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Water Quality Variability in a Bioswell and Concrete Drainage Pipe, Southwest Lincoln, Nebraska

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WATER QUALITY VARIABILITY IN A BIOSWELL AND CONCRETE DRAINAGE PIPE, SOUTHWEST LINCOLN, NEBRASKA

by

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University of Nebraska, 2009

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Abstract

The goal of this project is to evaluate the effectiveness of bioswells in protecting water quality from urban runoff. The hypothesis tested in this project is that water in bioswells improves water quality. Water quality in both a bioswell and an underground concrete lined ditch, both containing ground and surface water, were tested for certain water quality parameters. These parameters consisted of: Dissolved Oxygen, pH, water temperature, weather temperature, Total Dissolved Solids, Specific Conductivity, Alkalinity, Total Dissolved Carbon, Chemical Oxygen Demand, and depth and width of the sampling site. An additional contaminant that was looked at was motor oil. This was measured by comparing Total Organic Carbon with Chemical Oxygen Demand. A variety of different methods to measure the water quality parameters were utilized. The concrete site had more stable readings, but much higher water temperatures. However, the bioswell water is mainly from surface water runoff, and the underground concrete lined pipe is from underground water, so the two cannot be directly compared. The bioswell had high readings, especially pertaining to Oxygen Demand, Total Organic Carbon, and Specific Conductivity in early test dates. But, these readings improved as they were filtered though the bioswell. As plant activity increased and the weather began to warm up there were more stable readings. It is concluded that bioswells are an effective way to reduce problems associated with urban runoff pertaining to certain water quality parameters.

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Preface

This undergraduate thesis was made a more enhanced learning experience and easier with the help of several people. A big thanks to Dr. David Gosselin in his dual role as my thesis advisor and emphasis advisor. His encouragement, patience, and guidance throughout the whole process was essential in the completion of this research. His genuine passion for teaching is appreciated and admired. This project could not have been possible without my environmental studies advisor, Sara Yendra. Not only did she suggest the idea for the project, but also was my partner-in-sampling. Other people who were essential to this project were Tadd Barrow, assistant extension educator for the School of Natural Resources, and Tim Golden, head of the Science Department at Southwest High School.

Chapter I. Introduction

Urban development affects the quality and rate of water runoff entering streams to varying degrees. Although contaminants from sources such as commercial and residential sources may appear to be insignificant at their source, they are quickly carried by rain and snowmelt into storm drains that lead straight to rivers, lakes, and oceans.

Contaminants can accumulate on paved surfaces over dry periods and be quickly carried to drainage areas when precipitation events occur. These contaminants can include nutrients, sediments, pathogens, toxins, fertilizer, pesticides, motor oil, road salt, and animal waste (Environmental Protection Division 1999). A common drainage system is concrete lined ditches or underground concrete pipes. However, a more natural design of a drainage system is a bioswell. Bioswells are man-made drainage ditches that are lined with vegetation, usually native plants, that need to be maintained if they become over contaminated.

The objective of this research is to examine water quality variability over time, by focusing on the potential impacts of urban runoff on a bioswell. The hypothesis to be tested is that if runoff is filtered through a bioswell, then we will expect to see better water quality compared to runoff that isn’t filtered.

Chapter II. The Research Problem and Review of the Literature

Water quality plays an important role in the health of streams and for human use. Human use of water will continue to be important in the future as the world's population and pressures on our water resources increase. According to the World Resources Institute's 2000 Pilot Analysis of Global Ecosystems, at least 3.5 billion, or 48% of the world population will live in water-stressed river basins by 2025. However, this projection is based on current water usage (Brown 2002). If surface and groundwater is severely degraded, several things could happen including: the cost of water could increase and more people wouldn't have access to clean water. In addition to having more degraded water resources, build up of toxicity in water could have a wide range of impacts on humans including cancer, skin irritation, and death if in large doses (Denton 2005).

Bioswells collect runoff from elevated urban areas and higher places in the landscape. The runoff from these elevated areas goes into a vegetative covered bioswell. Bioswells have a plethora of positive impacts on water quality. It is an effective and natural way of dealing with non-point sources in urban areas. It is a more economical way of dealing with runoff contamination, opposed to trying to remove the pollutants after-the-fact (Environmental Protection Division 1999). In addition, bioswells can slow water runoff before entering streams, which mitigates the impacts of flooding.

In addition to sampling surface water, groundwater was also sampled from a pipe that discharges water from a sump pump. Groundwater varies greatly throughout the state of Nebraska. Groundwater quality depends on the materials it must pass through on its way to the groundwater reservoir and the depth to groundwater. Naturally occurring chemicals affect the quality as well.

Stormwater runoff from roads has a largely adverse impact on water quality for both ground and surface water. Stormwater runoff is generally from impervious surfaces. Stromwater can accumulate contaminants, which can infiltrate into the soil, be taken up by plants, or go into bodies of water. There are many ways that groundwater and surface water can be contaminated. Contaminants that can impact groundwater and surface water include pesticide and fertilizer application from lawns and agriculture, increased sediments, pathogens, toxins, road salt, animal waste, and motor oil (Environmental Protection Division 1999).

Water quality plays a crucial role in our ecosystem. There are major ramifications if water quality is degraded. In bioswells there can be a build-up of contamination. Some of the contaminants remain or bind with sediments. As these metallic and/or organic contaminants accumulate, their concentration could exceed levels that have toxic effects on organisms that live or feed in the water. This may also impact the predators that consume these organisms. Other adverse effects including eutrophication-- low oxygen levels, which could cause fish kills (Denton 2005), may also occur. Other damaging effects include reproduction and feeding problems for animals that come in contact with the water.

Motor oil is a major urban contaminant that impacts water quality. For instance, it is estimated that cars and light commercial vehicles lose 2.8 ml of oil per 1000 km driven. Of the total oil sold, 20 to 40% of that is either leaked or combusted (Denton 2005). Used oil that is leaked, spilled or disposed of improperly can be carried away in storm water runoff. This could eventually affect the environmental health of the bodies of water that receive the runoff. The Clean Water Act (CWA) specifies that oil and grease should not be present at levels that produce a visible oily sheen, but no numbers have been set. However, there are numeric criteria for aquatic life protection that have been established for some constituents found in used oil such as:

arsenic, cadmium, chromium, lead, nickel, and zinc (Denton 2005).

It is continually more important to preserve our natural resources and to find the best possible ways to do that. By examining how humans affect the water quality of lakes and streams, it will be easier to see why we need to protect them. Many people fail to make the connection between the fluid leaking from their automobile or the fertilizer they apply to their lawn, to the parking lot or the road it leaks on, to the storm drain and to the stream to which it eventually leads (Damm 2005). Without something to control these contaminants, like a bioswell or other preventative measures, runoff could affect a wider spectrum of the environment.

Chapter III. Materials and Methods

This study focuses on the site of Southwest High School in Lincoln, Nebraska, near the intersection of 14th and Pine Lake Road (Figure 1). This project specifically looks at how runoff contaminants from parking lots and fields, impacts the bioswell at designated sites.

There are two drainage areas that were studied. The first drainage area consists of the bioswell. The bioswell was constructed about eight years ago. It collects runoff from the student parking lot, business lots adjacent to the student parking lot, the school's practice fields, and other wetland areas. Water in the bioswell flows adjacent to the parking lots and soccer fields before being drained into the culvert that leads into Salt Creek. The second study area is an underground concrete lined drain that is almost a ½ mile long. The source of the water in the concrete pipe is groundwater that is pumped from a sump pump in Southwest High School.

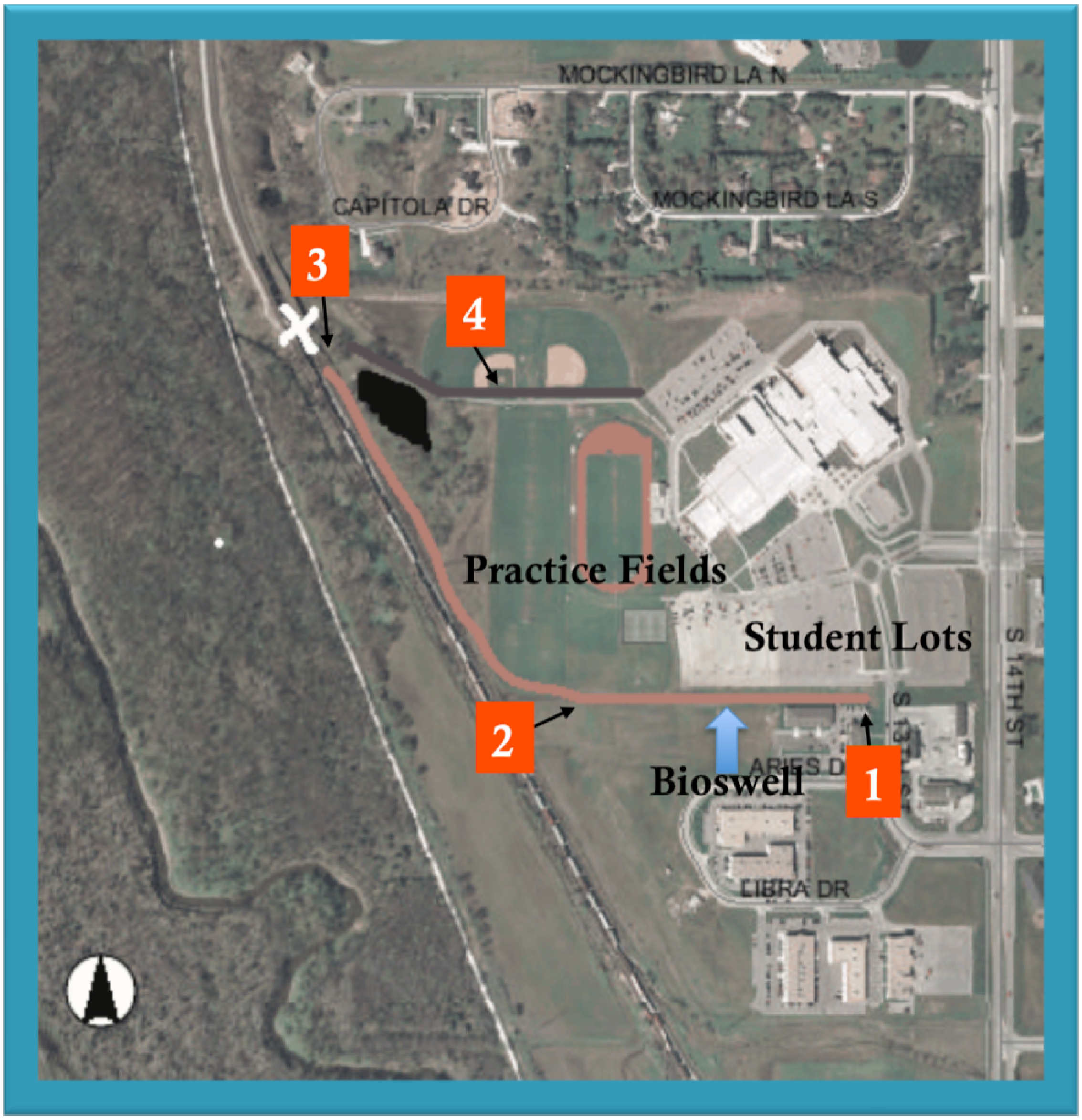

Figure I. Study area of sites 1 to 4. The "X" on the map denotes where the culvert is. This is where the water from the bioswell exits and eventually leads to Salt Creek.

There were four sample sites (Figure 1). Bioswell site 1 is at the beginning of the bioswell where water had a constant flow and an average depth of 5.80 cm. This site receives the majority of its water from two adjacent parking lots and nearby roads as well. Bioswell 2 is in the middle of the bioswell. It generally had standing water, but was occasionally dry. This site was located at the edge of a soccer field and also received runoff from the parking lot.

Bioswell site 3 is at the end of the bioswell where the water from the bioswell drains into the culvert that leads to Salt Creek. This site had water depths between 6.32 cm and 32.2 cm and minimal flow most of the time. Besides containing runoff water, site 3 also contained some groundwater since the site always had a substantial amount of water in it, despite if it had rained or not. Concrete site 4 is where the water exits the underground concrete pipe whose source of water is groundwater from the sump pump in the basement of Southwest High School.

Data for the water quality parameters in Table 1 were collected ten times between February 25, 2009 and April 22, 2009. Total Organic Carbon (TOC) and Chemical Oxygen Demand (COD) were collected five times on: March 4, March 25, April 8, April 10, and April 15, 2009. All samples were collected between 11 am and 2 pm.

The water quality parameters that were tested were as follows:

Table 1:

- Dissolved Oxygen (ppm)
- pH
- Water Temperature (degree Celsius)
- Total Dissolved Solids (mg/L)
- Specific Conductivity (µS/cm)
- Width Across Stream (centimeters)
- Depth of Stream (centimeters)
- Alkalinity (mg/L)
- Total Organic Carbon (ppm)
- Chemical Oxygen Demand (mg/L)
- Weather Conditions (degree Celsius)

A Hydrolab measured dissolved oxygen, pH, water temperature, total dissolved solids, and specific conductance. A Hydrolab is a multi-probe sensor that is held in water at the designated sample site until stable readings are reached. To ensure the accuracy and precision of data on the Hydrolab, readings were only taken after they were stable and the sensors were kept wet at all times. The Hydrolab was also checked to see if it needed calibrating between sampling events. Alkalinity was measured using a Hach titration kit. Depth and width of the sample site was taken using measuring tape. The flow rate was not directly measured. Instead, the depth and width of the water were used as a substitute for water flow.

To estimate the impact of oil on the water, Chemical Oxygen Demand (COD) and the Total Organic Carbon(TOC) were measured because the amount of oil and the amount of oxygen content are highly correlated (Denton 2006). COD and TOC were collected in bottles and preserved with sulfuric acid and then brought to the Water Center at the University of Nebraska, Lincoln to be analyzed.

Chapter IV. Results and Discussion

Dissolved Oxygen

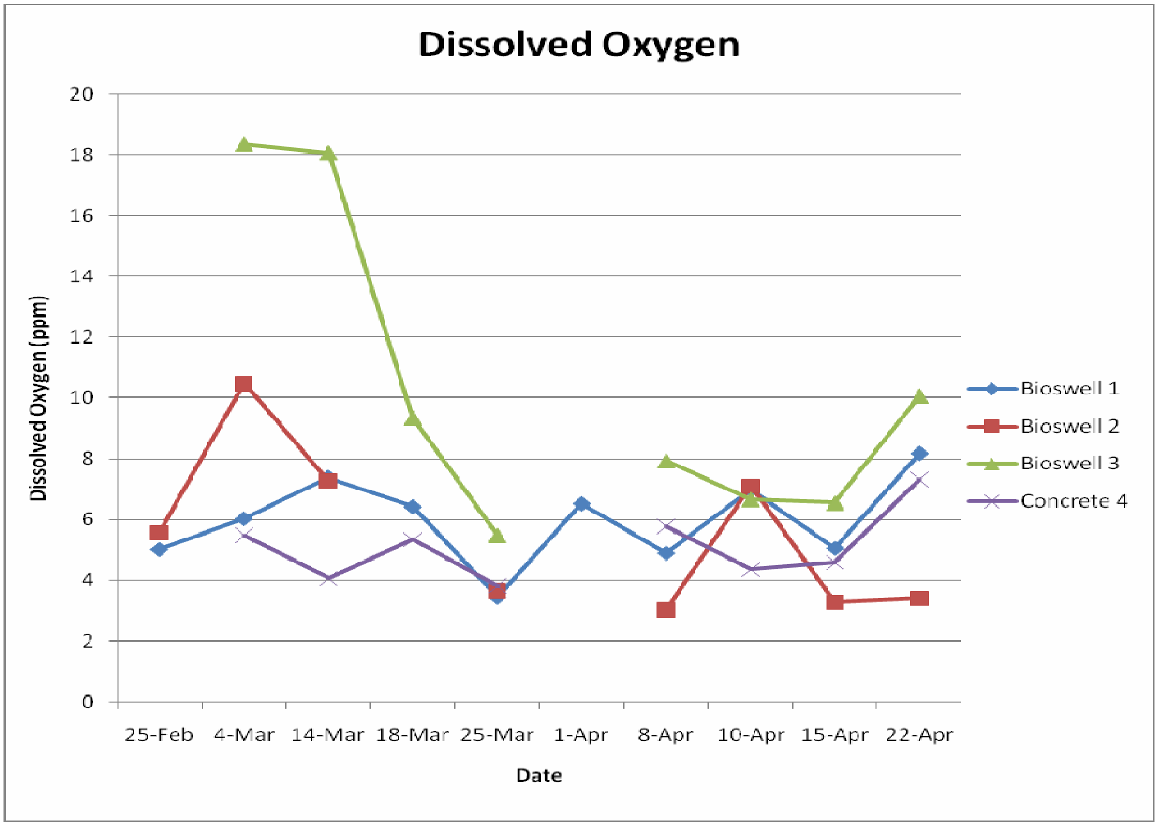

Figure 2. Dissolved oxygen for sites 1 to 4 from February 25, 2009 to April 22, 2009.

Dissolved oxygen (DO) concentrations can be one of the best indicators of the health of an aquatic ecosystem. It is the measure of the amount of oxygen dissolved in the water and is controlled by consumption of aquatic organisms, consumption of plants, natural re-aeration, water temperature, flow and depth. It ranges from 0-18 ppm, but the most ideal levels for supporting a diverse population ranges above 5-6 ppm.

Oxygen enters the water in two ways, either by direct absorption from the atmosphere or by plant photosynthesis. Plants and animals remove oxygen from the water through respiration and decomposition of organic matter. In addition, it is used by aerobic bacteria, which consume oxygen during decomposition. Decreased DO levels can cause changes in the types and numbers of aquatic macroinvertebrates in the water ecosystem (Murphy 2007). Factors affecting DO levels can include the time of day, temperature, season, and weather. Comparisons should be made during the same time of day, and with a temperature range of only 10^{o} Celsius from the previous reading.

The average dissolved oxygen concentrations for sites 1 to 4 are as follows: 6.0 ppm, 5.5 ppm, 10.3 ppm, and 5.1 ppm respectively, as seen in figure 2. Site 3 had the greatest range, with a maximum of 18.8 ppm and a minimum of 5.5 ppm, as well as the highest average of DO. Site 4 had the smallest range, with a maximum of 7.3 ppm and a minimum of 3.8 ppm (Refer to Table 2). The higher DO readings appear at earlier dates in the bioswell sites. Readings for DO at concrete site 4 did not vary throughout the testing period as expected.

Colder water temperatures are correlated with higher levels of dissolved oxygen. Shading caused by trees can cause lower water temperatures, leading to increased DO. Measurements for DO in the bioswell at the beginning of sampling were quite high, especially at sites 2 and 3. These sites had on average, deeper water. As the weather started to warm up, the readings were in the normal 5-6 ppm range. This was due to the increased activity levels of the vegetation in the bioswell, since sunlight and warmer temperatures can raise activity levels in animal and plant life.

In addition, the percent saturation can impact DO. If a site is oversaturated, the more DO it can contain. To get such a high DO reading of over 18 ppm, site 3 was oversaturated. Dry and wet seasons can also impact DO levels. In dry seasons, water levels decrease and the flow rate of the river slows, causing DO concentrations to be low (Murphy 2007). In contrast, during the rainy season DO concentrations are higher because rain interacts with oxygen in the air as it falls. These trends did not show up in these data collected. This is likely due to the short sampling period and the variety of the sites.

Site 2 had standing water, which resulted in slightly lower readings because in slower or stagnant water oxygen is only found in the top layer of water. Site 3 had the greatest range in DO concentrations because of the greater water depths at this site (Murphy 2007).

Another observation to note is that there was a rain event on April 10th. The DO readings for all the bioswell sites had all similar readings of 7 ppm, whereas the fourth site had a lower reading of 4 ppm. The water in the bioswell had a better chance of interacting with the rain, thus increasing the oxygen levels.

Large storms can also create “first flush” events. During a “first flush” the high concentrations of contaminants occur in the early parts of storm events. Whereas a *seasonal* first flush is when higher pollution concentration occurs in the first few storms of the rainy season (Stenstrom 2005). These can create a more polluted discharge than normally seen.

<u>Water Temperature</u>

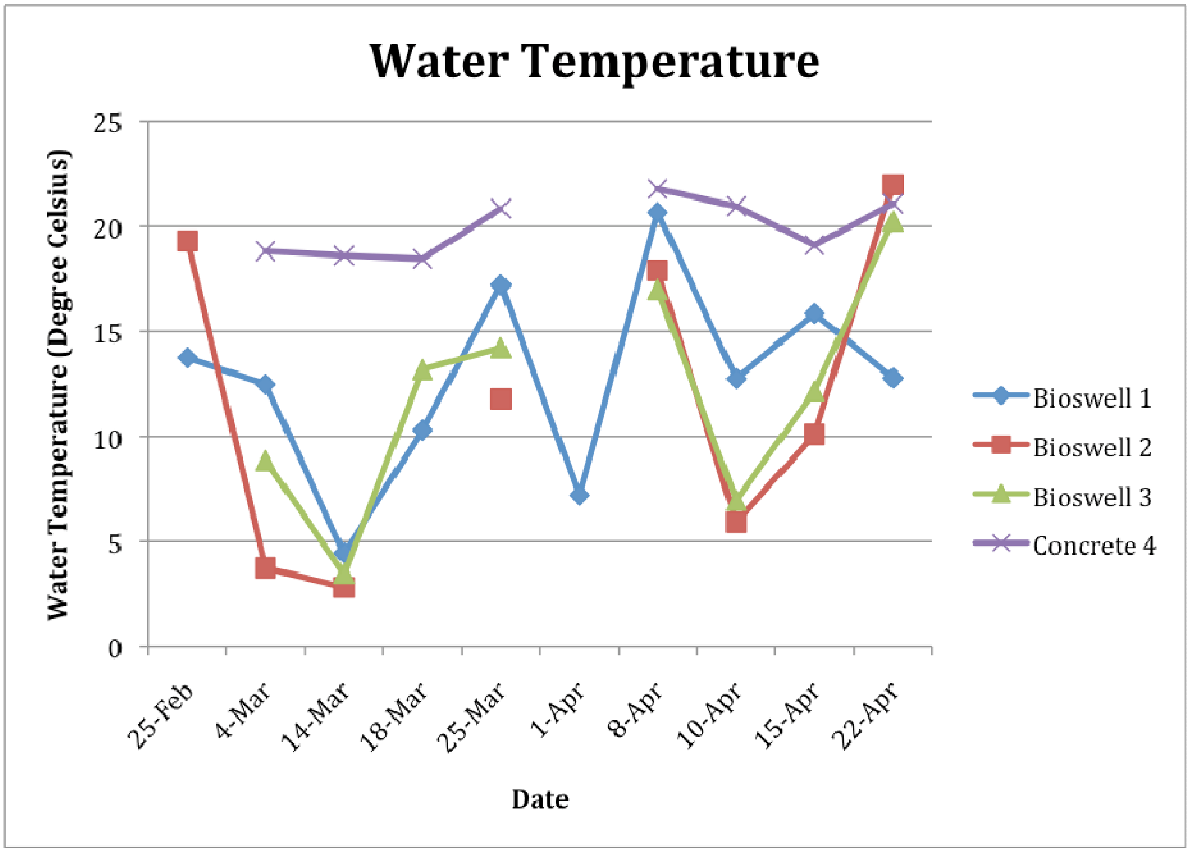

Figure 3. Water temperature for sites 1 to 4 from February 25, 2009 to April 22, 2009. Note that concrete site 4 has a significantly higher temperature than the rest of the sites, whereas the other sites have lower and more variable water temperatures.

All the bioswell sites followed the same temperature trends and had roughly the same range of 17° C between maximum and minimum temperatures (Refer to Table 3 and Figure 3). The temperature of water can impact aquatic life as well as affect the concentration of dissolved oxygen and the rate of photosynthesis.

Paved surfaces can affect water temperatures in a variety of ways. For the bioswell sites, site 1 had the highest water temperature average of 12.7° C. Black surfaces absorb solar radiation, which assists in heating up the runoff. During runoff events water from parking lots and roads raise the water temperature. Also, runoff water coming from paved surfaces can widen stream channels because of increased volume and velocity of the runoff. These shallower, wider streams heat up faster than narrower, deeper streams (Murphy 2007).

Research has also shown that riparian vegetation can prevent the water from heating up and can help stabilize water temperatures. This is beneficial for wildlife since rapid water temperature changes can be harmful. However, the data pertaining to the bioswells have a wide range. All the bioswell sites had the same fluctuations and follow the same trend. Although there was a wide range of water temperatures these sites are not likely to have as much variation as a concrete lined drainage ditch would. Research has shown that plants help regulate water temperatures.

Site 4, where the water's source is groundwater coming from an underground concrete drain, was significantly warmer than the other sites. The main reasons for this are because the water was coming from a sump pump, it is groundwater, and to some extent it is exposed to the higher building temperatures. This warmer water has an impact on its surrounding environment. Water from site 4 creates a pond. In the summer, a thermocline is created in the pond when the water is deeper than 3 meters (Golden 2009). In addition, later in the spring Leopard frogs (*Rana Pipiens*) can be found only in this pond. This is important since frogs are bioindicators. Habitat loss and polluted water have been attributed to this species and other frog's population decline in the last few decades. This water is relatively free from pollution since it is contained in a cemented drainage pipe.

Lemna minor, more commonly known as duckweed, was prevalent in the pond that the concrete lined drain flows into as well. *Lemna minor* is a green free floating small plant. They tend to grow in quiet, warm waters in dense colonies and require large amounts of nutrients coming from nitrate and phosphorous. They can be quite aggressive and can easily cover surface water. This in turn can cause oxygen depletions, which causes fish kills and submerged plants to die because the sunlight is blocked. But, they can also provide habitat for microinvertebrates (Department of Wildlife and Fisheries Sciences, Texas A&M University). The warm waters may have attributed to the growth of the duckweed.

pH

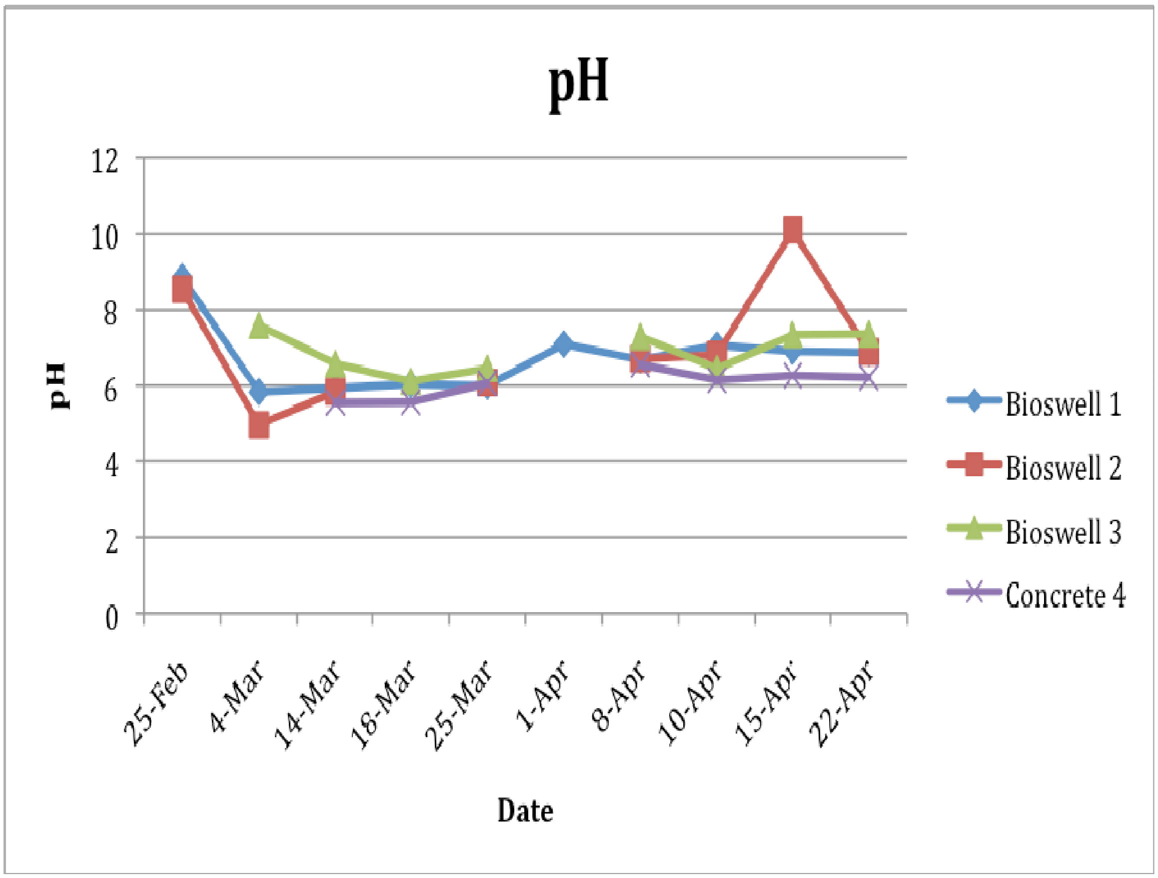

Figure 6. pH for sites 1 to 4 from February 25, 2009 to April 22, 2009.

Overall, there is little pH variation within all four sites. The average ph for all the sites ranged from 6.1 to 7.0. Site's 2 pH range was from 10.1 to 4.99, with two outliers (Refer to Table 5 and Figure 5). pH is the concentration of hydrogen ions in water. pH levels between 4.5 and 9.5 are suitable for most aquatic organisms. The EPA has a secondary regulation for pH of 6.5-8.5 (EPA 2009). Unpolluted rainwater can be acidic as pH 5.6 and neutral water has a pH of

7. Typically, the more pure the water is, the more neutral the pH (pH 7 at 25^{o} C).

Although there were not significant differences in pH between sites, the pH at concrete site 4 was slightly lower than the bioswell sites. This was caused by lower carbon dioxide in the water. There isn't vegetation at this sampling site, so there is less photosynthesis occurring. Carbon dioxide can come from the atmosphere, runoff, bacteria in the water, and respiration form aquatic organisms. In addition, drainage water from forests and marshes can be slightly acidic because of the presence of organic acids produced by decaying vegetation (Murphy 2007).

The second site had the largest range of pH. This could be attributed to the fact that this site had standing water. It could have also had to do with this sites tendency to dry out, which can dramatically change a site's characteristics. Site 4 had a lower pH, which has to do more with the groundwater composition, not with the groundwater interacting with the concrete pipe.

Alkalinity

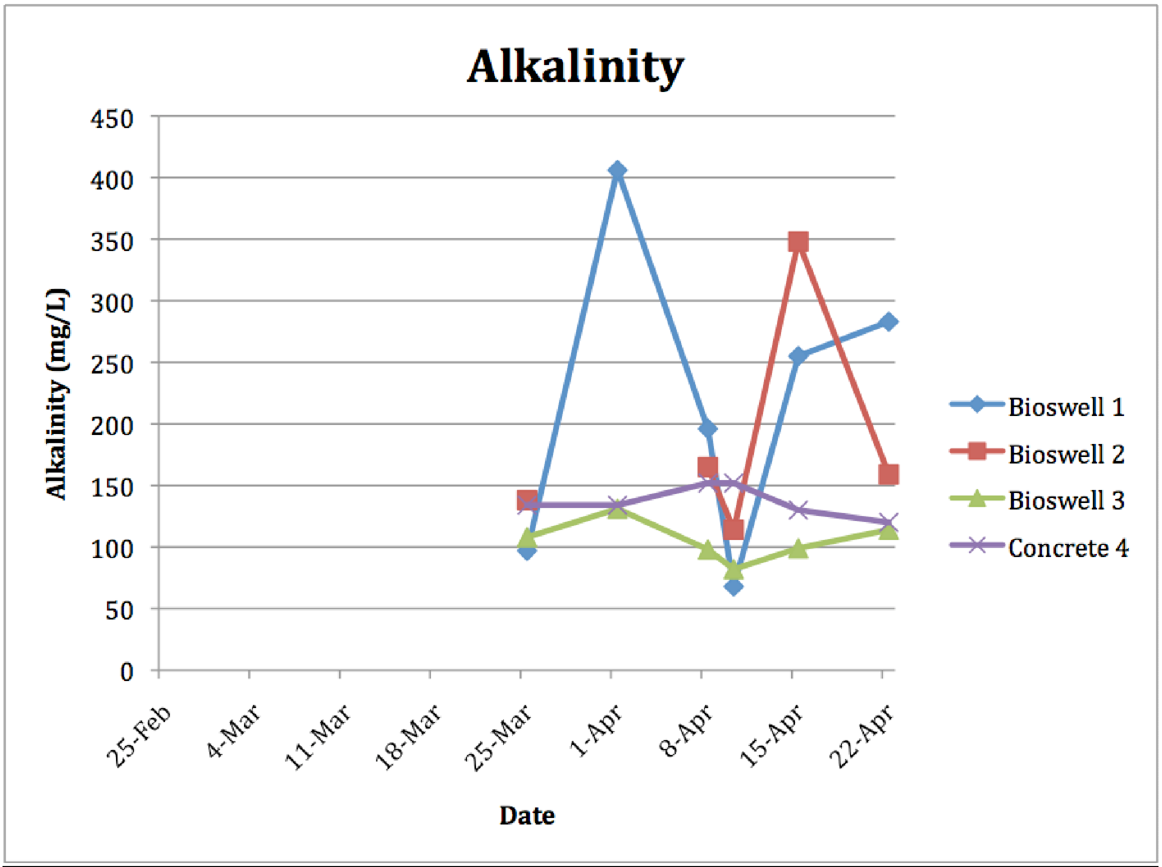

Figure 7. Alkalinity for sites 1 to 4 from February 25, 2009 to April 22, 2009.

Alkalinity measures the buffering capacity of water. It determines how well water is at neutralizing acidic pollution from rainfall and the ability to resist change in pH. If a stream has low alkalinity, then it could be more susceptible to changes in pH. Typical levels for freshwater streams are between 20-200 mg/L of $CaCO_3$, but levels of 100-200 mg/L will stabilize the pH level in a stream. Lakes in reservoirs in Nebraska are typically between 100- 175 mg/L (Barrow 2009). If alkalinity levels are below 10 mg/L then the stream is poorly buffered and very susceptible to changes in pH (Murphy 2007). Factors affecting alkalinity include geology and soils.

Average alkalinity concentrations were all within normal ranges except for site 1, which ranged from 68 mg/L to 406 mg/L. This could do with site 1 containing the most urban runoff from parking lots. Site 4 had the least variability with a maximum of 152 mg/L and a minimum of 120 mg/L (Refer to Table 6 and Figure 7). Alkalinity was not sampled from February 25, 2009 through March 18, 2009 because an alkalinity testing kit was not available.

Overall, the alkalinity readings within all the sites did not vary from the expected norm for Nebraska of the 100-175 mg/L range. Sites 3 and 4 had the most constant alkalinity, which could be attributed to both of these sites containing groundwater. Sites 1 and 2 had the most fluctuation for both alkalinity and pH. These sites only contain surface water runoff.

<u>Water Depth and Stream Width</u>

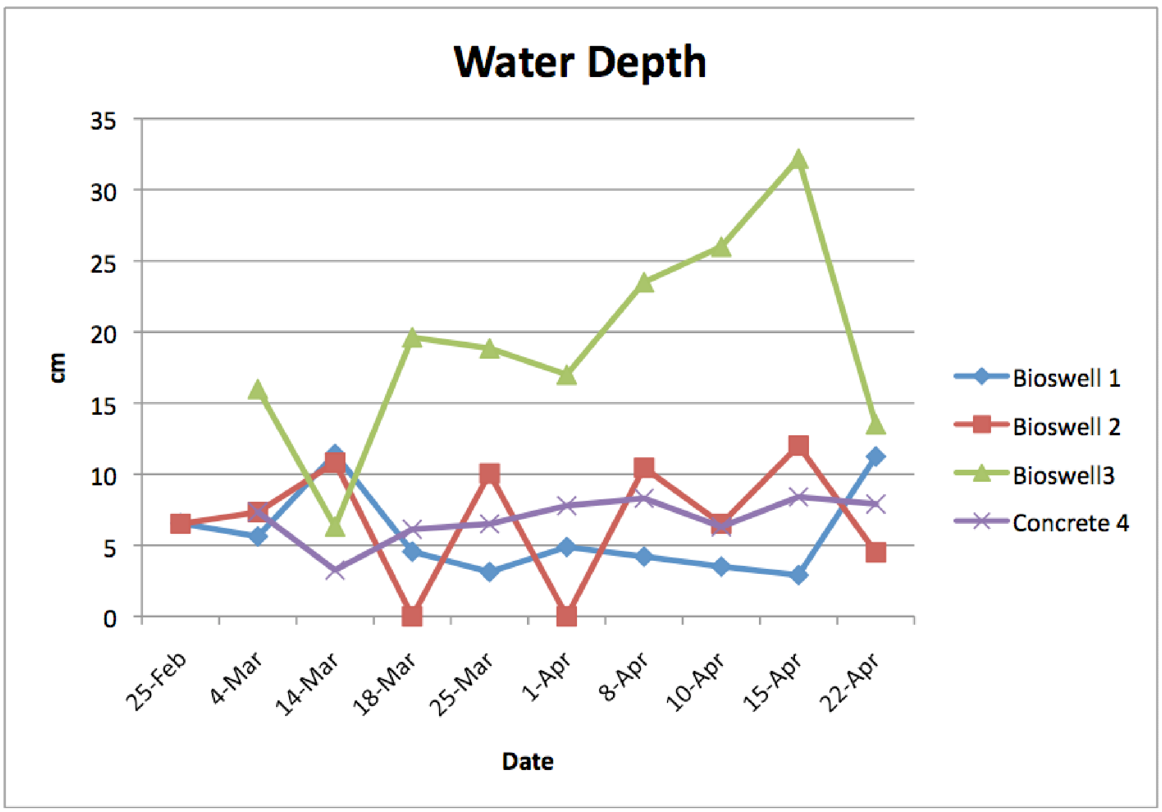

Figure 8. Water depth for sites 1 to 4 from February 25, 2009 to April 22, 2009.

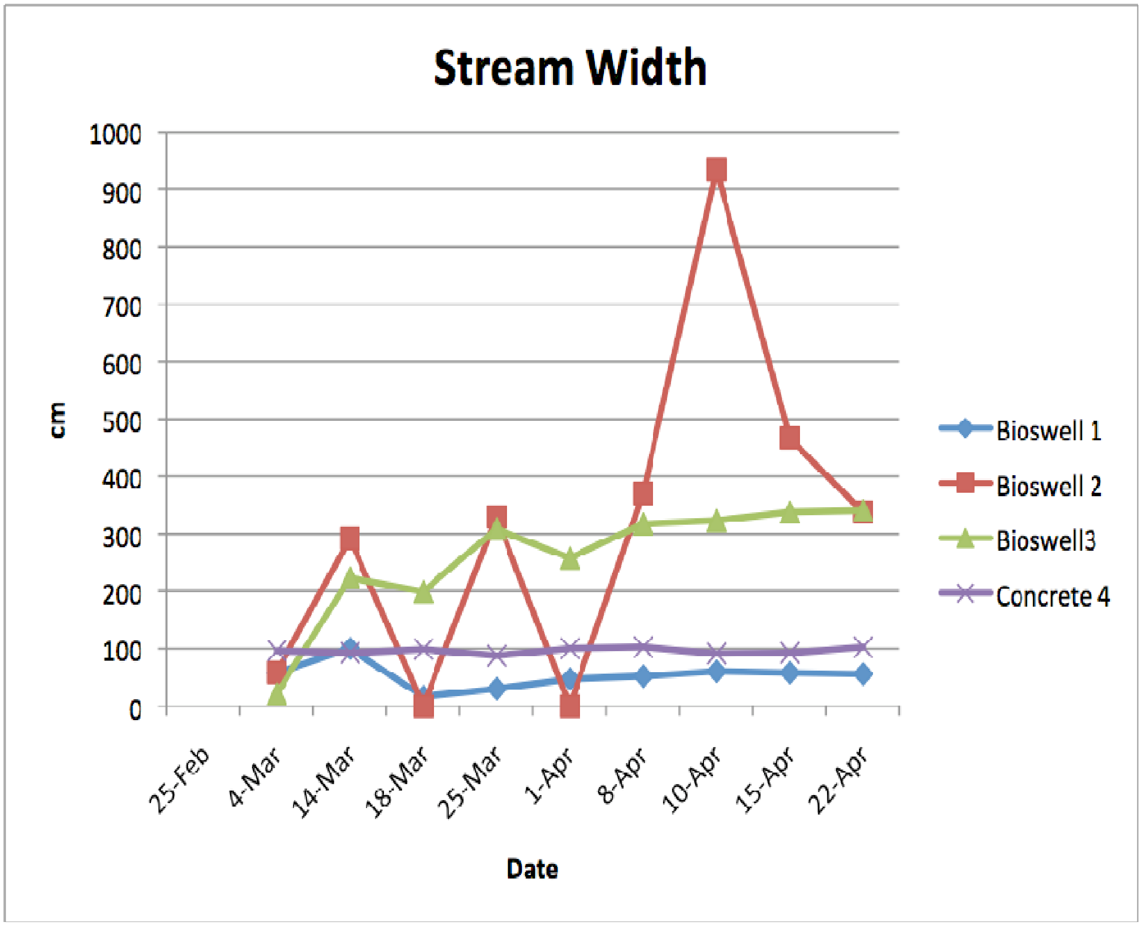

Figure 9. Stream width for sites 1 to 4 from February 25, 2009 to April 22, 2009. Note the bioswell 2 sites tendency to dry up.

Streamflow is the volume of water that moves over a designated point during a certain amount of time. It is related to how much water from watershed goes into a stream. Although streamflow was not measured directly in this project, depth and width of the stream were measured as a proxy for the amount of water flowing at a sampling location.

The average width of site 1 through 4 is as follows: 53.1 cm, 310.2 cm, 258.7 cm, and 96.2 cm. Site 2 had the most variability, with the maximum range of 934.7 cm, to it being completely dried up (Refer to Tables 7 & 8 and Figures 8 & 9). Although this site had the biggest width, it is a flat area.

Water depth was most variable on sites 2 and 3. Note that after the April 10th rain event the width and depth of the sampling sites were much larger. Sites 1 and 4 had a steady streamflow, narrower width, and lower depth. However, site 1 contains surface water and site 4 is groundwater, so these sites aren't comparable.

Total Dissolved Solids

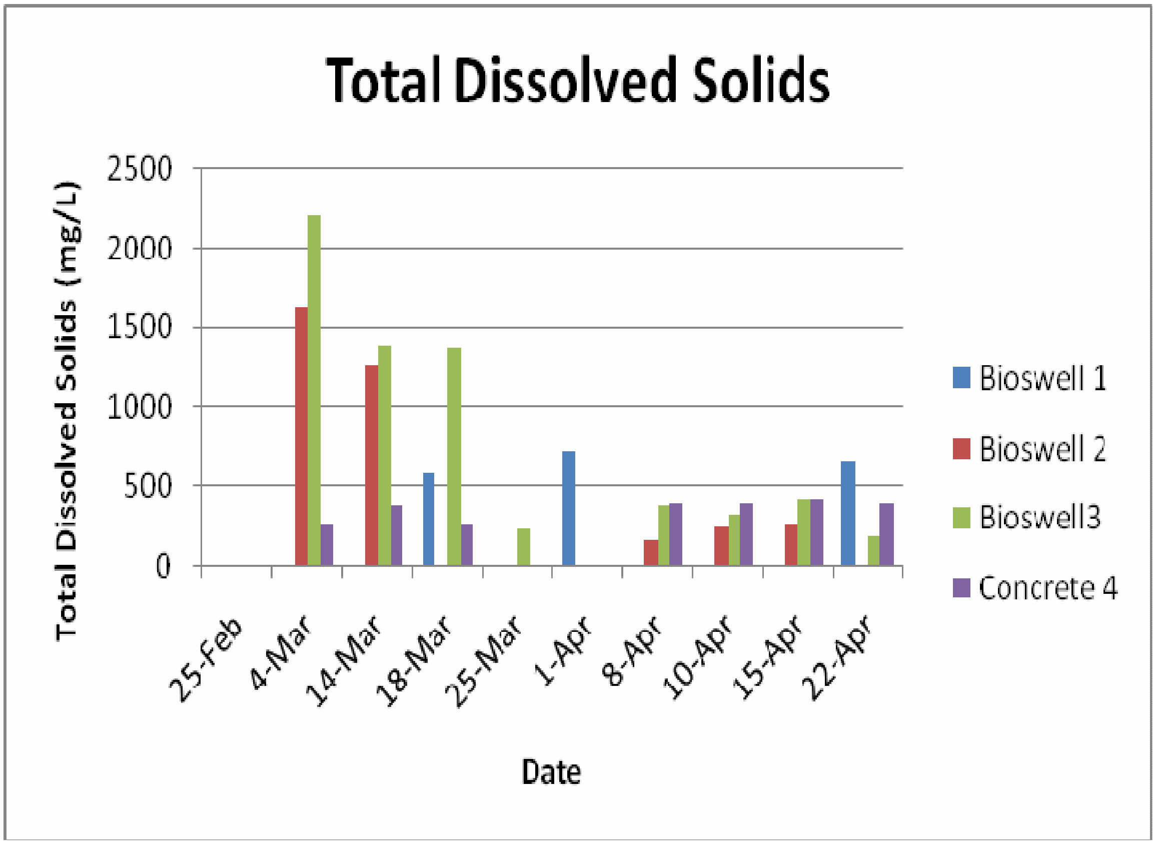

Figure 10. Total Dissolved Solid for sites 1 to 4 from February 25, 2009 to April 22, 2009. Some data was not used due to shallow depths for the sensors to properly measure total dissolved solids.

Total dissolved solids (TDS) are the total weight of all solids that are dissolved in a given volume of water that can be trapped by a filter. It is an indicator of the potential buffering capacity of water. The average TDS for sites 1 to 4 is as follows: 675 mg/L, 649 mg/L, 609 mg/L, and site's 4 average is 348 mg/L (Refer to Table 10 and Figure 10). Higher water temperatures did not correlate to higher TDS levels at the fourth site. The main cause of this is because this site only contains groundwater.

The first site had slightly higher TDS. This could be attributed to the fact that it was at the beginning of the bioswell. There were snow events that occurred which would potentially contribute road slat to runoff as snowmelt occurred (Refer to Table 5). From February 26 to March 4 is when the greatest amount of snow fell during the sampling period. The greatest TDS was recorded on March 4, March 14, and March 18, when snow melting occurred. Bioswell site 1 collected surface runoff mainly from parking lots, so it would have the potential to have runoff with the greatest contribution from road salt. Also, the runoff selected had less of a chance to be filtered or to settle since it was at the beginning of the bioswell. The TDS measurements were the lowest at the end of the bioswell, which suggests that the bioswell was helping to filter out the contamination from salt that was put on the roads. It is hard to analyze and compare TDS with other water quality parameters that were tested because much of the TDS data are incomplete.

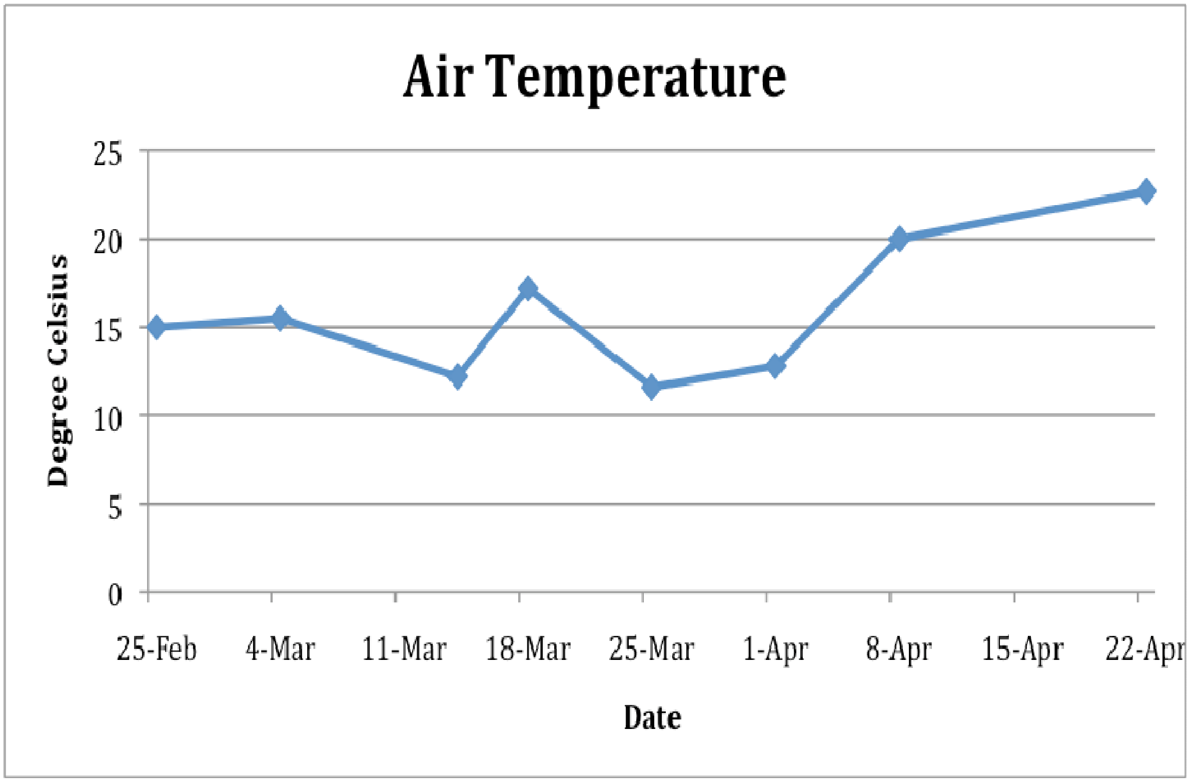

Figure 4. Air temperatures for the specific dates sampled.

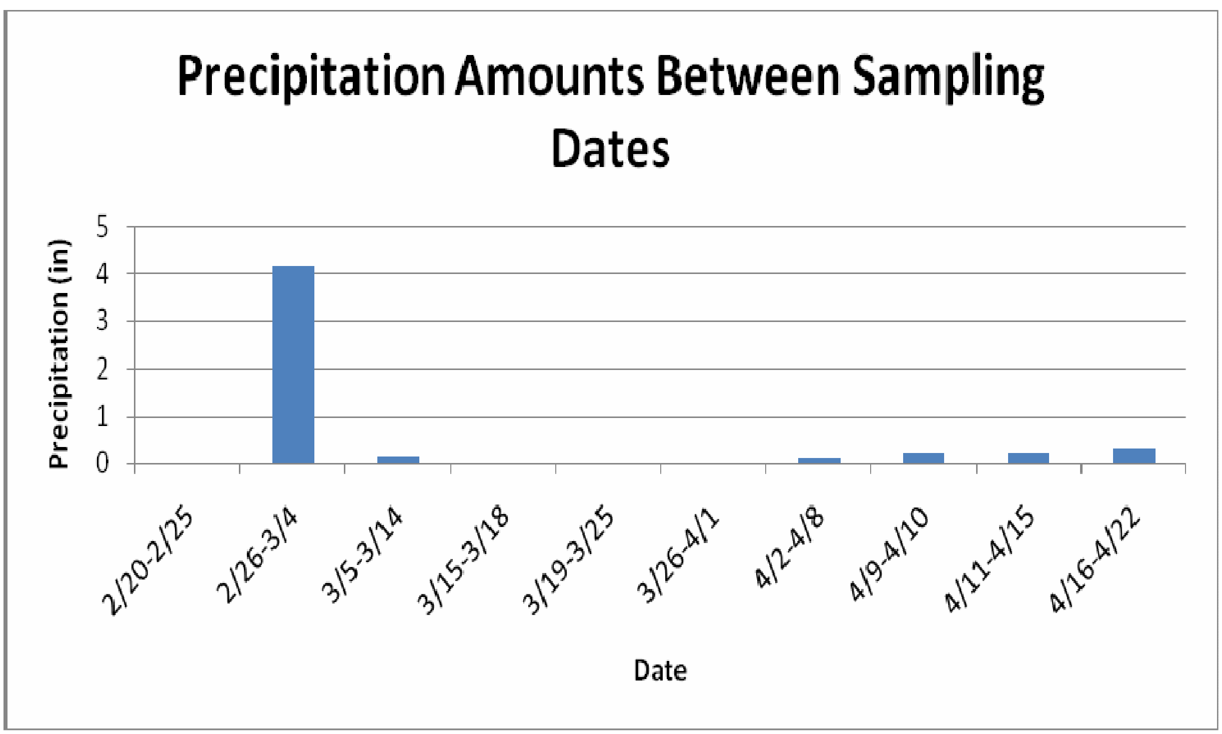

Figure 5. Snow and rain precipitation accumulations between sampling events from February 25, 2009 to April 22, 2009.

<u>Specific Conductance</u>

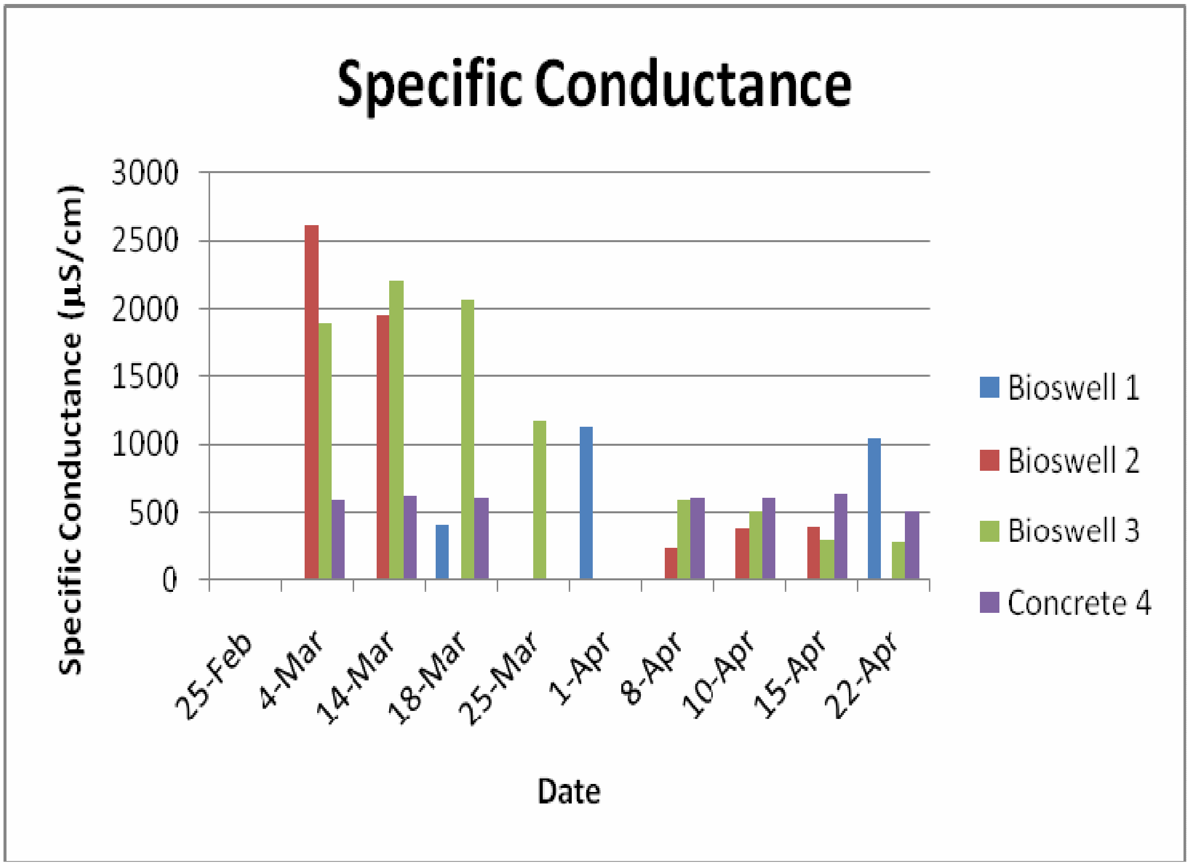

Figure 11. Specific Conductance for sites 1 to 4 from February 25, 2009 to April 25, 2009. Some data was not used due to too shallow depths for the sensors to properly measure specific conductivity.

Specific conductance measures how well water can conduct an electrical current. It is an indirect measure of dissolved solids, so it can be used to indicate the water quality level. Usually the more pure the water, the lower the specific conductance. Pristine conditions range from 0-200 µS/cm. Mid range and normal range for conductance is from 200 to 1000 µS/cm. Whereas, high conductance ranges from 1000 to 10,000 µS/cm indicate saline conditions. The geology and soil of the surrounding areas of the watershed can affect specific conductivity. In addition, runoff from fertilizers and road runoff can impact the specific conductance (Murphy 2007).

Automobile fluids and salts used to de-ice roads can affect specific conductance the most.

Average specific conductance values for sites 1-4 averages were as follows: 858 μS/cm, 376 μS/cm, 205 μS/cm, and 594 μS/cm respectively (Refer to Table 11 and Figure 11). Some data was not used because of too shallow depths for the sensors to properly measure specific conductivity. Site 4 had the most stable specific conductance readings reflecting the groundwater composition.

The range of specific conductance values at the sites sampled were all within normal ranges, expect for in the bioswell sites at the beginning of the testing dates. Since TDS and specific conductivity are highly correlated, these data have a similar pattern and are affected by similar contaminants. When there is road salt in the runoff, it can greatly raise specific conductance. But, as seen in the TDS results, the specific conductance levels went down at each bioswell site as the water made its way to the end of the bioswell. The supports the hypothesis that bioswell have a positive impact on water quality. As snow melt and associated runoff ended and the weather go warmer, the specific conductance measurements started to level off to more normal readings between 200 μS/cm and 600 μS/cm. Again however, much of this data is missing so it is harder to assess if there are any trends in the data and it is difficult to compare it to other water quality parameters tested.

Total Organic Carbon

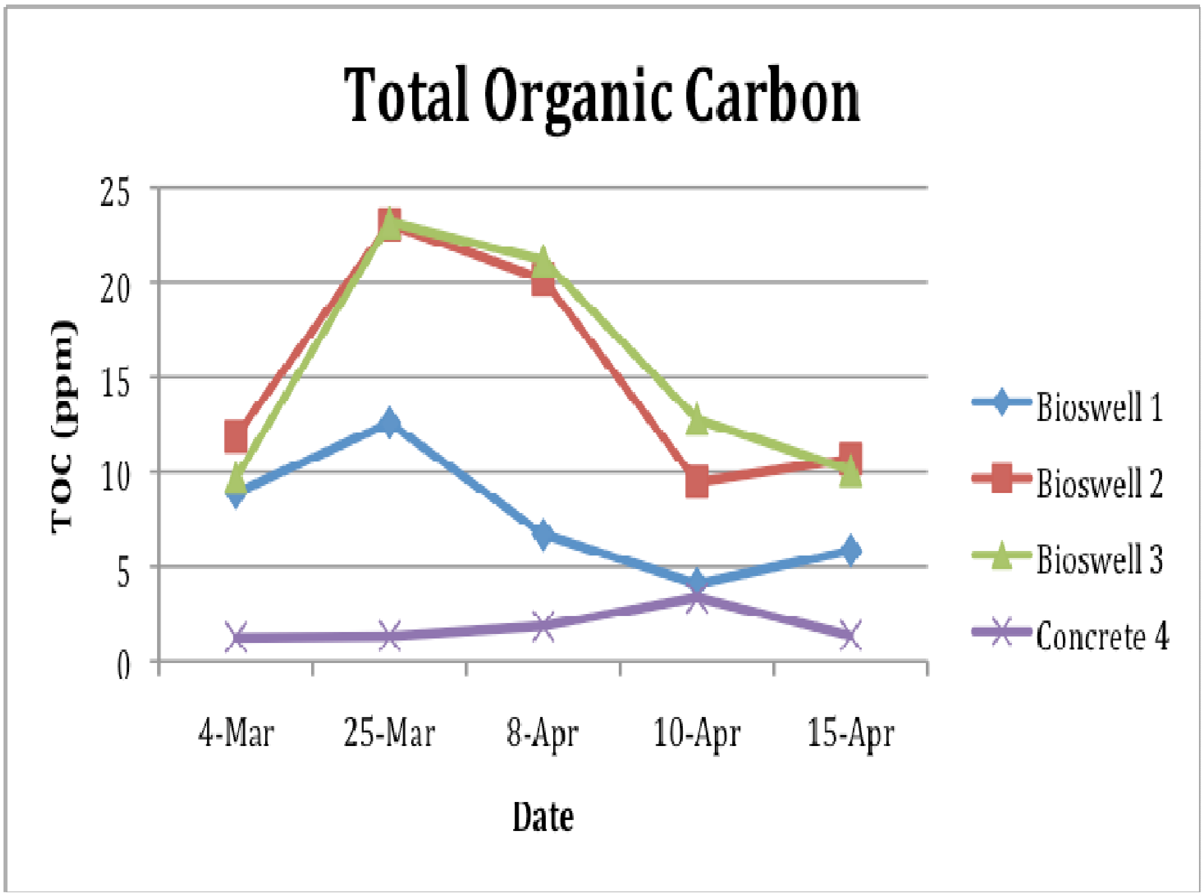

Figure 12. TOC for sites 1 to 4 sampled on: March 4, March 25, April 8, April 10, and April 15, 2009.

TOC plays an important facet in aquatic systems. It can affect nutrient cycling, biological availability, and chemical transport (Barber 2007). It is a more direct expression of the organic chemical content than COD. TOC is used to determine the number of carbon-containing compounds in a source, but does not specify the source. The larger the carbon or organic content, the more oxygen is consumed. Factors affecting TOC are vegetation and climate. A high organic content means an increase in the growth of microorganisms, which contributes to the depletion of oxygen supplies. For the purpose of this study TOC and COD are also used to determine the amount of oil by comparing the ratios.

It has been found that there is a strong correlation (R2=.9) between COD and TOC, when these aggregate organic constituents in oil and grease were found. A linear mathematical relationship was derived and for highway runoff it determined to be the best method to estimate oil and grease mean concentrations (Stenstrom and Kayhanian 2005). Measuring for oil by comparing TOC and COD is much more accurate than measuring for oil directly. When oil is measured directly it tends to not produce accurate results because oil adheres to tubing and sample bottle surfaces (Denton 2006). This is because of oil's physical property of adhering to particles, litter and other materials which accumulate and then are released. Higher readings are likely to be found when sampling from discrete sources and concentrations tend to be high in commercial areas (Denton 2005). This method also includes organic compounds or oxygen demanding compounds that are not oil and grease.

Sites 1-3 TOC averages were 7.64 ppm, 15.1 ppm, and 15.4 ppm respectively (Table 12 and Figure 12). Site 4 had the least amount of TOC with an average reading of 1.8 ppm. Site one had the least amount of TOC for the bioswell, but these levels increased in sites 2 and 3, which shows the bioswell is effective at increasing total organic carbon. One reason for this is these sites have more runoff coming from wetland areas. Overall, these readings decreased in later sampling dates, even though plant activity was increasing. Water can support more wildlife since there is more oxygen in the water.

<u>Chemical Oxygen Demand</u>

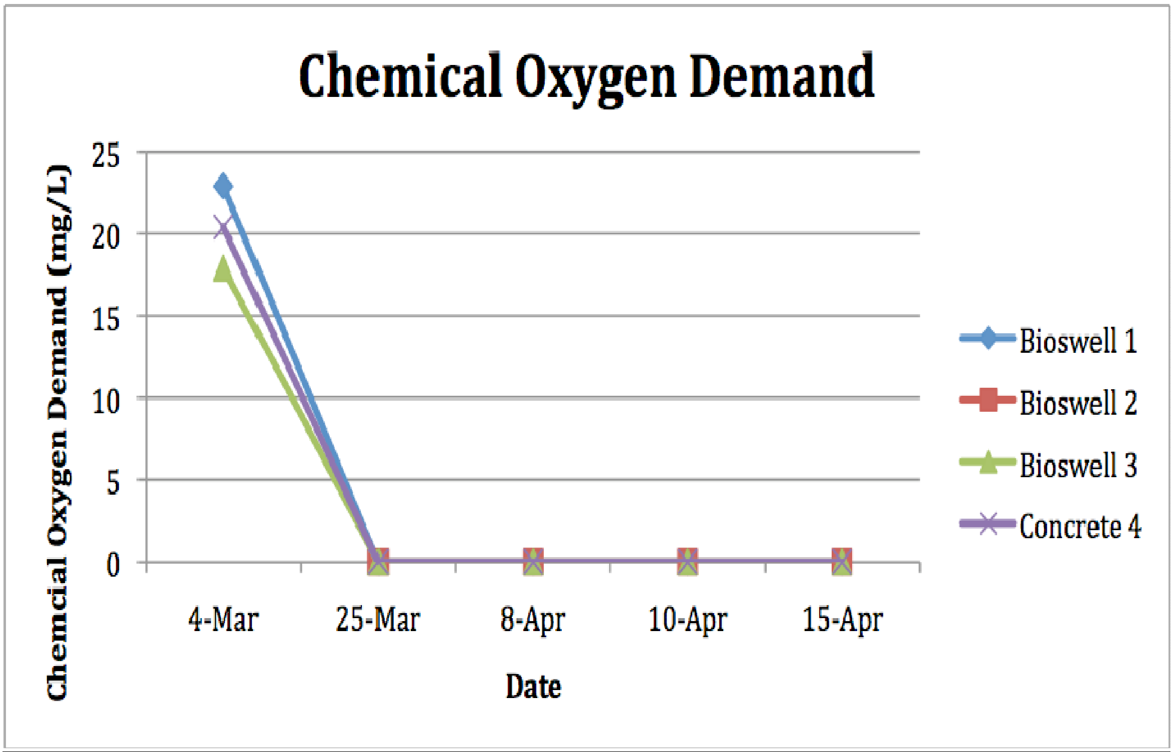

Figure 13. COD for sites 1 to 4 sampled on: March 4, March 25, April 8, April 10, and April 15, 2009.

COD is the amount of oxygen required to oxidize the organic and inorganic matter in wastewater. It measures the chemical oxidation of the wastewater by a strong oxidizing agent in an acid solution. TOC and COD measure similar properties. COD measures the tendency to react to oxygen. The two are related depending on the form of the carbon (Stenstrom 2005). Chemical oxygen demand does not distinguish between biologically available and inert organic matter like Biological Oxygen Demand (BOD) would. It measures the total quantity of oxygen required to oxidize all organic material into carbon dioxide and water.

On the first date of sampling there was high oxygen demand. But, all the later readings showed there wasn't any or there was less than 5 mg/L. This is mainly due to the increase in plant activity and other organic matter in the system. So the bioswell is effective at maintaining adequate amounts of oxygen in the water for wildlife since there isn't a high demand for it. But, the readings could tend to be quite high during colder temperatures when plant activity is low.

At the first sampling date there may have been higher than normal oil concentrations in the water. But after that date, COD and TOC were at opposite ends of the spectrum, which suggests that the bioswell oil products are being consumed or converted. However, oil runoff is impacted by other factors, like the presence of other chemicals, the size of the receiving body of water, and the frequency and duration of the discharge.

Limitations

There were several limitations that existed in this study. When the site was first surveyed in the fall there was much more water and the bioswell was saturated the entire length. However, during the winter and the beginning of spring when sampling occurred, there were only certain areas that were saturated for the majority of the time. During these months the bioswell was only saturated after a major rain event occurred on April 10th. Therefore, water leaving the bioswell, going toward Salt Creek, could not be measured since there was usually not enough water.

To compound this issue, it was an especially dry winter. During March, when the majority of the water sampling was done, it was the 7th driest March in the last 123 years in Nebraska. It would be interesting to compare the water quality from samples that are taken through the wet season or when wetter conditions were more prevalent. In addition, the results would have been more interesting if there were more samples taken after rain events.

Another limitation that could be easily fixed is measuring for specific conductance and total dissolved solids properly. If the water was not deep enough the hydrolab could not determine these parameters and instead had near zero readings. This problem was especially prevalent at the first site, since the water was normally shallow here. To fix this problem a separate container with water from the site should have been used to assure there was an adequate depth for the sensors to be fully covered and give an accurate reading.

Also, it was not discovered until later in the study that the water from the concrete drainage site was groundwater. It was assumed that it was surface water runoff. This changed the original project. To improve the study a different concrete lined drain in the area, that contains surface water, should be sampled instead. Lastly, samples were taken within an eight-week time period, which limits the extent to which the conclusions from this study can be transferred to predicting long-term trends in the study area.

Chapter V. Conclusion

Bioswells can be an effective means of protecting some surface water quality from runoff contamination, particularly pertaining to oxygen demand, total organic carbon, and specific conductance. High values for DO, TOC and specific conductance at the bioswell sites in the beginning of the testing dates in February and early March were caused by road salt runoff. But, these levels progressively got lower at each sample site as it was filtered throughout the bioswell.

Overall, the underground concrete pipe had more stable readings in all the water quality parameters tested. This was because this site was supplied entirely with groundwater. This site also had much higher water temperature that potentially affected the wildlife in the pond into which the pipe drained. The duckweed could have been attributed to the warmer water. The duckweed in the pond could harm wildlife if it becomes too excessive. But at the same time, the pond provides habitat for Leopard frogs (*Rana Pipiens*), which aren't found anywhere else in the area. However, the two drainage areas cannot be closely compared since the concrete lined drainage ditch comes completely from a groundwater source and the bioswell water comes mainly from surface water runoff.

In order to keep the bioswell from being an effective means to increase water quality it is important for the bioswell to be maintained. Where the bioswell flowed parallel to the student lot, there was trash covering the bioswell. This trash mainly originates from the students and the other business lots that are adjacent to the bioswell on the other side. Although the bioswell prevents trash from getting into other streams and rivers, it must be picked up from the bioswell site so it doesn't affect the wildlife, impact water quality, or reduce the aesthetics of the bioswell. It is suggested that there are continued testing of the sites to see if further trends can be interpreted and how the results differ throughout the seasons.

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Appendix

Data tables for graphs in results section of paper

**NM denotes Not Measured*
**TSM denotes Too Shallow to Measure with sensors*
** HOB denotes Hydrolab Out of Batteries*
**NW denotes No Water at site*

Table II.

Dissolved Oxygen (ppm)				
	Bioswell 1	**Bioswell 2**	**Bioswell 3**	**Concrete 4**
25-Feb	5.0	5.6	NM	NM
4-Mar	6.0	11	18	5.5
14-Mar	7.4	7.3	18	4.1
18-Mar	6.4	NW	9.4	5.3
25-Mar	3.4	3.7	5.5	3.8
1-Apr	6.5	NW	HOB	HOB
8-Apr	4.9	3.0	7.9	5.8
10-Apr	7.0	7.1	6.7	4.4
15-Apr	5.1	3.3	6.6	4.6
22-Apr	8.2	3.4	10	7.3
Average	6.0	5.5	10	5.1
Max	8.2	11	18.4	7.3
Min	3.4	3.0	5.5	3.8

Table III.

Water Temperature (degrees Celsius)				
	Bioswell 1	**Bioswell 2**	**Bioswell 3**	**Concrete 4**
25-Feb	14	19	NM	NM
4-Mar	13	3.8	8.9	19
14-Mar	4.4	2.8	3.5	19

18-Mar	10.3	NW	13	19
25-Mar	17	12	14	21
1-Apr	7.2	NW	HOB	HOB
8-Apr	21	18	17	22
10-Apr	13	5.9	7	21
15-Apr	16	10	12	19
22-Apr	13	23	20	21
Average	13	12	12	20
Max	21	22	20	22
Min	4.4	2.8	3.5	19

Table IV.

Air Temperature (degrees Celsius)	
25-Feb	15
4-Mar	15.5
14-Mar	12.2
18-Mar	17.2
25-Mar	11.6
1-Apr	12.8
8-Apr	20
10-Apr	12.8
15-Apr	19.5
22-Apr	22.7
Average	15.9
Max	22.7
Min	11.6

Table V.

Total Precipitation Between Sampling Events (in)			
	Snow (inches of water)	**Rain**	**Total**
2/20-2/25	0	0	0
2/26-3/4	4	0.16	4.16
3/5-3/14	0	0.15	0.15
3/15-3/18	0	0.01	0.01
3/19-3/25	0	0.02	0.02
3/26-4/1	0	0	0
4/2-4/8	0	0.12	0.12

4/9-4/10	0	0.2	0.2
4/11-4/15	0	0.22	0.22
4/16-4/22	0	0.3	0.3

Table VI.

pH				
	Bioswell 1	**Bioswell 2**	**Bioswell 3**	**Bioswell 4**
25-Feb	8.9	8.5	NM	NM
4-Mar	5.8	5.0	7.6	6.5
14-Mar	5.9	5.8	6.6	5.6
18-Mar	6.0	NW	6.1	5.6
25-Mar	6.0	6.1	6.5	6.1
1-Apr	7.1	NW	HOB	HOB
8-Apr	6.7	6.7	7.3	6.6
10-Apr	7.1	6.8	6.4	6.1
15-Apr	6.9	10	7.3	6.3
22-Apr	6.9	6.9	7.4	6.2
Average	6.7	7.0	6.9	6.1
Max	8.9	10	7.6	6.6
Min	5.8	5.0	6.1	5.6

Table VII.

Alkalinity (mg/L)				
	Bioswell 1	**Bioswell 2**	**Bioswell 3**	**Bioswell 4**
25-Feb	NM	NM	NM	NM
4-Mar	NM	NM	NM	NM
14-Mar	NM	NM	NM	NM
18-Mar	NM	NM	NM	NM
25-Mar	97	138	108	134

1-Apr	406	NW	131	134
8-Apr	196	165	98	152
10-Apr	68	114	82	152
15-Apr	255	248	99	130
22-Apr	283	159	114	120
Average	218	165	105	137
Max	406	248	131	152
Min	68	114	82	120

Table VIII.

Water Depth (cm)				
	Bioswell 1	**Bioswell 2**	**Bioswell 3**	**Concrete 4**
25-Feb	6.5	6.5	NM	NM
4-Mar	5.6	7.3	16	7.3
14-Mar	11	10.8	6.3	3.3
18-Mar	4.6	0.0	20	6.1
25-Mar	3.1	10	19	6.5
1-Apr	4.9	0	17	7.8
8-Apr	4.2	11	24	8.3
10-Apr	3.5	6.5	26	6.3
15-Apr	2.9	12	32	8.4
22-Apr	11	4.5	14	7.9
Average	5.8	6.8	19	6.9
Max	10	12	32	8.4
Min	2.9	0	6.3	3.3

Table IX.

Width of Stream (cm)				
	Bioswell 1	**Bioswell 2**	**Bioswell 3**	**Concrete 4**
25-Feb	NM	NM	NM	NM
4-Mar	57.2	58.4	20.9	96.5
14-Mar	100.3	292	224	92.7
18-Mar	16.5	0	199	99.1
25-Mar	30.2	330	309	87.6

1-Apr	47.0	0	258	101
8-Apr	52.1	371	318	103
10-Apr	60.6	934	323	91.4
15-Apr	57.9	467	338	92.7
22-Apr	55.9	338	340	103
Average	53.1	310.2	259	96.2
Max	100.3	935	340	103
Min	16.5	0	20.9	87.6

Table X.

Total Dissolved Solids (mg/L)				
	Bioswell 1	**Bioswell 2**	**Bioswell 3**	**Concrete 4**
25-Feb	NM	NM	NM	NM
4-Mar	TSM	1626	2201	243
14-Mar	TSM	1263	1390	374
18-Mar	574	NW	1374	248
25-Mar	TSM	TSM	225	TSM
1-Apr	720	NW	HOB	HOB
8-Apr	TSM	156	378	387
10-Apr	TSM	233	318	388
15-Apr	TSM	256	407	407
22-Apr	663	TSM	172	391
Average	675	649	609	348
Max	759	1950	1390	407
Min	574	156	172	243

Table XI.

Specific Conductivity (uS/cm)				
	Bioswell 1	**Bioswell 2**	**Bioswell 3**	**Concrete 4**
25-Feb	NM	NM	NM	NM
4-Mar	TSM	2620	1900	593
14-Mar	TSM	1951	2215	625
18-Mar	414	NW	2067	612
25-Mar	TSM	TSM	1170	TSM

1-Apr	1130	NW	HOB	HOB
8-Apr	TSM	224	588	603
10-Apr	TSM	365	503	606
15-Apr	TSM	400	277	636
22-Apr	1040	TSM	265	510
Average	858	1140	1140	594
Max	1130	2620	2230	636
Min	411	224	265	510

Table XII.

Total Organic Carbon (ppm)				
	Bioswell 1	**Bioswell 2**	**Bioswell 3**	**Concrete 4**
4-Mar	8.9	12	9.7	1.3
25-Mar	13	23	23	1.3
8-Apr	6.7	20	21	1.9
10-Apr	4.1	9.5	13	3.4
15-Apr	5.9	10.1	10.0	1.4
Average	7.6	15	15	1.8
Max	13	23	23	3.4
Min	4.1	9.5	9.7	1.3

Table XIII.

Chemical Oxygen Demand (mg/L)				
	Bioswell 1	**Bioswell 2**	**Bioswell 3**	**Concrete 4**
4-Mar	22.9		17.9	20.4
25-Mar	<5.0	<5.0	<5.0	<5.0
8-Apr	<5.0	<5.0	<5.0	<5.0
10-Apr	<5.0	<5.0	<5.0	<5.0
15-Apr	<5.0	<5.0	<5.0	<5.0