THE HEALTH OF THE SHENANDOAH RIVER IN AUGUSTA AND ROCKINGHAM COUNTY: THE FOSR WATER TESTING PROGRAM

APRIL 2005

A PAPER PREPARED BY THE FRIENDS OF THE SHENANDOAH RIVER WITH THE COOPERATION OF THE VOLUNTEER MONITORS OF AUGUSTA AND ROCKINGHAM COUNTY

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ABSTRACT

The “Health of the Shenandoah River in Augusta and Rockingham County” report is the fifth and last in a series of “County” reports being prepared by the Friends of the Shenandoah River (FOSR). These five reports now cover all of the counties in the Shenandoah River watershed in Virginia.

These reports focus mostly on the status and the trends of water quality as revealed by the extensive monitoring efforts of volunteer monitors. Some attention is devoted to the question of why water quality is good is some places and poor in others, and what could be done to improve water quality, but a more thorough analysis must wait for out next report which updates and integrates the isolated county report into one volume. More importantly, it will delve more deeply into the causes of poor water quality, and in overcoming the challenges faced by the region’s stakeholders to improve the water quality.

This report analyses the water quality data in Rockingham and Augusta counties for N, P, NH4, pH, T, DO that have been collected twice a month by the volunteers of the Friends of the Shenandoah River and its partners since January 1, 1997. During this more than seven year time period more than 6000 samples were collected from 46 sites in Augusta and Rockingham, and more than 31,000 lab tests were carried out to determine the concentrations of the six parameters. In addition, collection of fecal coliform data started this year, and will be the subject of separate report.

It was found that the water quality in the streams and rivers of Augusta and Rockingham County is poor. The concentrations of nutrients composed of nitrogen phosphorus, and concentration of sediments as measured by turbidity are well above the impaired levels for both streams and river sections, and except for phosphorus, there has been no improvement in water quality since January 1997. In fact, water quality is getting worse.

Though the general factors that affect water quality are well known, as are some of the remedial actions, there are few studies that quantitatively link cause and effect. Despite this lack of precise knowledge, however, a number of organizations in the public and private sector, and private volunteer groups have been successfully involved in slowing down and reducing pollution levels. These efforts, though well designed and energetically carried out, and successful at the micro level (such as for a small stream) have evidently not been large enough to counter the worsening trend caused by increasing and haphazard urbanization, poor agricultural practices, deforestation, and high population growth.

It is clear that more effective and extensive efforts need to be taken to reverse the deteriorating trend in water quality in both Rockingham and Augusta County, and the rest of the Shenandoah River watershed. This is a challenging task that we hope to discuss in our next report, in addition to the update on water quality. Typical issues to be addressed include better enforcement of existing regulations, criteria for water quality, more education and involvement of the public and stakeholders; better integration and coordination among the numerous Federal, State and local government agencies involved with water quality; more education and involvement of the public; and sustainability of funding for research, monitoring and implementation of remedial programs.

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- The volunteer monitors of Rockingham and Augusta county.
- River Network, Canaan Valley Institute, and Izaak Walton League
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Chapter 1 Introduction

The Friends of the Shenandoah River [1] was established in 1989 in response to the severe contamination of the Shenandoah River with polychlorinated biphenyls (PCBs) by the Avtex Plant. Monitoring by the FOSR started on a very limited basis but, in response to the rapid growth in the Shenandoah River watershed, monitoring expanded both in scope – it now covers the entire watershed – and in the number of the chemical parameters tested. We now test for N, P, NH4, pH, T, DO, and recently have started testing for fecal coliform.

Every two weeks since January 1, 1997 the FOSR monitors have collected samples from the Shenandoah River and its tributaries in the Shenandoah River watershed. Thanks to the many volunteers involved with monitoring, a total of about 17,000 sample bottles were collected during the past eight years. Each bottle was tested for six important water quality parameters, and since 1997 the results of the tests were posted on the FOSR web page (www.fosr.org). This work is not cheap. For the Augusta and Rockingham counties alone, the cost of the sample collection in terms of volunteer time was about $70,000. And the cost of the laboratory operations for reagents, maintenance of instruments, and professional lab technician's time was about $95,000.

You may well ask why the FOSR is spending such effort and money on monitoring? The reason, as we shall read in this report, is that the quality of water in the Shenandoah River and its tributaries is far from ideal. Land use in the watershed is being altered for the worse. Forests, wetlands, and farmlands are being replaced by residential developments, poultry processing plants, and other activities that produce largely uncontrolled surface runoff of pollutants and degradation of groundwater. And despite the many efforts by the DEQ and other government organizations, civic groups such as the FOSR, and large numbers of volunteers and landowners, water quality seems to be getting worse.

The water quality database that the FOSR has developed has become an important tool to inform the public, civic institutions and government organizations, and schools and universities on the quality of water in the Shenandoah River watershed, what the problems are, where they seem to be worst (hot spots), and what can be done about correcting these problems. Monitoring water quality is, of course, the first step in this process.

A second step is the publication of these reports so as to provide the reader with a detailed picture of the health of the waters in the watershed. Except for the occasional bit of scum or dead fish floating by, the presence of massive algae populations or weed beds, or muddy water, the true health of a river is not always evident. These reports therefore usefully serve as a "thermometer" that provides scientific indications of the health of the Shenandoah River. And by identifying problem areas, these reports serve an essential first step in the restoration of specific sections of the river. They also provide a "benchmark" against which changes in the health of the river due to restoration efforts can be measured.

In December 2000, the FOSR completed their first report for the Main Stem of the River in Clarke County. The second report covering the South Fork in Page County was completed in October 2001. The third report covered the North Fork in Shenandoah County was completed in January 2003. The fourth report was published in 2003 and covered the South Fork and its

[1] Charles Vandervoort, a member of the FOSR, prepared this report. The water samples collected by the Rockingham and Augusta County volunteers were analyzed in the FOSR laboratory in space generously provided by Shenandoah University. The laboratory is operated by Karen Andersen, the FOSR Program Director. The author acknowledges the excellent cooperation and valuable contributions made by Paul Bugas, Bruce Wiggins, Meryl Christiansen, Milton Boyce and the many other volunteers and monitors who made this report possible. The Robins Foundation deserves much credit for encouraging the production of these reports, and for providing funds for the operation of the laboratory

tributaries in Warren County. This report is the final report in the "county" series, and will be followed next year by a comprehensive report on the whole Shenandoah River watershed in which the county reports are updated, more detail, the question of "why is water quality so bad" will be addressed in much more detail, and the institutional arrangements among the numerous government, private sector, voluntary, funding organizations and the public will be examined to find out if they can be better integrated and coordinated. All of these reports are, or will be posted on the FOSR web site www.fosr.org.

The four earlier reports show that the river and its tributaries in these counties indeed have health problems. For example, the nitrogen (measured as nitrate-nitrite) levels in many of the tributaries of the Main Stem in Clarke County are well above the impaired level; the nitrogen levels in the South Fork in Page County are high, and both the North Fork and many of its tributaries in Shenandoah County are well above the impaired level. It is only in Warren County where the water quality is reasonably good.

The FOSR laboratory uses water chemistry to test the water [2] by measuring the concentrations of: nitrate-nitrite (N), ortho-phosphorus (P), ammonia(NH3 and $NH4^{+)}$, acidity (pH), turbidity (T), and dissolved oxygen (DO).

N, P, and NH4 are important for normal growth of aquatic plants. But when their concentrations reach high levels, they encourage excessive growth of algae and aquatic plants during the warmer months of the year. The excessive aquatic plant life eventually dies and, through decay or eutrophication, contributes to major problems to our river and our downstream neighbors along the Potomac River and Chesapeake Bay. And high levels of ammonia, even though temporary, can kill fish very quickly.

It was found that rivers and streams in Rockingham and Augusta Counties frequently carry excessive levels of nitrogen, phosphorus, and turbidity (sediment). However, they are rarely too acidic (thanks to the limestone rich soils) and the average levels of dissolved oxygen is almost never a problem. Turbidity appears to be the most serious problem; and high turbidity levels are a strong indicator of excessive surface water runoff that, in addition to carrying sediment, also carries nutrients into the rivers and streams.

High turbidity indicates excessive sediment in the river: it fills up cracks (bottom interstices) and plugs up the habitat for the small bottom dwellers (benthic organisms) that the fish need for food, and thereby reduces the health of the fish population. It is well known that excessive turbidity can be corrected by best management practices (BMPs)[3] such as installing riparian buffers that reduce water run-off from construction projects, impervious urban surfaces, and farm land.

Turbidity, nitrogen pollution, and phosphorus pollution go hand-in-hand since their underlying cause is the same: runoff of surface water. If one can control turbidity, it is very likely that nitrogen and phosphorus will also be controlled. It is easy and inexpensive (no costly reagents are required) to test for turbidity, and this parameter should perhaps be more extensively applied in

[2] There are many ways to test the quality of stream water. For example, some organizations such as the Izaak Walton League test water by monitoring the types and numbers of benthic organisms that are present. Unpolluted water supports organisms that are quite different from those living in polluted water. See: Barbour, M.T. et al, Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macro invertebrates and Fish. Second Edition. EPA 841-B-99-002, 1999.

[3] BMPs include measures to reduce channel and other erosion and fertilizer runoff from farm fields by restoring streamside forested buffers, rehabilitating stream banks to reduce erosion, preserving forest land, discouraging construction of impervious surfaces (asphalt or concrete pavements), and by applying the best available technology to STPs and septic systems to reduce the concentration of nutrients and other pollutants in their discharge.

monitoring. For example, “hot spots” could be monitored more frequently than twice a month to determine if corrective measures are taking effect.

Chapter 2 : Profiles of Water Quality in Augusta and Rockingham County.

In this chapter we analyze the vast amount of water quality data collected by the FOSR monitors over the past seven and a half years. This analysis clearly shows that average water quality in Shenandoah River watershed in Augusta County and especially in the Rockingham County is very poor, the concentrations of nitrogen, phosphorus, and turbidity are often above impaired levels. Not only are the average levels high, the fluctuations in these levels, as measured by their standard deviation, are also large. This means that for much of the time during the year, the concentrations of several important water quality parameters not only exceed the "impaired", but closely approach and sometimes exceed the "extremely impaired" level.

This chapter also compares the pollution concentrations in Rockingham and Augusta Counties with those in other counties in the Shenandoah River watershed. The streams and rivers in the North River watersheds of Rockingham are by far the worst.

Finally, we will look at some of the factors, such as the presence of poultry rendering plants, poor management of streamside buffers, lack of forest coverage, and lack of control of cattle and other poor agricultural practices that explain some of the high pollution readings.

What we observed

Table 2.1 below shows a summary for the average level of nitrogen pollution in the streams and rivers of Augusta and Rockingham counties. The average is calculated over the whole span from January 1, 1997 to April 26, 2004. The table also includes the "spread" around the average as measured by the standard deviation [4] of the observations. This standard deviation is used to calculate (as shown in the right-hand column) the probability that observations fall above the severely impaired levels.

Table 2.1 below makes strikingly clear that the average nitrogen concentrations in both the small streams and in the South, Middle, and North Rivers in Augusta and Rockingham counties are well above the ecologically impaired level of 1.0 PPM. As expected, the levels in the streams are higher than the levels in the rivers because, for each mile of length of a waterway, a river offers a much greater volume of dilutive power for the surface runoff than a stream.

[4] Standard deviation is a measure of the spread of observations around their mean. Since the observations approximately follow a normal distribution, a statistical calculation can be used to calculate the probability that a parameter will exceed the "impaired" or "severely impaired" level. This is useful since "hot spots" can be identified without going through detailed enumeration of all observations. It should be noted, of course, that these probabilities are only approximate since the observations don't perfectly follow the ideal normal distribution..

Table 2.1: Average PPM for Nitrogen in Streams and Rivers of Augusta and Rockingham Counties

Streams	Average PPM (Sample Size, N)	Std. Dev.	Probability of exceeding 10 PPM (State WQ Standard)
Rockingham	3.2 PPM; (1076)	3.0	1%
Augusta	1.3 PPM; (1990)	1.1	0%
Rivers			
Rockingham	1.9 PPM; (461)	6.5	11%
Augusta	1.2 PPM; (1534)	0.8	0%

Table 2.2: Average NTU for Turbidity in Rivers and Streams shows the concentrations for turbidity, the second highest pollutant in the rivers and streams of Augusta and Rockingham counties. (NTU stands for Nephelometric turbidity units). It is again clear that the average turbidity is far above the impaired level of 4 PPM (See Table 2.6 for critical levels). And from the large standard deviations it is safe to conclude that the pollution level very frequently exceeds the "severely impaired" level of 7 NTU, particularly after rain storms.

Table 2.2: Average NTU for Turbidity in Rivers and Streams

Streams	Average NTU (Sample Seize, N)	Std. Dev.	Probability of exceeding 7 NTU
Rockingham	6.7 NTU (1045)	8.45	49%
Augusta	5.6 NTU (1902)	14.5	46%
Rivers			
Rockingham	3.0 NTU (445)	4.0	16%
Augusta	5.4 NTU (1460)	15.3	46%

Phosphorus, as shown in Table 2.3: Average Concentration for Phosphorus in Rivers and Streams. below, is also a major polluter, although the levels have declined sharply over the past five years (see Figure 2-12 page 20), is still a major polluter..

Table 2.3: Average Concentration for Phosphorus in Rivers and Streams.

Streams	Average. PPM (Sample Seize, N)	Std. Dev.	Prob. of exceeding 0.1 PPM
Rockingham	0.26 PPM (1068)	0.5	63%
Augusta	0.15 PPM (1958)	0.3	57%
Rivers			
Rockingham	0.33 PPM (457)	0.8	61%
Augusta	0.29 PPM (1517)	0.7	61%

The three bar graphs below, Figure 2-1, Figure 2-2, and Figure 2-3 show the same information as in the three tables above. The impaired levels for nitrogen, phosphorus, and turbidity are shown on the graph and make it even more evident that, except for turbidity in the Middle River in Augusta County, the levels were well above the impaired limit.

Figure 2-1:Average PPM for Nitrogen in Streams and Rivers of Rockingham/Augusta County

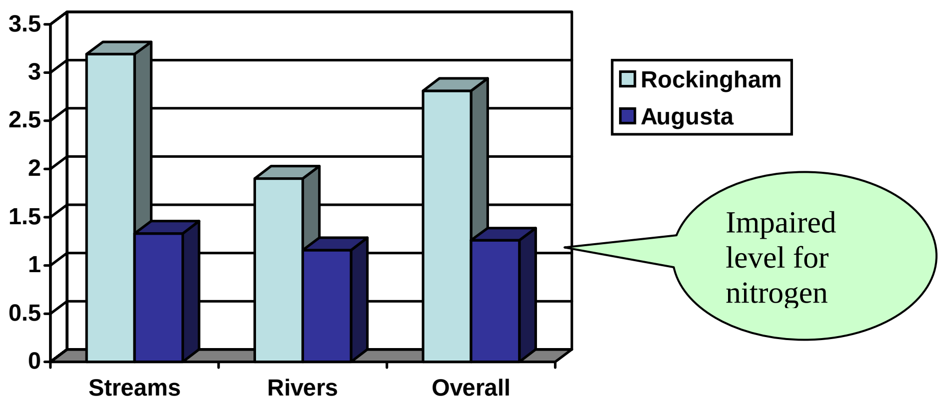


Figure 2-2: Average PPM for Phosphorus in Streams and Rivers of Augusta and Rockingham Counties

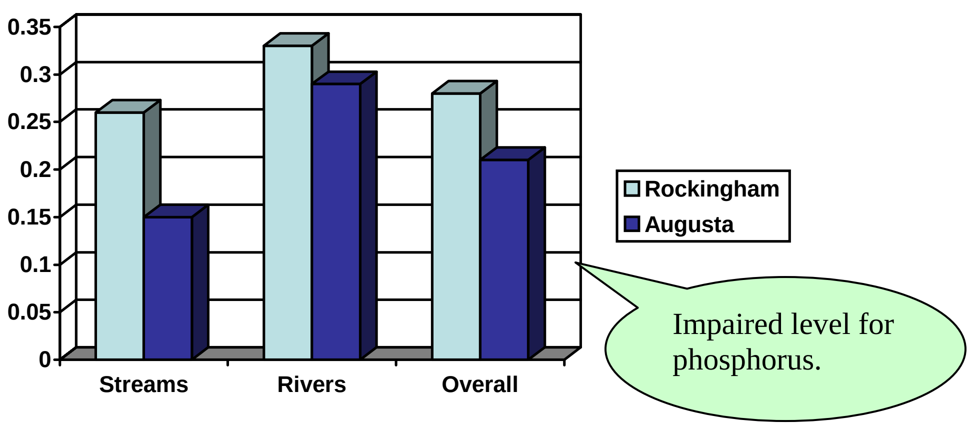
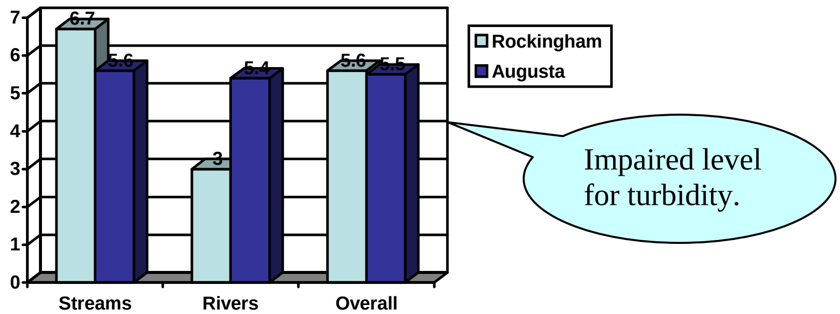


Figure 2-3: Average Turbidity in Streams and Rivers of Rockingham/Augusta County



The spread of the observations around the average

There are many factors that influence the concentrations of the pollutants at the time the samples are taken. Foremost are the systematic factors that influence all the stream samples to the same extent; for example, heavy rains or snow melt on the day the sample is taken will generally raise the turbidity, phosphorus, and nitrogen levels in all the samples taken that day. But the impact will not be the same for all streams – some streams may suffer less because they have well protected banks with ample vegetation to absorb the runoff, while others will be exposed to the full effect of the runoff.[5] In addition we have the unsystematic factors that affect one stream but not any of the others. A typical example of this will be a stream that, just before the sample was taken, suffered a pollutant spill, or was located close to a new environmentally unfriendly development such as perhaps a poorly planned housing development project. The combination of all such factors can give rise to large fluctuations in the parameter readings. And then there is the possibility of errors made during the taking of the sample (such as dipping the sample bottle downstream from where the monitor is standing and stirring up mud, instead of upstream), or during the lab testing. As explained in another chapter, however, the probability of such errors has been minimized by the establishment of rigorous protocols for monitoring and laboratory procedures. For example, lab results are randomly double checked, and suspect lab readings are sometimes triple checked for validity.

The Figure 2-4 below gives an example of a detailed graph of the sometimes wild fluctuation in nitrogen concentration for JR10, Pleasant Run in Rockingham county. The graph shows that the concentration is almost always above the impaired ecological range (1.0 ppm) and it is clear that during the peak observations (probably caused by heavy rain or snow) in August 2001 and January 2003 the severely impaired level (10.0 ppm) was exceeded several times. It is also clear that the trend for nitrogen pollution is up.

Figure 2-4 Nitrogen Levels in JR10, Pleasant Run

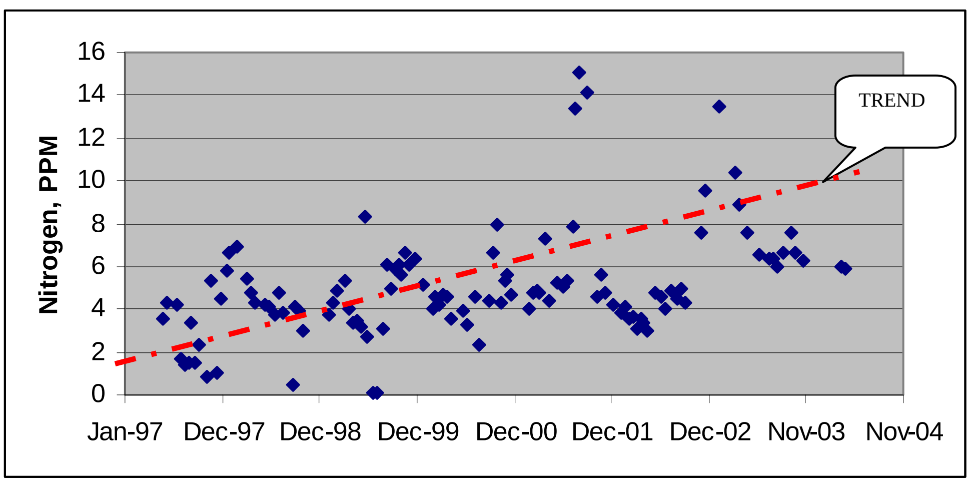
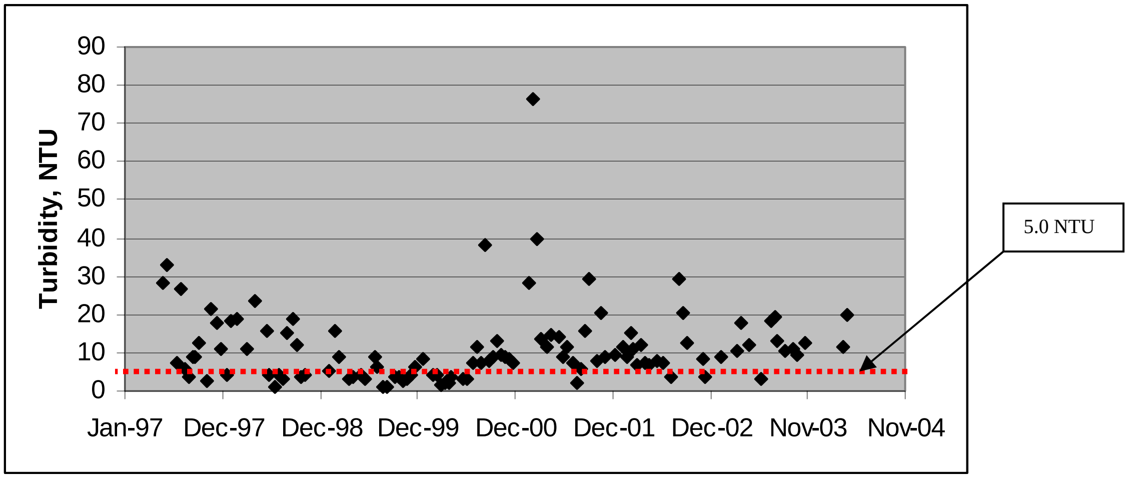


Table 2.5 present similar information for turbidity. For Pleasant Run, as for nitrogen, the levels of turbidity are elevated far above safe levels for most of the time. Out of a total of 115 observations, 74 observations (or 64%) had an NTU above 7 (cloudy), and 48 of these

[5] The technical annex chapter shows some photographs of poorly protected streams.

impaired observations (42%) were higher than 10 NTU, a level at which the water practically opaque.

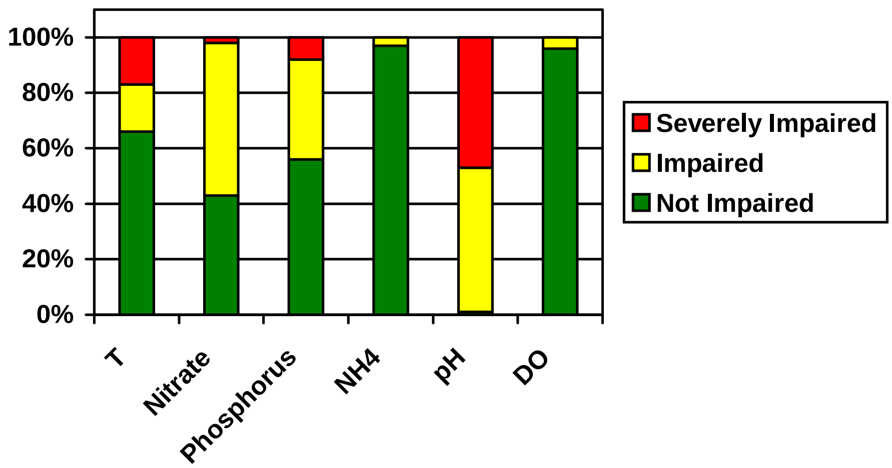
Figure 2-5: Turbidity levels at JR10, Pleasant Run



Plotting and examining a graph for each of the streams is a time consuming task. Instead, and discussed earlier, we can summarize the variability of all the observations for a stream by calculating the standard deviation. Large standard deviations, such as those for Rockingham and Augusta counties, may indicate serious erosion and sedimentation problems. This is especially true for the rivers in Rockingham, where the standard deviation of 6.5 is more than triple the average value of 1.9 ppm.

The implications of high average values combined with a large standard deviations can be seen in the Figure 2-6 below. For example, for the streams in Augusta county, the turbidity was above the severely impaired level about 18% of the time, and was at impaired levels also about 18% of the time. For dissolved oxygen where the standard deviation is quite small, we can see that the concentration was almost never above the impaired level.

Figure 2-6: Frequency distribution of observations for Augusta county streams



Reasons for the high pollution levels

One of the most important reasons for excessive nutrient and sediment in the water are the large flows of surface runoff from both urban and farm land during periods of heavy precipitation. Runoff carries soil particles, nitrogen and phosphorus and these will flow into the river unless stopped by good stream vegetation or man-made buffers. In addition to the often heavy precipitation, additional factors causing problems are development without adequate measures to protect exposed soil, cattle wading in streams and stirring up mud, and waste from poultry processing plants. The aerial photo below shows the lack of a stream buffer on the right side of the stream, and the inadequate stream buffer of the left side of the stream. Also noteworthy is the runoff from the large muddy area near the cattle barn. The technical annex shows more of these photos taken from both the air and the ground of some of the causes of erosion.

Photo 1: Aerial photo showing erosion along Pleasant Run

Turbidity is becoming a heightened concern for many researchers doing testing out in the field these days. Why? Mainly because high and persistent turbidity is the number one pollutant in the Shenandoah Valley. In addition, turbidity is a sensitive erosion indicator that warns of the impact that poorly planned and executed land, water run-off, and other causes of pollution are having on aquatic environments. Finally, in addition to being a good indicator to work with, it is relatively easy and expensive to test in the laboratory. However, as discussed in the report mentioned in Footnote 10 (page 35), collecting the samples is hard work. Since turbidity is a rather fleeting event – it shoots up after a rain shower but then rapidly declines and the monitor must, for best results, collect the sample shortly after a storm – the time of day the monitor collects the sample is at the whim of the weather. But the effort to collect turbidity data is well worth while: high and persistent turbidity in the Shenandoah River watershed is becoming a serious problem.

How do Augusta and Rockingham Counties Rank With Other Counties in the Shenandoah River watershed?

In this section the findings for Augusta and Rockingham are compared with those of the other counties in the Shenandoah River watershed. This is done in Figure 2-7 below for the rivers. The Figure 2-8 shows it for the streams.

Rockingham county with average nitrogen concentration of 2.1 PPM clearly has the highest ambient concentration of nitrate in the Shenandoah River watershed. One would think that the pollution in the North River (the highest average) would wash downstream to contaminate the rivers in the other counties. But this does not seem to be the case. A reason may be that the downstream rivers get a large amount of their flow from clean tributaries and uncontaminated ground water. Another reason is that it might get absorbed by aquatic grasses. More research on groundwater flows and the impact of aquatic grasses, and other topics clearly is required to explain this phenomenon.

Figure 2-7: Average Nitrogen Concentration in Rivers, All Counties, 1997-2004 average

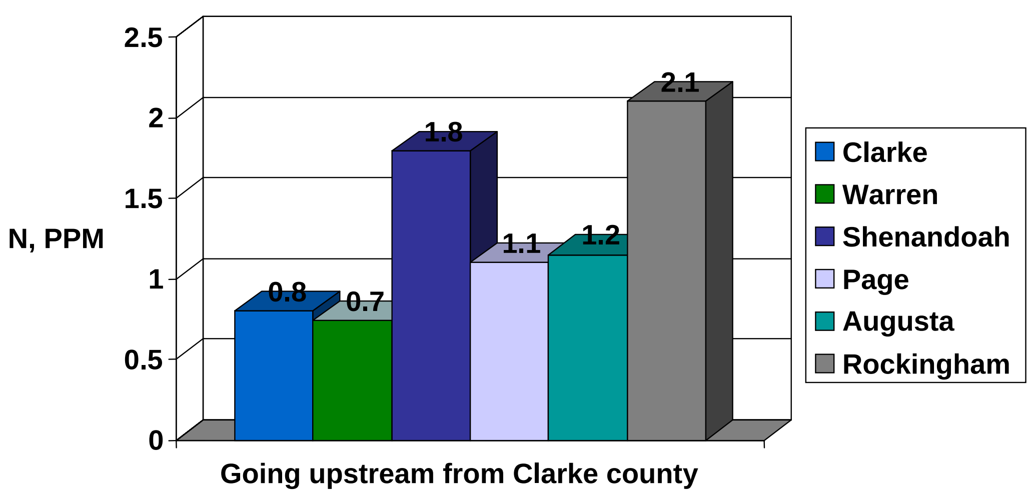
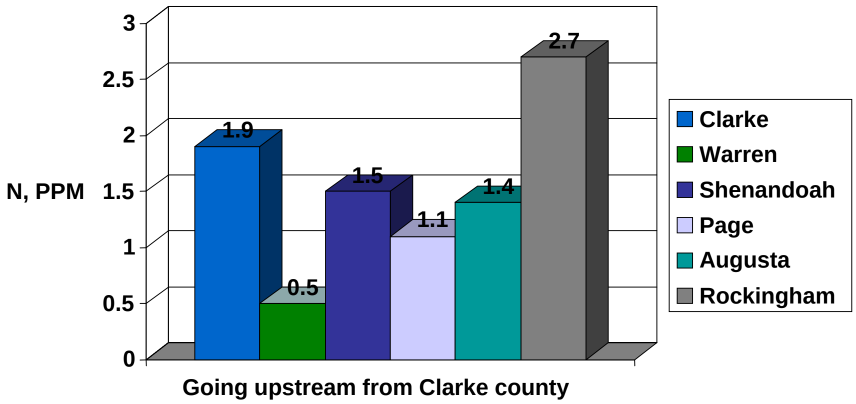


Figure 2-8 ranks the counties in terms of the nitrogen levels found in the streams, as opposed to the rivers as shown in the earlier graph. It is clear that the turbidity levels in the streams in Rockingham county are well above those in the other counties. One of the major reasons, as explained later, is that the number of poultry processing plants in Rockingham is greater than those in the other counties.

Figure 2-8: Average Nitrogen Concentration in Streams, All Counties, 1997-2004 Average



Sites with the Worst Nitrogen and Turbidity Pollution in Rockingham .

Table 2.4 and Table 2.5 show the ten sites in Rockingham and Augusta that, during 2003, has the highest levels of levels of nitrogen pollution and the highest level of turbidity. For example, the top-listed site for both nitrogen and turbidity pollution is JR07, Cooks Creek at the North River. The average nitrogen level there is 10 PPM for the year 2003 – this level exceeds the safety limit set for drinking water. JR07 also ranked as the worst site for turbidity. The average level was 16.4 for the years 2003 – this levels exceeds the "very impaired" or "cloudy" level of 7.0 NTU. The 10 PPM level also is harmful to farm animals, causing abortion in cattle and other livestock. The percentage of the time this level was exceeded was about 84%. Thus the year 2003 was a very bad year for JR07. This may have been a fluke since the earlier years had less pollution, but not by much.

Table 2.4: The Ten Sites in Rockingham/Augusta with the Worst Nitrogen Pollution in the Year 2003.

Site ID	PPM, 2003	Std. Dev.	Probability N exceeds 10 PPM	Name	Notes
JR07	10.87	3.08	61%	Cooks Creek-North River	Many cows in stream
NR05	9.00	1.61	27%	Cedar Run	
JR10	7.73	2.21	15%	Pleasant Run-North River	
JR01	6.72	2.78	12%	Muddy Creek-North River	Downstream poultry plant
JR06	5.48	2.09	2%	Long Glade Creek-North River	
JR13	4.25	0.93	0%	Cub Run-North River	
JR11	3.32	1.07	0%	North River below HRRSA	Many cows in stream, down from STP

JR09	3.29	1.08	0%	North River above HRRSA	Up from STP
JR12	3.13	1.68	0%	Mill Creek-North river	
JR08	2.77	1.12	0%	Blacks Run-North River	

Table 2.5: The Ten Sites in Rockingham/Augusta with the Worst Turbidity Pollution (Year 2003)

Site ID	Turbidity	Std. Dev.	Probability T exceeds 7 NTU	Name of Site	Notes
JR07	**16.4**	**9.6**	**86%**	**Cooks Creek-North River**	**Very poor riparian area**
GA28	**16.2**	**22.6**	**66%**	**Christians Creek Middle_Route 794 bridge**	
JR06	**12.8**	**15.7**	**64%**	**Long Glade Creek-North River**	**Very poor riparian area**
GA17	**12.4**	**8.7**	**73%**	**Middle River_Route 703 bridge**	**Very poor riparian area**
JR10	**12.2**	**4.3**	**88%**	**Pleasant Run-North River**	
GA20	**12.1**	**26.7**	**58%**	**Lower Lewis Creek**	**Urban Runoff**
GA29	**11.9**	**13.9**	**64%**	**Christians Creek Lower_Route 907 bridge**	
JR01	**10.2**	**11.6**	**61%**	**Muddy Creek-North River**	
GA12	**10.1**	**14.2**	**59%**	**Middle River Clines Lane - Route 642**	
GA13	**8.7**	**10.9**	**56%**	**Middle River Lebanon Church - Route 742**	

Not all sites in Rockingham and Augusta, however, are bad. Table 2.6 below shows the sites with the best water quality in Rockingham and Augusta counties. But even this table shows that the lower ranked "best" sites, such as GA23 with an average nitrogen level of 0.9, has levels of pollution much too close for comfort to the impaired level.

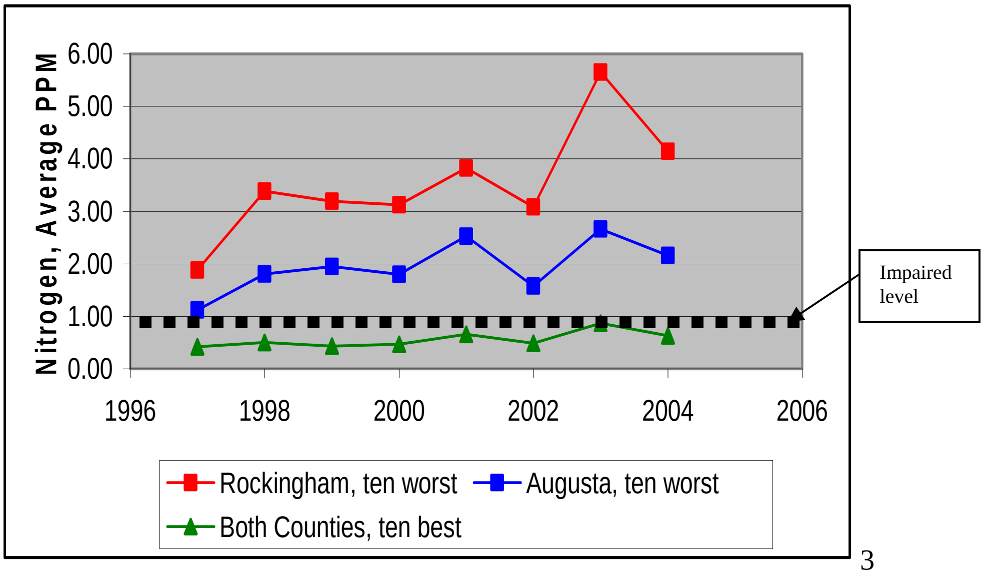
Table 2.6: Sites in Rockingham and Augusta with lowest Nitrate (1997-2004)

Site ID	Nitrate PPM	Ortho Phos PPM	Amm PPM	pH	Turbidity	DO mg/L	*Name*
GA21	0.2	0.1	0.2	7.8	3.5	8.5	*Jones Hollow DuPont rec field*
GA24	0.2	0.1	0.2	7.2	4.6	9.1	*Stony Run Route 608*
GA22	0.2	0.1	0.2	7.7	1.6	9.2	*Back Creek Route 624 bridge*
GA37	0.2	0.1	0.2	7.6	0.7	8.6	*North River Forest Service Road 95 above Elkhorn L*
GA34	0.6	0.1	0.2	8.0	1.3	8.9	*Jennings Branch, Middle River Watershed*
GA13	0.7	0.1	0.3	8.0	5.5	8.7	*Middle River Lebanon Church - Route 742*
GA25	0.8	0.1	0.6	8.0	5.1	8.2	*Poor Creek Below Campground dam*
GA33	0.8	0.1	0.2	8.0	3.5	9.0	*Moffett Creek Route 732 bridge*
JR02	0.8	0.2	0.2	7.7	2.8	8.5	*Dry River-North River*
GA23	0.9	0.2	0.2	7.8	3.8	8.4	*South River Lyndhurst - Route 664 bridge*
CRITICAL LEVELS							
Not Impaired	< 1.0 PPM	<0.1 PPM	<1.0 PPM	6.5 to 8	0 – 4, Clear	< 5 (no fish)	
Impaired	1.0 to 10.0 PPM	0.1 to 2.0 PPM	> 1.0 PPM	< 6.5	4 to 7, Fairly Clear	5 - 8 Good	
Severely Impaired	> 10.0 PPM	>2.0 PPM	> 10 PPM	> 8.0	> 7 Cloudy	> 8 Excellent	

The Trends

We have seen, so far, that the average water quality of the Shenandoah River and tributaries measured since 1997 leaves much to be desired. But what about the trends? Is the water quality getting better or worse? Have the measures enacted in the Clean Water Act and other policies had any effect? Unfortunately, and except for phosphorus, the answer is no. Figure 2-9, Figure 2-10, and **Error! Reference source not found.** below show the trend in water quality for the 10 worst sites in Augusta and Rockingham counties. For nitrogen the trend is up rather steeply for Rockingham, and even for the best sites the nitrogen levels seem to be increasing. .

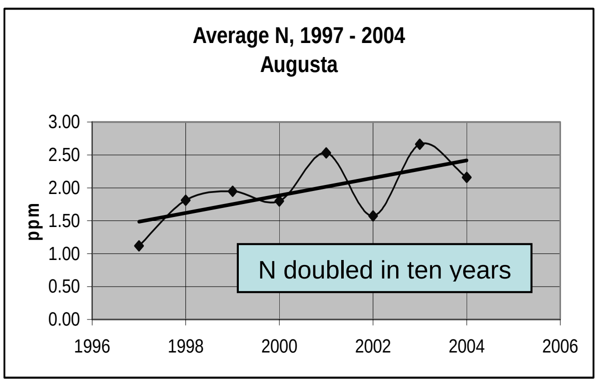
Figure 2-9: Trends for N Pollution January 1997 – April 2004 for the ten best and ten worst sites.



[3]

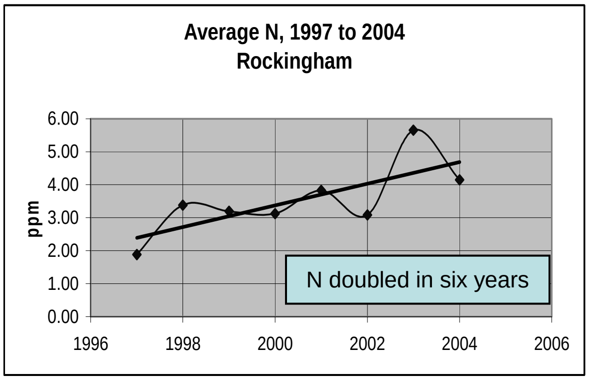
The next two graphs, show the trend for nitrogen in Augusta and Rockingham county in more detail. The graph implies that for the ten worst streams in Augusta County, and if nothing is done, the nitrogen pollution will double every ten years.

Figure 2-10: Nitrogen trend for the ten worst streams in Augusta County



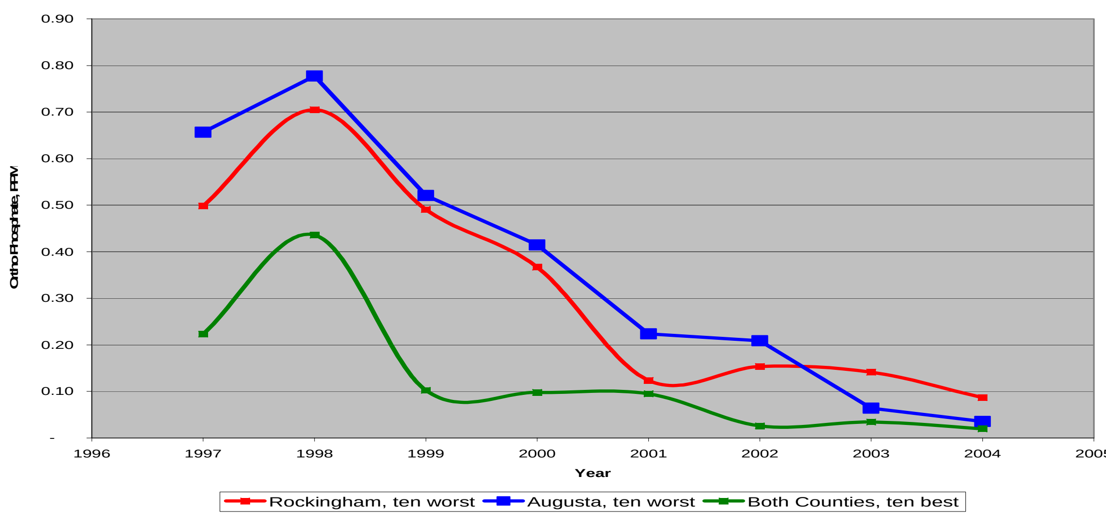
The situation is worse for the streams in Rockingham county. The nitrogen pollution will double every six years if nothing is done.

Figure 2-11: Trend for Nitrogen Pollution in the ten worst streams in Rockingham County



Phosphorus pollution over the 1997 – 2004 time period shows a sharply different picture (see Figure 2-12 below). Starting around 1998 the ortho-phosphate pollution started dropping fast to levels in 2004 that are just below the impaired level of 0.1 PPM. Much of this decline can probably be ascribed to Federal and State laws limiting the amount of phosphorus in household detergents.

Figure 2-12: Trends for P Pollution, 1997 - 2004 for ten best and worst sites.

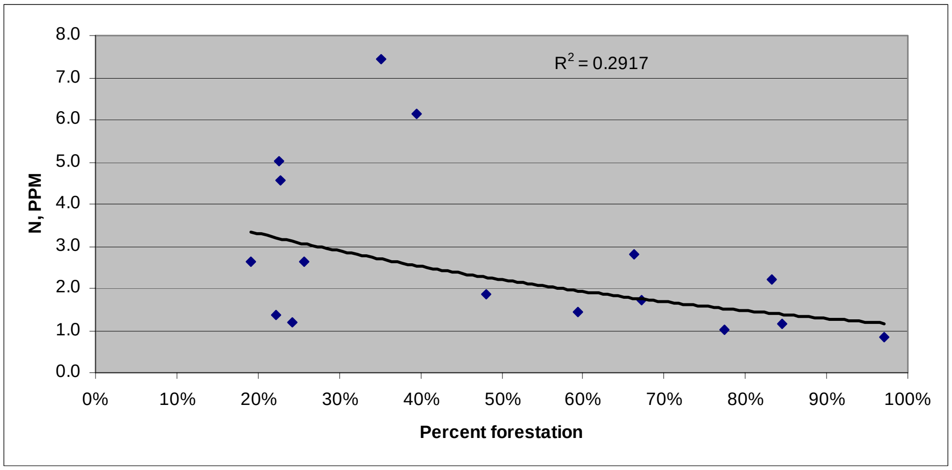


The Technical Annex chapter presents a more detailed report on these findings.

Some of the reasons

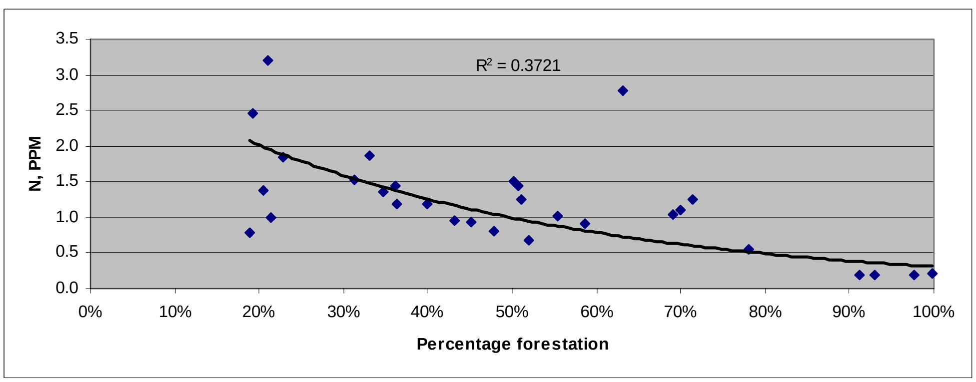
Deforestation is frequently mentioned as a cause of pollution in streams and rivers, and as shown in Figure 2-13 and Figure 2-14, there seems indeed to be a pronounced relationship between forest cover and pollution. The Water Window developed by James Madison University provided an excellent tool for constructing this graph because it gives landuse in the watershed (or hinterland) for each of the sites monitored by the FOSR. The strength of the correlation is only moderate for N -- the R squared is 0.29 implying that about 30% of the variation in is explained by the degree of deforestation. – it does show that replacing forests with agricultural or urban land will increase pollution. But much of this pollution can, of course, be significantly be reduced by improving agricultural practices and by taking measures such as controlling stormwater in urban areas. (see Figure 4-5 and Figure 4-6, page 36 for an illustration of the much stronger relationship between forest coverage and turbidity).

Figure 2-13: Nitrogen vs. forestation, Rockingham



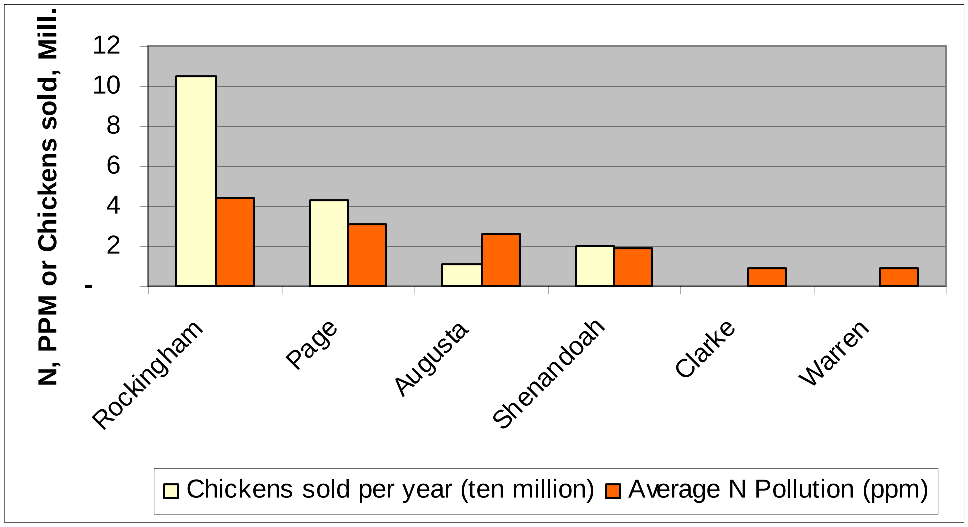
The relationship for Augusta county is better, and about 37% of the variation in N is explained by the amount of forest land. And since there are more samples for Augusta, our confidence in the significance of the correlation is higher.

Figure 2-14: Nitrogen vs. forestation, Augusta



In an attempt to find other variables we examined possible relationships between the intensity and type of animal industry and nitrogen levels. We were limited to do this by county, and therefore is at a rather aggregate level. But data by sampling site were not available. All the various types of animal industry including cattle, hogs, and poultry affect pollution levels were examined, but the relation for poultry is the strongest. Figure 2-15 shows the results. For example, Rockingham sold more than 10 million chickens in 2002, and its nitrogen pollution level is slightly over 4.0 PPM. It is clear that, as the number of chickens sold in a county goes up, the nitrogen levels tend to increase. And Rockingham has by far the highest level of poultry industry, and explains to a large degree why this county is so much worse as far as pollution is concerned than Augusta.

Figure 2-15: How the poultry industry affect pollution.



Stream Restoration – it works!

FOSR monitoring of Chapel Run in Clarke County shows the possible beneficial impact of stream restoration on water quality. Chapel Run, a six-mile long spring-fed stream runs through soil that is a mixture of sand, silt, and clay, and is easily eroded. Cattle walking along the stream banks to get water and to cool off have severely eroded the stream banks.

About five years ago, Bud Nagelvoort, one of the Clarke County monitors and also the Chair the Lord Fairfax Soil and Water Conservation District became concerned about the deterioration of what used to be a good trout stream.

He worked with one of the large farmers whose 600 acre cattle farm is along one mile of the six-mile long Chapel Run, and together with the LFSWCD and the Natural Resources Conservation Service of the U.S. Department of Agriculture they developed a plan for stream restoration.

The plan involved adding about one mile of fence with much of it parallel to the stream to keep the cattle out of the stream. This also required installing new wells and waterlines for drinking water for the cattle.

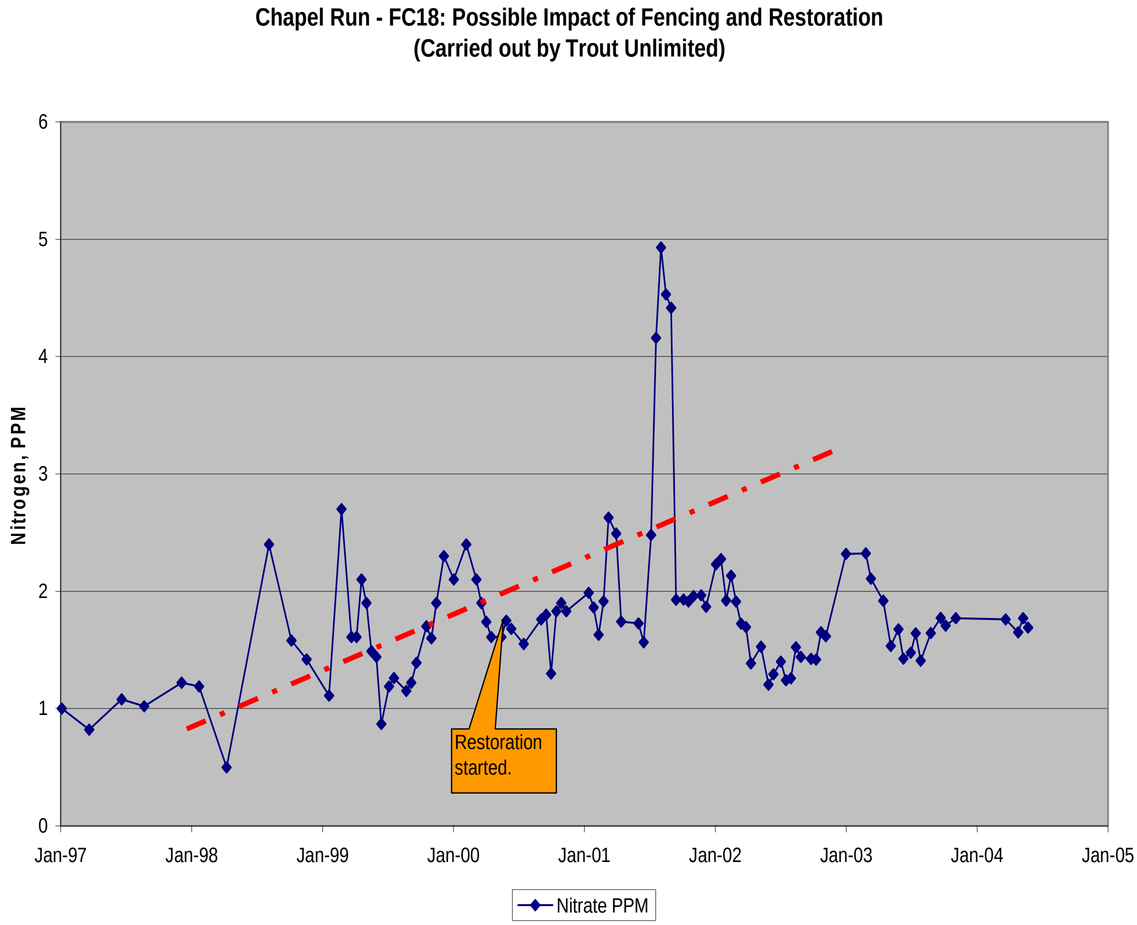
The total cost of the fencing and watering facilities was about $76,000, of which 75% was provided by cost-sharing funds through the Soil and Water Conservation District. The remaining 25% was paid by the landowners.

Also helping with the restoration were members of Trout Unlimited who volunteered their time to install tree trunks in the stream to prevent silt buildup and provide shelter for fish.

Figure 2-16 below shows the nitrogen concentration in Chapel run before and after the restoration started. Before the start, the nitrogen levels trended upward from about 1 ppm in 1997 to about 2 ppm in early 2000. But by early January 2001 the nitrogen levels had leveled off to 2 ppm, and after the restoration was completed, in May 2004, the nitrogen levels seem to be declining. And the water quality was judged good enough to warrant restocking the stream with trout.

What is impressive is that beneficial effects are already being seen from restoration involving only one-sixth of the total length of the stream.

Figure 2-16: Impact of restoration on water quality



Chapter 3 The Laboratory in Shenandoah University, and the monitoring program.

Shenandoah University provides the FOSR with laboratory space. Equipment, testing materials and staff are provided by the FOSR. The lab is well equipped and uses the best possible instruments, materials, procedures, and staff to test the water samples. The staff consists of a full time laboratory technician who is responsible for maintaining the high quality of the data and efficiency of the testing process. She is assisted by volunteers from the FOSR, students from Shenandoah University, and by several part-time paid lab assistants.

Operating the lab is financed from dues and donations from the FOSR members, special fund raising events, grants from local, state and federal governments and organizations including the Virginia Environmental Endowment, River Network, Robins Foundation, Canaan Valley Institute, Izaak Walton League, Chesapeake Bay License Fund, the Chesapeake Bay Alliance, and the Fish and Wildlife Foundation. The lab also tests, at cost, water samples submitted by other organizations.

The laboratory was modernized in 2001 by the addition of a Lachat QuickChem Flow Injection Analysis Instrument. This $60,000 automated testing machine (financed by a grant from the Virginia General Assembly) automatically rather than manually tests samples for ammonia, nitrogen and ortho-phosphorus content. This enables more rapid testing of the samples, reduces the cost of reagents used in the analyses, and also largely eliminates direct exposure of the staff to hazardous reagents such as cadmium.

Virtually all aspects involved in the determination of the concentrations of nutrients, pH, dissolved oxygen, turbidity, and temperature of the Shenandoah River water samples are strictly set out in the FOSR Quality Assurance Project Plan (QAPP). The QAPP was approved in 1997 by the Virginia Department of Conservation Resources (VADCR) and by the U.S. Environmental Protection Agency. In 2004 it was approved by the VA Department of Environmental Quality and the lab is now a DEQ certified laboratory. The QAPP specifies the protocols for sample collection, preservation, analytical methods, record-keeping, and presentation of the results.

FOSR’s methods for analysis of nitrogen, orthophosphate, and ammonia are taken from Standard Methods for the Examination of Water and Wastewater (1992); they are methods 353.3, 365.4, and 350.1, respectively. All are colorimetric methods that use various reagents that are added to the water sample. These reagents change the color of the solution, and the specific wavelength of the colored solution is measured by means of a spectrophotometer. This wavelength is directly proportional to the concentration of the chemical being tested..

The FOSR is continually upgrading its field and laboratory instruments and procedures. For example, a recently acquired set of WTW Multiline P4 Field Instruments are now used by monitors to measure pH, temperature, and dissolved oxygen at the streamside rather than by collecting water in a sample bottle for later analysis in the laboratory. The advantage of these streamside instruments (SSI) is that they provide an instantaneous reading of the three parameters (pH, temperature, and dissolved oxygen) and minimize possible degradation of the samples during transport to the laboratory. They also reduce the time spent by the lab in analyzing the samples.

The results of the analysis are tabulated on the FOSR computers and are reported to the US Environmental Protection Agency and the Virginia Department of Environmental Quality to be used in their water quality analysis. These data are added to the FOSR web page shortly after each monitoring date.

The data collected include the six water quality indicators: nitrogen, phosphorus, ammonia, pH (acidity), turbidity, and dissolved oxygen. The FOSR is examining how to broaden its testing program to include tests for fecal coliform and toxic materials such as mercury and PCBs.

The FOSR Monitoring Program in Augusta and Rockingham Counties.

Over the past several years the volunteer monitors in Augusta and Rockingham county have taken water samples from 44 sites, and as shown in Figure 3-1. The total FOSR testing program in the whole Shenandoah River watershed covers about 180 sites. After being collected, the water samples are immediately put on ice and delivered to the FOSR laboratory at Shenandoah University for analysis. Samples for those indicators whose quality deteriorates over time, such as dissolved oxygen, pH, and turbidity, are analyzed within 24 hours after being delivered to the lab.

Figure 3-1: Map of Rockingham and Augusta sampling sites.

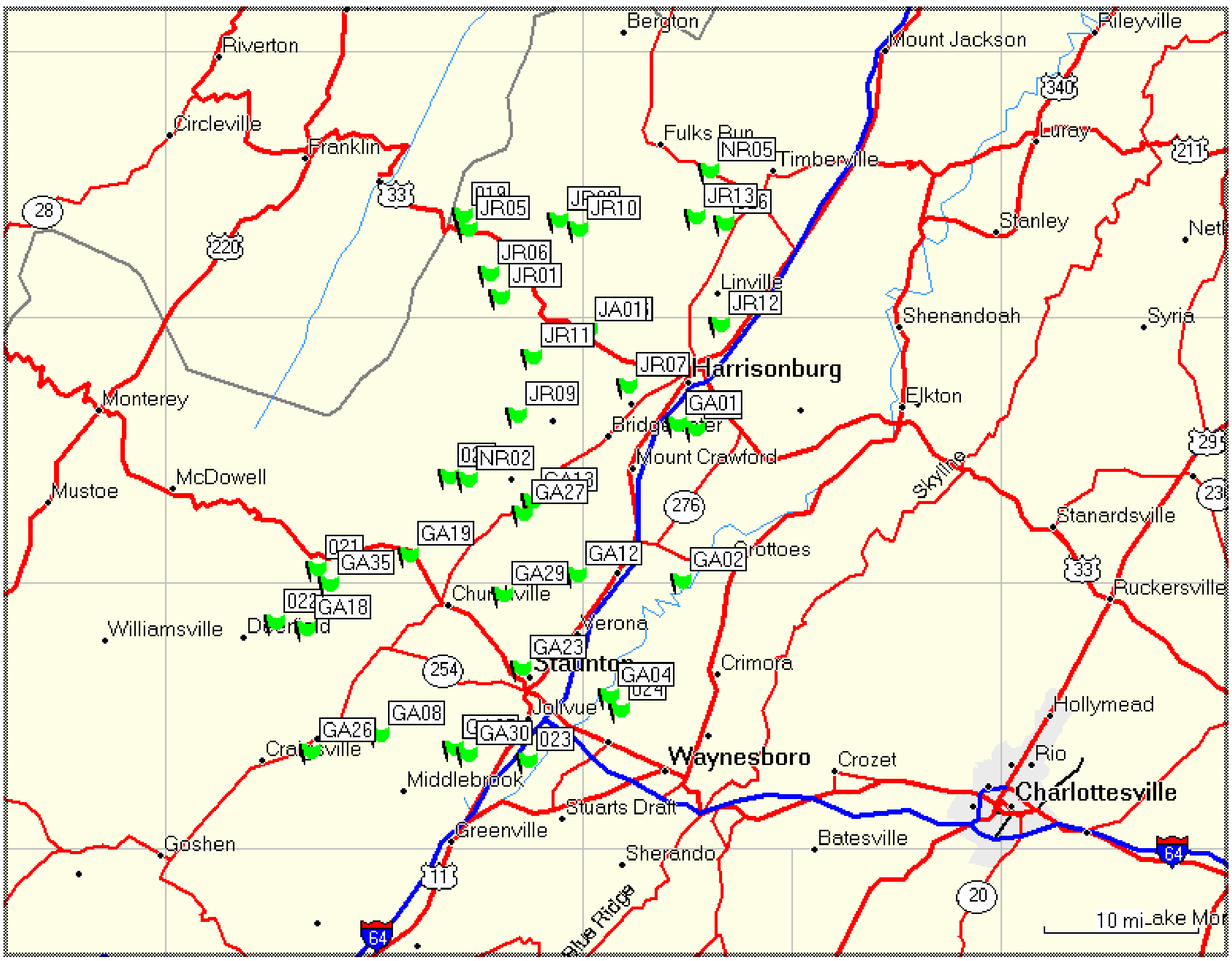


Table 3.1 provides the physical characteristics of the sites, including whether or not they are active, the full name and Site ID, the location along a river or stream (no direct outfalls from STPs were sampled in Augusta and Rockingham), the latitude and longitude, and the number of observations taken during the 1/1/1997 to 4/26/2004 period.

Table 3.1 : Site Characteristics

Site ID	Activity	Name	Type	Lat, N	Long, W	Count	Note
GA01	Active	South River/Port Republic	River	38 17 40	78 48 32	140	
GA02	Active	South River/Harriston	River	38 13 11	78 50 18	141	
GA04	Active	South River/Below Waynesboro	River	38 05 20	78 52 37	147	Also Called "Hopeman"
GA08	Active	South River/Wilda	River	38 01 31	79 05 58	147	
GA10	Active	Middle River/Mt. Meridian	River	38 15 45	78 51 45	132	
GA11	Active	Middle River Knightly bridge - Route 778	River	#N/A	#N/A	132	STP-Indirect Measurement
GA12	Active	Middle River Clines Lane - Route 642	River	38 11 25	78 58 15	144	
GA13	Active	Middle River Lebanon Church – Route 742	River	38 14 32	79 02 10	133	
GA17	Active	Middle River_Route 703 bridge	River	38 09 08	79 10 50	143	
GA18	Active	Middle River/Summerdean	River	38 04 49	79 15 30	138	
GA19	Active	Lewis Creek Upper Near old Furr's Stockyard	Stream	38 07 56	79 05 45	128	Due To New Highway, Replaced With Ga-19A,
GA20	Active	Lewis Creek Lower	Stream	38 11 15	78 58 15	143	
GA21	Active	Jones Hollow DuPont rec field	Stream	38 03 58	78 52 59	133	May Run Dry During Drought
GA22	Active	Back Creek Route 624 bridge	Stream	38 01 43	78 55 55	132	Fed From Dams Which May Be Shut Down
GA23	Active	South River Lyndhurst - Route 664 bridge	River	38 02 47	78 56 51	141	
GA24	Active	Stony Run Route 608	Stream	38 00 53	79 03 74	119	May Run Dry During Drought
GA25	Active	Poor Creek Below Campground dam	Stream	37 59 38	79 09 02	140	
GA26	Active	Broadhead Creek Route 675 bridge	Stream	37 59 37	79 11 52	141	
GA27	Active	Meadow Run Route	Stream	38 11	78 55	138	

		907 bridge		46	56		
GA28	Active	Christians Creek Middle_Route 794 bridge	Stream	38 11 54	78 56 11	137	
GA29	Active	Christians Creek Lower_Route 907 bridge	Stream	38 07 42	78 59 41	138	STP-Indirect Measurement
GA30	Active	Barterbrook Branch Route 648 bridge	Stream	38 04 06	79 01 44	135	
GA31	Active	Folly Mills Creek Route 648 bridge	Stream	38 05 22	79 03 55	136	
GA32	Active	Christians Creek Upper Route 340 bridge	Stream	38 02 40	79 05 22	125	Replaced By Ga-32A, Due To Heavy Traffic On Bridge
GA33	Active	Moffett Creek Route 732 bridge	Stream	38 14 36	79 05 07	127	
GA34	Active	Middle River Watershed/Jennings Branch	Stream	38 13 27	79 08 16	134	
GA35	Active	Edison Creek Route 703 bridge	Stream	38 08 40	79 09 56	136	
GA36	Active	North River_Route 276 bridge	River	38 18 32	78 53 40	126	
GA37	Active	North River Forest Service Road 95 above Elkhorn L	River	38 20 11	79 14 39	113	
JA01	Active	Naked Creek-North River	Stream	38 18 29.66	78 55 29	129	
JR01	Active	Muddy Creek-North River	Stream	38 25 54.35	78 58 48	138	Downstream From Poultry Plant
JR02	Active	Dry River-North River	River	38 26 01.36	78 59 09	136	
JR03	Active	Briery Branch-North River	Stream	38 23 58.82	79 01 23	137	
JR04	Active	Upper North River-North River	River	38 23 42.42	79 01 51	138	
JR05	Active	Mossy Creek-North river	Stream	38 23 10.70	79 00 50	138	
JR06	Active	Long Glade Creek-North River	Stream	38 22 38.61	78 58 53	137	
JR07	Active	Cooks Creek-North River	Stream	38 22 22.23	78 56 05	128	Many Cows In The Stream
JR08	Active	Blacks Run-North River	Stream	38 22 42.79	78 55 41	129	
JR09	Active	North River above	River	38 20	78 55	128	Up River From

		HRRSA		44.25	59		STP
JR10	Active	Pleasant Run-North River	Stream	38 20 47.88	78 55 32	129	
JR11	Active	North River below HRRSA	River	38 20 40.45	78 54 58	129	Many Cows In The Stream, Downriver From STP
JR12	Active	Mill Creek-North river	Stream	38 18 56.68	78 49 07	115	
JR13	Active	Cub Run-North River	Stream	38 20 42.92	78 43 54	106	
NR05	Active	Cedar Run	Stream	38 38 14.00	78 46 30	85	

Active Augusta and Rockingham County Monitoring Sites

Collecting the samples analyzed for this report took a prodigious amount of effort. During the 88 months from January 1997 to mid April 2004, the monitors in Augusta and Rockingham counties collected a total of 6,291 samples were collected from the 46 active [6] sites. The cost of volunteer in-kind labor is estimated at $69,000. And the 31,072 lab tests (excluding the tests required for quality control) carried out in the Shenandoah University laboratory cost another $94,000.

Indicators of Water Quality and Suggested Standards

Listed below is a brief description of the water quality indicators currently used in the FOSR testing program. These can be divided into the three nutrients consisting of nitrogen (nitrate nitrite), phosphorus (ortho-phosphate), and ammonia (NH_3 & NH_4^+). These are called "nutrients" because they provide are the building blocks of life, and in appropriate concentrations, are not considered pollutants.

Nutrients in the river come from municipal wastewater, septic systems, industrial wastes, and most importantly, runoff containing fertilizer and manure from agricultural lands and from urban areas. Some nitrogen comes directly from the atmosphere itself. High concentrations of nutrients will stimulate excessive growth of algae and other water plants. The algal blooms and large quantities of water plants eventually die and decompose. Besides causing unsightly and smelly debris along the shoreline, the decomposition uses up much of the available oxygen in the water. Depleted oxygen levels harm aquatic life (including game fish such as trout and bass) and can cause large fish kills, especially in the Potomac River and Chesapeake Bay downstream from the Shenandoah River.

[6] The active sites include those sites where monitoring was carried out carried out for lengths of time that were long enough to allow reliable calculations of trends or averages. In addition to the active sites, a number of other sites were monitored only for a for a short time because, for example, the need to conduct only a short-term study or to collect specialized data for a particular site, or because of the loss of a volunteer monitor, or the dropping of a site because it duplicated another site.

Nitrate Nitrite (N) Standard for Nitrogen:

Nitrate-Nitrite is called "nitrogen" in this report. From Page 14 of the December 1999 EPA Report "*From the Mountains to the Sea: The State of Maryland's Freshwater Streams*" the statement is made that streams with nitrogen concentration greater than 1.0 mg/L (or PPM) are considered unnaturally high, compared to streams with minimal human influences. Concentrations greater than 10 mg/L of nitrate-nitrogen exceed the human health standard for safe drinking water for adults, and higher levels have caused methemoglobinemia [blue baby] in infants. Higher levels can also substantially increase the number of still-births of cattle.

Ortho-Phosphate (P) Standard:

Ortho-phosphate is called phosphorus in this report. From page 7 of the 1998 USGS Report '*Water Quality in the Potomac River Basin: Maryland, Pennsylvania, Virginia, West Virginia and the district of Columbia, 1992-1996*' the statement is made that "To control eutrophication, the U.S. Environmental Protection Agency (1986) recommends that the total phosphorus concentrations in flowing waters not exceed 0.1 mg/L (or PPM)." It also states that the ortho-phosphate is the most common form of dissolved phosphorus in natural waters.

Phosphorus in water is not considered directly toxic to humans or animals so no drinking water standards have been established. Any toxicity caused by phosphorus pollution in fresh waters is indirect, through stimulation of toxic algal blooms or resulting oxygen depletion. The EPA recommends that total phosphorus concentrations should be less than 0.1 mg/L in rivers, and less than 0.05 mg/L where rivers enter lakes and reservoirs because concentrations greater than this could contribute to eutrophication.

Ammonia Standard

In water, ammonia exists in two forms, which, together, are called "total ammonia nitrogen." These two forms consist of un-ionized ammonia (NH3) and ammonium ion ($NH4^+$). They exist in a state of equilibrium in the water solution, and the fractions of each depend on pH and temperature of the water.

Un-ionized ammonia (NH3) is very toxic to fish and other aqueous organisms that breathe through gills. It is a dissolved gas that can pass unimpeded through the membranes of the gills. Continuous exposure [7] [8] to more than .02 to .05 PPM of the un-ionized form can cause reduced growth, increased susceptibility to disease and premature death. It is especially toxic to young fish and aqueous water life. At levels above .05 PPM the un-ionized ammonia causes more and more damage, and at 2.0 PPM all fish will die.

The FOSR laboratory test results are published for the level of total ammonia in the water. The amounts of toxic NH3 and non-toxic $NH4^+$ ion in total ammonia depend primarily on the level of pH and temperature of the water. Higher temperature and higher pH result in higher percentages of NH3. For lower pH and colder water the fraction of toxic ammonia (NH3) decreases; and one would think this is a good thing. Unfortunately, at lower levels of pH less un-ionized ammonia NH3 is needed to kill fish and other forms of water life.

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[7] EPA "Fact sheet: 1999 Update of ambient Water Quality Criteria for Ammonia - Technical Version", EPA 823-F-99-024, December 1999.

[8] Document FA-16, Fisheries and Aquatic Sciences, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, June 1996

Because the amount of un-ionized ammonia depends on both temperature and pH, it is not possible to prescribe a single number – one must refer to tables such as developed by Emerson [9]. Such tables state that, for example, at a pH of 8.0 and a temperature of 86 degrees Fahrenheit, a concentration of 1 PPM of total ammonia corresponds to a level of .074 PPM of un-ionized ammonia, NH3. This is well above the impaired range of .02 to .05 for NH3.

As another example, and at the same pH of 8.0 but a lower temperature of 75 degrees Fahrenheit a concentration of 1 PPM of total ammonia corresponds to a level of .05 PPM of un-ionized ammonia. This is at the high end of the impaired range. At the same pH for a still lower temperature of 60 degrees Fahrenheit the level of un-ionized ammonia is .03 – this is also still within the impaired range.

By studying tables such as Emerson's for the values of pH and temperature prevalent in the waters of the Shenandoah River Watershed, the following approximate rule can be developed: total ammonia is unimpaired at a level less than 1 PPM; it is impaired between 1 and 10 PPM, and is severely impaired for levels above 10 PPM.

[9] Emerson, K et al "Aqueous ammonia equilibrium calculations effect on pH and temperature," Journal of Fisheries Research Board of Canada. 32: 2379-2383

Chapter 4 : Technical Annex

Table 4.1: Average Values of the Parameters for the streams in Augusta and Rockingham Counties shows the distribution of all six parameters in Rockingham county. The turbidity in the streams is above the impaired level more than 40% of the time, and are severely impaired about 25% of the time. Nitrogen in the streams is impaired almost 80 % of the time, and the impairment of phosphorus is about 60%. pH is also a problem with the streams being impaired roughly half the time. However, the impairment is almost all due to the water being to alkaline, not too acid. And alkalinity is less of a threat to habitat. NH4 and dissolved oxygen are not a problem for Augusta county.

Table 4.1: Average Values of the Parameters for the streams in Augusta and Rockingham Counties

Site ID	Site Name	County	Nitrate PPM	Ortho Phos PPM	Amm PPM	pH	Turbidity	DO mg/L
GA19	Lewis Creek Upper Near old Furr's Stockyard	Augusta	1.84	0.10	0.34	7.99	5.68	8.93
GA20	Lewis Creek Lower	Augusta	1.45	0.10	0.30	8.02	7.20	8.87
GA21	Jones Hollow DuPont rec field	Augusta	0.18	0.08	0.21	7.79	3.49	8.54
GA22	Back Creek Route 624 bridge	Augusta	0.20	0.09	0.15	7.72	1.61	9.19
GA24	Stony Run Route 608	Augusta	0.19	0.10	0.17	7.19	4.63	9.05
GA25	Poor Creek Below Campground dam	Augusta	0.79	0.08	0.57	7.99	5.14	8.21
GA26	Broadhead Creek Route 675 bridge	Augusta	1.53	0.07	0.26	8.01	4.94	8.87
GA27	Meadow Run Route 907 bridge	Augusta	1.38	0.12	0.35	7.93	5.35	8.36
GA28	Christians Creek Middle_Route 794 bridge	Augusta	1.44	0.33	0.30	8.06	5.60	8.36
GA29	Christians Creek Lower_Route 907 bridge	Augusta	2.47	0.67	0.38	7.96	9.92	8.54
GA30	Barterbrook Branch Route 648 bridge	Augusta	3.19	0.15	0.41	7.89	8.63	8.38
GA31	Folly Mills Creek Route 648 bridge	Augusta	1.19	0.11	0.32	8.09	6.62	8.93

GA32	Christians Creek Upper Route 340 bridge	Augusta	1.36	0.09	0.33	7.97	5.89	8.23
GA33	Moffett Creek Route 732 bridge	Augusta	0.80	0.11	0.25	8.01	3.47	8.96
GA34	Middle River Watershed/Jennings Branch	Augusta	0.55	0.08	0.18	7.97	1.30	8.90
GA35	Edison Creek Route 703 bridge	Augusta	0.99	0.07	0.30	8.01	6.06	8.52
JA01	Naked Creek-North River	Augusta	1.87	0.20	0.26	7.88	8.41	7.97
JR01	Muddy Creek-North River	Rockingham	6.13	0.50	0.25	7.75	4.08	8.11
JR03	Briery Branch-North River	Rockingham	1.17	0.15	0.12	7.61	1.88	8.95
JR05	Mossy Creek-North river	Rockingham	1.18	0.17	0.18	7.81	5.04	8.64
JR06	Long Glade Creek-North River	Rockingham	2.64	0.18	0.39	7.61	8.73	7.31
JR07	Cooks Creek-North River	Rockingham	4.56	0.31	0.52	7.80	12.61	8.02
JR08	Blacks Run-North River	Rockingham	1.43	0.15	0.29	7.83	8.41	8.26
JR10	Pleasant Run-North River	Rockingham	5.01	0.40	0.63	7.71	11.20	7.65
JR12	Mill Creek-North river	Rockingham	1.38	0.14	0.31	7.76	5.02	7.82
JR13	Cub Run-North River	Rockingham	1.84	0.17	0.29	7.75	4.77	8.00
NR05	Cedar Run	Rockingham	7.43	0.43	0.23	8.04	4.31	8.60

Table 4.2: Average Values of the Parameters for the RIVERS in Augusta and Rockingham Counties

Site ID	**Name**	**County**	**Nitrate PPM**	**Ortho Phos PPM**	**Amm PPM**	**pH**	**Turbidity**	**DO mg/L**
GA01	**South River/Port Republic**	**Augusta**	**1.02**	**0.06**	**0.04**	**7.71**	**4.52**	**9.61**
GA02	**South River/Harriston**	**Augusta**	**0.98**	**0.05**	**0.12**	**7.77**	**5.79**	**9.28**
GA04	**South River/Below Waynesboro**	**Augusta**	**0.91**	**0.05**	**0.06**	**7.66**	**4.27**	**9.35**
GA08	**South River/Wilda**	**Augusta**	**1.35**	**0.01**	**0.05**	**8.00**	**6.03**	**9.65**

GA10	**Middle River/Mt. Meridian**	**August a**	**1.57**	**0.05**	**0.03**	**7.93**	**6.39**	**9.08**
GA11	**Middle River Knightly bridge - Route 778**	**August a**	**1.42**	**0.04**	**0.01**	**7.99**	**5.17**	**9.13**
GA12	**Middle River Clines Lane - Route 642**	**August a**	**1.37**	**0.04**	**0.03**	**7.98**	**10.13**	**9.47**
GA13	**Middle River Lebanon Church - Route 742**	**August a**	**1.13**	**0.03**	**0.12**	**7.92**	**8.71**	**9.42**
GA17	**Middle River Route 703 bridge**	**August a**	**1.78**	**0.03**	**0.04**	**7.94**	**12.43**	**9.37**
GA18	**Middle River/Summerdea n**	**August a**	**1.52**	**0.02**	**0.04**	**7.83**	**6.98**	**9.44**
GA23	**South River Lyndhurst - Route 664 bridge**	**August a**	**1.09**	**0.04**	**0.07**	**7.64**	**6.22**	**8.83**
GA36	**North River Route 276 bridge**	**August a**	**3.01**	**0.15**	**0.06**	**7.71**	**7.86**	**9.37**
JR02	**Dry River-North River**	**Rockin gham**	**1.61**	**0.01**	**0.02**	**7.67**	**0.80**	**9.98**
JR04	**Upper North River-North River**	**Rockin gham**	**1.60**	**0.02**	**0.02**	**7.61**	**1.63**	**9.75**
JR09	**North River above HRRSA**	**Rockin gham**	**3.29**	**0.09**	**0.02**	**7.80**	**3.48**	**9.47**
JR11	**North River below HRRSA**	**Rockin gham**	**3.32**	**0.16**	**0.10**	**7.78**	**4.96**	**9.57**
GA02A	**South River Grand Caverns bridge**	**August a**	**0.98**	**0.05**	**0.09**	**7.75**	**6.16**	**9.21**
GA02B	**South River Grottoes Park**	**August a**	**0.98**	**0.05**	**0.14**	**7.67**	**5.25**	**9.05**
GA17M R	**Middle River, above the confluence with Back Creek**	**August a**	**1.09**	**0.03**	**0.06**	**7.86**	**16.03**	**8.84**
GA38	**Middle River, Rte 250 Bridge**	**August a**	**1.00**	**0.01**	**0.01**	**7.74**	**3.35**	**10.04**

Figure 4-1 shows the profound fluctuation in turbidity at JR07 (Cooks Creek-North River), one of the most polluted sites in Rockingham and with an average turbidity of 12.7 NTU. This is well above the severely impaired level, and indicates that the water is almost opaque. And though the trend has not been increasing, it is not going down either.

Figure 4-1: Showing week-to-week variation in Turbidity at JR07

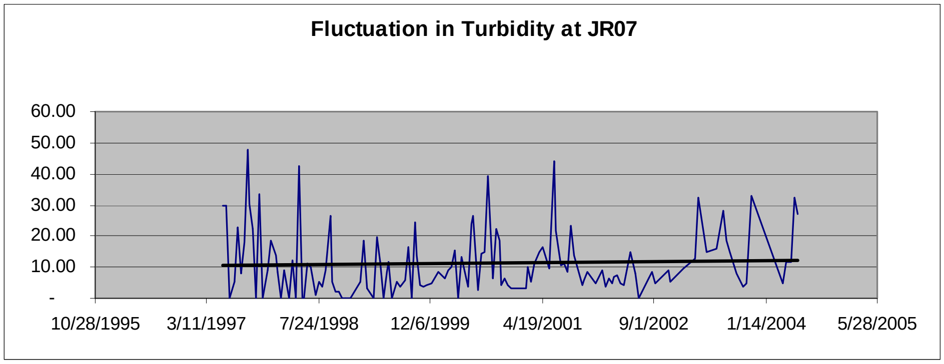
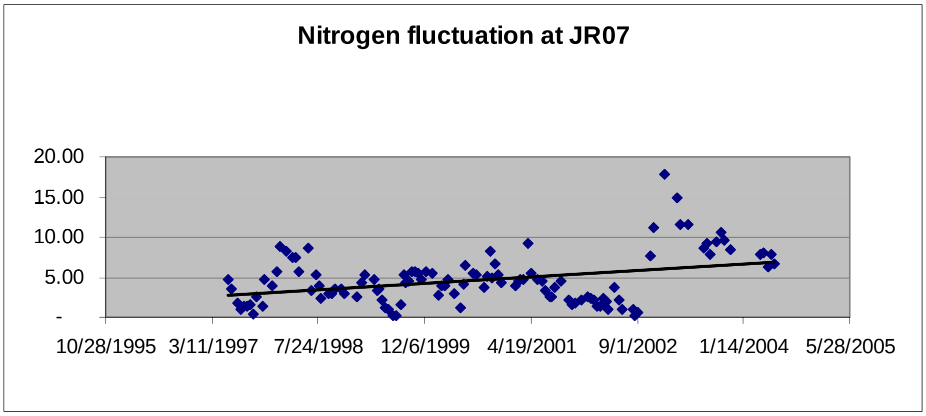


Figure 4-2 below shows the fluctuation in nitrogen at JR07 around the average level of 4.56 PPM. This is well above the impaired level of 1.0 PPM and one-half way towards the severely impaired level (unsafe for human consumption) of 10.0 PPM. The peak level of 17.2 PPM recorded on 1/11/2003 was probably die to heavy snow and rain precipitation during that time. And it can be seen that from 11/16/2003 to 4/26/2004 the PPM maintained its very high and unhealthy level above ten PPM.

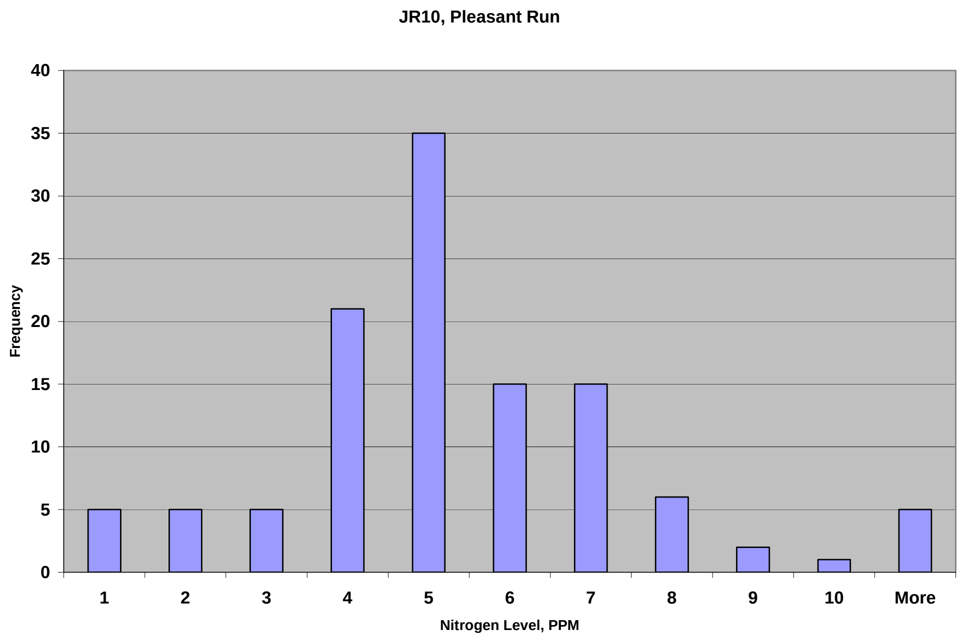
Figure 4-2:Showing week-to-week variation in Nitrogen at JR07.



Distribution of Parameters

Except for turbidity, it can generally be assumed that the frequency distributions for the parameters follow a distribution known in statistics as the “normal” distribution. For example, Figure 4-3 is for nitrogen, and shows that the spread around the average of 5.0 PPM taken during the past 7 ½ years (115 observations). The sample site is at JR10 in Rockingham County. This characteristic allows using the short-cut procedure suggested earlier for identifying hot spots. JR10 is among the ten worst of all sites in Rockingham and Augusta counties, and this fact is clearly shown in the figure. For example, there are only two sample values that fell in the unimpaired range between 0 and 1 PPM. And five observations fell above the severely impaired” level of 5 PPM.

Figure 4-3: Frequency Distribution for Nitrogen at JR10



For Turbidity the frequency distribution is extremely skewed, as shown in Figure 4-4. The reason for this skewness is carefully explained in a recent research report [10] prepared by Shenandoah University. By carrying out water sampling at two-hour intervals after a rainstorm, and for several days, the researchers were able to show that nitrogen concentration peaked slowly after the rain started falling, and then gradually returned to the normal background level. But turbidity (and to as lesser degree phosphorus) peaked very quickly and sharply after the rain started falling, but also returned quickly – over several hours – to the normal background level.

Since the FOSR procedures are to monitor at fixed intervals -- every two weeks during rain or shine -- it is relatively rare that a sample is taken soon after a rain storm. Therefore, the FOSR samples do not capture the extremes in turbidity. It does happen by pure chance, however. Note the 200 observations above the level of 10 NTU; and the maximum NTU observed during the seven year period was 400 NTU..

[10] Elizabeth A. Johnston and Woodward S. Bousquet, October 3, 2004. *What happens when it rains; A study of water quality in Abrams Creek and Town Run, Winchester and Frederick County, Virginia* .Environmental Studies Program, Shenandoah University, Virginia.

Figure 4-4: Turbidity in Augusta County Streams taken 1997 to 2004

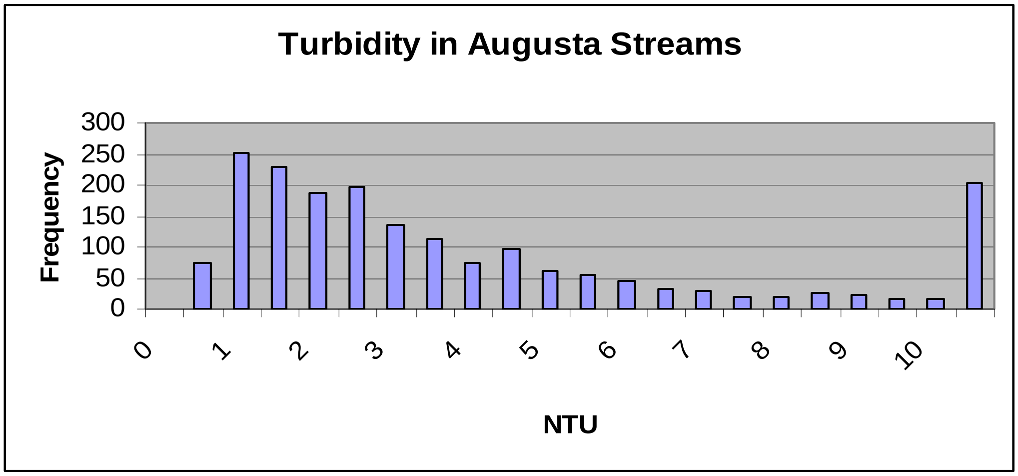
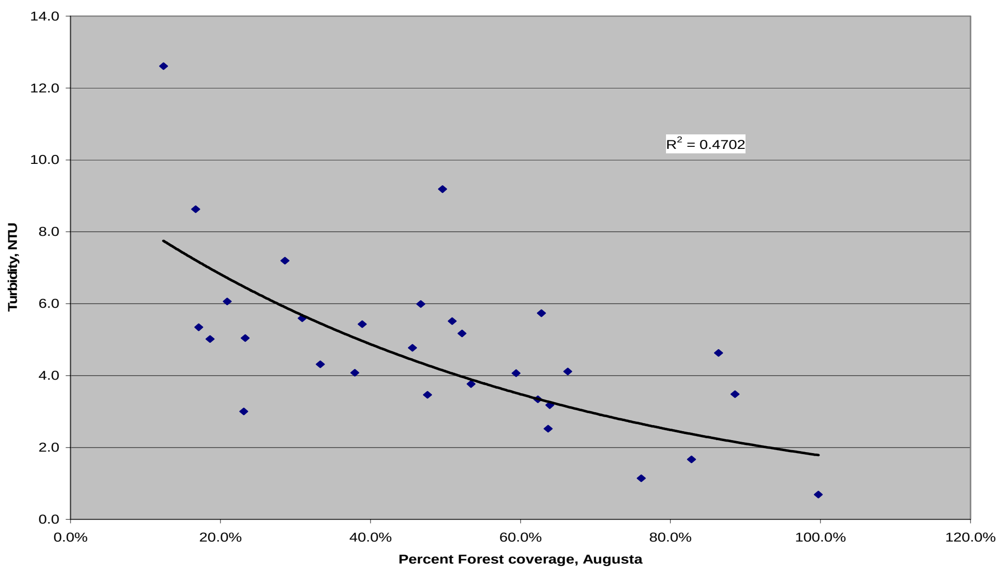
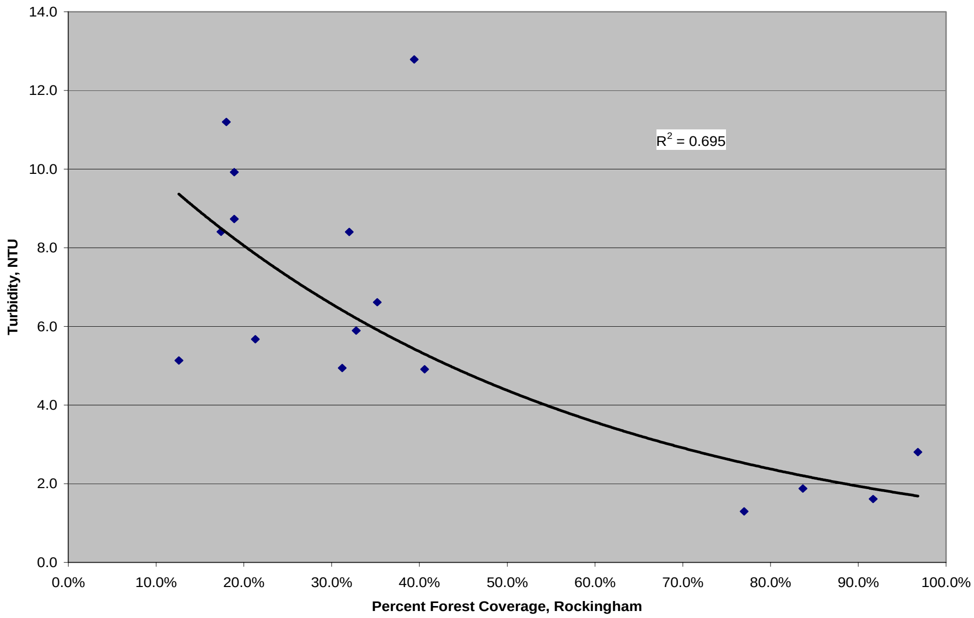


Figure 4-5: Turbidity vs Forest Cover, Augusta County



As made clear in Figure 4-5 and Figure 4-6, there is a strong relationship between percentage forest cover in the catchment area of a sampling site, and the turbidity measured at that site. For example, and as shown for Rockingham County below, the turbidity for low percentages of forest cover such as between 10% and 30%, the turbidity ranges between 5 NTU (fairly clear)and 12 NTU (extremely cloudy). But for sample sites with high forest coverage such as between 80% and 100 %, the turbidity falls around 2 NTU which indicates very "clear" water.

Figure 4-6: Turbidity vs Forest Cover, Rockingham County



Photos taken during an aerial survey in October 2004

Photographs taken during an aerial survey in October 2004, and illustrating the impact on stream quality from lack of stream protection.

Photo 2: Erosion caused by cows, near Smith Creek

Erosion from a cow pasture eventually flows into Smith Creek.

Photo 3: Muddy water from cow pasture flowing into Smith Creek

Muddy water from an unprotected small run dirties up Smith Creek

Photo 4: Cows around and in stream, no buffer, Middle River

An example of a stream without protection of a fence or vegetation buffer, and very vulnerable to the impact of cattle.

Photo 5: Erosion, Middle River

Hard to tell if this is good or bad. Could be a good habitat for wild life.

Photo 6: Poultry Farm, Holman's Creek, Shenandoah County

Rockingham county has over three hundred poultry rendering plants. According to the Chesapeake Bay Foundation, large-scale poultry operations produce more waste than hog, cattle, or dairy farms and up to 150 percent more of the nutrient pollution generated by human waste in the same area. In addition, poultry waste creates four times more nitrogen and 24 times more phosphorous than hog waste in Virginia

Photo 7: Trees and vegetation buffers, North Fork

Example of a good stream buffer.

Photo 8: Erosion with and without fencing, Willow Brook

The fencing seems to control erosion.

Photo 9: Earth moving, Pleasant Run

Muddy water can be seen to flow into one of the tributaries of Pleasant Run

Chapter 5 Summary

In summary, it was found that the rivers and streams in Rockingham and Augusta Counties often carry excessive levels of nitrogen, phosphorus, and sediment. However, the waters are rarely too acidic thanks to the limestone-rich soils, and the average levels of oxygen is almost never a problem. Though the nutrients including nitrogen, phosphorus are often high and impact very negatively on downstream water bodies such as the Chesapeake Bay, turbidity appears to be the most serious problem for the Shenandoah River watershed. High turbidity indicates excessive sediment in the water: it fills up bottom interstices used by small bottom dwellers, blocks sunlight, and kills small fish by plugging up their gills.

The average level of phosphorus, though still impaired, has dropped from its very high levels several years ago. One of the reasons for this may be the laws that were enacted top limit phosphorus content in household detergents. The trends for nitrogen and turbidity, unfortunately, are up. In Augusta County the concentration of nitrogen doubled, and in Rockingham County. the nitrogen concentration increased six fold over the last ten years.

It was found that the degree of forestation strongly influences turbidity, and also -- but to a lesser extent -- that of nitrogen. The graphs included in this report show quantitatively that, as forests coverage is reduced and is replaced by agricultural and urban land, the practices to control run-off and erosion are inadequate. Similar graphs show that counties with a large poultry industry also then to have very significantly stronger concentrations of nitrogen in their rivers and streams. It is not clear whether this is due directly to the poultry industry, or whether it is because of the use that is made of the waste products of that industry.

Finally, it is clear that more effective and extensive efforts need to be taken to reverse the deteriorating trend in water quality in both Rockingham and Augusta County, and the rest of the Shenandoah River watershed. This is a challenging task that we hope to discuss in our next report, in addition to the update on water quality.