

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

(UPDATED)

March, 2001

A Paper Prepared By the Friends of the Shenandoah River

Introduction

This paper¹ analyzes the database accumulated by the FOSR over the past three years to evaluate the health of the Main Stem of the Shenandoah River and its tributaries². The paper focuses only on water quality as indicated by water chemistry. Other important factors determining the quality of the physical habitat of the aquatic life are those of stream flow and groundwater. Stream flow is not addressed in this paper. It is however being addressed by the Minimum Instream Flow study now ongoing in the North Fork, and which eventually will also be done for the Main Stem. The quality of ground water is also not addressed in this paper. Clarke County is currently doing a ground water study.

The water quality indicators including nitrate nitrogen, phosphorus, ammonia, dissolved oxygen, acidity (pH), and turbidity (clarity) in the data base show that the river water in the Main Stem and its tributaries is generally safe for swimming, fishing and for municipal water supply although fecal coliform measurements are not included. The stream also provides a moderately healthy environment for fish and other aquatic animals. The average nutrient levels, however, are rather high -- especially for phosphorus -- and this encourages excessive growth of algae and aquatic plants during certain parts of the year. The excessive aquatic plant life eventually dies and, through eutrophication, contributes to major problems to our river and our neighbors downstream.

The levels of pollutants for parts of the year exceed the average by significant amounts. Such deviations may harm aquatic life. For example, during 1999 the level of nitrate nitrogen varied from a low of 0.11 parts per million (PPM³) to a high of 1.73 PPM at the Berryville water intake -- a multiple of more than 15. Phosphorus concentration varied from 0.09 to .7 during that year -- a multiple of about 8. It is for this reason that, although costly in consumption of volunteer time and chemical reagents and materials for the laboratory, the FOSR collects water samples every two weeks. Testing only once every quarter or half year, though saving money, could give misleading results.

Though, on average, the concentrations of contaminants in the Main Stem are tolerable, their variability is a cause of concern. For many days of the year the levels exceed tolerances. For example, the water in the Main Stem is too alkaline 61% of the time. The levels of nitrate nitrogen and especially phosphorus in the Main Stem are impaired 23%

¹ Charles Vandervoort, lead-monitor of the FOSR for the Clarke County monitoring sites prepared this report. The monitors consisting of Tim Lawrence, Bud Nagelvoort and Dan Frese provided the data for the Clarke County portion of the main stem, and the samples collected by the monitors every two weeks 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 Meryl Christianson, the Executive Director. The author wishes to acknowledge the valuable comments provided by Bud Nagelvoort, Meryl Christianson, and the other members of the FOSR who made this report possible.

² The FOSR intends to publish in the near future similar studies of the other streams in the Shenandoah River Basin.

³ For the concentrations discussed in this paper one PPM is equivalent to 1 milligram per liter in water.

and 89% of the time respectively, and phosphorus exceeds the severely impaired level 2% of the time. The water in the Main Stem is never too acidic -- thanks to the limestone rich soils - and dissolved oxygen, ammonia, and turbidity of the river water is almost always unimpaired.

In the tributaries such as Chapel Creek and Spout Run the dissolved oxygen, ammonia, turbidity, and pH are also good. But the percentage of the time that nitrate nitrogen and phosphorus levels exceed the impaired level is 80% and 49% respectively.

Besides the fact that pollution levels are too high for many days of the year, a major concern is that the trend in these pollution levels is up. This is a pity because one could have hoped that, with the institution of best management practices, riparian buffers, and other measures, the trends would be down ⁴.

For the Main Stem, the trend for nitrate nitrogen and phosphorus is increasing at annual rates of 0.06 and 0.03 PPM respectively. At these rates phosphorus (whose average level already exceeds the impaired value of 0.1 PPM) will exceed the high level of 1 PPM by the year 2018. Nitrate nitrogen will exceed the impaired level of 1.0 PPM in the year 2018.

Water quality in the runs, especially in Spout Run, is deteriorating faster than for the Main Stem. Nitrate nitrogen is rising at an annual rate of 0.43 PPM. Already at an impaired level today of more than 1.0 PPM, nitrogen in Spout Run could reach the severely impaired level of 10 PPM by the year 2020.

One of the reasons for these elevated levels is the very high concentration of contaminants discharged by the Boyce and Berryville sewage treatment plants (STPs) into the runs and the river.

At the Boyce STP the average levels for nitrate nitrogen and phosphorus are currently at 36 and 12 PPM respectively. Nitrate nitrogen is increasing at an annual rate of 18%, while the annual rate of increase for phosphorus is 20%. The level of ammonia, however, is now at a negligible level and is dropping.

The average level of contamination at the Berryville STP is lower for nitrate nitrogen (8 PPM) and phosphorus (5 PPM) than for Boyce. The trends for nitrate nitrogen and phosphorus at the Berryville STP are also less than for Boyce, but still of concern. But for ammonia both the concentration at about 6 PPM and the trend is higher. Applying better technology at both of the STPs to extract nitrate nitrogen and phosphorus before discharge into the river and runs could be usefully considered.

⁴ It is possible that the effects of non-point source nutrient reduction practices will become evident only over a long period of time so it may be premature to expect to see reductions at this time. However, point source reductions should become evident quickly.

The FOSR analysis in this paper of the quality of water in the Main Stem and its tributaries thus reveals that contaminant levels for nitrogen and phosphorus are not decreasing -- rather they are going up and some are increasing rather steeply indeed.

To prevent further harm to the river in the years to come we need to intensify efforts to protect our streams through measures such as reducing runoff from farm fields, restoring streamside forested buffers, rehabilitating stream banks, preserving forest land and discouragement of construction of impervious surfaces (asphalt parking lots), and by applying the best available technology to STPs to reduce the concentration of nutrients in their outfalls. We also need to undertake studies that relate the impact of various other human activities on the health of the Shenandoah River and its tributaries such as the amount of nitrates reaching surface waters through air pollution.

The FOSR Database

Every two weeks for the past 12 years the FOSR monitoring teams have taken water samples from the Shenandoah River and its tributaries at about 180 sites. After being collected, the water samples are immediately put on ice and delivered the same day or the next morning for analysis to the FOSR laboratory at Shenandoah University. Samples for the indicators whose quality deteriorates over time, such as dissolved oxygen, pH, and turbidity are analyzed within a few hours after being delivered to the lab.

Shenandoah University provides the FOSR laboratory space, and where the 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 chemist 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 paid lab assistants.

Operating the lab is financed from dues and donations from the FOSR members, special fund raising events, grants from local governments including Clarke County, grants from the state and federal governments and the Virginia Environmental Endowment, the 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 has recently been modernized by the addition of a \$60,000 automated testing machine (financed by a grant from the Virginia General Assembly) that will enable more rapid testing of the samples, will reduce the cost of reagents used in the analyses, and will also reduce the direct exposure of the staff to hazardous reagents such as cadmium.

The results of the analysis are tabulated on the FOSR computers and are reported to the Environmental Protection Agency and the Department of Environmental Quality to be

used in their research. These data will soon be listed on the FOSR web page, which is now under construction.

The data collected include the water quality indicators pH (acidity), dissolved oxygen, turbidity, nitrate nitrogen, phosphorus, and ammonia. At some sites data are also being collected on fecal coliform. Funding is now being sought to broaden the FOSR program by expanding tests for fecal coliform and by adding tests for toxic materials such as mercury and PCB.

The FOSR Monitoring Program in Clarke County

The Clarke County FOSR monitors check the water quality of the Shenandoah River at 11 monitoring sites. (See Exhibit 1). At four of these sites water is taken directly from the main stem. These sites are at the Route 50 bridge, Berryville water intake, Lockes Landing, and the Route 7 bridge. Five sampling sites are located on the small streams that feed into the main stem. These include Spout Run, Lewis Run, Dog Run, Page Brook, and Chapel Creek. And at two of the sites water is taken directly from the pipes that lead from the Berryville and Boyce wastewater treatment plants into the main stem. As we will see below, the quality of the water differs markedly between the mainstream, small streams, and the sewage treatment plant outfalls.

Indicators of Water Quality

Appendix 1 gives a list and brief description of the water quality indicators in the FOSR testing program. These can be divided into the three nutrients consisting of nitrogen (nitrate nitrogen), phosphorus (ortho-phosphate), and ammonia (NH₄). These are called "nutrients" because they provide food for water plants.

Nutrients in the river come from municipal wastewater, industrial wastes, and runoff from agricultural lands containing fertilizer and manure and from urban areas. Some come directly from the atmosphere itself. High concentrations of these nutrients will stimulate excessive growth of algae and 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. The depleted oxygen levels can harm fish -- especially game fish such as trout and bass -- and can even cause large fish kills, especially downstream from the Shenandoah River in the Chesapeake Bay.

Results of the Testing Program

Present Health of the Shenandoah River

Exhibit 2 presents a table giving the average quality of water in the Shenandoah River and its tributaries. This is calculated by averaging, for each indicator, all of the data collected during the three-year testing period. The table also shows the tolerances that should not be exceeded.

The averages give an interesting first impression of the health of the river. For the Main Stem, only phosphorus has an average concentration that is impaired. The average for all the other indicators is at the unimpaired level. This is good news, but somewhat misleading because the deviations from the average are large. As we shall see later, the concentration of several pollutants is at the impaired or severely impaired level for much of the year even though the average concentration is low.

Exhibit 3 shows how the concentrations of the pollutants in the main stem vary over the three year of the testing period. The average level of nitrate nitrogen in the main stem is less than .75 PPM. This is well below the level of 1.0 PPM at which the water is considered impaired. For P, the average level is about .45 PPM. This is well above the impaired level of .1 PPM. The average level for ammonia, or NH₄, is .37 PPM. This is well below the tolerance limit of 1 PPM generally considered as acceptable.

The average levels of pH, turbidity, and dissolved oxygen are quite satisfactory for the main stem. Because the streams flow through areas with much limestone, their acidity (pH) is slightly below neutral. While the average turbidity of the water in the streams is good, high turbidity numbers appear at times following storm events: this is an indication of serious erosion and runoff from land which could be prevented by better measures and policies to control storm water.

The average level of dissolved oxygen is also very good, and explains the abundance of fish and other aquatic life forms, and the significant presence of bird life such as ospreys, cormorants, and bald eagles feeding on these life forms.

The runs (see Exhibit 4) have an average nitrate nitrogen level of 1.6 PPM. This is double that for the main stem, and follows because one of the runs is the direct recipient of treated wastewater from a sewage treatment plant outfall. Ammonia is also slightly higher, but well below the critical level (the sewage treatment plant at Boyce meets its ammonia permit discharge standard. It does not have a permit limitation for nitrate nitrogen discharge.)

The level of contaminants in the sewage treatment plant outfalls (see Exhibit 5), not surprisingly, is very high. The average level of the present concentrations taxes the

dilutive powers of the main stem and the runs as evidenced by the excessive growth of algae and other aquatic vegetation appearing in the summer.

Exhibit 6 shows the time series for the data on DO, pH, and turbidity. The average values are good though there are a few large deviations which represent considerable erosion and consequent silt and sediment pollution. Heavy rains cause the steep rise in turbidity from time to time. The same is true for the nutrients. During heavy rains their runoff can be very considerable. As cited in a recent report⁵ the June 1996, spring flood from heavy snow melt carried an estimated 3,300,000 pounds of nitrogen into the Potomac river. Hurricane Fran in September of that same year also caused major erosion damage and nitrogen runoff.

Deviations from the Average

Exhibits 3 - 5 show the large variability of the data over time. For example, at the Berryville water intake the level of nitrogen over the past three years varied from a low of 0.11 parts per million (PPM) to a high of 1.73 PPM -- a multiple of more than 15. It is for this reason that, although costly in consumption of volunteer time and chemical reagents and materials for the laboratory, the FOSR collects water samples every two weeks. Testing only once every quarter or half year, though saving money, could give misleading results.

Exhibits 7 for the main stem and 8 for the runs show the percentage of the time that the indicators are at the unimpaired, impaired, and severely impaired levels. The exhibits show that, for the main stem, the level of phosphorus is impaired 89% of the time. Phosphorus exceeds the severely impaired level 2% of the time. Such a high level of phosphorus may explain the unsightly white and gray foam often seen floating in the main stem. Verifying this relationship would make a good research topic.

The nitrate nitrogen levels for the main stem are better than for phosphorus. Nitrate nitrogen is at the impaired level 23% of the time, and is never severely impaired.

Though at times too alkaline, the water in the main stem has not been shown to be too acidic -- thanks to the limestone rich soils - and dissolved oxygen, ammonia, and turbidity of the river water, except for turbidity spikes indicating serious erosion problems, are almost always unimpaired.

For the streams such as Chapel Creek and Spout Run the concentrations of dissolved oxygen, ammonia, pH, and turbidity of the water are good most of the time. But nitrate nitrogen is at the impaired level 80% of the time. This is somewhat higher than that for the main stem.

⁵ Scott W. Ator et al "Water Quality in the Potomac River Basin: Maryland, Pennsylvania, Virginia, West Virginia and the District of Columbia, 1992-1996," USGS Circular 1166, 1998.

The percentage of time that phosphorus is at the impaired level (49%) is much lower than for the main stem (89%). It is not clear why, though the average concentration for phosphorus in the runs is higher, the variability is lower. Since the volume of water in the main stem is much higher than that for the runs, one would expect it to be the other way around. This, in fact, is the case for nitrate nitrogen.

It is not known how serious it is to have a temporary high reading for a certain indicator, such as nitrate nitrogen. It will depend a lot on how "temporary" the reading is. It should be noted that the water samples are taken at two-week intervals. Thus, a high reading on the day of sampling could mean that the concentration was high for as much as two weeks before the sampling, and stayed high for two weeks afterwards. Thus, a high reading could mean that the river was out of tolerance for a whole month. This could have a pronounced effect on aquatic life.

The Trends

The graphs in the preceding exhibits show that, despite the variability of the data, there seem to be definite trends. And most of the trends seem to be up. This section applies statistical techniques to calculate the trends in water quality.

Trend lines based on least squares linear regression were fitted to a number of the graphs. Such trends are known as "straight line" fits. They are of value in that they cut through the scatter of data points to give the mathematically correct estimate of rates of increase or decrease over time for variables that behave very irregularly.

Exhibit 9 shows the trend lines for nitrate nitrogen and phosphorus for the monitoring site located at the mid-point of the main stem at the Berryville water intake (FC-04). (The trend for NH_4 is not calculated since it is clearly down). The phosphorus concentration is increasing at a rate of .03 PPM (about 7%) each year. This is a fairly high rate and since it is starting from a high and already impaired base level of about .37 PPM, the severely impaired level of 2 PPM will be exceeded in another 40 years or so.

For nitrate nitrogen, the annual increase is .06 PPM (also about 7%) from a base level of .61 PPM. At this rate nitrate nitrogen will exceed the impaired level of 2 PPM in another 20 years. As with phosphorus, it will take about another 40 years for nitrate nitrogen to reach the severely impaired level of 10 PPM.

For the runs, only the trend for nitrate nitrogen is on the increase. Exhibit 10 shows the detailed trends for Spout Run, a run strongly influenced by effluent from the Boyce STP. The concentration for nitrate nitrogen is increasing at about .43 PPM per year. Starting from a base of about 2.8 by the end of the year 2000, it will take less than twenty years for the nitrogen concentration in that run to exceed the critically impaired level of 10 PPM. Fortunately, the trends for phosphorus and NH_4 are down.

Exhibit 11 shows the concentration of Nitrate Nitrogen, Phosphorus, and Ammonia at the Berryville Sewage Treatment Plant (STP) outfall since January 1997 to August 2000. The samples are collected directly from the pipe that discharges into the main stem of the Shenandoah River. Not surprisingly, the levels of N, P, and ammonia in the outfall are well above the levels that would be tolerated in the main stem of the Shenandoah River and the streams that feed into it. The enormous flow of the River dilutes these contaminants in a mixing zone to levels, which the State permits, at least during non-drought conditions.

There is concern, however, that the trends (the red lines) seem to be increasing at rapid rates for all three contaminants. This is especially true for nitrate nitrogen where the concentration increases by about 4.4 PPM (29%) each year. (The last reading for nitrate nitrogen in June 2000 was 15 PPM. And the annual increase as given by the trend line is 4.4 PPM, or 29%).

For phosphorus and ammonia the annual increase is about 25% and 44% respectively. Since the outfall of the Berryville STP pours directly into the main stem, the pollution -- if allowed to continue unchecked -- will increase even more rapidly than indicated in the linear trend lines.

As a side note, the very sharp and increasingly high peaks that occur for ammonia during the late-winter and early spring of each year are interesting. The cause and significance of this phenomenon warrants further investigation. It probably occurs because the State permit does not require ammonia reduction during the winter months so the town saves money by not aerating as much in the winter and that reduces the oxidation of ammonia to nitrate nitrogen. The rationale is that the presence of ammonia in the River in the winter will not significantly impact DO at that time because of the capacity of cold water to hold more DO.

Exhibit 12 shows that the concentrations of nitrogen, phosphorus, and ammonia in the Boyce STP outfall are significantly higher than those for Berryville. The Boyce outfall discharges into Roseville Run, a short tributary of Spout Run. Spout Run, in turn, flows for about five miles through mixed cattle and crop area before discharging into the main stem. At the Boyce STP the levels for nitrate nitrogen and phosphorus are currently at 70 and 15 PPM respectively. Nitrate nitrogen is increasing at an annual rate of 18%, while the annual rate of increase for phosphorus is 20%. The level of ammonia, however, is now at a negligible level and is dropping because Boyce aerates its waste water to oxidize ammonia.

A Comment on Trend Lines

It must be noted that trend lines based on straight-line extrapolations, though useful, are only indicative. They are useful in providing a signal that, unless something is done now

or soon, there may be problems ahead. For example, the trend lines clearly show that nutrients such as nitrogen and phosphorus are not diminishing as many of us had hoped.

But a weakness of the trend lines is that the only factor being considered is that of time. Therefore, the extrapolations are valid only under the assumption that nothing changes except time. In reality, of course, there are many other factors that can explain the degree of pollution of the Shenandoah River.

Some of these are the percentage of urbanization and impervious surfaces in the area through which the stream flows. Others, to mention just a few, are the degree of success of "best management practices, BMP"⁶ applied by farmers; the extent of factories, coal mines, and power plants, the presence of riparian buffers, new technology that can be used by waste treatment plants, and the long-hoped-for new technology that reduces consumption of fossil fuel by transport vehicles and electric generating plants.

A multiple regression or factor analysis approach that takes these other factors into account can shed much insight on how much each of these factors contributes to the problem of pollution. With this knowledge it will then be easier to efficiently set criteria and priorities for water quality regulatory programs.

Next Steps

What can be done to reverse the adverse trends in water quality? Much is already being done by expanding and intensifying current efforts aimed at promoting programs for BMPs, encouraging planting of riparian buffers, improving the efficiency of STPs to reduce the nitrogen and phosphorus content of their outfall, educating the public on the need to preserve trees and minimize impervious surfaces, and reducing the emission pollutants from transport vehicles and fossil fueled electric generating plants. However, these efforts have to become more efficient and more targeted if we are to make real headway in halting the increasing trend in pollution.

We also need to develop a better understanding of the importance, with regard to the Shenandoah River, of those factors that cause pollution. For example, nitrate nitrogen in the Shenandoah River already at an average level of .65 PPM is very close to the impaired level of 1 PPM. How much of this is contributed by runoff from farm fields, how much by the STPs, how much from urbanization, etc.? Right now we do not have a complete answer to this question⁷, and can not therefore set priorities for remedial actions. In this respect we are far behind the State of Maryland which in a recent study⁸ on the condition of freshwater streams in Maryland developed data on human activities which have the most effect on streams, and where

⁶ BMP - The most effective management practices for converting or reducing the amount of pollution generated by non-point sources, such as farmland.

⁷ We do have some indications since DEQ provides an indication of discharges from STPs and the VA Trib Strategy estimates the amounts coming from non-point sources.

⁸ EPA and State Of Maryland Department of Natural Resources, 1999, From the Mountains to the Sea: The State of Maryland's Freshwater Streams, EPA/903/R-99/023.

these activities are most pronounced. The information developed in that study can be used as a tool for planners for developing policy, and for targeting areas for restoration and preservation.

Developing such a model is, of course, a daunting task that is well beyond the financial and professional resources of volunteer organizations such as the FOSR. It must be done by a combined effort of State and Federal organizations assisted by the local volunteer groups such as the FOSR.

It should be noted that the Minimum Instream Flow study currently being undertaken by the USGS and VA Tech on the North Fork is addressing some of the important aspects of the physical habitat question. In time, the MIF study will be extended to the South Fork and the main stem.

The condition of the groundwater is also an important factor that must be studied. In this area we are better off because Clarke County, in a separate effort, is examining the quality and reliability of groundwater. Because of the very large reliance placed by the citizens of Clarke County on wells, the importance of that study cannot be overemphasized. Furthermore, much of the region's groundwater trickles into and provides the base flow of the Shenandoah River. Understanding the groundwater situation can therefore explain much of what is happening to the quantity of water in the Shenandoah river.

APPENDIX 1: WATER QUALITY TESTS

INDICATORS

- ◆ Nitrate-Nitrite
- ◆ Phosphate
- ◆ Ammonia
- ◆ pH
- ◆ Turbidity
- ◆ Dissolved Oxygen (DO)
- ◆ Temperature
- ◆ Fecal Coliform

NITRATE-NITRITE

- ◆ reported as PPM of nitrite
- ◆ promotes excessive algae and aquatic plant growth.
- ◆ high values of 10 PPM can cause, blue babies, and abortion of fetuses in cattle.
- ◆ the 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 0.5ppm is High
- ◆ Causes Excessive Algae Growth
- ◆ Decreased DO
- ◆ Usually associated with high Turbidity
- ◆ Water Discoloration

PHOSPHORUS SOURCES

- ◆ Human, Animal and Industrial Waste
- ◆ Sewage from Wastewater Treatment Plants and Septic Tanks
- ◆ Soil Erosion from Farming (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
- ◆ Less than 1 PPM normal
- ◆ 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 household ammonia
- ◆ Preferable range 6.5 to 8.0
- ◆ Values below 6.0 (very acidic) considered harmful to aquatic life
- ◆ Affected by acid rain, 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
 - 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
 Absorbed directly into water from atmosphere and aquatic plants
 Values above 5mg/L best
 Values below 5mg/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 in the feces of Humans and other Warm Blooded Animals
- ◆ Most E-coli not Pathogenic, only an indicator organism that water is contaminated with sewage

- ◆ High Counts have Greater Chance for Presence of Pathogenic Organisms
- ◆ Swimmers have Greater Risk of getting sick due to disease causing Organisms

FECAL COLIFORM SOURCES

- ◆ Livestock pens
- ◆ Wildlife i.e. Deer, etc
- ◆ Sewage Sludge
- ◆ Sanitary Landfills
- ◆ Faulty Waste-water treatment
- ◆ Untreated sewage
- ◆ Failing septic systems

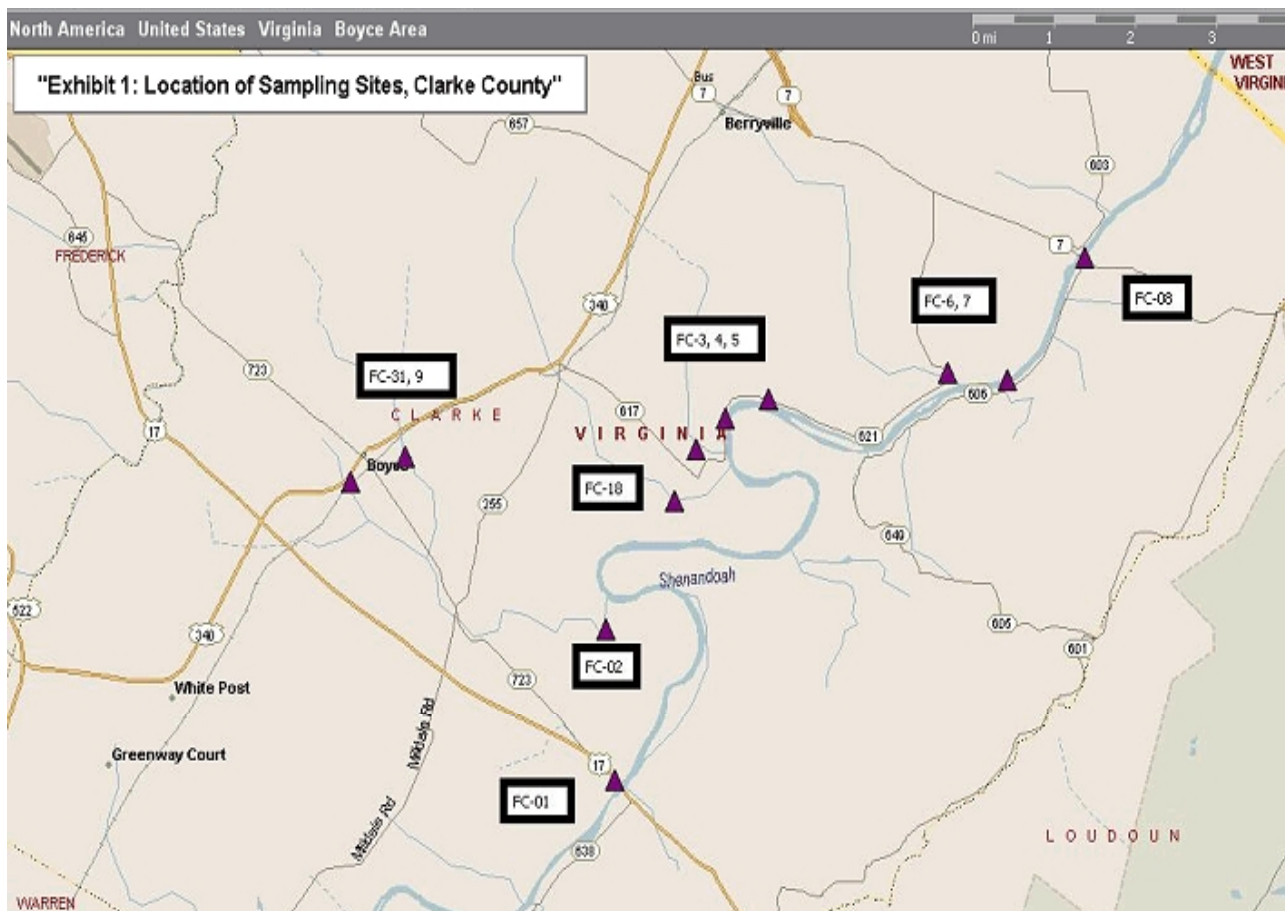
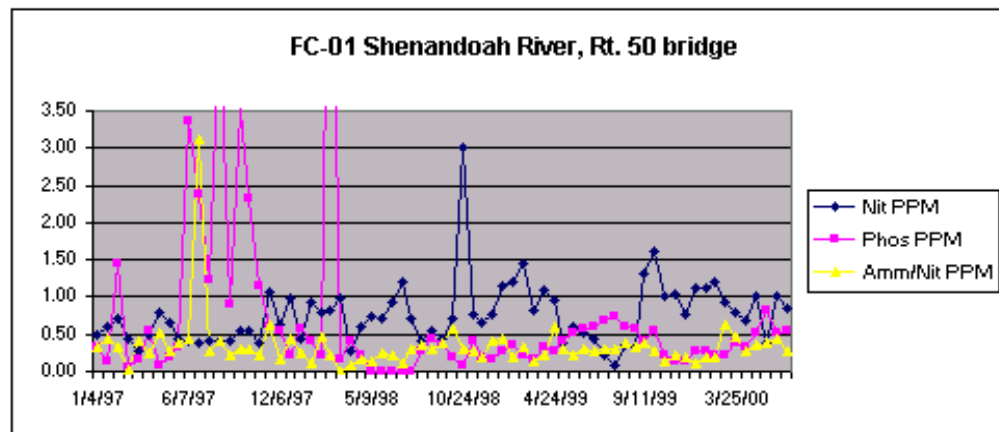


Exhibit 2 - Average quality of water in the Shenandoah River and its tributaries.

Site ID#	Average	Nit PPM	Phos PPM	Amm/Nit PPM	pH	Turb, NTU	DO, PPM
Main Stem							
FC-01	AVG	0.75	0.35	0.37	8.20	3.90	10.02
FC-04	AVG	0.61	0.37	0.37	8.20	3.91	9.94
FC-05	AVG	0.61	0.37	0.37	8.19	3.91	9.98
FC-08	AVG	0.61	0.37	0.37	8.19	3.91	9.98
Grand Average, Main Stem		0.65	0.36	0.37	8.20	3.91	9.98
Runs							
FC-02	AVG	1.20	0.30	0.46	7.58	3.51	8.61
FC-03	AVG	1.18	0.31	0.46	7.57	3.53	8.57
FC-18	AVG	1.27	0.14	0.34	7.53	1.75	8.49
FC-06	AVG	1.16	0.31	0.46	7.56	3.51	8.51
FC-09	AVG	1.15	0.27	0.41	7.48	2.54	8.57
Grand Average, Runs		1.19	0.27	0.43	7.54	2.97	8.55
Outfalls							
FC-07	AVG	25.22	9.06	5.64	7.65	5.60	7.54
FC-31	AVG	36.46	11.77	4.12	7.94	4.16	8.10
Grand Average, STP		30.84	10.41	4.88	7.80	4.88	7.82
		Nitrogen	Ortho-Phosphate	Ammonia	pH	Turbidity	DO
Unimpaired Water		< 1.0 PPM	< 0.1 PPM	< 1.0 PPM	6.5 to 8 preferable	0 - 4 Clear	< 5 Bad (no fish)
Impaired		1.0 to 10.0 PPM	0.1 to 2.0 PPM	≥ 1.0 PPM	< 6.5 Too acid	4-7 Fairly clear	5 - 8 Good (Bass, etc.)
Severely impaired		> 10.0 PPM	> 2.0 PPM		> 8 Too alkaline	> 7.0 Cloudy	> 8 Excellent (Trout)

Exhibit 3 - Concentrations of the pollutants in the main stem vary over the three year of the testing period.

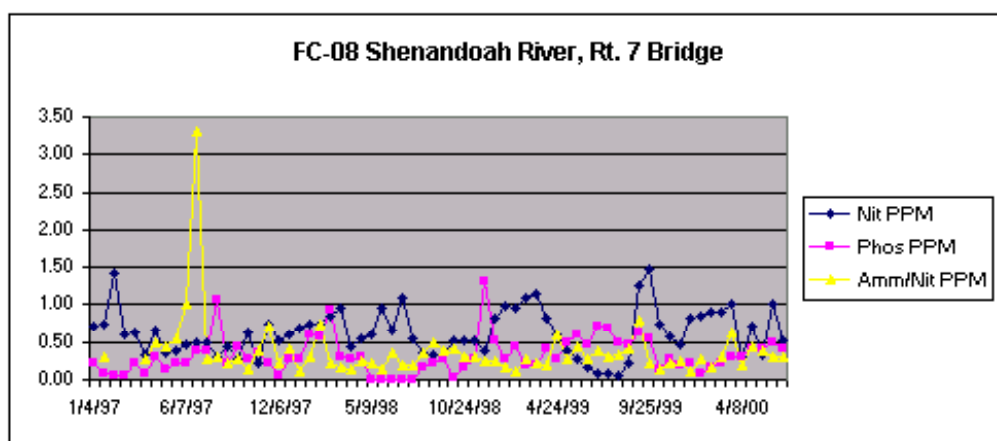
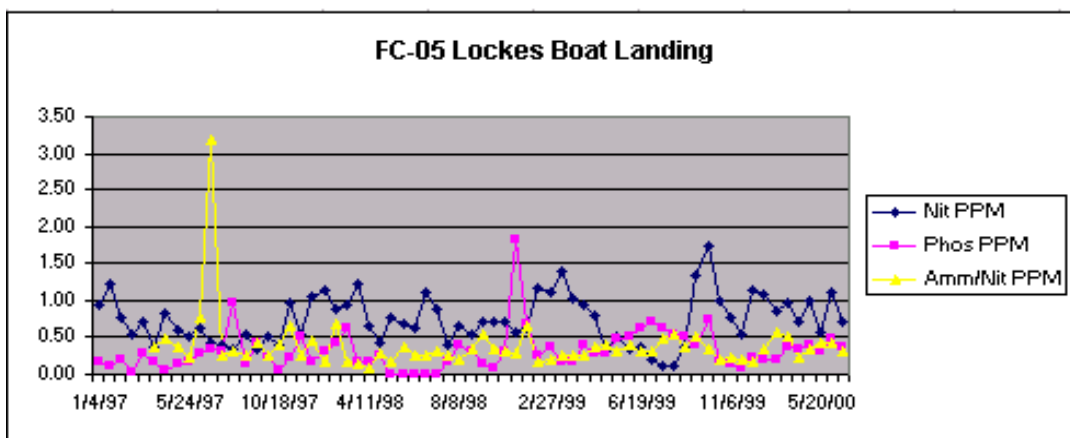
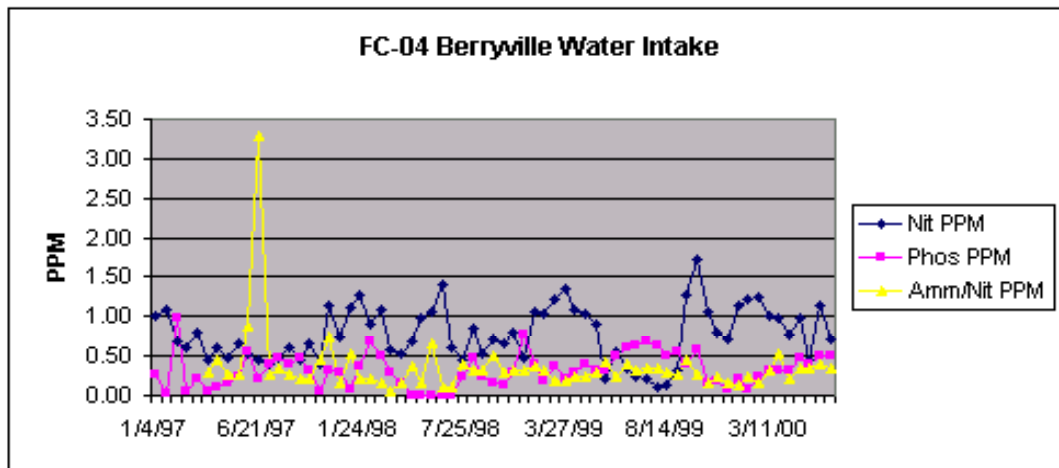
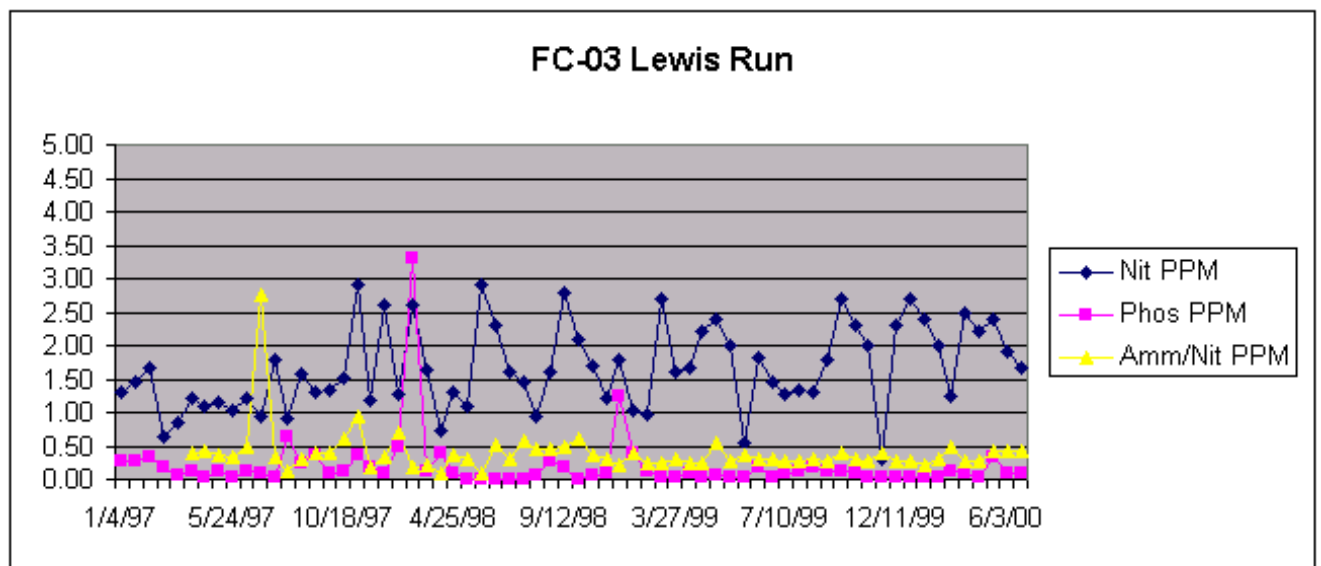
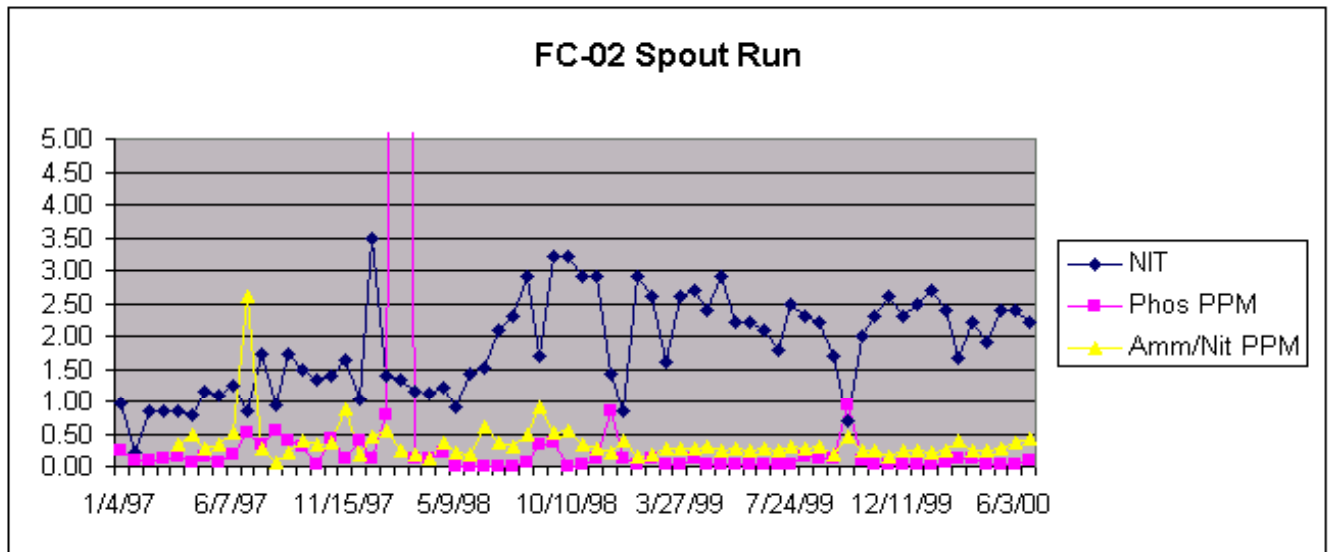
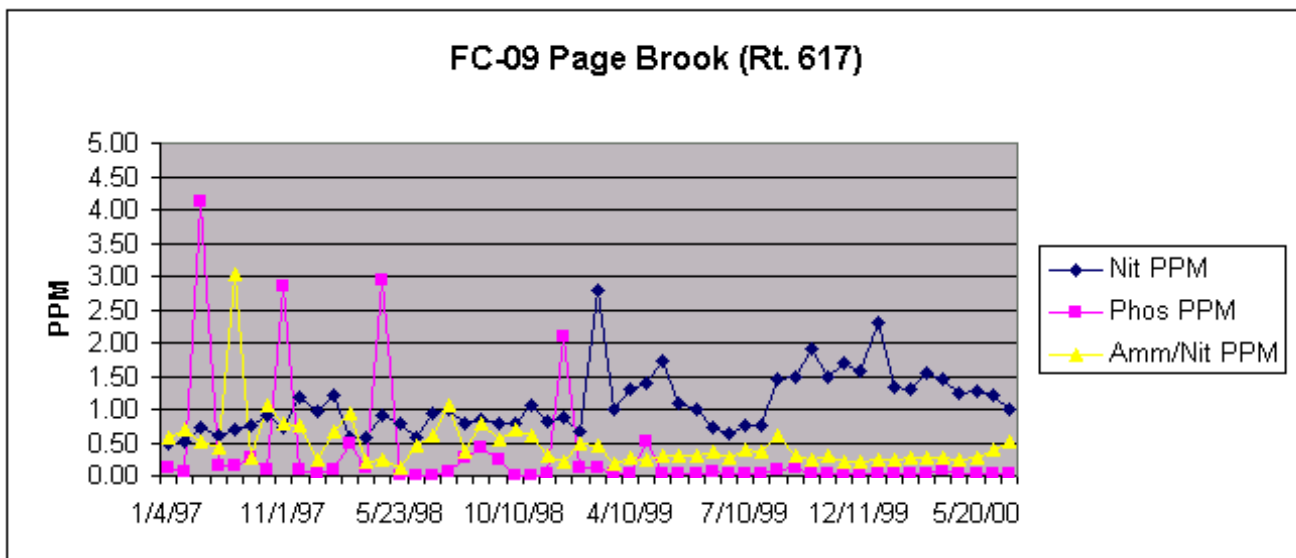
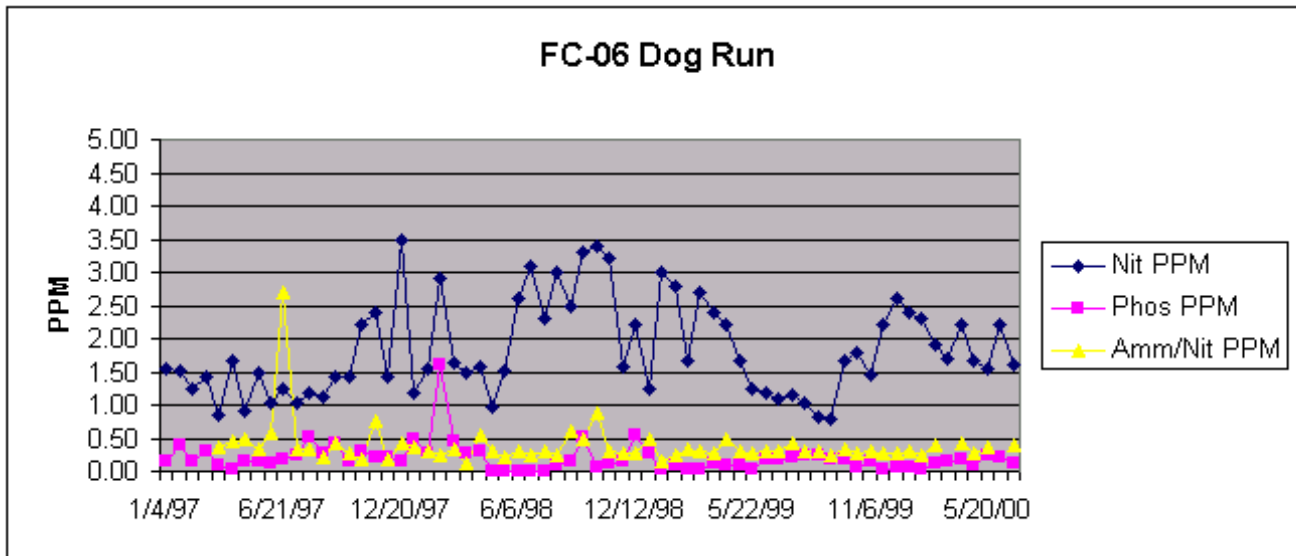


Exhibit 4 - Runs have an average nitrate nitrogen level of 1.6 PPM.





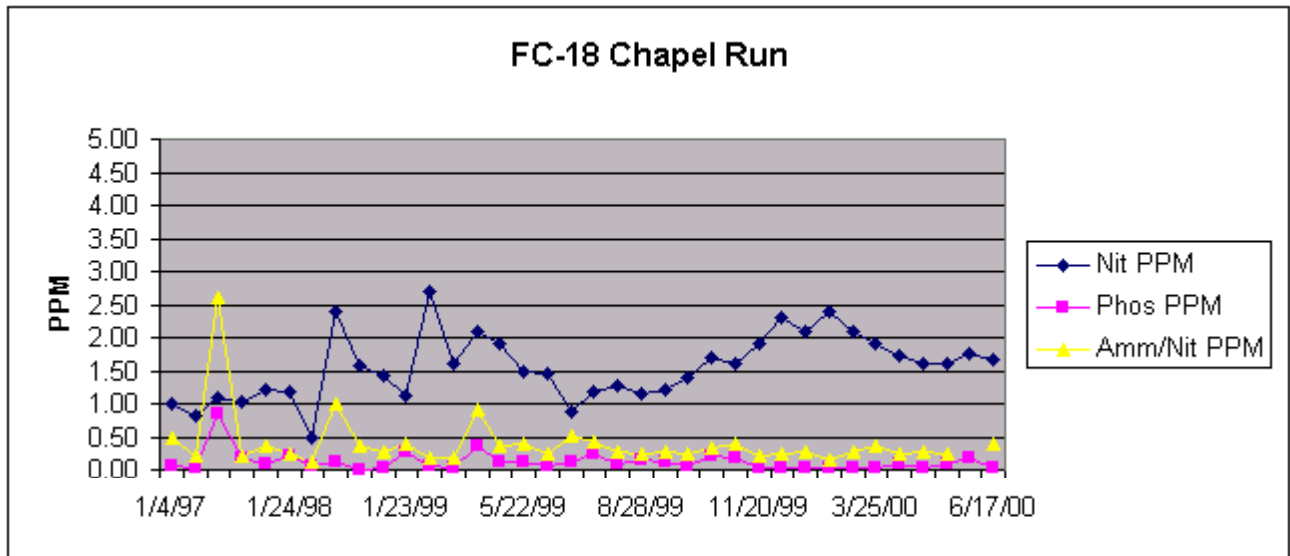
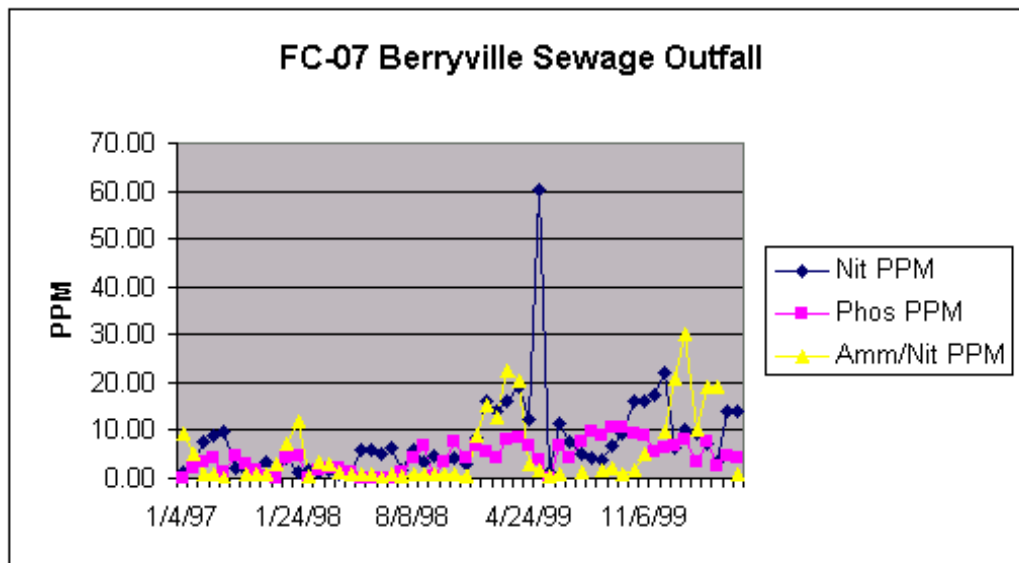


Exhibit 5 - The level of contaminants in the sewage treatment plant outfalls is very high.



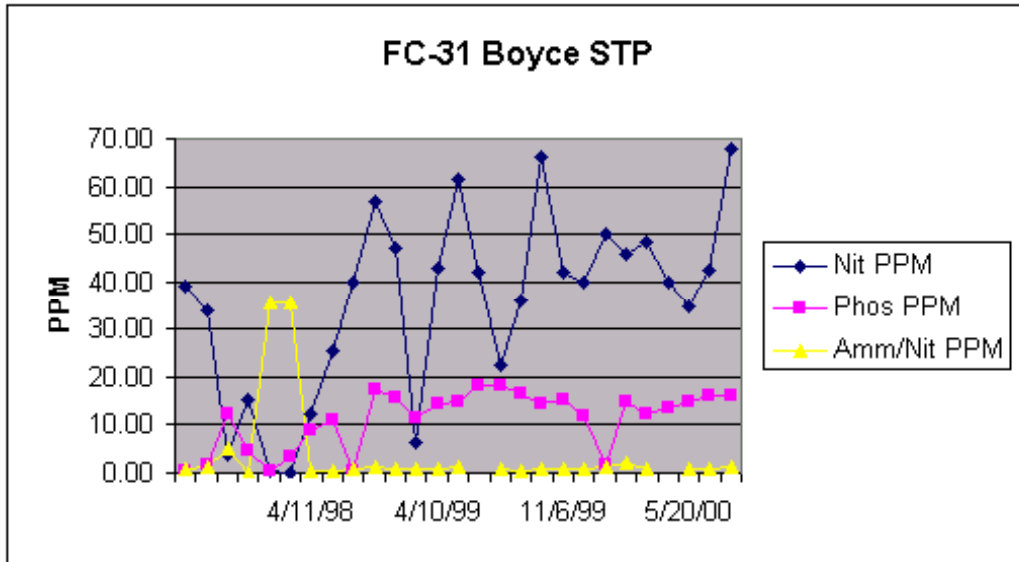
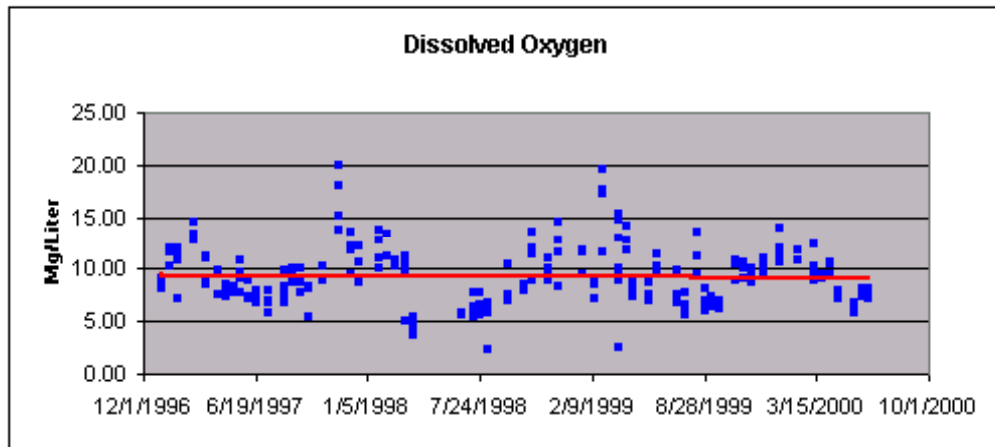


Exhibit 6 - Time series for the data on DO, pH, and turbidity.



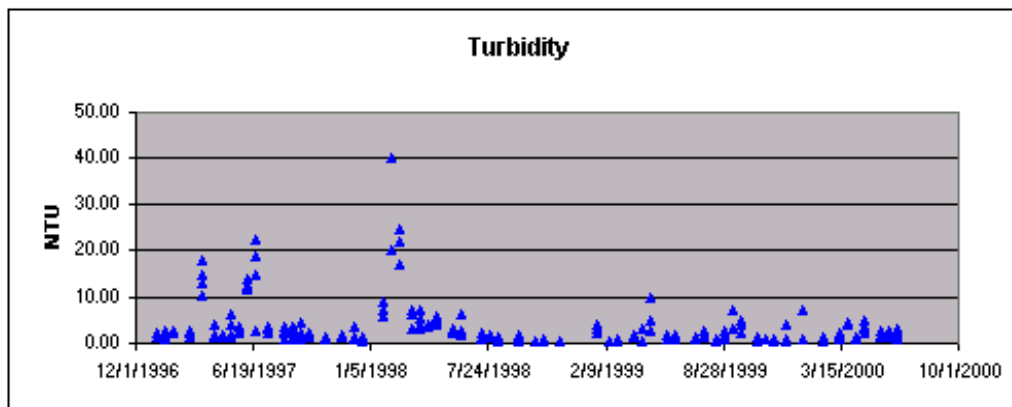
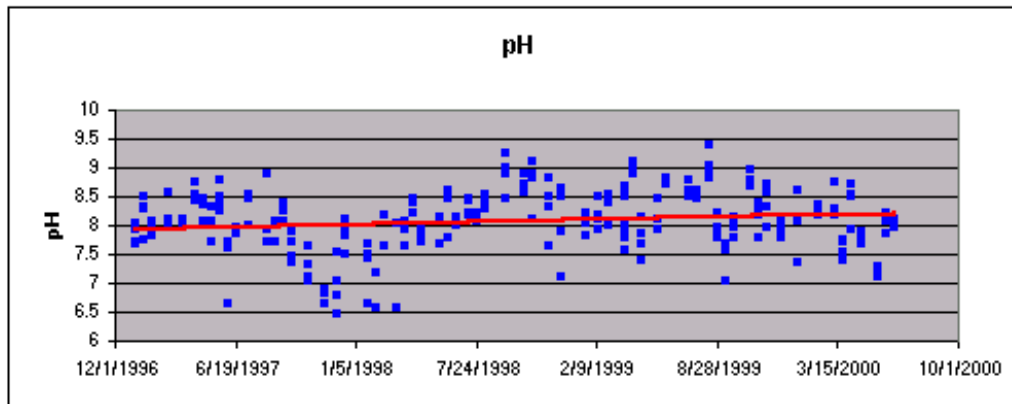
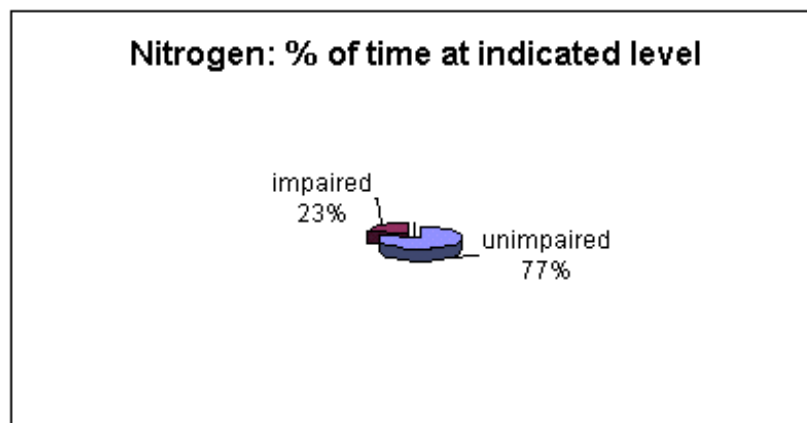
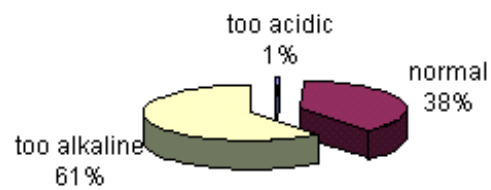
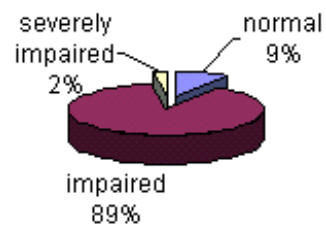
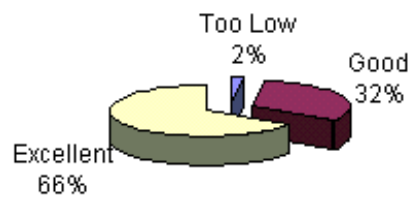


Exhibit 7: MAIN STEM - Percentage of time during the last three years the water quality measures were at the indicated level.



Ph: % of time at indicated level**Phosphorus: % of time at indicated level****Dissolved Oxygen: % of time at indicated level**

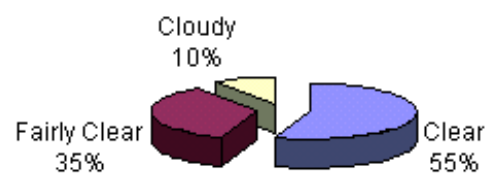
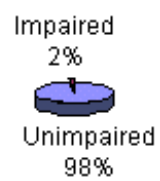
Turbidity: % of time at indicated level**Ammonia: % of time at indicated level**

Exhibit 8: RUNS - Percentage of time during the last three years that water quality indicators were at the indicated level

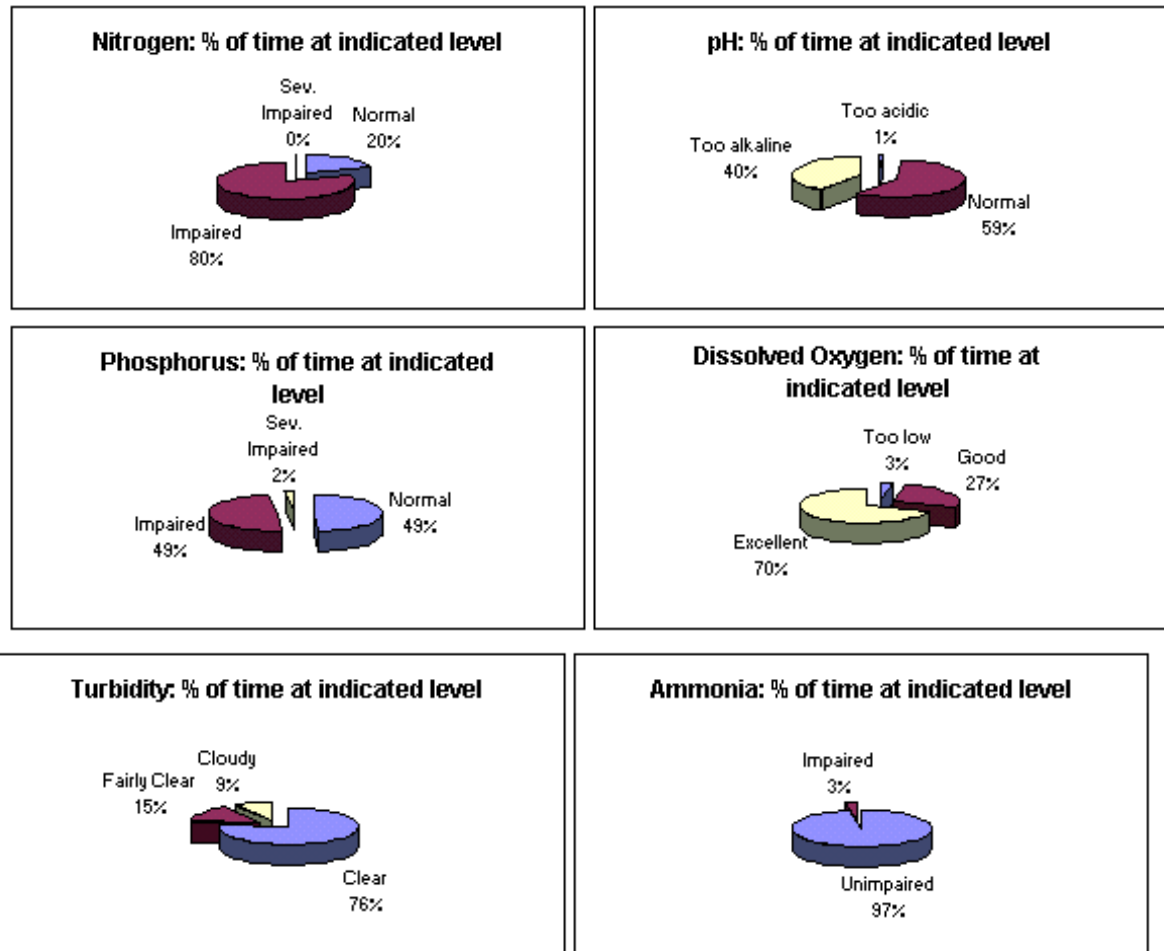
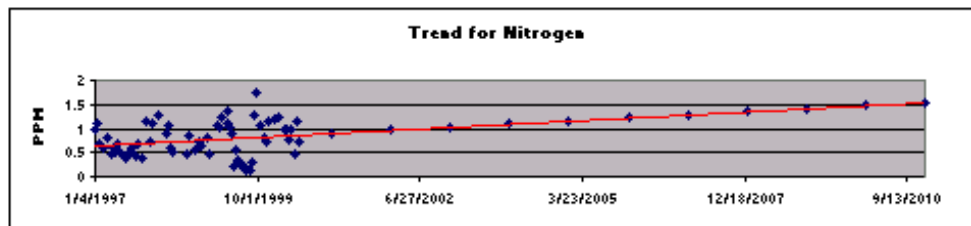
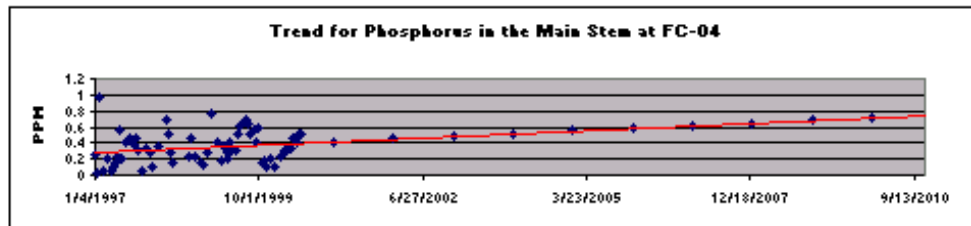
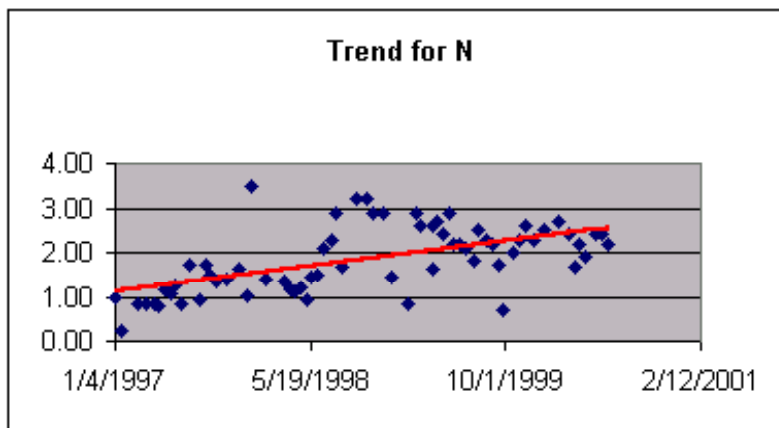


Exhibit 9 - Trends for N and P in the Main Stem at the Berryville Water Intake (FC-04)**Exhibit 10 - Trends for N, P, and NH4 in Spout Run (FC-02)**

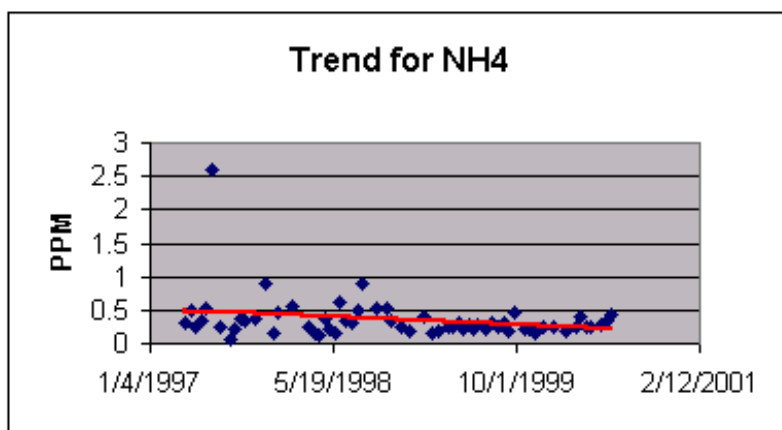
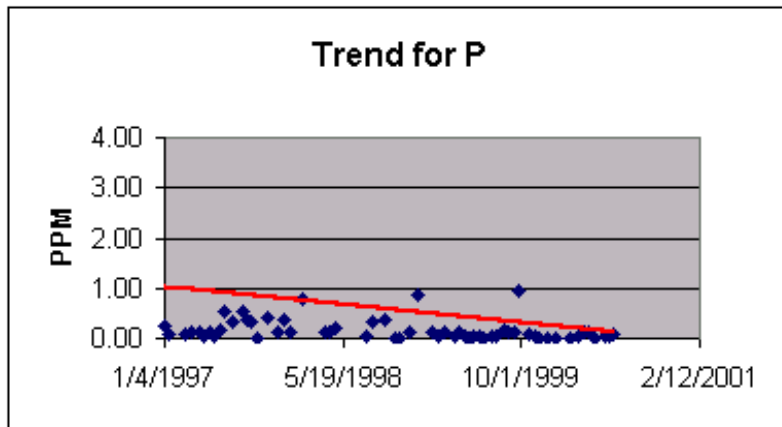


Exhibit 11 - Concentration of Nitrate Nitrogen, Phosphorus, and Ammonia at the Berryville Sewage Treatment Plant (STP) outfall since January 1997 to August 2000.

