THE HEALTH OF THE SHENANDOAH RIVER IN WARREN COUNTY: THE FOSR WATER TESTING PROGRAM

AUGUST 2003

A PAPER PREPARED BY THE FRIENDS OF THE SHENANDOAH RIVER WITH THE COOPERATION OF THE VOLUNTEER MONITORS OF WARREN COUNTY

ABSTRACT

The "Health of the Shenandoah River in Warren County" report is the fourth in a series of six being prepared by the Friends of the Shenandoah River (FOSR). These cover all of the counties in the Shenandoah River watershed in Virginia.

It was found that the surface waters in Warren county are less polluted than those for Clarke, Page, and Shenandoah County in Virginia covered in our earlier reports. In Warren county, and except for the sewage treatment plant, the average level of nitrogen (nitrate-nitrite) is almost always less than the impaired level. The average level of phosphorus (ortho-phosphate) in the South Fork and many of the tributaries are slightly above the impaired level, and ammonia and turbidity are mostly at unimpaired levels, although they show high peak concentrations from time to time. Trends in the concentration of pollutants were generally down.

Overall the nitrogen concentration (nitrate-nitrogen) measured in parts-per-million (ppm) averaged only 0.65 ppm for the South Fork of the Shenandoah River and 0.41 for the tributaries. This is well below the impaired level for nitrogen of 1.0 ppm. Even the sewage treatment plant in Front Royal, with a nitrogen concentration of 1.74 ppm of its effluent, is doing a good job of cleaning up its waste compared to STPs in other counties in the Shenandoah River watershed. The average nitrogen levels are declining.

The average ortho-phosphate level in the South Fork and its tributaries varied between 0.05 ppm and 0.58 ppm. And though most of the tributaries are shoe phosphorus levels above the impaired level of 0.1 PPM; this is well below the "severely" impaired level of 2.0 PPM. Only Leaches Run and Flint Run are unimpaired. The Manassas Run level of ortho-phosphate at 0.58 PPM was the highest. The trend in phosphorus levels is declining

The average levels of ammonia, pH, and turbidity are usually good, though ammonia and turbidity show sometimes large fluctuations (spikes) above the average. The exception is Manassas Run which has an average level of ammonia above the impaired level in addition to the aforementioned high level of P. The average turbidity of Snake Run is also slightly above the impaired level.

The spikes in levels of ammonia and turbidity are associated mostly with heavy rainfall; for example, a downpour of 2.5 inches of rainfall in one hour can cause a soil loss of almost 6 tons per acre from soils with poor groundcover. Failed septic systems and control problems in STPs can also cause temporary high levels. The spikes can be seen in the graphs in the main body of this report. And it is the high peak levels in turbidity that, in a very short time can destroy bottom dwellers and fish eggs, and spikes in ammonia can kill fish quickly.

Acknowledgements

Water quality assessments in this report were made possible by volunteer work, non-cash contributions, and funding from:

- Robins Foundation
- River Network, Canaan Valley Institute, and Izaak Walton League
- Virginia Environmental Endowment (VEE)
- Virginia Department of Environmental Quality (DEQ)
- National Fish and Wildlife Foundation (NFWF)
- Chesapeake Bay Small Watershed Grant
- Chesapeake Bay License fund
- Clear Water 2000
- Environmental Protection Agency (EPA)
- Virginia General Assembly
- James Madison University
- Shenandoah University
- Members of the Friends of the Shenandoah River (FOSR)

Chapter 1 Introduction

This Warren County report [1]is the fourth in a series being prepared by the FOSR on the Health of the Shenandoah River. It covers the South Fork and its tributaries in Warren County. The purpose of these reports is to provide the reader with a quantitative indication of the "health" of the river. 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 real health of a river is not always evident. These reports therefore usefully serve as a "thermometer" that provide quantitative and 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. These reports are posted on the FOSR web site www.fosr.org.

The three 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 some 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.

Analysis of the monitoring data compiled by the FOSR laboratory over the past six years shows that the health of the South Fork and most of its tributaries in Warren county is very good. This is a welcome relief from the three earlier and less flattering reports which showed significantly higher levels of pollution.

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).

These measurements indicate that fluctuations in the level of the water quality parameters above and below the average are very large. For example, during the January 1997 to August 2002 time period the level of nitrate nitrogen in the South Fork varied from an average of 0.65 (PPM[3])to a low of 0.006 PPM and a high of 2.0, and 70% of the time the concentration fell between 0.5 PPM and .95 PPM.[4]. The graphs discussed later in this report show a very high variability or "scatter" above and below the average. For this reason, although more costly in consumption of volunteer time to collect

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[1] Charles Vandervoort, a member of the FOSR, prepared this report. The names of the volunteer monitors who collected the data are shown in the Appendix. The water samples collected by the 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, and under the supervision of Bob Luce, the Laboratory Director. The author acknowledges the excellent cooperation and valuable contributions made by Charles Newton and other members of the FOSR who made this report possible. The Robins Foundation deserves credit for encouraging the production of these reports, and for providing funds for the operation of the laboratory.

[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] For the concentrations discussed in this paper one part per million (PPM) is equivalent to 1 milligram per liter in water. One ppm is equivalent to 1 milligram of pollutant per liter of water. To put this in perspective, 1 ppm is about the same as 1 drop of vermouth added to 15 gallons of gin (see G. M. Masters "Introduction to Environmental Engineering and Science, Prentice Hall, 1997

[4] As discussed in Chapter 4, water in streams is considered unimpaired below 1.0 PPM, impaired between 1.0 and 10.0 PPM, and severely impaired above 10.0 PPM.

and transport samples and in laboratory time and materials for laboratory analysis, the FOSR and its partners schedule sample collection twice per month. Testing only once every quarter or twice per year, though saving money, could give misleading results, and would make it difficult to establish a statistically valid trend.

High nutrient levels in rivers and streams 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.

In the South Fork the water is rarely too acidic (thanks to the limestone rich soils) and the average levels dissolved oxygen, and average level of turbidity of the river water is usually good, though there are spikes where the turbidity exceeds permissible levels. During the January 1997 to January 2003 time period, for example, the South Fork experienced roughly one spike in turbidity each month. Except for the effluent of the sewage treatment plant, average nitrogen and ammonia are at permissible levels in the South Fork. But average phosphorus levels are somewhat high – they slightly exceed the impaired level of 0.1 ppm , The trends in nitrogen, phosphorus, and ammonia are down and it seems that best management practices to reduce pollution such as riparian buffers and other measures are taking effect.

In the tributaries in Warren county the pollution levels are also quite low: of the fourteen creeks [5] analyzed in this report, only one (Happy Creek at Mouth, FW27) had an elevated level of nitrogen of 1.04. This is only slightly above the impaired level. The pollution levels in the other thirteen creeks were well below the impaired level. Levels of DO, pH and T in the tributaries were usually satisfactory though, after heavy rainfalls the turbidity sometimes rises.

High turbidity indicates excessive sediment in the river: it fills up cracks 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. High turbidity levels indicate that the river banks may be suffering from erosion since much of the sediment comes from channel erosion -- that can be corrected by best management practices (BMPs) [6] such as by installing riparian buffers and by reducing water run-off from construction projects and from development areas.

[5] A recent concern is that creeks in the Willow Brook-Crooked Run watershed contain harmful concentrations of fecal matter, a disease-causing pollutant. This pollutant was not monitored by the FOSR in Warren County. However, the FOSR is now tooling up to monitor this watershed for fecal matter and, with other organizations, initiate actions to remove this threat to health.

[6] 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.

Chapter 2 Friends of the Shenandoah River

The Friends of the Shenandoah River (FOSR) is a citizens organization that was legally established on September 8, 1989, shortly after the Avtex Plant closed after loading, for many years, the Shenandoah River with polychlorinated biphenyls (PCB) and a multitude of other bad chemicals. The FOSR is a nonprofit, scientific organization dedicated to the preservation and restoration of the aquatic environment of the Shenandoah River and its tributaries. It has two major goals: to monitor the river and its tributaries to discover the extent and sources of pollution; and to educate the people on the health of the river and to the importance of the river in their lives. The FOSR chooses to be science based rather than to be emotionally driven, and prefers non-confrontational methods to accomplish its goals.

Starting in a garage as a small organization with few monitors and resources to carry out the monitoring and education task, it now has a professional water testing laboratory which, every two weeks, receives sample bottles from a large group of volunteer monitors from the FOSR and from cooperating citizen volunteer organizations. The number of samples delivered every two weeks to the laboratory varies depending on the weather. For example, during the very high water flows encountered during June 2003, about 110 sample bottles were received by the laboratory. And several times during the 2003 winter monitoring was cancelled because of dangerous conditions. During good weather, however, the number of samples delivered to the lab on a monitoring day can reach more that 150.

Running a good laboratory, managing the supporting monitoring system, and carrying out the educational and office functions – even with volunteers--is not cheap. It costs about $10,000 annually -- mostly provided by membership dues-- to maintain the general functions of the organization. These include maintenance of an office, insurance, maintenance of a web site, publishing reports, and publication of a quarterly newsletter. The cost of the laboratory, monitoring equipment, and educational services comes from grants from Federal, State, and County governments and adds up to about $70,000 per year.

Some of the more significant achievements of the FOSR in the recent past include:

- Enhancement of the water monitoring program by (1) use of direct streamside measuring instruments to measure dissolved oxygen, pH, and temperature; and (2) preparation of a standard operating procedure for the streamside measurement of DO, pH, and temperature that has been approved by the Virginia Department of Environmental Quality.
- Acceptance of FOSR data by Governments: FOSR monitoring data along with biological data will be used in the development of TMDLs in the Shenandoah River and Opequon Creek watersheds. (TMDLs are the Total Maximum Daily Loads of pollutants that a body of water can accept and still meet water quality requirements of the Federal Clean Water Act). In addition, the FOSR monitoring data are reported to the US Environmental Protection Agency and the Virginia Department of Environmental Quality to be used in their water quality analysis.
- Use of FOSR data by technical organizations: James Madison University and the Canaan Valley Institute of West Virginia are using FOSR data posted on the FOSR web page to develop a Geographic Information System (GIS) for the Shenandoah Valley River Watershed. When fully developed, the GIS system will improve tracing pollution to its source, and remedial action can be more sharply focused on problem areas.
- Maintenance of a professional web site (www.fosr.org) that contains information on the FOSR, reports and newsletters, educational information, and access to all the FOSR monitoring data.

Chapter 3 The FOSR Laboratory and Monitoring Program.

Over the past several years the volunteer monitors in Warren county have taken water samples from 28 sites of the Shenandoah River and its tributaries (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.

The Laboratory in Shenandoah University

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, Canaan Valley Institute, Izaak Walton League, Chesapeake Bay License Fund, the Chesapeake Bay Alliance, and the Fish and Wildlife Fund. The lab also tests, at cost, water samples submitted by other organizations.

The laboratory was modernized in 2001 by the addition of a $60,000 automated testing machine (financed by a grant from the Virginia General Assembly) which automatically rather than manually tests samples for ammonia, nitrogen and ortho-phosphorus content. This Lachat QuickChem Flow Injection Analysis Instrument 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. It 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. Reagents that react with the chemical species of interest are added to the water sample. The absorbance of light at a specific wavelength by the colored solution is measured by means of a spectrophotometer. It is directly proportional to the concentration of the chemical species.

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 exploring 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 Warren county

The total number of volunteer monitoring sites in Warren county totals 28 (See Table 7-3) The monitoring at 12 of these sites, however, was carried out for lengths of time that were too short to allow reliable calculations of trends or averages. Reasons for the short time frame is because, for example, the need to conduct only a short-term study or to collect specialized data for a particular site, loss of a volunteer monitor, or the dropping of a site because it duplicated another site. These sites are called "inactive" sites in this report.

The other 16 sites (See Table 5-1) that were monitored for most of the time during the January 1997 and January 2003 time period are called "active" sites. In this report the main focus will be on the active sites because their larger time frame provides better estimates of trends and other statistics. For those readers interested in the inactive sites, Table 7-3 gives their average concentrations of the pollutants. Because of the short time frame, it was not possible to derive trend lines, and the average concentration has a wide margin of uncertainty.

The active sampling sites included two river sites: FW14, the Front Royal water intake on the South Fork; and FW 06, The Shenandoah River at Poe's campground. The only active sewage treatment plant was FW28, the Front Royal Sewage Outfall. The twelve active tributary sites include: Manassas Run behind Linden Mall, Snake Run at Route 55 bridge, Manassas Run at Route 647 bridge, Manassas Run at the campground, Happy Creek at the Youth Center, Spring Feed at Cedarville, Happy Creek below 4H center, Happy Creek below US Customs, Happy Creek below Rappawan and Wines construction, Flint Run, Gooney Creek, Happy Creek at Mouth, and Leaches Run.

Chapter 4 Indicators of Water Quality and Suggested Standards

The Appendix (page 25) gives a list and 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 (NH3 & NH4+). These are called "nutrients" because they provide food (fertilizer) for plants.

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. 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,.

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 mg/L 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." 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 5 Health of the River, Tributaries, and STPs in Warren County.

Overall Statistics

Table 5-1 below shows the average concentration of the six water quality parameters for the active sites.

Table 5-1: Average concentration of the six parameters for active sites

Site ID	Nitrate PPM	Ortho Phos PPM	Amm PPM	pH	Turbidity NTU	DO mg/L	Site name
FW28	1.74	0.50	0.35	8.18	3.80	8.34	Front Royal Sewage Outfall
FW27	1.04	0.22	0.20	7.91	2.14	8.55	Happy Creek at mouth
FW14	0.65	0.27	0.18	8.27	2.09	8.00	Front Royal Water Intake
FW06	0.64	0.32	0.31	8.30	2.39	8.76	Shenandoah River @ Poe's Campground
FW29	0.53	0.10	0.21	8.03	2.12	8.79	Leaches Run
FW01	0.50	0.58	1.90	7.81	1.98	9.12	Manassas Run behind Linden Mall
FW22	0.48	0.25	0.17	8.28	1.39	8.23	Gooney Creek
FW09	0.38	0.09	0.14	7.86	2.26	9.43	Happy Creek below 4H center
FW04	0.38	0.22	0.24	7.89	1.75	9.53	Manassas Run Campground
FW11	0.34	0.11	0.18	7.92	3.45	9.41	Happy Creek below Rappawan and Wines cons
FW05	0.32	0.15	0.26	7.93	2.11	9.13	Happy Creek at Youth Center
FW03	0.32	0.18	0.22	7.69	2.14	9.13	Manassas Run @ Route 647 bridge
FW10	0.30	0.17	0.31	7.91	2.15	9.28	Happy Creek below US customs
FW07	0.29	0.15	0.18	7.77	1.71	9.29	Spring Feed at Cedarville
FW02	0.22	0.15	0.20	7.82	4.16	9.33	Snake Run at Rt 55 bridge
FW21	0.17	0.05	0.13	7.65	1.47	8.35	Flint Run
Not Impaired	< 1.0 PPM	<0.1 PPM	<1.0 PPM	6.5 to 8	0 - 4	< 5 (no fish)	
Impaired	1.0 to 10.0 PPM	0.1 to 2.0 PPM	> 1.0 PPM	< 6.5 or >8	4 to 7	5 - 8 Good	
Severely Impaired	> 10.0 PPM	>2.0 PPM	> 10 PPM	NA	> 7	> 8 Excellent	

Table 7-3 (Page 22)shows the average concentration of the six parameters N, P, AMMONIA, pH, DO, and T measured over the past five years at all the Warren county sites, including both the 12 inactive and the 16 active sites. (As discussed in Chapter 3, the sampling at the active sites was more frequent and was carried out over a longer time interval than for the inactive sites). It can be seen that both the inactive and the active sites have low levels of nitrogen and are unimpaired as far as nutrients are concerned. The ortho-phosphate levels are slightly above the "impaired" level of 0.1 but well below the "severely impaired" level of 2.0, and the level of ammonia (except for Manassas Run, FW01) is good.

The pH, which measures the acidity or alkalinity of the water, should be between 6.5 and 8.0. If it is below 6.5 the water is to "acid." This could be caused by acid rain, mining waste, of industrial waste water. If the pH falls above 8.0, it is too alkaline, and as could be caused by pollution from industrial waste.

In general, because of the limestone-rich soils through which the river and tributaries flow, the water in Warren County is almost always at the proper level of pH. Without the limestone-rich soils the impact of the acid rains prevalent in the Shenandoah valley could have had an adverse effect on water quality. The average levels of turbidity and dissolved oxygen are good for both the creeks and the rivers. However, as will be discussed later, it is not the average level of turbidity that counts; rather it is the number of peaks in turbidity that occur after events, such as a rain storm, or a lapse of sediment control at a construction site.

Since the sites we call "inactive" cover a much shorter time frame than the active sites, their summary statistics tend to be less reliable. The rest of this report therefore focuses on the active sites.

Health of the South Fork

Nutrient Levels: Over the past five and one half years the South Fork of the Shenandoah River has been quite "healthy." Levels of nitrogen and ammonia were almost always unimpaired. The table below (see Table 5-2) shows that, since monitoring of nutrients started in January, 1997, the nitrogen levels in the South Fork were unimpaired almost 84 percent of the time, and never impaired only 16% of the time. The South Fork did not contain any sites with "severely impaired" nitrogen concentrations. For ammonia, the water in the South Fork is unimpaired practically all the time. The situation for phosphorus is not as good: though never severely impaired, the readings of phosphorus fell in the impaired level 86% of the time.

Table 5-2: Average Nitrogen Pollution in the South Fork of Warren County at the Front Royal water intake

Level of contamination	Number of observations at indicated level	Percentage
Unimpaired: < 1 PPM	84	84%
Impaired: between 1 and 10 PPM	14	16%
Severely Impaired: more than 10 PPM	0	0%
		100%

Figure 5-1 below shows the level of nitrogen pollution in the South Fork at the Front Royal Water Intake (FW14). The long-term average of nitrogen concentration is 0.65 PPM. This is well below the impaired level of 1.0 PPM. And the trendline shows that the recent average is approaching 0.5 PPM. As can be seen from the graph, the many factors that affect water quality produce considerable "scatter" of the data above and below this average. However, none of the deviations above the average exceeds 2 PPM. Normally these deviations come in groups, or "spikes, that are associated with heavy rainfalls that wash the nitrogen from agricultural and other land into the river. It is noteworthy that the South Fork, except for the sharp rise in nitrogen concentration that can be observed during the wet winter of 2003, has few of these spikes.

Figure 5-1: Nitrogen levels (PPM) in the South Fork FW14, the Front Royal water intake

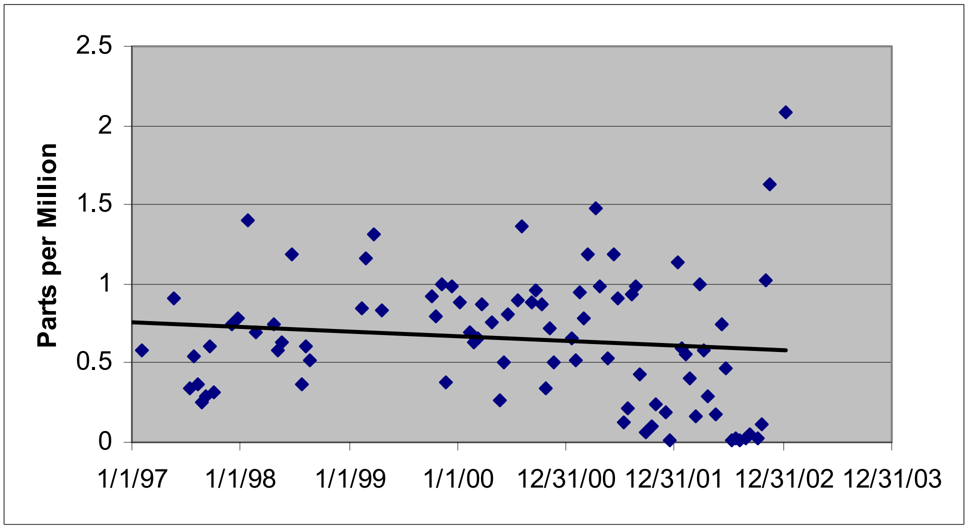
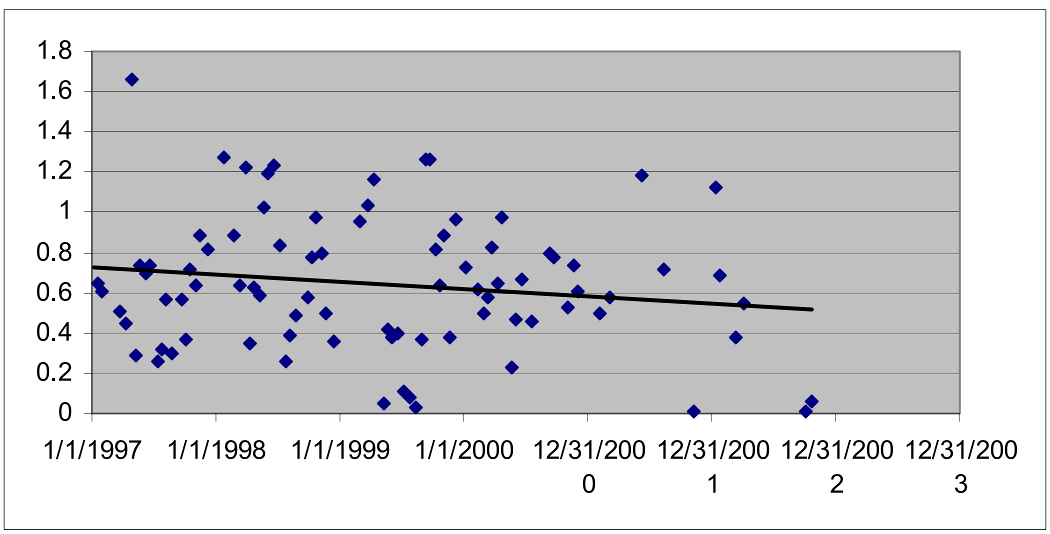


Figure 5-1 also shows the trendline for the concentration of nitrogen in the South Fork. The trendline shows a small decrease in the nitrogen concentration of about 0.04 PPM per years. The South Fork in Warren County is one of the few sections in the Shenandoah river watershed so far where we found both low average pollution levels and a slow decrease in pollution levels.

Figure 5-2 below shows the nitrogen concentration at FW06, the second other of the two monitoring site on the South Fork. The long term average is very close to that for the previous site, and the trend is also down. One significant difference between FW14 and FW06 is that the latter does not show the sharp increase in nitrogen concentration that, we believe, was caused by the very wet winter of 2003.

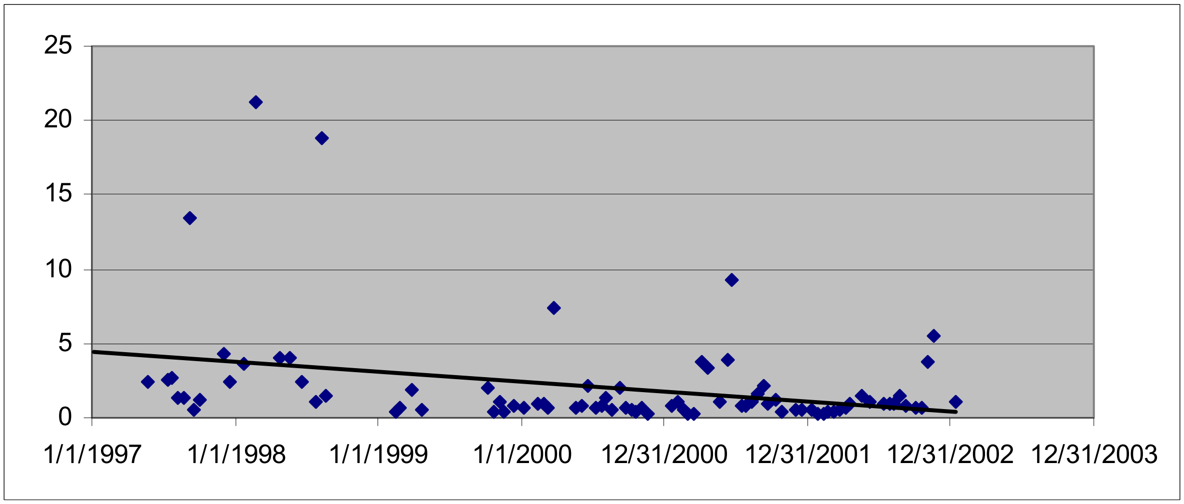
Figure 5-2: Nitrogen levels for the South Fork at Poe's Campground, FW06



Though extrapolation of the trends could indicate even lower levels of nitrogen pollution in the South Fork within, say, ten years, it must be kept in mind that the simple linear trends calculated here take into account only historic time-related information. Extrapolation basically assumes that the conditions in the past will also prevail in the future. They do not take into account, basically because we lack the quantitative information, other important factors affecting nitrogen pollution. These include, to mention just a few: rainfall, agricultural practices, land use and urbanization, industrialization with an especially important one being animal rendering factories, technological improvements for waste water treatment, and acceptance of BMPs. Once data on these factors become available, a more sophisticated trend analysis can be applied.

The average turbidity levels in the two monitoring sites in the South Fork run around 2.0 NTU; this is well below the impaired level of 7.0 NTU (see Figure 5-3 below for the level at FW14, the Front Royal water intake). And the trendline shows that the turbidity is declining. There are, however, bothersome spikes in turbidity. For example, we can see that since early 1997 the turbidity at the Front Royal water intake on the South Fork has exceeded the impaired level of 7.0 NTU five times, and that the maximum level of turbidity was 21.3 NTU. The second sampling site on the South Fork at Poe's Campground (not shown) had seven spikes that exceeded the 7.0 NTU level, and the largest spike was 26.4.

Figure 5-3: Turbidity in the South Fork at FW14, the Front Royal water intake



Even though the average turbidity is low most of the time, the spikes in turbidity can deposit harmful deposits of sediment on the river bottom. These deposits can quickly kill fish eggs and small bottom dwellers. These spikes in turbidity therefore are a problem in Warren County. For example, the turbidity in Warren County (excluding the STP) exceeded the severely impaired level of 7 NTU 74 times, or about one spike per month.

Turbidity is a naturally occurring process resulting from erosion, and there are a number of things that can be done to limit erosion. The most important is providing good ground cover. For example, a heavy rainstorm of 2.44 inches in one hour can cause a soil loss of 5.55 tons per acre if the ground cover is poor (10% of ground covered with plants). The soil loss is reduced to 0.5 tons per acre if the ground cover is fair (37% of ground covered with plants), and is reduced still further to only 0.05 tons per acre if the ground cover is good (60-75% of ground covered with plants)[10]. Poorly executed construction activities can be major contributors to erosion. For example, erosion rates of land are increased from 4 to 9 times by agricultural development; and may be increased by a factor of 100 as a result of poorly controlled construction activities[11].

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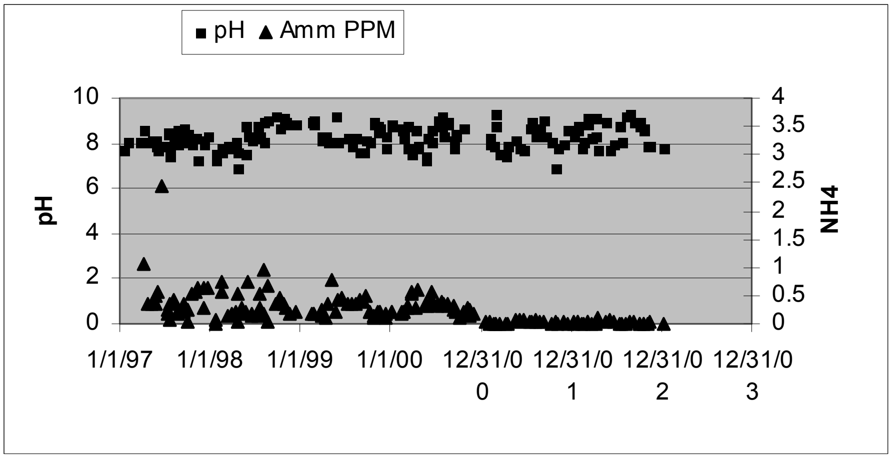
[10] H. Stephen Stoker and Spencer L. Seager, "Environmental Chemistry: Air and Water Pollution," Scott, Foresman and Company, 1976.

[11] Ibid

Levels of pH and ammonia in the South Fork as shown in Figure 5-9 indicate that their levels are good, though pH was slightly on the alkaline side. And except for the year 1997 which contained several spikes in ammonia concentration, the levels thereafter were well below the 1/0 PPM impaired level.

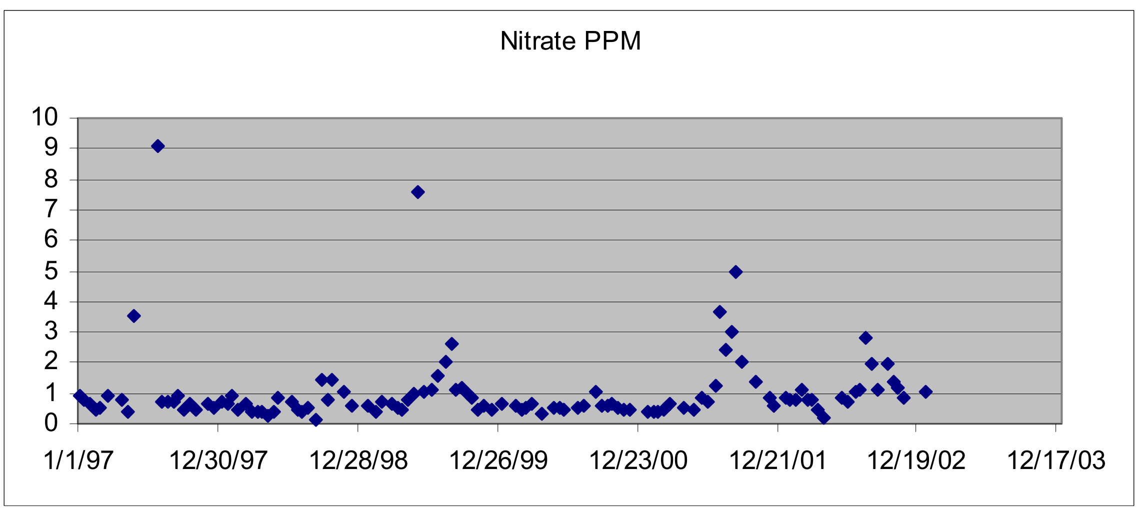
Figure 5-4: Levels of pH and ammonia in the South Fork (FW06 and FW14 combined)



Health of the Tributaries

The pollution of the creeks in Warren county is also low: of the fourteen creeks analyzed in this report, only one had an average level of nitrogen above the impaired level, and this deviation was slight. This was FW27, Happy Creek at Mouth that had a level of nitrogen 1.04PPM. (See Figure 5-5).

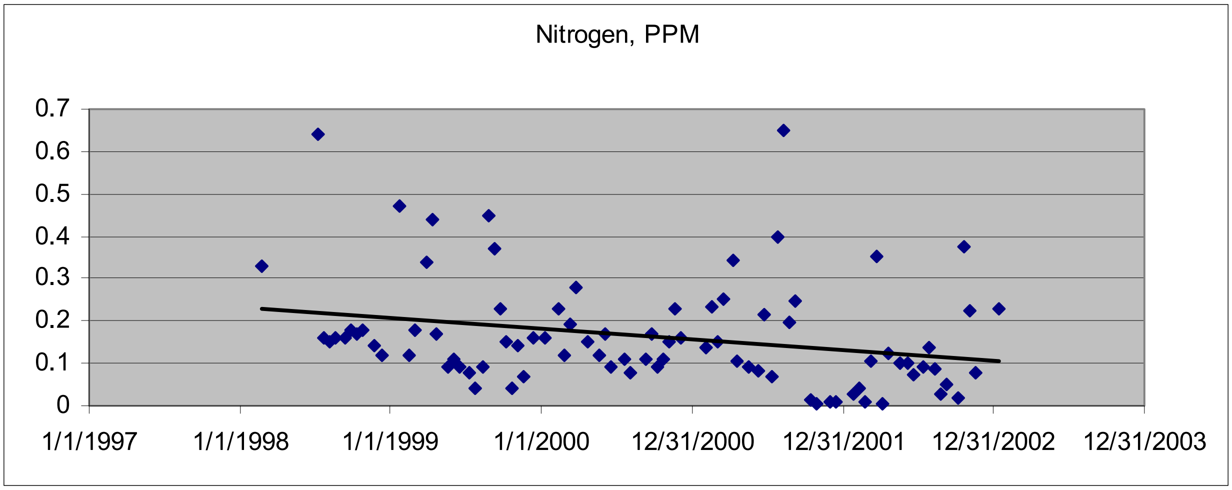
Figure 5-5: Nitrogen level at Happy Creek at Mouth, FW27



The creek is located close to Front Royal in a region of moderate population density with many old homes. Agriculture is not important and we can therefore not attribute the above-average level of nitrogen pollution to runoff of fertilizer from fields. There is also little industry, and there are no poultry rendering plants.

The nitrogen pollution level for the best creek – Flint Run -- is shown in Figure 5-6.(Note that the scale of this figure is much smaller than the scale for FW27, and the deviations are therefore exaggerated). Since 1997 the average level of nitrogen ranged around 0.17 PPM -- and well below polluted levels -- and the trend is down sharply. The reason for the good condition of this creek is that its drainage area is partly in the Shenandoah National Park, and flows through a sparsely populated area. It also contains very little agriculture, no poultry rendering plants, and little industry.

Figure 5-6: Nitrogen level in Flint Run FW21

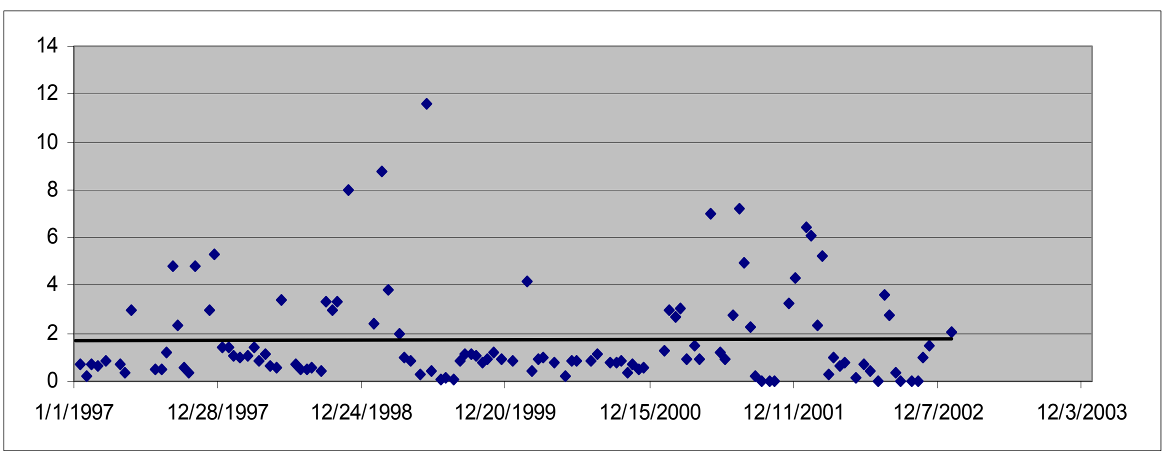


Levels of DO, pH and T in the small streams were usually satisfactory, though there are worrisome spikes in turbidity.

The Sewage Treatment Plants

The sewage treatment plant at Front Royal does a good job of treating water before release of its effluent. As shown below in Figure 5-7, the average level of nitrogen pollution is about 1.74 PPM (slightly above the 1.0 impaired level, but well below the 10.0 severely impaired level. The trend has been level since early 1997.

Figure 5-7: Nitrogen Pollution at the Front Royal STP (FW28)



This compares very favorably with the pollution levels measured at STPs in Clarke, Page, and Shenandoah counties (see Table 7-1: Comparison of Average Values of Parameters of the Shenandoah River for Clarke, Page, Shenandoah County and Warren county)

The turbidity in the discharge from the Front Royal STP (see Figure 5-8 below) has improved by a great deal since 1998, and is now less than less than 7 Nephelometric Turbidity Units, or NTU. This is very good for an STP.

Figure 5-8: Turbidity at the Front Royal STP

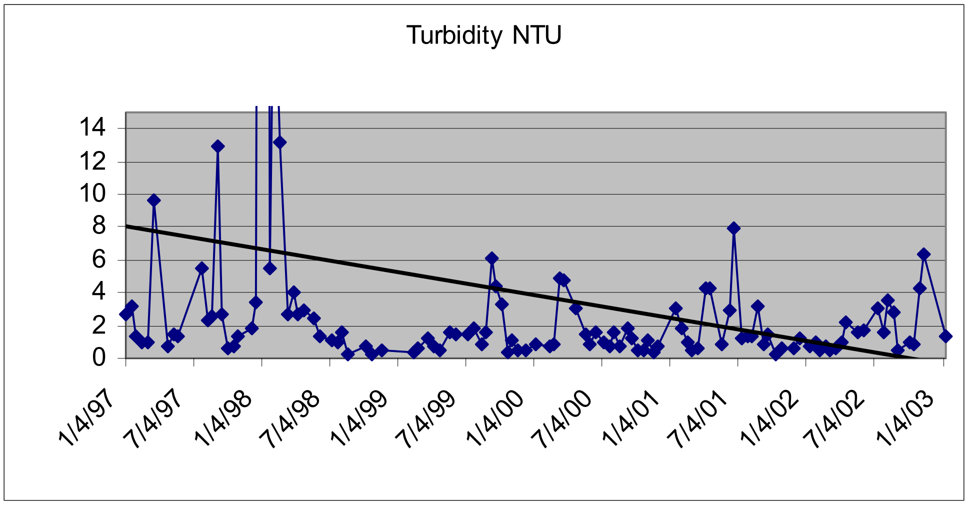
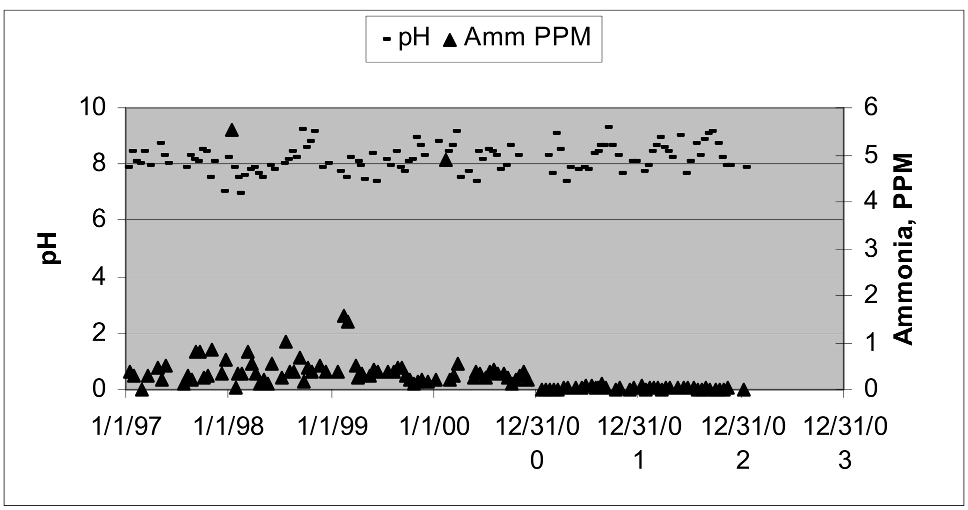


Figure 5-9 below shows that the pH and ammonia levels in the Front Royal discharge are not a problem. The pH is slightly on the alkaline level, and this is normal for almost all the surface water in the Shenandoah river watershed. And the pH stays well above the dangerous range below 6.0.

The levels of ammonia (total ammonia nitrogen) is also good. There are a few spikes with a big one in January 10, 1998 and February 12 2000 where the levels slightly exceeded 5.0 PPM, but the level stayed well below the severely impaired level of 10.0 PPM which is toxic to fish.

Figure 5-9: Levels of pH and AMMONIA in the Front Royal STP discharge, FW28.

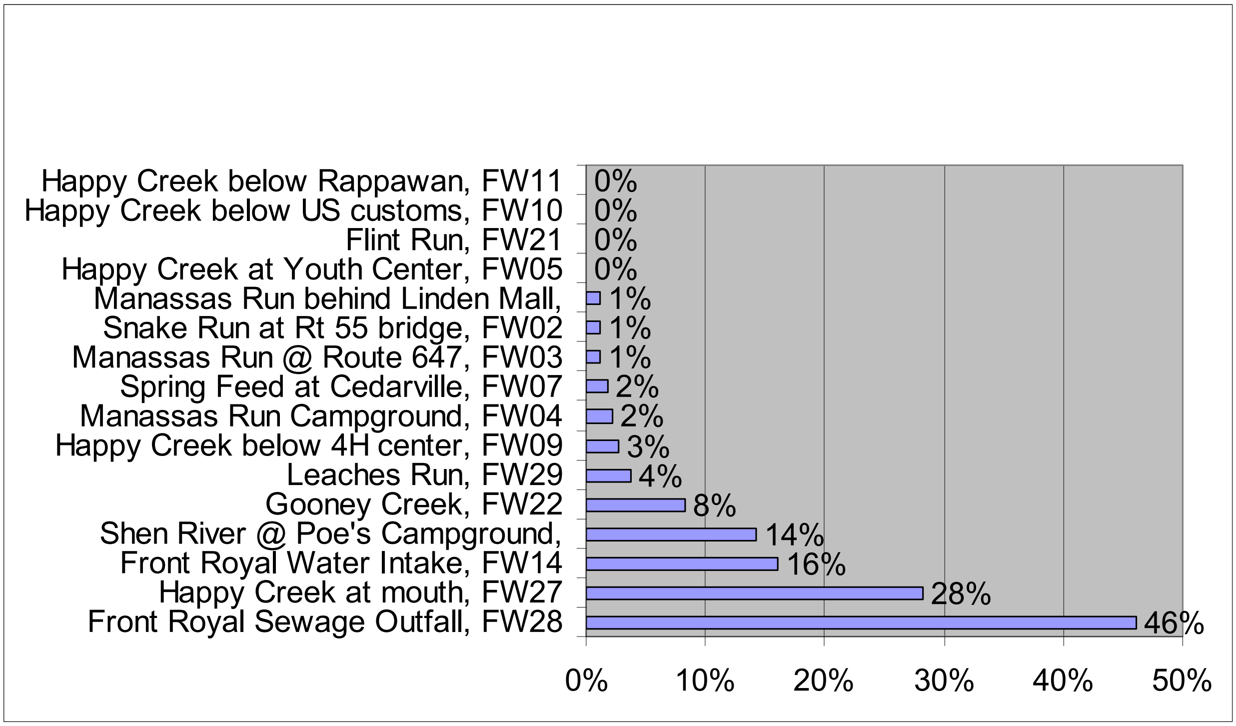


Chapter 6 Summary of the Health of South Fork, Tributaries, and STP in Warren County

Figure 6-1 provides a summary of the condition of the surface waters in Warren County. It shows the ranking of the percentage of the time since January 1, 1997 that the nitrogen levels fell above 1.0

PPM. Ranked at the bottom is the STP: 46% of the samples contained nitrogen levels exceeding the impaired level of 1.0 ppm, although only one sample bottle had a nitrogen level above the severely impaired level of 10.0 PPM. As discussed earlier, this STP does a good job of cleaning up its effluent (see Figure 5-7 for details on this STP).

Figure 6-1: Average time (percentage) that the nitrogen levels in the surface waters in Warren County are impaired (fall between 1.0 and 10.0 PPM)



The monitoring site at the Happy Creek at Mouth tributary is ranked at the bottom because 28% of its readings fall above the impaired level. The details for this monitoring station are shown in Figure 5-5, page 15. This tributary provides an example of how, as one moves from the origin of a tributary to its mouth at the river, the nutrient levels tend to increase; the sites FW10, FW11, FW05, and FW09 are also on Happy Happy Creek but further upstream to the source of that tributary, and have low levels of nutrients, but nitrogen levels at FW27 at the end shows a sharp increase.

Chapter 7 Comparison of the South Fork in Warren County with other sections of the River

It is interesting to compare the findings for Warren county with the results from earlier reports prepared by the Friends of the Shenandoah River on the Health of the Shenandoah River in Clarke County, Page County, and Shenandoah County.

Compared with the conditions in the river of the other three counties (see Table 7-1 below), the average levels of nitrogen and phosphorus at 0.64 PPM and 0.27 PPM in the South Fork in Warren county are much lower than those for the river segments in Page County (0.99 PPM and 0.70 PPM respectively) and Shenandoah County (1.87 PPM and 0.47 PPM respectively). The reason for this is that Page and Shenandoah County lie upstream (South) from Warren County and receive the full impact of the numerous animal rendering plants and hog farms in Rockingham and Augusta County. The level of nitrogen in the Main Stem of Clarke County (North and downstream from Warren County) are only slightly higher than that for the South Fork in Warren County. The reason for this is that Clarke County is well away from the pollution coming from upstream, and the nutrient levels are contributed mostly by the runoff from the many farms in Clarke County.

Table 7-1: Comparison of Average Values of Parameters of the Shenandoah River for Clarke, Page, Shenandoah County and Warren county

		N, ppm	P, ppm	AMMONIA, ppm	DO, ppm	pH	T, NTU
Shenandoah County	North Fork	1.87	0.47	0.44	9.66	8.26	2.69
Page County	South Fork	0.99	0.70	0.37	8.94	8.22	3.16
Clarke County	Main Stem	0.65	0.36	0.37	9.98	8.20	3.91
Warren County	South Fork	0.64	0.27	0.18	8.27	8.00	2.09

Shenandoah County	Creeks	1.20	0.10	0.20	8.60	8.00	2.00
Clarke County	Creeks	1.19	0.27	0.43	8.55	7.54	2.97
Page County	Creeks	0.80	0.13	0.26	8.77	7.75	1.59
Warren County	Creeks	0.42	0.20	0.32	7.95	8.92	2.32

The concentration of nitrogen in the tributaries in the four counties do not follow the same pattern as that for the river segments – the concentrations are more or less randomly distributed though Warren County has a significantly lower level of nitrogen concentration. The reason is that the creeks, of course, are independent from the river, and not affected by the pollution coming from the South.

Exhibits

Map 7-1 below identifies the 20 active sites that are now being monitored. Each site is identified by a flag which gives the site number. Site names and coordinates are given in Table 7-2, page 21; two of the sites are so close together that they overlap: FW28 partially hides FW09 and FW27 partially hides FW06.

Map 7-1: Active Warren county Monitoring Sites

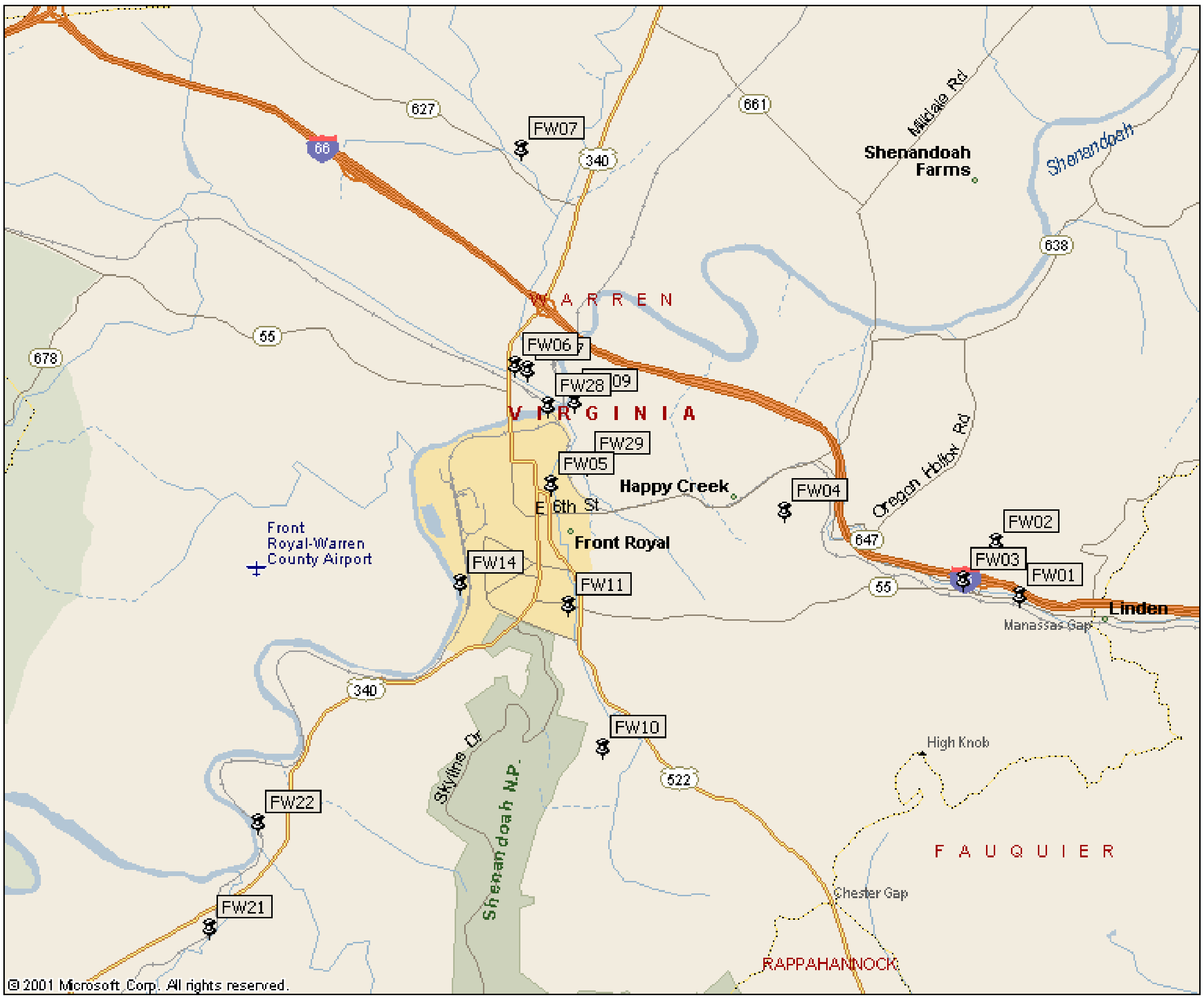


Table 7-2 below gives the names and longitude/latitude of all the active sites the sites shown in the map above. Also shown is the type of site, i.e., whether the site is on a river, tributary, or from the direct discharge of an STP.

Table 7-2: Site Names and Coordinates of Active Sites

Site ID	Name	Type	Latitude (N)	Longitude (W)
FW-01	Manassas Run behind Linden Mall	tributary	38.91	-78.09
FW-02	Snake Run at Rt 55 bridge	tributary	38.92	-78.10
FW-03	Manassas Run @ Route 647 bridge	tributary	38.91	-78.10
FW-04	Manassas Run Campground	tributary	38.93	-78.14
FW-05	Happy Creek ay Youth Center	tributary	38.93	-78.19
FW-06	Shenandoah River @ Poe's Campground	tributary	38.95	-78.20
FW-07	Spring Feed at Cedarville	tributary	38.99	-78.20
FW-09	Happy Creek below 4H center	tributary	38.94	-78.19
FW-10	Happy Creek below US customs	tributary	38.89	-78.18
FW-11	Happy Creek below Rappawan and Wines construction	tributary	38.91	-78.19
FW-12	South Fork across from Avtex	river	38.92	-78.22
FW-13	Old Dump Run	tributary	38.92	-78.22
FW-14	Front Royal Water Intake	river	38.91	-78.21
FW-27	Happy Creek at mouth	tributary	38.95	-78.20
FW-28	Front Royal Sewage Outfall	STP	38.94	-78.19
FW-29	Leaches Run	tributary	38.93	-78.18

Table 7-3 below shows the average levels for all six parameters. The averages are over all measurements since January 1, 1997 to January 11, 2003.

Table 7-3: Average Parameter Levels at all Warren County sites (Active sites are shaded)

Site ID	Site name	Nitrate PPM	Ortho Phos PPM	Amm PPM	pH	Turbidity	DO mg/L
FW01	Manassas Run behind Linden Mall	0.50	0.58	1.90	7.81	1.98	9.12
FW02	Snake Run at Rt 55 bridge	0.22	0.15	0.20	7.82	4.16	9.33
FW03	Manassas Run @ Route 647 bridge	0.32	0.18	0.22	7.69	2.14	9.13
FW04	Manassas Run Campground	0.38	0.22	0.24	7.89	1.75	9.53
FW05	Happy Creek at Youth Center	0.32	0.15	0.26	7.93	2.11	9.13
FW06	Shen River @ Poe's Campground	0.64	0.32	0.31	8.30	2.39	8.76
FW07	Spring Feed at Cedarville	0.29	0.15	0.18	7.77	1.71	9.29
FW09	Happy Creek below 4H center	0.38	0.09	0.14	7.86	2.26	9.43
FW10	Happy Creek below US customs	0.30	0.17	0.31	7.91	2.15	9.28
FW11	Happy Creek below Rappawan and Wines construction	0.34	0.11	0.18	7.92	3.45	9.41
FW12	South Fork across from Avtex	0.55	0.38	0.25	8.25	3.32	7.57
FW13	Old Dump Run	0.88	0.55	0.40	7.78	18.08	8.61
FW14	Front Royal Water Intake	0.65	0.27	0.18	8.27	2.09	8.00
FW15	Riverton Public Boat Landing	0.89	0.61	0.35	8.16	5.86	8.64
FW16	Unassigned Site	0.71	1.05	0.34	8.02	12.24	10.75
FW18	Dry Run	0.18	0.26	0.26	7.78	1.98	7.80
FW21	Flint Run	0.17	0.05	0.13	7.65	1.47	8.35
FW22	Gooney Creek	0.48	0.25	0.17	8.28	1.39	8.23
FW23	Passage Creek on Rt. 110	0.19	0.29	0.45	8.06	2.44	9.46
FW24	North Fork Shenandoah River	0.84	0.21	0.50	7.95	5.25	8.87
FW25	Cedar Creek at low water bridge	0.60	0.20	0.51	7.94	5.30	9.56
FW26	North Fork at North Fork Campground	0.74	0.18	0.52	7.99	3.20	9.58
FW27	Happy Creek at mouth	1.04	0.22	0.20	7.91	2.14	8.55
FW28	Front Royal Sewage Outfall	1.74	0.50	0.35	8.18	3.80	8.34

FW29	Leaches Run	0.53	0.10	0.21	8.03	2.12	8.79
FW30	Shenandoah River Estates	0.73	0.56	0.57	8.19	11.19	8.74
FW35	Morgan's Ford	0.74	0.20	0.02	8.34	1.71	10.87
FW4H	Manassas Run @ Mouth	0.90	0.31	0.24	8.28	1.43	9.73
	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 Figures below are discussed in various places in the preceding text.

Figure 7-1: Phosphorus Impairment in the South Fork, FW14 (Front Royal Water Intake)

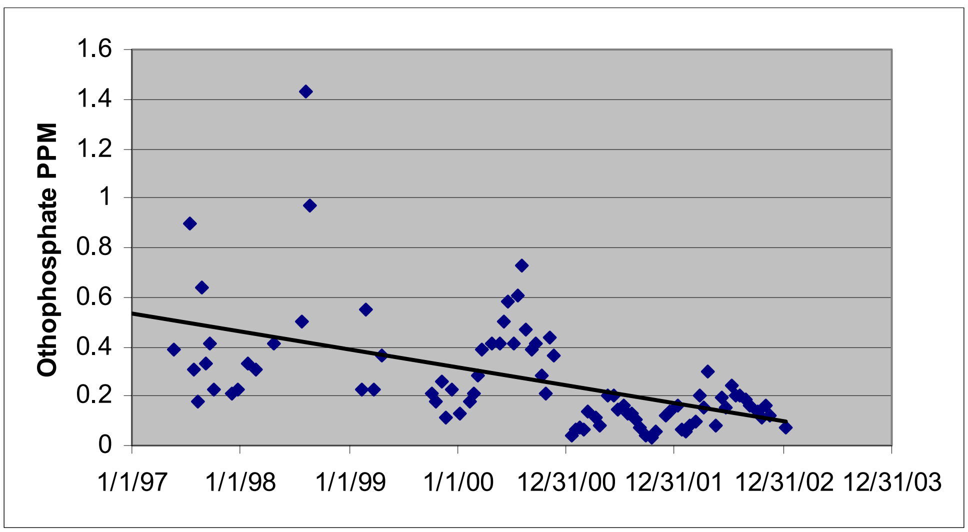


Figure 7-2: N and P concentrations at FW06, Shenandoah River at Poe's Campground

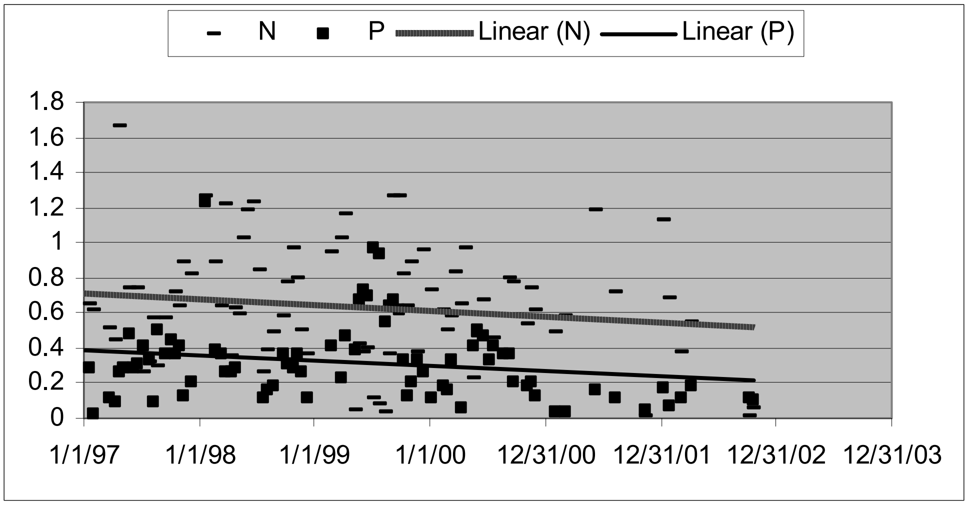
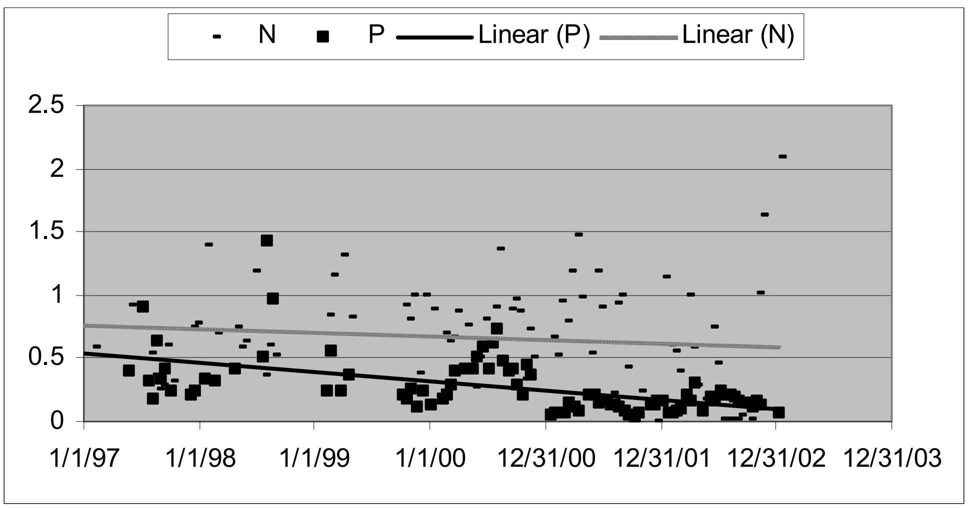


Figure 7-3: N and P concentrations at FW14, Front Royal Water Intake



APPENDIX

WATER QUALITY TESTS

INDICATORS

- **Nitrate-Nitrite (N)**
- **Phosphate (P)**
- **Ammonia**
- **pH**
- **Turbidity (T)**
- **Dissolved Oxygen (DO)**
- **Temperature**
- **Fecal Coliform**

NITRATE-NITRITE

- reported as PPM of nitrogen
- promotes excessive algae and aquatic plant growth.
- high values of less than 10 PPM can cause blue babies, and abortion of fetuses in cattle.
- US EPA considers concentrations larger than 1 PPM as impaired and larger than 10 PPM as severely impaired.

NITRATE-NITRITE SOURCES

- Waste-water Treatment plants
- Run-off from Fertilized Cropland and Animal Manure Storage areas
- Failing Septic Systems
- Air Pollution/Acid Rain

PHOSPHATE

- Essential Element for Life Processes
- Measured in Part Per Million (PPM)
- Reported as Ortho or Reactive Phosphate
- In water, Phosphorus is present naturally and in very low concentrations
- EPA (1986) recommends that total phosphorus in flowing waters not exceed .1 PPM

HIGH CONCENTRATIONS OF PHOSPHORUS

- Above 0.5 ppm is High
- Causes Excessive Algae Growth
- Decreased Dissolved Oxygen (DO)
- Usually associated with high Turbidity (T)

- Water Discoloration

PHOSPHORUS SOURCES

- Human, Animal and Industrial Waste
- Sewage from Wastewater Treatment Plants and Septic Tanks
- Soil Erosion from Farming (especially plowing) & Construction (soil disruption)
- Excessive use of Fertilizers for Crops, Lawns, Home Gardens
- Draining of Swamps and Marshes

AMMONIA

- Reported as Ammonia-Nitrogen in PPM
- Formed during decay of Plants or Animals
- Levels above 1 PPM can cause toxic effects
- Harmful to aquatic biology; insects, fish

pH

- Measurement of acidity or alkalinity
- Scale from 1.0 to 14.0
- 7.0 is neutral, 3.0 is the level of lemon juice, 11.0 is the level of household ammonia
- Preferable range 6.5 to 8.0
- Values below 6.0 (very acidic) considered harmful to aquatic life
- Affected by acid rain, soil/rock type, industrial waste

TURBIDITY

- Measure of Water Turbidity by Nephelometric Turbidity Units (NTU)
- NTU 1-2 Clear; NTU 4-7 Fairly Cloudy
- Caused by:
- Plant Pigments i.e. Chlorophyll
- Suspended particles i.e. Clay, Silt, Plankton, Organic Matter, Sewage and Industrial Waste
- High Levels of Turbidity
    - Allow Less Light Penetration
    - Water Less able to Support Aquatic Life
    - Water becomes Warmer as Suspended Particles Absorb Heat =
    - Lower DO

DISSOLVED OXYGEN (DO)

- Vital to aquatic organisms (plants and animals)
- Absorbed directly into water from atmosphere and aquatic plants
- Values above 5 mg/L best

- Values below 5 mg /L stressful to aquatic organisms

LOW DISSOLVED OXYGEN

- Higher Water temp = lower DO
- Still Water = lower DO
- Breakdown of Organic Waste from:
- Algae "Bloom" Decay
- Municipal Waste
- Agricultural Waste
- Industrial Sources

FECAL COLIFORM

- Bacteria found the in Feces of Humans and other Warm Blooded Animals
- Most E-coil not Pathogenic, only an indicator organism that water is contaminated with human or animal wastes
- High Counts indicate Greater Chance for Presence of Pathogenic Organisms
- Swimmers have Greater Risk of getting sick due to disease causing Organisms

FECAL COLIFORM SOURCES

- Livestock in confined feeding areas or in streams
- Improperly treated Sewage Sludge or Manure
- Faulty Waste-water treatment
- Untreated sewage
- Failing septic systems
- Wildlife i.e. Deer, Bear etc.
- Leaky Sanitary Landfills

Volunteer Monitors

Don Orr – Lead Monitor

Scott and Famil Cooper

Kelly Hoynonski

Gene and Jolissa Mathews

Karen Sorrel

Don and Billie Neighbors