2016

Final Report: Storm Water Pollutant Inputs to the Little Miami River via Yellow Springs and Birch Creeks

Audrey E. McGowin
Wright State University - Main Campus, audrey.mcgowin@wright.edu

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Storm Water Pollutant Inputs to the Little Miami River via Yellow Springs and Birch Creeks

FINAL REPORT
Audrey McGowin, Ph.D.
Department of Chemistry
Wright State University
Dayton, OH 45435

Summary of Significant Findings

This report describes the results of research performed with funds from the Sture Fredrik Anliot Grant Fund granted in March 2015. The primary aim of the project was to identify and measure various stormwater pollutant inputs to Yellow Springs Creek and Birch Creek into Glen Helen Nature Preserve and then into the Little Miami River in Greene County, Ohio from Spring 2015 to Winter 2016.

In order to better understand pollutant flow into Glen Helen and subsequently into the Little Miami River, three different types of samples were taken. One type of sample was a “grab” sample taken under normal flow conditions when there was no precipitation that day or the day before. The second type was grab samples taken immediately following a significant rain event (≥0.25 inches). The third type of sample was collected using runoff samplers deployed in a dry ditch that carries stormwater runoff or, in the case of Birch Creek, above the normal water level.

Three major types of analyses were performed on each sample including 1) *Escherichia coli* colony counts, 2) anion analysis, and 3) heavy metals analysis. Typical water quality parameters (dissolved oxygen, temperature, conductivity, and pH) were checked to confirm that they were within acceptable limits throughout the course of the study. There was no analysis of organic contaminants such as pesticides and persistent organic pollutants (POPs).

The most significant findings include the following:

*E. coli Contamination*

1) When there has been no precipitation, *Escherichia coli* at most sites in Yellow Springs Creek, Birch Creek, and the Little Miami River are near or above the “Ohio EPA Primary Contact Recreation Limit” for Class B waters of 161 colony-forming units (CFU) per 100 mL (30-day average) or 362 CFU/100 mL (7-day average), especially in summer. The wastewater treatment plant (WWTP) in winter months (October through May) when sterilization of the effluent is not required by their discharge (NPDES) permit contains *E. coli* counts significantly above Class B recreational levels. Fortunately, the results indicate that downstream from the WWTP in winter (Covered Bridge site on Yellow Springs Creek) the *E. coli* levels are below recreational limits.

2) Stormwater runoff into Glen Helen and the Little Miami River contains extremely high levels of *E. coli*, often many times the Class B Recreation Limits. The highest levels, often too numerous to count (TNTC, >10,000 CFU/100 mL), were measured in urban stormwater runoff.
in a ditch coming from storm drains on the south side of the Village of Yellow Springs. Water from this ditch flows under East Hyde Road into a tributary that flows into Glen Helen.

3) Also, there was an exceptionally high *E. coli* count in January 2016 in Yellow Springs Creek by the bridge at the bottom of the stairs from the Trailside Museum. This could have been from recent animal droppings directly into the creek inside Glen Helen or overflow from the sanitary sewer lift station at Highway 68.

4) *E. coli* showed a positive association with amount of precipitation. More *E. coli* was found with greater amounts of precipitation. The results demonstrate that animal wastes are washed from streets and lawns when it rains and they end up in area puddles, creeks, and streams. Contact with stormwater runoff could pose a serious health risk for people and pets, and especially children, who are more susceptible to infectious diseases.

**Nitrate Contamination**

5) The highest concentrations of nitrate (17-23 ppm, parts-per-million, mg/L) were measured in the normal grab samples in June 2015 in all of the streams. This corresponds to late spring/early summer application of agricultural fertilizers. These samples were taken when there had been no rainfall. Amounts measured were below the EPA Drinking Water Limit of 45 ppm as nitrate or 10 ppm as nitrate-N.

6) Nitrate levels did not correlate with precipitation. Nitrate measurements taken when there had been no rain were not significantly different than when there had been precipitation. This demonstrates how ubiquitous nitrate is in the environment. Some occurs naturally, some comes from atmospheric deposition (acid rain, etc.) and some from fertilizers and animal wastes.

7) Although nitrate concentrations did not correlate with rainfall, there was an exception for the dry ditch runoff samples taken from the ditch sampler near Highway 68. The highest nitrate concentration (17-21 ppm) in stormwater runoff samples was in the ditch that flows from downtown/north Yellow Springs into Yellow Springs Creek (August 31 and September 12). The timing of this occurrence corresponds with lawn fertilizer application in late summer/early fall.

8) Nitrate concentrations measured in Yellow Springs Creek entering Glen Helen at Highway 68 and in the Little Miami River at the Jacoby Road Canoe Launch are almost the same year round. Nitrate concentrations entering Glen Helen in Birch Creek show a similar trend but are slightly lower.

9) One notable exception with regard to nitrate is that the level of nitrate in Birch Creek at the stone crossing just above the confluence of Birch and Yellow Springs Creeks. The nitrate at this site is consistently about 17 ppm year round and is higher than the nitrate measured in Birch Creek as it enters Glen Helen at the Old Stage Road Bridge. This indicates that there is a source of nitrogen (as nitrate) that is seeping into Birch Creek somewhere between the Old Stage Road Bridge and the Stone Crossing upstream from the confluence of Yellow Springs and Birch Creeks.

10) The Yellow Springs Wastewater Treatment Plant (WWTP) is the highest contributor of nitrate to Yellow Springs Creek, although the concentration of nitrate did not exceed the EPA Drinking Water Limit of 10 ppm nitrate-N.
Phosphate Contamination

11) Phosphate input to Yellow Springs Creek detected from the WWTP in August 2015 (NPDES Violation) and January 2016 was also observed as a small increase at the downstream “Covered Bridge” site.
12) Phosphate was measured in runoff samples in September, October, and November in the urban runoff samplers. This supports the observations of nitrate measurements in the late summer and fall months when people and businesses are applying fertilizers to their lawns.

Strontium Metal

13) Strontium (Sr) was the only significant metal detected in the water samples, which was highest (1.2 parts-per-million) in the Little Miami River grab samples taken after a significant rainfall.
14) Low levels of Sr were found throughout Glen Helen, except for normal grab samples taken in the south glen in Yellow Springs Creek at the covered bridge site (July-October, 0.6-0.8 ppm) just before it flows into the Little Miami River. Since Sr in the wastewater treatment plant effluent ranged from 0.2-0.4 ppm, the strontium appears to be coming from a natural source, perhaps from the dissolution of limestone containing Sr in some areas.

NPDES Violation

15) The Morris Bean foundry pond runoff site was dry most of the time so only small amounts of sample could be retrieved at irregular intervals after rainstorms. According to their EPA Discharge Monitoring Report (DMR, outfall 1IN00095001), wastewater containing “treated process wastewater, non-contact cooling water, and storm water” is being discharged from the plant at a rate of between 50,000 and 100,000 gallons per day into the waste pond, yet there is seldom any overflow observed exiting the plant property in the effluent ditch that flows into Glen Helen. EPA has previously shown that this waste stream flows down sinkholes directly to groundwater.

These significant findings show that *E. coli*, nutrients (nitrate and phosphate), and the Morris Bean discharge site should continue to be monitored. Land use is the greatest indicator of stormwater quality. Efforts should be made to reduce *E coli* in urban stormwater runoff by reducing the amount of animal wastes, for example, encouraging village residents and visitors to Glen Helen to pick up after their pets. Nitrate concentrations in surface and groundwater need to be more fully investigated to determine the sources of higher-than-normal seeps of nitrogen that contribute to excess nutrient runoff into streams year round. It would also be useful to determine the atmospheric contribution of nitrogen by collecting and analyzing rainwater. The use of lawn fertilizers in the fall and agricultural fertilizers in the spring need to be reduced to bring down overall nutrient loadings to the Little Miami River.
Storm Water Pollutant Inputs to the Little Miami River via Yellow Springs and Birch Creeks

FINAL REPORT

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Introduction

Purpose and Scope

The rationale for this study was to assess various nonpoint pollutant source threats to the Little Miami River in and around Yellow Springs and Glen Helen Nature Preserve in Greene County, Ohio over the course of one year.

The Little Miami River is considered a State and National Scenic River that flows into the Ohio River. The Little Miami River is habitat for countless freshwater flora and fauna, is a source of drinking water for animals and people, and it provides a place for recreation. It also carries away treated and untreated wastewater along with farm, urban, and construction runoff. Since there are many users of this water source for drinking water, the criteria for drinking water were used to assess the quality of the water sources examined in this study as well as Ohio EPA limits for a Class B Recreational Waterway.

The list of analytes and their significance can be found in Table 1 in the Appendix. These include anions, toxic heavy metals, and the bacteria \textit{(Escherichia coli)} found in human and animal wastes that can contain disease-causing strains.

The anions, nitrate, nitrite, and phosphate are considered “nutrients” in that they supply food for the growth of algae in surface waters. As they are used up, the algae begin to die and are consumed by bacteria, which in turn use up available oxygen in the water. This condition is called anoxia and are responsible for the formation of “dead zones” where fish and other aquatic organisms cannot survive. Nitrate and phosphate discharged into Yellow Springs and Birch Creeks can end up as far away as the Gulf of Mexico. Last fall, a 650-mile long algae bloom formed in the Ohio River as a result of nutrient runoff (\textit{The Columbus Dispatch}, October 3, 2016). Algae blooms can contain blue-green algae that produce neurotoxins in “Harmful Algae Blooms” or HABs. Nutrient pollution is such a pervasive problem in Ohio that the Ohio Department of Health maintains a website to inform citizens of the locations and hazards of algae blooms in state lakes and rivers (\url{https://www.odh.ohio.gov/odhprograms/eh/HABs/algablooms.aspx}).

Heavy metals tend to precipitate in sediments and form areas that are toxic to fish and invertebrates. Over time, even very low concentrations of heavy metals in water can accumulate in sediments levels that are very toxic to aquatic organisms.
Escherichia coli, better known as E. coli, is a bacterium that is found in great numbers in human and animal feces. Its detection in water indicates that feces are being discharged into or deposited in surface waters or that it is being washed off land where feces are being deposited. While not all strains of E. coli cause disease, there is no safe level for drinking water. The State of Ohio has set various acceptable levels for E. coli contamination depending on the use.

Methods

Site Selection

The Glen Helen Nature Preserve receives flow from two different watersheds. Table 2 in the Appendix is a list of the sample sites selected including a description, sample code, and the GPS coordinates of each. A map of the study area is presented in the Appendix in Figure 1. Flow from the Yellow Springs Creek, with input from the Yellow Spring and Birch Creek, joins the Little Miami River near the bridge on Grinnell Road.

In order to better understand pollutant flow into Glen Helen and subsequently into the Little Miami River, three different types of samples were taken. One type of sample was a “grab” sample taken under normal flow conditions when there was no precipitation that day or the day before. The second type was grab samples taken immediately following a significant rain event (≥0.25 inches). The third type of sample was collected using runoff samplers.

Sampling locations were selected using judgmental sampling for all sites. For the deployment of stormwater collection devices, Unattended First Flush Grab Sample collectors were installed in dry ditches (ditch mount) or alongside Birch Creek above normal water flow (stream mount) at the locations listed as “RO” for runoff. These sites have flow only when there has been significant rain so only runoff was collected.

Sample Collection

Three types of samples were taken for analysis including “grab” sampling of flowing streams under normal conditions (no rain the previous 3 days) to establish a baseline, “grab” sampling of flowing streams just following a rain event (>0.25 inches), and samples taken from dry ditches that collect runoff by using deployed samplers. Grab samples are those collected directly from a water source with a cup connected to a pole. Samples were collected in pre-cleaned 125-mL polypropylene bottles and transported back to the laboratory in coolers to keep them chilled to at or near 4 °C to minimize microbiological activity. Once at the lab, 5-mL aliquot was removed for E. coli counts and the rest was placed in a refrigerator at 4 °C awaiting anion analysis. A second set of samples was collected in pre-cleaned 125-mL polypropylene bottles and transported back to the laboratory in coolers but these samples were filtered immediately and acidified to pH<2 with trace-metal grade nitric acid to preserve them for analysis of heavy metals.
The stormwater runoff samplers consisted of a 1-Liter HDPE (high-density polyethylene) bottle installed inside of a mounting tube attached to secure metal bracket. The bottle has a dome at the top to prevent debris from entering the bottle and a ball valve to shut off flow when the bottle is full. Bottles were installed prior to anticipated rain events and collected within hours of the conclusion of the rain event.

Baseline sampling under normal flow conditions was scheduled to occur monthly during the study period. Anticipation of a significant (> 0.3 inches) rain event triggered the deployment of the sample collection bottles into the sample collection devices that were installed in the dry ditches. As soon as the rain stopped and when it was safe to do so, the runoff sample bottles were retrieved and transported to the lab. Not all rain events were sampled. Additionally, immediately following the same rain events, grab samples were taken from the stream sites at many of the locations where normal flow sampling was also performed.

**Sample Analysis**

**Water Quality Parameters**

A YSI Professional Plus Multimeter (YSI Incorporated, Yellow Springs, OH 45387, USA) was used to measure typical water quality parameters (dissolved oxygen, temperature, specific conductivity, and pH) at each site when collecting grab samples.

*Escherichia coli* Counts

Aqueous samples were analyzed for *E. coli* and coliforms using 3M Petrifilm plates. Petrifilm is composed of a dehydrated agar rich in nutrients for supporting coliform growth. Each plate also contains a dye that reacts with an enzyme produced by *E. coli* to produce a blue color thus identifying it relative to the other coliforms, which appear pink. While this method can identify colonies of *E. coli*, it cannot identify the individual strains of bacteria.

One milliliter of sample was added to the dehydrated plate and the plates were incubated for two days at 37 °C. Results are reported as the average of Colony Forming Units (CFU) per 100 mL for two replicates of each sample.

**Anion Analysis**

Anion analysis (fluoride, chloride, nitrite, bromide, nitrate, phosphate, and sulfate) was performed by ion chromatography (IC) according to EPA Method 300.1, Determination of inorganic anions in drinking water by ion chromatography, Revision 1.0. A Dionex IC 1500 ion chromatograph with an AS40 autosampler were employed to separate and qualify the analytes. The chromatograph was outfitted with a Dionex IonPac AS22 anion-exchange column (4 x 250 mm) with a particle diameter of 65 μm and a matching Dionex AG22 guard column (4 x 50 mm). A Quality Assurance Standard, blanks, and 5-point calibration curves were used to obtain accurate results. All samples and standards were injected in duplicate.
Metals Analysis

Eleven environmentally relevant heavy metals (aluminum, arsenic, cadmium, chromium, copper, iron, lead, manganese, nickel, strontium, and zinc) were analyzed in each water sample according to USEPA Method 200.7. A Varian 700 ICP-OES inductively coupled plasma-optical emission spectrometer supplied with high-purity grade (99.99%) argon gas and an autosampler was used to determine metal concentrations in the acidified samples. A Quality Assurance Standard, blanks, and 5-point calibration curves were used to obtain accurate results. All samples and standards were analyzed in triplicate.

Results and Discussion

YSI Multimeter Water Quality Parameter Measurements

The YSI Multimeter water quality parameter measurements (dissolved oxygen, temperature, specific conductivity, pH) were all within expected and acceptable values. This indicates that the sites are, in general, of good water quality.

Escherichia coli Contamination

When there has been no precipitation, *Escherichia coli* in grab samples at most sites in Yellow Springs Creek, Birch Creek, and the Little Miami River are near or above the “Ohio EPA Primary Contact Recreation Limit” for Class B waters of 161 colony-forming units (CFU) per 100 mL (30-day average) or 362 CFU/100 mL (7-day average), especially in summer months. These results can be seen in Figure 2 in the Appendix. The wastewater treatment plant (WWTP) effluent, in winter months (October through May) when sterilization of the effluent is not required by their discharge (NPDES) permit, contains *E. coli* counts significantly above Class B recreational levels. Results from downstream of the WWTP indicate that the Covered Bridge site on Yellow Springs Creek *E. coli* levels are below recreational limits.

Stormwater runoff into Glen Helen and the Little Miami River contains extremely high levels of *E. coli*, often many times the Class B Recreation Limits. The grab samples taken after a significant precipitation event show that all runoff waters are above all recreational limits (Figure 3) with July runoff grab samples particularly high especially in Yellow Springs Creek as it enters Glen Helen. As can be seen in Figure 4, the highest levels, often too numerous to count (TNTC, >10,000 CFU/100 mL), were measured in urban stormwater runoff in a ditch coming from storm drains on the south side of the Village of Yellow Springs (EHR-RO). Water from this ditch flows under East Hyde Road into a tributary that flows into Glen Helen. These extreme levels are a year round occurrence.

Also, there was an exceptionally high *E. coli* count in January 2016 in Yellow Springs Creek by the bridge at the bottom of the stairs from the Trailside Museum. This could have been from recent animal droppings directly into the creek inside Glen Helen or overflow from the sanitary sewer lift station at Highway 68.
A comparison of *E. coli* entering Glen Helen in Yellow Springs Creek (Figure 5) and in Birch Creek (Figure 6) with precipitation amount shows that precipitation carries bacteria from streets, farmland, and lawns into the creeks. Here, the precipitation in inches is shown as blue diamonds. *E. coli* counts in the three different types of samples are shown as lines; the black lines are normal grab samples where there was no recent precipitation, the green lines are grab samples taken on rain days, and the red lines are the counts taken from the deployed runoff samplers that collected only runoff. The contamination levels are extremely high year round. Although there was no stormwater runoff collection device installed in the Little Miami River, Figure 7 shows that the same phenomenon occurs here as well as demonstrated with stormwater grab samples.

Figure 8 is a graph of *E. coli* counts with precipitation in inches. Although not particularly linear, there is a positive association of amount of precipitation with bacteria numbers. More *E. coli* was found with greater amounts of precipitation. The results demonstrate that animal wastes are washed from streets and lawns when it rains and they end up in area puddles, creeks, and streams. Contact with stormwater runoff could pose a serious health risk for people and pets, and especially children, who are more susceptible to infectious diseases.

*E. coli* die-off rates show that most bacteria can only survive for several hours but a few can survive for up to a few days in a stream even though they are nonculturable (Easton, et al, 2005). Lower temperatures were shown to have lower die-off rates for *E. coli* O157:H7, a known pathogenic strain that can be found in sewage contaminated waters. This study did not assess bacteria strains so it is now known if any of the samples from Yellow Springs Creek, Birch Creek, or the Little Miami River contained any pathogenic strains.

**Nitrate**

Nitrate is a pollutant that is known to migrate into groundwater and can sicken or kill livestock and harm infants causing “blue baby” syndrome since it interferes with the blood’s ability to carry oxygen. The EPA Drinking Water Limit is 45 ppm as nitrate or 10 ppm as nitrate-N.

Figure 9 shows nitrate concentrations along Yellow Springs Creek from north to south to the Little Miami River. Inputs from Birch Creek and the WWTP are included as reddish-colored bars. The Yellow Springs Wastewater Treatment Plant (WWTP) is the highest contributor of nitrate to Yellow Springs Creek, although the concentration of nitrate did not exceed the EPA Drinking Water Limit of 10 ppm nitrate-N. The input from the WWTP shows up as a higher nitrate level at the covered bridge site downstream. Nitrate in the Little Miami River tends to be slightly higher except for the contribution by Birch Creek (measured at the stone crossing just above the confluence of Birch and Yellow Springs Creeks, BCSC)). The nitrate at this site is consistently about 17 ppm year round and is higher than the nitrate measured in Birch Creek as it enters Glen Helen at the Old Stage Road Bridge (BCOSR). This indicates that there is a source of nitrogen (as nitrate) that is seeping into Birch Creek somewhere between the Old Stage Road Bridge and the Stone Crossing upstream from the confluence of Yellow Springs and Birch Creeks.

A comparison of nitrate levels with and without precipitation in Yellow Springs Creek entering Glen Helen at Highway 68 (HWY68) is shown in Figure 10. As in the previous figures, precipitation in inches is shown as blue diamonds. Nitrate concentration when there was no rainfall is shown as a
heavy black line, when there was significant rainfall as a heavy green line, and in the runoff samplers as a red line. Similarly, nitrate in Birch Creek (BCOSR) and in the Little Miami River at the Canoe Launch (LMR) show similar trends, although the overall nitrate in Birch Creek at Old Stage Road is lower. See Figures 11 and 12, respectively.

Nitrate levels did not correlate with precipitation at any site. Nitrate measurements taken when there had been no rain were not significantly different than when there had been precipitation. This demonstrates how ubiquitous nitrate is in the environment. Some occurs naturally, some comes from atmospheric deposition (acid rain, etc.) and some from fertilizers and animal wastes.

Although nitrate concentrations did not correlate with rainfall, there was an exception for the dry ditch runoff samples taken from the ditch sampler near Highway 68. The highest nitrate concentration (17-21 ppm) in stormwater runoff samples was in the ditch that flows from downtown/north Yellow Springs into Yellow Springs Creek (August 31 and September 12). The timing of this occurrence corresponds with lawn fertilizer application in late summer/early fall.

**Phosphate**

Phosphate (Figure 13) was only detected in the WWTP effluent in August 2015 and January 2016 and downstream at the covered bridge (YSCVB). The August level represents a violation of the NPDES permit limit of 1.5 mg/L weekly and 1.0 mg/L monthly. There is no limit for winter.

Phosphate was also measured at significantly high concentrations in runoff samples in September, October, and November in the urban runoff samplers (Figures 16-18). This supports the observations of nitrate measurements in the late summer and fall months when people and businesses are applying fertilizers to their lawns. This source is a contributor to the phosphorus loading of the Little Miami River in fall.

**Fluoride**

Fluoride (Figure 14(a)) from the Yellow Spring is a contributor to the Yellow Springs Creek, however it does not significantly increase the concentration of fluoride downstream. The Little Miami River is consistently higher in fluoride but it is not coming from Glen Helen waters. The fluoride is most likely coming from minerals deposits that are natural sources. The levels measures are all well below the EPA maximum contaminant level (MCL) of 4 ppm or mg/L.

**Sulfate**

Sulfate (Figure 14(b)) is found in higher levels coming from the WWTP and from the Yellow Spring. Both elevated levels are not above levels of concern and probably result from dissolution of natural deposits and the fact that the Village of Yellow Springs uses well water as their drinking water source. The Morris Bean foundry pond runoff site was dry most of the time so only small amounts of sample could be retrieved at irregular intervals after rainstorms. Sulfate concentrations were high in the few samples that were collected.
Chloride

An increase in chloride concentration can be seen in Figure 15 as Yellow Springs Creek flows from north to south. The major contributor is the WWTP and again an elevated level can be seen at the downstream site, the covered bridge (YSCVB). The chloride concentration in the Little Miami River is consistently lower.

Metals - Strontium

Strontium (Sr) was the only significant metal detected in the water samples, which was highest (1.2 parts-per-million) in the Little Miami River grab samples taken after a significant rainfall. Low levels of Sr were found throughout Glen Helen. Sr in the wastewater treatment plant effluent ranged from 0.2-0.4 ppm. Previous measurements of Sr in the Little Miami River at the Grinnell Road Bridge site and at the Jacoby Road Canoe Launch site have shown that the Little Miami River has much higher Sr levels than those found inside Glen Helen waters (unpublished data). Some of the area limestone deposits contain significant concentrations of Sr and since rainfall tends to be slightly acidic, it may be dissolving enough to cause an increase of Sr in runoff.

Morris Bean

According to their EPA Discharge Monitoring Report (DMR, outfall 1IN00095001), wastewater containing “treated process wastewater, non-contact cooling water, and storm water” is being discharged from the plant at a rate of between 50,000 and 100,000 gallons per day into the waste pond, yet there is seldom any flow observed exiting the plant property in the effluent ditch that flows into Glen Helen. EPA has previously shown that this waste stream flows down sinkholes directly to groundwater. Several attempts to obtain samples from the drainage ditch documented that there was no flow from the wastewater pond overflow. If waste water is flowing down a sinkhole on the Morris Bean property, it has the potential to contaminate area groundwater drinking water sources.

Conclusions

Land use is the greatest indicator of stormwater quality. Efforts should be made to reduce E. coli in urban stormwater runoff by reducing the amount of animal wastes, for example, encouraging village residents and visitors to Glen Helen to pick up after their pets. These significant findings show that E. coli, nutrients (nitrate and phosphate), and the Morris Bean discharge site should continue to be monitored. Nitrate concentrations in surface and groundwater need to be more fully investigated to determine the sources of higher-than-normal seeps of nitrogen that contribute to excess nutrient runoff into streams year round. It would also be useful to determine the atmospheric contribution of nitrogen by collecting and analyzing rainwater. Additionally, the use of lawn fertilizers in the fall and agricultural fertilizers in the spring need to continue to be reduced to bring down overall nutrient loadings to the Little Miami River.
Acknowledgments

Support for this project was provided by a grant from the Sture Fredrik Anliot Fund dedicated to the “improvement of water quality in the Little Miami River.” Additional funding was provided by the Department of Chemistry and the College of Science and Mathematics at Wright State University. The author would like to acknowledge Ms. Jessica McKinley for most of the data collection and sample analysis. Appreciation goes to William Kent and Gayle Gyure for allowing the use of their property as a runoff sample site. Gratitude goes to the staff of Glen Helen for input regarding sampling site selection and for allowing sampling access for many of the sites; Nick Boutis, George Bieri, and Ben Silliman. I would also like to “espresso” my appreciation to Dino’s Cappuccinos for providing logistics support and access to sustaining seasonal beverages for those cold and hot sampling days.

References


Reckhow, K and Stow, C., Monitoring design and data analysis for trend detection, Lake and Reservoir Management, 1990, 6(1): 49-60. They found that most of the data (monthly N, P, and specific conductance values) exhibited seasonal trends and inverse relations with flow.

“Toxic algae bloom now stretches 650 miles along Ohio River,” The Columbus Dispatch, October 3, 2016.


U.S. Environmental Protection Agency Method 300.1, Determination of inorganic anions in drinking water by ion chromatography, Revision 1.0, 1997.
Appendix
Table 1. Analytes and Their Significance

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dissolved oxygen (DO, mg/L)</strong></td>
<td>Suffocation of invertebrates and vertebrates will result from low values, depends on species</td>
</tr>
<tr>
<td><strong>Temperature (°C)</strong></td>
<td>Sharp temperature changes affect DO, high temperature reduces DO</td>
</tr>
<tr>
<td><strong>Specific Conductivity (µS/cm)</strong></td>
<td>Can indicate amount of calcium, magnesium, and iron or “hardness” or salt pollution</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>Determines the solubility and biological availability of nutrients and heavy metals, 6.6-8.5</td>
</tr>
<tr>
<td><strong>Ammonium + Ammonia (mg/L) - N</strong></td>
<td>Can indicate human/animal wastes, no health-based value available, taste threshold is 30 mg/L</td>
</tr>
<tr>
<td><strong>E. coli (CFU/100 mL)</strong></td>
<td><em>Escherichia coli</em> is a pathogenic organism that occurs in human and animal wastes, limit depends on use, recreational limit is 523</td>
</tr>
<tr>
<td><strong>Anions (mg/L)</strong></td>
<td></td>
</tr>
<tr>
<td>Fluoride (F⁻)</td>
<td>Can come from erosion of natural deposits; or discharge from fertilizer and aluminum factories</td>
</tr>
<tr>
<td>Chloride (Cl⁻)</td>
<td>A secondary contaminant, affects taste, indicates road salt or wastewater</td>
</tr>
<tr>
<td>Nitrite (NO₂⁻) as nitrogen (N)</td>
<td>Runoff from fertilizer use; leaking from septic tanks, sewage; erosion of natural deposits, atmosphere, contributes to harmful algae blooms</td>
</tr>
<tr>
<td>Bromide (Br⁻)</td>
<td>Is found in wastewater from oil wells</td>
</tr>
<tr>
<td>Nitrate (NO₃⁻) as nitrogen (N)</td>
<td>Runoff from fertilizer use; leaking from septic tanks, sewage; erosion of natural deposits, atmosphere</td>
</tr>
<tr>
<td>Phosphate (PO₄³⁻) as phosphorus (P)</td>
<td>Contributes to algal growth in surface water and harmful algae blooms</td>
</tr>
<tr>
<td>Sulfate (SO₄²⁻)</td>
<td>Can affect color and taste</td>
</tr>
<tr>
<td><strong>Metals (mg/L)</strong></td>
<td></td>
</tr>
<tr>
<td>Aluminum (Al)</td>
<td>High concentrations will create colored water</td>
</tr>
<tr>
<td>Arsenic (As)</td>
<td>The level of As found is normal for this area of Ohio, erosion of natural deposits with high in iron</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>Can come from erosion of galvanized pipes or natural deposits</td>
</tr>
<tr>
<td>Chromium (Cr) total</td>
<td>Corrosion or natural deposits</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>Corrosion of household plumbing, erosion of natural deposits</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>Affects taste and color, natural deposits in Ohio, normal for Ohio are high</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>Another secondary nuisance chemical, affects color and taste</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>No standard though health risks at 1 mg/L</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>Corrosion of household plumbing systems; erosion of natural deposits</td>
</tr>
<tr>
<td>Strontium (Sr)</td>
<td>Often found in limestone, health advisory at 25 mg/L for a 10-kg or less child</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>Can cause metallic taste</td>
</tr>
</tbody>
</table>

(Note: µS is micro Siemens, ppm is parts-per-million or milligrams per liter, CFU is colony-forming units)
<table>
<thead>
<tr>
<th>Description</th>
<th>GPS Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>HWY68</td>
<td>Yellow Springs Creek, north entry into Glen Helen 39° 48’ 31” N, 83° 53’ 04” W</td>
</tr>
<tr>
<td>YLS-RO</td>
<td>North Yellow Springs street runoff near lift station (ditch mount) 39° 48’ 30” N, 83° 53’ 06” W</td>
</tr>
<tr>
<td>YLS</td>
<td>Yellow Springs Creek, stone crossing by lift station 39° 48’ 30” N, 83° 53’ 05” W</td>
</tr>
<tr>
<td>BCOSR</td>
<td>Birch Creek, north entry into Glen Helen, Old Stage Road Bridge 39° 48’ 16” N, 83° 52’ 43” W</td>
</tr>
<tr>
<td>BSCOR-RO</td>
<td>Stormwater discharge into Birch Creek at Old Stage Road Bridge (stream mount) 39° 48’ 17” N, 83° 52’ 45” W</td>
</tr>
<tr>
<td>BCSC</td>
<td>Birch Creek, stone crossing below Trailside Museum 39° 48’ 03” N, 83° 52’ 59” W</td>
</tr>
<tr>
<td>YS</td>
<td>The Yellow Spring 39° 48’ 14” N, 83° 53’ 00” W</td>
</tr>
<tr>
<td>EYS-RO</td>
<td>Storm water culvert behind Glen Helen Building (ditch mount) draining east side of Yellow Springs downtown 39° 48’ 08” N, 83° 52’ 10” W</td>
</tr>
<tr>
<td>YSTMB</td>
<td>Yellow Springs Creek, bridge below Trailside Museum 39° 48’ 13” N, 83° 53’ 21” W</td>
</tr>
<tr>
<td>YSCUP</td>
<td>Yellow Springs Creek, upstream from WWTP 39° 47’ 30” N, 83° 52’ 48” W</td>
</tr>
<tr>
<td>WWTP</td>
<td>Yellow Springs Water Reclamation Facility Outfall 39° 47’ 28” N, 83° 53’ 19” W</td>
</tr>
<tr>
<td>YSCVB</td>
<td>Covered Bridge downstream from WWTP 39° 47’ 06” N, 83° 52’ 45” W</td>
</tr>
<tr>
<td>LMRG</td>
<td>Little Miami River – Grinnell Road Bridge 39° 46’ 60” N, 83° 52’ 32” W</td>
</tr>
<tr>
<td>LMR</td>
<td>Little Miami River – Jacoby Road Canoe Launch 39° 45’ 50” N, 83° 54’ 8” W</td>
</tr>
<tr>
<td>JRS</td>
<td>Jacoby Road Spring – at Birch Manor House 39° 45’ 55” N, 83° 53’49” W</td>
</tr>
<tr>
<td>EHR-RO</td>
<td>South Yellow Springs street runoff near East Hyde Road (ditch mount) 39° 47’ 28” N, 83° 52’51” W</td>
</tr>
<tr>
<td>MOR-RO</td>
<td>Foundry waste settling pond effluent in to Glen Helen (ditch mount) 39° 46’ 31” N, 83° 53’ 40” W</td>
</tr>
</tbody>
</table>
Figure 1. Map of Glen Helen and surrounding area showing sample sites.
Figure 2. *E. coli* contamination at all sites tested during condition when there was no rain. Class B Recreation limits are 161 CFU/100 mL for a 30-day average and 362 CFU/100 mL for a 7-day average.
Figure 3. *E. coli* contamination in grab samples on rain days.

Figure 4. *E. coli* contamination in runoff samplers on rain days.
Figure 5. Comparison of *E. coli* in grab samples with rain, no rain, and ditch sampler runoff with precipitation entering Yellow Springs Creek at Highway 68.
Figure 6. Comparison of *E. coli* in grab samples with rain, no rain, and runoff sampler with precipitation entering Glen Helen in Birch Creek at the Old Stage Road Bridge.
Figure 7. Comparison of *E. coli* in grab samples with rain and no rain with precipitation in the Little Miami River with precipitation.
Figure 8. Positive association between *E. coli* in grab samples with amount of precipitation.
Figure 9. Nitrate concentrations along Yellow Springs Creek from Highway 68 to the Little Miami River showing inputs from Birch Creek, and the WWTP. No nitrate was detected in the Yellow Spring so it was not included in this figure. The drinking water standard is 45 mg/L (ppm).
Figure 10. Comparison of nitrate in grab samples with rain, no rain, and ditch runoff sampler with precipitation entering Glen Helen in Yellow Springs Creek at Highway 68.
Figure 11. Comparison of nitrate in grab samples with rain, no rain, and runoff sampler with precipitation entering Glen Helen in Birch Creek at the Old Stage Road Bridge.
Figure 12. Comparison of nitrate in grab samples with rain and no rain conditions with precipitation in the Little Miami River downstream from Yellow Springs Creek.
Figure 13. Phosphate concentrations along Yellow Springs Creek from Highway 68 to the Little Miami River with inputs from Birch Creek and the WWTP. Phosphate was only detected in WWTP effluent and downstream at the covered bridge (YSCVB). The August level represents a violation of the NPDES permit limit of 1.5 mg/L weekly and 1.0 mg/L monthly. There is no limit for winter.
Figure 14. (a) Fluoride and (b) sulfate concentrations along Yellow Springs Creek to the Little Miami River with inputs from The Yellow Spring, Birch Creek, and the WWTP.
Figure 15. Chloride concentrations along Yellow Springs Creek to the Little Miami River with inputs from The Yellow Spring, Birch Creek, and the WWTP. The major contributor to chloride is the WWTP.
Figure 16. Anion concentrations in Yellow Springs Village stormwater runoff (a) North Yellow Springs streets and downtown (YSLS-RO) and (b) from the east side of Yellow Springs behind the Glen Helen Building (EYS-RO). These graphs are on the same scale to show the relative proportions.
Figure 17. Anion concentrations in Yellow Springs Village stormwater runoff from the South Yellow Springs residential street storm drain that flows under East Hyde Road (EHR-RO) and into Glen Helen.
Figure 18. Anion concentrations in samplers of stormwater runoff (a) into Birch Creek at Old Stage Road (BCOSR-RO) and (b) from Morris Bean Pond ditch (MOR-RO).
Figure 19. Strontium concentrations (a) in grab samples during no rain conditions and (b) grab samples on rain days.