A Study of the Lyman Lakes and Spring Creek

Geology 120: Introduction to Environmental Geology
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Introduction

Much has been done to study water pollution and its effects on aquatic ecology. It is estimated that 14,000 miles of stream in thirty-nine states have been polluted by toxic substances, and that over a half million acres of lakes in sixteen states...have been adversely affected by industrial wastewater (Theodore and Theodore, 1996). More specifically, about 50 to 70 percent of impaired or threatened surface waters are affected by non-point-source pollution from agricultural activities (Theodore and Theodore, 1996). The Lyman Lakes and Spring Creek (Figure 1), on and around the Carleton College campus in rural Northfield, Minnesota, are thus heavily susceptible to pollution by means of agricultural wastewater runoff. Further, the polluting of Spring Creek could bring about more serious consequences, as the creek flows into the Cannon River, which then flows into the Mississippi River.

Due to its bad smell in some locations, as well as people's knowledge of bicycles and empty beer kegs being present in the lakes, the Lyman Lakes are believed to be rather polluted by many in the Carleton community. Many different departments at the college have conducted research on the Lyman Lakes and Spring Creeks in the past. However, because the research has never been considered comprehensively, not much action has been taken to reverse or stop the negative effects caused by pollution.

We believe that the Lyman Lakes and Spring Creek are constantly changing and are affected by significant amounts of pollutants deriving from wastewater runoff, either from agricultural uses or the upstream Northfield Golf Course. By testing this hypothesis, we can also demonstrate in what ways the quality of the water in the lakes and stream affect the wildlife that either reside in or use the lake and stream in some way. By analyzing the water content of the Lyman Lakes and Spring Creek, we should also be able to give some suggestions on what measures can be taken to reduce pollution.

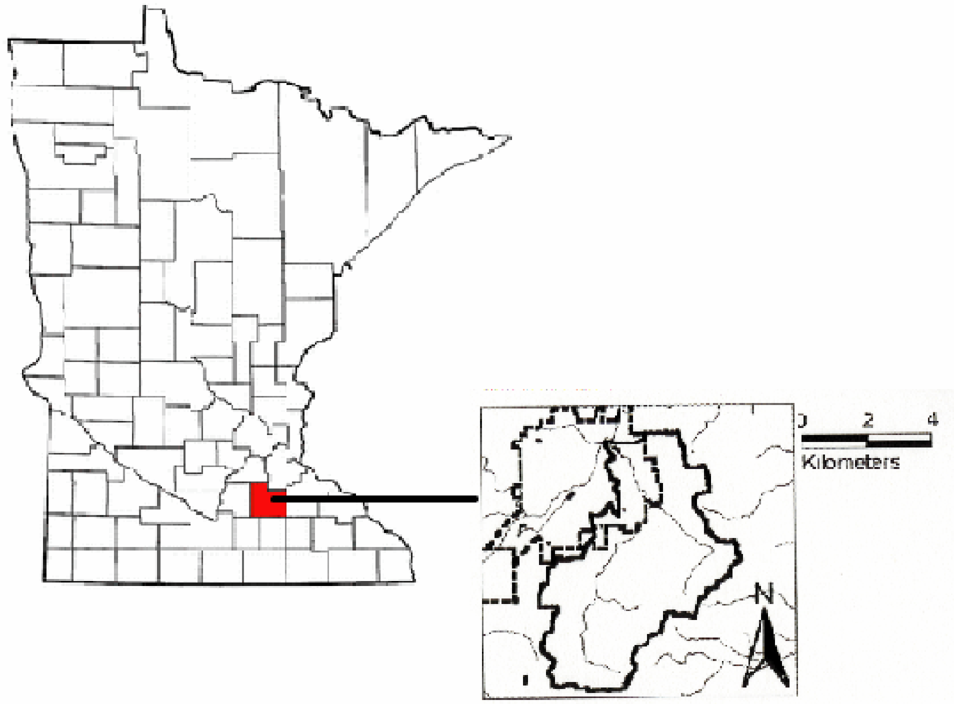

Figure 1: Spring Creek Watershed (bold line) in reference to Northfield (dotted line) of Rice County, MN

Methods

To thoroughly analyze the water chemistry in Spring Creek and the Lyman Lakes, we employed various methods and instruments at each water sample site. We used a Model 85 Yellow Springs Instrument to measure the conductivity, salinity, and temperature. We measured the rate of water flow at each site in meters per second by using a water flow meter. We also measured the water turbidity, by using a Secchi tube that measures in centimeters. Besides this, we obtained a water sample from each site to later test the water for five different anions - fluoride, choloride, nitrite, nitrate, and sulfate - in ppm by using a Dionex 600 Ion Chromatographer.

Specifically, we collected water samples from: Lower Spring Creek on October 4, 2004 and October 25, 2004 at three locations; from Lower Lyman Lake on October 11, 2004 from twelve locations; from Upper Lyman Lake on October 25, 2004 and November 11, 2004 from four locations; and from Upper Spring Creek on October 25, 2004 from four locations (figure 2). By doing this, we can determine if the lake or stream ecology is being affected by any fertilizers from agriculture or the upstream golf course by analyzing the data and comparing any trends we find with those of previously performed research.

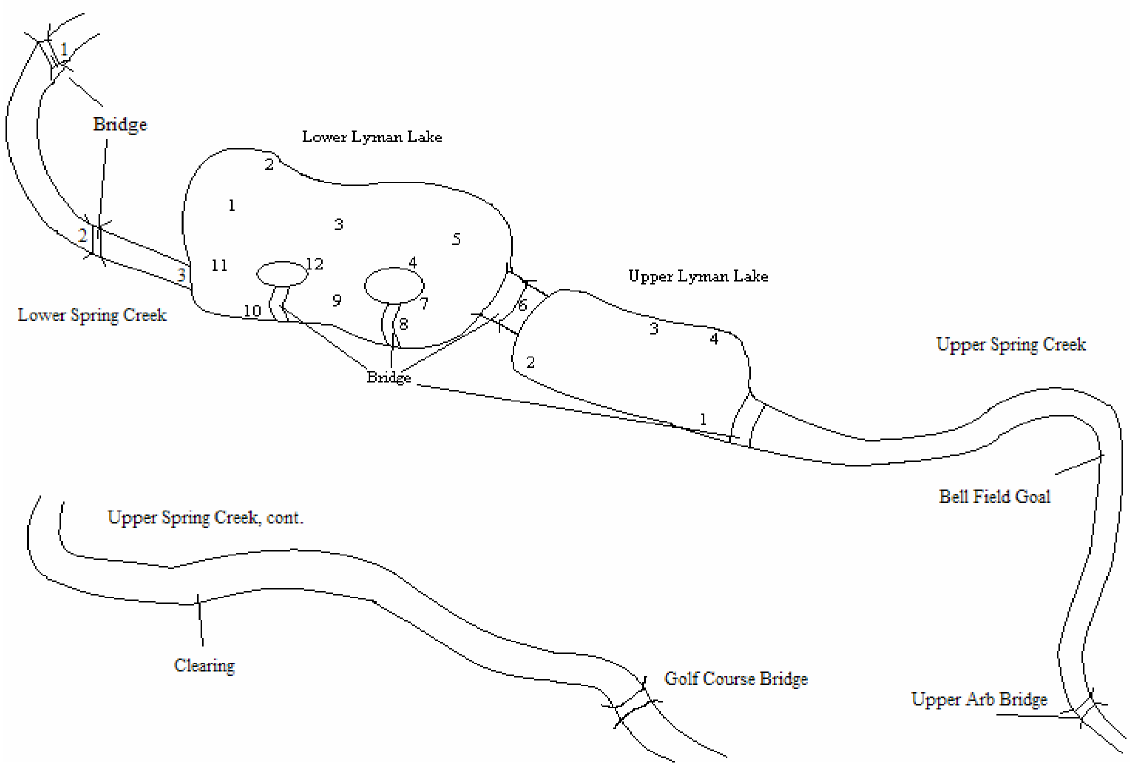

Figure 2: A rough representation of the sample testing sites along the Lyman Lakes and Spring Creek. Samples were collected on October 4th, October 11th, October 25th, and November 11th of 2004.

Previous Work

A group of Carleton Geology students in the fall of 2003 performed a similar research project as the one being performed by our group, with the exception that their study was concentrated solely on Upper Lyman Lake. The group concluded that high levels of nitrogen were found in Upper Lyman Lake, which then leads to high algae populations.

Carleton Geology Professor Mary Savina has coordinated numerous research studies dealing with the hydrology and geomorphology of the lakes and stream during her tenure at Carleton College. She also advised Annie Winker of the Class of 2000 in her comps project in which she compiled numerous studies performed by students and faculty over the years dealing with biological and geological processes occuring in the lakes and stream.

Discussion

After collecting and assembling the data (Table 1), we calculated averages for separate bodies of water, dividing sample results into Upper Spring Creek, Upper Lyman Lake, Lower Lyman Lake, and Lower Spring Creek groups (Table 2). A comparison of these averages reveals interesting trends in conductivity and anion content. Both conductivity (Figure 3) and anion content tested high in the Upper Spring Creek and Upper Lyman Lake sampling, decreased in the Lower Lyman Lake, and increased in the downstream Lower Spring Creek. The trend is understandable, as conductivity is a general measure of the amount of anions present at a certain site. This trend, most distinct in the abrupt decrease between Upper and Lower Lyman Lakes, is conducive to all of the anions found in the water, except for nitrite (Figure 7).

Sulfate (Figure 8) was the most prevalent anion found out of all the samples, and remained fairly constant between each region, with the lowest average being 31.81 ppm in Lower Lyman Lake and the highest being 34.19 ppm Lower Spring Creek. Chloride (Figure 4) levels also were generally consistent, ranging from 17.97 ppm in Upper Spring Creek to 15.99 ppm in Lower Lyman Lake. Nitrate (Figure 6) levels fluxuated over a broad range, increasing from 18.07 to 21.47 ppm from Upper Spring Creek to Upper Lyman Lake, decreasing significantly to 11.95 ppm in Lower Lyman Lake, and then increasing subtly to 12.74 ppm in the Lower Spring Creek. Fluoride (Figure 5) and nitrite traces were scarce in the samples we collected. But, as above mentioned, nitrite was the only anion that did not follow the same trend that all other anions followed; rather, it dropped from about 0.08 ppm to 0.04 ppm between Upper Spring Creek and Upper Lyman Lake, rose drastically to 0.14 ppm in Lower Lyman Lake, and dropped again to about 0.07 ppm in Lower Spring Creek.   However, this can be explained because the process of nitrogen fixation converts excess nitrate into nitrite.

The results from our turbidity, temperature, flow rate, and salinity tests reveal few discernible trends. The turbidity (Figure 9) of the water increases consistently from upstream to downstream, changing from a 75.63 cm reading in Upper Spring Creek to 42.13 cm reading in Lower Spring Creek. The murkiness of the Lyman Lakes would rationally produce the highest turbidity measurements, especially when compared to the faster-moving water in both Upper and Lower Spring Creek. Incongruency in the turbidity testing is most likely a result of the subjectivity of the test and human error, such as disturbance of creek sediment. The average temperature of the water, which was not defined by any trend, ranged from 13.87 degrees celcius in Lower Lyman Lake to 9.3

degrees celcius in Upper Lyman Lake. However, the lower average in Upper Lyman Lake can be justified by the samples collected from the Lake in November. The water average flow rate shows the water in both creeks to have a much greater velocity than that of either lake, with both lakes averaging .01 m/s and the Upper and Lower Spring Creek averaging 0.11 m/s and 0.12 m/s, respectively. Lastly, Salinity remained at a constant 0.3 ppt, regardless of the testing site.

The significant change in anion (thus, conductivity) levels between Upper and Lower Lyman Lakes is probably due to a natural filtration system that has developed due to the dam that separates the two lakes. As the water sits in Upper Lyman Lake, the nutrients settle to the bottom. Surface water then flows over the dam into the lower lake, leaving a significant amount of the sediments behind. Evidence of this is shown in the difference in plant and animal life between the two lakes. Upper Lyman Lake, which has higher levels of nutrients, is a more eutrophic lake, with lots of algae and plant life. Fish living in this lake are small because of the abundant food and lack of large predators. Lower Lyman Lake, which is lower in nutrients, has less algae and less plant life in general.

Although high concentrations of some anions make it seem as if they may be harmful to one's health, all anion levels met EPA drinking water standards. Sulfate, which consistently remained around 30 ppm among the samples, is present in the water most likely due to chemical reactions that occur while groundwater is permeating through soil. The chloride found in all samples is likely caused by road salt runoff. This explains the elevated levels of chloride in Upper and Lower Spring Creek, as both parts of the creek run under bridges. Nitrate, which experienced the most diverse changes in levels of all the anions tested, is likely derived from nitrogen-based fertilizer used upstream for agriculture or the Northfield Golf Course. We found nitrate content to be highest where Upper Spring Creek meets Upper Lyman Lake, most likely a result of any fertilizer they spread on Bell Field added with any fertilizer runoff that might have already been present in the water.

When examining all anions and their levels relative to EPA drinking water standards, nitrate is the pollutant that comes the closest to meeting its regulated amount; in this case, 10 mg/L of nitrogen (nitrate is divided by 4.43 to get its nitrogen level). However, we must take into account that these nitrate measurements are from the fall, and there is a great probability that the measurements would be much higher during the summer, the peak farming season. Anhydrous ammonia is the common nitrogen-based fertilizer spread on fields. The ammonia-rich runoff is converted to nitrate by bacteria in the soil and water (Orr and Pfeiffer, 1995). Because studies show that most nitrate-rich environments in water are caused by agricultural processes, along with the findings of a previous study on Lyman Lakes that concluded that nitrate runoff came from upstream (Orr and Pfeiffer, 1995), we can safely assume the elevated nitrate levels found in the samples in the Spring Creek and Lyman Lakes are caused by upstream agricultural activites.

The presence of anions does have a significant impact on the habitat and ecology of the stream and lakes. Even though it may not seem so, fish and other species are affected by any amount of pollutants present in their environment. In fact, aquatic organisms that are exposed to various pollutants in which they live will take in those chemicals and retain them in their body tissues (Wardzinski, 1995). Aquatic life is also affected by the anaerobic environment created by algae, which thrive on nutrients in the water and depletes a body of water of dissolved oxygen. The reduction of pollutants in the creek and lakes would clearly assist the sustainability of aquatic species.

Conclusion

Although all of the water sampled is within the EPA standards for what we tested for, it is clear that Spring Creek and Lyman Lakes have been strongly and negatively affected by upstream runoff. A comparison to a study of Kelly Dudley Lake, a lake without tributaries, reveals the significance of the levels of anions we found to be present in the Lyman Lakes. The Kelly Dudley Lake had similar sulfate and chloride levels, but had only tracery amounts of nitrate, nitrite, and fluoride.

If the Lyman Lakes continue to be polluted by runoff, algal proliferation and other negative effects of water pollution will cause the Lyman Lakes and surrounding bodies of water to eventually become uninhabitable to aquatic species. There are a few actions that could be taken to reduce the amount of pollutants that run off into the stream from agriculture. Most notably, clay-rich soil and plastic, both of which have very low permeability, could be installed underneath farmland, in conjunction with making drainage ditches. This way, polluted water would not enter into the groundwater and collect in the drainage ditch. Another option farmers have is to gradually discontinue the use of nitrogen-based fertilizer and start to use more natural fertilizers, like the corn-based fertilizer Carleton College uses on a good portion of its property. Of course, this and many other similar methods would be costly and inconvenient for farmers, but would cut back on water pollution, which makes for healthier streams, lakes, and groundwater.

A few possible sources of error encountered while taking measurements were an unstable boat which may have affected flow rate readings, an unstable Secchi tube which could have affected our turbidity readings, human error, and any malfunction with our instruments that might have happened.

Acknowledgements

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Environmental Protection Agency websites:

>http://www.epa.gov/safewater/<

>http://www.epa.gov/OGWDW/mcl.html#mcls<

Appendix

Table 1: Complete test results for each site, rounded to two decimal places. A zero indicates that an anion was nonexistant in a sample; likewise, an N/A indicates that a measurement was not able to be taken.

Sample Location	SC Bridge #1	SC Bridge #2	SC Below Dam #3	
Date	10/4/2004	10/4/2004	10/4/2004	
Conductivity (ms)	636	620	618	
Turbidity (cm)	67	48.4	42.4	
Temperature (centigrade)	12.5	12.2	12.2	
Salinity (ppt)	0.3	0.3	0.3	
Depth (cm)	37	14	24.6	
Flow rate (m/s)	0.06	0.36	0.04	
Fluoride (mg/L)	0.14	0	0.13	
Chloride (mg/L)	15.87	14.99	15.07	
Nitrite (mg/L)	0.15	0	0	
Nitrate (mg/L)	11.22	11.6	12.02	
Sulfate (mg/L)	34.62	33.99	34.11	
Sample Location	SC LL #1	SC LL #2	SC LL #3	SC LL #4
Date	10/11/2004	10/11/2004	10/11/2004	10/11/2004
Conductivity (ms)	621	569	632	536
Turbidity (cm)	56	60	46	52
Temperature (centigrade)	12.5	15.4	12.15	14.9
Salinity (ppt)	0.3	0.3	0.3	0.3
Depth (cm)	N/A	35	N/A	29
Flow rate (m/s)	0.01	0.01	0.01	0.01
Fluoride (mg/L)	0	0.1321	0.12	0.1335
Chloride (mg/L)	15.88	15.78	15.91	16.52
Nitrite (mg/L)	0.13	0.16	0.14	0.21
Nitrate (mg/L)	11.71	11.39	11.61	11.14
Sulfate (mg/L)	31.38	31.56	31.45	31.55
Sample Location	SC LL #5	SC LL #6	SC LL #7	SC LL #8
Date	10/11/2004	10/11/2004	10/11/2004	10/11/2004
Conductivity (ms)	614	603	562	589
Turbidity (cm)	56	79	46	69
Temperature (centigrade)	12.8	14.1	14.8	13.8
Salinity (ppt)	0.3	0.3	0.3	0.3
Depth (cm)	N/A	92	55	N/A
Flow rate (m/s)	0.01	0.01	0.01	0.01
Fluoride (mg/L)	0.11	0.13	0	0.12
Chloride (mg/L)	15.82	17.18	15.91	15.85
Nitrite (mg/L)	0.18	0.12	0.17	0
Nitrate (mg/L)	11.25	16.81	11.25	11.4
Sulfate (mg/L)	31.52	31.47	31.41	31.7

Table 1 continued.

Sample Location	SC LL #9	SC LL #10	SC LL #11	SC LL #12
Date	10/11/2004	10/11/2004	10/11/2004	10/11/2004
Conductivity (ms)	600	571	616	569
Turbidity (cm)	84	57	70	56
Temperature (centigrade)	12.9	14.8	13	15.3
Salinity (ppt)	0.3	0.3	0.3	0.3
Depth (cm)	N/A	35	N/A	35
Flow rate (m/s)	0.01	0.01	0.01	0.01
Fluoride (mg/L)	0	0.12	0	0
Chloride (mg/L)	15.55	14.98	15.67	16.84
Nitrite (mg/L)	0.14	0.14	0.13	0.17
Nitrate (mg/L)	11.15	10.85	11.23	13.76
Sulfate (mg/L)	31.77	30.72	31.67	35.46

Sample Location	SC UL #1	SC UL #2	SC UL #3	SC UL #4
Date	10/25/2004	10/25/2004	11/11/2004	11/11/2004
Conductivity (ms)	671	660	648	659
Turbidity (cm)	74.5	66	N/A	N/A
Temperature (centigrade)	11.3	11.2	7.7	7
Salinity (ppt)	0.3	0.3	0.3	0.3
Depth (cm)	N/A	N/A	25	17
Flow rate (m/s)	0.01	0.01	0.01	0.01
Fluoride (mg/L)	0.14	0.15	0.11	0.11
Chloride (mg/L)	18.13	18.33	18.25	15.44
Nitrite (mg/L)	0	0	0.15	0
Nitrate (mg/L)	22.38	18.02	24	20.46
Sulfate (mg/L)	34.44	34.37	35.87	30

Sample Location	SC Bridge #1	SC Bridge #2	SC Below Dam #3
Date	10/25/2004	10/25/2004	10/25/2004
Conductivity (ms)	642	640	688
Turbidity (cm)	30	37	28
Temperature (centigrade)	12.5	12.4	12.4
Salinity (ppt)	0.3	0.3	0.3
Depth (cm)	22	18	32
Flow rate (m/s)	0.02	0.17	0.07
Fluoride (mg/L)	0.16	0.16	0.1
Chloride (mg/L)	17.64	17.23	16.23
Nitrite (mg/L)	0.19	0	0.06
Nitrate (mg/L)	15.45	13.5	12.66
Sulfate (mg/L)	33.02	35.77	33.64

Table 2: Data averages by region.

	Upper Spring Creek	Upper Lyman Lake	Lower Lyman Lake	Lower Spring Creek
Conductivity (µs)	645.75	659.5	590.17	640.67
Turbidity (cm)	75.63	70.25	60.91	42.13
Temperature (centigrade)	11.43	9.3	13.87	12.37
Salinity (ppt)	0.3	0.3	0.3	0.3
Flow Rate (m/s)	0.11	0.01	0.01	0.12
Fluoride	0.1	0.13	0.07	0.12
Chloride	17.97	17.54	15.99	16.17
Nitrite	0.08	0.04	0.14	0.07
Nitrate	18.07	21.47	11.95	12.74
Sulfate	34.06	33.67	31.81	34.19

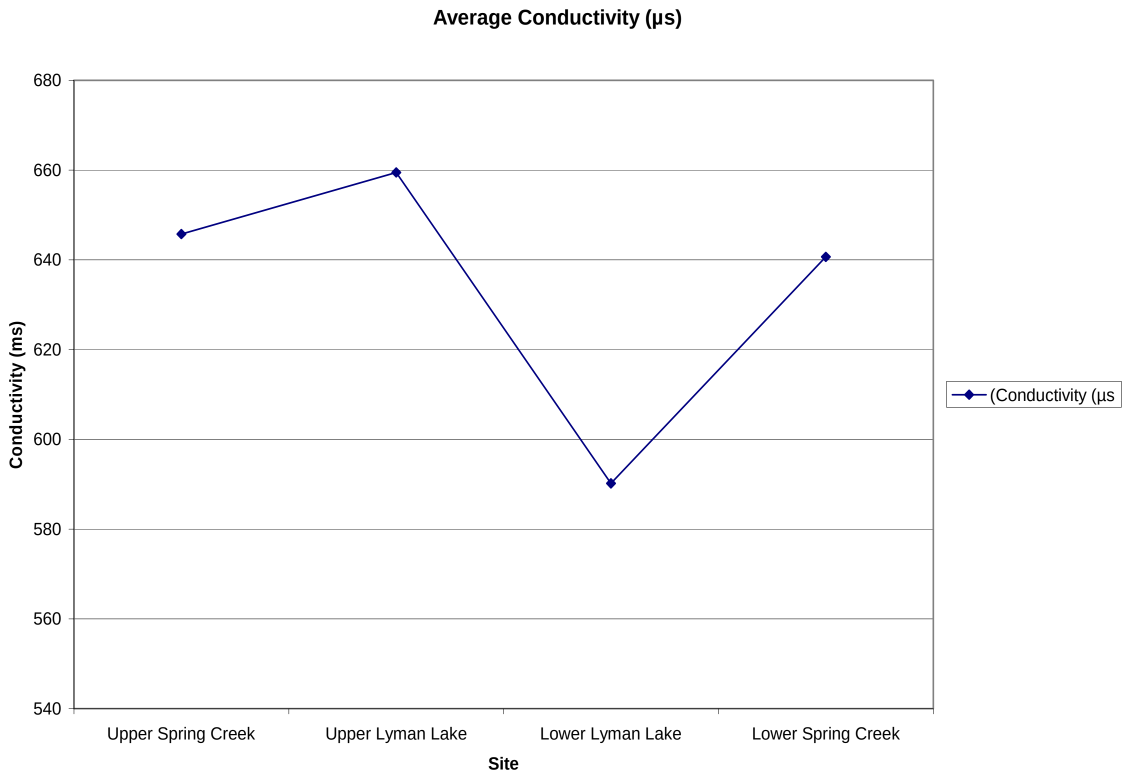

Figure 3: Average conductivity in µs. Conductivity rose gradually between Upper Spring Creek and Upper Lyman Lake, dropped significantly between Upper and Lower Lyman Lake, and rose once more between Lower Lyman Lake and Lower Spring Creek. This trend in conductivity is reflected in many anion levels.

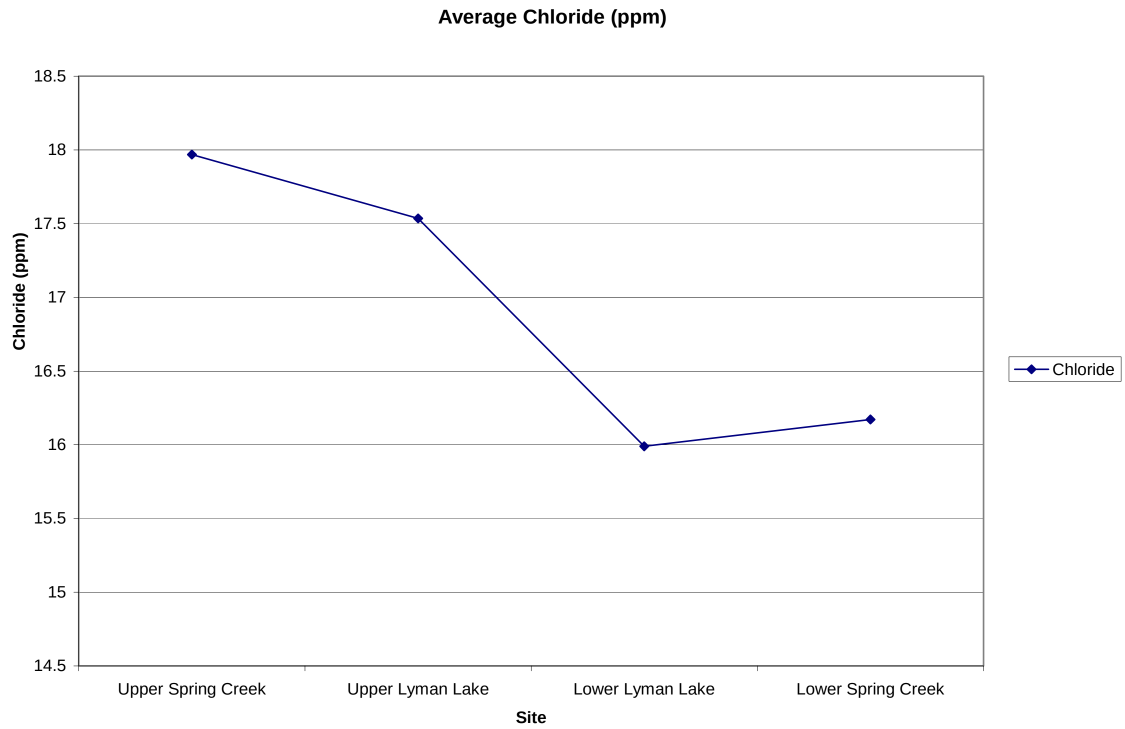

Figure 4: Average chloride levels in parts per million.

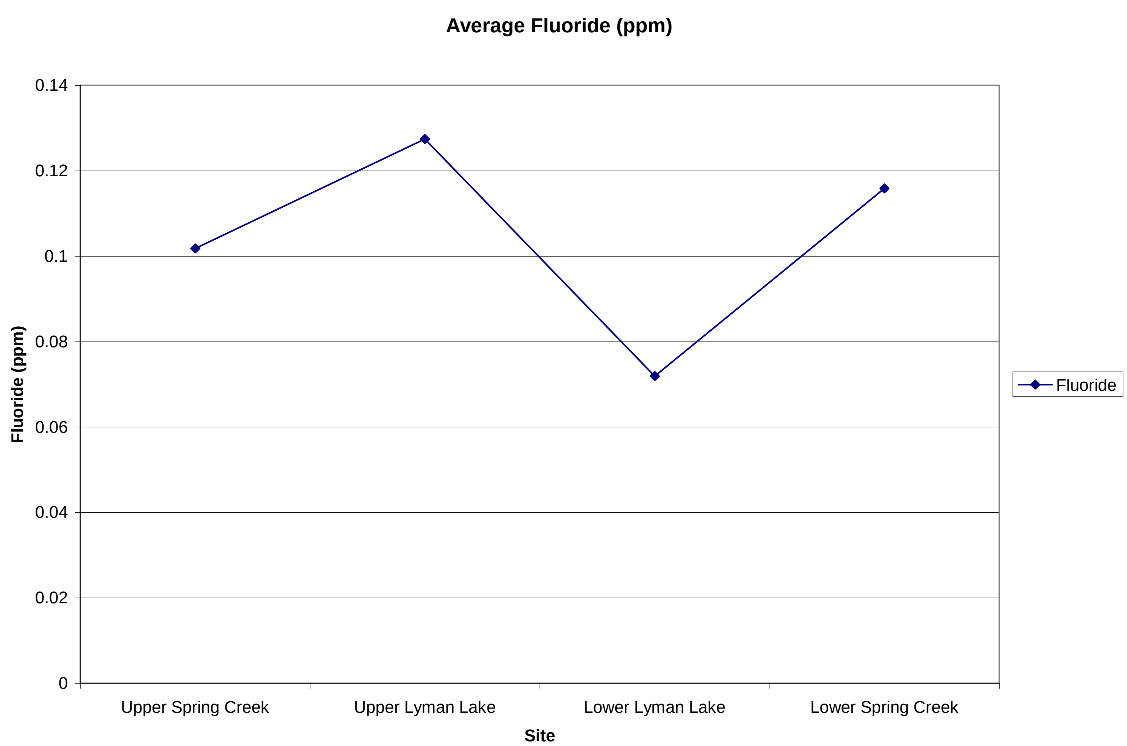

Figure 5: Average fluoride levels in parts per million**.**

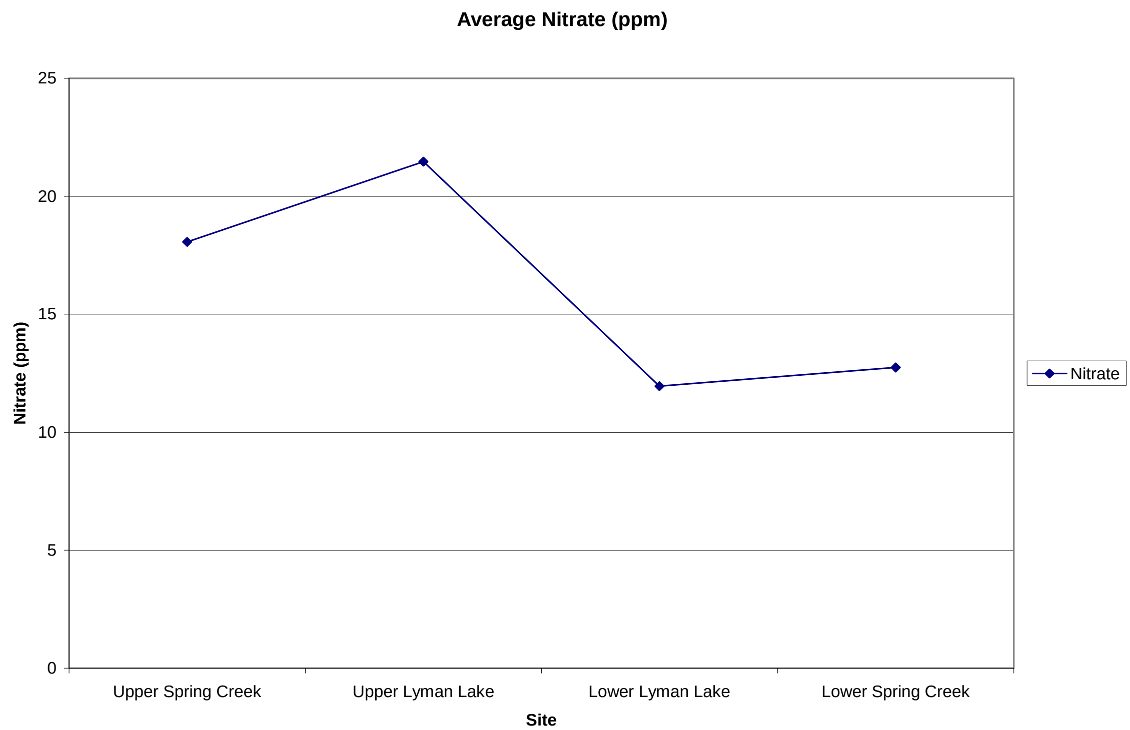

Figure 6: Average nitrate levels in parts per million**.**

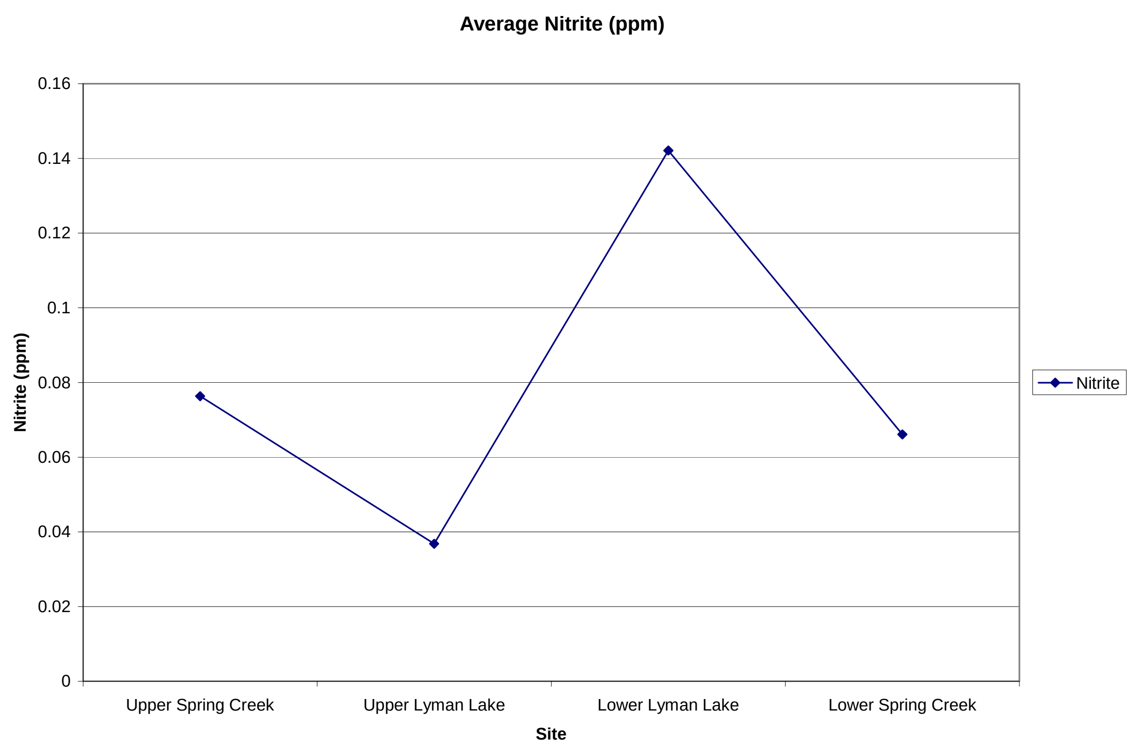

Figure 7: Average nitrite levels in parts per million.

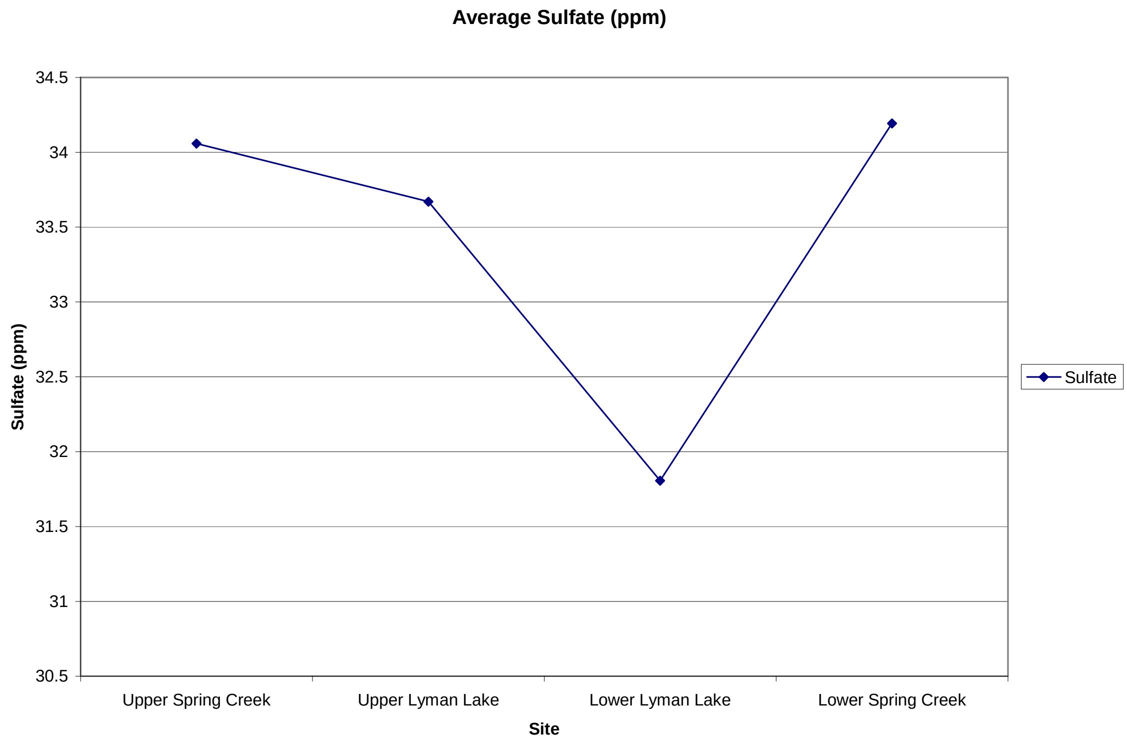

Figure 8: Average sulfate levels in parts per million.

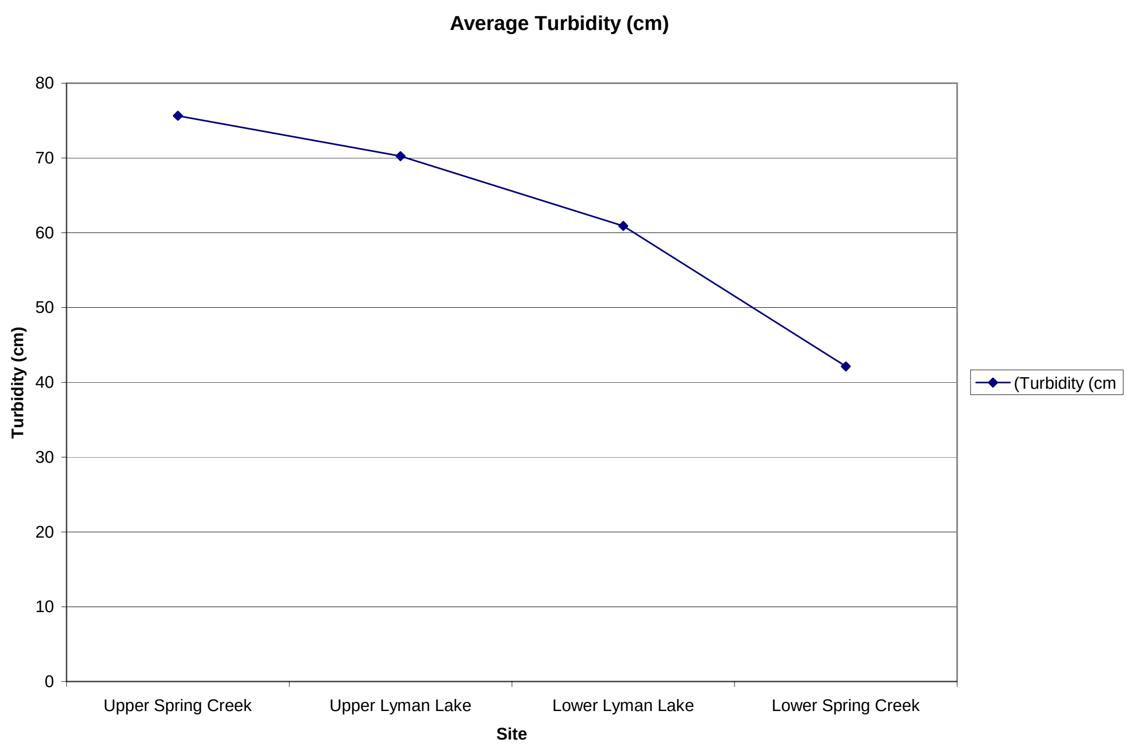

Figure 9: Average turbidity measurements in centimeters.