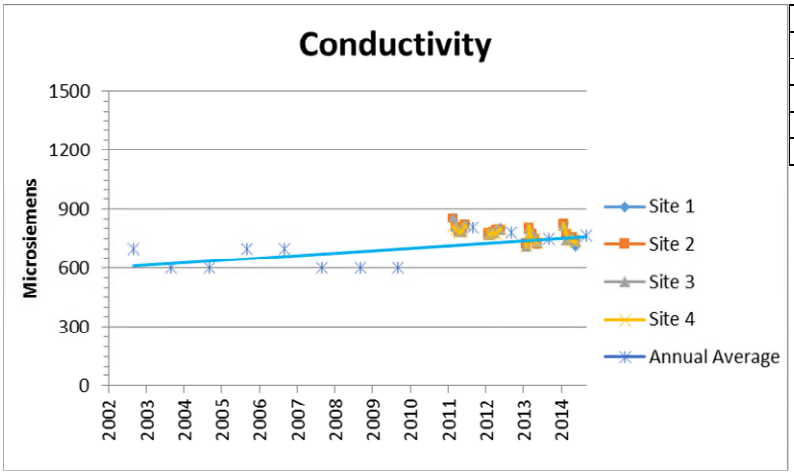


Total Dissolved Solids (ppm)					
	April	May	June	July	August
Site 1	413	385	376	380	356
Site 2	411	386	375	377	368
Site 3	406	370	375	376	368
Site 4	414	383	374	369	366
			Season Average		381

Discussion

The total dissolved solids increased over the testing history, showing that the lake is accumulating more substances. The increase has been slow and the past three years have shown a reversal of this trend. This may have been due to increased rainfall, which helped to flush the lake.



Conductivity (µS)					
	April	May	June	July	August
Site 1	826	771	752	754	713
Site 2	825	771	752	754	737
Site 3	813	741	750	751	736
Site 4	818	767	749	737	733
			Season Average		763

Discussion

Like the TDS, Conductivity increased over the testing history. Conductivity is an extension of TDS and measures the amount of ionic molecules in the water (which conduct electricity, usually salts). We will look for this trend to slow in future years of testing.

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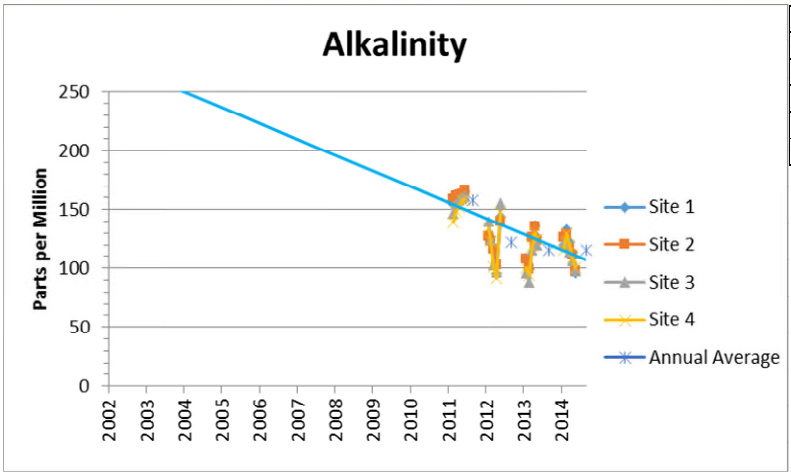
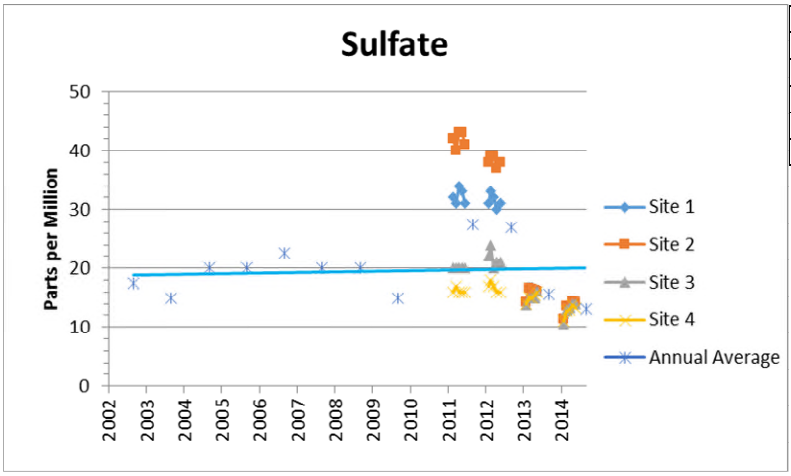


Alkalinity (ppm)					
	April	May	June	July	August
Site 1	120	133	122	114	96
Site 2	126	129	117	111	98
Site 3	121	124	114	106	98
Site 4	115	130	120	109	100
			Season Average		115

Discussion

Alkalinity was first included in the testing in 2011, so the historical data is much shorter than other parameters. The long term trend for alkalinity is downward. This could be due to above average rainfall in recent years. Because rain water is slightly acidic, carbonate ions work as a buffer to prevent major shifts in pH. This results in less alkalinity in our tests. As rainwater infiltrates the ground, it will reach the natural groundwater aquifers where it will dissolve calcium carbonate and replenish the alkalinity when it enters the lake.



Sulfate (ppm)					
	April	May	June	July	August
Site 1	11.6	13.3	12.8	14.1	13.9
Site 2	11.4	13.6	13.0	14.5	14.2
Site 3	10.5	12.9	13.3	14.0	13.9
Site 4	11.1	12.7	12.9	13.8	13.2
			Season Average		13.0

Discussion

Sulfate has increased very slightly over the course of testing and the two most recent years and well below the trend line. It is important that this parameter stay within the target range and any sharp increases are quickly investigated.

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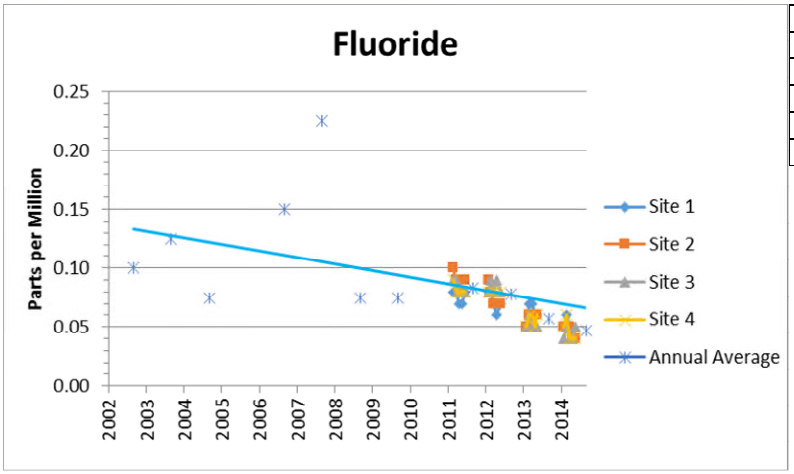
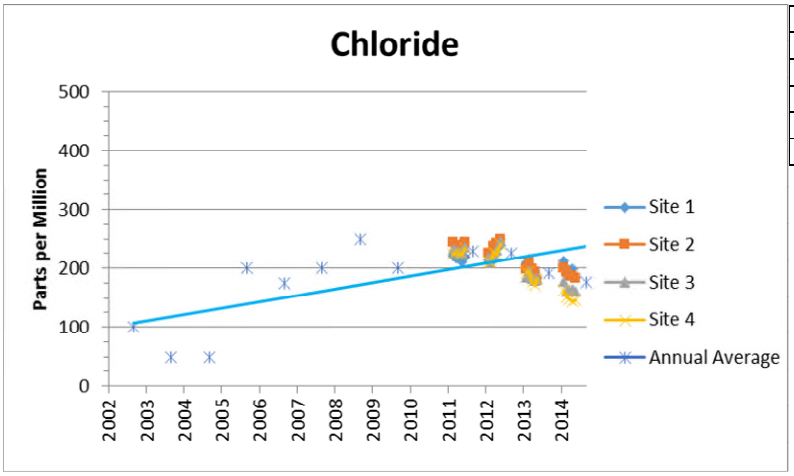


Fluoride (ppm)					
	April	May	June	July	August
Site 1	0.05	0.06	0.05	0.05	0.04
Site 2	0.05	0.05	0.05	0.04	0.04
Site 3	0.04	0.05	0.04	0.04	0.05
Site 4	0.05	0.06	0.04	0.04	0.04
			Season Average		0.05

Discussion

Fluoride has decreased in the lake since testing began in 2002. It is important that this parameter stay within the target range and any sharp increases are quickly investigated.



Chloride (ppm)					
	April	May	June	July	August
Site 1	212	201	194	198	185
Site 2	201	193	187	187	183
Site 3	179	161	163	164	162
Site 4	163	152	147	145	146
			Season Average		176

Discussion

The trend line for Chloride shows a steady increase in Chloride. The actual data points show the Chloride has been relatively consistent since 2005. With concerns about road salt entering lakes, it is important that this parameter remain within the target range and any increases are quickly investigated.

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Analysis Information

Temperature:	The water temperature directly affects the amount of oxygen that is able to dissolve into the water. The temperature of surface waters is not indicative of the entire water column.
Transparency:	The ability of light to penetrate the water column is determined by the amount of dissolved and suspended particles in the water. Although aesthetically desirable, transparent water allows increased light to reach the lake bed and may result in vegetation growth.
pH:	pH is a measure of acidity or alkalinity. pH is a general measure of lake health and can roughly indicate the range of other measurements such as alkalinity and hardness.
TDS:	Total Dissolved Solids is the amount of all organic and inorganic substances in the water in a molecular or ionized state. Higher values generally indicate richer and more productive water. Lower values usually indicate cleaner and less productive water.
Conductivity:	Conductivity is a measure of the ability of water to conduct electricity. Dissolved ions in the water increase conductivity, thus TDS and Conductivity are closely related.
Alkalinity:	Alkalinity refers to the ability of the water to neutralize acids, mainly through the hydrogenation of carbonate ions. This is why the alkalinity is expressed as "ppm as $CaCO_3$". However, other basic molecules in the water can also contribute to alkalinity.
Dissolved Oxygen:	D.O. is a measure of the amount of oxygen dissolved in the water. This oxygen is available to fish and other animals for respiration. Vegetation generally increases DO, particularly during the day and early evening. Animals and other respiring organisms consume the oxygen, mostly during the day. Oxygen is also added to the lake through wave action, rain, fountains and aerators.
Total Phosphorus:	Phosphorus is an essential nutrient for plant growth. However, concentrations exceeding 100 ppb can impair the water and results in nuisance vegetation growth.
Phosphates:	Phosphate is the form of phosphorous that is most readily available to plants and algae.
Nitrate:	Nitrogen is also essential for plant growth. Nitrate is the predominant form of nitrogen in water. Excessive nitrate concentrations may also result in pollution and increased vegetation.
Chlorophyll-a:	Chlorophyll-a is a direct measurement of the amount of green pigment produced by plants and phytoplankton. This indicates the amount of plant growth and is used to calculate a Trophic State Index.
Sulfate:	Sulfate occurs naturally as minerals, such as calcium sulfate and magnesium sulfate. In fresh water, sulfate is usually the second or third most abundant anion. Other sources of sulfate include water material from pulp mills, steel mills, food processing operations, and municipal wastes. Under low oxygen conditions, sulfate can by reduced to hydrogen sulfide gas, which smells like rotten eggs.
Fluoride:	Fluoride may occur naturally or be added to public drinking water supplies.
Chloride:	Chloride is one of the major anions found in water and sewage. The presence of chlorides may be due to water passing through salt formations in the earth or pollution from industrial processes, domestic wastes, or road salt. The salt content of water affects the

distribution of plant and animal life in an aquatic system, based on the amount of slat they can tolerate.

Fecal Coliforms: Non-fecal coliforms are naturally found as soil organisms. Fecal Coliforms, such as *E. coli*, are coliforms found in the intestines of warm-blooded animals and humans. The presence of fecal coliforms indicates contamination from either animals or humans.

Trophic States

Oligotrophic: Water is very clear. Nutrient levels are generally low. Plant and algae productivity is also low. Sufficient dissolved oxygen in the bottom, cooler waters allows cold-water fish to survive, such as salmon and trout.

Mesotrophic: Water is moderately clear. Nutrient levels are slightly elevated. Plant and algae productivity is present, but generally not a nuisance. Oxygen and temperature in the lower portion of the lake allow walleye and perch to survive.

Eutrophic: Water is not clear due to high nutrients levels, increased turbidity, and excessive algal growth. There is no oxygen in the bottom, cooler waters, restricting the lake to warm water species, such as bass and bluegill.

Hypereutrophic: Nutrient levels are extremely high, promoting very high algae productivity. Blue-green algae blooms are likely. High turbidity and algae growth make the water opaque. Little plant growth is restricted to invasive plants. The only fish that can survive this environment are rough fish, such as carp, catfish, and mudminnows.

Sample Sites: