Assessment of *Escherichia coli* and Chemical Data in the Surface Waters of Jefferson County, West Virginia

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ABSTRACT

Two streams in the Potomac and Shenandoah drainages of Jefferson County, West Virginia, were sampled for levels of Escherichia coli and nutrients from November 2008 to February 2009. Earlier bacteria data from May 2006 to Feb 2007 is summarized. Assessment of the bacterial levels in Jefferson County waters indicates extremely high bacteria levels in all streams sampled and indicates widespread E.coli bacterial contamination of surface waters of Jefferson County. Of the 426 samples 364 were main stream samples and 62 were sampled from springs. 39-92% of the samples in streams sampled more than five times exceeded the EPA criteria of 409 CFU/100 mL for lightly used waters with full body contact. Ion chromatography data for SO_4^{-2}, NO_3^{-1} *and* Cl^{-1} *sampled for two dates in 2008 and 2009 revealed high levels, especially for chloride and nitrate. Physical data for temperature, turbidity, pH, dissolved oxygen, redox values, specific conductivity and salinity were within the normal range of expected values. Jefferson County streams sampled are highly polluted suggesting a significant level of human impact. However, only three percent of the 62 samples taken in springs exceeded the EPA criteria for bacteria. To the extent that spring samples represent the groundwater bacteria levels, it appears that surface water bacteria levels are due to input from shallow subsurface and overland flow. Nevertheless, higher nitrate levels in some spring samples indicates high levels of groundwater nutrient input rather than input from surface or shallow subsurface input. This has implications for the mitigation of surface water nutrient contributions to the Chesapeake Bay.*

KEYWORDS: bacteria; *Escherichia coli*; Jefferson County; nutrients; streamwater chemistry

1. INTRODUCTION

1.1 Jefferson County

Jefferson County is located in the eastern panhandle of West Virginia. Due to its proximity to the Washington D.C. metropolitan area, Jefferson County has experienced a high rate of growth and development over the past decade. In 2000 there was a population of 42,190 people, which included an increase of 17.5% for the preceding ten years [6]. It is expected that the next census will continue to reveal rapid population growth for the county. This population increase impacts the infrastructure and the natural resources of the county, specifically the aquatic ecosystems. The three main anthropogenic influences on county waters are agriculture, septic systems, and waste water treatment.

Jefferson County has a strong agricultural history with corn and soybean as the predominant crops. Agricultural fertilizers and livestock effluent can contribute to nutrient and bacteria levels in streams. While feedlot operations contribute to point source inputs, most agricultural inputs are nonpoint source (NPS). In 2008 11,500 acres of corn and 9,000 acres of soybeans were planted [7]. Cattle are the most important livestock, with 13,000 head raised in the Kabletown district alone during 2008 [7].

Septic systems and waste water treatment overflow can also release nutrients and bacteria, and in Jefferson County 55% of residents use septic systems [7]. Improperly managed septic systems can contaminate groundwater or surface waters depending on soils and karst features in the area.

Wildlife contributions are another possible contributor. As habitat declines due to development and increased agriculture, animals become more densely concentrated. Riparian areas are commonly not developed and thus those areas become frequently populated by resident or migrating populations.

An important physical factor affecting the cycling of nutrients and bacteria in streams is local geology. Eighty-six percent of Jefferson County is underlain by limestone karst [4]. Karst is soluble and is typically accompanied by caves and sinkholes. Water from the surface will more easily infiltrate to groundwater in this type of geology, which results in groundwater contamination [5]. Groundwater contamination is common in karst areas. For example, 32% of wells studied in neighboring Berkeley County were contaminated with *E.coli.* No comparable data exist for Jefferson County [3].

Given these potential impacts to the surface waters and even though county waters ultimately flow into the Chesapeake Bay, there has been little study on quantitatively assessing the water quality of the county's surface waters. The objective of this study was to assess bacterial levels and streamwater chemistry in surface waters of Jefferson County.

1.2 Sites

Ten 1st to 3rd order streams were sampled, primarily in the eastern half of the county, from 2006 to 2009 (Figure 1). All streams drain into either the Potomac or Shenandoah River and ultimately into the Chesapeake Bay. Of the ten streams four were sampled more than five times; Town Run, Evitt's Run, Bullskin Run, and Hubbard, a tributary of Evitt's Run.

Samples were taken in the mainstem of the creek or from springs that fed into the creek.

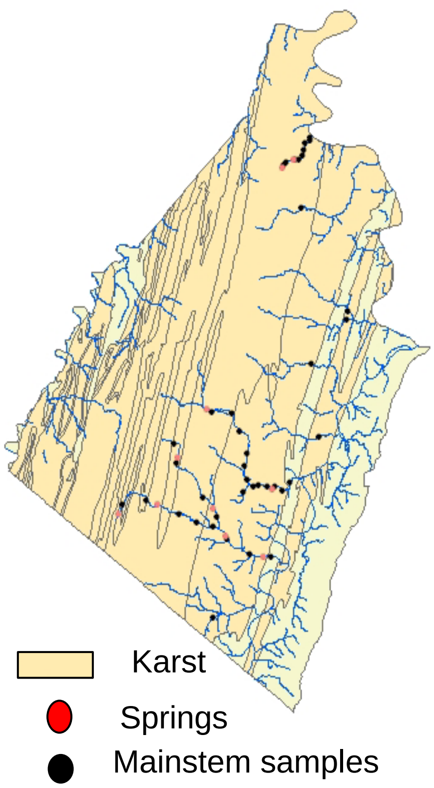

Figure 1. Sampled streams in Jefferson County indicating karst areas in the county and mainstem and spring sampling sites.

1.3 Escherichia coli

E.coli bacteria are enteric in origin and normally enter streams as a result of contamination from septic systems, from agricultural runoff, such as concentrated feed lots, or from concentrated populations of wildlife [1]. *E. coli* is utilized as an indicator organism. The presence of indicator organisms in a sample indicates that it is likely that other pathogenic organisms are also present. Pathogenic organisms include viruses, protozoa, and bacteria and include diseases such as typhoid, cholera, enteric fevers, and bacterial dysentery. While possible to assess directly the presence of pathogenic organisms, it is not practical. Each organism (virus, protozoa and bacteria) would require a different time-consuming and usually expensive test to detect its presence and number in the environment. A more practical procedure is to detect the presence of other organisms, called indicator organisms, which are easier to detect. If these indicator organisms are present it would indicate that it is likely that other pathogenic organisms are present [8]. The family Enterobacteriaceae includes important pathogenic bacteria such as *Salmonella*, *Klebsiella pneumoniae*, and *Escherichia coli*. Whether exposure to the pathogenic organisms results in symptoms depends upon the health of the individual, the state of their immune system, and the number of pathogenic cells required. For children or people with a compromised immune system, exposure can be life-threatening [1]. Acceptable levels of *E. coli* depend upon the type of water use. Single sample maximum for a designated beach area is 235 CFU/mL; 298 CFU/mL for moderate full body contact recreation; 409 CFU/mL for lightly used full body contact recreation, and 575 CFU/ml for infrequently used full body contact recreation [2]. The 409 CFU/mL criteria was utilized in this study.

2. MATERIALS AND METHODS

2.1 Bacteria

Samples were tested for *E.coli* bacteria using the EPA-approved IDEXX Quanti-Tray Colilert 18 method (IDEXX, Maine, U.S.A.). Sterilized and sealed bottles were used to collect samples. 100ml of sample was mixed with a proprietary reagent. The mixture was poured into a 96-well Quanti-Tray, which was sealed and examined after 18 hours in a 35° Celsius chamber. The methodology allows for readings up to 2,419 CFU/100 mL; CFU/100 mL values exceeding this number require dilutions and were not completed for this study.

2.2 Chemistry

Ion chromatography (Dionex IC S-1500 Ion Chromotography System) was used to analyze samples for chloride, sulfate, and nitrate. Two samples were taken at each site, placed in a cooler on-site, refrigerated at the laboratory, and examined within 24 hours.

2.3 Physical Parameters

Each site was measured for temperature, turbidity, pH, dissolved oxygen, and specific conductivity utilizing a Eureka Manta multi-parameter probe (Eureka Environmental, Texas, U.S.A.).

3. RESULTS

3.1 Bacteria

A total of 426 samples were taken from the ten streams sampled from 2004-2009; 364 samples were main-stream samples and 62 samples were from springs. 39-92% of the samples in streams sampled more than five times exceeded the EPA criteria of 409 CFU/100 mL for lightly used waters with full body contact (Figure 2). Only 3% of spring samples exceeded the 409 CFU 100mL EPA criteria.

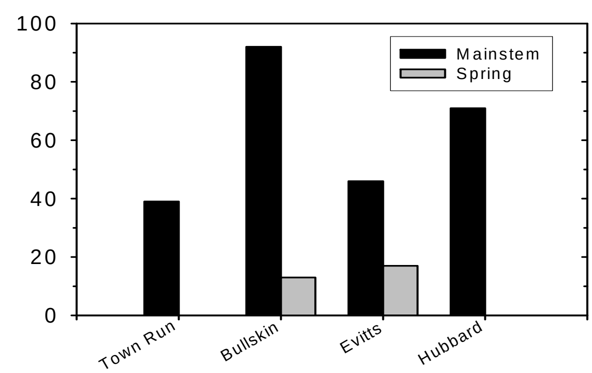

Figure 2. Percent of samples exceeding 409 CFU/100 mL *E.coli* for streams/tributaries sampled more than 5 times (Vila manuscript in preparation)

Five sites in Evitts Run exceeded the 409 CFU 100 mL criteria over the two sampling dates (Figure 3).

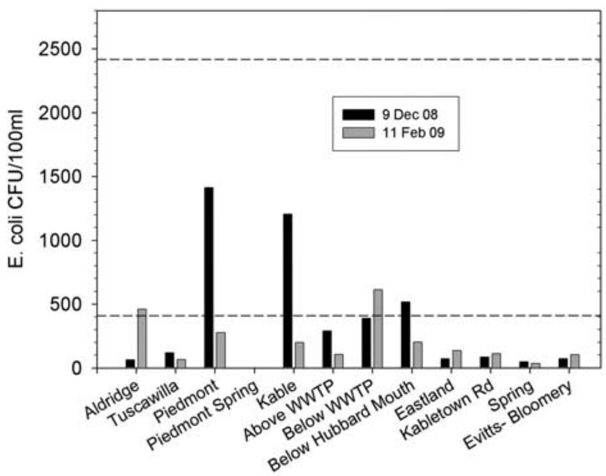

Figure 3. *E.coli* levels for two sampling dates from headwater to mouth (left to right) in Evitts Run. The bottom dashed line indicates the 409 CFU 100mL standard and the upper dashed line indicates the 2419 CFU 100mL limit of the method.

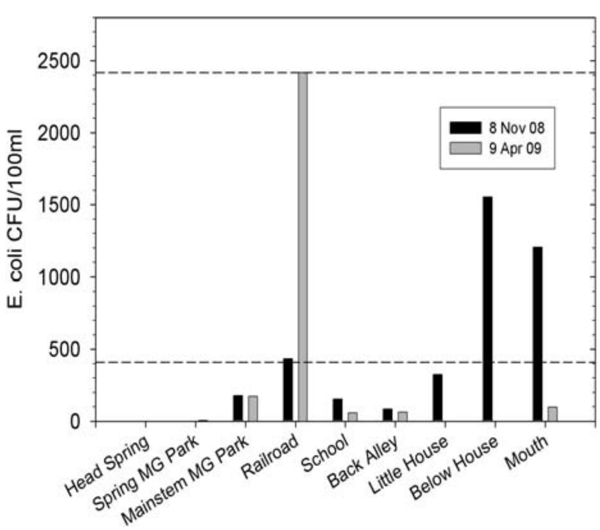

Figure 4. *E.coli* levels for two sampling dates from headwater to mouth in Town Run (left to right). The bottom dashed line indicates the 409 CFU 100mL standard and the upper dashed line indicates the 2419 CFU 100mL limit of the method.

Three sites in Town Run exceeded the 409 CFU 100 mL criteria over the two sampling dates (Figure 4).

3.2 Chemistry

Phosphate levels were below detection limits for all sites.

Evitts Run chloride mainstem values (Fig. 5) increase downstream from 10-20 mg/L at the headwaters above the waste water treatment plant (ATP) to 40-70 mg/L below the waste water treatment site (BTP). Spring chloride levels are similar to levels in the mainstem.

Sulfate levels (Fig. 6) increase from approximately 10 mg/L at the headwaters to 20 mg/L at the mouth.

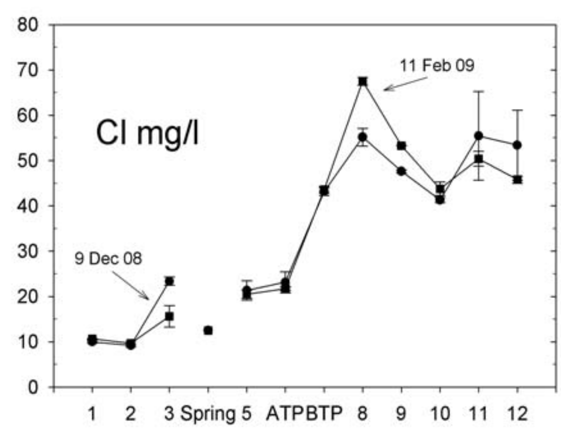

Figure 5. Evitts Run chloride levels for two sampling dates for head-water (left) to mouth (right) sites. Mean ± SD. Upper headwater "Spring" site flows into mainstem Evitts at site 3. ATP = above waste water treatment site; BTP = below waste water treatment site.

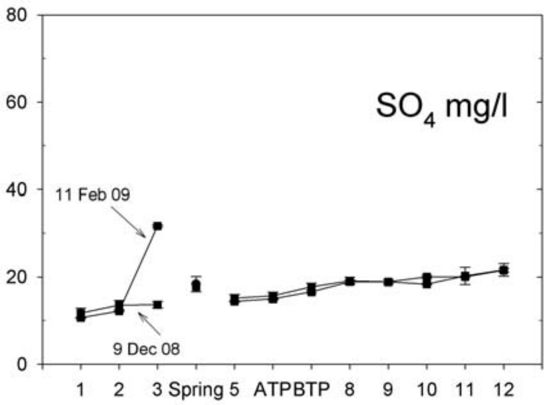

Figure 6. Evitts Run sulfate levels for two sampling dates for headwater (left) to mouth (right) sites. Mean ± SD. Upper headwater "Spring" site flows into the mainstem Evitts at site 3. ATP = above waste water treatment site; BTP = below waste water treatment site.

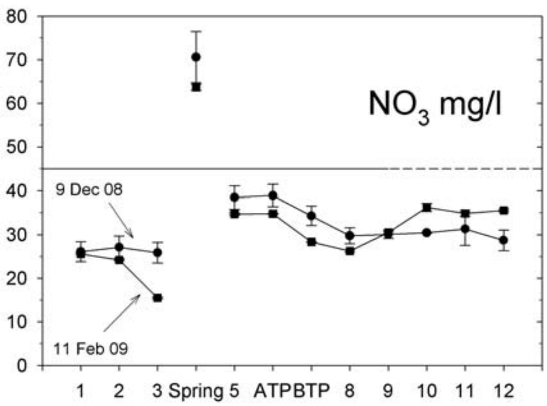

Figure 7. Evitts Run nitrate levels for the two sampling dates for headwater sites (left) to mouth (right). Mean ± SD. Upper headwater "Spring" site flows into the mainstem Evitts at site 3. ATP = above waste water treatment site; BTP = below waste water treatment site. Line indicates NO_3 drinking water standard of 10 mg/L NO_3-N.

Evitts Run nitrate levels (Fig. 7) are high in the headwater sites above the waste water treatment plant (15-30 mg/L). These values increase to 30-40 mg/L below the waste water treatment plant. Spring values, however, are extraordinarily high at 60-70 mg/L and exceed drinking water standards of 10 mg/L - N.

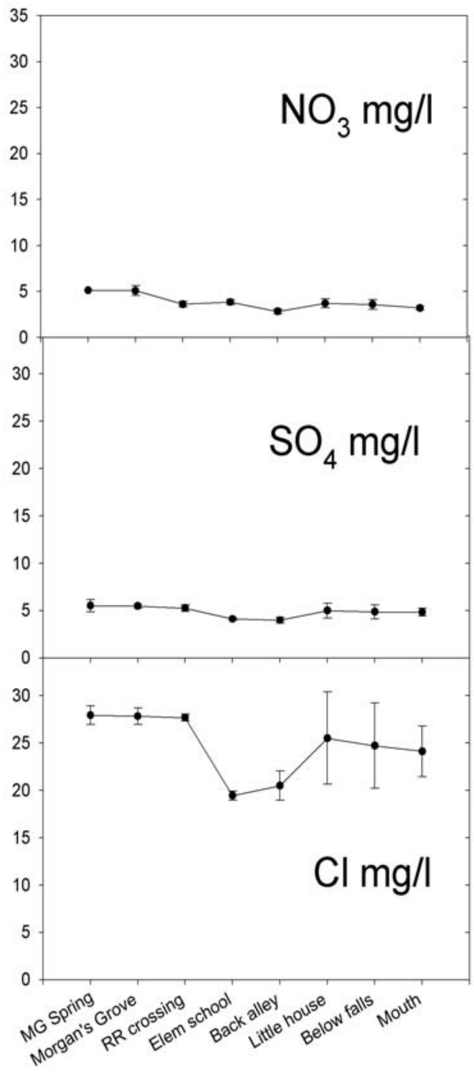

Figure 8. Town Run nutrient levels for the two sampling dates for headwater sites (left) to mouth at the Potomac River(right). Mean ± SD.

Chloride levels in the Town Run (Figure 8 bottom) are also approximately 25 mg/L at the headwaters but do not increase downstream indicating high spring inputs along the longitudinal profile and low impacts from anthropogenic inputs. Sulfate and nitrate levels of approximately 5 mg/L along the longitudinal profile are also much lower at (Figure 8 middle and top) indicating lower input from springs.

3.3 Physical parameters

Physical parameters were all within expected values.

Temperature for Evitts Run (Figure 9 bottom) ranged from 5-10 ^{o}C in the mainstem. Spring groundwater water, with less exposure to cold air temperatures was warmer at 12-13 ^{o}C. Dissolved oxygen (Fig. 9 middle) ranged from 10-13 mg/L in the mainstem and increased downstream. Supersaturated values (Fig. 9 top) indicated high levels of photosynthesis expected from the high nutrients and open canopy allowing sunlight penetration to the stream. Dissolved oxygen levels and percent saturation in the spring (Fig. 9 middle and top) were lower due to respiration in groundwater prior to the waters emergence.

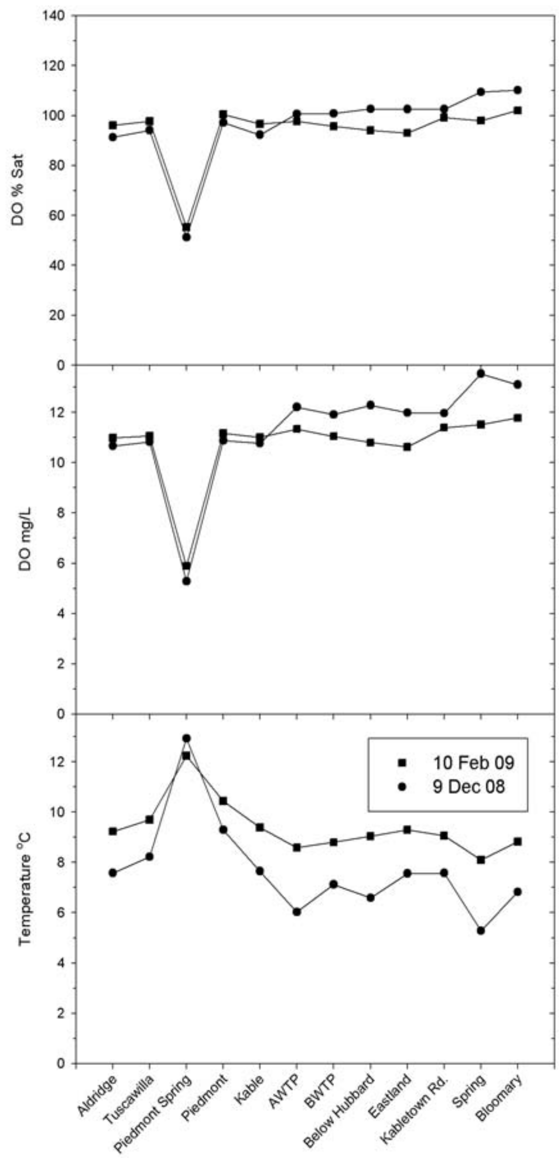

Figure 9. Evitts Run temperature (bottom), dissolved oxygen (middle) and percent oxygen saturation (top) for the two sampling dates for headwater sites (left) to mouth at the Shenandoah River(right).

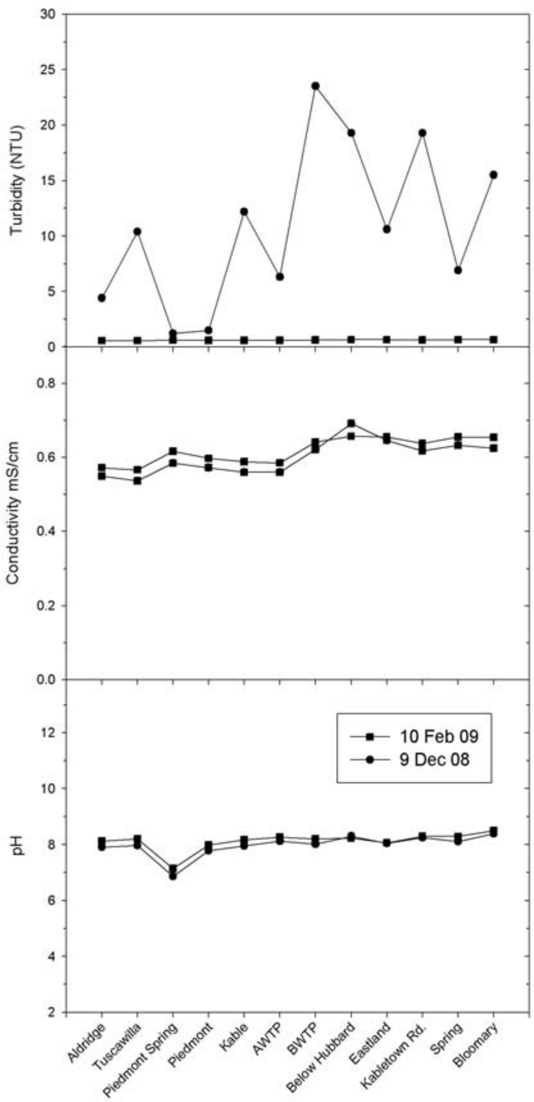

Figure 10. Evitts Run pH (bottom), conductivity (middle) and turbidity (top) for the two sampling dates for headwater sites (left) to mouth at the Shenandoah River(right).

pH, conductivity and turbidity for Evitts Run (Fig. 10 bottom, middle, and top, respectively) were within normal values in karst surface waters. As expected, pH was lower in the spring waters due to bacterial respiration in the groundwater prior to its emergence. Turbidity was relatively high on 9 Dec 08 but not unexpected for streams that drain agricultural land or have been impacted from development.

Town Run temperature, dissolved oxygen, and percent saturation values have similar trends as those values in Evitts Run (Fig. 11 bottom, middle, and top, respectively). Percent oxygen saturation is lower in the springs and all sites were at saturation or supersaturated on 23 Apr 09, reflecting the high primary productivity observed in the stream on that date. pH, conductivity, and turbidity are all within ranges expected for surface waters in a karst region. As expected pH is lower in spring sites.

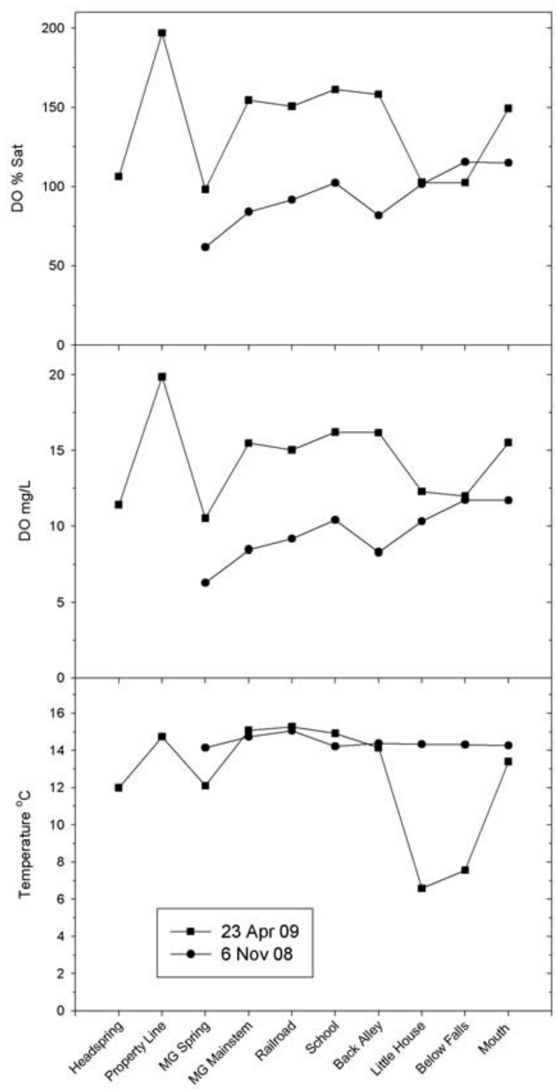

Figure 11. Town Run temperature (bottom), dissolved oxygen (middle) and percent oxygen saturation (top) for the two sampling dates for headwater sites (left) to mouth at the Potomac River (right).

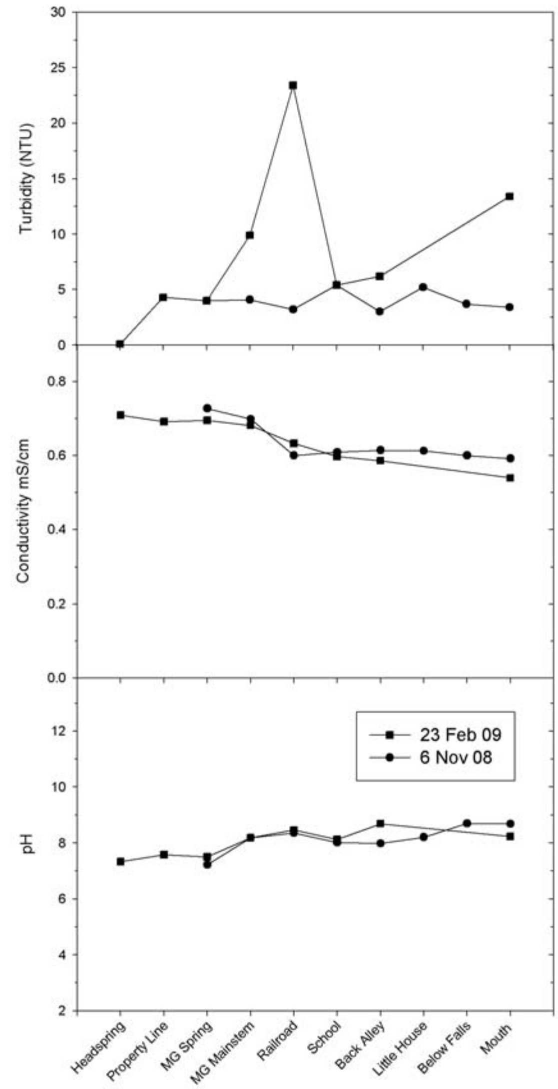

Figure 12. Town Run pH (bottom) conductivity (middle) and turbidity (top) for the two sampling dates for headwater sites (left) to the mouth at the Potomac River (right).

4. CONCLUSIONS

4.1 Bacteria

Bacterial levels in the streams of Jefferson County are extraordinarily high with mainstream samples in the streams sampled exceeding EPA criteria. Samples from springs tended to be lower, with only 0-17% of spring samples for each of the most frequently sampled streams exceeding the EPA 409 CFU/100mL criteria. If water emerging from springs is representative of groundwater, this indicates that mainstem contamination is from overland and shallow subsurface flow, and not from groundwater.

E. coli levels are expected to be low in the cold waters in winter as *E. coli* is enteric in origin. That 3-5 sites in the two streams exceed the EPA criteria indicates a continuous source. Detailed sampling could determine point sources.

Bacterial contamination originates from three main sources; failing septic systems, agricultural runoff such as from feedlots or manure applications, or from wildlife. Bacterial source tracking will be required to determine the relative contributions of each to the bacterial contamination.

4.2 Chemistry

Chloride has little biological uptake. Changes in concentrations along the stream profile reflect dilution from waters with lower chloride concentrations or increases from waters with higher chloride concentrations. Spring chloride values range from 10-25 mg/L. Chloride values in Town run are similar along the longitudinal profile indicating high groundwater flows into the stream. However, chloride values in Evitts Run increase dramatically downstream to approximately 70 mg/L indicating high anthropogenic input. These are winter samples and concentrations could decline as salt applied to roads flushes through the system.

Nitrate and sulfate have strong biological uptake. In Evitts Run sulfate and nitrate levels increase from headwaters to the mouth indicating high inputs. Measured levels do not increase downstream as chloride probably due to biological uptake by phytoplankton and submerged aquatic vegetation. The canopy is open allowing sunlight to penetrate; high levels of primary production are indicated by the supersaturated oxygen levels.

Nitrate levels in the Town Run are approximately 5 mg/L at all sites, spring or mainstem. However, the spring at Evitts Run had exceptionally high values of approximately 65 mg/L. This high concentration indicates high groundwater nitrate concentrations that contribute to surface waters. The spatial variability in nitrate levels of springs needs to be evaluated to determine the amount springs contribute to high nutrient levels of surface waters.

It will be especially important to investigate groundwater nitrate levels since these streams are in the Chesapeake Bay watershed. Mitigation of nutrient levels in surface water to the bay will be impacted by the relative level of nutrients in the groundwater. Surface water inputs can be controlled; groundwater inputs will be difficult to control.

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