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# Lower Susquehanna Subbasin

## Small Watershed Study: Yellow Breeches Creek

*A Bacteriological Assessment, February - November 2006*

**SRBC**

**SUSQUEHANNA RIVER BASIN COMMISSION**



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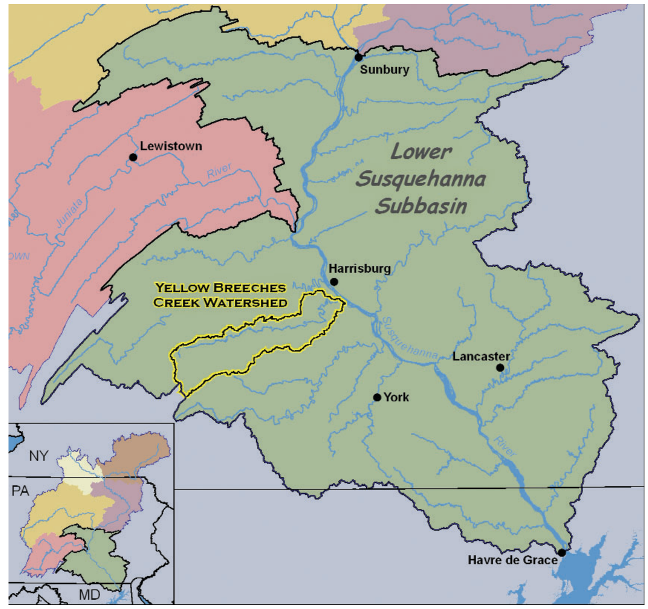
## INTRODUCTION




J. Zimmerman

***Figure 1.** Location of Yellow Breeches Creek Watershed in the Lower Susquehanna Subbasin.*

The Susquehanna River Basin Commission (SRBC) completed a water quality survey in the Yellow Breeches Creek Watershed from February-November 2006 as part of the Year-2 small watershed study in the Lower Susquehanna River Subbasin (Figure 1). The Year-1 study of more than 100 sites throughout the entire Lower Susquehanna Subbasin was conducted from June-November 2005 (Buda, 2006). This study of the Yellow Breeches Creek Watershed was somewhat different from other Year-2 studies conducted by SRBC, as it focused primarily on recreational water quality. Concurrently with this project, SRBC was involved in an Instream Comprehensive Evaluation assessment within the Yellow Breeches Creek Watershed, with a focus on the impaired stream reaches, for the Pennsylvania Department of Environmental Protection (PADEP). SRBC and PADEP are both interested in the implications bacteria may have on recreational water quality, because the Yellow Breeches Creek is used heavily for recreational purposes, including fishing, swimming, kayaking, tubing, and canoeing. The potential impacts of bacteria on drinking water are also of concern, as there are several drinking water intakes located on the Yellow Breeches Creek.

SRBC staff members also participate in the activities of the Yellow Breeches Watershed Association (YBWA) through its board of directors. The YBWA recently completed a watershed assessment and rivers conservation plan and is working with Cumberland and York Counties and the Pennsylvania Fish and Boat Commission (PFBC) to develop a water trail in the lower watershed area for recreational use.

Courtesy PA Environmental Council

*Yellow Breeches Creek provides many excellent recreational opportunities.*

In June 2003, through a grant from PADEP, SRBC prepared Source Water Assessment and Protection (SWAP) reports for Pennsylvania American Water Company (PAWC) and United Water of Pennsylvania for the water intakes on the Yellow Breeches Creek. United Water treats approximately 2.3 million gallons per day (mgd), and serves more than 25,000 people in the Mechanicsburg area (PADEP, 2003). PAWC treats about 5.4 mgd and serves more than 87,400 people, in addition to industrial and commercial customers (PADEP, 2003). According to the SWAP reports, the primary contaminant concerns for the Yellow Breeches Creek are associated with low-intensity development and agricultural activity (PADEP, 2003). Runoff from development and agriculture often are associated with increased bacteria levels. The primary goals of this Year-2 study were to characterize the extent of bacteria contamination in the Yellow Breeches Creek Watershed and to compare the outcomes of sampling three different types of pathogen indicator bacteria. The data from this study can be used as background information by PADEP for future Total Maximum Daily Load (TMDL) or water quality standards work, and by other interested parties, such as water suppliers, watershed associations, and conservation groups in the Yellow Breeches Creek Watershed.

## DESCRIPTION
### of the Yellow Breeches Creek Watershed

The Yellow Breeches Creek drains 219 square miles and flows east through Adams, York, and Cumberland Counties before joining the Susquehanna River at New Cumberland, Pa. The creek is designated as High-Quality Cold Water Fishes, and in 1992 it also was designated as a Scenic River by the Commonwealth of Pennsylvania. In addition, Mountain Creek, a tributary of the Yellow Breeches Creek, is designated for trout stocking from Mt. Holly Springs to the mouth.

About 79 percent of the Yellow Breeches Creek Watershed is located in Cumberland County, 18 percent is in York County, and just 3 percent is in Adams County. The origin of the mainstem of the Yellow Breeches Creek is west of the town of Walnut Bottom, Cumberland County, and the creek flows eastward toward Mt. Holly Springs, Cumberland County. The largest tributary, Mountain Creek, begins in northern Adams County and joins the Yellow Breeches Creek in Mt. Holly Springs. For more than 21 miles of its length, from Williams Grove to New Cumberland, the Yellow Breeches Creek serves as the boundary between Cumberland and York counties. There are 22 municipalities fully or partially located in the Yellow Breeches Creek Watershed, with the majority being in Cumberland County: Camp Hill, Lemoyne, Mechanicsburg, Mt. Holly Springs, New Cumberland, and Shiremanstown Boroughs; Cooke, Dickinson, Hampden, Lower Allen, Monroe, Penn, Southampton, South Middletown, and Upper Allen Townships. The remaining municipalities are: Dillsburg Borough, and Carroll, Fairview, Franklin, and Monaghan Townships in York County; and Huntington and Menallen Townships in Adams County.

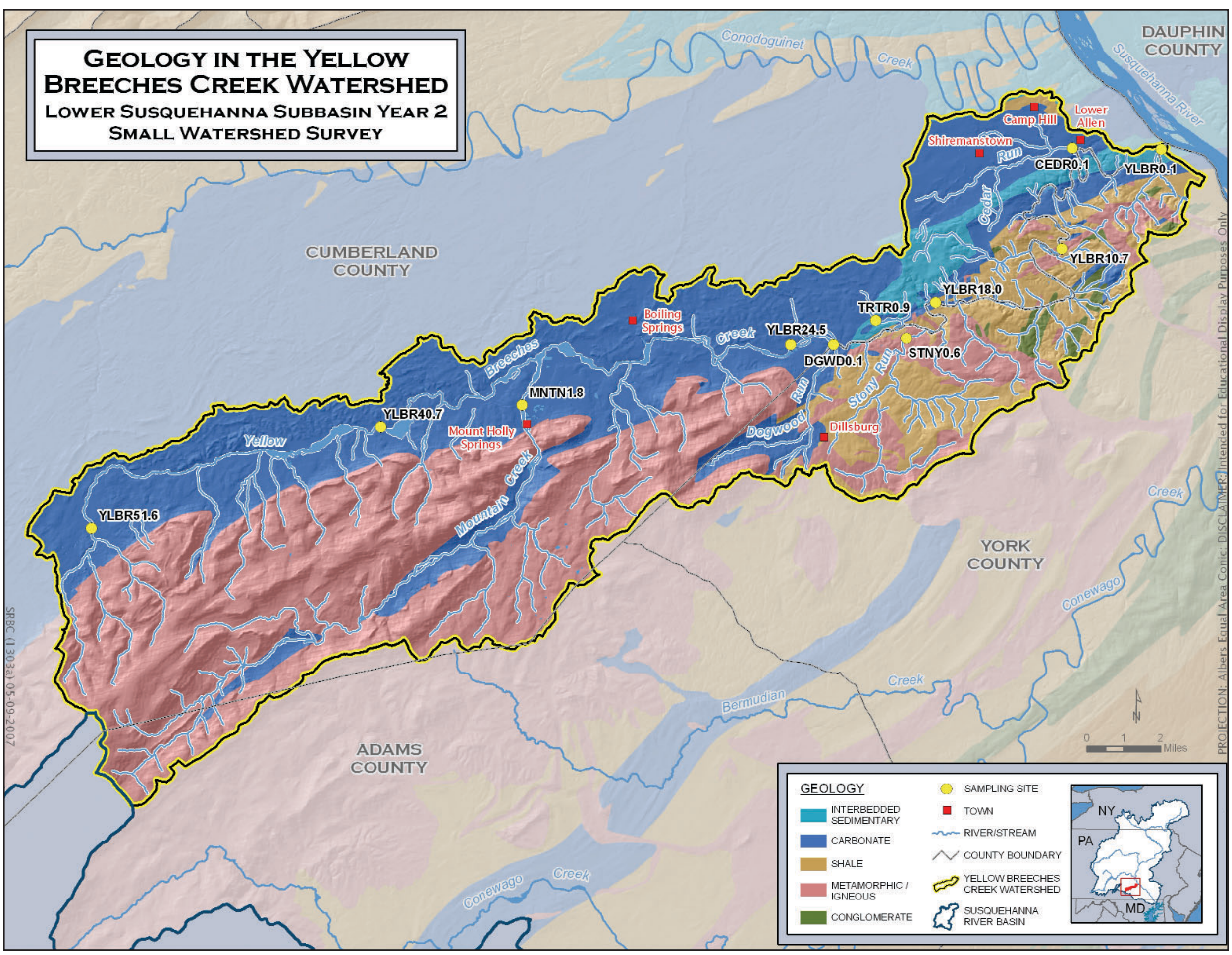



***Figure 2.*** *Geology and Sampling Site Locations in Yellow Breeches Creek Watershed.*

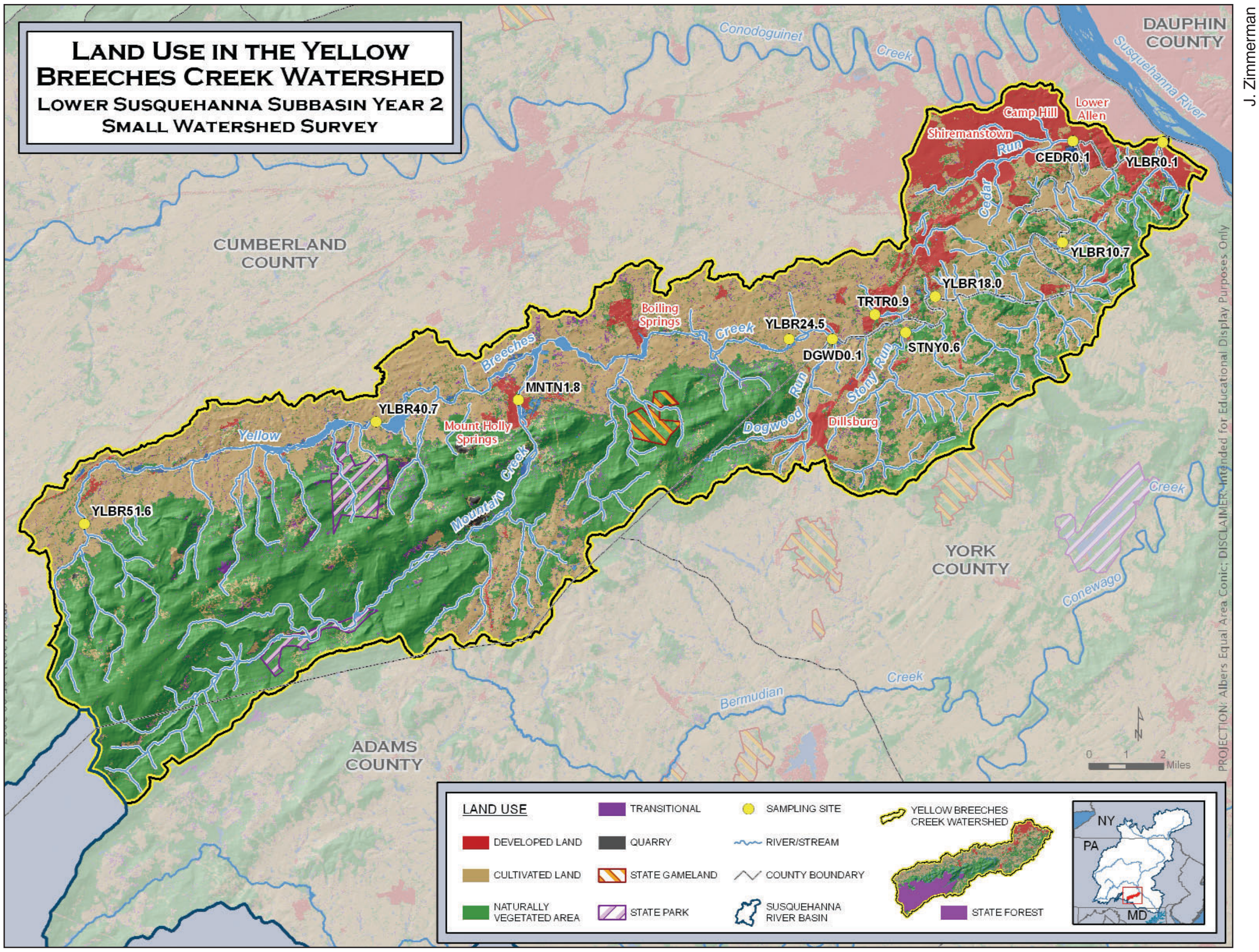



***Figure 3.*** *Land Use and Sampling Site Locations in Yellow Breeches Creek Watershed.*

The Yellow Breeches Creek and its tributaries flow within three physiographic provinces: Central Appalachian Ridge and Valley (Ecoregion 67), Blue Ridge (Ecoregion 66), and Northern Piedmont (Ecoregion 64). Within the Ridge and Valley province, the majority of the mainstem Yellow Breeches Creek falls into the Northern Limestone/Dolomite Valley subecoregion (67a). The headwaters of the Yellow Breeches Creek and most of Mountain Creek flow through the Blue Ridge province, including subecoregions 66a and 66b, Northern Sedimentary and Metasedimentary Ridges, and Northern Igneous Ridges, respectively. A short segment of the Yellow Breeches Creek and a few small southeastern tributaries are located in the Northern Piedmont province, in the Triassic Lowlands subecoregion (64a).

The surficial geology in the watershed is composed of 38 percent carbonate, 49 percent metamorphic/igneous, 10 percent shale and the remaining 3 percent are interbedded sedimentary and conglomerate rock (PADEP, 2003). Metamorphic and carbonate are the two dominant rock types and comprise the entire southwestern portion of the watershed, including all areas in which headwaters originate. Carbonate rock lies primarily along the northern border of the watershed in Cumberland County and surrounds most of the mainstem Yellow Breeches Creek. Metamorphic rock is prevalent along the southern border of the watershed and is the underlying geology for all of the tributaries that join the Yellow Breeches Creek from the south. Shale, sandstone, and interbedded sedimentary rock begin along the southern border of the watershed in York County and along the York and Cumberland County border. These rock types primarily are contained between the span of Route 15 and the southern border of the watershed, continuing to the confluence of the Yellow Breeches Creek and the Susquehanna River (Figure 2).

*"The surficial geology in the watershed is composed of 38 percent carbonate, 49 percent metamorphic/igneous, 10 percent shale and the remaining 3 percent are interbedded sedimentary and conglomerate rock."*

The land use in the Yellow Breeches Creek Watershed is also mixed. Overall, more than 50 percent of the watershed is forested, 38 percent is agricultural land, and about 8 percent is urbanized land (Figure 3). The majority of the agricultural land follows the carbonate geology surrounding the upper 75 percent of the mainstem Yellow Breeches Creek Watershed. The southern tributaries, including Mountain Creek, run through primarily forested land, including parts of the 85,000-acre Micheaux State Forest and all of the 696-acre Pine Grove Furnace State Park. The lower quarter of the Yellow Breeches Creek Watershed contains most of the developed land, including the Cedar Run Watershed, which is 70 percent urbanized.

# BACKGROUND

Recreational water quality is based primarily on the presence and pervasiveness of pathogens in the water that can pose risks to human health through body contact or ingestion. Since it is not practical to analyze for every possible pathogen found in human waste, indicator bacteria typically are used. Concentrations of these bacteria are relatively easy and cost effective to analyze and are good indicators of fecal contamination. Indicator bacteria results provide regulators with a means to determine the likelihood that human pathogens may be present in recreational waters. Historically, many states have used total fecal coliform as the indicator bacteria for determining the sanitary condition of recreational waters to protect human health. Fecal coliform primarily are found in the waste of humans or other warm-blooded animals; however, at least one type has non-fecal sources, including the effluent of paper mills, textile processing plants, and cotton mills (Wilhelm and Maluk, 1998).

In 1986, the U.S. Environmental Protection Agency (USEPA) published updated recommendations for states based on better knowledge of which indicator bacteria best correlated with gastrointestinal illness in humans. The USEPA recommends that states use either *Escherichia coli (E. coli)* or enterococci as indicators in freshwater and enterococci for saltwater (USEPA, 1986; USEPA, 2002). The presence of *E. coli* and enterococci in recreational waters is direct evidence that fecal contamination from humans or other warm-blooded animals has occurred (USGS, 2006).

The USEPA-recommended criteria are intended to control pathogens by keeping concentrations of indicator organisms at a level that corresponds with acceptable risks of acute gastrointestinal illness to recreational water users (USEPA, 2002). Gastroenteritis is a term for a variety of diseases that affect the gastrointestinal tract and are rarely life-threatening. Symptoms include vomiting, diarrhea, stomach ache, nausea, headache, and fever. Most people affected by gastroenteritis will experience these flu-like symptoms several days after exposure but rarely associate their illness with the ingestion of pathogen contaminated water. Other illnesses or conditions affecting the eyes, ears, skin, and upper respiratory tract can be contracted from contaminated water as well. Although people are affected differently, certain subgroups, such as children and the elderly, are more susceptible to contracting waterborne illnesses. In some studies, gastroenteritis was linked more closely to enterococci exposure, while skin rashes and ear ailments were linked to fecal and total coliform (Noble et al., 2000).

Ongoing research on which types of indicator bacteria are correlated most closely with outbreaks of gastroenteritis in humans continues to show that *E. Coli* and enterococci are both better indicators than fecal coliform (USEPA, 2002). Enterococci typically are used as the indicator bacteria in marine systems because they have a longer life in saltwater then do *E. coli*. However, some studies show that enterococci are a more sensitive indicator in freshwater, resulting in many more recreational closings due to high levels of bacteria (Kinzelman et al., 2003; John and Rose, 2005). In a California study, researchers found that one out of every three indicator bacteria violations was for enterococci alone and that fewer than half of the enterococci violations were paired with an exceedance of another indicator bacteria type. This suggests enterococci are a more sensitive indicator of bacteriological water quality than either total or fecal coliform (Noble et al., 2000). In another study, children who drank from private wells that tested positive for coliform were not at risk for diarrheal disease. However, children who drank from private wells that contained enterococci were six times as likely to become ill with diarrhea (Borchardt et al., 2003).

Some states have replaced their fecal coliform criteria with water quality criteria for *E. coli* and/or enterococci; however, many states, including Pennsylvania, have not yet made the transition (USEPA, 2002). In this study of the Yellow Breeches Creek Watershed, all three of the indicator bacteria (*E. coli*, enterococci, and fecal coliform) were sampled and the results were compared.

# METHODS

## DATA COLLECTION

SRBC staff collected bacteriological samples using standard PADEP protocol (PADEP, 2006). Four 30-day periods were sampled during the 2006 calendar year: February and early March, May, August, and November. Bacteria samples were collected by hand at eleven sites in 125-ml screw-capped polypropylene wide-mouth bottles that had been pre-sterilized and contained sodium thiosulfate. Samples were collected from the middle of the channel, and any sediment disturbed by the collector was allowed to settle before the sample was collected. Bottles were submersed approximately eight inches under the surface of the water, facing upstream, and filled with water. Bottles were immediately capped, put into a plastic zip-sealed bag, and placed on ice. Duplicate bacteria samples were collected at a rate of at least one per day and were taken once at each site during the 30-day sampling period. A field blank also was taken at least once per day to test for any kind of field contamination. Samples were delivered to the PADEP laboratory within 24 hours of collection.

The sampling sites (Appendix A) were selected so that data collected during this survey can be utilized as background information by PADEP and other interested parties, including water suppliers in the Yellow Breeches Creek Watershed. Additional sites have been added on tributary streams to provide better coverage of the watershed. The locations for sites were chosen to evaluate the pervasiveness of bacteria pollution along the mainstem and contamination in and from the various tributaries.

In addition to bacteria sampling, during each sampling visit, staff measured stream discharge and completed field chemistry measurements at each site. Stream flow was measured at each site using a Scientific Instruments pygmy or AA meter according to U.S. Geological Survey (USGS) methods (Buchanan and Somers, 1969). The only exception was the site at the mouth of the Yellow Breeches Creek where flow conditions did not allow SRBC staff to take a wading discharge measurement. At this site, stream discharge was estimated using the USGS gage located three miles upstream combined with water withdrawal information from the water supplier directly upstream of the site.

Staff collected water for field chemistry using a hand-held, depth integrated sampler at six verticals across the stream channel. The water was put into a churn splitter, mixed thoroughly, and used to determine temperature, dissolved oxygen, conductivity, pH, turbidity, field acidity, and field alkalinity. Temperature was measured in degrees Celsius with a field thermometer. A Cole-Parmer Model 5996 meter was used to measure pH. Conductivity was measured with a Cole-Parmer 1481 meter and dissolved oxygen was measured with a YSI 55 meter. Turbidity was measured using a Hach 2100P portable turbidimeter. Alkalinity and acidity were determined using field titrations. Alkalinity was measured in the field by titrating a known volume of sample water to pH 4.5 with 0.02N $H_2SO_4$. Acidity was measured in the field by titrating a known volume of sample water to pH 8.3 with 0.02N NaOH.

## DATA ANALYSIS

The 1986 USEPA-recommended criteria were used to determine violations for enterococci and *E. coli*. The single sample maximum standards for the USEPA-recommended criteria are based on level of human body contact. The most stringent criteria are for designated beach areas, followed by "moderate use full body contact" recreation, "light use full body contact" recreation, and the least stringent standards are in areas of "infrequent use full body contact" recreation. For this analysis, the single sample maximum standards for "moderate use full body contact" recreation were used for *E. coli* and enterococci. This criteria level was chosen because the Yellow Breeches Creek is used heavily throughout the year for a variety of recreational activities, such as swimming, tubing, fishing, kayaking, and canoeing.

**Table 1.** *Laboratory Methods for Bacteria Enumeration*

| Bacteria Type | Description | Method |
|---|---|---|
| Fecal coliform | Fecal coliform membrane filter procedure | Standard Method 9222D |
| *E. Coli* | Modified mTEC agar with membrane filtration | USEPA Method 821/R-97/004 |
| Enterococci | mEI agar with membrane filtration | USEPA Method 1600 |

The current recreational water quality criterion in the Commonwealth of Pennsylvania is based on fecal coliform as the indicator bacteria, and there are different standards during and outside of the recreation season. Indicator bacteria concentrations generally are reported as colony forming units per 100 milliliters of sample (cfu/100 ml). The recreation season is from May 1-September 30, and during this time the geometric mean limit is 200 cfu/100 ml, or no greater than 10 percent of the samples may exceed 400 cfu/100 ml. During the remainder of the year, the geometric mean standard is 2,000 cfu/100 ml, and there are no single sample maximum criteria during this time (Table 2).

Currently, there are no USEPA-recommended criteria for *E. coli* or enterococci that differentiate between limits based on a recreational season; USEPA leaves that up to each individual state's discretion. Therefore, only data for the recreational season, from May to September, were used in this analysis to compare the fecal coliform results to those of enterococci and *E. coli*. The enterococci and *E. coli* data for February and November are summarized according to the USEPA-recommended standards.

Steady state value is used synonymously with geometric mean throughout the report and refers to the calculated geometric mean of the six samples (five different days and one duplicate sample) taken throughout the 30-day sampling period. There are three geometric means, one for each type of indicator bacteria, calculated for each of the 11 sampling locations for all four sampling periods. Single sample maximum refers to the concentration of bacteria that cannot be exceeded by more than 10 percent of the samples. This number varies with indicator bacteria type and the designated water use. The geometric mean is used instead of the arithmetic mean, because it reduces the effect of very high or very low values. This is helpful when analyzing bacteria concentrations because levels may vary widely over a given period.

When bacteria results were reported at lower than the detection limit (PBQ), one-half of the detection limit was used in the geometric mean calculation. For a majority of the samples, the detection limit was 20 cfu/100 ml; thus, 10 cfu/100 ml was used in the calculations. For a few samples taken between February 28, 2006, and March 6, 2006, the detection limit was 10 cfu/100 ml, and in these cases 5 cfu/100 ml was used in the calculations. In all cases, a PBQ was listed in the results when the reported value was below the detection limit, and in no case did using half the detection


J. Hoffman

*Bacteria sampling in Yellow Breeches Creek.*

limit cause a site to be in violation. Field blanks were taken at least once per day to determine any source of bacterial contamination coming from field sampling protocol. All of the blanks came back below the detection limit, showing no bacterial contamination in the field sampling procedure.

Precipitation data were obtained from three National Oceanic and Atmospheric Administration rain gages located in Pine Grove Furnace State Park, in the southwest portion of the watershed; in Shippensburg, just outside the northwestern watershed boundary; and in Harrisburg, just outside the eastern watershed boundary. These three rain gages recorded daily rainfall totals and were the closest available sites to the Yellow Breeches Creek Watershed that had a continuous rainfall record for all of the sampling periods. The data from the three locations were averaged together to get an estimated daily rainfall value for the watershed.

***Table 2.*** *Water Quality Standards and Aquatic Life Tolerances*

| Parameter | Limit | Reference Code |
|---|---|---|
| Temperature | > 25 degrees | a,d |
| Dissolved oxygen | < 4 mg/l | a,e |
| Conductivity | > 800 mmhos/cm | c |
| pH | < 5 | b,d |
| Alkalinity | < 20 mg/l | a,e |
| Total fecal coliform | Geometric mean of 200 CFUs/100ml during recreation season or a single sample result of 400 CFUs/100 ml; 2000 CFUs/100 ml during non-recreation season | a |
| *E. coli* | Geometric mean of 126 CFUs/100 ml or a single sample maximum of 298 CFUs/100 ml for moderate full body contact recreation | f |
| Enterococci | Geometric mean of 33 CFUs/100 ml or a single sample maximum of 78 CFUs/100 ml for moderate full body contact | f |

**Reference Code & References**

a. http://www.pacode.com/secure/data/025/chapter93/s93.7.html
b. Gagen and Sharpe (1987) and Baker and Schofield (1982)
c. http://www.uky.edu/WaterResources/Watershed/KRB_AR/wq_standards.htm
d. http://www.hach.com/h2ou/h2wtrqual.htm
e. http://sites.state.pa.us/PA_Exec/Fish_Boat/education/catalog/pondstream.pdf
f. EPA recommended criteria, Ambient Water Quality Criteria for Bacteria – 1986

## RESULTS

Of the 11 sampling sites, 6 were on the mainstem Yellow Breeches Creek, which included sites from the headwaters to the mouth (Figure 4). Results are organized from upstream to downstream with the tributaries discussed in the order in which they enter the mainstem. Tributaries sampled included Mountain Creek, Dogwood Run, Trout Run, Stony Run, and Cedar Run. Numbers following the stream abbreviation denote river mile distance from mouth to sampling site.

***Table 3.*** *Steady State Violations at YLBR 51.6*

| Month | *E. coli* | | Enterococci | | Fecal coliform | |
|---|---|---|---|---|---|---|
| | *Geometric mean standard (cfu/100ml)* | Calculated geometric mean (cfu/100 ml) | *Geometric mean standard (cfu/100ml)* | Calculated geometric mean (cfu/100 ml) | *Geometric mean standard (cfu/100ml)* | Calculated geometric mean (cfu/100 ml) |
| August 2006 | *126* | 305 | *33* | 337 | *200* | 462 |

### BY SAMPLING LOCATION

#### Yellow Breeches Creek 51.6

The most upstream sampling point was YLBR 51.6, located along Rehoboth Road near New Lancaster, Cumberland County. The majority of the 12-square-mile drainage area to this site is forested; however, the adjacent land use is agricultural crop land. Bacteria levels exceeded the geometric mean for each of the three indicator bacteria in August, but there were no other steady state violations at this site (Table 3).

A majority of the single sample exceedances were in August at this site for all three indicator bacteria types, with the exception of one enterococci violation in November. Overall, 25 percent of the fecal coliform samples and 21 percent of the *E. coli* and enterococci samples exceeded their single sample maximum limits at YLBR 51.6.

Stream flow at YLBR 51.6 was quite variable with very low flows of only 0.2 cubic feet per second (cfs) in the summer and up to 40 cfs after rain events. There was a general trend of decreasing levels of bacteria with increasing stream flow. This suggests that there is some relatively constant source of bacteria contamination that becomes more concentrated at low flow and is diluted at higher flows. Possible sources of contamination for this site could be improperly functioning septic systems, as it is a very rural area with no public sewer service, and cattle access to the stream, which was observed several times during sampling. The data for this site did not show any increase in bacteria levels after a rainfall event.

#### Yellow Breeches Creek 40.7

The next downstream mainstem site was YLBR 40.7, located along West Yellow Breeches Creek Road east of Montsera, Cumberland County. This site drains 46.8 square miles of primarily agricultural land, with some low density residential areas. YLBR 40.7 is located within a stream reach that is impaired

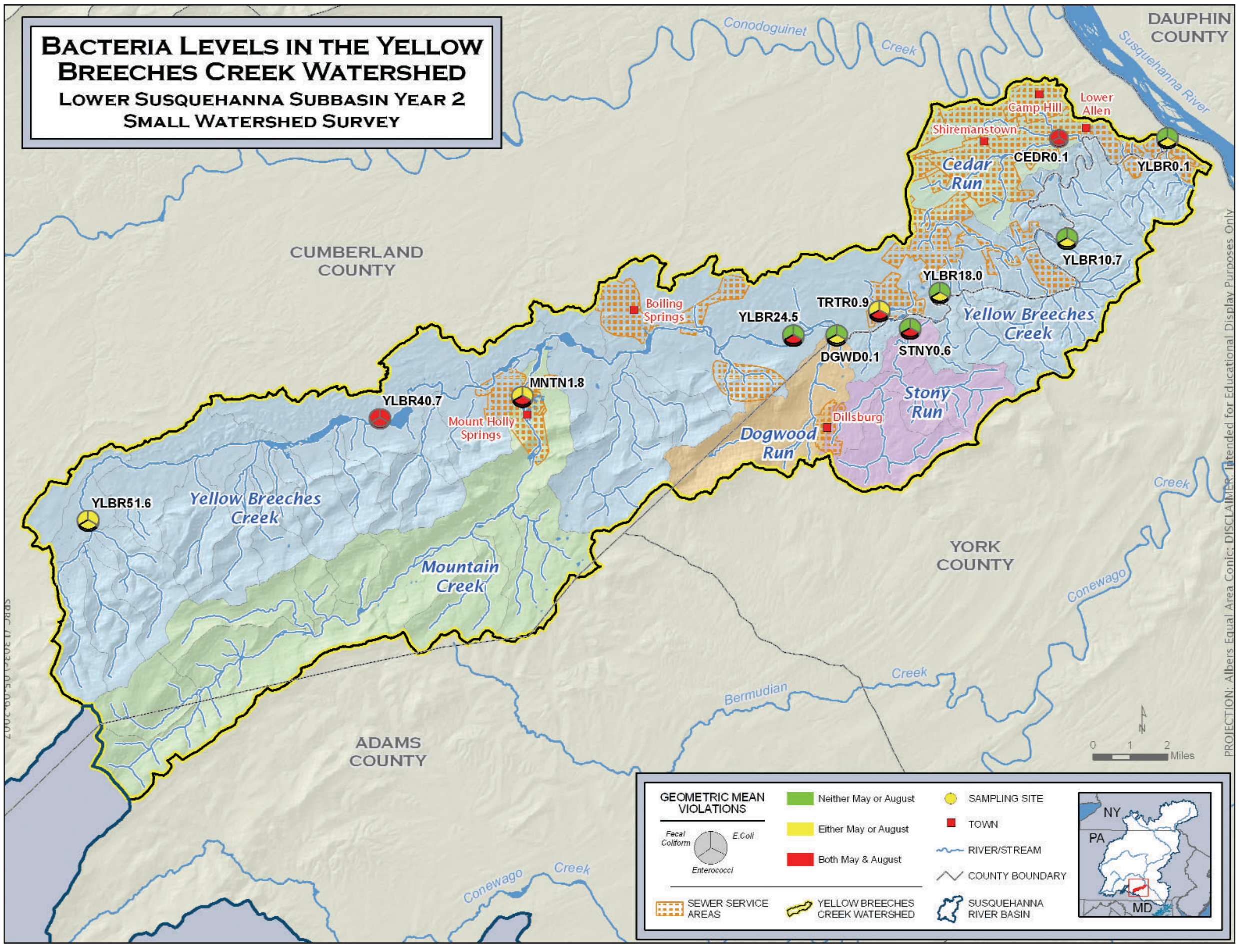



***Figure 4.*** *Bacteria levels in the Yellow Breeches Creek Watershed.*

for human health by poly-chlorinated biphenols (PCBs) and is located downstream of the Huntsdale State Fish Hatchery. Located adjacent to the stream at this site is a small farm pond that is home to numerous species of waterfowl, which were present during each sampling event.

The geometric mean values for all three of the indicator bacteria were exceeded at YLBR 40.7 during the May and August sampling events. Also, there was an additional violation for enterococci in November (Table 4).

Single sample maximums were exceeded in 54 percent of the enterococci samples, 21 percent of the fecal coliform samples, and 17 percent of the *E. coli* samples. Stream discharge measurements at YLBR 40.7 ranged from 35 cfs to 64 cfs, and there was no clear correlation between stream flow and the concentration of any of the indicator bacteria types. Bacteria levels were quite variable for all three indicator bacteria throughout the range of flows. Waterfowl may be a prime source of bacterial contamination at this site. However, faulty septic systems may also be a problem, as there is no public sewer service in this area.

***Table 4.*** *Steady State Violations at YLBR 40.7*

| Month | E. coli | | Enterococci | | Fecal coliform | |
|---|---|---|---|---|---|---|
| | Geometric mean standard (cfu/100ml) | Calculated geometric mean (cfu/100 ml) | Geometric mean standard (cfu/100ml) | Calculated geometric mean (cfu/100 ml) | Geometric mean standard (cfu/100ml) | Calculated geometric mean (cfu/100 ml) |
| May 2006 | 126 | 157 | 33 | 78 | 200 | 238 |
| August 2006 | 126 | 400 | 33 | 490 | 200 | 537 |
| November 2006 | 126 | NV | 33 | 76 | 2,000 | NV |

NV = no violation

### Mountain Creek 1.8

Mountain Creek, the largest tributary to the Yellow Breeches Creek, is 20.7 miles long and drains a 46-square-mile area. The sampling site on Mountain Creek, MNTN 1.8, was located near the mouth in Mt. Holly Springs along Route 34 in Cumberland County. Mountain Creek enters the Yellow Breeches Creek about seven miles downstream of YLBR 40.7 and flows in a generally southwest to northeast direction. The area directly surrounding this sampling location is mainly low density residential development. However, the majority of the land upstream draining into Mountain Creek is forested. Much of this forested land is within Micheaux State Forest and Pine Grove Furnace State Park, which is located in the headwaters of Mountain Creek. This sampling site is downstream of a National Pollutant Discharge Elimination System (NPDES) discharge from Mt. Holly Springs Municipal Authority as well as two other private industrial discharges.

In Mountain Creek, steady state violations existed for all three indicator bacteria during the month of August as well as an enterococci violation in May (Table 5).

There were also numerous single sample maximum violations in Mountain Creek for each indicator bacteria. The greatest percentage (42 percent) of total samples exceeded the single sample maximum for enterococci. *E. coli* and fecal coliform single samples exceeded the single sample limit 4 percent of the time. Discharge measurements in Mountain Creek ranged from 17 cfs to 80 cfs, and there was a general trend of higher levels of indicator bacteria at lower flows. Similarly to YLBR 51.6, there may be a consistent source of bacteria contamination going into Mountain Creek that is more concentrated in lower flows and more dilute at higher flows. The surrounding residential development in Mt. Holly Springs is served by a public sewer system; however, the majority of the Mountain Creek Watershed is not.

***Table 5.*** *Steady State Violations at MNTN 1.8*

| Month | *E. coli* | | Enterococci | | Fecal coliform | |
|---|---|---|---|---|---|---|
| | Geometric mean standard (cfu/100ml) | Calculated geometric mean (cfu/100 ml) | Geometric mean standard (cfu/100ml) | Calculated geometric mean (cfu/100 ml) | Geometric mean standard (cfu/100ml) | Calculated geometric mean (cfu/100 ml) |
| May 2006 | 126 | NV | 33 | 54 | 200 | NV |
| August 2006 | 126 | 149 | 33 | 629 | 200 | 260 |

NV = no violation

### Yellow Breeches Creek 24.5

On the mainstem Yellow Breeches Creek, sampling site YLBR 24.5 was located along Park Place Road near Williams Grove, Cumberland County. This section of the Yellow Breeches Creek is 9.5 miles downstream of Mountain Creek and is directly downstream of a treated sewage discharge from South Middletown Township Municipal Authority. The primary land use in the 142-square-mile-drainage area is forest with a minimal amount of agricultural lands and residential development.

The two geometric mean violations at YLBR 24.5 were for enterococci in May and August. There were no steady state violations for *E. coli* and fecal coliform (Table 6).

Single sample maximums also were exceeded only for enterococci, which had 25 percent of samples over the 78 cfu/100 ml standard. *E. coli* and fecal coliform had no exceedances for geometric means or single sample maximums. Stream flows at this location ranged from 87 cfs to 217 cfs, but there was no correlation between stream flows and levels of the bacteria indicators. Bacteria concentrations were quite varied along most of the flow regime; however, at the highest flows, all of the indicator bacteria were relatively low. This suggests that bacteria contamination from runoff is not a major problem at this location. This was one of the least bacteria-contaminated sites in the upper reaches of the Yellow Breeches Creek Watershed.

***Table 6.*** *Steady State Violations at YLBR 24.5*

| Month | Enterococci | |
|---|---|---|
| | Geometric mean standard (cfu/100ml) | Calculated geometric mean (cfu/100 ml) |
| May 2006 | 33 | 58 |
| August 2006 | 33 | 134 |

### Dogwood Run 0.1

Dogwood Run enters the Yellow Breeches Creek from the south near the town of Williams Grove, Cumberland County, and is about 1.5 miles downstream

L. Steffy

*Yellow Breeches Creek along Park Place Road.*

of YLBR 24.5. The sampling site, DGWD 0.1, was located at the mouth of Dogwood Run along Creek Road. Dogwood Run flows generally in a south to north direction and is about six miles in length. Just upstream of the sampling site on Dogwood Run is a large spring complex that accounts for about one-third of the flow at the sampling site during low flow periods. The entire mainstem of Dogwood Run was designated as impaired for recreational uses by an unknown source of pathogens in 2004 by PADEP. Dogwood Run drains nine square miles and includes Dillsburg Borough, York County, on the east, and mostly forest and agricultural land on the west. Dillsburg is serviced by a public sewer system, but the NPDES discharge for the Dillsburg Borough Municipal Authority discharges only wastewater and industrial waste, not treated sewage, into Dogwood Run (NPDES PA 0024431).

Dogwood Run had the fewest monthly violations of any sampling site in the entire Yellow Breeches Creek Watershed, with only one violation for enterococci, during the month of August (Table 7). Single sample maximums were exceeded in Dogwood Run only for enterococci, as 30 percent of the samples taken were greater than 78 cfu/100 ml. The flow in Dogwood Run ranged from 5 cfs to 48 cfs, but there was no clear trend between discharge rate and bacteria concentrations. However, at the highest flows, all of the indicator bacteria concentrations were relatively low. Of the streams sampled, Dogwood Run was the least impacted tributary in the entire watershed in terms of bacteria contamination.

***Table 7.*** *Steady State Violations at DGWD 0.1*

| Month | Enterococci | |
|---|---|---|
| | Geometric mean standard (cfu/100ml) | Calculated geometric mean (cfu/100 ml) |
| August 2006 | 33 | 210 |

### Trout Run 0.9

Trout Run is a small tributary to the Yellow Breeches Creek that drains 3.5 square miles near Grantham, Cumberland County. Trout Run joins the mainstem Yellow Breeches Creek from the north, downstream of Dogwood Run. The surrounding land use for Trout Run is primarily low density residential. Trout Run is a spring-fed tributary, and the water quality at sampling point TRTR 0.9 was reflective of that characteristic, with a constant temperature and flow throughout the year. Trout Run flows in a northwest to southeast direction and is about two miles long.

In Trout Run, geometric mean values for enterococci exceeded the standard of 33 cfu/100 ml in all four of the sampling periods.This site was the only location to exceed any criteria during the February sampling period. In August, fecal coliform and *E. coli* also exceeded geometric mean standards (Table 8).

Single sample maximum criteria were exceeded in Trout Run in 71 percent of all the enterococci samples collected. In addition, 12.5 percent of all the *E. coli* and fecal coliform samples collected exceeded the allowable single sample limits for recreation. Due to the substantial contribution of spring water in Trout Run, the discharge was fairly consistent over the year, ranging from 4 cfs to 8.7 cfs. Bacteria enter the groundwater system from many of the same sources that contaminate surface water, but through slightly different processes. Fecal contamination seeps into groundwater from the land surface or from underground sources, such as biosolid land application, sewage lagoons, unlined sanitary landfills, improperly functioning septic tank systems, and leaking underground sewer lines (USGS, 2006). A majority of the residential areas in Trout Run Watershed are connected to public sewer lines.

***Table 8.*** *Steady State Violations at TRTR 0.9*

| Month | E. coli | | Enterococci | | Fecal coliform | |
|---|---|---|---|---|---|---|
| | Geometric mean standard (cfu/100ml) | Calculated geometric mean (cfu/100 ml) | Geometric mean standard (cfu/100ml) | Calculated geometric mean (cfu/100 ml) | Geometric mean standard (cfu/100ml) | Calculated geometric mean (cfu/100 ml) |
| May 2006 | 126 | NV | 33 | 43 | 2,000 | NV |
| May 2006 | 126 | NV | 33 | 127 | 200 | NV |
| August 2006 | 126 | 265 | 33 | 380 | 200 | 312 |
| November 2006 | 126 | NV | 33 | 75 | 2,000 | NV |

NV = no violation

L. Steffy

*Trout Run, a tributary to the Yellow Breeches Creek.*

### Stony Run 0.6

Stony Run is another tributary to the Yellow Breeches Creek, and the sampling site STNY 0.6 was located near the mouth of the creek northwest of Siddonsburg, York County, along Stony Run Road. Stony Run drains 12.5 square miles of mostly agricultural land, with some forested land in the headwaters. It flows generally in a south to north direction, is approximately eight miles in length, and joins the Yellow Breeches Creek downstream of Trout Run and just upstream of YLBR 18.0. This sampling site was downstream of a small wastewater treatment plant. In Stony Run, there were steady state enterococci violations in May, August, and November, but no violations for *E. Coli* or fecal coliform (Table 9).

***Table 9.*** *Steady State Violations at STNY 0.6*

| Month | Enterococci | |
|---|---|---|
| | Geometric mean standard (cfu/100ml) | Calculated geometric mean (cfu/100 ml) |
| May 2006 | 33 | 57 |
| August 2006 | 33 | 369 |
| November 2006 | 33 | 150 |

There were numerous single sample violations in Stony Run as well. The single sample maximum for enterococci is 78 cfu/100 ml, and in Stony Run, this value was exceeded in 54 percent of the samples collected. The single sample maximum for *E. coli* (235 cfu/100ml) was exceeded in eight percent of the samples. Discharge in Stony Run ranged between 0.6 cfs and 36 cfs; however, there was no correlation between stream flow and any of the indicator bacteria levels. There were high bacteria concentrations at low flows and at high flows. Potential sources of bacteria to this site include faulty septic systems, agriculture, and residential runoff.

### Yellow Breeches Creek 18.0

The next site downstream on the mainstem Yellow Breeches Creek was YLBR 18.0, located at Market Street near Bowmansdale, Cumberland County. YLBR 18.0 drains 177 square miles of the Yellow Breeches Creek Watershed and is downstream of the discharge for Upper Allen Township Municipal Authority. The primary land use in the surrounding area is low density residential development along with some pasture land. This site is also downstream of the three tributaries mentioned previously: Dogwood Run, Trout Run, and Stony Run.

Bacteria concentrations at YLBR 18.0 exceeded the geometric mean standard for enterococci in August and November. There were no steady state violations for *E. coli* or fecal coliform (Table 10). Forty-two percent of the enterococci samples and four percent of the *E. coli* samples exceeded single sample maximums. Stream flow ranged from 131 cfs to 304 cfs at this site, but there was no trend between bacteria levels and stream flow.

***Table 10.*** *Steady State Violations at YLBR 18.0*

| Month | Enterococci | |
|---|---|---|
| | Geometric mean standard (cfu/100ml) | Calculated geometric mean (cfu/100 ml) |
| August 2006 | 33 | 194 |
| November 2006 | 33 | 66 |

The November 2, 2006, sampling results showed very high concentrations of all three indicator bacteria at the lower three sites on the mainstem Yellow Breeches Creek, starting with YLBR 18.0. The concentrations were more than 10 times greater than any other sample throughout the year, and were the highest on that day at this site in Bowmansdale (YLBR 18.0). There was a significant rainfall two days prior to sampling; however, similar amounts of rainfall other times of the year did not cause these same elevated levels of bacteria. There were no reported problems at any of the upstream sewage treatment plants, so it was unlikely to be a point source problem. Possible causes include runoff from newly applied manure or biosolids, increased septic system failure due to saturated ground conditions, or a combination of these. These high levels of bacteria appear to have been an anomaly for this stretch of the Yellow Breeches Creek.

### Yellow Breeches Creek 10.7

The next downstream site was YLBR 10.7, located at Sheepford Road, near Rossmoyne, Cumberland County. This site drains 194 square miles, and the adjacent land uses to the site are primarily forested and pasture land, with some low density residential development. Enterococci concentrations at YLBR 10.7 exceeded the geometric mean criteria during the August and November sampling periods. There was also a violation for *E. coli* during the month of November, but there were no geometric mean violations for fecal coliform at this sampling location (Table 11).

The single sample maximum of 78 cfu/100 ml for enterococci was exceeded in 29 percent of the samples, with a maximum value of 2900 cfu/100 ml.

***Table 11.*** *Steady State Violations at YLBR 10.7*

| Month | *E. coli* | | Enterococci | |
|---|---|---|---|---|
| | Geometric mean standard (cfu/100ml) | Calculated geometric mean (cfu/100 ml) | Geometric mean standard (cfu/100ml) | Calculated geometric mean (cfu/100 ml) |
| August 2006 | 126 | NV | 33 | 150 |
| November 2006 | 126 | 145 | 33 | 194 |

NV = no violation

L. Steffy

*Yellow Breeches Creek at Sheepford Road.*

Additionally, eight percent of all samples collected were above the single sample maximum standard of 298 cfu/100 ml for *E. coli*. Stream discharge ranged from 129 cfs to 346 cfs, and there was no correlation between flow and concentration of any indicator bacteria. This site also was affected by the elevated bacteria levels first observed upstream at YLBR 18.0 on November 2, 2006. Possible sources of bacteria contamination at this site include faulty septic systems or agricultural inputs.

### Cedar Run 0.1

Cedar Run enters the Yellow Breeches Creek about four miles upstream of the mouth and is the most degraded tributary in the watershed. The sampling site on Cedar Run, CEDR 0.1, is at the mouth near Eberly's Mill, Cumberland County. Cedar Run flows generally in a southwest to northeast direction, and the mainstem is about 7.3 miles long. According to the Coldwater Conservation Plan for the watershed, the 13.8-square-mile drainage area for Cedar Run contains greater than 50 percent impervious surface and the land use is primarily high density development (Alliance for the Chesapeake Bay and Pennsylvania Environmental Council, 2005). A large majority of Cedar Run Watershed is serviced by public sewer systems.

Cedar Run had the most combined geometric mean exceedances of any of the sampled locations in the Yellow Breeches Creek Watershed, with 8 of the 12 (67 percent) geometric mean values exceeding the standards throughout the year. Enterococci exceeded the geometric mean limit in May, August, and November. *E. coli* and fecal coliform exceeded the geometric mean limits in May and August (Table 12).

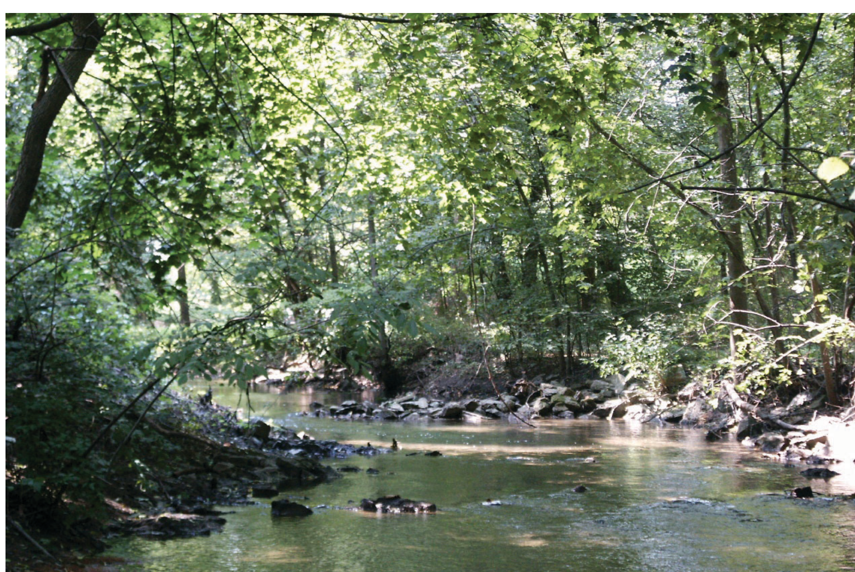
Single sample maximums were exceeded routinely in Cedar Run for all three indicator bacteria. Enterococci values exceeded the 78 cfu/100 ml limit 62 percent of the time with a maximum single sample value of 4,100 cfu/100 ml. *E. coli* standards were exceeded in 42 percent of the samples, with a maximum value of 920 cfu/100 ml.

The flow in Cedar Run was variable over the course of the sampling period, ranging from 2 cfs to 31 cfs. There was no discernible trend between higher flows and increasing bacteria levels. However, at the highest flows, the bacteria levels were below the detection limit. This suggests that there are constant sources of bacteria contamination coming from this urbanized watershed, not just impacts related to wet weather events.

***Table 12.*** *Steady State Violations at CEDR 0.1*

| Month | E. coli | | Enterococci | | Fecal coliform | |
|---|---|---|---|---|---|---|
| | Geometric mean standard (cfu/100ml) | Calculated geometric mean (cfu/100 ml) | Geometric mean standard (cfu/100ml) | Calculated geometric mean (cfu/100 ml) | Geometric mean standard (cfu/100ml) | Calculated geometric mean (cfu/100 ml) |
| May 2006 | 126 | 229 | 33 | 187 | 200 | 334 |
| August 2006 | 126 | 428 | 33 | 993 | 200 | 833 |
| November 2006 | 126 | NV | 33 | 209 | 2,000 | NV |

NV = no violation



L. Steffy

*Cedar Run near Eberly's Mill.*

### Yellow Breeches Creek 0.1

The Yellow Breeches Creek empties into the Susquehanna River at New Cumberland, Cumberland County. YLBR 0.1 is located just upstream of the mouth of the Yellow Breeches Creek at Bridge Street, and drains the entire 219-square-mile watershed. This site is downstream of Cedar Run and is located in an area dominated by high density residential development, a majority of which are connected to public sewer systems. Bacteria levels at YLBR 0.1 were relatively low with the only two steady state violations occurring in August and November for enterococci (Table 13).

***Table 13.*** *Steady State Violations at YLBR 0.1*

| Month | Enterococci | |
|---|---|---|
| | Geometric mean standard (cfu/100ml) | Calculated geometric mean (cfu/100 ml) |
| August 2006 | 33 | 70 |
| November 2006 | 33 | 75 |

Single sample maximums were never exceeded for *E. coli* or fecal coliform at YLBR 0.1. However, 38 percent of all samples collected for enterococci exceeded the single sample maximums. Discharge measurements ranged from 135 cfs to 333 cfs at the mouth of the Yellow Breeches Creek, and, except for the unusually high value on November 2, 2006, there was a general trend of decreasing bacteria concentrations with increasing stream flows. On the mainstem, this site was the least affected by bacteria contamination, and even the two steady state violations for enterococci were not as elevated as at other sites in the watershed.

## FOR THE ENTIRE WATERSHED

Using the USEPA-recommended criteria for steady state concentrations over a 30-day sampling period, there were 8 geometric mean violations (18 percent) for *E. coli* and 26 geometric mean violations (59 percent) for enterococci throughout the year (Figure 5). However, the current method of determining recreational water quality impairment in Pennsylvania uses fecal coliform as the indicator bacteria. The results of fecal coliform analysis in the Yellow Breeches Creek showed a similar number of geometric mean violations as did the *E. coli* analysis. Geometric mean standards for fecal coliform were exceeded seven times (16 percent) throughout the sampling period (Figure 5). The geometric mean violations for fecal coliform occurred only during the recreation season, when the standard is 200 cfu/100 ml. During the rest of the year, the geometric mean standard is 2,000 cfu/100 ml, and this value was not exceeded in the Yellow Breeches Creek Watershed during any of the sampling periods.

During the recreation season (May-September), 5 of the 11 sampling sites exceeded the geometric mean standard for *E. coli* and fecal coliform during at least one of the months (Figure 4). In addition, all 11 of the sampling sites exceeded the geometric mean standard for enterococci for at least one of the months.

The other element of the USEPA-recommended criterion is based on single sample maximums, which were exceeded in the Yellow Breeches Creek 28 times (11 percent) for *E. coli* and 113 times (43 percent) for enterococci (Figure 6 and Figure 7). The current single sample regulations for fecal coliform in Pennsylvania apply only to the recreational season, and this maximum value of 400 cfu/100 ml was exceeded 24 times, which is 9 percent of the samples (Figure 8). There were other very high single sample values outside of the recreational season that are not considered violations under current PADEP regulations. For single sample violations during the recreation season, there were 23 for *E. coli*, 24 for fecal coliform, and 84 for enterococci.

The above data are based on classifying the Yellow Breeches Creek as being a "moderate use, full body contact" stream due to the large amount of recreational use associated with the watershed. This is the second most stringent level in the USEPA-recommended standards, only after designated beach areas. Additionally, there are two other recreational use categories designated in the USEPA recommendations; "light use, full body contact," and "infrequent use, full body contact." These categories can be used in streams that are used less frequently for "full body contact recreation," but still need to be monitored. At both these lower levels, the acceptable concentration of indicator bacteria is higher, reflecting a greater risk to human health, which is theoretically balanced out by fewer recreational users. Table 14 shows the percentage of samples that exceeded the recommended single sample maximums for each recreational use classification on each tributary as well as on the mainstem Yellow Breeches Creek. There are numerous violations of even the least protective standards, which correspond to the highest level of risk, especially for enterococci in the Yellow Breeches Creek (Table 14). More than 40 percent of all enterococci samples violated the "infrequent use, full body contact" criteria at three sampling locations. This is significant given the research correlating enterococci with increased

***"For single sample violations during the recreation season, there were 23 for E. coli, 24 for fecal coliform, and 84 for enterococci."***

incidences of gastroenteritis and the large number of people who use the Yellow Breeches Creek for recreational purposes.

Numerous other studies have tried to link indicator bacteria concentrations with basic water chemistry parameters such as temperature, conductivity, and turbidity, with little success (Cinotto, 2005; Ohio EPA, 2006). The same held true in the Yellow Breeches Creek; there was no clear correlation between any field parameter and bacteria concentrations. Water quality informational data collected during each sampling visit was similar at all of the mainstem sites except YLBR 51.6. All other mainstem sites had an average pH between 7.3-7.6, average conductivity between 214-306 uS/cm, and an average alkalinity of between 84-112 mg/l. Conversely, the average conductivity at YLBR 51.6 was 29 uS/cm, the average pH was 5.1, and the average alkalinity was 1.8 mg/l. Alkalinity and pH at YLBR 51.6 exceeded water quality standards numerous times throughout the sampling period.

Field chemistry for the tributaries entering the Yellow Breeches Creek was quite varied. Mountain Creek had similar characteristics to YLBR 51.6, with lower pH, alkalinity, and conductivity. This likely is due to natural conditions based on the geology of much of the drainage area. The field chemistry in Cedar Run reflects the urban setting of this watershed. It is characterized by high conductivity and the highest average temperature of any of the sampled locations. The high alkalinity in Cedar Run likely is due to the underlying carbonate geology. Dogwood Run had an average temperature of 11.7°C and never rose above 17°C, which probably was due to the spring influence directly upstream of the sampling site. Trout Run had a fairly high conductivity and a high alkalinity, both of which are likely related to the spring water that comprises this stream. The average temperature was higher in Trout Run than in Dogwood Run, even though both are spring fed, because the Trout Run sampling site was farther from the spring source. Stony Run had a moderate alkalinity, conductivity, and pH.

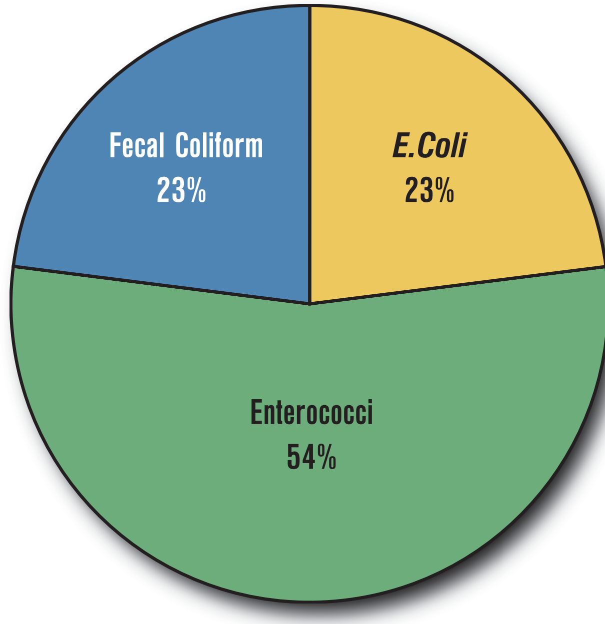



***Figure 5.*** *Percentage of Geometric Mean Violations for Indicator Bacteria in the Yellow Breeches Creek Watershed During the Recreational Season.*

Generally, the prevailing theory regarding recreational water quality is that bacteria levels rise in streams and rivers following rain events, specifically due to runoff originating from urban and agricultural areas. Several studies by the USGS have attempted to correlate indicator bacteria concentrations with rainfall, runoff, and wastewater practices. These studies have shown that fecal indicator bacteria concentrations can be highly unpredictable along urban streams and can exceed recreational water quality standards even in the absence of significant rainfall (USGS, 2006). Bacteria data from the Yellow Breeches Creek were extremely variable, and showed no consistent patterns following a rain event or during low-flow months in the summer.

During the 2006 sampling, August was the driest sampling period, with only 0.7 inches of rain on average across the Yellow Breeches Creek Watershed for the entire month. The August sampling period bacteria results showed more than double the number of geometric mean violations and almost three times as many single sample maximum violations. If urban or agricultural runoff contributed the primary source of bacteria contamination after storm events, this would not be the case. In this study, there was no correlation between bacteria concentrations and amount of rainfall on the day of sampling, one day before sampling, or two days before sampling. It appears that throughout the Yellow Breeches Creek Watershed, there are continuous inputs of bacteria contamination that are more concentrated in low flows, and more dilute during high flows.

> *Generally, the prevailing theory regarding recreational water quality is that bacteria levels rise in streams and rivers following rain events, specifically due to runoff originating from urban and agricultural areas.*

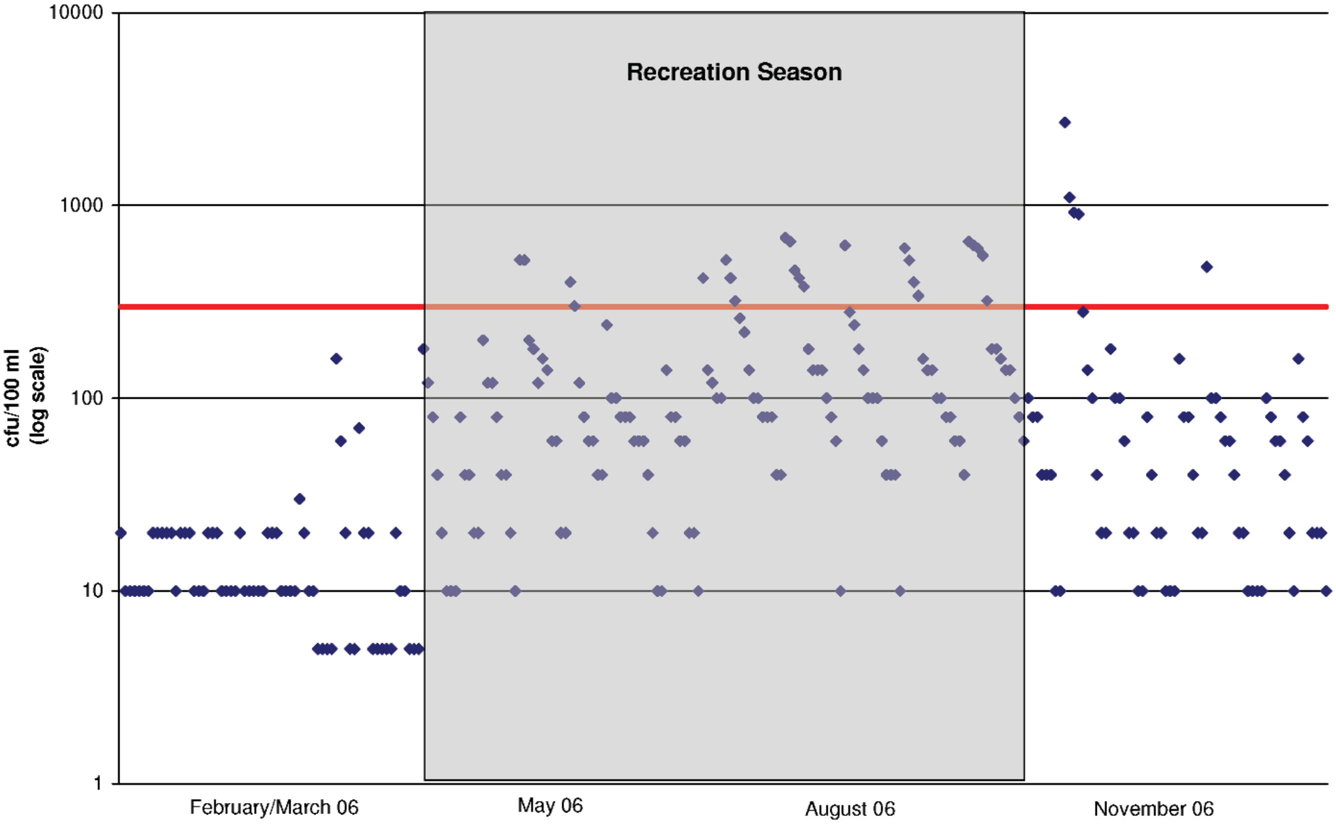



**Figure 6. Single Sample *E. Coli* Concentrations**

***(red line indicates EPA recommended single sample maximum)***

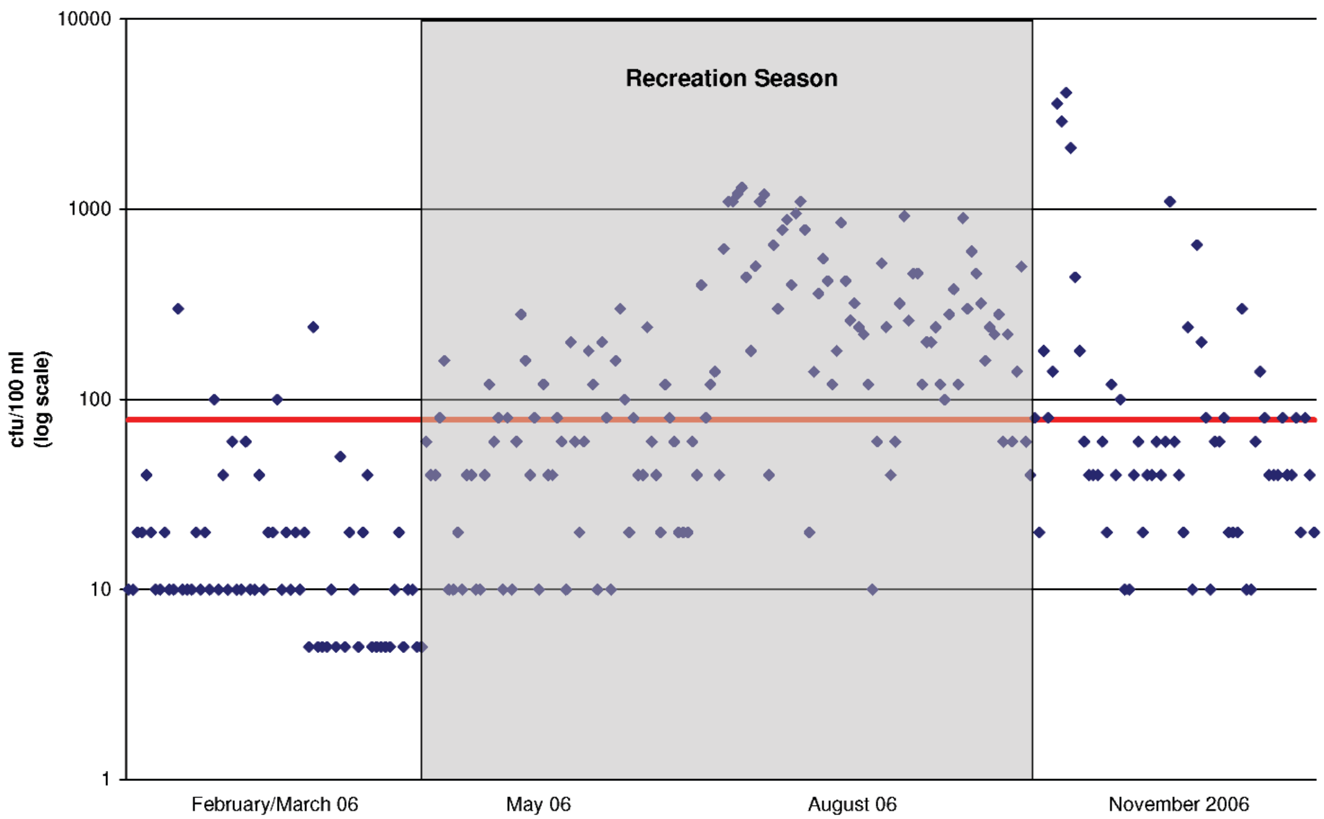



**Figure 7. Single Sample Enterococci Concentrations**

***(red line indicates EPA recommended single sample maximum)***

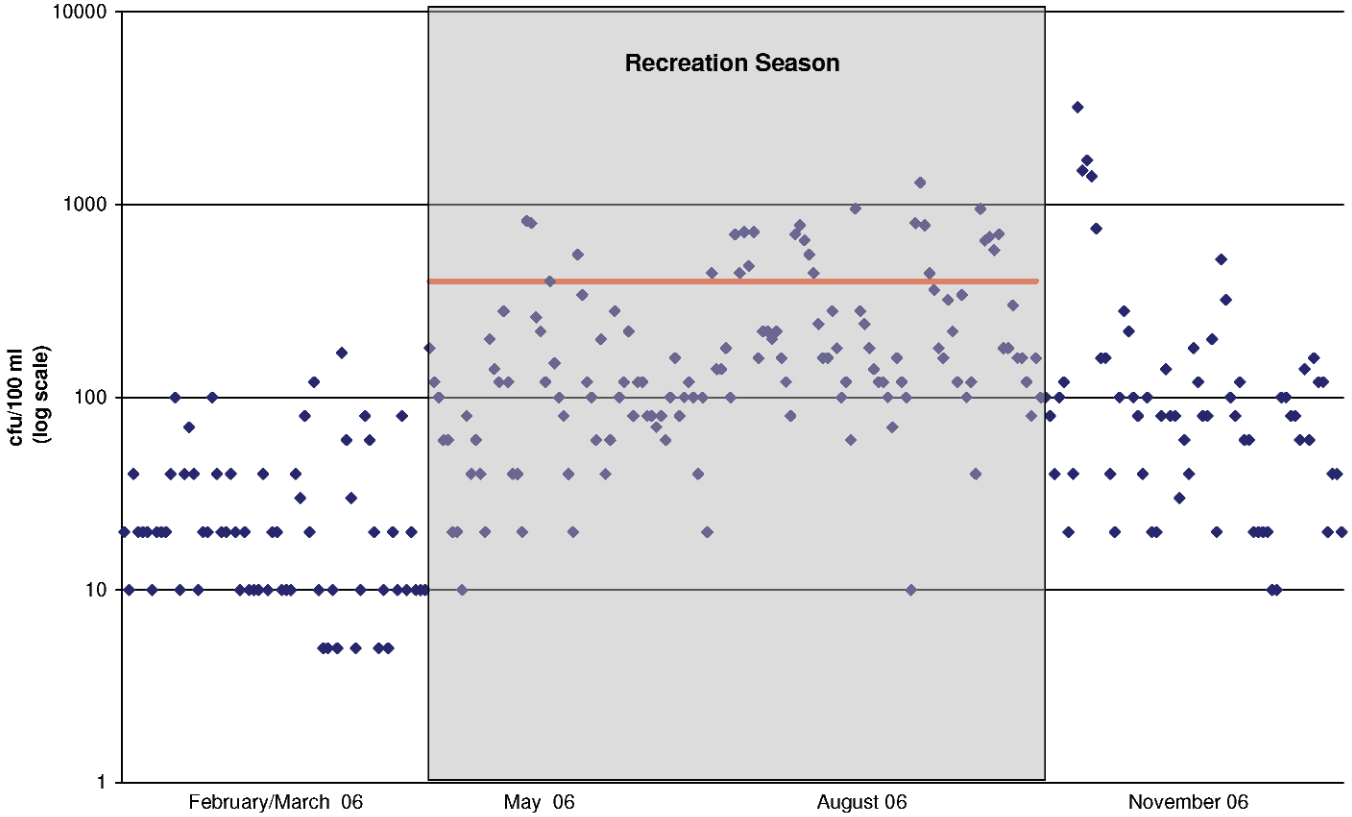



**Figure 8. Single Sample Fecal Coliform Concentrations**
***(red line indicates current PADEP standards for single sample maximum for May-September)***

Table 14. A Comparison of Samples Exceeding Standards at Various Risk Levels

| PA DEP Standard for May-September Only | | | EPA Recommended Criteria | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Fecal Coliform | E. coli | | | Enterococci | | |
| **Watershed** | **Sample size** | **Percent >400 CFU/100 ml** | **Percent >298 CFU/100 ml (Moderate use full-body contact)** | **Percent >409 CFU/100 ml (Light use, full body contact)** | **Percent >575 CFU/100 ml (Infrequent use, full body contact)** | **Percent >78 CFU/100 ml (Moderate use full-body contact)** | **Percent >107 CFU/100 ml (Light use, full body contact)** | **Percent >151 CFU/100 ml (Infrequent use, full body contact)** |
| Cedar Run | 24 | 41.7 | 41.7 | 33.3 | 12.5 | 62.5 | 62.5 | 62.5 |
| Stony Creek | 24 | 0 | 8.3 | 4.2 | 0 | 54.2 | 50 | 41.7 |
| Trout Run | 24 | 12.5 | 12.5 | 12.5 | 4.2 | 70.8 | 50 | 41.7 |
| Dogwood Run | 24 | 0 | 0 | 0 | 0 | 29.2 | 25 | 20.8 |
| Mountain Creek | 24 | 4.2 | 4.2 | 4.2 | 4.2 | 41.7 | 25 | 25 |
| Yellow Breeches Mainstem | 144 | 6.9 | 8.3 | 5.6 | 4.2 | 35.4 | 27.8 | 20.1 |
| All Samples | 264 | 9.1 | 10.6 | 8 | 4.2 | 42.8 | 34.5 | 28.4 |

## DISCUSSION

There are a wide variety of potential sources of fecal indicator bacteria that could be contaminating the Yellow Breeches Creek. It is impossible to identify one source that is causing elevated levels of bacteria at any individual site, because in most cases a number of sources may contribute to the problem. There are both point and nonpoint sources of fecal indicator bacteria in the Yellow Breeches Creek Watershed. Municipal and industrial discharges are the most common point sources, while agricultural, urban runoff, and wildlife wastes are examples of nonpoint sources. Agricultural sources include animal waste, application of manure and biosolids to fields, and crop irrigation from contaminated storage ponds (Wilhelm and Maluk, 1998). Other sources of bacteria and potential pathogens from agricultural land can include: poorly managed or uncontrolled runoff from animal feeding operations, spills or releases from manure handling operations, runoff from manure applied to farm fields, and direct access to streams by grazing animals (Ohio EPA, 2006).

Urban and suburban sources of bacteria contamination include failed on-lot waste disposal systems, leaking sewer lines, pet waste, and landfill leakage. During rainfall events, these nonpoint sources can have a more direct impact on water bodies, as stormwater runoff transports everything from the land into the streams and rivers. This includes runoff from agricultural fields or feedlots, drainage from septic tanks, combined sewer overflows, and residential runoff carrying pet and wildlife feces.

The presence and distribution of fecal indicator bacteria have been related directly to land use and land cover characteristics in numerous study areas (Clark and Gamper, 2003). Concentrations of fecal indicator bacteria were higher in agricultural and urban areas compared to rangeland and forested land in Washington State (Embrey, 1992). In North and South Carolina, maximum fecal indicator bacteria concentrations were found in agricultural areas but the highest median concentrations were in urban areas (Wilhelm and Maluk, 1998). In Wyoming, concentrations of fecal indicator bacteria were two to three times higher in urban and agricultural land than forested land (Clark and Gamper, 2003).

In the Yellow Breeches Creek Watershed, Cedar Run has the greatest percentage of urban land cover. It also had the highest median and maximum values for fecal coliform, *E. coli*, and enterococci. A large majority of Cedar Run is served by public sewers, so leaking sewer pipes could be a possible cause of the bacteria contamination. In the Yellow Breeches Creek Watershed, the most concentrated area of agriculture is along the mainstem of the creek from its origin to 25 miles downstream (Figure 3). Three sites on the mainstem Yellow Breeches Creek are located in primarily agricultural use area. These sites, YLBR 51.6, YLBR 40.7, and YLBR 24.5, show very different results for level of bacteria contamination. YLBR 51.6 had violations for all three indicator bacteria one time during the summer months. YLBR 40.7 samples exceeded the standards for all three indicators during both summer months, and YLBR 24.5 showed no violations at all for *E. coli* or fecal coliform. Obviously, much variability exists in bacteria concentrations among site locations in the Yellow Breeches Creek, indicating that there are multiple factors influencing recreational water quality throughout the watershed.


L. Steffy

*Water fowl are a potential source of bacteria in the Yellow Breeches Creek Watershed.*

Failing or improperly designed on-site wastewater systems potentially can result in significant loadings of bacteria to adjacent waterways. Septic systems process wastewater from about 25 million rural and suburban households, which is 25 percent of all the households in the United States (Borchardt et al., 2003). In these on-site waste disposal systems, effluent is released directly into the land subsurface, where enteric microorganisms are removed by soil filtration and adsorption. The effectiveness of this process can be limited depending on environmental conditions and whether or not proper routine maintenance is performed. Septic systems that are not functioning correctly or are not being properly maintained can be a large and continual source of fecal contamination.

Septic systems remain a common method of wastewater disposal in the United States as the population continues to expand into more rural and suburban areas that are not served by municipal sewers. Even if septic systems are not discharging or leaking directly into surface water, they can contaminate groundwater. Soil acts as a natural filter for water percolating down through the ground, but this does not guarantee that groundwater supplies cannot become contaminated and eventually pollute the surface water as well (Bickford et al., 1996).

Less than 25 percent of the Yellow Breeches Creek Watershed is served by central sewage systems (Figure 4), leaving a large majority of the watershed using either on-lot or centralized septic systems as a means of waste disposal. This study did not attempt to formally quantify the extent of this problem but general trends can be observed. With the exception of Cedar Run, sites in sewered areas had fewer recreational water quality violations. In the Yellow Breeches Creek Watershed, it appears that the NPDES wastewater treatment plants are doing an adequate job of controlling effluent bacteria counts to within acceptable levels, and that these point sources are not the primary problem.

In water bodies like the Yellow Breeches Creek, which support primary contact recreational uses such as swimming, kayaking, and wading, as well as secondary contact uses including canoeing and fishing, it is vitally important to monitor the level of pathogen contamination to protect human health. Waters contaminated with human feces generally are regarded as a greater risk to human health as they are more likely to contain human-specific enteric pathogens, including *Salmonella, Shingella* spp, hepatitis A virus, and Norwalk-group viruses (Scott et al., 2002). However, animal feces also can carry a variety of enteric pathogens such as *Salmonella, E. coli*, and *Cryptosporidium* spp. (Scott et al., 2002). Monitoring for these human pathogens would provide direct evidence of their presence or absence in the water; however, these pathogens usually are not readily detectable in the environment because they are often present in low numbers. At the same time, many of these pathogens have a considerable low infectious dose, meaning that even in low concentrations these pathogens can be hazardous to human health (Scott et al., 2002). Monitoring for fecal indicator bacteria, and subsequent follow up with warnings and/or closures of recreational areas, is the most practical way to keep the risk to human health low and allow for the continuing recreational uses in the Yellow Breeches Creek.

> ***The results of this study clearly show that bacteria contamination is an important issue that needs to be addressed in the Yellow Breeches Creek Watershed.***

## FUTURE IMPLICATIONS

Recent research has indicated that bacteria have the ability to live in sediment and act as a source of contamination when the sediment is disturbed and sediment is re-suspended in the water column. One USGS study determined that bacteria concentrations in the sediment were two to 100 times higher than in the water column at base flow conditions (Cinotto, 2005). In this same study, a major impact on the bacteria populations was the particle distribution, as *E. coli* preferred sand-sized sediment and enterococci preferred silt. This could be important in the Yellow Breeches Creek since recreational activities can easily stir up sediments, increasing the amount of bacteria in the water column, and thus increasing the risk to human health. Future studies could be done to determine the extent of bacteria in the sediments throughout the Yellow Breeches Creek Watershed.

Although it is impossible to differentiate between sources of bacteria from just the raw indicator bacteria concentrations, other methods to determine the sources can be used. Microbial source tracking is a fairly new technique that uses various molecular methods (i.e., Ribotyping, polymerase chain reaction (PCR), molecular markers) to differentiate between waste from humans and various kinds of animals, both wild and domestic. This technique is fairly expensive but can be useful to identify sources of bacteria. However, even if the source is known, the method of transference may not be. For example, if there is a human source, it could be faulty septic systems, leaking sewer lines, or improperly functioning wastewater treatment plants. If the source is determined to be bovine, it could be from cattle with access to the stream, runoff from manure storage, or runoff from manure spread on fields. However, some level of microbial source tracking may be useful in the Yellow Breeches Creek Watershed.

The results of this study clearly show that bacteria contamination is an important issue that needs to be addressed in the Yellow Breeches Creek Watershed. Numerous locations along the mainstem and tributaries are in violation of the current PADEP fecal coliform standards for the recreational season. When the data were compared to the USEPA-recommended standards for *E. coli* and enterococci, the *E. coli* results were similar to the fecal coliform. However, when using enterococci as the indicator bacteria, there were more than two times the number of geometric mean violations in the watershed.

Additionally, the samples that were collected in February and November, when recreation activities are typically less, showed that bacteria levels can be quite elevated even in these months and could pose health risks to off-season recreational users. According to the Rivers Conservation Plan for the Yellow Breeches Creek, feedback from the community indicated that the aesthetic value of the creek and its ability to provide recreational opportunities were considered its primary strengths (YBWA, 2005). This emphasizes the need to address the recreational water quality requirements of the watershed.

Data from this study will be used by SRBC in managing the water resources of the basin. Additionally, all the data from this bacteria study, as well as the data from the concurrent Instream Comprehensive Evaluation assessment, have been given to PADEP for its consideration and use in improving recreational water quality. Raw data from this project also will be available to the public on the SRBC website.

## Appendix A

| Site # | Station name | Latitude | Longitude | Site description | Drainage Area ($mi^2$) |
|---|---|---|---|---|---|
| Y6 | YLBR51.6 | 40.074378 | -77.409758 | Headwaters of Yellow Breeches Creek; at Rehoboth Rd. near New Lancaster | 12 |
| Y5 | YLBR40.7 | 40.123753 | -77.227756 | Yellow Breeches Creek at pond and fishing area along West Yellow Breeches Creek Rd. | 46.8 |
| Y4 | YLBR24.5 | 40.142633 | -77.090906 | Yellow Breeches Creek at Park Place Rd. | 142.4 |
| Y3 | YLBR18.0 | 40.164056 | -76.976650 | Yellow Breeches Creek at Market St., near Bowmansdale | 176.7 |
| Y2 | YLBR10.7 | 40.167683 | -76.905783 | Yellow Breeches Creek at Sheepford Rd. | 194.1 |
| Y1 | YLBR0.1 | 40.224322 | -76.860700 | Mouth of Yellow Breeches Creek at Bridge St. in New Cumberland | 0.1 |
| T1 | TRTR0.9 | 40.156967 | -77.007458 | Trout Run, downstream of large spring, at Gettysburg Rd. | 3.6 |
| S1 | STNY0.6 | 40.151147 | -76.985783 | Stony Run at Stony Run Rd. | 12.5 |
| M1 | MNTN1.8 | 40.137525 | -77.180122 | Mountain Creek, downstream of RR bridge, behind apartment complex along Rt. 34 in Mt. Holly Springs | 46 |
| D1 | DGWD0.1 | 40.147467 | -77.029119 | Mouth of Dogwood at Creek Rd. | 9.3 |
| C1 | CEDR0.1 | 40.224872 | -76.906394 | Mouth of Cedar Run at Eberlys Mill | 12.5 |

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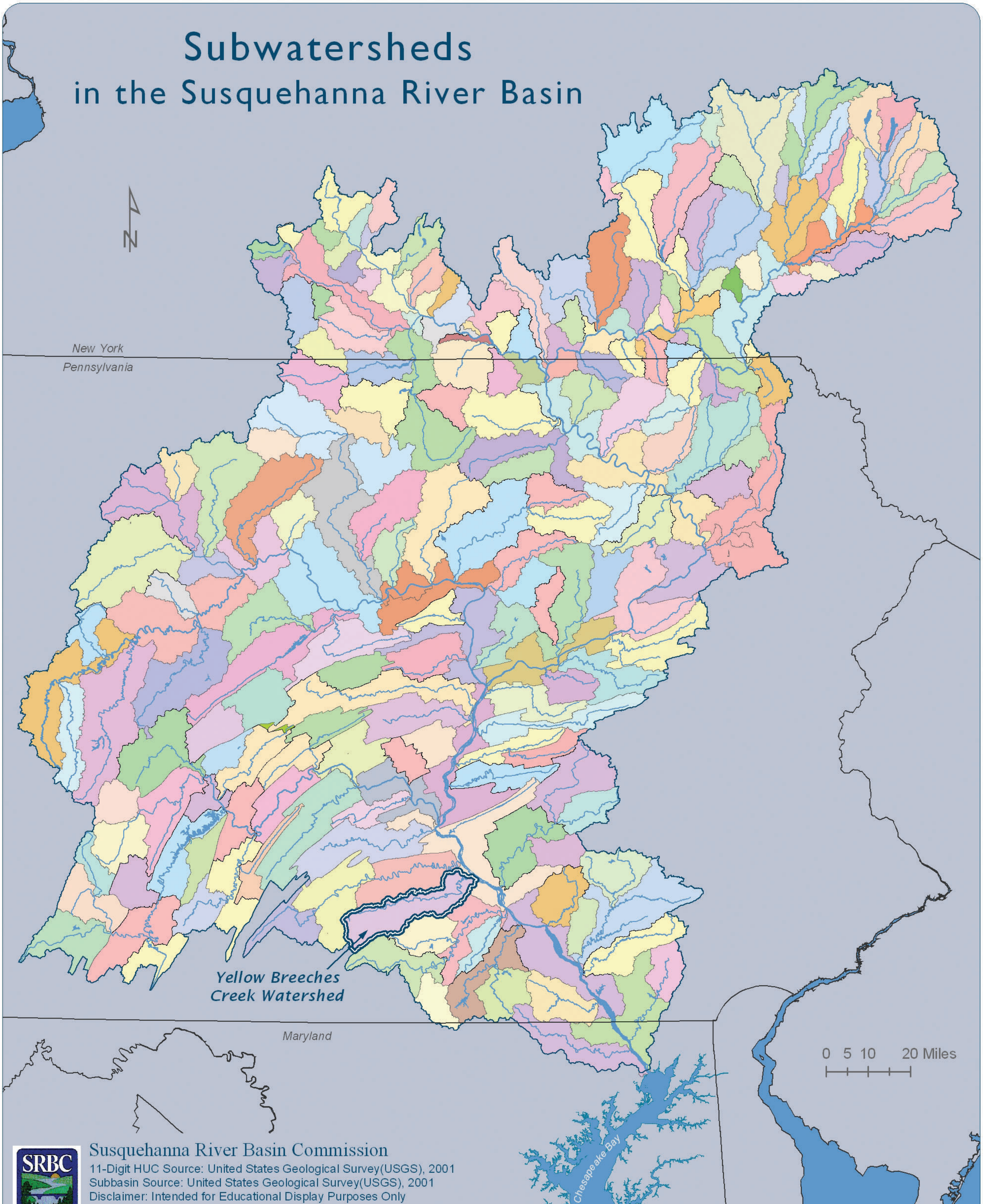
Subwatersheds
in the Susquehanna River Basin
New York
Pennsylvania
Maryland
Yellow Breeches
Creek Watershed
Chesapeake Bay
0 5 10 20 Miles
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J. Zimmerman


L. Steffy

*Headwaters of Yellow Breeches Creek near New Lancaster.*

## SUSQUEHANNA RIVER BASIN COMMISSION



*In 1971, the Susquehanna River Basin Commission was created as an independent agency by a federal-interstate compact among the states of Maryland, New York, and the Commonwealth of Pennsylvania, and the federal government. In creating the Commission, the Congress and state legislatures formally recognized the water resources of the Susquehanna River Basin as a regional asset vested with local, state, and national interests for which all the parties share responsibility. As the single federal-interstate water resources agency with basinwide authority, the Commission's goal is to coordinate the planning, conservation, management, utilization, development and control of the basin's water resources among the public and private sectors.*


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