

II. WATER QUALITY PRIMER

West Virginia is known for its high quality rivers and streams. These waters generate income for the State and provide recreational opportunities for residents and tourists, as well as water for drinking, irrigation, and industry. In order to protect this vital resource, state and federal agencies and other organizations conduct water quality studies to determine the characteristics of the water and identify waters in need of improvement. The quality of every stream's water is affected by natural factors such as geology, soils, and forest type. They can also be impacted by the activities of people, and it is human effects that are, in excess, described as pollution.

How much of a substance is needed for it to be considered pollution? A typical definition would be the amount of a man-made or man-induced substance needed to cause harm to the environment or to human health. Water quality standards are designed to prevent these harms based on the best available science. Therefore, where water quality standards exist, by definition, water is polluted if the amount of that substance exceeds the standard. Two of the parameters in this report; fecal coliform bacteria, and ammonia-nitrogen, have water quality standards.

Where relevant water quality standards do not exist, however, the term pollution is problematic. This report discusses two nutrients; nitrate-nitrogen, and phosphorus, which do not yet have relevant water quality standards. While a drinking water standard exists for nitrate-nitrogen (10 mg/l), it relates to a level of concern for human health, and no standard currently exists in West Virginia (WV) relevant to nutrient levels that cause environmental harms. WV is currently developing such criteria for nutrients through a statewide Nutrient Criteria Committee process that has proposed the following definitions of impairment (NCC, 5/29/2003):

“A water of the State is impaired by nutrients if nitrogen, phosphorus, or a resulting water quality characteristic prevents attainment of a designated or existing use. In particular:

- Category A - Public Water Supply. A water of the State fails to attain this use if nutrients directly or indirectly threaten human health, produce unacceptable taste or odor of the water, or unreasonably impact conventional treatment (i.e.: settling and disinfection).
- Category B - Propagation and maintenance of fish and other aquatic life. A water of the State fails to attain this use if nutrients directly or indirectly cause a shift in community integrity. A shift in community integrity is defined as increasing or decreasing the relative abundance of species or diversity of indigenous communities of fish, shellfish, other aquatic life, or wildlife - outside the normal range of variability.
- Category C - Water contact recreation. A water of the State is impaired if nutrients directly or indirectly cause nuisance algae, unacceptable water clarity, unacceptable odor, or unacceptable microbial growth.”

Until objective water quality standards for nutrients based on harm to a designated use are established, it may be inappropriate to discuss nutrient concentrations in terms of “good” or “bad” levels; so this report discusses nutrients as “higher” or “lower” in relation to findings in other sites and to the overall WV Department of Agriculture (WVDA) dataset.

The nutrients and bacteria of concern in this study can enter our streams in any number of ways, but in general they can be described as coming from either a **point source** or a **non point source**. A point source has an easily identifiable human cause, like a factory or a sewage treatment plant, and pollution from a point source enters the environment at a clearly identifiable location, such as a pipe or a

smokestack. The flow of pollutants from point sources is usually regulated by the State and Federal governments, is fairly constant and predictable, and control measures can be applied at the source.

Non-point sources of nutrients and bacteria are basically those human affects that do not flow from a concentrated source that requires a permit. Non point sources include streets, parking lots, lawns, farm-fields, barnyards, and construction sites. The flow of pollutants from non-point sources to streams is very unpredictable, difficult to control, and mostly occurs due to rain and snowmelt washing the surface of the land and saturating soils.

There are two main methods scientists use to assess water quality – **concentration** and **load**. Concentration is a measure of how much of some substance is found in a certain volume of water - often expressed as milligrams per liter (mg/L) or parts per million (ppm). Water quality standards are principally designed to protect people and aquatic life, and are based on harmful concentrations of a pollutant. For example, the nitrate (a form of nitrogen) standard for drinking water is 10 ppm because larger amounts than that have been linked to health concerns. Concentration is most useful in assessing local impacts, impacts that affect the people and environment in the watershed where pollutants are generated.

The load is the total amount of a substance that passes by some point in a certain amount of time - as in pounds per hour or tons per year. The load is calculated by multiplying the concentration by the total volume of water flowing at the time the sample is collected, so load requires an accurate measure of water volume as well as concentration. While water quality standards are not based on load, total load can be the most relevant way to determine the potential impacts of non-point source pollution. This is because major non point pollution events may occur rarely (usually due to heavy precipitation), the total amount of pollution delivered during these events may greatly exceed the sum of the loads delivered at all other times.

The load is often used in assessing downstream impacts, impacts that affect the people and environment downstream of where the pollutants are generated. WV is currently working to reduce nutrient and sediment loads that originate in WV's Potomac watershed region and contribute to the impairment of the Chesapeake Bay. If WV's strategy to reduce existing loads fails to achieve the necessary reductions by the year 2010, the USEPA will begin the Total Maximum Daily Load (TMDL) process and place significant additional restrictions on pollution sources in WV.

The TMDL process is a mathematical tool for assessing pollution. This process is triggered when waters fail a State's water quality standards: i.e. when the waters are impaired. Under the Clean Water Act Section 303(d), states are required to develop lists of impaired waters. Seven rivers in WV's Potomac Highlands -- the Lost River, South Branch of the Potomac, North Fork of the South Branch, South Fork of the South Branch, Mill Creek, Lunice Creek, and Anderson Run --were on the 303(d) list due to fecal contamination when WVDA began its sampling program. The law required that TMDLs be developed for these waters. A TMDL determines the pollutant loads that a water body can assimilate without violating water quality standards, and then allocates those loads to point source and non point source categories based on the best available science. Once established and approved through regulatory action, TMDLs are implemented through both regulatory and non-regulatory programs. Or, more simply, a TMDL provides a pollution budget for a watershed that allocates the amount each pollutant source is allowed to release while still attaining water quality standards.

1998 – 2004: A Region in Flux

The primary purpose of the WVDA Potomac Headwaters Water Quality Monitoring Program was to collect sufficient data to accurately establish the condition of the WV Potomac Highland's rivers and



streams. The program began in 1998 and continues today; this report covers data collected during the period from July 1998 until June 2004. The Potomac Headwaters region during this time experienced changes that had the potential to impact study results, including hydrological conditions, a changing agricultural scene, and growth. This section describes these factors.

Hydrologic condition.

Many of the potential sources of nutrients and bacteria in the Potomac Highlands are non point in nature and it is precipitation in the form of rainfall or snowmelt, in most cases, that mobilizes non point source pollutants. That relationship can be as simple as the direct washing of nutrients and bacteria off the land into a stream via surface runoff, in which case increased concentrations are tied directly to precipitation. Some constituents, such as nitrate-nitrogen, once mobilized by precipitation may infiltrate the ground before moving into streams. Where non point source pollution is impacting water quality after passing through soil there is a much more complex relationship between precipitation and concentration. Of course, not all precipitation causes runoff or significant infiltration. Increased concentrations depend on hydrological conditions that are always in flux including, but not limited to; intensity, frequency, and duration as well as the proximity of precipitation to the stream; type of ground cover, and soil moisture; and a dynamic host of seemingly “non hydrological” conditions such as temperature, soil compaction, and topography. Stream flow is a reasonable measure of the hydrologic condition of a watershed because it represents conditions after the stream has integrated all of the above factors.

Stream Flow, a factor of the volume and speed of a stream, is often measured in cubic feet per second (cfs).

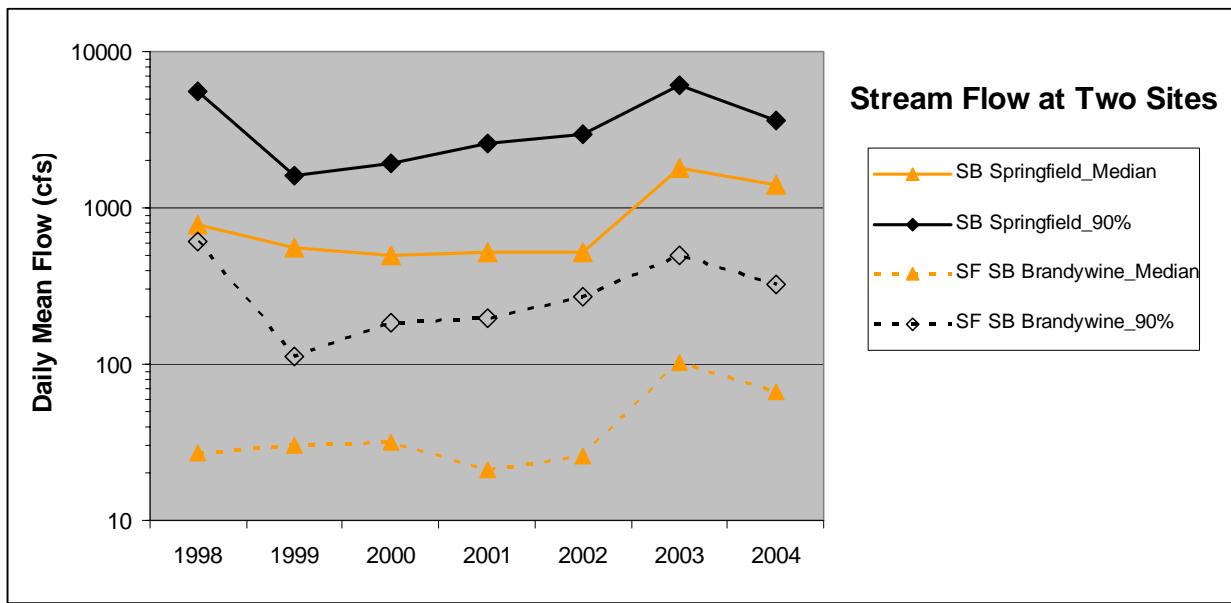


Figure 5. Annual USGS Daily Mean Stream Flows for South Branch and South Fork 1998-2004.

Figure 5 provides yearly stream flow statistics for two USGS flow stations in the study area (USGS, 2006) during the 1998 to 2004 study period; the graphs include data from January of 1998 through September of 2004. One site, the South Branch of the Potomac River at Springfield, WV, has a watershed area of 1486 sq. mi. The other site, the South Fork of the South Branch at Brandywine, WV,



has a much smaller watershed area of 103 sq. mi. They are representative of the broad range of both watershed size and geographic area of watersheds within the Potomac highlands. The statistics shown for each site are the yearly median and 90th percentile. While the flow in the larger watershed is much higher than in the small watershed, the year-to-year 90th percentile patterns are quite similar. The difference in median patterns may relate to the difference in hydrologic behavior of small streams that are relatively “flashy” (i.e.: they rise and fall quickly) and large streams that respond more slowly to changing conditions. Median flows were relatively low and varied narrowly from 1998 to 2002 at both sites. The lowest median flow at the Brandywine site was 21 cfs in 2001, the lowest at Springfield was 502 cfs in 2000. Median flows jumped sharply in 2003 to 102 and 1780 cfs at Brandywine and Springfield, respectively, and remained high in 2004. The pattern exhibited by the 90th percentile of yearly flows was quite different, beginning with high values in 1998, a sharp drop in 1999 followed by a slow rise through 2002 and then a distinct increase in 2003 and 2004 that mirrored medians.

The 90th percentile is a useful indicator of the magnitude and frequency of high flows. Ten percent of the daily mean flow measurements exceed this value.

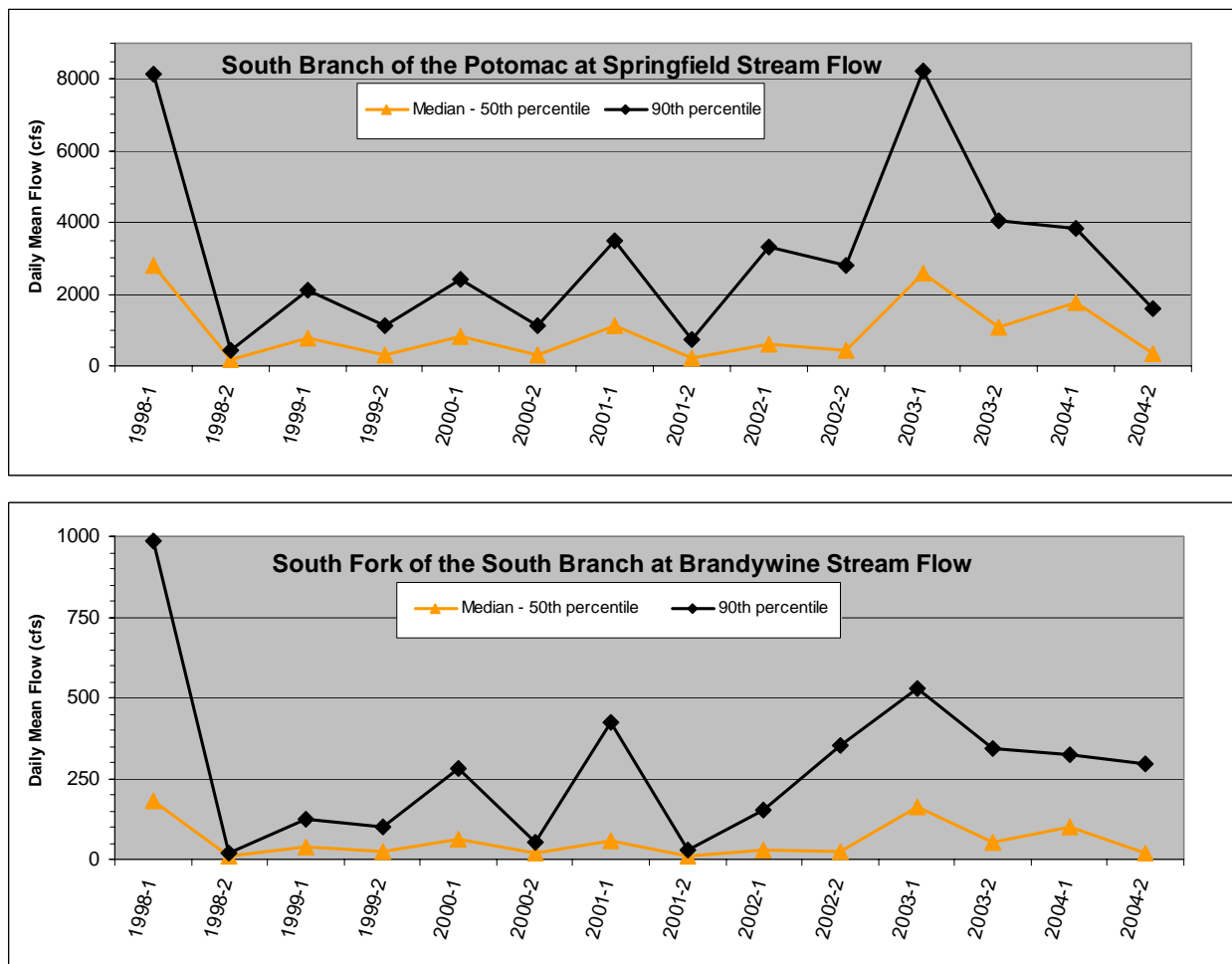


Figure 6. Biannual USGS Daily Mean Stream Flows for South Branch and South Fork 1998-2004.

A closer look at stream flow trends during the sampling period reveals a complex pattern (Figure 6). The first half of 1998 was very wet, with median and 90th percentile stream flows at their highest. During the second half of 1998, median and 90th percentile stream flows were very low, as low, or lower than any other time during the study period. Median and 90th percentile flows were low throughout 1999, followed

by a return to a more normal pattern of higher flows in the winter/spring than the summer/fall period. Winter/spring flows in 2002 were low, followed by relatively frequent high flows in the summer/fall of 2002, as indicated by the 90th percentile. Stream flows indicate that 2003 was very wet throughout the year, as was the first half of 2004.

Another measure of hydrologic condition is the Palmer Drought Severity Index (PDSI). Historic data available on the NOAA.gov website (NOAA, 2006) parallels the 90th percentile for flows above. 1998 started out with extremely moist soil conditions, shifting to more normal moisture in June before moving into severe drought by the last three months of the year. 1999 was very dry with conditions mostly ranging from moderate to severe drought; the year ended with a return to more normal conditions. Normal conditions were the rule from 2000 through 2002, while 2003 and 2004 ranged from very to extremely moist.

The extreme changes in hydrological conditions during the July 1998 to June 2004 study period provide an essential backdrop when investigating changes in water quality during that same time frame. During wet years the potential for movement of non point source pollutants into streams is increased, but concentrations may not increase dramatically due to dilution effects. Also during wet years, the impact of point sources on parameter concentrations decreases due to increased dilution. The impact of point sources on stream quality (concentration) is greatest during dry years.

Agriculture.

As with the hydrologic changes described above, activity in the agricultural sector was dynamic during the study years. As noted in the introduction, the WVDA began this study, at least in part, to address water quality questions that arose because of the expansion of agricultural activity in WV's Potomac Basin. In particular, the poultry industry completed an expansion that tripled production in the region, leading to specific concerns that increased use of poultry litter (a mixture of poultry manure and bedding materials) as fertilizer might impact water quality. To address those concerns, the Potomac Headwaters Land Treatment Program was initiated in the mid-1990's. This government cost share project focused on accelerated development of nutrient management plans and installation of agriculture waste storage structures, mortality composters and livestock confinement areas. Eighty-five percent of poultry growers in the five county area of the Potomac Valley Conservation District are currently participating.

Population Growth and Development.

While current population density in the region is low compared to the nearby Baltimore Washington urban corridor, much of the region experienced dramatic population growth in the 1990s. This trend is expected to accelerate. New development and major construction projects occurred throughout the region. These projects included a major new highway, industrial expansion, and residential development, all of which have the potential to contribute pollutants and change hydrologic patterns.

And so, as backdrop to this report, the Potomac Highlands region during the period of study was in a state of hydrological, agricultural, and development flux. All of these factors had the potential to impact water quality.

County	Population	% Growth 1990-2000
Morgan	14,943	23.2
Hampshire	20,203	22.5
Hardy	12,669	15.4
Grant	11,299	8.4
Mineral	27,078	1.4
Pendleton	8,196	1.8

