# GEOMORPHOLOGY AND WATER QUALITY OF THE WOLF CREEK BASIN WITHIN THE CANNON RIVER WATERSHED, MINNESOTA

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## INTRODUCTION

The Cannon River, a tributary of the Mississippi River located in southeastern Minnesota, has been the focus of many studies. However, there has been little scientific attention paid to most of the Cannon River's tributaries. Wolf Creek, a major tributary (107 $km^2$), has its headwaters just east of Lake Mazaska and flows through Fox Lake and Circle Lake. Below Circle Lake, the creek flows east, reaching the Cannon River just south of Dundas, MN (Figure 1). Along its course, three tributaries, numerous springs, and agricultural drainage tiles flow into the main channel. The drainage basin is highly impacted by agricultural uses; 91.3% of land (approx. 289,240 acres) is used for livestock or cropland (Minn. BWSR 1997). Along most of the farmland bordering Wolf Creek, there is a recognizable wooded riparian zone ranging from approximately 0.5 m to 50 m wide. The basin is also located between two growing towns, Northfield and Faribault (Figure 1), making it a potential area for future residential expansion.

The purpose of this paper is to characterize the geomorphology and water chemistry of the Wolf Creek basin, to propose possible major water sources for the creek, and to compare the creek's water quality indicators with the standards of the Minnesota Pollution Control Agency (MPCA).

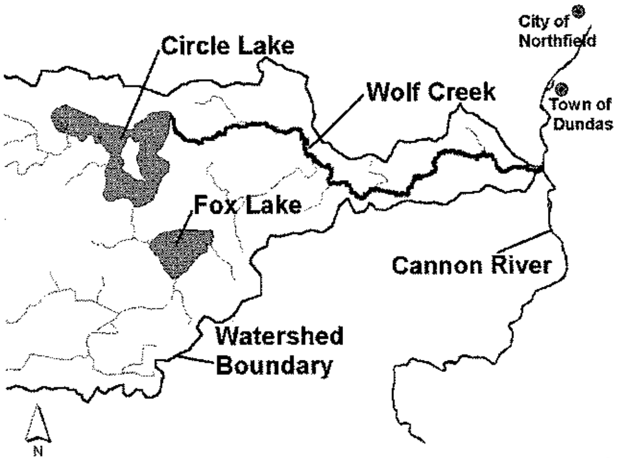


**Figure 1.** View of the Wolf Creek basin as it flows east from Circle Lake to its mouth. Faribault (southwest of Northfield) is not shown on this map.

## METHODS

**Field Work.** Five sites were chosen based on their accessibility along the stream and for their representation of three settings: wooded riparian zones, open pastures, and ditched areas. At each site, a cross-section was constructed using an automatic level and stadia rod, and a water sample was taken. Water samples were also taken at two other locations along the stream, as well as at Circle Lake, a private water well, an agricultural drainage tile, a tributary and two shallow bedrock springs (Figure 2). GPS points were recorded using a Trimble GeoExplorer II unit. In addition, velocity and depth measurements were taken on two dates at each cross-section location. Salinity, temperature, conductivity, and pH were measured at all locations. A datalogger was installed at site WC-300 to record temperature, conductivity, salinity, and water depth. This information was downloaded on two dates during the study period.

**Lab Work.** All water samples were tested for nitrite, nitrate, and phosphate using a HACH Datalogging Colorimeter (Hach 1997), and underwent atomic absorption analysis for calcium content. In addition to nutrient tests, the samples from sites WC-400a, WC-500, and WCS-4 (Figure 2) were tested for fecal coliform. Maps and statistical calculations were completed using ArcView GIS version 3.2 and Microsoft Excel '97.

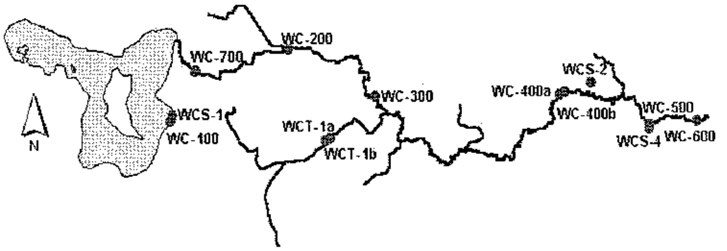


**Figure 2.** Sample sites from Circle Lake to the mouth of the Cannon River.

## RESULTS (refer to Table 1 for all geochemical and discharge data)

Cross-sections from the wooded riparian zones and open pasture have variable channel shapes. These cross-sections show that each area has one steep bank and one gentle bank, whereas the ditched cross section (WC-700) has a distinct U-shape with two steep banks (Figure 3). Discharge measurements demonstrated two important trends: that discharge almost doubled between Circle Lake and the Cannon River, and that it decreased continuously throughout the study period (Figure 4 and Table 1). The wooded riparian buffers are discontinuous throughout the basin. Within each buffer of 100 m, 20 m, and 2 m widths, there is 38.8%, 54.8%, and 78.5% tree cover, respectively. GIS data show that the stream's gradient increases drastically towards the mouth. The creek's sinuosity is 1.78. Because this value is greater than 1.5, Wolf Creek is considered a meandering stream (Leopold, et al., 1964).

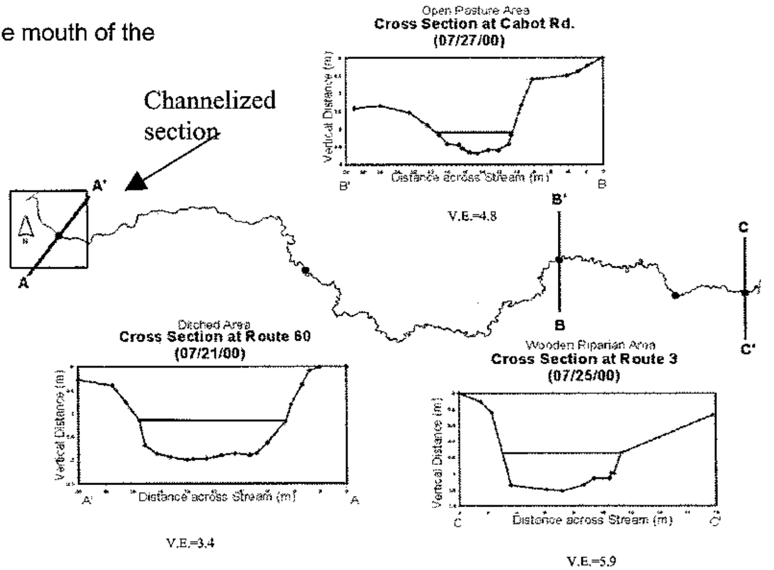


**Figure 3.** Cross-Sections taken along Wolf Creek. Each diagram represents a different setting. (V.E. - Vertical Exaggeration.)

The salinity value for all but one of the creek samples was 0.2 ppt. Salinity of the well, drainage tile, tributary, and springs was 0.4 ppt. The average temperature of the stream was 23.8 °C, while temperature of

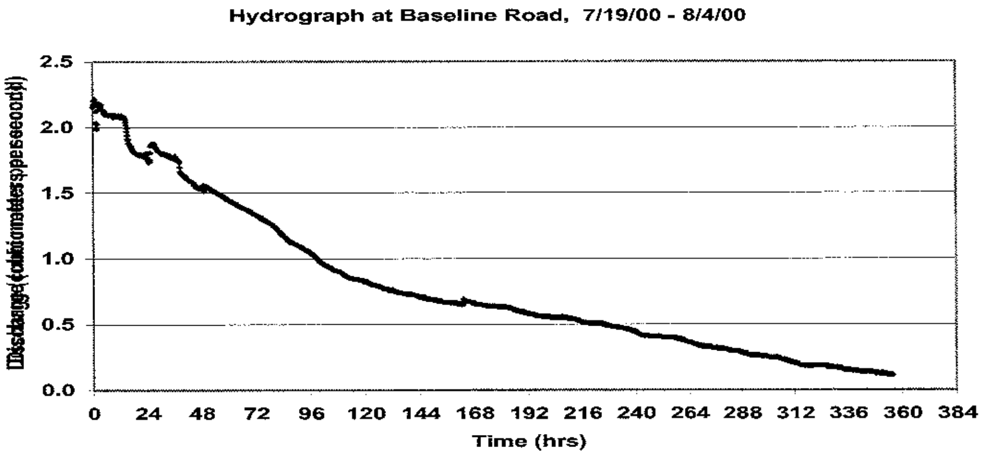
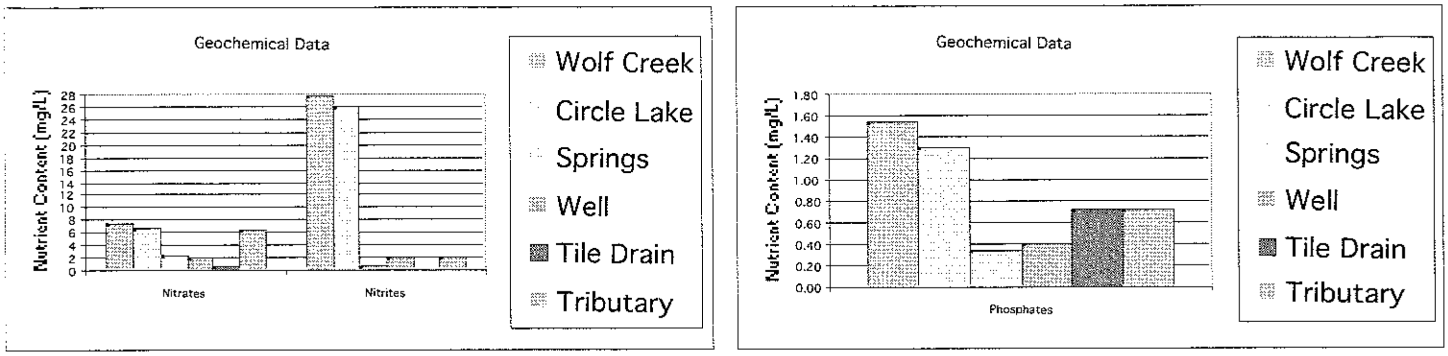


**Figure 4.** Discharge decreased continuously throughout the study period.

**Figures 5 and 6**. Average nutrient levels of Wolf Creek, Circle Lake, springs, well, tile drain, and tributary



the subsurface waters averaged 12.7 °C. Conductivity of the creek samples ranged from 300 µS to 400 µS, while conductivity of the other samples ranged from 530 µS to 900 µS. The calcium concentration of the creek samples increased from 9.0 mg/L at the westernmost site to 11.1 mg/L at the easternmost site; Ca concentration of the spring and well samples averaged 16.6 mg/L; the tile drain sample was much higher at 34 mg/L. The pH values for the lake and creek samples ranged from 8.4 to 9.6. The pH value for the well, drainage tile, tributary, and springs were 7.5, 8.2, 8.0, and 8.1, respectively. Also, the pH in the stream was higher near Circle Lake and decreased as it flowed downstream. Nitrite, nitrate, and phosphate values are summarized in Figures 5 and 6 and Table 1. The coliform value at site WC-400a was 7600 cfu/100 mL, while WC-500 was 9400 cfu/100 mL. The coliform value for the spring at site WCS-2 was 100 cfu/100 mL.

**Table 1 Geochemical Data**. Summary of geochemical analysis of all water samples taken beginning at Circle Lake and moving downstream. Table is sorted first by date then by distance from Circle Lake. Calcium concentrations not included in table.

| Location | Distance (km)* | Date | Nitrates (mg/L) | Nitrites (mg/L) | Phosphates (mg/L) | Salinity (ppt) | Conductivity (mS) | Temp °C | pH | Q ($m^3$/sec) |
|---|---|---|---|---|---|---|---|---|---|---|
| WC-300 | 3.10 | 07/20/2000 | NT | NT | NT | 0.2 | 315.7 | 24.5 | NM | NM |
| ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ |
| WC-700 | 0.64 | 07/21/2000 | NT | NT | NT | 0.2 | 310.6 | 23.4 | NM | 1.50 |
| WC-300 | 3.10 | 07/21/2000 | NT | NT | NT | 0.2 | 309.4 | 25.1 | NM | 1.60 |
| WC-500 | 15.71 | 07/21/2000 | NT | NT | NT | 0.2 | 352.4 | 21.2 | NM | 2.71 |
| ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ |
| WC-100 | 0 | 07/24/2000 | 6.7 | 25.9 | 1.30 | 0.2 | 310.2 | 23.3 | 8.6 | NM |
| WCS-1 (W) | 0.01 | 07/24/2000 | 2.0 | 1.9 | 0.40 | 0.4 | 725.0 | 14.1 | 7.5 | NM |
| WC-700 | 0.64 | 07/24/2000 | 7.7 | 25.3 | 1.57 | 0.2 | 302.7 | 24.3 | 9.2 | NM |
| WC-200 | 2.62 | 07/24/2000 | 7.4 | 28.1 | 1.52 | 0.1 | 302.4 | 24.5 | 9.6 | NM |
| WC-300 | 3.10 | 07/24/2000 | 6.9 | 25.2 | 1.51 | 0.2 | 313.5 | 24.1 | 9.3 | NM |
| WC-400a | 12.91 | 07/24/2000 | 6.8 | 28.1 | 1.66 | 0.2 | 336.6 | 23.0 | 9.1 | NM |
| WCS-2 (S) | 13.75 | 07/24/2000 | 0.9 | 1.0 | 0.34 | 0.4 | 738.0 | 9.0 | 8.0 | NM |
| WCS-4 (S) | 15.71 | 07/24/2000 | 4.0 | 0.5 | 0.33 | 0.4 | 530.0 | 10.2 | 8.2 | NM |
| WC-500 | 15.71 | 07/24/2000 | 7.6 | 29.8 | 1.43 | 0.2 | 346.6 | 23.7 | 9.1 | NM |
| WC-600 | 16.70 | 07/24/2000 | 8.7 | 29.1 | 1.37 | 0.2 | 358.6 | 23.5 | 9.1 | NM |
| ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ |
| WC-600 | 16.70 | 07/25/2000 | NT | NT | NT | NM | NM | NM | NM | 1.04 |
| ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ |
| WC-300** | 3.10 | 07/27/2000 | NT | NT | NT | 0.2 | 325.8 | 23.8 | NM | 0.70 |
| WCT-1a (T) | 3.49 | 07/27/2000 | 0.6 | 0.0 | 0.73 | 0.4 | 878.0 | 17.4 | 8.2 | NM |
| WCT-1b (Tr) | 3.49 | 07/27/2000 | 6.5 | 2.0 | 0.72 | 0.4 | 716.0 | 18.5 | 8.0 | NM |
| WC-400b** | 13.02 | 07/27/2000 | 7.7 | 27.6 | 1.70 | 0.2 | 362.8 | 23.2 | 8.8 | 0.65 |
| ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ | ◆◆◆ |
| WC-100 | 0 | 07/31/2000 | NT | NT | NT | 0.2 | 314.2 | 24.8 | 8.9 | NM |
| WC-700 | 0.64 | 07/31/2000 | NT | NT | NT | 0.2 | 315.6 | 25.7 | 8.9 | 0.21 |
| WC-400b | 13.02 | 07/31/2000 | NT | NT | NT | 0.2 | 358.4 | 22.5 | 8.5 | 0.36 |
| WC-500 | 15.71 | 07/31/2000 | NT | NT | NT | 0.2 | 381.7 | 23.8 | 8.7 | 0.67 |
| WC-600 | 16.70 | 07/31/2000 | NT | NT | NT | 0.2 | 393.3 | 23.3 | 8.4 | 0.59 |

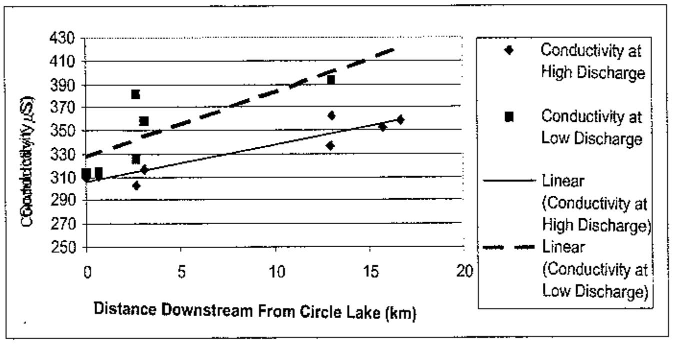
*Distance from Circle Lake (moving downstream)
**Experimental error - data inconclusive
W Well

NT Not tested on date indicated
NM Not measured on date indicated
Tr Tributary

S Spring
Q Discharge ($m^3$/sec)

# DISCUSSION

The ditched portion of Wolf Creek (County ditch 30) has a symmetrical cross-section, a dike, a bed of more even topography, and a lower sinuosity than the other areas of the stream. The discharge and geochemistry data suggest that there are significant downstream influxes of water in addition to the tile drain, tributary, well, and springs mentioned in this study. As discharge decreased over the period of the study, conductivity increased (Figures 4 and 7). Evidence of this is the near-doubling of discharge between the westernmost and easternmost sample sites downstream of Circle Lake. The increase in conductivity and calcium downstream suggests that groundwater is a major source of the water influx as groundwater is characteristically high in dissolved solids and calcium ions because of its interaction with the Paleozoic bedrock. Another trend is the simultaneous increase in nutrient levels and discharge as the creek flows downstream. Although groundwater nutrient levels are low, unobserved tile drains are a possible source of added nutrients. In fact, the neighboring basin of Rice Creek has tile drains with nitrate levels as high as 11.3 mg/L. The geochemical data provides three main factors that indicate poor water quality. First, Wolf Creek's pH levels are markedly high in comparison to the pH levels of neighboring Rice Creek and Heath Creek (Figure 8). The pH level also fails to meet the standard for natural surface water according to the MPCA (MPCA 2000). Noting that high pH is characteristic of eutrophic waters (Chapman 1992), and that Circle Lake has been declared hypereutrophic (MPCA 1999), it is reasonable to suggest that Wolf Creek's high pH, particularly the portion of the stream proximate to the lake, is rooted in biological conditions.



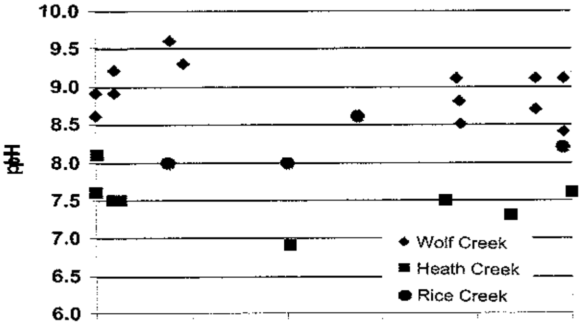


**Figure 8.** pH levels in Wolf Creek and neighboring streams.

Wolf Creek's high nutrient levels are the second indicator of its poor water quality. The nitrate and nitrite levels fail to meet state water quality standards for Wolf Creek's uses (Table 2). Surface water nitrate concentrations greater than 5.0 mg/L indicate pollution by human or animal waste or by fertilizer run-off (Chapman 1992). Since there are thirteen feedlots along Wolf Creek, its high nitrate levels are expected. The creek's high nitrite levels are likely explained by the idea that "unsatisfactory microbiological quality of water" leads to nitrite production (Chapman 1992).

**Table 2.** Wolf Creek does not meet the water quality standards for its uses, which are "Aesthetic Enjoyment and Navigation," "Industrial Consumption," "Agricultural Irrigation," and" Agricultural Livestock and Wildlife." Below are listed some water quality indicators. For each indicator, the most stringent standard among the different uses is given along with the creek's average values.

| | Water Quality Standards | Average Values of Creek Samples |
|---|---|---|
| pH * | 6.0-8.5 | 8.9 |
| Total Salinity (ppt)* | 0.1 | 0.2 |
| Fecal Coliform (cfu's/100mL)* | 400 | 8500 |
| Nitrate (mg/L)** | 5.0 | 7.4 |
| Nitrite (mg/L)** | 1.0 | 27.4 |

*(MPCA 2000)
**(Chapman 1992)

The third indication of poor water quality is the fecal coliform found in the two water samples, WC-400a (7600 cfu/100 mL) and WC-500 (9400 cfu/100 mL). These levels are approximately 20 times higher than the MPCA's standard for a clean agricultural stream.

## CONCLUSION

Overall, this study has led to a better understanding of the characteristics of Wolf Creek. Anthropogenic influences such as ditches, pastures, and tile drains have had an impact on the geomorphology and water quality of the creek. Based on the similarities in water chemistry between Wolf Creek and Circle Lake, this study recognizes the lake as a major source of water to the creek and therefore recognizes its direct effect on the creek's water quality. The discharge, conductivity, and calcium levels suggest that groundwater is another significant water source to the creek (through springs and dissemination of the groundwater). Tile drains are considered a source of water as well as a source of excess nutrients.

Wolf Creek is currently in a state of poor water quality. The creek fails to meet the MPCA standard concentrations of pH, nitrates, nitrites and fecal coliform for an agricultural, industrial, and recreational stream.

The time frame of this study was limited from mid-July to mid-August, 2000, during which time the study area received a negligible amount of precipitation. In order to have a more comprehensive grasp of the ongoing dynamics, characteristics, and processes of the Wolf Creek basin, a longer term study is needed. Such a study would take into account significant hydrological events and seasonal trends. It should also examine groundwater's influence on the creek and provide more information on the locations and chemistry of tile drains and any other agricultural land uses (e.g. pasture land). In addition, a future study should attempt to explain the high pH and current trophic levels of Circle Lake and Wolf Creek. Lastly, since this study focused only on the stretch from Circle Lake to the Cannon River, the upstream portion also requires future analysis.

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# A STUDY OF THE GEOMORPHOLOGY AND WATER QUALITY OF THE RICE CREEK WATERSHED, CANNON RIVER WATERSHED, MINNESOTA DURING JULY-AUGUST 2000

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## INTRODUCTION

The Rice Creek Watershed is located near the eastern margin of the Des Moines Lobe deposits, in southeastern Minnesota. Its headwaters are near I-35 and it is one of three tributaries that flow east into the Cannon River (Figure 1). The upper 2/3 of this watershed is drained by County Ditch 22 and the lower 1/3 is frequently referred to as "Spring Brook Creek". The Rice Creek drainage basin covers 18 km$^2$ of mainly agricultural land (81.2%) and lies between the cities of Northfield and Dundas in Rice County. The subsurface of the Rice Creek basin consists of a thin layer of glacial deposits overlying the Prairie du Chien dolomite and the Jordan Sandstone (a major aquifer that is the region's source of drinking water).

Rice Creek is the only creek in the Northfield area with water temperatures that are cool enough to support wild brook trout populations. The trout is a unique resource in the area because many of the other trout streams in southeastern Minnesota are concentrated near the Mississippi River. The trout population, however, can be potentially threatened by changes in land use and urban development because Rice Creek is located near two rapidly expanding towns. Thus, geological and environmental monitoring of this stream is of increasing importance. The purpose of this study is to characterize the geomorphology and water chemistry of the Rice Creek watershed, to document the possible sources of water influx into the stream, and to evaluate the stream's water quality conditions as they relate to the trout population of the creek.

## METHODS

**Field Work.** Between July and August of 2000, sixteen study sites were chosen along the stream in the two different observed settings: the ditched/channelized areas and the non-ditched areas (which included wooded riparian areas and residential areas) (Figure 1). At each site, a cross-section was constructed using an automatic level and stadia rod, and GPS points were recorded using a Trimble GeoExplorer II unit. A datalogger was installed in April 2000 at site RC-10 but its data were not available to be downloaded during the study period.

Due to the lack of water at all sixteen points, discharge was measured at only twelve sites between July 17th and July 26th. On the 26th of July, twelve water samples were also taken from various points along the stream, from two private water wells, and from two agricultural drainage tiles (Figure 1). Salinity, temperature, and conductivity were measured in these samples using a YSI30 SCT meter Model 30/10ft and pH readings were collected using an Orion Research pH meter Model SA250.

**Lab Work.** All water samples were tested for nitrate, nitrite, and phosphate using a HACH Datalogging Colorimeter (Hach 1997). Nitrate was measured using the High Range Cadmium Reduction Method 8039 and phosphate was measured using the PhosVer 3 Method 8048 (Standard Methods for the Examination of Water and Waste Water, cited in HACH 1997). Nitrite levels were tested using the High Range Ferrous Sulfate Method 8153 (McAlpine 1933, cited in Hach 1997). In addition to nutrient tests, the