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2014 Forest 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 Forest Lake. Water samples were taken at two 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 Forest 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 trend lines allow us to quickly see which direction each water quality parameter is moving.

Results

Parameter	2014 Season		
	Average	Target Range	Status
Temperature	68.9 °F	Less Than 75 °F	● Healthy
Dissolved Oxygen	7.8 mg/L	4.0 – 12.0 mg/L	● Healthy
Total Phosphorus	71 ppb	0 – 100 ppb	● Healthy
Phosphate	40 ppb	0 – 100 ppb	● Healthy
Nitrate	383 ppb	0 – 1,000 ppb	● Healthy
Chlorophyll-a	3.1 ppb	0 – 7.3 ppb	● Healthy
Transparency	11.2 feet	More than 6.5 feet	● Healthy
pH	7.91 S.U.	7.0 – 9.0 S.U.	● Healthy
Total Dissolved Solids	516 ppm	0 – 1,000 ppm	● Healthy
Conductivity	1,031 ppm	0 – 1,500 ppm	● Healthy
Alkalinity	126 ppm	100 – 250 ppm	● Healthy
Sulfate	13.9 ppm	3 – 30 ppm	● Healthy
Fluoride	0.09 ppm	0.01 – 0.30 ppm	● Healthy
Chloride	312 ppm	0 – 230 ppm	● High

Year-End Discussion

Forest Lake’s water quality was very good throughout 2014. The season average for most parameters were within the target ranges. The only parameter not within the target range was the Chloride, which is discussed below.

Temperature and Dissolved Oxygen

The average surface water temperature in 2014 was similar to previous years. The previous winter was extremely cold and most Michigan lakes had above average ice and snow cover. This led to cool water temperatures in the

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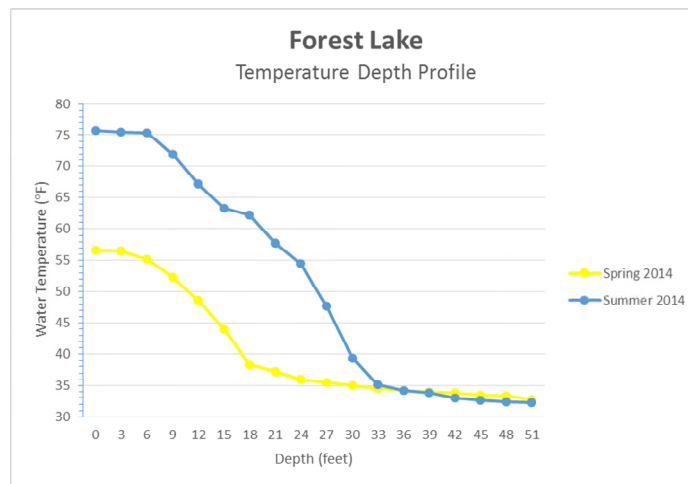


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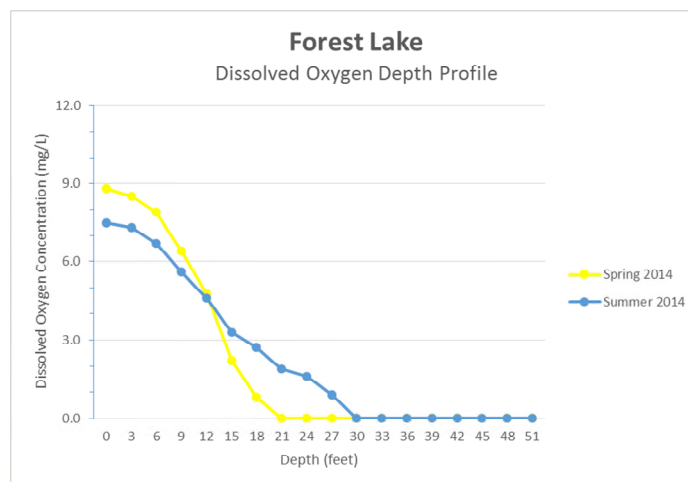
spring. Furthermore, the early summer of 2014 brought below average temperatures, slowing the warm-up of the lake. As a result, the water temperatures later in the summer were not as high as usual (i.e. into the 80's).

We also measure temperature at various depths to create a depth profile. This data shows how the temperature changes with depth and whether or not a thermocline is present in the lake. This year, there was not a defined thermocline in the water. During both tests, there was not a defined thermocline where the water temperatures decreased sharply. The bottom, cold portion of the lake was clearly defined during both tests. This area began at 18 feet in the spring and fell to 33 feet in the summer.



There is a limit on how much dissolved oxygen can be in the water, which depends upon water temperature. Because water temperatures were lower this summer, the water was able to hold more dissolved oxygen. In 2014, Forest Lake had excellent dissolved oxygen concentrations throughout the summer. Dissolved oxygen is vital for a healthy aquatic ecosystem, so this year's concentrations were a positive for lake.

The depth profile protocol was followed and measurements were also taken for dissolved oxygen. This allowed us to see how the oxygen concentration changes throughout the water column. A concentration of 3.0 milligrams per liter is a general limit for fish, so this graph shows us that there was enough oxygen in the water around 15 feet to support fish.



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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 except for one sample. Phosphate, which is the form of phosphorus usable to plants, was 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. 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 just over 11 feet.

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 Forest Lake were:

Category	Water Quality Parameter	Trophic State Index (season average)	Classification
Nutrients	Total Phosphorus	65	Eutrophic
Plant Production	Chlorophyll	41	Mesotrophic
Clarity	Transparency	43	Mesotrophic

The TSI for Total Phosphorus classified the lake as Eutrophic, or highly productive. This is based on the high availability of nutrients to fuel plant productivity. The TSI for Chlorophyll, however, is lower than the nutrient score. This suggests that despite the availability of nutrients, the plants did not grow to the levels supported by the nutrients. The TSI for Transparency also classified the lake as Mesotrophic. This shows that the water clarity was not as good as expected from the chlorophyll, so other particles also contributed to the slightly lower water clarity.

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 summer. The Total Dissolved Solids (TDS) showed there were moderate 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.

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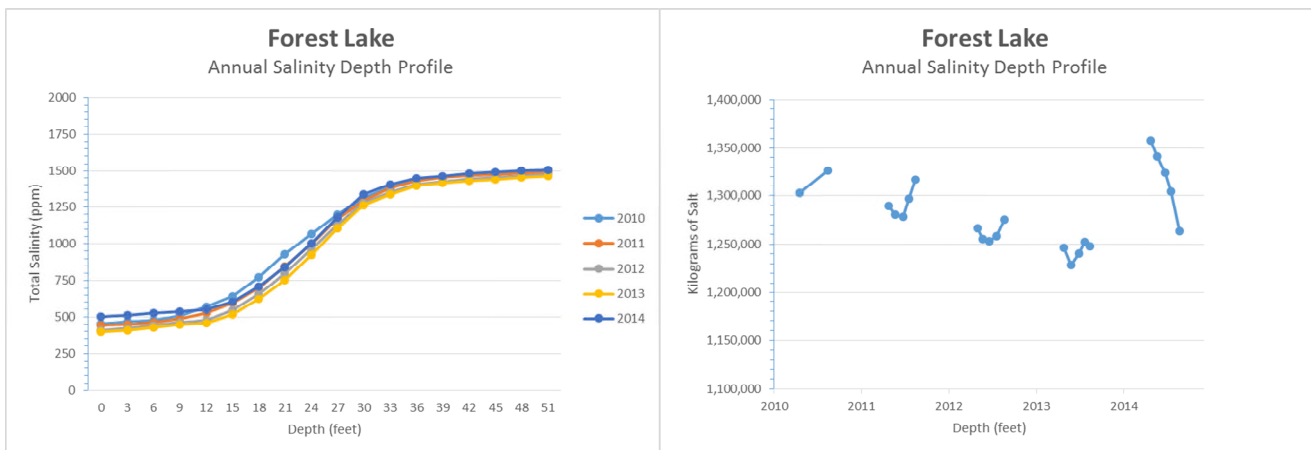
Conductivity, which measures ionic molecules in the water, usually follows the TDS. This parameter measures the ability of molecules in the water to conduct electricity. Thus, it is particularly sensitive to salts, which are excellent conductors. In 2014, the Conductivity was in the middle of the target range.

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 elevated levels can indicate pollution from within the watershed and may pose a risk to the ecosystem. Throughout 2014, the fluoride and sulfate concentrations were within their target ranges. Chloride was above the target range for all of 2014, but did show improvement over the course of summer.

Chloride is a main constituent of total salinity. The depth profile protocol was followed and measurements were also taken for salinity. This allowed us to see how this parameter changes throughout the water column. We also use the readings and volume at each depth to calculate a volume weighted load.



The first graph shows the average annual salinity at 3-foot depth intervals. This graph shows the salinity increases with depth and ranges from about 500 parts per million at the surface to about 1,500 parts per million in the deepest portion of the lake.

Based on the amount of water at each depth interval and the concentration of salts, we are able to calculate a total salt load for the lake. The second graph shows those calculated loads during each testing event. 2014 started with the highest salt loads of our testing history. The salt decreased throughout the year, showing some improvement. The most likely cause for the improvement was the large amount of rain during the summer that helped flush salt from the surface water.

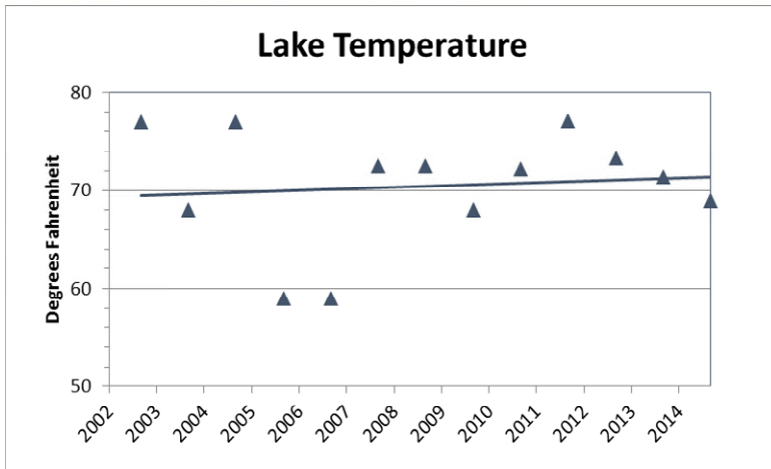
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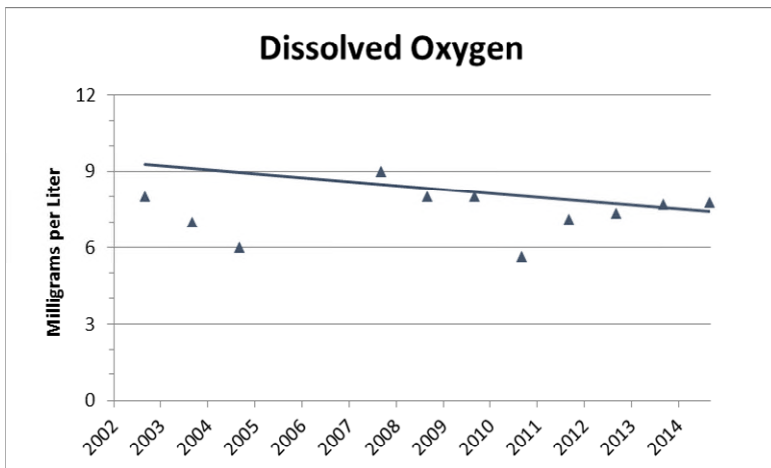
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Lake Temperature (°F)					
	April	May	June	July	August
West	56.7	61.8	74.0	76.1	75.7
East	57.6	62.0	73.8	76.0	75.7
Season Average					68.9

Discussion

The long term trend for water temperature is slightly upward. The 2014 season average was below the trend. 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
West	8.8	7.4	6.8	7.0	7.5
East	9.4	7.9	7.6	7.5	7.8
Season Average					7.8

Discussion

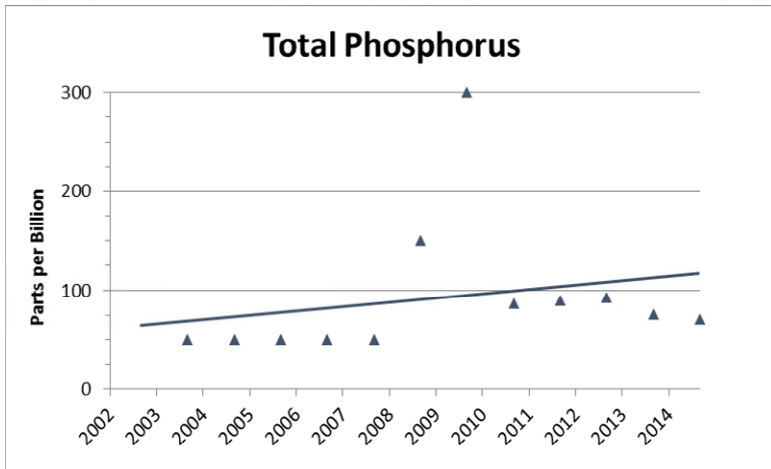
As expected with increasing temperatures, the dissolved oxygen trend is slightly downward. As water temperature increases, the oxygen solubility decreases. This is a negative change for the lake because sufficient oxygen is necessary for a healthy ecosystem. We will look for this trend to slow and flatten in the future.





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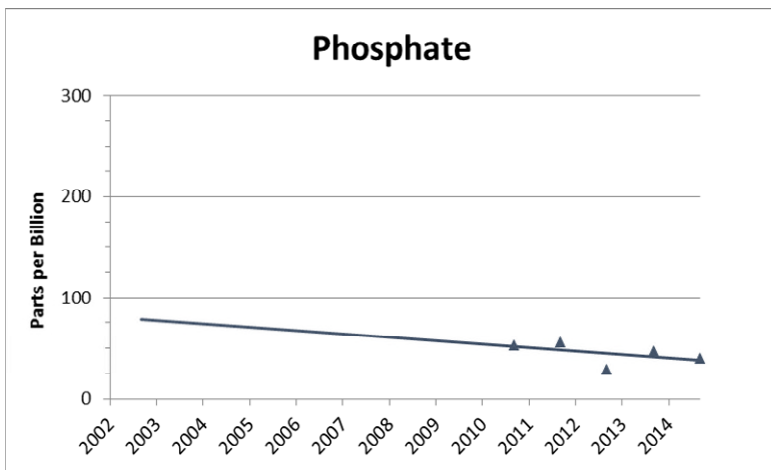
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Total Phosphorus (ppb)					
	April	May	June	July	August
West	50	80	110	90	70
East	40	60	70	80	60
Season Average					71
Trophic State Index					65

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. Since testing began in 2003, the trend for Total Phosphorus has increased slightly. The 2008 and 2009 concentrations were much higher than all other years of testing, which helped to turn the trend upward. 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
West	30	50	60	50	40
East	30	40	40	30	30
Season Average					40

Discussion

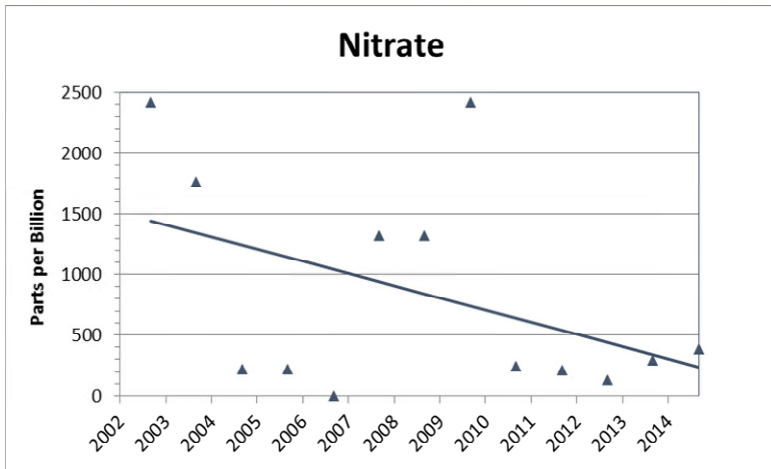
As more total phosphorus accumulates in the lake, so too will the phosphates. There is no historical data available for phosphates, so the trendline reflects the changes during three years of LakePro’s testing. The trend is slightly downward, but the phosphate concentrations remained well below the target threshold.





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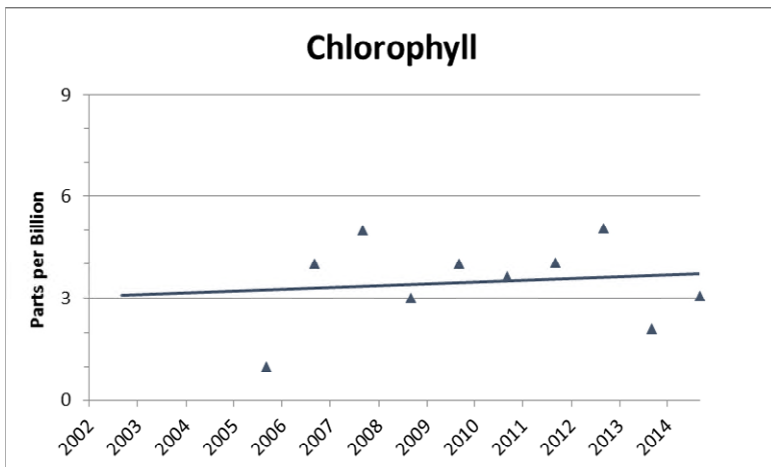
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Nitrate (ppb)					
	April	May	June	July	August
West	308	396	396	308	264
East	528	484	440	396	308
Season Average					383

Discussion

Similar to phosphorus, lakes generally accumulate more nitrate. The historical trend for nitrate is downward, due mostly to extremely high values in 2002, 2003, and 2007 through 2009. The past five years show the concentration of nitrate well within the target range, with a slight upward trend due to increasing values in 2013 and 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
West	1.9	2.6	4.3	3.8	3.4
East	1.7	2.1	4.3	3.6	3.1
Season Average					3.1
Trophic State Index					41

Discussion

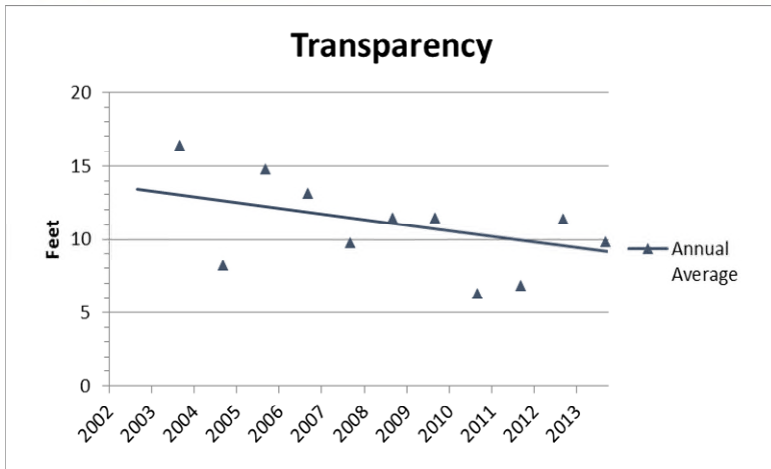
Chlorophyll has trended upward over the testing history, but 2013 and 2014 were below this trend. This is most likely a product of increasing phosphorus concentrations and sufficient nitrates. The annual chlorophyll averages remained within the target range. Continuing to mechanically harvest will remove 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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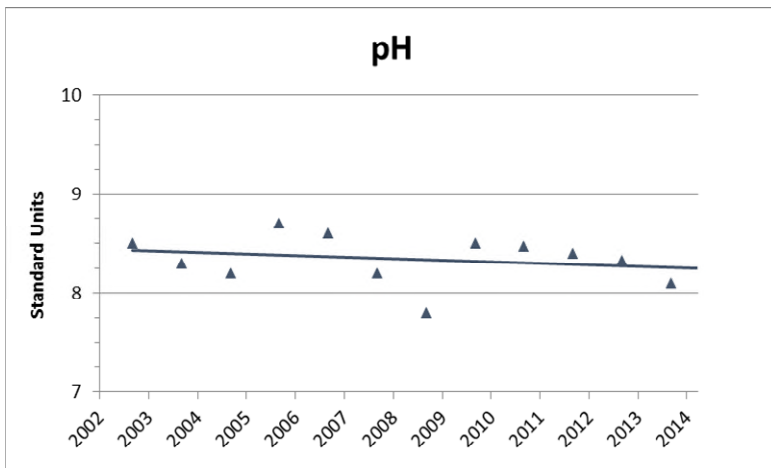
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Transparency (feet)					
	April	May	June	July	August
West	4.3	15.6	14.7	9.7	12.7
East	5.0	15.8	14.0	9.2	11.0
Season Average					11.2
Trophic State Index					43

Discussion

Chlorophyll is used as an indicator of plant growth, including algae that clouds the water. Therefore, the increasing chlorophyll concentrations lead to lower transparency over the testing history. The decreasing water clarity could also be due to more rain storms, higher dissolved solids, or higher suspended solids (e.g. sediment). Although the clarity is trending downward, it is still above the target depth.



pH (Standard Units)					
	April	May	June	July	August
West	7.5	8.0	8.0	8.1	8.4
East	7.7	7.8	7.7	8.1	7.9
Season Average					7.9

Discussion

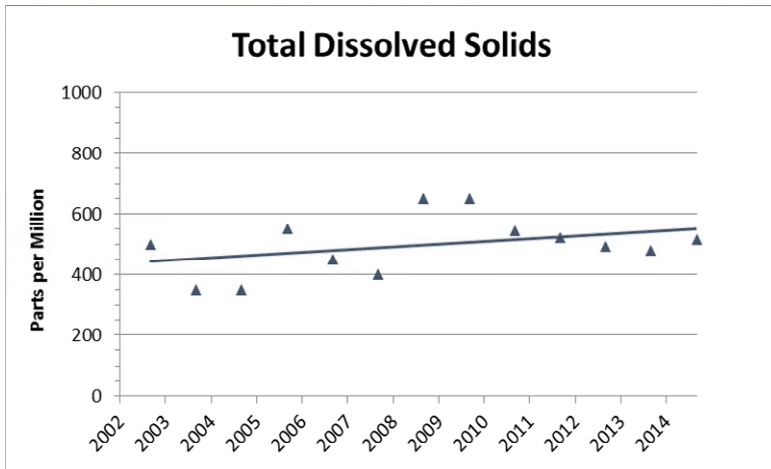
The pH has decreased very slightly over the testing history. The shift has moved annual values closer to 8, the middle of the target range. This change has not had a major impact on the lake, but any sharp changes may need to be quickly investigated.





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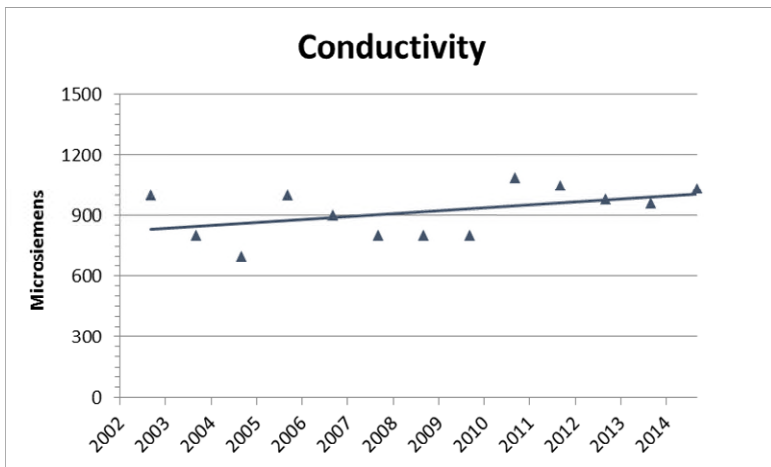
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Total Dissolved Solids (ppm)					
	April	May	June	July	August
West	521	511	525	518	508
East	536	511	504	515	511
Season Average					516

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 recent history has 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
West	1,045	1,022	1,050	1,035	1,016
East	1,060	1,022	1,009	1,033	1,022
Season Average					1,031

Discussion

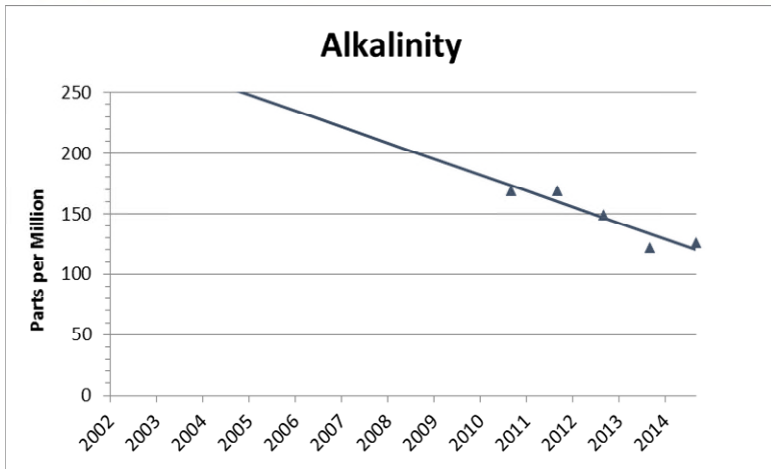
Like the TDS, Conductivity increased over the testing history. Conductivity is an extension of TDS and measures the amount of ionic molecules in the water (which conduct electricity, usually salts). We will look for this trend to slow in future years of testing.





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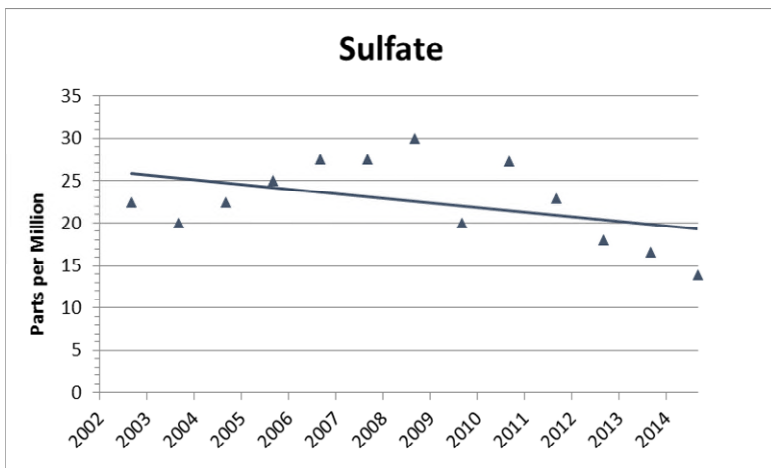
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Alkalinity (ppm)					
	April	May	June	July	August
West	138	131	122	116	120
East	139	130	125	116	127
Season Average					126

Discussion

Alkalinity was first included in the testing in 2010, so the historical data is more limited than other parameters. During the past five years, alkalinity has slowly decreased.



Sulfate (ppm)					
	April	May	June	July	August
West	12.3	13.1	15.5	14.7	14.5
East	12.5	12.8	15.4	14.3	14.3
Season Average					13.9

Discussion

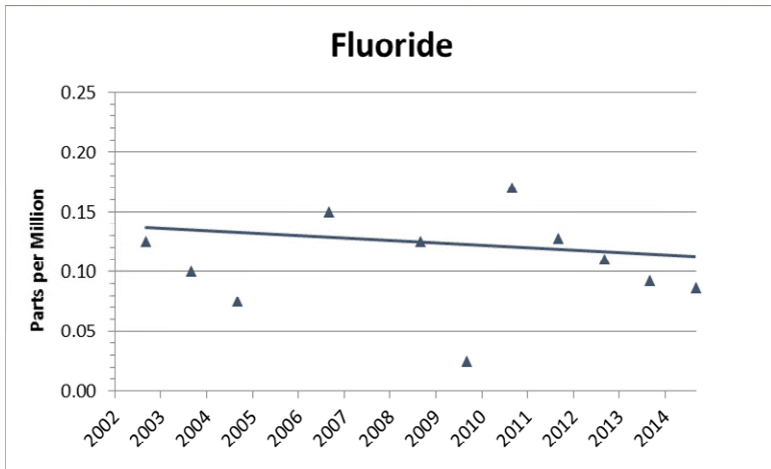
Sulfate has decreased slightly over the course of testing. The concentration in 2014 was the lowest annual average since testing began. It is important that this parameter stay within the target range and any sharp increases are quickly investigated.





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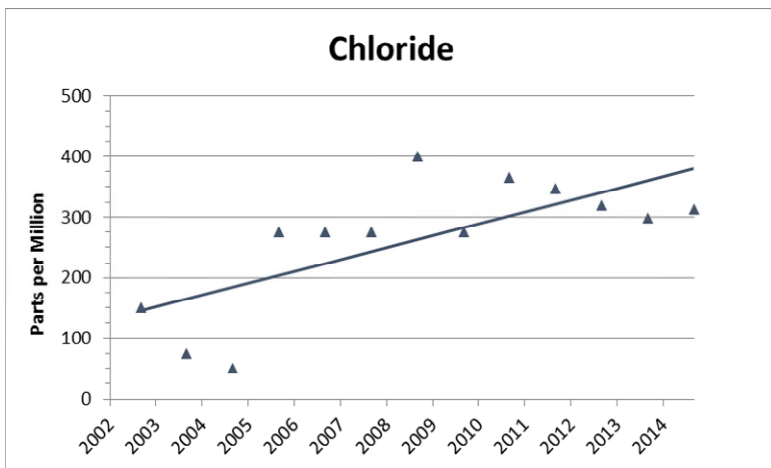
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Fluoride (ppm)					
	April	May	June	July	August
West	0.06	0.08	0.10	0.10	0.10
East	0.07	0.08	0.10	0.09	0.09
Season Average					0.09

Discussion

Fluoride has decreased slightly over the testing history. 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
West	342	336	307	299	291
East	334	331	303	292	288
Season Average					312

Discussion

The trend line for Chloride shows a steady increase in Chloride, but the five most recent years show a recent downward trend. Because the Chloride in Forest Lake remains above the target range, we will continue to investigate methods to remediate the accumulation of salt in the lake.





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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.
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.
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.
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 be 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 salt they can tolerate.

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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:



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