Introduction to Geology

Final Projects

Instructor
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Carleton College, Northfield Minnesota
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Table of Contents

Introduction

Rice County is one of the fasted growing counties in Minnesota. Historically dominated by corn and soybean fields, it now sits at the intersection of rural and urban Minnesota. Growth from the Minneapolis-St. Paul metro region threatens to take over.

At the moment some of the lakes and rivers are threatened by pollution, especially non-point source from agriculture. As more land is the county is developed, the source of pollution will change form, from agricultural to urban. In order to monitor the lakes and streams in the county, students in my introduction to geology class have been working on class projects related to aspects of surface water chemistry in Rice County and wrote the projects included in this edition.

In these projects, students collected water samples from local streams and lakes, and then analyzed their chemistry. At the moment, data collected is used to educate students on the potential of non-point source pollution problems within the watershed and help reduce these problems. Later on, I hope these results will be used with land-use planning in the county.

While doing these projects, my students gained tremendous knowledge on data collection and interpretation.

Bereket Haileab 2010

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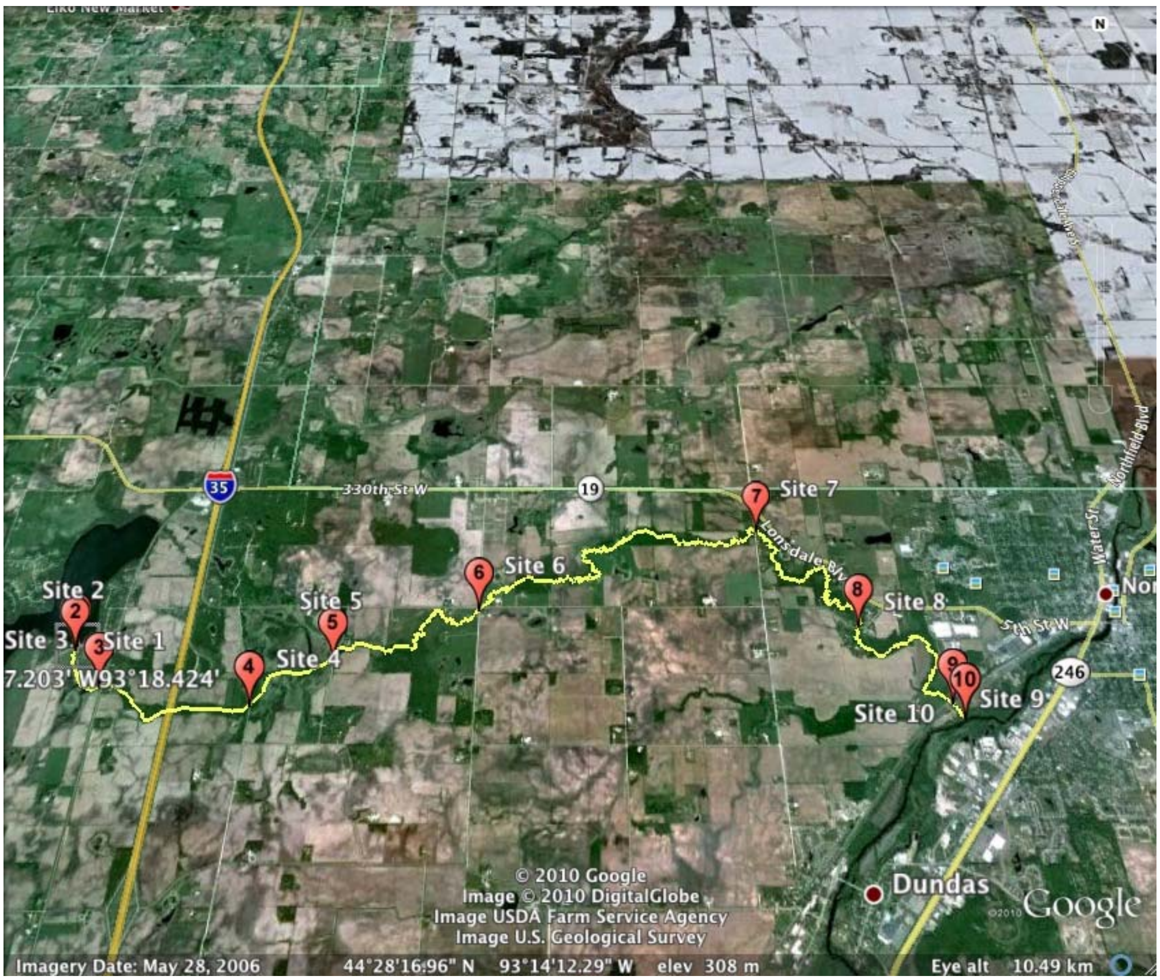

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November, 2010

Introduction

Heath Creek flows from Union Lake in north-central Rice County, Minnesota, east to the Cannon River in Northfield, MN. As a tributary of the Cannon River, Heath Creek plays a significant part in the Cannon River Watershed. Previous studies have shown that the Cannon River and some of its tributaries are considered impaired waters (Savina et al., 2001), threatened by both agricultural and human development. Elevated nutrient levels have been documented in Heath Creek, particularly nitrates (Barger et al., 2001).

As previously stated, agriculture and development are the two main factors that affect the Cannon River Watershed (Fig. 4). Fertilizer and animal waste runoff from nearby farms and poorly maintained septic systems in residential areas currently pose the biggest threat to Heath Creek.

The city of Northfield, MN, is a growing population center, and more development and expansion is expected in the near future. Along Interstate 35, south of Highway 19, 1,080 acres have been rezoned for commercial use (Fig. 5) (Peterson, 2005 and Rice, 2009). This land intersects the Heath Creek watershed and is a potential source of pollution for the stream.

In this study, we will explore the geochemistry of Heath Creek. It is important to monitor its geochemistry because the stream will soon be affected by the increased city development.

We are most interested in the creek's conductivity and nitrate levels. These two measurements provide information about total chemical contamination and fertilizer contamination, respectively. Nitrate levels are associated with agricultural pollution, as well as sewage leakage and erosion of naturally-occurring deposits (Savina et al., 2001). By monitoring nitrate we will be able to assess whether a later increase in pollution is associated with the I-35 development.

In 2004 Stoddard, et al. recorded nitrate levels on October 4 and 25. This study is generally content with the health of Heath Creek—the various dissolved solids that they measured were at acceptably low levels. Unfortunately, they only took nitrate measurements at five of their ten sample sites, limiting our ability to compare data and analyze change over time.

The Minnesota Pollution Control Agency also studied Heath Creek in 2004. It took readings at only one site; it was between our fifth and sixth locations, far off the road. This again makes direct comparison of our results impossible.

Methods

Measurements were taken at all eight road crossings of Heath creek along its 21.5 kilometer span, as well as at its headwaters at Union Lake and its mouth on the Cannon River, for a total of ten points. We used a Garmin 72 GPS monitor to track our location at each sampling site. We coded the ten locations as follows:

Table 1: Location Coding

No.	Street Name	GPS coordinates	No.	Street Name	GPS coordinates
1	Union Lake	N44°27.203’ W93°18.424’	6	Baldwin Avenue	N44°27.419’ W93°15.094’
2	County Road 59	N44°27.178’ W93°18.424	7	Decker Avenue	N44°27.958’ W93°12.643’
3	Bagely Avenue	N44°26.527’ W93°18.329’	8	Old Dutch Road	N44°27.281’ W93°11.823’
4	Baseline Road	N44°26.811’ W93°16.893’	9	Armstrong Road	N44°26.789’ W93°11.223’

5	Albers Avenue	N44°27.089’ W93°16.268’	10	Cannon River	N44°26.704’ W93°11.149’

Table 1. In the study we refer to sampling sites by road name and numerical order, but we recorded the GPS coordinates of each place for future studies.

Each of these sites was tested a week apart during the autumn of 2010, on November 2 and November 9. Photos were taken of each site, and local features that might impact readings were noted.

We used a Model 30 YSI meter to measure temperature, salinity, and conductivity. The meter probe was fully submerged in an unimpeded section of moving water and gently agitated for these readings.

The YSI 30 meter yields two conductivity readings—the first measurement is taken using the actual water temperature, and the second is adjusted as if the water temperature is 25°C. We used the adjusted readings in our study, though the uncorrected numbers can be found in the appendix (Table 3).

At each of the ten sample locations, we collected water samples to be analyzed in the lab. We used pHydrion Mikro pH strips to test the pH level of the November 9th samples. We compared the depth of color on the test strip to the pH key on the package to estimate the pH of each sample.

Professor Bereket Haileab and senior Carleton College undergraduates attempted to analyze the nitrate levels of our water samples. The WQ-NO3 sensor, however, was not working correctly; this prevented us from acquiring nitrates measurements.

Results

Temperature of Heath Creek on our two sample days showed opposing trends. On November 2 the temperature decreased as water traveled further from Union Lake. Conversely, on November 9 temperature increased with distance. At Armstrong Road and the Cannon River (locations 9 and 10) the temperature difference between the two days was as large as 2.3°C (Fig. 1 and Table 4).

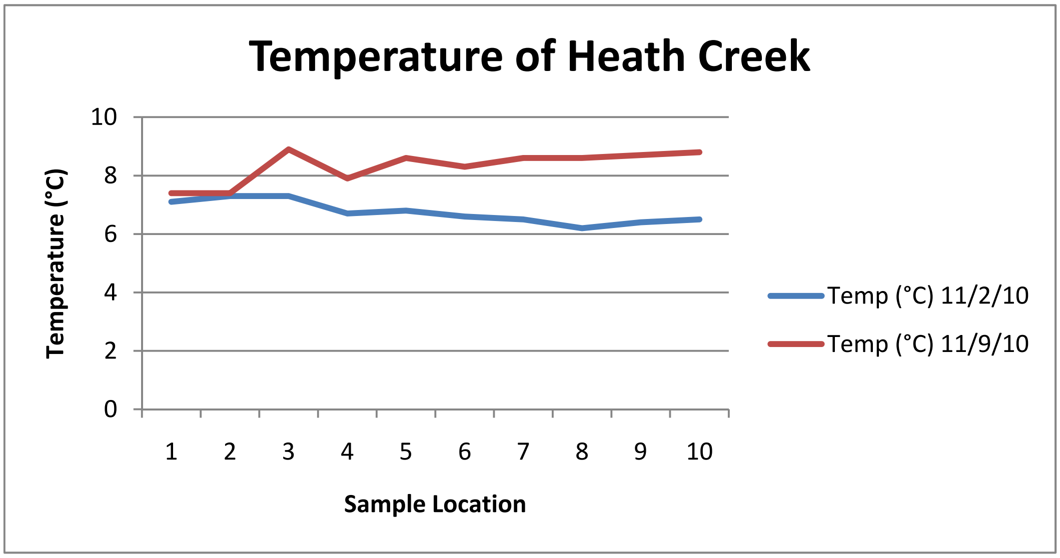

Figure 1. Opposite temperature trends were demonstrated on our two sample days. On 11/2 temperature decreased with distance from Union Lake. On 11/9 temperature increased with distance.

We measured salinity in parts per thousand. The salinity was constant at 0.2ppt on both days, at each location (Table 5).

We measured pH in the Nov. 9^{th} samples and found the results to be fairly constant, with a neutral pH. All variability ranged between pH 7 and pH 8 (Table 6).

On both days conductivity increased with distance from Union Lake. Graphically they show the same trend, just translated upward by about 50 µS on Nov. 9 from Nov. 2 (Figure 2). Looking at calibrated measurements from the YSI meter, Union Lake's conductivity was 235.3 µS on Nov. 2 and 270.8 µS on Nov. 9. At the Cannon River conductivity was 270 µS on Nov. 2 and 332.5 µS on the Nov. 9. Data for all locations can be found in the Appendix (Table 3).

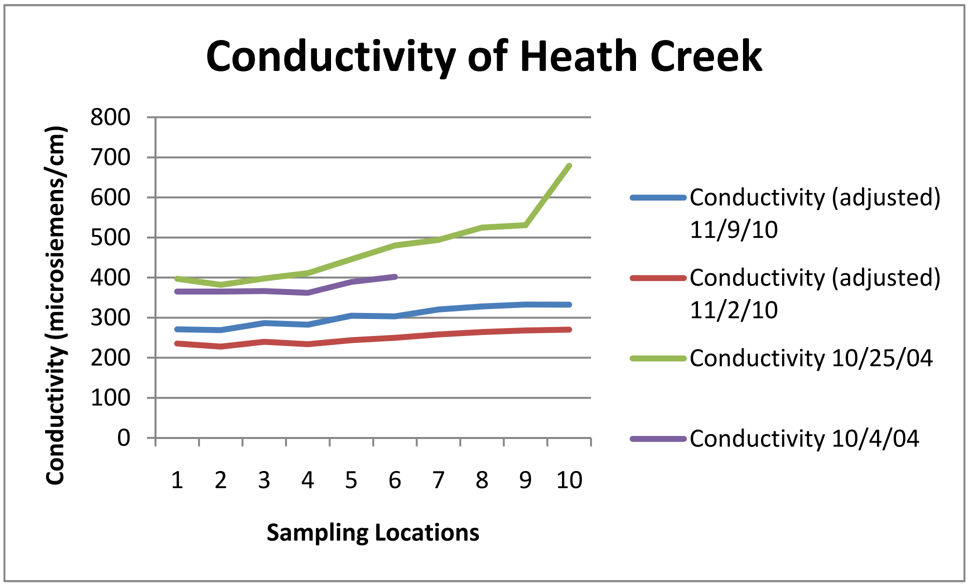

Figure 2. On both test days, conductivity increased as distance from Union Lake increased. This trend was also seen in a previous 2004 study. We used our adjusted measurements to compare to 2004's data. It is ambiguous which measurement Stoddard et al. used, meaning their data should only be analyzed for general trend and not absolute value.

Data from previous years indicates that nitrate levels increase as Heath Creek approaches the Cannon. The Stoddard, et al. nitrate measurements were only recorded at the final five sampling locations but still demonstrated an increasing trend (Table 2).

Table 2: Nitrate levels (mg/L) of 2004 Stoddard, et al. study.

Location	6	7	8	9	10 (Cannon River)
Oct. 11	–	2.23	2.40	2.68	26.98
Oct. 25	1.001	2.52	3.38	3.53	22.40

Table 2. The table shows the nitrate levels in 2004 measured by Stoddard et al. Nitrate increases as Heath Creek nears the Cannon River.

The Minnesota Pollution Control Agency took nitrate measurements in 2004 at a single sample location. That location, located between our points five and six, showed a value of 0.09 mg/L, much lower than other readings.

Discussion

Our visits to Heath Creek occurred on November 2, 2010 and November 9, 2010. The week in between had unseasonably warm temperatures and no rain. We suspect the warmer temperature accounts for the increased water temperature on Nov. 9. Union Lake is large, and therefore resistant to temperature changes. Locations along the stream, however, are shallower and contain less water, allowing them to more easily fluctuate with air temperature.

We are not surprised to see the constant salinity level in Heath Creek. We expect salinity changes to occur during winter and spring as a result of road salt in water runoff. Our readings are from autumn before any significant snowfall. This means the roads have not been salted in over six months, allowing salinity levels to stabilize.

We found pH to be fairly constant and neutral at all sample locations. This bodes well for the health of Heath Creek—whatever pollution it contains has not made it dangerously basic or acidic. If a significant change in pH is observed in the coming years it can likely be attributed to pollution from the I-35 corridor development.

We did not measure turbidity, but did note that water was clear throughout the entire creek. Additionally, Union Lake was free of algae on both sample days. The clarity of the water indicates that there is not overmuch bacterial activity, another indication of water health.

Figure 3. Union Lake on November 2, 2010. The surface is clear, with no algae cover.

Another encouraging indicator of Heath Creek's current health is the relatively low conductivity. The EPA considers a range of 150-500µS to be ideal for healthy stream habitats (Conductivity, 2010). The highest conductivity level we measured in Heath Creek was 332.7 µS.

The most interesting statistic concerning Heath Creek is its nitrate contamination. The maximum contaminate level for drinking water, according to the EPA, is 10 mg/L (Drinking, 2010). Previous studies indicate that Heath Creek has low nitrogen levels—in 2004 the MPCA measured nitrogen in the creek as only 0.09 mg/L. Additionally, a study done by Barger et al in 2001, found nitrate levels to be fairly constant 0.8-1.0 mg/L between Union Lake and Baldwin Avenue (points 1-6). Then nitrate levels increased from Decker Ave. towards the Cannon (points 7-10), peaking at 1.7 mg/L. Even this high number is still well within the EPA standards.

Heath Creek runs primarily through agricultural farmland, but also encounters undeveloped fields and suburban neighborhoods (Fig. 4). We noted an agricultural tile outlet on Baseline Rd (location 4) very near to Heath Creek. The low values noted at location four by Barger, et al. indicate this tile does not pollute Heath Creek. However, we have no way of knowing when the tile was installed—it may be more recent than 2004.

Unfortunately, the WQ-NO3 sensor was not repaired prior to the end of this study. Consequently we are not able to assess the possible ramifications of the tile, nor assess potential change in nitrate levels since previous studies. If given more time we would certainly include and analyze nitrate levels from 2010. Future studies should collect nitrate data in order to more accurately assess nitrate trends.

We believe that it will be helpful to measure turbidity in future studies. We regret bypassing this measurement, since it helps assess the level of bacterial contamination, not just chemical contamination. This measurement will give a fuller picture of the Heath Creek's overall health.

Conclusion

We believe Heath Creek to be fairly healthy surface waters. The low conductivity and salinity, as well as the safe nitrate levels noted in previous studies, all indicate that the stream is not dangerously contaminated. It would be interesting to retest the water in the spring, when melting snow will transport fertilizer and other nutrients into the stream. We are unsure how much seasonal variability there is in Heath Creek's health.

With the information we currently possess, we believe Heath Creek to be a healthy stream. Continued monitoring will be necessary in order to assess the effect of urban development from the town of Northfield and also future developments along I-35.

Acknowledgements

We would like to thank the Environmental Protection Agency and the Minnesota Pollution Control Agency. We are also grateful to previous researchers and Introduction to Geology students for studying Heath Creek and recording their data. Finally, great thanks to Griffin Williams and Lilly Betke-Brunswick, our lab TAs, and also to Professor Bereket Haileab for their encouragement and assistance.

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Appendix

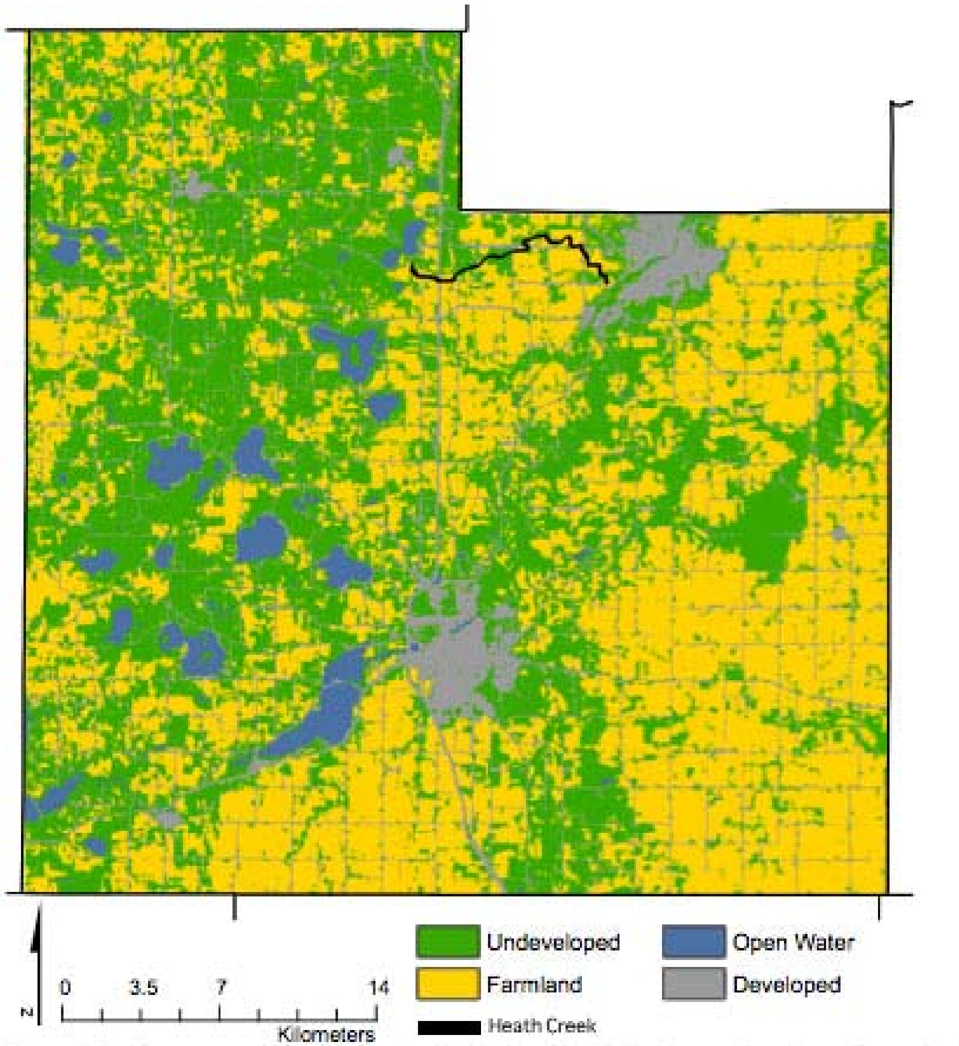


Figure 4. A map of land usage in Rice County. Heath Creek is in the north-central area of the county, running from Union Lake (just below the county corner) to the Cannon River near Northfield. Made by students from GEO 370 in Winter 2010, modified by Caroline Scheevel in Fall 2010.

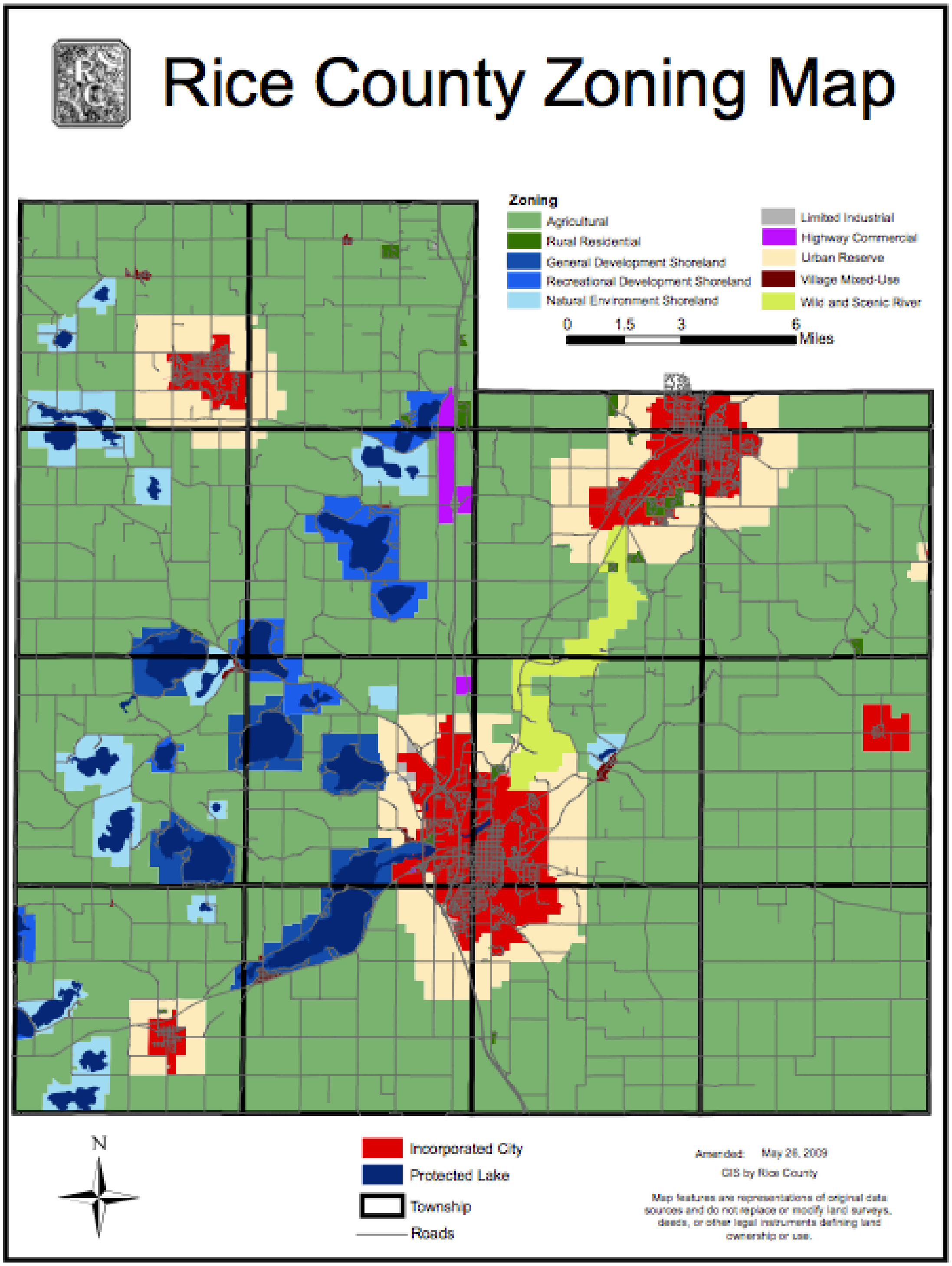


Figure 5. The purple section east of I-35 is the proposed development that endangers Heath Creek. Union lake is immediately east of the development.

Table 3: November 2010 Conductivity Readings of Heath Creek (µS/cm)					
Site	**1**	**2**	**3**	**4**	**5**
Nov. 2 Adjusted	235.3	227.7	240.0	234.0	243.8
Nov. 2 Unadjusted	355.5	345	358.0	359.8	373.2
Nov. 9 Adjusted	270.8	269.0	286.7	282.5	304.7
Nov. 9 Unadjusted	412.2	405.7	414.9	419.8	445
Site	**6**	**7**	**8**	**9**	**10**
Nov. 2 Adjusted	250	258	264	268	270
Nov. 2 Unadjusted	384	400	411	415	417
Nov. 9 Adjusted	303.4	320.6	327.9	332.7	332.5
Nov. 9 Unadjusted	446.0	467.8	483.3	483.9	482.3

Table 3. Adjusted readings show conductivity at the standard temperature, 25°C. The unadjusted measurements show conductivity at the actual water temperature.

Table 4: November 2010 Temperature of Heath Creek (°C)					
Site	**1**	**2**	**3**	**4**	**5**
Nov. 2	7.1	7.3	7.3	6.7	6.8
Nov. 9	7.4	7.4	8.9	7.9	8.6
Site	**6**	**7**	**8**	**9**	**10**
Nov. 2	6.6	6.5	6.2	6.4	6.5
Nov. 9	8.3	8.6	8.6	8.7	8.8

Table 4. Temperatures from Nov. 2 and Nov. 9 show opposing trends as they move away from Union Lake.

Table 5: Salinity of Heath Creek (ppt)										
Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Nov. 2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Nov. 9	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Table 5. Salinity shows no variation on either day at any location.

Table 6: pH of Heath Creek										
Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Nov. 9	7	7	7.5	7.5	7.5	8	8	8	7	7.5

Table 6. pH was measured only on Nov. 9. Though some samples were slightly basic, the stream seems to be neutral.

RICE CREEK

WATER QUALITY ASSESMENT

Fall 2010

Geology 110

Professor B. Haileab

Muira McCammon, Matt Harrison, Kaitlin Randolph, Lydia English

Introduction

Within the Minnesotan geological community Rice Creek, also known as Spring Brook, is known as a unique watershed as it is one of only a few aquatic habitats in the state that can sustain brook trout populations. These "brookies" require clear, cool (50-68°F), and especially clean water, but agricultural runoff, subsequent thermal pollution, stream manipulation and ongoing urban development have severely threatened the ecological integrity of Rice Creek (Cannon River Watershed Partnership, 2008). Despite governmental monitoring of Rice Creek, its neighboring streams, as well as the Cannon River Watershed, Rice Creek has previously passed the U.S. Environmental Protection Agency's maximum allowance for nitrates (EPA/620/5-94/004), and in addition, it has also joined Minnesota's 303d list of impaired waters (Minnesota Pollution Control Agency, 2009). These concerns and previous studies documenting poor and degraded brook trout habitats have not slowed down the influx of applications to annex part of Rice Creek as of 2009 (B. Haileab, Personal Communication, October 19, 2010).

We decided to engage ourselves in a rigorous examination of the water quality of Rice Creek. Our purpose is to expand upon previous studies conducted by Kizzy Charles-Guzman (2002), Rice Creek Concerned Citizens Group (2009), and prior students under the supervision of Professor B. Haileab (Burks et al., 2003; Devereux et al., 2010). More specifically, we will measure levels of dissolved oxygen, nitrates, phosphates, salinity, turbidity, and temperature at five sites along Rice Creek to support the hypothesis that the overall water quality is continuing to worsen. We will give special emphasis to quantitative assessments, and support our evidence with qualitative observations.

The scientific documentation of the ecological health along Rice Creek dates back to the early 1990s, but manmade disruption of the Rice Creek watershed dates back to the 1940s when county officials drained natural wetlands and set up a network of agricultural ditches (Rice Creek Concerned Citizens Group, 2009). Rice Creek is unique not only in its biological composition but also in its connection to the community. Water quality of Rice Creek is related to the implementation of safe agricultural practices. Previous studies have identified thirty-nine main pesticides that form run-off from agricultural fields and are transported through surface waters (Capel et al., 2001). The U.S. Geological Survey in cooperation with the Minnesota Board of Water and Soil Resources continues to actively assess nutrient and suspended-sediment concentrations, along with other water-quality conditions, in the Minnesota River Basin. Throughout this process ongoing emphasis has been placed on the effects of changes in fertilizer management on water quality trends (Nagia et al., 2008).

For these reasons, Rice Creek provides a special environment for government monitoring and collegiate geologic research. Rice Creek is considered to have a trout habitat downstream, while the upstream portion is a county ditch (J. Crea, personal communication, November 9, 2010). The upstream area, as tracked by Minnesota Pollution Control Agency, has a history of impairment according to its turbidity (2006), nitrate levels (2010), and *Escherichia coli* (2010). Local intervention in the management of Rice Creek dates pack to the 1930s, as an agricultural waterway and then more formally in 1948 as County Ditch 22 (Map 4).

Methods:

Our group went to the field four times, September 28, October 9 and 19, and November 2 in 2010, and tested five sites along Rice Creek (Map 2). We used a YSI Meter to test for temperature, dissolved oxygen, conductivity and salinity. Dissolved Oxygen is the amount of oxygen dissolved in water that is available for use by aquatic organisms. Percent saturation of dissolved oxygen factors out the effects of temperature. “Saturation level” is the maximum concentration of dissolved oxygen at a specific temperature. Conductivity is the measured amount of dissolved ions in water recorded in micro Siemens (μS). Salinity refers to the amount of dissolved salt per kg of water measured in parts per thousand (ppt). For example, a reading of 0.3 ppt correlates to water that is roughly .03% salt.

We used a secchi tube to test for turbidity, or the cloudiness of water caused by particles invisible to human eye. In other words, turbidity is a measure of water's inability to transmit light. Finally, we tested stream velocity using a Flow Meter.

Site 1 (N44° 44.484' W093° 19.180') is the farthest downstream site that we tested. It is located just upstream from a large metal drainage system that flows beneath county/state highway 78. It is just downstream from a cattle pasture that surrounds the stream. During two of the tests cows were present. Site 2 (N44° 44.572' W093° 21.146') is located just upstream of Decker Ave bridge. The stream takes a curve and is fed by a small tributary called Spring Brook. Testing took place just downstream of where they converge. According to a nearby resident, Spring Brook apparently used to be fed by springs close State Highway 1, but was mostly destroyed in the 1960s due to agricultural expansion (Rice Creek Property Owners Along Rice Creek, personal communication, 2010). Site 3 (N44° 44.088' W093° 21.146') is located on Cates Ave by a barn. A drainage tile feeds the creek just downstream of the testing site. Another nearby resident, curious as to what we were up to, informed us that during heavy rain the whole creek upstream from the road fills with sediment rich water and rushes downstream in a presumably harmful way.

Upstream from site 3, the creek turns into a drainage ditch for farm fields. Site 4 (N44° 42.876' W093° 24.185') is located at the intersection of Cabot Road and County/State Highway 1. We tested just where the stream goes under the road. The ditch is lined with limestone, and contains many algae. Site 5 (N44° 24.686' W093° 15.401') is located halfway down Bachrach Road. This is the farthest upstream point we tested. It is merely a narrow ditch between farms.

Observations and Results

Temperature measurements consistently declined over the four-week course in which we measured data, as air temperatures also dropped. Between sites, differences in temperature were only 1-2°C and overall temperatures ranged from a low of 7.5 °C to 15.4 °C (Figure 1).

Our measurements of dissolved oxygen and percent dissolved oxygen consistently showed that oxygen content in Rice Creek increased from 10/9/10—11/2/10 (Figure 4 and Figure 5). In some cases, namely sites 1 and 4 (N 44° 44.484' W 093° 19.180' and N 44° 42.876' W 093° 19.180'), oxygen content nearly doubled. In addition, water-flow velocity declined as we moved upstream, and in most sites also declined (in some cases significantly) from 10/9/10—11/2/10 (Figure 3).

Conductivity measurements neither stayed constant over the course of our measurement period, nor did the data appear similar across sites, especially on 11/2/10 (Figure 2). Some sites' conductivity dropped between 10/9/10 and 10/19/10 but then rose again on 11/2/10. The highest conductivity was measured at site 5 (N 44°24.686' W 093° 15.401) on 11/2/10 and was 697 μS.

All our data, except for two measurements taken on 10/9/10 at sites 1 and 2 (N 44° 44.484' W 093° 19.180' and N 44° 44.572' W 093° 21.146'), show that Rice Creek water was exceptionally clear (Table 1).

Table 1: Turbidity measurements of Rice Creek along five sites. Measurements are in centimeters (cm). If water was clear at 120cm, the upper limit of the measurement device, data is denoted as >120 .

	N 44° 44.484’ W 093° 19.180’	N 44° 44.572’ W 093° 21.146’	N 44° 44.088’ W 093° 21.146’	N 44° 42.876’ W 093° 24.185’	N 44° 24.686’ W 093° 15.401’
10/9/10	32	85.3	>120	>120	------
10/19/10	>120	>120	>120	-------	>120
11/2/10	>120	>120	>120	>120	>120

Salinity measurements along Rice Creek were fairly constant. At each site, water usually had a salinity of 0.3 ppt. The only anomaly occurred on 11/2/10 at Site 2 (N 44° 44.572’ W 093° 21.146’) where we measured a salinity of 0.2 ppt.

Discussion:

Our results, collected along Rice Creek over a four-week period in the fall of 2010, show decreases in water temperature, increases in oxygen content, declines in water-flow velocity, wide-ranging levels of conductivity, and fairly consistent levels of salinity and turbidity.

Water temperature decreased accordingly with the changing of the seasons. This decrease in temperature allowed the water in Rice Creek to hold more dissolved gases, and therefore we saw drastic increases in dissolved oxygen and percent dissolved oxygen.

The decreases in stream velocity were most likely due to the flooding that occurred in Rice County just a few weeks prior to our data collection. On 10/9/10, our first day of data collection, the Rice Creek drainage was still partially flooded, and evidence on the raised water levels could be seen along the river banks. Therefore, as the weeks progressed and data collection continued, it makes sense that stream velocity declined. This decline was significant in parts downstream where water-flow is the highest, and less so upstream.

The inconsistent conductivity levels of Rice Creek from 10/9/10—11/2/10 are perhaps attributed to the surrounding areas of farming and animals lots relative to each site (Map 2). While conductivity does not measure the amount of chemicals that are directly in the water, it is an indicator of dissolved ions, and therefore higher conductivity can be correlated with higher levels of chemicals such as phosphates, sulfates, and nitrates. The close proximity that much of the stream has to farmland makes it extremely susceptible to chemical waste and runoff from fertilizers.

According to our secchi tube readings, the only levels of turbidity less than 120 centimeters were collected on 10/9/10 at sites 1 and 2 (N 44° 44.484'W 093° 19.180' and N 44° 44.572' W 093° 21.146'). Our lack of experience with the instruments likely contributed to the two readings in which the stream was not >120cm. Lastly, our only salinity measurement of 0.2 ppt probably does not bear significance with the rest of our data. Most fresh water has a salinity of 0.3 ppt, and this is consistent with nearly all of our data.

Based on these findings, we must consider the level of human error included in our results, specifically from the YSI meter. Despite our efforts to calibrate all electronic measuring devices appropriately, we cannot guarantee their accuracy or full functionality. In addition to this problem, we were unable to prevent a small amount of variation within each site location, due to the fact that we returned to sites based on memory.

In this process it is essential to also note that in our efforts to ascertain data pertinent to the water quality of Rice Creek our scope remained limited. While engaging in personal communication with Jennifer Crea, an employee of the Minnesota Pollution Control Agency, it became evident that public agencies, like us, do not possess the proper monitoring devices to track daily and weekly changes in the composition, contamination, and cation concentrations of Rice Creek. Therefore in our studies we were unable to identify what constituted an impaired waterway. Although we sought to further explore how to best use components of aquatic geochemistry to assess Rice Creek's overall health, we lacked the tools to test for *Escherichia coli,* nitrates, phosphates, sulfates, and additional chemicals. While we rigorously and continually collected water samples from all of our sites on each given day of fieldwork, we stumbled into problems in the final days of data analysis, when the testing instruments owned by the Geology department malfunctioned and could not provide appropriate readings upon request. We did not have a large sample size or a consistent distribution of sampling along Rice Creek since we chose sites along areas that would be easily accessible by our vehicle.

To this effect, it is slightly difficult to position our own data in relation to previous studies, especially those of previous Carleton students. Nevertheless, it is still worth summarizing previous findings. One study (Devereux et al., 2010) concluded that the springs and rivers in the eastern region of Rice County are characterized by higher hydraulic conductivity levels than those in the western region. We did not detect a significantly large enough difference in the conductivity samples to map these deviations according to geography. All of our measurements fall below a level of 1000 uS, the EPA standard for contamination.

Our findings did mirror those of 2004 (Herrara et al., 2004), wherein the turbidity measurements stayed close to 1.2 meters for the majority of data collection. Our results also followed trends previously established in the 2004 study regarding temperature declines in the water with the oncoming of December. Salinity measurements in our study as well as previous studies (Herrara et al., 2004) follow a similar direction of constancy at 0.3 ppt. For Rice Creek trout, monitoring these levels is important in order to maintain their desired habitat.

Conclusion

Despite our extensive research, a myriad of questions concerning the temperature, dissolved oxygen, conductivity, turbidity, stream velocity and salinity of Rice Creek remain. We identified a decrease in temperature and stream velocities, as well as an increase in dissolved oxygen and percent dissolved oxygen. Turbidity and salinity, with some small variation, stayed constant. We did, however, experience some bumps along the way. For instance, we were not able to test the water samples we collected for nitrates, which would have given us more insight into the water quality.

The Concerned Citizens Group report (2009) lays out a list of nine recommendations for the welfare of Rice Creek's trout population. These recommendations include; increased cooperation between governmental unites in the Rice Creek area, employment and coordination of stream protections efforts, identification of land use problems and cooperation with landowners and farmer, rehabilitation of local wetlands, monitoring of well drilling in the area, and many others. It is clear from our observations, brief interviews with locals, and review of current government policy that these efforts are not consistently receiving due attention.

For further study we would highly recommend a more in-depth study of Rice Creek. We would suggest more extensive research on the following subjects; water quality, monitoring by the Minnesota Pollution Control Agency, local farmers' differences in land usage (especially wells), effects of pesticides on local Brook Trout, and groundwater recharge and tracking. As for methods, we would suggest a larger group of students, more time for research, a longer training period in geological measurement devices, and more thorough communication with previous field researchers.

Furthermore, pathways of human influence on streams and creeks receive little attention, but this remains a tremendously critical topic for small towns heavily dependent on these smaller watercourses (Poole and Berman, 1999). Thus, we would highly encourage a more substantial review of human impact on environments along and near Rice Creek. In addition, further studies could benefit by researching ions in the Rice Creek, bacteria, discharge, groundwater recharge and trout populations over time. More information on land use and the possible effects of increased development would also be valuable. With more of this information at our disposal we would have been able to formulate a more complete picture of chemical and biological interactions in Rice Creek.

On one day of testing alone, three separate property owners approached us to ask for our data on the creek and to offer their own comments and suggestions. The concern of citizens suggests the need for an outlet to accommodate community participation, prevent development, and preserve and improve the condition of the creek. Listening to this concern was a very impactful and valuable aspect of our project.

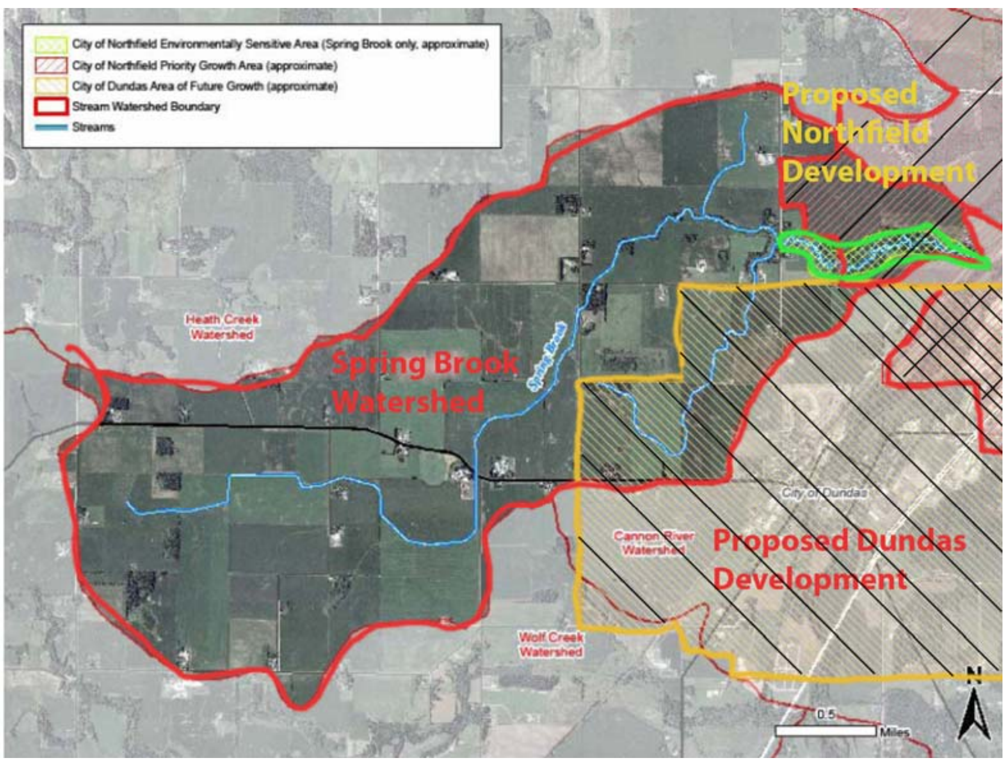
Acknowledgements

A thousand thanks to *[Professor] Bereket* for his continuous advising and informative tips.

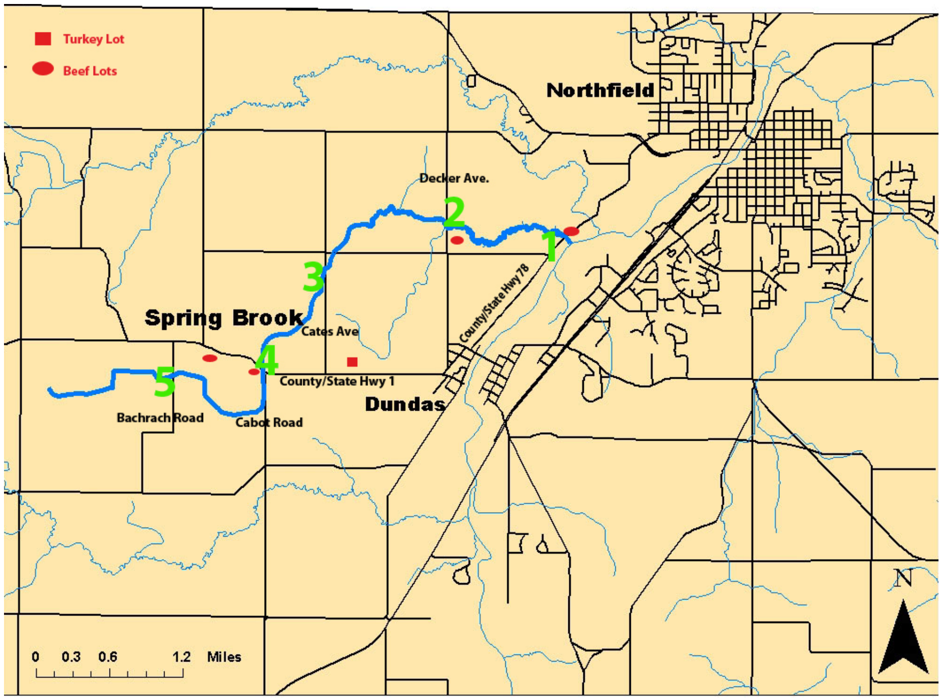
We want to express our gratitude to Jennifer Crea (at the Minnesota Pollution Control Agency) for her clarification of Rice Creek data measurements. We also want to show our appreciation for all the commentary and reflections provided by Rice County locals, interested in research pertaining to the region. We wish to fully thank our beloved TAs (Sarah Marks, Griffin Williams

& Lilly Betke-Brunswick) and Zac Montes for their commitment to our project and willingness to devote extra time to our driving needs. Last but not least, extra thanks to Tim Vick for his explanation of department-related materials.

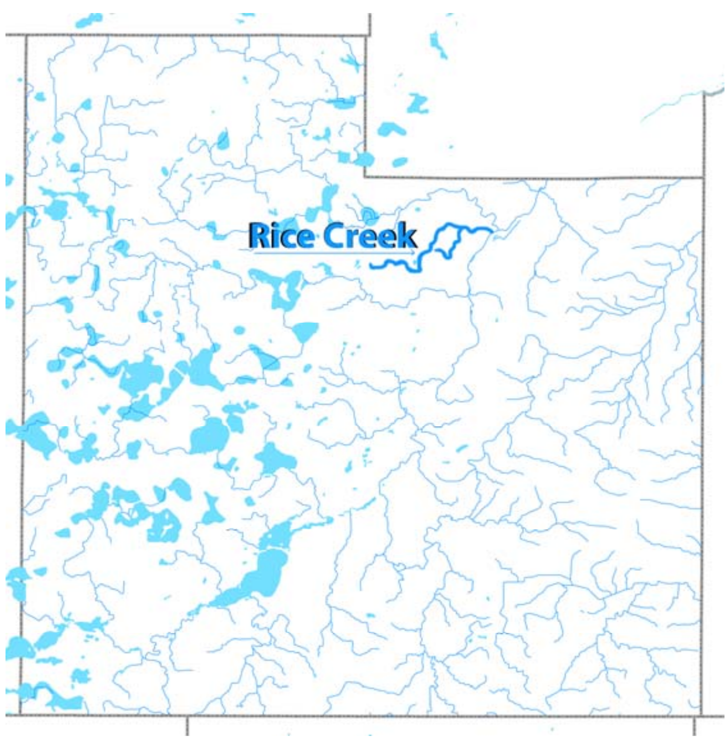
Figure Appendix



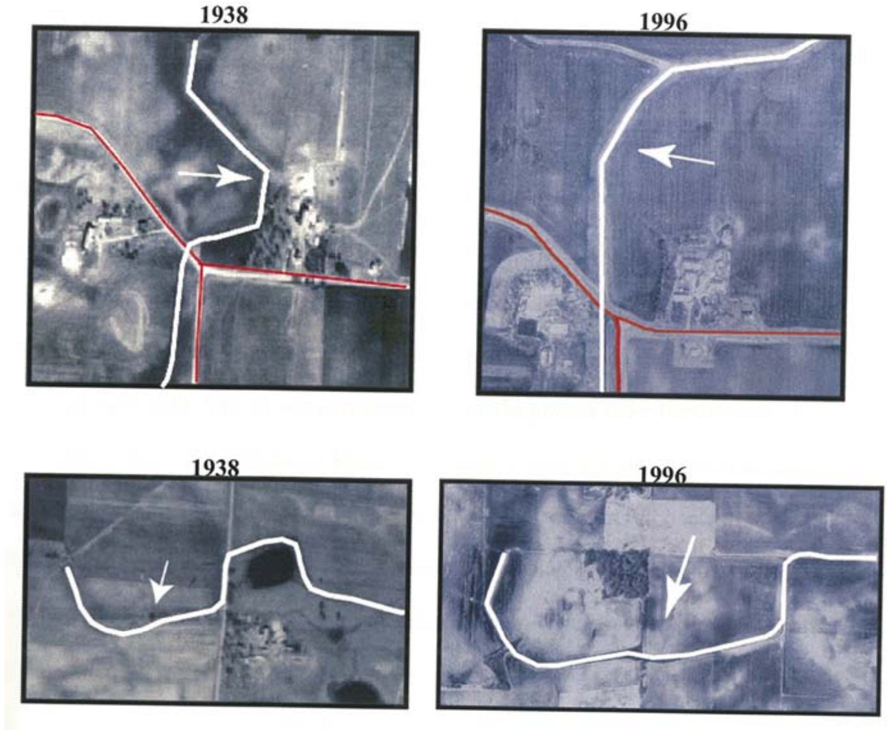
Map 1: Spring Brook watershed and with proposed annexation development colored in. (Source: Cannon River Watershed Protection Agency)



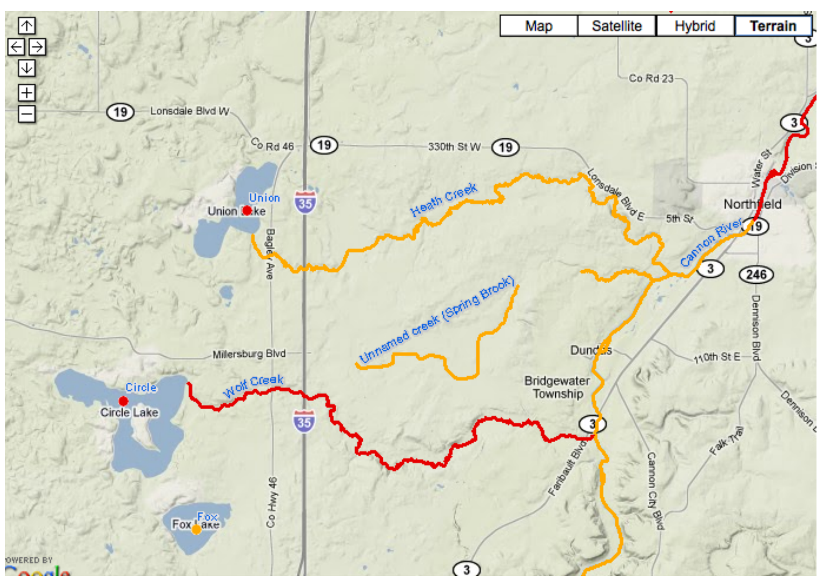
Map 2: Spring brook with five collection sites marked. Nearby turkey and beef lots marked in red. (Source: B. Haileab)



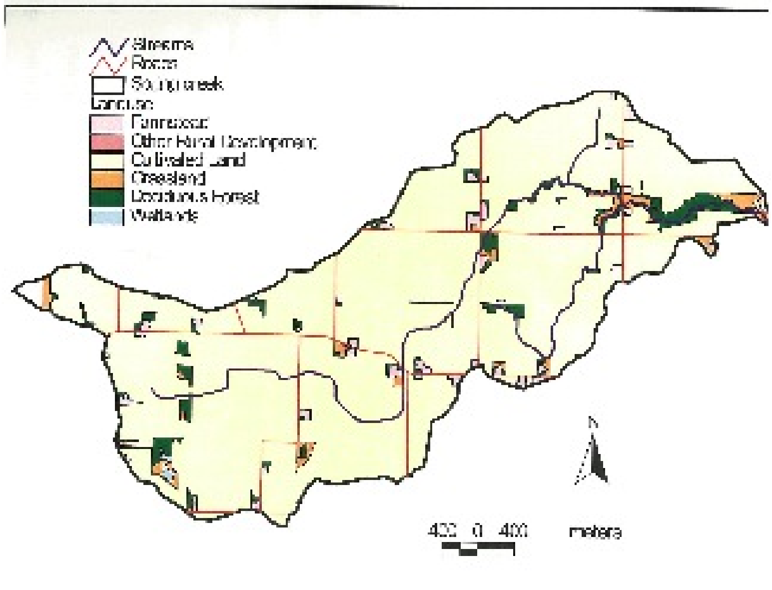
Map 3: Surface water of Rice County with Rice Creek delineated in dark blue. (Source: Nick Holshuh)



Map 4: Aerial photographs of sections of Rice Creek and its management and alterations from the 1930s to 1960s (Source: K. Charles-Guzman).



Map 5: 2009 impaired waters. Yellow indicates recently assessed impaired waters while red delineates waters that were previously impaired. (Source: MPCA)



Map 6: Land use of Rice Creek Watershed in 2002. (Source: K. Charles-Guzman, MN Department of Natural Resources Deli)

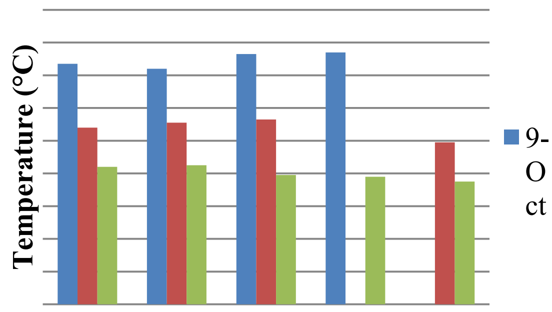


Figure 1: Temperature of Rice Creek along five sites. Data were collected on three dates.

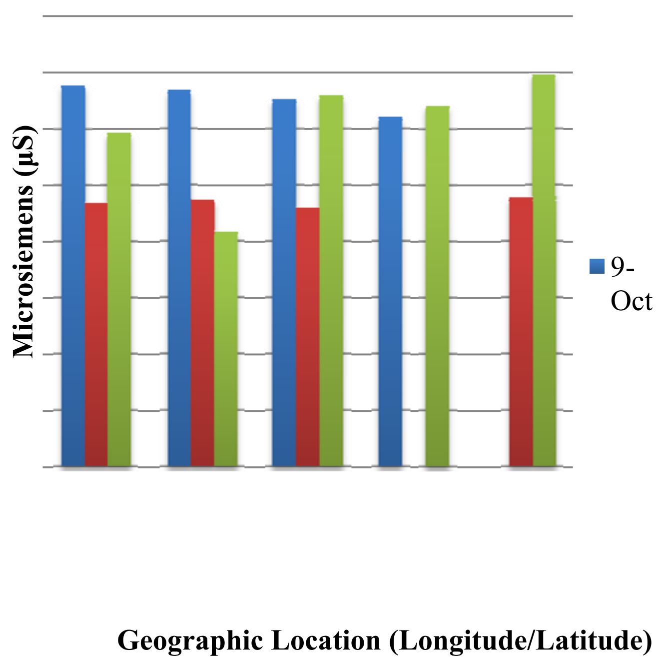


Figure 2: Conductivity Of Rice Creek along five sites. Data were collected on three dates.

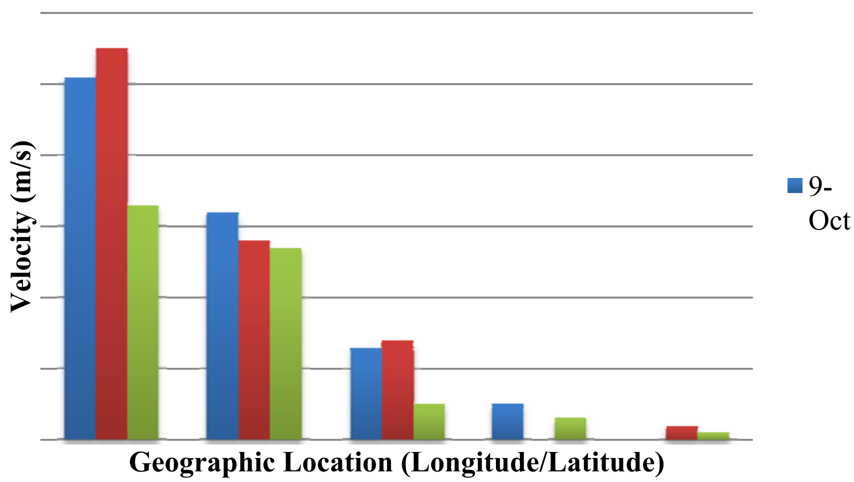


Figure 3: Waterflow velocity of Rice Creek along five sites. Data for various locations was collected on three dates.

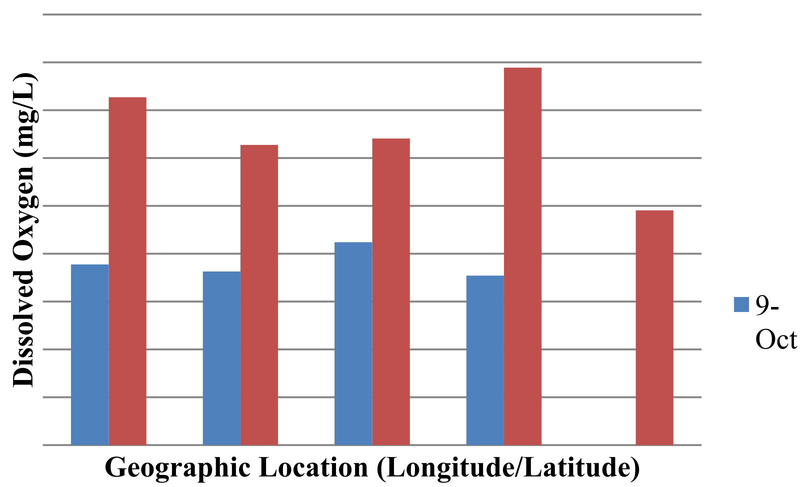


Figure 4: Dissolved Oxygen of Rice Creek along five sites. Data was collected on two dates.

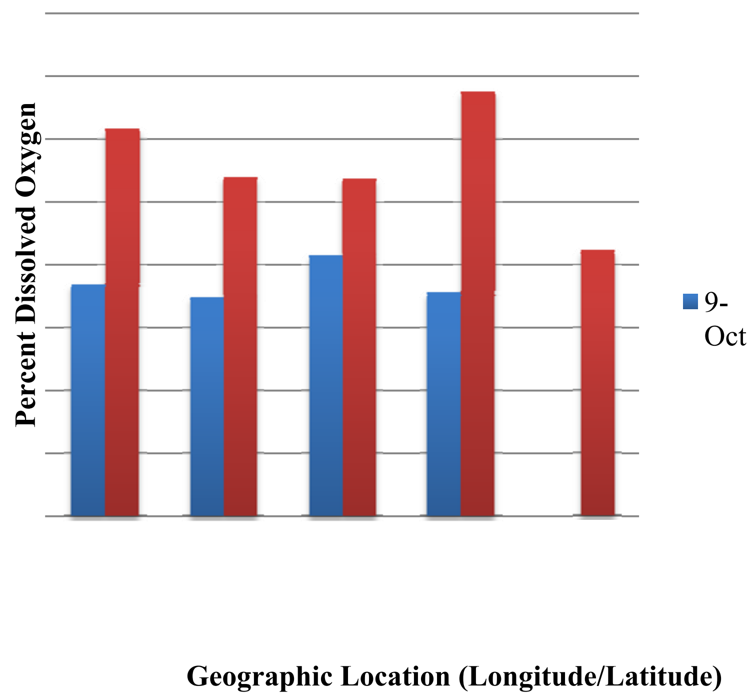


Figure 5: Percent Dissolved Oxygen of Rice Creek along five sites. Data was collected on two dates.

TABLE 1. COMPILATION OF NATIONAL WATER QUALITY STANDARDS.

Water Quality Ions	**MPCA Maximum Contaminant Level (MCL)** **MPCA Drinking Water Standard (DW-MPCA)** **Allan (1995) Range for ion in freshwater (FWR)** **EPA Drinking Water Standard (DW)**
Calcium	4-100 mg/L (FWR)
Potassium	---
Magnesium	5-50 mg/L (FWR)
Sodium	150.3 mg/L (DW-MPCA) 250 mg/L (MCL)
Ammonia	---
Nitrate-N	10 mg/L (DW, MCL)
Nitrite-N	1 mg/L (DW)
Sulfate	250 mg/L (MCL)
Chloride	250 mg/L (MCL)
Fluoride	4 mg/L (MCL)

Note: Values for potassium and ammonia not found. Water quality standards vary by state and it was not possible to obtain Minnesota water quality standards that referred exclusively to natural surface waters. Sources: MPCA and EPA Office of Water.

TABLE 2. CATION CONCENTRATIONS IN THE RICE CREEK STREAM SAMPLES.

Constituent	**Minimum**	**Mean**	**Maximum**
Na^+	6.88	8.35	10.98
K^+	3.11	5.67	7.73
Ca^{2+}	98.29	104.62	111.69
NH_4^+	trace	0.37	0.48
Mg^{2+}	33.49	35.48	37.88

Note: all units are in mg/L.

Figure 6: Water quality standards for ions and their relation concentrations in Rice Creek as of 2002. (Source: K. Charles-Guzman)

45

TABLE 4. FISH POPULATION DATA.

Date of electrofishing sampling	Number of Species Found	Estimated number of trout population	Estimated number of fish population (all species)	Species
June 7th, 1972	11	158	1373	Brook trout, Brown trout, Johnny darter, Brook stickleback, White sucker, Stoneroller, Creek chub, Pearl dace, Blacknose dace, Feathead minnow, Bluntnose minnow
September 11th, 1976	2	121	123	Brook Trout, and Gammarus
October 1990	9	215	448	Brook trout, Common stoneroller, Blacknose dace, Fathead minnow, Creek chub, White sucker, Brook stickleback, Johnny darter, Green sunfish
June 4th, 1998	1	67	67	Brook Trout
June 19th, 2001	1	89	89	Brook Trout

Note: Population assessment conducted at the same reaches of Rice Creek; all below CAF. Each reach was sampled using a backpack-mounted electroshocking unit.
Source: MN Department of Natural Resources, Fisheries Division.

Figure 7: Fish Species Population of Rice Creek from 1972-2001. (Source: K. Charles-Guzman)

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The Water Quality of Wolf Creek, Rice County, Minnesota

Fall 2010

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Introduction to Geology

Carleton College

Professor Bereket Haileab

Introduction:

Wolf Creek is a stream located in Southeastern Minnesota. This body of water is 107 km^2 and is part of the Cannon River Watershed (Charles-Guzman et. al 2001). It flows from Mazaska through Fox Lake and Circle Lake and into the Cannon River, which is a major tributary of the Mississippi River. Sedimentary rock layers of sandstone, limestone, and dolostone characterize the geology of the area; the topmost of which are Prairie du Chien dolostone, St. Peter Sandstone, and Dechora Shale (Cannon River Watershed Partnership). 91.3% of the area around Wolf Creek is used for livestock and agriculture. The drainage basin is located between the cities of Faribault and Northfield (Charles-Guzman et. al 2001). *Map 1* and *Map 2* show the geographic area surrounding the stream.

The purpose of our investigation is to measure the current water quality of Wolf Creek for future reference. Wolf Creek is located in between two growing cities, Northfield and Faribault. As these cities grow, the water system and environment will be affected by development, and by measuring the current water quality, there will be something to compare the changes to. Some important aspects of water quality are turbidity, temperature, dissolved oxygen, conductivity, and flow measurements. We tested the water at seven locations between Circle Lake and Cannon River, as shown in *Map 1*. The first location, Site #1, is off of Canby Avenue, just after Wolf Creek flows out of Circle Lake. Site #2 is on Bagley Avenue, and the Site #3 is on Baseline Road. Site #4 is on Cabot Road, followed by site #5 on Dundas Boulevard. Sites #6 and #7 are both on Faribault Boulevard, the last of which is the Cannon River.

Carleton College's Introduction to Geology students analyzed Wolf Creek's water quality in 2004. These students found that the water quality of the creek was very healthy according to EPA, World Health Organization, and the Minnesota Polution Control Association standards

(Franco et. al 2004). This data is significant to our project because we can compare changes in the water quality over a longer period of time, and see if Wolf Creek is still at a healthy level.

There have been a several scholarly papers written on Wolf

Creek and on monitoring the water quality of streams in general. In *Biological Intregrity: A Long-Neglected Aspect of Water Resource Management*, James R. Karr discusses the ethical reasons for water management and monitoring. He states that "regions with dense human populations were the earliest areas at risk [for pollution], but waters in isolated areas have also experienced degradation" (Karr 1991). This statement directly relates to our project, since we are collecting and analyzing data on Wolf Creek because the area is becoming more and more urbanized. Karr comments that the quality of water resources throughout the country has deteriorated, though nothing is being done to improve the quality. He suggests several reasons for why it has taken so long to improve water quality: limited legal and regulatory programs, different definitions of ecological health, and a "short-sighted and incomplete approach to water resource management" (Karr 1991).

The article *Water Quality in Southeastern Minnesota Streams: Observations Along a Gradient of Land Use and Geology* by Nels Troelstrup, Jr and James A. Perry discusses the effect of agriculture on the streams in Southeastern Minnesota. In their study, they found that stream temperature, turbidity, and percent of sediment in the substrate were higher in streams adjacent to land used for agricultural purposes (Perry and Troelstrup 1989). These findings are significant to our project because Wolf Creek, a stream in Southeastern Minnesota similar to the ones discussed in the paper, is completely surrounded by agricultural land, which can account for the high levels of turbidity, temperature, and sediment levels we may discover. The article *Stream Flow in Minnesota: Indicator of Climate Change* by Eric V. Novotny and Heinz G. Stefan discusses the peak flow of streams in Minnesota. Although the authors found a positive correlation between the peak flow of streams and precipitation, they also suggest that land use changes influence streamflow (Novotny and Stefan 2006). These findings are noteworthy because they can give us insight into how both precepitation and land use affect the stream flow of Wolf Creek. Since our samples were taken after the late-September 2010 flood of the Cannon River, the flooding and heavy precipitation prior to flood may have had an impact on our data. In addition, the agricultural land use around Wolf Creek will likely dictate the data we find.

Methods:

On Tuesday, October 19, 2010, Lilly slowly and carefully drove up to Site #1 (N 44.25.060 W093.30178) on Canby Avenue at 2:07pm. We got out of the car, and were surprised to see a large retention pond, farms, and housing developments right next to the stream, as shown in *Image 1*. There were tall grasses on both sides of the river, and a lot of frogs floating around in it. First we used our GPS to measure the exact coordinates of the location. Then Laura strapped into a pair of oversized waders and hesitantly stepped into the stream. She noted that the bottom of the stream was very muddy and squishy, and that the stream did not have a nice smell. We also noticed little bubbles in the stream and many small green particles floating around. We tossed our Yellow Springs Instrument (YSI) into the water and recorded the water temperature in degrees Celsius, the salinity in parts per thousand, the dissolved oxygen content as both a percentage and in milligrams per liter, the conductivity, and the conductivity with temperature calibration, both in microsiemens. Laura tried to make her way to the middle of the stream, but the water was too deep, so she went as far as she could. Here she filled up the Secci tube to measure turbidity – once filled, we released the water until we could see the black and white circle at the bottom of the tube, and the remaining water level represented the turbidity level of the water. *Image 2* illustrates how we used the Secci tube. Still towards the middle of the stream, Laura placed the flow meter 15cm below the surface of the water, facing upstream, which gave us a measurement of how fast the water was flowing. Laura also collected two water samples from as close to the middle of the stream as possible in glass bottles, which may be analyzed in the future.

After we recovered from the excitement of the first stop, we got back into the car. We got out again at Site #2 (N 44.42115 W 093.30178), on Bagley Avenue, leaving the front seat of the car wet and muddy from Laura's waders. We noticed that farms also surrounded this site, and that a little further upstream, Wolf Creek flows through a pond that looked, and definitely smelled, like it was filled with manure. Once again, there were green particles floating on the surface and the bottom was very muddy. The banks of the stream had a lot of grass and sticks, and there was also some trash and a lot of bugs, as shown in *Image 3*. We repeated all the measurements that we did at the Site #1, and once again the water was too deep for Laura to go to the very middle of the stream. The noticeably faster current also intimidated her.

At the Site #3 (N 44.42389 W093.28190), on Baseline Road, the river was much shallower, only reaching the height of Laura's knees. This time she was able to take her measurements from the middle. There were trees lining the stream, and farmland and roads on the other side of these trees. Upstream there was a tree that fell over and created a little waterfall, and downstream the river made a sharp bend that led into an area thickly populated by trees, as shown in *Image 4*. The stream was filled with aquatic grasses and leaves, and although the edges were quite muddy, the bottom of the middle of the stream felt sandier. Laura reached her hand in and picked up a handful of very dark sand. Once again, we repeated all of the measurements and took more samples.

By the time we reached the Site #4 (N 44.41464 W 093.24104), on Cabot Road, it was about 3:40pm. This site was right next to farmland, where cows and horses were grazing right up to the edges, as shown in *Image 5*. Upstream the river looked much healthier, with lush vegetation along the edges, as shown in *Image 6*. This stream also had dark sand at the bottom of it, though it was a bit muddier than Site #3. The mud and sediment on the right bank of the river was piled higher than the surface of the water. We took the measurements and samples from the middle of the stream again, and moved on.

We arrived at the Site #5 (N44.41043 W 093.22081), on Dundas Boulevard, at 4:00pm. Upstream, the river ran through farmland and trees. On both banks of the stream there were many large rocks, called riprap, separating the water from the grass. The bottom of the stream was very sandy, and also had rocks of various sizes. The right side of the stream was knee-deep, but the left bank was extremely shallow because of a huge sediment bed (4 to 5 meters long, with the width of half of the stream), called a point bar. In *Image 7*, Laura is standing on the point bar. Once again, we repeated the measurements in the middle of the stream.

Site #6 (N 44.41090 W 093.21031) was on Faribault Boulevard, underneath the freeway. The edges were very muddy, and the stream was very deep, so Laura had to take the measurements from closer to the edge, as shown in *Image 8*. At 4:25, we continued just a little bit further down Faribault Boulevard to the Site #7 (N 44.41428 W 093.20769), the Cannon River. Once again, we took the measurements from the edge because Laura would have drowned in her oversized waders if she tried to go to the middle. On the edges, the bottom of the stream was made up of soft, mushy, fine-grained mud.

We returned to all seven of these stops again two weeks later, on November 2, 2010, between 2:30 and 4:00pm. This time went quicker because we were now experts at using the measuring tools, and Griffin is a faster driver than Lilly. At each stop we took the same measurements that we previously took, though this time Emily wore the waders and went into the stream. We noticed a lot of geese at the first site, and we also noticed that the stream was near a cemetery, which Griffin noted could be a possible base for erosion. All of the stops looked pretty much the same as they did the first time; even the big point bar at Site #5 was still there, along with some St. Olaf students. At the Cannon River stop we noticed limestone on the side of the river, which was placed there as a form of stream control.

Results:

Table 1 and *Figure 1* show the temperature readings in Celsius from seven different locations on different days, from 2004 and 2010. In the 2004 readings, Site #1 was always warmer than the other sites downstream. In 2010, Site #2 was consistently the warmest out of all the stops. On October 5th, 2004 the temperature ranged from 10.6 to 14.4°C. On October 12th, 2004 all the sites ranged from 12-12.9, except the first stop, which was 16.1°C. On October 26, 2004 the temperature measured consistently between 8.8 and 10.2°C for all the test sites. In 2010, the October 19th water temperature ranged from 12.0 to 13.5°C. On November 2, 2010, the water temperature ranged from 7.1 to 9.7°C.

Table 2 and *Figure 2* display the measurements of conductivity in µS from seven different locations on different days, from 2004 and from 2010. On all five dates, the conductivity was lowest at Site #1 and got higher the farther downstream the measurements were taken. At Site #7, the Cannon River, the conductivity was always significantly higher. The levels of conductivity measured fairly stable throughout the study, with November 2, 2010 having the lowest readings, and October 26th, 2004 and October 19th, 2010 having similarly high readings.

Table 3 and *Figure 3* show the dissolved oxygen levels in mg/L from seven different locations on different days, from 2004 and from 2010. In 2004, the dissolved oxygen levels stayed relatively stable, ranging site to site from 8-11 mg/L. In the 2010 levels, the dissolved oxygen level was the highest at Site #1 just downstream of Circle Lake, and decreased further downstream. Site #7, the Cannon, had slightly higher levels than Site #6, right before Wolf Creek joins the Cannon.

Table 4 and *Figure 4* show the measurements of turbidity in centimeters from seven different locations on different days, from 2004 and from 2010. The 2004 data shows that the clarity of the water increased between Sites #1 and #6. In 2004, Site #7, the Cannon River, had less clear water than their Site #6 measurements from either day. On October 19, 2010, turbidity ranged from 32.8 to 38.1cm for Sites #1 to #6, and on November 2, 2010, turbidity ranged from 62.4 to 74.8cm for Sites #1 to #6. Site #7, The Cannon River, was 30cm on October 19, 2010 and 53.2cm on November 2, 2010, less clear than the last test site on Wolf Creek.

Table 5 and *Figure 5* show the measurements of salinity in parts per thousand from seven different locations on October 19, 2010 and November 2, 2010. The salinity fluctuated between .1 and .2 ppt, except for the Cannon on November 2, 2010, which measured .3 ppt.

Table 6 and *Figure 6* show the flow rates from seven different locations on October 19, 2010 and November 2, 2010. The flow rate increases downstream from Sites #1 to #4. Site #5 on November 2, 2010 was faster than Site #4, but slower on October 19, 2010. Sites #6 and #7 have staggered rates because the flow was not taken from the centers of the creek and river.

Discussion:

Temperature affects many aspects of creeks. Variants in temperature have an affect on thermal pollution. High and low temperatures dictate the amount of dissolved oxygen that is present in the creek. Plants and other life forms use this dissolved oxygen, therefore causing fluctuations in the byproducts they give off.

Figure 1 shows the change in temperature (°C) from three dates in 2004 and two dates from 2010. The dates correlate with each other, spanning between October and November. The closest two dates from both 2004 and 2010 are October 19th and October 12th – the dark blue line and the purple line. Site #4 was colder on October 5 than on October 12th in 2004. For both 2010 readings, Site #2 was the warmest, whereas Site #1 was the warmest in 2004. Because Site #2 temperatures were not documented in 2004, it is not clear what the overall pattern is. There is a slight trend for the temperature to decrease as it gets farther away from Circle Lake. This decrease is also due to the fact that spring water is added to the creek. Spring water is usually 7°C, whereas the water from Circle Lake is usually warmer. The general temperature pattern gets colder because the dates are approaching the winter months. Overall the shape of the lines does not significantly fluctuate between the dates.

Conductivity is usually very consistent for each respective body of water. This is important because if the conductivity begins to fluctuate it is usually an indicator that agents of pollution have entered the water. Pollution has an effect on how organisms and small life forms behave in their natural ecosystems (Stream Team Website). The conductivity increases steadily as the river gets closer to the Cannon, and conductivity of the Cannon is a big jump. This is seen by the steep increase at Site #7. This data suggests that there is an increase in general pollution as the creek approaches the Cannon River. This could possibly be due to the fact that the creek enters an area of higher human population. The dark blue and purple lines almost overlap, although the blue line is a little higher – this means that the conductivity from 2004 to 2010 has not changed much, except in 2004 the conductivity was a little lower. In 2004, there is an increase in conductivity as the time progresses. However, it is the opposite in 2010 – the conductivity is higher in October than in November. Perhaps this year there was more pollution in October than in November.

Dissolved oxygen is a measure of the gaseous oxygen present in water. Dissolved oxygen is important to aquatic life: aquatic animals need a certain level of dissolved oxygen to survive. Dissolved oxygen levels are controlled by the oxygen in the air that enters the water and by oxygen released from aquatic plants (KY Water Watch). In 2004, the dissolved oxygen levels for each date all followed the same pattern – they first increased, and then decreased between Sites #5 and #6. However, in 2010 there was an overall decrease in dissolved oxygen as the stream approached the Cannon River. There was an increase in dissolved oxygen between the last two stops in both November and October. The dissolved oxygen was overall higher in November 2010 than in October of 2010 and in all of the 2004 dates. The increases and decreases in dissolved oxygen between different stops could be due to the amount of aquatic plants at each location. More plants would mean more dissolved oxygen and fewer plants would mean less dissolved oxygen.

Turbidity measures the clarity of the water. It is affected by rain, waste discharges, runoff, algae or aquatic weeds, humic acids and other compounds from decaying plants or plant matter, high concentrations of minerals, and air bubbles (EPA 1999). For both 2004 and for 2010, the overall turbidity trends increase as the season progresses. Since turbidity is highly influenced by rainwater, this makes sense because the rainfall increases as the dates get later and the season gets rainier. In 2004, for all of the dates the turbidity increases between Sites #3 and #6, and then decreases between Sites #6 and #7. In 2010, the turbidity remained steady until Site #4, where it decreased in November, but increased in October. Starting at Site #5, both dates in 2010 experienced a decrease in turbidity. This shows that in 2010, the water got clearer starting at Site #5. The discrepancy in how the water changed between Sites #3 and #4 in 2010 is unclear, though this could be due to the fact that measuring turbidity can vary based on the person measuring and the amount of sunlight around the Secci tube.

Salinity is the measure of the concentration of dissolved salts in the water. Salinity is influenced by soil, photosynthesis from plants, and other water inputs into the stream (OzCoasts 2010). There is only data on salinity from 2010, but for the two dates measured in 2010 there was an increase in salinity as the creek got closer to the Cannon River. The salinity levels remained within the same range between October and November. In the study conducted by Kizzy Charles-Guzman, Jacob Cooper, Raycine Hodo, Christina Kaba, and Evelyn Kim, the data showed a constant level of salinity at 0.2 ppt (Charles-Guzman et. al 2001). The majority of our salinity measurements were at 0.2 ppt, though there was some variation, perhaps due to erratic patterns.

The flow is the speed at which the body of water flows. The flow is important to the fish population and dictates what sediments the body of water carries. Faster streams or rivers will bring bigger sediments, while slower streams and rivers can only carry smaller sediments with it. The flow for Wolf Creek was only measured in 2010. There is a steady increase in speed from Site #1 to Site #4. Then there is a large drop before the water meets the Cannon River. At the last stop, measurement in the Cannon River, the flow was significantly higher in November than in October. This could perhaps be due to an increase in rainfall. The last two stops have very low flow rates because we were on the edge of the river, since it was too deep to go to the middle where it flows faster. The part of the river in which we measured may have affected the flow rates.

Conclusion:

By obtaining data, temperature, dissolved oxygen, salinity, flow, turbidity, and conductivity along seven points of Wolf Creek, we were able to compare our data to similar data from 2004. Our data tells us that Wolf Creek has remained relatively consistent in its characteristics and therefore is healthy. Aside from minor fluctuations, the data from 2004 has remained consistent with our data from 2010, with the exception of turbidity. The turbidity measurements were very erratic between all of the dates on which we collected data. This is not surprising, because the measurement of turbidity is highly dependent on recent rainfall, and its methods of measurement contain many potential errors. For instance, the water was not always collected from the same exact spot of the river from date to date and year to year. In addition, the four group members did not always see the black and white circle of the Secci tube consistently. Another margin of error from our data collection was the possible inconsistencies of using the flow meter. We always measured 15cm below the surface of the water, but some parts of the stream were too shallow to obtain the measurement from this height, and it was impossible to hold the meter perfectly still and in the right place.

We hope that our project will help to continue awareness of Wolf Creek's features. This awareness is important because as the land around the creek changes and becomes more urbanized, the health of the creek will reveal key environmental damage to the community. Our data will be useful in determining if the creek is becoming polluted or changing in any way. In the future, this data can be used as another point of reference for measuring the year-to-year health of Wolf Creek.

Acknowledgements:

We would like to thank Bereket Haileab, our geology professor, for all of the support, wisdom, direction, and jokes he has given us. The geology department at Carleton College deserves a huge thank you for their funding and the use of their instruments. We would also like to thank the intro to geology lab teaching assistants, Lilly Betke-Brunswick and Griffin Williams, for driving us to the locations and helping us take the measurements.

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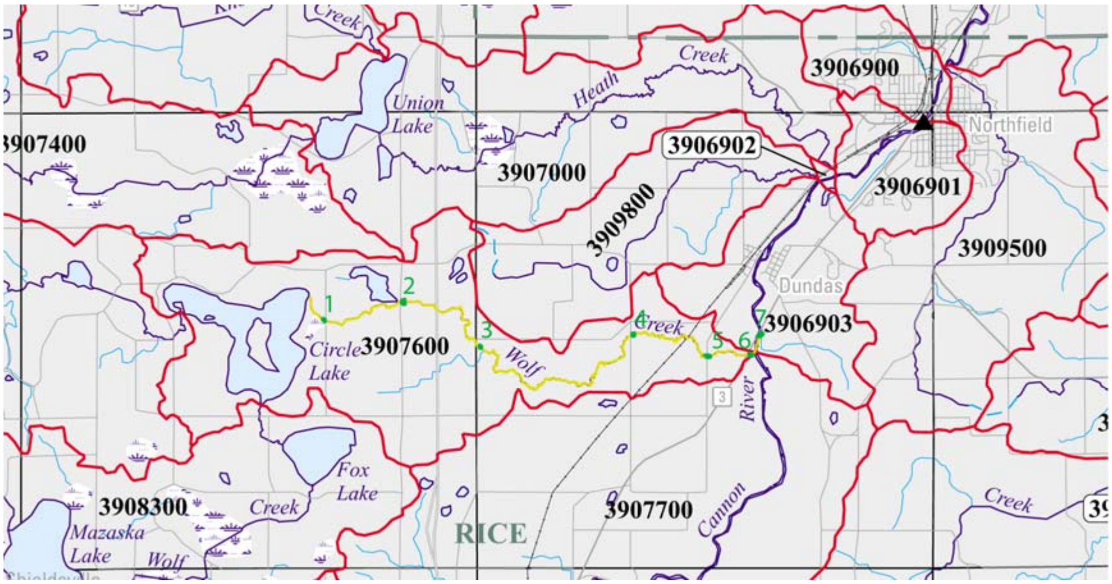
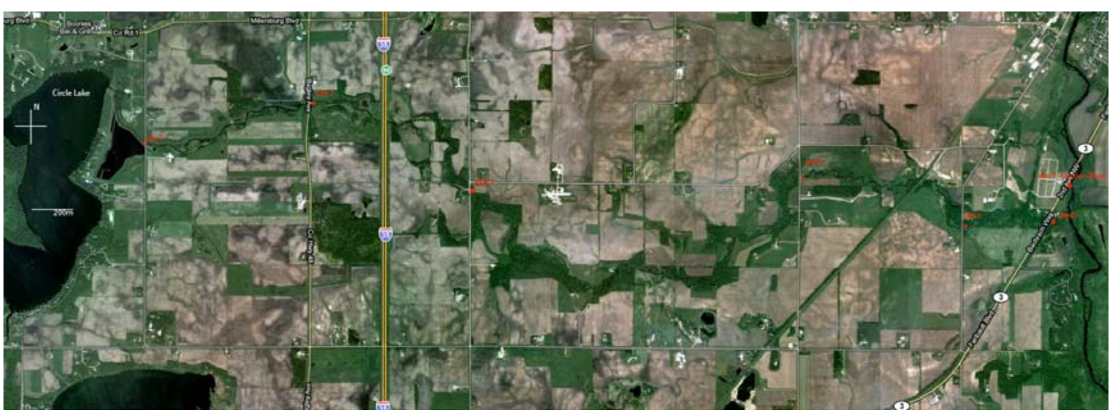
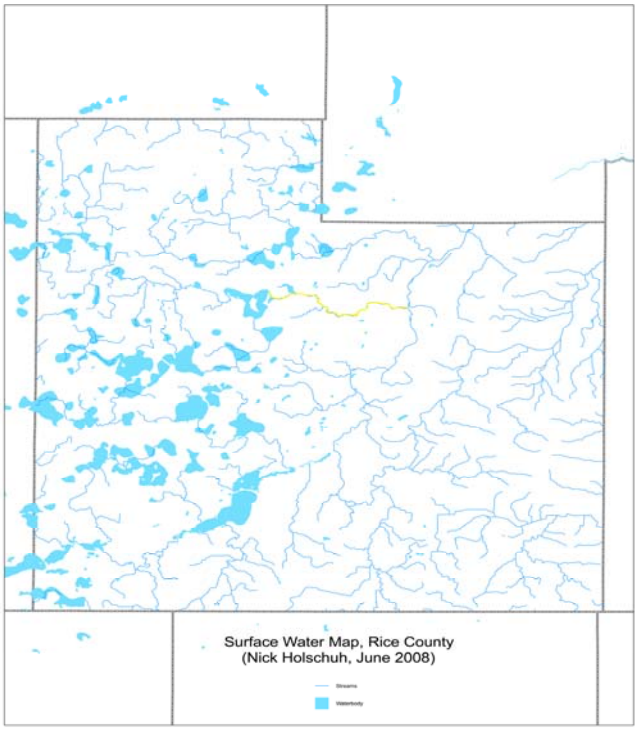
Appendix:



Map 1. **Wolf Creek is highlighted in yellow and each of the seven sites in labeled with green dots. Wolf Creek originates in Circle Lake and ends where it meets the Cannon River. It is Approximately 13Km from Circle Lake to the Cannon River.**





Map 2. Wolf Creek highlighted in yellow to demonstrate its influence in the Rice County water system.

Image 1. This is site #1, on Canby Avenue. On the left you can see the retention pond and on the right and in the background you can see the big housing developments and farms. In the foreground Emily is standing on the right side of the stream, since the water is too deep for her to reach the middle.

Aerial 1 **Satellite image courtesy of ©Google Imagery ©2010. Red dot identifies site #1. This aerial shows the close proximity of the stream to the retention pond, as well as its location downstream of circle lake. Just after test site 1, the creek runs through farmland.**

Image 2. Ted and Anna use the Secci tube to measure turbidity; Anna is releasing the water while Ted looks to see if the black and white circle is visible.

Image 3. At site #2, on Bagley Avenue, there were a lot of sticks and grasses on both banks of the river. Laura is measuring the flow of the river with the flow meter, from a location as close to the middle as she can get while still feeling safe.

Aerial 2. **Satellite image courtesy of ©Google Imagery ©2010. Red dot identifies site #2. This image demonstrates that the part leading up to test site #2 runs through farmland with little vegetation along the banks.**

Image 4. This is an image of site #3, on Baseline Road. There are trees lining the river, which separates it from the farmland and roads. Towards the back of the picture you can see that the river makes a sharp turn that leads into an area with many trees.

Aerial 3. **Satellite image courtesy of ©Google Imagery ©2010. Red dot identifies site #3. Up and downstream of site 3 has nice vegetation bordering the stream.**

Image 5. This is site #4, on Cabot Road. The edges of the river are very eroded because they are connected to the farmland, and cows and horses have grazed all the way up to the edge of the river.

Image 6. As we look upstream at site #4, there is much more vegetation and the stream looks healthier, since it is not connected to the farmland.

Aerial 4. Satellite image courtesy of ©Google Imagery ©2010. Red dot identifies site #4. This satellite image clearly shows the distinct difference between the nicely vegetated banks upstream of site 4 and the eroded banks of the creek downstream of the test site.

Aerial 5. Satellite image courtesy of ©Google Imagery ©2010. Red dot identifies site #5.

Image 7. This is site #5, on Dundas Boulevard. Laura is standing on the point bar, which is a large pile of sediment on the left side of the stream. On the left side of the picture you can see that the riprap that separated the grass from the stream.

Image 8. This is site #6, on Faribault Boulevard. Laura is measuring the flow pretty close to the edge of the stream because the water is too deep for her to go to the middle.

Aerial 5. Satellite image courtesy of ©Google Imagery ©2010. Red dots identify sites #6 and #7. Site #6 is the last test site on Wolf Creek before it meets the Cannon River. Site 7 is along the Cannon just after the merger.

***Table 1*- Temperature (°C)**

	10/19/10	11/2/10	10/5/04	10/12/04	10/26/04
Stop 1: N 44.25.060 W093.30178	13.5	8.5	14.4	16.1	9.7
Stop 2: N 44.42115 W 093.30178	14.4	9.7			
Stop 3: N 44.42389 W093.28190	13.2	8	12.4	12.8	8.8
Stop 4: N 44.41464 W 093.24104	12	7.1	10.6	12	9.1
Stop 5: N44.41043 W 093.22081	12.4	7.6	12.1	12.8	9.1
Stop 6: N 44.41090 W 093.21031	12.4	8.2	12.2	12.3	9.1
Stop 7: N 44.41428 W 093.20769	12.1	7.5		12.9	10.2

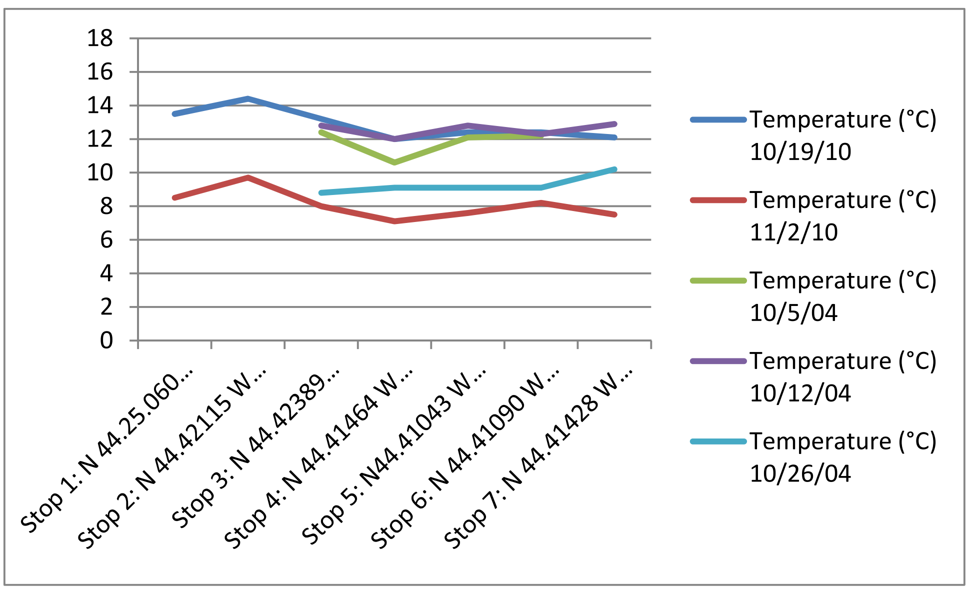


***Figure 1* – Temperature**

Table 2 – **Conductivity (μS)**

	10/19/10	11/2/10	10/5/04	10/12/04	10/26/04
Stop 1: N 44.25.060 W093.30178	275.5	202.2	264.6	282.8	272.1
Stop 2: N 44.42115 W 093.30178	279.4	212.6			
Stop 3: N 44.42389 W093.28190	305.9	217.2	273.2	291.3	283.2
Stop 4: N 44.41464 W 093.24104	351.2	237	272.1	334.4	323.6
Stop 5: N44.41043 W 093.22081	365.3	252.4	321.2	358.9	348.6
Stop 6: N 44.41090 W 093.21031	371.6	261.3	329.1	364.5	361.8
Stop 7: N 44.41428 W 093.20769	448.3	397.8		475	489

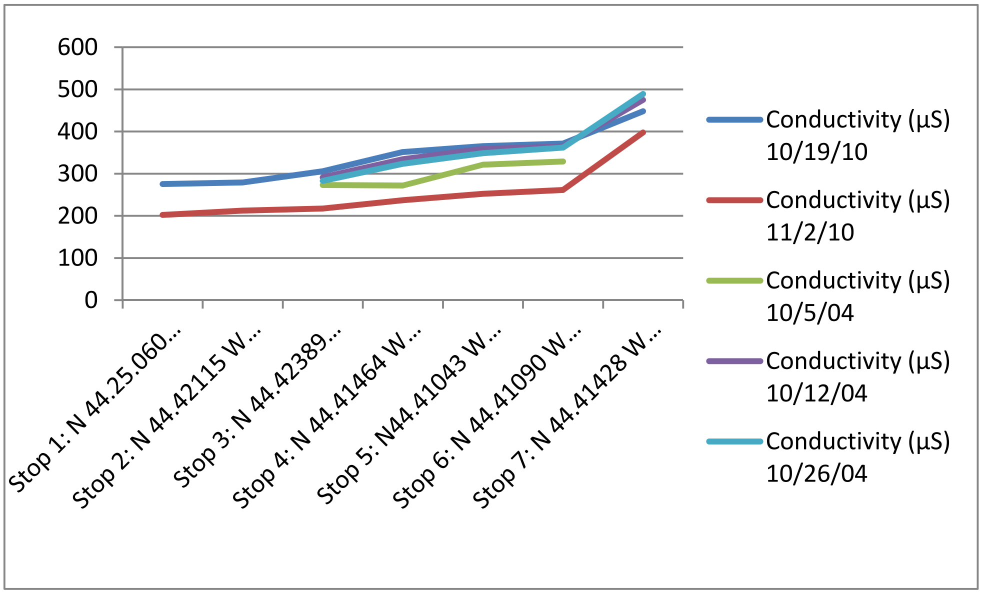


Figure 2 **– Conductivity**

Table 3 **– Dissolved oxygen (mg/L)**

	10/19/10	11/2/10	10/5/04	10/12/04	10/26/04
Stop 1: N 44.25.060 W093.30178	12.5	14.57	9.64	10.04	8.79
Stop 2: N 44.42115 W 093.30178	11.61	13.39			
Stop 3: N 44.42389 W093.28190	10.48	14.08	9.6	9.07	7.72
Stop 4: N 44.41464 W 093.24104	10.04	12.48	9.56	8.78	9.37
Stop 5: N44.41043 W 093.22081	10.71	12.41	10	10.45	10.77
Stop 6: N 44.41090 W 093.21031	9.37	11.24	9.04	10.12	8.93
Stop 7: N 44.41428 W 093.20769	10.46	12.1			

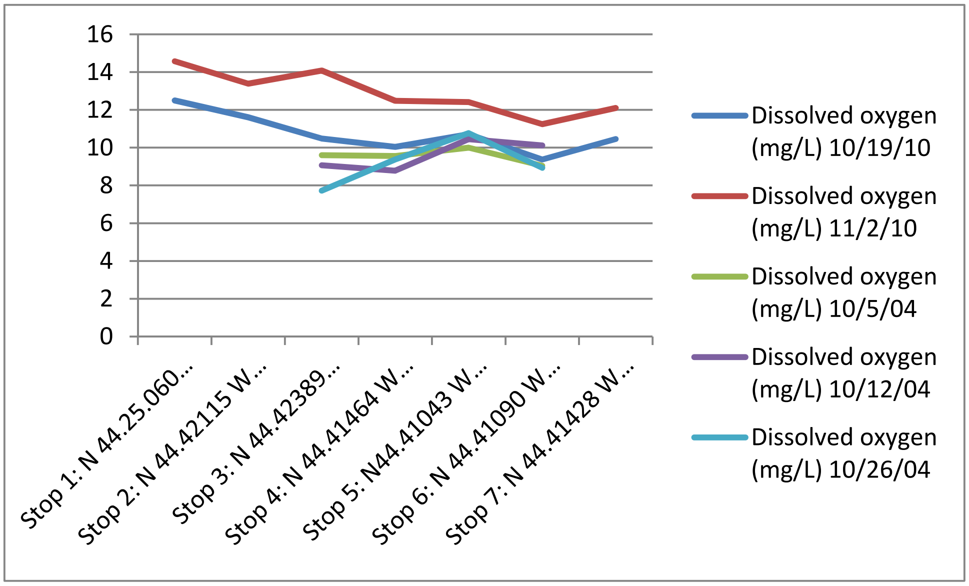


Figure 3 **– Dissolved oxygen**

Table 4 **– Turbidity (cm)**

	10/19/10	11/2/10	10/5/04	10/12/04	10/19/04	10/26/04
Stop 1: N 44.25.060 W093.30178	32.8	74.8	22	18	34	26
Stop 2: N 44.42115 W 093.30178	36.9	73				
Stop 3: N 44.42389 W093.28190	35.3	74.6	23	22	34	33
Stop 4: N 44.41464 W 093.24104	49	62.4	30	36	56	54
Stop 5: N44.41043 W 093.22081	38.1	72.8	33	36	59	70
Stop 6: N 44.41090 W 093.21031	34.8	68.6	40	42	70	81
Stop 7: N 44.41428 W 093.20769	30	53.2		39	49	65

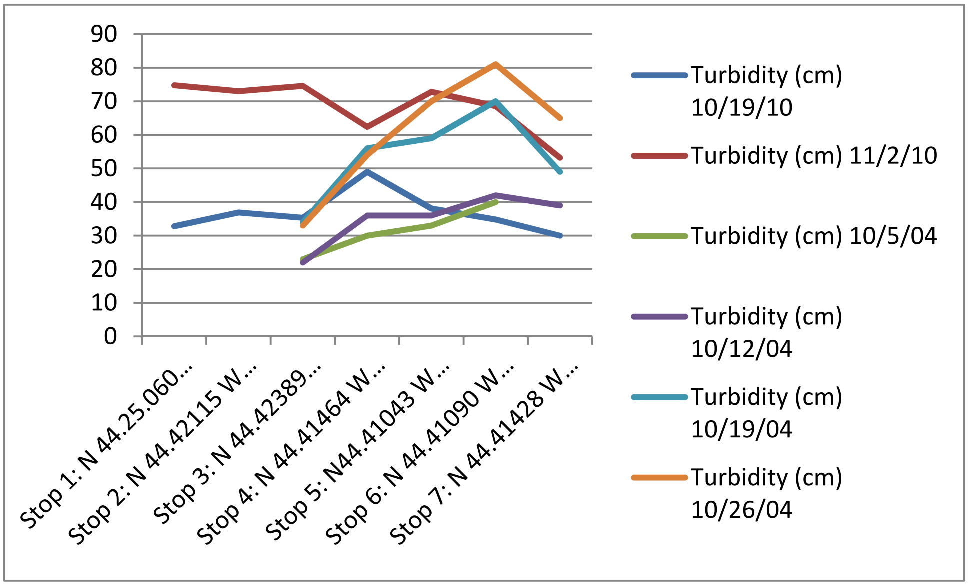


Figure 4 **– Turbidity**

Table 5 **– Sailinity (ppt)**

	10/19/10	11/2/10
Stop 1: N 44.25.060 W093.30178	0.1	0.1
Stop 2: N 44.42115 W 093.30178	0.1	0.1
Stop 3: N 44.42389 W093.28190	0.1	0.2
Stop 4: N 44.41464 W 093.24104	0.1	0.2

Stop 5: N44.41043 W 093.22081	0.2	0.2
Stop 6: N 44.41090 W 093.21031	0.2	0.2
Stop 7: N 44.41428 W 093.20769	0.2	0.3

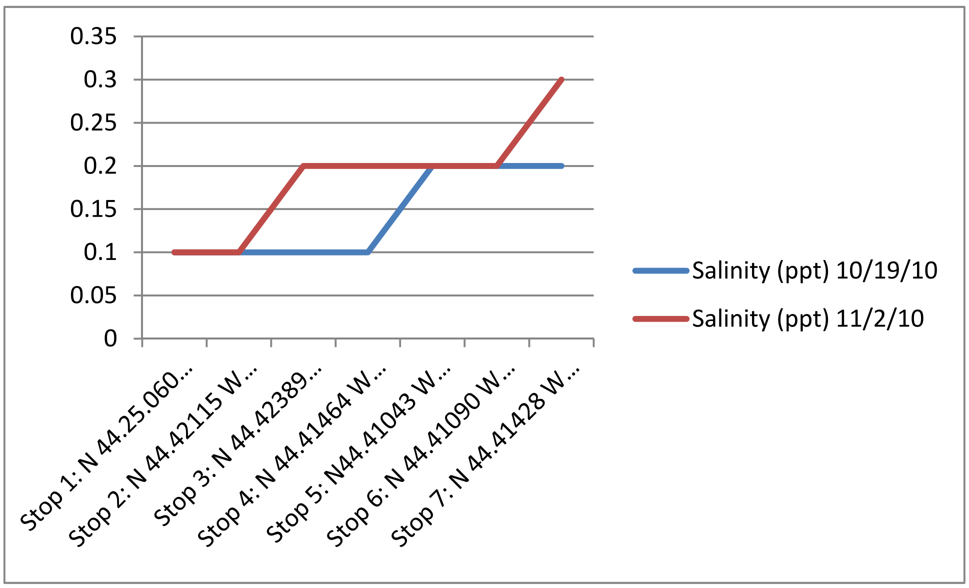


***Figure 5* – Salinity**

Table 6 – **Flow (m/s) measured 15 cm from surface**

	10/19/10	11/2/10
Stop 1: N 44.25.060 W093.30178	0.08	0.08
Stop 2: N 44.42115 W 093.30178	0.2	0.18
Stop 3: N 44.42389 W093.28190	0.26	0.21
Stop 4: N 44.41464 W 093.24104	0.45	0.35
Stop 5: N44.41043 W 093.22081	0.42	0.6
Stop 6: N 44.41090 W 093.21031	0.19	0.09
Stop 7: N 44.41428 W 093.20769	0.11	0.34

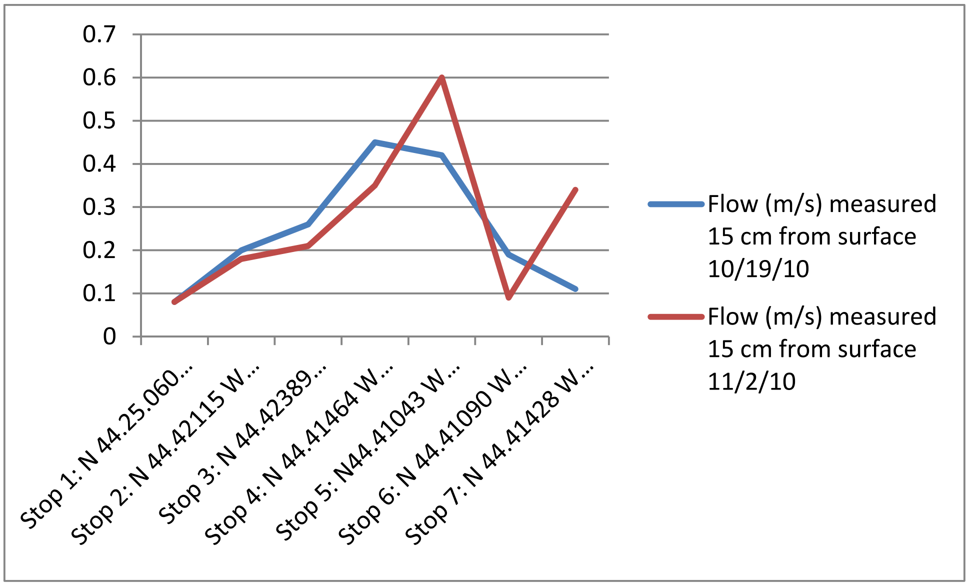


***Figure 6*- Flow**

Conductivity and Prairie Creek

An Ongoing Research Project

Morgan Marks

Niko Duffy

Devin Holewinski

Geology 110 - Fall 2010

Professor Bereket Haileab

Carleton College Geology Department

Introduction

Over the past 40,000 years, Rice County, located in southeastern Minnesota, has experienced repeated glaciation. As a result, the county's water system is now divided along a north-south axis, the western portion containing lakes and the eastern portion containing rivers and steams, such as Prairie Creek (see Appendix 1). Because streams are better for irrigation, agriculture has developed more on the east side of Rice County; this concentration of farms could have adverse effects on the water system (Devereaux et al.). Past projects have used nitrogen content as an indicator of agricultural pollution.

Nitrogen (and nitrates – the compound created when nitrogen is added to water), while naturally occurring in low levels in rivers and streams, is built up by "fertilizer application, nitrogen fixation by legume crops, human and animal waste disposal, and fossil fuel combustion" in surrounding areas (Peterson et al.). In rural Rice County, it could be expected that higher than normal nitrate content could be linked to agricultural run-off and pollution.

Past projects have meticulously taken and analyzed samples from water systems across the county, including analysis for nitrate content. Although this particular extension of the ongoing report did not analyze for nitrate content, the conductivity of the water was measured; conductivity is generally correlated with and can serve as a proxy for nitrogen content (Haileab). The Environmental Protect Agency (EPA) says that "[d]ischarges to streams can change the conductivity," including "nitrate;" an increase in conductivity in the sampled water could mean an increase in nitrate content in that water. The EPA further says that "the conductivity of rivers in the United States generally ranges from 50 to 1500 µmhos/cm."

The purpose of our renewed investigation of Prairie Creek is to identify its condition relative to those of creeks and streams on the western side of Rice County. We aim to show that Prairie Creek, because of the abundance of agricultural activity surrounding it on the eastern portion of Rice County, is more contaminated than comparable water systems located on the western portion of Rice County. We intend to prove this claim by extensively sampling Prairie Creek for conductivity (as a proxy to nitrate pollution) and comparing our data to previous data collected, both for Prairie Creek and for the entire watershed system of Rice County.

Methods

During the months of October and November, we collected data from seven points along Prairie Creek and a Prairie Creek tributary (see Appendix 3 and 4). For most of these sites we have data from two dates, Oct. 19 and Nov. 2. We used a YSI Meter (Yellow Springs Instrument Model 85) to measure conductivity, salinity, and temperature of the water. Conductivity, measured in μS, tells us how many dissolved particles (usually pollutants) are in the water. Transparency was measured using a Secchi tube. The 120 cm tube is filled with water and slowly drained while being watched from above to see at what level the bottom of the tube can be seen. We also measured the flow of the creek (in m/s) with a flow meter (see Appendix 7). In addition we took water samples during each collection for potential further analysis.

In addition to gathering new data, our primary scientific method involved the examination and comparison of previous data collected by those who have worked on the same project

Results

Table 1. Longitude, Latitude, Flow, Conductivity, Temperature, and Transparency of seven sites along Prairie Creek, Rice County, Minnesota

Site	Latitude and Longitude	Flow (m/s)	Conductivity (μS)	Corrected Conductivity (μS)	Temperature (C)	Transparency (cm)
	10/19/2010					
2	N44.34191 W93.13153	.46	599	429	10.2	120+
3	N44.37831 W93.08439	.04	587	421	10.3	120+
4	N44.40703 W93.06715	.12	616	436	9.8	115
5	N44.42470 W93.05999	.05	616	452	10.9	120+
6	N44.42846 W93.04457	1.03	637	467	11.1	120+
7	N44.44318 W93.04433	.1	614	452	11.2	80
	11/2/2010					
1	N44.32678 W93.10723	.27	604	405	7.8	120+
2	N44.34191 W93.13153	.3	605	391	6.5	120+
3	N44.37831 W93.08439	.01	590	374	5.7	120+

4	N44.40703 W93.06715	.13	619	406	7	120+
5	N44.42470 W93.05999	.04	608	420	8.7	120+
6	N44.42846 W93.04457	.9	643	440	8.4	120+
7	N44.44318 W93.04433	.02	620	423	8.4	120+

Table 1 shows all of the data collected by our group during two different days at a total of 7 different sites. The data includes the location, flow, conductivity (both uncorrected and corrected for temperature), temperature and transparency.

Table 2. Conductivity Measurements (μS) for Prairie Creek, Rice County, Minnesota

	Site 1	Site 2	Site 4
17-Jun-08	631	1854	623
30-Sep-08	814	2309	653
24-Mar-09	654	262.5	613
16-Jun-09	-	814	553
19-Oct-10	-	429	436
2-Nov-10	405	391	406

Table 2 displays the conductivity measurements for the three sites that both our group and previous groups sampled over a 2-year period. This is core relevant data for our analysis and for the greater study of Rice County water systems.

Discussion

The new data gathered by this leg of the ongoing project does little to confirm the claimed dichotomy of the Rice County water system. While measurements of flow (m/s) and transparency (cm) were taken, the only information relevant to the claim is the conductivity of the water, particularly at the sites previously studied (see Table 2). Even then, the measurements of conductivity were taken at seven discrete sites along Prairie Creek over a two-week period; such samples only represent a part of the geochemical makeup and pattern of eastern Rice County. More importantly, no new data from western Rice County was collected, leaving the evidence supporting the claim entirely up to previously published data and analysis.

An anomaly in the previously collected conductivity measurements of Prairie Creek is worth noting, however. While our conductivity measurements for sites 1 and 3 (see Appendix 3) were not strikingly different from those previously collected (see Table 2), our two samplings of site 2 had conductivity readings much lower than the 1854µS and 2309µS measured previously. A closer look at the collated data, however, shows that it was the previous readings that were anomalous to the greater trend. These two spikes in conductivity could have been caused by the presence of a hot spring or the dissolution of glacial till into the creek (Haileab).

Finally, the flood events that predated our sampling dates are important to mention. Rice County experienced a 135-year flood from the 22nd through the 25th of September 2010 (Youngblood et al). It is within the realm of possibility that the flood changed the geochemistry of Prairie Creek and that the conductivity readings were affected because of it.

Conclusion

There is not an overwhelmingly large amount we can say about the new data collected and analyzed by our group. We have shown that Prairie Creek's conductivity, and by default, nitrate content, is within similar ranges of and follows similar patterns to most river systems on the east side of Rice County. We took no samples of any river system on the west side of the county, so no new conclusion can be drawn.

Our project, however, is but a small contribution to the greater body of scientific research concerning Rice County water systems. The little new data we have has been formatted to match the existing data and will be used in the future as studies continue.

We can say that there is an obvious need for continued, frequent data collection and analysis of these river systems. Questions remain unanswered. While the conductivity of Prairie Creek as measured by our group falls well within the general range as dictated by the EPA, future development of the county, as well as natural occurrences (such as future floods) could change this. The anomalies mentioned previously are also worth investigating; the cause of abnormally high conductivity (but no spike in nitrate concentration) has yet to be determined. While it currently seems as though future development in Rice County will be concentrated on the western and not eastern side of the county (Haileab), any information gathered will be crucial for future generations of developers and scientists alike.

Acknowledgements

We would like to thank Charles Priore for his assistance with the research process; Nick Holschuh for all of his previous data collection and analysis on Prairie Creek; our teaching assistants, Griffin and Lily, for always being there to help; Tim Vick for providing maps; and finally our professor, Bereket Haileab, for his enthusiastic support and helpful guidance.

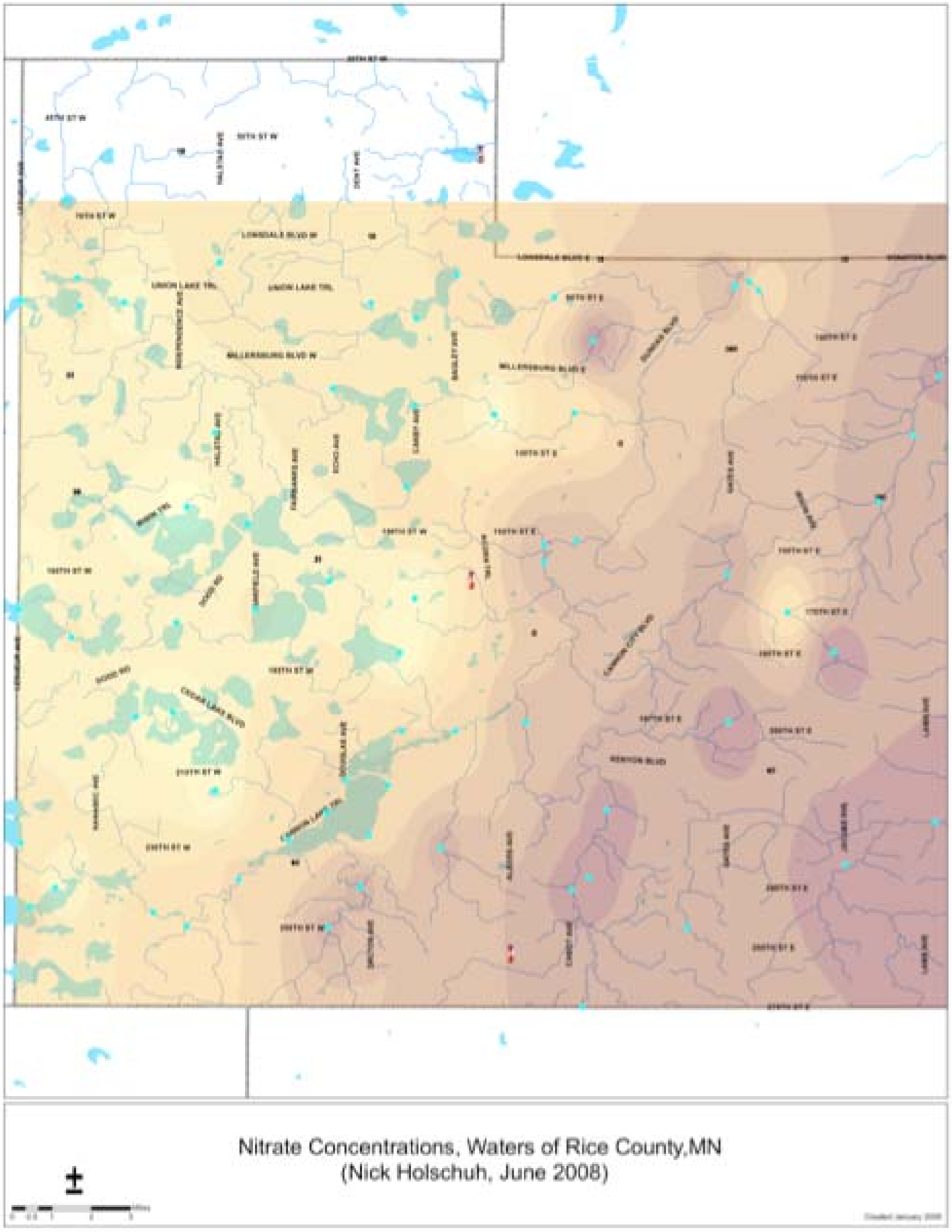
APPENDIX

Appendix 1. Satellite view of Rice county with our collection sites marked.
Appendix 2. Satellite view of Rice County with all of Nick Hulschuh's collection sites.

Appendix 3. Close-up of our collection sites on Prairie Creek.

Appendix 4. Satellite view which shows the tributary of Prairie Creek. Sites 5 and 7 are on Prairie Creek, and site 6 is on the tributary.

Appendix 5. Seasonal variations in conductivity of surface water of Rice County, figure created by Devereux et al.



Appendix 6. Nitrate concentrations in the waters of rice county, figure created by Nick Holschuh.

c

Appendix 7. Devin Holewinski using a flow meter to measure flow of Prairie Creek.

Site	Summer 2008 NO3 - ppm	Summer 2008 Temp. C	Summer 2008 Conductivity uS	Summer 2008 Date	Fall 2008 NO3 - ppm	Fall 2008 Temp. C	Fall 2008 Conductivity uS	Fall 2008 Date	Spring 2009 Temp. C	Spring 2009 Conductivity uS	Spring 2009 Date
1	95.48	12.8	631	17-Jun-08	5.35	10.9	814	30-Sep-08	15.6	654	24-Mar-09
2	8.24	14.3	1854	17-Jun-08	2.97	14.2	2309	30-Sep-08	9.9	262.5	24-Mar-09
3								30-Sep-08			
4	66.23	15.1	623	17-Jun-08	17.5	11.7	653	30-Sep-08	10.6	613	38434
5											
6											
7											

Site	Summer 2009 Temp. C	Summer 2009 Conductivity uS	Summer 2009 Date	Oct-10 Temp. C	Oct-10 Conductivity uS	Oct-10 Date	Nov-10 Temp. C	Nov-10 Conductivity uS	Nov-10 Date
1							7.8	405	11/2/2010
2	14.1	814	16-Jun-09	10.2	429	19-Oct	6.5	391	11/2/2010
3				10.3	421	19-Oct	5.7	374	11/2/2010
4	13.7	553	16-Jun-09	9.8	436	19-Oct	7	406	11/2/2010
5				10.9	452	19-Oct	8.7	420	11/2/2010
6				11.1	467	19-Oct	8.4	440	11/2/2010
7				11.2	452	19-Oct	8.4	423	11/2/2010

Appendix 8. These tables show a combination of our data and Nick Hulschuh's data on Prairie Creek. Three of our sites, 1, 2, and 4 correspond with sites that Hulschuh monitored.

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Water Quality of Rice County Lakes
Fall 2010

Wells Lake
Cannon Lake
Sprague Lake
Sakatah Lake
Cedar Lake
Roberds Lake
Kelly Lake
French Lake
Mazaska Lake
Shields Lake
Hunt Lake
Caron Lake
Rice Lake
Fox Lake
Mud Lake
Cody Lake
Union Lake
Matogga Lake
Hatch Lake
Phelps Lake
LeMay Lake

Linnea Bullion
Galen Gorski
Megan Teplitsky
Prof. Haileab
Carleton College
Geology 120

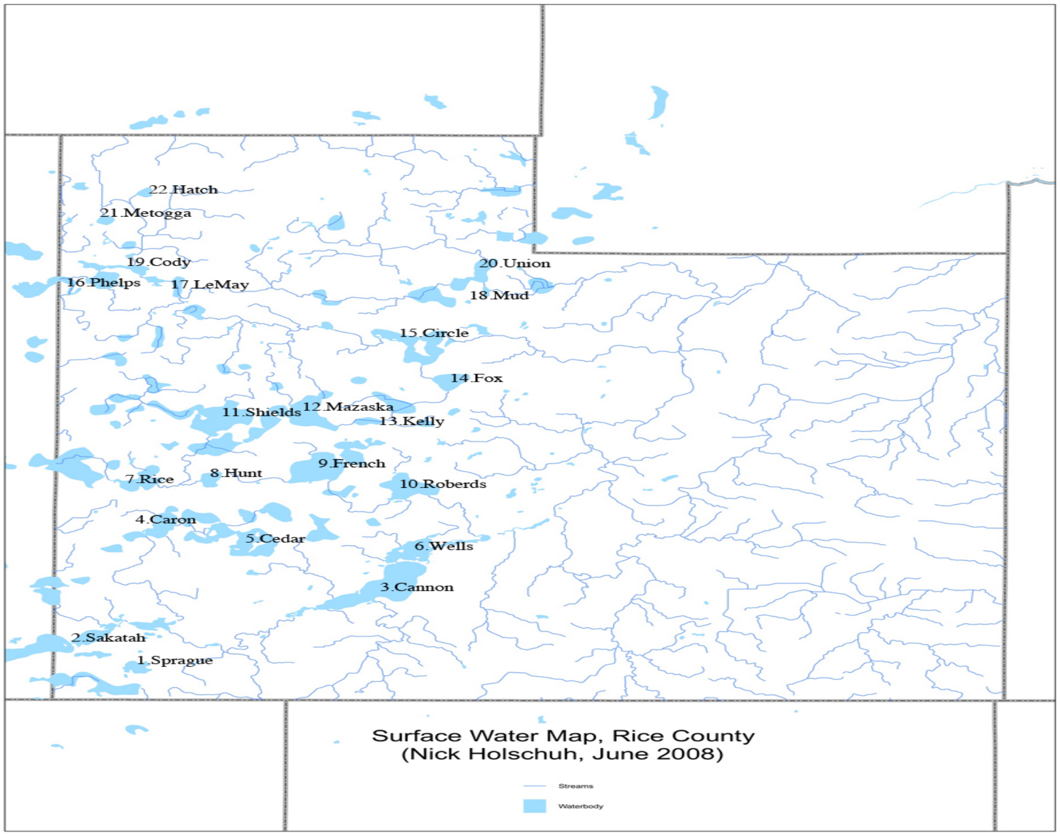

Figure 1: Hydrological Map of sites visited.

Introduction:

Lakes form an integral part of Minnesota's ecosystem. Rice County's lakes were formed by depressions left by retreating glaciers. These lakes are clustered in the western portion of the county. Unfortunately, runoff from agriculture, global warming, and other human activities have impacted the overall water quality of these important, vulnerable natural resources. Using research from the years 2003, 2004, and 2006 as a baseline, and with increasing scarcity of clean water in mind, we tested the water quality of lakes in western Rice County in order to gather data on their quality and analyze the impact of human activity in the area. “Lakes are known to sensitive to a wide array of changes in climate. Even small changes in seconds can produce large changes in lake level and salinity" (Stephan and Foufoula-Georgiou, 2001). Because of this fact, lakes can provide an important bell weather for climate change and further research. The data that we have collected this term can hopefully be used as a baseline on which future geology students can build.

Throughout October and November of 2010, we visited various lakes to collect data on the conductivity, salinity, clarity, dissolved oxygen concentration, and temperature of 22 lakes. Adding to the research of various students from 2003, 2004, and 2006, we hope to expand the knowledge and understanding of the lake water quality in Rice County. We expect to find lower oxygen content and clarity in lakes closer to agricultural areas because of fertilizer runoff. We predicted that there would be an increase in nitrates in the water from the increased amount of agricultural activity in the area, but did not have the means to confirm this prediction.

First we will present the reader with the data and then we will discuss the implications of it on the lakes. Finally, we will point out potential flaws in our experiment and suggest avenues for future study.

Methods:

The data collection for this lab was done in two parts. The first involved visiting the field to obtain measurements and water samples and the second involved water sample testing in the lab at Carleton College.

In the field, all measurements were taken as far into the water as possible on foot. This involved using boat docks or standing at the shoreline and reaching as far as possible. The turbidity of the water was measured with a 1.2 m Secchi tube. Water was drained until the black and white symbol was visible, and the corresponding level of the meniscus was recorded. The water from the Secchi tube was then drained into two sample bottles to be taken back to the lab for later analysis. Temperature, conductivity, dissolved oxygen and salinity of the water were measured using a Yellow Springs, Inc. meter.

Results:

Table 1: Field Measurements

Lake	**µs**	**µs**	**ppt**	**Turbidity**	**Temp in Celcius**	**% oxygen**	**mg/l**	**GPS Coordinates**
Wells	414.1		0.2	61.3	15.8	79.3	8.15	N44º17.589' W093º19.145'
Cannon	335	432	0.2	69	15.5	92.1	8.98	N44º15.982' W093º20.446'
Sprague	169.8	207.5	0.1	74	15.6	15.1	1.7	N44º12.714' W093º29.066'
Sakatah	375.5	448.4	0.2	52	16.8	34.1	4.44	N44º13.814' W093º30.419'
Cedar	221	263.	0.1	>120	16.6	63.1	6.84	N44º18.251'

	.5	5						W093º26.731'
Roberds	265	317.3	0.2	>120*	16.3	53.8	6.09	N44º19.384' W093º19.838'
Kelly	184.9	271.8	0.1	>120	9.9	60.8	0.81	N44º21.459' W093º21.826'
French	196.3	248.4	0.1	45	14	75	7.6	N44º20.971' W093º23.441'
Mazaska	229.7	287.6	0.1	74.3	14.4	83.3	7.95	N44º21.882' W093º23.415'
Shields	269.4	334.1	0.2	7.1	14.8	98	9.89	N44º22.430' W093º25.494'
Shields II*	260.8	330.8	0.2	>120	13.9	69.5	7.64	N44º21.591' W093º26.547'
Hunt	282.5	353.7	0.2	32.5	14.5	74	8.01	N44º19.917' W093º27.097'
Caron	229.7	296.2	0.1	>120	13.3	51.2	7.53	N44º18.205' W093º27.838'
Rice	240.1	310.3	0.1	67.5	13.2	60.7	6.25	N44º19.902' W093º29.859'
Fox	244.1	305.4	0.1	98	14.5	96.1	9.73	N44º23.522' W093º19.920'
Circle	268.3	293.9	0.1	36.0	7.1	63.4	8.55	N44º25.496' W093º21.547'
LeMay	198.5	201.6	.1	106.0	6.8	60.9	7.41	N44º27.331' W093º28.378'
Phelps	241.3	274.9	.2	56.6	6.2	78.8	9.72	N44º27.452' W093º29.599'
Cody	180.4	198.4	.1	41.3	6.7	71.8	8.72	N44º27.624' W093º30.203'
Metogga	283.4	300.4	.1	33.0	6.0	81.3	9.86	N44º29.629' W093º29.877'
Hatch	262.6	281.1	.2	8.1	8.0	11.3	2.35	N44º30.613' W093º28.968'
Union	292.4	313.4	.2	84.2	6.8	78	9.75	N44º27.718' W093º18.256'
Mud	87.6	133.5	.1	>120	6.3	Not Available	Not Available	N44º43.936' W093º31.315'

* Second sample obtained at the same lake because the first site was covered in algae

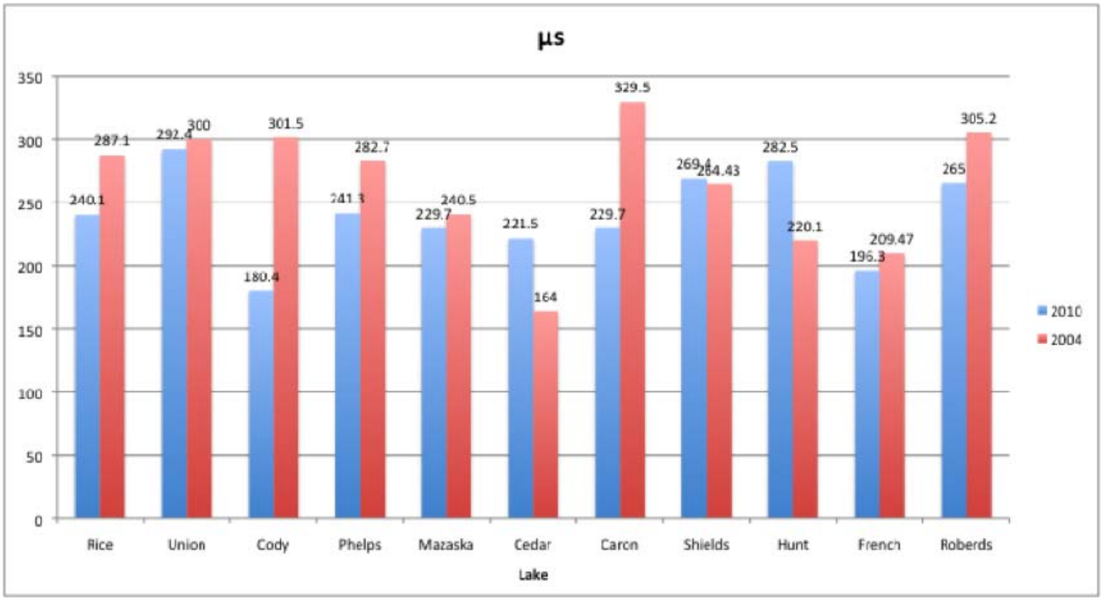

Figure 2: Conductivity of lake water for 2010 and 2004. Measurements taken with a YSI meter.

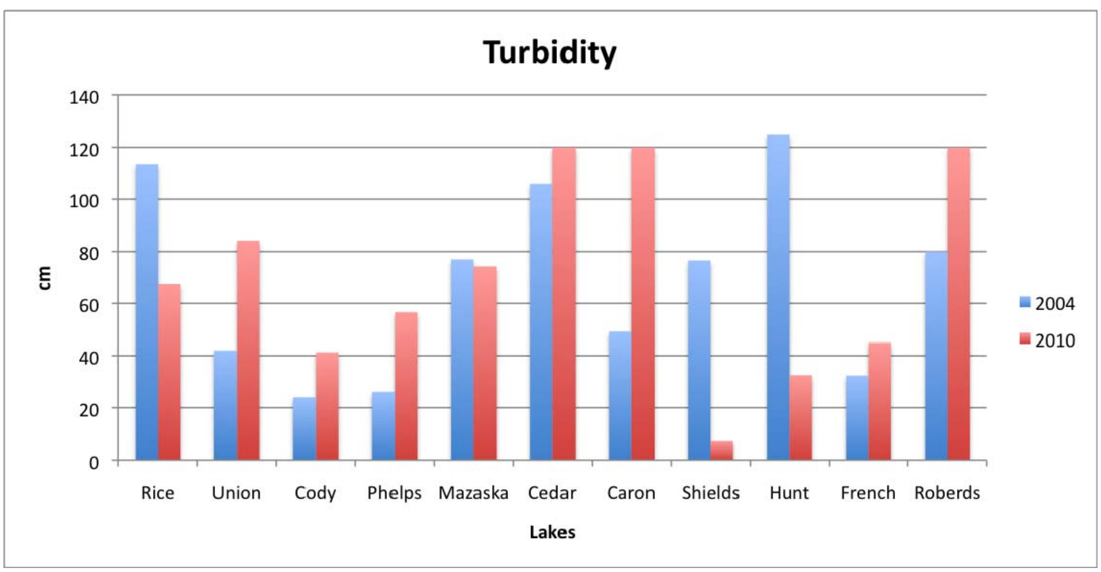

Figure 3: Tubidity of lake water for 2010 and 2004. Measurements taken with a secchi tube.

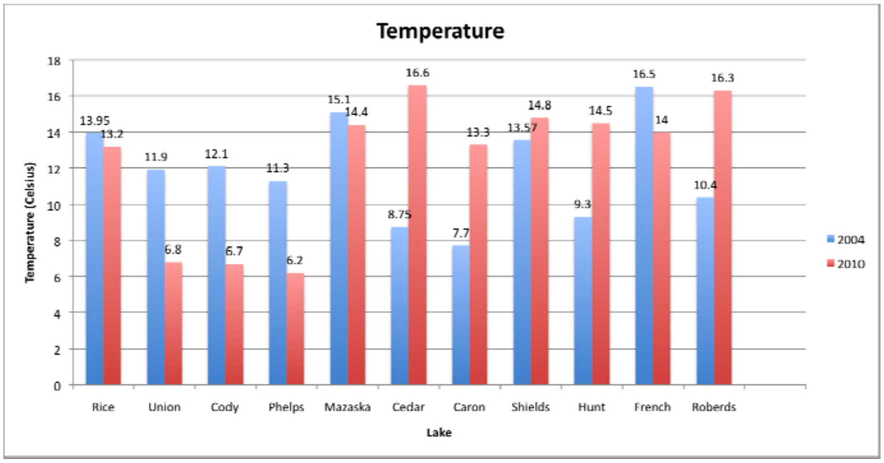

Figure 4: Temperature of lake water for 2004 and 2010. 2004 data contains averaged temperatures for the three dates that were in their report. Measurements were taken with a YSI meter.

Table 2: Near Lakes Oct. 25th, 2004

Lake	**µs**	**µs**	**ppt**	**Turbidity**	**Temp. (celcius)**	mg/l
Rice*	287.1	394.8	0.20	113.5 cm	13.95	5.23
Union	300.00	400.00	0.20	42 cm	11.90	3.40
Cody	301.5	402.10	0.20	24 cm	12.10	9.19
Phelps	282.7	383.10	0.20	26.10 cm	11.30	9.10
Mazaska *	240.5	296.65	.1	77	15.1	41
Cedar*	164	238.55	.1	105.9	8.75	10.03
Caron	329.5	220.3	.2	49.2	7.7	5.66
Shields*	264.43	338.27	.2	76.6	13.57	7.61
Hunt	220.1	314.1	.2	125 cm	9.3	83.4
French*	209.47	250.77	.1	32.37	16.5	10.33
Roberds *	305.2	219.7	.1	80	10.4	N/A

- Data was averaged over the three different dates provided from the 2004 data for simplicity of analysis

Discussion:

In comparing the dissolved oxygen content and the temperatures of the different lakes we measured to those of past years, we must take into account the time of year and ambient air temperature at the time of the sample. It is relevant to note that past studies took multiple samples of each lake, whereas in our study we were limited by time and could not make multiple visits to the twenty-two lakes. Our intention was not to create a time series study, but rather to create a baseline for future water analysis to be made by other classes. In the coming years, these lakes will become increasingly more important in the study of climate change. Small stagnant lakes, like the ones we studied, are very sensitive to small changes in atmospheric temperature and are an important resource in monitoring global warming. With this in mind, our goal was to create a comprehensive study that future students could build on, eventually leading to the formation of hypotheses regarding how temperature shifts are affecting Rice County's ecosystems.

Note: the data that we had for the percentage of dissolved oxygen in the lakes is most likely unreliable. We believe that the YSI meter was improperly calibrated because it gave us readings as high as 98% dissolved oxygen at some sites, which is not logical. We further confirmed this belief by juxtaposing our data with the data from 2004. We do not believe that there has been enough change in the area to cause such an immense fluctuation in data.

Conclusion:

We found little correlation between the data we collected and the geographical location of the lakes. Our intent was not to provide a testable hypothesis, but to provide data upon which future groups can build. Our recommendation is that future geologists continue monitoring Rice County's lakes, paying special attention to changes in average temperature across the years as an indicator for the severity of climate change. It is also important for them to make sure that the YSI meters are correctly calibrated, as we had some skewed results from an improperly calibrated meter. Also, future groups should track urban development and its impact on water quality. If possible, all lakes should be tested the same day so that the temperature data would be standardized. The data would ideally be taken on the same day every year to make extrapolations as accurate as possible. As previously mentioned, we cannot make any conclusions from our data, but can only provide the means for future groups to do so.

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