INTERIM REPORT ON
WATER QUALITY STUDIES IN THE
LOST RIVER, NORTH RIVER AND SOUTH BRANCH OF THE POTOMAC RIVER
WATERSHEDS OF WEST VIRGINIA

SUMMARY DOCUMENT
JUNE 30, 1999

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Interim Report on Water Quality Studies in the Lost, North and South Branch of the Potomac River Watersheds of West Virginia.

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Introduction and Purpose

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 potential water quality impacts are widespread. The purpose of this interim report is to provide an overview of data from Cacapon Institute's multi- year study of land use influences on nutrient and bacteria concentrations in the Lost River, North River and South Branch of the Potomac River watersheds, three West Virginia basins with varying densities of integrated poultry agriculture.

Background

The Potomac Headwaters region of West Virginia is located in the state's eastern panhandle and contains Hampshire, Hardy, Grant, Mineral and Pendleton counties. Agriculture is a key element in the region's economy, led by the integrated poultry industry and beef cattle production. The rapid expansion of the Headwater's poultry industry beginning in the early 1990s fueled concerns over the potential for water quality problems caused by this industry (Constantz et al, 1993; Ramsey, 1997).

In 1992, state and federal agencies recognized the need for a coordinated and comprehensive approach to protecting and enhancing ground and surface water quality in the area and formed the Potomac Headwaters Interagency Water Quality Office (PHIWQO), which was charged with protecting the waters of the Potomac while maintaining a strong agricultural industry. The cooperating agencies agreed to provide financial and technical assistance to area farmers to reduce and prevent water quality degradation arising from agricultural and urban lands.

As part of the PHIWQO effort, the USDA-Natural Resources Conservation Service contracted with the U.S. Geological Survey (USGS) to conduct a surveillance level water quality study in 1994 and 1995 to assess the condition of the South Branch of the Potomac and the Lost River (headwaters of the Cacapon) watersheds. Their study "did not indicate high nutrient concentrations at any site" but noted algal growth that might be related to stream nutrient loading. They found fecal coliform bacteria in excess of the 200 cfu/100ml in one third of their samples. Nitrate and fecal coliform concentrations were positively correlated with numbers of feedlots and poultry houses.

The USGS study and studies in the Cacapon River by Pine Cabin Run Ecological Laboratory (now Cacapon Institute) did not detect particularly high concentrations of nutrients in the area's streams, despite the high density of agriculture in some of the Headwater watersheds studied. This was unexpected and required further investigation.

The Study

In March of 1997, Cacapon Institute started an intensive study of land use influences on water quality in the Lost River watershed, which was ranked first on the PHIWQO list of watersheds in need of agricultural best management practice implementation (Table 1). Storm sampling was included as an integral component of the study design, an important element lacking in previous studies.

Table 1. Priority ranking of subwatersheds for agricultural best management practice implementation in the Potomac Headwaters Watershed, West Virginia. Adapted from "Potomac Headwaters Land Treatment Watershed Project: Hardy, Hampshire, Mineral, Grant, and Pendleton Counties, West Virginia" (NRCS, 1996).

Subwatershed	Ranked No. Poultry	Ranked litter production ver-	Overall Rank
Lost River	4	1	1[2]
South Fork (of the S. Branch)	3	2	2[2]
South Branch (below Petersburg)	1	8	3[2]
South Branch (above Upper Tract)	2	7	4
N. & S. Mill Creek	6	3	5[2]
Lunice Creek	7	4	6[2]
North Fork	5	9	7
South Branch (Upper Tract to Pe-	10	5	8
Patterson Creek	8	10	9
North River	9	13	10[2]

Note 1: Ranked number of poultry houses/feedlots based on actual number of facilities, not number per square mile.

The North River and the South Branch of the Potomac River watersheds were added to the study in June 1998 to compare to the Lost River basin. The North River was included to establish nutrient water quality patterns in a low intensity agricultural basin. The South Branch watershed, much larger than the Lost, contains municipal and industrial point sources and varying levels of agricultural intensity; it was included to determine if water quality patterns detected in the Lost were indicative of other Potomac Headwater streams.

These studies were designed to answer four questions:

- Are nutrients applied to the basin's agricultural soils entering the river?
- Do streams with different land use characteristics have different nutrient and bacterial concentrations?
- What are peak loadings contributed by each stream and by each watershed as a whole?
- Does implementation of agricultural BMPs have a positive impact on water quality?

The purpose of this summary report is to provide an overview of data collected during regularly scheduled sampling thus far. (For a review of early results associated with storm

sampling in the Lost River watershed, refer to Gillies, 1998c.)

Study Area

The study area (Fig.1) lies within the Valley and Ridge physiographic province in West Virginia, a mountainous region which consists of long, parallel valleys and ridges that run from the northeast to the southwest. Major rivers in this area are the North and South Branches of the Potomac and the Cacapon (including the Lost and North rivers). All of these rivers flow by way of the Potomac to the Chesapeake Bay.

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)

Agriculture is forced by topography to remain largely confined to the narrow valleys and gentle slopes, and from 65-85% of these basins remain forested (USGS, 1996). Most of the region's cropland and prime hay land is found in floodplains and river terraces. Cropland receives the most intensive nutrient application of animal wastes and fertilizer (NRCS, 1996). Hayfields, poultry houses and feedlots are located throughout these watersheds 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.

The integrated poultry industry dominates agriculture in many of the study area's watersheds. However, 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 in the area.

Residences are scattered at low density throughout these watersheds. No municipal water and sewer facilities, large industrial point sources or large towns exist in the Lost and North river basins, although three small package sewage treatment plants serve two schools and one continuous care facility at the lower end of the Lost River watershed. On the other hand, the South Branch watershed in the study area contains the towns of Moorefield and Petersburg (1990 populations 2148 and 2360, respectively) with associated municipal water and sewer facilities, and large industrial point sources, including two poultry processing plants along the South Fork of the South Branch in Moorefield.

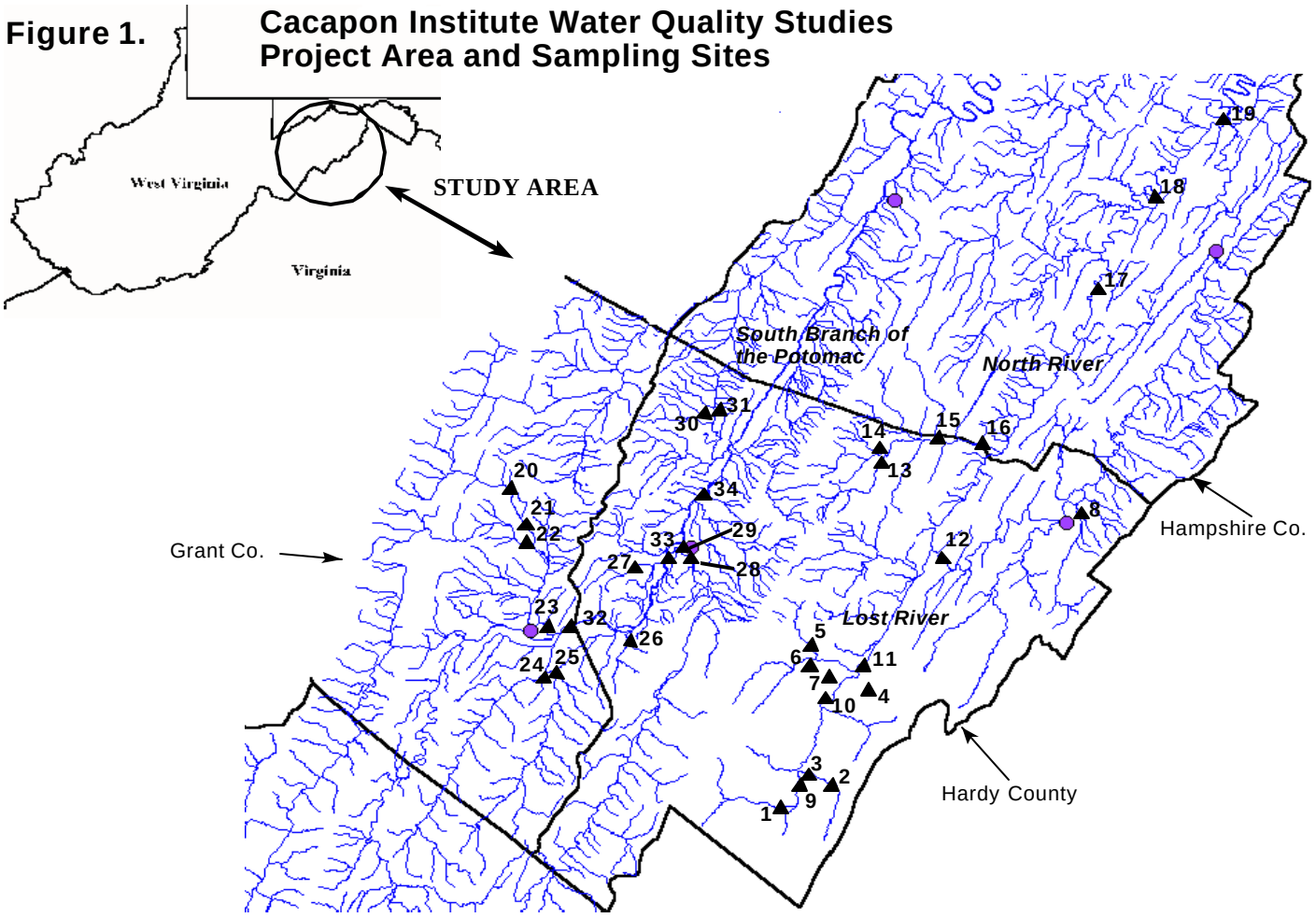
Field and Laboratory Methods

Tributary and mainstem sites were selected with the aid of local representatives of the USDA-Natural Resources Conservation Service, West Virginia University, the US Fish and Wildlife Service and the Potomac Headwaters Resource Alliance. Each site represents a different mix of land uses. Small watersheds with differing land uses are used as indicator sites for specific sources. Mainstem sites are used to accumulate impacts from many sources.

Samples were collected under two different protocols: regularly scheduled synoptic sampling and opportunistic storm event sampling. 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. Storm sampling focused on either one or a few streams per event, and samples were collected repeatedly during and after storms.

This report includes only data collected during synoptic sampling of all sites in each study area.

Figure 1. **Cacapon Institute Water Quality Studies**
Project Area and Sampling Sites



Study Parameters

The main parameters included in this study were phosphorus (orthophosphate --**OP** and total phosphorus --**TP**), turbidity, nitrate and fecal coliform bacteria.

Phosphorus. OP is the form of P most readily available to plants; however, experimental evidence indicates that TP is the better indicator of potential for periphyton and plankton growth.

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.

Nitrate (NO_3-N). Nitrate readily dissolves in water, is chemically stable over a broad range of environmental conditions and moves easily through ground and surface waters. Researchers found nitrate was the major dissolved form of nitrogen detected in different environmental settings in the Chesapeake Bay watershed. We selected nitrate-nitrogen as the best quantitative indicator of nitrogen losses into the river. **Fecal Coliform Bacteria**. Researchers use the presence of fecal coliforms as an indication that water is contaminated with fecal matter and this parameter is the one most commonly used to determine if a river is suitable for water contact recreation. The Lost River is currently on the USEPA's 303(d) list for water bodies not meeting their designated use due to fecal contamination. It is not included in the North River study. The water quality standards for fecal coliforms are subject to some interpretation; however, counts of 200 and 400 colony forming units (cfu)/100 ml are considered benchmark levels indicating contamination and cause for concern.

Algal cover. Algal cover at each site is estimated subjectively, on a scale ranging from very light to very very heavy.

LOST RIVER WATERSHED

The Lost River headwaters of the Cacapon River, in Hardy County, drain 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 followed by beef cattle and raising hay and corn as feed. Agriculture is forced by topography to remain largely confined to the narrow valleys and gentle slopes, and over 80% of the basin remains forested. Some residential developments occur on ridgetops overlooking the valley.

A woody riparian corridor exists along much of each Lost River's tributaries. This is not the case along the Lost River's mainstem, where most trees were removed many years ago and crops, hay and pastureland often extend to the river's edge.

Eight tributary and 4 mainstem sites were selected with the aid of local agents of the NRCS, West Virginia University and the US Fish and Wildlife Service (Table 2, Figure 1). Each site represents a different mix of land uses, ranging from 100% forested to heavily agricultural. Site abbreviations from Table 2 will be used in figures.

Summary Results for regular sampling (March 1997 through May 1999)

Precipitation for the study period (through March 1999) is presented in Figure 2, providing daily, 10 day and thirty day cumulative precipitation totals on all regular sampling days. Of particular note on this graph are the light rainfall at the start of the study, a major rainfall

Table 2. Lost River sampling sites with land use descriptions. Feed lot and poultry house count approximate (Mathes, 1996; NRCS, 1996). Land use data subjective. Currently developing quantitative land use information.

Location (site abbreviation)	Description
1. Cullers Run km 0.4 (CuR)(11.3)	**Tributary**, 14 poultry houses in 12 square miles, only tributary with significant cropland. Pasture, hay and feedlots also.
2&3. Upper Cove Run Sites 3.3 (**UCR3**) & km	**Tributary**, 29 poultry houses in 9 sq miles, most in one large complex 0.5 km upstream of UCR3. UCR1 in town (Mathias). Limited cropland, pasture/hay, sev-
4. Mill Gap Run km 1.2 (**MGR**)(2.5)	**Tributary**, no poultry, no crop, little pasture. Mostly forested, residential development on ridge tops.
5. Camp Branch Run km 0.05 (**CBRS**)(8)	**Tributary**, several poultry houses just upstream of sampling site, otherwise forested and pasture.
6. Kimsey Run km 4.3 (**KR**)(29.1)	**Tributary**, 11 poultry houses, 1 feedlot, no crop, pasture mostly away from stream
7. NoName Trib km 1.5 (**NNT**) (1)	**Tributary**, 100% forested
8. Waites Run km 1.7 (**WR**)(18)	**Tributary** of Cacapon R., not in Lost River watershed, 2 poultry houses well off stream, heavily forested, light residential along stream
9. Lost R. at Mathias km 166.4 (**LR-LRM**)(22.8)	**Mainstem** bisects heavily agricultural floodplain, Cullers Run (see above) main tributary influence
10. Lost R. at Lost City km 157.5 (**LR-LC**) (67.5)	**Mainstem** bisects heavily agricultural floodplain, see Fig. 1 for tributary influences
11. Lost R. at Lost River km 152.6 (**LR-LR**)(109)	**Mainstem** bisects heavily agricultural floodplain, see Fig. 1 for tributary influences
12. 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 UCR3 was first regularly sampled in October 1997. Prior to that time, a site 1.5 km further downstream had been included in the project but had to be relocated upstream to km 3.3 when a new bridge construction

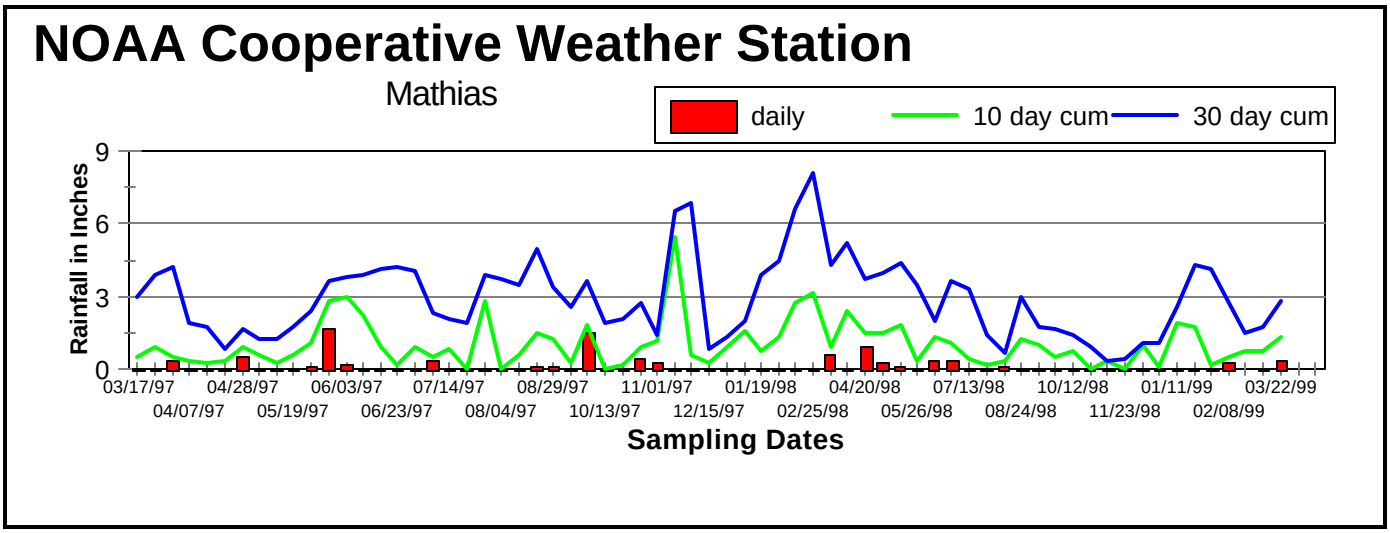
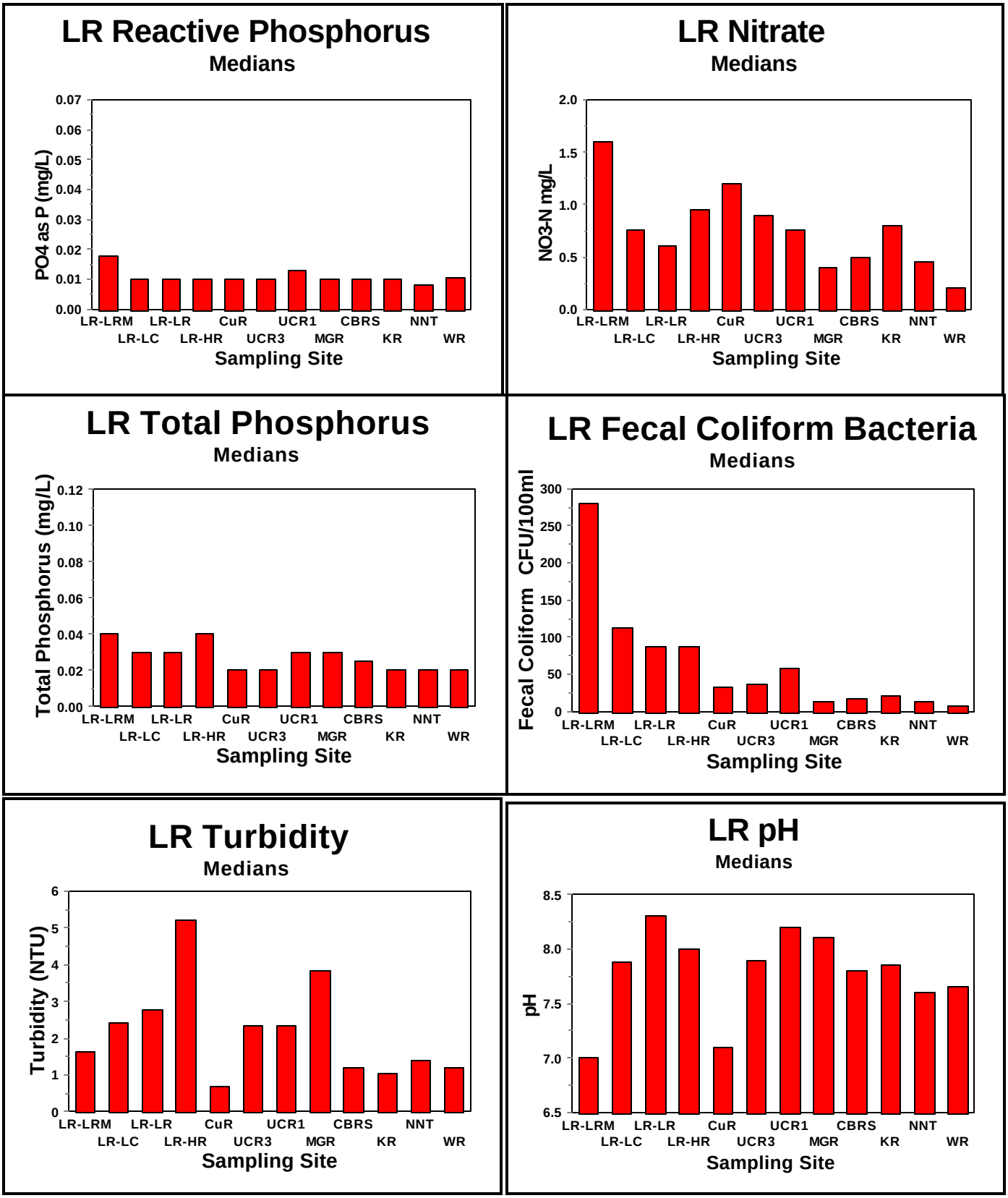


Figure 2. Rainfall on sampling dates from the NOAA Cooperative Weather Station at Mathias. Daily, 10 day and 30 day cumulative totals are provided.

Figure 3. Lost River parameter medians by site.



event in early November 1997, the wet winter and spring of 1998 followed by dry conditions from the middle of June 1998 through December 1998.

OP, TP, turbidity, nitrate and fecal coliform bacteria were present at detectable levels at all sampling sites. Graphs of medians for each parameter by site are presented in Fig. 3.

Median OP and TP concentrations were low at all sites. Median OP ranged narrowly from 0.008 mg/L at NoName Tributary to 0.018 mg/L at Lost River@Mathias . Despite the narrow range, the OP median concentration at Lost River@Mathias (0.018 mg/L) was significantly higher than all sites except Upper Cove Run 1 (median 0.013 mg/L).

Median TP concentrations ranged narrowly from 0.02 to 0.04 mg/L. The highest medians were detected at Lost River@Mathias and Lost River@Hanging Rock (0.04 mg/L), the lowest (0.02 mg/L) at Cullers Run, Upper Cove Run 3, Kimsey Run, NoName Tributary and Waites Run.

Median turbidity ranged broadly from a low of 0.67 NTU at Cullers Run to a high of 5.2 NTU at Lost River@Hanging Rock. Following Lost River@Hanging Rock, the highest median turbidities were found in Mill Gap Run, Lost River@Lost River, Lost River@Lost City, Upper Cove Run 3 and Upper Cove Run 1. The water at Lost River@Hanging Rock was often cloudy and green in color, leading us to suspect that turbidity was biological in origin

Median concentrations at the twelve sites varied more widely than the two forms of phosphorus, ranging from 0.2 to 1.6 mg/L. The highest median concentration was detected at the Lost River@Mathias site (1.6 mg/L), which was statistically distinct from all sites except Lost River@Hanging Rock, Cullers Run and Upper Cove Run 3 (0.95, 1.2 and 0.90 mg/L, respectively). The lowest median concentrations were found at Waites Run, Mill Gap Run and

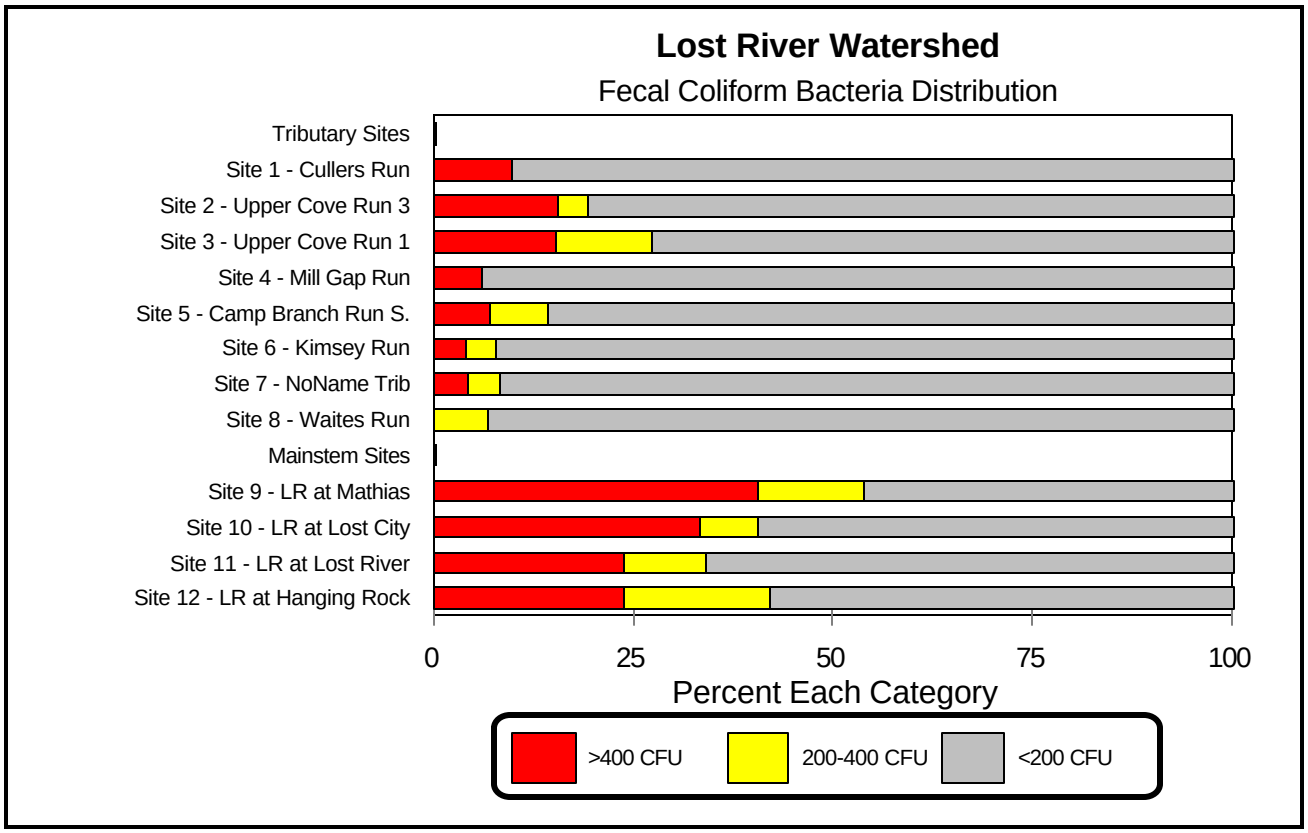


Figure 4. Percent distribution of fecal coliform bacteria at Lost River sampling sites by water quality standard categories.

NoName Tributary ((0.2, 0.4 and 0.45 mg/L, respectively).

Median fecal coliform bacteria concentrations ranged widely, from a high of 280 colony forming units/ 100 ml (cfus/100ml) at Lost River@Mathias to a low of 7 cfus/100 ml at Waites Run. The second highest median bacteria count was 112 at Lost River@Lost City. Despite the wide range of medians, large variability at each site prevented statistical comparisons from separating Lost River@Mathias from the other mainstem sites and Upper Cove Run 3 and Upper Cove Run 1.

Figure 4 provides percent distribution of fecal coliform bacteria data in the categories < 200 cfu/100ml, 200-400 cfu and >400 cfu. Across the study period the Lost River@Mathias exceeded the water quality benchmark of 400 cfu/100ml in more than 40% of the samples collected, and exceeded 200 cfu/100 ml in more than 50% of samples. The other mainstem sites were more likely than tributary sites to exceed the standard as well.

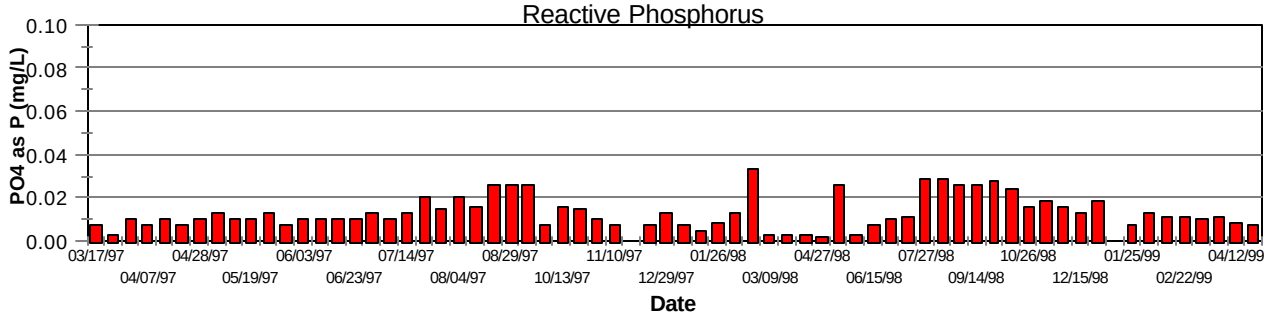
Lost River@Mathias and Cullers Run had distinctly lower pH than other sampling sites, with medians of 7.0 and 7.1, respectively. pH at other sites ranged from 7.6 to 8.2. pH readings in excess of the state standard of 9.0 were detected at Lost River@Lost River, Lost River@Hanging Rock, Upper Cove Run 1, Kimsey Run and NoName Tributary; in all cases these high levels were associated with moderately heavy to heavy growth of algae.

Lost River Time Series Data

Graphs of the Lost River data along a time series were informative. Of particular interest were:

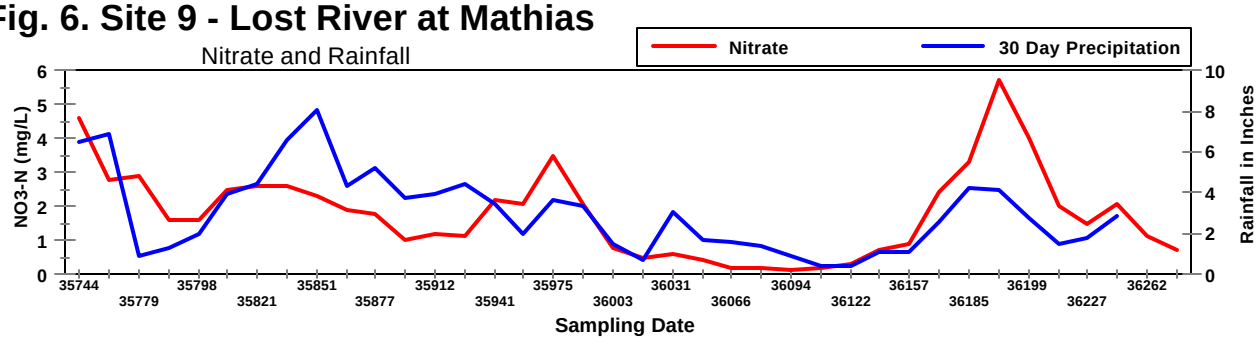
- Distinctly high OP, TP and turbidity concentrations were episodic, short lived and occurred during precipitation events. A number of very high turbidity readings were recorded at Upper Cove Run 1 and Upper Cove Run 3, caused by erosion from a construction site upstream.
- All sites had small periodic variations in OP and P levels, and for turbidity at some sites as well; the reasons for most of these variations remain obscure. However, periods of relatively high OP levels at Waites Run, ranging from 0.04 to 0.06 mg/L, occurred during low flow (Figure 5). This phosphorus was traced to a spring that seeped into Waites Run in the vicinity of the sampling site. Nitrate concentrations in the seep were low and ranged from 0.1 to 0.2 mg/L.
- Unlike phosphorus, nitrate concentrations showed extended responses to precipitation at many sites, specifically at sites for which nitrate was strongly correlated to 10 and 30 day precipitation totals. Particularly large responses were evident for sites with cropland like Lost River@Mathias (Figure 6), Cullers Run, Lost River@Lost City,Lost River@Lost River, Lost River@Hanging Rock (in descending order) but an apparent long term increase in ni-

Figure 5. Site 8 - Waites Run.



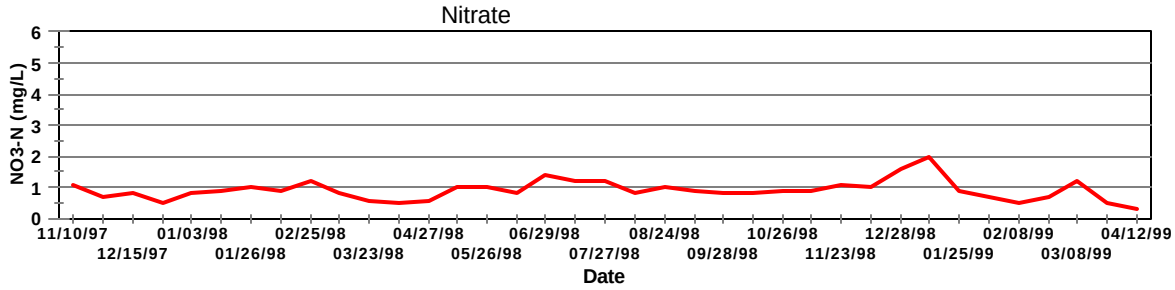
trate following heavy precipitation was also seen in Upper Cove Run 1, Camp Branch Run South, Kimsey Run and NoName Tributary. Mostly forested sites Mill Gap Run and Waites Run showed no apparent increase due to precipitation, while the forested tributary NoName Tributary did.

Fig. 6. Site 9 - Lost River at Mathias



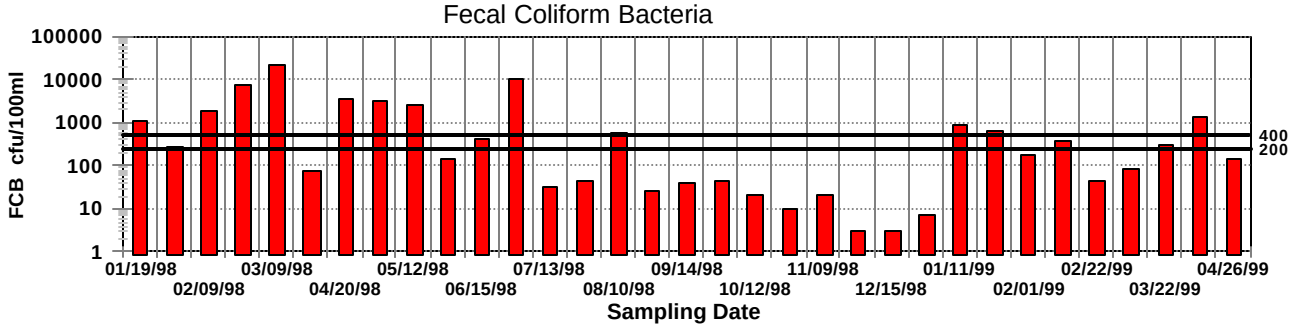
- At most sites nitrate levels dropped to nearly zero during the very dry summer and fall of 1998, as seen in Figure 6 above. However, Cullers Run and Upper Cove Run 3 (Figure 7) maintained relatively high nitrate levels during this same period. The persistent nitrate source in Upper Cove Run 3 was traced to a perennial spring located upgradient from a large complex of poultry houses. The pattern seen at Cullers Run may also indicate the presence of a nitrate-bearing spring. Although nitrate levels in Mill Gap Run were never elevated, a small spring in that watershed was found to have a nitrate concentration comparable to the spring at Upper Cove Run 3.
- Time series graphs of fecal coliform bacteria show that exceedences of the 200 and 400

Figure 7. Site 2 - Upper Cove Run 3



cfu/100ml levels occurred almost exclusively during the first seven months of 1998 and following the snow and ice storms of January 1999 (Figure 8).

Fig. 8 Site 9 - Lost River at Mathias



NORTH RIVER WATERSHED

The North River, the largest tributary of the Cacapon River, is slightly larger than the Lost; it drains 205 square miles - 30% of the total Cacapon drainage area. Agriculture in this watershed is less intense than in the Lost River basin and mostly consists of pasture/hayland and cattle; the few poultry houses (appx 13) are located in the headwaters area upstream of Rio and below Rt. 50.

A woody riparian corridor, ranging from a narrow band of trees to hundreds of feet wide, exists along much of this river's length in contrast to the Lost River mainstem's mostly denuded banks.

One tributary and six mainstem sites were selected for water quality comparisons to the Lost River (Table 3, Figure 1). Fecal coliform bacteria were not collected in this watershed. Monthly sampling of these sites began in July 1998. Site abbreviations from Table 3 will be used in figures.

Results of regular synoptic sampling in the North River for the period from July 1998 through May 1999

Precipitation for the study period is presented in Figure 9, providing daily, 10 day and thirty day cumulative precipitation totals on all regular sampling days. The pattern of precipitation observed at this site was similar to that for the same period in the Lost River basin; a period of unusually dry weather temporarily broken by a period of ice and snow in January 1999. This reduced the frequency and impact of nonpoint source events which also reduced our ability to make comparisons between North River and Lost River sites.

OP, TP, turbidity and nitrate were present at detectable levels at all sampling sites. Graphs of medians for each parameter by site are presented in Fig. 10. There were significant differences between at least some of the sites for all parameters measured.

Median OP and TP concentrations were low at all sites. Median OP ranged narrowly from 0.007 to 0.014 mg/L, a range similar to the Lost River. The highest median OP concentrations were found at Skaggs Run and North River@Forks of Cacapon (0.013 and 0.014, respectively). Analysis of variance detected a difference between sites; however, multiple comparison tests were unable to locate the differences

Table 3. North River sampling sites with land use descriptions. Feed lot and poultry house count approximate (NRCS, 1996). Land use data subjective. Currently developing quantitative land use information.

Location (abbreviation) (drainage area sq mi)	Description
13. Skaggs Run at North	Tributary. 1 feedlot and until recently 2 poultry houses. Poultry litter
14. North River at Skaggs	Mainstem upstream of Skaggs Run. Appx 2 poultry houses, some crop-
15. North River at Ford Hill	Mainstem, upstream of Grassy Lick Run.
16. North River at Rio	Mainstem, upstream of Sperry Run.
17. North River at Rt. 50	Mainstem, upstream of unnamed trib at Stuart Hollow.
18. North River at Ice Moun-	Mainstem, downstream of Maple Run.
19. North River at Forks of Cacapon (and Rt 127)	Mainstem, above confluence with Cacapon River.

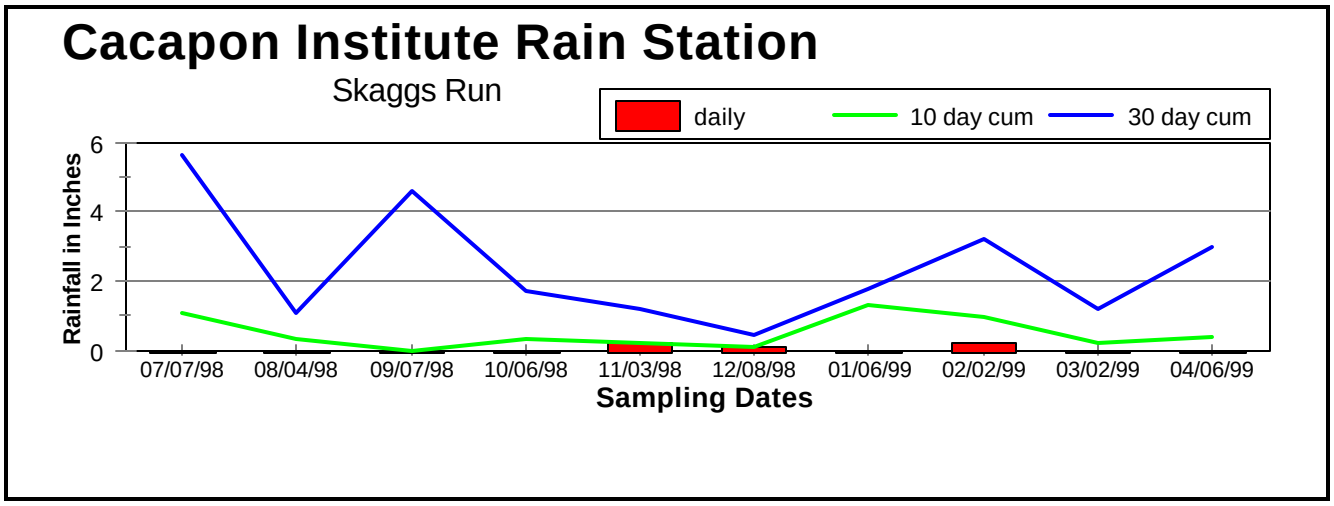


Figure 9. Rainfall on sampling dates from the Cacapon Institute rain station located along Skaggs Run in the North River watershed. Daily, 10 day and 30 day cumulative totals are provided.

Median TP concentrations ranged narrowly from 0.01 to 0.03 mg/L, slightly lower than the Lost River. The highest median TP concentrations were found at Skaggs Run and North River@Forks of Cacapon (0.03 and 0.025 mg/L, respectively). Sites were not significantly different.

Median nitrate concentrations varied more widely than the two forms of phosphorus, ranging from 0.1 to 0.4 mg/L. The highest median concentrations were detected at North River@Skaggs Run, Skaggs Run and North River@Rio (0.40, 0.30, 0.30 mg/L, respectively). No significant differences were detected between sites. The peak concentration observed was 2.4 mg/L at Skaggs Run. During this same period of time, median nitrate levels in the Lost River mainstem ranged from 0.2 mg/L at Lost River@Lost City to 0.8 mg/L at Lost River@Mathias; a peak concentration of 5.7 mg/L was observed at Lost River@Mathias.

Turbidity was generally low at all sites and medians ranged narrowly from 0.66 NTU at North River@Rio to 1.9 NTU at North River@Forks of Cacapon. During this same period of time, median turbidity levels in the Lost River mainstem ranged more broadly from 0.97 NTU at Lost River@Mathias to 4.1 NTU at Lost River@Hanging Rock.

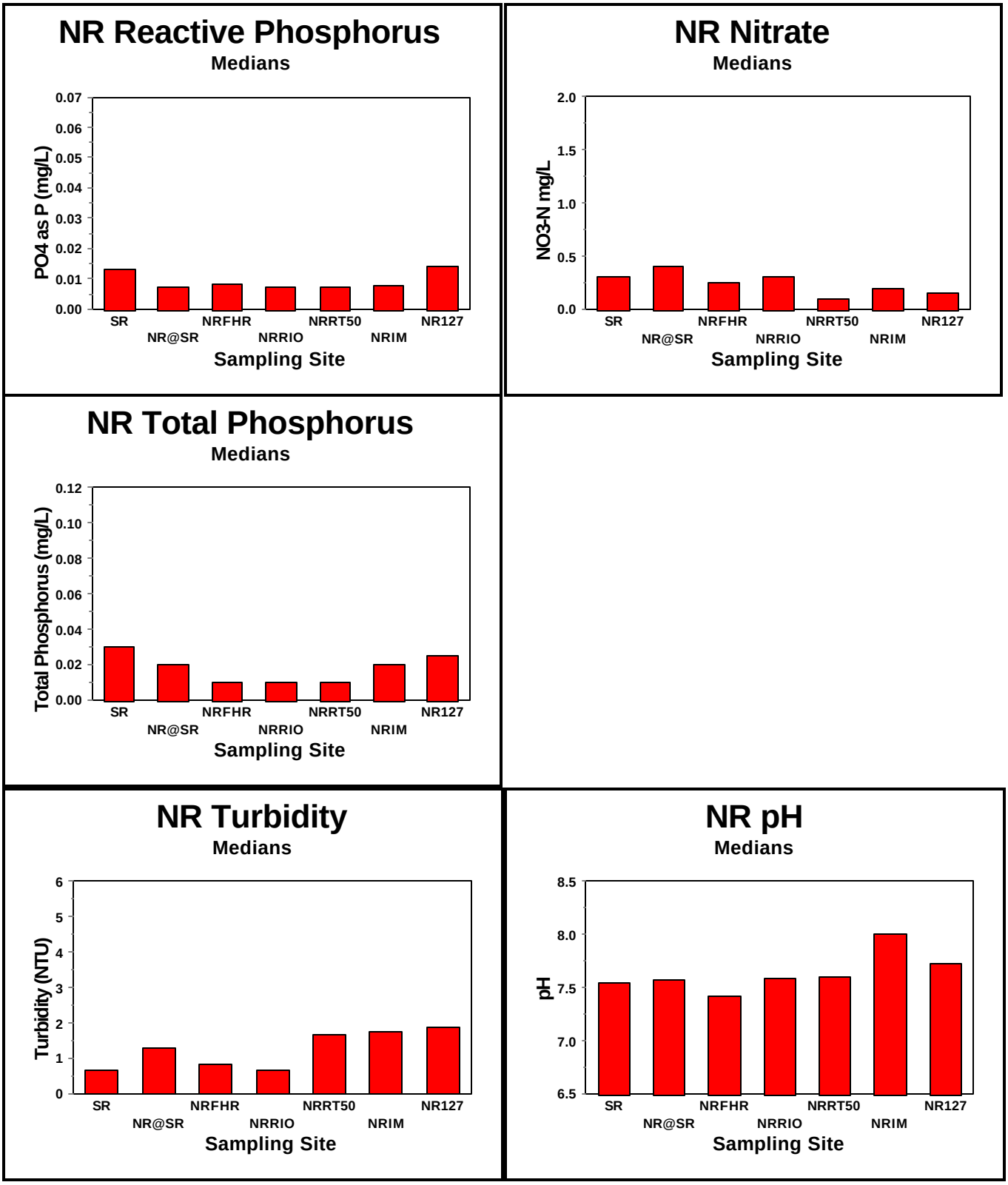
Median pH values ranged from a low of 7.4 at North River@Ford Hill Road to 8.0 at North River@Ice Mountain. This was a much narrower range of medians than observed in the Lost River.

North River Time Series data

No high concentrations of OP, TP and turbidity were observed during regular sampling.

Nitrate concentrations at all sites increased in response to precipitation in January 1999. However, this increase was of smaller magnitude and shorter duration than observed at Lost River mainstem sites during the same period. The largest increase was observed at the North River confluence with Skaggs Run. Figure 14 (page 23) provides a comparison of nitrate concentrations between the North and Lost rivers and the South Branch's Lunice Creek associated with this January weather.

Figure 10. North River parameter medians by site.



SOUTH BRANCH OF THE POTOMAC WATERSHED

The South Branch of the Potomac watershed is much larger than the Lost, with 1241 square miles in drainage area at the most downstream sampling site. The watershed contains municipal and industrial point sources and varying levels of agricultural intensity. Agriculture in this watershed is largely confined to the valleys and gentle slopes; floodplain valleys along the mainstem are much wider than those in the Lost River.

Twelve tributary and three mainstem sites were selected with the aid of local representatives of the USDA-NRCS, West Virginia University, the US Fish and Wildlife Service and the Potomac Headwaters Resource Alliance (Table 4, Figure 1). Each site represents a different mix of land uses; however, at this time land use data is subjective. Monthly sampling in the South Branch began in June 1998.

Results of regular sampling in the South Branch of the Potomac watershed for the period from June 1998 through May 1999

Precipitation for the study period is presented in Figure 11, providing daily, 10 day and thirty day cumulative precipitation totals on all regular sampling days. The pattern of precipitation observed at this site was similar to that for the same period in the Lost River basin; a period of unusually dry weather temporarily broken by a period of ice and snow in January 1999. This reduced the frequency and impact of nonpoint source events which also reduced our ability to make comparisons between sites within the South Branch watershed and the Lost River.

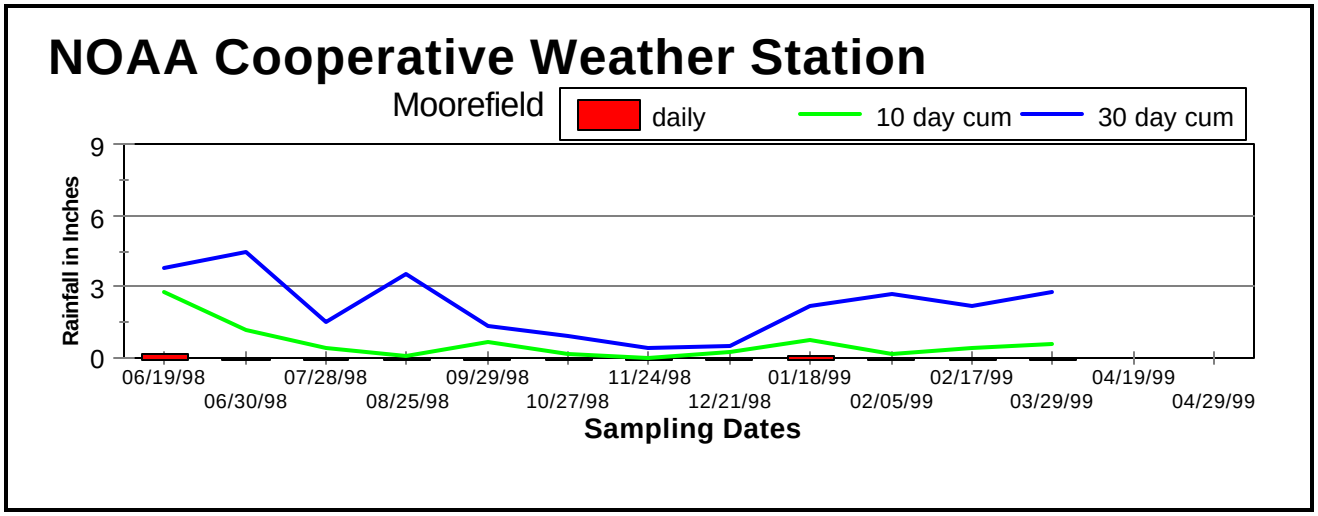


Figure 11. Rainfall on sampling dates from the NOAA Cooperative Weather Station at Moorefield. Daily, 10 day and 30 day cumulative totals are provided.

Table 4. South Branch of the Potomac sampling sites with land use descriptions. Feed lot and poultry house count approximate (Mathes, 1996; NRCS, 1996). Land use data subjective.

Location (abbreviation) (drainage area sq mi)	Description
Site 20. Lunice Creek North Fork at Maysville	**Tributary**. Located at Turner Park. Upstream of most poultry houses and feedlots in Lunice Creek watershed. Downstream of Maysville.
Site 21. Lunice Creek North Fork (LCNF) (appx. 27.5)	**Tributary**. Well downstream of concentration of poultry houses below Maysville. Hay/pasture dominates low lying areas.
Site 22. Lunice Creek South	**Tributary**. Immediately downstream of large agricultural operation with cat-
Site 23. Lunice Creek at	**Tributary**, 21 feedlots, 65 poultry houses. The majority of poultry houses,
Site 24. North Mill Creek (MCNF) (47.4)	**Tributary**. 20 feedlots and 77 poultry houses are found in North and South Mill Creek **combined**. The majority of Mill Creek feedlots are found in the
Site 25. South Mill Creek (MCSF) (47.1)	**Tributary**. 20 feedlots and 77 poultry houses are found in North and South Mill Creek **combined**. The majority of Mill Creek poultry houses are found in the South Mill Creek watershed. Also found in the South Mill Creek wa-
Site 26. Jenkins Run (JR) (appx. 2)	**Tributary**. No feedlots or poultry houses. Some cattle pastured periodically just upstream of sampling site. This tributary has relatively high residential
Site 27. Hutton Run (at CR	**Tributary**. Poultry houses and feedlots located in headwaters. Much of
Site 28. South Fork South Branch above Rt 55	**Tributary**. 32 feedlots, 98 poultry houses. Located upstream of industrial outfalls from Hester and Wampler processing plants in Moorefield.
Site 29. South Fork South Branch below industrial out-	**Tributary**. 32 feedlots, 98 poultry houses. Located downstream of industrial outfalls from Hester and Wampler processing plants in Moorefield.
Site 30. Turnmill Run (TM) (1.87)	**Tributary** sampled just upstream of Mudlick Run. No feedlots or poultry houses, pasture receives sludge application. Upland soils are shallow,
Site 31. Mudlick Run (MUD)	**Tributary** sampled just upstream of Turnmill Run. Poultry houses, feedlots.
Site 32. South Branch at	**Mainstem**. 128 feedlots, 265 poultry houses. Downstream of Petersburg.
Site 33. South Branch at	**Mainstem**. Below Hutton Run. Upstream of Moorefield. 157 feedlots, 313
Site 34. South Branch at	**Mainstem**. Downstream of Moorefield and South Fork of the South Branch.

Note: Sites 28 and 29 were added to the study in November (site 28) and December (Site 29) of 1998. Prior to this time, samples in the South Fork were collected at the Moorefield Water Treatment Plant. How-

C

Nitrate, TP, OP and fecal coliform bacteria were present at detectable levels at all sampling sites. Graphs of medians for each parameter by site are presented in Fig. 12. There were significant differences between at least some of the sites for all constituents measured.

Median OP and TP concentrations were low at most sites. Median OP ranged from 0.007 to 0.068 mg/L), a much wider range than seen in the Lost River. OP at several sites exceeded the highest median concentration observed in the Lost River. The sites were, in ascending order, Hutton Run, South Branch@Old Fields, Mudlick Run, South Fork South Branch Below Outfalls, and South Mill Creek (0.020, 0.023, 0.029, 0.064 and 0.068 mg/L, respectively). The relatively high OP concentrations at South Fork South Branch Below Outfalls and South Mill Creek were associated with point source discharges. Elevated OP concentrations at the South Branch at Old Fields may also be associated with upstream point sources in Moorefield (two poultry plants, one sewage treatment plant).

Median TP concentrations ranged from 0.01 to 0.10 mg/L. As with OP, the highest median concentrations were found at Hutton Run, South Branch@Old Fields, Mudlick Run, South Fork South Branch Below Outfalls, and South Mill Creek (0.03, 0.04, 0.04, 0.09, and 0.10 mg/L, respectively). Elevated TP concentrations in the South Branch at Old Fields may be associated with upstream point sources. The two high TP medians values associated with point sources exceeded the highest seen in the Lost River.

Median turbidity ranged narrowly from a low of 0.52 NTU at South Fork South Branch above Rt. 55 to a high of 2.2 NTU at Hutton Run. Following Lost River@Hanging Rock, the highest median turbidities were found in Mill Gap Run, Lost River@Lost River, Lost River@Lost City, Upper Cove Run 3 and Upper Cove Run 1.

Median nitrate concentrations at the fifteen sites varied more widely than the two forms of phosphorus, ranging from 0.2 mg/L at Jenkins Run to 1.8 mg/L at South Fork South Branch Below Outfalls; the peak concentration (10.0 mg/L) was also detected at South Fork South Branch Below Outfalls. The relatively high nitrate concentrations at South Fork South Branch Below Outfalls were associated with point source discharges. Elevated nitrate concentrations in the South Branch at Old Fields appear to be primarily associated with upstream point sources during dry periods when little nitrate was observed in the South Branch at Fisher. During the South Branch sampling period from June 1998 through April 1999, median nitrate levels in the Lost River watershed ranged from 0.2 mg/L (at Lost River@Lost City and Waites Run) to 1.2 mg/L at Cullers Run and 0.9 mg/L at Lost River@Mathias; the peak concentration (5.7 mg/L) was observed at Lost River@Mathias.

Median fecal coliform bacteria concentrations ranged widely, from a high of 128 colony forming units/ 100 ml (cfus/100ml) at Hutton Run to a low of 3 cfus/100 ml at South Fork South Branch above Rt. 55 and South Fork South Branch Below Outfalls. Statistical comparisons were not performed on this data. During the South Branch sampling period from June 1998 through April 1999, fecal coliform bacteria levels were also low in the Lost watershed.

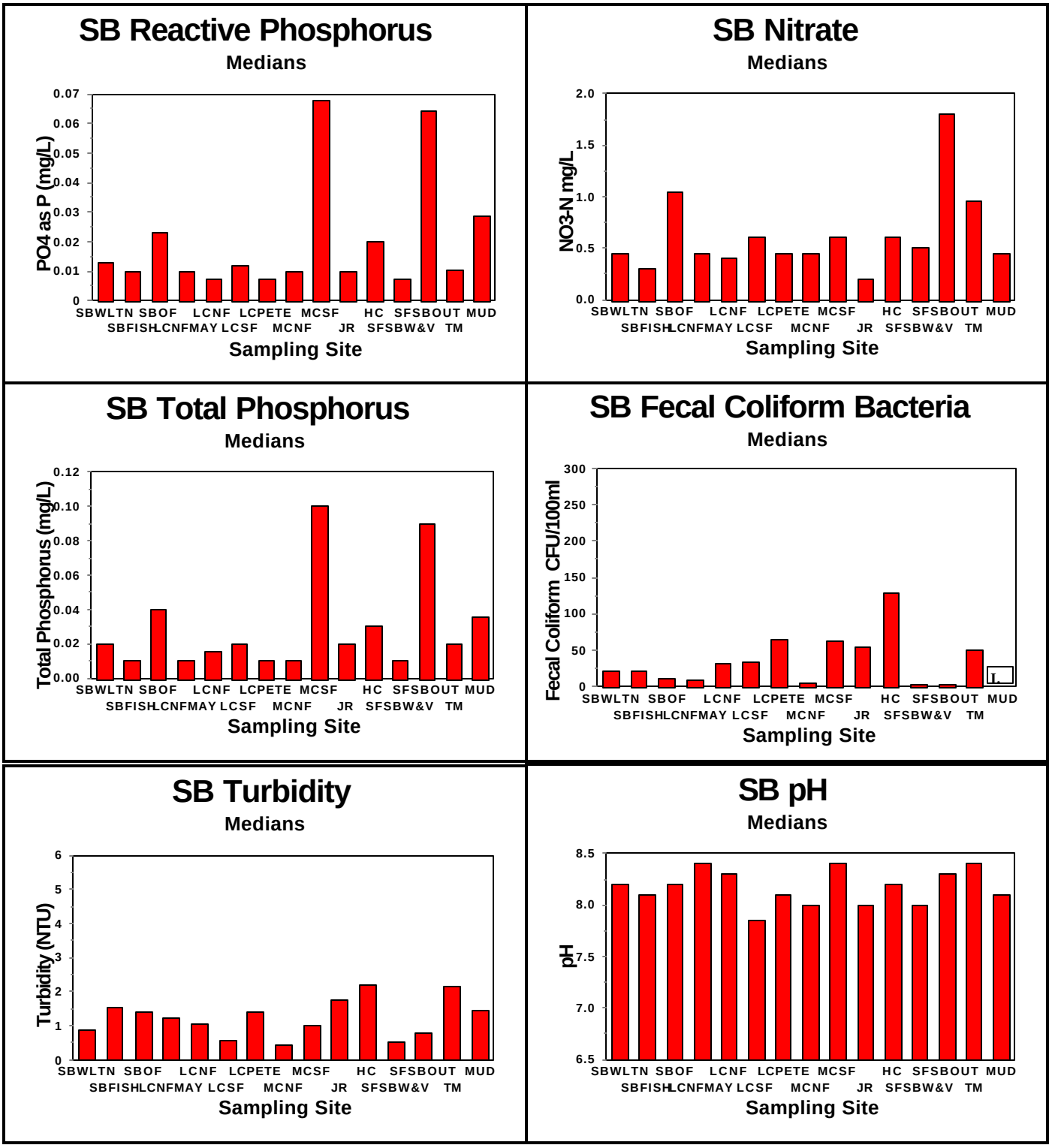
Figure 13 provides percent distribution of fecal coliform bacteria data in the categories < 200 cfu/100ml, 200-400 cfu and >400 cfu. Jenkins Run, Hutton Run and South Fork Lunice Creek were the sites most likely to have bacterial counts exceeding 200 (Fig. 9). In Jenkins Run and Hutton Run these high counts had no apparent pattern. Both South Fork Lunice Creek and Jenkins Run became nearly dry during the Summer and fall of 1998. Bacteria samples were not collected in February 1999.

Median pHs at South Branch sites ranged from 7.9 at South Fork Lunice Creek to 8.4 at North Fork Lunice Creek@Maysville and Turnmill Run.

Time Series Data

Graphs of the South Branch data along a time series were informative. Of particular interest were:

Figure 12. South Branch of the Potomac parameter medians by site.



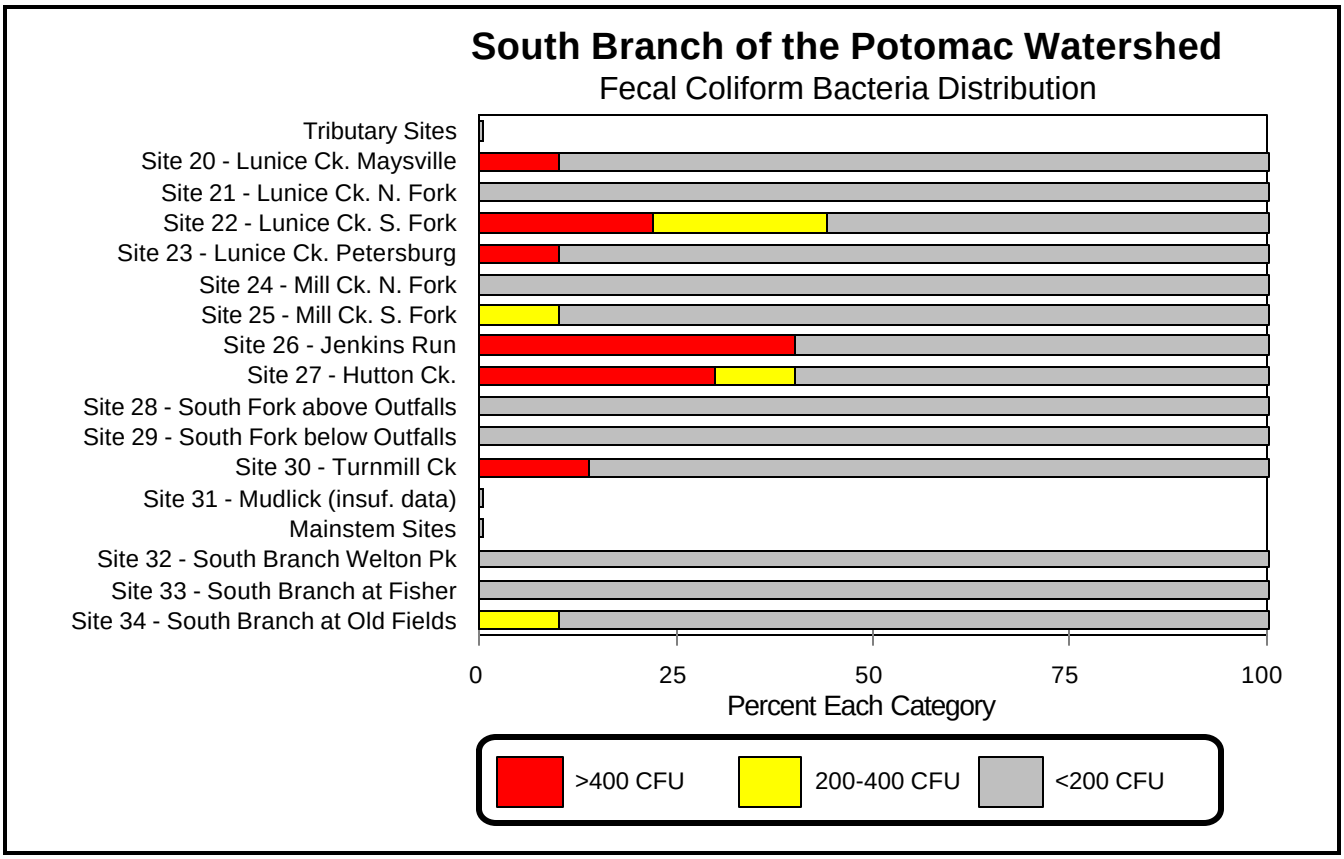
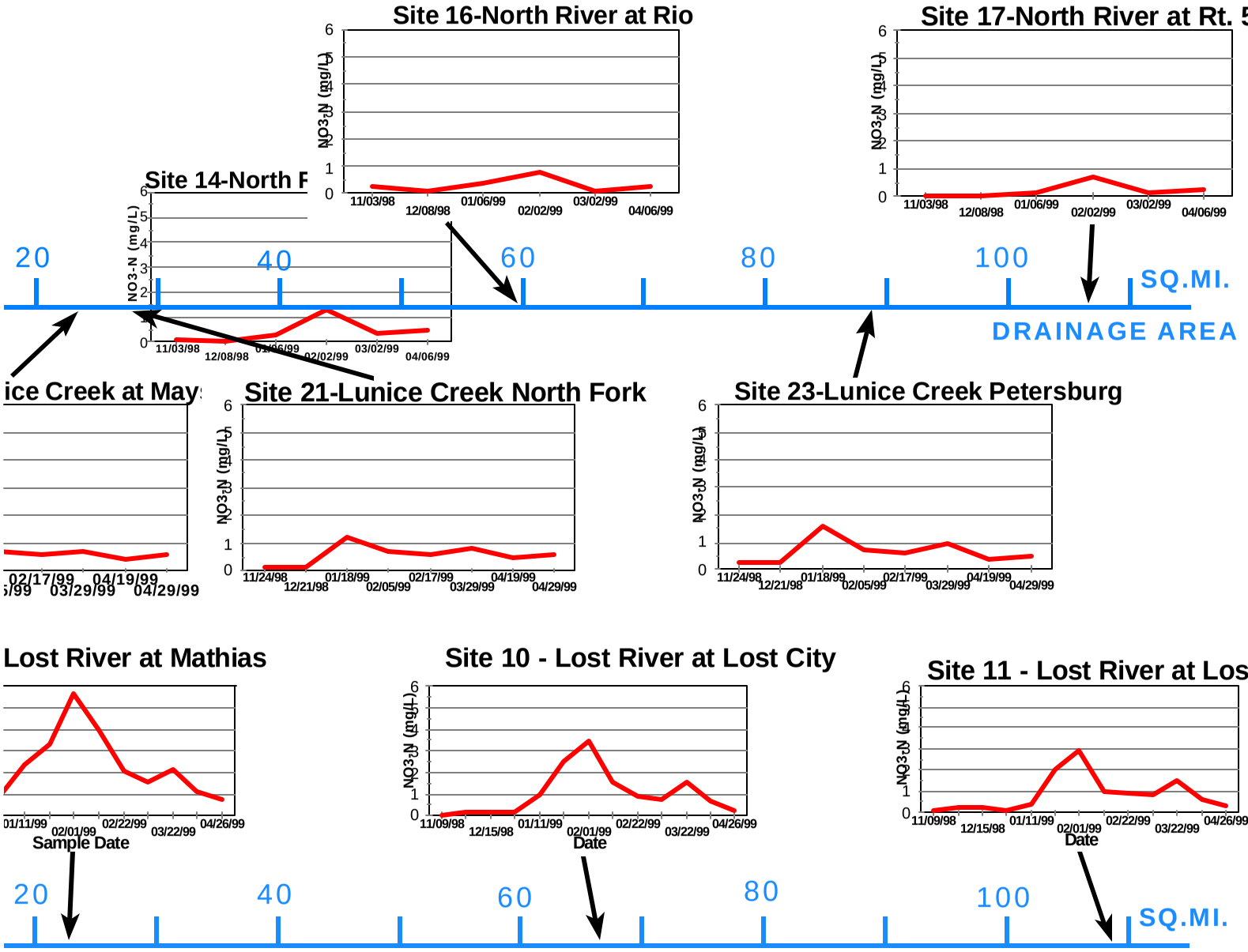


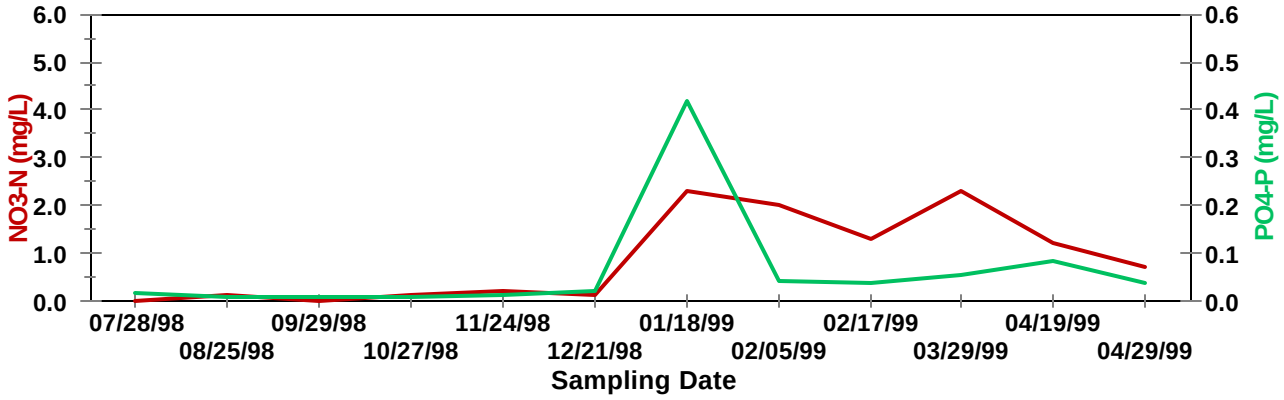
Figure 13. Percent distribution of fecal coliform bacteria at South Branch sampling sites by water quality benchmark categories.

- High concentrations of OP, TP and turbidity associated with precipitation were observed infrequently in the South Branch, as in the Lost River during this same period of unusually dry weather.
- Persistently high concentrations of OP and TP were observed in South Mill Creek and South Fork South Branch Below Outfalls; as stated above, these were associated with point sources. Elevated phosphorus concentrations observed in the South Branch at Old Fields also appear to be primarily associated with point sources located well upstream in Moorefield.
- As in the Lost River, nitrate concentrations showed extended increases following the January 1999 precipitation at many sites; this was evident at all Lunice Creek sites, North Mill Creek, the South Fork South Branch above Rt. 55, the South Branch at both Welton Park and Fisher, and Mudlick Run.
- Elevated nitrate concentrations at the South Branch at Old Fields appeared to be primarily associated with upstream point sources in Moorefield during dry periods when little nitrate was observed in the South Branch at Fisher, which is located upstream of the Moorefield point sources.


Site 16-North River at Rio
Site 17-North River at Rt. 50
Site 14-North F
NO3-N (mg/L)
11/03/98
12/08/98
01/06/99
02/02/99
03/02/99
04/06/99
20
40
60
80
100
SQ.MI.
DRAINAGE AREA
ice Creek at May
Site 21-Lunice Creek North Fork
Site 23-Lunice Creek Petersburg
11/24/98
12/21/98
01/18/99
02/05/99
02/17/99
03/29/99
04/19/99
04/29/99
Lost River at Mathias
Site 10 - Lost River at Lost City
Site 11 - Lost River at Lost River
01/11/99
02/01/99
02/22/99
03/22/99
04/26/99
Sample Date
11/09/98
12/15/98
Date

- Hutton Run and Turnmill Run had relatively high nitrate concentrations throughout the study period. Both streams retained strong flow throughout 1998's very dry summer and autumn and we suspect they, like Upper Cove Run 3 in the Lost River, were fed by springs with moderately high levels of nitrate.
- A January 1999 storm was widespread and of similar intensity in the Lost, North and South Branch study areas. It provided a rare opportunity to compare the three study areas and their characteristic land use influences on water quality. We chose to compare nitrate concentrations in the Lost and North rivers and the South Branch's Lunice Creek along a time series due to the extended response of nitrate to precipitation noted above (Figure 14). These three watersheds are comparable in size but have different levels of agricultural intensity, ranging from low in the North to moderate in Lunice to high in the Lost (according to NRCS 1996 data). The figure shows three sites from each basin arranged in order of increasing draiange area. The North River showed a short term increase in nitrate levels followed by a decrease to previous levels the following month. Nitrate at all three sites in Lunice Ck. increased following the storm and remained somewhat elevated through April. Lost River sites increased to a much greater extent than seen in the other basins, particularly at the Lost River at Mathias headwater site and remained somewhat elevated through early April.
- Time series graphs of fecal coliform bacteria showed that exceedences of the 200 and 400 cfu/100ml levels, as in the Lost River, rarely occurred during the very dry summer and autumn of 1998. In fact, they rarely occurred at any time. Jenkins Run, Hutton Run and South Fork Lunice Creek were the sites most likely to have bacterial counts exceeding 200 (Fig. 13). In Jenkins Run and Hutton Run these high counts had no apparent pattern. In South Fork Lunice Creek, they did not occur during the dry spell. It should be noted that South Fork Lunice Creek and Jenkins Run both became nearly dry. Bacteria samples were not collected in February 1999.
- Phosphorus and nitrate levels in Mudlick Run increased dramatically in response to the ice storms in January 1999 and remained elevated throughout the spring of 1999- a phosphorus pattern not observed at any other site in this study (including the Lost and North rivers) (Figure 15) This small stream was also unique among the study sites in that it was occluded with algae throughout the summer and fall of 1998. Turnmill Run, which flows into Mudlick at the sampling site, has persistent high nitrate and very light algal growth.

Figure 15. Site 31-Mudlick Run



Summary

In general and in the absence of point sources, phosphorus and turbidity were low except during runoff events in all basins. In addition to the obvious sources of manure concentrations and fertilized lands, phosphorus has been found associated with naturally phosphorus rich soils at a construction site (Gillies, 1998c) and in springs.

Nitrate was much more variable. Many sites showed an extended increase in nitrate concentration following periods of substantial precipitation; paramount among these were the Lost River's mainstem and Cullers Run. Some sites never or very rarely had elevated nitrate concentrations. Other sites had persistent sources of nitrate that appeared to be associated with groundwater/springs.

Fecal coliform bacteria counts were low at almost all sites during the dry summer and fall of 1998. High levels were generally associated with periods of average or above average rainfall. Bacteria counts above the water quality benchmarks for fecal coliforms in recreational waters were observed more frequently in the Lost River than in the South Branch watershed; however, South Branch's bacteria counts may well have been low due to the dry conditions that prevailed throughout that basin's shorter study period. In fact, when we looked at the Lost River data for the same sampling period we found bacteria counts to be low as well.

Abnormally dry conditions from the summer of 1998 through the end of the study period reported here hampered our ability to detect differences among sites and between basins, particularly for parameters that respond to periods of precipitation such as nitrate and fecal coliform bacteria. We hope that a return to more normal precipitation patterns will enable us to better compare water quality pattens in the three study watersheds.

A few sites stood out by having unusually high concentrations of 2 or more parameters. In the South Branch, such sites were generally downstream of point sources (South Mill Creek, South Fork South Branch below Outfalls, South Branch@Old Fields). In the Lost River basin these were usually mainstem sites without point sources; this was particularly true of the Lost River at Mathias. No sites in the North River had high concentrations of the parameters measured.

The Lost River at Mathias stood out among all sites in all basins as having distinctly elevated nitrate, phosphorus and fecal coliform bacteria. It also had the greatest nitrate response to precipitation, reaching a concentration of 6.8 mg/L for several days following a saturating storm in November 1997 (Gillies, 1998c). This stream flows almost continuously through lands used for crops, hay, pasture and feedlots. Its only major tributary influence comes from Cullers Run, which has similar land uses in its lower third but was rarely observed to contribute high bacteria and phosphorus concentrations; it did have persistently elevated nitrate.

We will continue regular sampling in all three watersheds, augmented by storm sampling and other special studies, including a nutrient survey of springs. Our plans to complete calibration of all flow stations this spring were hampered by the dry conditions. Once all stations have been properly calibrated, we will convert concentration data to total loads and load per square mile for each watershed. Another challenge is to develop accurate land use data for these watersheds, with an emphasis on the Lost River. We are hoping to find partners to help develop the same information for the South Branch.

These studies illustrate the difficulty in understanding patterns of nutrient and bacteria fluxes in the Potomac Headwaters. The answers are never as simple as they appear from a distance. However, we are well on our way to developing a detailed understanding of water quality patterns in these watersheds.

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