EXECUTIVE SUMMARY

I. INTRODUCTION

The Monocacy Creek watershed occupies approximately 48.8 square miles, mostly within Northampton County but also partly within Lehigh County, Pennsylvania. The mouth of this limestone stream is located in the City of Bethlehem where it converges with the Lehigh River. Monocacy Creek is a well-reknowned stream for its ability to sustain a naturally reproducing trout population, a rarity in city environments.

Wildlands Conservancy has received a Pennsylvania Rivers Conservation Program Planning Grant for Monocacy Creek. A study of the Monocacy Creek, and the preparation and publication of a comprehensive Monocacy Creek Watershed Management Plan were the intended outcomes of the grant. The Pennsylvania Rivers Conservation Program was recently created by the Pennsylvania Department of Conservation and Natural Resources (DCNR). The objective of the program is to conserve, restore, and enhance Pennsylvania's rivers through partnership, education, awareness, and stewardship.

The primary goals of the Monocacy Project are to restore the physical and biological health of the stream; establish management practices to prevent additional degradation of the stream; preserve critical cultural and natural resource areas within the watershed; and ultimately have the Monocacy Creek listed on the Pennsylvania Rivers Registry. Inclusion on the Registry will qualify the Monocacy Creek corridor for technical and financial assistance from the state for restoration and improvement projects.

In order for Monocacy Creek to be included on the Registry, the management plan must identify the historical, cultural, natural, and physical resources along the creek. The plan must also characterize the water quality and aquatic life of the stream, as well as identify any problem areas along the stream. In addition, the plan must contain recommendations for conservation and preservation of the Monocacy Creek based partly on input from public hearings and informational meetings with municipalities.

The Monocacy Creek was chosen for this project because of its importance to the Lehigh Valley as a natural resource. The Monocacy Creek is classified, in Chapter 93 of the PA Water Quality Standards, as a "High Quality-Cold Water Fishery" (HQ-CWF). The excellent water quality of the creek provides many uses to the residents and visitors of Lehigh and Northampton Counties. Recreational and aesthetic uses of the Monocacy are especially important to the region. These factors combined with the easy accessibility of the creek's resources make it imperative to restore and conserve the Monocacy Creek watershed for today and future generations.

1.0. PHYSICAL RESOURCES

1.1. Location/Description of Watershed

The Monocacy Creek is one of only 56 limestone streams in the state of Pennsylvania and a tributary of the Lehigh River. The drainage basin of the Monocacy Creek encompasses approximately 48.8 square miles in Lehigh and Northampton Counties, with the majority in the latter (Shaw, 1984). The headwaters of the Monocacy Creek Main Branch are located in Moore Township, north of Chapman Borough, in Northampton County. From this point the stream flows south, approximately 20.3 miles south to its mouth at Sand Island, Bethlehem (Shaw, 1984). The East Branch of the creek begins northeast of Chapman Borough, near the village of Moorestown. These two branches converge near the town of Steuben and proceed the remaining distance to Bethlehem. A third minor branch originates in Bushkill Township, slightly northwest of Nazareth, and joins the East Branch in Lower Nazareth Township. Along its journey the creek passes through Chapman and Bath Boroughs; Moore, Bushkill, Upper Nazareth, Lower Nazareth, East Allen, Hanover, and Bethlehem Townships; and the City of Bethlehem. A characteristic view of Monocacy Creek is shown in Figure 1. The location of the Monocacy Creek watershed in relation to Pennsylvania is shown in Figure 2. A map of the watershed including its boundaries, drainage pathways, and municipalities, can be viewed on Figure 3.

Figure 1. Monocacy Creek as it flows through Northampton County, PA.

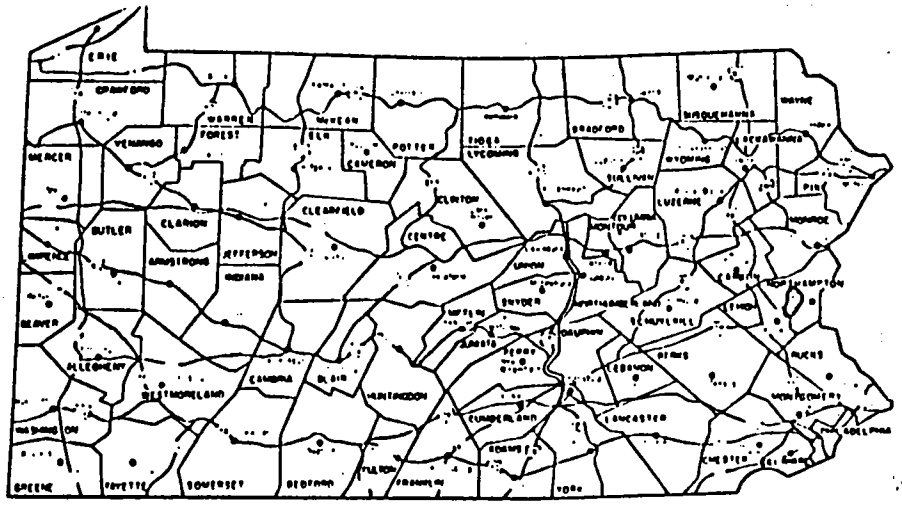


Figure 2. Monocacy Creek watershed delineated and shown in Northampton County with relation to Pennsylvania.

1.2. Geology

Water quality characteristics of a watershed are linked to the geology of the region. Therefore, knowing the geology of the Monocacy Creek watershed is important to developing a management plan. A map and description of the bedrock formations within the watershed are contained in Figure 4 and Table 1.

The geology of the Monocacy Creek in Northampton County has been evolving for more than 200 billion years. The bedrock in the watershed was formed during three geological time periods. These three periods include the Precambrian (more than 570 million years old), Cambrian (more than 500 but less than 570 million years old), and the Ordovician (more than 430 but less than 500 million years old). The bedrock in the upper reaches of the watershed is slaty, whereas the bedrock in the lower two-thirds is predominantly limestone (Miller, 1939).

The two distinct types of bedrock found in the watershed play a major role in determining the quality of water in the Monocacy Creek. The slaty bedrock at the headwaters provides very little buffering capacity, so the creek is very sensitive to acid contamination. As a result, the aquatic life in the creek may suffer from variability in pH.

The Monocacy has been touted as a valued treasure of the Lehigh Valley, as it is one of only 56 limestone streams in the state of Pennsylvania. The ability of the Monocacy Creek to

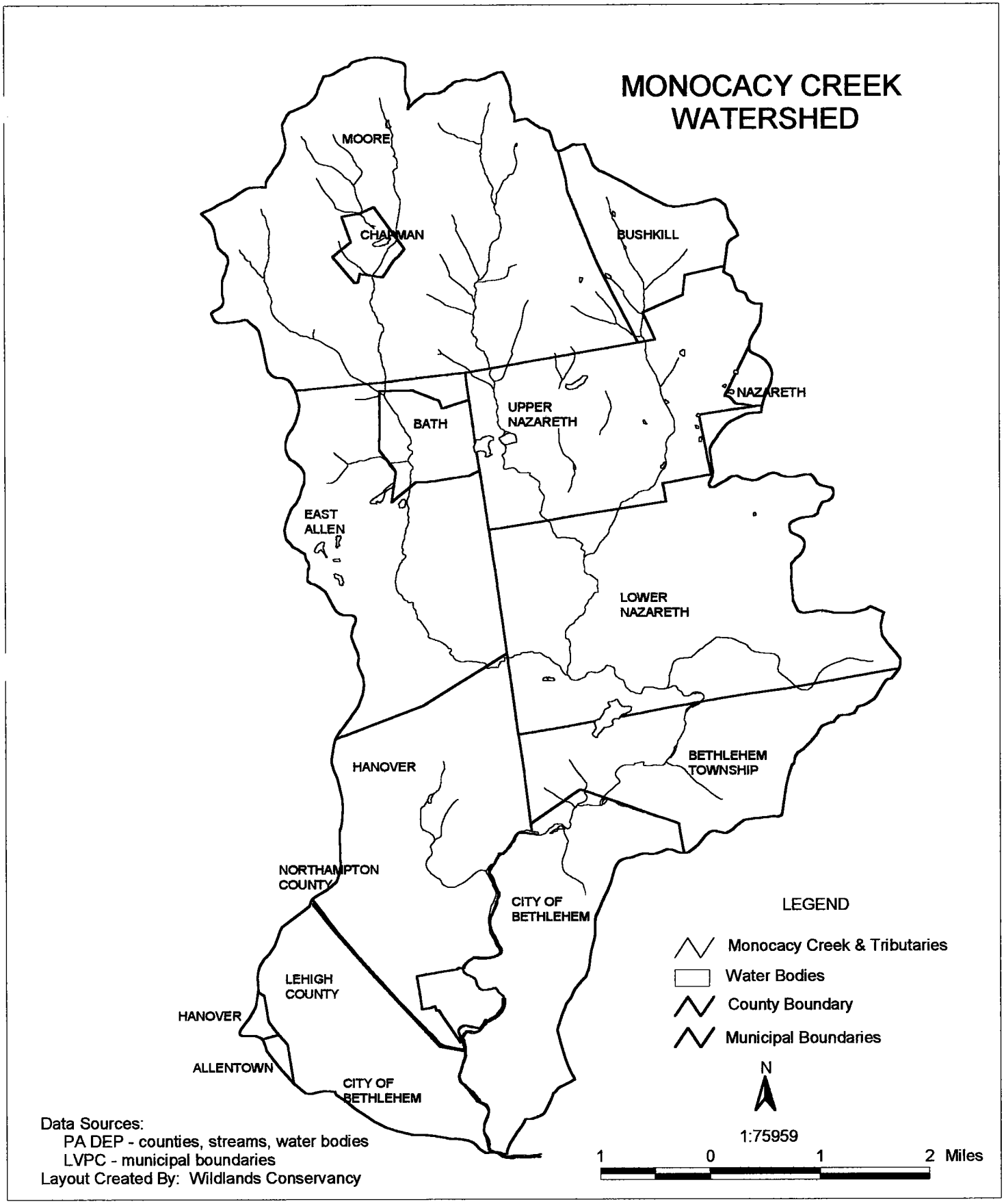


Figure 3. Monocacy Creek watershed delineation, political divisions, and surface water bodies.

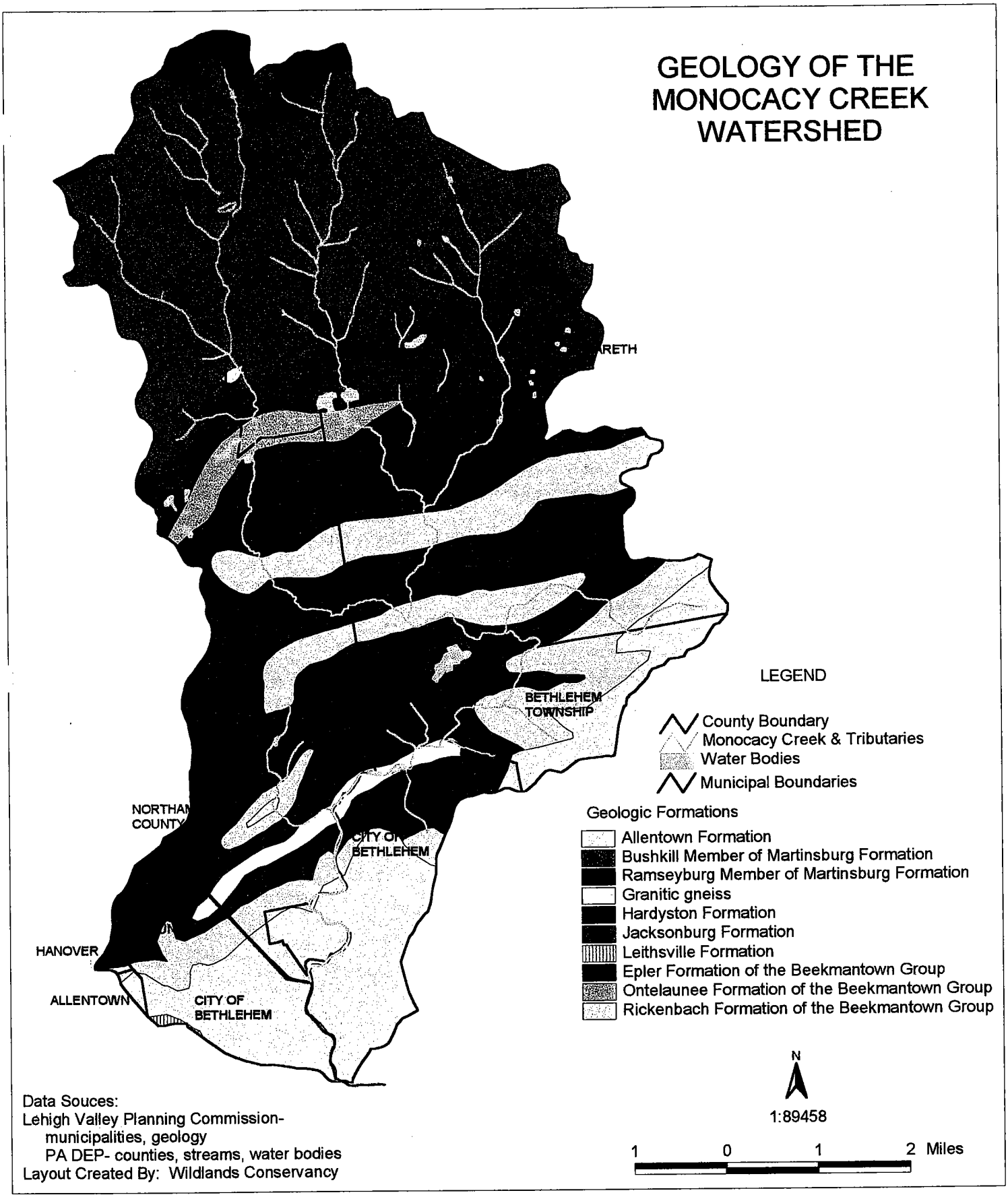


Figure 4. Geologic formations within the Monocacy Creek watershed.

Table 1. Descriptions of bedrock formations within the Monocacy Creek watershed.

GEOLOGIC UNIT	DESCRIPTION
Martinsburg shale Fm.	Formed during Ordivician period; composed of gray to dark-gray shale and slate; also contains some sandstone beds of varying thickness.
Jacksonburg Fm.	Composed of dark gray, shaly limestones with slaty cleavage; these limestones are commonly used to manufacture cement.
Allentown Fm.	Formed during Cambrian period; composed of broad-banded magnesian limestones; typically bluish-gray to gray in beds 6 to 18 inches thick; alternating light and dark beds are characteristic and caused by varied quantities of carbonaceous matter and amount of magnesian carbonate.
Beekmantown Group	
Ontelaunee Fm.	Almost singly limestone; mostly dolomitic; extensively quarried; Medium-dark-gray, finely crystalline dolomite; massively to finely laminated; turns grayish yellow when weathered; thick-bedded with dark-gray chert layer at base.
Epler Fm.	Thick-bedded; medium to medium-dark-gray, finely crystalline limestone; inter-bedded with medium-dark-gray, finely crystalline dolomite; limestone turns light gray when weathered and dolomite turns yellowish gray; contains edgewise conglomerate,fossil fragments, and oolitic lenses.

Table 1 (Cont.)...

Rickenbach Fm.	Medium to dark-gray, coarsely crystaline dolomite in lower part; medium to medium-light-gray, finely crystaline dolomite in upper part; contains chert lenses, beds, and nodules.
Leithsville Fm.	Medium to dark-gray, crystaline dolomite, which is light-olive-gray in some places; turns light gray and yellowish brown when weathered; massively bedded with interbeds of thin shale and dolomitic shale; contains pink to gray mottled chert and dark-gray chert, as well as scattered sand grains; upper part of formation very shaly.
Byram gneiss Fm.	Formed during Pre-Cambrian period; variety of composition, texture, and sturcture; normal texture is average granitic; finely and coarsely granitic textures do appear; many places have well-developed sets of joints.
Hardyston quartzite Fm.	Formed during Cambrian period; only small portion composed of quartzite; contains feldspathic sandstones, conglomerates, jasper, chert, and shales among others; color ranges from white to dark-gray.

Data Source: Miller, 1939.

support a naturally reproducing trout population within the urbanized setting of the City of Bethlehem, is perhaps its most unique and valued quality. Limestone formations underlying approximately 2/3 of the watershed are essential to the productivity of the stream. Limestone streams are well known for their ability to sustain a great diversity and abundance of aquatic plant and animal life that is important to maintaining an ecological balance in a riparian ecosystem. Limestone provides a very good buffering capacity, which serves to maintain a constant pH that is critical to providing thriving populations of fish, macroinvertebrates, and other aquatic life. Maintaining an abundant and diverse macroinvertebrate population in the Monocacy is important, as they are a basic component of the food chain.

The configuration of calcareous formations in the northern half of the watershed sometimes causes a situation commonly referred to as a "losing stream." This means that the water in the creek is being lost to groundwater. Limestone is a very permeable medium, making it easy for surface waters to seep into the ground. This process occurs so readily that during dry spells or droughts the channel may become completely dry. This problem is most notable on the East Branch near the confluence with the Main Branch. However, the stream is replenished downstream from Camel's Hump, with spring water that has entered the ground and travelled through these limestone formations.

The geologic formation known as Camel's Hump is critical to the Monocacy's classification as a "high quality-cold water fishery" (HQ-CWF). Camel's Hump is composed of relatively impermeable bedrock when compared to the surrounding hydrologically conductive limestones. When groundwater is flowing through the limestone, it suddenly hits the Byram gneiss of Camel's Hump. This formation acts as a wall, forcing the water to the surface. The result is an abundance of springs that provide cold, well-buffered water to the Monocacy, establishing a valuable habitat for fish and other aquatic life from Camel's Hump to the confluence with the Lehigh River. An example of a spring is shown in Figure 5 (Miller, 1939).

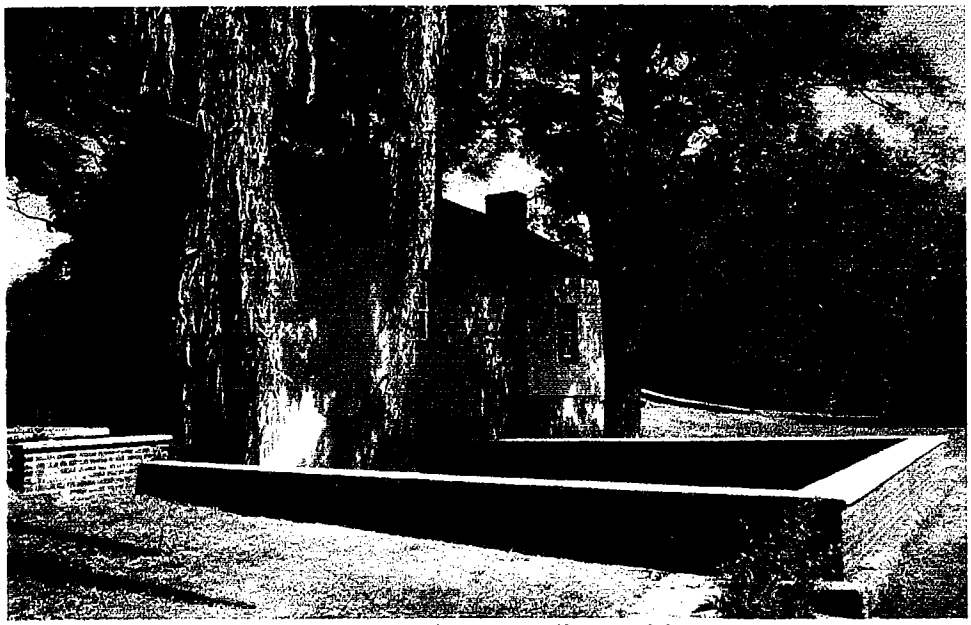


Figure 5. A preserved spring that supplies cold ground water to Monocacy Creek.

1.3. Topography

The combination of bedrock and flowing water plays a major role in determining the topography of a region. The Monocacy Creek watershed is located in the Great Valley Section of the Valley and Ridge Physiographic Province of Eastern Pennsylvania. The topography of the upper one-third of the watershed, underlain by the Martinsburg Shale Formation, consists of low flat-topped hills dissected by streams and producing steep-sided slopes. This region is dotted by slate quarries, such as the one shown in Figure 6.

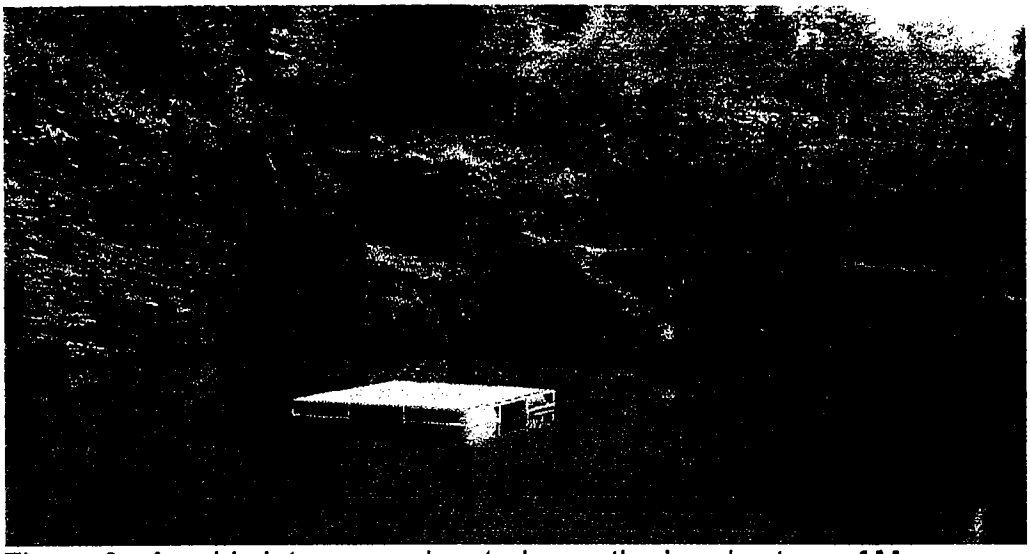


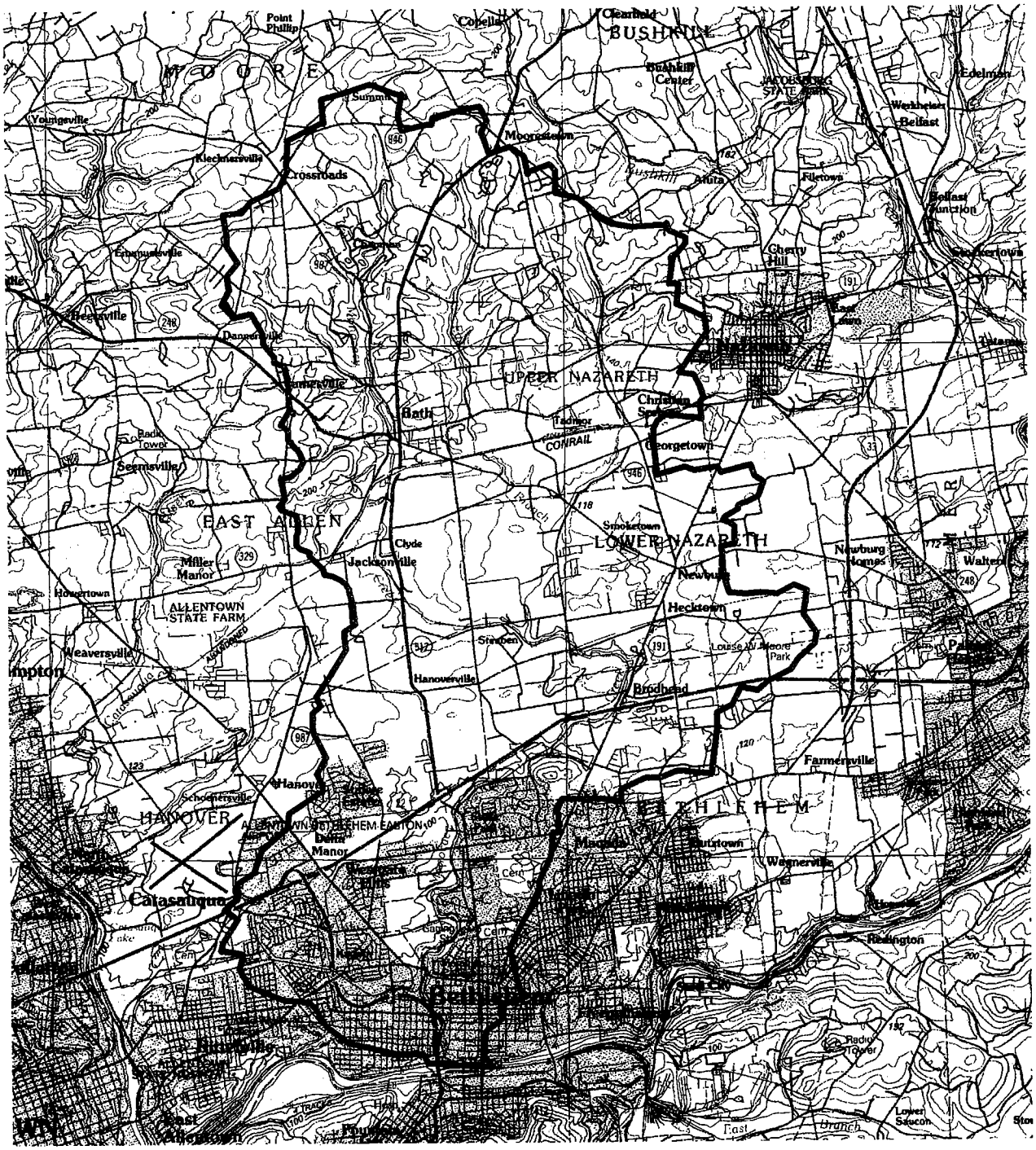
Figure 6. An old slate quarry located near the headwaters of Monocacy Creek.

The lower two-thirds of the watershed, underlain predominantly by limestone, consists of flat land with gently rolling valleys. The limestone bedrock yields karst topography, which is typified by the abundance of sinkholes and closed depressions. This landscape is also dotted with several quarries, although mostly limestone (Shaw, 1984).

The most dominant topographic feature within the watershed is Camel's Hump. This is the area in Northern Bethlehem underlain by Byram gneiss. Due to the impermeability of the bedrock, this land is not easily eroded. Thus a topographic high is formed overlooking the surrounding watershed. This hill has historically been used as a surveying site within the Lehigh Valley and is shown in Figure 7. The topography of the watershed is shown on a USGS map on Figure 8. (Shaw, 1984).

Figure 7. Camel's Hump, an outstanding geologic and topographic feature of Monocacy Creek watershed.

MONOCACY CREEK WATERSHED USGS TOPOGRAPHIC MAP



Data Source: Department of Environmental Protection

Layout Created By: Wildlands Conservancy

Figure 8. Topographic map delineating Monocacy Creek watershed.

1.4. Soils

Like geology, soils play an important role in determining stream chemistry. Soil information is also important for development and land use planning purposes. Properties such as thickness, texture, and moisture capacity make some soil associations better suited to a given use than others. There are a few different soil associations in Northampton County through which the Monocacy Creek flows. These include the Berks-Bedington-Comly, Duffield-Clarksburg-Ryder, Washington-Urban, and the Connestoga-Hollinger associations (Staley, 1974).

A digitized map, provided by LVPC, showing each distinct soil series within the above associations and a list of these soil series with a brief description, its capability unit, the municipalities it is located in, and a description of the capability units can be found in Appendix 2. To receive this appendix, contact Wildlands Conservancy.

The northern third of the watershed consists of soils in the Berks-Bedington-Comly association. Shallow bedrock and an abundance of coarse fragments in the soil make it unsuitable to most potential uses. For example, housing developments with basements may not be sensible due to extraordinary amounts of bedrock that may need to be removed. Problems may also arise with agriculture as excessive erosion may expose bedrock and prevent cultivation (Staley, 1974).

The Duffield-Clarksburg-Ryder association is present in a narrow band across the central part of the watershed. Sewage disposal is the major limit to land use on this association. Slow permeability and a seasonally high water table increases the risk of surface and groundwater contamination from activities such as sewage disposal (Staley, 1974).

The Washington-Urban association is found in the southern part of the watershed. The limitations of the urban series can not be identified, as these soils have been drastically altered by development and require individual site assessments. However, there are few limitations to uses on the Washington series, which is well suited to cultivation (Staley, 1974).

Finally, the Connestoga-Hollinger association covers the small area of the watershed known from its geology as Camel's Hump. Due to the presence of stones and boulders in this association, it is not suited to cultivation. Nor is it suited to residential development where it occurs on steep slopes, as is often the case. As a result of these limitations, most areas remain wooded (Staley, 1974).

Two specific soil types within the watershed that have hydric properties include the Brinkerton and Holly silt loams. These soils typically occur along floodplains and drainage ways and are characteristically deep and poorly to very poorly drained. These soils also have slow to moderate permeability, a high water table, and are occasionally inundated or have ponding after precipitation events. The presence of hydric soils is one characteristic taken into account when a wetland delineation is determined. Development should be avoided on these soils as they generally help to assimilate floodwaters.

2.0. AQUATIC RESOURCES

2.1. Surface Water

The Monocacy Creek is a fourth order stream with its source near Chapman, at an elevation of 900 feet, and its mouth in Bethlehem, at an elevation of 212 feet. The length of the stream is approximately 20.3 miles with a drainage area of approximately 48.8 square miles. The slope of the channel is 17.4 feet/mile. The creek forms a dendritic drainage pattern, with between 23 and 31 minor tributaries. The upper and middle reaches of the stream flow through hills with a widening valley and moderate slopes. The lower stretches of the creek flow through rolling hills in a wide valley with mild slopes. The mean annual precipitation within the watershed is approximately 44 inches. The flow of the Monocacy Creek is sustained by springs that feed the creek in the vicinity of Camels Hump, where groundwater is forced to the surface upon reaching the relatively impermeable Byram gneiss after passing through the limestone region. Above the entrance of these springs, the creek periodically runs dry as a result of droughts occurring in the summer months (Shaw, 1984).

Almost all wet soils within the watershed occur along the stream and its tributaries. The presence of wet soils indicates that the area may be a wetland, even if it is not currently designated as such by the National Wetland Inventory (NWI). The soils, vegetation, and hydrology of these areas should be examined to determine if wetland designations are necessary. A few wetlands, designated as such by NWI, are scattered throughout the watershed, not all of which are located along the stream. Many of these designations however, are based solely upon aerial photo interpretation. Field delineations by a trained expert may be essential to determining the proper status of the area under question. The headwaters of the Monocacy originate in a wetland setting as seen in Figure 9. Other locations of wet soils and wetlands can be viewed on Figure 10. It is important to protect and conserve these resources because they provide wildlife habitat, absorb nutrients, transform harmful chemicals, and act as sponges for storing floodwaters, thus lessening the threat of downstream flooding. The gradual release of water from wetlands may also aid in maintaining stream flow during dry spells.

2.2. Groundwater

An aquifer is considered to be any water-bearing zone that may yield quantities of water sufficient to meet the needs of its user. Usually, each rock formation is considered to be a separate aquifer because changes in geology cause changes in hydrologic characteristics. Information regarding aquifers of the Monocacy watershed was obtained from a report on Lehigh County because many of the aquifers are the same as in Northampton County.

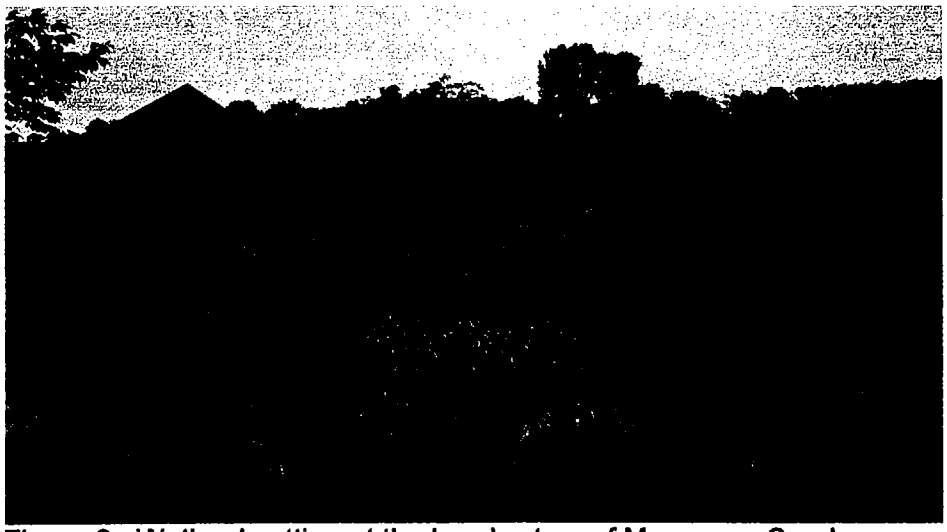


Figure 9. Wetland setting at the headwaters of Monocacy Creek.

Although the information is in reference to the same aquifers, there may be slight differences due to the geographic and topographic locations of each aquifer in the counties. For this reason, the data provided should only be taken as a general idea or approximation of the actual water yielding properties in Northampton County.

The Martinsburg formation is not a preferred aquifer to investigate for use as an industrial or public water supply. This aquifer is best suited to domestic purposes. The specific capacity, which is the discharge of a well per foot of drawdown in the aquifer, in the Martinsburg formation is related to topography. Specific capacities are greatest in valleys and least on hilltops. Wells with low specific capacities should be avoided as they will be overdrawn more easily and may be subject to going dry. Therefore one should attempt to drill a well in the valleys of this aquifer first. This shaley formation typically yields groundwater with low dissolved solids, and calcium and magnesium are usually the dominant cations. The median concentrations of chemical constituents in groundwater from the Martinsburg formation are shown in Table 2 (Wood, 1972).

When comparing the various limestone aquifers, Jacksonburg yields the lowest quantity of water. The Allentown, Beekmantown, and Leithsville aquifers have significantly higher yields. Like the Martinsburg aquifer, the Allentown aquifer has higher specific capacities in valleys than in uplands. The reported median yield for these wells is 75 gpm, although 750 gpm is thought to be the potential median yield of these wells. An even better option when drilling a well in the Monocacy watershed may be the Beekmantown aquifer. Most wells drilled in this aquifer have yields slightly higher than the average for the Allentown formation. Almost any well drilled in this formation will yield enough water for a domestic supply. Some deep wells have even exceeded 2000 gpm. The Leithsville aquifer, like the Beekmantown, is almost guaranteed to yield a sufficient domestic supply. Numerous public and industrial water supplies in this aquifer have yields exceeding 1000 gpm. The chemical constituents of the carbonate rock aquifers are shown in Table 3 (Wood, 1972).

Water from these aquifers is also high in dissolved solids, hardness, and specific conductance. Limestone aquifers are also more prone to contamination than many other aquifers, due to solution cavities and the preferential flow of groundwater through this porous media.

Table 2. Median concentrations of chemical constituents in groundwater from the Martinsburg formation.

	Median[1] of indicated constituent, in milligrams per liter, except as indicated		
Constituent	Pen Argyl Member	Ramseyburg Member	Bushkill Member
Silica (SiO_2)	14	12	12
Iron (Fe), total	.04	.30	.17
Manganese (Mn), total	.00	.00	.01
Calcium (Ca)	37	28	29
Magnesium (Mg)	6.8	6.4	8.0
Sodium (Na)	4.5	7.2	5.3
Potassium (K)	0.8	0.9	0.8
Bicarbonate (HCO_3)	79	61	66
Sulfate (SO_4)	24	34	42
Chloride (Cl)	11	6.7	6.6
Fluoride (F)	0.0	0.0	0.0
Nitrate (NO_3)	7	16	10
Dissolved solids (residue at 180°C)	164	143	153
Calcium-magnesium hardness (as $CaCO_3$)	120	93	94
Noncarbonate hardness (as $CaCO_3$)	65	50	46
Specific conductance	258	232	236
pH	7.7	7.6	7.6

[1] Medians of 3 to 6 analyses in the Pen Argyl Member, 8 to 14 analyses in the Ramseyburg Member, and 13 to 18 analyses in the Bushkill Member for each constituent.

Data Source: Wood et al., 1972

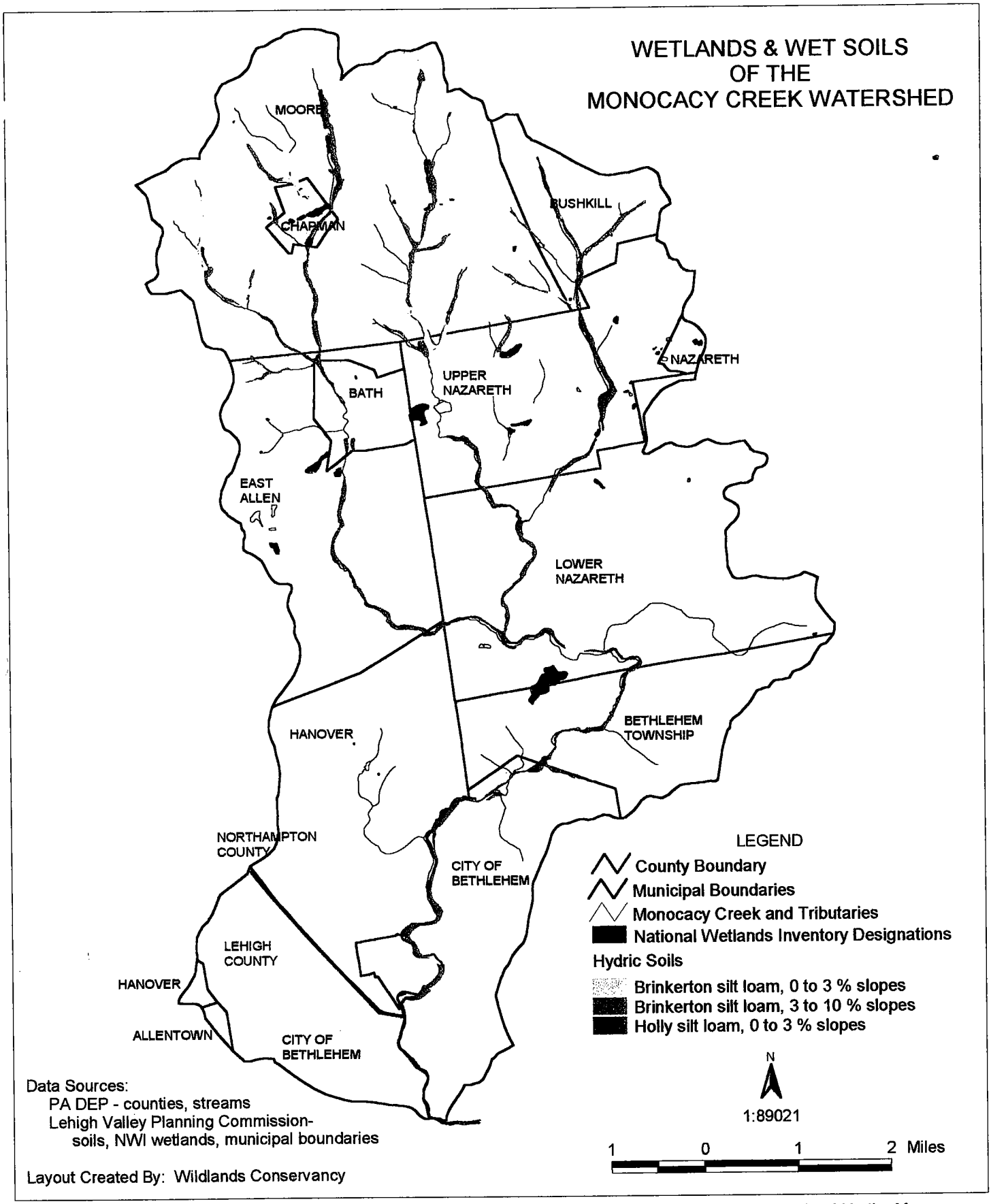


Figure 10. Wetlands based on National Wetlands Inventory (NWI) and potential wetlands based on hydric soils within the Monocacy Creek watershed.

Table 3. Median concentrations of chemical constituents in groundwater from the carbonate-rock aquifers.

	Median of indicated constituent, in milligrams per liter, except as indicated				
	Jacksonburg Formation		Beekmantown Group	Allentown Formation	Leithsville Formation
Constituent	Cement rock	Cement limestone			
Silica (SiO_2)	9.5	8.7	8.4	9.6	11
Iron (Fe), total	.08	.04	.05	.08	.13
Manganese (Mn), total	.00	.05	.01	.01	.02
Calcium (Ca)	80	90	45	33	36
Magnesium (Mg)	12	14	12.5	22	22
Sodium (Na)	7.5	11	4.1	7.0	8.3
Potassium (K)	1.1	1.4	1.5	2.7	3.1
Bicarbonate (HCO_3)	194	140	164	165	158
Sulfate (SO_4)	92	53	40	31	23
Chloride (Cl)	18	8.5	9.0	7.8	6.4
Fluoride (F)	0.0	0.0	0.0	0.1	0.0
Nitrate (NO_3)	4.3	9.2	11	16	8.6
Phosphate (PO_4)	0.0	0.0	0.0	0.0	0.0
Dissolved Solids (residue at 180°C)	359	400	231	230	244
Calcium, magnesium hardness as $CaCO_3$	263	196	173	170	164
Noncarbonate hardness as $CaCO_3$	109	94	53	43	31
Specific Conductance (micromhos at 25°C)	633	593	408	390	298
Temperature (°C)	11	11	11	12	12
pH Laboratory	7.8	7.8	7.8	8.1	8.0
Field	7.4	7.3	7.5	7.7	7.5
Number of analyses used:	7 to 11	5 to 8[1]	10 to 22	11 to 26	5 to 8

[1] Includes analytical data for undifferentiated part of formation.

Data Source: Wood et al., 1972.

Finally, although the Hardyston aquifer is a reliable source for a domestic water supply, it is not recommended. The drilling and casing costs for a domestic well in the Hardyston formation are expensive. In addition, public or industrial supply wells are not recommended. Several drilling attempts may be necessary before a sufficient yield is produced, which is not economically sensible. The median concentrations of chemical constituents in groundwater from the Hardyston formation are contained in Table 4 (Wood, 1972).

Table 4. Median concentrations of chemical constituents in groundwater from the Hardyston formation.

Constituent	Hardyston Formation
Silica (SiO_2)	13
Iron (Fe), total	.06
Manganese (Mn), total	.00
Zinc (Zn)	---
Calcium (Ca)	4.1
Magnesium (Mg)	1.6
Sodium (Na)	2.8
Potassium (K)	1.4
Bicarbonate (HCO_3)	30
Sulfate (SO_4)	2.4
Chloride (Cl)	1.4
Fluoride (F)	0.0
Nitrate (NO_3)	3.4
Dissolved solids (residue at 180°C)	61
Calcium, magnesium hardness (as $CaCO_3$)	17
Noncarbonate hardness (as $CaCO_3$)	0.0
Specific Conductance (micromhos at 25°C)	60
pH	7.6

Data Source: Wood et al., 1972.

Community water supplies within the Monocacy Creek watershed may be protected on a voluntary basis by each municipality. The LVPC has prepared a "Wellhead Protection Model Ordinance" as part of the EPA's *Wellhead Protection Demonstration Project.* This ordinance is designed to protect water supply wells by dealing with zoning, subdivision, land development, and special provision issues. The ordinance defines three areas of protection surrounding a well. *Wellhead protection area 1* (WHPA 1), consists of a small circular area with a radius between 100 and 400 feet around the well. *Wellhead protection area 2* (WHPA 2), is a larger region through which water is drawn to the well by pumping. This region is also referred to as the zone of diversion. The last zone, *Wellhead protection area 3* (WHPA 3), is the land area that naturally drains to the well based on topography. This zone is also referred to as the zone of contribution. The definitions of these wellhead protection areas are based upon the DEP regulations that became effective October 8, 1994 for new wells. Activities that are regulated within these WHPAs include light industry, agriculture, storage tanks, sewage disposal, land developments, solid waste disposal, manufacturing, injection wells, sewage sludge land application, and subdivisions. These activities are regulated most stringently in WHPA 1, and to a progressively lesser degree in WHPAs 2 and 3. Wells with

defined WHPAs within the watershed are shown on Figure 11 (Lehigh Valley Planning Commission, 1996).

2.3. Hydrologic Budget

A preliminary hydrologic budget for the Monocacy creek watershed was prepared by LVPC. A complete copy of this report can be obtained from LVPC. This report defines a hydrologic budget as the "accounting of the fate of precipitation as surface runoff, soil moisture, groundwater flow, and return to atmospheric moisture." To complete a water budget one must numerically balance the water entering the watershed to the water leaving the basin through various phases of the hydrologic cycle, plus or minus any change in storage. A typical equation for determining a hydrologic budget is shown below.

$$P=R+ET+U\pm SMS\pm GWS\pm D$$

where,

P is Precipitation expressed in inches of water
R is surface Runoff or streamflow
ET is EvapoTransporation or water re-entering the atmosphere either directly through evaporation or indirectly through plant uptake
U is groundwater Underflow
SMS is the change in Soil Moisture Storage during the time period
GWS is the change in Groundwater Storage during the time period
D is Diversions of water in or out of the watershed by man

Surface flow data used in preparing the budget report was obtained from USGS gaging stations on the Monocacy from 1949 to the present. Annual precipitation, annual baseflow, and annual baseflow as a percentage of streamflow were also analyzed for the same period to identify any significant hydrologic trends. Baseflow is the portion of streamflow contributed from groundwater. Due to the very limited amount of groundwater flow data available, sophisticated water budget analyses were not possible within the scope of this project.

A report prepared by USGS investigator Charles Wood, was contained in *Water Resources of Lehigh County, Pennsylvania.* In this report known as the "Wood Study", a water budget was calculated for Monocacy Creek for the years 1946 to 1962. A simplified version of the above equation was used to compute the budget because there was no significant changes in soil moisture or ground water storage during this time, allowing these factors to be eliminated from the equation. There were also no known diversions in or out of the watershed during this period of record. The resulting equation was:

$$P=R+ET+U$$

Substituting data from the period of record yielded the following equation and results:

$$45.72 \text{ inches}=15.60 \text{ inches}+26.4 \text{ inches}+ U \text{ and}$$
$$U=3.72 \text{ inches}$$

This means that from approximately 46 inches of precipitation that fell on the watershed, only 3.7 inches of water that did not evaporate, were not recorded by the gaging station. This water contributed to underflow that would resurface by the mouth of the creek at the Lehigh River. This water budget represents the Monocacy watershed at a time of near equilibrium. Precipitation levels were near normal and land developments over the short 16-year period shouldn't have had much effect on hydrology. Present concerns are that the watershed will not stay in equilibrium as development occurs at heightened rates. The budget developed for this time period should be used to compare studies of more current periods. However, since data for non-equilibrium periods (periods involving changes in soil moisture and groundwater storage) is not readily available, the best assessment of impacts from development requires a more in-depth evaluation of stream gage data (USGS, 1972).

The key findings that were reported based on analysis of the water budget and data collected from 1949 to 1996 are as follows:

- Precipitation, streamflow, and baseflow (portion of streamflow contributed by groundwater), appear to follow cyclical patterns throughout the period of record.
- Trend analyses indicate a fairly constant level of precipitation with only a very slight increasing trend from 1949 to 1996.
- Trend analyses indicate that the portion of precipitation that becomes streamflow is increasing over time.
- Trend analyses indicate that, within the limitations of the method used to quantify baseflow, the portion of precipitation that becomes baseflow is also increasing over time.
- Trend analyses indicate that baseflow represents a fairly constant proportion of streamflow over time.
- No evidence is provided by this evaluation to suggest that baseflow or groundwater levels in the watershed are decreasing over time, however, more rigorous trend analyses would be required to verify these preliminary findings, especially the unexpected trend of increasing baseflows.

The recommendations made by LVPC with regard to this project include:

- Evaluation of baseflow separation techniques used should be conducted to determine if the methodology is providing reasonable results for the Monocacy Creek situation.
- A more rigorous water budget and trend analysis should be prepared to verify these preliminary trends.

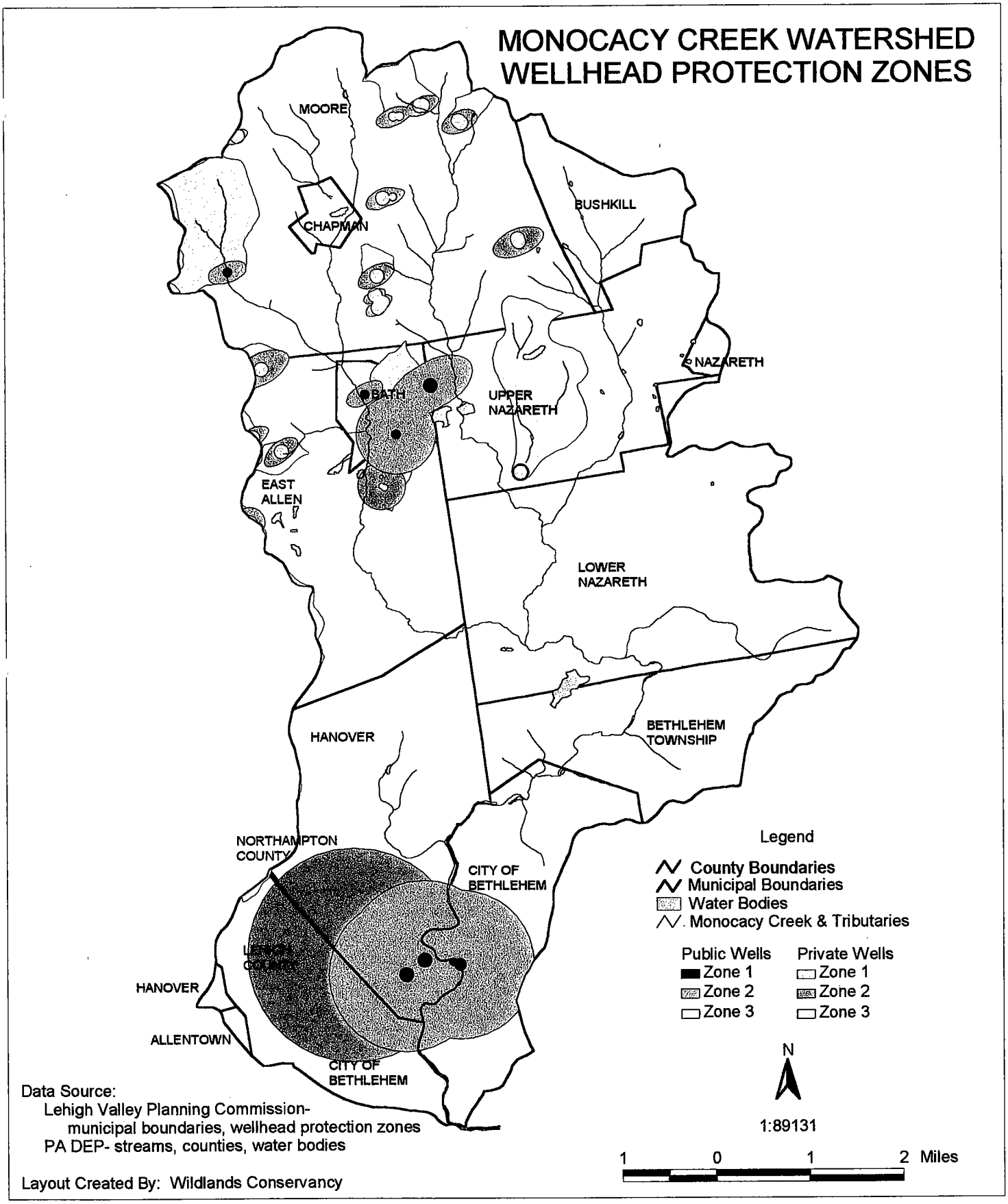


Figure 11. Protection zones for public and private wells within the Monocacy Creek watershed.

3.0. BIOLOGICAL RESOURCES

3.1. Flora and Fauna

The Pennsylvania Natural Diversity Inventory (PNDI), a cooperative program of DEP, The Nature Conservancy, and Western Pennsylvania Conservancy, maintains records of the state's rare, endangered, or otherwise significant flora and fauna. With regard to the Monocacy Creek watershed, there are no species of special concern that have been spotted and consequently reported to PNDI. However, to date, there has been no directed effort to inventory the flora and fauna present. Therefore some threatened, endangered, or species of special concern to the area, may exist within the watershed that have not yet been discovered or identified. The Nature Conservancy has confirmed that five historical species are listed on their records, none of which have been sighted for at least the past twenty years. PNDI is currently working on a survey of Lehigh and Northampton Counties.

An inventory was conducted by the Bureau of Forestry in 1988 to identify trees and shrubs present at Burnside Plantation. The results of this investigation can be found on Table 5. In addition, a partial list of vegetative species suitable for planting in the Monocacy watershed is located in Table 6. This list is supplied so that property owners can make sound decisions as to what species would be best suited to plant along the Monocacy. Careful consideration to species planted is necessary to avoid planting of invasive or exotic species, which are detrimental to the ecology of the riparian habitat. This issue is discussed in more detail in section 7.6, which also contains a partial list of invasive species.

In general it is noted that the Monocacy Creek watershed has a healthy wildlife population that is characteristic of Eastern Pennsylvania. However, a report entitled " Biological Diversity in the Monocacy Creek Watershed", compiled by Karen Dolan in 1998 noted that very little research exists on the ecology of Monocacy Creek compared to the nearby Bushkill Creek, which runs through Jacobsburg Environmental Education Center. Therefore characterizing the flora and fauna of the watershed proved extremely difficult. A summary of the results of her data compilation is contained below.

The Monocacy corridor is well-known as a bird habitat. It plays an important role in the migration of birds from winter grounds to northern nesting sites. Linda Freedman, local birding expert and chairperson of the Lehigh Valley Audubon Society's conservation committee, reported the following findings within Monocacy watershed (Dolan, 1998).

- Out of 15 species listed on National Audubon Society's 1998 Watch List and noted as possible to be seen in PA, 10 have been spotted in the Monocacy Nature Center. Watch List species are species of special concern that have shown serious decline in recent years and require preservation of their habitat for continued existence. The Wood Thrush is one of these species and is known to nest within the watershed. It is highly treasured as the most beautiful avian songster in North America.
- The Seaside Sparrow is a Watch List species not even probable in PA that was once spotted in the Nature Center in 1982.

- In total, 166 bird species were observed by Ms. Freedman between 1993 and 1997 at the Nature Center, and another 131 were noted in Archibald Johnston Conservation Area. Of these species, 30 are known to nest at the nature center and another 21 nest at Johnston Conservation Area. Another 17 species are likely to nest in the vicinity, however confirmation is still needed.

Valuable habitat areas within the watershed include the Monocacy Nature Center, sometimes referred to as the Monocacy Sanctuary, and a majority of the corridor from Lower Nazareth Township to the confluence with the Lehigh River (Kita and Dolan, 1998).

Table 5. Trees and shrubs identified by Bureau of Forestry in 1988 at Burnside Plantation.

Common Name	Scientific Name
1. American Sycamore	1. Platanus occidentalis
2. Apple	2. Malus pumila
3. Black Locust	3. Robinia pseuodoacacia
4. Black Walnut	4. Juglans nigra
5. Box Elder	5. Acer negundo
6. Butternut Hickory	6. Carya cordiformis
7. Forsythia	7. Forsythia
8. Grape	8. Vitus
9. Hackberry	9. Celtis occidentalis
10. Mulberry	10. Morus
11. Pear	11. Pyrus communis
12. Red Maple	12. Acer rubrum
13. Red Oak	13. Quercus rubra
14. Scotch Pine	14. Pinus sylvestris
15. Slippery Elm	15. Ulmus rubra
16. Spruce	16. Picea
17. Staghorn Sumac	17. Rhus typhina
18. Tartarian Honey Suckle	18. Lonicera tatarica
19. Thornless Honey Suckle	19. Lonicera
20. Tree of Heaven	20. Ailanthus altissima
21. White Cherry	21. Prunus
22. White Oak	22. Quercus alba
23. White Pine	23. Pinus strobus
24. Wild Cherry	24. Prunus serotina
25. Virginia Creeper	25. Parthenocissus quinquefolia

Data Source: Baker, 1988.

Table 6. Partial list of native vegetative species recommended for planting within the Monocacy Creek watershed.

Common Name	Scientific Name
WILDFLOWERS	
Swamp Milkweed	Asclepias incarnata
Purple-stemmed Aster	Aster puniceus
Schreber's Aster	Aster schreberi
Turtlehead	Chelone glabra
Water-willow	Decodon verticillatus
Boneset	Eupatorium perfoliatum
Rough Bedstraw	Galium asprellum
Ditch Bedstraw	Galium palustre
Cleavers, Bedstraw	Galium tinctorium
Common Sneezeweed	Helenium autumnale
Showy Hibiscus	Hibiscus leavis
Rose-mallow	Hibiscus moscheutos
Canadian St.-John's-wort	Hypericum canadense
Pale St.-John's-wort	Hypericum ellipticum
Dwarf St.-John's-wort	Hypericum mutilum
Dwarf Crested Iris	Iris cristata
Slender Blue Flag	Iris prismatica
Northern Blue Flag	Iris versicolor
Cardinal-flower	Lobelia cardinalis
Great Lobilia	Lobelia siphilitica
Water Horehound	Lycopus uniflorus
Bugleweed	Lycopus virginicus
Allegheny Monkey-flower	Mimulus ringens
Wild Forget-me-not	Mysotis laxa
False Dragonhead	Physostegia virginiana
Mountain-mint	Pycnanthemum tenuifolium
Cutleaf Coneflower	Rudbeckia laciniata
Mad-dog Skullcap	Scutellaria lateriflora
Blue Vervain	Verbena hastata
New York Ironweed	Vernonia noveboracensis
GRASSES AND NUT SEDGES	
Creeping Bentgrass	Agrostis palustris
Short-awned Foxtail	Alopecurus aequalis
Brome Grass	Bromus altissimus

Table 6 (Cont.)...

Common Name	Scientific Name
Canada Bluejoint	Calamagrostis canadensis
Reedgrass	Calamagrostis cinnoides
Wood Reedgrass	Cinna arundinacea
Tufted Hairgrass	Deschampsia cespitosa
Riverbank Wild-rye	Elymus riparius
Virginia Wild-rye	Elymus virginicus
Lovegrass	Eragrostis frankii
Creeping Lovegrass	Eragrostis hypnoides
Rattlesnake Mannagrass	Glyceria canadensis
Reed Meadowgrass	Glyceria maxima
American Mannagrass	Glyceria grandis
Slender Mannagrass	Glyceria melicaria
Floating Mannagrass	Glyceria septentrionalis
Fowl Mannagrass	Glyceria striata
Rice Cutgrass	Leersia cryzoides
White Cutgrass	Leersia virginica
Spike Muhly	Muhlenbergia glomerata
Satin Grass	Muhlenbergia mexicana
Panic-grass	Panicum stipitatum
Reed Canary-grass	Phalaris arundinacea
Fowl Bluegrass	Poa palustris
Pale Mannagrass	Torreyochloa pallida
Umbrella Sedge	Cyperus dentatus
False Nutsedge	Cyperus strigosus
SEDGES	
Sedge	Carex baileyi
Sedge	Carex bromoides
Sedge	Carex canescens
Sedge	Carex comosa
Short Hair Sedge	Carex crinita
Sedge	Carex cristatella
Sedge	Carex davisii
Sedge	Carex echinata
Prickly Sedge	Carex emoryi
Sedge	Carex frankii
Sedge	Carex granularis

Table 6 (Cont.)...

Common Name	Scientific Name
Sedge	Carex gynandra
Sedge	Carex hystericina
Sedge	Carex lacustris
Sedge	Carex laevivagnata
Wooly Sedge	Carex lanuginosa
Sedge	Carex leptalea
Sedge	Carex lupulina
Sedge	Carex lurida
Sedge	Carex pellita
Sedge	Carex prasina
Beaked Sedge	Carex rostrata
Broom Sedge	Carex scoparia
Sedge	Carex stipata
Sedge	Carex straminea
Tussock Sedge	Carex stricta
Sedge	Carex torta
Sedge	Carex tribuloides
Sedge	Carex trichocarpa
Sedge	Carex utriculata
Fox Sedge	Carex vulpinoidea
Spike Rush	Eleocharis erythropoda
Creeping Spike-rush	Eleocharis palustris
Spike Rush	Eleocharis tenuis
Soft Rush	Juncus effusus
Three-square	Scirpus americanus
Black Bulrush	Scirpus atrovirens
Great Bulrush	Scirpus acutus
Wool-grass	Scirpus cyperinus
River Bulrush	Scirpus fluviatilis
Bulrush	Scirpus Hattorianus
Bulrush	Scirpus pendulus
Bulrush	Scirpus polyphyllus
Wood Bulrush or Clubrush	Scirpus expansus
Soft-stem Bulrush	Scirpus validus
Bur-reed	Sparganium americanum

Table 6 (Cont.)...

Common Name	Scientific Name
TREES	
Boxelder	Acer negundo
Red Maple	Acer rubrum
Silver Maple	Acer saccharinum
Sugar Maple	Acer saccharum
Black (Sweet/Cherry) Birch	Betula lenta
River Birch	Betula nigra
Paper Birch	Betula papyrifera
American Hornbeam	Carpinus caroliniana
Butternut Hickory	Carya cordiformis
Shagbark Hickory	Carya ovata
Hackberry	Celtis occidentalis
Redbud	Cercis canadensis
Fringetree	Chionanthus virginicus
Flowering Dogwood	Cornus florida
Persimmon	Diospyros virginiana
American Beech	Fagus grandifolia
White Ash	Fraxinus americana
Green Ash*	Fraxinus pennsylvanica
Honey Locust	Gleditsia triacanthos
American Holly	Ilex opaca
Black Walnut	Juglans nigra
Eastern Redcedar	Juniperus virginiana
Sweetgum	Liquidambar styraciflua
Tulip Poplar	Liriodendron tulipifera
Blackgum	Nyssa sylvatica
Hop-Hornbeam	Ostrya virginiana
White Pine	Pinus strobus
American Sycamore	Platanus occidentalis
Balsam Poplar	Populus balsamifera
Easter Cottonwood	Populus deltoides
Bigtooth Aspen	Populus grandidentata
Quaking Aspen	Populus tremuloides
White Oak	Quercus alba
Swamp White Oak	Quercus bicolor
Bur Oak	Quercus macrocarpa
Pin Oak	Quercus palustris
Willow Oak	Quercus phellos
Red Oak	Quercus rubra
Black Locust	Robinia pseuodoacacia

Table 6 (Cont.)...

Common Name	Scientific Name
Black Willow	Salix nigra
American Basswood	Tilia americana
Eastern Hemlock	Tsuga canadensis
American Elm	Ulmus americana
SHRUBS	
Smooth Alder	Alnus serrulata
Shadblow Serviceberry	Amelanchier canadensis
False Indigo	Amorpha fruitcosa
Red Chokeberry	Aronia arbutifolia
Black Chokeberry	Aronia melanocarpa
Eastern Baccharis	Baccharis halimifolia
Buttonbush	Cephalanthus occidentalis
Sweet Pepperbush	Clethera alnifolia
Silky Dogwood	Cornus amomum
Stiff Dogwood*	Cornus foemina
Gray Dogwood*	Cornus racemosa
Roundleaf Dogwood	Cornus rugosa
Red-osier Dogwood	Cornus sericea
American Hazlenut	Corylus americana
Witch-hazel	Hamamelis virginiana
Common Rose Mallow	Hibiscus moscheutos
Winterberry	Ilex verticillata
Virginia Sweetspire	Itea virginica
Leucothoe*	Leucothoe axillaris
Spicebush	Lindera benzoin
Fetterbush*	Lyonia lucida
Common Ninebark	Physocarpus opulifolius
Common Chokecherry	Prunus virginiana
Swamp Azalea	Rhododendron viscosum
Shining sumac	Rhus copallina
Smooth Sumac	Rhus glabra
Swamp Rose	Rosa palustris
Virginia Rose	Rosa virginiana
Allegheny Blackberry	Rubus allegheniensis
Bebb's Willow	Salix bebbiana
Pussy Willow	Salix discolor
Coyote Willow*	Salix exigua
Prairie Willow	Salix humilis
Sandbar Willow*	Salix interior

Table 6 (Cont.)...

Common Name	Scientific Name
Shining Willow	Salix lucida
Elderberry	Sambucus canadensis
Redberry Elder	Sambucus racemosa ssp. pubens
Meadowsweet Spirea	Spiraea alba
Hardhack Spirea	Spiraea tomentosa
High Bush Blueberry	Vaccinium corymbasum
Common Highbush Blueberry	Vaccinium corymbosum
Arrowwood	Viburnums dentatum
Nannyberry	Viburnum lentago
Blackhaw	Viburnum prunifolium
American Cranberry Bush	Viburnum trilobum
AQUATICS AND MISCELLANEOUS	
Broad-leaf Arrowhead "Duck Potato"	Sagittaria latifolia
Bull Tongue Arrowhead	Sagittaria loncifilia
Jack-in-the-Pulpit	Arisaema triphyllum
Green Dragon	Arisaema dracontium
Skunk Cabbage	Sypolcarpus foetidus
Arrow Arum	Peltandra virginica
Pickerelweed	Pontederia cordata
Turk's Cap Lily	Lilium superbum
Canada Lily	Lilium canadense
Trout Lily	Erythronium americanum
Lady tresses	Spirantres
Lizard's tail	Saururus cernuus
American Lotus	Nelumbo lutea
Marsh Marigold	Caltha palustris

Data Source: Wildlands Conservancy (work in progress).

Dolan's report also compiled reptile and amphibian records from a study conducted by Jeanne Knepper, Chemistry and Environmental teacher at Palmerton High School. The study was conducted from 1994 to 1997 and yielded the identification of twelve species of salamanders, frogs, and turtles as follows.

Salamanders: Redback salamander, Two-lined salamander, Red spotted newt
Frogs: American toad, Fowler's toad, Pickerel frog
Turtles: Eastern painted turtle, Midland painted turtle, Eastern map turtle, Musk turtle, and Red-eared slider.

Dolan's quest for information on flora species yielded only one species of special interest, red algae. This species is found exclusively in Monocacy Creek. It is likely that other significant species are present within the watershed and have not yet been located or identified. The limited information available on this topic points to the need for further investigation.

3.2. Fishery

Due to the limestone bedrock underlying the lower portion of the creek, the Monocacy maintains a thriving population of various fish species. Three sections of the Monocacy Creek are stocked annually with trout. The stretch of the creek flowing through Bath Borough is stocked with 1,800 brown and rainbow trout on a yearly basis. A three-mile section flowing through downtown Bethlehem to Sand Island is stocked with 3,200 brook and rainbow trout annually. Lastly a section 2.4 miles long is located outside the City of Bethlehem and is stocked with 2,800 brown, rainbow, and brook trout annually (Attardo, 1997).

In addition, the Monocacy is treasured for its 1.9 mile stretch of trophy trout fishing, extending from the Gertrude Fox Conservation Area, north of Bethlehem's Center Street Bridge, to Illick's Mill Dam. This stretch of the Monocacy Creek was added to the Trophy Trout Program in 1988. Although the count of large trout is low, possibly due to insufficient habitat conditions, the Monocacy population of wild brown trout has jumped tremendously as a result of the trophy trout designation. In order to maintain the wild brown trout population, special fishing restrictions are applied within the Trophy Trout section of the creek (Attardo, 1997). These restrictions include the following:

- Use of artificial lures only, which may be used with spinning or fly fishing gear, is permitted.
- Molded fascimiles or replicas of insects, earthworms, fish eggs, fish, or any invertebrate or vertebrate; either alone or in combination with other materials is strictly prohibited.
- Use or possession of natural bait or any other device natural or synthetic, capable of catching fish, other than artificial lures, is prohibited.
- There is no closed fishing season.
- Minimum catch size is 14 inches, when caught or possessed between 8 AM of opening day of regular trout season and midnight of Labor Day.
- There is a daily creel limit of two trout of any species that may be caught or possessed from 8 AM on opening day of trout season to midnight on Labor Day. The remainder of the year until 8 AM on the opening day of trout season the following year, trout may not be fished.

- Taking of baitfish or fishbait is prohibited.
- A Trout/Salmon permit is required.

There have also been scattered reports of native brook trout inhabiting Monocacy Creek. Other fish that are commonly found in the Monocacy Creek include the Horned Dace, Black-nosed Dace, Sunfish, American Eel, Johnny Darter, Common Shiner, Bluegill, and Common Sucker.

3.3. Macroinvertebrate Sampling Results

Prior to this study, reports showed that the most common organisms in the Monocacy were caddisflies, black flies, scuds, water penny (beetles), midges, sow bugs, and may flies. A recent study was conducted to confirm this information from previous reports and also to identify any changes or threats to the macroinvertebrate community of Monocacy Creek. This study was conducted during the 1997/98 school year by students at Muhlenberg College under the direction of Dr. Patricia Bradt, Director of the Biology Department. Sampling locations from this study are shown on Figure 12. A complete copy of the report can be obtained by contacting Wildlands Conservancy. The major results and conclusions of this study are reported below.

- EPT indicies, which measures the number of different genera of mayflies, stoneflies, and caddisflies, were very comparable for stations 3 and 4. However, the total number of pollution sensitive species was lower at station 4, which was dominated by true flies (chironomidae).
- In addition to station 4, station 16 also had high numbers of chironomidae. This species can be opportunistic and very tolerant of pollution. It frequently dominates habitats of enrichment, causing concern for stretches of the Monocacy flowing through stations 4 and 16. Station 4 is downstream of a sewage treatment plant and station 16 is in close proximity to a golf course. Both of these land uses may be contributing nutrient overloads to the stream and thus degrading water quality and ecological diversity.
- Another cause for concern is the change in the dominant organism found at site 16 as reported from the 1977 study by Jane Miller and the 1997 study. In October 1977 the dominant organism was the caddisfly (hydropsyche). However, in October 1997 the dominant organism was the beetle (stenelmus) and in February 1998 that organism was the true fly (chironomidae). These organisms are more tolerant of pollution than the previously dominant species. Further studies should be conducted to verify this change and determine its cause.

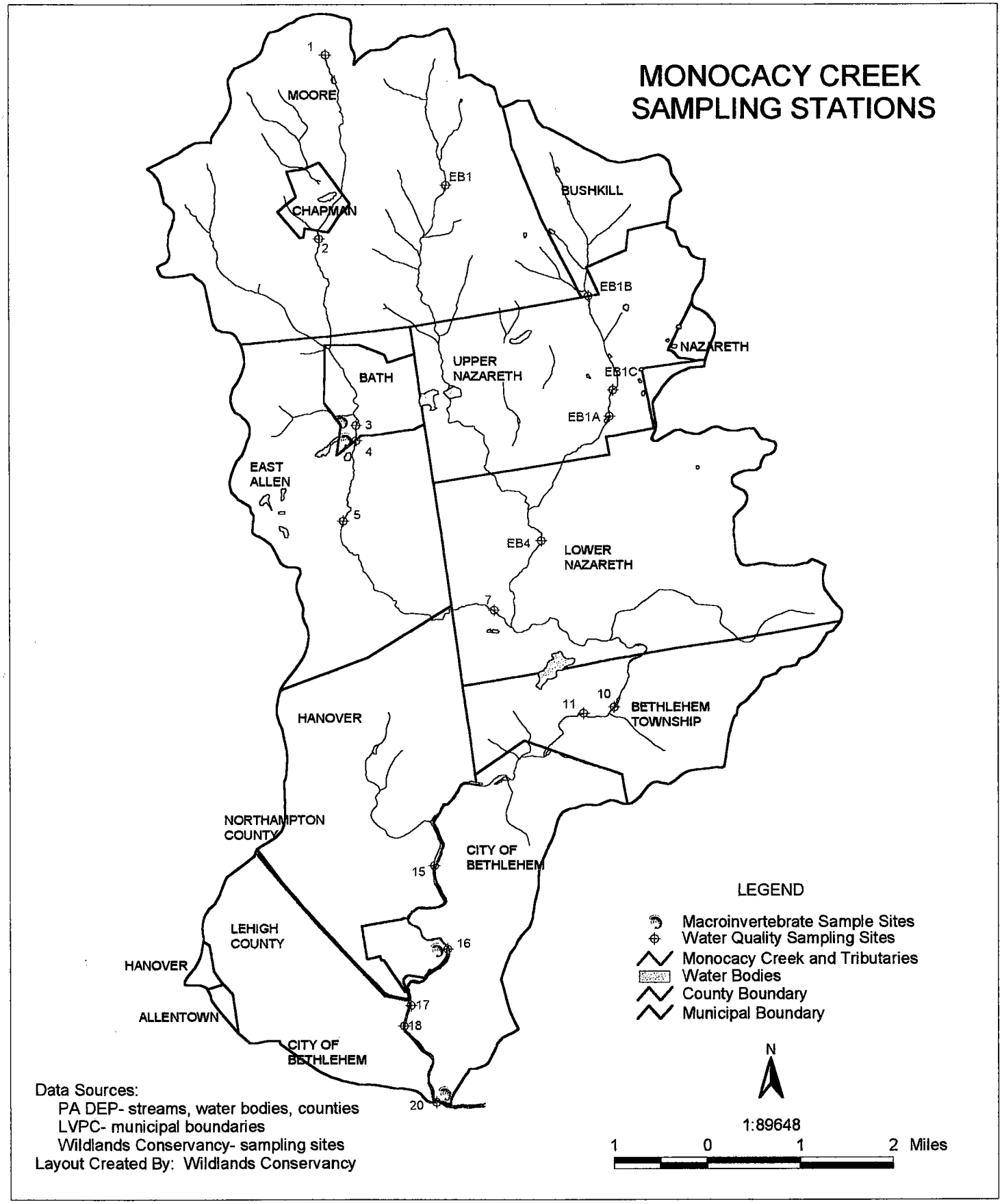


Figure 12. Water quality and macroinvertebrate sampling locations along Monocacy Creek.

4.0. CULTURAL RESOURCES

4.1. Historical/Archeological Background

The Monocacy Creek Watershed is an area rich in history, having been occupied for many centuries. The Monocacy Creek played a vital role in determining locations for settlement and subsequent development of the region. Historical and archeological evidence have shown that the watershed was occupied and utilized by an unknown number of Native American tribes for at least ten centuries before the arrival of the Lenni-Lenape. Supporting evidence of this inhabitance is vague as there are no written records; however, the abundance of stone artifacts found throughout the county have been dated back at least 10,000 years (Miller, 1939).

The Lenni-Lenape (meaning "real" or "original" people) are believed to have inhabited Pennsylvania during the early 1700's along with small bands of Shawnees, Nanticokes, and Mohicans. Originally the Lenni-Lenape were members of the American Indian People of the Ottawa river valley, who occupied areas of southern Ontario and some parts of Michigan (Lenni-Lenape Historical Society). They are ancestors of the Algonquins who covered a more extensive area than any other family in the 1600's. The Algonquins and subsequent ancestors believed that the earth and its resources should be held with great respect, and that it was their responsibility to care for and nurture the earth (Lenni-Lenape Historical Society). Stewardship could be seen in their farming, hunting, and fishing practices, which left little permanent impact upon the land (Lenni-Lenape Historical Society). The Lenni-Lenapes were originally a hunter and gatherer tribe who turned to farming approximately 1000 years before the arrival of Europeans (Lenni-Lenape Historical Society). When some of the Algonquin people broke off from their founding tribe and moved eastward, they settled in three distinct geographic regions (Miller, 1939). The Unami settled in the Lehigh Valley and had a turtle totem (Miller, 1939).

Within Pennsylvania, the Lenni-Lenape had only a few permanent villages that were located in Northampton County. There is strong evidence to support that a Unami village existed in the Monocacy Creek watershed, in the vicinity of Christian Springs. The establishment was named Nolemattink meaning "where the silkworm spins". The name was most likely derived from the cocoonery established near this area in 1752 by Reverend Bader. Historical documentation shows that Nolemattink had been established prior to the tenth century, before the domination of the Lenapes by the Iroquois (Miller, 1939).

The Lenni-Lenapes occupied the East Coast until the 17th and 18th centuries when the Europeans began to arrive in Pennsylvania (Martens, 1967). The Iroquois had fully overrun the Algonquin tribe by the time the Europeans settled in eastern Pennsylvania. In derision, the European settlers renamed the Lenapes the Delaware Indians and forced them westward (Martens, 1967).

The Moravians were the first Europeans to settle within the Monocacy Creek watershed. These German immigrants began to arrive in the watershed in1683. The Moravians were first welcomed to Pennsylvania in1722. They settled in the Nazareth area in 1740 and

moved to the Bethlehem area in 1741. The first house was completed in Bethlehem in 1741 and belonged to Count Zinzendorf and daughter Benigna. This date marks the beginning of a rich history within the watershed (Historic Bethlehem Inc., 1987).

The Moravians established an industrial center in what is now the City of Bethlehem. The remains of the Moravian business district are marked by a number of historic buildings that have been protected and preserved by Historic Bethlehem Inc. The historic district serves as a feature attraction for tourists visiting the City of Bethlehem. A major focus of the historic district is the first pumped municipal water system in the American Colonies that was constructed in 1755 (Historic Bethlehem Inc., 1987). The Monocacy Creek was diverted through these waterworks to turn a large waterwheel that provided the necessary pumping of spring water uphill to Bethlehem's living quarters (Historic Bethlehem Inc., 1987). The original waterworks were reconstructed in 1762 (Historic Bethlehem Inc., 1987). The associated spring house is a preserved historic structure (Historic Bethlehem Inc., 1987). The Waterworks is listed in the National Register of Historic Places, registered as a National and Local Historic Civil Engineering Landmark, and an American Waterworks Landmark (Historic Bethlehem Inc., 1987). Historic sites and structures within the watershed that are listed on the National Register of Historic Places are summarized in Table 7, including the name, address, and brief description of each site's historic significance. The location of these historic places can be seen on Figure 13.

Another historical attraction within the Monocacy watershed is the recently renovated Burnside Plantation (Figure 14). Burnside Plantation is a 6.5 acre property that composes the last remaining farm within the city limits of Bethlehem, Easton, or Allentown (Burnside Plantation Inc.). In 1986 the property was preserved for restoration of the 1748 to 1848 plantation, which operated on a collective basis known as "The Economy" (Burnside Plantation Inc.).

The Pennsylvania Historical and Museum Commission, Bureau of Historic Preservation was consulted to identify other cultural resources, including historical and archeological sites, within the watershed. The following account was provided:

> The Monocacy Creek Watershed's rich heritage is reflected in files that list twenty-three prehistoric archeological sites, eleven historic-period archeological sites and three properties listed in the National Register of Historic Places. Without question, these are not the only cultural resources located within the watershed boundaries, but just those currently on record. The archeological sites were recorded by local avocational archeologists or identified through project-specific field surveys in accordance with state and federal historic preservation mandates. The watershed area as a whole has not been systematically surveyed for such resources.

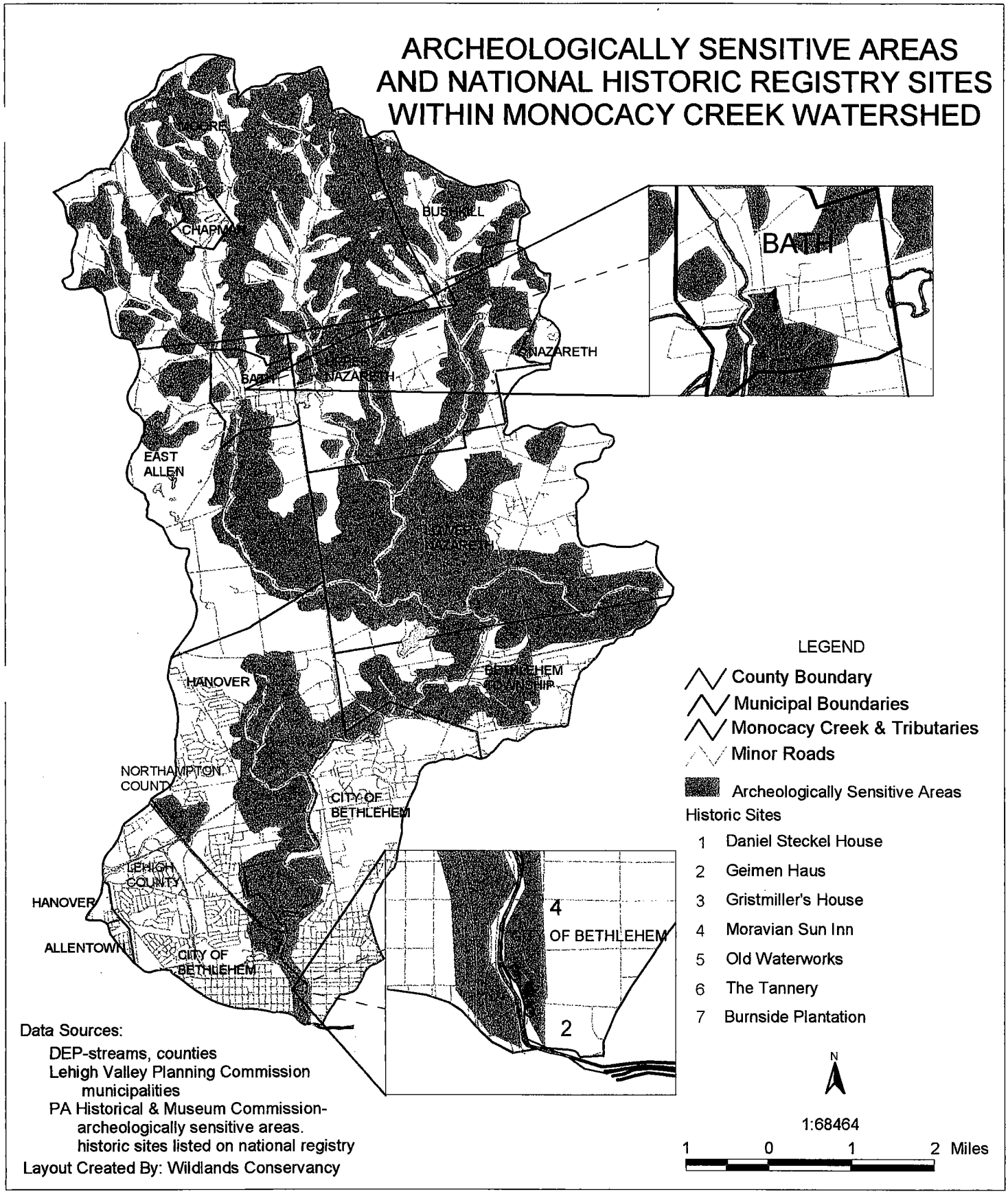


Figure 13. Sites listed on the "National Register of Historic Places" and archeologically sensitive areas within the Monocacy Creek watershed.

Table 7. Locations and descriptions of historic sites listed on the *National Register/Individual Properties and Historic Districts in Pennsylvania*, that are located within the Monocacy Creek Watershed.

SITE	LOCATION	DESCRIPTION
Daniel Steckel House	207 West Northampton St., Bath, PA	N/A
Central Bethlehem Historic District	Center City Bethlehem	18th Century industrial area that featured a tannery, waterworks, and various mills
Old Waterworks	East bank Monocacy Creek at Old York Rd., Bethlehem	log structure dated from 1754; stone replaced in 1762; housed 1st successful pumped water system in America; wooden pipes distributed water to community
Moravian Sun Inn	564 Main St., Bethlehem	built 1758; opened to public 1760; famous hostelry of 18th Century America; visited by Continental Congress Members; known for fine wine and excellent beer and cuisine; alterations entirely changed character over the years.
Gristmiller's House	459 Old York Rd., Bethlehem	built of stone in 1784; expanded 1831; one and one half story brick house characteristic of domestic architecture second quarter 19th Century.

Table 7. (Cont.)...

Geimen Haus	66 West Church St., Bethlehem	community house built in 1741; completed 1742; addition 1743; oldest building still standing in Bethlehem; may be largest log structure standing in U.S.; 2nd floor houses Bethlehem's 1st place of worship; rough cast 1800; clapboards added 1868.
The Tannery	Old York Rd.—Moravian Industrial Area, Bethlehem	3-story limestone structure built 1761; Monocacy Creek provided water needed for tanning processes.

Data Sources: Historic Bethlehem Inc., 1987.
Lehigh Valley Planning Commission, 1970.

Figure 14. Burnside Plantation, City of Bethlehem, PA.

Archeological resources are not randomly distributed across the landscape. Rather, these sites are closely related to certain environmental and topographic variables. The most important of these is proximity to water, including both active and extinct streams and springheads. Through extrapolation, the locations of known sites can effectively be used to predict the locations of currently unknown sites.

Archeologically sensitive areas, shown on the historical and archeological sensitivity map (Figure 13), are based on extrapolation of known site locational information. The shaded areas are considered to have potential for both historic and prehistoric archeological resources. As the sensitivity map indicates, much of the watershed area has good potential for such resources, and this is due in large part to hydrologic and topographic considerations. All of the sites included in current files are located within the shaded regions of the map.

The known prehistoric sites relate to the occupation of this area by Native Americans and date from approximately 8000 B.C. to the seventeenth-century A.D. The earliest recorded occupation dates to what is known as the Archaic Period of Pennsylvania prehistory. This period covers a time span from about 8000 B.C to 1000 B.C. Of the seven recorded Archaic period sites, four are located in floodplain settings or on stream terraces and three are located on upland flats or slopes.

The Woodland Period spans a time-frame from about 1000 B.C. to 1550 A.D. Currently, there are three Woodland sites recorded in the watershed. Two of these are in floodplain settings and one is in an upland location.

There are also three known multi-component prehistoric sites in the watershed. These sites represent the multiple occupation of a specific location by various prehistoric culture groups. Two of these sites are also located in or near a floodplain and one is on an upland slope.

The remaining ten recorded prehistoric sites are currently undateable, as no temporally diagnostic artifacts have as yet been reported from them. These sites could date to either of the aforementioned periods of prehistory and are found in the same types of settings as the more readily dateable sites.

The historic period archeological sites are related to farmstead occupations of the eighteenth and nineteenth centuries. Some of these sites are associated with extant structures, and some are not. All eleven of the recorded sites were identified through cultural resource surveys conducted in accordance with state and/or federal historic preservation programs. In general, yard and outbuilding areas of historic farms contain archeological information related to the occupation of the property in the past.

The Monocacy Creek watershed was first settled by Moravian sectarians in the 1740's. The city of Bethlehem contains a large Revolutionary War burial ground as well as a host of significant buildings dating to the eighteenth-century. In addition to the Bethlehem Historic District, the nearby Burnside Plantation and the Daniel Steckel House (located near Bath) are also listed in the National Register of Historic Places.

The presence of historical and archeological sites of interest indicates the irreplaceable cultural value found within the watershed. This rich history presents an important argument for preserving and maintaining the exceptional quality of the Monocacy Creek and its drainage basin. The dates of incorporation of each municipality in the watershed can be found in Table 8.

Due to the region's rich historical background, cultural resources are closely linked to historic sites within the Monocacy watershed. The Kemerer Museum, which displays such things as oriental rugs, antique furniture, Bohemian glass, grandfather clocks, and various works of art, is located in Bethlehem. The Moravian Museum is also located in Bethlehem and is housed by the Gemein Haus. Furniture, clocks, silver, musical instruments, religious articles, and Seminary art fashioned by the early Moravians are represented at the museum. In addition, Musikfest is held annually during the month of August. This nine day celebration of heritage is marked by music from around the world that is performed from noon until midnight at various sites within Bethlehem. Colleges and universities of the Lehigh Valley are another vital source of cultural entertainment for residents of the watershed (Lehigh Valley, PA, 1984).

Table 8. Incorporation dates of municipalities through which the Monocacy Creek flows.

MUNICIPALITY	INCORPORATION
Hanover Township	August 8, 1798 (Current boundaries set 1812)
Bushkill Township	August, 1813
Bath Borough	February 1, 1856 (First settled1758)
Bethlehem City	1741
Chapman Borough	1865
Moore Township	1765
East Allen Townhsip	1842
Bethlehem Township	1746
Lower Nazareth Township	April 22, 1807
Upper Nazareth Township	April 22, 1807

Data Source: Wright, 1988.

4.2. Socio-Economic Background

More than ninety percent of the Monocacy Creek watershed lies within Northampton County, with less than ten percent within Lehigh County. Socio-economic information for these two counties has been obtained from the Lehigh Valley Planning Commission (LVPC). The information is contained in the publication "Lehigh Valley Profile & Trends," which can be purchased from LVPC. The most recent census was taken in 1990, prior to that, a census was taken in 1980. All other data presented was forecasted by the LVPC. All census data and forecasted socio-economic information is contained in Appendix 2, available from Wildlands Conservancy.

Educational facilities are perhaps the most important economic resource to society. The resources and quality of school districts and universities within the watershed may have a major impact on the standard of living in the Monocacy watershed community. Within the watershed there are three public school districts, including Bethlehem Area, Northampton Area, and Nazareth Area School Districts. Moravian College and Northampton Area Community College are two universities located within the watershed.

The official LVPC Population Forecast predicts that growth between 1990 and 2000 in the Lehigh Valley will be approximately 7.0 percent. Bethlehem and Moore Townships are expected to experience major growth during the 1990s. In some instances, rapid population growth may lead to economic hardships such as an increase of unemployment rates, housing shortages, or lack of other facilities to meet the needs of a growing society. Expected land use changes correlate with the expected population increase. The most dramatic change appears to be an increase in land used for residential purposes.

Although unemployment rates continue to drop, the labor force is forecasted to expand for the ensuing decade. While the labor force is expanding, the number of employment opportunities in the fields of manufacturing, agriculture, and mining is steadily declining. Most employment opportunities available will be in the retail trade and service industries, which is consistent with trends across the nation. Many service employment positions might only provide minimal wages, which could impact the strength of the local economy.

Historically, the Monocacy Creek has been a center for industry within the Lehigh Valley. Today, Lehigh Valley industrial parks are still located within the Monocacy watershed. The abundance and location of major shopping centers, such as the one shown in Figure 15, within Northampton County also supports the importance of the Monocacy Creek watershed as a center for growth and development. This trend of growth and development within the watershed will result in less vacant land and more non-porous surfaces that will impact Monocacy Creek and threaten its quality. Flooding may also be a more common and severe problem as a direct result of increased development.

Figure 15. This shopping center shows how development is increasing non-porous surfaces throughout the watershed.

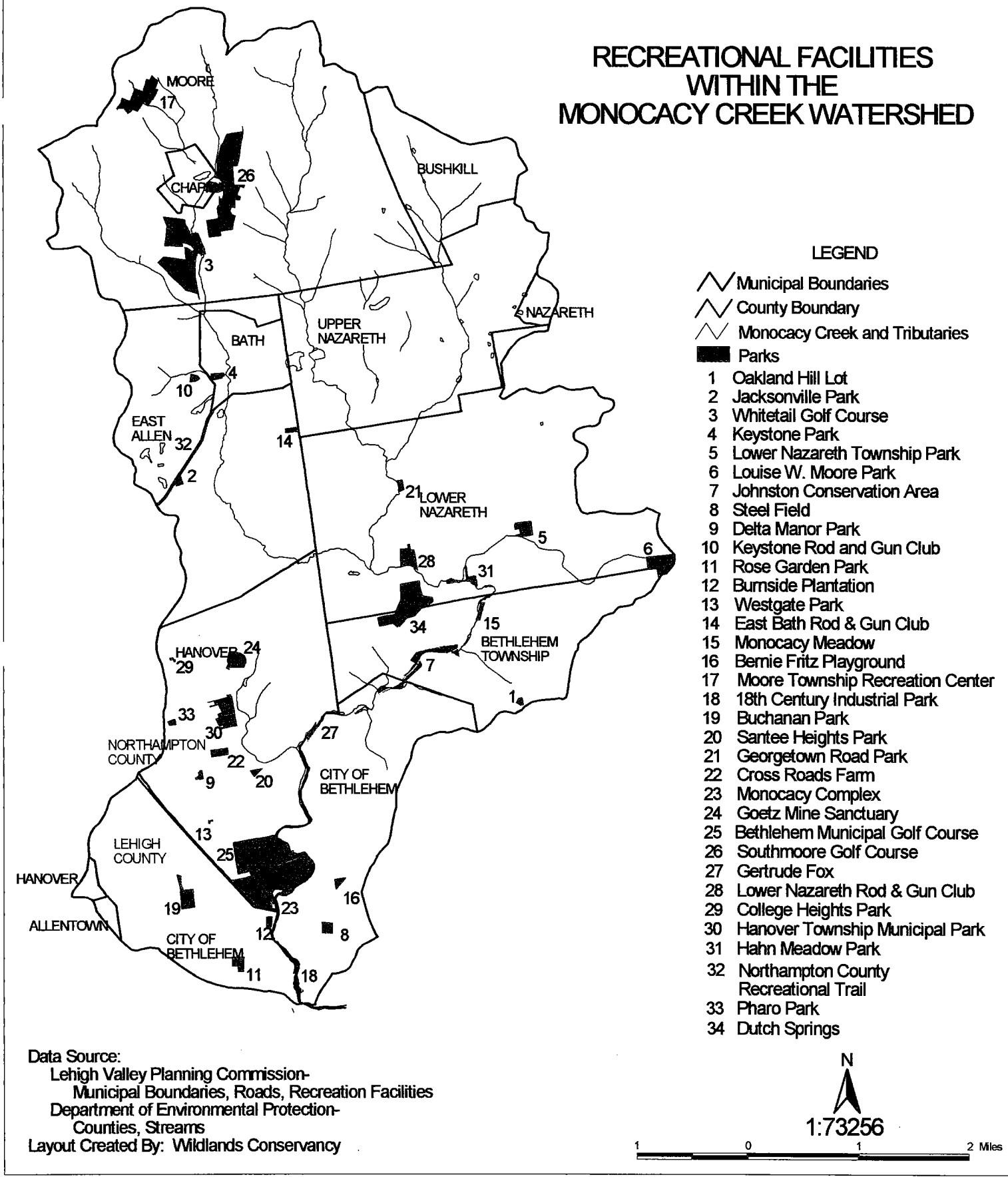
5.0. RECREATIONAL RESOURCES

5.1. Existing Facilities

Information on recreational facilities within the watershed was provided by LVPC in the form of digitized maps. Recreational facilities within the watershed, excluding playing areas and ball fields associated with schools, are shown on Figure 16.

Conservation parks, such as Archibald Johnston Conservation Area (Figure 17), along the Monocacy provide strong aesthetic value while preserving natural resources within the watershed. There are also three golf courses open to the public within the watershed. One course is located in the City of Bethlehem, and the other two are located in Moore Township. There is a positive correlation between population density and the distribution of parks throughout the watershed. An abundance of small active recreational facilities, such as ball fields, associated with developments and schools are also located within the watershed.

There appears to be a lack of recreational resources available within the drainage basin of the East Branch. However, low population density would limit benefits from parks in this portion of the watershed, which includes portions of Moore, Bushkill, and Lower and Upper Nazareth Townships. It is important though, to continue planning for future needs of the municipalities. Therefore, incorporation of recreational facilities in land use planning should take expected population growth into account, not only for the above townships, but for the entire watershed.



ıure 16. Recreation facilities within Monocacy Creek watershed, excluding school play areas.

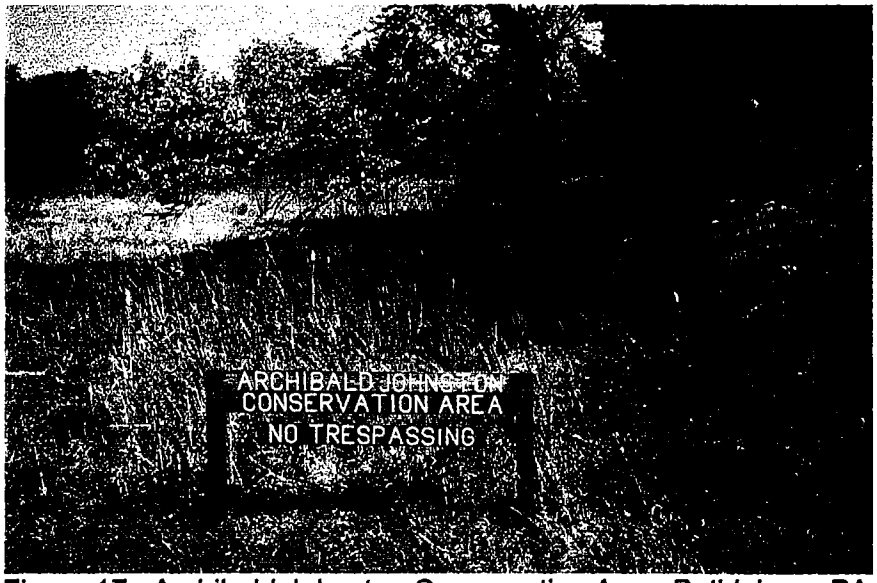


Figure 17. Archibald Johnston Conservation Area, Bethlehem, PA.

5.2. Trail Potential

One of the most exciting opportunities within the Monocacy watershed today, exists in the abandoned railway system. The vast potential of this valuable asset in the Monocacy watershed is largely unrecognized. Abandoned railways can serve to link the watershed with a common means of environmental education and stewardship goals, historic preservation, and recreational activity. With the interest and devotion of the watershed community, unused railways could be transformed to trails for walking, hiking, horseback riding, etc. The creation of trails would greatly improve the ability of municipalities to meet the diverse recreational demands of their expanding populations.

Currently, there is an interest by Chapman Borough and Moore Township to convert old, unused railways to recreational trails and horse trails, respectively. The railways proposed for horse trails are located at the headwaters of the Main Branch Monocacy Creek. In addition, Bath Borough is hoping to acquire the easement rights of a former railroad bed to establish a walking/nature trail that would start at Creek Road, connecting to Volunteer Firefighters' Park, and proceed ½ mile north. The full extent of abandoned railways is currently unknown and is a key issue within the watershed. A feasibility study identifying all unused railways, possible linkages between them, and approximate cost of trail constructions would be an appropriate first step toward investigating the revitalization of this overlooked resource. Turning these tracks into railways would not only provide recreational opportunities, but also preserve this important aspect of Lehigh Valley history.

6.0. INSTITUTIONAL RESOURCES

In comparison to many other watersheds, the Monocacy is blessed in that its preservation is strongly supported by the local community. Two organizations that formed to deal specifically with Monocacy Creek and its preservation and enhancement are Monocacy Creek Watershed Association (MCWA) and Monocacy Creek Citizens' Action Committee (CAC). The CAC was appointed to develop and implement projects that help protect and rehabilitate Monocacy Creek. They provide input from the community and serve as a vehicle for working with and reporting to the City of Bethlehem. MCWA is a non-profit corporation that compliments the work of the CAC and often works hand in hand with them to achieve similar goals. MCWA monitors the ecological welfare of Monocacy Creek, advocates its preservation to appropriate authorities, and sponsors research and educational activities. These organizations work hard and are dedicated to protecting the creek and addressing the concerns of the community.

Other organizations working within the watershed include Monocacy Creek Chapter of Trout Unlimited (TU), Coalition for Alternative Transportation (CAT), and Historic Bethlehem Partnership. TU volunteers often work together with other conservation organizations to complete remediation projects and educate others about cold water conservation. CAT is working to improve accessibility and recreational opportunities throughout the Lehigh Valley for those who are physically challenged or using non-traditional forms of transportation, such as bicycling. Historic Bethlehem Partnership is a collaborative effort among Burnside Plantation Inc., Historic Bethlehem Inc., Kemerer Museum of Decorative Arts, and Bethlehem Area Chamber of Commerce Foundation, to interpret the heritage of Bethlehem, PA through programs and activities that reflect the community's diversity. It is also their goal to preserve and maintain important buildings and sites, irreplaceable artifacts, and written documents, to help explain the changes that have occurred in Bethlehem's first 250 years. This organization is a great benefit to the Monocacy community as many historic sites and structures are located on the banks of the creek.

The Historic Bethlehem Partnership is an excellent example of how other agencies and organizations can work together to achieve their goals. County, state, and federal institutions can work together and with local organizations to share resources and further expand their accomplishments. For example, Lehigh Valley Planning Commission (LVPC), which compiles and publishes numerous informational, analytical, and policy oriented planning reports on a variety of subject matter, could partner with entities such as Northampton County Parks and Recreation, CAT, and MCWA to investigate possibilities for creating a trail system through the watershed. Federal and and state agencies such as PA Fish and Boat Commission, PA Department of Environmental Protection (DEP), PA Department of Conservation and Natural Resources (DCNR), and Environmental Protection Agency (EPA), have many programs that offer grants or assitance for projects like the one mentioned above. The LVPC could also partner with an organization such as Wildlands Conservancy to work with municipalities to develop more environmentally sound ordinances in an effort to protect our water and other natural resources.

Local educational institutions, such as Moravian College (Figure 18), are another asset for protection of the watershed. They are a valuable source of volunteers for various improvement projects such as streambank stabilization work and tree plantings. In addition, students often perform research projects on the stream, which provide indispensable information on the stream from year to year.

The opportunities for partnerships are virtually endless. The key to developing effective partnerships is communication. Open communication should provide each institution with knowledge about other potential and ongoing projects and grant opportunities within the watershed. This would allow them to make sound decisions regarding the planning of future projects and the desired level of involvement with current projects. The results of projects should also be shared among institutions to educate people outside the responsible organization and to ensure that duplicate or excessive work is not performed.

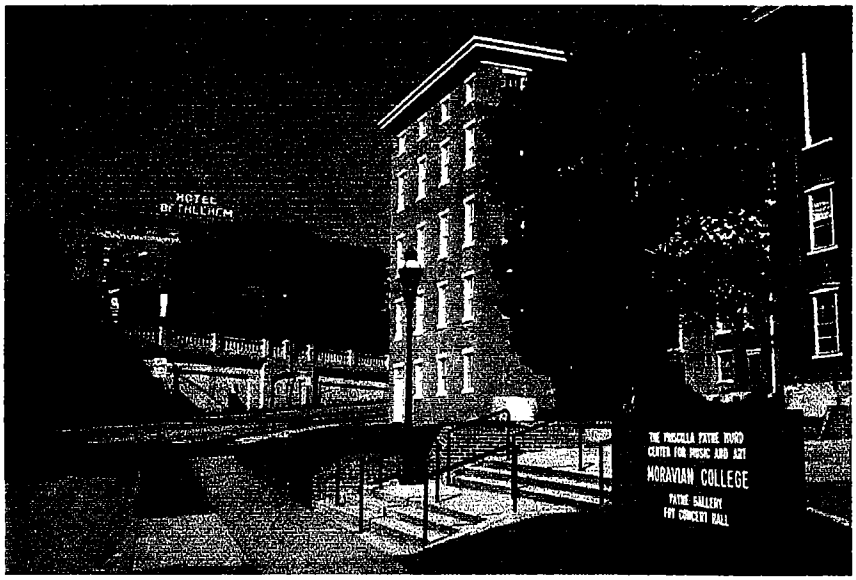


Figure 18. Moravian College located on the banks of Monocacy Creek, Bethlehem, PA.

7.0. WATERSHED ISSUES

7.1. Land Use

Land use statistics have been obtained from a geographic information system (GIS) coverage provided by LVPC. This information was used to assess the percentage of watershed surface area that each land use occupies. These percentages are shown in Figure 19. There is a distinct division of land use within the Monocacy Creek watershed. The northern 2/3 of the watershed is dominated by rural and agriculture uses, whereas the southern part of the watershed is dominated by residential use. Overall, agriculture accounts for approximately 45 percent of the land area and residential use occupies approximately 25 percent of the land area.

These two land uses have different affects on Monocacy Creek. Residential development limits groundwater recharge, and the increased population means that there are more opportunities for surface and groundwater to be contaminated by accidents or careless individuals. Agricultural lands are likely to subject the stream and groundwater to excess nutrients, while often stressing the ecosystem by the removal of streamside buffers.

Currently, approximately 14 percent of the land area is used as open space. Open space along the stream is very important to establishing wildlife habitat and providing shade and buffers for the stream. However, it is important to keep in mind that not all open space areas are managed with stream protection in mind. Several open space areas within the watershed compose recreational lands, such as golf courses, and do not provide the necessary streamside buffers to protect water quality. Land use analysis has shown that many open space areas within the watershed are neither wooded nor being used for recreation. This means that there is a strong potential for increasing buffer zones along streams and creating more forested areas throughout the watershed.

Additionally, industrial and institutional uses each account for approximately 3.5 percent of the land area. These uses are scattered throughout the watershed, diffusing their impact rather than concentrating it in one area. Lastly, commercial development occupies about four percent of the land area. Commercial development is concentrated in residential centers and has similar consequences on the watershed. The distribution of these land uses are displayed in Figure 20.

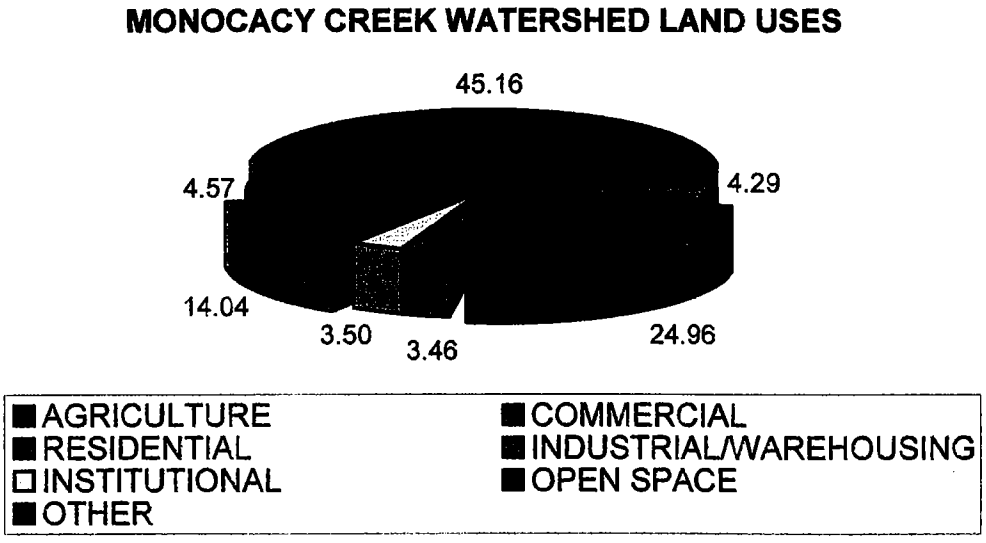


Figure 19. Land uses as a percentage of the watershed surface area for Monocacy Creek.

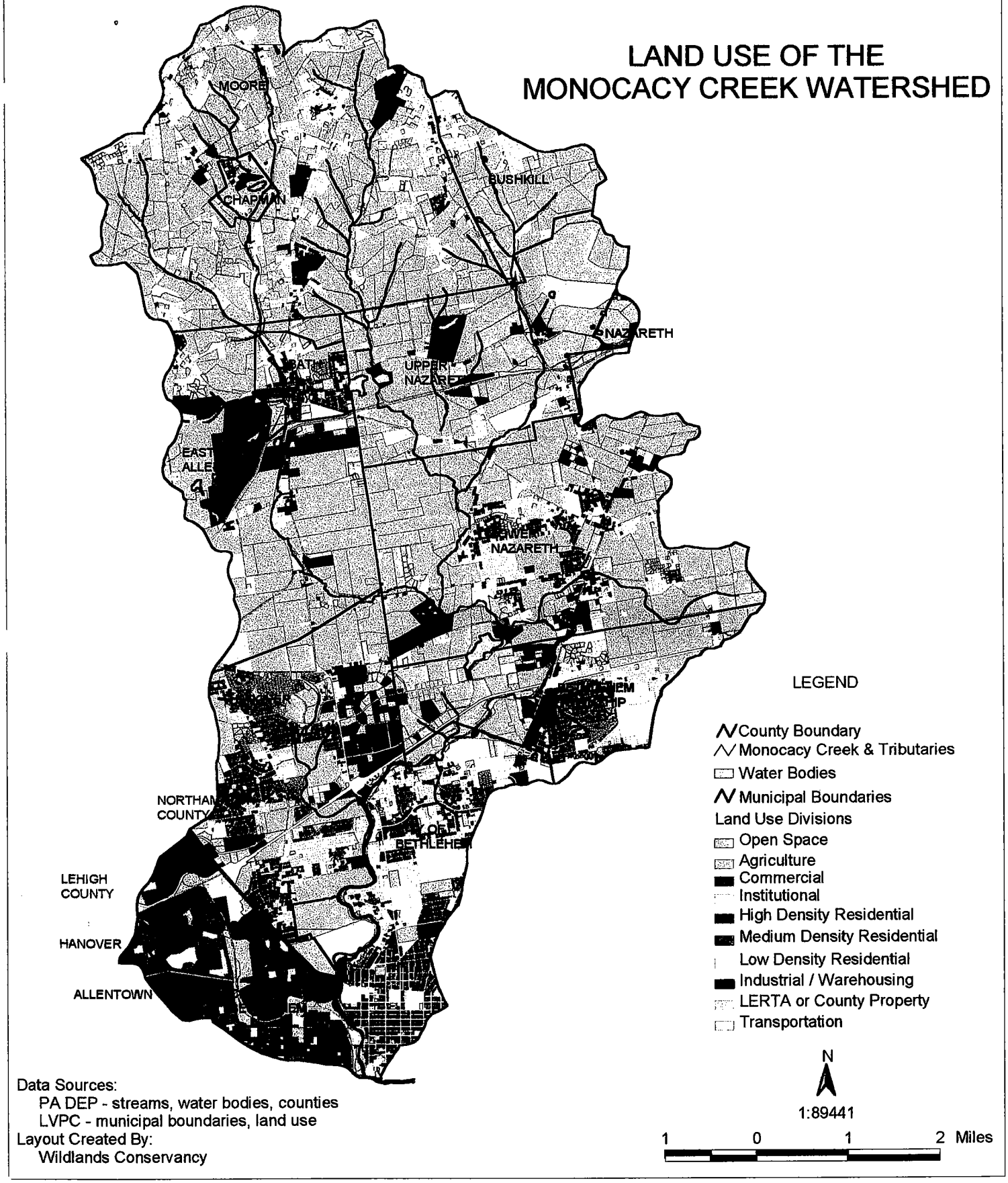


Figure 20. Distribution of land uses within the Monocacy Creek watershed.

7.2. Transportation

A solid infrastructure is integral to any economy. A well developed system of highways, roads, and railways exists within Monocacy watershed to support local industries and businesses. Major traffic routes traversing the watershed include Rts. 22, 191, 512, 248, 378, 946, and 987. In addition, road networks found in the City of Bethlehem and other urban areas provide several access points to Monocacy Creek for recreational purposes of local communities. Railways within the watershed are used to transport goods rather than as a mass transit system for the public. One major Conrail line runs east-west through the watershed between Bath Borough and Nazareth. Another line follows the Main Branch of Monocacy Creek from the south side of Bath Borough to the confluence with the Lehigh River in Bethlehem. Roads and railways within the watershed can be seen in Figure 21.

Despite the many assets this infrastructure provides for the Lehigh Valley, one must not overlook the harm it may inflict on Monocacy Creek and other local waterways. Heavy use of roadways leads to the build-up of contaminants and hydrocarbons from exhaust fumes and leaking automotive fluids. These contaminants are then washed from the paved surfaces during precipitation events into storm drains that frequently empty directly into the closest waterway, thus polluting the Monocacy and other treasured waters. In addition, frequent accidents causing oil spills often lead to pollution of Monocacy Creek due to improper clean-ups at the sites of accidents. Oil spills are detrimental to fish and other aquatic life and should be contained and cleaned as quickly and efficiently as possible to avoid fish kills and other negative impacts to the region's ecology. See Goal 6, Objective 2 under the "Management Options" section of this report for recommendations concerning these issues.

7.3. Critical Areas

Critical areas within the watershed include any areas that contain an important resource that should be protected and conserved or a sensitive area that requires special attention to prevent degradation of the Monocacy Creek. All of these critical areas are mapped on Figure 22. Some important resources that should be protected within the watershed include special conservation areas, wetlands, woodlands, and wellhead protection areas.

Most wooded areas within the watershed occur in strips along the creek and its tributaries. Wooded land composes approximately 8 percent of the watershed in Northampton County. Special conservation areas are located along the portion of the creek that forms the boundary between Hanover Township and the City of Bethlehem, as well as along a tributary in Hanover Township. Protection and preservation of such areas enhances the value of the land and ensures the availability of essential resources for future generations.

Some sensitive areas within the watershed include floodplains, alluvial soils, and steep slopes. Alluvial soils and soils on steep slopes are highly susceptible to erosion and subsequent sedimentation in the stream, which is harmful to aquatic life. The preservation of floodplains and alluvial soils will also aid in flood management. Development on floodplains and alluvial soils reduces the area of porous surfaces available to absorb and assimilate water, leading to increased frequency and severity of flooding.

7.4. Flooding and Storm Water Management

Regional growth in the watershed has led to many instances of development within the 100-year floodplain. In the upper, rural reaches of the watershed, scattered residences and encroachment associated with road crossings are the major types of development on the floodplain. In most cases, the downstream, urban portion of the watershed suffers from complete modification of the natural floodplain. As a result, there is higher potential for flood damage and a lower carrying capacity of the floodplain (LVPC, 1989).

Enforcement of Pennsylvania Act 166, the Floodplain Management Act, has limited future development so that there will be no significant alteration of carrying capacity of the floodplain or a resultant higher damage potential. Heightened awareness of floodplain importance, resulting partially from Act 166, has brought about an increase in the number of floodplain areas being dedicated to recreation or open space (LVPC, 1989).

Areas of storm drainage problems are shown in Figure 23 and described in Table 9. These problem areas were identified for the purpose of writing the Monocacy Creek Storm Water Management Plan, required by the Storm Water Management Act, Act 167. One major goal of this act was to prevent existing problems from getting worse, therefore the first task was to identify the problem areas.

Locations along the creek that contain significant obstructions were also mapped. A significant obstruction is basically considered to be any structure in, along, across, or protruding into a channel that causes flooding or backwater conditions. Within the Monocacy Creek Watershed, 16 such sites have been identified, three of which coincide with storm drainage problem areas. These sites are mapped in Figure 24 and their locations and descriptions are contained in Table 10. Not only does the Storm Water Management Plan identify these problem areas, but it also provides suggestions and guidelines for efficiently handling storm water runoff to reduce flooding and mitigate negative impacts on the creek associated with high flows. Flood zones in the Monocacy Creek watershed, based on Flood Insurance Plans, are shown on Figure 25 (LVPC, 1989). Although other areas in the watershed may be subject to flooding, no other flood zone mapping was available at the time of study.

7.5. Streamside Vegetation

Vegetation found along streamsides is commonly referred to as a "riparian buffer", riparian meaning along a stream or river and buffer because it serves as an area of defense between the water and its surrounding land uses. Riparian buffers protect the stream in many ways. First, they provide shade to keep the water temperature at optimal levels for cold water species. Second, they not only provide woody and leafy debris but also attract insects, all of which serve as either food or shelter for aquatic life. In addition, the roots trap sediment contained in runoff from adjacent lands, thus preventing it from entering the stream and destroying valuable spawning areas and macroinvertebrate habitats. Vegetation also uses nutrients contained in runoff that are essential for plant growth, thereby reducing damaging

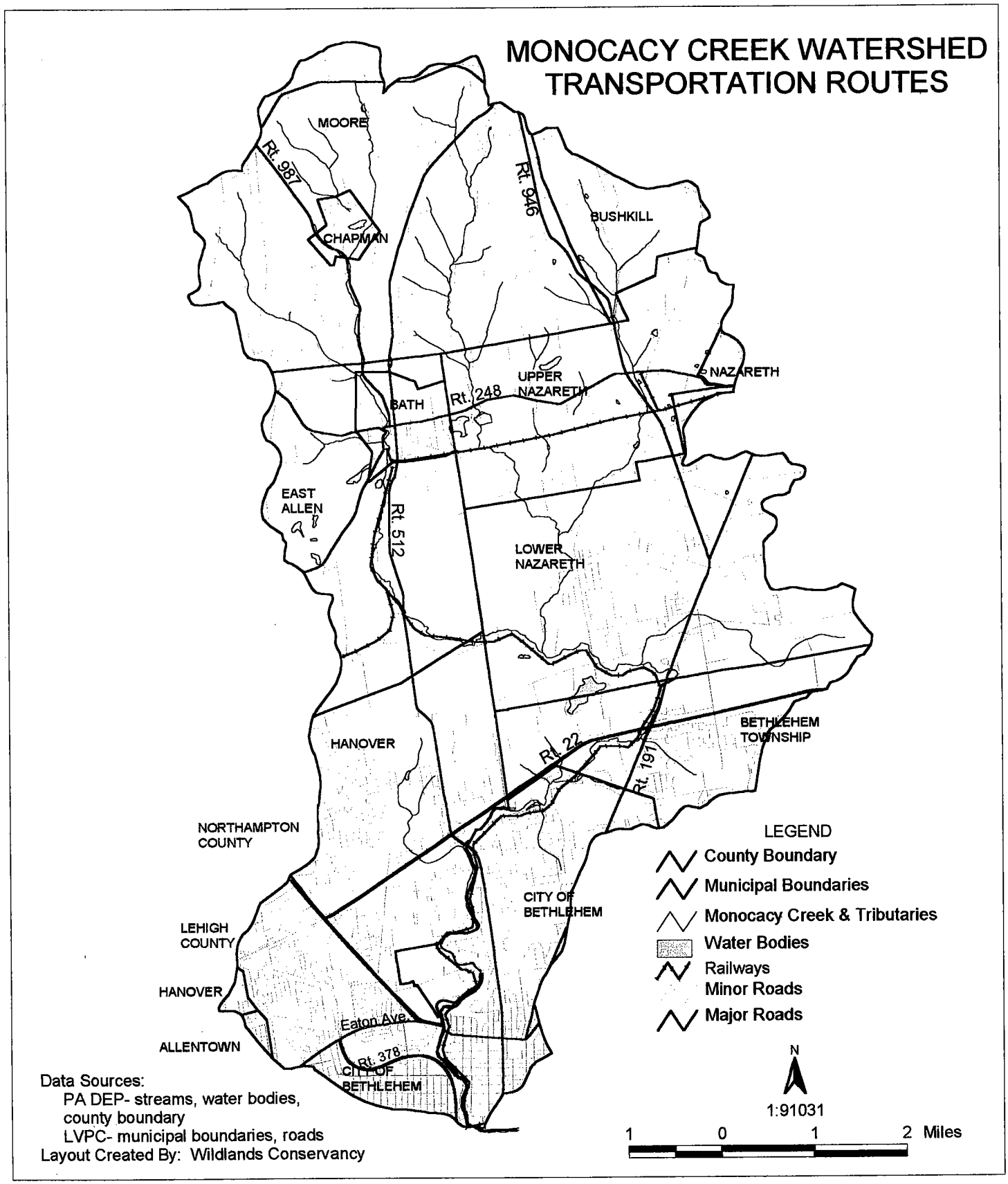
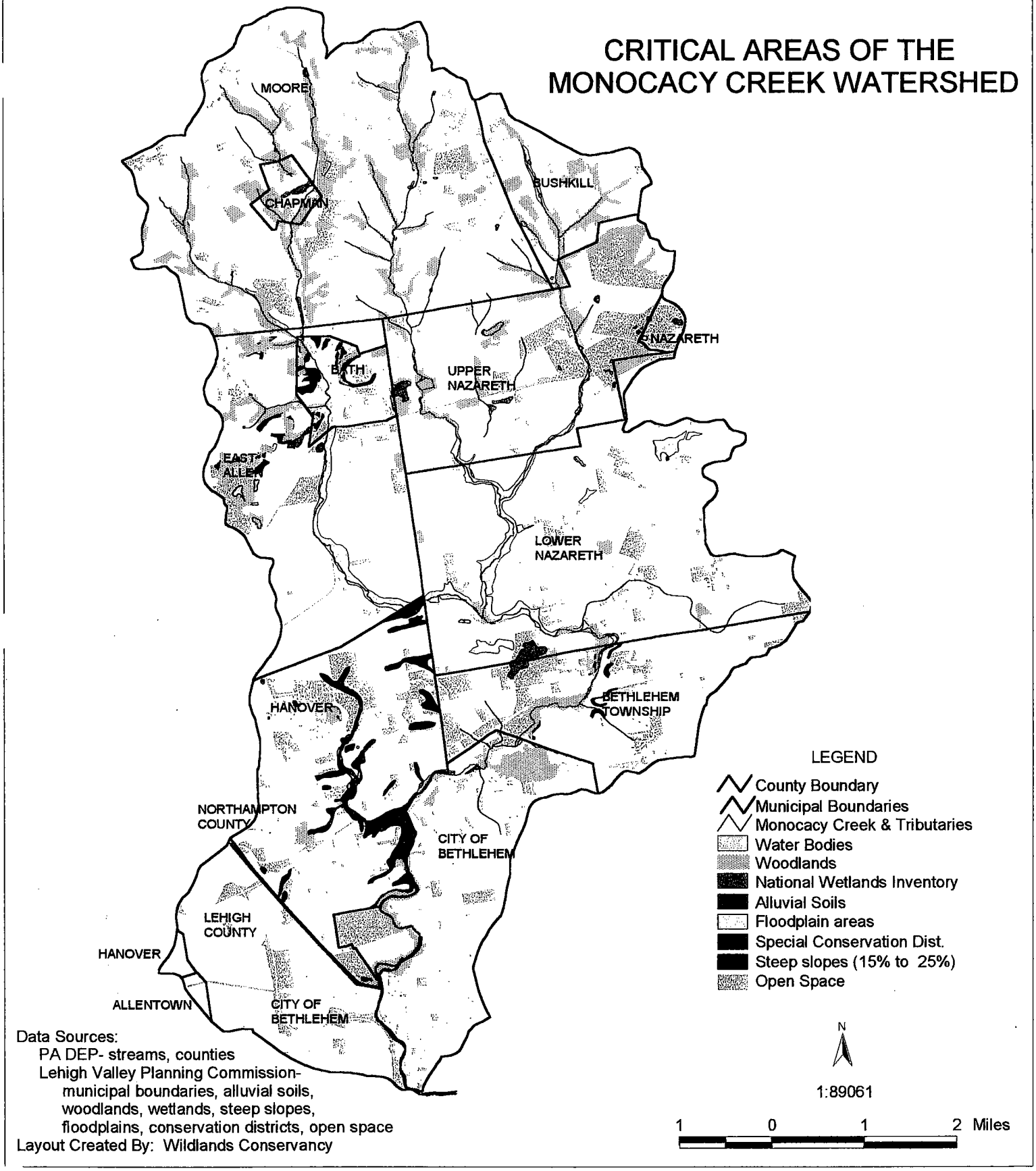


Figure 21. Roads and railways within the Monocacy Creek watershed.



gure 22. Critical areas within the Monocacy Creek watershed.

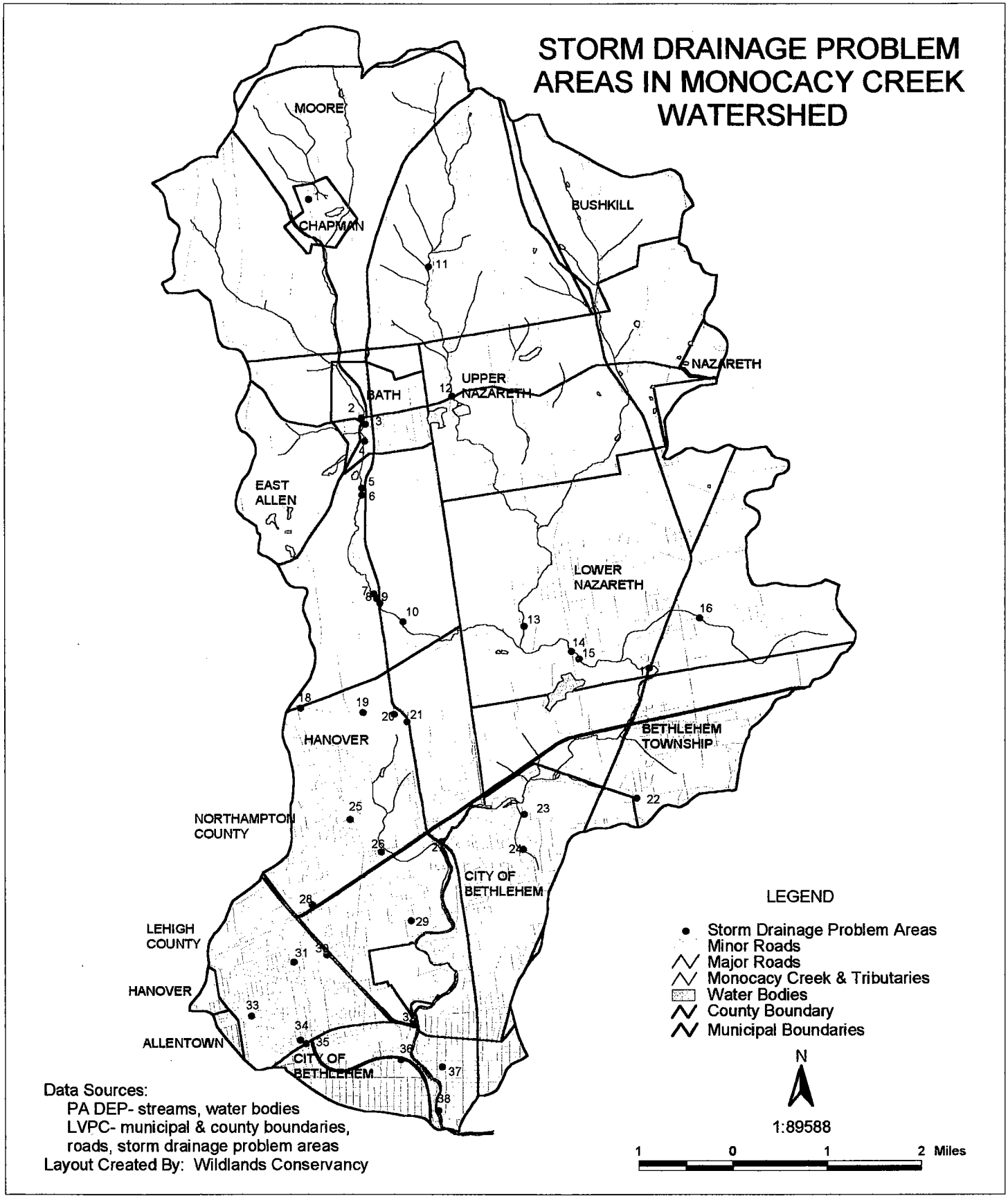


Figure 23. Storm drainage problem areas within Monocacy Creek watershed.

Table 9. Descriptions of strom drainage problem areas within Monocacy Creek watershed.

Number	Location	Municipality	Problem	Proposed Solution*
1	Yost Road & 5th St.	Borough of Chapman	Street & Property Flooding	New Access Route for E. Branch
2	Northampton St. Bridge	Borough of Bath	Street & Property Flooding	None Proposed
3	Main St.	Borough of Bath	Street & Property Flooding	None Proposed
4	Mill St.	Borough of Bath	Street & Property Flooding	None Proposed
5	Railroad Bridge	East Allen Twp.	Property Flooding	None Proposed
6	Private Road	East Allen Twp.	Street Flooding	None Proposed
7	Railroad Bridge	East Allen Twp.	Property Flooding	None Proposed
8	Route 512	East Allen Twp.	Street Flooding	None Proposed
9	Railroad Bridge	East Allen Twp.	Property Flooding	None Proposed
10	Railroad Bridge	East Allen Twp.	Property Flooding	None Proposed
11	Keeler Road	Moore Twp.	Localized Flooding	May have been solved by larger pipe installment
12	Route 248 near Penn Dixie Cement Company	Upper Nazareth Twp.	Street Flooding	Installation of diversion greatly reduced problem
13	Steuben Road	Lower Nazareth Twp.	Street Flooding	None Proposed
14	Georgetown Road	Lower Nazareth Twp.	Street Flooding	None Proposed
15	Hanoverville Road	Lower Nazareth Twp.	Street Flooding	None Proposed
16	Hecktown Road	Lower Nazareth Twp.	Street Flooding	None Proposed
17	PA Route 191	Lower Nazareth Twp.	Property Flooding	None Proposed
18	Culvert	Hanover Twp. (N)	Street Flooding	Cross Culverts
19	Culvert	Hanover Twp. (N)	Street Flooding	Cross Culverts
20	Culvert	Hanover Twp. (N)	Street Flooding	Cross Culverts
21	Route 512 at Ackerman's	Hanover Twp. (N)	Street Flooding	Shoulder Grading of Route 512
22	Oakland Road	Bethlehem Twp.	Street Flooding	None Proposed
23	Pine Top Trail/Fox Dr./ Bierys Bridge Road	City of Bethlehem	Property Flooding	Improve channel Capacity
24	Johnston Drive	City of Bethlehem	Street Flooding	None Proposed

Table 9 (Cont.)...

Number	Location	Municipality	Problem	Proposed Solution*
25	Stafore Estates/ Gaspar Area	Hanover Twp. (N)	Street & Property Flooding	Install and Extend Pipes
26	Stoke park Road Area	Hanover Twp. (N)	Street Flooding	Install Catch Basin/Improve Existing Ones
27	Monocacy Creek at Route 512	Hanover Twp. (N)	Localized Flooding	Box Culvert/Swale Construction
28	Hanover Farm Storm System	Hanover Twp. (N)	Street Flooding	Piped Collection/Conveyance System
29	Bridle Path Road Area	Hanover Twp. (N)	Street Flooding	Additional Piping
30	Westgate Area	Hanover Twp. (N)	Street Flooding	Detention/Additional Inlets/Increased Conveyance Capacity
31	Valley Park South Apts.	City of Bethlehem	Property Flooding	Additional Detention Upstream
32	Schoenersville Road	City of Bethlehem	Street Flooding	None Proposed
33	Pinehurst Road	City of Bethlehem	Street & Property Flooding	Detention Facility
34	Homestead Avenue	City of Bethlehem	Street & Rear Yard Flooding	None Proposed
35	Highland and Eaton Ave.	City of Bethlehem	Street and Property Flooding	None Proposed
36	5th Ave. at Route 378	City of Bethlehem	Property Flooding	Diversion of Runoff to Route 378
37	Goepp Street	City of Bethlehem	Street Flooding	Additional Inlets and Relief Pipe System
38	Historical Bethlehem Tannery Building	City of Bethlehem	Property Flooding	None Proposed

*Proposed solutions are generalized solutions as provided by municipal representatives either based upon specific studies of the problems or their knowledge of the particular circumstances.

Data Source: LVPC, 1989.

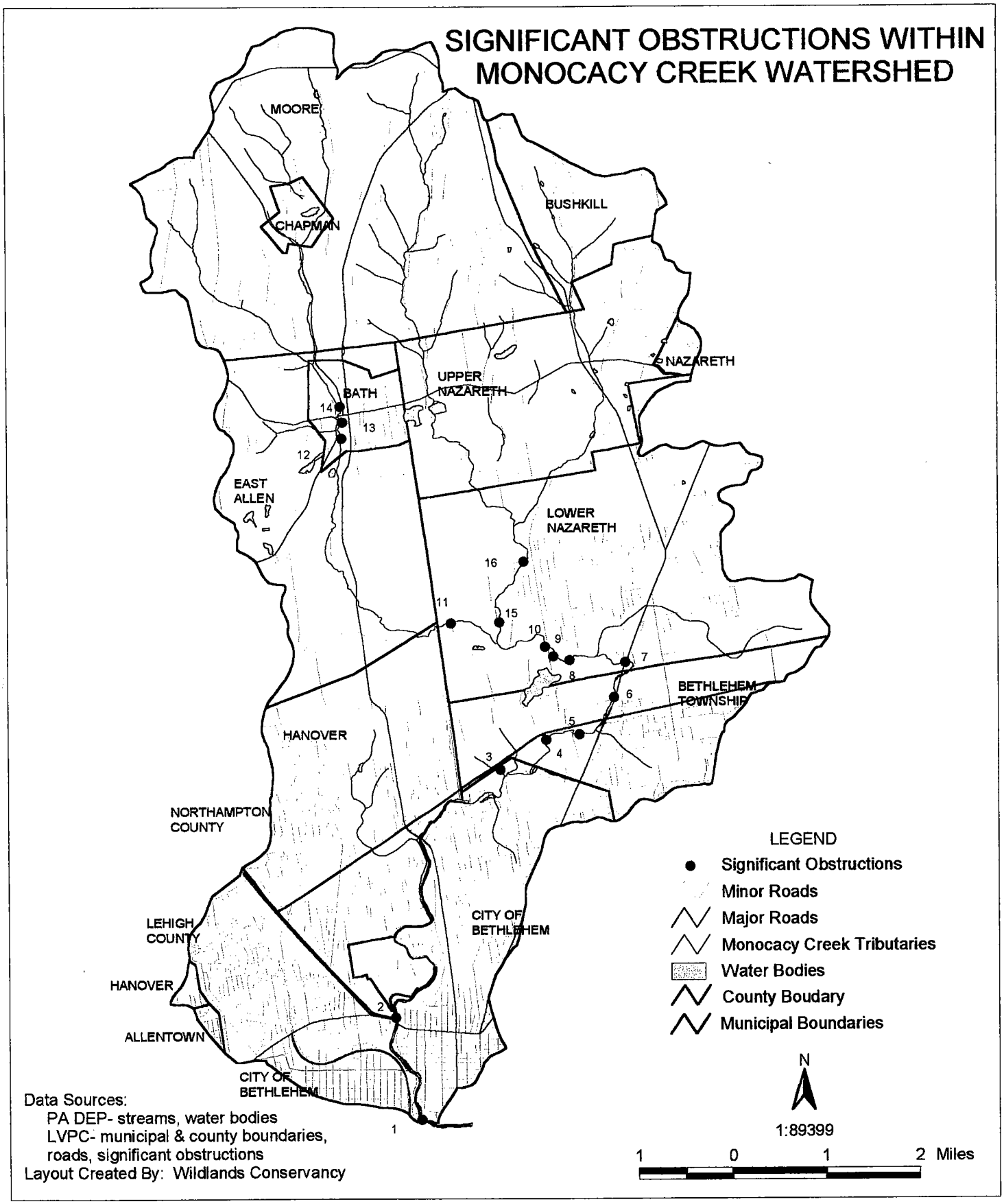
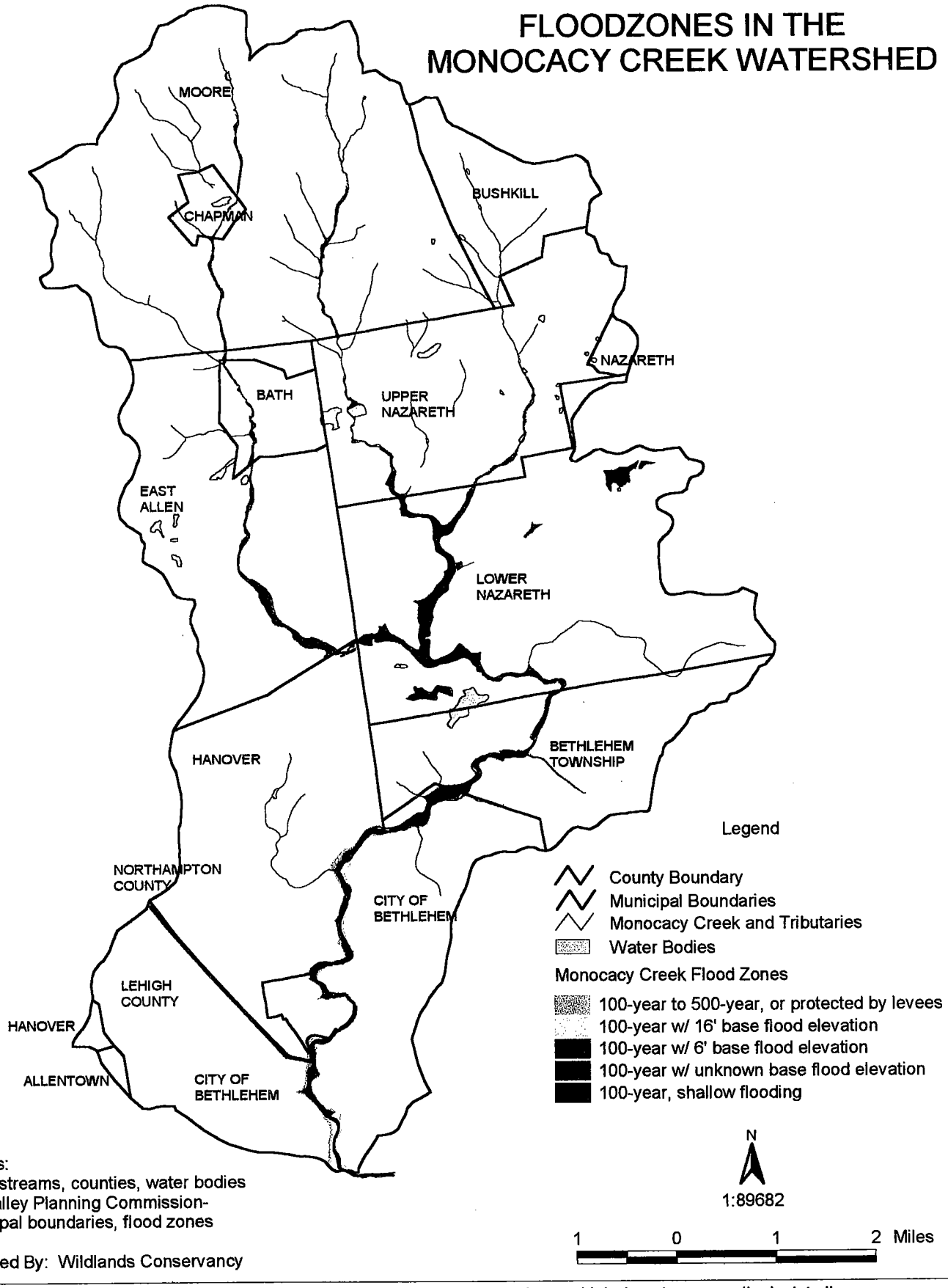


Figure 24. Significant obstructions to waterways within Monocacy Creek watershed.



ure 25. Floodzones for the Monocacy Creek watershed based on flood insurance plans, which do not necessarily depict all areas subject to flooding within the communities.

Table 10. Descriptions of significant obstructions within Monocacy Creek watershed.

Number**	Obstruction	Municipality	Approximate Flow Capacity (cfs)***
	-MAIN BRANCH MONOCACY CREEK-		
1	Abandoned Lehigh Canal	City of Bethlehem	4,500
2	Tunnel Bridge	City of Bethlehem	2,200
3	Conrail	City of Bethlehem	1,800
4	Conrail Crossing #2	Bethlehem Twp.	1,600
5	Conrail Crossing #3	Bethlehem Twp.	1,500
6	Brodhead Road	Bethlehem Twp.	4,500
7	State Route 191	Lower Nazareth Twp.	50,000
8	Conrail	Lower Nazareth Twp.	750
9	Conrail Bridge	Lower Nazareth Twp.	1,100
10	Georgetown Road	Lower Nazareth Twp.	2,200
11	Access Road	Lower Nazareth Twp.	330
12	Mill Street[1]	Borough of Bath	2,100
13	Main Street/State Rt. 248[2]	Borough of Bath	1,300
14	Silk Street	Borough of Bath	N/A
	-EAST BRANCH MONOCACY-		
15	Steuben Road[3]	Lower Nazareth Twp.	670
16	Access Road	Lower Nazareth Twp.	1,700

* Flood Insurance Administration
** Numbers are keyed with Significant Obstruction Map (Figure 14).
*** Estimated capacities are for illustration only and shall not be used as absolute capacities for storm water management decisions.

[1] Obstruction No. 12 coincides with Problem Area No. 4.
[2] Obstruction No. 13 coincides with Problem Area No. 3.
[3] Obstruction No. 15 coincides with Problem Area No. 13.

Data Source: LVPC, 1989.

nutrient loading of streams. Lastly, trees and other streamside vegetation are capable of withdrawing significant amounts of water from the ground, which reduces flooding during times of heavy precipitation.

It is important to maintain riparian buffers as they are perhaps the number one weapon in fighting nonpoint source pollution and in attaining a healthy, high quality water body. Increased development in recent years has led to the destruction of and/or encroachment

upon riparian buffers protecting Monocacy Creek. In addition, new challenges facing agricultural producers are driving many to remove streamside vegetation in order to cultivate more land.

7.6. Invasive and Exotic Vegetation

Invasive and exotic species of vegetation are a major environmental threat to many naturally vegetated regions. Many natural lands, which are becoming more frequently disturbed and fragmented, are increasingly susceptible to invasive and exotic species. When introduced to a new region, invasive vegetation spreads rapidly, overtaking the native habitat. The introduction of just a few invasive species is sufficient to severely limit the diversity of a natural system, especially if that system is also stressed by other environmental factors. Limiting vegetative diversity ultimately limits wildlife diversity, as birds and animals require different vegetative species for cover and food (Andropogon Associates, 1991).

Invasive species were abundantly and widely distributed when they were believed to be quick solutions to erosion problems. These invasive exotics have a shallow root system that spreads quickly to provide ground cover for bare slopes. However, these roots do not effectively stabilize soil, and stream banks continue to erode (Andropogon Associates, 1991).

Some invasive species, such as the Norway and sycamore maples, release toxins to the soil that inhibit the growth and reproduction of native species. Invasive trees are often overlooked because they do not have the dense vine or shrub form typical of exotics. The threat of the Norway maple in many regions is unnoticed because most trees are still saplings. However, by the time these saplings mature, the forested land will be composed almost exclusively of Norway maple. Even invasive trees do not provide adequate protection from erosion. These trees prevent the establishment of an herbaceous or shrub layer, leaving much of the soil bare and subject to erosion. This tree is no longer recommended, but a large demand still exists and it continues to be used on a widespread basis (Andropogon Associates, 1991).

Invasive species are a severe problem because there are no means of effectively controlling their spread (Andropogon Associates, 1991). Many invasive species are spread very rapidly over great distances by animal and bird disbursement (Andropogon Associates, 1991). The only means of control is to eliminate as many existing plants as possible, and restrict planting of new species (Andropogon Associates, 1991). No species that is proven or even suspected of being a successful invader should be planted.

Exotic species threaten the ecology of naturally vegetated areas, as they do not provide proper food and habitat for native wildlife. For example, if an aquatic macroinvertebrate did not evolve feeding from a Norway maple, it will not be edible to that species now. Therefore, that macroinvertebrate species may relocate or be wiped out entirely from the stream, if it can not find the feeding material on which it developed. Since macroinvertebrates are a basic building block in the food chain, a loss of them could disrupt the ecology within the riparian habitat. A list of known invasive and exotic species to the northeast is contained in Table 11.

One species identified as invading the Monocacy watershed, especially along railroad corridors, is Japanese knotweed. Invasive exotics that were identified at Burnside Plantation during a survey conducted by Wildlands Conservancy in 1988 include Norway maple, Tartarian honeysuckle, and crowned vetch (Baker, 1988). The Bureau of Forestry confirmed the presence of Tartarian honeysuckle during their March 25,1988 inventory (Baker, 1988). Other species spotted within the watershed during the time of this study include multiflora rose and purple loosestrife.

Table 11. Invasive exotic species found in Northeastern United States.

Common Name	Scientific Name
Trees	**Trees**
Norway maple	Acer platanoides
Sycamore maple	Acer pseudoplatanus
Russian olive	Eleagnus angustifolia
Autumn olive	Eleagnus umbellatus
White mulberry	Morus alba
White cottonwood	Populus alba
Shrubs and Small Trees	**Shrubs and Small Trees**
Barberry	Berberis japonica
Winged euonymous	Euonymous alatus
Amur honeysuckle	Lonicera maackii
Tartarian honeysuckle	Lonicera tatarica
Blunt-leaved privet	Ligustrum obtusifolium
Smooth buckthorn	Rhamnus cathartica
Shining buckthorn	Rhamnus frangula
Multiflora rose	Rosa multiflora
Vines	**Vines**
Porcelain berry	Ampelopsis brevipedunculata
Oriental bittersweet	Celastrus orbiculata
Japanese honeysuckle	Lonicera japonica
Kudzu	Pueraria lobata
Japanese Wisteria	Wisteria floribunda
Herbaceous Plants	**Herbaceous Plants**
Purple loosestrife	Lythrum salicaria
Japanese knotweed	polygonum cuspidatum

Data Source: Andropogon Associates, 1991.

7.7. Review of Existing Water Quality Reports

Evaluating the health of the Monocacy Creek greatly depends upon the condition of the creek prior to the study period. Previous studies provide a comparison for determining if the water quality and habitat conditions are improving or deteriorating. Four water quality studies have been selected from reports prepared during the past few decades to represent the quality of the Monocacy throughout this time period. The contents and bibliographic information from these reports are summarized below.

Learned, James B., Robert A. Fonte, Mark E. Alpert, and Merle J. Holsinger. 1970. "A Chemical and Ecological Study of Stream Recovery with Particular Emphasis on Entrapment-Entrainment Residual Pollution and Fish Habitat." Lehigh University, PA.

Observations reported during this study found that the shallow, warm agricultural portions of the stream were the most barren and devoid of life. Water quality samples were collected from December, 1969 to May, 1970. Analysis showed that pH ranged from 7.4 to 7.9, stabilizing at 7.8 in the lower portions of the watershed. Alkalinity values progressively increased moving downstream, ranging from 26 to 160 mg/L $CaCO_3$. Ortho-phosphate levels reached a maximum concentration in the middle of the watershed at 3.6 mg/L. Minimum levels of 0.01 mg/L were detected at the mouth of the creek. Nitrate levels were extremely high and showed seasonal fluctuations due to increased plant uptake during the growing season. Also contained in this report are lists of rooted aquatic and algae plants, as well as electro-shocking reports showing 12 species of identified fish.

Mushlitz, David and Wayne Miller. 1976. "A Chemical and Biological Analysis of the Improvement in the Water Quality of the Monocacy Creek since the Installation of Pollution Control Devices by Reichard-Coulston, Inc."

This report was based on a year-long study of three sample sites one each above, below, and adjacent to the Reichard-Coulston plant. Sampling took place from September, 1974 to September, 1975. Analysis results showed that levels of specific conductance, dissolved oxygen, temperature, chloride, biochemical oxygen demand, and ammonia were all fairly constant and within standards set for the Monocacy throughout the study period. Alkalinity values seemed to fluctuate on a weekly basis. This phenomenon was likely caused by discharges from National Portland Cement (NPC). Nitrate levels were high and sometimes exceeded 4 mg/L. Iron discharges were slightly higher than the standard of $\leq$ 1.5 mg/L until February, at which point they began to decline. Zinc and Copper levels were found to exceed the standards at all sites until NPC shut down. Macroinvertebrate studies conducted during this sample period showed that in one year's time, creek life jumped from deserted to well-developed. Although it was not an objective of the study, sampling showed a dramatic improvement of water quality after NPC ceased operation.

Davies, Jodi. 1982. "Sampling and Analysis of Stormwater Runoff into the Monocacy Creek." Northampton County Area Community College, PA.

This report was based on the analysis of stormwater runoff discharges from two urban and two rural watersheds into the Monocacy Creek. The study found notable differences between the urban and rural watersheds for six of the parameters tested. Levels of BOD, total suspended solids, nitrates, specific conductance, and total coliform counts were all higher for the urban watersheds. PH values were also noted as more alkaline in the urban watersheds. Conclusions of this report include the following:

- More organic and inorganic matter is carried in runoff from urban watersheds. This could be caused by more impervious surfaces leading to increased litter, traffic residuals, dirt and eroded materials. Also, there is more fine particulate matter suspended in the air and brought down by rainfall in urban watersheds.
- Nitrates may be high due to springtime measurements and high use of fertilizers at this time.
- There is a need for source control of suspended solids, organic matter, and nitrates entering the stream during storm events.
- Significant silt accumulation was apparent at both rural and one urban discharge.
- Source controls of storm effluent including reduction of air pollution, erosion control, improved street sweeping, and restricted chemical use, were recommended.

Tereska, Todd. 1990. "A Water Analysis on the Monocacy Creek."

Seven sample sites throughout the watershed were used to assess the impact of industry, home development, and drainage wastewater on Monocacy Creek. Four sampling runs were conducted during the spring of 1990. During these runs, twelve parameters were analyzed for each sample. Results of the analysis were as follows:

- Temperature fluctuated with the weather conditions and there was no evidence of thermal pollution except by Bath Sewage Treatment Plant, who has a permit to discharge wastewater.
- Dissolved oxygen levels were good throughout the study period for all sites.
- pH readings were stable and within standards set for Monocacy Creek.
- Total hardness showed a general trend of progressively increasing downstream.
- Magnesium and calcium hardness increased proportionally as well, with magnesium hardness as a percentage of total hardness always higher than calcium percentage of total hardness.
- Nitrate analysis showed a pattern of increasing levels in the middle of the watershed.
- Total coliform counts progressively increased downstream as expected.
- Fecal coliform counts were surprisingly lower below Bath Sewage Treatment Plant than above. This was probably due to chlorination of the water during treatment processes.

The overall finding of this report is that the Monocacy Creek has high quality water despite its shortcomings. This was attributed to the lack of industrial impacts as compared to fifteen or twenty years earlier. Regulations and permit requirements for point source discharges have greatly improved the quality of the Monocacy Creek over the past two decades.

7.8. Visual Assessment

Results of a streamwalk showed that sedimentation and the lack of riparian buffers have impaired extensive stretches of the creek. Accumulation of sedimentation progressively increased downstream. There are four main culprits of sedimentation. Runoff from urban and agricultural lands that are not lined with buffers is one major contributor to the situation. Another culprit is streambank erosion due to the lack of sufficient streambank stabilization. This is a problem that must be addressed in both the upper and lower parts of the watershed. The third culprit is the development of floodplains because it increases the flow and velocity of the creek water, giving it more potential to erode soil and deposit it downstream. Development decreases the ability of the floodplain to assimilate storm water, and therefore it is discharged to the stream, increasing the flow. Floodplain development is primarily a concern for the southern portion of the watershed. Lastly, dams contribute to sedimentation because they decrease the gradient of the stream, thereby decreasing the flow. When the flow gets too slow, the ability of the stream to carry and transport material decreases and sediment particles begin to settle out and deposit in the stream channel. Significant sediment buildup usually occurs right behind a dam. At least six dams were identified within the Monocacy watershed that contribute to sedimentation problems. An example of severe sedimentation in the creek is shown in Figure 26.

Figure 26. A streambank that has eroded along Monocacy Creek and deposited sediment on the stream bottom.

It was also noted that extensive sections of the streambank have been modified. Man-made stone, concrete, or wooden walls compose one or both sides of the streambank for several

segments, especially in the southern part of the watershed. Man-made walls are an obvious result of the impact that development can have on natural surroundings. The construction of retaining walls suggests that there is a lack of sufficient riparian buffers for the given stream segment. In addition, the retaining wall does not provide proper habitat for many aquatic species. One example of a modified streambank is shown in Figure 27.

Other problems that were noted include trash dumping in the stream and improper streamside management. Some portions of the creek appear to be accumulating large quantities of debris such as milk crates, tires, metal scraps, and shopping carts. Two areas where trash dumping is a major concern include the portion of the Main Branch that flows under a Rt. 512 bridge in Bethlehem, adjacent to the Aspen Inn, and a portion of the Archibald Johnston Conservation Area. Improper management, including mowing of lawns and parkways up to the edge of the streambank and disposal of clippings and other yard waste, occurs throughout the length of the creek.

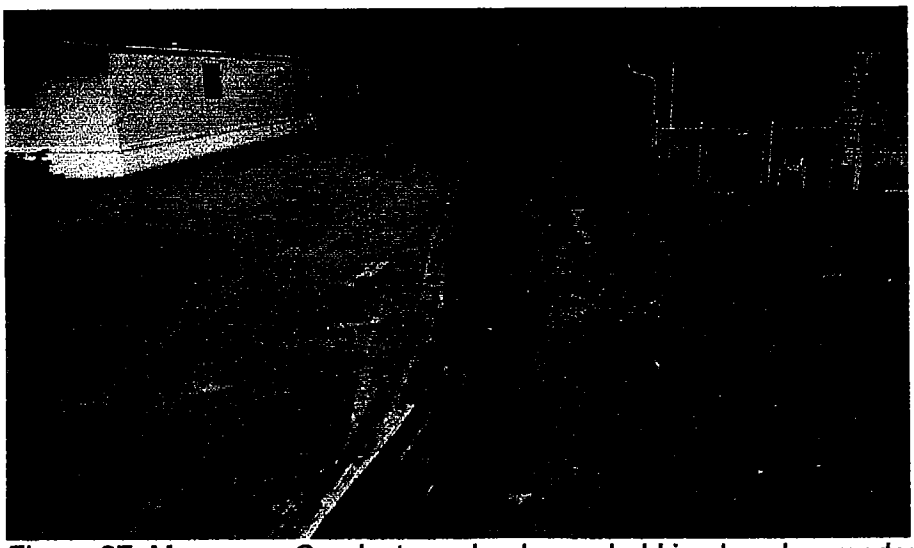


Figure 27. Monocacy Creek streambanks are held in place by wooden beams rather than by natural stabilization.

7.9. Temperature Survey

A temperature survey starting near St. Anne's Shrine was conducted in order to determine where springs began entering the creek and what effect they had on moderating stream temperature. A thermometer was used to check the stream temperature at 100-foot intervals around the Camel's Hump area. The results of this survey showed that the springs are supplying the stream with a flow consistently at 11 degrees Celsius. Seven springs were identified along the banks of the stream in the vicinity of Camel's Hump. The contribution of the springs helps the creek maintain healthy temperatures for aquatic life, even in the midst of the extreme heat and drought of summertime. Due to these springs the stream temperature in this area did not approach 19 degrees Celsius, the water quality standard for

a CWF. The average stream temperature appeared to decrease by approximately 2 degrees Celsius after the entrance of the springs.

7.10. Water Quality Monitoring Results

Water quality testing was conducted for a period of eight weeks during the summer of 1996 and for another six-week period during the summer of 1997. Testing was performed in order to characterize the quality of the Monocacy Creek and its main tributaries. Water quality information would provide insight to locations where the stream is in good health and also where it is beginning to deteriorate. With this goal in mind 25 initial monitoring stations were dispersed throughout the watershed. Based on the results of the 1996 data, the number of sampling stations was reduced to 17. The locations of these sites can be seen on Figure 12. Some water quality parameters were tested on site, but most were tested in a laboratory using a digital electronic colorimeter. The electronic colorimeter was not available for use during the 1996 sampling period, but it provided much more accurate results than former testing procedures. Therefore, the results from the 1996 sampling were discarded in favor of the more accurate and precise data collected during 1997. For more information regarding the background, possible sources, and water quality standards of the following parameters, turn to the water quality section in the appendix.

7.10.1. Temperature

Results of temperature analysis show that Monocacy Creek is being threatened by thermal pollution. Several readings from site 1 at the headwaters to site 10 in Bethlehem Township exceeded the temperature limit that may lead to growth impairment in brook trout. A few individual readings from these sites in the northern half of the watershed surpassed levels that may cause death to brook trout. The ability of the Monocacy to assimilate temperature rises and maintain optimal levels at the headwaters and mid-section of the watershed may be lessening due to the removal of streamside vegetation. The lower reaches of the stream, through the City of Bethlehem, benefit from the presence of springs. They help to maintain optimum temperatures, even during the summer months that tend to stress the stream with excessive heat and drought.

7.10.2. pH

The pH at the majority of the sampled sites on the Monocacy ranged from about 6.3 to 8.1. Values started low at the headwaters and increased downstream. The alkaline values obtained along the Monocacy Creek are a result of the limestone bedrock formations underlying the middle and lower portions of the watershed. The springs located along the stream near Camels Hump, north of Bethlehem, play an important role in maintaining a constant pH in the stream. It is critical to the survival, growth, and reproduction of fish and macroinvertabrates in the creek to maintain a constant pH. Slight variations of pH on a day to day basis or major changes over time, in a species' habitat can cause tremendous stress to that species. Some species are more tolerant of variations and can withstand a wider range of values than others, which may cause a change in the variety and quantity of

organisms found in the ecosystem. For this reason it is extremely important to monitor pH on a regular basis.

7.10.3. Dissolved Oxygen

Almost every dissolved oxygen test performed during the sampling period resulted in levels above the minimum water quality standard and levels were not cause for concern for the aquatic life in the stream. Most site averages ranged between 8.2 and 10 ppm. Several individual values were in excess of 10 ppm where the maximum concentration of DO for any water body is 18 ppm. Site 4, located in Bath Borough, and site 18, located in the City of Bethlehem upstream from the confluence, displayed extreme variability in DO levels and may be cause for concern. DO requirements for aquatic life vary, based upon the type of species, water temperature, amount of pollutants present, and the maturity of the organism in question. Since high temperatures and some pollutants restrict respiration and metabolism, DO needs may increase under the presence of these conditions. Some aquatic species may be more sensitive to sudden changes in DO than others, therefore sites with extreme variability should be monitored to detect any potential problems.

7.10.4. Specific Conductance and Total Dissolved Solids

Within Monocacy Creek, there is an obvious link between specific conductance and the type of bedrock underlying the creek. Sites 1, 2, EB1, and EB1b underlain by shale formations in the northern part of the watershed on both the Main and East Branches, have considerably lower conductance values than the remaining sites underlain by limestone in the lower two-thirds of the watershed. However, it is possible for sites within shale formations to have significant inclusions of carbonates, producing a higher result than expected. This seems to be the case for sites two through four on the Main Branch from Chapman Borough to Bath Borough in the northern part of the watershed. Sites within the Camels Hump vicinity, north of Bethlehem, show representative values for the Monocacy Creek, staying consistently around 550 micro-mhos. Only two individual excessively high readings were observed throughout the watershed, and they were likely to be associated with permitted point source discharges to the stream.

7.10.5. Alkalinity

Monocacy Creek alkalinity values ranged from approximately 20 mg/l at the headwater sites to 220 mg/l in the vicinity of Camels Hump, in the lower portion of the watershed north of Bethlehem. Ideal readings between 100 and 200 mg/L are found at sites underlain by limestone bedrock in the lower two-thirds of the watershed. High values identified by abrupt changes may be the result of concrete production within the watershed. Low values, such as those found in the northern part of the watershed, are typical for streams not underlain by carbonate geology. However, these sites have heightened susceptibility to acid contamination. There does not appear to be any major problems with excessively high or low alkalinity.

7.10.6. Nitrate

Within the Monocacy Creek, nitrate levels were far beyond the target level of 1 mg/L associated with unpolluted water. Most readings also exceeded the safe drinking water quality standard. The lowest levels existed in the northern half of the watershed with averages ranging from approximately 10 to 13 mg/L. Levels below the entrance of the springs at Camel's Hump jumped tremendously to averages ranging from approximately 12 to 18 mg/L. A sudden spike in nitrate where the springs begin to enter the stream suggests that the water was polluted upstream and entered the groundwater supply before having a chance to enter the stream at the pollution source. These levels may be high enough to be hazardous to human health and they should continue to be monitored on a regular basis. Maintaining acceptable levels of nitrate is a key to managing a healthy watershed.

7.10.7. Ortho-phosphate

Records from the summer of 1997 show that the entire length of the Monocacy is at risk of accelerated eutrophication due to high levels of ortho-phosphates. The most endangered portions of the creek are at the headwaters of the East Branch and from the confluence of the East and Main branch continuing upstream for about half the distance to Bath Borough. Readings from these sections ranged from approximately 0.3 to greater than 0.7 mg/L. Values at the remaining sites are still cause for concern as the averages ranged from approximately 0.1 mg/L to 0.3 mg/L. These problems are likely due to fertilizer runoff and other sources of organic waste.

7.10.8. Hardness

Except for the headwaters of the Each Branch, which are underlain by non-carbonate geology, the Monocacy Creek tested as either hard (121-180 mg/L) or very hard water (>180). Extremely high readings corresponded to the area where springs are entering the stream from carbonate aquifers, which indicates that these readings are the norm for the Monocacy Creek. Abrupt changes in data points may indicate possible abnormalities in East Allen and Upper Nazareth Townships. These deviations from the norm are unlikely to be due to changes of underlying bedrock.

7.10.9. Chloride

The average chloride values for the Monocacy Creek were relatively constant. The majority of the sites averaged between 15 and 25 mg/L, which is far below the water quality standard. The only major spike in chloride to be concerned about is on the East Branch near its confluence with the Main Branch. This could be explained by a natural deposit being leached in the vicinity. The average level of chloride at this site from the summer of 1997 was approximately 48 mg/l.

7.10.10. Sulfate

Average values for sulfate from the sample locations on the Main Branch centered around 40 mg/L, which is significantly lower than the maximum water quality standard. The middle section of the watershed seemed to produce higher values relative to the southern and northernmost portions of the watershed. However, the East Branch of the creek produced the highest values averaging around 120 mg/L. This level is still not significant enough to constitute a threat to the watershed.

7.10.11. Summary

Overall the Monocacy Creek exemplifies outstanding water quality that should be protected for future use. Some areas of concern that our studies and observations have identified include alarmingly high nutrient levels, the threat of stream warming, and excessive sedimentation of the stream bottom. These findings are generally in accordance with and support the findings of the previous studies discussed above. Recommendations to lessen the impact of water quality threats identified by the study are contained under the "Management Options" section of this report.

7.11. Water Quality/Land Use Analysis

Due to the connection between land use and water quality, the LVPC conducted a study in order to understand this relationship more thoroughly for both land use planning and water protection purposes. LVPC performed correlation analysis based on water quality data collected by Wildlands Conservancy and land use data contained in GIS format. The purpose of the analysis was to determine if there is any clear relationship between the monitored data and land use patterns within the watershed. The study produced the following results:

- Significant trends, both increases and decreases, were identified for 9 of the 14 water quality parameters analyzed including: specific conductance, total dissolved solids, ortho-phosphate, total hardness, calcium and magnesium hardness, alkalinity, sulfate, and chloride.
- Six of nine land use types appear to have significant trends for certain water quality parameters. These land uses include: institutional, industrial, residential, agricultural, open space, and woodlands.
- Trends are only preliminary as insufficient data is available to support any rigorous correlation.

Recommendations for use of this report include:

- Preliminary trends should be substantiated by additional water quality sampling over prolonged time periods and/or different analytical means used to draw conclusions.
- Future efforts to correlate land use and water quality should focus on expected increased residential and industrial development as indicated by zoning districts.
- Preliminary trends should only be viewed as potential correlations as many factors that influence water quality were not taken into account. Distinct changes in

geology within the Monocacy watershed may have stronger impacts on water quality and the results of this report than did land use.

- Measures to mitigate potential adverse impacts of land use activities on water quality should focus on preliminary trends identified and specific impacts of future residential and industrial development.

LVPC and Wildlands Conservancy both have a complete copy of this report entitled "Monocacy Creek Watershed Land Use/Water Quality Assessment" for your review.

7.12. Water Usage

Excluding individual domestic supply wells there are 15 public and private well supplies within the Monocacy Creek watershed. Data analyzed from 1993 shows average use of water from each well in gallons/day (GPD) and the safe yields for each of them. Results of the analysis show that use from one well supply within the watershed more than doubled the safe yield determined for that well. This is the well that supplies water to the Crossroads Mobile Home Park. Whereas the safe yield for this well was determined to be 1200 GPD, the average use of the well was actually 3,000 GPD. Circumstances like this, where overdrawing occurs, could lead to a lowering of the water table and a possibility of drawing the well completely dry. If a well goes dry, a new well will need to be drilled either in a different aquifer or deeper into the same aquifer. Since locating and drilling wells is a costly process, water withdrawal rates should be closely monitored to prevent depleting the aquifer. A listing of well ownership along with average 1993 water usage and safe yield are contained in Table 12.

Table 12. Well ownership and average 1993 water usage and safe yields, excluding individual domestic supply wells, for Monocacy Creek watershed.

Map Number	Water Supplier	Number of Wells	1993 Average Use GPD	Safe Yield GPD
1	Crossroads MHP	1	3,000	1,200
2	Clearview Farms	4	13,000	114,000
3	Hickory Hills MHP	3	66,000	87,000
4	Royal Oaks MHP	2	4,000	46,000
5	Evanwood	1	9,000	50,000
6	Herd Manufactured Homes	3	10,000	Not Available
7	Christian Springs	2	18,000	65,000
8	Bath Borough Authority	1	See No. 11	See No. 11
9	Valley View Manor	1	2,000	86,000
10	Millers Edgewood MHP	1	5,000	36,000
11	Bath Borough Authority	3	160,000	680,000
12	Greenbriar Village	3	38,000	318,000
13	Kellows MHP	1	2,000	31,000
14	West Gate	4	183,000	Not Available
15	Bethlehem City Authority	4	(Not in Use)	

Data Source: LVPC, 1998.

7.13. Activities Affecting Stream

There are many nonpoint sources of pollution in Monocacy Creek created by human activities. Stream chemistry is effected in several ways by agricultural production. Quite often crops are grown too close to the stream, which allows runoff to enter the stream more rapidly and without being filtered by streamside vegetation. One such instance is shown in Figure 28. Improper farming techniques including misapplication of fertilizers, herbicides, and pesticides contribute to chemical and nutrient loading of the stream. Sediment loads are also increased as a result of excess erosion from improper techniques. Since the American lawn is the largest crop grown in the United States, it is understandable that lawn care is also a major source of stream pollution. Fertilizers added to lawns are diluted when it rains and excess nutrients may be carried to the stream. Animal husbandry also affects stream health when the animals are permitted to freely enter and cross the stream. Animals trample the streambank, stir up the substrate, and defecate in the stream, which is unhealthy for both the aquatic organisms and the animals themselves.

Figure 28. Crops being grown too close to Monocacy Creek without protection from a riparian buffer.

Construction is another way that people alter stream habitat. Without proper protection of bare surfaces, erosion rates are accelerated thus contributing excessively high sediment loads to the stream.

As a result of regional development, impervious surface areas increase while surface areas permitting recharge decrease. Consequently, groundwater levels are frequently lowered by extraction rates in excess of recharge rates. In addition, impervious surfaces, such as asphalt, heat rain water as it runs overland toward the streams, thus contributing to problems of thermal pollution. Water flowing over such surfaces also picks up oils, grease, gas, hydrocarbons, salt, and other pollutants and introduces them to the stream.

Recreational activities also impair stream health. Fishing is just one example of how recreational activities may be detrimental to a stream. Streambanks are often trampled and torn apart as society pursues their outdoor recreational past times, resulting in higher stream sediment loads and the destruction of streambank vegetation.

Resource extraction, including mining and logging, makes the land surface more susceptible to erosion. This in turn causes accelerated sedimentation of the stream channel. Water extractions from both surface flows and underground aquifers may have severe effects on the stream and its ecosystem. Water extractions may lower the level of the stream or even cause it to run dry. Stream chemistry may be altered by the lowering of water levels. Lower water levels may increase concentrations of chemical parameters, imposing stress or initiating the death of aquatic life and vegetation.

Poor stream management is perhaps the most critical activity the Monocacy Creek faces. Proper stream management, such as not mowing to the edge of the streambank and allowing natural vegetation to form a buffer, would decrease the effects of the above activities as well as prevent the degradation of the stream corridor. Lack of education for streamside businesses and property owners contributes significantly to the problem of poor stream management. An example of poor streamside management along the Monocacy Creek is shown in Figure 29. Numerous potential nonpoint sources of pollution, including some of those mentioned above are shown on Figure 30.

Figure 29. Monocacy Creek is improperly managed through this rural section of the watershed.

Permitted discharges for such things as industrial and sewage waste also influence water quality. However, since the Clean Water Act (CWA) has implemented the National Pollutant Discharge Elimination System (NPDES), point source discharges are no longer a serious threat. This system sets limits on the amount of each specific pollutant being discharged, and a monitoring report is used to enforce these permit limits. Permit limits are set according

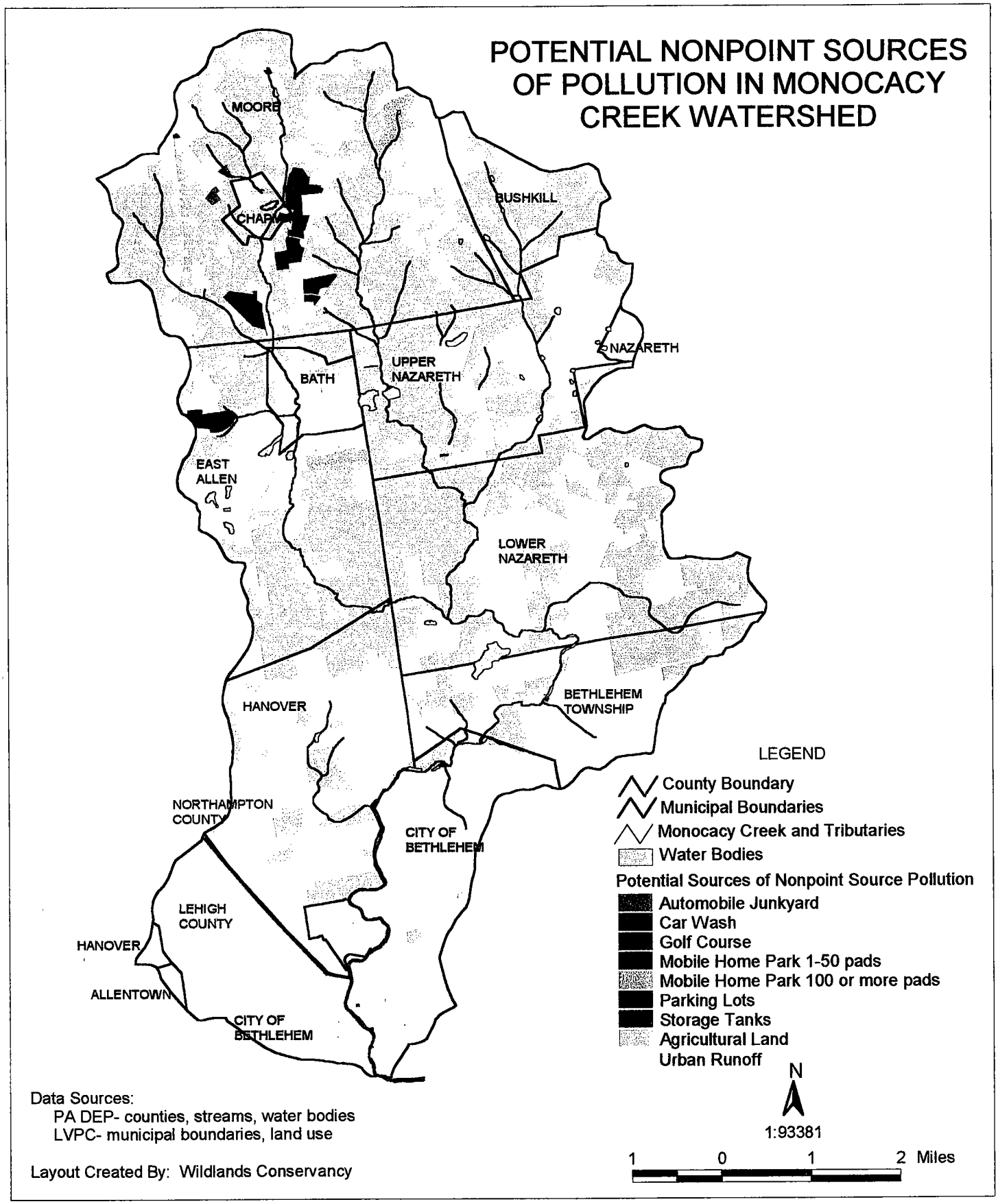


Figure 30. Potential nonpoint sources of pollution within the Monocacy Creek watershed.

to how much of a pollutant the water system can assimilate and how many other discharges enter that system. There are six permits issued for discharges directly to the Monocacy Creek. Two additional permits have been issued for discharges to Monocacy Creek tributaries. These discharges can be seen on Figure 31. Non-permitted discharges and permitted discharges that exceed limitations may endanger the stream habitat and wildlife communities, as well as threaten groundwater supplies.

8.0. MUNICIPALITY ISSUES

8.1. Vision and Future Management

Most municipalities had a desire to protect the stream from current threats and to preserve the natural resources of the stream so long as it proves economically feasible. Several municipalities were also interested in managing the Monocacy corridor to maximize recreational benefits. None of the municipalities predicted or desired any major land use changes within the stream corridor. Most municipalities in the northern half of the watershed were also dedicated to maintaining the rural character of the region. Land preservation and careful land use planning are key issues for the future of these municipalities. The City of Bethlehem recognized the importance of working together on a watershed-wide approach to improve Monocacy Creek, as many of the problems within the city originate upstream in the watershed.

8.2. Common Concerns

One issue raised by all municipalities is the seemingly ever-increasing frequency and severity of flooding. This is the problem most municipalities felt was a top priority, requiring the most immediate attention. Resolving the issue centers on revising stormwater management practices so that emphasis is placed on minimizing impervious surfaces and maximizing infiltration of precipitation to groundwater. Specific recommendations are provided in "Management Options" section of this plan.

Other common concerns shared by many municipalities include protection of the creek from development projects, excessive sedimentation of the stream bottom, and the lack of recreational trails within the watershed. Implementing best management practices (BMPs) and practicing stream stewardship could resolve many of these concerns. Just one well-organized project with a clear objective to protect or preserve stream corridor resources has the potential to remedy several concerns at once. Some recommendations to resolve these issues are detailed in following sections.

8.3. Development within Monocacy Watershed

Areas with pending and ongoing development are mapped on Figure 32, with information provided by LVPC. The following are descriptions of various proposed construction activities within the watershed.

Upper Nazareth Township has approved the planning of a housing development that will be located due west of Gracedale. This development will most likely consist of 100 homes, which has been reduced from the original plans of greater than 200. The municipality is interested in protecting the wetlands at this site by building around them or incorporating them in the plan for scenic or recreational value.

Moore and Bushkill Townships are both seeking to improve local roadways. Moore Township is interested in widening Penn Dixie Road, which runs adjacent to Monocacy Creek. Bushkill Township would like to resurface Knauss Road, including the removal of rock outcrops that present safety hazards on the narrow road.

Bath Borough is currently preparing a Comprehensive Plan for a community rehabilitation project, in which protecting the Monocacy plays a major role. Proposals in the plan will include historic property designation, traffic re-routing including bridge replacement, and acquisition of property for greenway expansion. The borough is seeking to acquire and demolish five properties adjacent to the stream for the development of a greenway and passive park improvements.

8.4. Municipal Ordinances and Zoning

The Monocacy Creek Watershed, Act 167 Storm Water Management Plan was prepared by the Lehigh Valley Planning Commission. All municipalities within the watershed were required to adopt the Act 167 Storm Water Management Ordinance contained in the plan. The ordinance sets forth guidelines and practices for mitigating the effect of land development on storm water runoff and flooding. Otherwise municipalities must devise their own ordinance containing provisions at least as stringent as those contained in the plan. Municipalities that are not entirely within the watershed are required to implement the ordinance for only that area which lies within the watershed boundary. One important note concerning current storm water management practices, is that they are focused predominantly on quantity of runoff, rather than both quantity and quality. Controlling the quality of storm water runoff is as equally important to protecting Monocacy Creek as controlling volumes of runoff.

In addition to providing the Act 167 Plan, Lehigh Valley Planning Commission has prepared a Wellhead Protection Model Ordinance for consideration by municipalities in the Lehigh Valley. As of the time this report was written, none of the municipalities within the Monocacy watershed had adopted the ordinance. Initiating wellhead protection programs could play a major role in ensuring safe, clean sources of water for future generations.

Zoning is the primary means by which natural resources are usually protected. Current zoning within the watershed only protects two percent of the land area as open space. This means that more measures will be necessary to preserve the watershed's current 14 percent of land dedicated to open space. In addition, 40 percent of land area is zoned for residential use. This points to a vast opportunity for expansion in this area as only 25 percent of land

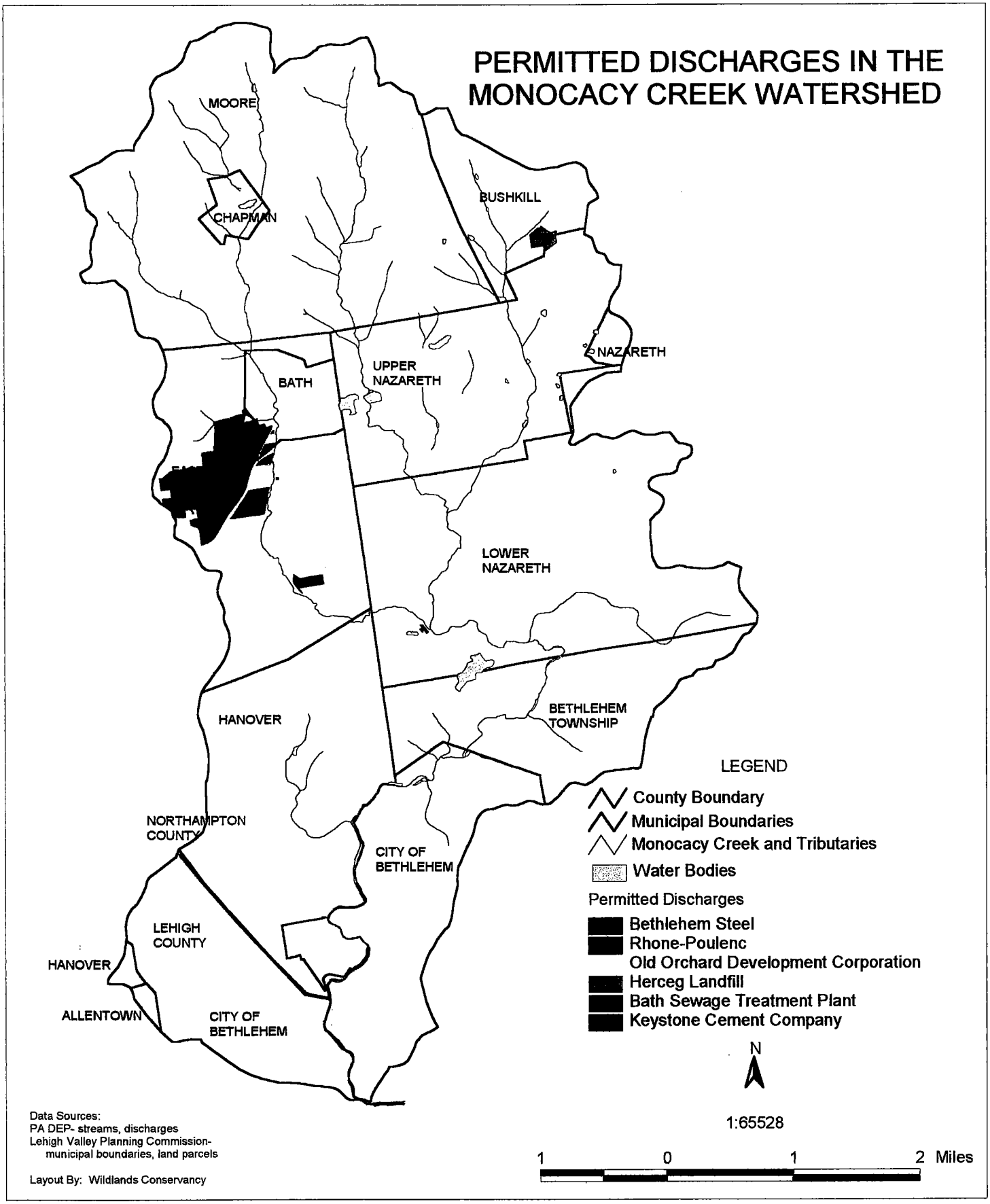


Figure 31. NPDES permitted discharges within the Monocacy Creek watershed.

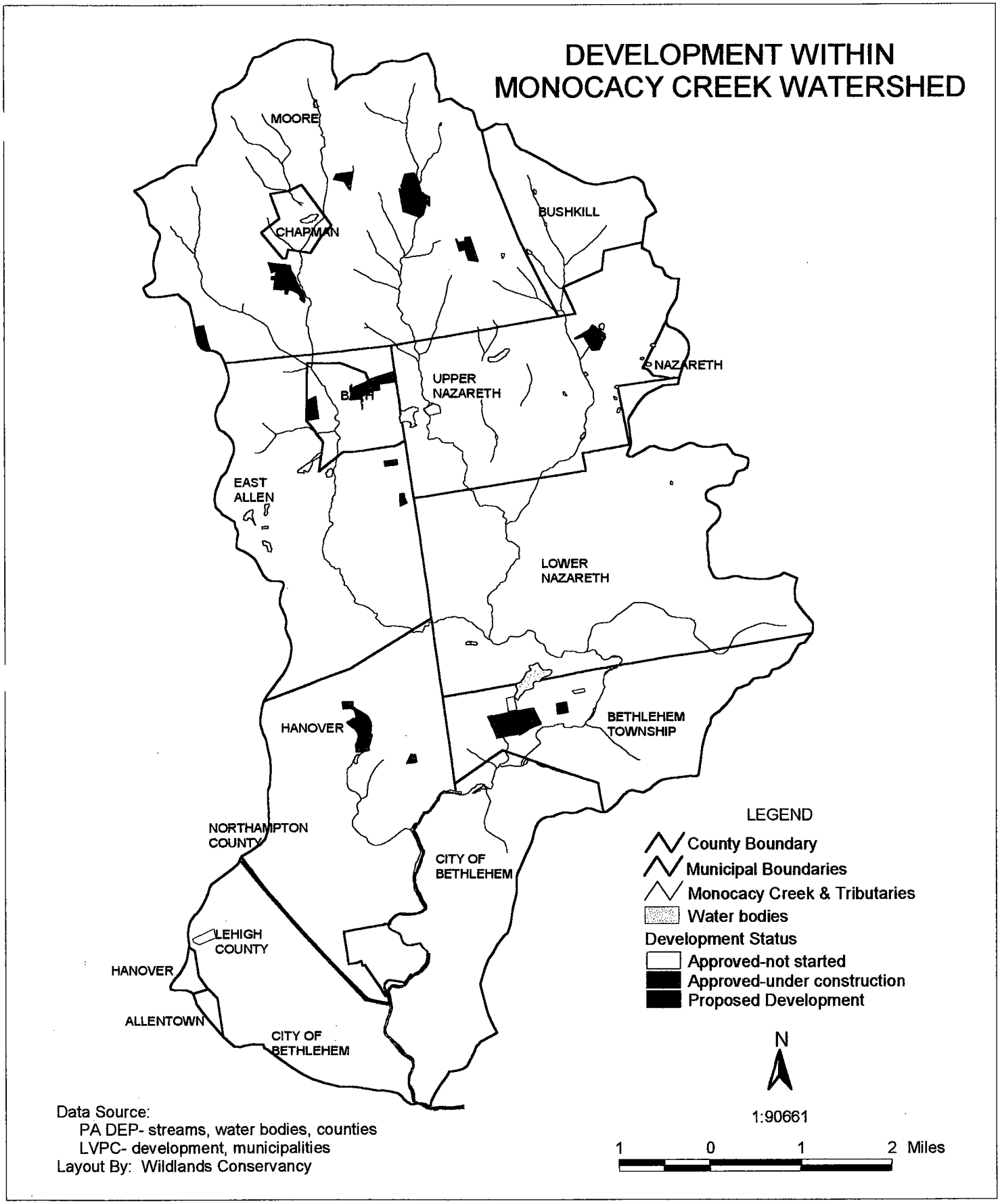


Figure 32. Proposed and approved development within Monocacy Creek watershed.

area is presently dedicated to this use. There is also room for expansion of industrial or wharehousing use. The expansion of these uses may infringe upon current open space areas.

Furthermore, only four out of the ten municipalities within the watershed include conservation areas in their zoning ordinances. However, these provide only limited conservation, as their goals are often aimed jointly at both natural resource and recreational resource protection. These are objectives for which management practices are not always compatible. Zoning regulations for recreational resources usually do not provide adequate protection of stream corridors. Altering current zoning districts to designate areas along the creek in a riparian buffer zone would significantly improve protection for the creek. Current zoning delineations are shown on Figure 33.

Likewise floodplain protection ordinances are commonly insufficient to protect these vital lands adjoining the creek. Most floodplain provisions merely limit activities within delineated floodplains. For floodplains and the functions they provide to truly be protected and preserved, a restriction of development of any kind within the delineated floodplain is really necessary. Contributing to the inadequacy of floodplain protection efforts is the unrealistic delineations of floodplain boundaries. Most floodplains have been seriously altered by urban development since delineations were performed. The resulting increase in flooding from stormwater runoff necessitates wider delineations of the floodplain. Floodplains could also be protected by incorporating them into the suggested riparian buffer zoning district.

9.0. MANAGEMENT OPTIONS REPORT

The recommendations contained below have been based upon the preliminary findings from literature reviews, field and laboratory studies, and suggestions and concerns broached by municipal leaders, conservation groups, and other interested organizations and individuals.

These recommendations were also developed in accordance with the primary goals of the Monocacy project. Those goals were to restore physical and biological health of the stream; establish management practices to prevent additional degradation of the stream; to preserve critical cultural and natural resource areas within the watershed; and to have the Monocacy Creek listed on the PA Rivers Conservation Registry.

Due to the wide variety, broad scope, and large scale of several potential projects and suggested recommendations, it should be recognized that this is a long-term plan for remediation and on-going management of the watershed. In order to facilitate implementation, an action plan containing a list of projects selected from the following recommendations should be devised for each implementation year. A proposed project schedule for 1999 and 2000 is included in the appendix.

The management options that follow have been divided into goals, objectives, and tasks or specific actions. All recommendations have been listed under one of six major goals. The

goals represent what Wildlands Conservancy aspires to achieve ensuing completion of the Management Plan. They are as follows:

1. Preservation of significant features and valuable resources,
2. Documentation of water quality and biological characteristics,
3. Preservation and enhancement of water quality and corridor habitat,
4. Increase environmental awareness to demonstrate the need for and to encourage stewardship by all members of the Monocacy Community,
5. Improve quality of life and property value, and
6. Reduce non-point source pollution.

The objectives listed under each goal are the projects or ideas that should be implemented or completed in order to attain that goal. The symbol "♦" denotes specific tasks or actions that are a possible means of accomplishing the objective. Examples of these tasks or supporting arguments/details for implementing the tasks are bulleted with the symbol "•".

GOAL 1. PRESERVATION OF SIGNIFICANT FEATURES AND VALUABLE RESOURCES

Objective 1. Historic Preservation: The historic resources of the Monocacy watershed are unique and valuable, and since the Lehigh Valley is a historically significant region of Pennsylvania, the following actions are recommended:

- ♦ Restore the raceway, springhouse, and stone water wall in the Bethlehem Historic District.

- ♦ Continue restoration and preservation of other known historic sites such as Illick's Mill and Burnside Plantation.

- ♦ Preserve abandoned railways by converting them to trails and possibly using them to establish a corridor for public education of environmental stewardship.

- ♦ Conduct a systematic survey of the watershed to identify and list potential national registry sites and structures, which should include but not be limited to the following:
  - Chapman Furnace Chimney
  - Chapman Quarries School
  - George Wolf Academy (East Allen Township)
  - Santee Grist Mill (Bethlehem)
  - Stone Arch Bridge (Bethlehem)
  - Illick's Mill (Bethlehem)
  - Octagonal School House (Upper Nazareth Township)
  - Gnadenthal (Upper Nazareth Township)
  - Christian's Spring (Upper Nazareth Township)
  - Paint Mill (Bethlehem)
  - White House at St. Francis Retreat (Bethlehem)
  - Ice House (Bethlehem)

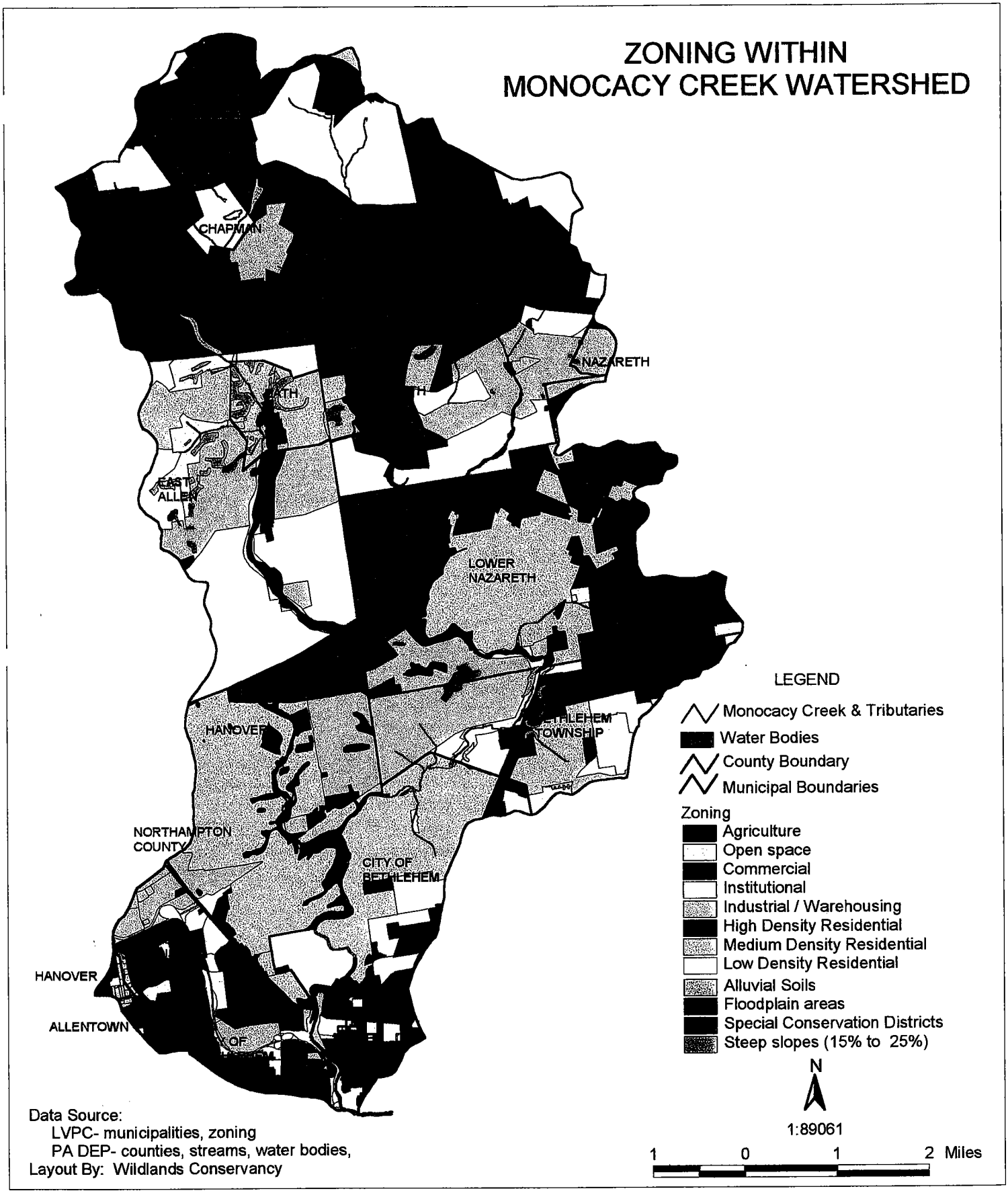


Figure 33. Zoning districts within Monocacy Creek watershed.

- Lehigh Canal (Bethlehem)

The criteria used to evaluate a site/structure for inclusion in the National Register of Historic places state that a site/structure must have:

- an association with events that have shaped history;
- an association with a significant person;
- possession of "distinctive characteristics" from a certain type of construction or time period, the work of a master, or high artistic value; or
- yielding or potential yielding of information.

These actions could be carried out by organizations with a special interest in a site such as Historic Bethlehem Inc. and Burnside Plantation Inc. The restoration of specific buildings throughout the watershed could fall in the hands of the related municipality or Northampton County Historical and Genealogical Society.

Objective 2. Farmland and Open Space Preservation: The Monocacy watershed is home both to some of the most fertile farmland of the Lehigh Valley as well as to critical open space areas. Preserving these valuable resources should be a top priority. Many state and federal programs exist to provide assistance for preservation activities.

- In order to benefit from financial assistance programs for farmland and open space preservation, it is critical to improve communication between the agricultural and land owning community with the appropriate agencies to find the sources of funding for acquisition and preservation of these valuable resources.

- Some programs that could be utilized by landowners to preserve sensitive areas include: Environmental Quality Incentives Program (Farm Service Agency, U.S. Dept. of Agriculture), Conservation Reserve Program (Farm Service Agency, U.S. Dept. of Agriculture), Drinking Water State Revolving Fund (DWSRF), and Conservation Buffer Initiative (Natural Resources Conservation Service, U.S. Department of Agriculture). For more information on these and other programs contact Wildlands Conservancy or your local conservation district.

Objective 3. Wetland Preservation: Wetlands are a very sensitive part of the ecosystem and perform many functions to benefit the Monocacy corridor. Most of the wetlands within the Monocacy watershed are small in size and are therefore often overlooked during development planning. In the past, wetlands were repeatedly filled in for development or agricultural purposes as they portrayed no real value to society. Studies in recent years have found that wetlands are a critical part of the ecosystem that, if managed properly, can provide many benefits for the community. Some functions of wetlands include:

- Water storage: During precipitation events, water collects in wetland areas and is released to streams at a slow rate, thus preventing or limiting flooding of the local area. These hydrologic properties of wetlands are also beneficial during dry spells when they may help sustain stream flow by the gradual release of stored water.
- Wetlands serve as a link between aquatic and terrestrial ecosystems, making them a valuable habitat to many wildlife species, especially waterfowl.

- Wetlands also help clean water by filtering out sediment and nutrients that would otherwise have entered and polluted the stream.
- Wetlands also have the capacity to transform harmful chemicals to less hazardous forms, thus somewhat purifying water as it passes through the wetland.

♦ Better compliance with wetland regulations is needed to protect these highly sensitive areas. Regulations currently exist to protect wetlands from construction and development. However, due to the small size of many remaining wetlands, they are often deemed insignificant and are consequently filled in, regardless of the value they still provide. Once a wetland is lost or destroyed, it is gone forever. "No net loss" practices, which require the construction of new wetlands to replace those that have been destroyed, are not sufficient to preserve the benefits that were originally provided. Often times artificial wetlands do not have the same hydrologic properties and vegetative species as the destroyed wetland, thus limiting the functions of the new wetland and not achieving the objectives of the "no net loss" philosophy.
  - Engaging in public education efforts is one means by which enforcement can be improved. When citizens and municipal leaders are informed of the functions and values provided by wetlands, they become a strong force to oppose destruction of wetlands. They can also assist by notifying Army Corps of Engineers of any potential violations of wetlands regulations.

♦ Efforts should focus on protecting existing wetlands from the planned development of Creek Side Meadows in Upper Nazareth Township. Support could be gained to save these wetlands and others in similar situations by educating the community on the benefits of wetlands. It is much more costly and less beneficial to create a new wetland to fulfill "no net loss" requirements than it is to preserve the existing natural wetlands. If special care is devoted to ensure that the natural functions of the wetland are not disturbed, the wetlands could be incorporated into the development plans as scenic or passive recreational space.

♦ Federal and state programs also exist to provide incentives for farmers and other landowners to preserve wetlands. Some of these programs include: Wetlands Reserve Program (Farm Service Agency, U.S. Department of Agriculture), Partners for Wildlife (Fish & Wildlife Service, U.S. Dept. of the Interior), Wetland Restoration/Creation Site Registry (Department of Environmental Protection). For more information on these and other programs contact Wildlands Conservancy.

Objective 4. Ordinance Revisions: The creation or adoption of ordinances structured to encourage stewardship of creek resources, protect wellhead areas, and limit land uses and activities within stream corridors and floodplains, would make great strides toward achieving the goal of preserving valuable stream resources. These ordinances would serve to preserve such resources as water supplies, wooded regions, wildlife, and aquatic habitats.

♦ Adopting an ordinance similar to the "Riparian Corridor Conservation District, 1995"

prepared by the Montgomery County Planning Commission, should be a top priority among municipalities. A copy of this ordinance is contained in Appendix 1.

- This riparian ordinance is preferred and recommended over revisions of current floodplain provisions as it provides better protection for the narrow floodplains of the Monocacy that are already overdeveloped. This ordinance would apply regulations to enhance and preserve vegetative buffers along the creek. The ordinance achieves this objective by creating a zoning overlay district based on Forest Service calculations.

- Other types of buffer ordinances to consider include fixed widths and separate zoning districts. The Forest Service standard for buffer zones is presently set at 75 feet.

- Adopting an ordinance to protect groundwater supplies, such as the "Wellhead Protection Model Ordinance" prepared by LVPC, is strongly advised. This ordinance is contained in Appendix 2, which is available from Wildlands Conservancy. A wellhead protection ordinance is highly recommended for the purpose of protecting groundwater supplies for today and future generations. Locating sufficient public water supplies is becoming increasingly difficult as more aquifers are being contaminated as a result of population growth and development. Wells in limestone formations are particularly vulnerable due to solution cavities allowing quick, preferential flow of fluids. The potential for well contamination and possible loss of an aquifer would be greatly reduced by the adoption of provisions similar to those contained in the "Wellhead Protection Model Ordinance."

- A cooperative effort among municipalities is encouraged to devise a common ordinance(s) such as those listed above to preserve watershed resources. Such an effort would be more beneficial and efficient than each municipality working individually. Each municipality could select one official to participate in a watershed committee to work on this issue. Common ordinances would be easier to implement and enforce than several different ones throughout the watershed.

- Other ordinances could be designed or updated for protection of the Monocacy Creek from erosion and sedimentation; loss of open space, wetlands, woodlands, and floodplains; and poor quality of storm water runoff.

GOAL 2. DOCUMENTATION OF WATER QUALITY AND BIOLOGICAL CHARACTERISTICS

Objective 1. Water Quality Monitoring: Results from Wildlands Conservancy's monitoring demonstrate a need for ongoing studies of water quality. Water quality data has shown that the Monocacy Creek is being increasingly stressed by development and other demands upon the land. Classified as a HQ-CWF, Monocacy Creek is very sensitive to changes in temperature and chemical composition. Without preventive measures, this classification may be threatened by nutrient loading and thermal pollution, two conditions that demand careful observation.

- Wildlands Conservancy, volunteer organizations, educational institutions, and other watershed interest groups or individuals should combine efforts to continue water sampling and analysis of the Monocacy Creek on a regular basis to:
    - Identify problem areas on which to focus remediation,
    - Monitor and document changes in overall health of the ecosystem for providing background information for future studies and projects, and
    - To note adjustments that should be made in management practices.

- Stream walks should also be performed annually through a cooperative effort as mentioned above in order to monitor physical changes within the watershed such as sedimentation, undercut banks and streambank stabilization, and vegetative cover and shading.

- Industries within the watershed that use the Monocacy for disposing waste or coolant water could contribute to water sampling by funding or providing technical assistance for analyzation of pesticides, herbicides, fertilizers, or metals for which the stream may not yet have been thoroughly screened. Such sampling could lead to a need for studies to determine the proper application rate of fertilizers, pesticides, and other chemical treatments for lawns and agricultural fields.

Objective 2. Biological Monitoring: Maintaining records of the condition of the stream corridor habitat and the vegetative, aquatic, and wildlife species present within the corridor, is essential to recognizing and assessing threats that may disrupt the balance of the ecosystem.

- Periodic inventories of vegetative communities are encouraged to:
    - Identify native and non-native plant species, and
    - Identify where invasive or exotic species are overtaking native vegetation within the watershed.

- Conducting periodic macroinvertebrate sampling is recommended to:
    - Provide additional support for water quality monitoring data, and
    - Assess the diversity and abundance of aquatic life serving as the base of the food chain.

- A cooperative effort should be developed to inventory the watershed to locate and identify the presence of any threatened or endangered species of flora and fauna. Although PNDI does not have a listing of any such species within the watershed, local residents have cited species of concern that should be reported to PNDI, Audubon Society, and other appropriate authorities and organizations for formal investigation and documentation.

Objective 3. Efficient Data Mangement and Distribution: A central clearinghouse for data acquired on the Monocacy Creek, through professional and volunteer monitoring and

inventory efforts, could greatly improve public awareness and communication between key conservation groups.

- With the formation of a central database, a concerned individual would know the appropriate contact for reporting or investigating important information. It would also be much easier to distribute information and make appropriate management decisions because information collected by various organizations would all be in one location. This location could also be used as a site for meetings concerning ventures that impact the creek.

- Developing a system for entering and displaying data on the internet would provide an excellent and efficient means of improving communication and providing easy access to data by almost any interested party. Websites are currently under construction for Wildlands Conservancy, Lehigh University, and MCWA. Any of these institutions could be the source of a link to a Monocacy Creek site. Lehigh University is currently considering development and maintenance of a website to house such information on the entire Lehigh River watershed, which could be divided by sub-watersheds including Monocacy Creek.

GOAL 3. PRESERVATION AND ENHANCEMENT OF WATER QUALITY AND CORRIDOR HABITAT

Objective 1. Implementation of Stream Rehabilitation Projects: Without cooperative efforts throughout the watershed to repair or rehabilitate damaged portions of the stream, it will continue to deteriorate. Preventing any further collapse or extensive undercutting of streambanks is imperative to protecting the aquatic life of the Monocacy. Many organizations are already either actively restoring sections of the stream or they may provide guidance and technical assistance to those wishing to pursue rehabilitation projects. Some of these organizations include: scouting troops, Trout Unlimited, Soil Conservation Districts, PA Fish Commission, Monocacy Creek Watershed Association (MCWA), Monocacy Corridor Citizens' Action Committee (CAC), and Wildlands Conservancy.

- Remediation activities that individuals or organizations, such as those mentioned above, should consider include: stream clean-ups, natural re-vegetation of streambanks, planting of riparian buffers, reconstructing streambanks, erosion control and other streambank stabilization techniques, construction of cattle crossings, streambank fencing, and habitat improvements. For use in riparian planting projects, a list of species suitable for planting in the watershed is contained in Table 6. Invasive and exotic species to avoid when planting within the watershed are listed in Table 10.

- Specific restoration and conservation projects recommended for the Monocacy Nature Center (Sanctuary), as advised by the PA Fish Commission, include the following:

    - Relocation of the streamside trail, extending from Illick's Mill parking lot to the end of the sanctuary, is necessary to prevent serious erosion of the streambank by trail

users. Moving the trail farther inland would prevent much of the streambank walking that currently occurs, and it would also provide a safer pathway as the current trail tends to get very slippery. Some parts of the trail have already been relocated however, the old trail continues to be heavily travelled. When the new trail is completed the original trail should be blocked off to encourage use of the new one. Informative signs explaining the closure of the old path may also be needed and helpful in preventing continued use of the old trail.

- A mini-boardwalk may be needed for the relocation of the trail approximately 100 feet upstream from the tailings mound. This is the worst case of erosion within the sanctuary, as people are forced to walk on the streambanks because the path is intermittently flooded during the spring, rainy season. Moving the trail inland would locate it within a wetland, which is equally wet and undesirable for trail users. To remedy problems with wet conditions a boardwalk could be simply constructed of two plastic planks, which would be raised slightly and anchored to the ground. The plastic planks are environmentally safe material and have gripping surfaces to prevent slips and falls. Such boardwalks are used frequently for nature trail construction.

- Fallen log deflectors are natural in appearance, and when placed at an appropriate angle they will divert the main flow of water toward the center of the stream and away from the eroding streambank. These devices also cause a backwater eddy of low velocity where silt will settle out, thus reclaiming previously eroding streambank. These structures also serve to improve aquatic habitat. It was noted that backfill may be needed in conjunction with the deflectors to prevent undercutting and scouring during high flows.

- The entire length of the creek through the sanctuary, with the exception of current riffle areas, would benefit from the placement of random boulders. Boulders placed in the stream channel will provide turbulence, aeration, and resting water. These factors combined provide excellent habitat for fish and aquatic insects. The stream channel is also scoured around these boulders, making the stream deeper and thus colder, which is beneficial to the cold water fishery.

- Multi-log deflectors would also be beneficial throughout most of the sanctuary for habitat improvement.

- Slow moving stream segments would benefit from anchoring brush deflectors to the banks. The addition of a few bundles of conifer trees along the banks would help stabilize already-accumulating silt to reclaim the stream banks. The collection of Christmas trees for this work would make an excellent community service project.

- Many areas are suffering from point source erosion, such as at muskrat holes, fallen trees, or runoff channels. These areas can be easily stabilized by "rip-rap". Rip-rap is stones or boulders placed along a streambank for stabilization. The

Monocacy only requires medium sized rocks to fill in weak areas. However, due to the delicate nature of the sanctuary, these rocks should be placed by hand, which requires significant manpower.

- Streamside and hardwood plantings of native species are also advised in areas of sparse vegetation throughout the sanctuary. The roots from vegetation will help stabilize the streambank when used in conjunction with the other methods mentioned above. Extensive stretches of the streambank are vegetated solely with invasive species. Although this is not healthy for native wildlife, removing all of the invasive species at one time would result in extremely heavy erosion and sedimentation problems. Therefore, plantings should be coordinated with the removal of invasive and exotic species, which should be done gradually.

♦ Other specific remediation, preservation, or enhancement projects within the watershed:

- Plant vegetation in areas where there is an overabundance of geese in order to take away their preferred habitat, i.e. Rt. 512 bridge by Aspen Inn.

- Investigation of potential erosion control devices for addressing problems caused by railroad trestles crossing the creek by Jacksonville Road in East Allen Township.

- Plant riparian buffers on the banks by Keystone Park, Bath Borough, to prevent erosion of very steep, unvegetated banks. Consideration should also be given to installing a temporary fence along the top of the bank to prevent safety hazards until vegetation is established.

- Removal of diseased trees and replacement with native species around Keystone Park.

- Prevention of roadside streambank erosion in Moore Township by construction of stream deflectors or other erosion control devices.

- Work is desperately needed by the Rt. 512 bridge and the Aspen Inn in Hanover Township (Figure 34). When this bridge was constructed, the creek banks were not properly terraced. As a result the stream is too wide and sluggish. Severe flooding and sedimentation are problems in this area that could be alleviated by reterracing the banks to approximate their original condition. However, due to the extremely wide conditions at the site and the extensive work that would be needed to correct existing problems, reterracing the banks would most likely be considered a violation of Clean Water Act regulations. An alternative action to improve the site would be the installation of brush deflectors combined with occasional biologs. These devices would serve to trap sediment and slowly reclaim the destructed streambank. Also, another log deflector extending from the existing deflector, located downstream of the spring, to the Rt. 512 bridge abutment would redirect flow toward the center of the stream. A large willow tree located downstream of

the bridge is also threatening to fail. Stabilization work should be concentrated around the tree to prevent it from being completely uprooted and taking massive amounts of streambank soil with it.

Figure 34. Restoration work is needed at this site along Monocacy Creek by a bridge on Route 512.

- A combination of stabilization and re-vegetation techniques such as live stakes, live fascines, biologs, and log deflectors are possibilities to prevent further erosion of the unvegetated areas by St. Anne's Shrine, located off Rt. 191 in Bethlehem Township.

- St. Francis Retreat contains approximately 500 feet of streambank that are currently unbuffered and have historically been contributing large amounts of sediment to the stream. The recent installation of 300 feet of biologs at the site through a combined Eagle Scout, Trout Unlimited, and MCWA project has significantly reduced erosion and sedimentation problems. Previous efforts of planting a riparian buffer failed, as the site is heavily used by anglers and many of the unprotected seedlings were trampled. Establishment of a riparian buffer is still a priority for the site. Future efforts should incorporate fencing of individual seedlings to improve the likelihood of survival and growth of the buffer zone.

- The section of the stream extending from the Gertrude Fox Conservation Area to Monocacy Park in the City of Bethlehem should also be planted with native species to establish a riparian buffer. Gertrude Fox Conservation Area marks the beginning of the trophy trout area and should be protected by a buffer to preserve this precious habitat for future generations. Sections upstream from the Trophy Trout area should also be planted to prevent sediment from eroding upstream and depositing downstream in the Trophy Trout area.

- Future plantings in areas known to have high beaver or deer populations, such as the Burnside Plantation and St. Francis Retreat areas, should be protected with the appropriate material so that it is not destroyed by the animals before having a chance to establish itself. Populations of these animals should be monitored and controlled to prevent a disruption of the ecological balance of species within the watershed.

- A farm located adjacent to Georgetown Road Park in Lower Nazareth Township is in need of streambank fencing to prevent free-roaming animals from damaging the stream. A cattle crossing should be incorporated into the fencing project. Once fencing is established, riparian plantings would further protect the stream. Eventually habitat improvement structures may be desired and added to the site.

- A farm property near the intersection of Steuben and Township Line Road has been recently fenced with the inclusion of a cattle crossing. Continued work at this site should focus on riparian plantings and eventually adding habitat devices.

Objective 2. Dam Removal: The Monocacy Creek is a low-gradient stream, meaning that there is not much change in elevation and it therefore flows fairly slowly under normal conditions. Dams slow the flow of water even more, which causes suspended sediment to settle to the streambed and build up behind the dam. As previously mentioned, sedimentation is detrimental to aquatic life and water quality.

- It is therefore recommended that a feasibility study be conducted on the removal of dams within the watershed, especially the dams no longer being utilized that are located within the Archibald-Johnston Conservation Area and in the section of the stream flowing past the Sisters of St. Francis property. Removal of the dams would increase the gradient of the stream, thus increasing its velocity and removing sediment accumulation. The study would be needed to determine the extent of sediment removal and any unforeseen impacts on the stream corridor.

Objective 3. Improve Point Source Discharges: Point source discharges are no longer a major threat to Monocacy Creek, however anytime waste is disposed in the creek it is degrading the water quality to some extent. Several actions can be taken to ensure that environmental degradation by point sources is minimized.

- Voluntary utilization of best available technology in waste treatment processes would further improve discharges beyond NPDES permit requirements, thereby enhancing the water quality of Monocacy Creek.

- Poor aesthetic qualities such as foul odors are often associated with discharges from sewage treatment plants. Although primary and secondary treatment of sewage is required of treatment facilities and is sufficient to meet NPDES permit requirements, tertiary treatment would further improve discharges and is only conducted on a voluntary basis. Initiating tertiary treatment is encouraged both for improvement of water quality and for improving aesthetic values of the creek near these facilities. Initiating tertiary

treatment should eliminate any unpleasantness and provide improved water quality that may support more diversity and abundance of aquatic life.

- Stream corridor improvements, such as those listed under objective 1, could be implemented by point source dischargers to help offset any adverse impacts caused by waste water entering the creek.

Objective 4. Improve Compliance with Erosion and Sedimentation Regulations: Sedimentation is the most abundant and threatening pollutant in the Monocacy Creek. Currently, regulations to control erosion and sedimentation are enforced through County Conservation Districts. The manpower and other resources of Conservation Districts are often inadequate to oversee activities that contribute to sedimentation, provide proper guidance for minimizing sedimentation, and to force violators of such regulations to comply with the law.

- More funding should be provided for and directed to the Lehigh and Northampton County Conservation Districts in order to adequately enforce erosion and sedimentation regulations that protect Monocacy Creek from its number one pollutant.

- Volunteer watch groups, non-profit organizations, and other interest groups and individuals can assist the Conservation Districts in enforcing the law. By reporting to the Conservation Districts, any activities along the stream corridor that may result in sedimentation of the streambed, qualified personnel can be sent to determine if there has been any violations of erosion and sedimentation regulations and what action, if any, needs to be taken. The Northampton County office number is 610-746-1971 and the Lehigh County office number is 610-820-3398.

- Possible violations of erosion and sedimentation regulations may also be reported to the PA Fish and Boat Commission, who could send a Waterways Conservation Officer to investigate the situation. The southeastern regional office number for reporting incidences on the Monocacy Creek is 717-626-0228.

GOAL 4. INCREASE ENVIRONMENTAL AWARENESS TO DEMONSTRATE THE NEED FOR AND TO ENCOURAGE STEWARDSHIP BY ALL MEMBERS OF THE MONOCACY COMMUNITY

Objective 1. Increase Availability of Educational Opportunities: Educating the general public, local industries and businesses, and political leaders about how their everyday actions can effect the environment is a key component to managing a watershed. Understanding how activities that impact a stream, such as those previously discussed, ultimately effect the community, often encourages people to practice better stewardship. More educational programs and opportunities should be instituted to benefit from a more knowledgeable, motivated society.

- Learning experiences should range from environmental awareness for children, to planning techniques for municipal leaders, to agricultural techniques for farmers.

- Parks should be managed in a more natural way and be supported by signing or kiosks explaining the significance of such things as un-mown grass and tree plantings. These signs could highlight issues of nutrient loading and proper fertilization, riparian buffers, and erosion and sedimentation.

- Post signs such as "No Dumping" and "No Geese Feeding" in critical areas to boost public awareness of stream threats. In particular, people should be educated on the harmful effects that bread feeding has on geese and how it causes an overpopulation in a small area.

- Incorporate environmental programming with school curriculums because children are the future of the watershed, and as children learn they may take the information home and share it with their families, which will get them involved as well.

- Coordinate fun activities and programs, such as a short stream walk, into festivals such as Earth Day to grab the attention and engage the interest of the entire community.

- Develop an environmental demonstration and education area to promote stewardship based on findings of water quality, biological, and wildlife studies conducted throughout the watershed.

- Continue and expand cooperative efforts between MCWA, CAC, Trout Unlimited, Wildlands Conservancy, and other organizations.

- Focus educational efforts on familiarizing all members of Monocacy community with best management practices (BMPs) for general stream care and stormwater management. This could be accomplished by creating and distributing a "Management Guide for Streamside Property Owners" that is focused specifically on the Monocacy Creek.

Objective 2. Establishment of Oil-Recycling Facilities: Currently, there are limited opportunities for recycling oil. Despite recent proposals by Northampton County to improve facilities, centers are sparse and primitive, and use of facilities is not widespread due to a lack of education and literature regarding the oil-recycling practice.

- Establishment of free, easy-to-use oil-recycling facilities in every community is encouraged to prevent the devastating impacts runoff oil has on stream life.

- Brochures should be distributed describing the oil-recycling process and the benefits of participating in the practice in order to gain support for the facilities and spread awareness of environmental degradation through oil runoff.

GOAL 5. IMPROVE QUALITY OF LIFE AND PROPERTY VALUE

Objective 1. Improve and Expand Recreational Facilities: Parks, greenspace and open spaces, including recreation areas, and/or scenic easements, are equally as important as economic development. These ideas are not mutually exclusive. More facilities, equipment, and opportunities will be needed to keep pace with the needs of a growing society. Recreational outlets are an incentive to bring tourists to and keep residents in the area, thus making economic advancements worthwhile. Having a thriving economic engine where no one wants to live, or where everyone is daily exhausted by the intensity of economic activity, is not a bargain. The value of such recreational facilities can be seen in Figure 35, which shows a family relaxing along the creek in the Monocacy Nature Center. Recreational advancements need to keep pace with economic advancements in order for society to achieve the maximum benefits that the land and its resources can provide.

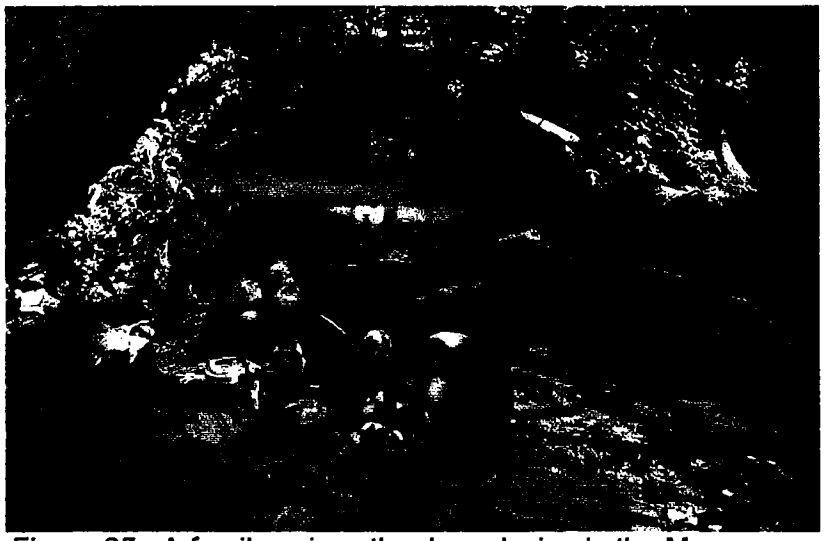


Figure 35. A family enjoys the day relaxing in the Monocacy Nature Center.

- Municipalities should actively seek acquisition of property, especially streamside plots, for the purpose of expanding recreational facilities. Lands acquired along the creek would best be used as special conservation districts or passive recreation areas, which allow the community to enjoy the land while simultaneously protecting creek resources.

- Development of a system for tracking streamside property sales would greatly benefit endeavors, particularly in the City of Bethlehem, to acquire streamside property for park use and preservation.

- Municipalities should focus their efforts on working to create a connective system of trails or conservation zones along the creek corridor. Such a system would improve quality of life by providing recreational opportunities for the growing society and enhancing the aesthetics and natural surroundings of watershed communities. It would also serve to help re-establish a riparian buffer zone along the creek that would provide many functions

to improve the water quality and habitat of the Monocacy corridor. This action is best approached by forming a committee with representatives from each municipality to discuss the interest, potential for implementation, and the desired level of involvement by each municipality.

- Dedication of open space on Sand Island is encouraged, especially on the two properties recently turned over to the City of Bethlehem. These properties should be torn down to develop the sites in accordance with their surroundings. The area is located on a floodplain and has already become a well-established recreational corridor. Although Bethlehem has plenty of park land, most lands on the north side of Bethlehem are used for golf courses. It is in the best interest of the municipality to preserve this area as open space for everyone's use, especially since it is currently successful as grounds for festivals and other events. If the land is dedicated to a special interest group, it will be lost to all other taxpayers. It would be tragic for the property to be altered for business, apartment, parking lot, visitors' center, or other high intensity uses. While the property is held by the City, it is owned by all the taxpayers who should have a strong voice in determining its usage.

- Investigate options for constructing a footbridge joining Old Forge Road to Volunteer Firefighters Park. More trees and an additional ballfield and playground equipment should also be planned and acquired for improving the park located in Bath Borough. In addition, installation of a walkway around the perimeter of the park would create a means of exercise for the community while promoting the protection and appreciation of the Monocacy Creek.

- Implement plans of Northampton County Parks and Recreation to extend the Nor-Bath Trail into Bath Borough and adjoin Keystone Park.

- The headwaters of Monocacy Creek in Moore Township should be protected by developing a conservation area through a zoning ordinance, acquisition of streamside property, or the purchase of easement rights for land adjacent to the stream.

- Incorporating the trophy trout area in a greenspace preservation program is advised. Such a program would prevent the streambanks from being heavily trodden, thus preventing vegetation destruction, erosion, and sedimentation.

- Existing pathways in Hanover Township should be connected by completing pathway sections that follow an unnamed tributary of Monocacy Creek that is lightly referred to as Hanover River.

- Monocacy Way path should be completed to connect Burnside Plantation, Johnson Park, and Sand Island. Currently the path traverses Johnson Park in the 18th century industrial area along the creek in Bethlehem.

- The possiblity for developing a creek access from Bella Vista Drive in the City of

Bethlehem should be investigated as several individuals are currently using this site to pursue recreational activities.

- Burnside Plantation facilities could be enhanced by creating a sensory trail with interpretive stations, possibly starting with a concentration on farmstead aspects.

- Physically challenged individuals would greatly benefit from the posting of signs at all recreational trails throughout the watershed that would describe accessibility conditions to be expected on the trails. The signs could contain such information as trail surface material, slope, unevenness, etc. With this information, each individual could make a sound decision as to whether or not the trail is suitable for their passage.

- Community wide support is encouraged for increasing awareness of trail users throughout the watershed to issues of safety and litter control. A coalition of partners could be assembled to discuss means of dealing with these issues.

Objective 2. Rail-to-Trail Conversions: Although the United States boasts one of the best national park systems in the world, most of these parks are located at great distances from population centers and they are limited in their ability to meet the growing recreation and conservation needs of society. Outdoor recreation is occurring more frequently in areas close to home or work places. This trend resulted in the recommendation in 1987 by the President's Commission on Americans Outdoors to establish a "network of greenways to provide people with access to open spaces close to where they live, and to link together the rural and urban space in the American landscape" (PKF Consulting, 1994).

Greenways can be defined as "corridors of protected open space managed for conservation and recreation purposes. They typically follow linear landscape features or they are created along canals, abandoned railroad lines, utility corridors, and other manmade features" (PKF Consulting, 1994).

Greenways along rail-trails provide benefits for wildlife and the environment. Wildlife often use greenways as a connector from one natural area to another. Biodiversity and wildlife areas are preserved through the protection of environmentally sensitive lands along rivers, streams, and wetlands. Greenways also protect water quality by buffering waterways from non-point source pollution. Finally, greenways may also serve as natural classrooms for teaching environmental issues.

- It is recommended that a feasibility study be conducted to assess the extent of abandoned rail lines, the possibilities of linking the lines, and the costs associated with acquiring the necessary lands or easements and converting and maintaining them as usable trails.

- Converting abandoned rail lines within the watershed to trails and greenways would

be an excellent means of stimulating local economy and providing the community with diverse opportunities for exercise and recreation. Economic benefits for communities include:

- the possibility of increased local tax revenues due to increased property values,
- stronger support of recreation-oriented businesses due to spending by trail users on related activities,
- new opportunities for businesses and commercial activities such as restaurants and bike and ski rental shops, and
- greenways along trails that can reduce public expenditures by lowering flood and other natural hazard costs.

♦ Rails-To-Trails Conservancy (RTC) is just one of several organizations dedicated to enriching communities and countrysides by creating a nationwide network of public trails from former rail lines and connecting corridors. RTC is a non-profit organization founded ten years ago for this purpose. Monocacy Creek communities should contact this and similar organizations to inquire about funding and implementation of rail-trail conversion projects along several stretches of abandoned railways in the watershed. Some unused railways within the watershed that have been noted to have potential to be converted to trail and greenway use are mentioned below. Such conversions are highly recommended to provide the numerous benefits discussed above.

- Cooperation with owner of unused railroad bed extending from Creek Road to Slate Post Road in Bath Borough, should be sought to convert the railway to a nature trail. This path would provide an excellent connection between the downtown urban region of Bath to a natural streamside setting that has been unavailable to date.

- Consideration should be given to converting the abandoned railway in the southern part of East Allen Township to a recreational trail.

- Investigate possibility of converting old railways near the headwaters of the Main Branch in Chapman Borough to recreational trails and greenspace.

- A consultant should be hired to examine the possibility of constructing multipurpose trails along the old railways by the headwaters in Moore Township. Some uses of such a trail include walking, running, hiking, bicycling, roller-blading, cross-country skiing, and horseback riding. The township is especially interested in developing horseback riding trails as many previously used dirt roads are being paved and are no longer suitable for riding. Abandoned railways provide an ideal corridor for such a use.

Objective 3. Roadway Cleanup: While industrial parks are remarkably free of litter, the roads leading to and from them are not. Although there is a desperate need in some areas, "adopt-a-highway" sections seem to be vanishing. Litter- free roadways improve the overall

appearance of the watershed and thus improve the quality of life for those residing within the watershed.

- Businesses and their leaders within the watershed are encouraged to exercise their civic responsibilities by organizing roadside cleanup efforts. Joining an endeavor such as "Adopt-a-Highway" would be a simple way to organize and implement cleanups.

Objective 4. Restrict Herbicide Spraying: Herbicide spraying along roadways destroys habitat; causes dust, dirt, and erosion; destroys litter-hiding capabilities of roadside vegetation; and promotes the growth of pure stands of poison ivy, which is apparently the only survivor of the sprays. While spraying may appear to be the most cost-effective means of dealing with traffic safety issues linked to roadside vegetation, it incurs a much greater environmental cost.

- Municipalities are strongly urged to consider reverting to roadside mowing to assure traffic safety rather than applying broad-spectrum herbicides that kill nearly all vegetation and eventually find their way into the nearest stream. Mowing roadsides would increase property values due to the protection of water quality and habitats regularly destroyed by herbicides as well as the prevention of appalling views of barren roadsides left behind after spraying.

Objective 5. Initiate Municipal Management Projects: Reducing illegal trash and hazardous substance disposal activities would result in a healthier, cleaner, and more beautiful waterway that may boost property value and quality of life, especially for those who live, work, and pass recreational time along the stream.

- Preventing illegal activities that occur on a frequent or regular basis, such as waste dumping, is an issue that should be addressed by all municipalities.

- The City of Bethlehem in particular, would benefit from implementing projects directed toward individual, site-specific problems, such as preventing illegal dumpings in the Biery's Bridge storm culvert.

GOAL 6. REDUCE NON-POINT SOURCE POLLUTION

Objective 1. Reduce Pollution at the Source: Non-point source pollution is the major contributor to water pollution problems today, especially within the Monocacy watershed. The best and most effective means of curbing this pollution is to limit and properly manage those activities that produce waste and runoff.

- Herbicide spraying along railways should be restricted as it may not only destroy sensitive or valuable vegetation and promote the establishment of invasive species, but excessive chemicals applied to the vegetation will eventually runoff and contaminate the creek.

- The agricultural community should take advantage of the recent innovations in the application of chemicals and fertilizers that will limit the leaching of chemicals and nutrients to the creek, which is currently a major threat to the health of the Monocacy. These innovations, primarily combined with GPS technology, allow for limited applications of pesticides, herbicides, and fertilizers to only those areas that need them. Such practices apparently pay for themselves, as there is a reduced need for applications.

- The development of Nutrient Management Plans for all agricultural lands within the watershed, with the assistance of Conservation Districts, would ensure that land owners are utilizing technology and best management practices for the betterment of the environment as was suggested above.

- Best Management Practices (BMPs) should be applied to any activities within the watershed that have the potential to affect water quality. BMPs go a long way toward reducing non-point source pollution and improving water quality. The purposes of implementing BMPs are as follows:
  - To restore and maintain the physical and biological health of the stream.
  - To protect surface and groundwater quality by preventing the flow of non-point source pollutants such as nutrients, sediment, animal derived organic matter, and pesticides, into surface and subsurface water bodies.
  - To protect and improve the health of existing natural trout populations. Trout fishing is a significant recreational activity on the Monocacy Creek.
  - To provide natural areas for passive recreation and wildlife habitat.

  Specific recommendations for best management practices for general stream care are outlined in Appendix 1.

- BMPs should always be applied during road construction activities. Especially important, are the measures taken when the roadway is adjacent to the creek. Buffers should be left along the creek whenever possible to stabilize the banks and prevent undercutting of the road. Preventive erosion control techniques will almost certainly be necessary to prevent excessive sedimentation if a road is planned for expansion in the direction of the creek.

- The development of sewage management programs by municipalities for areas dominated by on-lot sewage systems as well as promotion of proper maintenance of these systems is encouraged to reduce potential pollution problems from system malfunctions. Guidelines for proper management and maintenance are contained in the appendix.

Objective 2. Treat Pollution Before Reaching the Stream Corridor: If the amount of pollution produced by a source can not be controlled by methods such as those described under Objective 1, treating the pollution prior to its introduction to a water body is another option. The following suggestions can also help minimize the impact from non-point source pollutants.

- The installation of oil separators is advocated, especially at critical locations. Some of

these locations include the intersections of Rt. 22 and Rt. 512, and Rt. 22 and Rt. 191, where significant growth has led to frequent vehicular accidents, and consequently spills of oil, gasoline, antifreeze, and other liquids. While such devices are usually said to be "outside the scope of highway projects" (and consequent funding is denied), they are, in fact, a direct result of growth and traffic. If there is a need for a highway project, due to growth and traffic, then spills control should be a natural part of the project. Spills control provisions should be included, if not already, in the Rt. 22 project. There was a massive spill of detergent some years ago, at Rt. 22 and Rt. 512, which almost wiped out the entire downstream trout population. After the incident, PennDOT installed an oil separator, but it only protects Rt. 22, not 512, and there are many accidents on Rt. 512 now.

- Voluntary compliance by developers to control deleterious substances, such as oil, from leaking from their grounds is encouraged. Stormwater runoff from malls, roads, and parking lots containing leakage from thousands of vehicles is regularly drained into the nearest swale, eventually finding its way to the nearest stream or groundwater supply. Currently, only industrial facilities are required to control such substances. It is advised that developers and municipal approval boards advocate voluntary compliance with such regulations on the grounds that developers and owners should be responsible for problems created by them.

Objective 3. Revise Stormwater Management Philosophies and Practices: In addition to protecting the creek, reducing frequency and magnitude of flooding is a major concern of the municipalities. The Act 167, Storm Water Management Plan prepared by LVPC is a valuable tool for addressing flooding associated with storm water runoff. In this time of rapid development spurred by population growth, eliminating flooding events is not feasible. Minimizing flooding occurrences is however a realistic goal. Addressing this issue will require municipalities to abandon many traditional practices regarding stormwater management.

- BMPs for controlling stormwater quantity and quality should be implemented. Properly managing the quality of stormwater runoff is equally important as managing quantity of runoff and is strongly advised. Following BMPs for stormwater quality and quantity management would:
  - Protect Monocacy Creek from damaging impacts of stormwater runoff that directly enters the stream,
  - Improve water quality of Monocacy Creek by improving quality of stormwater discharges
  - Reduce frequency and magnitude of flooding events, and
  - Minimize potential flood damage and cost.

A list of suggestions for improving the quality and quantity of stormwater runoff entering the creek is contained in Appendix 1. These management techniques emphasize that direct discharges from storm drains to Monocacy Creek should be avoided at all costs. Also, permeable surfaces should be preserved whenever possible, as they will absorb overland flow, thus distributing the peak discharge over a greater length of time at a lower stream

height. In other words, these techniques would reduce the magnitude and frequency that the creek exceeds its bankfull stage resulting in flood conditions.

- An investigation should be conducted to determine if stormwater runoff from Rt. 987 can be diverted so that it does not directly enter the stream. This is just one example that has been pinpointed out of many instances of direct stormwater discharges to the stream that should be diverted if possible.

Objective 4. Floodplain Preservation: Preservation of floodplains and establishment and conservation of riparian buffers would both help protect the water quality of Monocacy Creek.

- Reassessment of the 100-year floodplain is necessary despite current requirements for detention basins. This is due to heavy precipitation events combined with extensive local development that are contributing to increased sheetflow runoff, which contains chemicals and nutrients detrimental to stream health. As runoff increases due to development, creek levels rise much faster making the floodplain much wider than previous delineations indicate. Establishing accurate floodplain delineations would help prevent development activities within the stream corridor that typically increase the amount of impervious surfaces that carry polluted runoff to the stream.

- Better compliance with existing floodplain regulations established by the municipalities is also necessary to achieve the goals that initially prompted the creation of the regulations.

- Incorporating floodplains in a riparian buffer zone is another means of ensuring their protection.

Objective 5: Link Public Sewer System to Recently Developed Areas: Industries and business located along route 191 are currently not connected to the public sewer system. Improperly working septic systems are a major source of pollution across the state and linking businesses and industries located in this area and others that have been recently developed to a public sewer system would eliminate a potential nonpoint source of pollution.

Objective 6: Riparian Buffer Restoration and Establishment: The riparian habitat is a key to the thriving aquatic life, wildlife, and scenic beauty of the Monocacy. Riparian buffers provide many functions that protect water quality and enhance the value of the Monocacy corridor. Riparian buffers provide:

- Structural Integrity: Roots from trees and shrubs are deeper than that of grass and better serve to anchor the soil in place and prevent it from eroding and causing sedimentation in the stream.
- Filtering of sediment runoff: As water flows overland from fields and urban areas, it carries sediment with it toward the stream. When the water reaches a riparian buffer, tree roots and other vegetation slow the flow and cause the sediment to drop out and settle on the floor of the forested region. Sediment that does not settle out may become trapped in the roots and is thus prevented from entering the stream.

- Sink for Nutrients: Fertilizers that are applied in excess contain nutrients that will leach into the ground and be transported to the creek via groundwater. Vegetation in the riparian buffers will uptake nitrate and other nutrients for their growth processes, thus preventing the nutrients from entering the stream and causing excessive plant and algae growth.
- Food and Habitat for Aquatic Life and Wildlife: Leaf litter and other debris from streamside buffers enters the stream and becomes the building block for biological activity in the stream. Macro-invertebrates use the debris for food and habitat. Fish and larger organisms then feed off the macro-invertebrates and so on. Riparian areas also serve as habitat for other wildlife such as birds, deer, and a variety of other species.
- Recreation Corridors: Riparian buffers also increase the scenic value of the stream, drawing more people to it for recreational activities such as fishing, walking, hiking, biking, birding, and other forms of nature observation.

♦ Property owners and municipalities should take prudent precautions to preserve riparian habitat so that the Monocacy Creek does not lose its historic status as a natural treasure and a showpiece, as it is one of few streams with a thriving population of trout in a city environment. Even economic and business interests within the watershed have used this to their advantage and would be losing an asset by the loss of riparian habitat.

♦ Devising or adopting an ordinance such as the "Riparian Corridor Conservation District" created by the Montgomery County Planning Commission and described under Goal 1, is an excellent way to approach restoration of riparian buffers.

♦ Educational programs and opportunities for land owners to learn about the benefits of riparian buffers and how they improve water quality would also encourage voluntary planting of streamside vegetation. The creation and distribution of a Streamside Property Owners Guide would be an effective way of spreading the word on these issues.

♦ Areas where buffers should be established or enhanced throughout the watershed are listed below according to municipality.

UPPER NAZARETH TOWNSHIP- Monocacy Creek flows unbuffered through a farm with a large pond on Blossom Hill Road. Buffering both the stream and the pond would provide shade, stabilization, and reduce problems with geese in the area.

A wider and/or more continuous buffer is recommended between the farm and stream north of Newburg Road, along Georgetown Road.

BATH BOROUGH- A small tributary to Main Branch Monocacy Creek that flows through Keystone Park has no buffer and steep, eroding streambanks. A buffer is needed at the park to protect both the stream and the kids playing in the park. This buffer should extend from the route 987 bridge at Green Street to the old pedestrian bridge located next to the basketball courts.

EAST ALLEN TOWNSHIP- A section of the Main Branch located downstream from the intersection of Route 512 and Locust Road (across from Timberline Inn) is in need of a buffer. This section is very meandering with grass that is currently mowed to the edge of the streambank, causing excessive erosion and sedimentation. A railroad crossing over the stream downstream of this segment is contributing to the problem.

LOWER NAZARETH TOWNSHIP- An open space area exists along the Main Branch between the Steuben Road crossing of the creek and the railroad crossing about 25 yards upstream. A buffer is also needed in the field along the creek downstream from the Steuben Road bridge toward the confluence with the East Branch.

The creek is fenced off with a cattle crossing upstream of the Township Line Road bridge, however a buffer is not yet established here. Downstream of this bridge a few trees have been planted to initiate a riparian corridor, however this initiative should be strengthened both upstream and downstream of Township Line Road.

The riparian corridor could also be enhanced along the stretch flowing through the Lower Nazareth Rod and Gun Club, which is located off Georgetown Road just north of the bridge near the intersection with Hanoverville Road.

Crops are also being grown too close to the stream along the East Branch both upstream and downstream of the Steuben Road crossing. This situation is contributing to nutrient overloading and sedimentation of the stream. A wider riparian buffer would aid in the filtration of these nutrients and sediment that are contained in runoff, preventing further degradation of the stream.

The Main Branch is also in need of buffer establishment in the area where the creek crosses route 191. The inside of the meander curve that follows Old Route 191, behind the car lot for Nazareth Auto Sales off Route 191, is in need of riparian plantings to provide shade and reduce the effects of thermal pollution. Upstream of northernmost bridge crossing Route 191, the stream is unprotected from erosion and sedimentation, thermal pollution, and stormwater runoff. Buffer establishment and stabilization work are needed in this section which passes behind the Self Storage lot and St. Anne's Shrine. Streambank erosion causing undercut banks behind St. Anne's Shrine is threatening the stability of several crosses stationed there. Some work has been done to stabilize trees in this section of the creek using cribbing, however, the work needs to be extended upstream and should be combined with riparian planting efforts.

MOORE TOWNSHIP- A tributary to the Main Branch extending from Dannersville Road to Whitetail Deer Drive is in need of a buffer near Dannersville Road. There is also no buffer established along Hatch Gravel Road, from the intersection of Stone Post and Trickle Creek Road, upstream past the intersection with Kuter Road, and to approximately 50 feet beyond a cement private drive bridge crossing the creek. It is important to establish vegetation along this stretch of the creek as it is very close to the roads and may cause problems with streambanks being undercut below the road.

BUSHKILL TOWNSHIP- Knauss Road is located veryclose to the stream and approximately two-tenths of a mile north of Daniels Road the bank is eroding toward the road without the protection of a buffer. Also, a few individual property owners along Knauss Road could benefit the creek by extending or creating buffer zones on their property.

BETHLEHEM TOWNSHIP- The area behind the intersection of Rt. 22 and Rt. 191 next to Hanna Car Wash was recently stripped of vegetation. Runoff from these routes now flows directly into the creek. This area is a top priority for revegetation to prevent deterioration from non-point source pollution.

CITY OF BETHLEHEM- There are many opportunities for private property owners on Biery's Bridge Road to plant riparian buffers.

More trees for shading and bank stabilization are needed upstream from the dam located near the junction of Township Line Road and Santee Mill Road in the Archibald Johnston Conservation Area.

- When not conflicting with designated park uses, trees and shrubs should be planted in and around recreational facilities.

- A riparian buffer could be planted on a local landowner's streamside property to serve as a model to show the benefits of riparian buffers to other landowners within the watershed.

- Warm season grasses and willow shrubs can play an important role in the establishment of riparian buffers. When warm season grasses are planted along agricultural lands, they provide the benefits of buffers during the spring and summer, but they can also be harvested in the fall to be used or sold by the producer. Willow shrubs are valuable buffer species because when live stakes are cut in the spring and inserted in the ground, they grow and establish themselves very quickly. This provides good immediate structural integrity for an area that was previously barren. Grasses and shrubs are preferred over trees in some environments, especially wet conditions, as trees don't develop deep root systems and can become top heavy and fall over. It is important to note that any grasses or willow shrubs planted in the stream corridor should be native species that can provide habitat benefits as well as stabilization.

- An example of a successful riparian habitat restoration project is shown in Figure 36. Work such as this should be used as a model for future projects.

Figure 36. A riparian buffer has been planted and fenced off along this previously poorly managed section of Monocacy Creek.

10.0. CONCLUSION

The Monocacy Watershed and its resources have been treasured by many since the first natives and European immigrants discovered the region. Through the years, population growth and associated development have eliminated, destroyed, or altered significant reserves of the watershed's valuable resources. Future growth of the watershed will put increased pressure on the remaining resources. How municipaliities choose to handle these pressures will impact not only the health of the watershed but also the well-being of its residents.

The consensus of municipalities in the northern part of the watershed to preserve the region's rural and historic character will aid in proper management of valuable resources. The challenge for this region will be to preserve prime agricultural lands while minimizing their contribution to nonpoint source pollution of the creek.

The challenge for urbanized areas of the watershed will be to improve the quality and reduce the quantity of storm water runoff entering the creek. Restoring riparian buffers wherever possible along the length of the creek is also a priority for conserving watershed resources.

The keys to achieving the goals of this project are education and communication. Knowledgeable citizens and organizations must continue to educate property owners, businesses, and political leaders, on the issues raised in this report. Open lines of communication between property owners and institutions must be established for the

watershed to benefit from conservation and preservation programs as well as the efficient use of its many resources.

This management plan should be used as a tool to build partnerships for enhancement of the watershed. It can be used as a guide to develop concerted efforts for improvement projects for many years to come. It is our hope that completion of this plan and resultant ongoing improvement efforts will continue to yield pride in the hearts of future generations for their treasured Monocacy Creek (Figure 37).

Figure 37. Monocacy Creek provides scenic beauty for the Lehigh Valley in addition to its many natural resources and functions that need to be preserved.

1.0. PHYSICAL RESOURCES

1.1. Location/Description of Watershed

The Monocacy Creek is one of only 56 limestone streams in the state of Pennsylvania and a tributary of the Lehigh River. The drainage basin of the Monocacy Creek encompasses approximately 48.8 square miles in Lehigh and Northampton Counties, with the majority in the latter (Shaw, 1984). The headwaters of the Monocacy Creek Main Branch are located in Moore Township, north of Chapman Borough, in Northampton County. From this point the stream flows south, approximately 20.3 miles south to its mouth at Sand Island, Bethlehem (Shaw, 1984). The East Branch of the creek begins northeast of Chapman Borough, near the village of Moorestown. These two branches converge near the town of Steuben and proceed the remaining distance to Bethlehem. A third minor branch originates in Bushkill Township, slightly northwest of Nazareth, and joins the East Branch in Lower Nazareth Township. Along its journey the creek passes through Chapman and Bath Boroughs; Moore, Bushkill, Upper Nazareth, Lower Nazareth, East Allen, Hanover, and Bethlehem Townships; and the City of Bethlehem. A characteristic view of Monocacy Creek is shown in Figure 1. The location of the Monocacy Creek watershed in relation to Pennsylvania is shown in Figure 2. A map of the watershed including its boundaries, drainage pathways, and municipalities, can be viewed on Figure 3.

Figure 1. Monocacy Creek as it flows through Northampton County, PA.

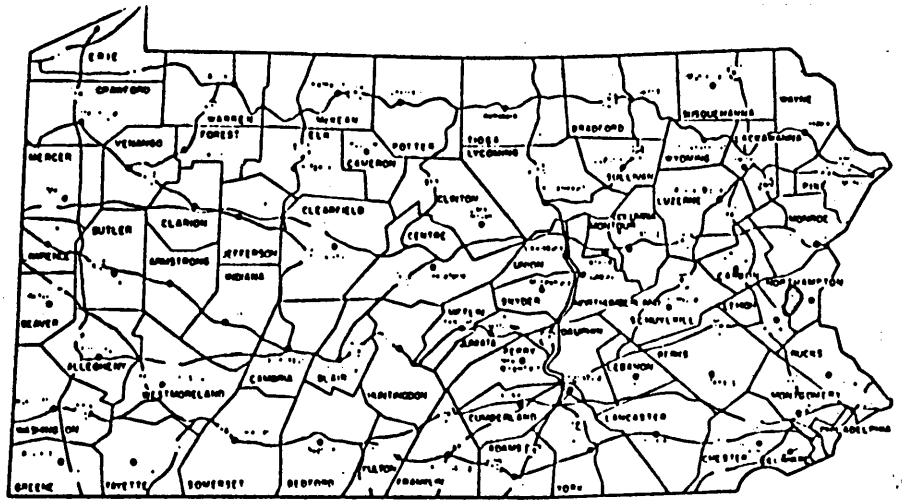


Figure 2. Monocacy Creek watershed delineated and shown in Northampton County with relation to Pennsylvania.

1.2. Geology

Water quality characteristics of a watershed are linked to the geology of the region. Therefore, knowing the geology of the Monocacy Creek watershed is important to developing a management plan. A map and description of the bedrock formations within the watershed are contained in Figure 4 and Table 1.

The geology of the Monocacy Creek in Northampton County has been evolving for more than 200 billion years. The bedrock in the watershed was formed during three geological time periods. These three periods include the Precambrian (more than 570 million years old), Cambrian (more than 500 but less than 570 million years old), and the Ordovician (more than 430 but less than 500 million years old). The bedrock in the upper reaches of the watershed is slaty, whereas the bedrock in the lower two-thirds is predominantly limestone (Miller, 1939).

The two distinct types of bedrock found in the watershed play a major role in determining the quality of water in the Monocacy Creek. The slaty bedrock at the headwaters provides very little buffering capacity, so the creek is very sensitive to acid contamination. As a result, the aquatic life in the creek may suffer from variability in pH.

The Monocacy has been touted as a valued treasure of the Lehigh Valley, as it is one of only 56 limestone streams in the state of Pennsylvania. The ability of the Monocacy Creek to

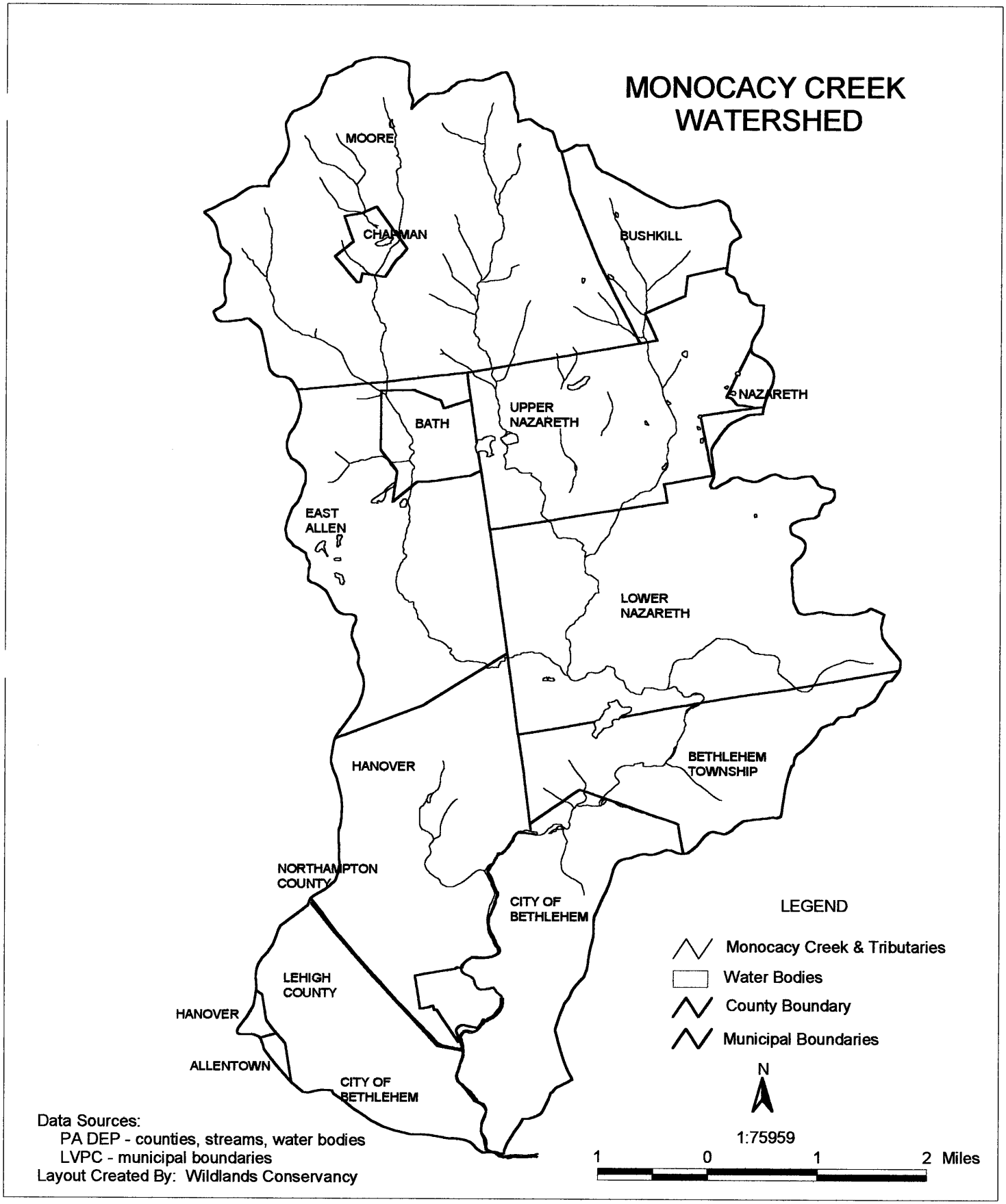


Figure 3. Monocacy Creek watershed delineation, political divisions, and surface water bodies.

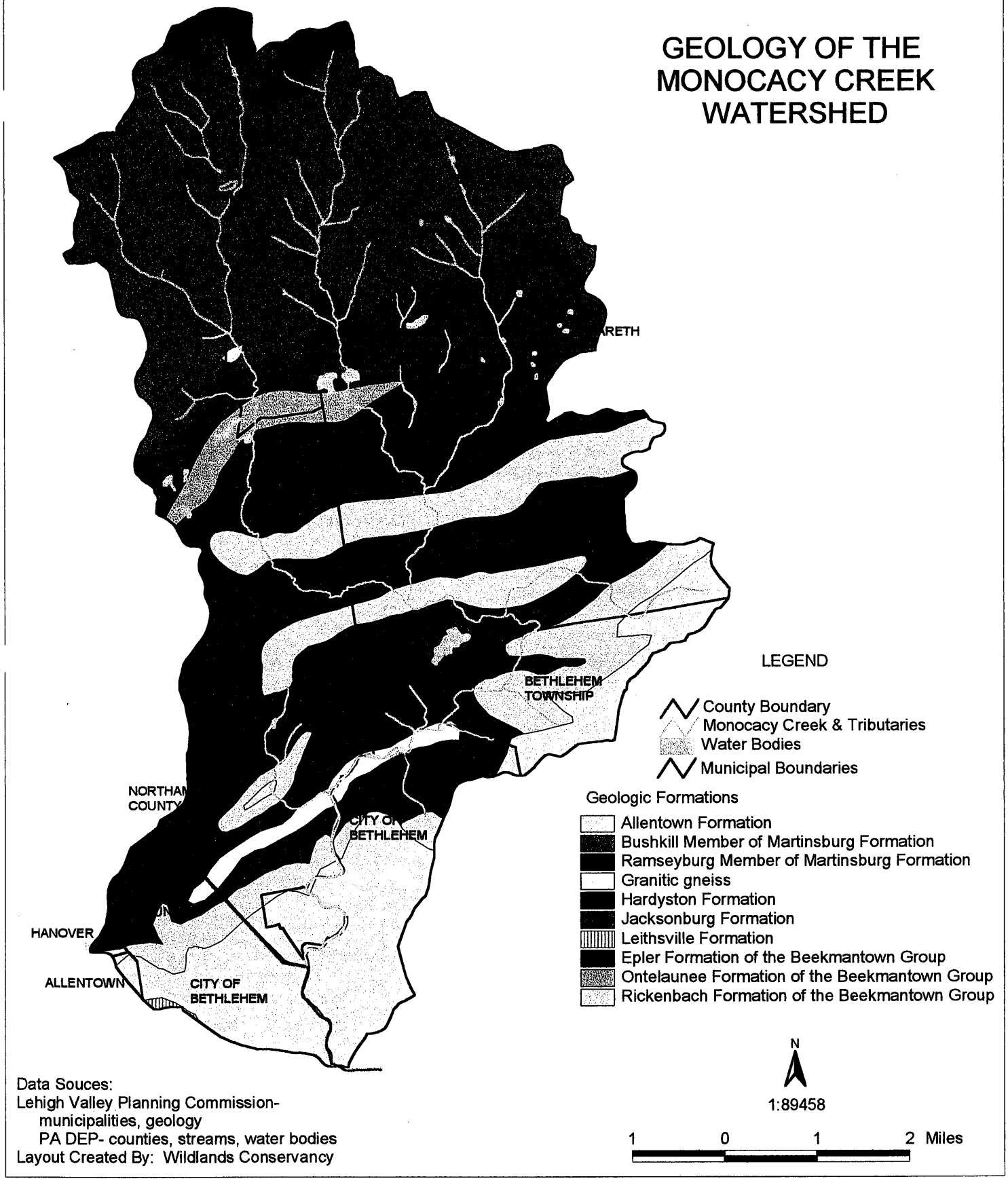


Figure 4. Geologic formations within the Monocacy Creek watershed.

Table 1. Descriptions of bedrock formations within the Monocacy Creek watershed.

GEOLOGIC UNIT	DESCRIPTION
Martinsburg shale Fm.	Formed during Ordivician period; composed of gray to dark-gray shale and slate; also contains some sandstone beds of varying thickness.
Jacksonburg Fm.	Composed of dark gray, shaly limestones with slaty cleavage; these limestones are commonly used to manufacture cement.
Allentown Fm.	Formed during Cambrian period; composed of broad-banded magnesian limestones; typically bluish-gray to gray in beds 6 to 18 inches thick; alternating light and dark beds are characteristic and caused by varied quantities of carbonaceous matter and amount of magnesian carbonate.
Beekmantown Group	
Ontelaunee Fm.	Almost singly limestone; mostly dolomitic; extensively quarried; Medium-dark-gray, finely crystalline dolomite; massively to finely laminated; turns grayish yellow when weathered; thick-bedded with dark-gray chert layer at base.
Epler Fm.	Thick-bedded; medium to medium-dark-gray, finely crystalline limestone; inter-bedded with medium-dark-gray, finely crystalline dolomite; limestone turns light gray when weathered and dolomite turns yellowish gray; contains edgewise conglomerate,fossil fragments, and oolitic lenses.

Table 1 (Cont.)...

Rickenbach Fm.	Medium to dark-gray, coarsely crystaline dolomite in lower part; medium to medium-light-gray, finely crystaline dolomite in upper part; contains chert lenses, beds, and nodules.
Leithsville Fm.	Medium to dark-gray, crystaline dolomite, which is light-olive-gray in some places; turns light gray and yellowish brown when weathered; massively bedded with interbeds of thin shale and dolomitic shale; contains pink to gray mottled chert and dark-gray chert, as well as scattered sand grains; upper part of formation very shaly.
Byram gneiss Fm.	Formed during Pre-Cambrian period; variety of composition, texture, and sturcture; normal texture is average granitic; finely and coarsely granitic textures do appear; many places have well-developed sets of joints.
Hardyston quartzite Fm.	Formed during Cambrian period; only small portion composed of quartzite; contains feldspathic sandstones, conglomerates, jasper, chert, and shales among others; color ranges from white to dark-gray.

Data Source: Miller, 1939.

support a naturally reproducing trout population within the urbanized setting of the City of Bethlehem, is perhaps its most unique and valued quality. Limestone formations underlying approximately 2/3 of the watershed are essential to the productivity of the stream. Limestone streams are well known for their ability to sustain a great diversity and abundance of aquatic plant and animal life that is important to maintaining an ecological balance in a riparian ecosystem. Limestone provides a very good buffering capacity, which serves to maintain a constant pH that is critical to providing thriving populations of fish, macroinvertebrates, and other aquatic life. Maintaining an abundant and diverse macroinvertebrate population in the Monocacy is important, as they are a basic component of the food chain.

The configuration of calcareous formations in the northern half of the watershed sometimes causes a situation commonly referred to as a "losing stream." This means that the water in the creek is being lost to groundwater. Limestone is a very permeable medium, making it easy for surface waters to seep into the ground. This process occurs so readily that during dry spells or droughts the channel may become completely dry. This problem is most notable on the East Branch near the confluence with the Main Branch. However, the stream is replenished downstream from Camel's Hump, with spring water that has entered the ground and travelled through these limestone formations.

The geologic formation known as Camel's Hump is critical to the Monocacy's classification as a "high quality-cold water fishery" (HQ-CWF). Camel's Hump is composed of relatively impermeable bedrock when compared to the surrounding hydrologically conductive limestones. When groundwater is flowing through the limestone, it suddenly hits the Byram gneiss of Camel's Hump. This formation acts as a wall, forcing the water to the surface. The result is an abundance of springs that provide cold, well-buffered water to the Monocacy, establishing a valuable habitat for fish and other aquatic life from Camel's Hump to the confluence with the Lehigh River. An example of a spring is shown in Figure 5 (Miller, 1939).

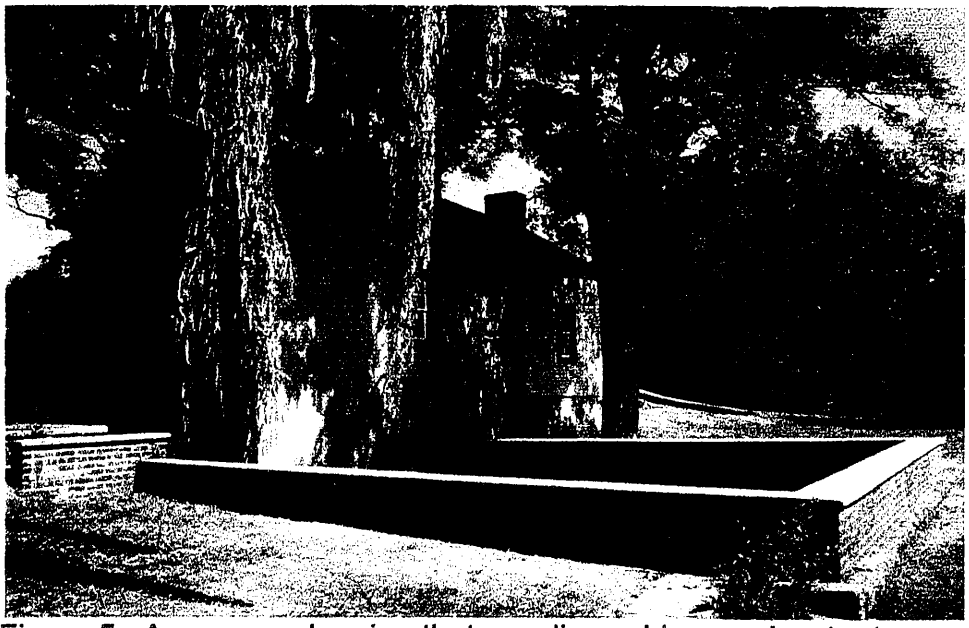


Figure 5. A preserved spring that supplies cold ground water to Monocacy Creek.

1.3. Topography

The combination of bedrock and flowing water plays a major role in determining the topography of a region. The Monocacy Creek watershed is located in the Great Valley Section of the Valley and Ridge Physiographic Province of Eastern Pennsylvania. The topography of the upper one-third of the watershed, underlain by the Martinsburg Shale Formation, consists of low flat-topped hills dissected by streams and producing steep-sided slopes. This region is dotted by slate quarries, such as the one shown in Figure 6.

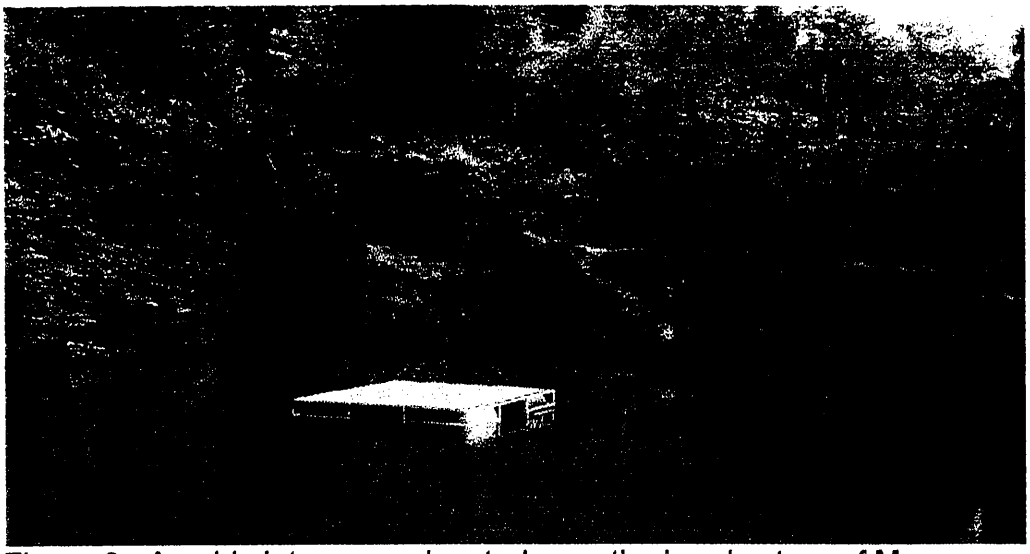


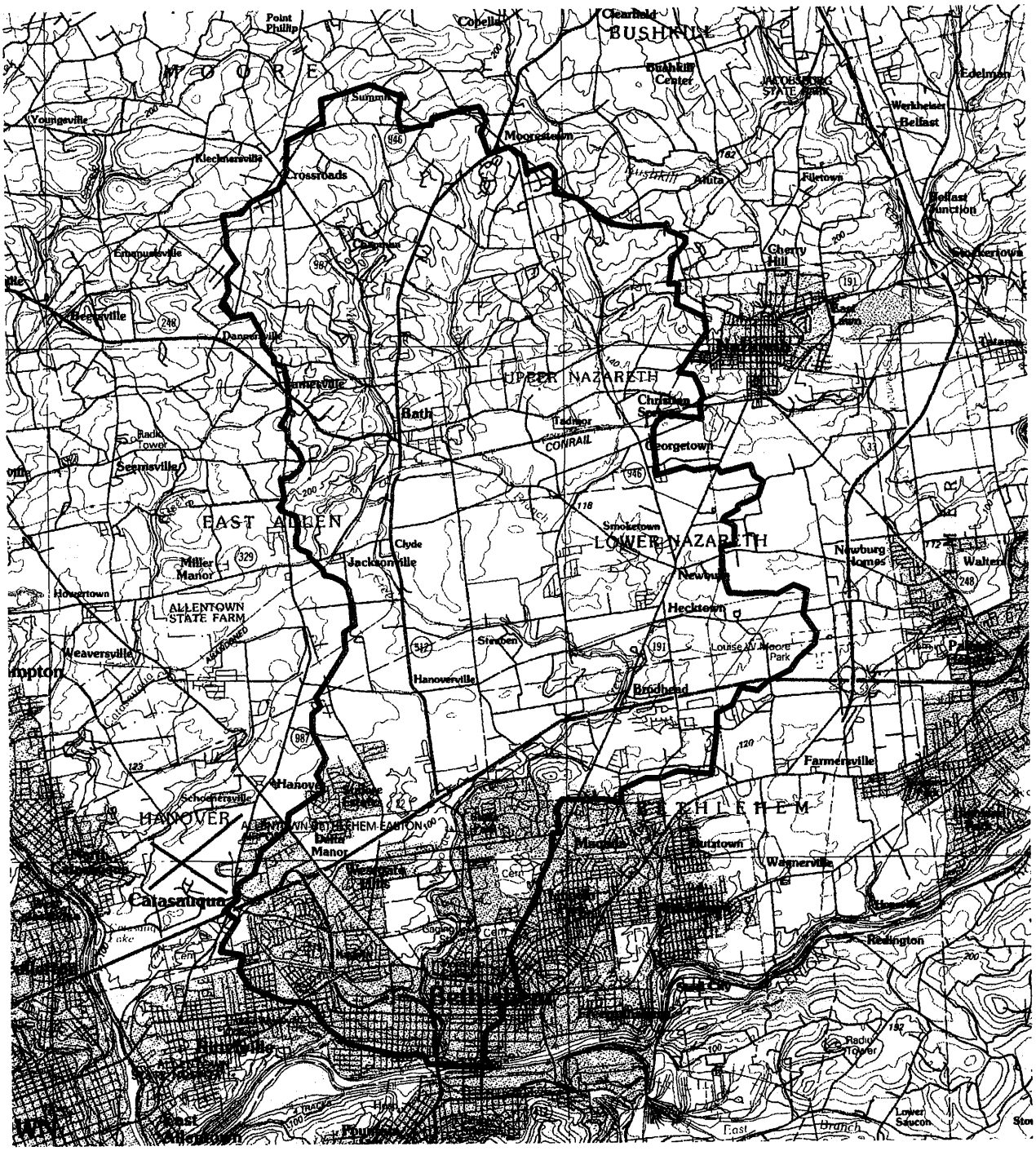
Figure 6. An old slate quarry located near the headwaters of Monocacy Creek.

The lower two-thirds of the watershed, underlain predominantly by limestone, consists of flat land with gently rolling valleys. The limestone bedrock yields karst topography, which is typified by the abundance of sinkholes and closed depressions. This landscape is also dotted with several quarries, although mostly limestone (Shaw, 1984).

The most dominant topographic feature within the watershed is Camel's Hump. This is the area in Northern Bethlehem underlain by Byram gneiss. Due to the impermeability of the bedrock, this land is not easily eroded. Thus a topographic high is formed overlooking the surrounding watershed. This hill has historically been used as a surveying site within the Lehigh Valley and is shown in Figure 7. The topography of the watershed is shown on a USGS map on Figure 8. (Shaw, 1984).

Figure 7. Camel's Hump, an outstanding geologic and topographic feature of Monocacy Creek watershed.

MONOCACY CREEK WATERSHED USGS TOPOGRAPHIC MAP



LEGEND

Monocacy Basin Boundary

1:119839

1 0 1 2 Miles

N

Data Source: Department of Environmental Protection

Layout Created By: Wildlands Conservancy

Figure 8. Topographic map delineating Monocacy Creek watershed.

1.4. Soils

Like geology, soils play an important role in determining stream chemistry. Soil information is also important for development and land use planning purposes. Properties such as thickness, texture, and moisture capacity make some soil associations better suited to a given use than others. There are a few different soil associations in Northampton County through which the Monocacy Creek flows. These include the Berks-Bedington-Comly, Duffield-Clarksburg-Ryder, Washington-Urban, and the Connestoga-Hollinger associations (Staley, 1974).

A digitized map, provided by LVPC, showing each distinct soil series within the above associations and a list of these soil series with a brief description, its capability unit, the municipalities it is located in, and a description of the capability units can be found in Appendix 2. To receive this appendix, contact Wildlands Conservancy.

The northern third of the watershed consists of soils in the Berks-Bedington-Comly association. Shallow bedrock and an abundance of coarse fragments in the soil make it unsuitable to most potential uses. For example, housing developments with basements may not be sensible due to extraordinary amounts of bedrock that may need to be removed. Problems may also arise with agriculture as excessive erosion may expose bedrock and prevent cultivation (Staley, 1974).

The Duffield-Clarksburg-Ryder association is present in a narrow band across the central part of the watershed. Sewage disposal is the major limit to land use on this association. Slow permeability and a seasonally high water table increases the risk of surface and groundwater contamination from activities such as sewage disposal (Staley, 1974).

The Washington-Urban association is found in the southern part of the watershed. The limitations of the urban series can not be identified, as these soils have been drastically altered by development and require individual site assessments. However, there are few limitations to uses on the Washington series, which is well suited to cultivation (Staley, 1974).

Finally, the Connestoga-Hollinger association covers the small area of the watershed known from its geology as Camel's Hump. Due to the presence of stones and boulders in this association, it is not suited to cultivation. Nor is it suited to residential development where it occurs on steep slopes, as is often the case. As a result of these limitations, most areas remain wooded (Staley, 1974).

Two specific soil types within the watershed that have hydric properties include the Brinkerton and Holly silt loams. These soils typically occur along floodplains and drainage ways and are characteristically deep and poorly to very poorly drained. These soils also have slow to moderate permeability, a high water table, and are occasionally inundated or have ponding after precipitation events. The presence of hydric soils is one characteristic taken into account when a wetland delineation is determined. Development should be avoided on these soils as they generally help to assimilate floodwaters.

2.0. AQUATIC RESOURCES

2.1. Surface Water

The Monocacy Creek is a fourth order stream with its source near Chapman, at an elevation of 900 feet, and its mouth in Bethlehem, at an elevation of 212 feet. The length of the stream is approximately 20.3 miles with a drainage area of approximately 48.8 square miles. The slope of the channel is 17.4 feet/mile. The creek forms a dendritic drainage pattern, with between 23 and 31 minor tributaries. The upper and middle reaches of the stream flow through hills with a widening valley and moderate slopes. The lower stretches of the creek flow through rolling hills in a wide valley with mild slopes. The mean annual precipitation within the watershed is approximately 44 inches. The flow of the Monocacy Creek is sustained by springs that feed the creek in the vicinity of Camels Hump, where groundwater is forced to the surface upon reaching the relatively impermeable Byram gneiss after passing through the limestone region. Above the entrance of these springs, the creek periodically runs dry as a result of droughts occurring in the summer months (Shaw, 1984).

Almost all wet soils within the watershed occur along the stream and its tributaries. The presence of wet soils indicates that the area may be a wetland, even if it is not currently designated as such by the National Wetland Inventory (NWI). The soils, vegetation, and hydrology of these areas should be examined to determine if wetland designations are necessary. A few wetlands, designated as such by NWI, are scattered throughout the watershed, not all of which are located along the stream. Many of these designations however, are based solely upon aerial photo interpretation. Field delineations by a trained expert may be essential to determining the proper status of the area under question. The headwaters of the Monocacy originate in a wetland setting as seen in Figure 9. Other locations of wet soils and wetlands can be viewed on Figure 10. It is important to protect and conserve these resources because they provide wildlife habitat, absorb nutrients, transform harmful chemicals, and act as sponges for storing floodwaters, thus lessening the threat of downstream flooding. The gradual release of water from wetlands may also aid in maintaining stream flow during dry spells.

2.2. Groundwater

An aquifer is considered to be any water-bearing zone that may yield quantities of water sufficient to meet the needs of its user. Usually, each rock formation is considered to be a separate aquifer because changes in geology cause changes in hydrologic characteristics. Information regarding aquifers of the Monocacy watershed was obtained from a report on Lehigh County because many of the aquifers are the same as in Northampton County.

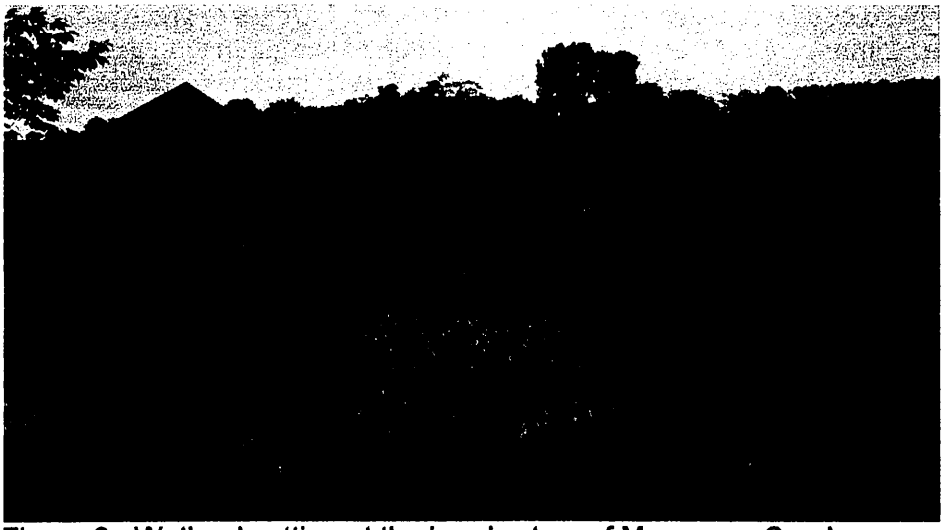


Figure 9. Wetland setting at the headwaters of Monocacy Creek.

Although the information is in reference to the same aquifers, there may be slight differences due to the geographic and topographic locations of each aquifer in the counties. For this reason, the data provided should only be taken as a general idea or approximation of the actual water yielding properties in Northampton County.

The Martinsburg formation is not a preferred aquifer to investigate for use as an industrial or public water supply. This aquifer is best suited to domestic purposes. The specific capacity, which is the discharge of a well per foot of drawdown in the aquifer, in the Martinsburg formation is related to topography. Specific capacities are greatest in valleys and least on hilltops. Wells with low specific capacities should be avoided as they will be overdrawn more easily and may be subject to going dry. Therefore one should attempt to drill a well in the valleys of this aquifer first. This shaley formation typically yields groundwater with low dissolved solids, and calcium and magnesium are usually the dominant cations. The median concentrations of chemical constituents in groundwater from the Martinsburg formation are shown in Table 2 (Wood, 1972).

When comparing the various limestone aquifers, Jacksonburg yields the lowest quantity of water. The Allentown, Beekmantown, and Leithsville aquifers have significantly higher yields. Like the Martinsburg aquifer, the Allentown aquifer has higher specific capacities in valleys than in uplands. The reported median yield for these wells is 75 gpm, although 750 gpm is thought to be the potential median yield of these wells. An even better option when drilling a well in the Monocacy watershed may be the Beekmantown aquifer. Most wells drilled in this aquifer have yields slightly higher than the average for the Allentown formation. Almost any well drilled in this formation will yield enough water for a domestic supply. Some deep wells have even exceeded 2000 gpm. The Leithsville aquifer, like the Beekmantown, is almost guaranteed to yield a sufficient domestic supply. Numerous public and industrial water supplies in this aquifer have yields exceeding 1000 gpm. The chemical constituents of the carbonate rock aquifers are shown in Table 3 (Wood, 1972).

Water from these aquifers is also high in dissolved solids, hardness, and specific conductance. Limestone aquifers are also more prone to contamination than many other aquifers, due to solution cavities and the preferential flow of groundwater through this porous media.

Table 2. Median concentrations of chemical constituents in groundwater from the Martinsburg formation.

	Median[1] of indicated constituent, in milligrams per liter, except as indicated		
Constituent	Pen Argyl Member	Ramseyburg Member	Bushkill Member
Silica (SiO_2)	14	12	12
Iron (Fe), total	.04	.30	.17
Manganese (Mn), total	.00	.00	.01
Calcium (Ca)	37	28	29
Magnesium (Mg)	6.8	6.4	8.0
Sodium (Na)	4.5	7.2	5.3
Potassium (K)	0.8	0.9	0.8
Bicarbonate (HCO_3)	79	61	66
Sulfate (SO_4)	24	34	42
Chloride (Cl)	11	6.7	6.6
Fluoride (F)	0.0	0.0	0.0
Nitrate (NO_3)	7	16	10
Dissolved solids (residue at 180°C)	164	143	153
Calcium-magnesium hardness (as $CaCO_3$)	120	93	94
Noncarbonate hardness (as $CaCO_3$)	65	50	46
Specific conductance	258	232	236
pH	7.7	7.6	7.6

[1] Medians of 3 to 6 analyses in the Pen Argyl Member, 8 to 14 analyses in the Ramseyburg Member, and 13 to 18 analyses in the Bushkill Member for each constituent.

Data Source: Wood et al., 1972

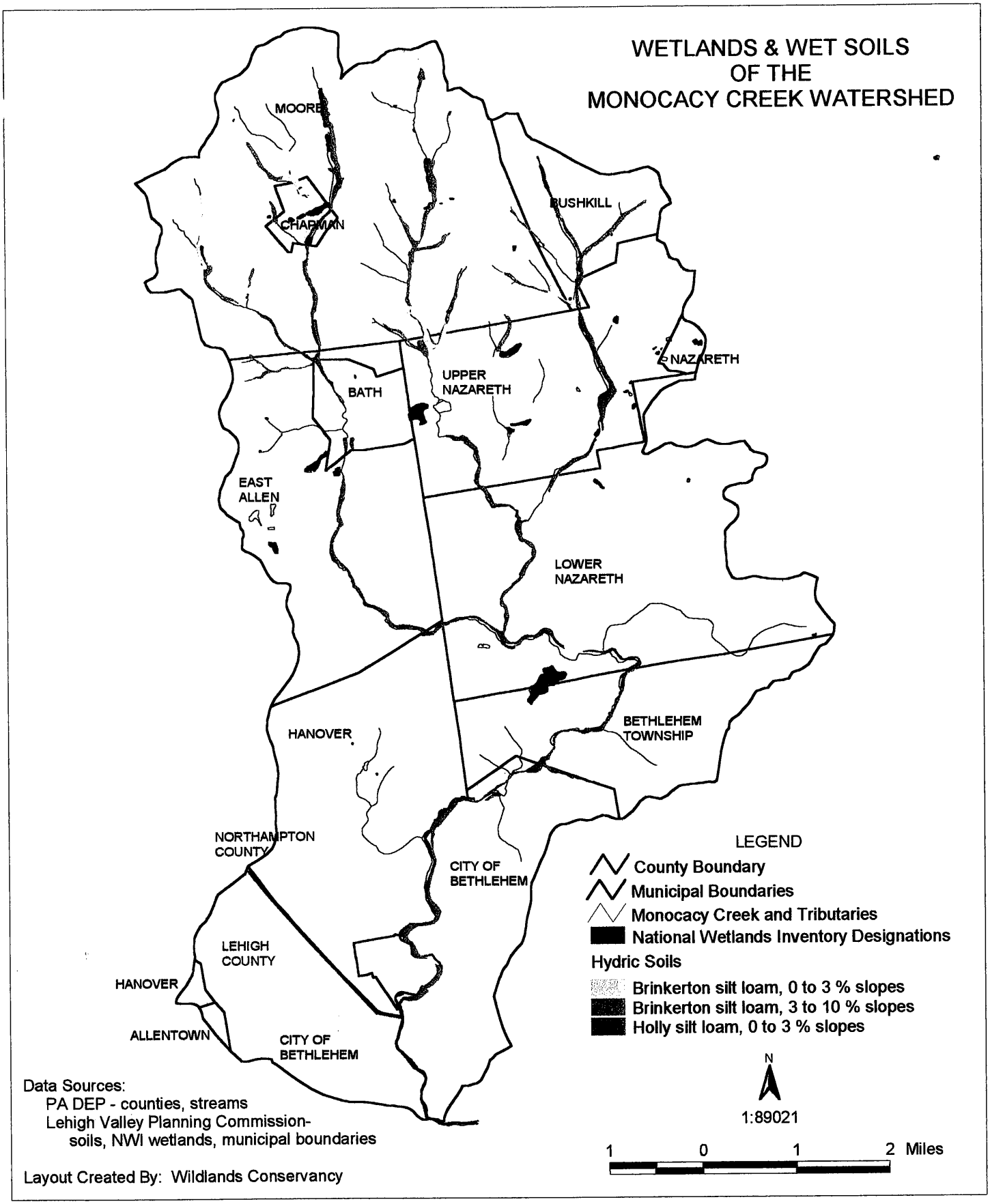


Figure 10. Wetlands based on National Wetlands Inventory (NWI) and potential wetlands based on hydric soils within the Monocacy Creek watershed.

Table 3. Median concentrations of chemical constituents in groundwater from the carbonate-rock aquifers.

	Median of indicated constituent, in milligrams per liter, except as indicated				
	Jacksonburg Formation		Beekmantown	Allentown	Leithsville
Constituent	Cement rock	Cement limestone	Group	Formation	Formation
Silica (SiO_2)	9.5	8.7	8.4	9.6	11
Iron (Fe), total	.08	.04	.05	.08	.13
Manganese (Mn), total	.00	.05	.01	.01	.02
Calcium (Ca)	80	90	45	33	36
Magnesium (Mg)	12	14	12.5	22	22
Sodium (Na)	7.5	11	4.1	7.0	8.3
Potassium (K)	1.1	1.4	1.5	2.7	3.1
Bicarbonate (HCO_3)	194	140	164	165	158
Sulfate (SO_4)	92	53	40	31	23
Chloride (Cl)	18	8.5	9.0	7.8	6.4
Fluoride (F)	0.0	0.0	0.0	0.1	0.0
Nitrate (NO_3)	4.3	9.2	11	16	8.6
Phosphate (PO_4)	0.0	0.0	0.0	0.0	0.0
Dissolved Solids (residue at 180°C)	359	400	231	230	244
Calcium, magnesium hardness as $CaCO_3$	263	196	173	170	164
Noncarbonate hardness as $CaCO_3$	109	94	53	43	31
Specific Conductance (micromhos at 25°C)	633	593	408	390	298
Temperature (°C)	11	11	11	12	12
pH Laboratory	7.8	7.8	7.8	8.1	8.0
Field	7.4	7.3	7.5	7.7	7.5
Number of analyses used:	7 to 11	5 to 8[1]	10 to 22	11 to 26	5 to 8

[1] Includes analytical data for undifferentiated part of formation.

Data Source: Wood et al., 1972.

Finally, although the Hardyston aquifer is a reliable source for a domestic water supply, it is not recommended. The drilling and casing costs for a domestic well in the Hardyston formation are expensive. In addition, public or industrial supply wells are not recommended. Several drilling attempts may be necessary before a sufficient yield is produced, which is not economically sensible. The median concentrations of chemical constituents in groundwater from the Hardyston formation are contained in Table 4 (Wood, 1972).

Table 4. Median concentrations of chemical constituents in groundwater from the Hardyston formation.

Constituent	Hardyston Formation
Silica (SiO_2)	13
Iron (Fe), total	.06
Manganese (Mn), total	.00
Zinc (Zn)	---
Calcium (Ca)	4.1
Magnesium (Mg)	1.6
Sodium (Na)	2.8
Potassium (K)	1.4
Bicarbonate (HCO_3)	30
Sulfate (SO_4)	2.4
Chloride (Cl)	1.4
Fluoride (F)	0.0
Nitrate (NO_3)	3.4
Dissolved solids (residue at 180°C)	61
Calcium, magnesium hardness (as $CaCO_3$)	17
Noncarbonate hardness (as $CaCO_3$)	0.0
Specific Conductance (micromhos at 25°C)	60
pH	7.6

Data Source: Wood et al., 1972.

Community water supplies within the Monocacy Creek watershed may be protected on a voluntary basis by each municipality. The LVPC has prepared a "Wellhead Protection Model Ordinance" as part of the EPA's *Wellhead Protection Demonstration Project.* This ordinance is designed to protect water supply wells by dealing with zoning, subdivision, land development, and special provision issues. The ordinance defines three areas of protection surrounding a well. *Wellhead protection area 1* (WHPA 1), consists of a small circular area with a radius between 100 and 400 feet around the well. *Wellhead protection area 2* (WHPA 2), is a larger region through which water is drawn to the well by pumping. This region is also referred to as the zone of diversion. The last zone, *Wellhead protection area 3* (WHPA 3), is the land area that naturally drains to the well based on topography. This zone is also referred to as the zone of contribution. The definitions of these wellhead protection areas are based upon the DEP regulations that became effective October 8, 1994 for new wells. Activities that are regulated within these WHPAs include light industry, agriculture, storage tanks, sewage disposal, land developments, solid waste disposal, manufacturing, injection wells, sewage sludge land application, and subdivisions. These activities are regulated most stringently in WHPA 1, and to a progressively lesser degree in WHPAs 2 and 3. Wells with

defined WHPAs within the watershed are shown on Figure 11 (Lehigh Valley Planning Commission, 1996).

2.3. Hydrologic Budget

A preliminary hydrologic budget for the Monocacy creek watershed was prepared by LVPC. A complete copy of this report can be obtained from LVPC. This report defines a hydrologic budget as the "accounting of the fate of precipitation as surface runoff, soil moisture, groundwater flow, and return to atmospheric moisture." To complete a water budget one must numerically balance the water entering the watershed to the water leaving the basin through various phases of the hydrologic cycle, plus or minus any change in storage. A typical equation for determining a hydrologic budget is shown below.

$$P=R+ET+U\pm SMS\pm GWS\pm D$$

where,

P is Precipitation expressed in inches of water
R is surface Runoff or streamflow
ET is EvapoTransporation or water re-entering the atmosphere either directly through evaporation or indirectly through plant uptake
U is groundwater Underflow
SMS is the change in Soil Moisture Storage during the time period
GWS is the change in Groundwater Storage during the time period
D is Diversions of water in or out of the watershed by man

Surface flow data used in preparing the budget report was obtained from USGS gaging stations on the Monocacy from 1949 to the present. Annual precipitation, annual baseflow, and annual baseflow as a percentage of streamflow were also analyzed for the same period to identify any significant hydrologic trends. Baseflow is the portion of streamflow contributed from groundwater. Due to the very limited amount of groundwater flow data available, sophisticated water budget analyses were not possible within the scope of this project.

A report prepared by USGS investigator Charles Wood, was contained in *Water Resources of Lehigh County, Pennsylvania.* In this report known as the "Wood Study", a water budget was calculated for Monocacy Creek for the years 1946 to 1962. A simplified version of the above equation was used to compute the budget because there was no significant changes in soil moisture or ground water storage during this time, allowing these factors to be eliminated from the equation. There were also no known diversions in or out of the watershed during this period of record. The resulting equation was:

$$P=R+ET+U$$

Substituting data from the period of record yielded the following equation and results:

45.72 inches=15.60 inches+26.4 inches+ U and
U=3.72 inches

This means that from approximately 46 inches of precipitation that fell on the watershed, only 3.7 inches of water that did not evaporate, were not recorded by the gaging station. This water contributed to underflow that would resurface by the mouth of the creek at the Lehigh River. This water budget represents the Monocacy watershed at a time of near equilibrium. Precipitation levels were near normal and land developments over the short 16-year period shouldn't have had much effect on hydrology. Present concerns are that the watershed will not stay in equilibrium as development occurs at heightened rates. The budget developed for this time period should be used to compare studies of more current periods. However, since data for non-equilibrium periods (periods involving changes in soil moisture and groundwater storage) is not readily available, the best assessment of impacts from development requires a more in-depth evaluation of stream gage data (USGS, 1972).

The key findings that were reported based on analysis of the water budget and data collected from 1949 to 1996 are as follows:

- Precipitation, streamflow, and baseflow (portion of streamflow contributed by groundwater), appear to follow cyclical patterns throughout the period of record.
- Trend analyses indicate a fairly constant level of precipitation with only a very slight increasing trend from 1949 to 1996.
- Trend analyses indicate that the portion of precipitation that becomes streamflow is increasing over time.
- Trend analyses indicate that, within the limitations of the method used to quantify baseflow, the portion of precipitation that becomes baseflow is also increasing over time.
- Trend analyses indicate that baseflow represents a fairly constant proportion of streamflow over time.
- No evidence is provided by this evaluation to suggest that baseflow or groundwater levels in the watershed are decreasing over time, however, more rigorous trend analyses would be required to verify these preliminary findings, especially the unexpected trend of increasing baseflows.

The recommendations made by LVPC with regard to this project include:

- Evaluation of baseflow separation techniques used should be conducted to determine if the methodology is providing reasonable results for the Monocacy Creek situation.
- A more rigorous water budget and trend analysis should be prepared to verify these preliminary trends.

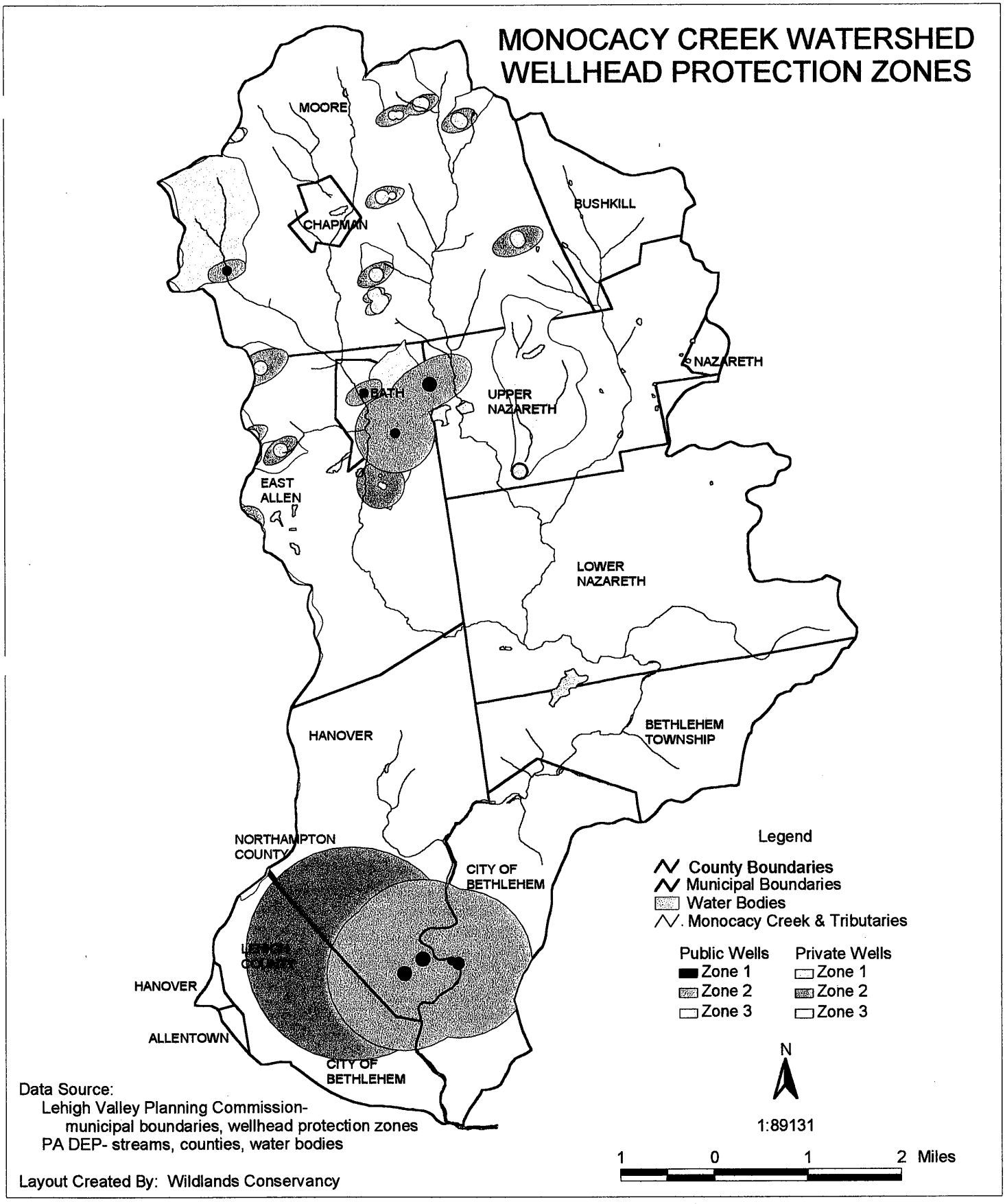


Figure 11. Protection zones for public and private wells within the Monocacy Creek watershed.

3.0. BIOLOGICAL RESOURCES

3.1. Flora and Fauna

The Pennsylvania Natural Diversity Inventory (PNDI), a cooperative program of DEP, The Nature Conservancy, and Western Pennsylvania Conservancy, maintains records of the state's rare, endangered, or otherwise significant flora and fauna. With regard to the Monocacy Creek watershed, there are no species of special concern that have been spotted and consequently reported to PNDI. However, to date, there has been no directed effort to inventory the flora and fauna present. Therefore some threatened, endangered, or species of special concern to the area, may exist within the watershed that have not yet been discovered or identified. The Nature Conservancy has confirmed that five historical species are listed on their records, none of which have been sighted for at least the past twenty years. PNDI is currently working on a survey of Lehigh and Northampton Counties.

An inventory was conducted by the Bureau of Forestry in 1988 to identify trees and shrubs present at Burnside Plantation. The results of this investigation can be found on Table 5. In addition, a partial list of vegetative species suitable for planting in the Monocacy watershed is located in Table 6. This list is supplied so that property owners can make sound decisions as to what species would be best suited to plant along the Monocacy. Careful consideration to species planted is necessary to avoid planting of invasive or exotic species, which are detrimental to the ecology of the riparian habitat. This issue is discussed in more detail in section 7.6, which also contains a partial list of invasive species.

In general it is noted that the Monocacy Creek watershed has a healthy wildlife population that is characteristic of Eastern Pennsylvania. However, a report entitled " Biological Diversity in the Monocacy Creek Watershed", compiled by Karen Dolan in 1998 noted that very little research exists on the ecology of Monocacy Creek compared to the nearby Bushkill Creek, which runs through Jacobsburg Environmental Education Center. Therefore characterizing the flora and fauna of the watershed proved extremely difficult. A summary of the results of her data compilation is contained below.

The Monocacy corridor is well-known as a bird habitat. It plays an important role in the migration of birds from winter grounds to northern nesting sites. Linda Freedman, local birding expert and chairperson of the Lehigh Valley Audubon Society's conservation committee, reported the following findings within Monocacy watershed (Dolan, 1998).

- Out of 15 species listed on National Audubon Society's 1998 Watch List and noted as possible to be seen in PA, 10 have been spotted in the Monocacy Nature Center. Watch List species are species of special concern that have shown serious decline in recent years and require preservation of their habitat for continued existence. The Wood Thrush is one of these species and is known to nest within the watershed. It is highly treasured as the most beautiful avian songster in North America.
- The Seaside Sparrow is a Watch List species not even probable in PA that was once spotted in the Nature Center in 1982.

- In total, 166 bird species were observed by Ms. Freedman between 1993 and 1997 at the Nature Center, and another 131 were noted in Archibald Johnston Conservation Area. Of these species, 30 are known to nest at the nature center and another 21 nest at Johnston Conservation Area. Another 17 species are likely to nest in the vicinity, however confirmation is still needed.

Valuable habitat areas within the watershed include the Monocacy Nature Center, sometimes referred to as the Monocacy Sanctuary, and a majority of the corridor from Lower Nazareth Township to the confluence with the Lehigh River (Kita and Dolan, 1998).

Table 5. Trees and shrubs identified by Bureau of Forestry in 1988 at Burnside Plantation.

Common Name	Scientific Name
1. American Sycamore	1. Platanus occidentalis
2. Apple	2. Malus pumila
3. Black Locust	3. Robinia pseuodoacacia
4. Black Walnut	4. Juglans nigra
5. Box Elder	5. Acer negundo
6. Butternut Hickory	6. Carya cordiformis
7. Forsythia	7. Forsythia
8. Grape	8. Vitus
9. Hackberry	9. Celtis occidentalis
10. Mulberry	10. Morus
11. Pear	11. Pyrus communis
12. Red Maple	12. Acer rubrum
13. Red Oak	13. Quercus rubra
14. Scotch Pine	14. Pinus sylvestris
15. Slippery Elm	15. Ulmus rubra
16. Spruce	16. Picea
17. Staghorn Sumac	17. Rhus typhina
18. Tartarian Honey Suckle	18. Lonicera tatarica
19. Thornless Honey Suckle	19. Lonicera
20. Tree of Heaven	20. Ailanthus altissima
21. White Cherry	21. Prunus
22. White Oak	22. Quercus alba
23. White Pine	23. Pinus strobus
24. Wild Cherry	24. Prunus serotina
25. Virginia Creeper	25. Parthenocissus quinquefolia

Data Source: Baker, 1988.

Table 6. Partial list of native vegetative species recommended for planting within the Monocacy Creek watershed.

Common Name	Scientific Name
WILDFLOWERS	
Swamp Milkweed	Asclepias incarnata
Purple-stemmed Aster	Aster puniceus
Schreber's Aster	Aster schreberi
Turtlehead	Chelone glabra
Water-willow	Decodon verticillatus
Boneset	Eupatorium perfoliatum
Rough Bedstraw	Galium asprellum
Ditch Bedstraw	Galium palustre
Cleavers, Bedstraw	Galium tinctorium
Common Sneezeweed	Helenium autumnale
Showy Hibiscus	Hibiscus leavis
Rose-mallow	Hibiscus moscheutos
Canadian St.-John's-wort	Hypericum canadense
Pale St.-John's-wort	Hypericum ellipticum
Dwarf St.-John's-wort	Hypericum mutilum
Dwarf Crested Iris	Iris cristata
Slender Blue Flag	Iris prismatica
Northern Blue Flag	Iris versicolor
Cardinal-flower	Lobelia cardinalis
Great Lobilia	Lobelia siphilitica
Water Horehound	Lycopus uniflorus
Bugleweed	Lycopus virginicus
Allegheny Monkey-flower	Mimulus ringens
Wild Forget-me-not	Mysotis laxa
False Dragonhead	Physostegia virginiana
Mountain-mint	Pycnanthemum tenuifolium
Cutleaf Coneflower	Rudbeckia laciniata
Mad-dog Skullcap	Scutellaria lateriflora
Blue Vervain	Verbena hastata
New York Ironweed	Vernonia noveboracensis
GRASSES AND NUT SEDGES	
Creeping Bentgrass	Agrostis palustris
Short-awned Foxtail	Alopecurus aequalis
Brome Grass	Bromus altissimus

Table 6 (Cont.)...

Common Name	Scientific Name
Canada Bluejoint	Calamagrostis canadensis
Reedgrass	Calamagrostis cinnoides
Wood Reedgrass	Cinna arundinacea
Tufted Hairgrass	Deschampsia cespitosa
Riverbank Wild-rye	Elymus riparius
Virginia Wild-rye	Elymus virginicus
Lovegrass	Eragrostis frankii
Creeping Lovegrass	Eragrostis hypnoides
Rattlesnake Mannagrass	Glyceria canadensis
Reed Meadowgrass	Glyceria maxima
American Mannagrass	Glyceria grandis
Slender Mannagrass	Glyceria melicaria
Floating Mannagrass	Glyceria septentrionalis
Fowl Mannagrass	Glyceria striata
Rice Cutgrass	Leersia cryzoides
White Cutgrass	Leersia virginica
Spike Muhly	Muhlenbergia glomerata
Satin Grass	Muhlenbergia mexicana
Panic-grass	Panicum stipitatum
Reed Canary-grass	Phalaris arundinacea
Fowl Bluegrass	Poa palustris
Pale Mannagrass	Torreyochloa pallida
Umbrella Sedge	Cyperus dentatus
False Nutsedge	Cyperus strigosus
SEDGES	
Sedge	Carex baileyi
Sedge	Carex bromoides
Sedge	Carex canescens
Sedge	Carex comosa
Short Hair Sedge	Carex crinita
Sedge	Carex cristatella
Sedge	Carex davisii
Sedge	Carex echinata
Prickly Sedge	Carex emoryi
Sedge	Carex frankii
Sedge	Carex granularis

Table 6 (Cont.)...

Common Name	Scientific Name
Sedge	Carex gynandra
Sedge	Carex hystericina
Sedge	Carex lacustris
Sedge	Carex laevivagnata
Wooly Sedge	Carex lanuginosa
Sedge	Carex leptalea
Sedge	Carex lupulina
Sedge	Carex lurida
Sedge	Carex pellita
Sedge	Carex prasina
Beaked Sedge	Carex rostrata
Broom Sedge	Carex scoparia
Sedge	Carex stipata
Sedge	Carex straminea
Tussock Sedge	Carex stricta
Sedge	Carex torta
Sedge	Carex tribuloides
Sedge	Carex trichocarpa
Sedge	Carex utriculata
Fox Sedge	Carex vulpinoidea
Spike Rush	Eleocharis erythropoda
Creeping Spike-rush	Eleocharis palustris
Spike Rush	Eleocharis tenuis
Soft Rush	Juncus effusus
Three-square	Scirpus americanus
Black Bulrush	Scirpus atrovirens
Great Bulrush	Scirpus acutus
Wool-grass	Scirpus cyperinus
River Bulrush	Scirpus fluviatilis
Bulrush	Scirpus Hattorianus
Bulrush	Scirpus pendulus
Bulrush	Scirpus polyphyllus
Wood Bulrush or Clubrush	Scirpus expansus
Soft-stem Bulrush	Scirpus validus
Bur-reed	Sparganium americanum

Table 6 (Cont.)...

Common Name	Scientific Name
TREES	
Boxelder	Acer negundo
Red Maple	Acer rubrum
Silver Maple	Acer saccharinum
Sugar Maple	Acer saccharum
Black (Sweet/Cherry) Birch	Betula lenta
River Birch	Betula nigra
Paper Birch	Betula papyrifera
American Hornbeam	Carpinus caroliniana
Butternut Hickory	Carya cordiformis
Shagbark Hickory	Carya ovata
Hackberry	Celtis occidentalis
Redbud	Cercis canadensis
Fringetree	Chionanthus virginicus
Flowering Dogwood	Cornus florida
Persimmon	Diospyros virginiana
American Beech	Fagus grandifolia
White Ash	Fraxinus americana
Green Ash*	Fraxinus pennsylvanica
Honey Locust	Gleditsia triacanthos
American Holly	Ilex opaca
Black Walnut	Juglans nigra
Eastern Redcedar	Juniperus virginiana
Sweetgum	Liquidambar styraciflua
Tulip Poplar	Liriodendron tulipifera
Blackgum	Nyssa sylvatica
Hop-Hornbeam	Ostrya virginiana
White Pine	Pinus strobus
American Sycamore	Platanus occidentalis
Balsam Poplar	Populus balsamifera
Easter Cottonwood	Populus deltoides
Bigtooth Aspen	Populus grandidentata
Quaking Aspen	Populus tremuloides
White Oak	Quercus alba
Swamp White Oak	Quercus bicolor
Bur Oak	Quercus macrocarpa
Pin Oak	Quercus palustris
Willow Oak	Quercus phellos
Red Oak	Quercus rubra
Black Locust	Robinia pseuodoacacia

Table 6 (Cont.)...

Common Name	Scientific Name
Black Willow	Salix nigra
American Basswood	Tilia americana
Eastern Hemlock	Tsuga canadensis
American Elm	Ulmus americana
SHRUBS	
Smooth Alder	Alnus serrulata
Shadblow Serviceberry	Amelanchier canadensis
False Indigo	Amorpha fruitcosa
Red Chokeberry	Aronia arbutifolia
Black Chokeberry	Aronia melanocarpa
Eastern Baccharis	Baccharis halimifolia
Buttonbush	Cephalanthus occidentalis
Sweet Pepperbush	Clethera alnifolia
Silky Dogwood	Cornus amomum
Stiff Dogwood*	Cornus foemina
Gray Dogwood*	Cornus racemosa
Roundleaf Dogwood	Cornus rugosa
Red-osier Dogwood	Cornus sericea
American Hazlenut	Corylus americana
Witch-hazel	Hamamelis virginiana
Common Rose Mallow	Hibiscus moscheutos
Winterberry	Ilex verticillata
Virginia Sweetspire	Itea virginica
Leucothoe*	Leucothoe axillaris
Spicebush	Lindera benzoin
Fetterbush*	Lyonia lucida
Common Ninebark	Physocarpus opulifolius
Common Chokecherry	Prunus virginiana
Swamp Azalea	Rhododendron viscosum
Shining sumac	Rhus copallina
Smooth Sumac	Rhus glabra
Swamp Rose	Rosa palustris
Virginia Rose	Rosa virginiana
Allegheny Blackberry	Rubus allegheniensis
Bebb's Willow	Salix bebbiana
Pussy Willow	Salix discolor
Coyote Willow*	Salix exigua
Prairie Willow	Salix humilis
Sandbar Willow*	Salix interior

Table 6 (Cont.)...

Common Name	Scientific Name
Shining Willow	Salix lucida
Elderberry	Sambucus canadensis
Redberry Elder	Sambucus racemosa ssp. pubens
Meadowsweet Spirea	Spiraea alba
Hardhack Spirea	Spiraea tomentosa
High Bush Blueberry	Vaccinium corymbasum
Common Highbush Blueberry	Vaccinium corymbosum
Arrowwood	Viburnums dentatum
Nannyberry	Viburnum lentago
Blackhaw	Viburnum prunifolium
American Cranberry Bush	Viburnum trilobum
AQUATICS AND MISCELLANEOUS	
Broad-leaf Arrowhead "Duck Potato"	Sagittaria latifolia
Bull Tongue Arrowhead	Sagittaria loncifilia
Jack-in-the-Pulpit	Arisaema triphyllum
Green Dragon	Arisaema dracontium
Skunk Cabbage	Sypolcarpus foetidus
Arrow Arum	Peltandra virginica
Pickerelweed	Pontederia cordata
Turk's Cap Lily	Lilium superbum
Canada Lily	Lilium canadense
Trout Lily	Erythronium americanum
Lady tresses	Spirantres
Lizard's tail	Saururus cernuus
American Lotus	Nelumbo lutea
Marsh Marigold	Caltha palustris

Data Source: Wildlands Conservancy (work in progress).

Dolan's report also compiled reptile and amphibian records from a study conducted by Jeanne Knepper, Chemistry and Environmental teacher at Palmerton High School. The study was conducted from 1994 to 1997 and yielded the identification of twelve species of salamanders, frogs, and turtles as follows.

Salamanders: Redback salamander, Two-lined salamander, Red spotted newt
Frogs: American toad, Fowler's toad, Pickerel frog
Turtles: Eastern painted turtle, Midland painted turtle, Eastern map turtle, Musk turtle, and Red-eared slider.

Dolan's quest for information on flora species yielded only one species of special interest, red algae. This species is found exclusively in Monocacy Creek. It is likely that other significant species are present within the watershed and have not yet been located or identified. The limited information available on this topic points to the need for further investigation.

3.2. Fishery

Due to the limestone bedrock underlying the lower portion of the creek, the Monocacy maintains a thriving population of various fish species. Three sections of the Monocacy Creek are stocked annually with trout. The stretch of the creek flowing through Bath Borough is stocked with 1,800 brown and rainbow trout on a yearly basis. A three-mile section flowing through downtown Bethlehem to Sand Island is stocked with 3,200 brook and rainbow trout annually. Lastly a section 2.4 miles long is located outside the City of Bethlehem and is stocked with 2,800 brown, rainbow, and brook trout annually (Attardo, 1997).

In addition, the Monocacy is treasured for its 1.9 mile stretch of trophy trout fishing, extending from the Gertrude Fox Conservation Area, north of Bethlehem's Center Street Bridge, to Illick's Mill Dam. This stretch of the Monocacy Creek was added to the Trophy Trout Program in 1988. Although the count of large trout is low, possibly due to insufficient habitat conditions, the Monocacy population of wild brown trout has jumped tremendously as a result of the trophy trout designation. In order to maintain the wild brown trout population, special fishing restrictions are applied within the Trophy Trout section of the creek (Attardo, 1997). These restrictions include the following:

- Use of artificial lures only, which may be used with spinning or fly fishing gear, is permitted.
- Molded fascimiles or replicas of insects, earthworms, fish eggs, fish, or any invertebrate or vertebrate; either alone or in combination with other materials is strictly prohibited.
- Use or possession of natural bait or any other device natural or synthetic, capable of catching fish, other than artificial lures, is prohibited.
- There is no closed fishing season.
- Minimum catch size is 14 inches, when caught or possessed between 8 AM of opening day of regular trout season and midnight of Labor Day.
- There is a daily creel limit of two trout of any species that may be caught or possessed from 8 AM on opening day of trout season to midnight on Labor Day. The remainder of the year until 8 AM on the opening day of trout season the following year, trout may not be fished.

- Taking of baitfish or fishbait is prohibited.
- A Trout/Salmon permit is required.

There have also been scattered reports of native brook trout inhabiting Monocacy Creek. Other fish that are commonly found in the Monocacy Creek include the Horned Dace, Black-nosed Dace, Sunfish, American Eel, Johnny Darter, Common Shiner, Bluegill, and Common Sucker.

3.3. Macroinvertebrate Sampling Results

Prior to this study, reports showed that the most common organisms in the Monocacy were caddisflies, black flies, scuds, water penny (beetles), midges, sow bugs, and may flies. A recent study was conducted to confirm this information from previous reports and also to identify any changes or threats to the macroinvertebrate community of Monocacy Creek. This study was conducted during the 1997/98 school year by students at Muhlenberg College under the direction of Dr. Patricia Bradt, Director of the Biology Department. Sampling locations from this study are shown on Figure 12. A complete copy of the report can be obtained by contacting Wildlands Conservancy. The major results and conclusions of this study are reported below.

- EPT indicies, which measures the number of different genera of mayflies, stoneflies, and caddisflies, were very comparable for stations 3 and 4. However, the total number of pollution sensitive species was lower at station 4, which was dominated by true flies (chironomidae).
- In addition to station 4, station 16 also had high numbers of chironomidae. This species can be opportunistic and very tolerant of pollution. It frequently dominates habitats of enrichment, causing concern for stretches of the Monocacy flowing through stations 4 and 16. Station 4 is downstream of a sewage treatment plant and station 16 is in close proximity to a golf course. Both of these land uses may be contributing nutrient overloads to the stream and thus degrading water quality and ecological diversity.
- Another cause for concern is the change in the dominant organism found at site 16 as reported from the 1977 study by Jane Miller and the 1997 study. In October 1977 the dominant organism was the caddisfly (hydropsyche). However, in October 1997 the dominant organism was the beetle (stenelmus) and in February 1998 that organism was the true fly (chironomidae). These organisms are more tolerant of pollution than the previously dominant species. Further studies should be conducted to verify this change and determine its cause.

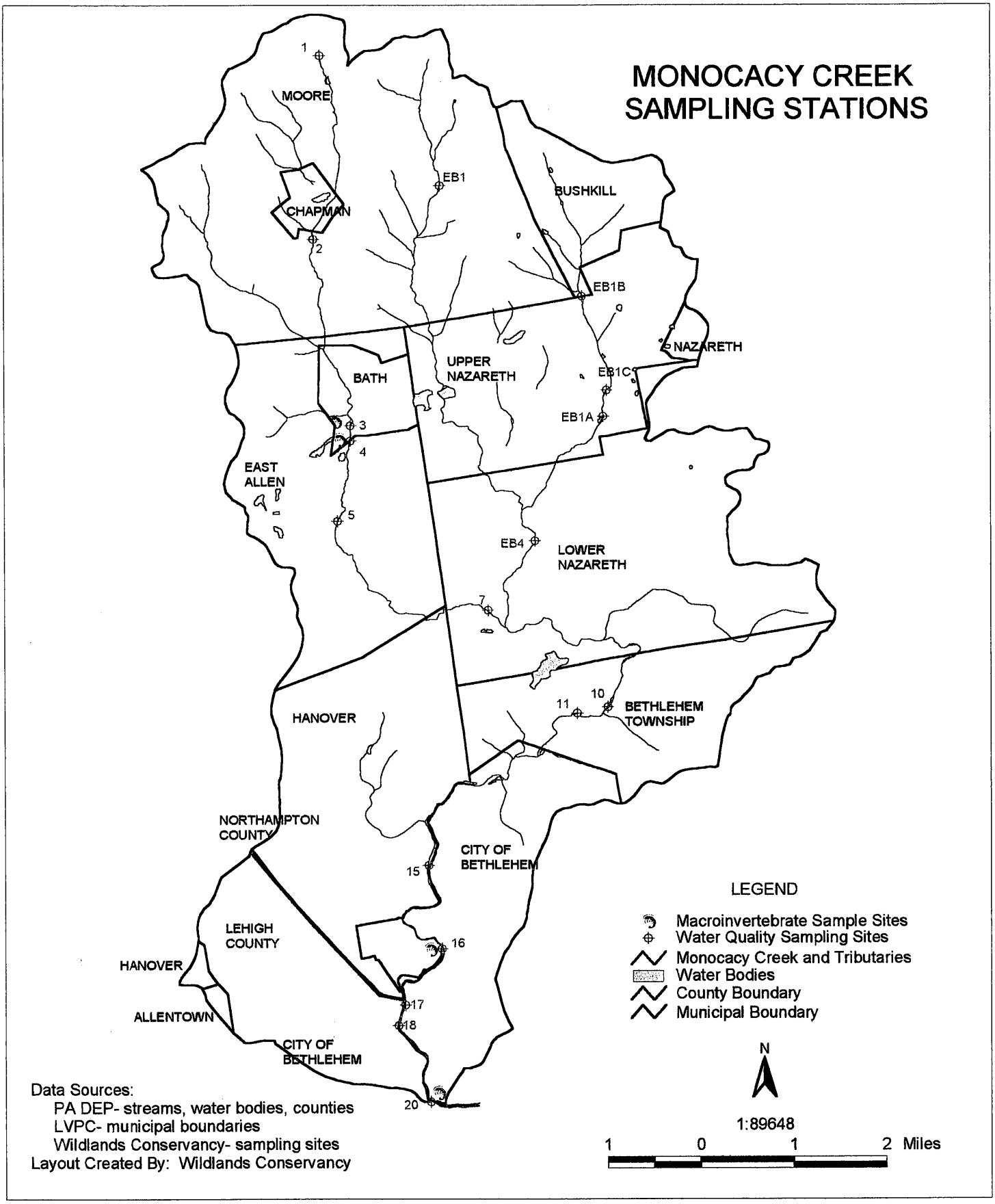


Figure 12. Water quality and macroinvertebrate sampling locations along Monocacy Creek.

4.0. CULTURAL RESOURCES

4.1. Historical/Archeological Background

The Monocacy Creek Watershed is an area rich in history, having been occupied for many centuries. The Monocacy Creek played a vital role in determining locations for settlement and subsequent development of the region. Historical and archeological evidence have shown that the watershed was occupied and utilized by an unknown number of Native American tribes for at least ten centuries before the arrival of the Lenni-Lenape. Supporting evidence of this inhabitance is vague as there are no written records; however, the abundance of stone artifacts found throughout the county have been dated back at least 10,000 years (Miller, 1939).

The Lenni-Lenape (meaning "real" or "original" people) are believed to have inhabited Pennsylvania during the early 1700's along with small bands of Shawnees, Nanticokes, and Mohicans. Originally the Lenni-Lenape were members of the American Indian People of the Ottawa river valley, who occupied areas of southern Ontario and some parts of Michigan (Lenni-Lenape Historical Society). They are ancestors of the Algonquins who covered a more extensive area than any other family in the 1600's. The Algonquins and subsequent ancestors believed that the earth and its resources should be held with great respect, and that it was their responsibility to care for and nurture the earth (Lenni-Lenape Historical Society). Stewardship could be seen in their farming, hunting, and fishing practices, which left little permanent impact upon the land (Lenni-Lenape Historical Society). The Lenni-Lenapes were originally a hunter and gatherer tribe who turned to farming approximately 1000 years before the arrival of Europeans (Lenni-Lenape Historical Society). When some of the Algonquin people broke off from their founding tribe and moved eastward, they settled in three distinct geographic regions (Miller, 1939). The Unami settled in the Lehigh Valley and had a turtle totem (Miller, 1939).

Within Pennsylvania, the Lenni-Lenape had only a few permanent villages that were located in Northampton County. There is strong evidence to support that a Unami village existed in the Monocacy Creek watershed, in the vicinity of Christian Springs. The establishment was named Nolemattink meaning "where the silkworm spins". The name was most likely derived from the cocoonery established near this area in 1752 by Reverend Bader. Historical documentation shows that Nolemattink had been established prior to the tenth century, before the domination of the Lenapes by the Iroquois (Miller, 1939).

The Lenni-Lenapes occupied the East Coast until the 17th and 18th centuries when the Europeans began to arrive in Pennsylvania (Martens, 1967). The Iroquois had fully overrun the Algonquin tribe by the time the Europeans settled in eastern Pennsylvania. In derision, the European settlers renamed the Lenapes the Delaware Indians and forced them westward (Martens, 1967).

The Moravians were the first Europeans to settle within the Monocacy Creek watershed. These German immigrants began to arrive in the watershed in1683. The Moravians were first welcomed to Pennsylvania in1722. They settled in the Nazareth area in 1740 and

moved to the Bethlehem area in 1741. The first house was completed in Bethlehem in 1741 and belonged to Count Zinzendorf and daughter Benigna. This date marks the beginning of a rich history within the watershed (Historic Bethlehem Inc., 1987).

The Moravians established an industrial center in what is now the City of Bethlehem. The remains of the Moravian business district are marked by a number of historic buildings that have been protected and preserved by Historic Bethlehem Inc. The historic district serves as a feature attraction for tourists visiting the City of Bethlehem. A major focus of the historic district is the first pumped municipal water system in the American Colonies that was constructed in 1755 (Historic Bethlehem Inc., 1987). The Monocacy Creek was diverted through these waterworks to turn a large waterwheel that provided the necessary pumping of spring water uphill to Bethlehem's living quarters (Historic Bethlehem Inc., 1987). The original waterworks were reconstructed in 1762 (Historic Bethlehem Inc., 1987). The associated spring house is a preserved historic structure (Historic Bethlehem Inc., 1987). The Waterworks is listed in the National Register of Historic Places, registered as a National and Local Historic Civil Engineering Landmark, and an American Waterworks Landmark (Historic Bethlehem Inc., 1987). Historic sites and structures within the watershed that are listed on the National Register of Historic Places are summarized in Table 7, including the name, address, and brief description of each site's historic significance. The location of these historic places can be seen on Figure 13.

Another historical attraction within the Monocacy watershed is the recently renovated Burnside Plantation (Figure 14). Burnside Plantation is a 6.5 acre property that composes the last remaining farm within the city limits of Bethlehem, Easton, or Allentown (Burnside Plantation Inc.). In 1986 the property was preserved for restoration of the 1748 to 1848 plantation, which operated on a collective basis known as "The Economy" (Burnside Plantation Inc.).

The Pennsylvania Historical and Museum Commission, Bureau of Historic Preservation was consulted to identify other cultural resources, including historical and archeological sites, within the watershed. The following account was provided:

> The Monocacy Creek Watershed's rich heritage is reflected in files that list twenty-three prehistoric archeological sites, eleven historic-period archeological sites and three properties listed in the National Register of Historic Places. Without question, these are not the only cultural resources located within the watershed boundaries, but just those currently on record. The archeological sites were recorded by local avocational archeologists or identified through project-specific field surveys in accordance with state and federal historic preservation mandates. The watershed area as a whole has not been systematically surveyed for such resources.

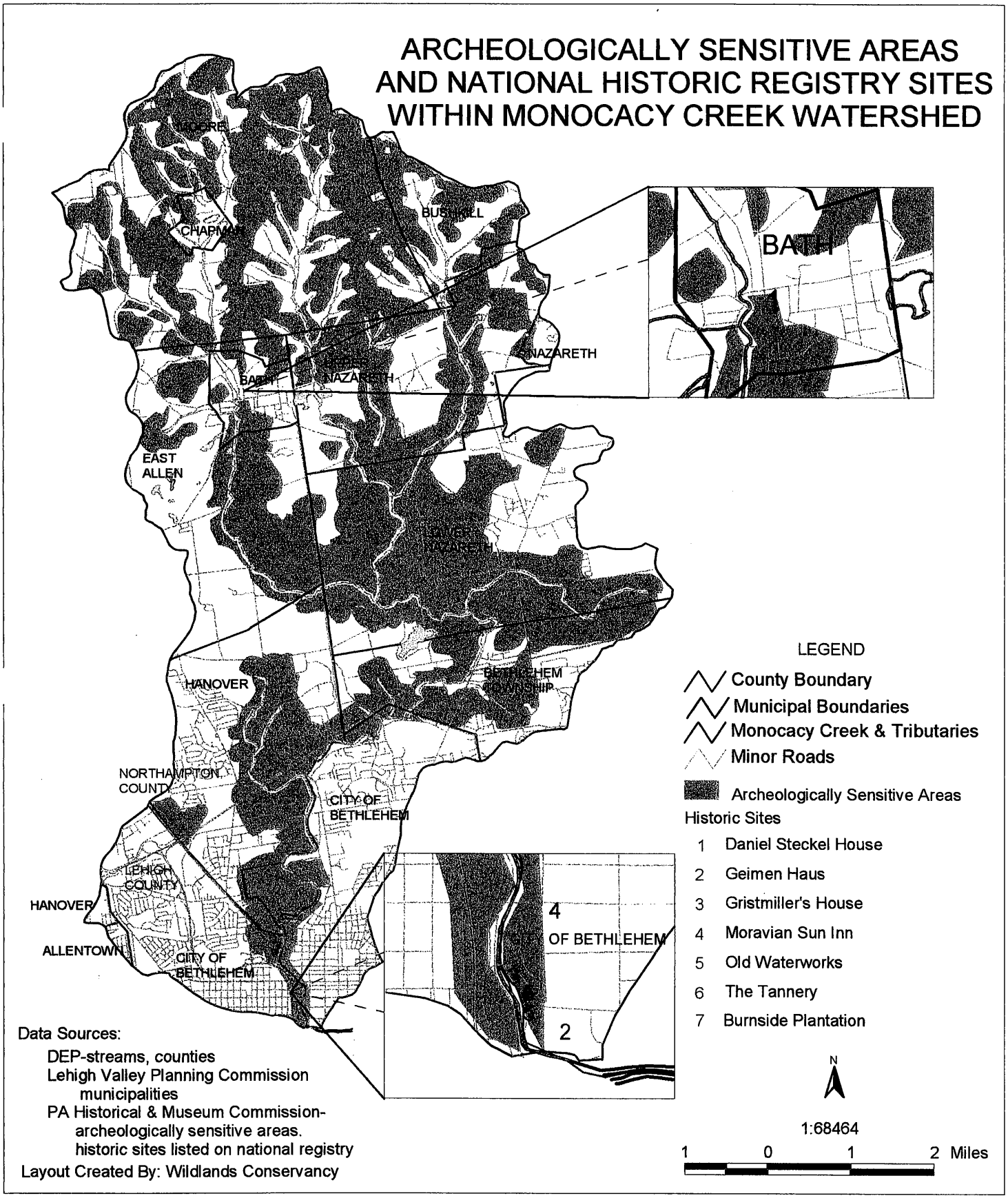


Figure 13. Sites listed on the "National Register of Historic Places" and archeologically sensitive areas within the Monocacy Creek watershed.

Table 7. Locations and descriptions of historic sites listed on the *National Register/Individual Properties and Historic Districts in Pennsylvania*, that are located within the Monocacy Creek Watershed.

SITE	LOCATION	DESCRIPTION
Daniel Steckel House	207 West Northampton St., Bath, PA	N/A
Central Bethlehem Historic District	Center City Bethlehem	18th Century industrial area that featured a tannery, waterworks, and various mills
Old Waterworks	East bank Monocacy Creek at Old York Rd., Bethlehem	log structure dated from 1754; stone replaced in 1762; housed 1st successful pumped water system in America; wooden pipes distributed water to community
Moravian Sun Inn	564 Main St., Bethlehem	built 1758; opened to public 1760; famous hostelry of 18th Century America; visited by Continental Congress Members; known for fine wine and excellent beer and cuisine; alterations entirely changed character over the years.
Gristmiller's House	459 Old York Rd., Bethlehem	built of stone in 1784; expanded 1831; one and one half story brick house characteristic of domestic architecture second quarter 19th Century.

Table 7. (Cont.)...

Geimen Haus	66 West Church St., Bethlehem	community house built in 1741; completed 1742; addition 1743; oldest building still standing in Bethlehem; may be largest log structure standing in U.S.; 2nd floor houses Bethlehem's 1st place of worship; rough cast 1800; clapboards added 1868.
The Tannery	Old York Rd.—Moravian Industrial Area, Bethlehem	3-story limestone structure built 1761; Monocacy Creek provided water needed for tanning processes.

Data Sources: Historic Bethlehem Inc., 1987.
Lehigh Valley Planning Commission, 1970.

Figure 14. Burnside Plantation, City of Bethlehem, PA.

Archeological resources are not randomly distributed across the landscape. Rather, these sites are closely related to certain environmental and topographic variables. The most important of these is proximity to water, including both active and extinct streams and springheads. Through extrapolation, the locations of known sites can effectively be used to predict the locations of currently unknown sites.

Archeologically sensitive areas, shown on the historical and archeological sensitivity map (Figure 13), are based on extrapolation of known site locational information. The shaded areas are considered to have potential for both historic and prehistoric archeological resources. As the sensitivity map indicates, much of the watershed area has good potential for such resources, and this is due in large part to hydrologic and topographic considerations. All of the sites included in current files are located within the shaded regions of the map.

The known prehistoric sites relate to the occupation of this area by Native Americans and date from approximately 8000 B.C. to the seventeenth-century A.D. The earliest recorded occupation dates to what is known as the Archaic Period of Pennsylvania prehistory. This period covers a time span from about 8000 B.C to 1000 B.C. Of the seven recorded Archaic period sites, four are located in floodplain settings or on stream terraces and three are located on upland flats or slopes.

The Woodland Period spans a time-frame from about 1000 B.C. to 1550 A.D. Currently, there are three Woodland sites recorded in the watershed. Two of these are in floodplain settings and one is in an upland location.

There are also three known multi-component prehistoric sites in the watershed. These sites represent the multiple occupation of a specific location by various prehistoric culture groups. Two of these sites are also located in or near a floodplain and one is on an upland slope.

The remaining ten recorded prehistoric sites are currently undateable, as no temporally diagnostic artifacts have as yet been reported from them. These sites could date to either of the aforementioned periods of prehistory and are found in the same types of settings as the more readily dateable sites.

The historic period archeological sites are related to farmstead occupations of the eighteenth and nineteenth centuries. Some of these sites are associated with extant structures, and some are not. All eleven of the recorded sites were identified through cultural resource surveys conducted in accordance with state and/or federal historic preservation programs. In general, yard and outbuilding areas of historic farms contain archeological information related to the occupation of the property in the past.

The Monocacy Creek watershed was first settled by Moravian sectarians in the 1740's. The city of Bethlehem contains a large Revolutionary War burial ground as well as a host of significant buildings dating to the eighteenth-century. In addition to the Bethlehem Historic District, the nearby Burnside Plantation and the Daniel Steckel House (located near Bath) are also listed in the National Register of Historic Places.

The presence of historical and archeological sites of interest indicates the irreplaceable cultural value found within the watershed. This rich history presents an important argument for preserving and maintaining the exceptional quality of the Monocacy Creek and its drainage basin. The dates of incorporation of each municipality in the watershed can be found in Table 8.

Due to the region's rich historical background, cultural resources are closely linked to historic sites within the Monocacy watershed. The Kemerer Museum, which displays such things as oriental rugs, antique furniture, Bohemian glass, grandfather clocks, and various works of art, is located in Bethlehem. The Moravian Museum is also located in Bethlehem and is housed by the Gemein Haus. Furniture, clocks, silver, musical instruments, religious articles, and Seminary art fashioned by the early Moravians are represented at the museum. In addition, Musikfest is held annually during the month of August. This nine day celebration of heritage is marked by music from around the world that is performed from noon until midnight at various sites within Bethlehem. Colleges and universities of the Lehigh Valley are another vital source of cultural entertainment for residents of the watershed (Lehigh Valley, PA, 1984).

Table 8. Incorporation dates of municipalities through which the Monocacy Creek flows.

MUNICIPALITY	INCORPORATION
Hanover Township	August 8, 1798 (Current boundaries set 1812)
Bushkill Township	August, 1813
Bath Borough	February 1, 1856 (First settled1758)
Bethlehem City	1741
Chapman Borough	1865
Moore Township	1765
East Allen Townhsip	1842
Bethlehem Township	1746
Lower Nazareth Township	April 22, 1807
Upper Nazareth Township	April 22, 1807

Data Source: Wright, 1988.

4.2. Socio-Economic Background

More than ninety percent of the Monocacy Creek watershed lies within Northampton County, with less than ten percent within Lehigh County. Socio-economic information for these two counties has been obtained from the Lehigh Valley Planning Commission (LVPC). The information is contained in the publication "Lehigh Valley Profile & Trends," which can be purchased from LVPC. The most recent census was taken in 1990, prior to that, a census was taken in 1980. All other data presented was forecasted by the LVPC. All census data and forecasted socio-economic information is contained in Appendix 2, available from Wildlands Conservancy.

Educational facilities are perhaps the most important economic resource to society. The resources and quality of school districts and universities within the watershed may have a major impact on the standard of living in the Monocacy watershed community. Within the watershed there are three public school districts, including Bethlehem Area, Northampton Area, and Nazareth Area School Districts. Moravian College and Northampton Area Community College are two universities located within the watershed.

The official LVPC Population Forecast predicts that growth between 1990 and 2000 in the Lehigh Valley will be approximately 7.0 percent. Bethlehem and Moore Townships are expected to experience major growth during the 1990s. In some instances, rapid population growth may lead to economic hardships such as an increase of unemployment rates, housing shortages, or lack of other facilities to meet the needs of a growing society. Expected land use changes correlate with the expected population increase. The most dramatic change appears to be an increase in land used for residential purposes.

Although unemployment rates continue to drop, the labor force is forecasted to expand for the ensuing decade. While the labor force is expanding, the number of employment opportunities in the fields of manufacturing, agriculture, and mining is steadily declining. Most employment opportunities available will be in the retail trade and service industries, which is consistent with trends across the nation. Many service employment positions might only provide minimal wages, which could impact the strength of the local economy.

Historically, the Monocacy Creek has been a center for industry within the Lehigh Valley. Today, Lehigh Valley industrial parks are still located within the Monocacy watershed. The abundance and location of major shopping centers, such as the one shown in Figure 15, within Northampton County also supports the importance of the Monocacy Creek watershed as a center for growth and development. This trend of growth and development within the watershed will result in less vacant land and more non-porous surfaces that will impact Monocacy Creek and threaten its quality. Flooding may also be a more common and severe problem as a direct result of increased development.

Figure 15. This shopping center shows how development is increasing non-porous surfaces throughout the watershed.

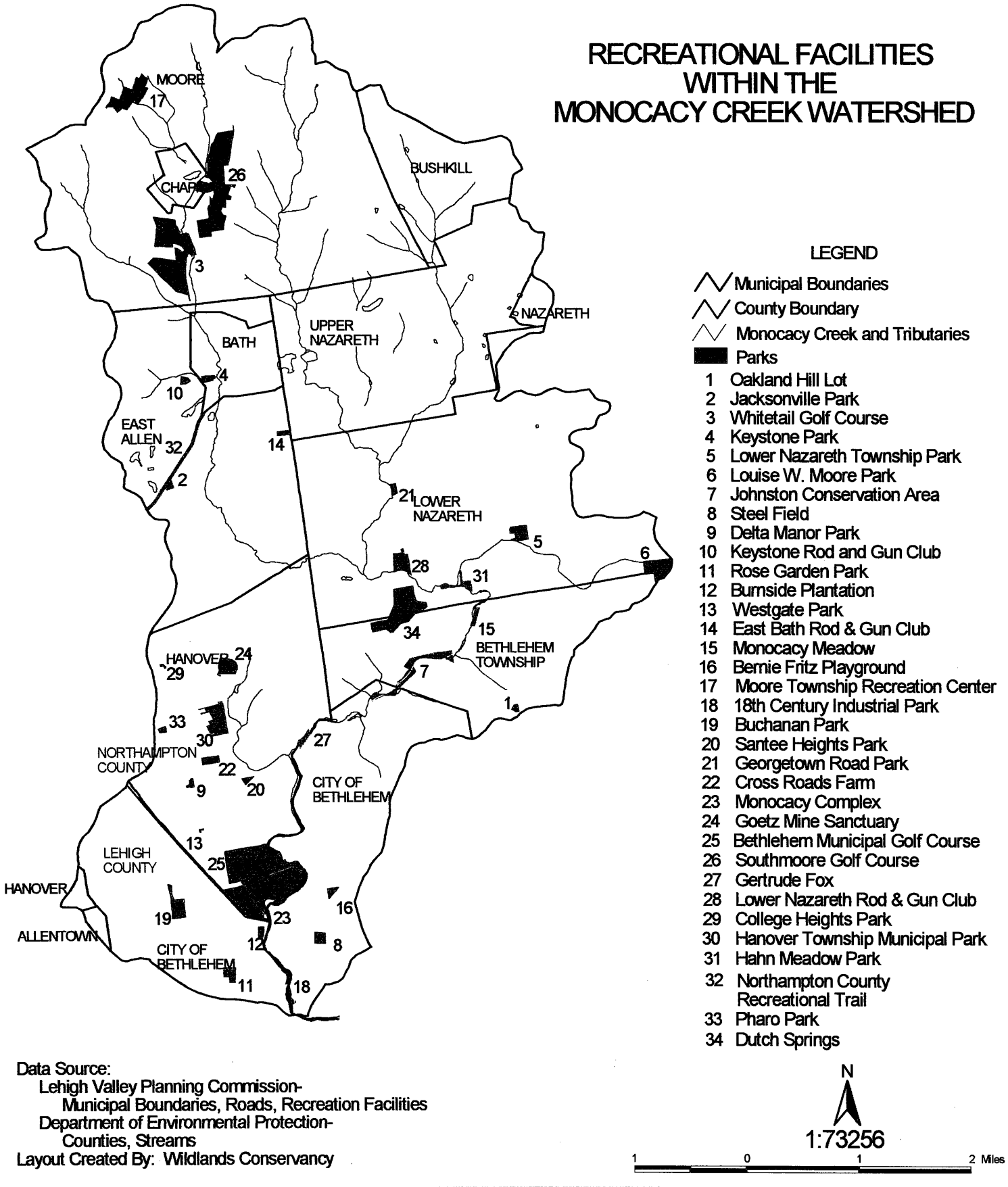
5.0. RECREATIONAL RESOURCES

5.1. Existing Facilities

Information on recreational facilities within the watershed was provided by LVPC in the form of digitized maps. Recreational facilities within the watershed, excluding playing areas and ball fields associated with schools, are shown on Figure 16.

Conservation parks, such as Archibald Johnston Conservation Area (Figure 17), along the Monocacy provide strong aesthetic value while preserving natural resources within the watershed. There are also three golf courses open to the public within the watershed. One course is located in the City of Bethlehem, and the other two are located in Moore Township. There is a positive correlation between population density and the distribution of parks throughout the watershed. An abundance of small active recreational facilities, such as ball fields, associated with developments and schools are also located within the watershed.

There appears to be a lack of recreational resources available within the drainage basin of the East Branch. However, low population density would limit benefits from parks in this portion of the watershed, which includes portions of Moore, Bushkill, and Lower and Upper Nazareth Townships. It is important though, to continue planning for future needs of the municipalities. Therefore, incorporation of recreational facilities in land use planning should take expected population growth into account, not only for the above townships, but for the entire watershed.



ıure 16. Recreation facilities within Monocacy Creek watershed, excluding school play areas.

Figure 17. Archibald Johnston Conservation Area, Bethlehem, PA.

5.2. Trail Potential

One of the most exciting opportunities within the Monocacy watershed today, exists in the abandoned railway system. The vast potential of this valuable asset in the Monocacy watershed is largely unrecognized. Abandoned railways can serve to link the watershed with a common means of environmental education and stewardship goals, historic preservation, and recreational activity. With the interest and devotion of the watershed community, unused railways could be transformed to trails for walking, hiking, horseback riding, etc. The creation of trails would greatly improve the ability of municipalities to meet the diverse recreational demands of their expanding populations.

Currently, there is an interest by Chapman Borough and Moore Township to convert old, unused railways to recreational trails and horse trails, respectively. The railways proposed for horse trails are located at the headwaters of the Main Branch Monocacy Creek. In addition, Bath Borough is hoping to acquire the easement rights of a former railroad bed to establish a walking/nature trail that would start at Creek Road, connecting to Volunteer Firefighters' Park, and proceed ½ mile north. The full extent of abandoned railways is currently unknown and is a key issue within the watershed. A feasibility study identifying all unused railways, possible linkages between them, and approximate cost of trail constructions would be an appropriate first step toward investigating the revitalization of this overlooked resource. Turning these tracks into railways would not only provide recreational opportunities, but also preserve this important aspect of Lehigh Valley history.

6.0. INSTITUTIONAL RESOURCES

In comparison to many other watersheds, the Monocacy is blessed in that its preservation is strongly supported by the local community. Two organizations that formed to deal specifically with Monocacy Creek and its preservation and enhancement are Monocacy Creek Watershed Association (MCWA) and Monocacy Creek Citizens' Action Committee (CAC). The CAC was appointed to develop and implement projects that help protect and rehabilitate Monocacy Creek. They provide input from the community and serve as a vehicle for working with and reporting to the City of Bethlehem. MCWA is a non-profit corporation that compliments the work of the CAC and often works hand in hand with them to achieve similar goals. MCWA monitors the ecological welfare of Monocacy Creek, advocates its preservation to appropriate authorities, and sponsors research and educational activities. These organizations work hard and are dedicated to protecting the creek and addressing the concerns of the community.

Other organizations working within the watershed include Monocacy Creek Chapter of Trout Unlimited (TU), Coalition for Alternative Transportation (CAT), and Historic Bethlehem Partnership. TU volunteers often work together with other conservation organizations to complete remediation projects and educate others about cold water conservation. CAT is working to improve accessibility and recreational opportunities throughout the Lehigh Valley for those who are physically challenged or using non-traditional forms of transportation, such as bicycling. Historic Bethlehem Partnership is a collaborative effort among Burnside Plantation Inc., Historic Bethlehem Inc., Kemerer Museum of Decorative Arts, and Bethlehem Area Chamber of Commerce Foundation, to interpret the heritage of Bethlehem, PA through programs and activities that reflect the community's diversity. It is also their goal to preserve and maintain important buildings and sites, irreplaceable artifacts, and written documents, to help explain the changes that have occurred in Bethlehem's first 250 years. This organization is a great benefit to the Monocacy community as many historic sites and structures are located on the banks of the creek.

The Historic Bethlehem Partnership is an excellent example of how other agencies and organizations can work together to achieve their goals. County, state, and federal institutions can work together and with local organizations to share resources and further expand their accomplishments. For example, Lehigh Valley Planning Commission (LVPC), which compiles and publishes numerous informational, analytical, and policy oriented planning reports on a variety of subject matter, could partner with entities such as Northampton County Parks and Recreation, CAT, and MCWA to investigate possibilities for creating a trail system through the watershed. Federal and and state agencies such as PA Fish and Boat Commission, PA Department of Environmental Protection (DEP), PA Department of Conservation and Natural Resources (DCNR), and Environmental Protection Agency (EPA), have many programs that offer grants or assitance for projects like the one mentioned above. The LVPC could also partner with an organization such as Wildlands Conservancy to work with municipalities to develop more environmentally sound ordinances in an effort to protect our water and other natural resources.

Local educational institutions, such as Moravian College (Figure 18), are another asset for protection of the watershed. They are a valuable source of volunteers for various improvement projects such as streambank stabilization work and tree plantings. In addition, students often perform research projects on the stream, which provide indispensable information on the stream from year to year.

The opportunities for partnerships are virtually endless. The key to developing effective partnerships is communication. Open communication should provide each institution with knowledge about other potential and ongoing projects and grant opportunities within the watershed. This would allow them to make sound decisions regarding the planning of future projects and the desired level of involvement with current projects. The results of projects should also be shared among institutions to educate people outside the responsible organization and to ensure that duplicate or excessive work is not performed.

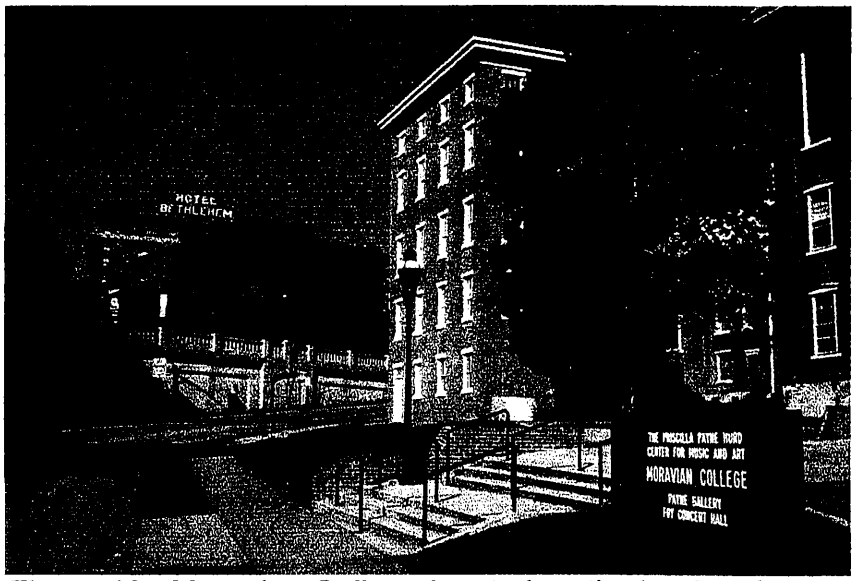


Figure 18. Moravian College located on the banks of Monocacy Creek, Bethlehem, PA.

7.0. WATERSHED ISSUES

7.1. Land Use

Land use statistics have been obtained from a geographic information system (GIS) coverage provided by LVPC. This information was used to assess the percentage of watershed surface area that each land use occupies. These percentages are shown in Figure 19. There is a distinct division of land use within the Monocacy Creek watershed. The northern 2/3 of the watershed is dominated by rural and agriculture uses, whereas the southern part of the watershed is dominated by residential use. Overall, agriculture accounts for approximately 45 percent of the land area and residential use occupies approximately 25 percent of the land area.

Local educational institutions, such as Moravian College (Figure 18), are another asset for protection of the watershed. They are a valuable source of volunteers for various improvement projects such as streambank stabilization work and tree plantings. In addition, students often perform research projects on the stream, which provide indispensable information on the stream from year to year.

The opportunities for partnerships are virtually endless. The key to developing effective partnerships is communication. Open communication should provide each institution with knowledge about other potential and ongoing projects and grant opportunities within the watershed. This would allow them to make sound decisions regarding the planning of future projects and the desired level of involvement with current projects. The results of projects should also be shared among institutions to educate people outside the responsible organization and to ensure that duplicate or excessive work is not performed.

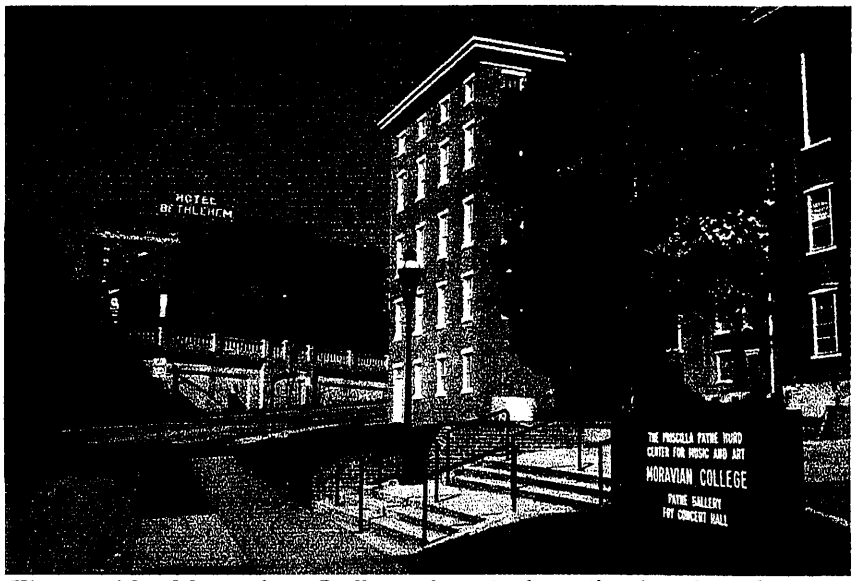


Figure 18. Moravian College located on the banks of Monocacy Creek, Bethlehem, PA.

7.0. WATERSHED ISSUES

7.1. Land Use

Land use statistics have been obtained from a geographic information system (GIS) coverage provided by LVPC. This information was used to assess the percentage of watershed surface area that each land use occupies. These percentages are shown in Figure 19. There is a distinct division of land use within the Monocacy Creek watershed. The northern 2/3 of the watershed is dominated by rural and agriculture uses, whereas the southern part of the watershed is dominated by residential use. Overall, agriculture accounts for approximately 45 percent of the land area and residential use occupies approximately 25 percent of the land area.

These two land uses have different affects on Monocacy Creek. Residential development limits groundwater recharge, and the increased population means that there are more opportunities for surface and groundwater to be contaminated by accidents or careless individuals. Agricultural lands are likely to subject the stream and groundwater to excess nutrients, while often stressing the ecosystem by the removal of streamside buffers.

Currently, approximately 14 percent of the land area is used as open space. Open space along the stream is very important to establishing wildlife habitat and providing shade and buffers for the stream. However, it is important to keep in mind that not all open space areas are managed with stream protection in mind. Several open space areas within the watershed compose recreational lands, such as golf courses, and do not provide the necessary streamside buffers to protect water quality. Land use analysis has shown that many open space areas within the watershed are neither wooded nor being used for recreation. This means that there is a strong potential for increasing buffer zones along streams and creating more forested areas throughout the watershed.

Additionally, industrial and institutional uses each account for approximately 3.5 percent of the land area. These uses are scattered throughout the watershed, diffusing their impact rather than concentrating it in one area. Lastly, commercial development occupies about four percent of the land area. Commercial development is concentrated in residential centers and has similar consequences on the watershed. The distribution of these land uses are displayed in Figure 20.

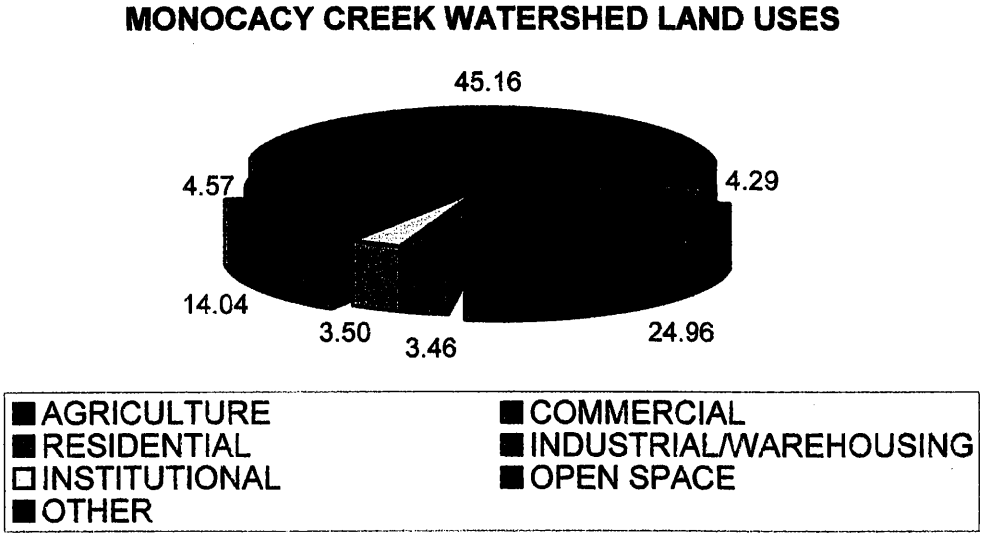


Figure 19. Land uses as a percentage of the watershed surface area for Monocacy Creek.

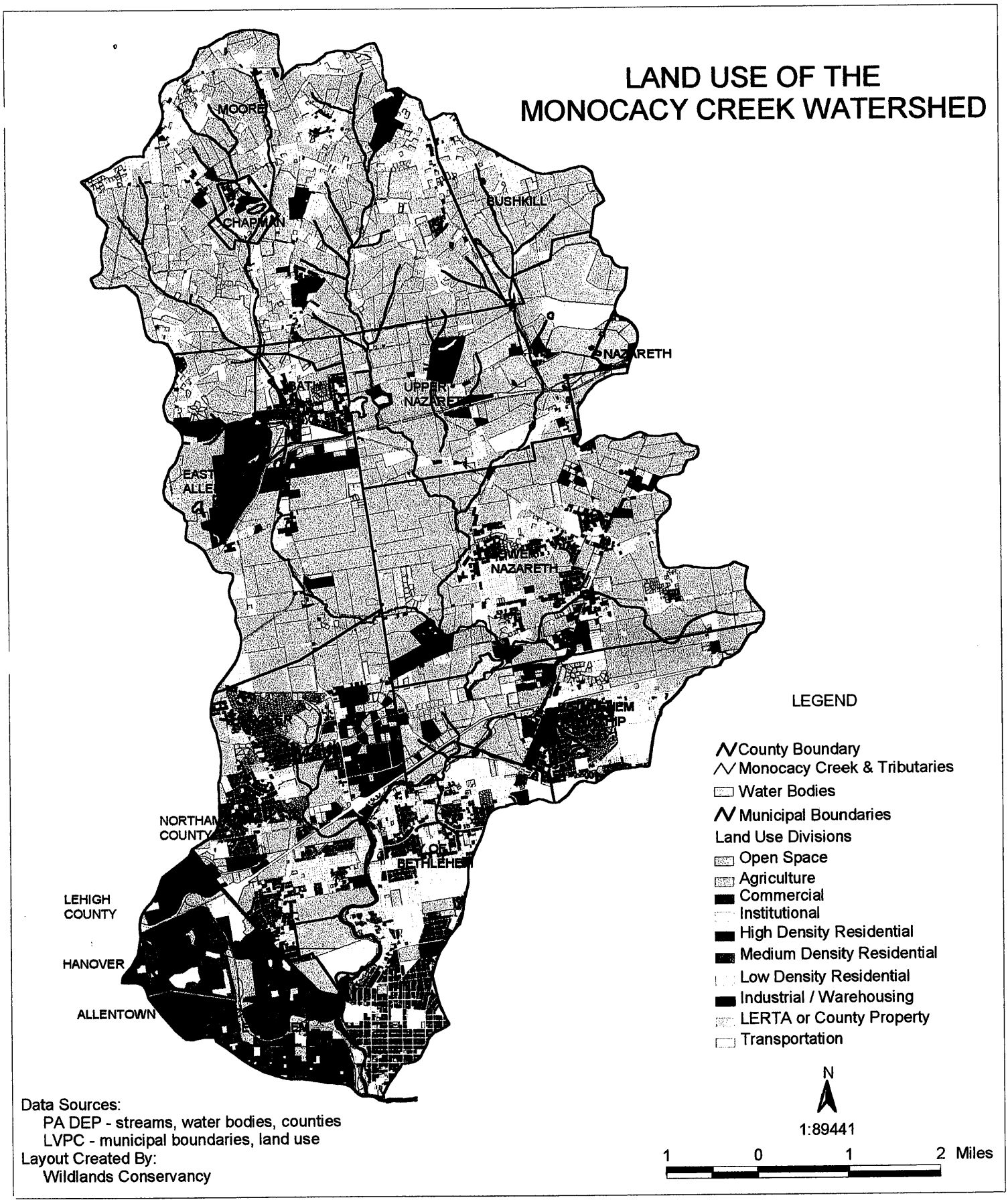


Figure 20. Distribution of land uses within the Monocacy Creek watershed.

7.2. Transportation

A solid infrastructure is integral to any economy. A well developed system of highways, roads, and railways exists within Monocacy watershed to support local industries and businesses. Major traffic routes traversing the watershed include Rts. 22, 191, 512, 248, 378, 946, and 987. In addition, road networks found in the City of Bethlehem and other urban areas provide several access points to Monocacy Creek for recreational purposes of local communities. Railways within the watershed are used to transport goods rather than as a mass transit system for the public. One major Conrail line runs east-west through the watershed between Bath Borough and Nazareth. Another line follows the Main Branch of Monocacy Creek from the south side of Bath Borough to the confluence with the Lehigh River in Bethlehem. Roads and railways within the watershed can be seen in Figure 21.

Despite the many assets this infrastructure provides for the Lehigh Valley, one must not overlook the harm it may inflict on Monocacy Creek and other local waterways. Heavy use of roadways leads to the build-up of contaminants and hydrocarbons from exhaust fumes and leaking automotive fluids. These contaminants are then washed from the paved surfaces during precipitation events into storm drains that frequently empty directly into the closest waterway, thus polluting the Monocacy and other treasured waters. In addition, frequent accidents causing oil spills often lead to pollution of Monocacy Creek due to improper clean-ups at the sites of accidents. Oil spills are detrimental to fish and other aquatic life and should be contained and cleaned as quickly and efficiently as possible to avoid fish kills and other negative impacts to the region's ecology. See Goal 6, Objective 2 under the "Management Options" section of this report for recommendations concerning these issues.

7.3. Critical Areas

Critical areas within the watershed include any areas that contain an important resource that should be protected and conserved or a sensitive area that requires special attention to prevent degradation of the Monocacy Creek. All of these critical areas are mapped on Figure 22. Some important resources that should be protected within the watershed include special conservation areas, wetlands, woodlands, and wellhead protection areas.

Most wooded areas within the watershed occur in strips along the creek and its tributaries. Wooded land composes approximately 8 percent of the watershed in Northampton County. Special conservation areas are located along the portion of the creek that forms the boundary between Hanover Township and the City of Bethlehem, as well as along a tributary in Hanover Township. Protection and preservation of such areas enhances the value of the land and ensures the availability of essential resources for future generations.

Some sensitive areas within the watershed include floodplains, alluvial soils, and steep slopes. Alluvial soils and soils on steep slopes are highly susceptible to erosion and subsequent sedimentation in the stream, which is harmful to aquatic life. The preservation of floodplains and alluvial soils will also aid in flood management. Development on floodplains and alluvial soils reduces the area of porous surfaces available to absorb and assimilate water, leading to increased frequency and severity of flooding.

7.4. Flooding and Storm Water Management

Regional growth in the watershed has led to many instances of development within the 100-year floodplain. In the upper, rural reaches of the watershed, scattered residences and encroachment associated with road crossings are the major types of development on the floodplain. In most cases, the downstream, urban portion of the watershed suffers from complete modification of the natural floodplain. As a result, there is higher potential for flood damage and a lower carrying capacity of the floodplain (LVPC, 1989).

Enforcement of Pennsylvania Act 166, the Floodplain Management Act, has limited future development so that there will be no significant alteration of carrying capacity of the floodplain or a resultant higher damage potential. Heightened awareness of floodplain importance, resulting partially from Act 166, has brought about an increase in the number of floodplain areas being dedicated to recreation or open space (LVPC, 1989).

Areas of storm drainage problems are shown in Figure 23 and described in Table 9. These problem areas were identified for the purpose of writing the Monocacy Creek Storm Water Management Plan, required by the Storm Water Management Act, Act 167. One major goal of this act was to prevent existing problems from getting worse, therefore the first task was to identify the problem areas.

Locations along the creek that contain significant obstructions were also mapped. A significant obstruction is basically considered to be any structure in, along, across, or protruding into a channel that causes flooding or backwater conditions. Within the Monocacy Creek Watershed, 16 such sites have been identified, three of which coincide with storm drainage problem areas. These sites are mapped in Figure 24 and their locations and descriptions are contained in Table 10. Not only does the Storm Water Management Plan identify these problem areas, but it also provides suggestions and guidelines for efficiently handling storm water runoff to reduce flooding and mitigate negative impacts on the creek associated with high flows. Flood zones in the Monocacy Creek watershed, based on Flood Insurance Plans, are shown on Figure 25 (LVPC, 1989). Although other areas in the watershed may be subject to flooding, no other flood zone mapping was available at the time of study.

7.5. Streamside Vegetation

Vegetation found along streamsides is commonly referred to as a "riparian buffer", riparian meaning along a stream or river and buffer because it serves as an area of defense between the water and its surrounding land uses. Riparian buffers protect the stream in many ways. First, they provide shade to keep the water temperature at optimal levels for cold water species. Second, they not only provide woody and leafy debris but also attract insects, all of which serve as either food or shelter for aquatic life. In addition, the roots trap sediment contained in runoff from adjacent lands, thus preventing it from entering the stream and destroying valuable spawning areas and macroinvertebrate habitats. Vegetation also uses nutrients contained in runoff that are essential for plant growth, thereby reducing damaging

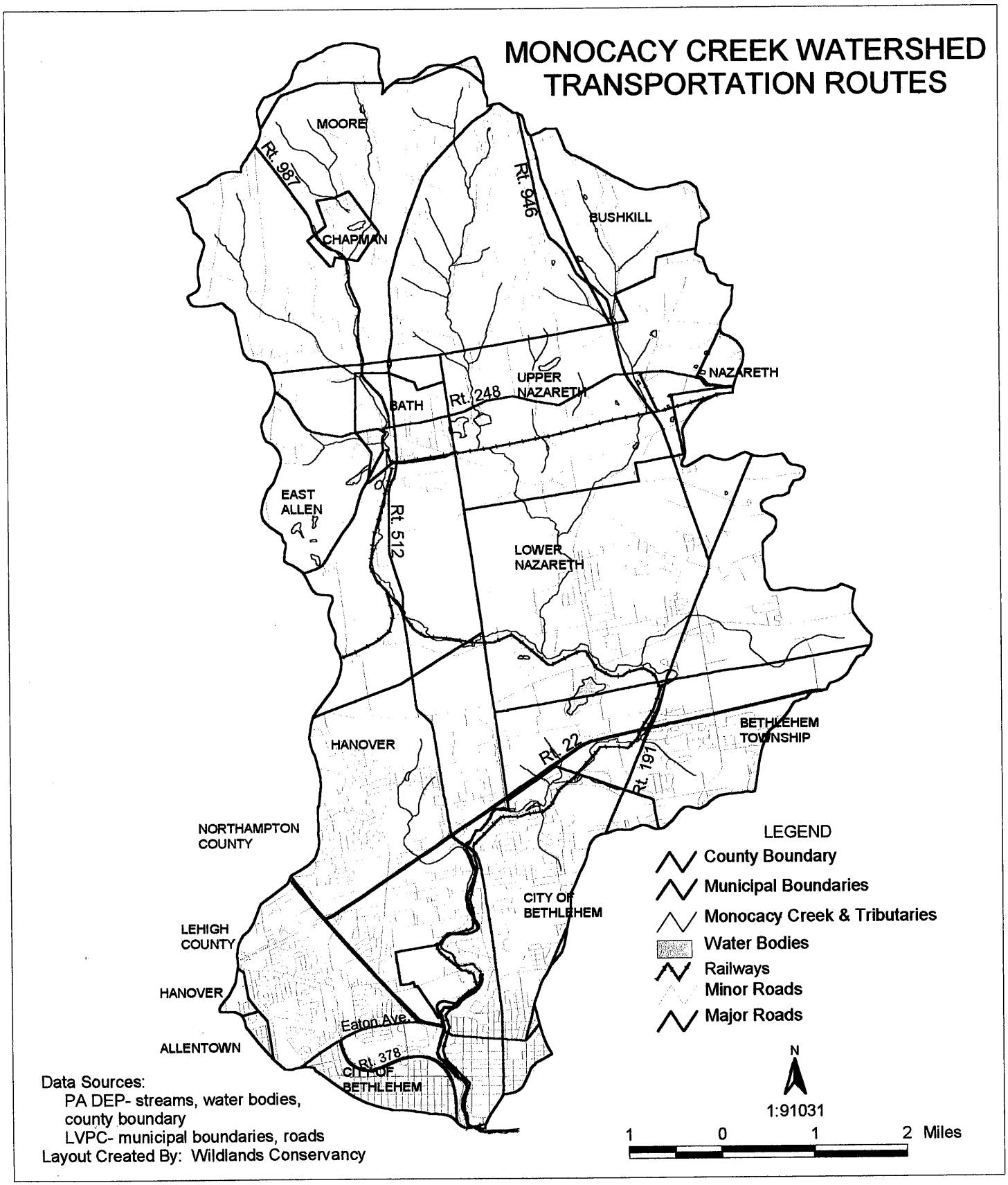
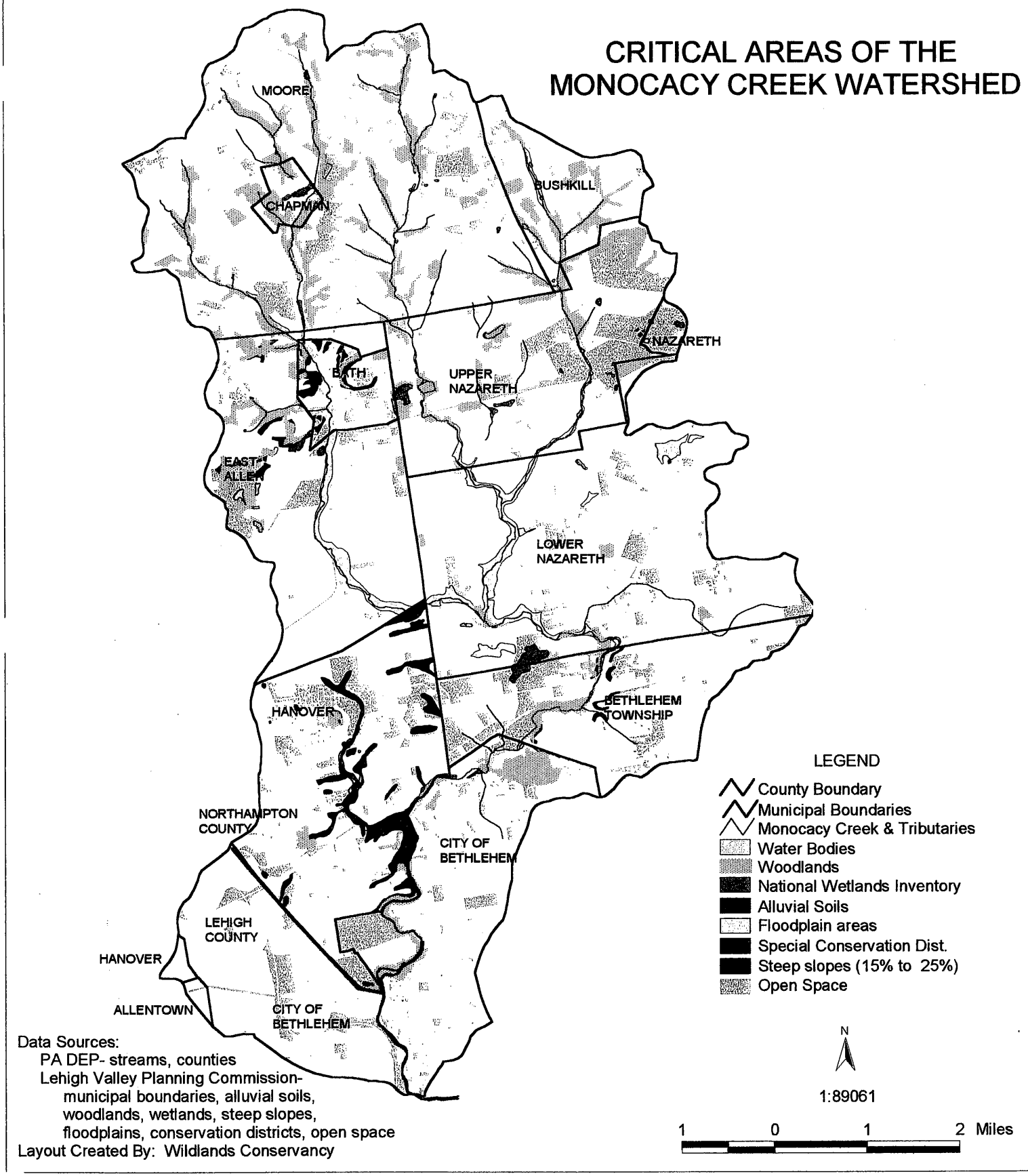


Figure 21. Roads and railways within the Monocacy Creek watershed.



gure 22. Critical areas within the Monocacy Creek watershed.

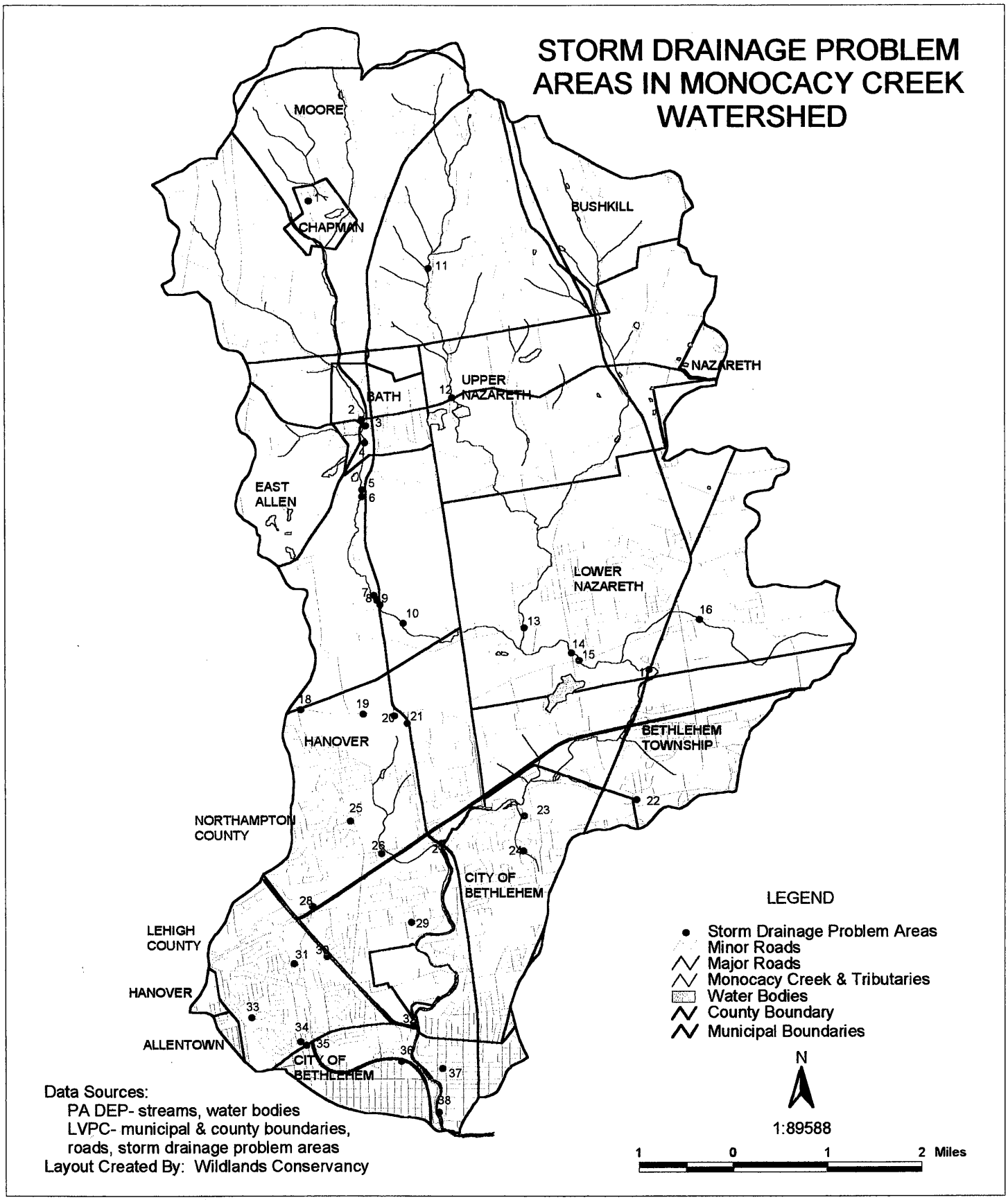


Figure 23. Storm drainage problem areas within Monocacy Creek watershed.

Table 9. Descriptions of strom drainage problem areas within Monocacy Creek watershed.

Number	Location	Municipality	Problem	Proposed Solution*
1	Yost Road & 5th St.	Borough of Chapman	Street & Property Flooding	New Access Route for E. Branch
2	Northampton St. Bridge	Borough of Bath	Street & Property Flooding	None Proposed
3	Main St.	Borough of Bath	Street & Property Flooding	None Proposed
4	Mill St.	Borough of Bath	Street & Property Flooding	None Proposed
5	Railroad Bridge	East Allen Twp.	Property Flooding	None Proposed
6	Private Road	East Allen Twp.	Street Flooding	None Proposed
7	Railroad Bridge	East Allen Twp.	Property Flooding	None Proposed
8	Route 512	East Allen Twp.	Street Flooding	None Proposed
9	Railroad Bridge	East Allen Twp.	Property Flooding	None Proposed
10	Railroad Bridge	East Allen Twp.	Property Flooding	None Proposed
11	Keeler Road	Moore Twp.	Localized Flooding	May have been solved by larger pipe installment
12	Route 248 near Penn Dixie Cement Company	Upper Nazareth Twp.	Street Flooding	Installation of diversion greatly reduced problem
13	Steuben Road	Lower Nazareth Twp.	Street Flooding	None Proposed
14	Georgetown Road	Lower Nazareth Twp.	Street Flooding	None Proposed
15	Hanoverville Road	Lower Nazareth Twp.	Street Flooding	None Proposed
16	Hecktown Road	Lower Nazareth Twp.	Street Flooding	None Proposed
17	PA Route 191	Lower Nazareth Twp.	Property Flooding	None Proposed
18	Culvert	Hanover Twp. (N)	Street Flooding	Cross Culverts
19	Culvert	Hanover Twp. (N)	Street Flooding	Cross Culverts
20	Culvert	Hanover Twp. (N)	Street Flooding	Cross Culverts
21	Route 512 at Ackerman's	Hanover Twp. (N)	Street Flooding	Shoulder Grading of Route 512
22	Oakland Road	Bethlehem Twp.	Street Flooding	None Proposed
23	Pine Top Trail/Fox Dr./ Bierys Bridge Road	City of Bethlehem	Property Flooding	Improve channel Capacity
24	Johnston Drive	City of Bethlehem	Street Flooding	None Proposed

Table 9 (Cont.)...

Number	Location	Municipality	Problem	Proposed Solution*
25	Stafore Estates/ Gaspar Area	Hanover Twp. (N)	Street & Property Flooding	Install and Extend Pipes
26	Stoke park Road Area	Hanover Twp. (N)	Street Flooding	Install Catch Basin/Improve Existing Ones
27	Monocacy Creek at Route 512	Hanover Twp. (N)	Localized Flooding	Box Culvert/Swale Construction
28	Hanover Farm Storm System	Hanover Twp. (N)	Street Flooding	Piped Collection/Conveyance System
29	Bridle Path Road Area	Hanover Twp. (N)	Street Flooding	Additional Piping
30	Westgate Area	Hanover Twp. (N)	Street Flooding	Detention/Additional Inlets/Increased Conveyance Capacity
31	Valley Park South Apts.	City of Bethlehem	Property Flooding	Additional Detention Upstream
32	Schoenersville Road	City of Bethlehem	Street Flooding	None Proposed
33	Pinehurst Road	City of Bethlehem	Street & Property Flooding	Detention Facility
34	Homestead Avenue	City of Bethlehem	Street & Rear Yard Flooding	None Proposed
35	Highland and Eaton Ave.	City of Bethlehem	Street and Property Flooding	None Proposed
36	5th Ave. at Route 378	City of Bethlehem	Property Flooding	Diversion of Runoff to Route 378
37	Goepp Street	City of Bethlehem	Street Flooding	Additional Inlets and Relief Pipe System
38	Historical Bethlehem Tannery Building	City of Bethlehem	Property Flooding	None Proposed

*Proposed solutions are generalized solutions as provided by municipal representatives either based upon specific studies of the problems or their knowledge of the particular circumstances.

Data Source: LVPC, 1989.

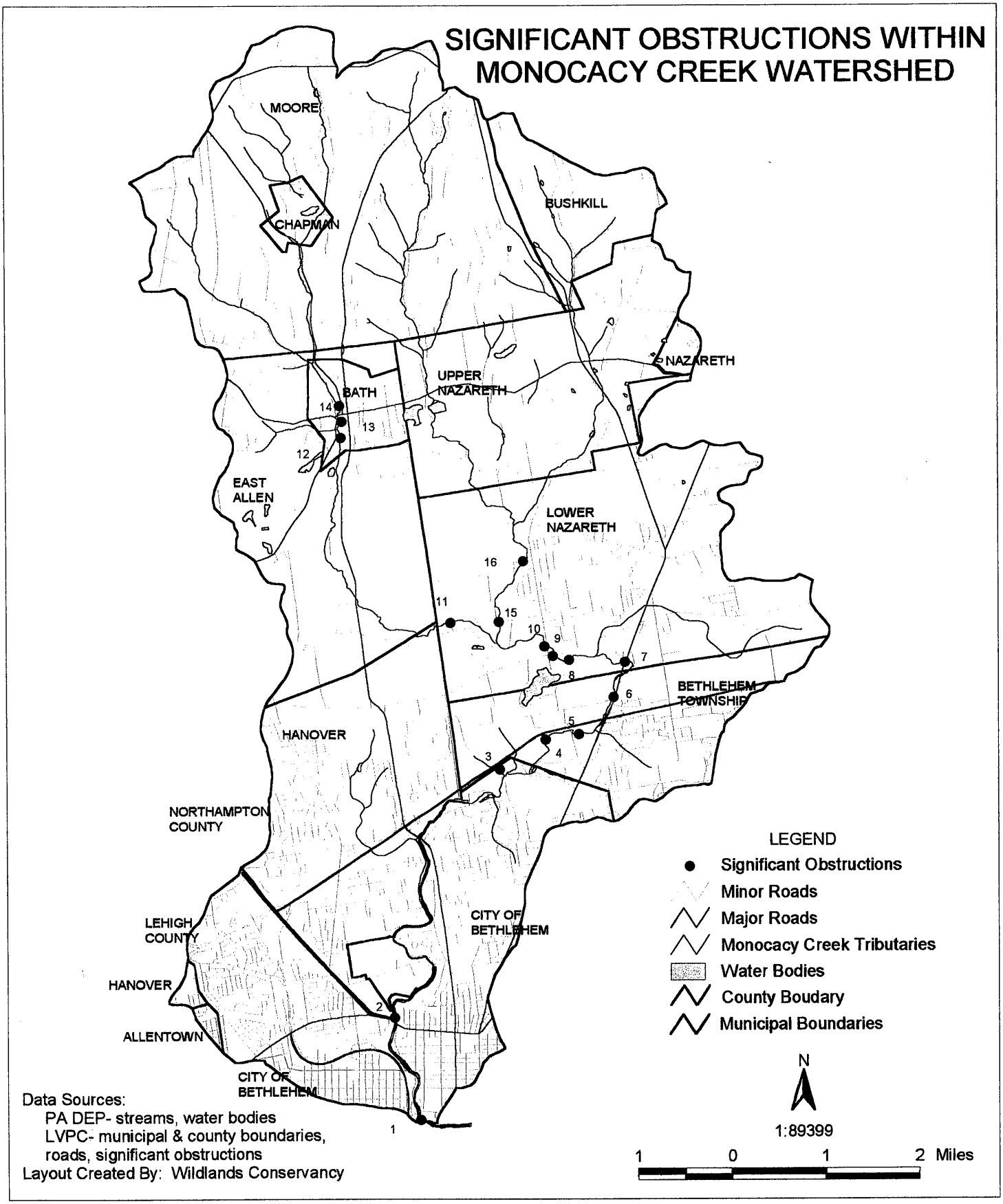
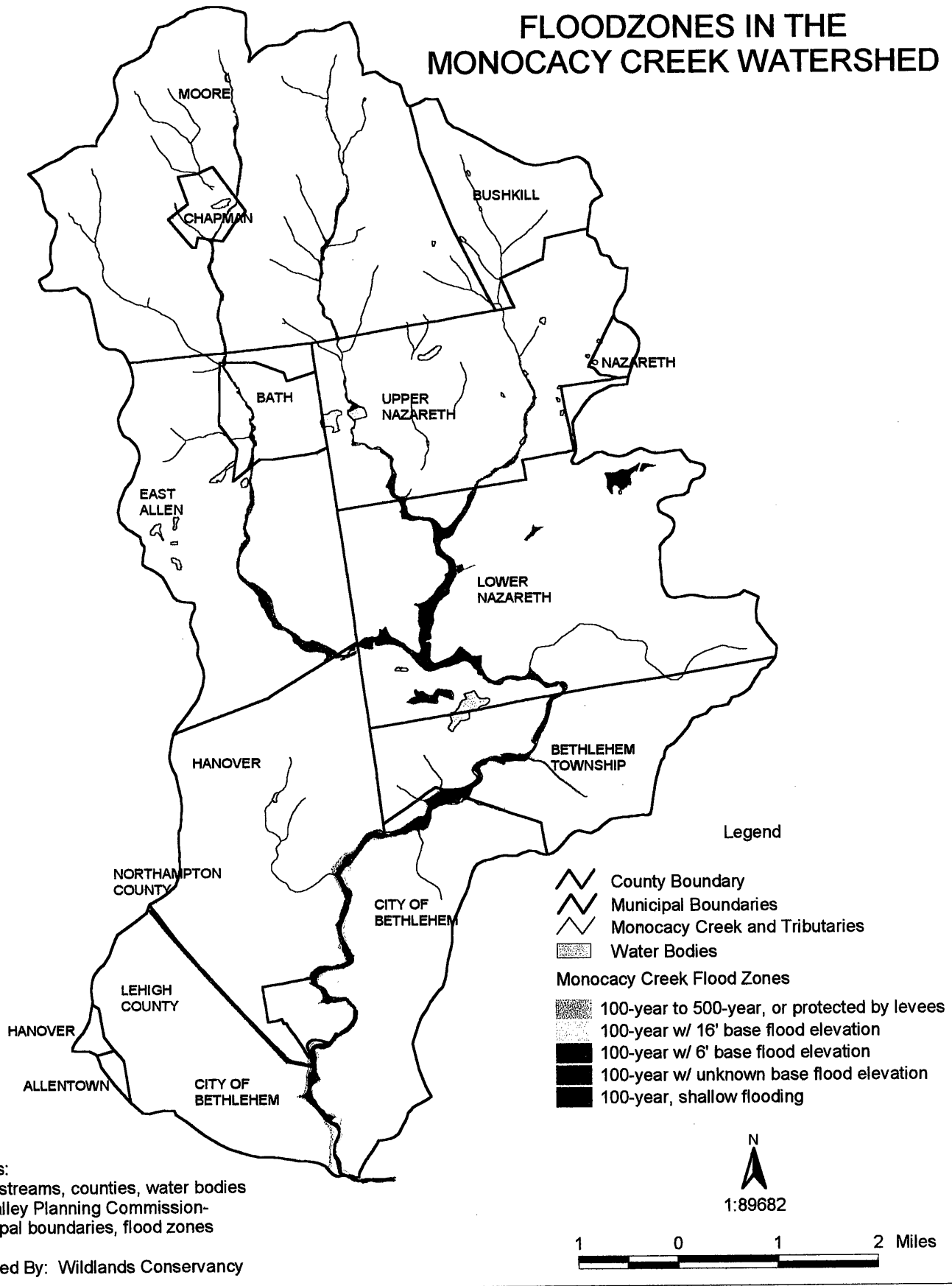


Figure 24. Significant obstructions to waterways within Monocacy Creek watershed.



ure 25. Floodzones for the Monocacy Creek watershed based on flood insurance plans, which do not necessarily depict all areas subject to flooding within the communities.

Table 10. Descriptions of significant obstructions within Monocacy Creek watershed.

Number**	Obstruction	Municipality	Approximate Flow Capacity (cfs)***
	-MAIN BRANCH MONOCACY CREEK-		
1	Abandoned Lehigh Canal	City of Bethlehem	4,500
2	Tunnel Bridge	City of Bethlehem	2,200
3	Conrail	City of Bethlehem	1,800
4	Conrail Crossing #2	Bethlehem Twp.	1,600
5	Conrail Crossing #3	Bethlehem Twp.	1,500
6	Brodhead Road	Bethlehem Twp.	4,500
7	State Route 191	Lower Nazareth Twp.	50,000
8	Conrail	Lower Nazareth Twp.	750
9	Conrail Bridge	Lower Nazareth Twp.	1,100
10	Georgetown Road	Lower Nazareth Twp.	2,200
11	Access Road	Lower Nazareth Twp.	330
12	Mill Street[1]	Borough of Bath	2,100
13	Main Street/State Rt. 248[2]	Borough of Bath	1,300
14	Silk Street	Borough of Bath	N/A
	-EAST BRANCH MONOCACY-		
15	Steuben Road[3]	Lower Nazareth Twp.	670
16	Access Road	Lower Nazareth Twp.	1,700

* Flood Insurance Administration
** Numbers are keyed with Significant Obstruction Map (Figure 14).
*** Estimated capacities are for illustration only and shall not be used as absolute capacities for storm water management decisions.

[1] Obstruction No. 12 coincides with Problem Area No. 4.
[2] Obstruction No. 13 coincides with Problem Area No. 3.
[3] Obstruction No. 15 coincides with Problem Area No. 13.

Data Source: LVPC, 1989.

nutrient loading of streams. Lastly, trees and other streamside vegetation are capable of withdrawing significant amounts of water from the ground, which reduces flooding during times of heavy precipitation.

It is important to maintain riparian buffers as they are perhaps the number one weapon in fighting nonpoint source pollution and in attaining a healthy, high quality water body. Increased development in recent years has led to the destruction of and/or encroachment

upon riparian buffers protecting Monocacy Creek. In addition, new challenges facing agricultural producers are driving many to remove streamside vegetation in order to cultivate more land.

7.6. Invasive and Exotic Vegetation

Invasive and exotic species of vegetation are a major environmental threat to many naturally vegetated regions. Many natural lands, which are becoming more frequently disturbed and fragmented, are increasingly susceptible to invasive and exotic species. When introduced to a new region, invasive vegetation spreads rapidly, overtaking the native habitat. The introduction of just a few invasive species is sufficient to severely limit the diversity of a natural system, especially if that system is also stressed by other environmental factors. Limiting vegetative diversity ultimately limits wildlife diversity, as birds and animals require different vegetative species for cover and food (Andropogon Associates, 1991).

Invasive species were abundantly and widely distributed when they were believed to be quick solutions to erosion problems. These invasive exotics have a shallow root system that spreads quickly to provide ground cover for bare slopes. However, these roots do not effectively stabilize soil, and stream banks continue to erode (Andropogon Associates, 1991).

Some invasive species, such as the Norway and sycamore maples, release toxins to the soil that inhibit the growth and reproduction of native species. Invasive trees are often overlooked because they do not have the dense vine or shrub form typical of exotics. The threat of the Norway maple in many regions is unnoticed because most trees are still saplings. However, by the time these saplings mature, the forested land will be composed almost exclusively of Norway maple. Even invasive trees do not provide adequate protection from erosion. These trees prevent the establishment of an herbaceous or shrub layer, leaving much of the soil bare and subject to erosion. This tree is no longer recommended, but a large demand still exists and it continues to be used on a widespread basis (Andropogon Associates, 1991).

Invasive species are a severe problem because there are no means of effectively controlling their spread (Andropogon Associates, 1991). Many invasive species are spread very rapidly over great distances by animal and bird disbursement (Andropogon Associates, 1991). The only means of control is to eliminate as many existing plants as possible, and restrict planting of new species (Andropogon Associates, 1991). No species that is proven or even suspected of being a successful invader should be planted.

Exotic species threaten the ecology of naturally vegetated areas, as they do not provide proper food and habitat for native wildlife. For example, if an aquatic macroinvertebrate did not evolve feeding from a Norway maple, it will not be edible to that species now. Therefore, that macroinvertebrate species may relocate or be wiped out entirely from the stream, if it can not find the feeding material on which it developed. Since macroinvertebrates are a basic building block in the food chain, a loss of them could disrupt the ecology within the riparian habitat. A list of known invasive and exotic species to the northeast is contained in Table 11.

One species identified as invading the Monocacy watershed, especially along railroad corridors, is Japanese knotweed. Invasive exotics that were identified at Burnside Plantation during a survey conducted by Wildlands Conservancy in 1988 include Norway maple, Tartarian honeysuckle, and crowned vetch (Baker, 1988). The Bureau of Forestry confirmed the presence of Tartarian honeysuckle during their March 25,1988 inventory (Baker, 1988). Other species spotted within the watershed during the time of this study include multiflora rose and purple loosestrife.

Table 11. Invasive exotic species found in Northeastern United States.

Common Name	Scientific Name
Trees	**Trees**
Norway maple	Acer platanoides
Sycamore maple	Acer pseudoplatanus
Russian olive	Eleagnus angustifolia
Autumn olive	Eleagnus umbellatus
White mulberry	Morus alba
White cottonwood	Populus alba
Shrubs and Small Trees	**Shrubs and Small Trees**
Barberry	Berberis japonica
Winged euonymous	Euonymous alatus
Amur honeysuckle	Lonicera maackii
Tartarian honeysuckle	Lonicera tatarica
Blunt-leaved privet	Ligustrum obtusifolium
Smooth buckthorn	Rhamnus cathartica
Shining buckthorn	Rhamnus frangula
Multiflora rose	Rosa multiflora
Vines	**Vines**
Porcelain berry	Ampelopsis brevipedunculata
Oriental bittersweet	Celastrus orbiculata
Japanese honeysuckle	Lonicera japonica
Kudzu	Pueraria lobata
Japanese Wisteria	Wisteria floribunda
Herbaceous Plants	**Herbaceous Plants**
Purple loosestrife	Lythrum salicaria
Japanese knotweed	polygonum cuspidatum

Data Source: Andropogon Associates, 1991.

7.7. Review of Existing Water Quality Reports

Evaluating the health of the Monocacy Creek greatly depends upon the condition of the creek prior to the study period. Previous studies provide a comparison for determining if the water quality and habitat conditions are improving or deteriorating. Four water quality studies have been selected from reports prepared during the past few decades to represent the quality of the Monocacy throughout this time period. The contents and bibliographic information from these reports are summarized below.

Learned, James B., Robert A. Fonte, Mark E. Alpert, and Merle J. Holsinger. 1970. "A Chemical and Ecological Study of Stream Recovery with Particular Emphasis on Entrapment-Entrainment Residual Pollution and Fish Habitat." Lehigh University, PA.

Observations reported during this study found that the shallow, warm agricultural portions of the stream were the most barren and devoid of life. Water quality samples were collected from December, 1969 to May, 1970. Analysis showed that pH ranged from 7.4 to 7.9, stabilizing at 7.8 in the lower portions of the watershed. Alkalinity values progressively increased moving downstream, ranging from 26 to 160 mg/L $CaCO_3$. Ortho-phosphate levels reached a maximum concentration in the middle of the watershed at 3.6 mg/L. Minimum levels of 0.01 mg/L were detected at the mouth of the creek. Nitrate levels were extremely high and showed seasonal fluctuations due to increased plant uptake during the growing season. Also contained in this report are lists of rooted aquatic and algae plants, as well as electro-shocking reports showing 12 species of identified fish.

Mushlitz, David and Wayne Miller. 1976. "A Chemical and Biological Analysis of the Improvement in the Water Quality of the Monocacy Creek since the Installation of Pollution Control Devices by Reichard-Coulston, Inc."

This report was based on a year-long study of three sample sites one each above, below, and adjacent to the Reichard-Coulston plant. Sampling took place from September, 1974 to September, 1975. Analysis results showed that levels of specific conductance, dissolved oxygen, temperature, chloride, biochemical oxygen demand, and ammonia were all fairly constant and within standards set for the Monocacy throughout the study period. Alkalinity values seemed to fluctuate on a weekly basis. This phenomenon was likely caused by discharges from National Portland Cement (NPC). Nitrate levels were high and sometimes exceeded 4 mg/L. Iron discharges were slightly higher than the standard of $\leq$ 1.5 mg/L until February, at which point they began to decline. Zinc and Copper levels were found to exceed the standards at all sites until NPC shut down. Macroinvertebrate studies conducted during this sample period showed that in one year's time, creek life jumped from deserted to well-developed. Although it was not an objective of the study, sampling showed a dramatic improvement of water quality after NPC ceased operation.

Davies, Jodi. 1982. "Sampling and Analysis of Stormwater Runoff into the Monocacy Creek." Northampton County Area Community College, PA.

This report was based on the analysis of stormwater runoff discharges from two urban and two rural watersheds into the Monocacy Creek. The study found notable differences between the urban and rural watersheds for six of the parameters tested. Levels of BOD, total suspended solids, nitrates, specific conductance, and total coliform counts were all higher for the urban watersheds. PH values were also noted as more alkaline in the urban watersheds. Conclusions of this report include the following:

- More organic and inorganic matter is carried in runoff from urban watersheds. This could be caused by more impervious surfaces leading to increased litter, traffic residuals, dirt and eroded materials. Also, there is more fine particulate matter suspended in the air and brought down by rainfall in urban watersheds.
- Nitrates may be high due to springtime measurements and high use of fertilizers at this time.
- There is a need for source control of suspended solids, organic matter, and nitrates entering the stream during storm events.
- Significant silt accumulation was apparent at both rural and one urban discharge.
- Source controls of storm effluent including reduction of air pollution, erosion control, improved street sweeping, and restricted chemical use, were recommended.

Tereska, Todd. 1990. "A Water Analysis on the Monocacy Creek."

Seven sample sites throughout the watershed were used to assess the impact of industry, home development, and drainage wastewater on Monocacy Creek. Four sampling runs were conducted during the spring of 1990. During these runs, twelve parameters were analyzed for each sample. Results of the analysis were as follows:

- Temperature fluctuated with the weather conditions and there was no evidence of thermal pollution except by Bath Sewage Treatment Plant, who has a permit to discharge wastewater.
- Dissolved oxygen levels were good throughout the study period for all sites.
- pH readings were stable and within standards set for Monocacy Creek.
- Total hardness showed a general trend of progressively increasing downstream.
- Magnesium and calcium hardness increased proportionally as well, with magnesium hardness as a percentage of total hardness always higher than calcium percentage of total hardness.
- Nitrate analysis showed a pattern of increasing levels in the middle of the watershed.
- Total coliform counts progressively increased downstream as expected.
- Fecal coliform counts were surprisingly lower below Bath Sewage Treatment Plant than above. This was probably due to chlorination of the water during treatment processes.

The overall finding of this report is that the Monocacy Creek has high quality water despite its shortcomings. This was attributed to the lack of industrial impacts as compared to fifteen or twenty years earlier. Regulations and permit requirements for point source discharges have greatly improved the quality of the Monocacy Creek over the past two decades.

7.8. Visual Assessment

Results of a streamwalk showed that sedimentation and the lack of riparian buffers have impaired extensive stretches of the creek. Accumulation of sedimentation progressively increased downstream. There are four main culprits of sedimentation. Runoff from urban and agricultural lands that are not lined with buffers is one major contributor to the situation. Another culprit is streambank erosion due to the lack of sufficient streambank stabilization. This is a problem that must be addressed in both the upper and lower parts of the watershed. The third culprit is the development of floodplains because it increases the flow and velocity of the creek water, giving it more potential to erode soil and deposit it downstream. Development decreases the ability of the floodplain to assimilate storm water, and therefore it is discharged to the stream, increasing the flow. Floodplain development is primarily a concern for the southern portion of the watershed. Lastly, dams contribute to sedimentation because they decrease the gradient of the stream, thereby decreasing the flow. When the flow gets too slow, the ability of the stream to carry and transport material decreases and sediment particles begin to settle out and deposit in the stream channel. Significant sediment buildup usually occurs right behind a dam. At least six dams were identified within the Monocacy watershed that contribute to sedimentation problems. An example of severe sedimentation in the creek is shown in Figure 26.

Figure 26. A streambank that has eroded along Monocacy Creek and deposited sediment on the stream bottom.

It was also noted that extensive sections of the streambank have been modified. Man-made stone, concrete, or wooden walls compose one or both sides of the streambank for several

segments, especially in the southern part of the watershed. Man-made walls are an obvious result of the impact that development can have on natural surroundings. The construction of retaining walls suggests that there is a lack of sufficient riparian buffers for the given stream segment. In addition, the retaining wall does not provide proper habitat for many aquatic species. One example of a modified streambank is shown in Figure 27.

Other problems that were noted include trash dumping in the stream and improper streamside management. Some portions of the creek appear to be accumulating large quantities of debris such as milk crates, tires, metal scraps, and shopping carts. Two areas where trash dumping is a major concern include the portion of the Main Branch that flows under a Rt. 512 bridge in Bethlehem, adjacent to the Aspen Inn, and a portion of the Archibald Johnston Conservation Area. Improper management, including mowing of lawns and parkways up to the edge of the streambank and disposal of clippings and other yard waste, occurs throughout the length of the creek.

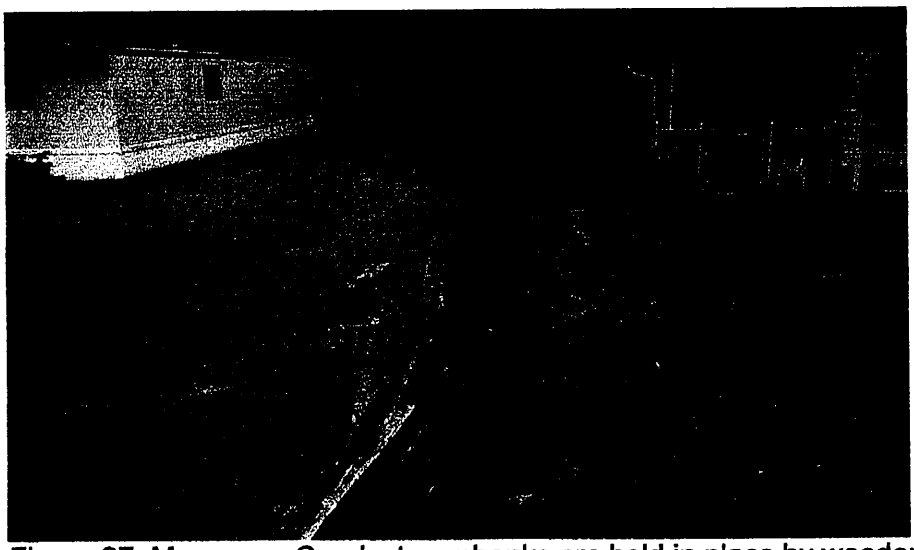


Figure 27. Monocacy Creek streambanks are held in place by wooden beams rather than by natural stabilization.

7.9. Temperature Survey

A temperature survey starting near St. Anne's Shrine was conducted in order to determine where springs began entering the creek and what effect they had on moderating stream temperature. A thermometer was used to check the stream temperature at 100-foot intervals around the Camel's Hump area. The results of this survey showed that the springs are supplying the stream with a flow consistently at 11 degrees Celsius. Seven springs were identified along the banks of the stream in the vicinity of Camel's Hump. The contribution of the springs helps the creek maintain healthy temperatures for aquatic life, even in the midst of the extreme heat and drought of summertime. Due to these springs the stream temperature in this area did not approach 19 degrees Celsius, the water quality standard for

a CWF. The average stream temperature appeared to decrease by approximately 2 degrees Celsius after the entrance of the springs.

7.10. Water Quality Monitoring Results

Water quality testing was conducted for a period of eight weeks during the summer of 1996 and for another six-week period during the summer of 1997. Testing was performed in order to characterize the quality of the Monocacy Creek and its main tributaries. Water quality information would provide insight to locations where the stream is in good health and also where it is beginning to deteriorate. With this goal in mind 25 initial monitoring stations were dispersed throughout the watershed. Based on the results of the 1996 data, the number of sampling stations was reduced to 17. The locations of these sites can be seen on Figure 12. Some water quality parameters were tested on site, but most were tested in a laboratory using a digital electronic colorimeter. The electronic colorimeter was not available for use during the 1996 sampling period, but it provided much more accurate results than former testing procedures. Therefore, the results from the 1996 sampling were discarded in favor of the more accurate and precise data collected during 1997. For more information regarding the background, possible sources, and water quality standards of the following parameters, turn to the water quality section in the appendix.

7.10.1. Temperature

Results of temperature analysis show that Monocacy Creek is being threatened by thermal pollution. Several readings from site 1 at the headwaters to site 10 in Bethlehem Township exceeded the temperature limit that may lead to growth impairment in brook trout. A few individual readings from these sites in the northern half of the watershed surpassed levels that may cause death to brook trout. The ability of the Monocacy to assimilate temperature rises and maintain optimal levels at the headwaters and mid-section of the watershed may be lessening due to the removal of streamside vegetation. The lower reaches of the stream, through the City of Bethlehem, benefit from the presence of springs. They help to maintain optimum temperatures, even during the summer months that tend to stress the stream with excessive heat and drought.

7.10.2. pH

The pH at the majority of the sampled sites on the Monocacy ranged from about 6.3 to 8.1. Values started low at the headwaters and increased downstream. The alkaline values obtained along the Monocacy Creek are a result of the limestone bedrock formations underlying the middle and lower portions of the watershed. The springs located along the stream near Camels Hump, north of Bethlehem, play an important role in maintaining a constant pH in the stream. It is critical to the survival, growth, and reproduction of fish and macroinvertabrates in the creek to maintain a constant pH. Slight variations of pH on a day to day basis or major changes over time, in a species' habitat can cause tremendous stress to that species. Some species are more tolerant of variations and can withstand a wider range of values than others, which may cause a change in the variety and quantity of

organisms found in the ecosystem. For this reason it is extremely important to monitor pH on a regular basis.

7.10.3. Dissolved Oxygen

Almost every dissolved oxygen test performed during the sampling period resulted in levels above the minimum water quality standard and levels were not cause for concern for the aquatic life in the stream. Most site averages ranged between 8.2 and 10 ppm. Several individual values were in excess of 10 ppm where the maximum concentration of DO for any water body is 18 ppm. Site 4, located in Bath Borough, and site 18, located in the City of Bethlehem upstream from the confluence, displayed extreme variability in DO levels and may be cause for concern. DO requirements for aquatic life vary, based upon the type of species, water temperature, amount of pollutants present, and the maturity of the organism in question. Since high temperatures and some pollutants restrict respiration and metabolism, DO needs may increase under the presence of these conditions. Some aquatic species may be more sensitive to sudden changes in DO than others, therefore sites with extreme variability should be monitored to detect any potential problems.

7.10.4. Specific Conductance and Total Dissolved Solids

Within Monocacy Creek, there is an obvious link between specific conductance and the type of bedrock underlying the creek. Sites 1, 2, EB1, and EB1b underlain by shale formations in the northern part of the watershed on both the Main and East Branches, have considerably lower conductance values than the remaining sites underlain by limestone in the lower two-thirds of the watershed. However, it is possible for sites within shale formations to have significant inclusions of carbonates, producing a higher result than expected. This seems to be the case for sites two through four on the Main Branch from Chapman Borough to Bath Borough in the northern part of the watershed. Sites within the Camels Hump vicinity, north of Bethlehem, show representative values for the Monocacy Creek, staying consistently around 550 micro-mhos. Only two individual excessively high readings were observed throughout the watershed, and they were likely to be associated with permitted point source discharges to the stream.

7.10.5. Alkalinity

Monocacy Creek alkalinity values ranged from approximately 20 mg/l at the headwater sites to 220 mg/l in the vicinity of Camels Hump, in the lower portion of the watershed north of Bethlehem. Ideal readings between 100 and 200 mg/L are found at sites underlain by limestone bedrock in the lower two-thirds of the watershed. High values identified by abrupt changes may be the result of concrete production within the watershed. Low values, such as those found in the northern part of the watershed, are typical for streams not underlain by carbonate geology. However, these sites have heightened susceptibility to acid contamination. There does not appear to be any major problems with excessively high or low alkalinity.

7.10.6. Nitrate

Within the Monocacy Creek, nitrate levels were far beyond the target level of 1 mg/L associated with unpolluted water. Most readings also exceeded the safe drinking water quality standard. The lowest levels existed in the northern half of the watershed with averages ranging from approximately 10 to 13 mg/L. Levels below the entrance of the springs at Camel's Hump jumped tremendously to averages ranging from approximately 12 to 18 mg/L. A sudden spike in nitrate where the springs begin to enter the stream suggests that the water was polluted upstream and entered the groundwater supply before having a chance to enter the stream at the pollution source. These levels may be high enough to be hazardous to human health and they should continue to be monitored on a regular basis. Maintaining acceptable levels of nitrate is a key to managing a healthy watershed.

7.10.7. Ortho-phosphate

Records from the summer of 1997 show that the entire length of the Monocacy is at risk of accelerated eutrophication due to high levels of ortho-phosphates. The most endangered portions of the creek are at the headwaters of the East Branch and from the confluence of the East and Main branch continuing upstream for about half the distance to Bath Borough. Readings from these sections ranged from approximately 0.3 to greater than 0.7 mg/L. Values at the remaining sites are still cause for concern as the averages ranged from approximately 0.1 mg/L to 0.3 mg/L. These problems are likely due to fertilizer runoff and other sources of organic waste.

7.10.8. Hardness

Except for the headwaters of the Each Branch, which are underlain by non-carbonate geology, the Monocacy Creek tested as either hard (121-180 mg/L) or very hard water (>180). Extremely high readings corresponded to the area where springs are entering the stream from carbonate aquifers, which indicates that these readings are the norm for the Monocacy Creek. Abrupt changes in data points may indicate possible abnormalities in East Allen and Upper Nazareth Townships. These deviations from the norm are unlikely to be due to changes of underlying bedrock.

7.10.9. Chloride

The average chloride values for the Monocacy Creek were relatively constant. The majority of the sites averaged between 15 and 25 mg/L, which is far below the water quality standard. The only major spike in chloride to be concerned about is on the East Branch near its confluence with the Main Branch. This could be explained by a natural deposit being leached in the vicinity. The average level of chloride at this site from the summer of 1997 was approximately 48 mg/l.

7.10.10. Sulfate

Average values for sulfate from the sample locations on the Main Branch centered around 40 mg/L, which is significantly lower than the maximum water quality standard. The middle section of the watershed seemed to produce higher values relative to the southern and northernmost portions of the watershed. However, the East Branch of the creek produced the highest values averaging around 120 mg/L. This level is still not significant enough to constitute a threat to the watershed.

7.10.11. Summary

Overall the Monocacy Creek exemplifies outstanding water quality that should be protected for future use. Some areas of concern that our studies and observations have identified include alarmingly high nutrient levels, the threat of stream warming, and excessive sedimentation of the stream bottom. These findings are generally in accordance with and support the findings of the previous studies discussed above. Recommendations to lessen the impact of water quality threats identified by the study are contained under the "Management Options" section of this report.

7.11. Water Quality/Land Use Analysis

Due to the connection between land use and water quality, the LVPC conducted a study in order to understand this relationship more thoroughly for both land use planning and water protection purposes. LVPC performed correlation analysis based on water quality data collected by Wildlands Conservancy and land use data contained in GIS format. The purpose of the analysis was to determine if there is any clear relationship between the monitored data and land use patterns within the watershed. The study produced the following results:

- Significant trends, both increases and decreases, were identified for 9 of the 14 water quality parameters analyzed including: specific conductance, total dissolved solids, ortho-phosphate, total hardness, calcium and magnesium hardness, alkalinity, sulfate, and chloride.
- Six of nine land use types appear to have significant trends for certain water quality parameters. These land uses include: institutional, industrial, residential, agricultural, open space, and woodlands.
- Trends are only preliminary as insufficient data is available to support any rigorous correlation.

Recommendations for use of this report include:

- Preliminary trends should be substantiated by additional water quality sampling over prolonged time periods and/or different analytical means used to draw conclusions.
- Future efforts to correlate land use and water quality should focus on expected increased residential and industrial development as indicated by zoning districts.
- Preliminary trends should only be viewed as potential correlations as many factors that influence water quality were not taken into account. Distinct changes in

geology within the Monocacy watershed may have stronger impacts on water quality and the results of this report than did land use.

- Measures to mitigate potential adverse impacts of land use activities on water quality should focus on preliminary trends identified and specific impacts of future residential and industrial development.

LVPC and Wildlands Conservancy both have a complete copy of this report entitled "Monocacy Creek Watershed Land Use/Water Quality Assessment" for your review.

7.12. Water Usage

Excluding individual domestic supply wells there are 15 public and private well supplies within the Monocacy Creek watershed. Data analyzed from 1993 shows average use of water from each well in gallons/day (GPD) and the safe yields for each of them. Results of the analysis show that use from one well supply within the watershed more than doubled the safe yield determined for that well. This is the well that supplies water to the Crossroads Mobile Home Park. Whereas the safe yield for this well was determined to be 1200 GPD, the average use of the well was actually 3,000 GPD. Circumstances like this, where overdrawing occurs, could lead to a lowering of the water table and a possibility of drawing the well completely dry. If a well goes dry, a new well will need to be drilled either in a different aquifer or deeper into the same aquifer. Since locating and drilling wells is a costly process, water withdrawal rates should be closely monitored to prevent depleting the aquifer. A listing of well ownership along with average 1993 water usage and safe yield are contained in Table 12.

Table 12. Well ownership and average 1993 water usage and safe yields, excluding individual domestic supply wells, for Monocacy Creek watershed.

Map Number	Water Supplier	Number of Wells	1993 Average Use GPD	Safe Yield GPD
1	Crossroads MHP	1	3,000	1,200
2	Clearview Farms	4	13,000	114,000
3	Hickory Hills MHP	3	66,000	87,000
4	Royal Oaks MHP	2	4,000	46,000
5	Evanwood	1	9,000	50,000
6	Herd Manufactured Homes	3	10,000	Not Available
7	Christian Springs	2	18,000	65,000
8	Bath Borough Authority	1	See No. 11	See No. 11
9	Valley View Manor	1	2,000	86,000
10	Millers Edgewood MHP	1	5,000	36,000
11	Bath Borough Authority	3	160,000	680,000
12	Greenbriar Village	3	38,000	318,000
13	Kellows MHP	1	2,000	31,000
14	West Gate	4	183,000	Not Available
15	Bethlehem City Authority	4	(Not in Use)	

Data Source: LVPC, 1998.

7.13. Activities Affecting Stream

There are many nonpoint sources of pollution in Monocacy Creek created by human activities. Stream chemistry is effected in several ways by agricultural production. Quite often crops are grown too close to the stream, which allows runoff to enter the stream more rapidly and without being filtered by streamside vegetation. One such instance is shown in Figure 28. Improper farming techniques including misapplication of fertilizers, herbicides, and pesticides contribute to chemical and nutrient loading of the stream. Sediment loads are also increased as a result of excess erosion from improper techniques. Since the American lawn is the largest crop grown in the United States, it is understandable that lawn care is also a major source of stream pollution. Fertilizers added to lawns are diluted when it rains and excess nutrients may be carried to the stream. Animal husbandry also affects stream health when the animals are permitted to freely enter and cross the stream. Animals trample the streambank, stir up the substrate, and defecate in the stream, which is unhealthy for both the aquatic organisms and the animals themselves.

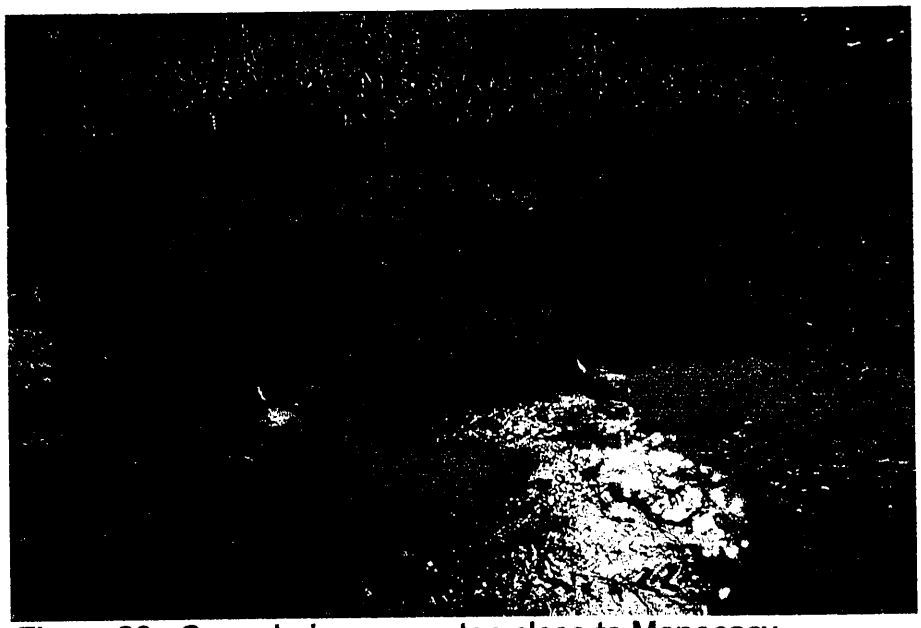


Figure 28. Crops being grown too close to Monocacy Creek without protection from a riparian buffer.

Construction is another way that people alter stream habitat. Without proper protection of bare surfaces, erosion rates are accelerated thus contributing excessively high sediment loads to the stream.

As a result of regional development, impervious surface areas increase while surface areas permitting recharge decrease. Consequently, groundwater levels are frequently lowered by extraction rates in excess of recharge rates. In addition, impervious surfaces, such as asphalt, heat rain water as it runs overland toward the streams, thus contributing to problems of thermal pollution. Water flowing over such surfaces also picks up oils, grease, gas, hydrocarbons, salt, and other pollutants and introduces them to the stream.

Recreational activities also impair stream health. Fishing is just one example of how recreational activities may be detrimental to a stream. Streambanks are often trampled and torn apart as society pursues their outdoor recreational past times, resulting in higher stream sediment loads and the destruction of streambank vegetation.

Resource extraction, including mining and logging, makes the land surface more susceptible to erosion. This in turn causes accelerated sedimentation of the stream channel. Water extractions from both surface flows and underground aquifers may have severe effects on the stream and its ecosystem. Water extractions may lower the level of the stream or even cause it to run dry. Stream chemistry may be altered by the lowering of water levels. Lower water levels may increase concentrations of chemical parameters, imposing stress or initiating the death of aquatic life and vegetation.

Poor stream management is perhaps the most critical activity the Monocacy Creek faces. Proper stream management, such as not mowing to the edge of the streambank and allowing natural vegetation to form a buffer, would decrease the effects of the above activities as well as prevent the degradation of the stream corridor. Lack of education for streamside businesses and property owners contributes significantly to the problem of poor stream management. An example of poor streamside management along the Monocacy Creek is shown in Figure 29. Numerous potential nonpoint sources of pollution, including some of those mentioned above are shown on Figure 30.

Figure 29. Monocacy Creek is improperly managed through this rural section of the watershed.

Permitted discharges for such things as industrial and sewage waste also influence water quality. However, since the Clean Water Act (CWA) has implemented the National Pollutant Discharge Elimination System (NPDES), point source discharges are no longer a serious threat. This system sets limits on the amount of each specific pollutant being discharged, and a monitoring report is used to enforce these permit limits. Permit limits are set according

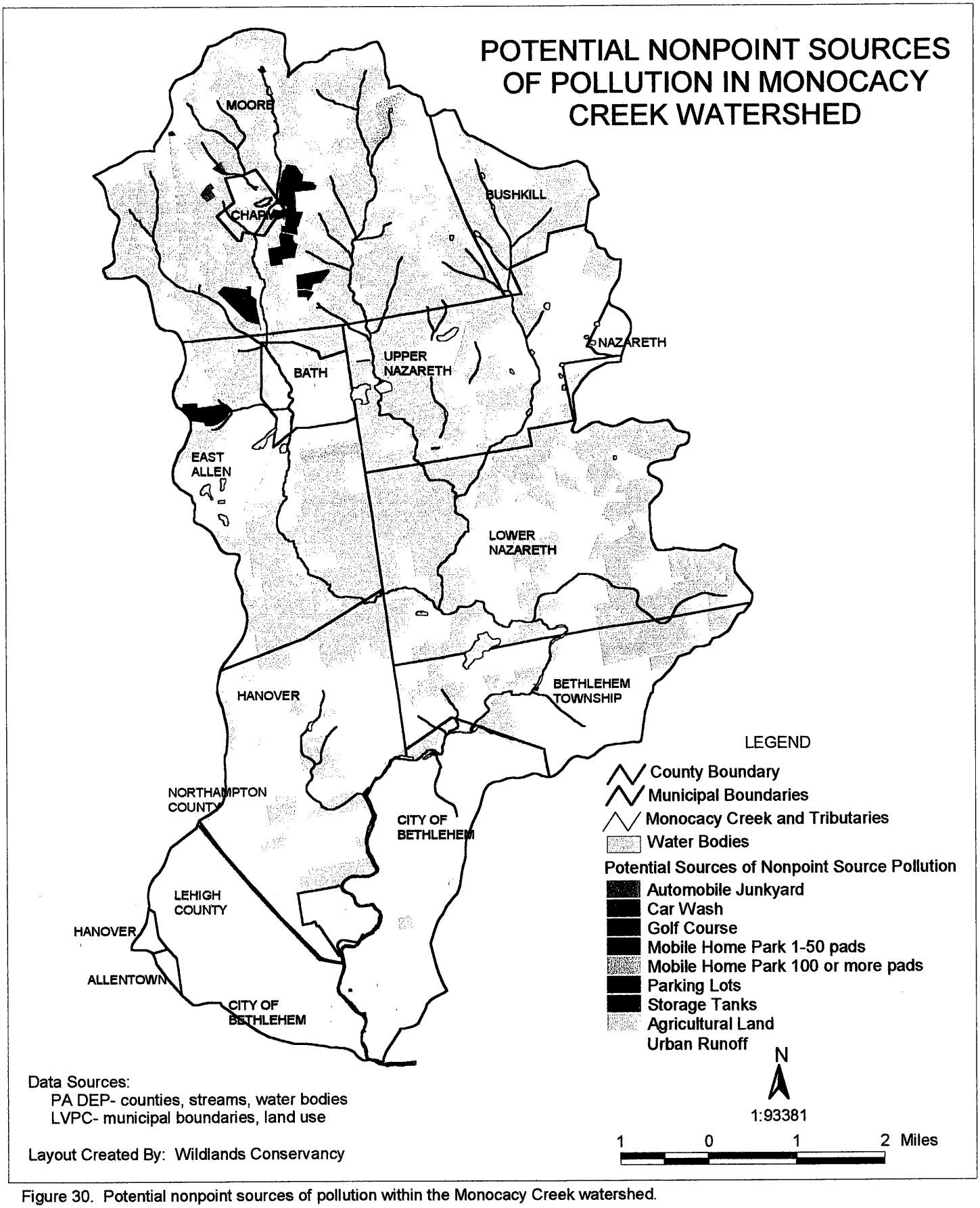


Figure 30. Potential nonpoint sources of pollution within the Monocacy Creek watershed.

to how much of a pollutant the water system can assimilate and how many other discharges enter that system. There are six permits issued for discharges directly to the Monocacy Creek. Two additional permits have been issued for discharges to Monocacy Creek tributaries. These discharges can be seen on Figure 31. Non-permitted discharges and permitted discharges that exceed limitations may endanger the stream habitat and wildlife communities, as well as threaten groundwater supplies.

8.0. MUNICIPALITY ISSUES

8.1. Vision and Future Management

Most municipalities had a desire to protect the stream from current threats and to preserve the natural resources of the stream so long as it proves economically feasible. Several municipalities were also interested in managing the Monocacy corridor to maximize recreational benefits. None of the municipalities predicted or desired any major land use changes within the stream corridor. Most municipalities in the northern half of the watershed were also dedicated to maintaining the rural character of the region. Land preservation and careful land use planning are key issues for the future of these municipalities. The City of Bethlehem recognized the importance of working together on a watershed-wide approach to improve Monocacy Creek, as many of the problems within the city originate upstream in the watershed.

8.2. Common Concerns

One issue raised by all municipalities is the seemingly ever-increasing frequency and severity of flooding. This is the problem most municipalities felt was a top priority, requiring the most immediate attention. Resolving the issue centers on revising stormwater management practices so that emphasis is placed on minimizing impervious surfaces and maximizing infiltration of precipitation to groundwater. Specific recommendations are provided in "Management Options" section of this plan.

Other common concerns shared by many municipalities include protection of the creek from development projects, excessive sedimentation of the stream bottom, and the lack of recreational trails within the watershed. Implementing best management practices (BMPs) and practicing stream stewardship could resolve many of these concerns. Just one well-organized project with a clear objective to protect or preserve stream corridor resources has the potential to remedy several concerns at once. Some recommendations to resolve these issues are detailed in following sections.

8.3. Development within Monocacy Watershed

Areas with pending and ongoing development are mapped on Figure 32, with information provided by LVPC. The following are descriptions of various proposed construction activities within the watershed.

to how much of a pollutant the water system can assimilate and how many other discharges enter that system. There are six permits issued for discharges directly to the Monocacy Creek. Two additional permits have been issued for discharges to Monocacy Creek tributaries. These discharges can be seen on Figure 31. Non-permitted discharges and permitted discharges that exceed limitations may endanger the stream habitat and wildlife communities, as well as threaten groundwater supplies.

8.0. MUNICIPALITY ISSUES

8.1. Vision and Future Management

Most municipalities had a desire to protect the stream from current threats and to preserve the natural resources of the stream so long as it proves economically feasible. Several municipalities were also interested in managing the Monocacy corridor to maximize recreational benefits. None of the municipalities predicted or desired any major land use changes within the stream corridor. Most municipalities in the northern half of the watershed were also dedicated to maintaining the rural character of the region. Land preservation and careful land use planning are key issues for the future of these municipalities. The City of Bethlehem recognized the importance of working together on a watershed-wide approach to improve Monocacy Creek, as many of the problems within the city originate upstream in the watershed.

8.2. Common Concerns

One issue raised by all municipalities is the seemingly ever-increasing frequency and severity of flooding. This is the problem most municipalities felt was a top priority, requiring the most immediate attention. Resolving the issue centers on revising stormwater management practices so that emphasis is placed on minimizing impervious surfaces and maximizing infiltration of precipitation to groundwater. Specific recommendations are provided in "Management Options" section of this plan.

Other common concerns shared by many municipalities include protection of the creek from development projects, excessive sedimentation of the stream bottom, and the lack of recreational trails within the watershed. Implementing best management practices (BMPs) and practicing stream stewardship could resolve many of these concerns. Just one well-organized project with a clear objective to protect or preserve stream corridor resources has the potential to remedy several concerns at once. Some recommendations to resolve these issues are detailed in following sections.

8.3. Development within Monocacy Watershed

Areas with pending and ongoing development are mapped on Figure 32, with information provided by LVPC. The following are descriptions of various proposed construction activities within the watershed.

Upper Nazareth Township has approved the planning of a housing development that will be located due west of Gracedale. This development will most likely consist of 100 homes, which has been reduced from the original plans of greater than 200. The municipality is interested in protecting the wetlands at this site by building around them or incorporating them in the plan for scenic or recreational value.

Moore and Bushkill Townships are both seeking to improve local roadways. Moore Township is interested in widening Penn Dixie Road, which runs adjacent to Monocacy Creek. Bushkill Township would like to resurface Knauss Road, including the removal of rock outcrops that present safety hazards on the narrow road.

Bath Borough is currently preparing a Comprehensive Plan for a community rehabilitation project, in which protecting the Monocacy plays a major role. Proposals in the plan will include historic property designation, traffic re-routing including bridge replacement, and acquisition of property for greenway expansion. The borough is seeking to acquire and demolish five properties adjacent to the stream for the development of a greenway and passive park improvements.

8.4. Municipal Ordinances and Zoning

The Monocacy Creek Watershed, Act 167 Storm Water Management Plan was prepared by the Lehigh Valley Planning Commission. All municipalities within the watershed were required to adopt the Act 167 Storm Water Management Ordinance contained in the plan. The ordinance sets forth guidelines and practices for mitigating the effect of land development on storm water runoff and flooding. Otherwise municipalities must devise their own ordinance containing provisions at least as stringent as those contained in the plan. Municipalities that are not entirely within the watershed are required to implement the ordinance for only that area which lies within the watershed boundary. One important note concerning current storm water management practices, is that they are focused predominantly on quantity of runoff, rather than both quantity and quality. Controlling the quality of storm water runoff is as equally important to protecting Monocacy Creek as controlling volumes of runoff.

In addition to providing the Act 167 Plan, Lehigh Valley Planning Commission has prepared a Wellhead Protection Model Ordinance for consideration by municipalities in the Lehigh Valley. As of the time this report was written, none of the municipalities within the Monocacy watershed had adopted the ordinance. Initiating wellhead protection programs could play a major role in ensuring safe, clean sources of water for future generations.

Zoning is the primary means by which natural resources are usually protected. Current zoning within the watershed only protects two percent of the land area as open space. This means that more measures will be necessary to preserve the watershed's current 14 percent of land dedicated to open space. In addition, 40 percent of land area is zoned for residential use. This points to a vast opportunity for expansion in this area as only 25 percent of land

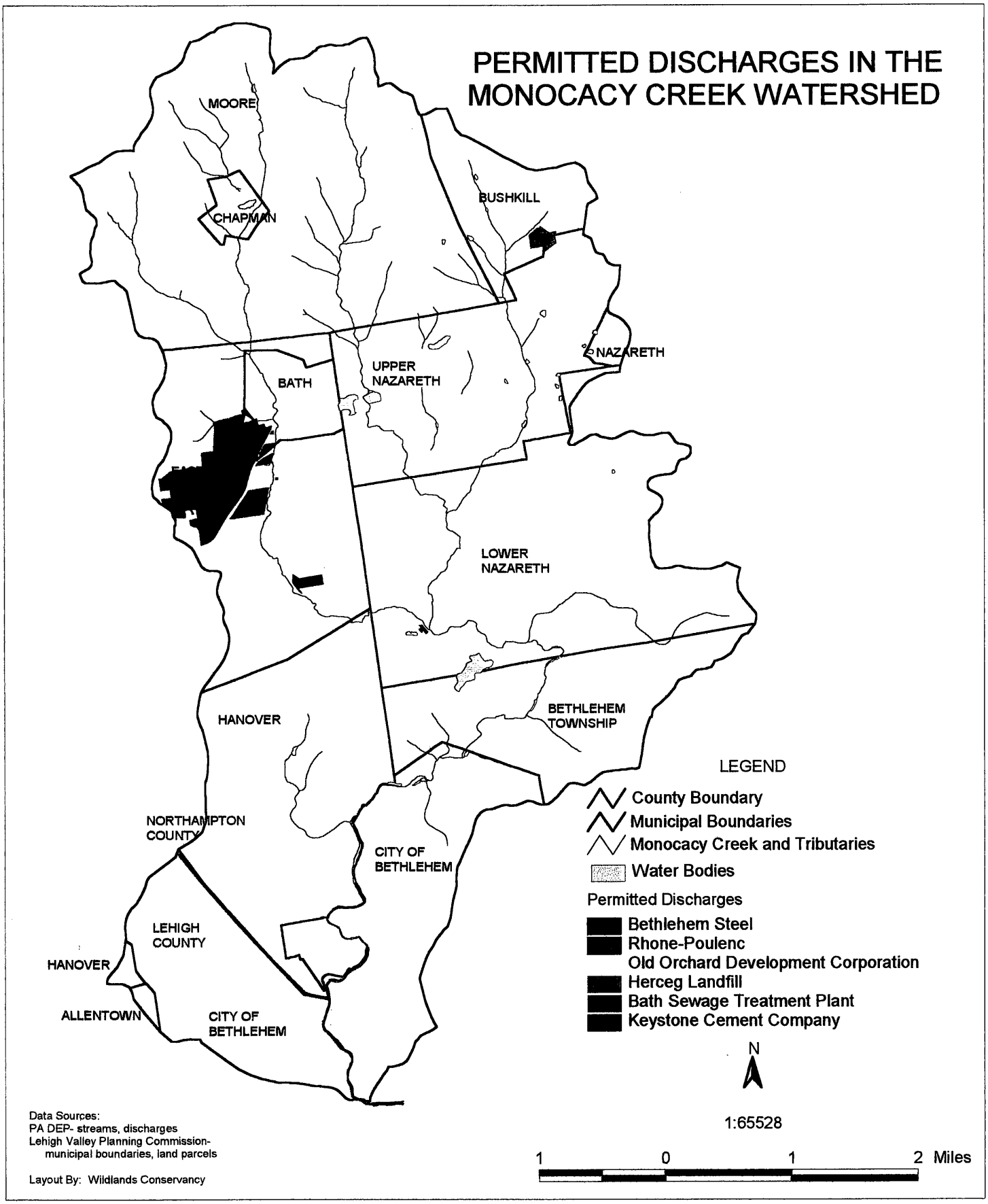


Figure 31. NPDES permitted discharges within the Monocacy Creek watershed.

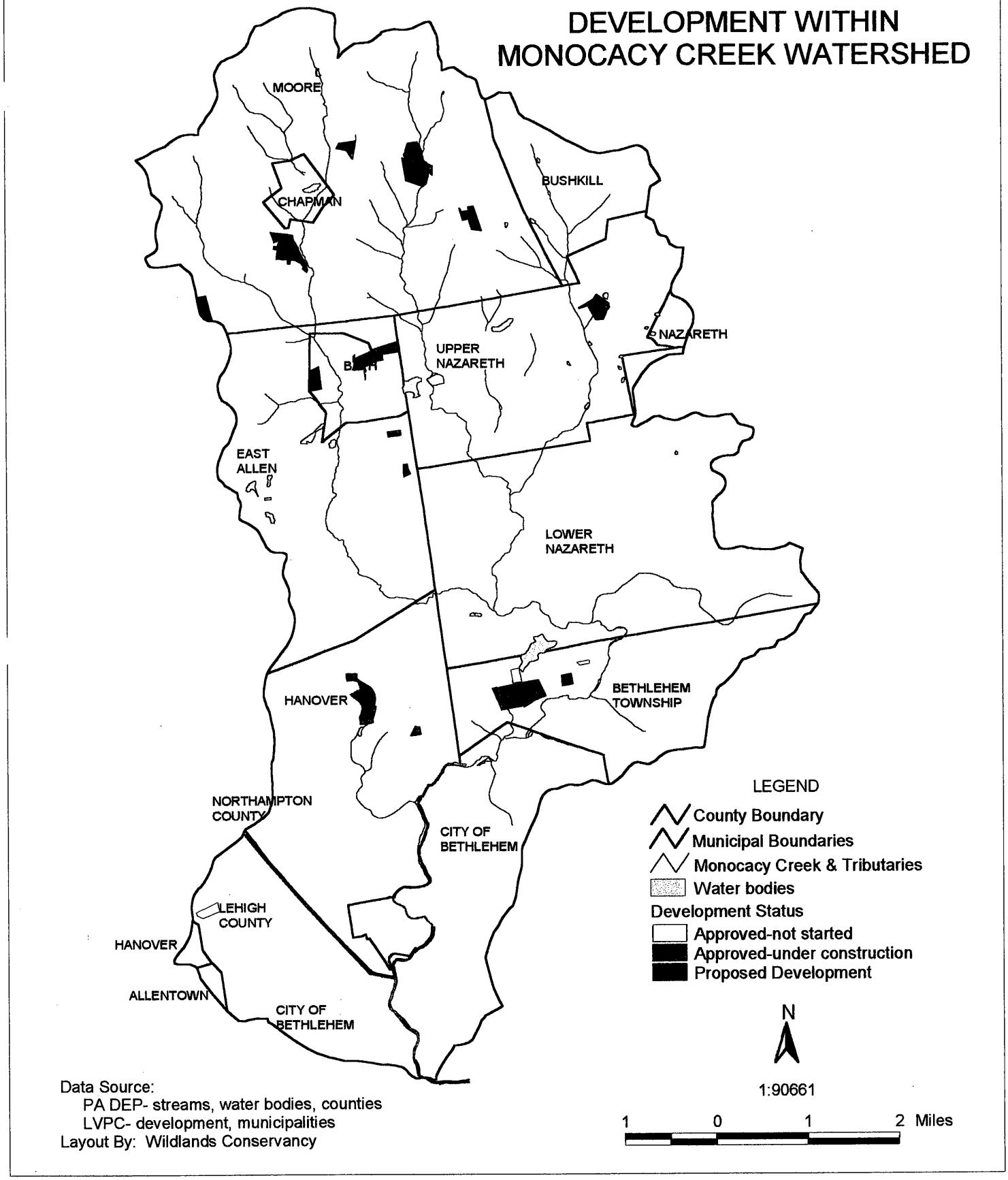


Figure 32. Proposed and approved development within Monocacy Creek watershed.

area is presently dedicated to this use. There is also room for expansion of industrial or wharehousing use. The expansion of these uses may infringe upon current open space areas.

Furthermore, only four out of the ten municipalities within the watershed include conservation areas in their zoning ordinances. However, these provide only limited conservation, as their goals are often aimed jointly at both natural resource and recreational resource protection. These are objectives for which management practices are not always compatible. Zoning regulations for recreational resources usually do not provide adequate protection of stream corridors. Altering current zoning districts to designate areas along the creek in a riparian buffer zone would significantly improve protection for the creek. Current zoning delineations are shown on Figure 33.

Likewise floodplain protection ordinances are commonly insufficient to protect these vital lands adjoining the creek. Most floodplain provisions merely limit activities within delineated floodplains. For floodplains and the functions they provide to truly be protected and preserved, a restriction of development of any kind within the delineated floodplain is really necessary. Contributing to the inadequacy of floodplain protection efforts is the unrealistic delineations of floodplain boundaries. Most floodplains have been seriously altered by urban development since delineations were performed. The resulting increase in flooding from stormwater runoff necessitates wider delineations of the floodplain. Floodplains could also be protected by incorporating them into the suggested riparian buffer zoning district.

9.0. MANAGEMENT OPTIONS REPORT

The recommendations contained below have been based upon the preliminary findings from literature reviews, field and laboratory studies, and suggestions and concerns broached by municipal leaders, conservation groups, and other interested organizations and individuals.

These recommendations were also developed in accordance with the primary goals of the Monocacy project. Those goals were to restore physical and biological health of the stream; establish management practices to prevent additional degradation of the stream; to preserve critical cultural and natural resource areas within the watershed; and to have the Monocacy Creek listed on the PA Rivers Conservation Registry.

Due to the wide variety, broad scope, and large scale of several potential projects and suggested recommendations, it should be recognized that this is a long-term plan for remediation and on-going management of the watershed. In order to facilitate implementation, an action plan containing a list of projects selected from the following recommendations should be devised for each implementation year. A proposed project schedule for 1999 and 2000 is included in the appendix.

The management options that follow have been divided into goals, objectives, and tasks or specific actions. All recommendations have been listed under one of six major goals. The

area is presently dedicated to this use. There is also room for expansion of industrial or wharehousing use. The expansion of these uses may infringe upon current open space areas.

Furthermore, only four out of the ten municipalities within the watershed include conservation areas in their zoning ordinances. However, these provide only limited conservation, as their goals are often aimed jointly at both natural resource and recreational resource protection. These are objectives for which management practices are not always compatible. Zoning regulations for recreational resources usually do not provide adequate protection of stream corridors. Altering current zoning districts to designate areas along the creek in a riparian buffer zone would significantly improve protection for the creek. Current zoning delineations are shown on Figure 33.

Likewise floodplain protection ordinances are commonly insufficient to protect these vital lands adjoining the creek. Most floodplain provisions merely limit activities within delineated floodplains. For floodplains and the functions they provide to truly be protected and preserved, a restriction of development of any kind within the delineated floodplain is really necessary. Contributing to the inadequacy of floodplain protection efforts is the unrealistic delineations of floodplain boundaries. Most floodplains have been seriously altered by urban development since delineations were performed. The resulting increase in flooding from stormwater runoff necessitates wider delineations of the floodplain. Floodplains could also be protected by incorporating them into the suggested riparian buffer zoning district.

9.0. MANAGEMENT OPTIONS REPORT

The recommendations contained below have been based upon the preliminary findings from literature reviews, field and laboratory studies, and suggestions and concerns broached by municipal leaders, conservation groups, and other interested organizations and individuals.

These recommendations were also developed in accordance with the primary goals of the Monocacy project. Those goals were to restore physical and biological health of the stream; establish management practices to prevent additional degradation of the stream; to preserve critical cultural and natural resource areas within the watershed; and to have the Monocacy Creek listed on the PA Rivers Conservation Registry.

Due to the wide variety, broad scope, and large scale of several potential projects and suggested recommendations, it should be recognized that this is a long-term plan for remediation and on-going management of the watershed. In order to facilitate implementation, an action plan containing a list of projects selected from the following recommendations should be devised for each implementation year. A proposed project schedule for 1999 and 2000 is included in the appendix.

The management options that follow have been divided into goals, objectives, and tasks or specific actions. All recommendations have been listed under one of six major goals. The

goals represent what Wildlands Conservancy aspires to achieve ensuing completion of the Management Plan. They are as follows:

1. Preservation of significant features and valuable resources,
2. Documentation of water quality and biological characteristics,
3. Preservation and enhancement of water quality and corridor habitat,
4. Increase environmental awareness to demonstrate the need for and to encourage stewardship by all members of the Monocacy Community,
5. Improve quality of life and property value, and
6. Reduce non-point source pollution.

The objectives listed under each goal are the projects or ideas that should be implemented or completed in order to attain that goal. The symbol "♦" denotes specific tasks or actions that are a possible means of accomplishing the objective. Examples of these tasks or supporting arguments/details for implementing the tasks are bulleted with the symbol "•".

GOAL 1. PRESERVATION OF SIGNIFICANT FEATURES AND VALUABLE RESOURCES

Objective 1. Historic Preservation: The historic resources of the Monocacy watershed are unique and valuable, and since the Lehigh Valley is a historically significant region of Pennsylvania, the following actions are recommended:

♦ Restore the raceway, springhouse, and stone water wall in the Bethlehem Historic District.

♦ Continue restoration and preservation of other known historic sites such as Illick's Mill and Burnside Plantation.

♦ Preserve abandoned railways by converting them to trails and possibly using them to establish a corridor for public education of environmental stewardship.

♦ Conduct a systematic survey of the watershed to identify and list potential national registry sites and structures, which should include but not be limited to the following:

- Chapman Furnace Chimney
- Chapman Quarries School
- George Wolf Academy (East Allen Township)
- Santee Grist Mill (Bethlehem)
- Stone Arch Bridge (Bethlehem)
- Illick's Mill (Bethlehem)
- Octagonal School House (Upper Nazareth Township)
- Gnadenthal (Upper Nazareth Township)
- Christian's Spring (Upper Nazareth Township)
- Paint Mill (Bethlehem)
- White House at St. Francis Retreat (Bethlehem)
- Ice House (Bethlehem)

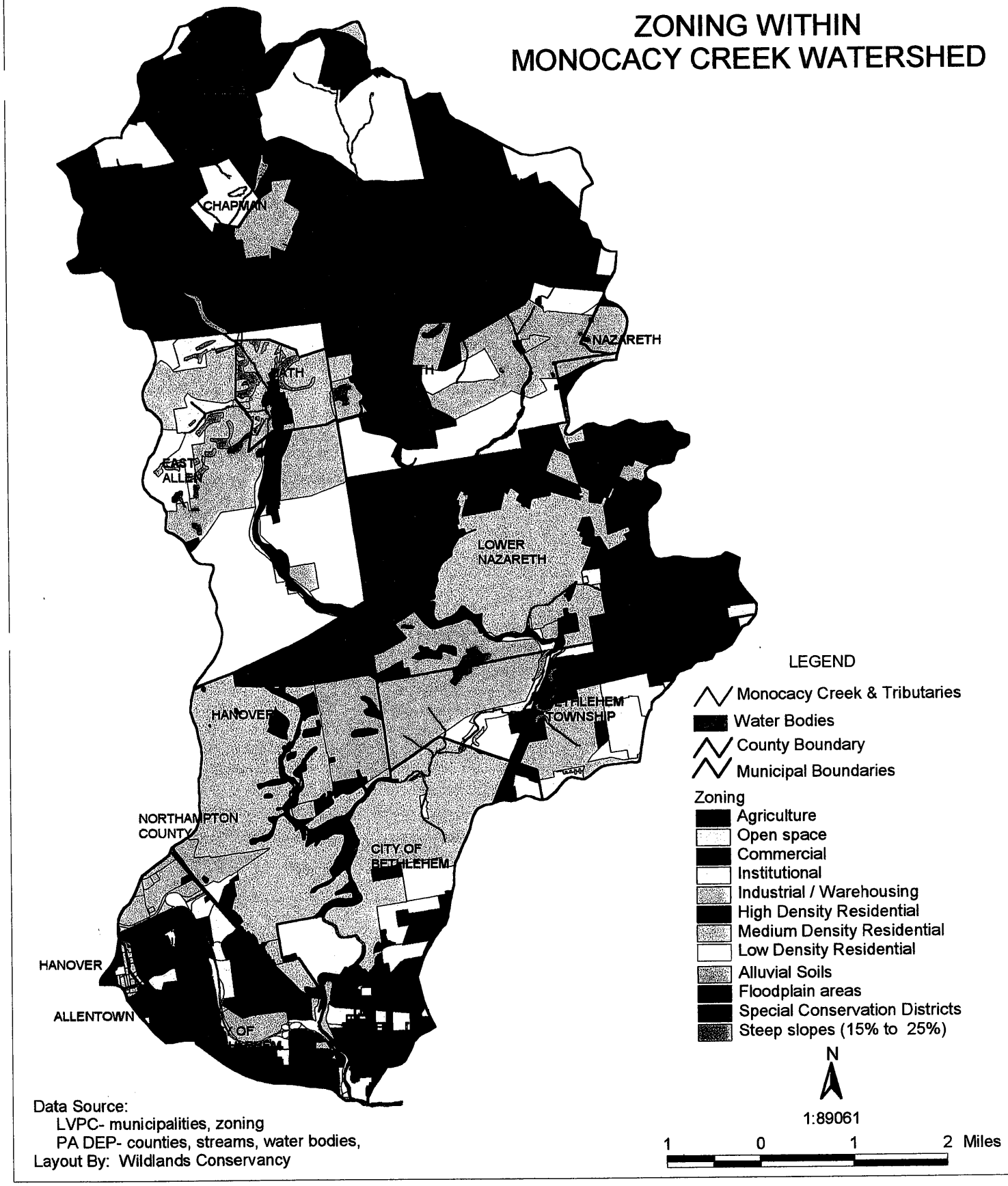


Figure 33. Zoning districts within Monocacy Creek watershed.

- Lehigh Canal (Bethlehem)

The criteria used to evaluate a site/structure for inclusion in the National Register of Historic places state that a site/structure must have:

- an association with events that have shaped history;
- an association with a significant person;
- possession of "distinctive characteristics" from a certain type of construction or time period, the work of a master, or high artistic value; or
- yielding or potential yielding of information.

These actions could be carried out by organizations with a special interest in a site such as Historic Bethlehem Inc. and Burnside Plantation Inc. The restoration of specific buildings throughout the watershed could fall in the hands of the related municipality or Northampton County Historical and Genealogical Society.

Objective 2. Farmland and Open Space Preservation: The Monocacy watershed is home both to some of the most fertile farmland of the Lehigh Valley as well as to critical open space areas. Preserving these valuable resources should be a top priority. Many state and federal programs exist to provide assistance for preservation activities.

- In order to benefit from financial assistance programs for farmland and open space preservation, it is critical to improve communication between the agricultural and land owning community with the appropriate agencies to find the sources of funding for acquisition and preservation of these valuable resources.

- Some programs that could be utilized by landowners to preserve sensitive areas include: Environmental Quality Incentives Program (Farm Service Agency, U.S. Dept. of Agriculture), Conservation Reserve Program (Farm Service Agency, U.S. Dept. of Agriculture), Drinking Water State Revolving Fund (DWSRF), and Conservation Buffer Initiative (Natural Resources Conservation Service, U.S. Department of Agriculture). For more information on these and other programs contact Wildlands Conservancy or your local conservation district.

Objective 3. Wetland Preservation: Wetlands are a very sensitive part of the ecosystem and perform many functions to benefit the Monocacy corridor. Most of the wetlands within the Monocacy watershed are small in size and are therefore often overlooked during development planning. In the past, wetlands were repeatedly filled in for development or agricultural purposes as they portrayed no real value to society. Studies in recent years have found that wetlands are a critical part of the ecosystem that, if managed properly, can provide many benefits for the community. Some functions of wetlands include:

- Water storage: During precipitation events, water collects in wetland areas and is released to streams at a slow rate, thus preventing or limiting flooding of the local area. These hydrologic properties of wetlands are also beneficial during dry spells when they may help sustain stream flow by the gradual release of stored water.
- Wetlands serve as a link between aquatic and terrestrial ecosystems, making them a valuable habitat to many wildlife species, especially waterfowl.

- Wetlands also help clean water by filtering out sediment and nutrients that would otherwise have entered and polluted the stream.
- Wetlands also have the capacity to transform harmful chemicals to less hazardous forms, thus somewhat purifying water as it passes through the wetland.

♦ Better compliance with wetland regulations is needed to protect these highly sensitive areas. Regulations currently exist to protect wetlands from construction and development. However, due to the small size of many remaining wetlands, they are often deemed insignificant and are consequently filled in, regardless of the value they still provide. Once a wetland is lost or destroyed, it is gone forever. "No net loss" practices, which require the construction of new wetlands to replace those that have been destroyed, are not sufficient to preserve the benefits that were originally provided. Often times artificial wetlands do not have the same hydrologic properties and vegetative species as the destroyed wetland, thus limiting the functions of the new wetland and not achieving the objectives of the "no net loss" philosophy.
  - Engaging in public education efforts is one means by which enforcement can be improved. When citizens and municipal leaders are informed of the functions and values provided by wetlands, they become a strong force to oppose destruction of wetlands. They can also assist by notifying Army Corps of Engineers of any potential violations of wetlands regulations.

♦ Efforts should focus on protecting existing wetlands from the planned development of Creek Side Meadows in Upper Nazareth Township. Support could be gained to save these wetlands and others in similar situations by educating the community on the benefits of wetlands. It is much more costly and less beneficial to create a new wetland to fulfill "no net loss" requirements than it is to preserve the existing natural wetlands. If special care is devoted to ensure that the natural functions of the wetland are not disturbed, the wetlands could be incorporated into the development plans as scenic or passive recreational space.

♦ Federal and state programs also exist to provide incentives for farmers and other landowners to preserve wetlands. Some of these programs include: Wetlands Reserve Program (Farm Service Agency, U.S. Department of Agriculture), Partners for Wildlife (Fish & Wildlife Service, U.S. Dept. of the Interior), Wetland Restoration/Creation Site Registry (Department of Environmental Protection). For more information on these and other programs contact Wildlands Conservancy.

Objective 4. Ordinance Revisions: The creation or adoption of ordinances structured to encourage stewardship of creek resources, protect wellhead areas, and limit land uses and activities within stream corridors and floodplains, would make great strides toward achieving the goal of preserving valuable stream resources. These ordinances would serve to preserve such resources as water supplies, wooded regions, wildlife, and aquatic habitats.

♦ Adopting an ordinance similar to the "Riparian Corridor Conservation District, 1995"

prepared by the Montgomery County Planning Commission, should be a top priority among municipalities. A copy of this ordinance is contained in Appendix 1.

- This riparian ordinance is preferred and recommended over revisions of current floodplain provisions as it provides better protection for the narrow floodplains of the Monocacy that are already overdeveloped. This ordinance would apply regulations to enhance and preserve vegetative buffers along the creek. The ordinance achieves this objective by creating a zoning overlay district based on Forest Service calculations.

- Other types of buffer ordinances to consider include fixed widths and separate zoning districts. The Forest Service standard for buffer zones is presently set at 75 feet.

- Adopting an ordinance to protect groundwater supplies, such as the "Wellhead Protection Model Ordinance" prepared by LVPC, is strongly advised. This ordinance is contained in Appendix 2, which is available from Wildlands Conservancy. A wellhead protection ordinance is highly recommended for the purpose of protecting groundwater supplies for today and future generations. Locating sufficient public water supplies is becoming increasingly difficult as more aquifers are being contaminated as a result of population growth and development. Wells in limestone formations are particularly vulnerable due to solution cavities allowing quick, preferential flow of fluids. The potential for well contamination and possible loss of an aquifer would be greatly reduced by the adoption of provisions similar to those contained in the "Wellhead Protection Model Ordinance."

- A cooperative effort among municipalities is encouraged to devise a common ordinance(s) such as those listed above to preserve watershed resources. Such an effort would be more beneficial and efficient than each municipality working individually. Each municipality could select one official to participate in a watershed committee to work on this issue. Common ordinances would be easier to implement and enforce than several different ones throughout the watershed.

- Other ordinances could be designed or updated for protection of the Monocacy Creek from erosion and sedimentation; loss of open space, wetlands, woodlands, and floodplains; and poor quality of storm water runoff.

GOAL 2. DOCUMENTATION OF WATER QUALITY AND BIOLOGICAL CHARACTERISTICS

Objective 1. Water Quality Monitoring: Results from Wildlands Conservancy's monitoring demonstrate a need for ongoing studies of water quality. Water quality data has shown that the Monocacy Creek is being increasingly stressed by development and other demands upon the land. Classified as a HQ-CWF, Monocacy Creek is very sensitive to changes in temperature and chemical composition. Without preventive measures, this classification may be threatened by nutrient loading and thermal pollution, two conditions that demand careful observation.

- Wildlands Conservancy, volunteer organizations, educational institutions, and other watershed interest groups or individuals should combine efforts to continue water sampling and analysis of the Monocacy Creek on a regular basis to:
    - Identify problem areas on which to focus remediation,
    - Monitor and document changes in overall health of the ecosystem for providing background information for future studies and projects, and
    - To note adjustments that should be made in management practices.

- Stream walks should also be performed annually through a cooperative effort as mentioned above in order to monitor physical changes within the watershed such as sedimentation, undercut banks and streambank stabilization, and vegetative cover and shading.

- Industries within the watershed that use the Monocacy for disposing waste or coolant water could contribute to water sampling by funding or providing technical assistance for analyzation of pesticides, herbicides, fertilizers, or metals for which the stream may not yet have been thoroughly screened. Such sampling could lead to a need for studies to determine the proper application rate of fertilizers, pesticides, and other chemical treatments for lawns and agricultural fields.

Objective 2. Biological Monitoring: Maintaining records of the condition of the stream corridor habitat and the vegetative, aquatic, and wildlife species present within the corridor, is essential to recognizing and assessing threats that may disrupt the balance of the ecosystem.

- Periodic inventories of vegetative communities are encouraged to:
    - Identify native and non-native plant species, and
    - Identify where invasive or exotic species are overtaking native vegetation within the watershed.

- Conducting periodic macroinvertebrate sampling is recommended to:
    - Provide additional support for water quality monitoring data, and
    - Assess the diversity and abundance of aquatic life serving as the base of the food chain.

- A cooperative effort should be developed to inventory the watershed to locate and identify the presence of any threatened or endangered species of flora and fauna. Although PNDI does not have a listing of any such species within the watershed, local residents have cited species of concern that should be reported to PNDI, Audubon Society, and other appropriate authorities and organizations for formal investigation and documentation.

Objective 3. Efficient Data Mangement and Distribution: A central clearinghouse for data acquired on the Monocacy Creek, through professional and volunteer monitoring and

inventory efforts, could greatly improve public awareness and communication between key conservation groups.

- With the formation of a central database, a concerned individual would know the appropriate contact for reporting or investigating important information. It would also be much easier to distribute information and make appropriate management decisions because information collected by various organizations would all be in one location. This location could also be used as a site for meetings concerning ventures that impact the creek.

- Developing a system for entering and displaying data on the internet would provide an excellent and efficient means of improving communication and providing easy access to data by almost any interested party. Websites are currently under construction for Wildlands Conservancy, Lehigh University, and MCWA. Any of these institutions could be the source of a link to a Monocacy Creek site. Lehigh University is currently considering development and maintenance of a website to house such information on the entire Lehigh River watershed, which could be divided by sub-watersheds including Monocacy Creek.

GOAL 3. PRESERVATION AND ENHANCEMENT OF WATER QUALITY AND CORRIDOR HABITAT

Objective 1. Implementation of Stream Rehabilitation Projects: Without cooperative efforts throughout the watershed to repair or rehabilitate damaged portions of the stream, it will continue to deteriorate. Preventing any further collapse or extensive undercutting of streambanks is imperative to protecting the aquatic life of the Monocacy. Many organizations are already either actively restoring sections of the stream or they may provide guidance and technical assistance to those wishing to pursue rehabilitation projects. Some of these organizations include: scouting troops, Trout Unlimited, Soil Conservation Districts, PA Fish Commission, Monocacy Creek Watershed Association (MCWA), Monocacy Corridor Citizens' Action Committee (CAC), and Wildlands Conservancy.

- Remediation activities that individuals or organizations, such as those mentioned above, should consider include: stream clean-ups, natural re-vegetation of streambanks, planting of riparian buffers, reconstructing streambanks, erosion control and other streambank stabilization techniques, construction of cattle crossings, streambank fencing, and habitat improvements. For use in riparian planting projects, a list of species suitable for planting in the watershed is contained in Table 6. Invasive and exotic species to avoid when planting within the watershed are listed in Table 10.

- Specific restoration and conservation projects recommended for the Monocacy Nature Center (Sanctuary), as advised by the PA Fish Commission, include the following:

    - Relocation of the streamside trail, extending from Illick's Mill parking lot to the end of the sanctuary, is necessary to prevent serious erosion of the streambank by trail

users. Moving the trail farther inland would prevent much of the streambank walking that currently occurs, and it would also provide a safer pathway as the current trail tends to get very slippery. Some parts of the trail have already been relocated however, the old trail continues to be heavily travelled. When the new trail is completed the original trail should be blocked off to encourage use of the new one. Informative signs explaining the closure of the old path may also be needed and helpful in preventing continued use of the old trail.

- A mini-boardwalk may be needed for the relocation of the trail approximately 100 feet upstream from the tailings mound. This is the worst case of erosion within the sanctuary, as people are forced to walk on the streambanks because the path is intermittently flooded during the spring, rainy season. Moving the trail inland would locate it within a wetland, which is equally wet and undesirable for trail users. To remedy problems with wet conditions a boardwalk could be simply constructed of two plastic planks, which would be raised slightly and anchored to the ground. The plastic planks are environmentally safe material and have gripping surfaces to prevent slips and falls. Such boardwalks are used frequently for nature trail construction.

- Fallen log deflectors are natural in appearance, and when placed at an appropriate angle they will divert the main flow of water toward the center of the stream and away from the eroding streambank. These devices also cause a backwater eddy of low velocity where silt will settle out, thus reclaiming previously eroding streambank. These structures also serve to improve aquatic habitat. It was noted that backfill may be needed in conjunction with the deflectors to prevent undercutting and scouring during high flows.

- The entire length of the creek through the sanctuary, with the exception of current riffle areas, would benefit from the placement of random boulders. Boulders placed in the stream channel will provide turbulence, aeration, and resting water. These factors combined provide excellent habitat for fish and aquatic insects. The stream channel is also scoured around these boulders, making the stream deeper and thus colder, which is beneficial to the cold water fishery.

- Multi-log deflectors would also be beneficial throughout most of the sanctuary for habitat improvement.

- Slow moving stream segments would benefit from anchoring brush deflectors to the banks. The addition of a few bundles of conifer trees along the banks would help stabilize already-accumulating silt to reclaim the stream banks. The collection of Christmas trees for this work would make an excellent community service project.

- Many areas are suffering from point source erosion, such as at muskrat holes, fallen trees, or runoff channels. These areas can be easily stabilized by "rip-rap". Rip-rap is stones or boulders placed along a streambank for stabilization. The

Monocacy only requires medium sized rocks to fill in weak areas. However, due to the delicate nature of the sanctuary, these rocks should be placed by hand, which requires significant manpower.

- Streamside and hardwood plantings of native species are also advised in areas of sparse vegetation throughout the sanctuary. The roots from vegetation will help stabilize the streambank when used in conjunction with the other methods mentioned above. Extensive stretches of the streambank are vegetated solely with invasive species. Although this is not healthy for native wildlife, removing all of the invasive species at one time would result in extremely heavy erosion and sedimentation problems. Therefore, plantings should be coordinated with the removal of invasive and exotic species, which should be done gradually.

♦ Other specific remediation, preservation, or enhancement projects within the watershed:

- Plant vegetation in areas where there is an overabundance of geese in order to take away their preferred habitat, i.e. Rt. 512 bridge by Aspen Inn.

- Investigation of potential erosion control devices for addressing problems caused by railroad trestles crossing the creek by Jacksonville Road in East Allen Township.

- Plant riparian buffers on the banks by Keystone Park, Bath Borough, to prevent erosion of very steep, unvegetated banks. Consideration should also be given to installing a temporary fence along the top of the bank to prevent safety hazards until vegetation is established.

- Removal of diseased trees and replacement with native species around Keystone Park.

- Prevention of roadside streambank erosion in Moore Township by construction of stream deflectors or other erosion control devices.

- Work is desperately needed by the Rt. 512 bridge and the Aspen Inn in Hanover Township (Figure 34). When this bridge was constructed, the creek banks were not properly terraced. As a result the stream is too wide and sluggish. Severe flooding and sedimentation are problems in this area that could be alleviated by reterracing the banks to approximate their original condition. However, due to the extremely wide conditions at the site and the extensive work that would be needed to correct existing problems, reterracing the banks would most likely be considered a violation of Clean Water Act regulations. An alternative action to improve the site would be the installation of brush deflectors combined with occasional biologs. These devices would serve to trap sediment and slowly reclaim the destructed streambank. Also, another log deflector extending from the existing deflector, located downstream of the spring, to the Rt. 512 bridge abutment would redirect flow toward the center of the stream. A large willow tree located downstream of

the bridge is also threatening to fall. Stabilization work should be concentrated around the tree to prevent it from being completely uprooted and taking massive amounts of streambank soil with it.

Figure 34. Restoration work is needed at this site along Monocacy Creek by a bridge on Route 512.

- A combination of stabilization and re-vegetation techniques such as live stakes, live fascines, biologs, and log deflectors are possibilities to prevent further erosion of the unvegetated areas by St. Anne's Shrine, located off Rt. 191 in Bethlehem Township.

- St. Francis Retreat contains approximately 500 feet of streambank that are currently unbuffered and have historically been contributing large amounts of sediment to the stream. The recent installation of 300 feet of biologs at the site through a combined Eagle Scout, Trout Unlimited, and MCWA project has significantly reduced erosion and sedimentation problems. Previous efforts of planting a riparian buffer failed, as the site is heavily used by anglers and many of the unprotected seedlings were trampled. Establishment of a riparian buffer is still a priority for the site. Future efforts should incorporate fencing of individual seedlings to improve the likelihood of survival and growth of the buffer zone.

- The section of the stream extending from the Gertrude Fox Conservation Area to Monocacy Park in the City of Bethlehem should also be planted with native species to establish a riparian buffer. Gertrude Fox Conservation Area marks the beginning of the trophy trout area and should be protected by a buffer to preserve this precious habitat for future generations. Sections upstream from the Trophy Trout area should also be planted to prevent sediment from eroding upstream and depositing downstream in the Trophy Trout area.

- Future plantings in areas known to have high beaver or deer populations, such as the Burnside Plantation and St. Francis Retreat areas, should be protected with the appropriate material so that it is not destroyed by the animals before having a chance to establish itself. Populations of these animals should be monitored and controlled to prevent a disruption of the ecological balance of species within the watershed.

- A farm located adjacent to Georgetown Road Park in Lower Nazareth Township is in need of streambank fencing to prevent free-roaming animals from damaging the stream. A cattle crossing should be incorporated into the fencing project. Once fencing is established, riparian plantings would further protect the stream. Eventually habitat improvement structures may be desired and added to the site.

- A farm property near the intersection of Steuben and Township Line Road has been recently fenced with the inclusion of a cattle crossing. Continued work at this site should focus on riparian plantings and eventually adding habitat devices.

Objective 2. Dam Removal: The Monocacy Creek is a low-gradient stream, meaning that there is not much change in elevation and it therefore flows fairly slowly under normal conditions. Dams slow the flow of water even more, which causes suspended sediment to settle to the streambed and build up behind the dam. As previously mentioned, sedimentation is detrimental to aquatic life and water quality.

- It is therefore recommended that a feasibility study be conducted on the removal of dams within the watershed, especially the dams no longer being utilized that are located within the Archibald-Johnston Conservation Area and in the section of the stream flowing past the Sisters of St. Francis property. Removal of the dams would increase the gradient of the stream, thus increasing its velocity and removing sediment accumulation. The study would be needed to determine the extent of sediment removal and any unforeseen impacts on the stream corridor.

Objective 3. Improve Point Source Discharges: Point source discharges are no longer a major threat to Monocacy Creek, however anytime waste is disposed in the creek it is degrading the water quality to some extent. Several actions can be taken to ensure that environmental degradation by point sources is minimized.

- Voluntary utilization of best available technology in waste treatment processes would further improve discharges beyond NPDES permit requirements, thereby enhancing the water quality of Monocacy Creek.

- Poor aesthetic qualities such as foul odors are often associated with discharges from sewage treatment plants. Although primary and secondary treatment of sewage is required of treatment facilities and is sufficient to meet NPDES permit requirements, tertiary treatment would further improve discharges and is only conducted on a voluntary basis. Initiating tertiary treatment is encouraged both for improvement of water quality and for improving aesthetic values of the creek near these facilities. Initiating tertiary

treatment should eliminate any unpleasantness and provide improved water quality that may support more diversity and abundance of aquatic life.

- Stream corridor improvements, such as those listed under objective 1, could be implemented by point source dischargers to help offset any adverse impacts caused by waste water entering the creek.

Objective 4. Improve Compliance with Erosion and Sedimentation Regulations: Sedimentation is the most abundant and threatening pollutant in the Monocacy Creek. Currently, regulations to control erosion and sedimentation are enforced through County Conservation Districts. The manpower and other resources of Conservation Districts are often inadequate to oversee activities that contribute to sedimentation, provide proper guidance for minimizing sedimentation, and to force violators of such regulations to comply with the law.

- More funding should be provided for and directed to the Lehigh and Northampton County Conservation Districts in order to adequately enforce erosion and sedimentation regulations that protect Monocacy Creek from its number one pollutant.

- Volunteer watch groups, non-profit organizations, and other interest groups and individuals can assist the Conservation Districts in enforcing the law. By reporting to the Conservation Districts, any activities along the stream corridor that may result in sedimentation of the streambed, qualified personnel can be sent to determine if there has been any violations of erosion and sedimentation regulations and what action, if any, needs to be taken. The Northampton County office number is 610-746-1971 and the Lehigh County office number is 610-820-3398.

- Possible violations of erosion and sedimentation regulations may also be reported to the PA Fish and Boat Commission, who could send a Waterways Conservation Officer to investigate the situation. The southeastern regional office number for reporting incidences on the Monocacy Creek is 717-626-0228.

GOAL 4. INCREASE ENVIRONMENTAL AWARENESS TO DEMONSTRATE THE NEED FOR AND TO ENCOURAGE STEWARDSHIP BY ALL MEMBERS OF THE MONOCACY COMMUNITY

Objective 1. Increase Availability of Educational Opportunities: Educating the general public, local industries and businesses, and political leaders about how their everyday actions can effect the environment is a key component to managing a watershed. Understanding how activities that impact a stream, such as those previously discussed, ultimately effect the community, often encourages people to practice better stewardship. More educational programs and opportunities should be instituted to benefit from a more knowledgeable, motivated society.

- Learning experiences should range from environmental awareness for children, to planning techniques for municipal leaders, to agricultural techniques for farmers.

- Parks should be managed in a more natural way and be supported by signing or kiosks explaining the significance of such things as un-mown grass and tree plantings. These signs could highlight issues of nutrient loading and proper fertilization, riparian buffers, and erosion and sedimentation.

- Post signs such as "No Dumping" and "No Geese Feeding" in critical areas to boost public awareness of stream threats. In particular, people should be educated on the harmful effects that bread feeding has on geese and how it causes an overpopulation in a small area.

- Incorporate environmental programming with school curriculums because children are the future of the watershed, and as children learn they may take the information home and share it with their families, which will get them involved as well.

- Coordinate fun activities and programs, such as a short stream walk, into festivals such as Earth Day to grab the attention and engage the interest of the entire community.

- Develop an environmental demonstration and education area to promote stewardship based on findings of water quality, biological, and wildlife studies conducted throughout the watershed.

- Continue and expand cooperative efforts between MCWA, CAC, Trout Unlimited, Wildlands Conservancy, and other organizations.

- Focus educational efforts on familiarizing all members of Monocacy community with best management practices (BMPs) for general stream care and stormwater management. This could be accomplished by creating and distributing a "Management Guide for Streamside Property Owners" that is focused specifically on the Monocacy Creek.

Objective 2. Establishment of Oil-Recycling Facilities: Currently, there are limited opportunities for recycling oil. Despite recent proposals by Northampton County to improve facilities, centers are sparse and primitive, and use of facilities is not widespread due to a lack of education and literature regarding the oil-recycling practice.

- Establishment of free, easy-to-use oil-recycling facilities in every community is encouraged to prevent the devastating impacts runoff oil has on stream life.

- Brochures should be distributed describing the oil-recycling process and the benefits of participating in the practice in order to gain support for the facilities and spread awareness of environmental degradation through oil runoff.

GOAL 5. IMPROVE QUALITY OF LIFE AND PROPERTY VALUE

Objective 1. Improve and Expand Recreational Facilities: Parks, greenspace and open spaces, including recreation areas, and/or scenic easements, are equally as important as economic development. These ideas are not mutually exclusive. More facilities, equipment, and opportunities will be needed to keep pace with the needs of a growing society. Recreational outlets are an incentive to bring tourists to and keep residents in the area, thus making economic advancements worthwhile. Having a thriving economic engine where no one wants to live, or where everyone is daily exhausted by the intensity of economic activity, is not a bargain. The value of such recreational facilities can be seen in Figure 35, which shows a family relaxing along the creek in the Monocacy Nature Center. Recreational advancements need to keep pace with economic advancements in order for society to achieve the maximum benefits that the land and its resources can provide.

Figure 35. A family enjoys the day relaxing in the Monocacy Nature Center.

- Municipalities should actively seek acquisition of property, especially streamside plots, for the purpose of expanding recreational facilities. Lands acquired along the creek would best be used as special conservation districts or passive recreation areas, which allow the community to enjoy the land while simultaneously protecting creek resources.

- Development of a system for tracking streamside property sales would greatly benefit endeavors, particularly in the City of Bethlehem, to acquire streamside property for park use and preservation.

- Municipalities should focus their efforts on working to create a connective system of trails or conservation zones along the creek corridor. Such a system would improve quality of life by providing recreational opportunities for the growing society and enhancing the aesthetics and natural surroundings of watershed communities. It would also serve to help re-establish a riparian buffer zone along the creek that would provide many functions

to improve the water quality and habitat of the Monocacy corridor. This action is best approached by forming a committee with representatives from each municipality to discuss the interest, potential for implementation, and the desired level of involvement by each municipality.

- Dedication of open space on Sand Island is encouraged, especially on the two properties recently turned over to the City of Bethlehem. These properties should be torn down to develop the sites in accordance with their surroundings. The area is located on a floodplain and has already become a well-established recreational corridor. Although Bethlehem has plenty of park land, most lands on the north side of Bethlehem are used for golf courses. It is in the best interest of the municipality to preserve this area as open space for everyone's use, especially since it is currently successful as grounds for festivals and other events. If the land is dedicated to a special interest group, it will be lost to all other taxpayers. It would be tragic for the property to be altered for business, apartment, parking lot, visitors' center, or other high intensity uses. While the property is held by the City, it is owned by all the taxpayers who should have a strong voice in determining its usage.

- Investigate options for constructing a footbridge joining Old Forge Road to Volunteer Firefighters Park. More trees and an additional ballfield and playground equipment should also be planned and acquired for improving the park located in Bath Borough. In addition, installation of a walkway around the perimeter of the park would create a means of exercise for the community while promoting the protection and appreciation of the Monocacy Creek.

- Implement plans of Northampton County Parks and Recreation to extend the Nor-Bath Trail into Bath Borough and adjoin Keystone Park.

- The headwaters of Monocacy Creek in Moore Township should be protected by developing a conservation area through a zoning ordinance, acquisition of streamside property, or the purchase of easement rights for land adjacent to the stream.

- Incorporating the trophy trout area in a greenspace preservation program is advised. Such a program would prevent the streambanks from being heavily trodden, thus preventing vegetation destruction, erosion, and sedimentation.

- Existing pathways in Hanover Township should be connected by completing pathway sections that follow an unnamed tributary of Monocacy Creek that is lightly referred to as Hanover River.

- Monocacy Way path should be completed to connect Burnside Plantation, Johnson Park, and Sand Island. Currently the path traverses Johnson Park in the 18th century industrial area along the creek in Bethlehem.

- The possiblity for developing a creek access from Bella Vista Drive in the City of

Bethlehem should be investigated as several individuals are currently using this site to pursue recreational activities.

- Burnside Plantation facilities could be enhanced by creating a sensory trail with interpretive stations, possibly starting with a concentration on farmstead aspects.

- Physically challenged individuals would greatly benefit from the posting of signs at all recreational trails throughout the watershed that would describe accessibility conditions to be expected on the trails. The signs could contain such information as trail surface material, slope, unevenness, etc. With this information, each individual could make a sound decision as to whether or not the trail is suitable for their passage.

- Community wide support is encouraged for increasing awareness of trail users throughout the watershed to issues of safety and litter control. A coalition of partners could be assembled to discuss means of dealing with these issues.

Objective 2. Rail-to-Trail Conversions: Although the United States boasts one of the best national park systems in the world, most of these parks are located at great distances from population centers and they are limited in their ability to meet the growing recreation and conservation needs of society. Outdoor recreation is occurring more frequently in areas close to home or work places. This trend resulted in the recommendation in 1987 by the President's Commission on Americans Outdoors to establish a "network of greenways to provide people with access to open spaces close to where they live, and to link together the rural and urban space in the American landscape" (PKF Consulting, 1994).

Greenways can be defined as "corridors of protected open space managed for conservation and recreation purposes. They typically follow linear landscape features or they are created along canals, abandoned railroad lines, utility corridors, and other manmade features" (PKF Consulting, 1994).

Greenways along rail-trails provide benefits for wildlife and the environment. Wildlife often use greenways as a connector from one natural area to another. Biodiversity and wildlife areas are preserved through the protection of environmentally sensitive lands along rivers, streams, and wetlands. Greenways also protect water quality by buffering waterways from non-point source pollution. Finally, greenways may also serve as natural classrooms for teaching environmental issues.

- It is recommended that a feasibility study be conducted to assess the extent of abandoned rail lines, the possibilities of linking the lines, and the costs associated with acquiring the necessary lands or easements and converting and maintaining them as usable trails.

- Converting abandoned rail lines within the watershed to trails and greenways would

be an excellent means of stimulating local economy and providing the community with diverse opportunities for exercise and recreation. Economic benefits for communities include:

- the possibility of increased local tax revenues due to increased property values,
- stronger support of recreation-oriented businesses due to spending by trail users on related activities,
- new opportunities for businesses and commercial activities such as restaurants and bike and ski rental shops, and
- greenways along trails that can reduce public expenditures by lowering flood and other natural hazard costs.

♦ Rails-To-Trails Conservancy (RTC) is just one of several organizations dedicated to enriching communities and countrysides by creating a nationwide network of public trails from former rail lines and connecting corridors. RTC is a non-profit organization founded ten years ago for this purpose. Monocacy Creek communities should contact this and similar organizations to inquire about funding and implementation of rail-trail conversion projects along several stretches of abandoned railways in the watershed. Some unused railways within the watershed that have been noted to have potential to be converted to trail and greenway use are mentioned below. Such conversions are highly recommended to provide the numerous benefits discussed above.

- Cooperation with owner of unused railroad bed extending from Creek Road to Slate Post Road in Bath Borough, should be sought to convert the railway to a nature trail. This path would provide an excellent connection between the downtown urban region of Bath to a natural streamside setting that has been unavailable to date.

- Consideration should be given to converting the abandoned railway in the southern part of East Allen Township to a recreational trail.

- Investigate possibility of converting old railways near the headwaters of the Main Branch in Chapman Borough to recreational trails and greenspace.

- A consultant should be hired to examine the possibility of constructing multipurpose trails along the old railways by the headwaters in Moore Township. Some uses of such a trail include walking, running, hiking, bicycling, roller-blading, cross-country skiing, and horseback riding. The township is especially interested in developing horseback riding trails as many previously used dirt roads are being paved and are no longer suitable for riding. Abandoned railways provide an ideal corridor for such a use.

Objective 3. Roadway Cleanup: While industrial parks are remarkably free of litter, the roads leading to and from them are not. Although there is a desperate need in some areas, "adopt-a-highway" sections seem to be vanishing. Litter- free roadways improve the overall

appearance of the watershed and thus improve the quality of life for those residing within the watershed.

- Businesses and their leaders within the watershed are encouraged to exercise their civic responsibilities by organizing roadside cleanup efforts. Joining an endeavor such as "Adopt-a-Highway" would be a simple way to organize and implement cleanups.

Objective 4. Restrict Herbicide Spraying: Herbicide spraying along roadways destroys habitat; causes dust, dirt, and erosion; destroys litter-hiding capabilities of roadside vegetation; and promotes the growth of pure stands of poison ivy, which is apparently the only survivor of the sprays. While spraying may appear to be the most cost-effective means of dealing with traffic safety issues linked to roadside vegetation, it incurs a much greater environmental cost.

- Municipalities are strongly urged to consider reverting to roadside mowing to assure traffic safety rather than applying broad-spectrum herbicides that kill nearly all vegetation and eventually find their way into the nearest stream. Mowing roadsides would increase property values due to the protection of water quality and habitats regularly destroyed by herbicides as well as the prevention of appalling views of barren roadsides left behind after spraying.

Objective 5. Initiate Municipal Management Projects: Reducing illegal trash and hazardous substance disposal activities would result in a healthier, cleaner, and more beautiful waterway that may boost property value and quality of life, especially for those who live, work, and pass recreational time along the stream.

- Preventing illegal activities that occur on a frequent or regular basis, such as waste dumping, is an issue that should be addressed by all municipalities.

- The City of Bethlehem in particular, would benefit from implementing projects directed toward individual, site-specific problems, such as preventing illegal dumpings in the Biery's Bridge storm culvert.

GOAL 6. REDUCE NON-POINT SOURCE POLLUTION

Objective 1. Reduce Pollution at the Source: Non-point source pollution is the major contributor to water pollution problems today, especially within the Monocacy watershed. The best and most effective means of curbing this pollution is to limit and properly manage those activities that produce waste and runoff.

- Herbicide spraying along railways should be restricted as it may not only destroy sensitive or valuable vegetation and promote the establishment of invasive species, but excessive chemicals applied to the vegetation will eventually runoff and contaminate the creek.

- The agricultural community should take advantage of the recent innovations in the application of chemicals and fertilizers that will limit the leaching of chemicals and nutrients to the creek, which is currently a major threat to the health of the Monocacy. These innovations, primarily combined with GPS technology, allow for limited applications of pesticides, herbicides, and fertilizers to only those areas that need them. Such practices apparently pay for themselves, as there is a reduced need for applications.

- The development of Nutrient Management Plans for all agricultural lands within the watershed, with the assistance of Conservation Districts, would ensure that land owners are utilizing technology and best management practices for the betterment of the environment as was suggested above.

- Best Management Practices (BMPs) should be applied to any activities within the watershed that have the potential to affect water quality. BMPs go a long way toward reducing non-point source pollution and improving water quality. The purposes of implementing BMPs are as follows:
  - To restore and maintain the physical and biological health of the stream.
  - To protect surface and groundwater quality by preventing the flow of non-point source pollutants such as nutrients, sediment, animal derived organic matter, and pesticides, into surface and subsurface water bodies.
  - To protect and improve the health of existing natural trout populations. Trout fishing is a significant recreational activity on the Monocacy Creek.
  - To provide natural areas for passive recreation and wildlife habitat.

  Specific recommendations for best management practices for general stream care are outlined in Appendix 1.

- BMPs should always be applied during road construction activities. Especially important, are the measures taken when the roadway is adjacent to the creek. Buffers should be left along the creek whenever possible to stabilize the banks and prevent undercutting of the road. Preventive erosion control techniques will almost certainly be necessary to prevent excessive sedimentation if a road is planned for expansion in the direction of the creek.

- The development of sewage management programs by municipalities for areas dominated by on-lot sewage systems as well as promotion of proper maintenance of these systems is encouraged to reduce potential pollution problems from system malfunctions. Guidelines for proper management and maintenance are contained in the appendix.

Objective 2. Treat Pollution Before Reaching the Stream Corridor: If the amount of pollution produced by a source can not be controlled by methods such as those described under Objective 1, treating the pollution prior to its introduction to a water body is another option. The following suggestions can also help minimize the impact from non-point source pollutants.

- The installation of oil separators is advocated, especially at critical locations. Some of

these locations include the intersections of Rt. 22 and Rt. 512, and Rt. 22 and Rt. 191, where significant growth has led to frequent vehicular accidents, and consequently spills of oil, gasoline, antifreeze, and other liquids. While such devices are usually said to be "outside the scope of highway projects" (and consequent funding is denied), they are, in fact, a direct result of growth and traffic. If there is a need for a highway project, due to growth and traffic, then spills control should be a natural part of the project. Spills control provisions should be included, if not already, in the Rt. 22 project. There was a massive spill of detergent some years ago, at Rt. 22 and Rt. 512, which almost wiped out the entire downstream trout population. After the incident, PennDOT installed an oil separator, but it only protects Rt. 22, not 512, and there are many accidents on Rt. 512 now.

- Voluntary compliance by developers to control deleterious substances, such as oil, from leaking from their grounds is encouraged. Stormwater runoff from malls, roads, and parking lots containing leakage from thousands of vehicles is regularly drained into the nearest swale, eventually finding its way to the nearest stream or groundwater supply. Currently, only industrial facilities are required to control such substances. It is advised that developers and municipal approval boards advocate voluntary compliance with such regulations on the grounds that developers and owners should be responsible for problems created by them.

Objective 3. Revise Stormwater Management Philosophies and Practices: In addition to protecting the creek, reducing frequency and magnitude of flooding is a major concern of the municipalities. The Act 167, Storm Water Management Plan prepared by LVPC is a valuable tool for addressing flooding associated with storm water runoff. In this time of rapid development spurred by population growth, eliminating flooding events is not feasible. Minimizing flooding occurrences is however a realistic goal. Addressing this issue will require municipalities to abandon many traditional practices regarding stormwater management.

- BMPs for controlling stormwater quantity and quality should be implemented. Properly managing the quality of stormwater runoff is equally important as managing quantity of runoff and is strongly advised. Following BMPs for stormwater quality and quantity management would:
  - Protect Monocacy Creek from damaging impacts of stormwater runoff that directly enters the stream,
  - Improve water quality of Monocacy Creek by improving quality of stormwater discharges
  - Reduce frequency and magnitude of flooding events, and
  - Minimize potential flood damage and cost.

A list of suggestions for improving the quality and quantity of stormwater runoff entering the creek is contained in Appendix 1. These management techniques emphasize that direct discharges from storm drains to Monocacy Creek should be avoided at all costs. Also, permeable surfaces should be preserved whenever possible, as they will absorb overland flow, thus distributing the peak discharge over a greater length of time at a lower stream

height. In other words, these techniques would reduce the magnitude and frequency that the creek exceeds its bankfull stage resulting in flood conditions.

- An investigation should be conducted to determine if stormwater runoff from Rt. 987 can be diverted so that it does not directly enter the stream. This is just one example that has been pinpointed out of many instances of direct stormwater discharges to the stream that should be diverted if possible.

Objective 4. Floodplain Preservation: Preservation of floodplains and establishment and conservation of riparian buffers would both help protect the water quality of Monocacy Creek.

- Reassessment of the 100-year floodplain is necessary despite current requirements for detention basins. This is due to heavy precipitation events combined with extensive local development that are contributing to increased sheetflow runoff, which contains chemicals and nutrients detrimental to stream health. As runoff increases due to development, creek levels rise much faster making the floodplain much wider than previous delineations indicate. Establishing accurate floodplain delineations would help prevent development activities within the stream corridor that typically increase the amount of impervious surfaces that carry polluted runoff to the stream.

- Better compliance with existing floodplain regulations established by the municipalities is also necessary to achieve the goals that initially prompted the creation of the regulations.

- Incorporating floodplains in a riparian buffer zone is another means of ensuring their protection.

Objective 5: Link Public Sewer System to Recently Developed Areas: Industries and business located along route 191 are currently not connected to the public sewer system. Improperly working septic systems are a major source of pollution across the state and linking businesses and industries located in this area and others that have been recently developed to a public sewer system would eliminate a potential nonpoint source of pollution.

Objective 6: Riparian Buffer Restoration and Establishment: The riparian habitat is a key to the thriving aquatic life, wildlife, and scenic beauty of the Monocacy. Riparian buffers provide many functions that protect water quality and enhance the value of the Monocacy corridor. Riparian buffers provide:

- Structural Integrity: Roots from trees and shrubs are deeper than that of grass and better serve to anchor the soil in place and prevent it from eroding and causing sedimentation in the stream.
- Filtering of sediment runoff: As water flows overland from fields and urban areas, it carries sediment with it toward the stream. When the water reaches a riparian buffer, tree roots and other vegetation slow the flow and cause the sediment to drop out and settle on the floor of the forested region. Sediment that does not settle out may become trapped in the roots and is thus prevented from entering the stream.

- Sink for Nutrients: Fertilizers that are applied in excess contain nutrients that will leach into the ground and be transported to the creek via groundwater. Vegetation in the riparian buffers will uptake nitrate and other nutrients for their growth processes, thus preventing the nutrients from entering the stream and causing excessive plant and algae growth.
- Food and Habitat for Aquatic Life and Wildlife: Leaf litter and other debris from streamside buffers enters the stream and becomes the building block for biological activity in the stream. Macro-invertebrates use the debris for food and habitat. Fish and larger organisms then feed off the macro-invertebrates and so on. Riparian areas also serve as habitat for other wildlife such as birds, deer, and a variety of other species.
- Recreation Corridors: Riparian buffers also increase the scenic value of the stream, drawing more people to it for recreational activities such as fishing, walking, hiking, biking, birding, and other forms of nature observation.

♦ Property owners and municipalities should take prudent precautions to preserve riparian habitat so that the Monocacy Creek does not lose its historic status as a natural treasure and a showpiece, as it is one of few streams with a thriving population of trout in a city environment. Even economic and business interests within the watershed have used this to their advantage and would be losing an asset by the loss of riparian habitat.

♦ Devising or adopting an ordinance such as the "Riparian Corridor Conservation District" created by the Montgomery County Planning Commission and described under Goal 1, is an excellent way to approach restoration of riparian buffers.

♦ Educational programs and opportunities for land owners to learn about the benefits of riparian buffers and how they improve water quality would also encourage voluntary planting of streamside vegetation. The creation and distribution of a Streamside Property Owners Guide would be an effective way of spreading the word on these issues.

♦ Areas where buffers should be established or enhanced throughout the watershed are listed below according to municipality.

UPPER NAZARETH TOWNSHIP- Monocacy Creek flows unbuffered through a farm with a large pond on Blossom Hill Road. Buffering both the stream and the pond would provide shade, stabilization, and reduce problems with geese in the area.

A wider and/or more continuous buffer is recommended between the farm and stream north of Newburg Road, along Georgetown Road.

BATH BOROUGH- A small tributary to Main Branch Monocacy Creek that flows through Keystone Park has no buffer and steep, eroding streambanks. A buffer is needed at the park to protect both the stream and the kids playing in the park. This buffer should extend from the route 987 bridge at Green Street to the old pedestrian bridge located next to the basketball courts.

EAST ALLEN TOWNSHIP- A section of the Main Branch located downstream from the intersection of Route 512 and Locust Road (across from Timberline Inn) is in need of a buffer. This section is very meandering with grass that is currently mowed to the edge of the streambank, causing excessive erosion and sedimentation. A railroad crossing over the stream downstream of this segment is contributing to the problem.

LOWER NAZARETH TOWNSHIP- An open space area exists along the Main Branch between the Steuben Road crossing of the creek and the railroad crossing about 25 yards upstream. A buffer is also needed in the field along the creek downstream from the Steuben Road bridge toward the confluence with the East Branch.

The creek is fenced off with a cattle crossing upstream of the Township Line Road bridge, however a buffer is not yet established here. Downstream of this bridge a few trees have been planted to initiate a riparian corridor, however this initiative should be strengthened both upstream and downstream of Township Line Road.

The riparian corridor could also be enhanced along the stretch flowing through the Lower Nazareth Rod and Gun Club, which is located off Georgetown Road just north of the bridge near the intersection with Hanoverville Road.

Crops are also being grown too close to the stream along the East Branch both upstream and downstream of the Steuben Road crossing. This situation is contributing to nutrient overloading and sedimentation of the stream. A wider riparian buffer would aid in the filtration of these nutrients and sediment that are contained in runoff, preventing further degradation of the stream.

The Main Branch is also in need of buffer establishment in the area where the creek crosses route 191. The inside of the meander curve that follows Old Route 191, behind the car lot for Nazareth Auto Sales off Route 191, is in need of riparian plantings to provide shade and reduce the effects of thermal pollution. Upstream of northernmost bridge crossing Route 191, the stream is unprotected from erosion and sedimentation, thermal pollution, and stormwater runoff. Buffer establishment and stabilization work are needed in this section which passes behind the Self Storage lot and St. Anne's Shrine. Streambank erosion causing undercut banks behind St. Anne's Shrine is threatening the stability of several crosses stationed there. Some work has been done to stabilize trees in this section of the creek using cribbing, however, the work needs to be extended upstream and should be combined with riparian planting efforts.

MOORE TOWNSHIP- A tributary to the Main Branch extending from Dannersville Road to Whitetail Deer Drive is in need of a buffer near Dannersville Road. There is also no buffer established along Hatch Gravel Road, from the intersection of Stone Post and Trickle Creek Road, upstream past the intersection with Kuter Road, and to approximately 50 feet beyond a cement private drive bridge crossing the creek. It is important to establish vegetation along this stretch of the creek as it is very close to the roads and may cause problems with streambanks being undercut below the road.

BUSHKILL TOWNSHIP- Knauss Road is located veryclose to the stream and approximately two-tenths of a mile north of Daniels Road the bank is eroding toward the road without the protection of a buffer. Also, a few individual property owners along Knauss Road could benefit the creek by extending or creating buffer zones on their property.

BETHLEHEM TOWNSHIP- The area behind the intersection of Rt. 22 and Rt. 191 next to Hanna Car Wash was recently stripped of vegetation. Runoff from these routes now flows directly into the creek. This area is a top priority for revegetation to prevent deterioration from non-point source pollution.

CITY OF BETHLEHEM- There are many opportunities for private property owners on Biery's Bridge Road to plant riparian buffers.

More trees for shading and bank stabilization are needed upstream from the dam located near the junction of Township Line Road and Santee Mill Road in the Archibald Johnston Conservation Area.

- When not conflicting with designated park uses, trees and shrubs should be planted in and around recreational facilities.

- A riparian buffer could be planted on a local landowner's streamside property to serve as a model to show the benefits of riparian buffers to other landowners within the watershed.

- Warm season grasses and willow shrubs can play an important role in the establishment of riparian buffers. When warm season grasses are planted along agricultural lands, they provide the benefits of buffers during the spring and summer, but they can also be harvested in the fall to be used or sold by the producer. Willow shrubs are valuable buffer species because when live stakes are cut in the spring and inserted in the ground, they grow and establish themselves very quickly. This provides good immediate structural integrity for an area that was previously barren. Grasses and shrubs are preferred over trees in some environments, especially wet conditions, as trees don't develop deep root systems and can become top heavy and fall over. It is important to note that any grasses or willow shrubs planted in the stream corridor should be native species that can provide habitat benefits as well as stabilization.

- An example of a successful riparian habitat restoration project is shown in Figure 36. Work such as this should be used as a model for future projects.

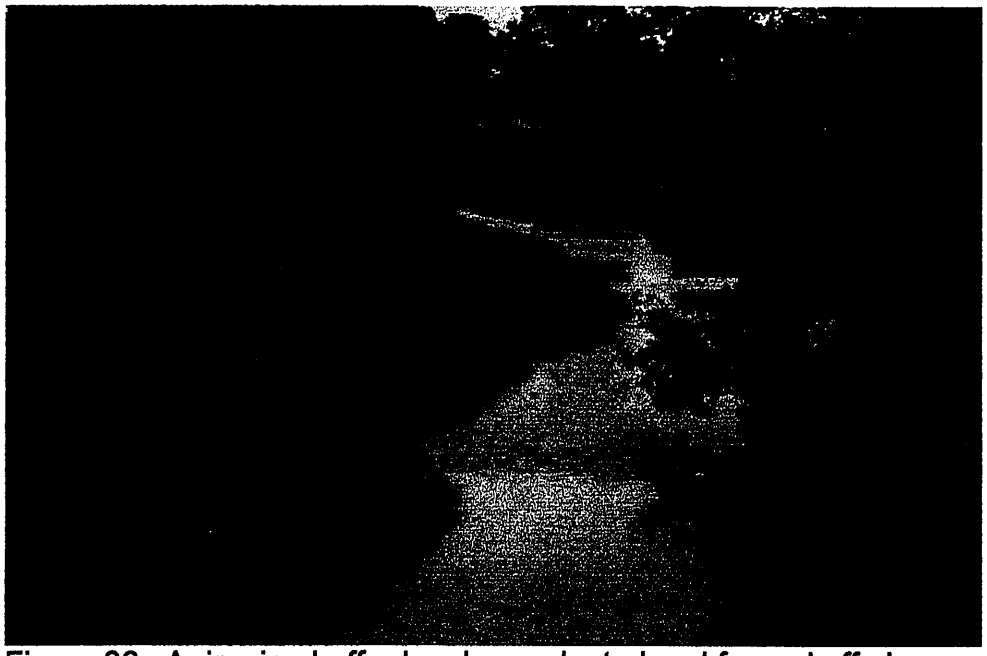


Figure 36. A riparian buffer has been planted and fenced off along this previously poorly managed section of Monocacy Creek.

10.0. CONCLUSION

The Monocacy Watershed and its resources have been treasured by many since the first natives and European immigrants discovered the region. Through the years, population growth and associated development have eliminated, destroyed, or altered significant reserves of the watershed's valuable resources. Future growth of the watershed will put increased pressure on the remaining resources. How municipaliities choose to handle these pressures will impact not only the health of the watershed but also the well-being of its residents.

The consensus of municipalities in the northern part of the watershed to preserve the region's rural and historic character will aid in proper management of valuable resources. The challenge for this region will be to preserve prime agricultural lands while minimizing their contribution to nonpoint source pollution of the creek.

The challenge for urbanized areas of the watershed will be to improve the quality and reduce the quantity of storm water runoff entering the creek. Restoring riparian buffers wherever possible along the length of the creek is also a priority for conserving watershed resources.

The keys to achieving the goals of this project are education and communication. Knowledgeable citizens and organizations must continue to educate property owners, businesses, and political leaders, on the issues raised in this report. Open lines of communication between property owners and institutions must be established for the

watershed to benefit from conservation and preservation programs as well as the efficient use of its many resources.

This management plan should be used as a tool to build partnerships for enhancement of the watershed. It can be used as a guide to develop concerted efforts for improvement projects for many years to come. It is our hope that completion of this plan and resultant ongoing improvement efforts will continue to yield pride in the hearts of future generations for their treasured Monocacy Creek (Figure 37).

Figure 37. Monocacy Creek provides scenic beauty for the Lehigh Valley in addition to its many natural resources and functions that need to be preserved.

LITERATURE CITED

Andropogon Associates. 1991. "Invasive Exotics". Landscape Management & Restoration Manual, in progress.

Attardo, Vic. 1997. " Lehigh Valley Trout Streams". Pennsylvania Angler & Boater. PA Fish and Boat Commission.

Baker, J., B. Lee, and P. McKinney. 1988. Burnside Plantation Flora/Fauna Inventory. Wildlands Conservancy.

Burnside Plantation Inc. pamphlet. Burnside Plantation: A Self-Guided Walking Tour.

Davies, Jodi. 1982. "Sampling and Analysis of Stormwater Runoff into the Monocacy Creek." Northampton County Area Community College. Bethlehem, PA.

Dolan, Karen. 1998. "Biological Diversity in the Monocacy creek Watershed." Bethlehem, PA.

Farber, Jenni L. 1997. letter. The Nature Conservancy.

Fraser, D.M., B.L. Miller, and R. L. Miller. 1939. Northampton County, PA. Pennsylvania Department of Environmental Resources. Harrisburg, PA.

Historic Bethlehem Inc. 1987. Handbook For Interpreters: 18th Century Industrial Area.

Kita, Bernard and Karen Dolan. 1998. "Our Migratory Highway, Is It In Danger?" The Bulletin of the Monocacy Creek Watershed Association. Bethlehem, PA.

Learned, James B., Robert A. Fonte, Mark E. Alpert, and Merle J. Holsinger. 1970. "A Chemical and Ecological Study of Stream Recovery with Particular Emphasis on Entrapment-Entrainment Residual Pollution and Fish Habitat." Lehigh University. Bethlehem, PA.

Lehigh Valley, PA. Visitor Guide and Map. 1984. Allentown-Lehigh County Tourist and Convention Bureau and Northampton County Tourism Council.

Lehigh Valley Planning Commission. 1996. Lehigh and Northampton Counties: Inventory of Parks and Other Outdoor Recreation Sites.

Lehigh Valley Planning Commission. 1996. Lehigh- Northampton Counties

Wellhead Protection Implementation Program.

Lehigh Valley Planning Commission. 1997. Lehigh Valley Profile and Trends.

Lehigh Valley Planning Commission. 1989. Monocacy Creek Watershed –Act 167- Storm Water Management Plan.

Lehigh Valley Planning Commission. 1998. Monocacy Creek Watershed Land Use/Water Quality Assessment.

Lehigh Valley Planning Commission. 1998. Monocacy Creek Watershed Preliminary Hydrologic Budget.

Lehigh Valley Planning Commission. 1970. Regional Recreation & Open Space Plan. Report 3: Historic Structures and Sites.

Lenni-Lenape Historical Society.

Martens, Henry C. 1967. Conygham, PA. New Hartford, NY.

McCormick, Kelly. 1998. "Macroinvertebrate Study of the Monocacy Creek, Northampton County." Muhlenberg College. Allentown, PA.

Mushlitz, David and Wayne Miller. 1976. "A Chemical and Biological Analysis of the Improvement in the Water Qualtiy of the Monocacy Creek Since the Installation of Pollution Control Devices by Reichard-Coulston, Inc."

Pennsylvania Historical & Museum Commission, Bureau for Historic Preservation. 1995.National Register Individual Properties and Historic Districts in Pennsylvania. Harrisburg, PA.

"Recommended Streamside Plants". Wildlands Conservancy. Emmaus, PA.

Shaw, Lewis C. 1984. Pennsylvania Gazetteer of Streams: Part II. Water Resources Bulletin No. 16.

Staley, Larry R. 1974. Soil Survey of Northampton County, Pennsylvania. United States Department of Agriculture: Soil Conservation Service. Washington, D.C.

"Suggested Planting List for Stream Banks". Wildlands Conservancy. Emmaus, PA.

Tereska, Todd. 1990. "A Water Analysis on the Monocacy Creek."

"Trees and Shrubs Suitable for Riparian Area Plantings in the Lehigh Valley". Wildlands Conservancy. Emmaus, PA.

Wood, Charles R., Herbert N. Flippo Jr., Joseph B. Lescinsky, and James L. Barker. 1972. Water Resources of Lehigh County, Pennsylvania. Pennsylvania Geological Survey. Harrisburg, PA.

Wright, James and Linda. 1988. Place Names of Northampton County, Pennsylvania.

OTHER REFERENCES

Ace, Roberta. 1975. "Parkway Extension and Alternative Plans for the Monocacy Creek".

Alderfer, E. Gordon. 1953. Northampton Heritage, the Story of an American County. Northampton County Historical and Genealogical Society. Easton, PA.

Barlieb, Catherine L. 1965. Bethlehem's Birds as I Found Them: 1933-1962. The Moravian College Conservation Association. Bethlehem, PA.

Bethlehem of PA: The First 100 Years. 1968. Bethlehem Chamber of Commerce. Bethlehem, PA.

Billingsley. 1987. Monocacy Creek (502C) Management Report Section 8. PA Fish Commission.

Billingsley and Bourke. 1985. Monocacy Creek (502C) Management Report Section 8. PA Fish Commission.

Billingsley, Bourke, Ercolani, Reiser, and Smith. 1987. Stream Examination Report. PA Fish Commission.

Billingsley, Hallowell, and Hannold. 1977. Stream Examination Report. PA Fish Commission.

Bradt, Patricia. 1985. "Statement to the Public Hearing on the Golfland Shopping Center and Its Potential Impact on the Monocacy Creek".

Bradt, Patricia. 1984. "Report to the Monocacy Creek Watershed Association".

Burns, Robert E. 1950. Geology Along Monocacy Creek at Bethlehem, Pennsylvania.

"Checklist of Pennsylvania Native Trees". 1995. Morris Arboretum of the University of Pennsylvania. Philadelphia, PA.

"Demographics of the Lehigh Valley: Selected Statistics for the Human Services Review of the Lehigh Valley Advisory Council-United Way". 1985. Compiled by Lehigh Valley Planning Commission.

Everett, Jeffrey J. 1976. Heavy Metals and Population Characteristics of Muskrats in Relation to Water Quality in Southeastern Pennsylvania. Penn State University. State College, PA.

Foley, Vincent P. 1964. The Old Waterworks Archaeological Project. Bethlehem, PA.

Freedman, Linda. 1994. "Census, Bird Population- 12 Months, starting November, 1993- Species Seen in Archibald Johnston".

Freedman, Linda. 1994. "Species Seen as of 6/8/94 in Archibald Johnston".

Frey, Robert F. 1973. Aquatic Biology Investigation-Monocacy Creek. PA Fish Commission.

Frey, Robert F. 1977. Aquatic Biology Investigation-Monocacy Creek 1.19.1A. PA Fish Commission.

Frey, Robert F. 1979. Aquatic Biology Investigation-Monocacy Creek 1.19.1A. PA Fish Commission.

"Gardening in Wet Places". 1997. U.S. EPA. Washington, D.C.

Hesser, R., J. Reed, and B. Hollender. 1971. Stream Survey Report. PA Fish Commission.

Hindle, Brooke. 1977. The Meaning of the Bethlehem Waterworks. Historic Bethlehem Inc. Bethlehem, PA.

Horner, Richard R. and Stephen M. Grason. 1981. An Ecological Study of the Monocacy Creek and its Groundwater Sources in the Vicinity of Camel's Hump (a report to the Monocacy Creek Watershed Association). Northampton County Area Community College. Bethlehem, PA.

Hower, Ned P. 1976. "A Chemical and Biological Analysis of the Monocacy Creek Between the Keystone Portland Cement Company and the National Portland Cement Company". Northampton County Area Community College.

Huetter, Karen Zerbe. 1976. The Bethlehem Waterworks. Historic Bethlehem Inc.

Huth Engineers Inc. 1989. Master Plan for Sand Island City of Bethlehem, PA. Allentown/Lancaster, PA.

Johnson, Norman L. 1909. Development of Water Power on the Monocacy Creek.

Kita, B.F. 1978. A Seasonal Guide to the Monocacy Nature Center. Bethlehem, PA.

Kochanov, William E. 1987. Sinkholes and Karst-Related Features of Northampton County, Pennsylvania. PA DER, Bureau of Topographic and Geologic Survey.

Lehigh Valley Planning Commission. 1982. Comprehensive plan for Lehigh-Northampton Counties. Allentown, PA.

Lehigh Valley Planning Commission. 1967. Drainage and Flood Plains: A Regional Plan Report. Lehigh Valley, PA.

Lehigh Valley Planning Commission. 1972. Environmental Enhancement Study. Lehigh Valley, PA.

Lehigh Valley Planning Commission. 1974. A Guide to Environmental Planning and Development. Lehigh Valley, PA.

Manacke, Ralph G. 1986. pamphlet. "Monocacy Nature Center Bird Census. August 1, 1983 to June 2, 1984". Wildlands Conservancy and Monocacy Creek Watershed Association.

Marshall, Richard and Craig Billingsley. 1975. Stream Survey Report. PA Fish Commission.

Miller, Jane E. 1978. "The Benthic Macroinvertebrate Community in the Monocacy Creek, Northampton County".

"Monocacy Nature Center Sanctuary". Brochure. Northampton County Area Community College Biology Students.

"Native Trees Suitable for Urban Plantings". Pennsylvania State University. Collegeville, PA.

"Recommended Species for Pennsylvania". National Wildlife Research Center. Austin, TX.

Savitz, Jacqueline D., Christopher Campbell, Richard Wiles, and Carolyn Hartmann. 1996. Dishonorable Discharge, Toxic Pollution of Pennsylvania Waters. Environmental Working Group. Washington, D.C.

Schray, T. 1979. "Stormwater Runoff: The Monocacy Creek Situation". Environmental Studies Department, Northampton County Area Community College. Bethlehem, PA.

Siska, Rian R. 1972. "Water Pollution and the Monocacy Creek". Moravian College. Bethlehem, PA.

Skillman, David B. 1954. Old Northampton County. Northampton County Historical and Genealogical Society. Easton, PA.

Smaby, Beverly Prior. 1988. The Transformation of Moravian Bethlehem: From Communal Mission to Family Economy. U. of Penn Press. Philadelphia, PA.

Snyder, Richard A. 1975. "Survey of the Monocacy Creek-Northampton County". PA Fish Commission.

Sommers, William. 1975. "Monocacy Creek: Chemical and Biological Inventory". Northampton County Area Community College.

Tetra Tech, Inc. 1996. "Aquatic Environmental Assessment of keystone Cement Company Activities Adjacent to Monocacy Creek Bath, PA". Owings Mills, MD.

Tourbier, J. Toby. 1987. "Water Resources Assessment for the Lehigh Valley Industrial Park IV". University of Delaware Water Resources Center.

Tourbier, J. Toby. "Water Resources Assessment for the Bethlehem Square Shopping Center". University of Delaware Water Resources Center.

U.S. EPA Storet System Data- Monocacy Creek. Retrieved: September 20, 1995. PA DEP: Bureau of Water Quality Management.

Water or Waste Quality Report. 1992. PA DER, Bureau of Laboratories.

Wildlands Conservancy. 1994. Little Lehigh Creek Stream Corridor Conservation Project Stream Status Report. Emmaus, PA.

Witty, Diane. 1984. "Monocacy Creek, Part 1". Wildlands Conservancy and Monocacy Creek Watershed Association.

Witty, Diane. 1983. "Monocacy Creek Summary of Available Literature".

"Scope of Services Proposal for the Monocacy Creek Stream Greenway Project Phase One". 1990. Wildlands Conservancy. Emmaus, PA.

APPENDIX 1

Public Hearing Transcript

Water Quality Information

Project Implementation Schedule

Best Management Practices

Riparian Corridor Conservation District 1995

MONOCRACY CREEK PUBLIC HEARING
11/12/98

Present: Lawson Ainsworth, Thom Mutchler, Stan Burns, Linda Crawford, John Chay, Bob Windolph, Bernie Kita, Chris Kocher, Heather Zellers, Tom Kerr, a local citizen, and Patrick Doherty.

Meeting Started: 7:08 P.M.

Tom Kerr: Good evening. Thank you all for coming tonight. I'm Tom Kerr. I've been with the Conservancy for twelve years, we've been involved with stream projects for about ten years. For about nine years, we've been involved in some way with the Monocacy Creek itself. For the last few years, the Conservancy has been focused on the Lehigh River Watershed. In fact, we've named the project the Lehigh River Watershed Initiative. In that same period, Chris Kocher, Heather Zellers, and Stacy Cromer, have come on board. For eighteen months, they have been working on this project and other projects . I think this project represents a culmination of where and how far the Conservancy has come. I think you will be even more impressed tonight with the quality of work that these folks have done. The Conservancy is involved with a lot of projects, which includes our Rivers Program. We're involved with acquisition and protection of open space, farm land, and park land. Environmental education has been fundamental in all our projects. Trail work is something which we have expanded into more recently, particularly the D&L corridor. This involves walking, biking, and hiking our water trails again on the river. The Lehigh River Watershed Initiative Project, in particular the Monocacy Creek, is a perfect example of what the Conservancy can accomplish. The Monocacy Creek Watershed Association doesn't need money to tell it what to do, or where to go. The Association has its own strengths, abilities, skills. But, there are some things we can uniquely do. Five people made up the staff at the Conservancy twelve years ago, currently the staff employs twenty-three people. Seventeen staff members are full-time capacity. It' s certainly a more sophisticated organization than it was twelve years ago. We are very excited about it. We can bring something to this, as Chris and Heather will explain the program itself. The stream project will elevate the Monocacy Creek to a place, in the state's eyes, where it hasn't been before. We think this is important work. We'd like if we could do that for this stream and others, as we go forward. I would like to thank Chris on a remarkably successful program, and I am excited that Chris is with our association.

Chris: Thanks Tom. What I'd like to do now is thank some people and distribute copies of the management plan. I apologize that we don't have color copies for everyone. Each project partner will receive a copy. We have been working on these for the past two and one-half to three years. Now, I would like to speak of partnerships. This project is a culmination of much hard work, not only the Conservancy staff, but other organizations as well. I would like to thank some of these organizations:

The Lehigh Valley Planning Commission being one. They were involved with the project from its inception. We did some contract work with the commission. They were involved in creating some of the GIS coverages which you see in the document plus some work on the water quality and land use analysis.

Lehigh University was involved with the GIS aspects with some interns and we thank them for their support.

Muhlenberg College provided us with an intern, Kelly, who assisted with macro-invertebrate assessment, and Dr. Bradt who assisted with that as well.

The Monocacy Creek Watershed Association assisted in the planning and also hosted some of the meetings. We also thank Citizen's Action Committee for similar types of things.

Moravian College for hosting the meetings and providing interns throughout the project.

Monocacy Trout Unlimited for their assistance, again in the planning process.

Historic Bethlehem Partnership for their assistance in the historical aspect of the plan.

I 'm impressed with Tom Getting's (Rodale Press) photography. I'm sure that most of you have seen some of the amazing pictures that he has taken.

Karen Dolan for piecing together the Biological Diversity Report.

Gordon Heller (Northampton County Parks Association).

I'd like to mention all the municipalities for their support in helping us devise and come up with recommendations that were incorporated in the plan. Heather Zellers will be more specific about those recommendations in the plan.
I also want to take a moment to thank all of the people that supported the project monetarily throughout the entire project. We had to come up with some matching funds. We received a fifty-thousand dollar grant from Rivers Conservation Program. But we had to match that, and those funds came from local individuals and industries interested in the protection of the Monocacy

Creek. Even though most of you have attended most of prior meetings, it should be noted that these meetings are a state requirement.

After Heather is done, I'd like to take a few minutes to explain to you the future timeline and what you can expect from the state as well as Monocacy Creek, and we'll outline the steps we need to go through to get the stream on the registry, and then what the registry means not only for the creek but also for the project partners that helped form the report.

Heather: I'm passing out copies of the executive summary, so you can page through it as we go along. One of the main tasks that was required, prior to completion of the management plan, was to inventory the resources in the watershed. Those included the physical, biological, and aquatic, as well as recreational and institutional resources. That was a major task and I don't want to spend a lot of time going through those individually. We already had a preliminary findings meeting where we identified those and we talked about them again at the meeting to discuss the rough draft of the management plan. I want to emphasize that we did look at the Monocacy Creek on a watershed-wide basis, because all the activities that go on within the watershed impact the creek and its corridor. One of the ways we looked at it from a watershed-wide basis was by meeting with all the municipalities within the watershed and also with watershed interest groups to get their opinions on the major issues within the watershed, their key concerns, and what we should be addressing in the management plan. Most importantly, I wanted to review the recommendations of the management plan. The recommendations of the management plan were broken up into six major goals. These goals can be found in the executive summary.

The first major goal was the preservation of the valuable resources within the watershed and that includes historical resources, open space and valuable farm land, wetlands, and those type of resources. We must work to protect these resources.

We're also working to document and would like to see more documentation of the water quality and biological resources within the watershed by instituting an ongoing monitoring program for water quality and doing more macro-invertebrate studies on a regular basis. We would be working with other organizations to do that. Examples of such organizations are volunteer groups, local educational institutions and so forth.

Involved with that would also be the establishment of a central database for information collected so that we would not have to run to various organizations for information on the watershed. Hopefully, that can be done through an internet web site possibly developed by Lehigh University. Lehigh University is developing a grant to attain a web site for the entire Lehigh River Watershed.

The Monocacy Creek would be included in this web site and hopefully we could house all of the information and research that's been done on the watershed.

Conservation and enhancement of water quality and corridor habitat is also a recommendation and major goal that would be done through stream bank stabilization projects and habitat improvement projects, such as the one at St. Francis, as an example. The management plan has mentioned several specific projects that we would like to see done in the nature center and in other portions of the watershed. That's where we focused the conservation and enhancement of water quality.

Another key issue that we addressed is the necessity to increase environmental awareness throughout the watershed. One way that we have identified to do that is by creating and distributing a stream-side property owners management guide. Hopefully, we can get some grant money for this guide, and be able to distribute it to everyone along the creek. We recently had a meeting with someone who lives along the Monocacy Creek, and they were concerned about what their neighbors were doing to the corridor. The native vegetation was at risk. They were very interested in doing the right thing and just didn't know what that was. This is the reason for distribution of the management guide to the stream-side property owners. This could be a major benefit to the watershed.

We would like to improve the quality of life and property value throughout the watershed. A start would be to engage in stream and roadway cleanup efforts throughout the watershed to make it more aesthetically pleasing. Also, restricting herbicide spraying along the rail and roadways would be enforced to prevent destruction of a lot of native vegetation. Spraying promotes the growth of invasive species and noxious weeds. Along with improving the quality of life would also be to increase recreational opportunities. Something that a lot of municipalities were interested in, was developing a trail system throughout the watershed, and possibly a connected trail system. Investigating these possibilities is one of our major recommendations in the management plan. This can be done through partnerships and help from Lehigh Valley Planning Commission.

We would like to see a reduction in the non-point source pollution in the watershed. There are numerous ways of approaching this. It is a major issue, not only to the Monocacy Creek watershed but also throughout Pennsylvania and the entire United States. Non-point source pollution has become one of the major threats to our waterways. So that needs to be focused on right now and can be accomplished through better management of storm water runoff, cutting down pollution at the source, and reducing the pollution before it actually enters the stream.

We have an implementation schedule that lists various projects that we believe would bring some of the most immediate improvements to the watershed. This

is located on the back of your executive summary. It focuses on stream bank and habitat improvement projects and also educational opportunities, like I mentioned the stream-side property owners management guide and also a lecture series for the public that the Conservancy could organize. These are some things we have included in the implementation schedule. The schedule is in no way definitive, but is a general guide to provide ideas for the types of projects you can do and the items that require the most immediate attention. It doesn't restrict your ability to do other things within the watershed. Anything contained in the management plan and not just on the project schedule, you can receive funding for. As I mentioned earlier, this is only a guide. There are numerous opportunities to do work within the watershed and it is not restricted to the implementation schedule.

Chris, Do you want to talk about the future (of the project) and where we are headed right now?

Chris: The executive summary has really just been outlined with everything included within the management plan. Pay particular attention to the recommendations section that is in the management plan because that becomes our funding opportunity, our tool for the future. Anything that is within the document can become funded through the Pennsylvania Rivers Conservation Program, over time, once the stream is on the Pennsylvania Registry. So it becomes a great learning tool, as well as a management guide, and also as a formal document to bring together sources of information that already existed or were collected into one document used as a reference. We are happy to put that all together and in place and hopefully we can use in the future to better manage, preserve, enhance and protect the Monocacy Creek. I would like to focus on getting the stream onto the registry. This is our final public hearing. After this point, we actually have a tape of the proceedings, a transcript will be sent to all the municipalities and project partners along with a copy of the executive summary of the management plan. We need one resolution in order to get the stream on the registry. So it is very important that at least one municipality passes a resolution supporting the project and other municipalities can bring letters of support in. Also, any organization or group that wants to use this plan in order to receive funds in the future should submit a letter of support supporting the Monocacy Creek Management Plan. This is pretty easy, writing a letter, and opening up a funding source for many years. I don't know if we have any municipalities present tonight. It is very important that we get the word out to them that they need to approve the plan. It is only a plan, and in no way set in stone, but it is more of a management guide for the Monocacy. I feel that it contains a lot of historical information that can be used in the future. So getting back to the future, we are going to submit this to the municipalities. Hopefully the municipalities will act on it and pass a resolution. Once we receive the resolutions and letters of support from the municipalities and local project partners we will send it out to the state in one packet with some additional

information like our GIS coverages, geographic information system coverages, the management plan itself, and some of the notes from the prior meetings. We will petition the state to put the Monocacy Creek on the Pennsylvania Rivers Registry. Then there is some process that the state goes through, and the stream is on the registry for the stream improvement dollars. Currently, there are only ten streams in Pennsylvania that are on the registry. The Monocacy is part of the '95 funding cycle. We are close to the front as far as being on the registry. In the first year twenty- two grants were given out, and we will probably be the eleventh or twelfth stream on the registry. We were hoping to get this done a little earlier, but things have taken more time than planned. Again, I want to thank everyone for all of your support. I see a lot of familiar faces. We have been dealing with a lot of you over the past couple of years and we appreciate your interest. Again I want to stress the fact this is in no way the Wildlands Conservancy Program, this is our plan, this is the Watershed Partners' Plan. We need to work together in the future to protect and enhance the Monocacy. This document can be a tool in order to make that happen. I believe the things that have happened along the Monocacy and the support even before the Conservancy came is excellent. I think with the cooperation of the Conservancy, the Monocacy Creek Watershed Association, Citizens Action Committee, Trout Unlimited and all the other project partners, we can enhance this coalition and use this document to reach it's goals and hopefully benefit the stream. Thank you very much for everything that you have done. Thank you for attending these meetings. I must admit that we have found it very valuable to have these meetings. We have received a lot of information from the groups at these meetings, a lot of the reports that have been put together by the schools and private individuals have come out of discussions at these meetings. You have the plan, if there are any comments, we would appreciate them positive or negative . We are pretty much at the end of the line for adding things into the plan. We have had several comment periods and some organizations had input into the plan. The information from tonight will become an appendix of the document.

Question and Answer Period:

1. Did you bring any slides to the presentation?

   No, We thought that most of the people would have already viewed the slides. Therefore, we decided to use the time to present the plan and ask for comments.
2. Have you been to other municipalities and what was their response?

   The municipal involvement started at the inception. In order to receive a grant from Pennsylvania Rivers Conservation Program we needed letters of support along with resolutions from fifty percent of the municipalities. At present, fifty percent have supported this project. We met with each municipality individually to focus on their problems and goals for the Watershed Plan. A majority of the information is in the recommendations section. We also had them review the content to ensure everything is right and relative to the municipality. I feel confident that we will get the needed resolution and letters of support from the municipalities. We put a lot of "pet" projects into the plan in hopes that they would support the plan. Projects they have within could potentially be funded through this program.
3. We worked with you so long and share a lot of the common projects. Have you done similar work with other organizations or municipalities? I'm aware that Lower Nazareth Township has a number of pet projects and I am sure that you would like to see this in here. I'm sure you've got them in here without reading the whole thing on the spot.

   Like I said there are many comment periods and we have met with each municipality. A wish list was devised of projects to happen. It is in there, if not specifically it is in there in general so that funding can come from the general comments.

4. Is it possible to pick out the items that relate directly to Hanover Township?

   It can certainly be done. We can-take a look at the plan with respect to Hanover Township.
5. There might be some well informed documents from the township manager in light of the support for the project?

   Yes
6. You mentioned other organizations . What other organizations have you spoken with besides us?

The Planning Commission, some individuals on the rail trail aspect, municipalities, Historic Bethlehem Partnership, D&L Heritage Corridor Commission, Gordon Heller- Northampton Parks

7. It is not likely, but I would like to know if there were any environmental or conservation organizations that we have not heard from?

   They are in the plan. Everyone that we met with is there. There was, I think, one Environmental Advisory Council (EAC) within the watershed. I believe that Lower Nazareth and Bath may have one. We felt they obviously had an interest in the watershed.

   A lot of the maps that you see in there were produced in cooperation with The Lehigh Valley Planning Commission. We did some work ourselves on the layouts and actually the planning commission printed them out. It is a valuable resource for the Watershed partners. Not only the maps are involved, but a spacial database. This will be housed in the Regional Data Center that Heather mentioned before, as well as at Wildlands Conservancy. You will be able to look at the data spatially. It's a neat way to get maps and to look at the data spatially in the watershed. You will be able to pull out attributes of the system. You can query the system to find out the land use of a particular part of the watershed or township. You could also add information to the database over time. For example the water quality is tied into the GIS. It is a valuable tool in the future. Other project partners can benefit from the different coverages which were compiled and all the information which is present.

8. How many coverages did we end up with?

   Heather... Seventeen or eighteen different data sets for the watershed. Some of those maps have different data sets. It is pretty comprehensive and we appreciate the Lehigh Valley Planning Commission for taking the time to piece that together.

9. What about the DEP proposal on the controlling of non-point source pollution?

   We addressed non-point source pollution very heavily

10. A lot of the local townships use to control the roadside weeds. It was their policy to kill everything, it was messy. We were complaining about this for years and now all of a sudden this has stopped. Did you have anything to do with that?

    No we didn't. It's in the management plan though. There was a long time battle with the railroad. Maybe more people were reached than we

thought with the management plan. We addressed that issue and other issues like it in the management plan. It really becomes a guide to better manage the resources as a whole. Like Heather said, we took a look at it on the watershed basis. It doesn't matter what municipality or county. We realize the key is looking from the perspective of the watershed basis.

It was a far cry from twelve years ago. We are happy that its is done and very fortunate that we got the partnership involved as we did. We couldn't have come close to that document had it not been for the pre-mentioned people, most of those people are currently in the room

11. What role do you see us in with the project?

Keep on doing what you are doing. This is Our vision. The Conservancy is very willing. You can't go for more than one project per year. You need to have the multiple organizations go for funding. For example, the Conservancy can go for a implementation grant, the Citizen's Action Committee, and then the Watershed Association.. So you see we can get a lot of the projects done with through the funding.. It is important to remember that we are in competition with other streams on the registry. For example there was 1 million (end 1st side)

12. Are there any organizations like ours. This isn't going to happen unless the folks like you help us.

It's not only in Pennsylvania, It started out west and everyone seems to be pushing on that. It was a little late in coming, fifty years too late.

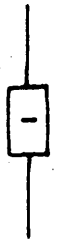
Well, I hate to give something and then take it back, but we actually need the copies back because we have a limited number. We need to get these to the municipalities ASAP. One to be kept for the organizational register, and the executive summary will go to each of the project partners.

13. When is it appropriate for organization to prepare newsletters?

Once we get the plans together, we'll submit one to each project partner and municipality. A copy will be sent to each president of the organization, and then to the municipalities. Then we will package and send it to the state.

EXPLANATION OF WATER QUALITY PARAMETERS AND ANALYZATION TECHNIQUES

The results of water quality tests were analyzed using a software program called Statgraphics that created multiple box-and-whisker plots. Plots of the analyzed characteristics are contained following the descriptions of the parameters. These plots are a statistical summary of a set of univariate observations. Such plots provide easy visualization of data including comparisons of medians, ranges, and extreme values within each group of data. A normal plot, consisting of at least five data points, divides data into four areas of equal frequency. The box encloses the middle 50 percent of observations. The median is drawn as a horizontal line inside the box. Vertical lines (whiskers), which extend from the end of each box, show the outer frequencies. Data points that are statistically outside the range of the whiskers are shown as separate points on the graph (.). Distant outliers are displayed as separate points overlain with a cross-hatch. When data is closely grouped, plotted results may appear in a number of different forms. Some common representations of data results can be interpreted as follows:



Fifty percent of the data falls within the boxed range. Twenty-five percent of the data falls within the range shown by each whisker. The horizontal line inside the box depicts the median.

If no whiskers are shown, data is grouped closely and 100% of the data falls within the boxed range.

If only one whisker is shown, a portion of data is grouped closely and 75% of the data falls within the boxed range.

If only the median line is shown, all data points are the same.

TEMPERATURE

Background: Temperature is a key determinant of what species can survive in a particular environment. Although temperature preferences vary widely among species, they do have one commonality. All species are negatively impacted by rapid fluctuations in temperature.

Sources of Abnormal Readings: Discharges of coolant and waste waters from industrial or utility plants, runoff from heated surfaces such as pavement and roofs, and lack of stream cover to provide shading are among the top sources of thermal pollution.

Standards: Life and the reproductive necessities for trout are the target standards for water temperature. Growth is impaired in an adult brook trout at temperatures above 66°F or about 19°C. Death of brook trout will occur at temperatures above 75°F or about 24°C. DEP Water Quality Standards dictate a temperature no greater than 66°F for a high quality, cold water fishery (HQCWF). There should also be no fluctuation greater than 2°F in a one-hour period.

pH

Background: pH is based on a scale from 0 to 14. On this scale, 0 is the most acidic value, and 14 is the most alkaline value. Seven would be neutral. A change of one pH unit represents a 10-fold change in acidity or alkalinity. Type of bedrock and other natural conditions may affect pH readings. For instance, streams underlain by limestone may reach a pH as high as 9. In addition, abundance of algae may cause pH to become more acidic after sundown, then increase after dawn due to changes in carbon dioxide concentrations. However abnormal pH values may be indicative of pollution.

Sources of Abnormal Readings: Sources of abnormal readings include acid mine drainage, industrial effluent, acid rain, sewage lagoons, and livestock containment areas. Sources of alkaline conditions include concrete plants, water treatment plants, and raw sewage.

Standards: pH levels between 6.5 and 8.2 are optimal for most aquatic organisms. The DEP Water Quality Standard for pH is between 6 and 9.

DISSOLVED OXYGEN (DO)

Background: Dissolved oxygen is absorbed from the atmosphere and its concentration is related to the temperature and density of the water. Cold water can hold more oxygen than warm water. Therefore low values can sometimes be attributed to shallow, poorly shaded water, which can cause warming and decrease the amount of oxygen the water can hold. Plant life also influences dissolved oxygen content. Plant life may cause a diurnal fluctuation in DO levels. During the day, while plants are undergoing photosynthesis, they emit oxygen to

the stream. However, the DO level will drop at night while the plants are not producing oxygen but fish and other aquatic life are still consuming it. The result is a drop in DO at night, reaching a minimum just before dawn, then rising to a peak by late afternoon. Thus, plant life may have a dramatic impact on DO levels.

Sources of Abnormal Readings: In areas of dense algae growth, DO levels are likely to drop significantly at night or increase excessively during the day. Low readings may also be indicative of pollutants, such as inadequately treated sewage, introduced to the water supply that consume the available oxygen so that it is not available to aquatic life. Bacteria are capable of consuming large quantities of oxygen during the decomposition of organic material. High DO levels may occur where turbulent conditions increase the natural aeration of the stream.

Standards: Trout require a dissolved oxygen (DO) level of at least 7 mg/L for unimpaired production, which is the minimum Water Quality Standard set by the DEP for a high quality, cold water fishery (HQCWF) such as the Monocacy Creek.

SPECIFIC CONDUCTANCE/TOTAL DISSOLVED SOLIDS (TDS)

Background: The specific conductance of a stream measures the quantity of ions in the water, or the ability of the water to conduct an electrical current. Conductivity is typically measured in micromho units, which is equivalent to microsiemens. Geologic formations have significant impact on the specific conductance of a stream. Streams flowing through carbonate bedrocks often yield high conductivity. Specific conductance values typically have a direct relationship to TDS, which is the concentration of dissolved materials, such as salts, found in the water.

Sources of Abnormal Readings: A specific conductance or TDS value falling outside the normal range for a site may be caused by almost any pollutant. Point source discharges as well as storm water runoff may be contributors to excessive readings. Basically these testing parameters serve as a check to make sure pollutants are not being overlooked that are not part of the regular sampling routine.

ALKALINITY

Background: Alkalinity measures the ability of a stream to resist changes in pH. This property is often referred to as the buffering capacity of a stream. Buffering capacity is important because it allows a stream to assimilate acidic pollution or contamination. Like specific conductance, alkalinity is greatly determined by the type of underlying bedrock and also the soil type through which the water flows.

Source of Abnormal Readings: Alkalinity values in excess of what bedrock types indicate as normal may be a result of sewage, livestock wastes, and/or the production of concrete. Very low readings may be due to heavy rains or other acidic contamination. Abrupt changes in alkalinity may signify pollution.

Standards: Alkalinity levels between 100 and 200 mg/l provide ideal buffering within a stream. Endurable pH levels may be maintained at this level of alkalinity, and aquatic life may be protected from acidic shock. This occurs when there is a sudden decrease in pH that aquatic life can not rapidly adapt to for survival.

NITRATE

Background: Nitrogen exists in several forms in the aquatic environment. Nitrate is the most completely oxidized state of nitrogen commonly found in water, and is the most readily available state utilized for plant growth. Since nitrate plays a key role in stimulating plant growth, it is heavily used as a nutrient component of fertilizer. High nitrate levels in streams cause excessive plant and algae growth and promote a deteriorating process called eutrophication.

Sources of Abnormal Readings: Fertilizer runoff resulting from improper application, human and animal wastes from failing septic systems and livestock confinement areas, and decomposing organic matter are all causes for elevated nitrate readings.

Standards: Unpolluted waters will normally have a nitrate level less than 1 mg/L. The DEP Water Quality Standard for nitrate is 10 mg/L. At higher concentrations water is unsafe to drink due to the possible presence of altered forms of nitrite, which may cause serious illness to both man and wildlife.

ORTHO-PHOSPHATE

Background: Ortho-phosphate is just one form of phosphorus found in natural waters. This is the tested form of phosphate because it is the form of phosphate used in fertilizer and applied to agricultural fields and residential lawns. Other forms of phosphorus found in natural waters that have not been tested include polyphosphates, and organically bound phosphates. Phosphates naturally found in water are derived from decomposing organic material and leaching of phosphorus rich bedrock. Like nitrates, phosphates negatively impact water by causing accelerated rates of eutrophication.

Sources of Abnormal Readings: Fertilizer runoff; human and animal waste from failing septic systems, sewage treatment plants, and livestock confinement areas; mass quantities of decomposing organic matter; industrial effluent; and detergent wastewater are all possible sources of elevated phosphate levels.

Detergent wastewaters are responsible for approximately half of the phosphates polluting natural waters.

Standards: Phosphate levels below 0.03 mg/l are generally considered to be unpolluted. Levels between 0.03 and 0.1 mg/l are sufficient to stimulate plant growth. The critical level for avoiding accelerated eutrophication is 0.1 mg/L. Levels above 0.1 mg/l are considered problem areas. There has not been a standard set for safe drinking water because humans can tolerate extremely high levels before it even takes affect on the digestive system.

HARDNESS

Background: Total hardness tests usually measure the calcium and magnesium carbonate concentration in a water sample. These are the major components of hardness, which is the amount of dissolved minerals in water. Minerals are dissolved from bedrock and soil as water passes through them. The calcium component of hardness is very important to aquatic life as it is used for the cell walls of plants and the shells and bones of aquatic organisms. However, high levels of hardness can cause precipitation and deposition of calcium carbonate on the stream bottom, which disrupts normal stream activity. Water with high hardness may also cause plumbing problems. Hard water also aids buffering capacity as heavy metals and other toxic compounds may be more detrimental in soft water than in hard water.

Sources of Abnormal Readings: High hardness values are often associated with limestone formations.

Standards: Optimal values of hardness for aquatic life range from 100 to 200 mg/L. At levels above 250 mg/L, calcium carbonate will begin to precipitate. Hardness values should be slightly higher than alkalinity values. If there is a major difference between the two values, chloride and sulfate ions may be present.

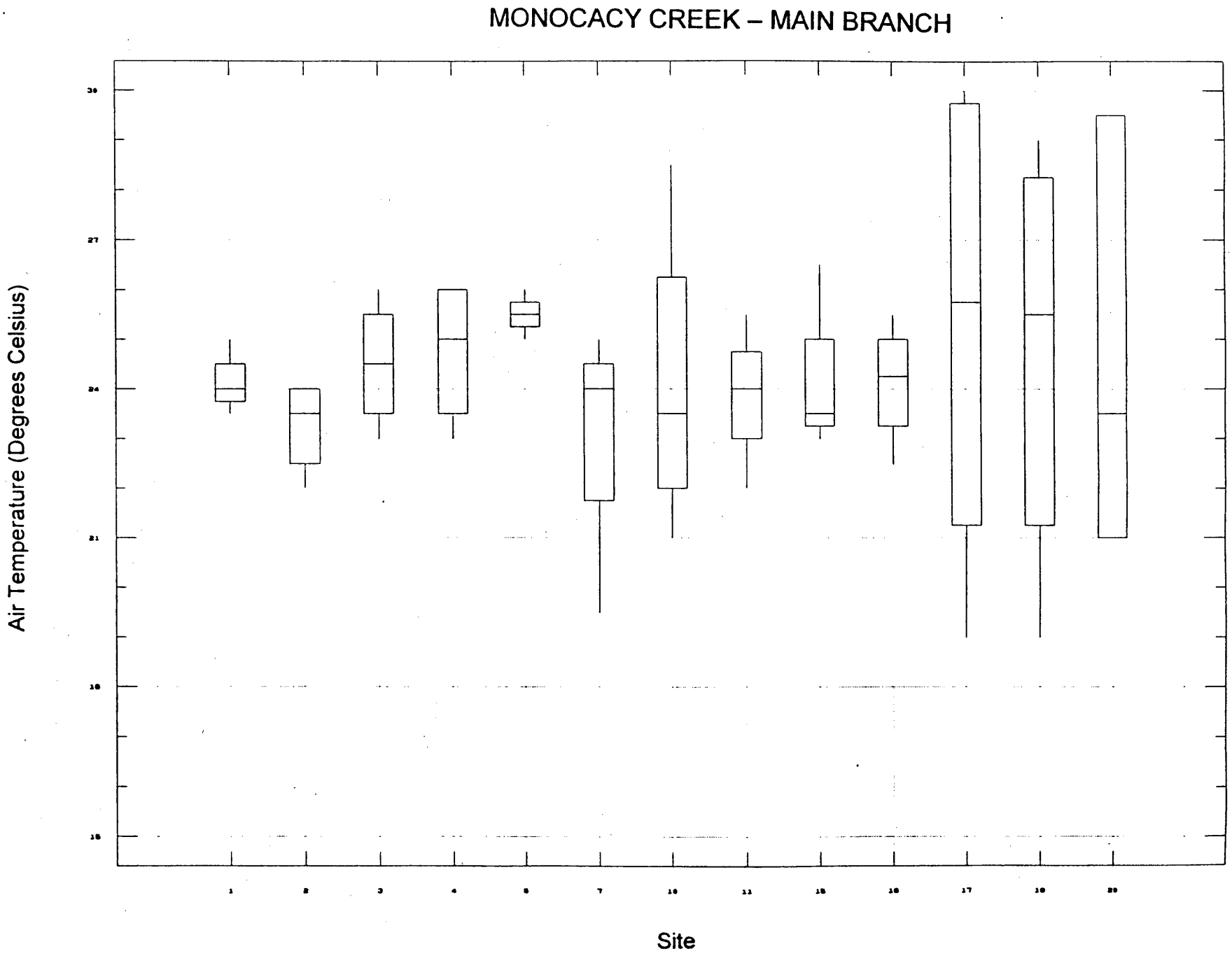
SULFUR

Background: Sulfur is commonly found as a component of sedimentary and igneous rocks in the form of metallic sulfides. Sulfides are oxidized upon contact with aerated water, producing sulfate ions in solution. The combustion of fuel and ore smelting processes are major anthropocentric causes of sulfate found in natural waters. Sulfides may also be present in soils that are oxidized through natural processes or organic waste treatment. Sulfate also occurs in evaporite sediments such as anhydrite and gypsum.

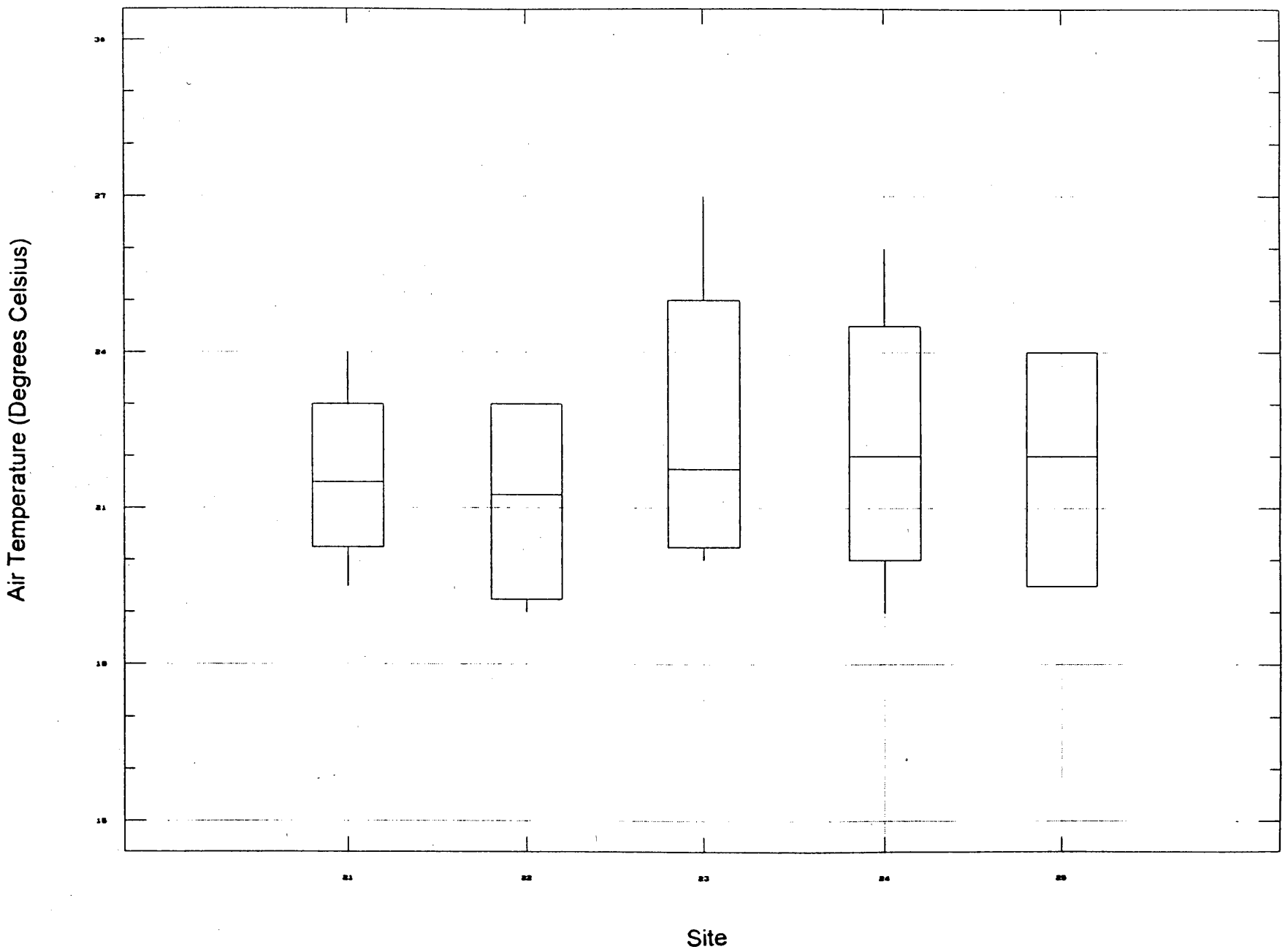
Sources of Abnormal Readings: Excessively high sulfate readings are often associated with mine drainage. The oxidation of minerals such as pyrite is the main culprit. High sulfate as well as chloride concentrations may be found in

residual runoff from irrigated areas due to water that was lost through evapotranspiration.

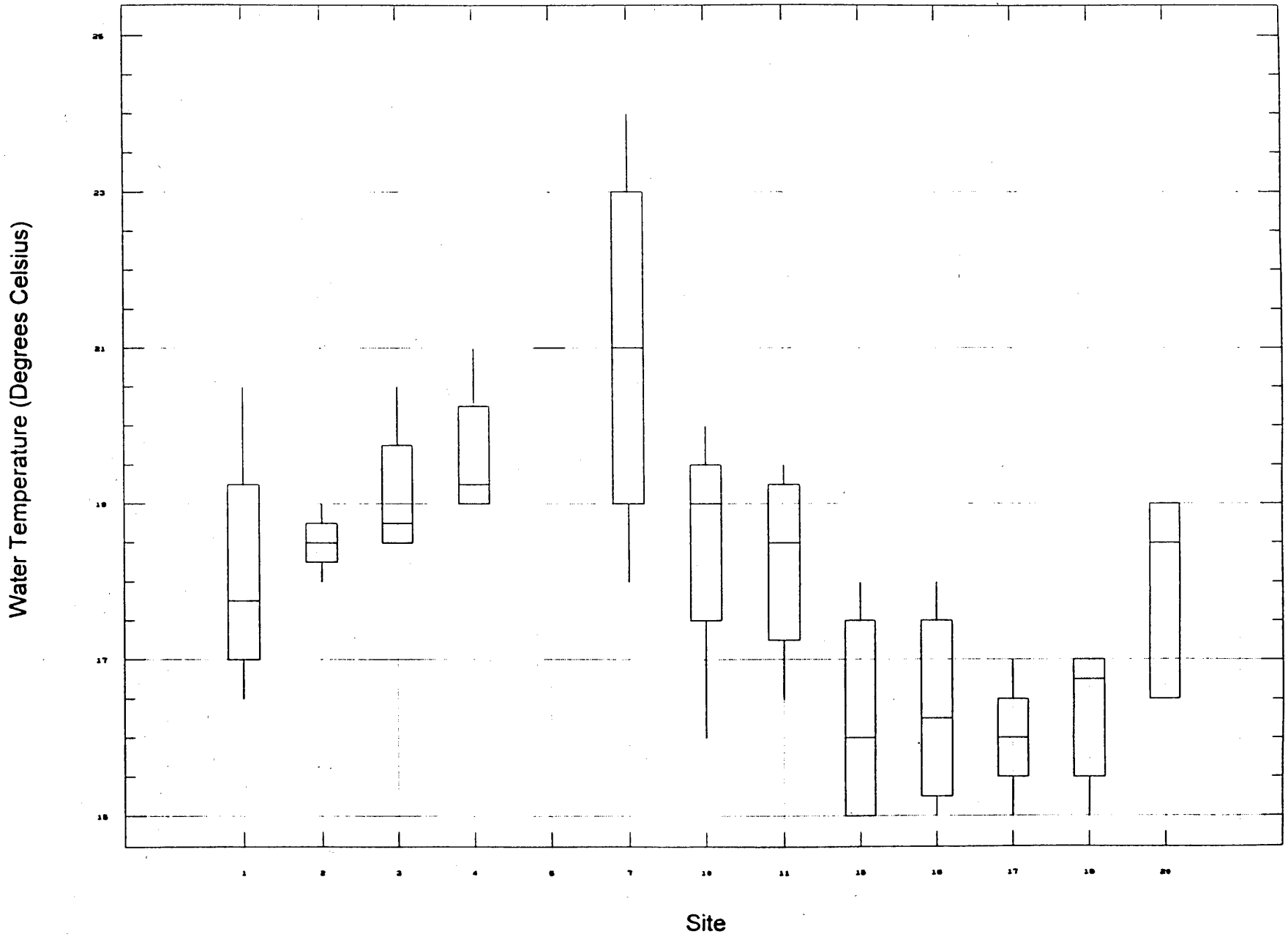
Standards: The drinking water standard for sulfate is 250 mg/L. Beyond this point, sulfate levels may cause illness in humans.


MONOCACY CREEK – MAIN BRANCH
Air Temperature (Degrees Celsius)
30
27
24
21
18
15
1
2
3
4
5
7
10
11
15
16
17
19
20
Site

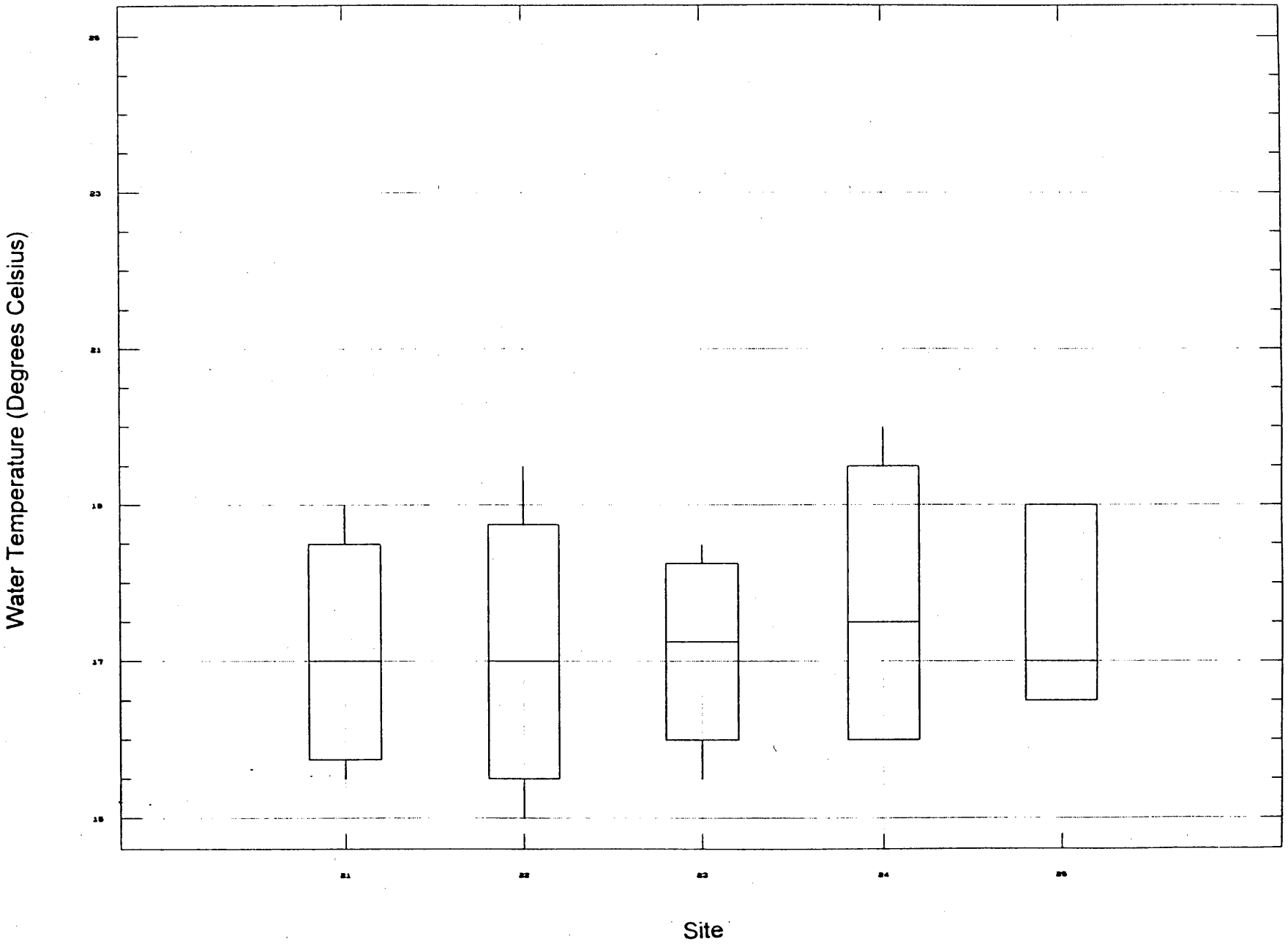
MONOCACY CREEK – EAST BRANCH



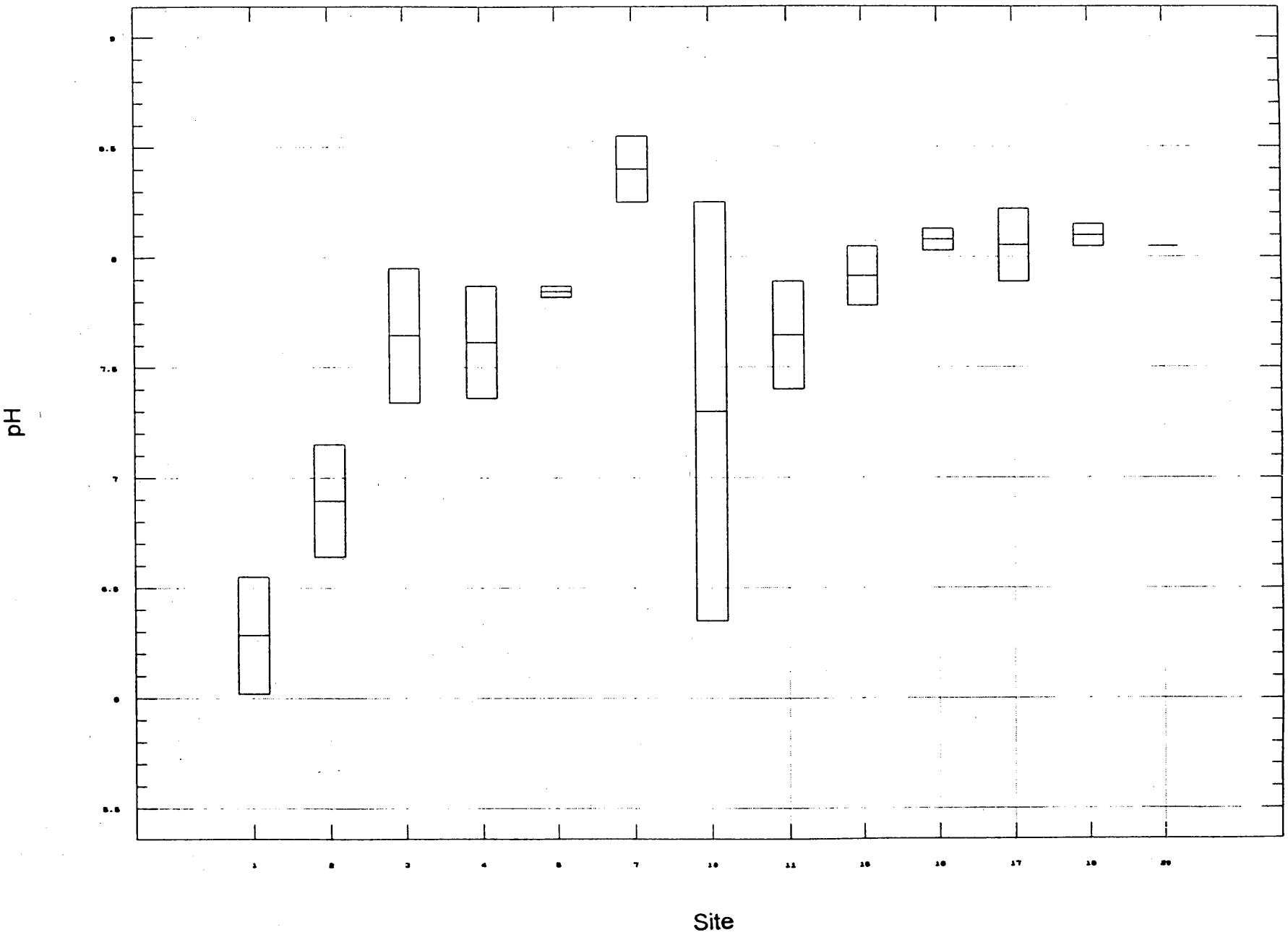
MONOCACY CREEK – MAIN BRANCH



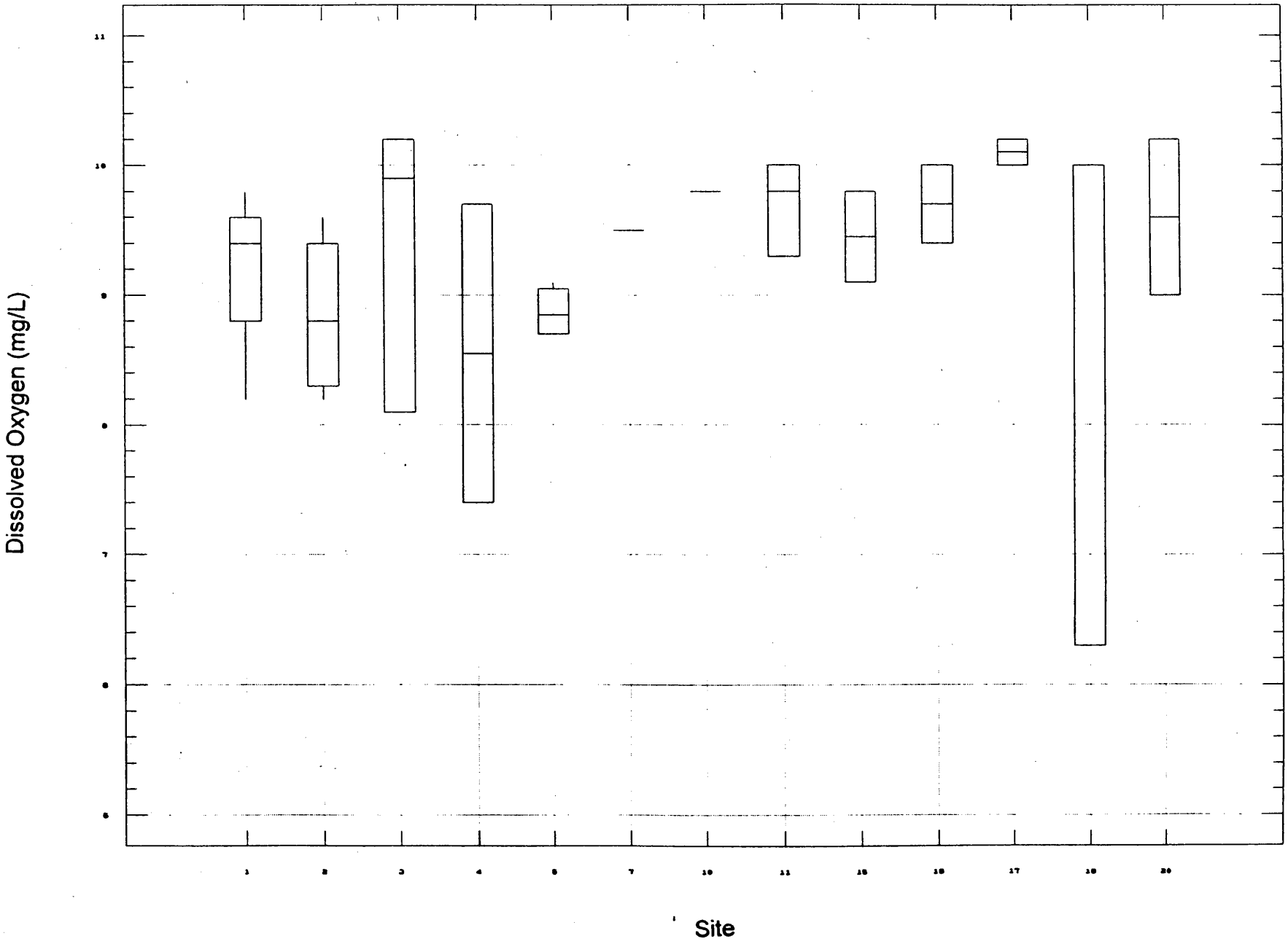
MONOCACY CREEK – EAST BRANCH



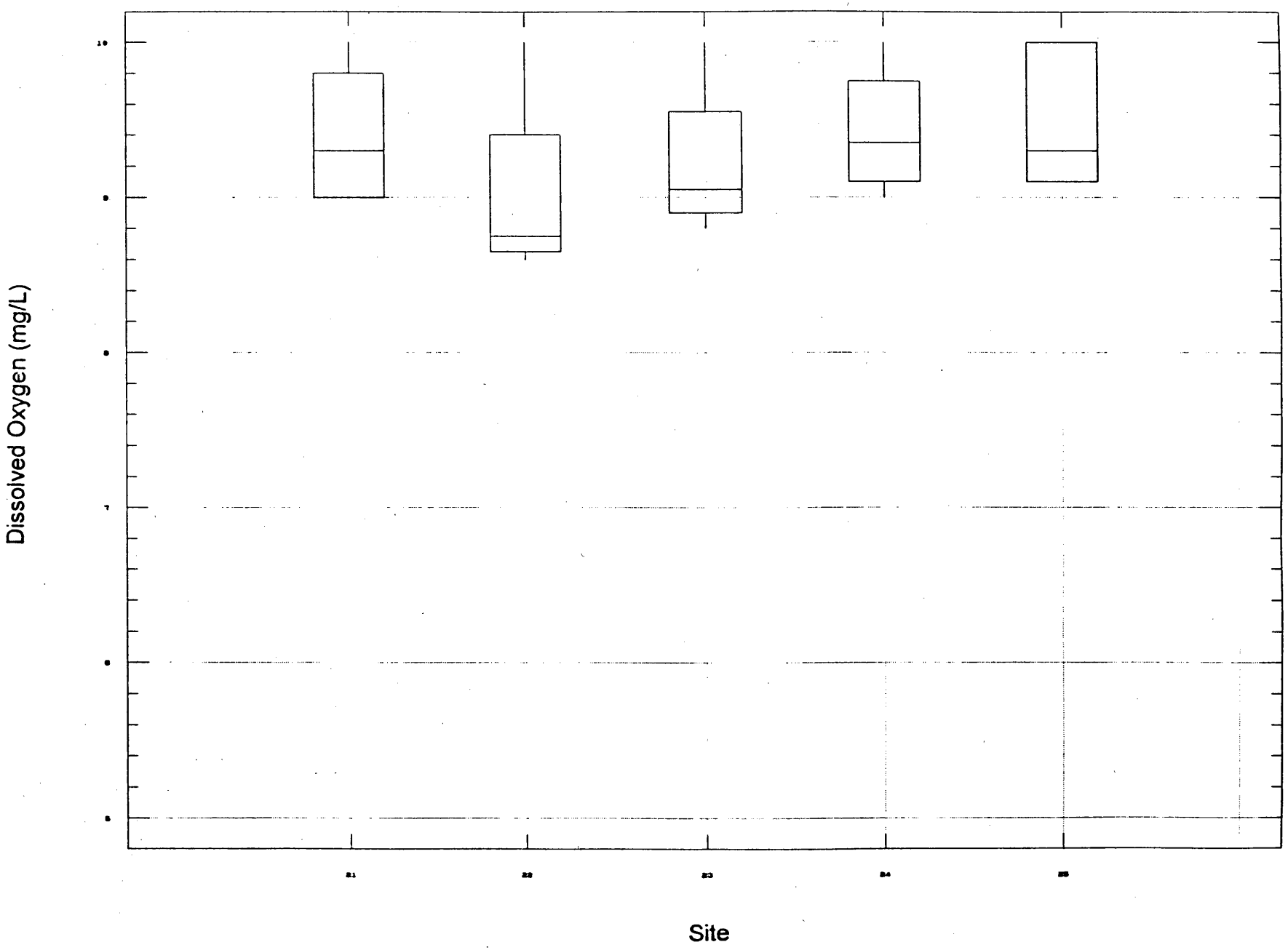
MONOCACY CREEK – MAIN BRANCH



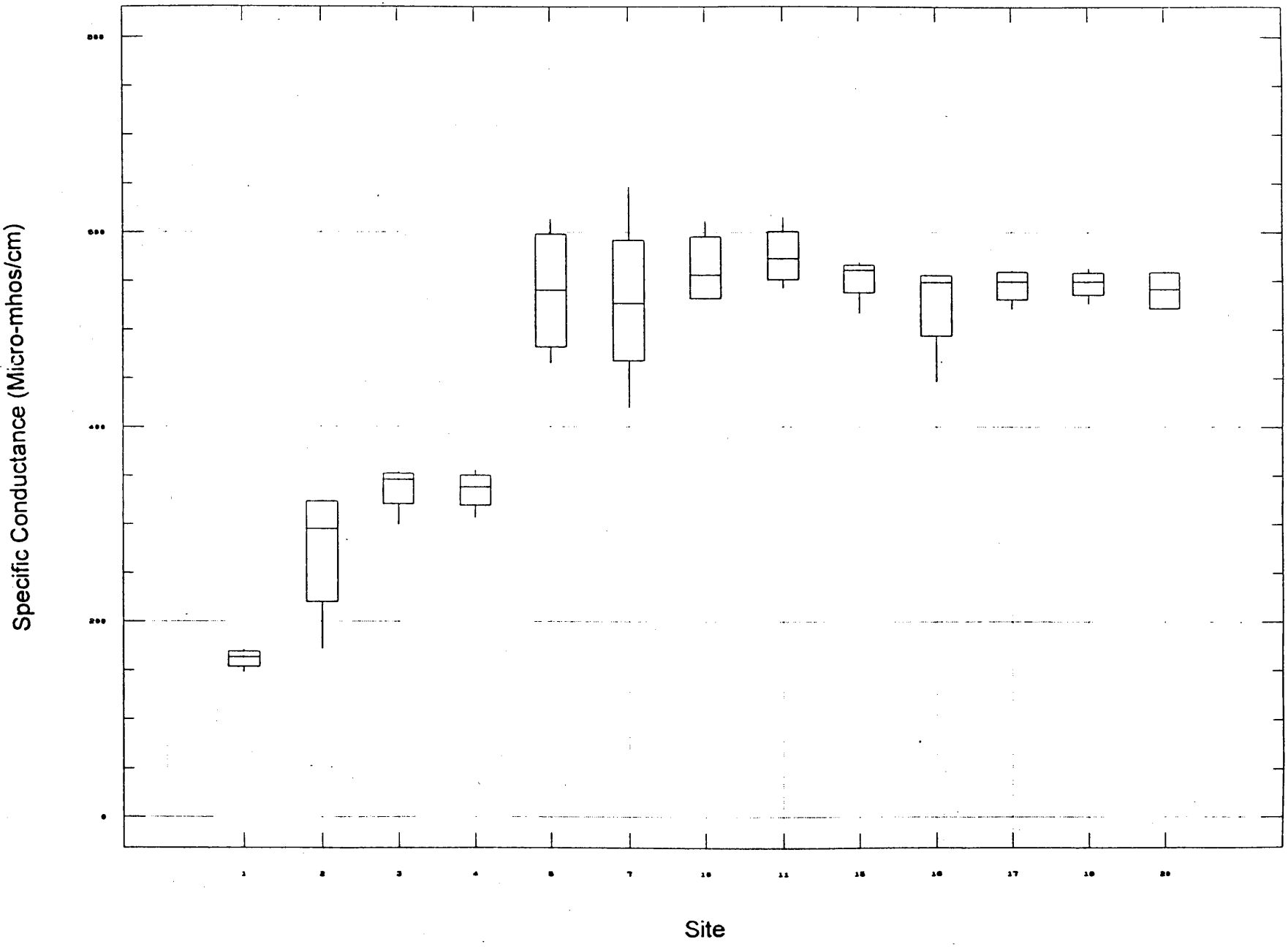
MONOCACY CREEK – MAIN BRANCH



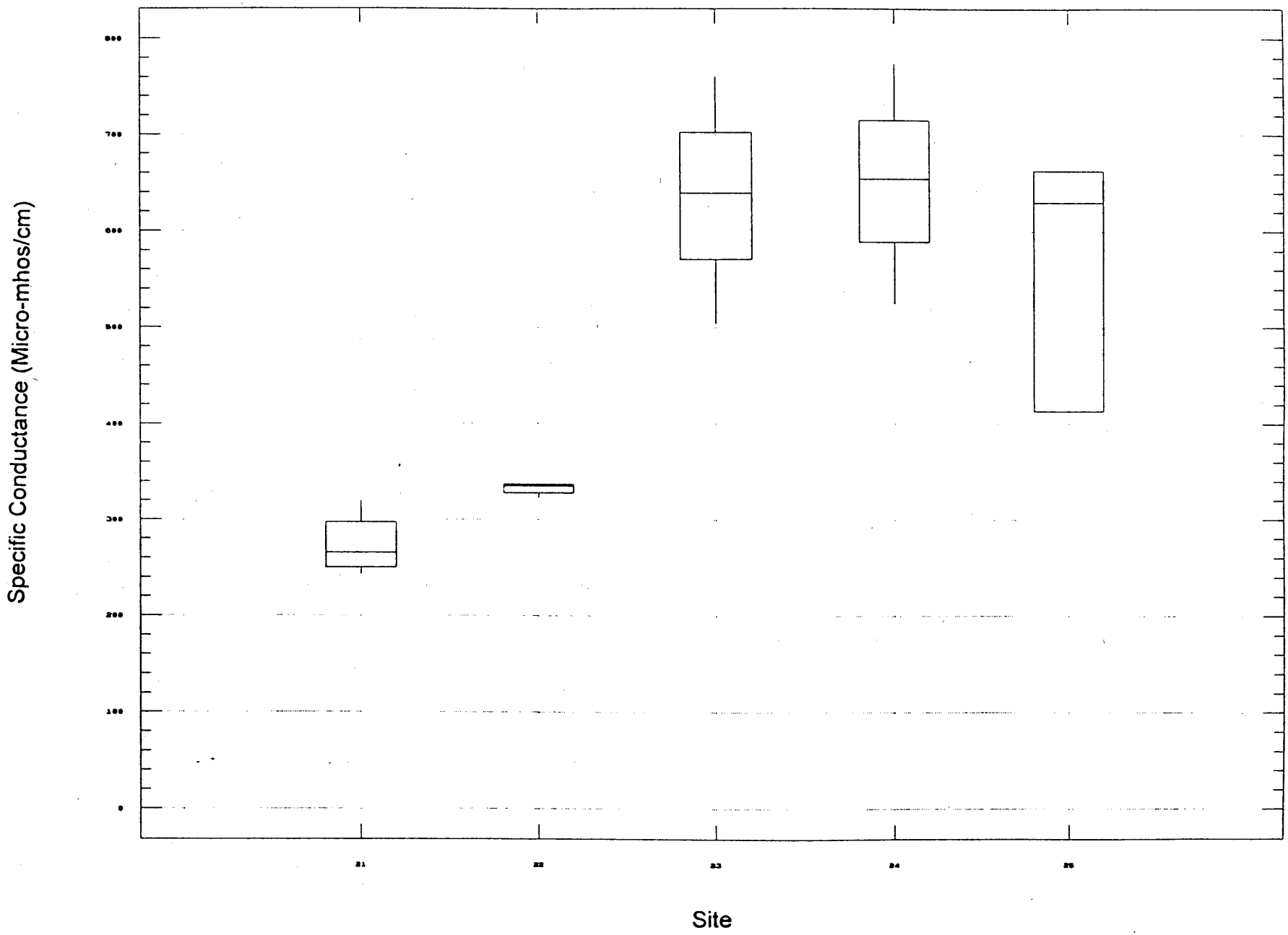
MONOCACY CREEK – EAST BRANCH



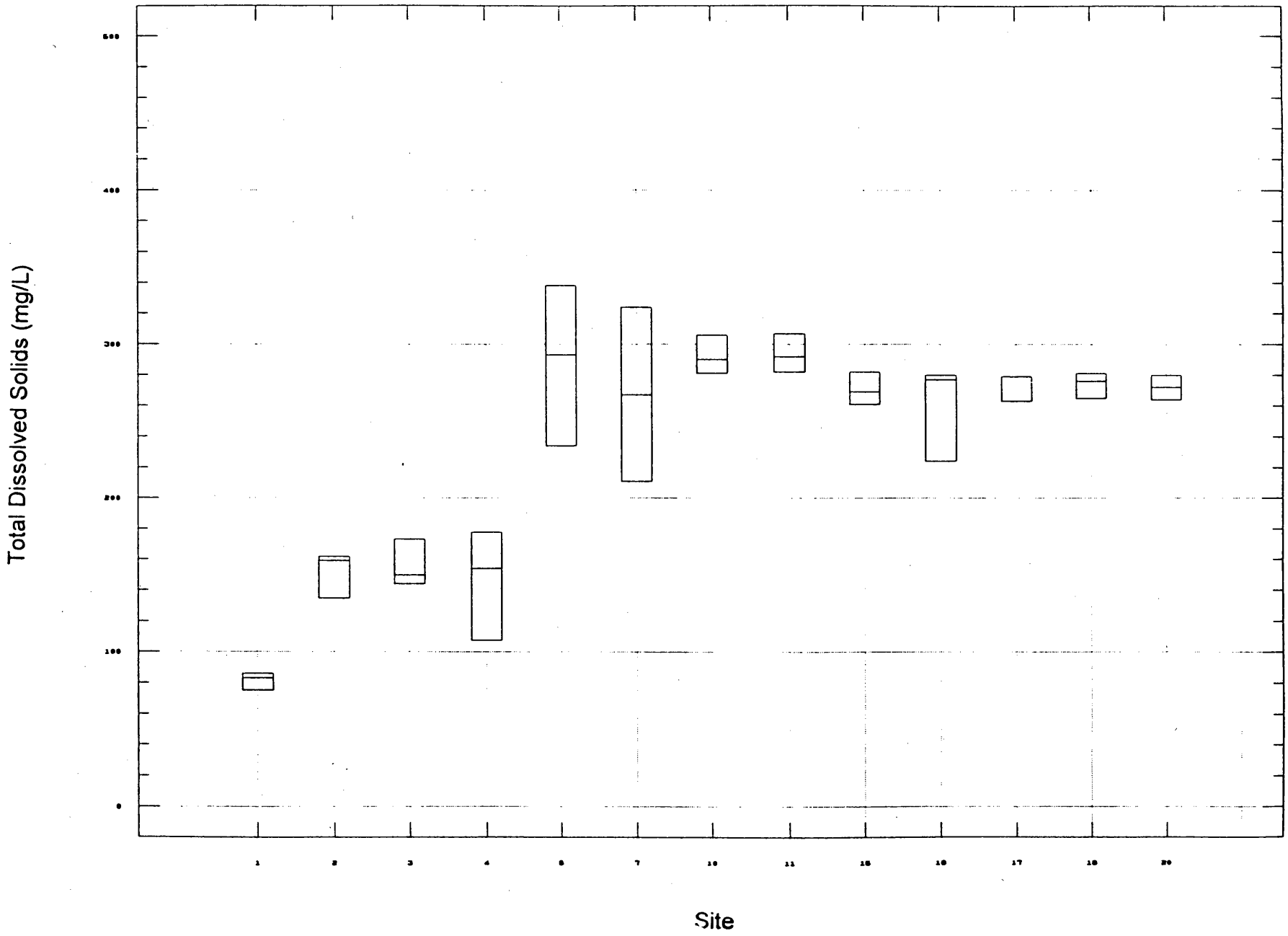
MONOCACY CREEK – MAIN BRANCH



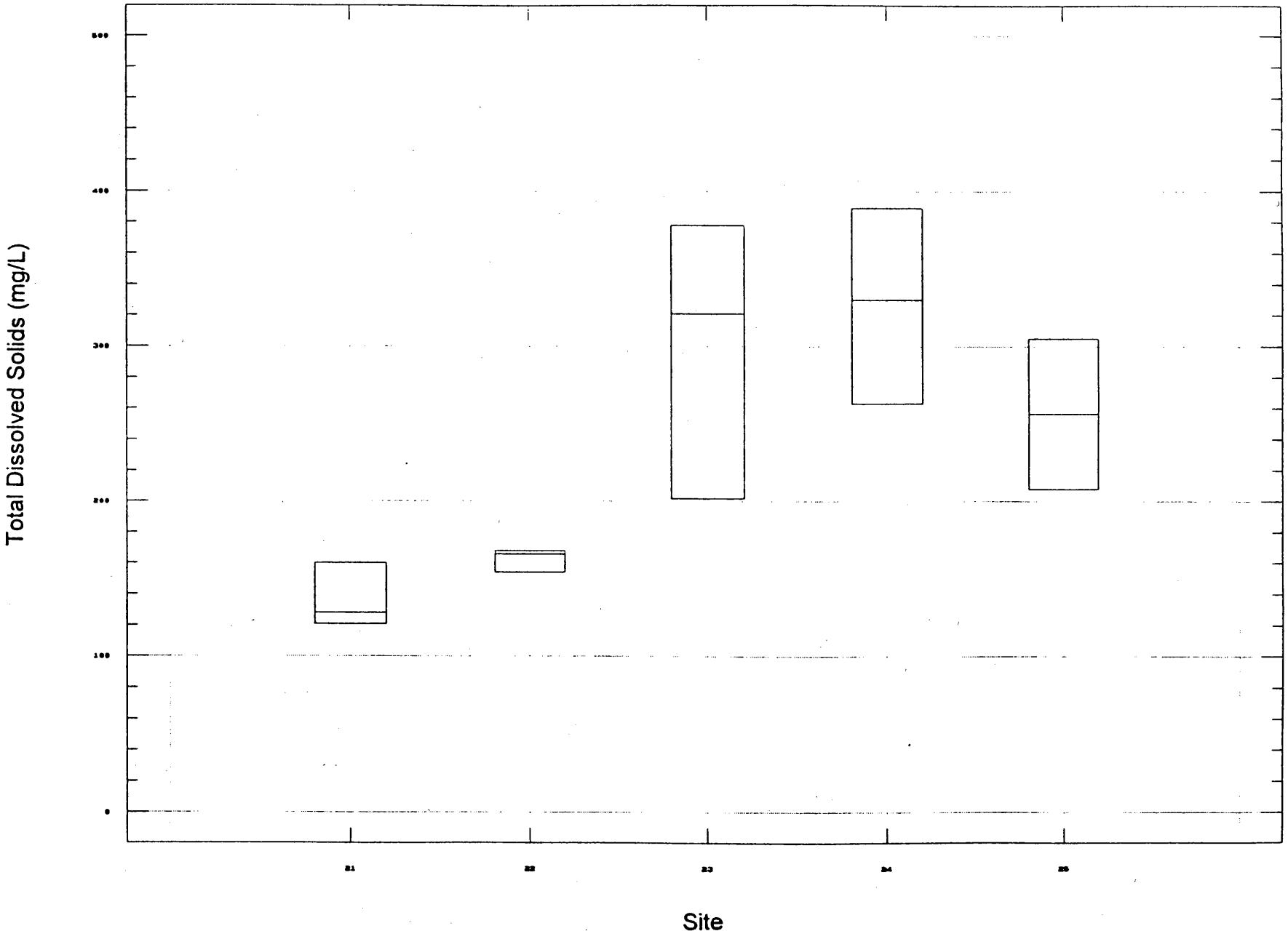
MONOCACY CREEK – EAST BRANCH

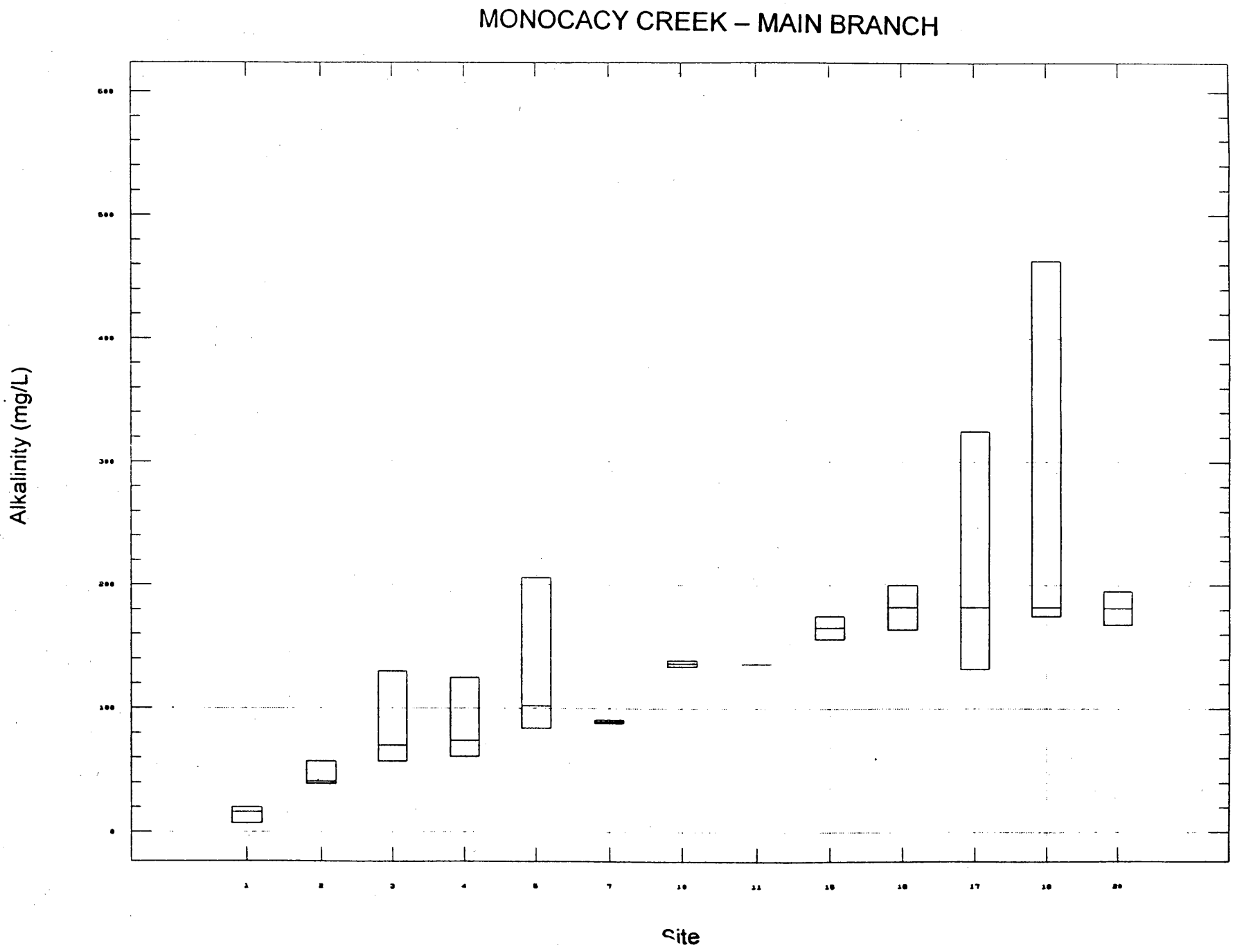


MONOCACY CREEK – MAIN BRANCH

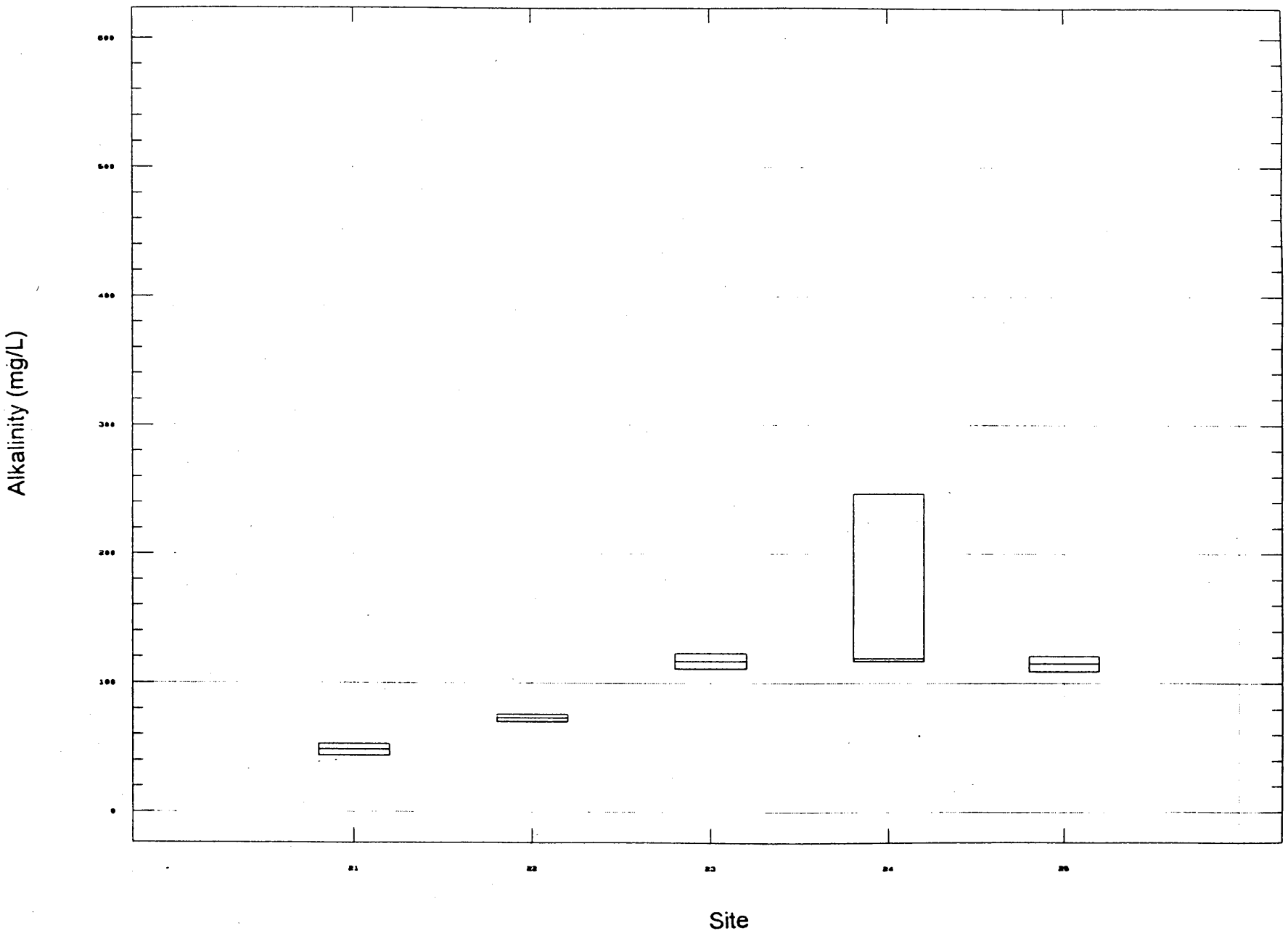


MONOCACY CREEK – EAST BRANCH

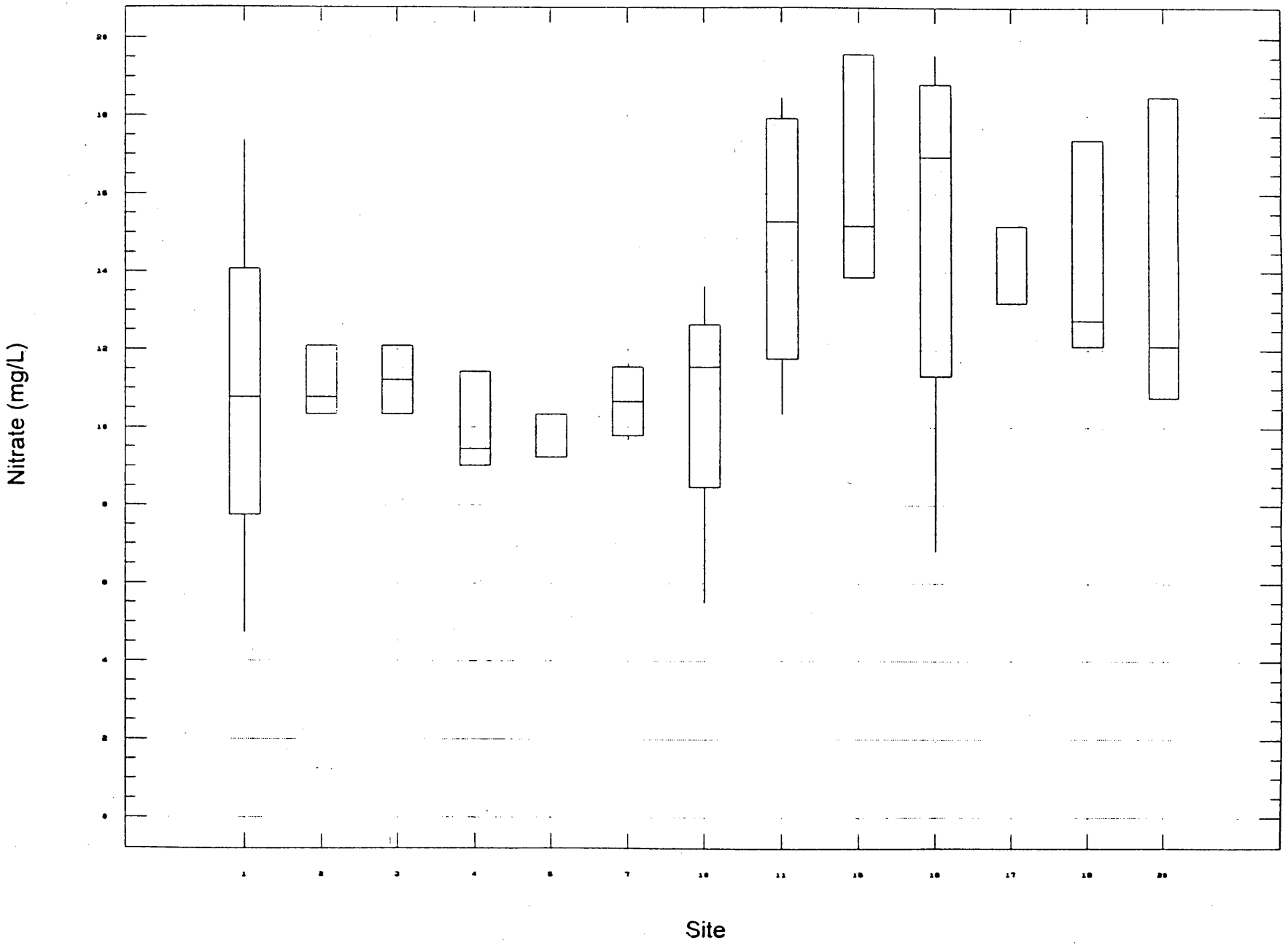



MONOCACY CREEK – MAIN BRANCH
Alkalinity (mg/L)
Site

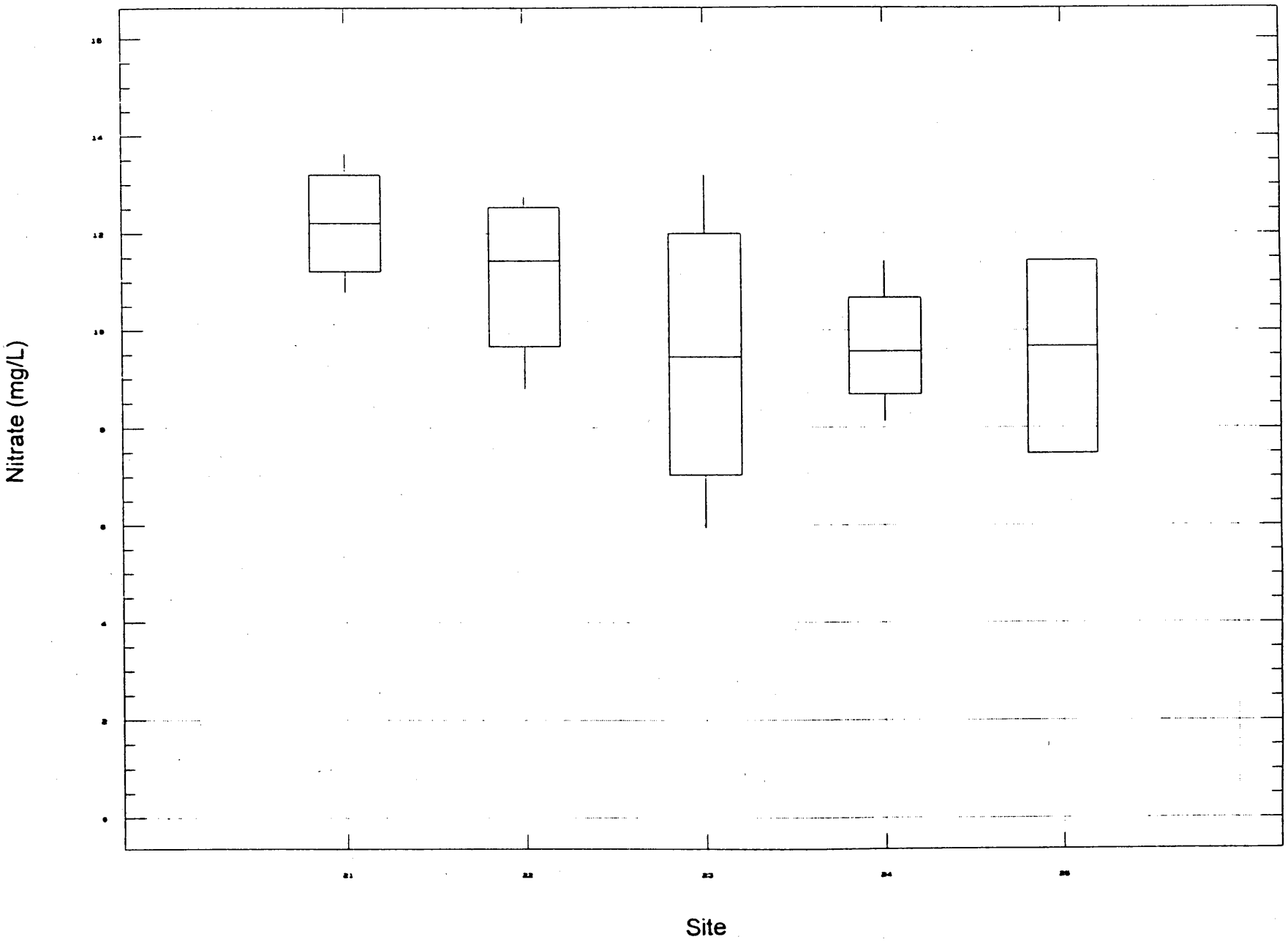
MONOCACY CREEK – EAST BRANCH



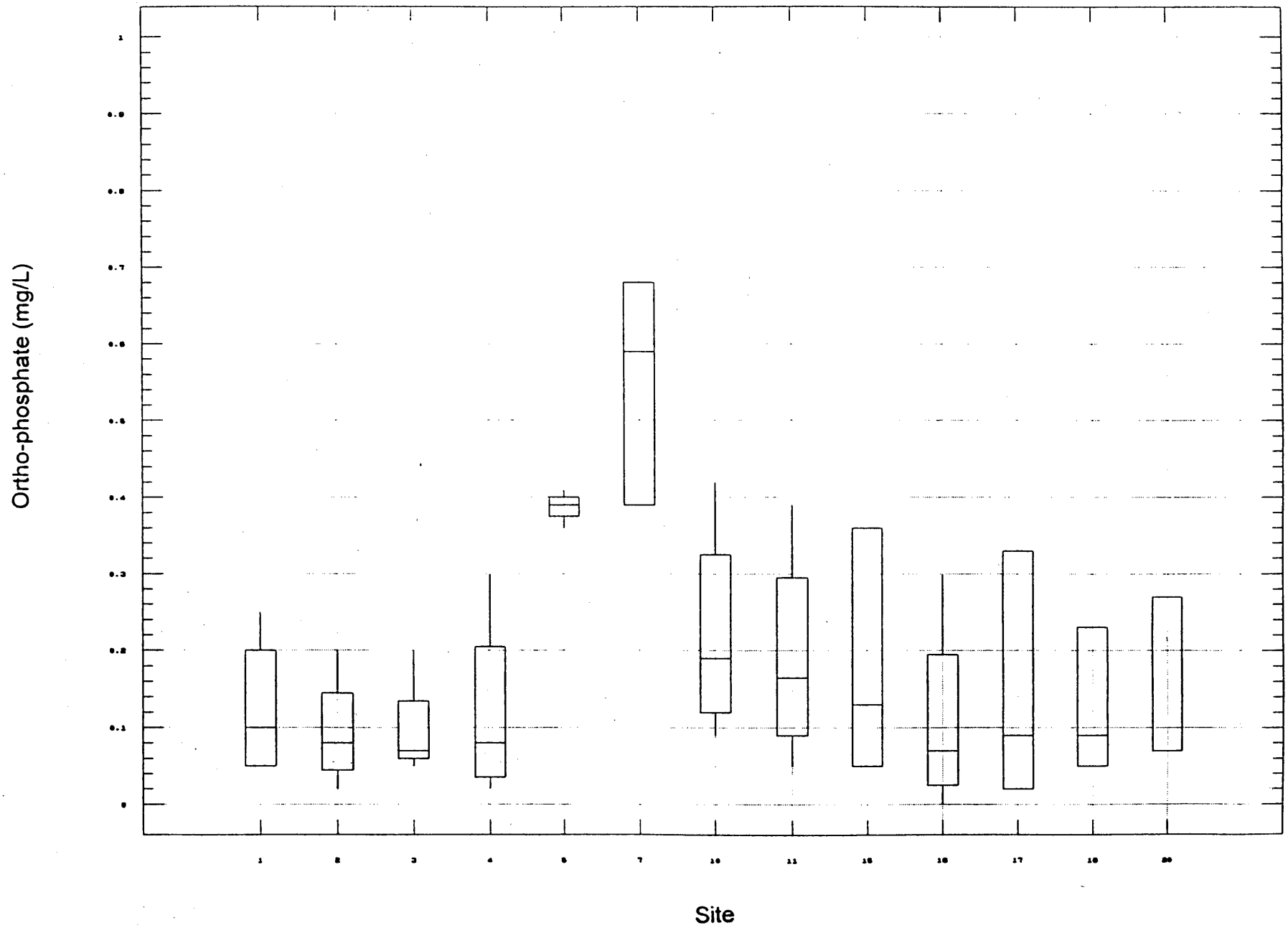
MONOCACY CREEK – MAIN BRANCH



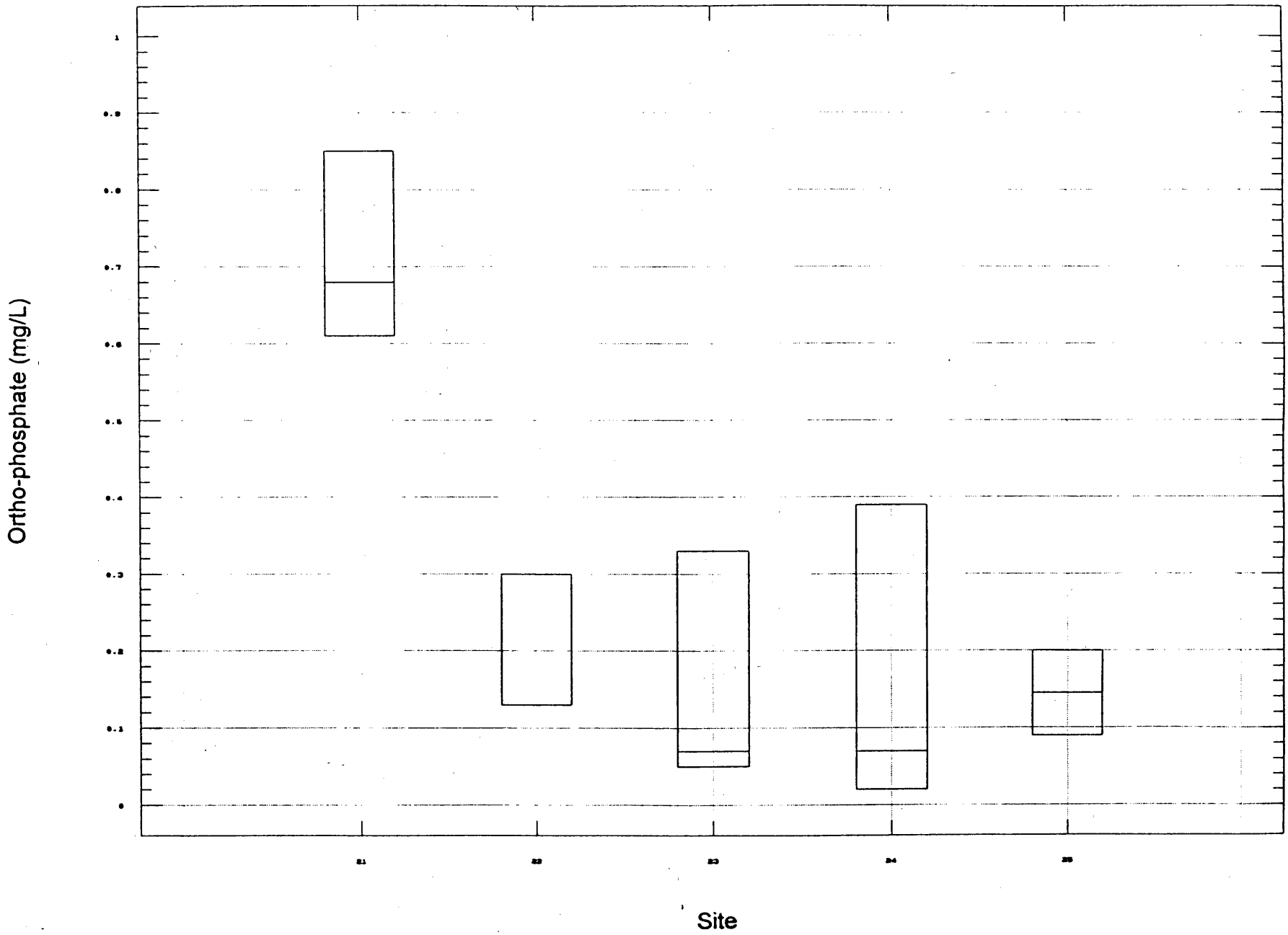
MONOCACY CREEK – EAST BRANCH



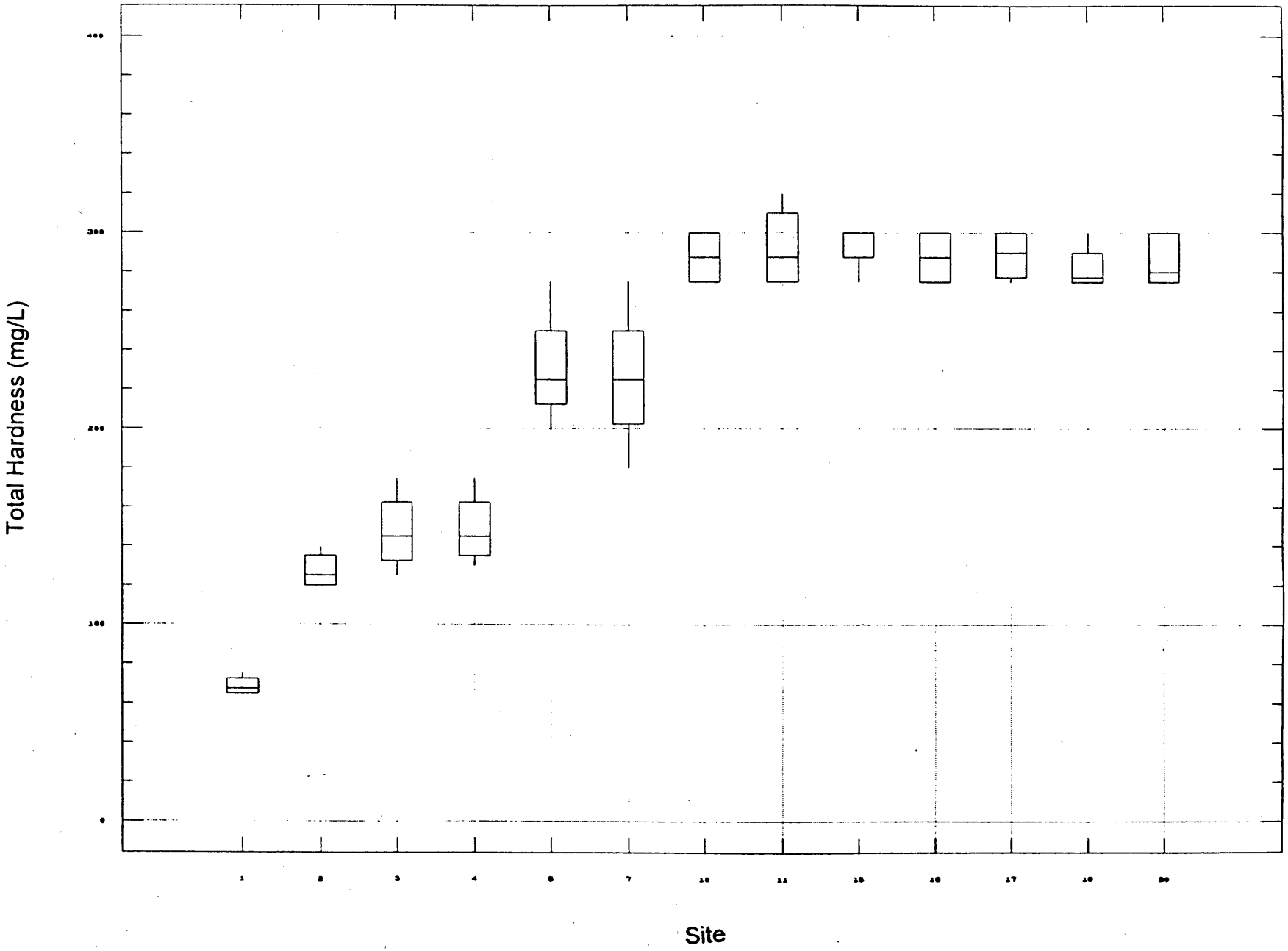
MONOCACY CREEK – MAIN BRANCH

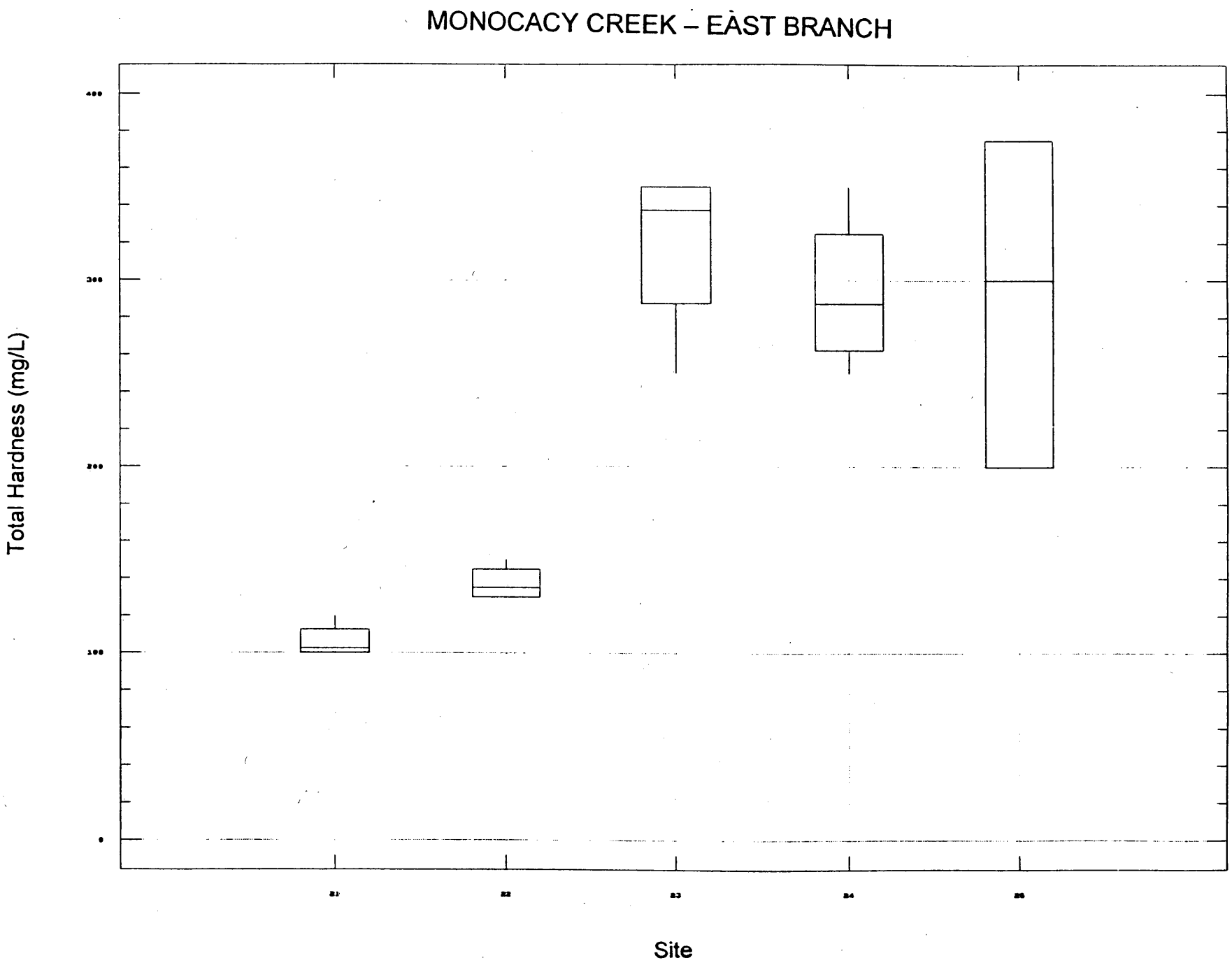


MONOCACY CREEK – EAST BRANCH

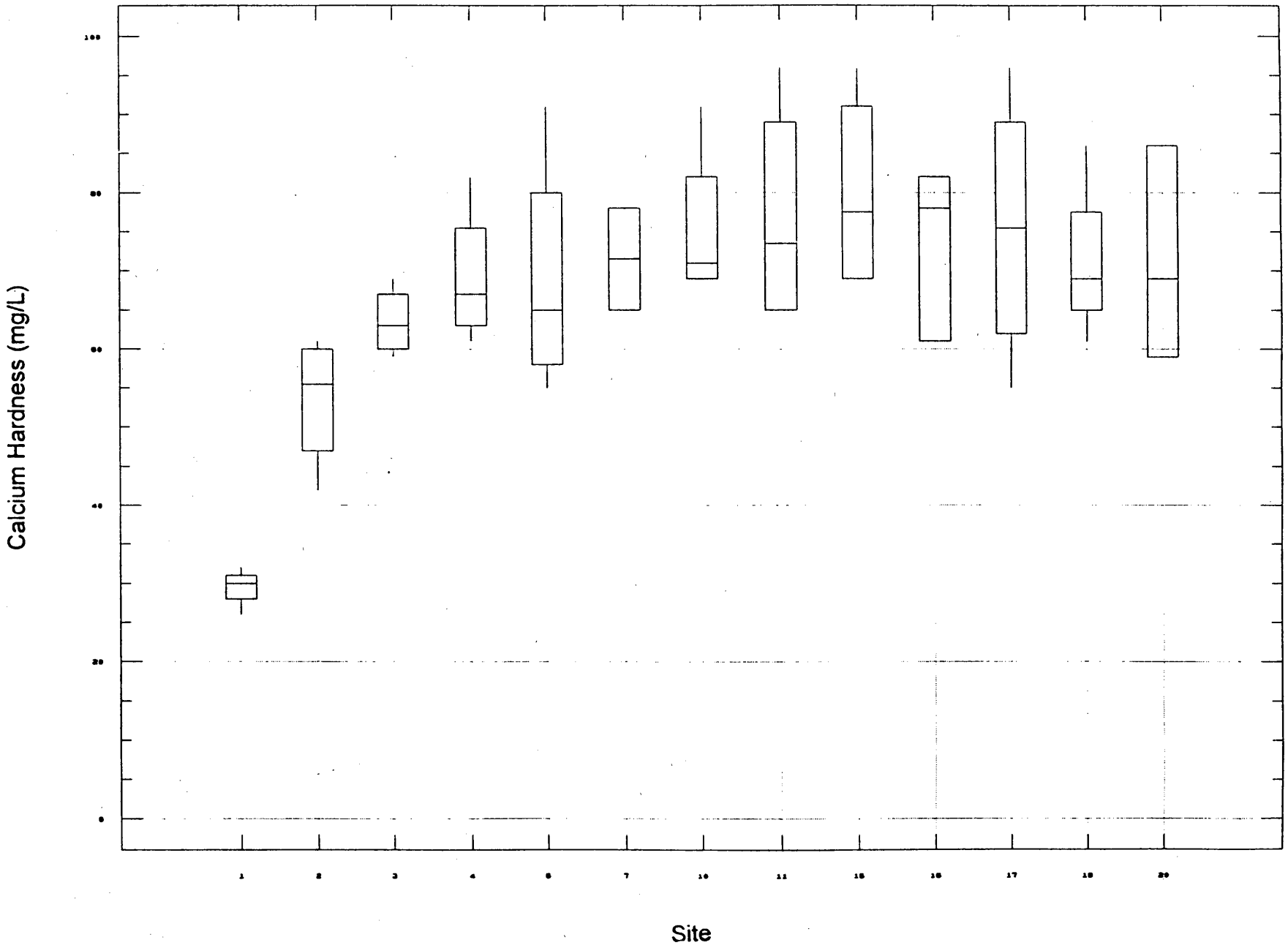


MONOCACY CREEK – MAIN BRANCH

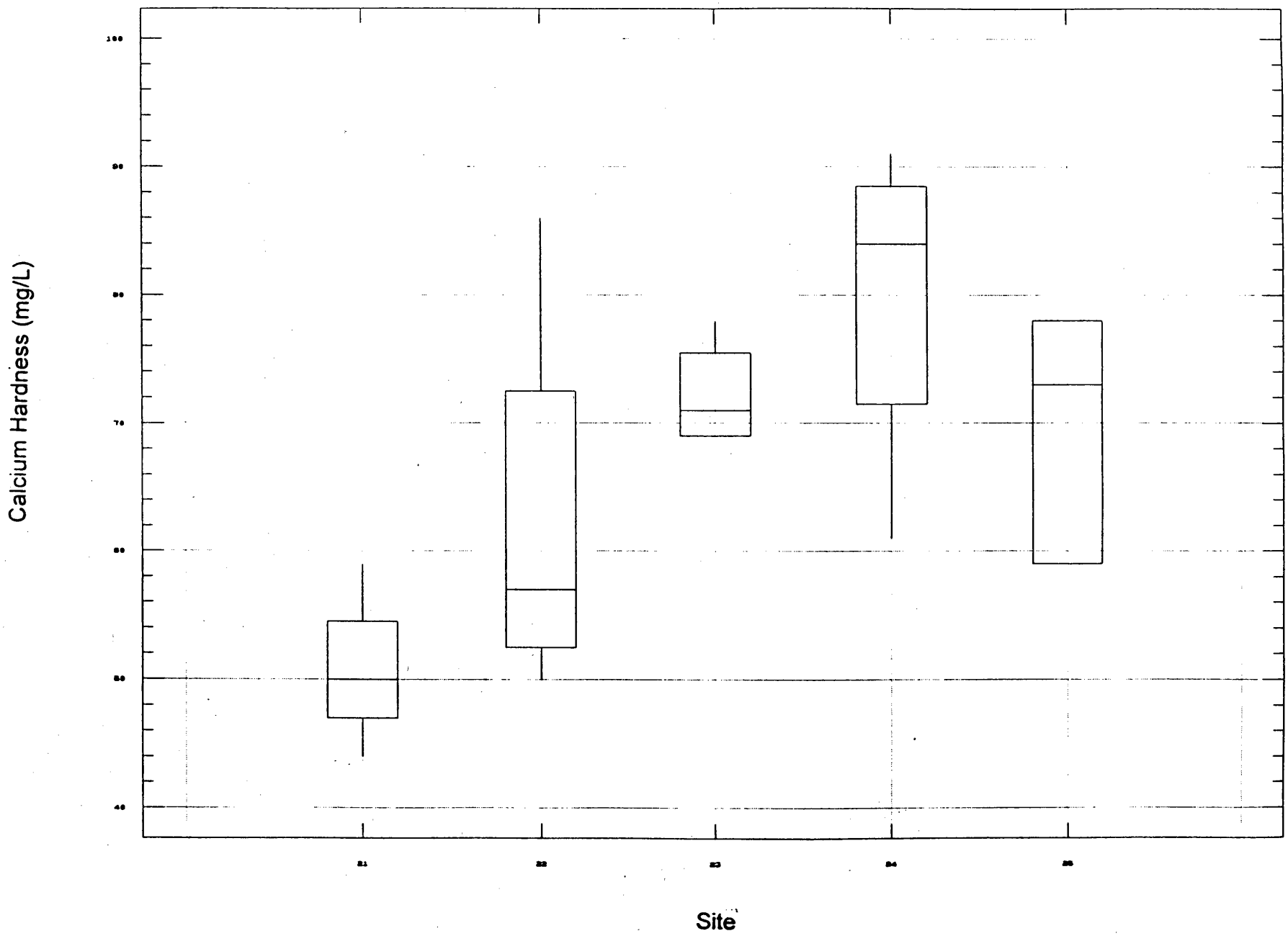



MONOCACY CREEK – EAST BRANCH
Total Hardness (mg/L)
400
300
200
100
0
S1
S2
S3
S4
S5
Site

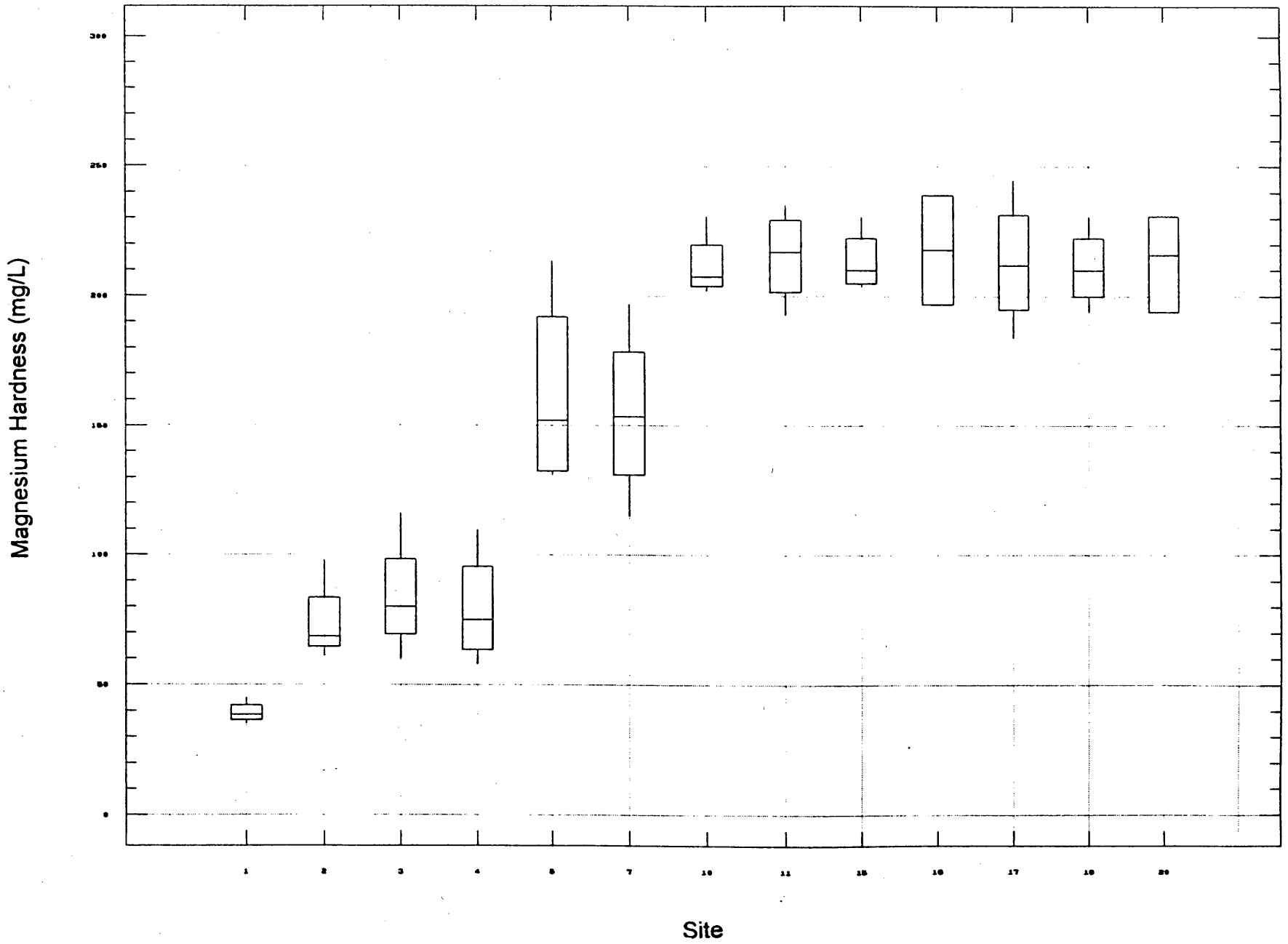
MONOCACY CREEK – MAIN BRANCH



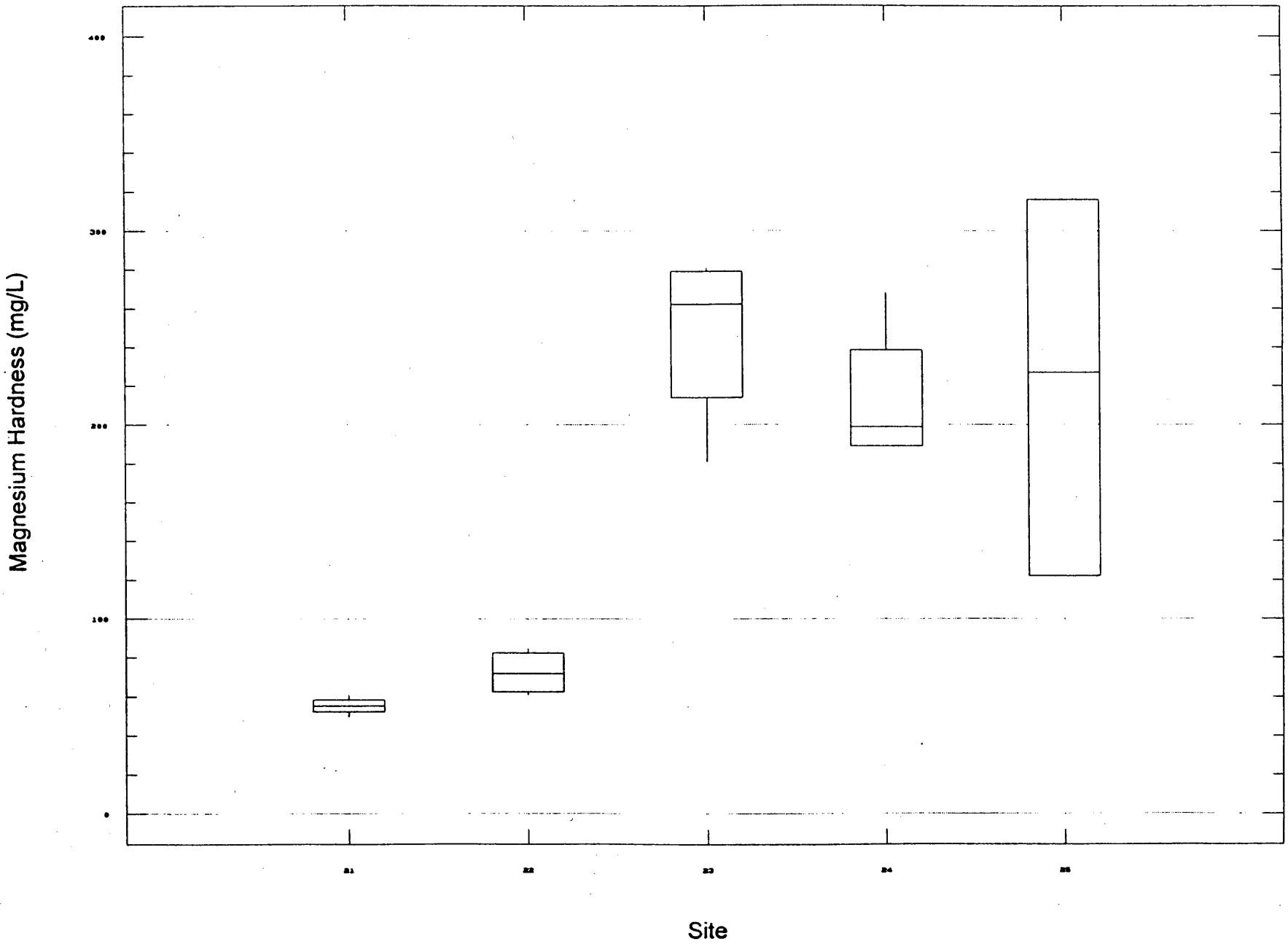
MONOCACY CREEK – EAST BRANCH



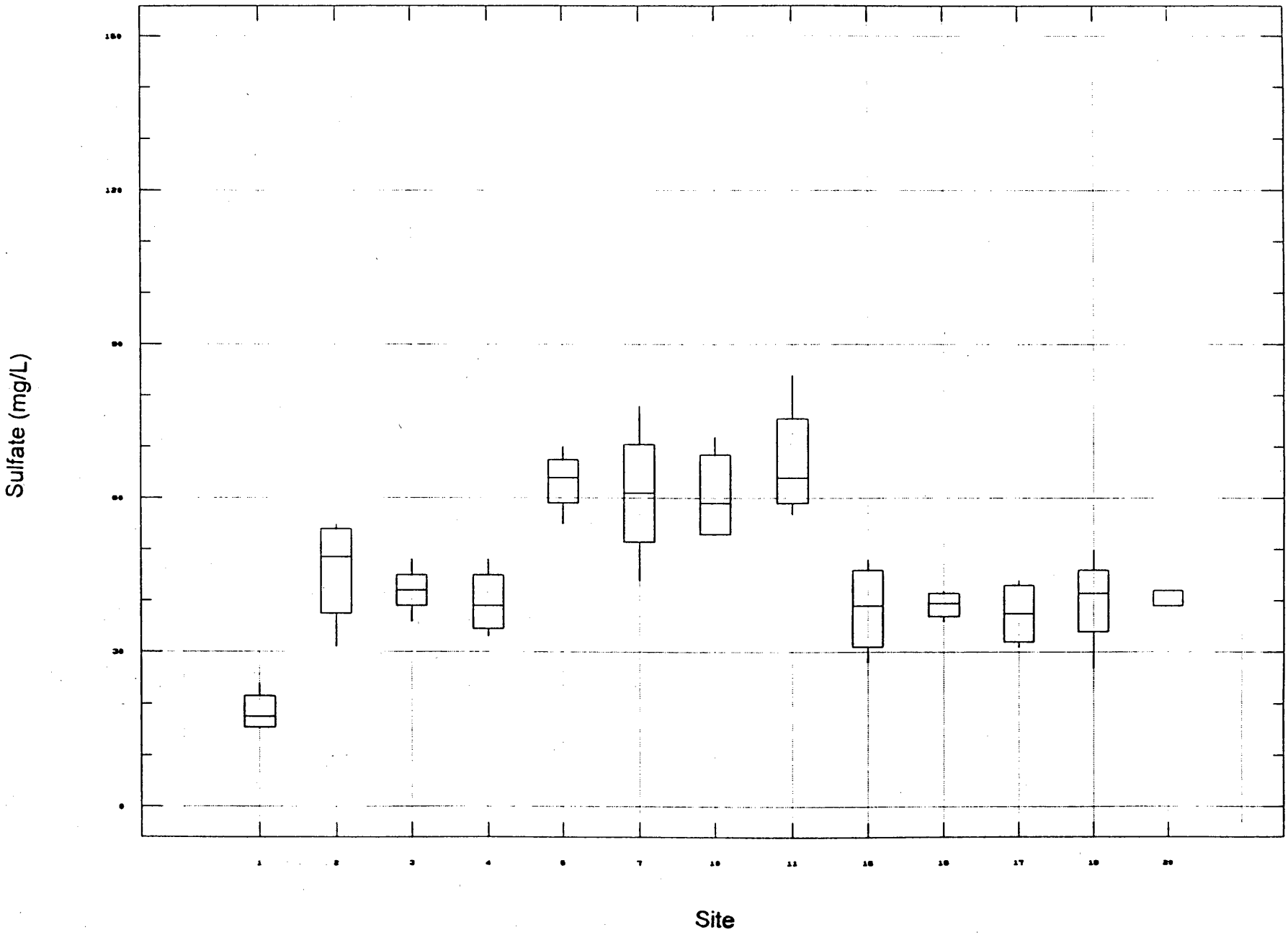
MONOCACY CREEK – MAIN BRANCH



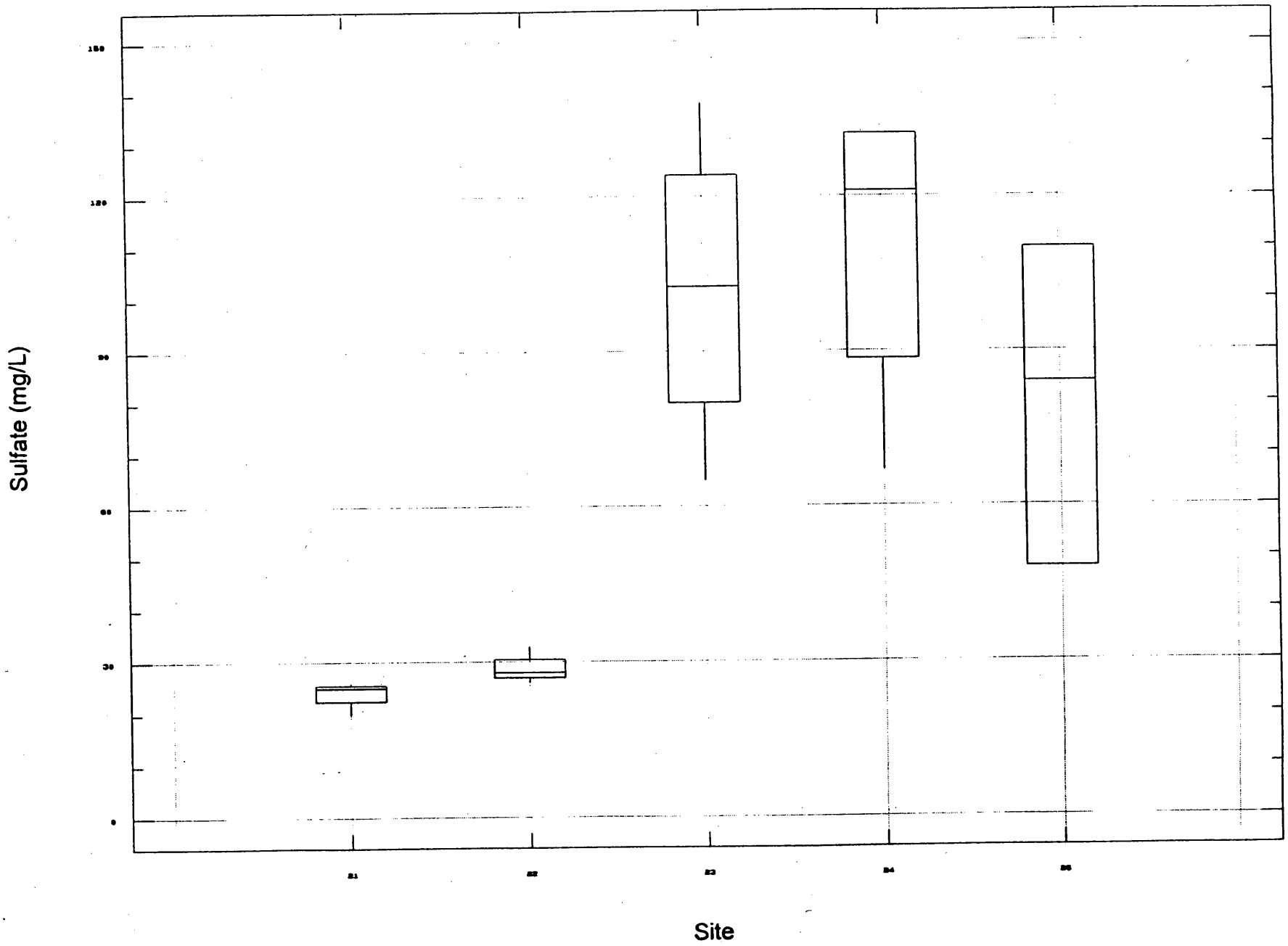
MONOCACY CREEK – EAST BRANCH



MONOCACY CREEK – MAIN BRANCH



MONOCACY CREEK – EAST BRANCH



MONOCACY CREEK PROJECT IMPLEMENTATION SCHEDULE 1999-2003

Project Description	Potential Project Partners	Grant Application Year	Project Year
1. Establishment of streamside vegetation at Maple Grove Farms	MCWA, Wildlands Conservancy, CAC, Boy Scouts		1999
2. Develop Streamside Property Owner Management Guide	Wildlands Conservancy, LVPC, MCWA	1999	2000
3. Restoration of area flowing under Rt. 512 bridge in Hanover Township (includes stabilization of threatened willow tree, installation of brush and log deflectors, educational signing, stabilization of bank upstream from bridge, and planting of native species).	Wildlands Conservancy, Trout Unlimited, Boy Souts, Hanover Township, City of Bethlehem, PFBC, private property owners	1999	2000
4. Educational Lecture Series	Wildlands Conservancy	1999	2000
5. Habitat and corridor improvements through Monocacy Nature Center (includes trail maintenance and/or relocation, boulder placement, multilog and brush deflectors, removal of invasive species, and planting of native species).	MCWA, CAC, Audobon Society, Sierra Club, Trout Unlimited, Boy Scouts, Northampton County Parks, PFBC	2000	2001
6. Streambank fencing of property along Georgetown Road adjacent to park (includes constructing cattle crossing, fencing streambank, installing habitat improvement devices, and establishing streamside vegetation).	Wildlands Conservancy, PFBC, Game Commission, MCWA, private property owner	2000	2001
7. Feasibility study of trail development (to assess potential for creating a connective system trails throughout the watershed).	LVPC, Northampton County Parks, municipalities Rails to Trails, Audobon Society	2000	2001
8. Develop an on-going water quality and ecological monitoring program.	EASI, MCWA, Wildlands Conservancy	2001	2002
9. Removal or breaching of dams throughout the watershed.	DEP, Army Corps of Engineers, Wildlands Conservancy, MCWA, CAC, municipalities	2001	2002
10. St. Anne's Shrine area restoration work (includes streambank stabilization and habitat improvement with biologs and multilogs and riparian buffer establishment).	MCWA, CAC, Wildlands Conservancy, Boy Scouts, Trout Unlimited, PFBC	2002	2003
11. Riparian buffer establishment and streambank fencing as need and desire is recognized by property owners	Wildlands Conservancy, property owners, PFBC Game Commission	1999-2002	2000-2003

MCWA- Monocacy Creek Watershed Association
LVPC- Lehigh Valley Planning Commission
EASI- Environmental Alliance for Senior Involvement
CAC- Citizens' Action Committee
DEP- Department of Environmental Protection
DCNR- Department of Conservation and Natural Resources
PFBC- PA Fish & Boat Commission

POSSIBLE GRANT SOURCES

DEP-WRAP (Watershed Restoration & Assistance Program)
DCNR- Keystone Acquisition & Development Grant Programs:
- Keystone Community Grant Program
- Keystone Rails-to-Trails Program
- Keystone Rivers Conservation Grant Program

William Penn Foundation
Canaan Valley Institute

Wildlands Conservancy

Best Management Practices for Streams

DON'T remove native vegetation growing adjacent to the streams.
WHY: Trees and shrubs shade the stream (trout require cool waters for survival), and provide leaf litter which forms the base of the aquatic food web.

DO plant native trees and shrubs along unvegetated areas of the stream bank.
WHY: The root systems of woody vegetation stabilize streambanks and prevents erosion.

DON'T mow your lawn right up to the stream, allow at least 5-10 feet of buffer along the stream.
WHY: An unmowed, naturally vegetated streambank buffer helps prevent erosion and filters out lawn chemicals which are damaging to stream life.

DO limit your use of lawn chemicals such as fertilizers, pesticides, and herbicides.
WHY: These chemicals easily find their way into the stream and can kill stream life including vegetation, insects, fish, and birds.

DON'T throw your grass clippings (or any other refuse) into the stream.
WHY: Grass clippings in the stream will cause water quality problems and will suffocate fish and other aquatic organisms.

DO restrict livestock from streamside areas.
WHY: Trampled banks release sediment into the streams and fecal bacteria from animal wastes can cause serious water quality and health problems.

DON'T dump used oil, antifreeze, etc. into storm drains.
WHY: These dangerous chemicals enter the streams directly through storm drains.

DO leave wetlands in a naturally vegetated, undisturbed condition.
WHY: Wetlands act as reservoirs and reduce flood damage, provide removal of pollutants from stormwater runoff before it reaches the stream, and provide unique passive recreational opportunities.

DON'T remove stable, naturally occurring, instream debris, such as fallen logs.
WHY: Instream debris holds rock fragments and organic particles for processing by aquatic animal life and provides cover and cooling shade for fish and other organisms.

DON'T create recreational paths within 25 feet of the streambank.
WHY: Paths result in soil compaction, destruction of root systems, and the eventual death of vegetation. Streambanks rely on a strong, healthy root system for cohesion and structural integrity. A stabilized streambank minimizes collapse of land areas and undercutting of structures such as by erosion.

DO urge your local municipality to manage streamside parks in a more natural way.
WHY: Many governing bodies believe that well-manicured parks are the only kind that are acceptable to residents. They need to hear a different opinion. In addition, mowing and manicuring requires large amounts of time, effort, and taxpayer money.

3701 Orchid Place, Emmaus, Pennsylvania 18049-1637 • 610-965-4397

Wildlands Conservancy is a tax-exempt organization as provided by IRS regulations. A copy of the official registration and financial information may be obtained from the Pennsylvania Department of State by calling toll-free, within Pennsylvania, 1-800-732-0999. Registration does not imply endorsement.

STORM WATER QUALITY MANAGEMENT AND FLOOD CONTROL

- Ensure the proper maintenance and operation of existing retention and detention basins, as they are frequently clogged and not working efficiently.

- Keep development to a minimum and avoid developing the floodplain whenever possible. This will limit the amount of impervious surfaces that prevent infiltration and storage of floodwaters.

- Natural vegetation should be permitted to grow on floodplains whenever possible. Plants uptake water and their root systems make soil more porous for percolation of precipitation.

- When development is necessary, incorporate porous surfaces as much as possible. For example, a type of porous asphalt has been created that can be used for driveways and parking lots. Such materials should be used whenever possible rather than traditional concrete or asphalt, which prevent percolation of precipitation and cause increased runoff. Porous asphalt application should be combined with construction of underground recharge beds in order to maximize the benefits of this technique.

- Line roadways, parking lots, and other developed areas with trees. The canopy would intercept throughfall during precipitation events and lessen the degree of flooding. This practice would also aid in reducing thermal pollution by providing shade for roadways, thus keeping down the temperature of runoff entering the stream.

- Storm water runoff should be converted to sheet flow over a porous medium or channeled to an infiltration structure, such as a seepage pit or trench, that directs runoff into the ground rather than directly to the stream. Directing water through or over a porous medium that is naturally vegetated would not only increase infiltration, but also filter out pollutants and cool the water before it enters the creek. This process would greatly reduce non-point source pollution and thermal pollution typically caused by storm water runoff. If natural areas are not available for storm water management purposes, infiltration structures are recommended.

- Closed depressions often associated with karst topography should not be filled. These depressions serve as groundwater recharge basins, where storm water collects naturally or where it may be directed to reduce peak discharges in streams and roadway flooding.

- Implementation of storm water quality methods such as two-stage biofilter ponds is also recommended.

JPC *Joint Planning Commission*
Lehigh-Northampton Counties

Sewage Facilities Bulletin #1

Your Septic System:

Operation and Maintenance

May 1996

Joint Planning Commission
Lehigh-Northampton Counties
961 Marcon Boulevard, Suite 310
Allentown, Pennsylvania 18103-9397
(610) 264-5544

Introduction

On-site septic systems are sewage systems located on the homeowner's property. Septic systems are used in many rural and suburban areas where public sewage systems are not available. Approximately one-third of Pennsylvanians rely on septic systems to treat their sewage. A properly working septic system treats and disposes of household sewage (which may contain harmful bacteria and viruses) through natural processes. A failing system, however, cannot perform these tasks. A failing system could result in sewage backup into your home or sewage surfacing above ground. Contamination of wells, streams and lakes may occur as well. In addition to the health threats, a failing system may be a financial burden on you, the homeowner, if it must be replaced or repaired.

If a system has been properly designed, constructed and installed, then the most probable cause for failure is improper operation and maintenance. A properly maintained system can significantly improve the life of a system and its performance. This brochure provides tips on what you can do to keep your septic system working for you.

How your septic system works

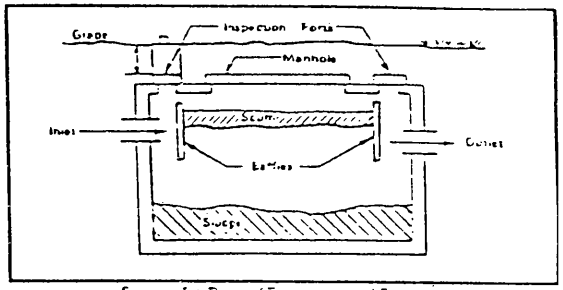
A typical on-site septic system consists of two basic parts or units:

1. the septic tank,
2. the soil absorption area.

Figure 1 shows a cross section of a typical septic tank. Sewage flows from the house into the septic tank, or primary treatment unit, where the sewage is partially treated. Household sewage includes toilet and sink wastes, and laundry and bath water. During this level of treatment, large solids (sludge) settle to the bottom of the tank while lighter solids and grease (scum) float on the top of the wastewater. The inlet and outlet baffles retain the sludge and scum within the septic tank. Naturally occurring microorganisms work to decompose the solids and scum, however, solids and scum will accumulate within the tank. Therefore, this waste material must be pumped out of the tank on a regular basis.

The partially treated wastewater then flows out of the tank and into the soil absorption area or secondary treatment unit. Perforated pipes in the absorption area evenly distribute the wastewater to the soil. Any remaining solids are filtered out and decomposed by microorganisms within the soil. This is the final chance for removal of harmful pollutants before entering groundwater or surface water.

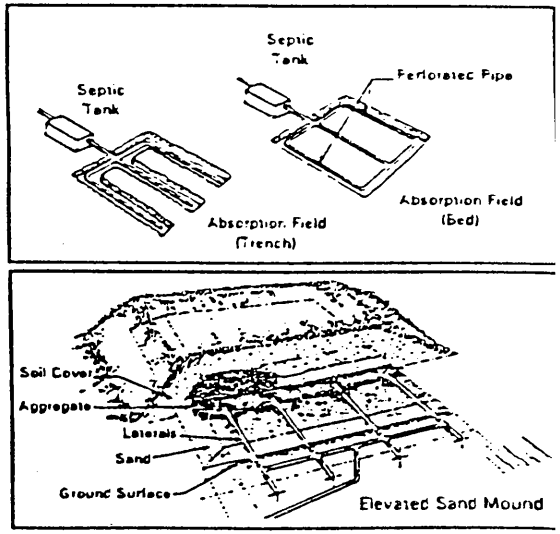
FIGURE 1
CROSS SECTION OF SEPTIC TANK



Source: PA Dept. of Environmental Protection

There are several types of absorption areas commonly used homeowners. These include trenches, seepage beds and elevated s mounds. The basic layout of these systems is shown in Figure 2. type of system suitable for your home is dependent on a combinatio factors including soil type, slope of the land, depth to the water tabl bedrock and space constraints.

FIGURE 2
ABSORPTION AREA DESIGNS



Source: PA Dept. of Environmental Protection

Note: Other types of on-lot sewage disposal systems are available to the homeowner such as an aerobic treatment system. A septic system and aerobic system are similar in that natural processes are involved in treating the sewage. However, unlike a septic system, an aerobic system requires oxygen to initiate the decomposition process. If you rely on an aerobic system or other type of on-lot system, contact the manufacturer or your municipal Sewage Enforcement Officer (SEO) for proper operation and maintenance procedures.

How to recognize septic system failure

Septic system failure occurs whenever your septic system does not effectively treat or dispose of sewage. Effective treatment and disposal prevents harmful pollutants from getting into your well and nearby lakes and streams. There are a number of warning signs of potential system failure that you should recognize:

- Sewage backup in your drains or toilet.
- Unusually slow draining sinks, tub or toilet.
- Raw sewage surfacing above your septic system.
- Presence of rich green grass above the absorption area.
- Unpleasant sewage odors around the house.
- An abundance of algae in any water bodies next to your home.
- Tests revealing the presence of bacteria in your well water.

While these signs may be an early indication of failure (and certainly not the only possible signs), failure may also occur without any warning. With this in mind, it makes good sense to have your septic system inspected regularly.

Preventive maintenance

As discussed earlier, the most common reason for septic system failure — if the system was properly designed, constructed and installed — is improper maintenance. A little preventive maintenance today can go a long way towards ensuring a safe and environmentally friendly septic system tomorrow. There are a number of practices you should include in your operation and maintenance routine:

- Have your septic tank pumped at regular intervals. Your septic tank should be pumped approximately every 3-5 years depending on tank and household size. However, pumping frequency should be increased for older systems. The use of a garbage disposal unit necessitates more frequent pumping due to the increase in solids within the septic tank.

Preventive maintenance (continued)

- Have your septic system inspected regularly. Your septic system should be inspected at least as often as you have your septic tank pumped.
- Redirect surface water flow (from roof downspouts and driveways) away from the absorption area.
- Conserve water in your home. This will reduce the wasteflow into the septic tank and absorption area. Excessive flows are a common cause for septic system failure. There are several conservation techniques that can easily become part of your daily routine:
  - ✓ Take quick showers instead of baths.
  - ✓ Turn off the faucet while shaving, brushing your teeth or washing the dishes.
  - ✓ Use your dishwasher and clothes washer only with full loads.

  Additional water conservation information is available in a brochure published in August 1995 by the Joint Planning Commission (JPC). If you are interested in a free copy of the brochure, please contact the JPC at 610-264-4544.
- Avoid septic tank additives. Certain additives may cause scum to carry over into the absorption area resulting in a clogged system.
- Avoid putting hazardous chemicals such as paints and pesticides into the septic system. These chemicals can destroy the microorganisms needed to break down the wastes.
- Avoid driving heavy vehicles and equipment over the absorption area. Pipes may be crushed or broken.
- Avoid planting trees or shrubs over or close to the absorption area.
- Avoid putting bulky, hard to decompose wastes such as disposable diapers, sanitary napkins, coffee grounds and cigarette filters in the system.

Finally, you should maintain a map of your property which includes the location of your septic system. This will make it much easier to find for inspection or pumping. In addition, you should maintain all records involving your system. This would include design, installation, inspections, pumpings, and any malfunctions and repairs.

Any repairs or modifications to the system require a permit issued by the Sewage Enforcement Officer (SEO). However, routine maintenance such as pumping does not need to involve the SEO. If any problems should arise with your septic system or if you have any questions about your system, contact your municipal Sewage Enforcement Officer.

Lehigh Valley Planning Commission

Sewage Facilities Bulletin #2

On-Site Sewage Management Programs

March 1997

Lehigh Valley Planning Commission
961 Marcon Boulevard, Suite 310
Allentown, Pennsylvania 18103-9397
Telephone: (610) 264-4544
FAX: (610) 264-2616
e-mail: lvpc@early.com

Introduction

The Pennsylvania Sewage Facilities Act (Act 537 of 1966) requires all municipalities to develop and maintain an up-to-date official sewage facilities plan to protect public health from water-borne diseases, prevent future sewage disposal problems and protect the quality of the state's surface water and ground water. A sewage facilities plan must describe how the municipality will address both existing and future municipal sewage needs. An update may be necessary when the existing plan is inadequate to meet the needs of the municipality.

As part of a municipal sewage facilities plan update, the municipality should consider developing a sewage management program for on-site sewage disposal systems. Municipalities are required by Act 537 to assure the proper operation and maintenance of sewage facilities within their borders which include various types of on-site systems. A major reason for on-site system malfunction is the lack of proper system operation and maintenance. A sewage management program is designed to ensure that sewage systems are properly operated and maintained, significantly increasing the functional life of the systems.

Sewage Management Program Requirements

While municipalities are required by Act 537 to assure the proper operation and maintenance of sewage facilities, it is not required that municipalities develop a sewage management program. The Department of Environmental Protection (DEP), the state agency responsible for implementing Act 537, will encourage municipalities to adopt sewage management programs. However, a sewage management program may be required by DEP when on-site sewage disposal malfunctions pose a significant threat to public health and the environment. Even under this circumstance, DEP will not define the type of management program the municipality must select. The design of a sewage management program can vary from municipality to municipality. Sewage management programs can be as simple or as comprehensive as warranted based on each municipality's specific needs and available resources. Typically, an annual fee is charged to homeowners in a sewage management area to cover the municipal costs of administering the program. Costs of a program can vary depending on the complexity of the program selected.

Some of the requirements that can be included in a sewage management program are as follows:

- Pumping of septage (solids) from the system once every 3 years or when a system inspection shows the need for septage removal.
- The use of water conservation plumbing devices.
- Diversion of stormwater away from the system for protection against damage.
- The use of only licensed septage haulers pumpers.
- A requirement for an undisturbed tested replacement absorption area. The sewage disposal policies of the Lehigh Valley Planning Commission (LVPC) include a recommendation for a tested replacement absorption area. An additional absorption area would be reserved for each lot proposed for on-site sewage disposal. This would allow for the availability of a suitable replacement area in the event of a primary absorption area malfunction.
- Public education of proper system operation. Brochures, annual newsletters or public workshops can be considered with emphasis on how on-site systems work, what wastes are appropriate and how to protect the system. The LVPC has prepared brochures on septic system operation and maintenance (May 1996) and water conservation (August 1995). For free copies of the brochures, please contact the LVPC at (610) 264-4544.

For existing on-site sewage disposal problem areas, the LVPC developed a solution hierarchy in its *Water Supply and Sewage Facilities Plan*, December 1995. According to the *Plan*, improved operation and maintenance should be considered first because it may provide a least cost solution to the problem. In the *Plan*, the LVPC identified 77 potential on-site sewage disposal problem areas within Lehigh and

Northampton counties. At a minimum, sewage management programs should be considered for these areas.

A sewage management program is implemented through locally developed and adopted ordinances. Several DEP model ordinances are available that reflect the requirements of different types of programs. Further, DEP guidance is available for assistance in developing a sewage management program to meet the specific needs of a municipality. For more information, please contact DEP at (717) 826-2553.

Types of Sewage Management Programs

As discussed earlier, a municipality should select a program based on identification of needs and resources available to fund the program. Specific needs of a municipality can be identified through a systems inventory. A municipality should inventory all on-site sewage disposal systems within its borders to evaluate both the condition of the systems and the suitability (based on site conditions) for the continuing use of on-site systems. A sewage management program would be beneficial for all on-site systems within a municipality. However, a program can be developed for specific areas of a municipality where it is determined that systems are not functioning properly due to inadequate operation and maintenance.

Two types of program options available for municipal consideration are listed and briefly discussed below. Variations of these programs can be developed as well.

- *Property Owner Operation and Maintenance*
  Under this type of program, the property owner is responsible for proper operation and maintenance. However, the property owner is required to provide proof of maintenance to the municipality. For example, the municipality may issue a maintenance permit requiring the property owner to meet certain periodic maintenance requirements including sewage system pumping and system inspection. The permit can only be renewed after the property owner provides proof to the municipality that the maintenance was carried out. This type of program is the simplest for a municipality to implement.

- *Municipal Maintenance*
  Under this type of program, the homeowner still owns the system and is responsible for replacement or repairs. However, the municipality is responsible for system maintenance. Typically, the municipal Sewage Enforcement Officer will conduct the periodic inspections of the systems. Septage pumping can be provided through municipally contracted services. Any maintenance work completed, including system pumping and inspection, would be billed to the homeowner.

It should be noted that under the Municipal Maintenance program, legal issues may be raised concerning routine entrance on private property. Therefore, selection of program type should be considered very carefully.

Benefits of a Sewage Management Program

The establishment of an on-site sewage management program can be beneficial to both the municipality and homeowner. With the establishment of sewage management programs, municipalities can assure the proper operation and maintenance of sewage facilities within their borders. The useful life of a properly designed and installed system can be extended through adequate operation and maintenance. In this way, the homeowner may avoid the untimely repair or replacement of a malfunctioning system. For systems already malfunctioning, once repaired or replaced, a sewage management program may help the homeowner avoid the occurrence of future system malfunctions. Further, by properly maintaining on-site systems through a sewage management program, the public health and environment can be protected from potential contamination of wells, streams and lakes due to malfunctioning systems.

For further information, contact the Lehigh Valley Planning Commission at (610) 264-4544.

COUNTYWIDE MODEL

RIPARIAN CORRIDOR CONSERVATION DISTRICT

1995

Montgomery County Planning Commission Norristown, Pennsylvania

First version done on July '96

COUNTYWIDE MODEL

RIPARIAN CORRIDOR CONSERVATION DISTRICT

Section 1. Legislative Intent.

Notes:

Under the authority of Article I, Section 27 of the Pennsylvania Constitution, Act 247, the Municipalities Planning Code as amended, other Commonwealth and Federal statutes, and in recognition of the fact that natural features contribute to the welfare of its residents, the following regulations have been enacted to provide reasonable controls governing the restoration, conservation, disturbance and management of existing riparian corridors by establishing designated Riparian Corridor Conservation Districts ("District") . In addition, the specific purposes and intent of this Article are to:

1. Reduce the amount of nutrients, sediment, organic matter, pesticides, and other harmful substances that reach watercourses, wetlands, subsurface and surface water bodies by using scientifically proven processes including filtration, deposition, absorption, adsorption, plant uptake, and denitrification, and by improving infiltration, encouraging sheet flow, and stabilizing concentrated flows.

2. Improve and maintain the safety, reliability, and adequacy of the water supply for domestic, agricultural, commercial, industrial, and recreational uses along with sustaining diverse populations of aquatic flora and fauna.

3. Regulate the land use, siting, and engineering of all development so to be consistent with the intent and objectives of this ordinance, accepted conservation practices, and to work within the carrying capacity of existing natural resources.

4. Assist in the implementation of pertinent state laws concerning erosion and sediment control practices, specifically Erosion Control, of the Pennsylvania Clean Streams Law, Act 394, P.L. 1987, Chapter 102 of the Administrative Code (as amended October 10, 1980 Act 157 P.L.), Title 25 and any subsequent amendments thereto, as

administered by the Pennsylvania Department of Environmental Protection and the Montgomery County Conservation District.

Notes:

5. Conserve the natural features important to land or water resource (e.g. headwater areas, groundwater recharge zones, floodway, floodplain, springs, streams, wetlands, woodlands, prime wildlife habitats) and other features constituting high recreational value or containing amenities which exist on developed and undeveloped land.

6. Work with the Floodplain, Steep Slope, and other Ordinances that regulate environmentally sensitive areas to minimize hazards to life, property and riparian features.

7. Conserve natural, scenic, and recreation areas within and adjacent to riparian areas for the community's benefit.

Section 2. Definition, Establishment, and Width Determination of the Riparian Corridor Conservation District

A. Definition. The Riparian Corridor Conservation District is defined as an Overlay District consisting of:

1. Areas surrounding municipally designated surface water bodies, including creeks, lakes, intermittent watercourses, and wetlands which intercept surface water runoff, wastewater, subsurface flow, and/or deep groundwater flows from upland sources and function to remove or buffer the effects of associated nutrients, sediment, organic matter, pesticides or other pollutants prior to entry into surface waters. This area may also provide wildlife habitat, control water temperature, attenuate flood flow, and provide opportunities for passive recreation. This corridor area may or may not contain trees and other native vegetation at the time of ordinance enactment.

B. Establishment.

Notes:

1. The establishment of the Riparian Corridor Conservation District applies to the following areas which are identified on the Municipal Riparian Corridor Map:

    a. Lands adjacent to municipally designated streams within the municipality;

    b. Lands adjacent to municipally designated intermittent water courses within the municipality;

    c. Lands at the margins of municipally designated lakes and wetlands;

2. The measurement of The Riparian Corridor Conservation Overlay District shall extend a minimum of 75 feet from each defined edge of an identified watercourse or surface water body at normal flow or level, or shall equal the extent of the 100 year floodplain, whichever is greater. The District will consist of two distinct zones designated as:

    a. **Zone One**: This zone will begin at each edge of an identified waterway (which can include wetlands and intermittent watercourses) and occupy a margin of land with a minimum width of 25 feet measured horizontally on a line perpendicular to the edge of water at normal flow. The width of Zone One may be required to extend beyond the minimum 25 feet depending upon existing topography, woodlands, and other natural conditions. This determination will be made by the municipal engineer, governing body, or its appointed representative.

        1. Where steep slopes (in excess of 25%) are located within 25 feet of a municipally designated watercourse, Zone One shall extend the entire distance of this sloped area. If the distance of this sloped area is greater

than 75 feet, there will be no requirement for the establishment of Zone Two. If the distance is less than 75 feet, the width of Zone Two will be adjusted so that the total corridor width (Zone One and Two) will be 75 feet maximum.

Notes:

b. **Zone Two:** This zone will begin at the outer edge of Zone One and occupy a minimum width of 50 feet in addition to Zone One.

1. Where the 100-year floodplain extends greater than 75 feet from the waterway, Zone One shall remain a minimum of 25 feet wide, and Zone Two shall extend from the outer edge of Zone One to the outer edge of the 100-year floodplain.

C. Width Determination. The developer, applicant, or his representative shall be responsible for the initial width determination of the Riparian Corridor and identifying this area on any plan that is submitted to the municipality for subdivision, land development, or other improvements that require plan submissions or permits. This initial determination shall be subject to review and approval by the municipal engineer, governing body, or its appointed representative.

Section 3. Uses Permitted in the Riparian Corridor Conservation District

The following uses are permitted, either by right or as a conditional use in the Riparian Corridor Conservation District. However, within any corridor, no construction, development, use, activity, or encroachment shall be permitted unless the activity is described in the Corridor Management Plan *(guidelines for this document are contained in Appendix A)*.

A. Zone One

1. Uses Permitted by Right

Open space uses that are primarily passive in character shall be permitted to extend into the area defined as Zone One, including:

a. Wildlife sanctuaries, nature preserves, forest preserves, fishing areas, passive areas of public and private parklands, and reforestation in compliance with the guidelines of the Corridor Management Plan.

b. Streambank stabilization in compliance with the guidelines of the Corridor Management Plan.

2. Uses Permitted by Conditional Use

a. Corridor crossings by farm vehicles and livestock, recreational trails, roads, railroads, centralized sewer and/or water lines, and public utility transmission lines, provided that any disturbance is offset by corridor improvements identified in the Corridor Management Plan.

b. Selective removal of extremely high economic value trees when removal is consistent with approved standards in the Corridor Management Plan.

retain Canton in system

B. Zone Two

1. Uses Permitted By Right.

The following uses that are primarily passive in character shall be permitted by right to extend into the area defined as Zone Two:

a. Open space uses including wildlife sanctuaries, nature preserves, forest preserves, passive areas of public and private parklands, and recreational trails conducted in compliance with methods prescribed by Chapter 102 of Title 25 of the Pennsylvania Administrative Code.

b. Reforestation in compliance with the guidelines of the Corridor Management Plan.

c. Minimum required front, side, and rear yards on private lots, provided that no yard may extend into Zone Two more

than half the distance between the outer boundaries of Zone One and Zone Two.

Notes:

d. Agricultural uses existing at the time of adoption of this ordinance, so long as they are conducted in compliance with methods prescribed by Chapter 102 of Title 25 of the Pennsylvania Administrative Code.

2. **Uses Permitted by Conditional Use.**

a. Agricultural uses in compliance with methods prescribed by Chapter 102.4(b) of Title 25 of the Pennsylvania Administrative Code.

b. Corridor crossings by farm vehicles and livestock, roads, railroads, centralized sewer and/or water lines, and public utility transmission lines provided that any disturbance is, at a minimum, offset by corridor improvements identified in the Corridor Management Plan.

c. Centralized sewer and/or water lines, and public utility transmission lines running along the corridor, provided that any disturbance is, at a minimum, offset by corridor improvements identified in the Corridor Management Plan. These lines shall be located as far from Zone One as practical.

d. Selective cutting of trees when removal is consistent with approved standards in the Corridor Management Plan.

e. Passive use areas such as camps, campgrounds, picnic areas, and golf courses. Active recreation areas such as ballfields, playgrounds, and courts provided that these uses are designed in a manner that will not permit concentrated flow.

f. Naturalized stormwater basins in compliance with the guidelines in the Corridor Management Plan. The entire basin shall be located a minimum of 50 feet from the defined edge of identified watercourses.

Notes:

Section 4. Uses Specifically Prohibited in the Riparian Corridor District

Any use or activity not authorized within Section Three shall be prohibited within the Riparian Corridor Conservation District. By way of example, the following activities and facilities are specifically prohibited:

Exercise is to prevent Sedimentation NPS Excess runoff

A. Clearcutting of trees and other vegetation

B. Selective cutting of trees and/or the clearing of other vegetation within Zone One, except where such clearing is necessary to prepare land for a use permitted under Section 3.A.2. and where the effects of these actions are mitigated by revegetation as specified under Section 8.C. herewithin.

C. Selective cutting of trees and/or the clearing of other vegetation within Zone Two, except where such clearing is necessary to prepare land for a use permitted by Section 3.B.2. and where the effects of these actions are mitigated by revegetation as specified under Section 8.C. herewithin.

D. Removal of trees in excess of selective cutting, except where such removal is necessary as a means to eliminate dead, diseased, or hazardous tree stands which jeopardize public safety or as part of a reforestation project, provided that the removal is in compliance with a Corridor Management Plan approved by the municipal engineer, governing body, or its appointed representative.

E. Removal or disturbance of vegetation in a manner that is inconsistent with erosion control and corridor protection.

F. Storage of any hazardous or noxious materials.

G. Use of fertilizers, pesticides, herbicides, and/or other chemicals in excess of prescribed industry standards, or the recommendations of the Montgomery County Conservation District.

Notes:

H. Roads or driveways, except where permitted as corridor crossings in compliance with Sections 3.A.2.(a) or 3.B.2.(b),

I. Motor vehicle or wheeled vehicle traffic in any area not designed to accommodate adequately the type and volume.

J. Parking lots.

K. Any type of permanent structure, including fences, except structures needed for a use permitted in Section Three.

L. Subsurface sewage disposal areas.

M. Sod farming.

Section 5. Nonconforming Structures and Uses in the Riparian Forest Corridor District

Nonconforming structures and uses of land within the Riparian Corridor Conservation District shall be regulated under the provisions of Article ___ herein **(existing non-conformance regulations)**, and the following additional regulations also shall apply.

A. Existing nonconforming structures or uses within Zones One or Two that are not permitted under Section Three may be continued, but shall not have the existing building footprint or uses expanded or enlarged.

B. Discontinued nonconforming uses may be resumed any time within one year from such discontinuance, but not thereafter when showing clear indications of abandonment. No change or resumption shall be permitted that is more detrimental to the Riparian Corridor Conservation District, as measured against the intent and objectives under Section One, than the existing or former nonconforming use.

C. This one year time frame shall not apply to agricultural uses which are following prescribed Best Management Practices for crop rotation.

Notes:

Section 6. Boundary Interpretation and Appeals Procedure

A. When a landowner or applicant disputes the Zone (One or Two) boundaries of the Riparian Corridor, or the defined edge of a watercourse, surface water body, or wetland, the landowner or applicant shall submit evidence to the municipality that describes the boundary, presents the landowner or applicant's proposed boundary, and all justification for the proposed boundary change.

B. The Municipal Engineer, Governing Body, or appointed representative shall evaluate all material submitted and shall make a written determination within 45 days, a copy of which shall be submitted to the Elected Officials, Municipal Planning Commission, and landowner or applicant.

C. Any party aggrieved by any such determination or other decision or determination under this Section may appeal to the Zoning Hearing Board under the provisions of **(existing Zoning Hearing Board Article)** of this ordinance. The party contesting the location of the district boundary shall have the burden of proof in case of any such appeal.

Section 7. Inspection of Riparian Corridor Conservation District

A. Lands within or adjacent to an identified Riparian Corridor Conservation District will be inspected by the municipal representative when:

1. a subdivision or land development plan is submitted;

2. a building permit is requested;

3. a change or resumption of nonconforming use is proposed.

Appendix A
Corridor Management Guidelines

Corridor management plans are essential for ensuring a successful riparian corridor environment. Each plan should clearly answer the question "What is going to happen in that riparian corridor?" For example, if an existing meadow is intended to revert to a woodland over 20 years, this should be understood by all parties concerned. Similarly, if an area of the riparian corridor will be destroyed, then the mitigation measures that will offset the disturbance should be identified. Responsibilities for implementing the plan and actions to be taken to fulfill the goals should also be clear. In essence, the plan should provide the framework to implement the long-term management strategies for the riparian corridor.

All landowners and developers that are proposing subdivision or development of land within the riparian corridor must submit a corridor management plan. Certain requirements of the plan may overlap with other subdivision and land development requirements, such as the existing conditions plan. Landowners with no plans for subdivision or development are encouraged to submit corridor management plans on a voluntary basis.

The corridor management plan, which will include scale drawings and explanatory text, should be prepared by a landscape architect, engineer, or other qualified professional. This plan should be submitted and approved as part of the municipal subdivision and land development review process.
The corridor management plan should include the following four elements:

Section I: Existing Conditions

This section should include a sketch plan showing the boundaries of Zone 1, Zone 2, and existing environmental conditions (such as contours with steep slopes and swales highlighted, wetlands, floodplain, woodlands, vegetation, and any existing structures). A written description of unusual or significant conditions should also be included.

Section II: Goals

An analysis should be done that identifies the goals for the entire tract in relation to the intent of the riparian corridor district. For example, the goal for the 25 feet back from the stream may be to preserve the woodland as is, and the goal for the next 50 feet back may be to maintain the area as a wildflower meadow. The goal outside the riparian corridor may be to develop a residence and a barn. For those areas that include improvements, a discussion should be included that addresses how disturbance to the corridor will be minimized and offset with corridor improvements. A schematic plan to illustrate the goals should also be included.

Section III: Proposed Activities

This section should include a plan and a discussion of activities proposed for Zone 1, Zone 2, and land adjacent to the corridor. The plan should show those areas that will be disturbed and those that will be protected and preserved. The plan should identify which proposed activities are permitted by right, which will require a conditional use, and which will require mitigation measures.

Section IV: Management

The final section of the corridor management plan should include a discussion of how the goals identified in Section II will be met given the proposed activities from Section III. The plan should be specific in terms of when the construction, planting, or other activities are to begin and end and should address long and short term maintenance and improvement activities necessary for the long term preservation of the corridor.

Details for restoration measures for existing vegetation would include application of herbicides, identification of invasive plants to be removed, and required spacing for newly planted trees. All other activities necessary to reach the goals stated in the schematic plan should be referenced. These may include mowing schedules, farming practices, tree and shrub plantings, renovations to structures, and all other related functions.

Pages 4 through 17 of this appendix contain information to guide landowners in reaching various land management goals.

Pages 18 through 20 of this appendix contain guidelines for mitigation measures that can offset disturbances to Zones 1 and 2 of the riparian corridor.

Page 21 of this appendix gives general guidance and a reference for streambank stabilization.

Pages 22 through 25 of this appendix contain guidance on best management practices for certain activities within and near the riparian corridor.

Pages 26 through 28 of this appendix contain guidelines for designing stormwater management systems in and near the riparian corridor.

There are some basic guidelines that landowners should consider prior to deciding how to manage their riparian areas. They are as follows:

- Three distinct layers of vegetation are recommended to protect stream resources. The three layers include trees that form an overhead canopy, shrubs that provide an immediate layer, and herbaceous plants that serve as groundcover.

- Maintaining land as lawn is one of the most expensive methods for managing land

on a suburban property.

- Native species should be used whenever possible as they will adapt the best to existing site conditions.

- The creation of additional edges should be minimized and the a reduction in existing edges should be sought.

- The landowner should plan for managing the riparian area in accordance with his financial resources so that maintenance does not become a problem.

Landscape Management Guidelines

This section provides general guidance on how to manage certain landscape types to reach certain goals. However, choosing which procedure to follow is up to each landowner or developer and should be based on site specific conditions. For example, because preventing the disturbance of woodlands directly adjacent to streams is very important, managing a degraded woodland in Zone 1 should be approached differently than managing a degraded woodland in Zone 2.

In general, it is ideal to maintain or create forested areas in Zone 1 (adjacent to the streams), to have a managed woodlands with three layers of vegetation in Zone 2, and to have a thick layer of ground cover, such as a managed meadow, adjacent to Zone 2 in order to maximize ground contact with the runoff.

The following matrix outlines the options for landscape management and provides the page numbers of the detailed guidelines for each:

EXISTING CONDITION	Preserve	Restore	Convert to Woodlands	Convert to Meadow
Woodlands				
Healthy	5			
Degraded		5		
Highly Degraded				5-6
Meadow				
Healthy	6		6-7	
Degraded		7	7-8	
Pasture				
Healthy	8		9	9
Degraded		9-10	10-11	11
Old Field/Shrub			11-12	12
Lawn/Landscaping			13	13-14

Existing Condition: Woodlands

A healthy woodland is one that is well-stocked with native trees, free of exotic invasive plants, and is not degraded by excessive deer use. The degree of native tree growth will be commensurate with the age of the wooded area and the conditions of the site; for example, a healthy steep slope woodland area will not contain the dense growth of trees that a flat area will.

A degraded woodland is one that has exotic invasive vegetation, lacks advanced tree and shrub regeneration due to over browsing by deer, has been polluted by the

dumping of construction and landscaping debris, or is eroded. In general, invasive plants tend to thrive and be the most damaging where they have access to the greatest amount of light. As a result, woodlands tend to be the most degraded at their edges and in interior gaps. Common examples of invasive plants include oriental bittersweet, Japanese honeysuckle, grape, porcelain berry, Norway maple, multiflora rose, and bush honeysuckle.

Preserve Healthy Woodland

If the woodland is healthy, the best management approach is to minimize disturbance. In addition, the site should be monitored on a regular basis for the presence of invasive vegetation, reduced levels of regeneration due to excessive browsing of deer and other herbivores, or increases in air or water pollution that harm existing vegetation. If these conditions are found, then the woodlands should be treated as degraded.

Restore Degraded Woodland

The actions needed to restore a degraded woodland to its healthy state depend on the extent of the degradation. The following guidelines should be considered when developing a plan for restoring degraded woodlands:

(1) Identify the source of degradation (vines, deer, soils, etc.) as soon as possible so that restoration costs can be kept to a minimum.

(2) The larger invasive vines on canopy trees should be eliminated first. Then, the smaller invasive plants, such as tree seedlings and shrubs, should be removed.

(3) Gaps in the woodlands should be replanted with native trees. These trees should be protected from deer with fencing, tree shelters, or flexible deer guards.

(4) Remove invasive trees last as they help provide shade and keep invasive vines to a minimum. Replace them with native tree species

(5) Correct soil erosion by rerouting trails along the contour and/or by controlling the water source. Fill gullies and plant with an annual rye and/or oats and native trees and shrubs. Avoid the use of standard conservation seed mixes as they may introduce exotic species.

(6) Minimize use of heavy equipment.

(7) Inspect annually to address further degradation as it occurs.

Convert Highly Degraded Woodland to Meadow

If the degree of degradation of the woodlands is excessive (more than 75% of the canopy trees have been killed or deformed by vines or Norway Maple is the domi-

nant species), it may be preferable to convert part or all of the woodland to a meadow. If the degraded woodland is in Zone 1, it would be preferable to manage the area with as little landscape disturbance as possible.

(1) Eliminate all existing vegetation. Remove trees and shrubs and use herbicides and cultivation several times at two week intervals to eliminate existing grasses and herbaceous plants. Avoid spraying herbicides within 50 feet of the stream.

(2) Use grass and wildflower species appropriate for site conditions, as suggested in Appendix B. By adding annual rye or oat to the seed, you can create a quick growth cover that will aid in controlling erosion. Plant in spring or early fall.

(3) Mow the young meadow twice a year. The first mowing should be done as early as possible in the spring (mid April is a good estimate). The second mowing should be done between late May and mid June. This second mowing will act to control thistle and other weeds and will allow the warm season grasses and wildflowers to grow. No mowing should occur after that time as the grasses need time to grow and go to seed.

Existing Condition: Meadow

Healthy meadows are open areas containing high grass and wildflowers. Meadows are effective landscapes for controlling erosion, buffering streams, and providing wildlife habitat.

A degraded meadow is one that contains invasive plants, vines, shrubs, and herbaceous perennials (such as thistle). Meadows that have eroded soils and have been used for dumping are also considered degraded.

Preserve Healthy Meadows

(1) Mow young meadows twice a year. The first mowing should be done as early as possible in the spring (mid April is a good estimate). The second mowing should be done between late May and mid June. This second mowing will act to control thistle and other weeds and will allow the warm season grasses and wildflowers to grow. A mature meadow can be mowed once a year, in early to mid spring. No mowing should occur after mid June as the grasses need time to grow and go to seed.

(2) Monitor the meadow for intrusion by invasive plants.

(3) Augment existing meadow species with native species appropriate to site conditions through overseeding or installation of plugs as needed. Refer to Appendix B, List of Recommended Plants, for suggestions.

Convert to Woodland

A landowner may choose to convert a healthy meadow to woodland if it is adjacent to the stream itself, if additional edge is needed adjacent to a degraded woodland, or

if a wildlife corridor is needed.

(1) Plantings should be spaced to allow for control of competing vegetation with available mowing equipment, but close enough for the canopy to close quickly. The specific arrangement and size of the plantings will depend on site conditions. Plantings that mimic nature are preferable.

(2) Select species appropriate for site conditions. See Appendix B, List of Recommended Plants, for suggestions.

(3) Use protective measures such as fencing, tree shelters, and flexible tree guards to minimize deer damage.

(4) Reduce vegetative competition through cultural techniques around base of tree or by mowing at least four times during the growing season until the canopy has closed. Selective herbicides could also be used, but not sprayed within 50 feet of the stream. After closure, monitor for invasive plants and control as needed.

Restore Degraded Meadow to a Healthy State

(1) Regrade and seed eroded areas with a mix of native grasses and wildflowers and annual rye or oats to control erosion.

(2) Remove trash and dispose of according to current DEP regulations.

(3) Eliminate invasives through spot spraying or wick application of appropriate herbicide or manual or mechanical pulling. Avoid spraying herbicides within 50 feet of streams. Areas that are disturbed should be seeded with annual rye and/or oats and mulched to hinder reestablishment of invasives.

(4) Mow young meadows twice a year. The first mowing should be done as early as possible in the spring (mid April is a good estimate). The second mowing should be done between late May and mid June. This second mowing will act to control thistle and other weeds and will allow the warm season grasses and wildflowers to grow. A mature meadow can be mowed once a year, in early to mid spring. No mowing should occur after mid June as the grasses need time to grow and go to seed.

(5) If desired or needed, augment existing meadow species with species appropriate to site conditions through overseeding or installation of plugs.

(6) Monitor for intrusion by invasive plants.

Convert Degraded Meadow to Woodland

A landowner may choose to convert a healthy meadow to woodland if it is adjacent to the stream itself, if additional edge is needed adjacent to a degraded woodland, or if a wildlife corridor is needed.

(1) Plantings should be spaced to allow for control of competing vegetation with available mowing equipment, but close enough for the canopy to close quickly. The specific arrangement and size of the plantings will depend on site conditions. Plantings that mimic nature are preferable.

(2) Select species appropriate for site conditions. See Appendix B, List of Recommended Plants, for suggestions.

(3) Use protective measures such as fencing, tree shelters, and flexible tree guards to minimize deer damage.

(4) Reduce vegetative competition through selective herbicide use around base of tree or by mowing at least four times during the growing season until the canopy has closed. After closure, monitor for invasive plants and control as needed.

Existing Condition: Pasture

Pastures are open areas of short grass and forbs that are used for livestock grazing. A healthy pasture can provide greater environmental benefits than a lawn, be less costly to maintain, and be an attractive part of the landscape.

Pasture becomes degraded when it is overgrazed or not mowed on a timely basis. This can lead to the establishment of invasive plants, soil erosion, and an unattractive landscape.

Preserve Healthy Pasture

(1) Establish proper stocking density as per recommendations by the Soil Conservation Service (P.O. Box 380, Rt. 113, Creamery, PA 19430, or phone 215-489-6071). Appropriate densities will vary with soil type. Generally, it is best not to exceed one horse per acre.

(2) Mow at least three times per year to stimulate forage growth and discourage undesirable plants such as woody vegetation, thistle, and multiflora rose and to limit plants that are undesirable as animal forage.

(3) Inspect for exposed soil as this indicates overgrazing. If found, adjust the stocking density to maintain permanent cover over entire pasture.

(4) Fence pasture to keep livestock out of streams

(5) Streams and ponds should be buffered from pasture areas on each side by woodland or meadow that has a width equal to the greater of 25 feet or 20% of the perpendicular width of all adjacent pasture; except that pasture may be maintained along a section of the pond not to exceed 30 feet to allow for

access for livestock, a foot bridge, or as a trail (preferably, less than 8 feet in width and at least 10 feet from the stream or pond bank) within the buffer area. The pasture or meadow area within 10 feet of the stream or pond bank should be mowed with a walk-behind mower or weed whip to prevent degradation of the bank by heavy tractors.

Convert Healthy Pasture to Woodland

A landowner may choose to convert a healthy pasture to woodland if it is adjacent to the stream itself, if additional edge is needed adjacent to a degraded woodland, or if a wildlife corridor is needed.

(1) Planting design should be spaced to allow for control of competing vegetation with available mowing equipment, but close enough for the canopy to close quickly. The specific arrangement and size of the plantings will depend on site conditions. Plantings that mimic nature are preferable.

(2) Select species appropriate for site conditions. See Appendix B, List of Recommended Plants, for suggestions.

(3) Use protective measures such as fencing, tree shelters, and flexible tree guards to minimize deer damage.

(4) Reduce vegetative competition through selective herbicide use around base of tree or mowing at least four times during the growing season until the canopy has closed. After closure monitor for invasive plants and control as needed.

Convert Healthy Pasture to Meadow

Meadows provide more environmental and ecological benefits than pastures and are less costly to maintain. Converting pasture to meadow would be a preferred option if grazing animals were no longer kept on site.

(1) Mow twice a year. The first mowing should be done as early as possible in the spring (mid April is a good estimate). The second mowing should be done between late May and mid June. This second mowing will act to control thistle and other weeds and will allow the warm season grasses and wildflowers to grow. No mowing should occur after mid June as the grasses need time to grow and go to seed.

(2) If desired or needed, augment existing meadow with species appropriate to site conditions through overseeding or installation of plugs.

(3) Monitor the meadow for intrusion by invasive plants and treat as needed.

Restore Degraded Pasture to a Healthy State

This is the preferred option if the property owners maintain the appropriate livestock facilities on site.

(1) Eliminate invasives manually, mechanically, or through chemical application according to Penn State Cooperative Extension recommendations.

(2) Apply lime, fertilizer, and organic matter as prescribed buy a Penn State University (or comparable laboratory) soil analysis recommendation. Soil test kits are available from the Penn State Cooperative Extension (P.O. Box 20, 1015 Rt. 113, Creamery, PA 19430-0020, or phone 215-489-3415).

(3) Regrade and seed any exposed areas according to Penn State Cooperative Extension recommendations.

(4) Establish proper stocking density as per recommendations by the Soil Conservation Service (P. O. Box 380, Rt. 113, Creamery, PA 19430, or phone 215-489-6071).

(5) Mow at least three times per year to stimulate forage growth and to discourage undesirable plants such as woody vegetation, thistle, and multiflora rose.

(6) Exposed soil indicates overgrazing. Correct stocking density in order to maintain permanent cover over entire pasture.

(7) Fence pasture to keep livestock out of streams.

(8) Herbicides and pesticides should not be applied to pasture except as part of the restoration process. Avoid spraying within 50 feet of the stream.

(9) Streams and ponds should be buffered from pasture areas on each side by woodland or meadow that has a width equal to the greater of 25 feet or 20% of the perpendicular width of all adjacent pastures.

Convert Degraded Pasture to Woodland

A landowner may choose to convert a degraded pasture to woodland if it is adjacent to the stream itself, if additional edge is needed adjacent to a degraded woodland, or if a wildlife corridor is needed.

(1) Eliminate invasives manually, mechanically, or through chemical application according to Penn State Cooperative Extension recommendations. Avoid spraying chemicals within 50 feet of the stream.

(2) Regrade and seed any exposed or eroded areas with a combination of a perennial native grass and annual rye or oats.

(3) Planting design should be spaced to allow for control of competing vegetation with available mowing equipment, but close enough for the canopy to close quickly. The specific arrangement and size of the plantings will depend on site conditions. Plantings that mimic nature are preferable.

(4) Select species appropriate for site conditions. See Appendix B, List of Recommended Plants, for suggestions.

(5) Use protective measures such as fencing, tree shelters, and flexible tree guards to minimize deer damage.

(6) Reduce vegetative competition through selective herbicide use around base of tree or mowing at least four times during the growing season until the canopy has closed. After closure monitor for invasive plants and control as needed.

Convert Degraded Pasture to Meadow

Meadows provide more environmental and ecological benefits than pastures and are less costly to maintain. This would be a preferred option if grazing animals were no longer kept on site.

(1) Eliminate invasives manually, mechanically, or through chemical application. Avoid spraying chemicals within 50 feet of the stream. Use a combination of herbicide application and cultivation several times at two week intervals to eliminate existing grasses and herbaceous plants.

(2) Regrade and seed any exposed or eroded areas with a mix of native grasses and forbs. Add annual rye or oats to the mix to provide quick erosion control.

(3) Reduce mowing schedule to twice a year. The first mowing should be done as early as possible in the spring (mid April is a good estimate). The second mowing should be done between late May and mid June. This second mowing will act to control thistle and other weeds and will allow the warm season grasses and wildflowers to grow. No mowing should occur after mid June as the grasses need time to grow and go to seed.

(4) If desired or needed, augment existing meadow species with species appropriate to site conditions through overseeding or installation of plugs. Refer to Appendix B for suggestions.

(5) Monitor the meadow annually for intrusion by invasive plants and treat as needed.

Existing Condition: Old Field/Shrub

Old field/shrub areas are formerly open sites with small shrubs and trees such as Red Cedar. Although old field/shrub areas provide unique ecological benefits (wildlife habitat), they are costly to maintain (requiring heavy equipment to clear) and are ideal sites for invasive plants to become established.

Convert Old Field to Woodland

This preferred option can be either the easiest or hardest to achieve depending on

the degree of succession and degradation by invasive plants. It will be the least costly if trees are about to dominate the site and the amount of invasive plant material is small. It will be the most difficult option if invasive plants are prominent.

(1) Identify trees and release from competition with invasive plants by cutting or wick application of herbicide. Avoid spraying herbicides within 50 feet of the stream. Use protective measures such as fencing, tree shelters, and flexible tree guards to minimize deer damage.

(2) If necessary, augment natural tree regeneration by planting tree seedlings appropriate to site conditions. Refer to Appendix B for suggestions. Use protective measures such as fencing, tree shelters, and flexible tree guards to minimize deer damage.

(3) Monitor annually for invasives and treat as necessary.

Convert Old Field to Meadow

This option would be best if the site is heavily overgrown with invasive plants.

(1) Prepare the area for seeding by eliminating all existing vegetation. Remove trees and shrubs manually or mechanically; use a combination of herbicide application and cultivation several times at two week intervals to eliminate existing grasses and herbaceous plants. Avoid spraying herbicides within 50 feet of the stream.

(2) Use native grass and wildflower species appropriate to site conditions. Add annual rye or oats to the seed mix to provide a quick cover for erosion control. Plan in spring or early fall.

(3) Mow twice a year. The first mowing should be done as early as possible in the spring (mid April is a good estimate). The second mowing should be done between late May and mid June. This second mowing will act to control thistle and other weeds and will allow the warm season grasses and wildflowers to grow. No mowing should occur after mid June as the grasses need time to grow and go to seed.

(4) If desired or needed, augment existing meadow species with native species appropriate to site conditions through overseeding or installation of plugs. Refer to Appendix B for suggestions.

Existing Condition: Lawn/Landscaped Areas

Lawns and landscaped areas afford the least environmental and ecological benefits (indeed they can create environmental problems if not managed properly) and usually require the most financial commitment to maintain. For these reasons, their use should be minimized in riparian corridors.

Convert Lawn to Woodlands

This option is preferred if the existing lawn or landscaped area borders the stream or is dominated by hydric soils or steep slopes.

(1) Planting design should be spaced to allow for control of competing vegetation with available mowing equipment, but close enough for the canopy to close quickly. The specific arrangement and size of the plantings will depend on site conditions. Plantings that mimic nature are preferable.

(2) Select species appropriate for site conditions. See Appendix B, List of Recommended Plants, for suggestions.

(3) Use protective measures such as fencing, tree shelters, and flexible tree guards to minimize deer damage.

(4) Reduce vegetative competition through selective herbicide use around base of tree or mowing at least four times during the growing season until the canopy has closed. After closure monitor for invasive plants and control as needed.

Convert Lawn to Meadow

Converting lawn/landscaped areas is especially beneficial if it augments an existing meadow or is located on a wet or steep site. Meadow can be "created" from lawn areas simply by reducing the mowing frequency to once or twice a year or through eliminating the existing vegetation and planting. The latter option is preferable in that it allows the landowner to introduce desired species and to eliminate undesirable grasses (tall fescue and perennial rye) or herbs that compete with desirable species. The former option, however, may be more appropriate on wet or steep areas where meadow establishment procedures would be more difficult and could create environmental problems.

Any plan that calls for the elimination of existing vegetation to establish meadow on wet or steep (>15%) areas should follow Soil Conservation Service (P. O. Box 380, Rt. 113, Creamery, PA 19430, 215-489-6071) recommendations to minimize environmental impacts.

(1) If establishing a new vegetative cover, prepare the area for seeding by eliminating all existing vegetation. Remove trees and shrubs (native species could be transplanted to a wooded area) and use a combination of herbicide application and cultivation several times at two week intervals to eliminate grasses and herbaceous plants. Avoid spraying herbicides within 50 feet of streams.

(2) Use native grass and wildflower species appropriate to site conditions. Add annual rye or oats to the seed mix to provide a quick cover for erosion control. Plant in spring or early fall. Liming and fertilizing are not necessary for native species.

(3) Mow twice a year. The first mowing should be done as early as possible in the spring (mid April is a good estimate). The second mowing should be done between late May and mid June. This second mowing will act to control thistle and other weeds and will allow the warm season grasses and wildflowers to grow. No mowing should occur after mid June as the grasses need time to grow and go to seed.

(4) If desired or needed, augment existing meadow species with species appropriate to site conditions through overseeding or installation of plugs.

(5) Monitor the meadow for intrusion by invasive plants and treat as needed.

Mitigation Measures to Offset Corridor Disturbances

While preservation is the goal of the riparian corridor district, there will be cases where disturbance to a portion of the corridor is unavoidable. The ordinance permits certain disturbances to the corridor as conditional uses provided they are offset by corridor improvements. These disturbances include the following:

Corridor crossings by farm vehicles
Corridor crossings by animals
Roads
Recreational trails
Railroads
Centralized sewer lines
Centralized water lines
Public utilities
Transmission lines

When one of these uses is permitted by conditional use, certain measures can help to offset the negative impact of the disturbances. Mitigation or offsetting measures work by increasing the efficiency and effectiveness of one part of the buffer which compensates for the decrease in effectiveness caused by the disturbance. The specific actions needed to offset a disturbance will depend on site specific conditions and the nature and extent of the disturbance. Basically, are three ways to offset disturbances to the corridor:

Increase the Width of Zones 1 and 2

Within this ordinance, the riparian buffer district is defined as 75 feet from each defined edge of an identified watercourse or surface water body at normal flow or level, or the extent of the 100 year floodplain, whichever is greater. This area is considered to be the minimum necessary to be effective in preserving water quality and maintaining the general viability of the stream. However, wider buffers go farther toward reaching these goals and serve additional purposes as well.

Landowners and developers seeking to offset corridor disturbances should consider their site conditions and the intensity of the proposed disturbance to gauge the extent of corridor widening necessary. As a general rule, the width of the buffer should increase in proportion to the size of the areas contributing runoff, sediment, and nutrients, the steepness of the slopes, and the intensity of the activities and disturbances in the upland areas such as agriculture, forestry, suburban or urban development. In addition, the following table outlines the range of widths considered necessary to meet certain goals in the riparian district:

Goal	Necessary Width
Sediment Control	up to 150 feet
Nutrient Removal	up to 150 feet
Temperature Control	up to 80 feet
Wildlife Habitat	100-330 feet

The areas and extent of widening proposed should be shown and explained in the Corridor Management Plan.

Add Layers of Vegetation

In addition to wider corridors, the addition of layers of vegetation improves the effectiveness of the riparian area. For maximum effectiveness, the riparian areas should have three distinct layers of vegetation that are present in mature woodlands: (1) trees that form an overhead canopy, (2) shrubs that provide an immediate layer of cover, and (3) herbaceous plants that serve as ground cover. These layers work together to provide a roughness and diversity that increases filtration efficiency and creates habitat for a wider range of wildlife.

Overstory trees are deciduous or evergreen trees with heights ranging between thirty and one hundred feet. Typical species include oak, hickory, maple gum. beech, sycamore, spruce, hemlock, pine, and fir. Overstory trees shade the stream and other layers of forest vegetation and protect them from rain and wind. The evergreen and deciduous shrubs (such as elderberry, viburnum, azalea, rhododendron, holly, laurel, and alders) provide habitat and food for wildlife and are key to stabilizing the forest floor. The ground cover vegetation such as ferns, sorrel, trillium, violet, Virginia creeper, nettle, phlox, aster, and worts mixes with decomposing leaves, organic litter, and debris from other layers and water to create a rich, moist forest floor essential to the sustenance of the other layers.

Over time, the successional cycle will create this diverse riparian habitat naturally. However, by planting, the environment can be created and the riparian buffer can go farther toward achieving our goals much sooner.
Convert to more effective landscape

Landscapes ranging from woodlands to meadows could exist within the riparian buffer zones. However, the various landscape types are not equal in their ability to filter sediment and enhance water quality. For example, woodlands are more effective than meadows in achieving the goals of the riparian zones. However, meadows are much more effective than lawns or degraded pastures. The following landscape types are listed in order of effectiveness:

Woodland
Meadow
Shrub, Old Field, Pasture

Landowners and developers can improve the effectiveness of their riparian buffer zones by converting the existing landscape to one that is more effective. The guidelines contained in pages 4 through 17 of this appendix give more specific information about how to convert various landscape types to others.

Streambank Stabilization Measures

Stream banks erode when loose soil and sediment are washed from the bank and carried away by the stream. In some cases, the erosion leads to stream bank failure where a large section of the bank collapses and falls into the stream. Stream bank erosion and collapse degrade the stream by making it more shallow, reducing the carrying capacity of the stream, and by increasing the potential for flooding. In addition, eroded soil entering the stream is initially suspended in the water. This decreases the amount of sunlight reaching aquatic plants, inhibiting their growth and reproduction. Suspended sediment also clogs fish gills, thereby inhibiting water circulation and aeration of the blood. Finally, erosion increases the amount of phosphorus reaching the stream as 85 percent of available phosphorus is bound to sediment.

There are many effective ways to stabilize eroding stream banks. Finding the most effective technique, however, depends on the cause of the erosion and the goal of the owner. Those needing to stabilize their stream banks should consult the publication entitled A Streambank Stabilization and Management Guide for Pennsylvania Landowners, published by the Pennsylvania Department of Environmental Resources.

Best Management Practices for Riparian Areas

Riparian area BMPs are tied to the function of riparian areas. These functions are filtering of sediment, bank stability, water storage, and recharge of aquifers. The roughness of vegetative cover slows runoff, allowing sediment to settle out of stormwater. Additional sediment is trapped by vegetation as stormwater flows across it. The removal of sediment helps to build up the banks of streams. The vegetation on the banks stabilizes the banks, enabling them to withstand high velocities of water without eroding. Runoff that is slowed by vegetation is able to soak into banks and riparian areas. This decreases peak storm flow, recharges groundwater, and helps maintain stream baseflow during the summer months.

Stream channels that experience scouring and downcutting become narrow and deep, reducing the access to the floodplain, where it would normally spread out and be absorbed. Thus, groundwater recharge and water available to maintain base flow are reduced. Through management, these conditions can be reversed. Restoration of riparian vegetation encourages deposition of sediment, reversing channel degradation. As the stream widens and fills in, the area for water absorption increases and aquifer recharge improves. The sensitivity of a riparian corridor to degradation, or its ability to rebound from over use, is dependent on several environmental factors. These include soil type, gradient, weather, geology, and other physical features. Because these environmental factors differ from stream to stream, some modification of the BMPs presented here may be necessary in implementation, to adjust for local conditions.

Preserve Existing Woody Vegetation

Preserving existing woody vegetation benefits the riparian corridor, and well as the stream. These benefits include control of stormwater flows, habitat, and stream quality.

Trees, shrubs, and grasses all intercept precipitation as it falls or flows along the ground as runoff, reducing its velocity. By reducing the velocity, the vegetation reduces the potential of erosion, filters out sediment, encourages infiltration, and allows for the uptake of nutrients. Therefore, it is important to preserve riparian vegetation in an undisturbed state. Vehicular traffic and intensive recreation should be avoided as they compact the soil, which decreases percolation and aeration and eventually kills the existing vegetation.

Disturbance of vegetation should be minimized to the greatest extent possible. Removal of trees and other vegetation should be limited to diseased or invasive species. Disturbed areas resulting from removal of vegetation should be mulched and revegetated as soon as possible.

Revegetate the Area

When there is little or no existing stream side vegetation, replanting will regain many of the benefits of the riparian area. Native vegetation should be used in replanting efforts.

Three layers of vegetation are recommended when replanting. The layers include trees that form an overhead canopy, shrubs that form an immediate layer, and herbaceous plants that serve as ground cover. Until vegetation is established, it may be necessary to supplement the natural sediment trapping function of the greenway with retention basins or vegetated berms.

Leave Fallen Branches and Other Organic Material Intact

Wherever possible, logs, branches, and other organic material should be allowed to remain where they have fallen. Woody debris in and along streams contributes 50% or more of the habitat found in the corridor. Substantial amounts of woody debris is deposited within the stream corridor, where it provides habitat for small mammals and invertebrates, which in turn act as prey for larger predators. Woody material which falls in the stream provides habitat, by creating small dams and pools. Riparian vegetation is the main source of nutrients and energy in an aquatic ecosystem. Without the woody debris accumulations, much of the biodiversity and productivity of the riparian zone would disappear.

Agriculture

The following conservation practices serve many goals consistent with the preservation of riparian areas, as described below:

- Crop rotations to maintain or improve soil productivity and reduce erosion.
- Contour plowing to reduce soil erosion and conserve water. Field tillage should follow recommended contouring methods to reduce erosion of topsoil into the stream.
- Conservation tillage (any tillage or planting system that maintains at least 30% of the soil surface covered by plant residue) to reduce soil erosion, conserves soil moisture, and improves wildlife habitat.
- Cover cropping (a crop of close growing grasses, legumes, or small rains) for seasonal protection and soil improvement. It also reduces soil erosion, increases organic matter, and improves wildlife habitat.
- Strip cropping (alternating strips of grass with cultivated crops on the contour or across the general slope) to reduce erosion and conserve water.
- Grassed waterways (an outlet that is vegetated and used for safe disposal of stormwater runoff) to prevent gullies, provide outlets for diversions and terraces, and provide wildlife habitat and travel lanes.
- Diversions (grassed channels constructed across the slope) to divert water runoff

and prevent gullies, reduce soil erosion, and divert excess water runoff to safe outlets.

- Terraces (an embankment and channel constructed across the slope) to intercept and store water runoff. They also reduce erosion and improve soil moisture.

Stream Fencing

Stream fencing improves water quality, protects herd health, provides habitat for small mammals and birds, and improves fish habitat. Fencing promotes the growth of vegetation adjacent to the stream. The vegetation intercepts runoff from fields, trapping sediment and reducing fertilizers and pesticides. Stream side vegetation also shades the stream and contributes organic material, thus improving aquatic habitat. Birds and small mammals also benefit from the food and protection provided by vegetation which grows along the fencing. Installing fencing some distance back from the stream encourages a wider swath of vegetation to form, resulting in greater water quality and habitat benefits.

Fencing should be used to prevent livestock from standing in the stream. Animals should not be permitted to graze along stream banks as they destroy vegetation and degrade the water with their waste. Fencing livestock out of streams prevents destruction of stream banks and sedimentation that follows, reduces livestock contact with waterborne bacteria, and reduces the risk of leg injury to livestock caused by crumbling stream banks.

As an alternative, livestock can drink from designated stock watering areas that have limited access. To minimize erosion, these watering sites should be reinforced with material such as stone or railroad ties.

Another alternative is to develop springs, wells, or ponds with watering troughs. Hydraulic ram or pasture pumps may be used to transport water to the sites. These methods can be better form the livestock as they are more reliable and reduce the risk of disease that arises when livestock drink and dump into the same body of water.

Limit the Input of Nutrients and Toxic Chemicals.

An undisturbed vegetated strip should be maintained between the cultivated fields or development sites and the stream as a means of filtering sediments.

A planned system for managing agricultural liquid and solid waste, including runoff from areas where the potential contaminant is concentrated, is needed to improve water quality, improve herd health, and reduce fertilizer needs.

Stream Access

Any roads crossing streams should do so at 90 degree angles to minimize contact

while still allowing access. If there is a road near the stream, a heavy vegetated corridor should be maintained between the roadway and the stream. Build steps instead of a ramp between the top and bottom of a bank if access is needed to the stream.

Recreation

While recreation activities are largely compatible with stream preservation, they must be undertaken carefully to ensure stream and riparian area preservation. For example playing fields, parks, parking areas, and lawns should be outside the vegetated corridor. Necessary access points and crossings should be located along the most stable stream bank areas (not on stream curves), be limited in size, and should be re-stabilized after construction.

Stormwater Runoff

Limit stormwater runoff through a reduction in the amount of impervious surfacing. Also, wherever possible, stormwater should be collected in an infiltration basin, and allowed to soak into the ground.

Permit no more than 10% of impervious coverage on small lots. Large lots should limit impervious coverage to less than 10%.

Construction

Limit erosion and sedimentation from construction through the use of erosion and sedimentation controls, based on an approved erosion and sedimentation control plan. Sediment inspectors should visit the site at least every two weeks to ensure the sediment control plan is being followed.

Reduce the area and length of time that a site is cleared and graded. The potential for erosion can be reduced by designing the site layout to preserve as much undisturbed open space as possible and by phasing construction so that the amount of disturbed area exposed at any given time is limited. This is especially important in the late stages of construction when sediment runoff potential is greatest.

Establish grass or mulch cover as quickly as possible on cleared and graded areas. This action can reduce downstream suspended sediment level sixfold.

Restrict construction of Principle Structures on Slopes of 15% or Greater

Restrict the amount of vegetation that can be cleared for construction to 20% of lot area.

Stormwater Basins

Stormwater basins require special design and maintenance to make them safe, functional, environmentally sensitive, and attractive. These factors are especially important for basins located within riparian areas. Detailed guidance on developing sound stormwater basins can be found in Montgomery County Planning Commission's "Stormwater Impounding Basins: Towards Making Them More Functional and Attractive."

The most important aspect of designing stormwater basins in riparian areas is that they be naturalized to harmonize with their surroundings. Naturalized basins offer benefits such as reduced mowing, enhanced animal habitat, and improved water quality protection. Creating a naturalized basin requires sensitive design and should be done by an expert.

Landscaping is the most important ingredient in developing naturalized basins. Naturalized planting materials, such as wild flowers and non-aggressive meadow grasses, which tolerate wet, intermittently wet and usually dry areas of the basin should be planted throughout the basin. Trees and shrubs can be planted in the basin in areas where they will not interfere with the function of the basin. No large trees should be planted on the berm areas.

The appropriate plants to use in creating the naturalized basin will depend on the moisture conditions and location within the basin, as follows:

- Zone 1, Deep Water Areas: These are areas of the basin that are permanently covered by over one foot of water. Plants that are well suited for these conditions include wild celery, sago pondweed, and floating plants such as duckweed.

- Zone 2, Shallow Water Areas: This zone is covered with up to one foot of water. Many wetland-emergent plants, such as cattail, arrowhead, and bulrush, thrive in these conditions. This area is a critical food source for wildlife, particularly waterfowl. Plants located in these shallow fringes can also play an important role in talking up waterborne nutrients.

- Zone 3, Pond Shoreline: Plants in this zone must be tolerant of both periodic inundations and dry conditions. Vegetation that is established here includes sedges, button , and cattail. Some shoreline vegetation can be used to prevent or limit access to the pond. This can be useful in managing wildlife in the basin.

- Zone 4, Riparian Fringe Area: Plants in this zone are able to tolerate both wet and dry conditions. Woody plants, such as red osier dogwood, high bush cranberry, and various types of willows, are suited for this zone. The primary purpose of this type of vegetation is soil stability and stormwater velocity control.

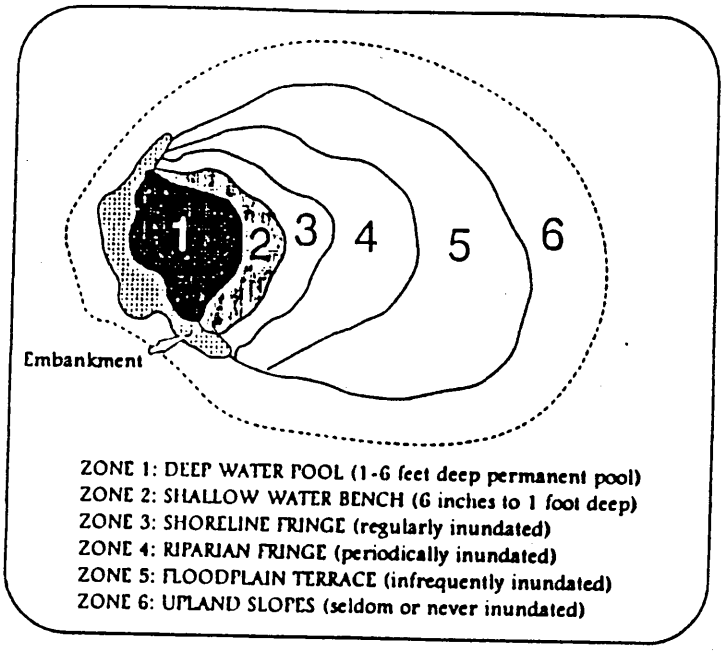
- Zone 5, Floodplain Terrace: This zone includes most of the pond embankment. Plants in this zone can survive in both dry and moist conditions. Generally, two

types of plant groups should be use in this zone: plants with shallow penetrating roots and herbaceous cover should be placed on the dam area and the other portions of the floodplain terrace can be planted with larger woody plants.

- Zone 6, Upland Area: This area is generally dry. Plantings in conformance with native species near the basin are appropriate.

There are some additional guidelines that apply to stormwater basins in riparian areas:

- The basin should be located in an area of the riparian corridor where it will cause the least amount of earth moving or disturbance of vegetation, and outside the corridor if possible.
- The shape of the basin should harmonize with the surrounding topography.



- All of the side slopes and berms should be gradual, at a pitch of no greater than 33%.
- The required stormwater control structures should be designed to minimize their visual impact. Aesthetic treatment of these control structures can be done through color, use of native materials, and buffering.
- Outlet structures should transform discharge to sheetflow.
- Wet ponds are effective in the riparian zone when there is a sufficient water source and suitable soils. These wet ponds support a permanent pool of water in addition to their stormwater storage capacity. Because of this design feature, safety considerations should be taken into account in designing wet ponds. Management requirements for wet ponds will also be different from typical basins.
- Constructed berms to dam up stormwater in a natural depression or valley is also effective for riparian areas. This berm could be made of earth or formed through a wall of rock filled gabions. The remainder of the basin is left in its natural condition as a forest or a field.

- If designed correctly, stormwater basins can reduce up to 90 percent of suspended pollutants. The following design considerations help to minimize water motion and maximize the length of time incoming flow is retain in the basin:

  - Creating a basin shape where length exceeds width by three to one.
  - Installing inlet and outlet structures at opposite ends of the basin.
  - Utilizing flow control structures such as riprap placed below the inlet structures.
  - Constructing a series of basins.
  - Utilizing a riser pipe instead of a ground level outflow pipe to maintain a nondrainable pool to encourage infiltration.
  - Developing vegetative cover on the basin floor.

Bibliography

Commonwealth of Pennsylvania, Department of Environmental Resources, Office of Resources Management, Bureau of Water Resources Management, Division of Scenic Rivers, A Streambank Stabilization and Management Guide for Pennsylvania Landowners, Commonwealth of Pennsylvania, 1986

Fink, Charles A, and Robert M. Searns of the Conservation Fund, Greenways, A Guide to Planning, Design, and Development, Island Press, 1993

Forman, Richard T.T., and Michel Godron, Landscape Ecology, John Wiley & Sons, 1986

Harper, Holly, Ann Hausmann, Andrew Pitz, David Steckel, Design and Management Handbook for Preservation Areas in Lower Merion Township, Montgomery County, Pennsylvania, Natural Lands Trust, Inc., 1993

Lalo, Julie and Karl J. Lutiz, Corridor Management for Pastureland Streams, Pennsylvania Fish and Boat Commission, 1994