Water Quality Studies
in a Watershed Dominated by Integrated Poultry Agriculture

W. Neil Gillies
Cacapon Institute
Rt. 1 Box 326
High View, WV 26808

PROCEEDINGS

NONPOINT SOURCE
"The Hidden Challenge"

West Virginia
NPS Conference
October 1, 2, 3, 1998

Water Quality Studies in a Watershed Dominated by Integrated Poultry Agriculture

W. Neil Gillies
Cacapon Institute, Rt. 1 Box 326, High View, WV 26808

Abstract. Poultry production in the Potomac Headwaters region of WV has more than doubled since the early 1990s. The waste byproducts of this industry are typically land applied and concerns over the water quality impacts of this waste are widespread. We studied nutrient concentrations and loads in the Lost River watershed in West Virginia, a basin with a high concentration of poultry houses and associated agriculture. Regular synoptic samples were collected at 12 sites with varying upstream land uses. Storm samples were also collected. Parameters included nitrate-nitrogen, total phosphorus, orthophosphate and turbidity. We observed significant differences in nutrient concentrations between sites with different land uses. The highest levels of nitrate-N were associated with flood plain cropland; the lowest levels were found in non-agricultural watersheds. In addition, nitrate levels were always higher, on a daily basis, in regions with cropland than other areas. While significant differences were detected in ortho- and total phosphorus concentrations between some sites, the differences were small and were not clearly related to any specific land use. Phosphorus concentrations were particularly elevated only during periods of active overland runoff. The mobility and chemical stability of nitrate make it a persistent and very useful indicator of nutrient loadings on the land. Non-point source phosphorus's lack of mobility and tendency to adsorb to soils of make it a poor indicator of terrestrial nutrient loadings.

Introduction

Poultry production in the Potomac Headwaters region of WV has more than doubled since the early 1990s. The waste byproducts of this industry are typically land applied, and concerns over water quality impacts are widespread. However, a lack of good data has made constructive dialog difficult. This paper presents preliminary results from a multi year study of nutrient concentrations and loads in the Lost River, Hardy County, WV, a watershed with a high density of poultry farms. It also focuses on lessons learned about water quality sampling in an agricultural non-point source (NPS) basin.

Background.

In 1992, due in large part to the area's rapidly expanding poultry industry, state and federal agencies recognized the need for a coordinated and comprehensive approach to protecting and enhancing ground and surface water quality in West Virginia's Potomac Headwaters region. The cooperating agencies agreed to provide financial and technical assistance to reduce and prevent water quality degradation arising from agricultural and urban lands.

The Lost River watershed was identified by these agencies as producing twice as much poultry litter, or manure, as the available agricultural land could use as a fertilizer for corn, hay and pasture land (NRCS, 1996). The Lost River basin, which constitutes only 2% of the Potomac Headwaters drainage area, contains 21% (appx. 185) of the region's poultry houses.

At more than one poultry house per sq. mile, it contains the highest density of poultry houses in the Potomac Headwaters. For the above reasons, the Lost River was designated #1 on the US Department of Agriculture-Natural Resources Conservation Service (NRCS) priority list for implementation of agricultural Best Management Practices (BMPs).

When the amount of manure produced substantially exceeds the amount needed to meet the nutrient requirements of crops, hay and pasture, as in the Lost River basin, something must be done with the excess. Both private and government programs are in place to move poultry litter out of the Lost River watershed, but it is generally accepted that excess remains. Keeney (1989) reported that animal manure is difficult to handle and often disposed of, rather than recycled, "by applying it to croplands at rates far in excess of fertilizer N needs." Nationally, nitrogen (N) is also often over-applied at a rate 24-32% in excess of crop needs because many farmers do not provide enough of a credit to nutrients contributed by legumes, manure and crop residues when determining application rates (Trachtenberg & Ogg, 1994)..

Animal manure typically has a nitrogen (N) to phosphorus (P) ratio of 3:1, while most grain and hay crops utilize N and P at a ratio of about 8:1. For this reason, P builds up in soils when manure is a major source of fertilizer, even when manure application is accurately calibrated to meet crop N needs (Daniel et al, 1994). This has led to an expectation that excess P must be polluting the Lost River and other Potomac Headwaters streams. However, studies conducted by the US Geological Survey (USGS) in 1995 (Mathes, 1996) and by Cacapon Institute between 1988 and 1995 (Constantz et al, 1993; Gillies, 1997) rarely detected elevated levels of P in the Lost River and its tributaries. Both the USGS and Cacapon Institute studied orthophosphate (OP), only one of several forms of P found in surface waters, and neither study was specifically designed to look for pollution in a region dominated by non point sources. The USGS study of twenty three stream sites in the South Branch of the Potomac and the Lost River watersheds observed heavy algal growth during the summer that might be associated with nutrient loading in streams. However, nitrogen concentrations were considerably lower than concentrations to the east of the study area in the Shenandoah River's Great Valley region, another agricultural region with integrated poultry agriculture (Mathes, 1996).

The purpose of this paper is to present new data from a study designed to quantify nutrient emissions in the Lost River watershed, a basin with a high concentration of poultry houses and associated agriculture. It will compare nutrient concentrations in streams of varying land uses and present time series data on nutrient losses associated with a large storm. With this information, state and local resource managers, as well as involved citizens, will have an improved understanding of patterns of nutrient loss in the Valley and Ridge province.

Location

The Lost River, so called because the lower part flows underground at base flow, is the headwaters of the Cacapon River, which flows northeast through Hardy, Hampshire and Morgan counties in West Virginia. The Cacapon River lies within the Valley and Ridge physiographic province, a mountainous region which consists of long, parallel valleys and ridges that run from the northeast to the southwest. Major rivers flow down the main valleys and their tributaries flow down the mountainsides in a perpendicular branching pattern known as a trellised drainage system.

The 178 km long Cacapon River, a tributary of the Potomac River, has a drainage area of 680 sq miles, about 7% of the Potomac drainage upstream of Virginia. The entire watershed contains only two incorporated communities and no heavy industry. Seventy-nine percent of the land in the Cacapon watershed is forested, while 19% is agricultural; the remaining 2% consists of residential development, barren lands and water (Constantz et. al., 1993).

The Lost River headwaters, in Hardy County, drains 179 square miles - 26% of the total Cacapon drainage area. This region contains the most intensive agricultural operations in the Cacapon watershed, dominated by the integrated poultry industry. Agriculture is forced by topography to remain largely confined to the narrow valleys and gentle slopes, and over 80% of the basin remains forested.

Lost River soils are formed from materials weathered from siltstone, sandstone, shale and limestone. The deep alluvial soils in the flood plain may be any combination of sand/loam/clay and range from well drained and coarse near the river to poorly drained and fine away from the river. Typically, river terrace soils are moderately well drained and upland soils are well drained. (Kesecker, personal communication)

Land use

Most of the basin's cropland is found along the mainstem of the Lost River, which bisects the heavily agricultural flood plain. Cropland receives the most intensive nutrient application of animal wastes and fertilizer (NRCS, 1996). Hayfields and poultry houses are located throughout the watershed where the land's slope allows equipment access. Most pasture also occurs on gentle slopes; however, some is located on steep, often eroding, shale hillsides. A woody riparian corridor exists along much of each tributary's length. This is not the case along the mainstem, where most trees were removed many years ago and crop, hay and pasture land typically extend to the river's edge.

The presence of poultry houses within a tributary watershed does not necessarily mean that the litter produced will be utilized there. Many poultry houses are sited in areas with insufficient land available nearby for spreading litter. This litter is transported to other areas; much presumably to flood plain and river terrace land along the mainstem. Litter is applied green or composted throughout the year. Unfortunately, quantitative data on these agricultural practices are not available.

Residences are scattered at low density throughout the watershed, few along the mainstem of the river. No municipal water or sewer facilities exist in this basin, although three small package sewage treatment plants that serve two schools and one continuous care facility are found at the lower end of the watershed.

Study Description

In March of 1997, Cacapon Institute started an intensive study of phosphorus (P) in the Lost River. During the first eight months of this project, parameters were limited to total phosphorus (TP), total orthophosphate (OP) and turbidity. Nitrate (NO_3-N) and fecal coliform bacteria were added as regular parameters in November 1997. Eight tributary and 4 mainstem sites were selected (Figure 1) with the aid of local agents of the NRCS, West Virginia

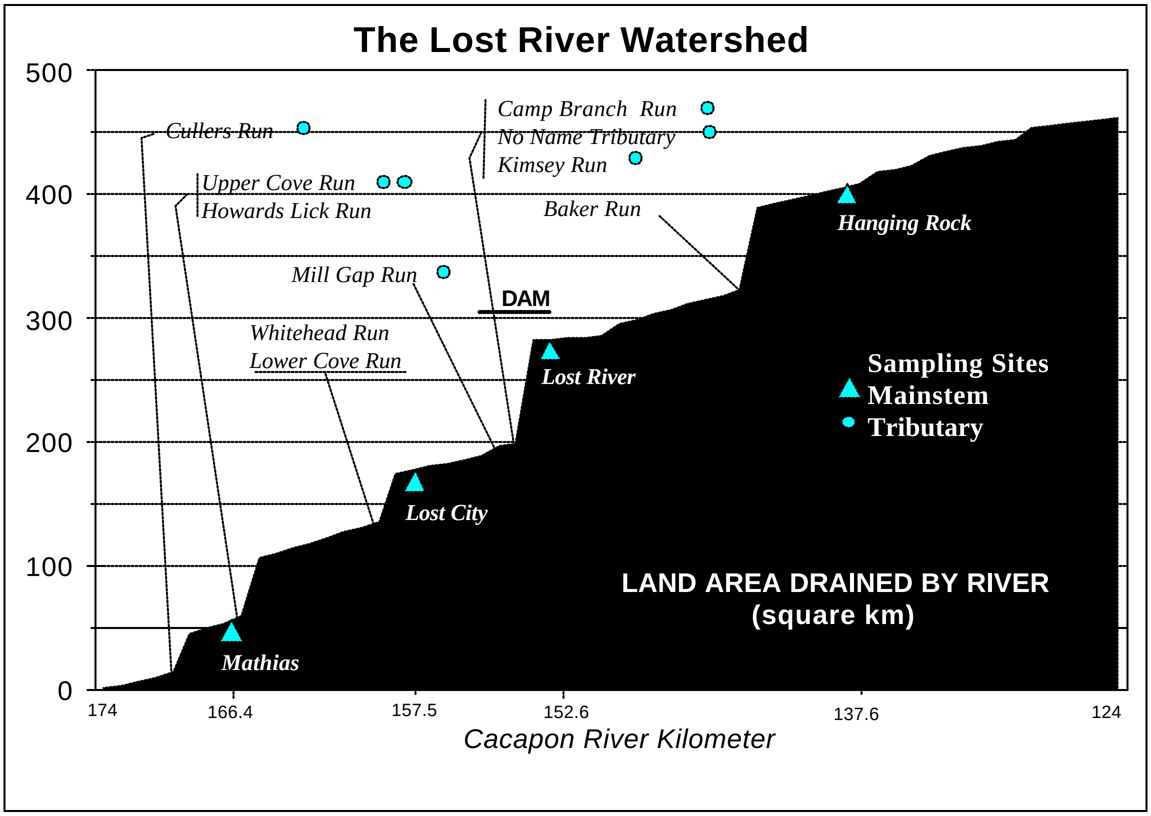


Figure 1. Drainage area map of the Lost River watershed, showing mainstem and tributary sampling sites. Waites Run, an out-of-basin tributary, is not indicated.

University and the US Fish and Wildlife Service. Each site

represents a different mix of land uses. See Table 1 for site descriptions; site abbreviations from the table will be used in the balance of this document.

The study was designed to answer three questions: 1- are nutrients applied to the basin's agricultural soils entering the river; 2- do streams with different land use characteristics contribute different nutrient concentrations; and 3- what are peak nutrient loadings contributed by each stream and by the river as a whole.

The parameters included in this study were selected as most likely to provide useful quantitative information about nitrogen and phosphorus concentrations and loadings.

Nitrate. Nitrate readily dissolves in water, is chemically stable over a broad range of environmental conditions and moves easily through ground and surface waters (Mueller et al, 1995) Correll et al (1994) compared the concentrations of aqueous species of N between different environmental settings in the Chesapeake Bay watershed. They found nitrate was the major dissolved form of nitrogen detected, with concentrations 10 to 20 fold higher than dissolved ammonium and organic nitrogen. Data collected by Cacapon Institute over several years also indicated that nitrate was the dominant form of nitrogen found in the Cacapon River (Gillies, 1997a; 1998b). For these reasons, we selected nitrate-nitrogen (NO_3-N) as the best quantitative indicator of nitrogen losses into the river. Phosphorus. Two phosphorus parameters were included in this study, total phosphorus (TP) and total orthophosphate (OP). OP, the most common form of dissolved phosphorus, is readily available to plants as a nutrient. OP is only moderately

Table 1. Sampling sites with land use desciptions. Feed lot and poultry house count approximate (Mathes, 1996; NRCS,1996). Land use data subjective. Currently developing quantitative land use information.

Location (abbreviation)	Description
Cullers Run km 0.4 (CuR)	Tributary, 14 poultry houses in 12 square miles, only tributary with significant cropland. Pasture, hay and feedlots also.
Upper Cove Run Sites km 1.8 & 3.3 (UCR23) & km 0.05 (UCR1)	Tributary, 29 PH in 9 sq miles, most in one large complex 0.5 km upstream of UCR23. UCR1 in town (Mathias). No cropland, little pasture/hay, several feedlots downstream of UCR23. See table note 2.
Mill Gap Run km 1.2 (MGR)	Tributary, no poultry, no crop, little pasture. Mostly forested, residential development on ridge tops.
Camp Branch Run km 0.05 (CBRS)	Tributary, 2 poultry houses just upstream of sampling site, otherwise forested and pasture.
Kimsey Run km 4.3 (KR)	Tributary, 11 poultry houses, 1 feedlot, no crop, pasture mostly away from stream
NoName Trib km 1.5 (NNT)	Tributary, 100% forested
Waites Run km 1.7 (WR)	Tributary of Cacapon R., not in Lost River watershed, 2 poultry houses well off stream, heavily forested, light residential along stream
Lost R. at Mathias km 166.4 (LR-LRM)	Mainstem bisects heavily agricultural floodplain, Cullers Run (see above) main tributary influence
Lost R. at Lost City km 157.5 (LR-LC)	Mainstem bisects heavily agricultural floodplain, see Fig. 1 for tributary influences
Lost R. at Lost River km 152.6 (LR-LR)	Mainstem bisects heavily agricultural floodplain, see Fig. 1 for tributary influences
Lost R. at Hanging Rock km 137.6 (LR-HR)	Mainstem bisects heavily agricultural floodplain, see Fig. 1 for tributary influences

Table Notes:1. river kilometer measurements upstream from mouth of river; for Lost R. measurement is from mouth of Cacapon R.. 2. Site UCR23 is actually a composite of two sites: UCR2 was located at km 1.8 and had to be relocated upstream to km 3.3 when a new bridge construction project precluded access. Data for these two sites is combined in analyses below unless otherwise noted.

soluble and readily adsorbs to sediments. TP is the sum of all forms of phosphorus: organic and inorganic, suspended and dissolved. While neither OP or TP move readily though ground water, erosion can transport large amounts of sediment-bound P to surface waters (Mueller et al, 1995). While OP is the form of P most readily available to plants, experimental evidence indicates that TP is the better indicator of potential for periphyton and plankton growth (Morris & Lewis, 1988; Dodds et. al., 1997). However, the ratio of OP to TP can be a useful indicator of source and, therefore, both parameters were included in this study.

Turbidity. Turbidity is a measure of water clarity and an indirect measure of the amount of sediment suspended in the water. It was included in this study as an indicator of sediment load. Since most P is attached to sediment, turbidity is a valuable indirect indicator of the potential for high P concentrations and of erosion producing storms.

Field and Laboratory Methods

Samples were collected under two different protocols: regularly scheduled synoptic sampling and opportunistic storm event sampling. The scheduled synoptic sampling regime, in which samples were collected at all sites within a three hour interval, occurred weekly from March through August 1997, bimonthly thereafter. Storm sampling focused on either one or a few streams per event, and samples were collected repeatedly during and after storms.

Water samples were collected midstream 10-15 cm below the surface. When water levels precluded wading into the river, samples were collected from shore or bridges using a 12 ft. extension sampler. Sample containers were rinsed three times with river water at the sampling site prior to collecting a sample. Sampling containers, storage conditions and holding times followed APHA (APHA, 1992).

Flow measurements were taken at several established staff gage stations, using a General Oceanics Mechanical Flowmeter Model 2030. At least five flow measurements over a broad range of flows were collected at each site to calibrate the flow curve to stream stage. A minimum of six flow readings were taken across the width of each stream for each flow calibration point. Rain measurements were taken at several sites in the watershed using rain gages built to U.S. Weather Bureau specifications.

Turbidity was measured using a Ratio Turbidimeter (Hach model 18900) calibrated with formazin primary standards (Hach #2461) and verified against Gelex secondary standards (Hach #22526-00) (EPA method 180.1). Nitrate-N (NO_3-N), total phosphorus (TP), and total reactive, or ortho, phosphorus (PO4 as P, OP) were determined colorimetrically using a Hach 2000 Spectrophotometer as follows: NO_3-N - cadmium reduction method (Hach Method 8171); TP - ascorbic acid method preceded by acid persulfate digestion (EPA method 365.2); OP - ascorbic acid method (EPA method 365.2). QA/QC procedures followed EPA standards .

The method used to enumerate nitrate also includes nitrite. However, nitrite occurs in significant concentrations only in the immediate vicinity of sewage, industrial food processing and organic waste disposal (Mueller et. al., 1995) and, in rivers, is quickly converted by natural processes to nitrate. In addition, the USGS study in this region only rarely found detectable concentrations of nitrite in their samples and, when detected, it constituted less than 4% of the NO_3-N + NO_2-N total (Mathes, 1996). Values reported here for NO_3-N are those obtained for NO_3-N + NO_2-N, on the assumption that NO_2-N concentrations throughout the study have been negligible.

Statistical methods.

The synoptic sampling regime was used to create a data base of samples collected at all sites under nearly the same hydrologic conditions on each sampling day. Each parameter's median for each daily set of synoptic samples was determined and the deviation of each site from that daily median was calculated. This metric was created to determine if, despite the large variability inherent in non-point source pollution data, relative concentrations between sites hidden by variability in raw data could be detected graphically and statistically. Storm sampling data that was not collected according to the synoptic protocol at all sites was excluded from the site comparative analyses presented below.

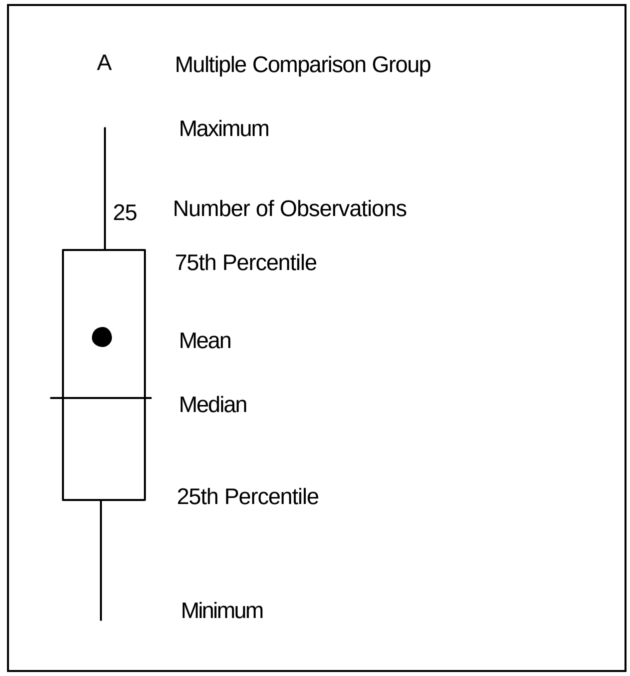


Figure 1. Example diagram and explanation of a boxplot.

Except for descriptive statistics, non-parametric methods of analysis were used. The methods used to analyze data were graphical and statistical. Data distributions were displayed using boxplots (Figure 2). Side-by-side boxplots can be used to visually compare two or more data distributions. One way analysis of variance (ANOVA) was run on rank transformed data for comparison of median concentration distributions and of the deviation from daily medians between sites. An alpha value of 0.05 was used to determine the significance of test results. If a significant difference among group medians was detected, Tukey's multiple comparison test was used on the rank transformed data to determine where differences were located (Helsel and Hirsh, 1992). Statistics were calculated using JMP Statistical Discovery Software (version 3.2).

Results of synoptic sampling for the period from March 1997 through February 1998.

NO_3-N, TP and OP were present at detectable levels at all sampling sites. There were significant differences between at least some of the sites for all constituents measured.

NO_3-N was added to the study in early November 1997, so the NO_3-N data presented here was biased towards seasonal effects of late fall and winter. Median NO_3-N concentrations at the twelve sites varied widely, ranging from 0.2 to 2.6 mg/L. The highest median concentration was detected at the LR-MTH site (2.6 mg/L), which was statistically distinct from all sites except CuR, LR-HR and LR-LC (1.7, 1.5 and 1.5 mg/L, respectively) (Figure 3A). The lowest median concentration was found at WR (0.2 mg/L), which was

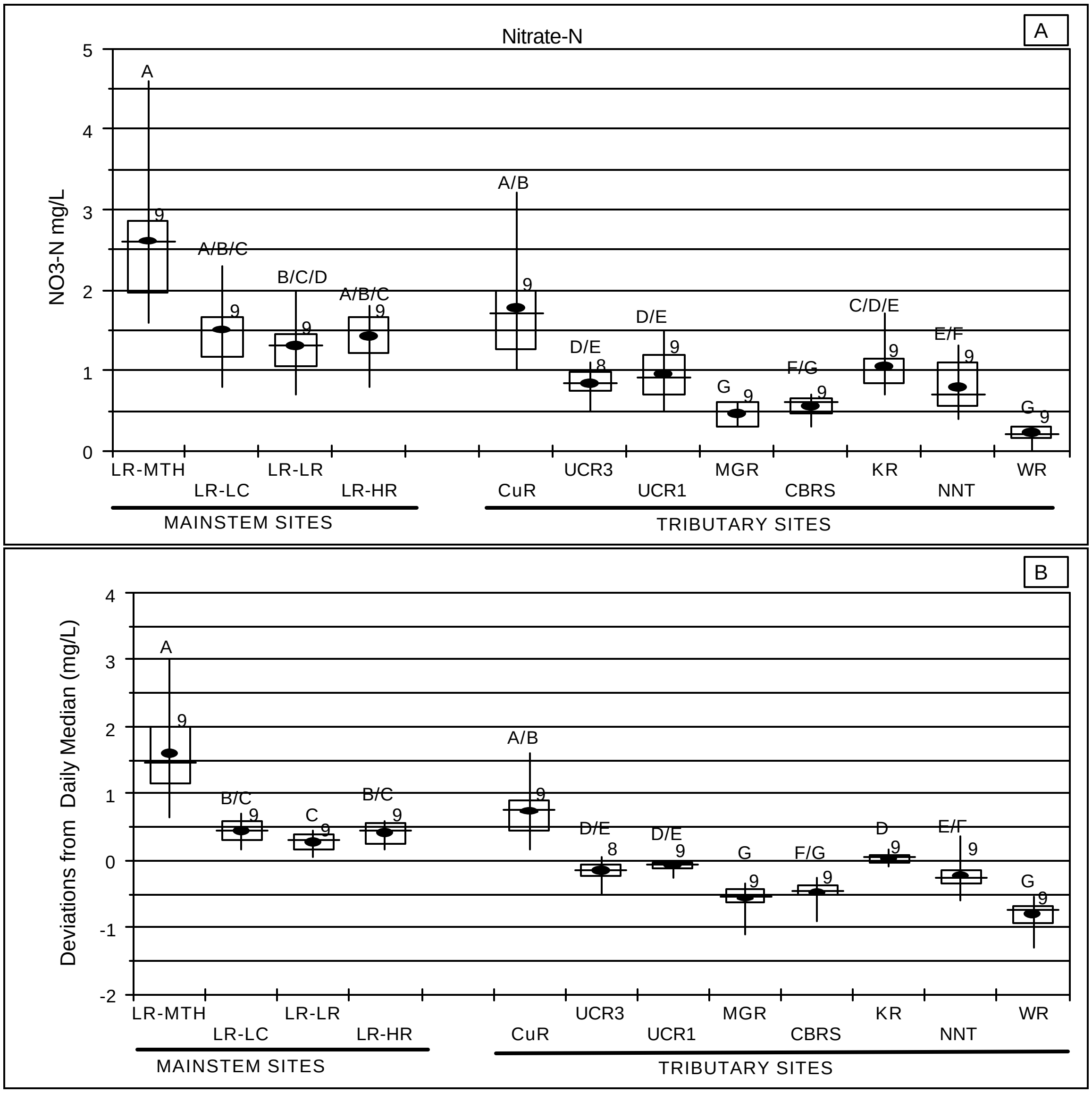


Figure 3. A. Nitrate-N concentrations at regular synoptic sampling sampling sites; B. Nitrate-N deviations from daily medians at regular synoptic sampling sites.

statistically distinct from all sites except MGR and CBRS (0.5 and 0.6 mg/L, respectively). Median NO3-N levels at NNT, the forested site, were in the low to midrange at 0.7 mg/L.

Analysis on deviations from daily medians indicated that relative NO3 concentrations between sites were consistent with and accentuated the relationships observed in the raw data (Figure 3B). NO_3-N concentrations at LR-MTH, CuR, LR-HR, LR-LC and LR-LR always exceeded the daily median, and were statistically distinct from the remaining seven sites. These five sites were selected to detect nutrient inputs from crop lands. With the exception of KR, concentrations at all other sites usually or always fell below the daily median.

Median TP concentrations were low at all sites, ranging narrowly from 0.02 to 0.05 mg/L (Figure 4a). The highest medians were detected at UCR1 (0.05 mg/L) and UCR23, CuR, LR-MTH and LR-HR (all 0.04 mg/L). The lowest medians were found at NNT (0.02 mg/L) and

KR (0.028 mg/L). Despite this narrow concentration range, analysis of variance detected significant differences between site medians at the range extremes.

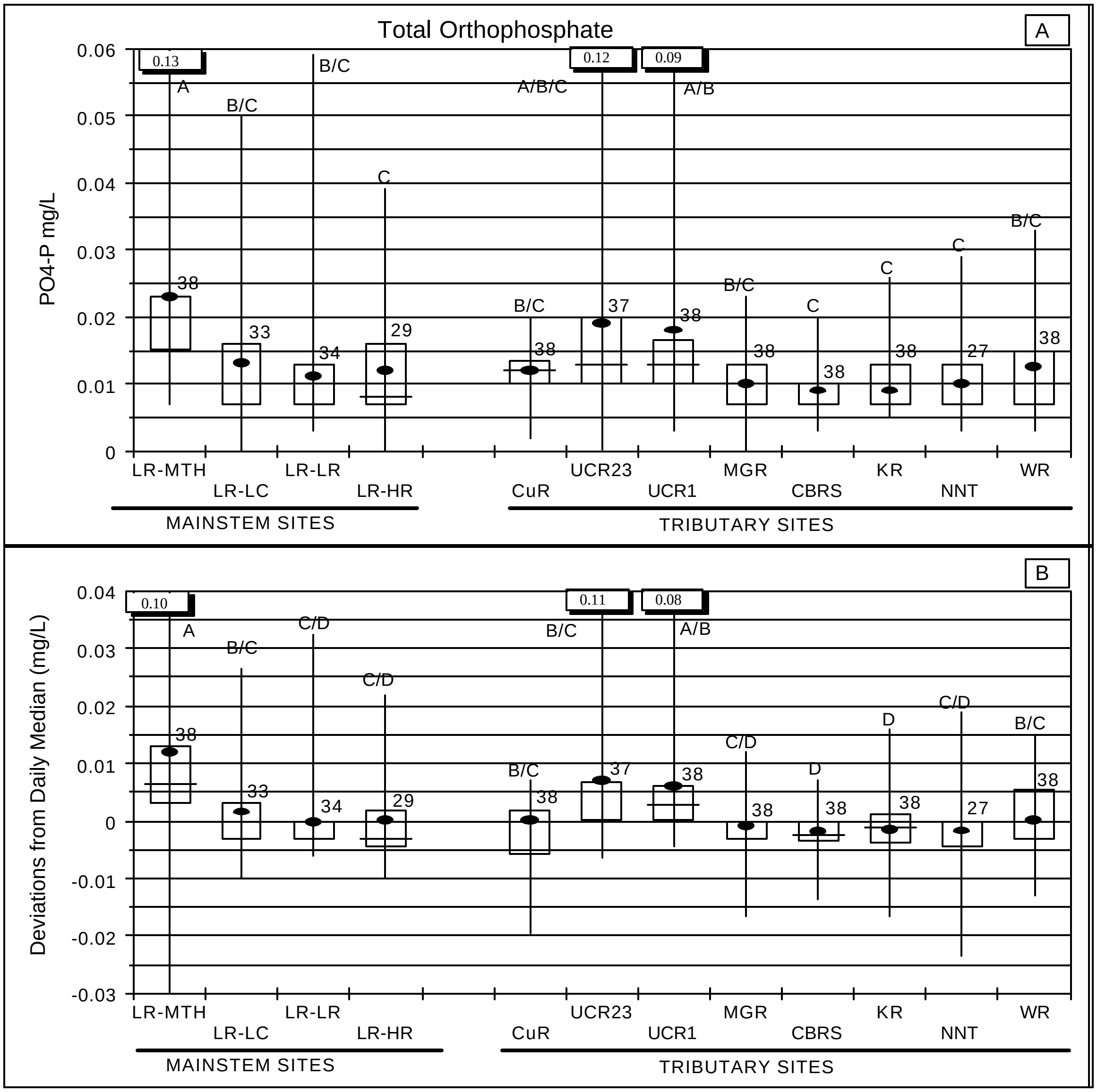


Figure 5. A. Orthophosphate-P concentrations at regular synoptic sampling sites; B. Orthophosphate-P deviations from daily medians at regular synoptic sampling sites.

Median TP concentrations at UCR1, LR-MTH and LR-HR were significantly higher than KR and NNT, and LR-MTH was higher than WR. Unlike NO_3-N, deviations from the daily median for TP (Figure 4b) did not indicate a distinct difference between sites with and without cropland. TP concentrations at LR-MTH, UCR23 and UCR1 consistently exceeded the daily median of all sites, while only KR and WR were consistently low. Analysis of variance on this data provided little additional information.

Median OP concentrations were low at all sites, ranging from 0.008 to 0.02 mg/L (Figure 5a). Despite the narrow range, the OP median concentration at LR-MTH (0.02 mg/L) was significantly higher than all sites except UCR23 and UCR1 (both median 0.013 mg/L). As with TP, analysis on deviations from the daily median for OP (Figure 5b) did not indicate a distinct difference between sites with and without cropland. OP concentrations at LR-MTH, UCR23 and UCR1 were consistently elevated in relation to the other sites, while LR-LR, MGR, CBRS, KR and NNT were consistently low. At WR, OP was higher in relation to the other sites than was TP; all of the high daily OP concentrations at WR occurred during extremely low base flow conditions. This data accentuated patterns observed in the raw data, with LR-MTH significantly different from every site except UCR1.

<u>Results - Storm Time Series</u>.

On November 7 and 8, 1997, a large storm passed through the Lost River watershed, ending a long dry period. Approximately 3" of rain fell over two days, 2 inches prior to sampling on 11/7/97. Added to 1.3 inches that fell 6 days previously, the basin's soils became visibly saturated. A total of 1.95 inches of rain fell over the following 49 days; no rains in excess of 0.5 inches/day occurred during this period. A limited number of samples were collected on the first day of the storm, followed by daily sampling on November 10 through 13 and regular bimonthly sampling thereafter.

Figure 6 presents concentration and load data for TP and NO_3-N at LR-HR for the interval from October 27, 1997 through November 24, 1997. Load calculations were based on flow measurements taken at the Institute's flow station at the Mathias (drainage area 41 sq. mi.) and extrapolated by relative drainage area to the Lost River Hanging Rock site (drainage area 155 sq. mi.). Load information is also extrapolated from instantaneous measurements to pounds per hour. It is recognized that both extrapolations represent potential sources of error.

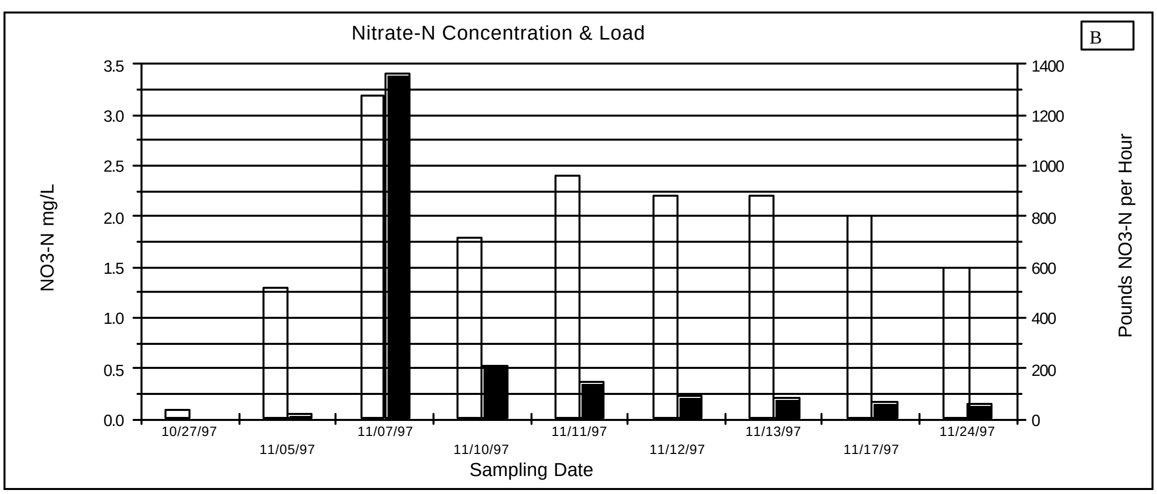
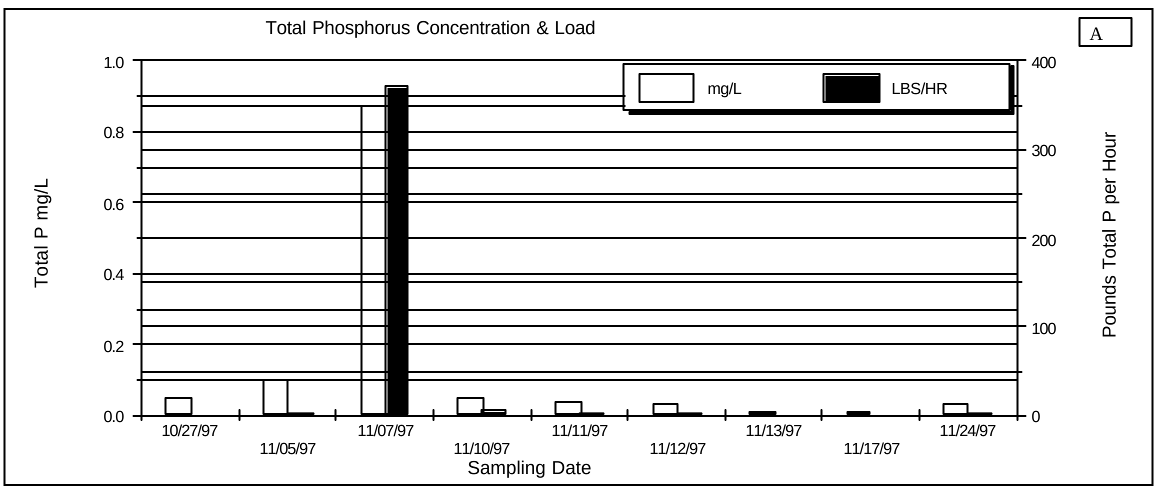


Figure 6. Results of storm and post storm sampling at the Lost River at Hanging Rock following a large, saturating storm on November 7, 1997. A. Total phosphorus concentrations and loads. B. Nitrate-N concentrations and loads.

TP concentration (Figure 6a) two days prior to the 11/7/97 storm was slightly elevated (0.1 mg/L) when compared to the typical range for the site, possibly due to rain several days previously. On 11/7/97, a peak concentration of 0.87 mg/L was recorded. This dropped to 0.61 mg/L 2.5 hours later. (Associated turbidity measurements also dropped during the same interval, from 605 to 440 NTU.) Three days following the storm, TP concentration had fallen to 0.05 mg/L and continued to fall over the succeeding days and weeks. The TP load was 1.7 lbs/hr two days prior to the 11/7/97 storm. On the day of the storm, a peak load of 372 lbs/hr was recorded. The load fell to 261 lbs/hr in 2.5 hours and to 5.8, 2.1, 1.3 and 0.4 lbs/hr in 3, 4, 5 and 6 days following the storm, respectively.

NO_3-N concentration (Figure 6b) rose from a pre-storm low of 0.1 mg/l on 10/27/97 to 1.3 mg/l on 11/5/97. On 11/7/97, the concentration was 3.2 mg/L both times the river was sampled. Three days following the storm, the NO_3-N concentration dropped to 1.8 mg/L, rose to 2.4 mg/L on the fourth day then fell gradually over the following days and weeks. The NO_3-N load was <1 lb/hr on 10/27/98, rose to 22 lbs/hr on 11/5/97 followed by a steep climb to



1370 lbs/hr on 11/7/97. Three days following the storm, the NO_3-N load dropped to 208 lbs/hr and continued a slow decline over the following days and weeks.

Time series NO_3-N data collected at a subset of the regular 12 sites is presented in Figure 7 for the interval from 11/7 to 12/29/97. Three sites with varying amounts of flood plain cropland in their drainage area (LR-MTH, CuR, and LR-HR, in order of more to less cropland as percentage of drainage area) and three sites with no cropland (KR, NNT, MGR) are shown. The three cropland sites showed an increase in NO_3-N concentrations five days following the storm. The highest concentration observed was at LR-MTH, which peaked at 6.8 mg/l on the fifth and sixth days after the storm before declining gradually over time. The second highest concentration was detected at CuR (3.6 mg/L), also on the fifth and sixth days after the storm. The pattern for LR-HR has been described above. The increase in NO_3-N concentrations at these sites was coincident with declining flow in the river. A pattern of slowly declining concentrations following the storm was observed at all three sites that lacked cropland. The NO_3-N concentration at MGR never exceeded 0.5 mg/L during this interval.

Discussion

NO_3-N concentrations observed in this study varied widely between sites, and elevated levels were clearly related to the amount of flood plain land in crops. This pattern is consistent with the water quality literature generally (Keeney, 1989; Mueller et. al., 1995) and specifically within the Potomac watershed. A recent summary of long term water quality data in the Potomac basin concluded that NO_3-N concentrations were common in areas of intensive row cropping underlain by carbonate rock. NO_3-N levels reported from Muddy Creek, a small carbonate drainage in an intensive poultry agricultural stream in the Shenandoah River's Great Valley to the east of the Lost River, were regularly much higher (median = 4.75, mean = 4.96, range = 2.5 to 8.4, N = 48; raw data from USGS, 1998; Ator et. al. 1998) than those reported here. The higher levels probably reflect the greater percentage of land in agriculture in the Great Valley (74%; Miller et. al., 1997) and the greater density of agriculture in the basin sampled. They are also due in part to karst terrain which allows ready transport of surface

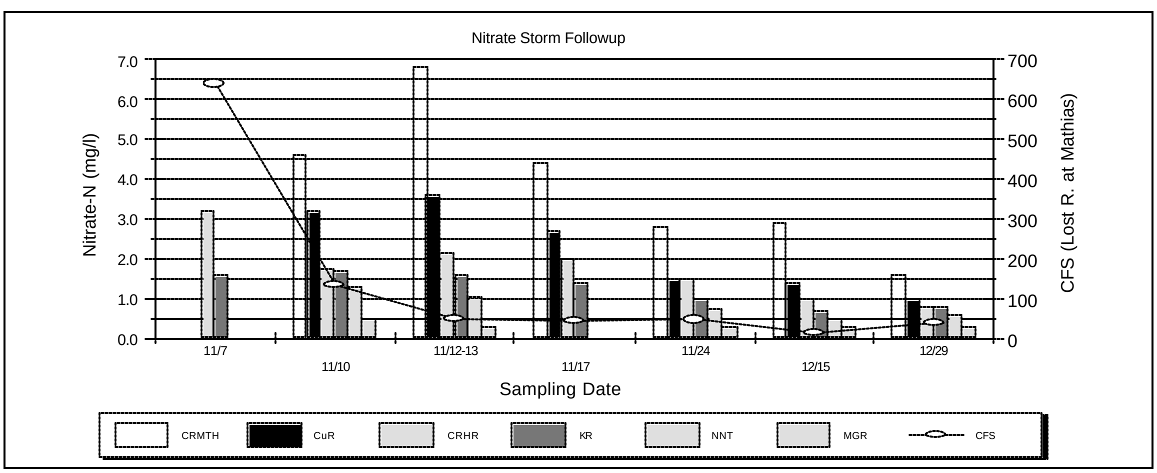


Figure 7. Nitrate-N time series data following November 7, 1997 storm for LR-MTH, CuR, LR-HR, KR, NNT, MGR. Data for 11/7/97 limited to LR-HR and KR; no data were collected for NNT and MGR on 11/17/97. River flows from the Lost River Mathias gage station are also indicated.

contaminants through ground water to streams, particularly dissolved constituents like NO_3-N (Boyer and Pasquarell, 1995).

The highest NO_3-N concentrations observed during the USGS study of 23 Potomac Headwater sites during 1994-1995 were found in the Lost River's Cullers Run (median 0.81 mg/L, range 0.60 to 1.88 mg/L, Matthes, 1996). The same site had the second highest median and maximum NO_3-N concentrations reported in this study. Elevated NO_3-N concentrations observed in cropland regions of the Lost River watershed for weeks after saturating storms suggests that NO_3-N does not move easily through the ground in this basin until precipitation saturates the soils, allowing substantial movement with interflow and into groundwater.

While median NO_3-N concentrations varied widely between sites, median TP and OP concentrations varied little and were low at all sites. The highest median P concentrations in the Lost River basin were found at one site with the greatest percentage of land in crops (LR-MTH) and two sites with the greatest density of poultry houses in the basin but little land available for land application of poultry litter (UCR1, UCR23). When one considers the difference in P inputs as fertilizer to various parts of the watershed, the lack of large differences in P concentration between sites appears remarkable. Because poultry litter is a major source of fertilizer, the mainstem flood plain receives excess P in relation to the N provided in manure (Sharpley, 1995), yet only N lost as NO_3-N is readily observed. This apparent contradiction is explained by the difference in pathways to the river available for NO_3-N and P. Nitrogen in the form of NO_3-N moves readily both with overland flow and through the soil profile, and nitrogen applied to crops as ammonium and organic N can be converted to NO_3-N by various chemical and biological pathways (Keeney, 1989).

Under most conditions, non-point sources of P move readily only with overland flow (surface runoff). Movement through the soil profile is low due to adsorption by P deficient subsoils (Sharpley, 1995). Even in agricultural karst regions, where one might expect land applied P to be readily transported through underground solution channels to surface waters, P concentrations are typically low for all land use categories (Miller et. al., 1997). Nationally, regularly elevated P concentrations are often associated with urban areas and point source discharges from large sewage treatment plants (Mueller et. al., 1995; Gillies et. al. 1998b), neither of which exist in the Lost River basin. However, leaching of land-applied phosphorus through soils into streams has been documented under certain conditions, such as in organic, peaty, sandy and waterlogged soils (Sharpley, 1995).

Little evidence for P leaching was apparent in this study. Slightly elevated P concentrations at LR-MTH are suggestive of a steady source, but it is uncertain if this comes from leaching through agricultural land, old septic fields (unlikely in this instance), seepage from manure in feedlots located adjacent to the river or its tributaries, or direct deposition of manure. (If leaching does occur along the mainstem, P concentrations are generally so low in this watershed that dilution from tributaries would likely mask this nutrient input at all sites downstream of LR-MTH.) Slightly less elevated median P concentrations at UCR1 and UCR23 offer the possibility that geology could be a source.

Storms in June and July 1997 (Gillies, 1997b&c) led to the discovery that agriculture was not the only important potential source of P in the watershed. Very high concentrations of TP were detected at both sampling sites in Upper Cove Run during the June storm (UCR2 - 1.39

mg/L; UCR1 - 0.94 mg/L). A series of stratified samples collected along the length of UCR during the July storm traced the largest source of P to a construction site. Every rainfall washed large amounts of sediment into the stream from this site, which lacked effective erosion control. This sediment was loaded with P (highest detected concentrations, collected in UCR immediately below the site, were: TP- 28.0 mg/L; OP- 4.3 mg/L; and turbidity - 37,000 NTU. Gillies, 1997c).

The construction site was covered in mature second growth forest prior to excavation. Later analysis of soil samples from the site (performed by D. K. Bhumbla at WV University) found TP (extracted using hydrofluoric acid) levels ranging from 151 to 2505 mg/kg (median 818, N=13) and Mehlich-1 P (the standard agricultural soil test) ranging from 3-1405 (median 27, N=13). The majority of subsoils in West Virginia have TP in the 500 to 1500 mg/kg range, with reported values as high as 3090 mg/kg (Jenks, 1969) and it is often difficult to distinguish between P losses from manure, fertilizer and native soil (Sharpley, 1995). Therefore, naturally occurring P eroded from exposed soils must be considered a potential source of high TP readings, particularly when elevated concentrations are associated with high turbidity.

The previous paragraphs discussed median concentrations of NO_3-N and P at various sites. Of equal or greater importance, however, are total and peak loads for each parameter. The time series data from the November storm clearly demonstrate that short lived peak loads occur for both NO_3-N and TP during major storms. However, the similarities end there. While the NO_3-N load diminished in the days following the main overland flush, it remained significant for many days (it dropped to 15% of the maximum detected load in three days). The main phosphorus load, however, passes down river in just a few hours. Three days after the main flush, the P load carried by the river was less than two percent of the peak detected load, the following day less than 1 percent.

Figure 8 follows concentration changes of TP and NO_3-N before, during and after a storm in June 1998. (River stage remained steady during the storm interval from 6/15/98 at

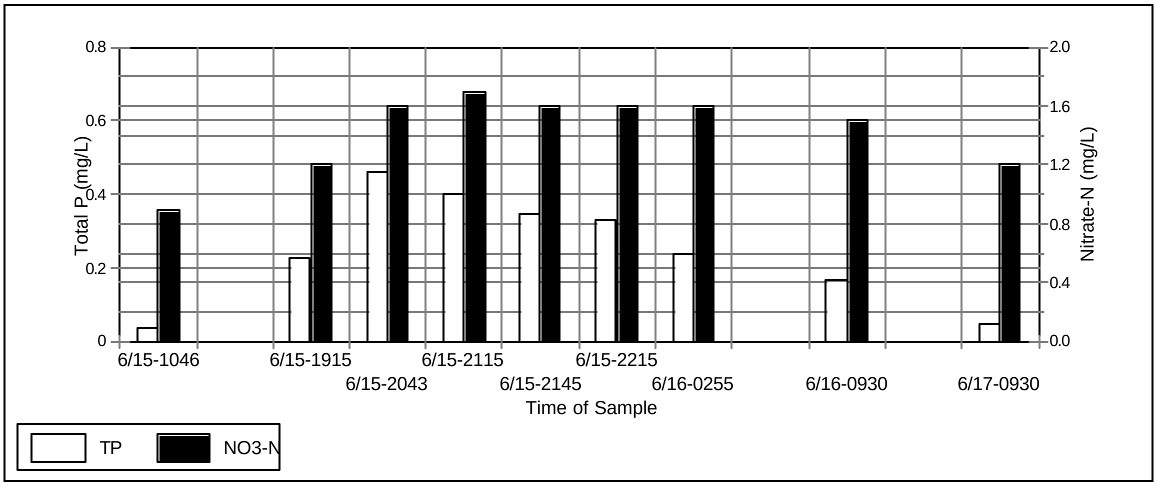


Figure 8. Storm time series data for total phosphorus and nitrate-N at the Lost River at Hanging Rock. Includes samples taken the before the storm at 1046 on 6/15/98, samples taken throughout the storm interval from 6/15/98 at 1915 through 6/16/98 at 0900, and the following day.

7:15 p.m. until 6/16/96 at 9:30 a.m., so the load profile would parallel the concentration profile for that time period.) TP concentration rose to a peak early in the storm, then fell rapidly - reduced by 50 percent six hours after the peak was reached, 65% after 12 hours. Thirty eight hours after the storm, TP concentrations had dropped to pre-storm levels. NO_3-N reached a plateau at the same time as TP and retained that level throughout the storm interval. Thirty eight hours after the storm, NO_3-N levels remained somewhat elevated. The river was visibly quite muddy throughout the storm interval; however, turbidity peaked at 500 NTU with TP early in the storm and dropped to 95 NTU by 0930 the following morning.

Over 75 percent of annual watershed runoff can occur during a small number of severe events (Edwards and Owens, 1991). Because P primarily moves in runoff, Sharpley (1995) estimates that over 90% of the annual P load can be delivered by these few events. Our data confirm that peak loads and concentrations of P are extremely short lived in the Lost River watershed. For these reasons, any attempt to project stream nutrient loadings without collection of substantial and very focused storm data must be met with skepticism; this is particularly true for P.

The peak loads of NO_3-N and P detected during storms probably came from a variety of sources that were available to wash overland into the river. The USGS (Blomquist et. al., 1996) estimates that atmospheric deposition, animal manure, and commercial fertilizers comprise 97 percent of the total N inputs to West Virginia's Valley and Ridge province (at 57, 26 and 14% of total N inputs, respectively). Ninety-five percent of total P inputs come from commercial fertilizer (39%) and animal manure (56%). Commercial fertilizer and animal manure are applied at the heaviest rates along the flood plain, particularly on cropland (NRCS, 1996). Atmospheric deposition of nitrogen is more evenly distributed throughout the watershed.

Median NO_3-N concentrations were relatively low in the non-agricultural sites in this study (WR, MGR, NNT- 0.2, 0.5 and 0.7 mg/L respectively). Although atmospheric deposition is the largest overall source of N in the Valley and Ridge, it is reasonable to conclude from this study that it is a relatively minor source of N to waterways in the Lost River basin. NNT, the only totally forested tributary, had the highest median NO_3-N concentration of the three non-agricultural sites. This apparent anomaly might be explained if the groundwater that feeds NNT is recharged from fertilized land outside the tributary's surface watershed.

The median NO_3-N concentration was also low (0.6 mg/L) at the CBRS sampling site, situated 30 m below a culvert receiving direct drainage from poultry houses. This indicates that locating poultry houses in close proximity to streams may not result in a continuous flow of nutrients into the stream. However, we detected runoff high in NO_3-N, OP and TP washing from this same site during several storms, even though no obvious accumulations of manure were apparent. On one occasion, this runoff occurred when the only other observed runoff flowed from roads. The relatively impervious ground around poultry houses may prove to be an important and ready source of nutrient laden runoff.

Considerable work remains, however, in determining relative contributions from various sources to the river's total nutrient load, particularly during the period of overland flush. This research would best be done by determining nutrient content of runoff using land based studies and extrapolating from that information to model the basin as a whole. Political realities in the Lost River watershed make that unlikely in the near future.

<u>Summary and Conclusions</u>.

We observed significant differences in nutrient concentrations between sites with different land uses. The highest levels of NO_3-N were associated with flood plain cropland; the lowest levels were found in non-agricultural watersheds. In addition, NO_3-N levels were always higher, on a daily basis, in cropland than other areas. The mobility and chemical stability of NO_3-N make it a persistent and very useful indicator of nutrient loadings on the land.

While significant differences were detected in OP and TP concentrations between some sites, the differences were small and were not clearly related to any specific land use. Phosphorus concentrations were only particularly elevated during periods of active overland runoff. Phosphorus from non-point sources general lack of mobility and tendency to adsorb to soils of make it a poor and problematic indicator of nutrient loadings on the land.

Discovery of a geologic source of P indicates care is required in interpreting data where sources may appear obvious. UCR was selected as the stream with the greatest density of poultry houses per square mile and, therefore, the largest production of manure per sq. mi. Had this project's access to UCR been severely restricted, as it is along the Lost River mainstem, it would have been easy to conclude, erroneously, that poultry waste was the primary source of P in that stream. The largest phosphorus source in the UCR watershed, at least until effective erosion control measures were implemented, was a construction site that exposed soils naturally high in P.

Good storm data is very difficult, time consuming and costly to collect. However, the extremely episodic nature of non-point source nutrient loads make it unlikely that studies lacking a focused storm sampling component can accurately assess nutrient loads generated by non-point sources. It is premature for this study to estimate peak and total loads from various sites.

Agricultural Best Management Practice (BMP) implementation is under way on many farms in the Lost River watershed. Much of this work started in 1998, more will begin in 1999. This study is well placed to determine the water quality impacts of Lost River BMPs.

In their report on water quality in the Potomac Headwaters, the USGS (Mathes, 1996) suggested that "future water quality sampling could include a network of several small tributary basins with varying degrees of agricultural land use, where samples collected during the same time period might provide statistical verification of suggested or apparent relations seen in this reconnaissance study." This research, at least in part, fulfills that need.

Acknowledgments.

Thanks to Fred Carter for the good work he did in the field and lab during the spring and summer of 1997, and to George Constantz and Nancy Ailes for review of interim reports. Thanks to Ed Kesecker, Chad Bucklew, Ron Estep, Ken Haid and Craig Savela of the NRCS, Tom Basden and D. K. Bhumbla of the WV University Extension Service, and Dan Ramsey and Linda Smith of the USFWS for technical support and guidance.

This continuing project is supported by the US Fish and Wildlife Service, the Potomac Headwaters Resource Alliance and the donations of private patrons of Cacapon Institute.

References

APHA, 1992. Standard Methods for the Examination of Water and Wastewater, 18th edition. American Public Health Association, Washington, DC Various pagination.

Blomquist, J. D., G. T. Fisher, J. M. Denis, J. W. Brakebill and W. H. Werkheiser, 1996. Water Quality Assessment of the Potomac River Basin: Basin Description and Analysis of Available Nutrient Data, 1970-90. USGS Water Resources Investigations Report 95-4221. 88p.

Boyer, D. G. and G. C. Pasquarell, 1995. Nitrate concentrations in karst springs in an extensively grazed area. Wat. Res. Bull. 31(4):729-736.

Constantz, G., N. Ailes & D. Malakoff, 1995. Portrait of a River: The Ecological Baseline of the Cacapon River. 30p

Correll, D. L., T. E. Jordan, and D. E. Weller, 1994. The Chesapeake Bay Watershed: Effects of Land Use and Geology on Dissolved Nitrogen Concentrations. IN: Toward a Sustainable Coastal Watershed: The Chesapeake Experiment. Proceedings of a Conference. Chesapeake Bay Consortium, Pub. No. 149, pp 639-648.

Daniel, T.C., A. N. Sharpley, D.R. Edwards, R. Wedepohl,a nd J.L.Lemunyon, 1994. Minimizing surface water eutrophication from agriculture by phosphorus management. J. Soil and Water Conserv. 49:30-38

Dodds, W. K., V. H. Smith and B. Zander, 1997. Developing nutrient targets to control benthic chlorophyll levels in streams: a case study of the Clark Fork River. Wat. Res. 31(7):1738-1750.

Gillies, W. N. 1997a. Cacapon watershed tributary study completed. Cacapon Vol. 7 No. 2: pp 6-8.

Gillies, W. N. 1997b. Phosphorus in the Lost River: an Interim Report. 2 p

Gillies, W. N. 1997c. Phosphorus in the Lost River: Interim Report #2 - Upper Cove Run. 4 p.

Gillies, W. N., 1998a. Ground breaking news. Cacapon 8(1):1-4.
Gillies, W. N., D. A. Malakoff, N. Ailes and G. Constantz, 1998b. Greenbrier: A Scientific Portrait of a West Virginia River. Cacapon Institute, High View, WV. 32 p.
Hach, 1992. Hach Water Analysis Handbook. Hach Co., Loveland, CO 831 pp.
Helsel, D. R., & R. M. Hirsh, 1992. Studies in Environmental Science 49: Statistical Methods in Water Resources. Elsevier Science Publishers B.V. 522 pp.
Jenks, E., 1969. Some chemical characteristics of the major soil series of West Virginia. Bulletin 582T, WV Univ. Agricultural Experiment Station.
Keeney, D. R., 1989. Sources of nitrate to groundwater. In: Nitrogen Management and Groundwater Protection, ed. By R. F. Follett, Elsevier Science Publishers B.V., Amsterdam. P 23-34.
Kesecker, E. 1998. Personal communication. USDA-NRCS District Conservationist, Moorefield, WV.
Mathes, M. V., 1996. Streamwater quality in the headwaters of the South Branch Potomac River basin, West Virginia, 1994-95, and the Lost River basin, West Virginia, 1995. USGS Administrative Report in. Potomac Headwaters Agricultural Water Quality Report. Potomac Headwaters Interagency Water Quality Office, May 1996.
Miller, C. V., J. M. Denis, S. W. Ator and J. W. Brakebill, 1997. Nutrients in streams during baseflow in selected environmental settings of the Potomac River basin. J. Am. Water Res. Assoc. 33(6): 1155-1171.
Morris, D. P. and W. M. Lewis, 1988. Phytoplankton nutrient limitation in Colorado mountain lakes. Freshwater Biology 20:315-327.
Mueller, D. K., P. A. Hamilton, D. R. Helsel, K. J. Hitt and B. C. Ruddy, 1995. Nutrients in Ground Water and Surface Water of the United States - An Analysis of Data Through 1992. USGS, Water Resources Investigations Report 95-4031. 74 p.
SAS Institute, 1995. JMP Statistics and Graphics Guide, Version 3.1. SAS Institute Inc., Cary, NC. 593 pp.
Sharpley, A. 1995. Fate and transport of nutrients: Phosphorus. RCA III: Working Paper No. 8. USDA Agricultural Research Service. 32 p.
Trachtenberg, E. and C. Ogg, 1994. Potential for reducing nitrogen pollution through improved agronomic practices. Water Resources Bull. 30(6):1109-1115.
USDA-NRCS, 1996. Potomac Headwaters Land Treatment Watershed Project Environmental Assessment. USDA- Natural Resources Conservation Service, various pagination.
USEPA, 1995. National Water Quality Inventory: 1994 Report to Congress. EPA 841-R-95-005. 497 p.
USGS, 1998. Potomac NAWQA site 01621050 - Muddy Creek at Mount Clinton, VA. http://md.usgs.gov/pnawqa/datarpt/data/fixQW/tabled/01621050_2702_75.htm
Wiley, J. B., M. L. Hunt and D. K. Stewart, 1996. Drainage Areas of the Potomac River Basin, West Virginia. U.S. Geological Survey Open File Report 95-292. 60 p.