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Hydrologic Analysis of the Major Tributaries Within the Lower Dan River Watershed Between Milton, NC and Paces, VA

by

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12/8/00
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ABSTRACT

Hydrologic Analysis of the Major Tributaries Within the Lower Dan River Watershed Between Milton, NC and Paces, VA

JULIET JEFFERSON BROWN

DIRECTOR: DR. JOSEPH E.GARCIA

According to the Clean Water Act of 1972, Virginia is required to develop Total Maximum Daily Loads (TMDLs) for its impaired waters. A TMDL is the maximum amount of particular contaminants that a body of water can accept, without violating federal and state water quality standards. Approximately 130 waters have been targeted for TMDL development, with fecal coliform contamination cited as one of the top five violations.

The purpose of this study was to examine a ten-mile segment of the Dan River that has been designated as impaired, along with seven tributaries that contribute to that segment. The segment is found along the VA and NC border in Pittsylvania and Halifax Counties. From February to September 2000, hydrologic and chemical data were gathered on six sampling events at ten sites: three on the Dan River and seven tributary locations. All of the waterways were tested for temperature, pH, conductivity, nitrates, nitrites, phosphates, and fecal coliform. Additionally, discharge was calculated for each tributary from field measurements.

Averages and standard deviations were calculated for each of the chemical parameters for each site. The analysis of variance for the chemical parameters shows no significant change from the upstream Dan River site to the downstream Dan River site.

Hydrographs were constructed for each of the tributaries, as were stage-discharge diagrams. For most of the streams, the correlation between stream depth and discharge, based on a linear regression, was very low; therefore, the diagrams should not be used for discharge prediction. Overall, the tributaries are not contributing a significant pollutant load to the river system based on chemical and hydrologic data.

ACKNOWLEDGEMENTS

I would like to express my appreciation to Dr. Garcia for his guidance and support throughout the duration of my project. I would also like to thank Bruce Pearce for serving on my committee, but more importantly, for helping me select site locations and calculate watershed areas. He, along with Linda Wallace and Billy Hoffer, from the Halifax Soil and Water Conservation District, were instrumental in providing background information on the TMDL initiative and land-use practices.

Dr. Wells, who thought she had retired from all of this, deserves special recognition for agreeing to be on my committee. Her assistance and advice over the last three years have helped me to finally reach this goal.

Special thanks to all of those individuals who "volunteered" to help me collect field data: Jeremy Hardcastle, Anne Oakes, Becky Butler, Jessica Worley, Kelli Baker, Erin Ganey, and Billy Hoffer. I would like to thank Kenny Daniel for allowing me to come on his property to access Byrds Branch. I would also like to thank Lawrence Butler and his wife for allowing me to access Double Creek and Barker Creek.

A special thanks to Mom and Dad for their continuous support. Perhaps the most deserving of recognition is my husband, Ethan, who not only helped me collect field data, but for three years filled in for a Mom who was taking classes or writing a paper. His patience extends beyond comprehension. Finally, I would like to thank the two most important reasons I can think of for trying to make this world a better place. For Alex and Timmy, I wish clean air to breathe, clean water to drink, and a planet where peace and understanding cross all boundaries.

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INTRODUCTION

TMDL Initiative

The Commonwealth of Virginia, along with many other states, in compliance with Section 303(d) of the Clean Water Act of 1972, is required to develop Total Maximum Daily Loads (TMDL) for its impaired waters. A TMDL is the maximum amount of a specified pollutant that a body of water can accept, given a reasonable margin of safety and seasonal fluctuations, without violating federal or state water quality standards (Adler 1998). Also, the term TMDL refers to the implementation plan that will reduce identified pollutants to the mandated level. Once a segment of a waterway within a particular state has been deemed impaired with regard to a particular pollutant by the Environmental Protection Agency (EPA), the respective state's environmental protection agency will then need to calculate how much of that pollutant can be allowed into the waterway without violating water quality standards established by the EPA. This pollutant level must then be apportioned to the "known" sources of the particular impairment for that stream segment. Point sources as well as non-point sources must be included as contributors in the calculation, with the pollutant level including a reasonable margin of safety to insure the integrity of the water sources (United States Environmental Protection Agency 1999a).

Over 21,000 U.S. bodies of water have been identified as polluted. This includes approximately 300,000 river and shoreline miles and 5 million acres of lakes. Excess sediments, nutrients, and harmful microorganisms are the leading reasons that 218 million Americans (the U.S. population is roughly 270 million) live within 10 miles of a polluted waterway (United States Environmental Protection Agency 2000a). In Virginia, there are over 1000 listed impairments and 131 waters have been targeted for TMDL development by April 2000. This goal was not met due to the fact that the top two sources for impairment are nonpoint sources (44%) and unknown sources (19%,) while only seven percent of impairments can be designated as point source (United States Environmental Protection Agency 2000).

On July 13, 2000, a final rule regarding the TMDL initiative was published in the EPA's *Federal Register*. This final rule provides a comprehensive list of all U.S. polluted waters, allows states to establish water quality standards and goals, and assures that TMDL plans are specific concerning actions and schedules for meeting established standards. Virginia's Department of Environmental Quality (DEQ) is charged with identifying impaired waters, setting the water quality standards, and developing TMDLs to improve water quality. Because of limited resources, manpower, and time, the Virginia DEQ enlists the help of local government agencies to assist in testing and identifying pollution sources.

Pollution Sources

In Virginia, 43 different types of pollution violations have been identified, with 16 of these constituting 95% of all impairments. Ammonia nitrogen, fecal coliform, benthic, and dissolved oxygen top the list of pollution violations (United States Environmental Protection Agency 2000b). The parameters most commonly monitored in streams and other bodies of water include flow, dissolved oxygen, temperature, pH, phosphorus, nitrates, total suspended solids (TSS), and fecal bacteria (United States Environmental Protection Agency 1997). Deviation from normal levels for any of these parameters indicate that water quality has become impaired and could have an effect on biological life and the overall health of the aquatic system.

According to Eleanor Daub (personal communication, October 6, 2000) of the Virginia DEQ, there are no established standards (limits) for nitrates, nitrites, pH, TSS, or phosphates. The established standard for fecal coliform is 1000 counts (colonies) per 100 ml. of sample for a single sample result or a mean of 200 on geometric analysis for two or more samples over a thirty-day period. While there are no established standards for phosphates, nitrates, nitrites, and TSS, excesses in each of these parameters can have a negative impact on water quality.

For example, it is known that excessive amounts of phosphorus can lead to an increase in plant growth. When these plants die, the aquatic system will be robbed of dissolved oxygen as the plants decay. Sources of phosphorus include runoff containing fertilizers, septic system wastes, and drainage from wetlands. Not all phosphorous input into an aquatic system is anthropogenic. Phosphorus particulates from weathered rock have the ability to sorb or bind to sediments in the water or to the substrate and are therefore transported into waterways by surface runoff with eroded sediments. Deposition of the sediment can, in effect, remove phosphorous from the system if left undisturbed; however, slow moving water and changes in system depth and chemistry can release phosphorus back into the water (United States Environmental Protection Agency 1999b).

Excess levels of nitrogen have the same negative effects as phosphorus. The EPA has not yet set a standard for nitrogen (as nitrates or nitrites) in streams, but a standard has been set for drinking water not to exceed 10 ppm as nitrates and 1 ppm as nitrites. Levels exceeding these standards can cause methemoglobinemia (Blue Baby Syndrome) in infants and levels in excess of 100 ppm nitrates can cause water to taste bitter and cause physiological distress (Straub 1989). Sources of excess nitrogen include manure runoff, failing septic systems, industrial discharges, and fertilizer runoff. Natural inputs of inorganic nitrogen do not bind to soil particles as strongly as phosphorus and can be transported in a dissolved phase or with particulate matter in runoff (United States Environmental Protection Agency 1999b).

Runoff of particulate matter can also elevate levels of total suspended solids, decreasing photosynthesis by reducing the amount of available sunlight. Elevated TSS levels can increase stream temperature, turbidity, and may increase the amount of silt and clay in the stream. Sources of total solids include industrial discharges, fertilizers, sewage, soil erosion, and runoff.

In Virginia, most rural watersheds that have been designated as impaired are a result of fecal coliform contamination. A potential source for the pollution is runoff from surrounding pastures and farmlands caused by the application of commercial fertilizers and wildlife activity. Other possible sources include spills from surrounding wastewater treatment plants and residential septic systems. For instance, in July 2000, in Eden, NC (upstream of the lower Dan) 44,200 gallons of untreated sewage spilled into the Dan River when power was cut off to a pump station in order to make repairs.

Hydrology Impacts

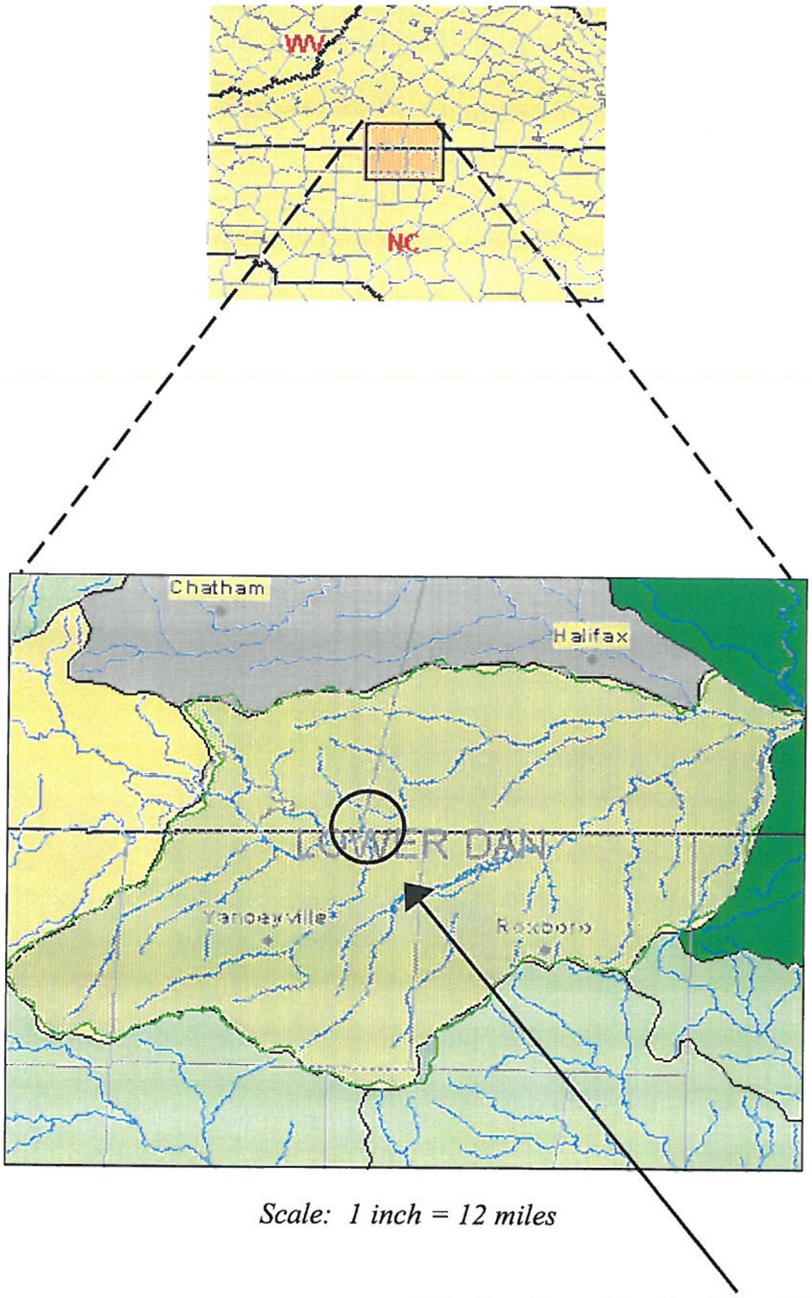
Stream flow can have a significant impact on the concentration of solutes, thereby affecting the overall stream quality. It is not only important to quantify levels of contaminates, but in order to accurately assess pollution levels, it is also necessary to determine upstream flow characteristics of the impaired stream system to analyze potential sources of contamination. Stream and river flow can directly influence physical features and may also indirectly influence nutrient uptake, thereby affecting pollutant levels (United States Environmental Protection Agency 1999b). In determining upstream effects on nutrient load, it is important to not only be aware of elevated pollution levels downstream, but it is also vital to know how much water is moving through the upstream system into the larger impaired downstream segment. In other words, knowledge of stream discharge into a larger body of water is essential in establishing pollutant loads.

There exists a magnitude effect when stream discharge increases. As a result of high flow, which could be caused by a significant rain event, contaminant levels may increase as a result of increased runoff. This elevated stream velocity would produce a churning effect, lifting sediment off the stream bottom. Not only would TSS levels increase, but contaminants which have settled to the stream bottom would now be in suspension. It is also possible, depending on the stream hydrology, that a significant rain event could dilute contaminant levels and flush out the system.

Once discharge has been established for a natural aquatic system at various depths, it is possible to construct a stage-discharge diagram. Once a regression equation has been calculated for the data, stream discharge can be determined in the future by simply measuring the depth and reading the stage-discharge diagram. If the contaminant concentration was known, pollutant load for that stream could be determined. This allows scientists to correlate rain events and the effect on discharge and pollutant loads. This information is also necessary in evaluating the effects of land use on runoff and stream quality.

Dan River Study

One of the impaired waters in Virginia listed under the TMDL initiative on the 1998 303(d) Priority List is a segment of the Dan River (USGS Hydrologic Unit Code 03010104), located in the Lower Dan River watershed (see *Figure 1*). The Dan River watershed includes approximately 153,856 acres, primarily in agricultural land usage (Dan River Land Use 2000).



Scale: 1 inch = 12 miles

Study site with the Dan River in blue

Figure 1. Study site within the Lower Dan Watershed.
Source: U.S. EPA 2000c.

According to the Index of Watershed Indicators, an index established by the EPA which describes the health of the aquatic resources for a watershed, the Lower Dan scored a 3 (on a scale from 1-6 with 1 representing very low vulnerability to pollutant loading stress), indicating less serious water quality problems and a low vulnerability to pollutant loadings (United States Environmental Protection Agency 2000c). The impaired segment was placed on the list due to a fecal coliform violation.

For this study, three points (upper, middle, and lower) along a ten-mile segment of the lower Dan River, which has been designated as impaired, were monitored during six sampling events for water quality. Additionally, seven tributaries that feed into the segment were monitored for water quality and hydrology. General atmospheric conditions were also noted for each of the sampling events.

The purpose of this study is to determine the contribution of several small watersheds on the water quality of the Lower Dan Watershed between Milton, NC and Paces,VA. If it is found that the watersheds have no individual or cumulative effect on the designated segment, then pollution effects (including point and nonpoint source) for the segment can be attributed to activities upstream. It is also possible that, given the hydrology of the tributaries, stream flows and subsequent nutrient loads may have no significant impact on the segment.

The hypothesis is that the smaller watersheds have no significant effect on the contaminant load of the impaired segment on the Dan River. It is also hypothesized that rain events will increase pollutant concentrations as a result of increased discharge.

METHODS

The first step in this study was to determine site locations. Seven tributaries were identified as feeding into a ten-mile segment of the Dan River, designated as impaired by the EPA: Sandy Creek, Wolfe Creek, Barker Creek, Double Creek, Winns Creek, Byrds Branch, and Powells Creek. Topographic and aerial maps were used to determine the best way to access each tributary and get as close as possible to the point where each tributary feeds into the river. Data were collected at a specified site at each of the seven tributaries and along the ten-mile segment of the Dan River: the uppermost point of the ten-mile segment (the Rt. 62 overpass in Milton), the middle point of the segment (Rt. 58 overpass), and the end of the segment (Melon Road overpass). *Figures 2-4* are topographic maps from the United States Geologic Survey which designate site locations where samples were collected and hydrologic measurements taken:

Figure 2:

1. Dan River at Rt. 62
2. Sandy Creek
3. Wolfe Creek

Figure 3:

4. Dan River at Rt. 58
5. Barker Creek
6. Double Creek

Figure 4:

7. Winns Creek
8. Byrds Branch
9. Powells Creek
10. Dan River at Paces

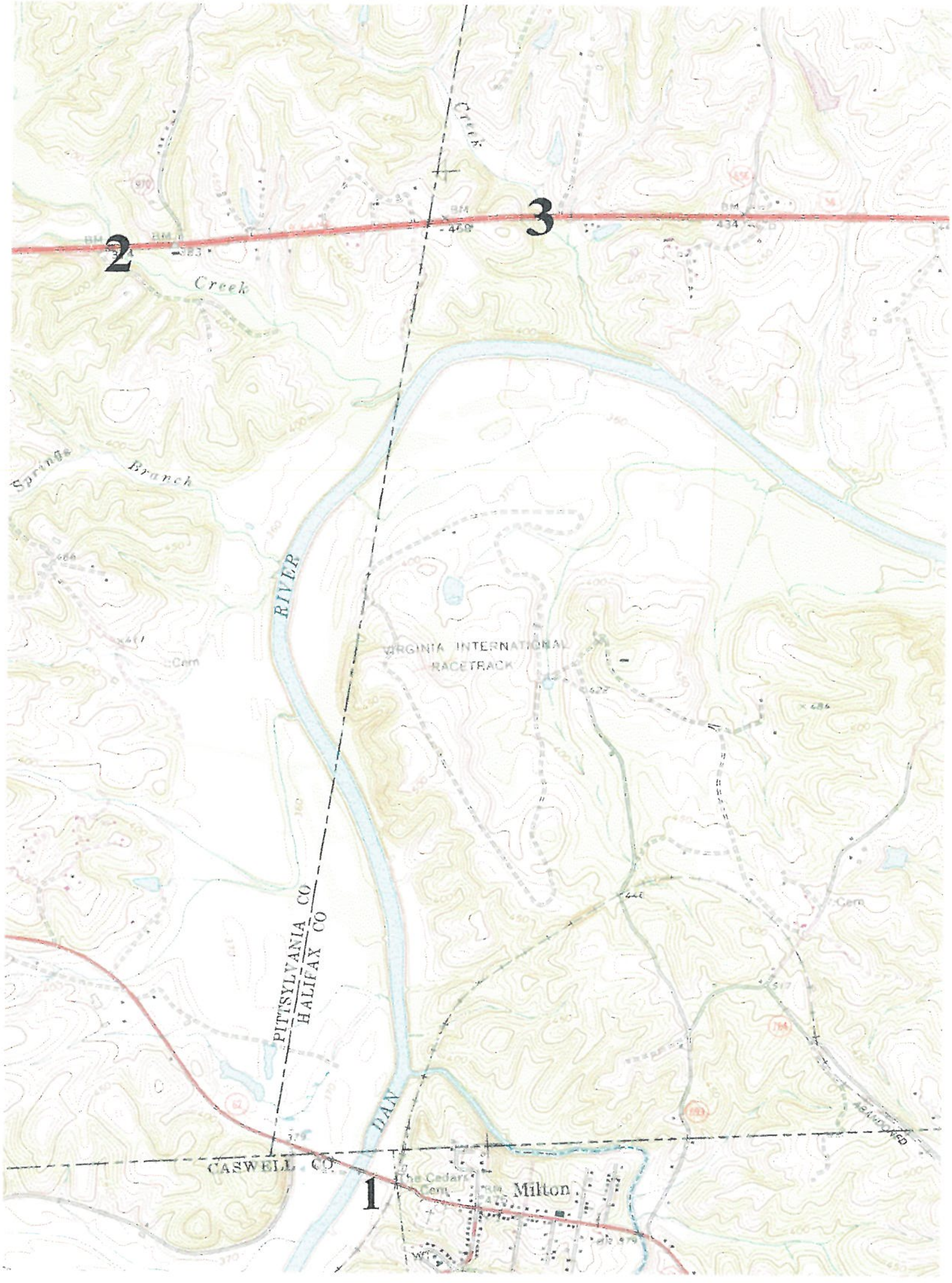


Figure 2. Milton Quadrangle, USGS (1968
(1=Dan River at Rt.62, 2=Sandy Creek, 3=Wolfe Creek)

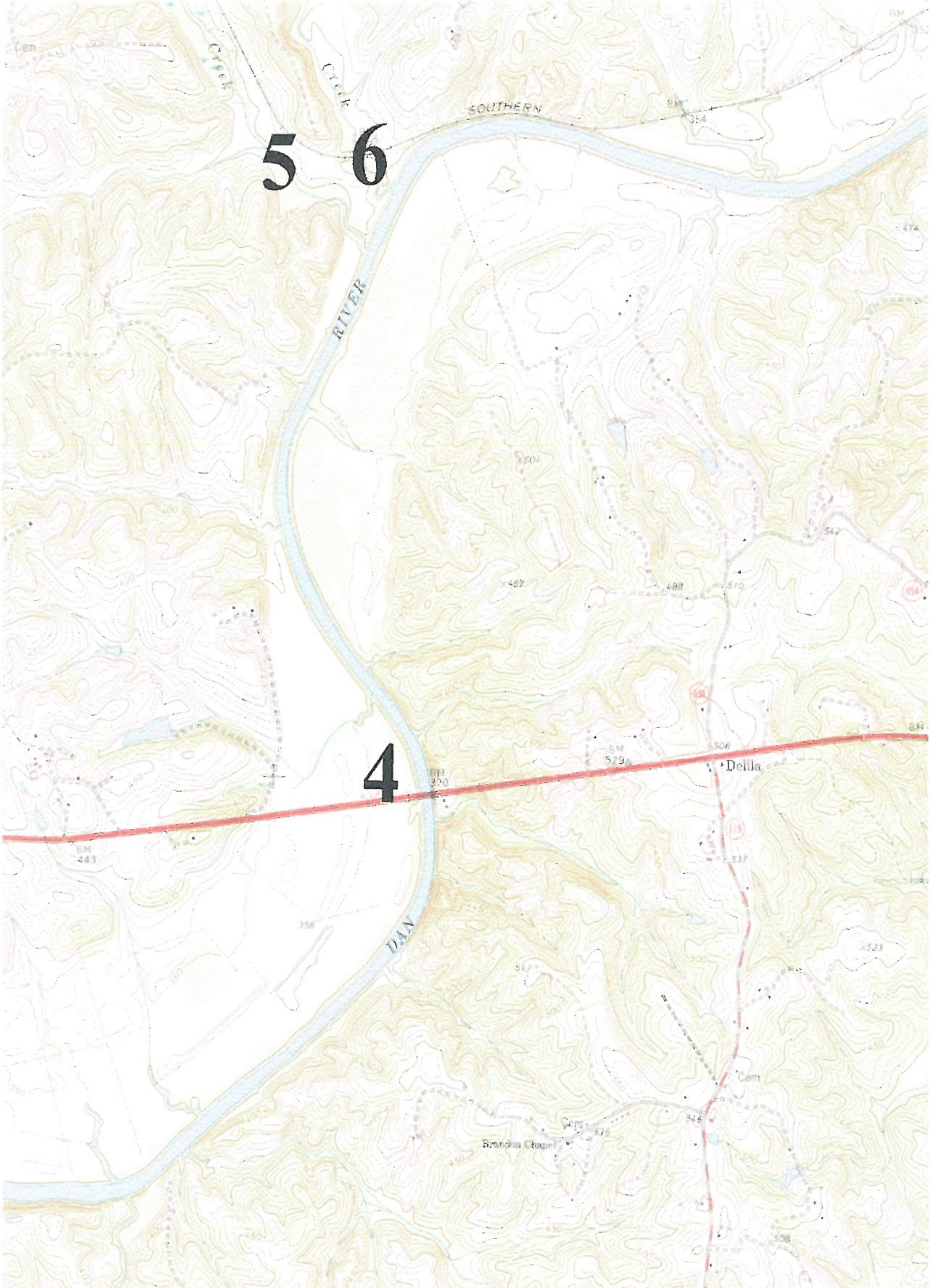


Figure 3. Milton Quadrangle, USGS (1968)
(4 = Dan River at Rt. 58, 5 = Barker Creek, 6 = Double Creek)

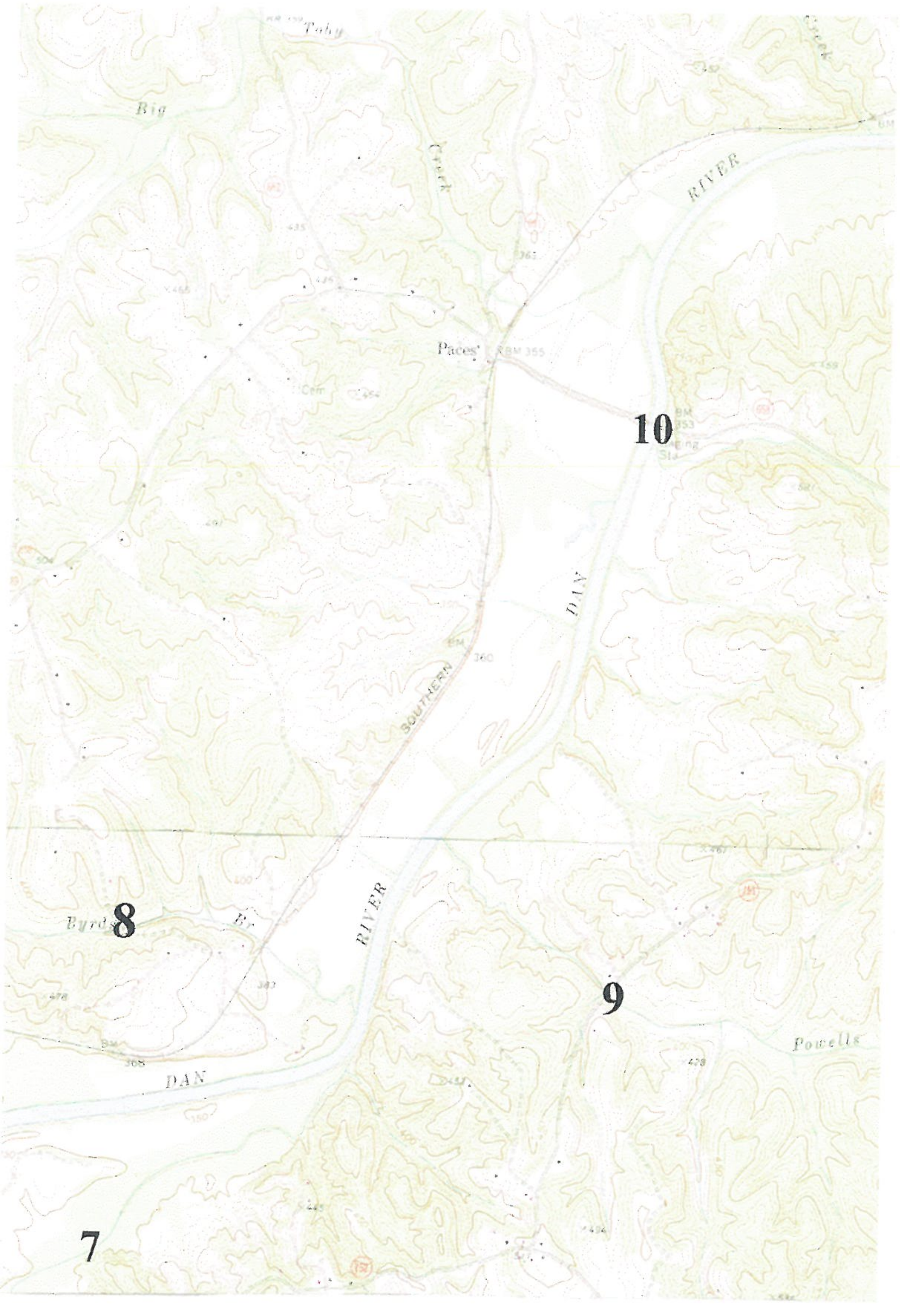


Figure 4. Alton and Oak LevelQuadrangles, USGS (1968)
(7 = Winns Creek, 8 = Byrds Branch, 9 = Powells Creek, 10 = Dan River at Paces)

The following field equipment was utilized on each sampling event: ten 250 ml polystyrene bottles were cleaned and labeled for each test site; these samples were used for the chemical tests as well as the total suspended solids test (TSS), ten sterile Whirl-pak® bags were also labeled for each site; these samples were used to test for the presence or absence of fecal coliform, an Oakton pH meter (Model 35624-20) which was calibrated in the laboratory using 4.0 and 7.0 buffer solutions, an Oakton TDS / conductivity meter (Model 35661-30) which was calibrated in the laboratory using a 440 Siemens standard. A Geopaks MJP flow meter (model mfp51), yard stick, alcohol thermometer, a reel-type measuring tape, and data sheet were gathered along with a cooler and ice to transport samples.

On each test date the ambient temperature was recorded along with the prevailing weather conditions (i.e. cloudy, overcast, clear). Recent precipitation events were also noted. At each site, the polystyrene bottle was filled by holding the bottle under the water (about 4inches), then removing the cap, allowing the water and possible suspended sediment to fill the container. The cap was secured with the bottle still submerged. The Whirl-pak® bags were filled by removing the perforated tabs and the bag was held closed under the water, then opened using the white tabs. The bag was closed under the water so that no oxygen was allowed in the bag. All of the samples were transported on ice back to the chemistry laboratory at Danville Community College for analysis.

Field data were also collected at each site. Water temperature was recorded in degrees Celsius using the thermometer, which was allowed to stabilize in the water for one minute. Conductivity (Siemens) and pH were recorded by holding each meter in the water such that the sensor or electrode was fully submerged and the reading stabilized.

Hydrologic Data

For each of the seven tributaries, stream width (in feet) was determined using the measuring tape. The stream was then divided into three sections or cells of equal width. The depth, recorded in feet, was determined for each cell at its midpoint using the yard stick. Also at each midpoint, the number of rotations per minute (clicks) was recorded using the flow meter, with the impeller stick held at 60% of the stream depth perpendicular to water flow. These data were used to calculate stream velocity in feet per second using the following equation: Velocity = 0.000854C + 0.05 where C represents the number of clicks (rotations) for that segment. The resultant number is in meters per second and was multiplied by 3.281 to convert the velocity to feet per second. Discharge in cubic feet per second was determined for each cell by multiplying the width of the cell, the depth of the cell, and the velocity of the cell. Total stream discharge was then calculated by adding the three cell discharges (Hauer and Lamberti 1996). On some of the sampling dates stream conditions made it difficult to divide a given stream into three cells. Equations were adjusted if less than three cells were used.

Watershed areas (in square miles) were calculated for each of the seven tributaries using *Toposout Maptech ed. 1.0*. They were estimated to be: 6.7 mi^2 for Sandy Creek, 2.8 mi^2 for Wolfe Creek, 7.1 mi^2 for Barker Creek, 14.7 mi^2 for Double Creek, 14.6 mi^2 for Winns Creek, 3.5 mi^2 for Byrds Branch, and 6.7 mi^2 for Powells Creek.

Total Suspended Solids (TSS):

Eleven 400 ml glass beakers were washed, labeled, and allowed to dry in a lab oven (Quincy Model 40GC) at 103°C for one hour. After cooling overnight, each beaker was weighed using a scale (Fisher Scientific XL-300, resolution 0.001g). At the start of the test, each sample was shaken vigorously and, using a 100 ml graduated cylinder, 100 ml of sample was transferred to the beaker. This was done for all ten samples and for distilled water, which was used as a control. The beakers were then placed in the oven overnight at 103°C to evaporate the liquid. The beakers were then allowed to cool to room temperature and were reweighed. This weight was subtracted from the initial weight to obtain the weight of the residue, which was multiplied by 10,000 to obtain results in mg/l. This procedure was followed from the *Field Manual for Water Quality Monitoring* (1996).

Fecal Coliform:

Twelve 50 x 9 mm sterile Gelman petri dishes with absorbent pads were labeled 1-10, control begin (CB) and control end (CE) with a permanent marker. Contents from a 2 ml ampoule of MFC broth with Rosolic acid were poured onto each pad. All samples were filtered to deposit fecal coliform (if present) onto the membrane filter. The filtering procedure used is as follows: a 150 ml Gelman magnetic filter funnel was placed in a 500 ml Erlenmeyer vacuum flask. Rubber tubing was connected from the flask sidearm to a water spout aspirator. The filter was rinsed with distilled water. A 47mm GN-6grid membrane filter (0.45 µm) was placed on the filter funnel using flame-sterilized tweezers. The water aspirator was then turned on and 40 ml of distilled water was placed in the funnel filter. The funnel sides were then rinsed with water. The vacuum seal was broken and the aspirator was turned off. The membrane filter was removed from the funnel apparatus and placed on the control (CB) pad. The filter apparatus was then rinsed thoroughly with distilled water. This filtering procedure was repeated for each of the ten samples. The test samples were shaken 25 times. After shaking, a disposable sterile pipette was used to place either 1ml or 3ml aliquots of sample onto the membrane filter. The funnel was rinsed between samples and the tweezers were sterilized between samples. After all twelve petri dishes were prepared in the above manner, they were inverted and placed in a sterile bag and the bag sealed. The bag was then placed into a Fisher Scientific Versa-Bath (Model 138), which was set at 44.5 °C (± 0.2 °C) for 24 hours (± 2 hours). At the end of the incubation period, blue colonies were counted on each dish. If 1 ml of sample was used, then the number of fecal colonies identified was multiplied by 100 to obtain results for # of colonies per 100 ml of sample. If 3 ml of sample was used, then the number of colonies was multiplied by 100 divided by 3 to give # of colonies per 100 ml of sample.

Nitrates, Nitrites, and Phosphates:

All three chemical parameters were assessed using a LaMotte DC1600 colorimeter. For each test (10 samples and a distilled water control), the colorimeter was adjusted to the correct wavelength for that particular test: 530 nm for nitrites and nitrates, and 605 nm for phosphates. To perform each test, the colorimeter was set to 100%

transmittance using the original sample and then the test procedure, using a color-developing reagent, was performed on the sample to quantify the absorbance of each sample. This absorbance was then correlated to a calibration chart (See Appendix A) to give results in parts per million (ppm).

For the nitrate test, the cadmium reduction method was used. Five milliliters of a mixed acid reagent (LaMotte V6278H) was added to the colorimeter tube containing 5 ml of sample. After 2 minutes, 0.2 g of nitrate reducing reagent (LaMotte V6279C) was added to the tube and the tube was then inverted 50 times. After 10 minutes, the tube was placed in the colorimeter and the % T was recorded. Using the calibration chart and a multiplication factor of 4.4, results were recorded as ppm nitrate (NO_3).

For the nitrite test, the diazotization method was used. Five milliliters of the mixed acid reagent (LaMotte V6278H) were added to the colorimeter tube containing 5 ml of sample. After mixing, 0.2 g of color developing reagent powder (LaMotte V6281C) was added to the tube, which was then shaken for one minute. After five minutes the %T was recorded. Using the calibration chart and a multiplication factor of 3.3, results were recorded as ppm nitrite (NO_2).

The ascorbic acid reduction method was used to determine the concentration of phosphates in each sample. One milliliter of phosphate acid reagent (LaMotte V6282H) was added to 10 ml of sample in the colorimeter tube. After mixing, 0.1g of phosphate reducing reagent (LaMotte V6283C) was added and shaken to dissolve the powder. After five minutes, %T was recorded and using the calibration chart, results were recorded in ppm phosphate.

Sampling Dates and Analysis: Samples were collected at all sites on the following dates:

February 10, 2000
March 9, 2000
April 11, 2000
May 11. 2000
August 9, 2000
September 2, 2000

The goal of the study was to collect the samples at about the same time each month. The last sample date (9-2-00) was earlier due to considerable precipitation the night before. This sample date was used to determine if chemical and other water quality analyses were affected by increased flow through the streams. Each of the above tests was completed on each of the test dates. The only missing data is from Byrds Branch on 5-11-00 due to irrigation pipes that blocked access to the testing site.

RESULTS and DISCUSSION

For each of the sampling dates, data was recorded on the data sheets and entered into *Excel* (Microsoft Office 2000) upon completion of testing for that date (see Appendix B). *Tables 1* and *2*, from sampling date 2/10/00, on the following pages serve as examples of the data sheets.

At the end of the sampling period, cumulative tables were prepared for each test site for each parameter and also for distilled water, which was used as a control (see Appendix C). *Table 3* is an example of a cumulative table from the Dan River – Paces site:

Paces

	pH	temp (^{0}C)	TSS (ppm)	F. Coliform (col./100 ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (μSiemens)
2/10/00	7.9	6.1	70	0	1.01	0.001	0.17	120
3/9/00	7.6	16	230	100	0.35	0.056	0.07	160
4/11/00	7.6	16	260	133	0.62	0.001	0.47	120
5/11/00	7.3	25	150	0	0.88	0.003	0.21	190
8/9/00	7.4	29.4	370	90	2.38	0.013	0.39	210
9/2/00	7.1	25	460	11200	2.46	0.001	1.73	340
Average	7.5	19.6	257	1921	1.28	0.013	0.51	190
Std. Dev.	0.28	8.52	142.22	4546.34	0.91	0.02	0.62	81.98
Avg. (w/out 9/2)	7.6	18.5	216	65	1.05	0.015	0.26	160
Std. Dev. (w/out 9/2)	0.23	9.05	113.49	61.08	0.79	0.02	0.16	40.62

* red text denotes fecal coliform count above Va. DEQ limits (1000 colonies/100 ml)

** blue text indicates highest parameter measurement for sampling period

Table 3. Cumulative data sheet for Dan River – Paces.

Table 1. Water Chemistry Data Sheet.

Date 2/10/00

Air Temp. 64 °F (High 64 °F)

Fecal -begin 8:15 PM
end 6:30 PM

Collection-begin 12:30 PM
end 4:30 PM

Weather Sunny - snowfall previous week

Precip. previous 24hr. 0.00" Precip. to month 0.00"

Collection Sites	pH Field	Temp. (°C)	pH lab	TSS (ppm)	F. Coliform (col./100 ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (microSiemens)
Dan River (Rt. 62)	7.5	6.8	7.7	160	67	0.84	0.001	0.19	130
Sandy Creek	7.6	7.5	7.6	90	0	0.97	0.001	0.19	90
Wolfe Creek	7.5	8.5	7.7	20	100	0.35	0.033	0.29	110
Dan River (Rt. 58)	7.6	6.5	7.2	150	67	0.79	0.001	0.24	120
Barker Creek	7.4	6.5	7.4	120	0	0.09	0.001	0.05	80
Double Creek	7.3	7.1	7.6	90	0	0.22	0.001	0.07	70
Winns Creek	7.4	7.5	7.7	30	0	0.13	0.001	0.03	70
Byrds Branch	7.6	4.9	7.8	60	400	0.79	0.001	0.1	90
Powells Creek	7.3	5.9	7.7	40	100	0.001	0.001	0.14	80
Paces	7.9	6.1	8	70	0	1.01	0.001	0.17	120
Distilled (Control)	7.8	21	7.8	0.001	0	0.001	0.063	0.01	0

Collection Sites	Notes	Beaker (g)	B+R (g)	Residual (g)
Dan River (Rt. 62)		131.715	131.731	0.016
Sandy Creek		153.546	153.555	0.009
Wolfe Creek		171.365	171.367	0.002
Dan River (Rt. 58)		151.992	152.007	0.015
Barker Creek		154.834	154.846	0.012
Double Creek		148.744	148.753	0.009
Winns Creek		144.150	144.153	0.003
Byrds Branch		166.294	166.300	0.006
Powells Creek		156.095	156.099	0.004
Paces		134.909	134.916	0.007
Distilled (Control)		157.895	157.893	-0.002

Table 2. Hydrology Data Sheet for 2/10/00.

Collection Sites	Cell 1 Width (ft)	Cell 1 depth at midpt (ft)	Cell 1 Clicks	Cell 1 Velocity (ft/s)	Cell 2 Width (ft)	Cell 2 depth at midpt (ft)	Cell 2 Clicks	Cell 2 Velocity (ft/s)
Sandy Creek	20.4	0.85	440	1.40				
Wolfe Creek	13.66	0.29	255	0.88				
Barker Creek	14.7	0.73	224	0.79				
Double Creek	12.9	0.375	351	1.15				
Winns Creek	9.5	1.34	207	0.74				
Byrds Branch	6.67	0.375	468	1.48				
Powells Creek	19.33	0.729	130	0.53				

Collection Sites	Notes	Cell 3 Width (ft)	Cell 3 depth at midpoint (ft)	Cell 3 Clicks	Cell 3 Velocity (ft/s)	Total Discharge (cfs)
Sandy Creek	** cell 1 width is width of stream					24.2
Wolfe Creek	cross section					3.48
Barker Creek						8.50
Double Creek						5.55
Winns Creek						9.47
Byrds Branch						3.69
Powells Creek						7.44

From these tables it is easy to compare changes for each site within the sampling period. The highest parameter reading for each test, for each site, is highlighted in blue. Fecal coliform results that are above the Va. DEQ limit are highlighted in red. Averages, noted in green, and standard deviations were calculated once for each site's data for all of the sampling days and again, eliminating sampling date 9/2/00 due to rain the day prior to testing. It was felt that, since on five of the six sampling dates there was no precipitation 24 hours prior to testing, the one inch of rain prior to sampling on 9/2/00 might affect the averages and therefore the standard deviations.

For each of the sampling sites the rain event on 9/2/00 did have an effect on the averages and the standard deviations. For some parameters the averages and standard deviations increased when the rain event was omitted and for others these values decreased. We would expect that TSS values would decline with the omission of 9/2/00 because most rain events will increase the suspended particulate matter in a stream and this is exactly what happens to those values in all cases (i.e. at all sites). We might also expect a similar trend with fecal coliform, in that rain events tend to wash wildlife and domesticated feces into the waterway; however, this trend is observed with only half of the sites. The remaining half showed an increase in fecal coliform with the omission of the rain event from the statistical analysis.

It can be noted that the standard deviations for all the sites are much lower and more consistent for the nitrate, nitrite, and phosphate tests. This is because there is not much variance between the results by sampling date and sampling site. Throughout the sampling period, no spikes were observed in the concentration for each of these chemical parameters; therefore, it might be easier to calculate average daily loads for these parameters. Fecal coliform, TSS, and discharge (where appropriate) show much higher standard deviations due to extreme fluctuations during the sampling period.

STREAM CHEMISTRY

For each sampling date, the number of high parameter readings (noted in blue) for each test was calculated and the total of high measurements was tallied (see *Table 4*). Percentages were then calculated (see *Figure 5*). From the chart and bar graph it is quite obvious that 8/9/00 and 9/2/00 were significant in that approximately 80% of the high parameter readings were recorded for these two sampling days. The hottest ambient temperature was recorded on the August sampling date and this was also the warmest water temperature date for most of the sites (refer to cumulative charts, Appendix C). It had been very dry prior to this sampling date and very hot. The September sampling date was approximately twelve hours after a rain event. This is the only sampling date that followed a rain event. For all of the other sampling dates there had been no recorded or observed precipitation for at least three days.

These two sampling days are very important in that they represent sampling condition extremes. Most of the elevated readings are recorded on one of these two dates and this should be expected. We would expect that increased rain would cause more runoff from adjacent fields. This increase in runoff should elevate pollutant loads, increase the amount of total suspended solids, and increase discharge. The chart clearly

Table 4. Number of high parameter measurements by date

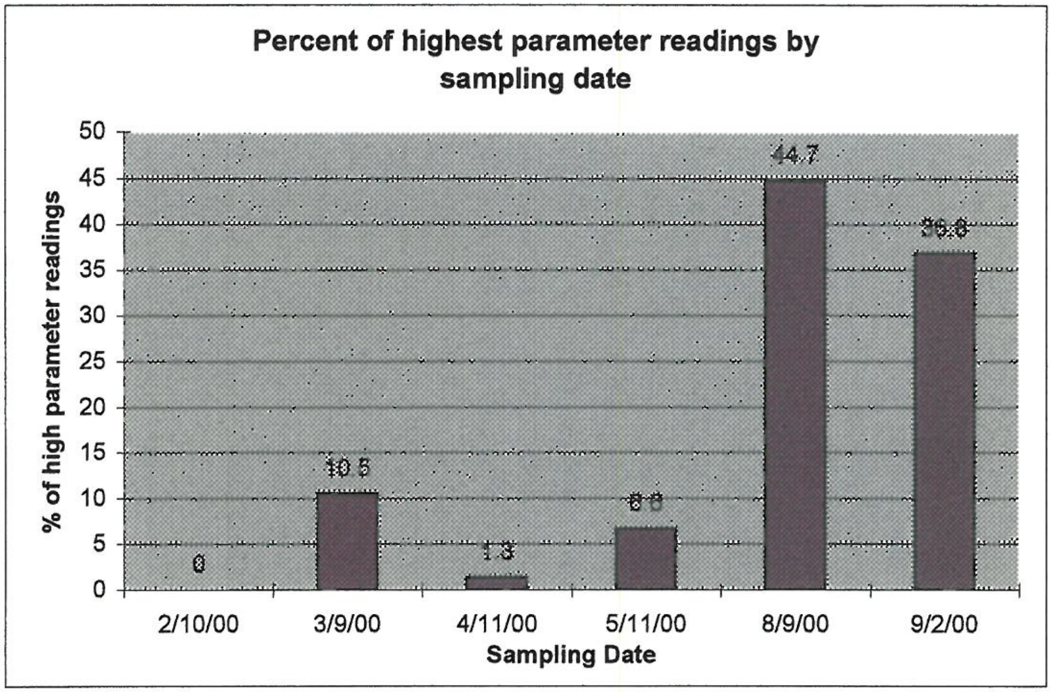
Sampling Date	# of high measurements	% of high measurements	Temp. (^0C)	TSS (ppm)	F. Coliform (col./100ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (µSiemens)
2/10/00	**0**	**0**							
3/9/00	**8**	**10.5**		1			5		2
4/11/00	**1**	**1.3**					1		
5/11/00	**5**	**6.6**				1	1	1	2
8/9/00	**34**	**44.7**	10	2	6	3	3	7	3
9/2/00	**28**	**36.8**	2	8	4	7		2	5

*excludes discharge and pH

**totals above 10 for each parameter indicate a repetition

Figure 5. Percent of highest parameter readings by sampling date

Sampling Date	% of high measurements
2/10/00	0
3/9/00	10.5
4/11/00	1.3
5/11/00	6.6
8/9/00	44.7
9/2/00	36.8



illustrates that for eight of the ten sites the highest TSS concentrations occur after a rain event. It is interesting to note that no nitrite concentration is highest after the rain event. This may be due in part because nitrite formation is an intermediate step between ammonia-nitrogen and nitrate formation. Nitrites are normally found in low concentrations; however, there may be so much water moving through the system that it is simply flushed of nitrites.

It is also interesting to note that at all ten of the sites, the highest fecal concentrations occurred on one of these two sampling dates. We would expect the fecal count to be higher after a rain event due to fecal runoff from adjacent fields. While 40% of the elevated levels occur after the rain event, the remaining 60% are recorded on the hottest sampling date. One possible explanation of this is that livestock are probably wading in the streams to get cool and are defecating in the streams, increasing the fecal coliform concentration.

Throughout the study, water temperature was positively correlated to ambient temperature. To determine if there is a relationship between water temperature and fecal coliform concentration, two linear regressions were calculated for each site: the first using the data from every sampling date and the second omitting 9/2/00 (see Appendix D). The calculated regressions for Sandy Creek serve as examples (*Table 5, Figures 6,7*). For the regression test, a 95% confidence level was established for statistical acceptance of a positive correlation. Omitting the rain event did increase the correlation coefficient (R^2) for eight of the sites. Overall, based on the correlation coefficients, there was no linear relationship between temperature and fecal coliform concentration.

Sandy Creek

	Temp. (^0C)	F. Coliform (col./100 ml)
2/10/00	7.5	0
3/9/00	15	33
4/11/00	16.1	33
5/11/00	18	110
8/9/00	24.2	1040
9/2/00	24	0

Table 5.

* Regression significance based on a 95% confidence level.

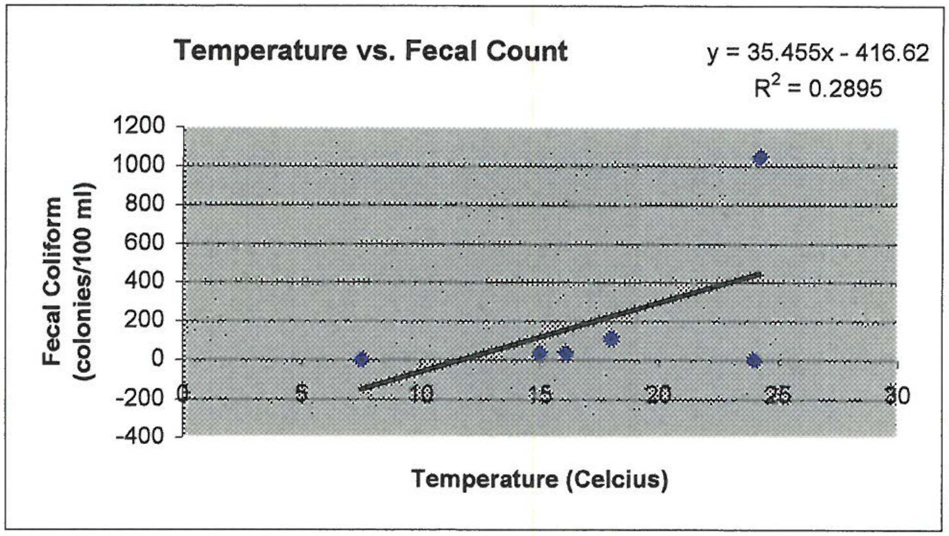


Figure 6.

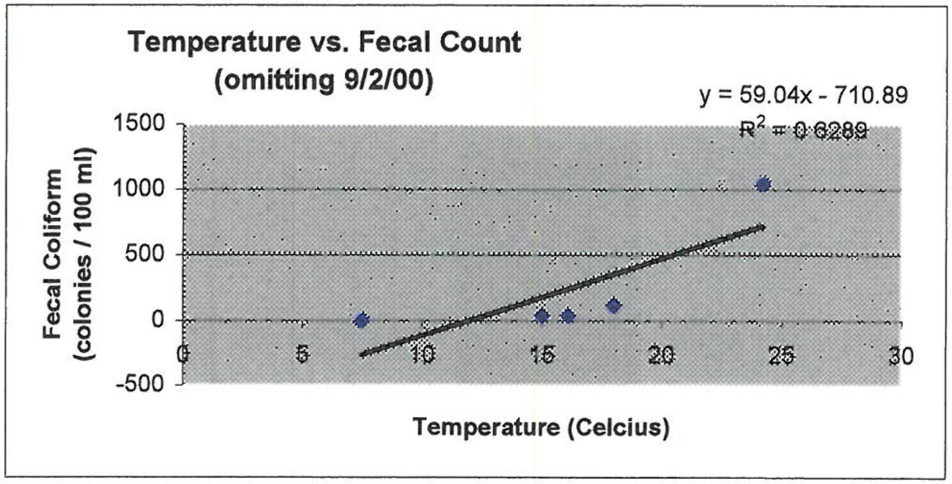


Figure 7.

TRIBUTARY EFFECTS

To determine if the tributaries located within the impaired segment are having an adverse effect on the Dan River, it was necessary to compare the water chemistry parameter results for each site with those of the Dan River site downstream. Dan River at Rt. 62 serves as a control and indicates water quality upstream from the testing sites. Results from the Dan River at Rt. 58 include the additive effects of Sandy and Wolfe Creeks. Finally, the results from Dan River at Paces include the additive effects of Barker, Double, Winns, Byrds Branch, and Powells Creeks.

Table 6 gives the averages for each parameter by site for the sampling period. From this, a comparison can be made between the Dan River sampling sites. To simplify the comparison, the Dan River – Rt. 58 overpass site can be omitted to note the overall trend from the upstream portion of the impaired segment (Rt. 62 overpass) to the downstream site (Paces/Melon Rd. overpass). Increases in parameter concentrations are recorded for TSS, fecal coliform, phosphates, and conductivity. Nitrate and nitrite concentrations decrease from the upstream to the downstream site.

While it is important to note that certain parameters increase and others decrease, it is even more important to determine if these observed trends are indeed real. In other words, are these observed changes from the upstream site to the downstream site due to some ecological factor or are they due to chance? To determine if the differences are real we must test to see if the differences are significant. A T-Test analysis was performed on each of the chemical parameters to determine if the differences (increase or decrease)

Table 6. Parameter analysis for sampling sites using averages

	pH	temp (°C)	TSS (ppm)	F. Coliform col./100 ml	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (mSiemens)	Total Discharge (cfs) X 100
Dan River (Rt. 62)	**7.5**	**19.2**	**212**	**192**	**1.52**	**0.02**	**0.23**	**175**	
Sandy Creek	7.5	17.5	202	203	0.62	0.012	0.14	97	576
Wolfe Creek	7.5	18.5	220	1428	1.41	0.13	0.48	137	58
Dan River (Rt. 58)	7.4	19.5	232	155	1.4	0.005	0.21	207	
Barker Creek	7.3	18.6	152	1703	0.24	0.012	0.12	103	305
Double Creek	7.4	18.2	183	299	0.42	0.013	0.07	82	404
Winns Creek	7.3	17.2	153	668	0.22	0.016	0.08	90	252
Byrds Branch	7.4	16.6	236	1902	0.6	0.025	0.21	142	96
Powells Creek	7.4	17.6	170	983	0.39	0.009	0.21	123	179
Dan River (Paces)	**7.5**	**19.6**	**257**	**1921**	**1.28**	**0.013**	**0.51**	**190**	
Distilled (Control)	7.3	21.8	-5	0	0.001	0.043	0.02	0	

between the upstream and downstream sites were significant. Once the T-Test value was calculated, it was compared to a critical value for a one-tailed test which is associated with the degrees of freedom (DF) for that measurement. The degrees of freedom is dependent upon the number of samples. For this study there were six samples for each of the two sites being compared. The calculated degrees of freedom was 10. The critical T-Test values, based on a 0.05 p-level, decrease with increasing degrees of freedom (see *Table 7*).

DF	T-Test	DF	T-Test
5	2.02	20	1.73
6	1.94	21	1.72
7	1.90	22	1.72
8	1.86	23	1.72
9	1.83	24	1.71
10	1.81	25	1.71
11	1.80	26	1.71
12	1.78	27	1.70
13	1.77	28	1.70
14	1.76	29	1.70
15	1.75	30	1.70
16	1.75	31	1.68
17	1.74	32	1.67
18	1.73	33	1.66
19	1.73	34	1.65

Table 7. Critical T-Test values for a one-tailed test (Rohlf and Sokal 1969).

A p-level of 0.05 was used to measure confidence, meaning that there was a 5% chance that the differences in water chemistry between the Dan River at Rt. 62 and the Dan

River at Paces occurred by chance. Inversely, we would be able to conclude that there was a 95% certainty that the differences did not occur by chance and are statistically significant. For all of the chemical parameters, based on the T-Test values (see *Table 8*), there was no significance in the difference between the upstream Dan River site and the downstream Dan River site. From this, we can conclude that with regard to water chemistry, the tributaries are having no noticeable detrimental effects on the river's quality.

Fecal	
Rt. 62	**Paces**
67	0
33	100
333	133
240	0
480	90
0	11200

T-test 0.1974

TSS	
Rt. 62	**Paces**
160	70
200	230
160	260
150	150
250	370
350	460

T-test 0.2579

Nitrates	
Rt. 62	**Paces**
0.84	1.01
0.48	0.35
0.44	0.62
1.27	0.88
3.34	2.38
2.73	2.46

T-test 0.3585

Phosphates	
Rt. 62	**Paces**
0.19	0.17
0.05	0.07
0.1	0.47
0.34	0.21
0.47	0.39
0.21	1.73

T-test 0.1625

Conductivity	
Rt. 62	**Paces**
130	120
170	160
110	120
190	190
300	210
150	340

T-test 0.3683

Nitrites	
Rt. 62	**Paces**
0.001	0.001
0.03	0.056
0.001	0.001
0.003	0.003
0.085	0.013
0.001	0.001

T-test 0.326

* Critical Value (5% p-level) = 1.81

**Degrees of freedom for every test was 10

Table 8. Analysis of variance for upstream versus downstream using chemistry data.

STREAM HYDROLOGY

As stated in the introduction, it is imperative not only to study changes in water chemistry, but also to examine changes in stream hydrology. For five of the six sampling dates there was no precipitation for at least three days prior to testing and the dates were randomly chosen. The last sampling date was planned to occur after a substantial rain event to determine the effects of precipitation and subsequent runoff on stream chemistry and hydrology.

It was expected that all of the streams would have the highest discharge of the sampling period after the rain event (see *Table 9*). This hypothesis was correct for five of the seven streams. Wolfe Creek had a higher discharge on the first sampling date (2/10/00) and Winns Creek's discharge was the highest on 4/11/00. Precipitation data was gathered from past issues of the *Danville Register and Bee* to determine the precipitation for the month prior to each sampling date. This information helps to explain some of the outliers. For instance, Winns Creek had its highest discharge on the April sampling date. While there was no rain prior to the sampling date, there was a substantial amount of precipitation for the month to date. Depending upon topographic factors and landuse (discussed below), Winns Creek might experience delayed elevations in discharge. Double Creek also had an extremely high discharge for this sampling date.

Wolfe Creek experienced its highest discharge on the first sampling date (2/10/00). While the table shows no precipitation for the month, it was noted on the data sheet (Appendix B) that there was snow on the ground. Again, depending on landuse and

Table 9. Precipitation and discharge comparisons for sampling period.

	Precipitation Previous 24 hr (in.)	Precipitation to month (in.)	Sandy Creek Total Discharge (cfs) X 100	Wolfe Creek Total Discharge (cfs) X 100	Barker Creek Total Discharge (cfs) X 100	Double Creek Total Discharge (cfs) X 100
2/10/00	0.00	0.00	2420	348	850	555
3/9/00	0.00	0.00	1728	106	1396	557
4/11/00	0.00	4.72	1910	216	1051	2629
5/11/00	0.00	0.00	690	123	457	1020
8/9/00	0.00	0.52	571	96	268	385
9/2/00	1.00	1.00	4579	255	1990	2812

	Precipitation Previous 24 hr (in.)	Precipitation to month (in.)	Winns Creek Total Discharge (cfs) X 100	Byrds Branch Total Discharge (cfs) X 100	Powells Creek Total Discharge (cfs) X 100
2/10/00	0.00	0.00	947	369	744
3/9/00	0.00	0.00	804	298	453
4/11/00	0.00	4.72	1193	240	681
5/11/00	0.00	0.00	545	missing data[1]	241
8/9/00	0.00	0.52	469	195	269
9/2/00	1.00	1.00	997	479	1131

** blue text denotes highest discharge for sampling period for each stream

[1] Irrigation pipes blocked access to site

topography, if the snow melted just prior to testing in the area adjacent to the test site, discharge could be increased substantially.

It was expected that streams with larger watersheds would have greater discharges after a rain event (see *Table 10*) based on an increased area from which the water would flow into a stream.

	Watershed Area (sq. miles)	Discharge on 9/2/00 (cfs x 100)
Sandy Creek	6.7	4579
Wolfe Creek	2.8	255
Barker Creek	7.1	1990
Double Creek	14.7	2812
Winns Creek	14.6	997
Byrds Branch	3.5	479
Powells Creek	6.7	1131

Table 10. Watershed area for each site and corresponding discharge after a rain event.

This assumption holds true for the two smallest watersheds, Wolfe Creek and Byrds Branch, but for the remaining tributaries, the size of the watershed is not the determining factor in affecting discharge. For example, Sandy Creek, the third smallest watershed, had the highest discharge after a rain event. Several explanations may account for this disparity.

Landuse within each watershed is not identical. Some streams are surrounded by forest, while others are surrounded by pastures and cropland. Landuse would affect the amount of precipitation that fell on the ground and how much of the rain infiltrated the ground. Forested areas would intercept some of the rain before it could reach the ground. Since the rain event was in September, deciduous trees were still in their growing season; therefore, there was a substantial amount of leaves on the trees. Double Creek and Barker Creek are surrounded by forested areas. In comparison, Sandy Creek is surrounded by more pastures.

Another important factor to examine when comparing discharges between tributaries is the topography of the surrounding area. While this study did not focus on landuse or topography, it is understood that if a stream is located at the bottom of two steep-sloping sides, water will flow very quickly into this system compared to a stream where the adjoining terrain is flat. Judging by the sampling sites, Sandy Creek has steeper slopes compared to Barker and Double Creek. This may account for the increase in discharge twelve hours after a rain event. It is possible that Barker and Double Creek may have elevated discharges within the next couple of days due to this same rain event.

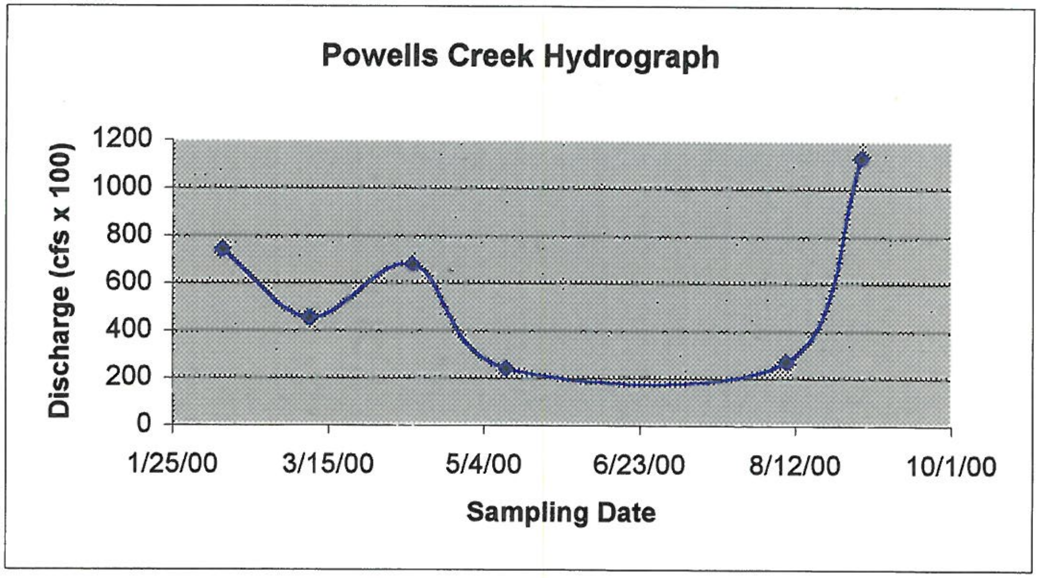
Using the calculated discharges for each sampling date, it is possible to construct hydrographs for each of the sampling sites (see Appendix E). A hydrograph shows the discharge trend for a test site over the sampling period. *Figure 8* is an example of the hydrograph for Powells Creek.

The hydrographs for each test site were compared to determine if during the study there was a trend between sites. Overall, similar trends were observed. In other words, on the same sampling date, most of the sites show corresponding increases and decreases. For the first half of the sampling period, the hydrographs for the test sites show a peak

Figure 8. Hydrograph for Powells Creek.

Powells Creek

	Total Discharge (cfs) X 100
2/10/00	744
3/9/00	453
4/11/00	681
5/11/00	241
8/9/00	269
9/2/00	1131



and then a leveling, similar to half of a sine curve. For the second half of the sampling period, the hydrographs take on an exponential trend across the sites.

Using this same discharge information, it is possible to construct stage-discharge diagrams for each of the test sites (see Appendix F). *Figure 9* is an example of a stage-discharge diagram for Barker Creek.

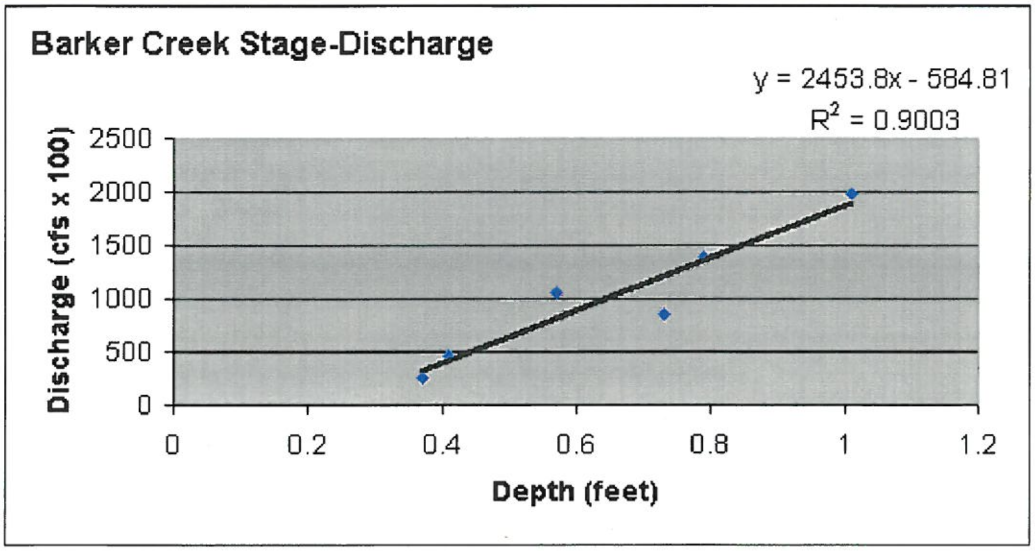


Figure 9. Stage-discharge diagram for Barker Creek.

A stage-discharge diagram plots average stream depth over a sampling period with a corresponding discharge at that depth. For each of the stage-discharge diagrams, a linear regression was calculated along with a corresponding correlation coefficient (R^2). For some of the streams the R^2 value was significantly higher (closer to one), as is the case with Barker Creek. The closer the R^2 value is to one, the more reliable the linear equation is in predicting discharge at a certain depth. In other words, if the correlation is significant (R^2 greater than 0.95 or 95%), than in the future, a researcher would only have to measure the depth to calculate the stream's discharge. For this study, Barker Creek and Double Creek are the only streams to have a correlation of .90 or better. These may be the only two streams where the discharge can somewhat accurately be predicted by measuring the depth. It is interesting to note that these two creeks are surrounded by flat terrain, where the other sites exhibit steeper slopes.

For each of the sites, the discharge data from 2/10/00 was omitted and the regression recalculated. This data was omitted due to lack of proper field equipment on this sampling date. Stream depth and width are more accurate for the remaining sample dates. Once the 2/10/00 data is omitted, the correlation coefficient improves for four of the seven streams. For three of the streams, the correlation is weakened. It appears that the data collected on 2/10/00 is just as valid as that collected on the other sampling dates. For some of the sites, this data improves the correlation and for others the correlation is weakened.

If the stage-discharge relationships were more valid, these diagrams could be used to predict pollutant loads. Once water chemistry has been determined under a variety of environmental conditions (temperature, previous precipitation) for each of the streams, a model can be designed to calculate pollutant load. The only information that would be required is stream depth.

CONCLUSION AND FUTURE WORK

The hypothesis of this study was that the seven tributaries that feed into the impaired segment of the Dan River have no significant impact on the water quality. As shown by the analysis of variance, there is no significant change in the water chemistry from the upstream segment of the Dan River to the downstream segment.

A secondary hypothesis was that rain events increase the chemical pollutant load of the tributaries along with the discharge. From the number of high parameters on the sampling date following a rain event, it is obvious that precipitation does increase pollutant concentrations. It is also obvious that days where there has been no rain and the temperature (water and ambient) is considerably hotter, pollutant concentrations also increase. Because these two conditions seem to elevate contaminant levels, it is important to perform hydrologic testing under these circumstances.

Initially, when I was collecting information on the impaired segment, I was finding that I was very critical of the VA DEQ because they collect samples on a specified schedule and do not give much consideration to previous weather conditions, the importance of which is stated above. I questioned why the VA DEQ did not sample more often and allow for precipitation effects or try to determine the effect of significant rain events. After going out on six sampling dates, I have more empathy for what the VA DEQ has to do. For this study I could not drop everything just because it rained to go sample my sites. I had to plan these sampling dates to a large extent. Given available manpower, I am more understanding as to why the VA DEQ adheres to a testing schedule.

As for future work, I can see the necessity of land use analysis. It would be informative to use Geographic Information System (GIS) technology, such as *ArcView*, to map the study area to note differences in topography and landuse. Additionally, more sampling events would provide more data making the statistical analysis more valid. One limitation of this study is that one rain event was used to determine the significance of precipitation with respect to discharge and water chemistry. Several rain events need to be monitored.

Since the conclusion of this research is that the tributaries are having no significant impact on the water quality of the Dan River, future work should focus on the pollutant load that is potentially being added upstream of the impaired segment. Possible sources for contamination include municipal sewage treatment facilities or industrial sites.

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Appendix A: Calibration Charts for Nitrates, Nitrites, and Phosphates

DC1600 NITRATE-NITROGEN CALIBRATION CHART

%T	9	8	7	6	5	4	3	2	1	0
90	0.02	0.03	0.05	0.06	0.07	0.08	0.10	0.11	0.12	0.14
80	0.15	0.16	0.18	0.19	0.20	0.22	0.23	0.25	0.26	0.27
70	0.29	0.30	0.32	0.34	0.35	0.37	0.38	0.40	0.42	0.43
60	0.45	0.47	0.48	0.50	0.52	0.54	0.56	0.58	0.60	0.62
50	0.64	0.66	0.68	0.70	0.72	0.74	0.76	0.78	0.81	0.83
40	0.86	0.88	0.90	0.93	0.96	0.98	1.01	1.04	1.07	1.10
30	1.13	1.16	1.19	1.22	1.25	1.29	1.32	1.36	1.40	1.44
20	1.48	1.52	1.56	1.61	1.65	1.70	1.75	1.80	1.86	1.92
10	1.98	2.04	2.11	2.18	2.26	2.34	2.43	2.52	2.63	2.74
0	2.87	3.01								

DC1600 NITRITE-NITROGEN CALIBRATION CHART

%T	9	8	7	6	5	4	3	2	1	0
100										0.001
90	0.004	0.006	0.008	0.010	0.012	0.015	0.017	0.019	0.021	0.024
80	0.026	0.029	0.031	0.033	0.036	0.039	0.041	0.044	0.046	0.049
70	0.052	0.054	0.057	0.060	0.063	0.066	0.068	0.071	0.074	0.077
60	0.081	0.084	0.087	0.090	0.093	0.097	0.100	0.103	0.107	0.110
50	0.114	0.118	0.121	0.125	0.129	0.133	0.137	0.141	0.145	0.150
40	0.154	0.158	0.163	0.168	0.172	0.177	0.182	0.187	0.192	0.198
30	0.203	0.209	0.214	0.220	0.226	0.233	0.239	0.246	0.253	0.260
20	0.267	0.275	0.283	0.291	0.299	0.308	0.317	0.327	0.337	0.348
10	0.359	0.371	0.383	0.397	0.411	0.426	0.442	0.460	0.479	0.500
0	0.523	0.549	0.578	0.612	0.653	0.702				

DC1600 PHOSPHATE ~ LOW RANGE CALIBRATION CHART

%T	9	8	7	6	5	4	3	2	1	0
90	0.01	0.03	0.05	0.07	0.10	0.12	0.14	0.17	0.19	0.21
80	0.24	0.26	0.29	0.31	0.34	0.36	0.39	0.41	0.44	0.47
70	0.49	0.52	0.55	0.58	0.61	0.63	0.66	0.69	0.72	0.75
60	0.79	0.82	0.85	0.88	0.92	0.95	0.98	1.02	1.06	1.09
50	1.13	1.17	1.20	1.24	1.28	1.32	1.37	1.41	1.45	1.50
40	1.54	1.59	1.64	1.68	1.73	1.79	1.84	1.89	1.95	2.00
30	2.06	2.12	2.19	2.25	2.32	2.39	2.46	2.53	2.61	2.69
20	2.78	2.86	2.95	3.05						
10										
0										

Calibration charts for nitrate, nitrite, and phosphate to convert from % transmittance to concentration (in ppm)

Appendix B: Summary of Chemical and Hydrologic Data

Organized by Sampling Date:

2/10/00
3/9/00
4/11/00
5/11/00
8/9/00
9/2/00

Chemical Analysis of Water Quality

Date 2/10/00

Air Temp. 64 °F (High 64 °F)

Fecal -begin 8:15 PM
end 6:30 PM

Collection-begin 12:30 PM
end 4:30 PM

Weather Sunny - snowfall previous week

Precip. previous 24hr. 0.00"
Precip. to month 0.00"

Collection Sites	pH Field	Temp. (^{0}C)	pH lab	TSS (ppm)	F. Coliform (col./100 ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (microSiemens)
Dan River (Rt. 62)	7.5	6.8	7.7	160	67	0.84	0.001	0.19	130
Sandy Creek	7.6	7.5	7.6	90	0	0.97	0.001	0.19	90
Wolfe Creek	7.5	8.5	7.7	20	100	0.35	0.033	0.29	110
Dan River (Rt. 58)	7.6	6.5	7.2	150	67	0.79	0.001	0.24	120
Barker Creek	7.4	6.5	7.4	120	0	0.09	0.001	0.05	80
Double Creek	7.3	7.1	7.6	90	0	0.22	0.001	0.07	70
Winns Creek	7.4	7.5	7.7	30	0	0.13	0.001	0.03	70
Byrds Branch	7.6	4.9	7.8	60	400	0.79	0.001	0.1	90
Powells Creek	7.3	5.9	7.7	40	100	0.001	0.001	0.14	80
Paces	7.9	6.1	8	70	0	1.01	0.001	0.17	120
Distilled (Control)	7.8	21	7.8	0.001	0	0.001	0.063	0.01	0

Collection Sites	Notes	Beaker (g)	B+R (g)	Residual (g)
Dan River (Rt. 62)		131.715	131.731	0.016
Sandy Creek		153.546	153.555	0.009
Wolfe Creek		171.365	171.367	0.002
Dan River (Rt. 58)		151.992	152.007	0.015
Barker Creek		154.834	154.846	0.012
Double Creek		148.744	148.753	0.009
Winns Creek		144.150	144.153	0.003
Byrds Branch		166.294	166.300	0.006
Powells Creek		156.095	156.099	0.004
Paces		134.909	134.916	0.007
Distilled (Control)		157.895	157.893	-0.002

Hydrology Data Sheet

2-10-00

Collection Sites	Cell 1 Width (ft)	Cell 1 depth at midpt (ft)	Cell 1 Clicks	Cell 1 Velocity (ft/s)	Cell 2 Width (ft)	Cell 2 depth at midpt (ft)	Cell 2 Clicks	Cell 2 Velocity (ft/s)
Sandy Creek	20.4	0.85	440	1.40				
Wolfe Creek	13.66	0.29	255	0.88				
Barker Creek	14.7	0.73	224	0.79				
Double Creek	12.9	0.375	351	1.15				
Winns Creek	9.5	1.34	207	0.74				
Byrds Branch	6.67	0.375	468	1.48				
Powells Creek	19.33	0.729	130	0.53				

Collection Sites	Notes	Cell 3 Width (ft)	Cell 3 depth at midpoint (ft)	Cell 3 Clicks	Cell 3 Velocity (ft/s)	Total Discharge (cfs)
Sandy Creek	** cell 1 width is width of stream					24.2
Wolfe Creek	cross section					3.48
Barker Creek						8.50
Double Creek						5.55
Winns Creek						9.47
Byrds Branch						3.69
Powells Creek						7.44

Chemical Analysis of Water Quality

Date 3/9/00

Fecal -begin 4:30 PM
end 5:40 PM

Collection-begin 12:00 PM
end 3:30 PM

Air Temp. 72 °F (High 82 °F)

Weather Sunny - no rain previous 2 weeks

Precip. previous 24hr. 0.00"

Precip. to month 0.00"

Collection Sites	pH Field	Temp. (°C)	pH lab	TSS (ppm)	F. Coliform (col./100 ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (microSiemens)
Dan River (Rt. 62)	7.3	15	7.6	200	33	0.484	0.033	0.05	170
Sandy Creek	7.4	15	7.4	210	33	0.264	0.050	0.07	110
Wolfe Creek	7.4	16.5	7.6	170	233	0.001	0.043	0.29	140
Dan River (Rt. 58)	7.5	16	7.4	130	33	0.704	0.003	0.1	170
Barker Creek	7.4	17	7.6	180	100	0.001	0.063	0.1	90
Double Creek	7.6	16.5	7.6	90	33	0.001	0.069	0.05	110
Winns Creek	7.4	14	7.4	220	167	0.001	0.086	0.03	80
Byrds Branch	7.6	14	7.6	190	233	0.001	0.119	0.1	110
Powells Creek	7.4	16	7.4	190	67	0.001	0.003	0.14	120
Paces	7.6	16	7.3	230	100	0.352	0.056	0.07	160
Distilled (Control)	7.8	21	7.8	40	0	0.001	0.063	0.01	0

Collection Sites	Notes	Beaker (g)	B+R (g)	Residual (g)
Dan River (Rt. 62)		131.712	131.732	0.020
Sandy Creek		153.539	153.560	0.021
Wolfe Creek		171.360	171.377	0.017
Dan River (Rt. 58)		151.993	152.006	0.013
Barker Creek		154.824	154.842	0.018
Double Creek		148.740	148.749	0.009
Winns Creek		144.140	144.162	0.022
Byrds Branch		166.289	166.308	0.019
Powells Creek		156.089	156.108	0.019
Paces		134.900	134.923	0.023
Distilled (Control)		157.886	157.890	0.004

Hydrology Data Sheet

3-9-00

Collection Sites	Cell 1 Width (ft)	Cell 1 depth at midpt (ft)	Cell 1 Clicks	Cell 1 Velocity (ft/s)	Cell 2 Width (ft)	Cell 2 depth at midpt (ft)	Cell 2 Clicks	Cell 2 Velocity (ft/s)
Sandy Creek	6.8	0.85	455	1.44	6.8	0.46	470	1.48
Wolfe Creek	4.25	0.29	9	0.19	4.25	0.4	26	0.24
Barker Creek	4.9	0.73	197	0.72	4.9	0.81	468	1.48
Double Creek	4.33	0.375	344	1.13	4.33	0.44	420	1.34
Winns Creek	4.33	1.34	129	0.53	4.33	1.04	185	0.68
Byrds Branch	7.5	0.375	320	1.06				
Powells Creek	3.92	0.729	85	0.40	3.92	0.73	169	0.64

Collection Sites	Notes	Cell 3 Width (ft)	Cell 3 depth at midpoint (ft)	Cell 3 Clicks	Cell 3 Velocity (ft/s)	Total Discharge (cfs)
Sandy Creek		6.8	0.46	436	1.39	17.28
Wolfe Creek		4.25	0.38	35	0.26	1.06
Barker Creek		4.9	0.83	428	1.36	13.96
Double Creek		4.33	0.42	173	0.65	5.57
Winns Creek		4.33	0.77	147	0.58	8.04
Byrds Branch	one cell only					2.98
Powells Creek		3.92	0.71	141	0.56	4.53

Chemical Analysis of Water Quality

Date 4/11/00

Air Temp. 74 °F (High 78 °F)

Fecal -begin 6:30 PM
end 7:35 PM

Collection-begin 12:30 PM
end 4:30 PM

Weather Sunny - rained 3 days prior

Precip. previous 24hr. 0.00"

Precip. to month 4.72"

Collection Sites	pH Field	Temp. (°C)	pH lab	TSS (ppm)	F. Coliform (col./100 ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (microSiemens)
Dan River (Rt. 62)	7.7	15.5	7.3	160	333	0.440	0.001	0.1	110
Sandy Creek	7.4	16.1	7.3	300	33	0.088	0.013	0.03	90
Wolfe Creek	7.5	18	7.3	240	633	0.001	0.001	0.41	120
Dan River (Rt. 58)	7.4	16	7.3	210	267	0.616	0.001	0.17	130
Barker Creek	7.6	18.2	7.3	90	0	0.001	0.001	0.1	100
Double Creek	7.4	18.2	7.3	150	100	0.088	0.001	0.01	80
Winns Creek	7.4	17	7.3	170	133	0.001	0.001	0.05	70
Byrds Branch	7.6	16	7.4	230	167	0.001	0.001	0.12	100
Powells Creek	7.6	17	7.3	130	533	0.001	0.001	0.14	110
Paces	7.6	16	7.4	260	133	0.616	0.001	0.47	120
Distilled (Control)	7.8	21	7.8	60	0	0.001	0.063	0.01	0

Collection Sites	Notes	Beaker (g)	B+R (g)	Residual (g)
Dan River (Rt. 62)		131.717	131.733	0.016
Sandy Creek		144.084	144.114	0.030
Wolfe Creek		171.365	171.389	0.024
Dan River (Rt. 58)		151.997	152.018	0.021
Barker Creek		154.829	154.838	0.009
Double Creek		148.740	148.755	0.015
Winns Creek		144.149	144.166	0.017
Byrds Branch		166.299	166.322	0.023
Powells Creek		141.818	141.831	0.013
Paces		134.907	134.933	0.026
Distilled (Control)		157.899	157.905	0.006

Hydrology Data Sheet
4-11-00

Collection Sites	Cell 1 Width (ft)	Cell 1 depth at midpt (ft)	Cell 1 Clicks	Cell 1 Velocity (ft/s)	Cell 2 Width (ft)	Cell 2 depth at midpt (ft)	Cell 2 Clicks	Cell 2 Velocity (ft/s)
Sandy Creek	6.94	0.65	375	1.21	6.94	0.67	494	1.55
Wolfe Creek	4.53	0.96	6	0.18	4.53	0.57	53	0.31
Barker Creek	4.89	0.69	451	1.43	4.89	0.52	550	1.71
Double Creek	6.83	0.38	506	1.58	6.83	0.54	716	2.17
Winns Creek	4.58	1.25	263	0.90	4.58	1.06	280	0.95
Byrds Branch	2.94	0.23	199	0.72	2.94	0.42	417	1.33
Powells Creek	5.19	0.94	149	0.58	5.19	0.75	257	0.88

Collection Sites	Notes	Cell 3 Width (ft)	Cell 3 depth at midpoint (ft)	Cell 3 Clicks	Cell 3 Velocity (ft/s)	Total Discharge (cfs)
Sandy Creek		6.94	0.68	427	1.36	19.10
Wolfe Creek		4.53	0.35	69	0.36	2.16
Barker Creek		4.89	0.5	140	0.56	10.51
Double Creek		6.83	0.92	747	2.26	26.29
Winns Creek		4.58	0.69	186	0.69	11.93
Byrds Branch		2.94	0.4	22	0.23	2.40
Powells Creek		5.19	0.31	59	0.33	6.81

Chemical Analysis of Water Quality

Date 5/11/00

Air Temp. 82 °F (High 83°F)

Fecal -begin 5:05 PM
end 6:15 PM

Collection-begin 12:00 PM
end 3:45 PM

Weather Sunny, "hot spell", no rain for ~2 weeks

Precip. previous 24 hr. 0.00"

Precip. to month 0.00"

Collection Sites	pH Field	Temp. (^{0}C)	pH lab	TSS (ppm)	F. Coliform (col./100 ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (microSiemens)
Dan River (Rt. 62)	7.8	24	7.4	150	240	1.270	0.003	0.34	190
Sandy Creek	7.6	18	7.3	50	110	0.790	0.003	0.29	110
Wolfe Creek	7.5	20	7.2	50	3600	1.980	0.079	0.47	160
Dan River (Rt. 58)	7.4	24	7.2	160	40	1.100	0.003	0.21	210
Barker Creek	6.9	19.8	7.4	50	20	0.260	0.003	0.12	130
Double Creek	7.1	19.4	7.4	270	100	0.480	0.003	0.1	80
Winns Creek	7.2	17.8	7.3	110	30	0.300	0.003	0.1	80
Byrds Branch									
Powells Creek	7.4	19	7.4	130	200	0.960	0.044	0.21	120
Paces	7.3	25	7.4	150	0	0.880	0.003	0.21	190
Distilled (Control)	7.8	21	7.8	-90	0	0.001	0.063	0.01	0

Collection Sites	Notes	Beaker (g)	B+R (g)	Residual (g)
Dan River (Rt. 62)		131.719	131.734	0.015
Sandy Creek		144.087	144.092	0.005
Wolfe Creek		171.375	171.380	0.005
Dan River (Rt. 58)		151.993	152.009	0.016
Barker Creek		154.838	154.843	0.005
Double Creek		148.736	148.763	0.027
Winns Creek		144.151	144.162	0.011
Byrds Branch	could not access stream due to irrigation			
Powells Creek		141.817	141.830	0.013
Paces		134.905	134.920	0.015
Distilled (Control)		157.903	157.894	-0.009

Hydrology Data Sheet

5-11-00

Collection Sites	Cell 1 Width (ft)	Cell 1 depth at midpt (ft)	Cell 1 Clicks	Cell 1 Velocity (ft/s)	Cell 2 Width (ft)	Cell 2 depth at midpt (ft)	Cell 2 Clicks	Cell 2 Velocity (ft/s)
Sandy Creek	6.72	0.375	166	0.63	6.72	0.39	404	1.30
Wolfe Creek	4.74	0.79	3	0.17	4.74	0.41	0	0.16
Barker Creek	3.89	0.6	353	1.15	3.89	0.29	320	1.06
Double Creek	6.78	0.29	177	0.66	6.78	0.58	329	1.09
Winns Creek	4.22	0.5	287	0.97	4.22	0.58	233	0.82
Byrds Branch								
Powells Creek	3.53	0.52	163	0.62	3.53	0.35	175	0.65

Collection Sites	Notes	Cell 3 Width (ft)	Cell 3 depth at midpoint (ft)	Cell 3 Clicks	Cell 3 Velocity (ft/s)	Total Discharge (cfs)
Sandy Creek		6.72	0.29	293	0.99	6.90
Wolfe Creek	slowed by leaf litter	4.74	0.33	3	0.17	1.23
Barker Creek		3.89	0.35	119	0.50	4.57
Double Creek		6.78	0.54	393	1.27	10.20
Winns Creek		4.22	0.37	263	0.90	5.45
Byrds Branch	could not access stream due to irrigation					
Powells Creek		3.53	0.25	130	0.53	2.41

Chemical Analysis of Water Quality

Date 8/9/00

Air Temp. 92 °F (High 93 °F)

Fecal -begin 3:05 PM
end 2:50 PM

Collection-begin 8:30 AM
end 12:45 PM

Weather Sunny, humid, no sig. rain for 5 days

Precip. previous 24 hr. 0.00"

Precip. to month 0.52"

Collection Sites	pH Field	Temp. (°C)	pH lab	TSS (ppm)	F. Coliform (col./100 ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (microSiemens)
Dan River (Rt. 62)	7.4	29.1	7.4	250	480	3.340	0.085	0.47	300
Sandy Creek	7.6	24.2	7.6	240	1040	0.310	0.003	0.12	110
Wolfe Creek	7.4	24	7.4	480	4000	5.500	0.617	1.06	170
Dan River (Rt. 58)	7.3	29.2	7.3	320	520	3.080	0.019	0.44	210
Barker Creek	7.6	25.8	7.6	170	1200	0.528	0.003	0.21	120
Double Creek	7.6	24.8	7.4	190	1360	0.088	0.003	0.14	80
Winns Creek	7.4	23.8	7.2	170	1180	0.264	0.003	0.01	80
Byrds Branch	7.4	25	7.4	330	3210	0.792	0.003	0.52	130
Powells Creek	7.4	23.9	7.5	280	2800	0.352	0.003	0.41	110
Paces	7.4	29.4	7.4	370	90	2.376	0.013	0.39	210
Distilled (Control)	6.4	23.5	6.4	80	0	0.001	0.003	0.05	0

Collection Sites	Notes	Beaker (g)	B+R (g)	Residual (g)
Dan River (Rt. 62)		131.710	131.735	0.025
Sandy Creek		144.071	144.095	0.024
Wolfe Creek		171.348	171.396	0.048
Dan River (Rt. 58)		151.980	152.012	0.032
Barker Creek		154.824	154.841	0.017
Double Creek		148.730	148.749	0.019
Winns Creek		144.138	144.155	0.017
Byrds Branch		166.276	166.309	0.033
Powells Creek		141.796	141.824	0.028
Paces		134.895	134.932	0.037
Distilled (Control)		157.880	157.888	0.008

Hydrology Data Sheet

8-9-00

Collection Sites	Cell 1 Width (ft)	Cell 1 depth at midpt (ft)	Cell 1 Clicks	Cell 1 Velocity (ft/s)	Cell 2 Width (ft)	Cell 2 depth at midpt (ft)	Cell 2 Clicks	Cell 2 Velocity (ft/s)
Sandy Creek	4.03	0.38	290	0.98	4.03	0.78	420	1.34
Wolfe Creek	4.47	0.6	4	0.18	4.47	0.39	3	0.17
Barker Creek	4.75	0.38	321	1.06	4.75	0.35	104	0.46
Double Creek	5.92	0.5	85	0.40	5.92	0.33	300	1.00
Winns Creek	4.14	0.88	192	0.70	4.14	0.58	164	0.62
Byrds Branch	3.42	0.35	206	0.74	3.42	0.33	279	0.95
Powells Creek	4.67	0.25	765	2.31	n/a	n/a	n/a	

Collection Sites	Notes	Cell 3 Width (ft)	Cell 3 depth at midpoint (ft)	Cell 3 Clicks	Cell 3 Velocity (ft/s)	Total Discharge (cfs)
Sandy Creek	2 cells	n/a				5.71
Wolfe Creek	3cells	4.47	0.25	3	0.17	0.96
Barker Creek	2 cells	n/a				2.68
Double Creek	3 cells	5.92	0.38	52	0.31	3.85
Winns Creek	3 cells	4.14	0.25	160	0.61	4.69
Byrds Branch	narrow - 2 cells	n/a				1.95
Powells Creek	too narrow - 1 cell	n/a				2.69

Chemical Analysis of Water Quality

Date 9/2/00

Fecal -begin 3:25 PM
end 4:15 PM

Collection-begin 9:45 AM
end 1:50 PM

Air Temp. 78 °F (High 81 °F)

Weather foggy, lots of rain the day before, overcast

Precip. previous 24 hr. 1.00"

Precip. to month 1.00"

Collection Sites	pH Field	Temp. (°C)	pH lab	TSS (ppm)	F. Coliform (col./100 ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (microSiemens)
Dan River (Rt. 62)	7.1	25	6.8	350	0	2.730	0.001	0.21	150
Sandy Creek	7.2	24	6.9	320	0	1.280	0.001	0.12	70
Wolfe Creek	7.4	24	6.9	360	0	0.620	0.001	0.34	120
Dan River (Rt. 58)	7.1	25	6.7	420	0	2.110	0.001	0.1	400
Barker Creek	7.0	24	6.6	300	8900	0.530	0.001	0.12	100
Double Creek	7.2	22.9	6.7	310	200	1.630	0.001	0.07	70
Winns Creek	6.9	23	6.6	220	2500	0.620	0.001	0.26	160
Byrds Branch	7	23	6.6	370	5500	1.410	0.001	0.19	280
Powells Creek	7.1	23.9	6.6	250	2200	1.010	0.001	0.21	200
Paces	7.1	25	6.8	460	11200	2.460	0.001	1.73	340
Distilled (Control)	6.4	23	6.4	80	0	0.001	0.003	0.05	0

Collection Sites	Notes	Beaker (g)	B+R (g)	Residual (g)
Dan River (Rt. 62)	**samples were filtered for	124.848	124.883	0.035
Sandy Creek	chemistry tests	136.576	136.608	0.032
Wolfe Creek		162.427	162.463	0.036
Dan River (Rt. 58)		144.067	144.109	0.042
Barker Creek		146.751	146.781	0.030
Double Creek		140.983	141.014	0.031
Winns Creek		136.637	136.659	0.022
Byrds Branch		157.624	157.661	0.037
Powells Creek		134.420	134.445	0.025
Paces		127.871	127.917	0.046
Distilled (Control)		149.660	149.668	0.008

Hydrology Data Sheet

9-2-00

Collection Sites	Cell 1 Width (ft)	Cell 1 depth at midpt (ft)	Cell 1 Clicks	Cell 1 Velocity (ft/s)	Cell 2 Width (ft)	Cell 2 depth at midpt (ft)	Cell 2 Clicks	Cell 2 Velocity (ft/s)
Sandy Creek	6.11	0.67	1006	2.98	6.11	0.88	1020	3.02
Wolfe Creek	4.33	0.75	17	0.21	4.33	0.67	81	0.39
Barker Creek	3.11	0.63	509	1.59	3.11	1.08	703	2.13
Double Creek	8	0.75	764	2.30	8	0.67	568	1.76
Winns Creek	5.78	0.5	494	1.55	5.78	0.54	308	1.03
Byrds Branch	2.5	0.29	410	1.31	2.5	0.38	830	2.49
Powells Creek	3.72	0.83	658	2.01	3.72	0.42	709	2.15

Collection Sites	Notes	Cell 3 Width (ft)	Cell 3 depth at midpoint (ft)	Cell 3 Clicks	Cell 3 Velocity (ft/s)	Total Discharge (cfs)
Sandy Creek		6.11	1.04	915	2.73	45.79
Wolfe Creek		4.33	0.29	149	0.58	2.55
Barker Creek		3.11	1.33	771	2.32	19.90
Double Creek		8	0.54	345	1.13	28.12
Winns Creek		5.78	0.73	135	0.54	9.97
Byrds Branch		2.5	0.42	443	1.41	4.79
Powells Creek		3.72	0.33	449	1.42	11.31

Appendix C: Cumulative Data Sheets by Site with Averages and Standard Deviations

Dan River Rt. 62

	pH	temp (^{0}C)	TSS (ppm)	F. Coliform (col./100 ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (μSiemens)
2/10/00	7.5	6.8	160	67	0.84	0.001	0.19	130
3/9/00	7.3	15	200	33	0.48	0.03	0.05	170
4/11/00	7.7	15.5	160	333	0.44	0.001	0.1	110
5/11/00	7.8	24	150	240	1.27	0.003	0.34	190
8/9/00	7.4	29.1	250	480	3.34	0.085	0.47	300
9/2/00	7.1	25	350	0	2.73	0.001	0.21	150
Average	7.5	19.2	212	192	1.52	0.020	0.23	175
Std. Dev.	0.26	8.24	77.31	191.26	1.23	0.03	0.16	67.45
Avg. (w/out 9/2)	7.5	18.1	184	231	1.27	0.024	0.23	180
Std. Dev. (w/out 9/2)	0.21	8.66	41.59	186.14	1.20	0.04	0.17	74.16

Dan River Rt. 58

	pH	temp (^{0}C)	TSS (ppm)	F. Coliform (col./100 ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (μSiemens)
2/10/00	7.6	6.5	150	67	0.79	0.001	0.24	120
3/9/00	7.5	16	130	33	0.7	0.003	0.1	170
4/11/00	7.4	16	210	267	0.62	0.001	0.17	130
5/11/00	7.4	24	160	40	1.1	0.003	0.21	210
8/9/00	7.3	29.2	320	520	3.08	0.019	0.44	210
9/2/00	7.1	25	420	0	2.11	0.001	0.1	400
Average	7.4	19.5	232	155	1.40	0.005	0.21	207
Std. Dev.	0.17	8.22	114.79	202.80	0.99	0.01	0.13	102.11
Avg. (w/out 9/2)	7.4	18.3	194	185	1.26	0.005	0.23	168
Std. Dev. (w/out 9/2)	0.11	8.68	76.35	210.36	1.03	0.01	0.13	42.66

Dan River Paces

	pH	temp (^{0}C)	TSS (ppm)	F. Coliform (col./100 ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (μSiemens)
2/10/00	7.9	6.1	70	0	1.01	0.001	0.17	120
3/9/00	7.6	16	230	100	0.35	0.056	0.07	160
4/11/00	7.6	16	260	133	0.62	0.001	0.47	120
5/11/00	7.3	25	150	0	0.88	0.003	0.21	190
8/9/00	7.4	29.4	370	90	2.38	0.013	0.39	210
9/2/00	7.1	25	460	11200	2.46	0.001	1.73	340
Average	7.5	19.6	257	1921	1.28	0.013	0.51	190
Std. Dev.	0.28	8.52	142.22	4546.34	0.91	0.02	0.62	81.98
Avg. (w/out 9/2)	7.6	18.5	216	65	1.05	0.015	0.26	160
Std. Dev. (w/out 9/2)	0.23	9.05	113.49	61.08	0.79	0.02	0.16	40.62

* red text denotes fecal coliform count above Va. DEQ limits (1000 colonies/100 ml)

** blue text indicates highest parameter measurement for sampling period

Sandy Creek

	pH	temp (°C)	TSS (ppm)	F. Coliform (col./100 ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (μSiemens)	Total Discharge (cfs) X 100
2/10/00	7.6	7.5	90	0	0.97	0.001	0.19	90	2420
3/9/00	7.4	15	210	33	0.26	0.05	0.07	110	1728
4/11/00	7.4	16.1	300	33	0.09	0.013	0.03	90	1910
5/11/00	7.6	18	50	110	0.79	0.003	0.29	110	690
8/9/00	7.6	24.2	240	1040	0.31	0.003	0.12	110	571
9/2/00	7.2	24	320	0	1.28	0.001	0.12	70	4579
Average	7.5	17.5	202	203	0.62	0.012	0.14	97	1983
Std. Dev.	0.16	6.25	110.17	412.17	0.47	0.02	0.09	16.33	1460.56
Avg. (w/out 9/2)	7.5	16	178	243	0.48	0.01	0.14	102	1464
Std. Dev.(w/out 9/2)	0.11	6.01	104.74	447.25	0.38	0.02	0.10	10.95	802.97

Wolfe Creek

	pH	temp (°C)	TSS (ppm)	F. Coliform (col./100 ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (μSiemens)	Total Discharge (cfs) X 100
2/10/00	7.5	8.5	20	100	0.35	0.033	0.29	110	348
3/9/00	7.4	16.5	170	233	0.001	0.043	0.29	140	106
4/11/00	7.5	18	240	633	0.001	0.001	0.41	120	216
5/11/00	7.5	20	50	3600	1.98	0.08	0.47	160	123
8/9/00	7.4	24	480	4000	5.5	0.62	1.06	170	96
9/2/00	7.4	24	360	0	0.62	0.001	0.34	120	255
Average	7.5	18.5	220	1428	1.41	0.130	0.48	137	191
Std. Dev.	0.05	5.78	178.33	1854.49	2.13	0.24	0.29	24.22	100.24
Avg. (w/out 9/2)	7.5	17.4	192	1713	1.57	0.155	0.50	140	178
Std. Dev.(w/out 9/2)	0.05	5.72	184.04	1920.27	2.35	0.26	0.32	25.50	106.39

* red text denotes fecal coliform count above Va. DEQ limits (1000 colonies/100 ml)

** blue text indicates highest parameter measurement for sampling period

Barker Creek

	pH	temp (°C)	TSS (ppm)	F. Coliform (col./100 ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (µSiemens)	Total Discharge (cfs) X 100
2/10/00	7.4	6.5	120	0	0.09	0.001	0.05	80	850
3/9/00	7.4	17	180	100	0.001	0.063	0.1	90	1396
4/11/00	7.6	18.2	90	0	0.001	0.001	0.1	100	1051
5/11/00	6.9	19.8	50	20	0.26	0.003	0.12	130	457
8/9/00	7.6	25.8	170	1200	0.53	0.003	0.21	120	268
9/2/00	7	24	300	8900	0.53	0.001	0.12	100	1990
Average	7.3	18.6	152	1703	0.24	0.012	0.12	103	1002
Std. Dev.	0.30	6.81	87.50	3556.75	0.25	0.03	0.05	18.62	631.29
Avg. (w/out 9/2)	7.4	17.5	122	264	0.18	0.014	0.12	104	804
Std. Dev.(w/out 9/2)	0.29	7.00	54.50	524.86	0.22	0.03	0.06	20.74	453.13

Double Creek

	pH	temp (°C)	TSS (ppm)	F. Coliform (col./100 ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (µSiemens)	Total Discharge (cfs) X 100
2/10/00	7.3	7.1	90	0	0.22	0.001	0.07	70	555
3/9/00	7.6	16.5	90	33	0.001	0.069	0.05	110	557
4/11/00	7.4	18.2	150	100	0.09	0.001	0.01	80	2629
5/11/00	7.1	19.4	270	100	0.48	0.003	0.1	80	1020
8/9/00	7.6	24.8	190	1360	0.09	0.003	0.14	80	385
9/2/00	7.2	22.9	310	200	1.63	0.001	0.07	70	2812
Average	7.4	18.2	183	299	0.42	0.013	0.07	82	1326
Std. Dev.	0.21	6.22	91.80	524.38	0.62	0.03	0.04	14.72	1101.90
Avg. (w/out 9/2)	7.4	17.2	158	319	0.18	0.015	0.07	84	1029
Std. Dev.(w/out 9/2)	0.21	6.44	75.63	583.77	0.19	0.03	0.05	15.17	924.97

* red text denotes fecal coliform count above Va. DEQ limits (1000 colonies/100 ml)

** blue text indicates highest parameter measurement for sampling period

Winns Creek

	pH	temp (^{0}C)	TSS (ppm)	F. Coliform (col./100 ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (μSiemens)	Total Discharge (cfs) X 100
2/10/00	7.4	7.5	30	0	0.13	0.001	0.03	70	947
3/9/00	7.4	14	220	167	0.001	0.086	0.03	80	804
4/11/00	7.4	17	170	133	0.001	0.001	0.05	70	1193
5/11/00	7.2	17.8	110	30	0.3	0.003	0.1	80	545
8/9/00	7.4	23.8	170	1180	0.26	0.003	0.01	80	469
9/2/00	6.9	23	220	2500	0.62	0.001	0.26	160	997
Average	7.3	17.2	153	668	0.22	0.016	0.08	90	826
Std. Dev.	0.20	6.03	72.85	1000.89	0.23	0.03	0.09	34.64	277.66
Avg. (w/out 9/2)	7.4	16.0	140	302	0.14	0.019	0.04	76	792
Std. Dev.(w/out 9/2)	0.09	5.94	72.80	495.70	0.14	0.04	0.03	5.48	295.93

Byrds Branch

	pH	temp (^{0}C)	TSS (ppm)	F. Coliform (col./100 ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (μSiemens)	Total Discharge (cfs) X 100
2/10/00	7.6	4.9	60	400	0.79	0.001	0.1	90	369
3/9/00	7.6	14	190	233	0.001	0.119	0.1	110	298
4/11/00	7.6	16	230	167	0.001	0.001	0.12	100	240
8/9/00	7.4	25	330	3210	0.79	0.003	0.52	130	195
9/2/00	7.0	23	370	5500	1.41	0.001	0.19	280	479
Average	7.4	16.6	236	1902	0.60	0.025	0.21	142	316
Std. Dev.	0.26	7.99	122.39	2382.66	0.60	0.05	0.18	78.55	111.94
Avg. (w/out 9/2)	7.6	15.0	203	1003	0.40	0.031	0.21	108	275.5
Std. Dev.(w/out 9/2)	0.10	8.25	111.77	1474.93	0.46	0.06	0.21	17.08	75.25

* red text denotes fecal coliform count above Va. DEQ limits (1000 colonies/100 ml)

** blue text indicates highest parameter measurement for sampling period

Powells Creek

	pH	temp (^{0}C)	TSS (ppm)	F. Coliform (col./100 ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (μSiemens)	Total Discharge (cfs) X 100
2/10/00	7.3	5.9	40	100	0.001	0.001	0.14	80	744
3/9/00	7.4	16	190	67	0.001	0.003	0.14	120	453
4/11/00	7.6	17	130	533	0.001	0.001	0.14	110	681
5/11/00	7.4	19	130	200	0.96	0.044	0.21	120	241
8/9/00	7.4	23.9	280	2800	0.35	0.003	0.41	110	269
9/2/00	7.1	23.9	250	2200	1.01	0.001	0.21	200	1131
Average	7.4	17.6	170	983	0.39	0.009	0.21	123	586.5
Std. Dev.	0.16	6.65	88.32	1201.41	0.48	0.02	0.10	40.33	337.11
Avg. (w/out 9/2)	7.4	16.4	154	740	0.26	0.010	0.21	108	478
Std. Dev.(w/out 9/2)	0.11	6.59	88.49	1166.25	0.42	0.02	0.12	16.43	230.46

Distilled Water

	pH	temp (^{0}C)	TSS (ppm)	F. Coliform (col./100 ml)	Nitrates (ppm)	Nitrites (ppm)	Phosphates (ppm)	Conductivity (μSiemens)
2/10/00	7.8	21	-200	0	0.001	0.063	0.01	0
3/9/00	7.8	21	40	0	0.001	0.063	0.01	0
4/11/00	7.8	21	60	0	0.001	0.063	0.01	0
5/11/00	7.8	21	-90	0	0.001	0.063	0.01	0
8/9/00	6.4	23.5	80	0	0.001	0.003	0.05	0
9/2/00	6.4	23	80	0	0.001	0.003	0.05	0
Average	7.3	21.8	-5	0	0.001	0.043	0.02	0
Std. Dev.	0.72	1.17	114.85	0.00	0.000	0.03	0.02	0.00

* red text denotes fecal coliform count above Va. DEQ limits (1000 colonies/100 ml)

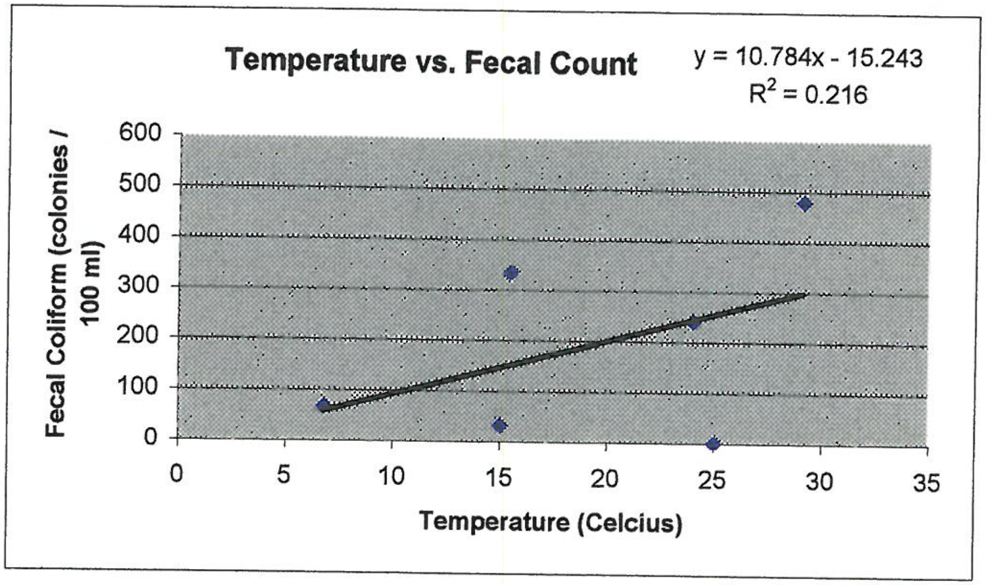
** blue text indicates highest parameter measurement for sampling period

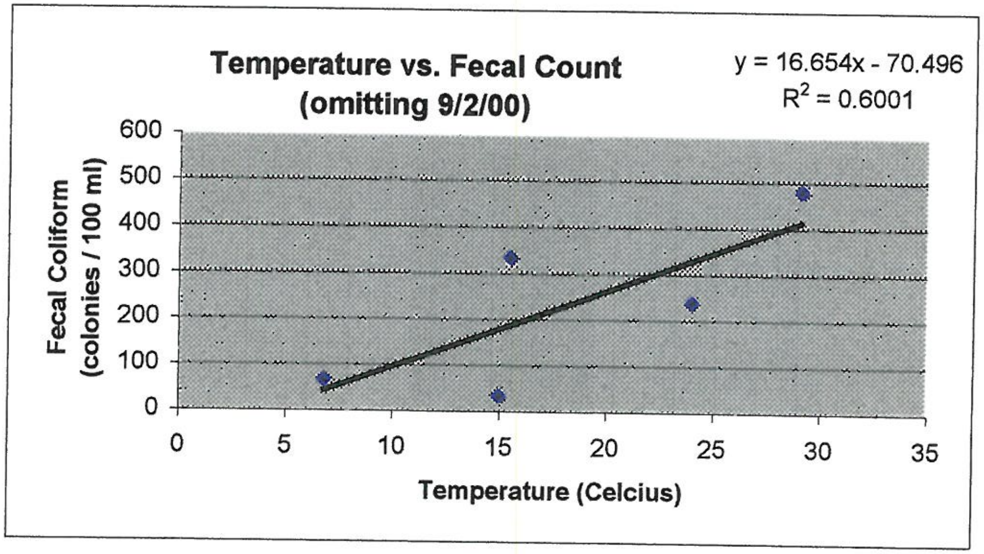
Appendix D: Correlation of Temperature and Fecal Count with Corresponding Regression Equations

Dan River at Rt. 62

	Temp. (^0C)	F. Coliform (col./100 ml)
2/10/00	6.8	67
3/9/00	15	33
4/11/00	15.5	333
5/11/00	24	240
8/9/00	29.1	480
9/2/00	25	0

* Regression significance based on a 95% confidence level.

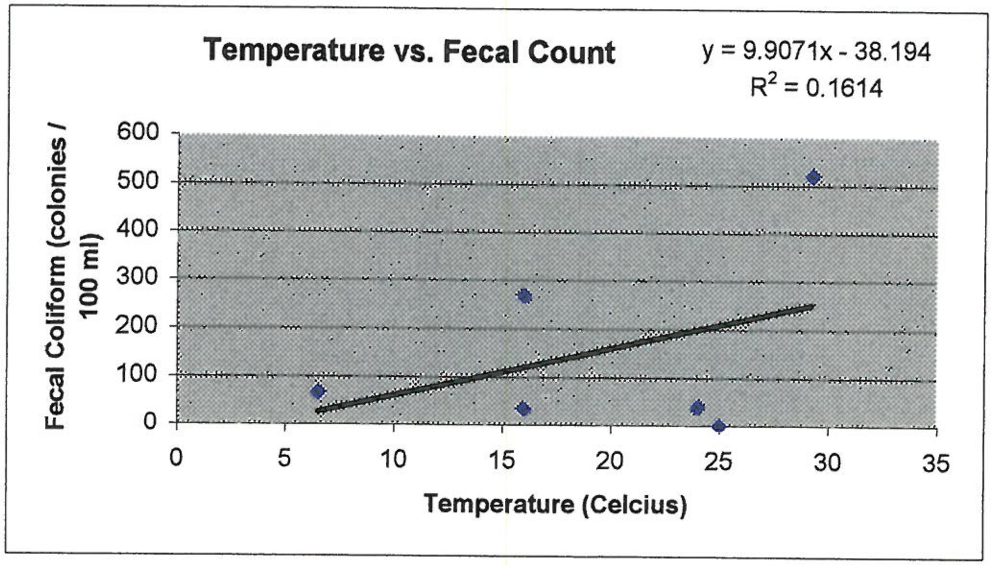


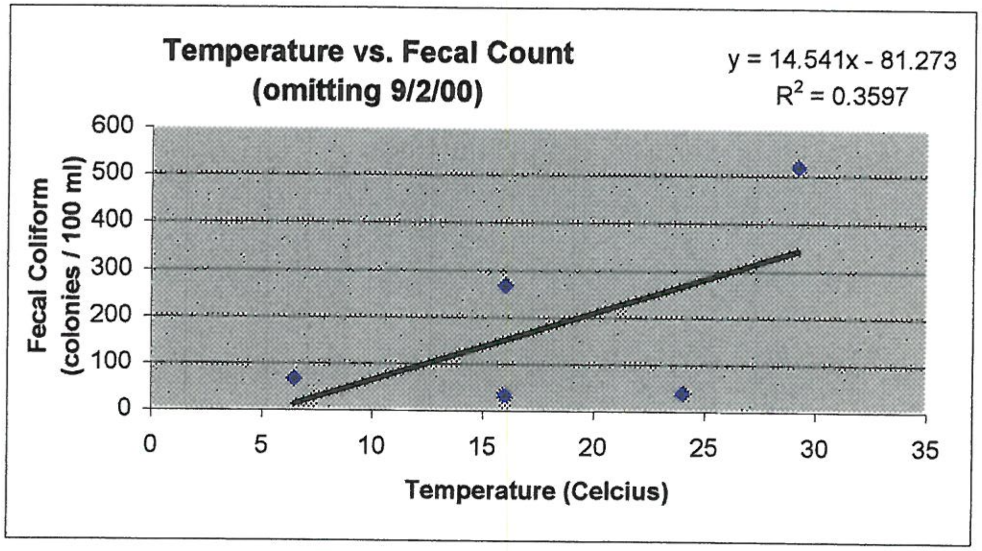


Dan River at Rt. 58

	Temp. (^{0}C)	F. Coliform (col./100 ml)
2/10/00	6.5	67
3/9/00	16	33
4/11/00	16	267
5/11/00	24	40
8/9/00	29.2	520
9/2/00	25	0

* Regression significance based on a 95% confidence level.

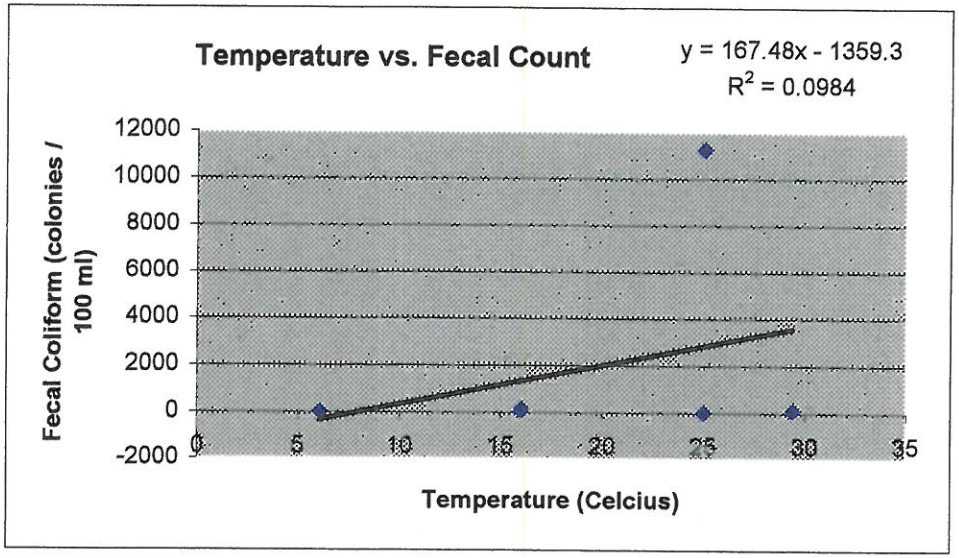


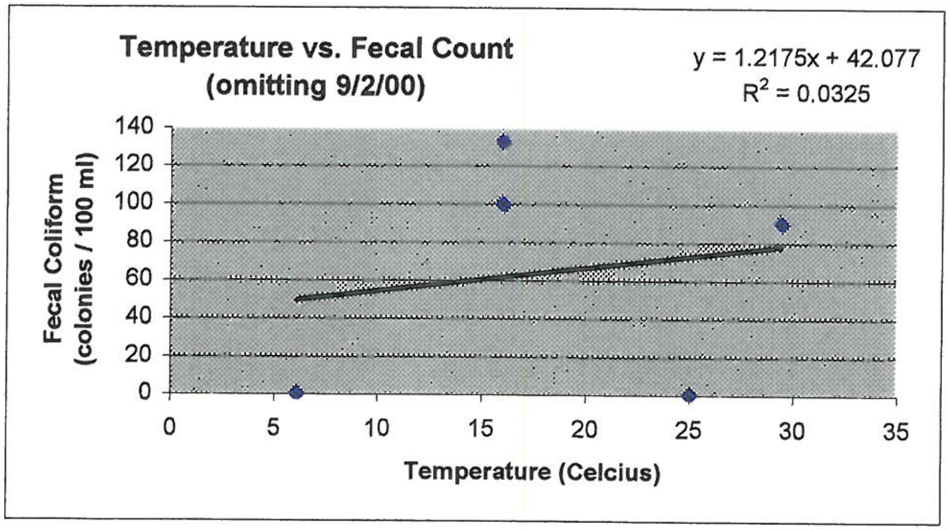


Dan River at Paces

	Temp. (°C)	F. Coliform (col./100 ml)
2/10/00	6.1	0
3/9/00	16	100
4/11/00	16	133
5/11/00	25	0
8/9/00	29.4	90
9/2/00	25	11200

* Regression significance based on a 95% confidence level.

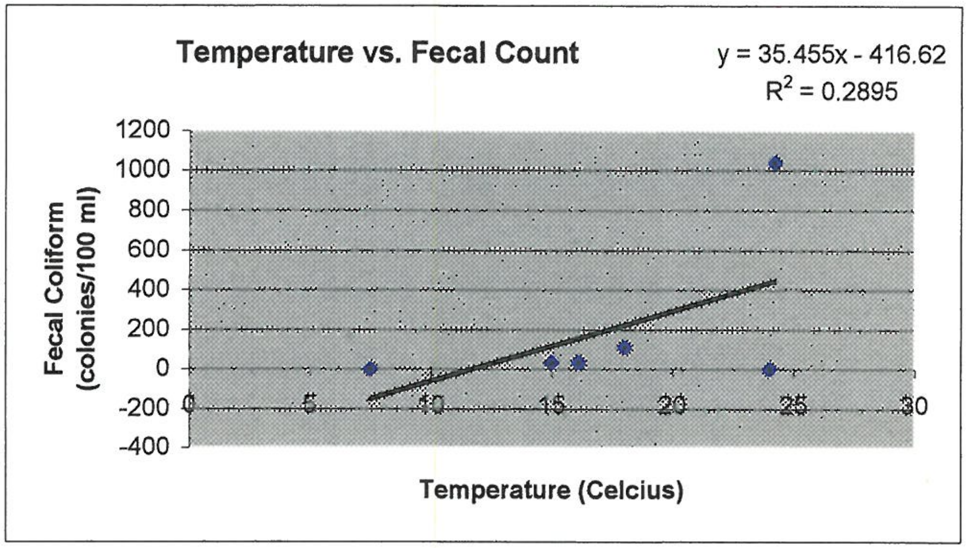


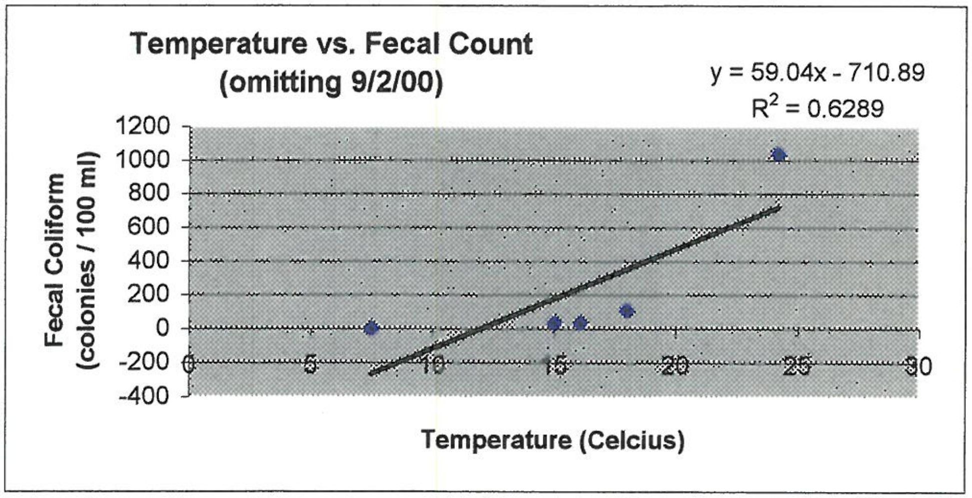


Sandy Creek

	Temp. (⁰C)	F. Coliform (col./100 ml)
2/10/00	7.5	0
3/9/00	15	33
4/11/00	16.1	33
5/11/00	18	110
8/9/00	24.2	1040
9/2/00	24	0

* Regression significance based on a 95% confidence level.

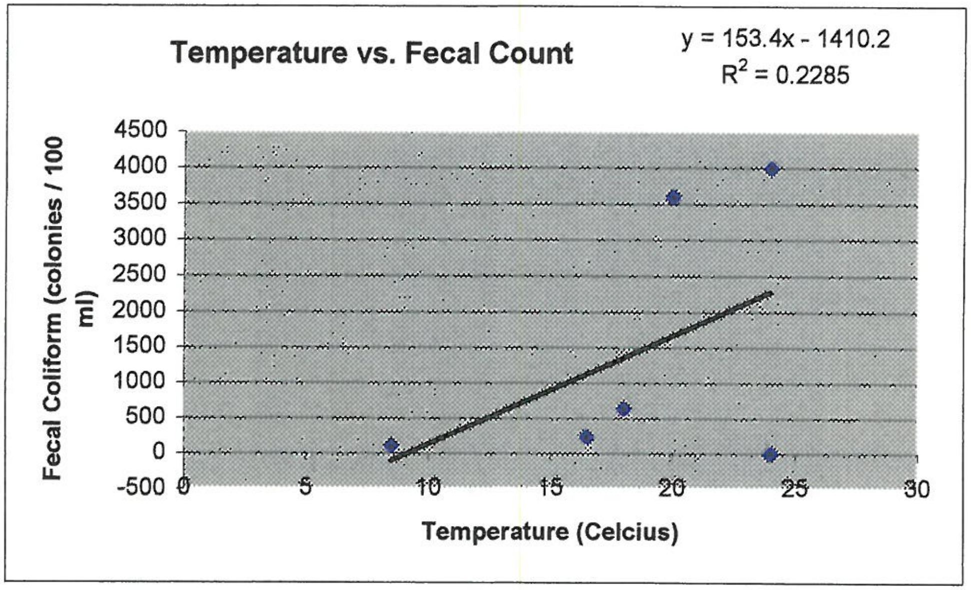




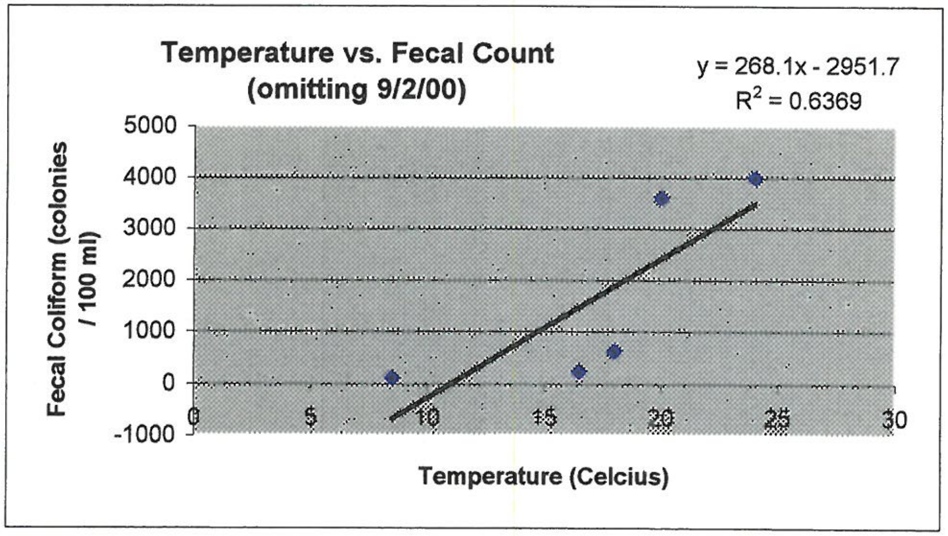
Wolfe Creek

	Temp. (^0C)	F. Coliform (col./100 ml)
2/10/00	8.5	100
3/9/00	16.5	233
4/11/00	18	633
5/11/00	20	3600
8/9/00	24	4000
9/2/00	24	0

* Regression significance based on a 95% confidence level.



Temperature vs. Fecal Count

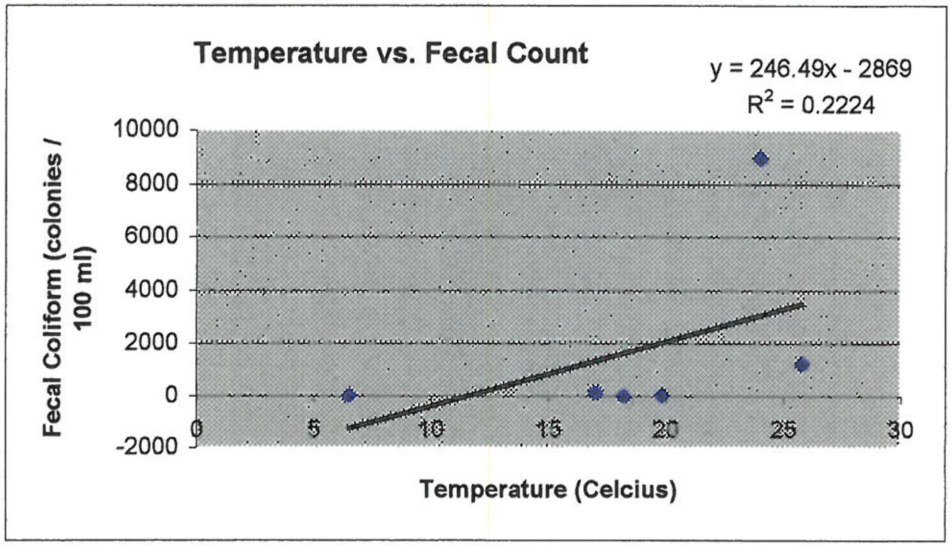


Temperature vs. Fecal Count (omitting 9/2/00)

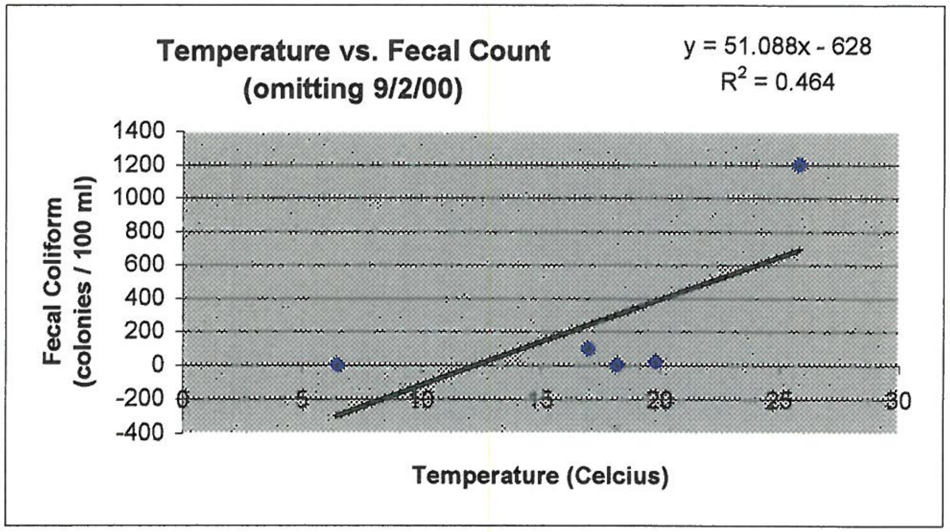
Barker Creek

	Temp. (⁰C)	F. Coliform (col./100 ml)
2/10/00	6.5	0
3/9/00	17	100
4/11/00	18.2	0
5/11/00	19.8	20
8/9/00	25.8	1200
9/2/00	24	8900

* Regression significance based on a 95% confidence level.



Temperature vs. Fecal Count

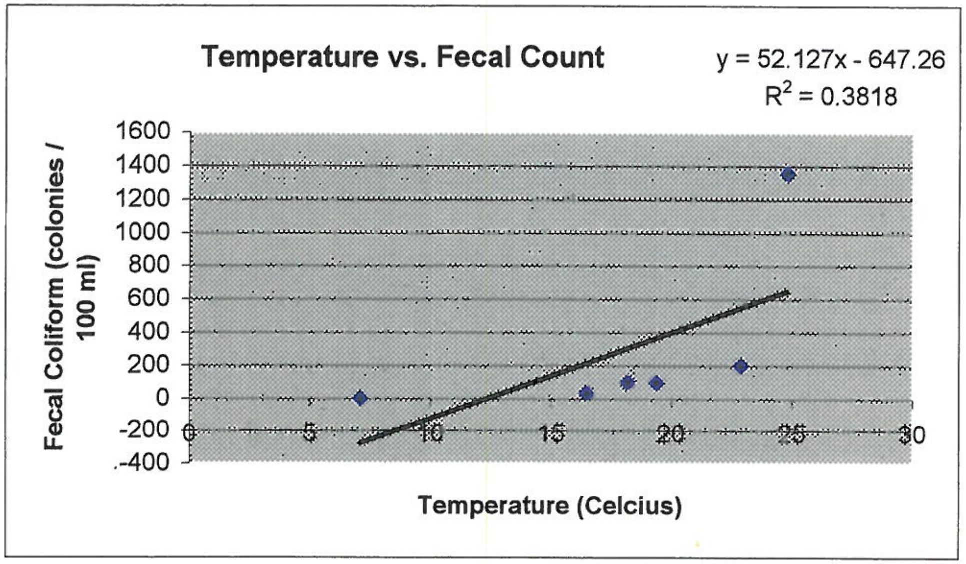


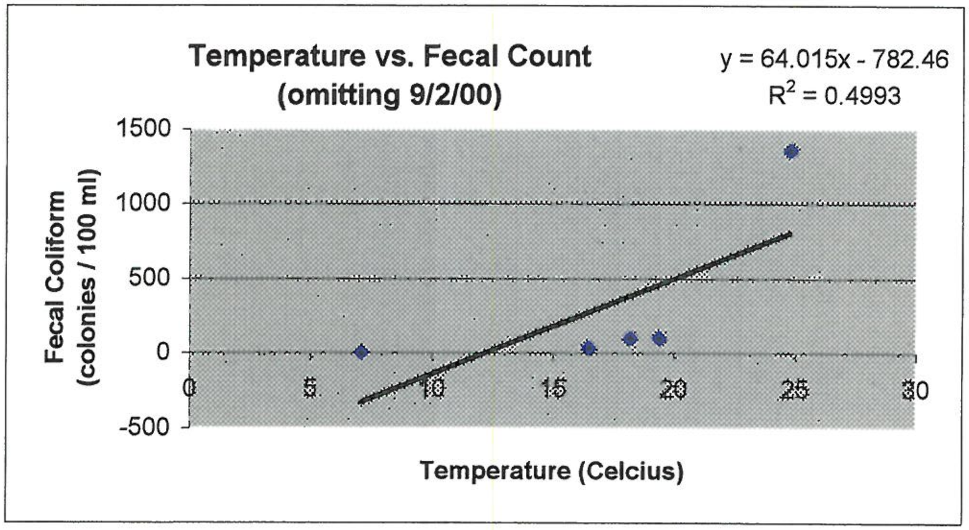
Temperature vs. Fecal Count (omitting 9/2/00)

Double Creek

	Temp. (^{0}C)	F. Coliform (col./100 ml)
2/10/00	7.1	0
3/9/00	16.5	33
4/11/00	18.2	100
5/11/00	19.4	100
8/9/00	24.8	1360
9/2/00	22.9	200

* Regression significance based on a 95% confidence level.

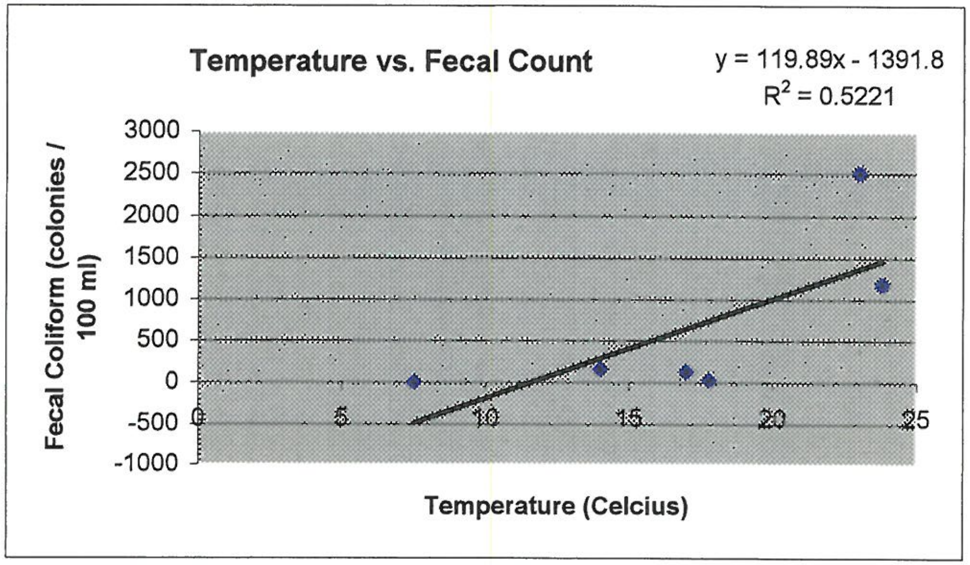

Temperature vs. Fecal Count

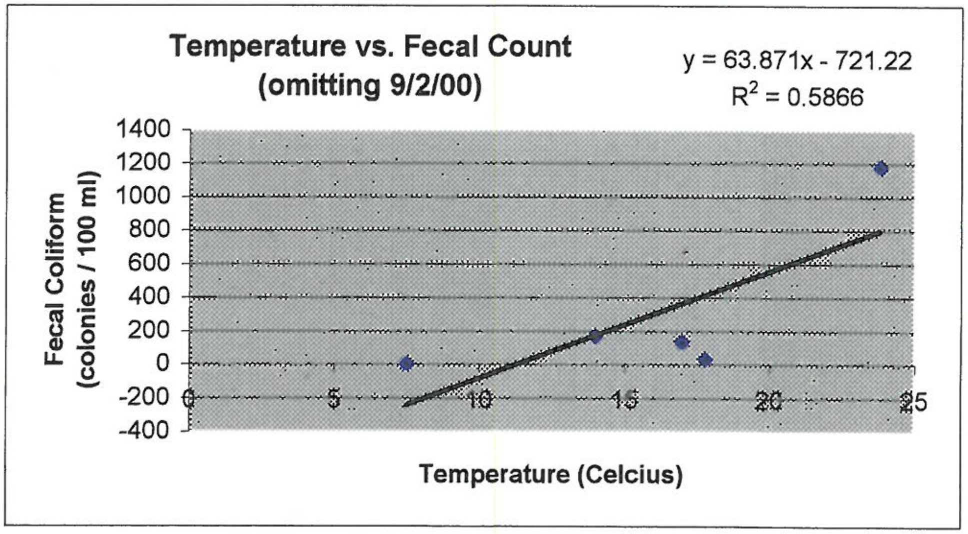

Temperature vs. Fecal Count (omitting 9/2/00)

Winns Creek

	Temp. (^{0}C)	F. Coliform (col./100 ml)
2/10/00	7.5	0
3/9/00	14	167
4/11/00	17	133
5/11/00	17.8	30
8/9/00	23.8	1180
9/2/00	23	2500

* Regression significance based on a 95% confidence level.

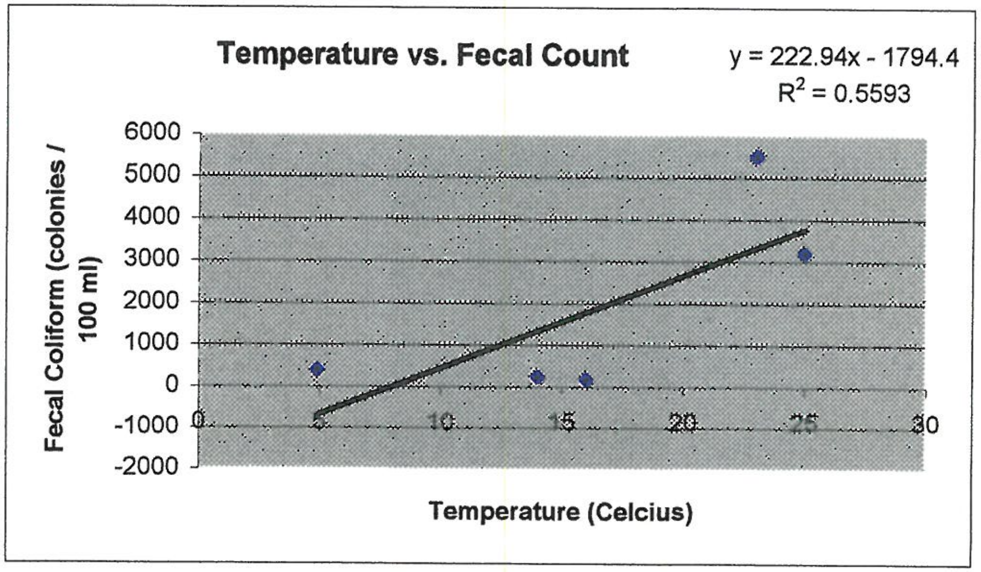


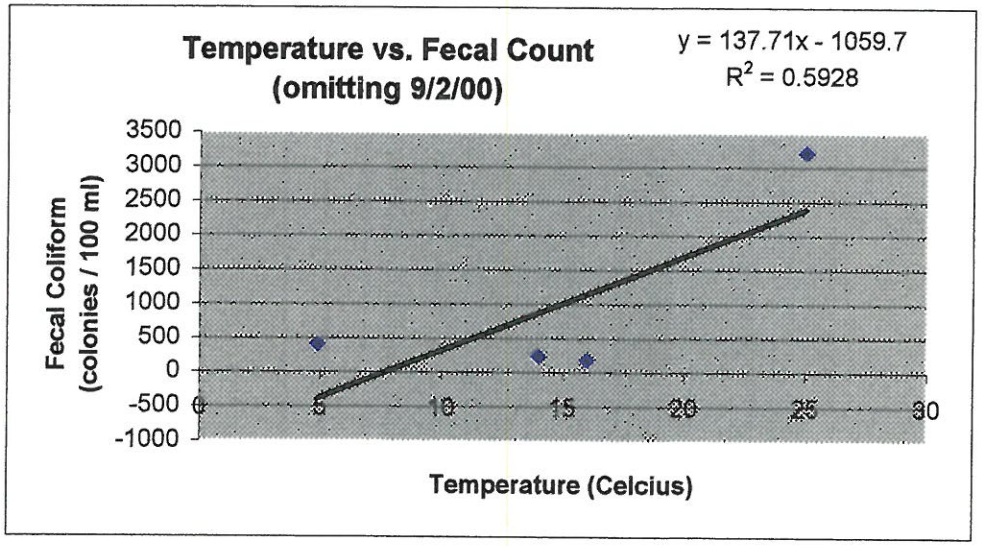


Byrds Branch

	Temp. (°C)	F. Coliform (col./100 ml)
2/10/00	4.9	400
3/9/00	14	233
4/11/00	16	167
8/9/00	25	3210
9/2/00	23	5500

* Regression significance based on a 95% confidence level.

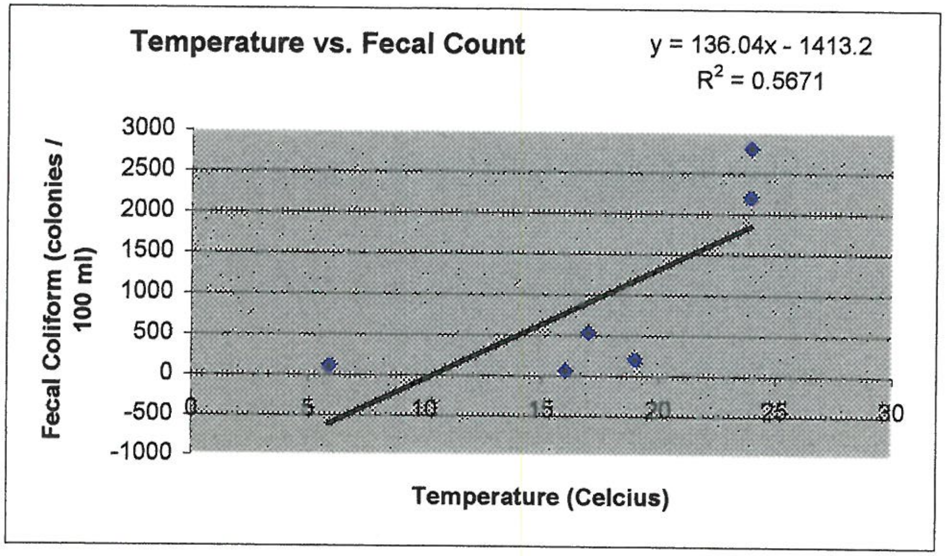


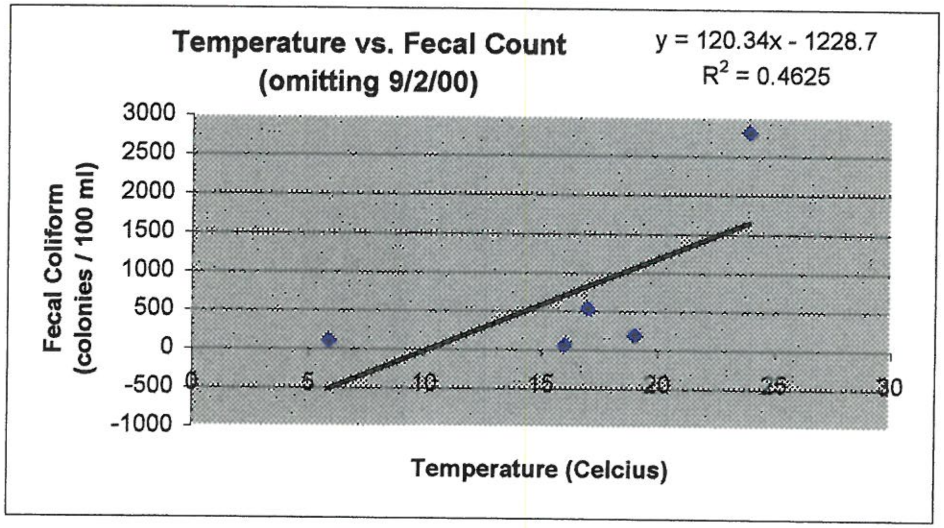


Powells Creek

	Temp. (⁰C)	F. Coliform (col./100 ml)
2/10/00	5.9	100
3/9/00	16	67
4/11/00	17	533
5/11/00	19	200
8/9/00	23.9	2800
9/2/00	23.9	2200

* Regression significance based on a 95% confidence level.

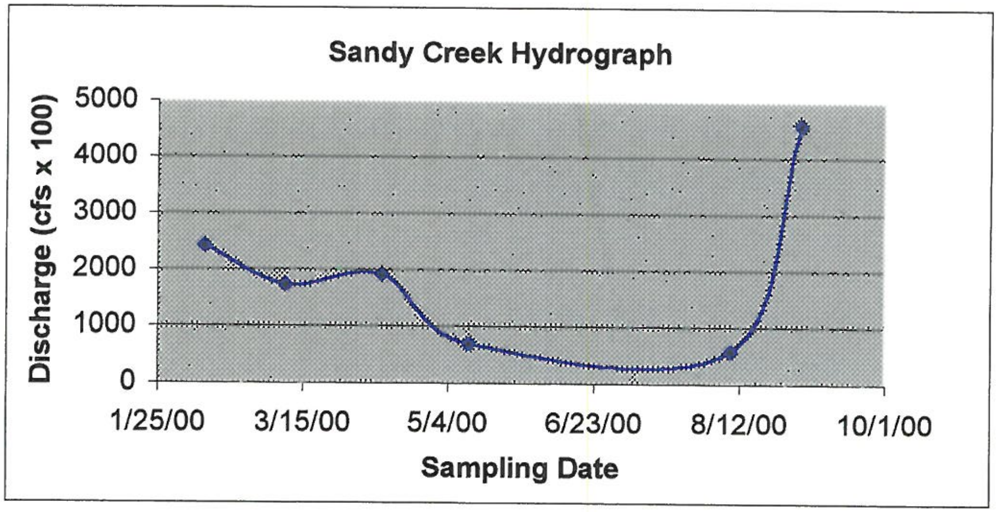




Appendix E: Hydrographs by Site

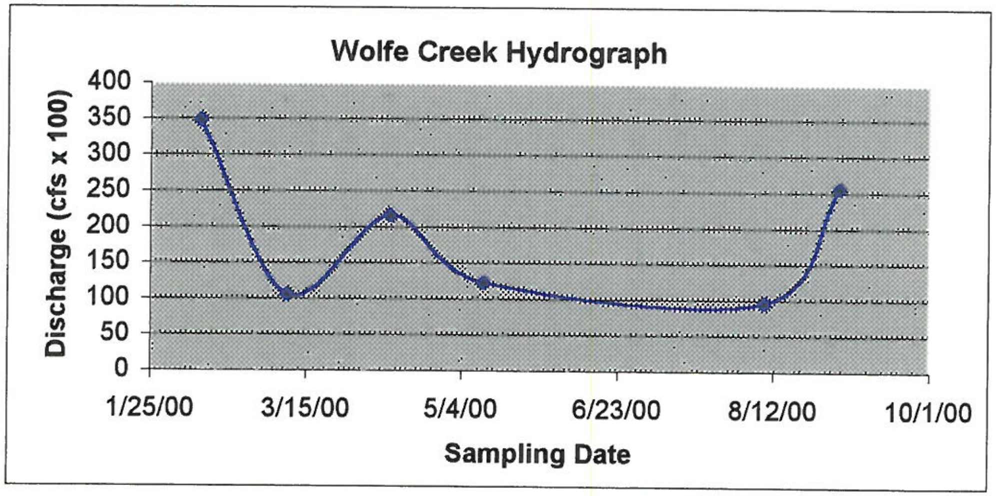
Sandy Creek

	Total Discharge (cfs) X 100
2/10/00	2420
3/9/00	1728
4/11/00	1910
5/11/00	690
8/9/00	571
9/2/00	4579



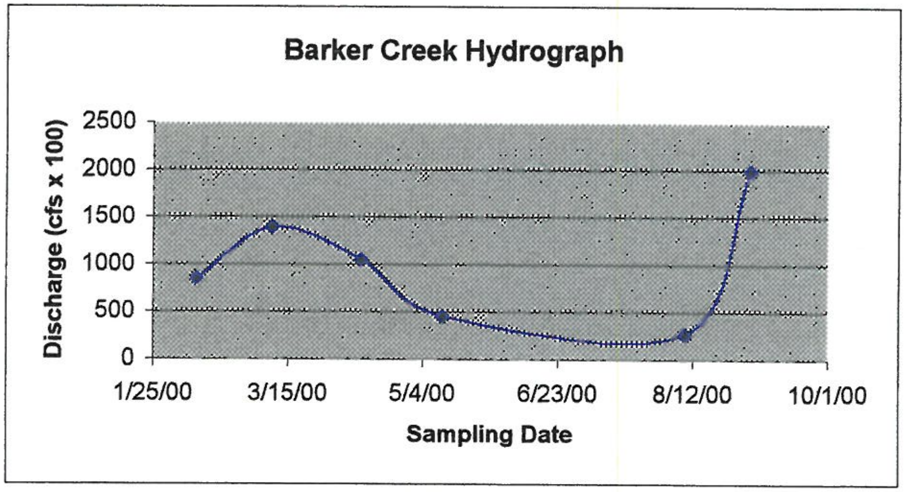
Wolfe Creek

	Total Discharge (cfs) X 100
2/10/00	348
3/9/00	106
4/11/00	216
5/11/00	123
8/9/00	96
9/2/00	255



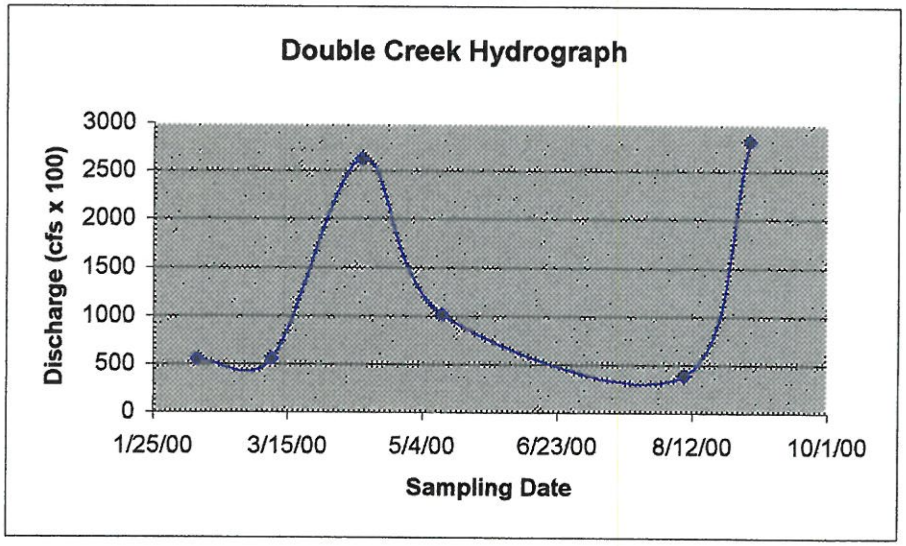
Barker Creek

	Total Discharge (cfs) X 100
2/10/00	850
3/9/00	1396
4/11/00	1051
5/11/00	457
8/9/00	268
9/2/00	1990


Barker Creek Hydrograph

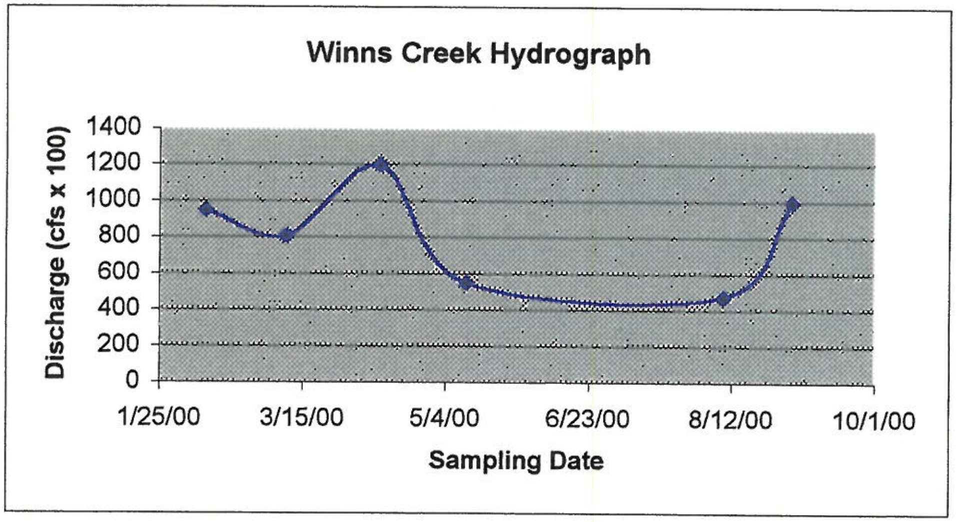
Double Creek

	Total Discharge (cfs) X 100
2/10/00	555
3/9/00	557
4/11/00	2629
5/11/00	1020
8/9/00	385
9/2/00	2812


Double Creek Hydrograph

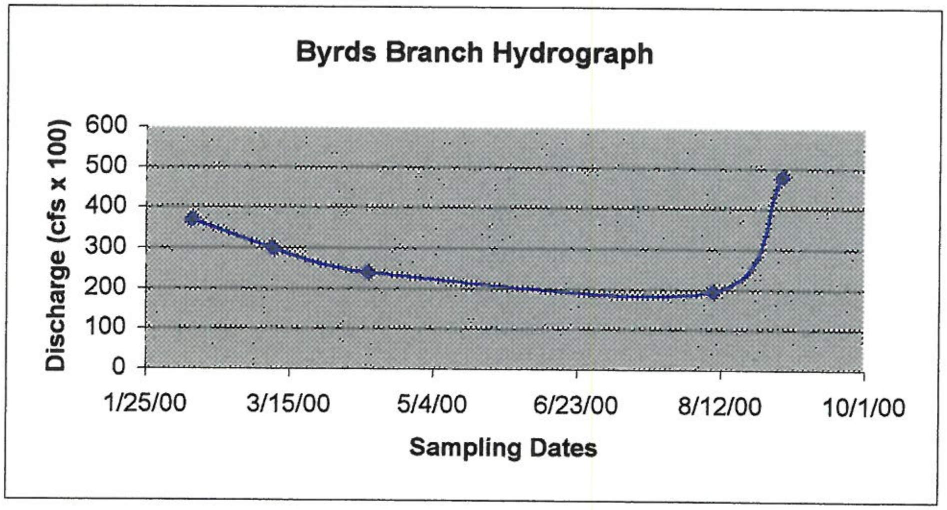
Winns Creek

	Total Discharge (cfs) X 100
2/10/00	947
3/9/00	804
4/11/00	1193
5/11/00	545
8/9/00	469
9/2/00	997



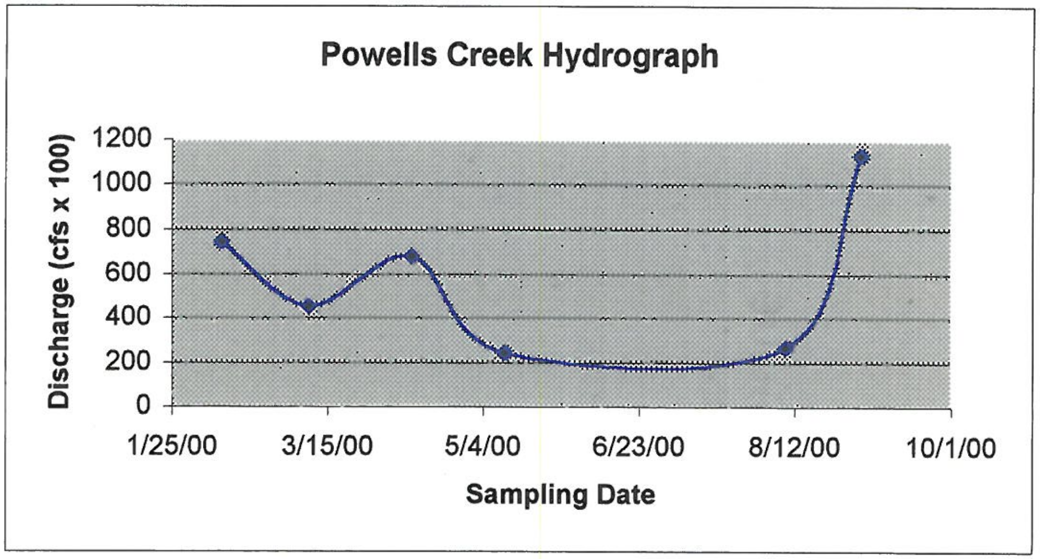
Byrds Branch

	Total Discharge (cfs) X 100
2/10/00	369
3/9/00	298
4/11/00	240
8/9/00	195
9/2/00	479



Powells Creek

	Total Discharge (cfs) X 100
2/10/00	744
3/9/00	453
4/11/00	681
5/11/00	241
8/9/00	269
9/2/00	1131

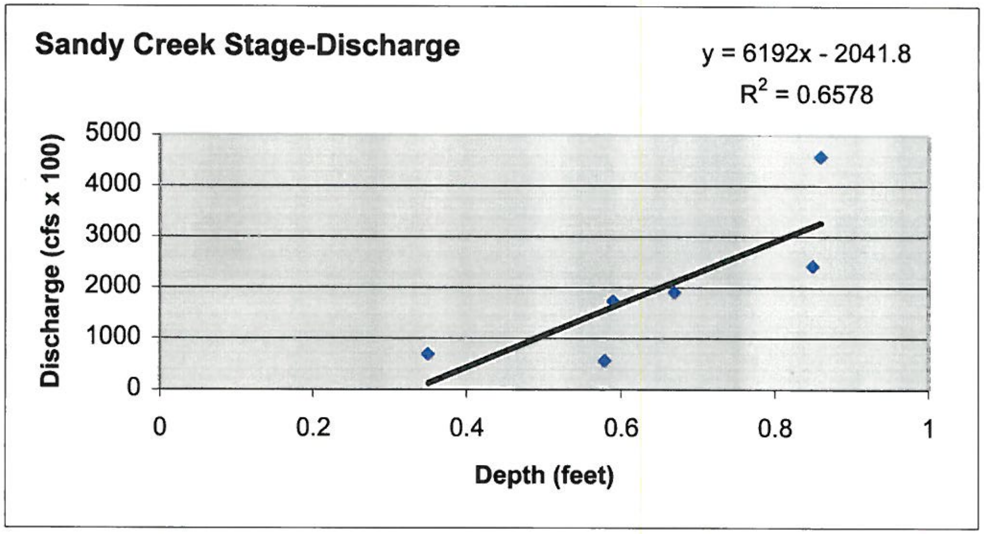


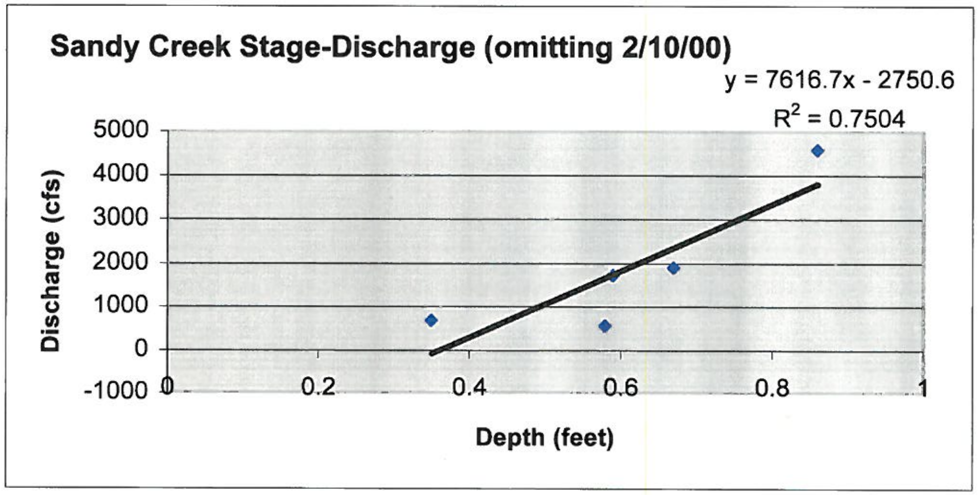
Appendix F: Stage – Discharge Diagrams by Site

Sandy Creek

Depth (ft)	Discharge (cfs x 100)
0.85	2420
0.59	1728
0.67	1910
0.35	690
0.58	571
0.86	4579

** Regression significance based on a 95% confidence level.

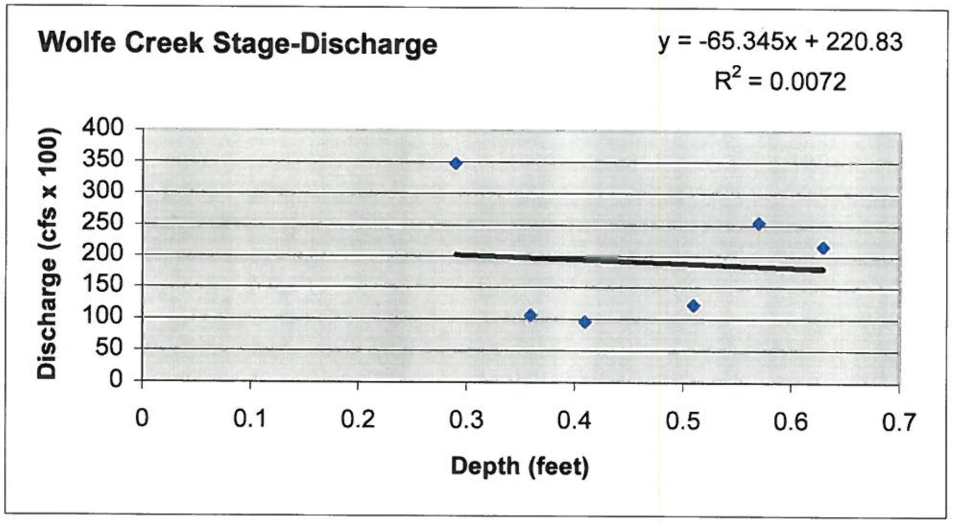

Sandy Creek Stage-Discharge

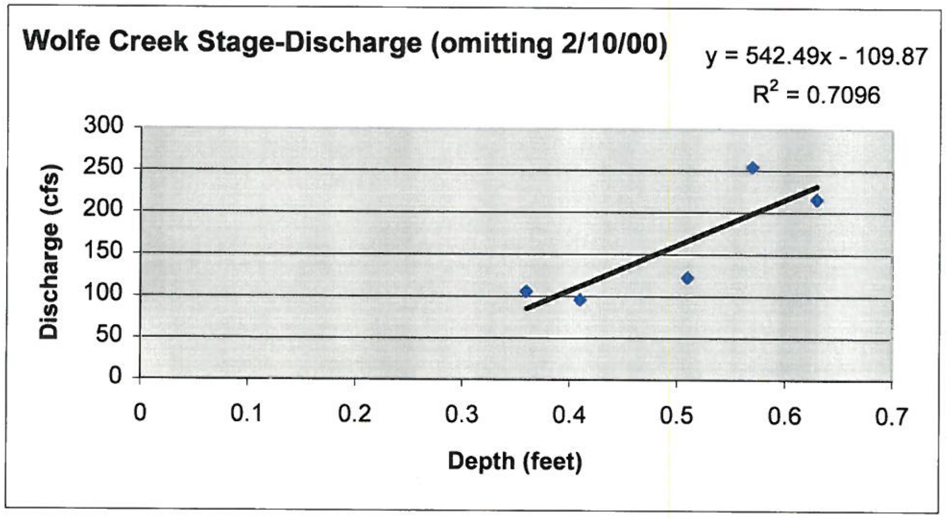

Sandy Creek Stage-Discharge (omitting 2/10/00)

Wolfe Creek

Depth (ft)	Discharge (cfs x 100)
0.29	348
0.36	106
0.63	216
0.51	123
0.41	96
0.57	255

** Regression significance based on a 95% confidence level.

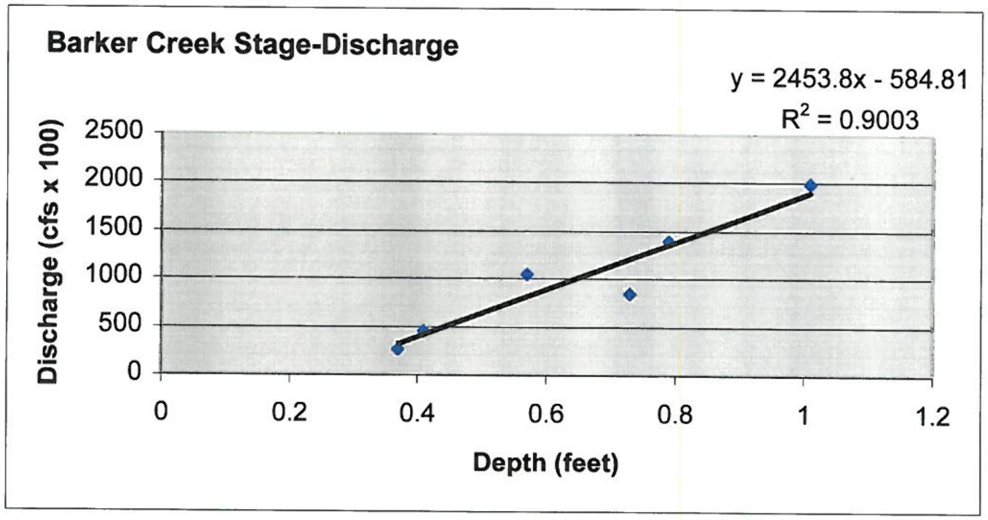




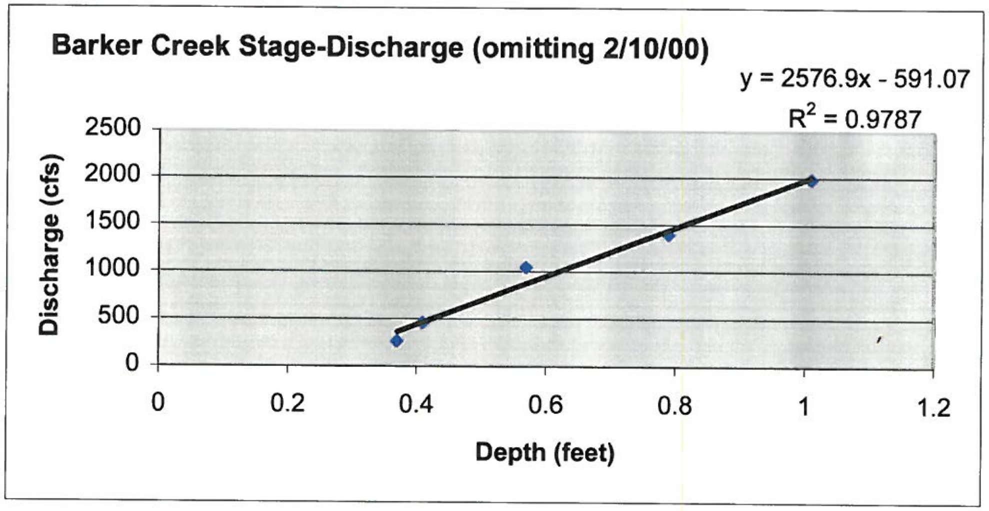
Barker Creek

Depth (ft)	Discharge (cfs x 100)
0.73	850
0.79	1396
0.57	1051
0.41	457
0.37	268
1.01	1990

** Regression significance based on a 95% confidence level.



Barker Creek Stage-Discharge

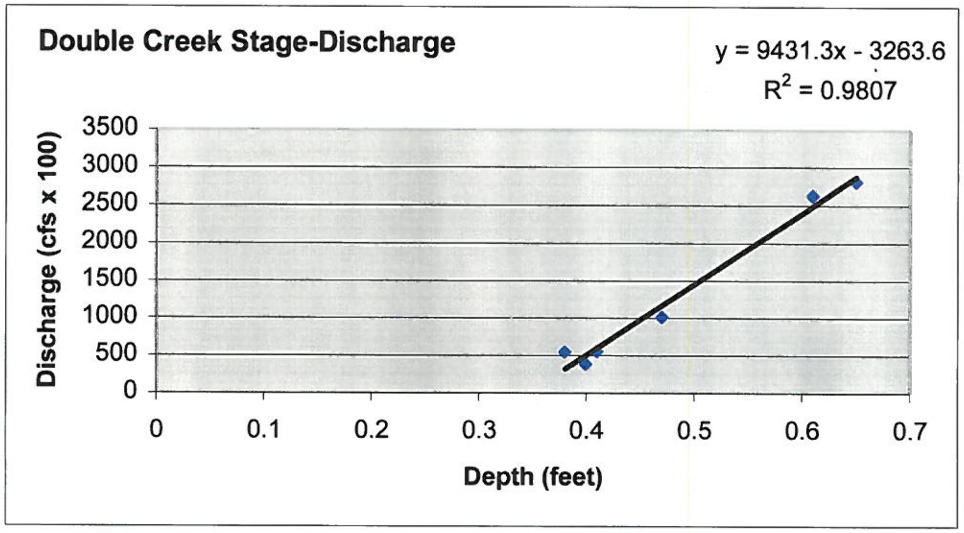


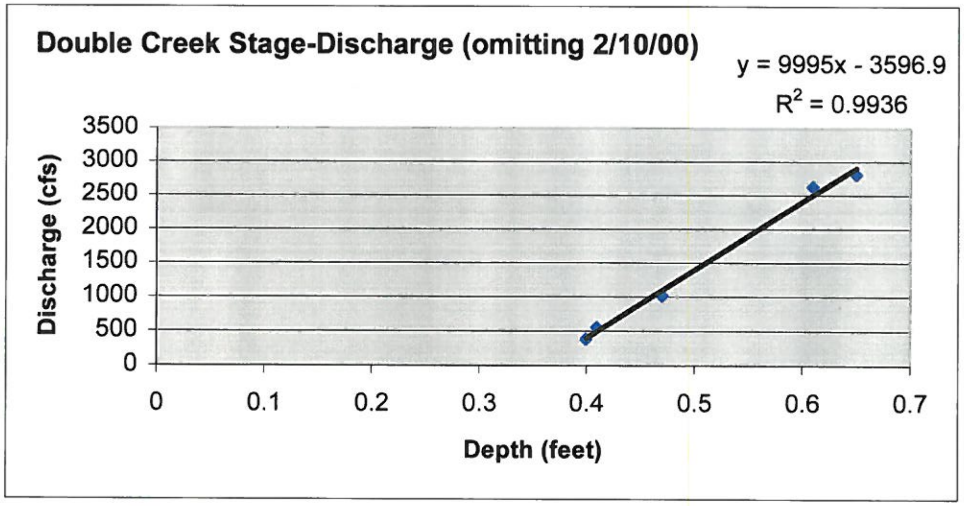
Barker Creek Stage-Discharge (omitting 2/10/00)

Double Creek

Depth (ft)	Discharge (cfs x 100)
0.38	555
0.41	557
0.61	2629
0.47	1020
0.4	385
0.65	2812

** Regression significance based on a 95% confidence level.

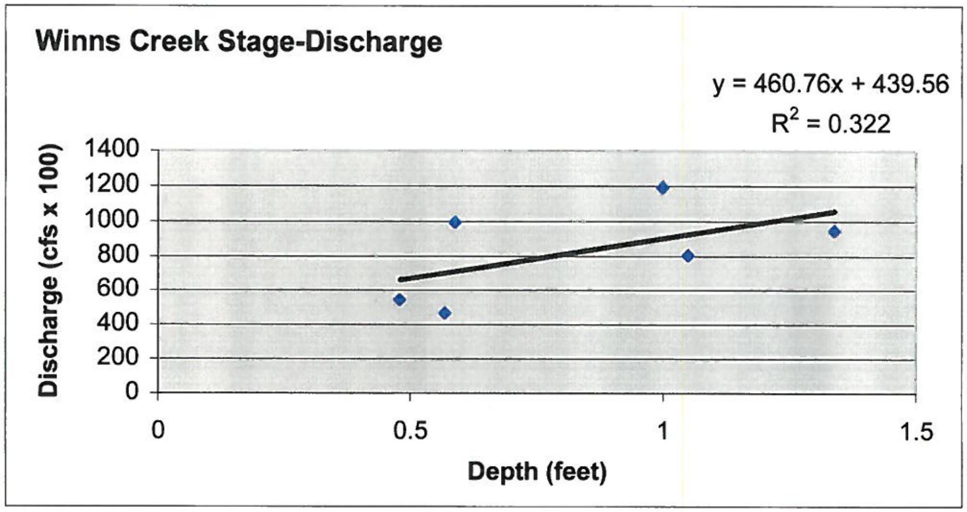


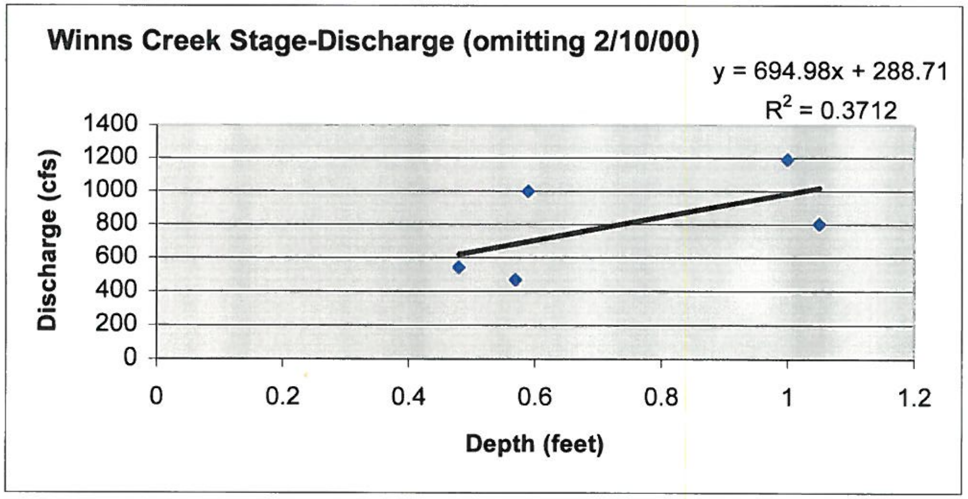


Winns Creek

Depth (ft)	Discharge (cfs x 100)
1.34	947
1.05	804
1	1193
0.48	545
0.57	469
0.59	997

** Regression significance based on a 95% confidence level.

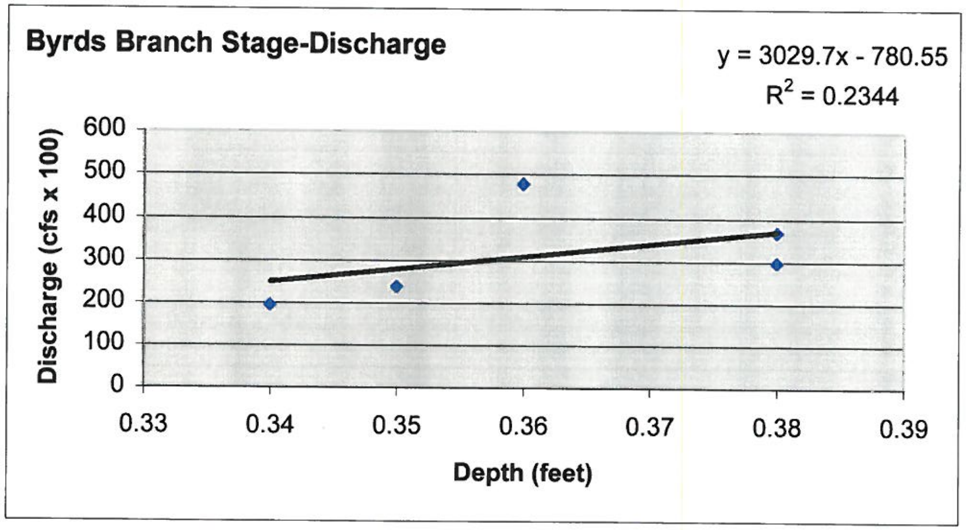


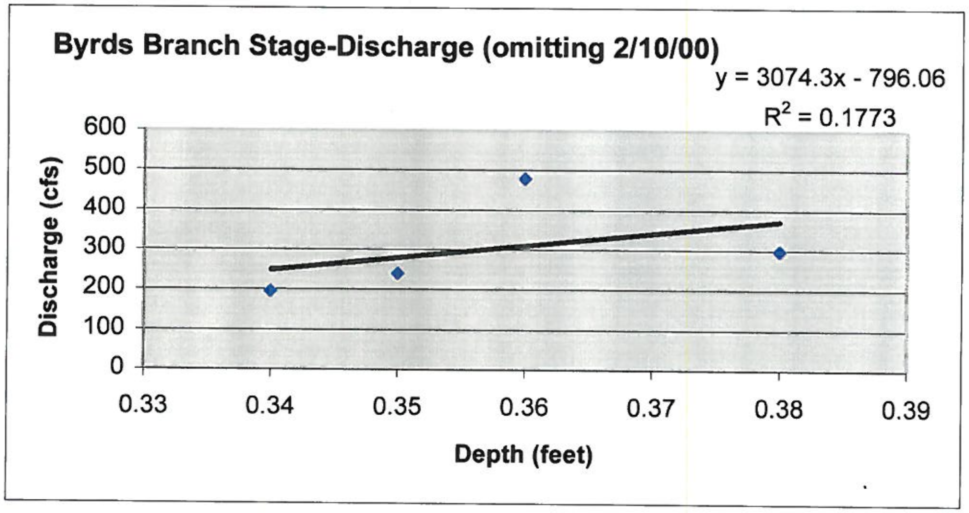


Byrds Branch

Depth (ft)	Discharge (cfs x 100)
0.38	369
0.38	298
0.35	240
0.34	195
0.36	479

** Regression significance based on a 95% confidence level.





Powells Creek

Depth (ft)	Discharge (cfs x 100)
0.73	744
0.72	453
0.67	681
0.37	241
0.25	269
0.53	1131

** Regression significance based on a 95% confidence level.