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In cooperation with the Chester County Water Resources Authority

ASSESSMENT OF STREAM QUALITY USING BIOLOGICAL INDICES AT SELECTED SITES IN THE BRANDYWINE CREEK BASIN, CHESTER COUNTY, PENNSYLVANIA, 1981-97

INTRODUCTION

In 1970, the Chester County Water Resources Authority (Pennsylvania) and the U.S. Geological Survey (USGS) established a long-term water-quality network with the goal of assessing the quality of streams in the county and understanding stream changes in response to urbanization using benthic-macroinvertebrate data (Lium, 1977). This database represents one of the longest continuous water-quality data sets in the country. Benthic macroinvertebrates are aquatic insects, such as mayflies, caddisflies, riffle beetles, and midges, and other invertebrates that live on the stream bottom. Benthic macroinvertebrates are useful in evaluating stream quality because their habitat preferences and low motility cause them to be affected directly by substances that enter the aquatic system. By evaluating the diversity and community structure of benthic-macroinvertebrate populations, a determination of stream quality can be made.

Between 1981 and 1997, the water-quality network consisted of 43 sites in 5 major basins in Chester County—Delaware, Schuylkill, Brandywine, Big Elk and Octoraro, and Red and White Clay. Benthic-macroinvertebrate, water-chemistry, and habitat data were collected each year in October or November during base-flow conditions (Reif, 1999; 2000). Using these data, Reif (2002) evaluated the overall water-quality condition of Chester County streams. This Fact Sheet summarizes the key findings from Reif (2002) for streams in the Brandywine Creek Basin. These streams include **West Branch Brandywine Creek** (sites 37 and 38), **Buck Run** (site 46), **Doe Run** (site 45), **East Branch Brandywine Creek** (sites 48, 42, 36, and 39), **Indian Run** (site 47), **West Valley Creek** (site 44), and **Main Stem Brandywine Creek** (site 40) (fig. 1). This summary includes an analysis of stream conditions based on benthic-macroinvertebrate samples and an analysis of trends in stream conditions for the 17-year study period.

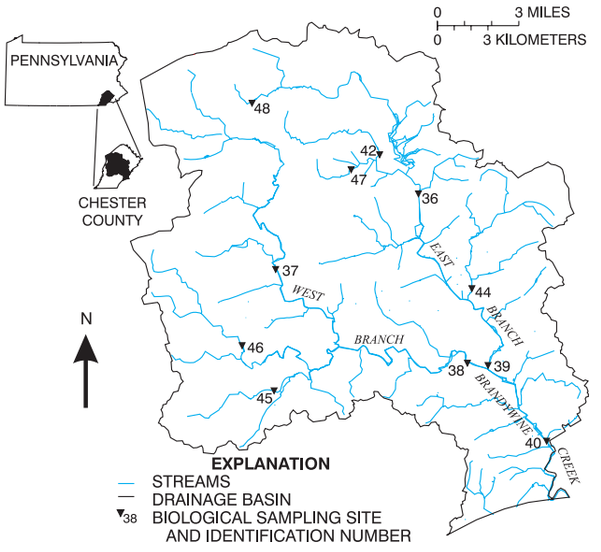

Figure 1. Location of sampling sites in the Brandywine Creek Basin, Chester County, Pennsylvania.

STUDY APPROACH

The analysis of overall stream quality on the basis of benthic-macroinvertebrate sampling uses biological metrics. Each biological metric is a mathematical expression of a different aspect of the benthic-macroinvertebrate community and how it relates to overall stream quality. By examining each biological metric, an evaluation of the overall stream quality can be made. The following biological metrics were used in the analysis: taxa richness, Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness, percent EPT, and Hilsenhoff's biotic index (HBI).

Taxa richness is a measure of the number of different kinds of organisms (taxa) in a collection. Richness measures the overall diversity of the biological community sampled. **EPT taxa richness** is the total number of taxa within the "pollution sensitive" orders **E**phemeroptera (mayflies), **P**lecoptera (stoneflies), and **T**richoptera (caddisflies). Taxa richness and EPT taxa richness will decrease with decreasing water quality (Weber, 1973). **Percent EPT** is the total number of EPT individuals divided by the total number of individuals in the sample.

The **HBI** is based on an organism's relative sensitivity to stream-quality conditions. The HBI uses assigned tolerance values that range from 0 to 10. A 0 is assigned to organisms least tolerant of organic pollution, and a 10 is assigned to organisms most tolerant of organic pollution. Species intermediate in their tolerance of organic pollution were assigned intermediate values (Hilsenhoff, 1982). Tolerance values are from the genus and species-level biotic index developed by the State of New York (Bode, 1991). HBI values from 0 to 4.5 are associated with nonimpacted sites, 4.51 to 6.50 with slightly impacted sites, 6.51 to 8.50 with moderately impacted sites, and 8.51 to 10 with severely impacted sites (Bode, 1993).

STREAM-QUALITY DESIGNATION CRITERIA

Streams in the network were designated as nonimpacted, slightly impacted, moderately impacted, or severely impacted on the basis of median biological metric values from 1981 to 1997 (table 1). Stream-quality refers to the overall condition of the physical habitat, water chemistry, and biological communities in the stream.

Table 1. *Stream-quality assessment criteria for Chester County, Pennsylvania, streams (adapted from Bode, 1993)*

[EPT, Ephemeroptera, Plecoptera, and Trichoptera: HBI, Hilsenhoff's biotic index; >, greater than]

Stream-quality assessment	Taxa richness	EPT taxa richness	HBI
Nonimpacted	>30	>10	0 - 4.50
Slightly impacted	21 - 30	6 - 10	4.51 - 6.50
Moderately impacted	11 - 20	2 - 5	6.51 - 8.50
Severely impacted	0 - 10	0 - 1	8.51 - 10

Nonimpacted: Biological metrics indicate excellent stream quality. The benthic-macroinvertebrate community is diverse, and the community is dominated by "pollution sensitive" and facultative organisms. "Pollution sensitive" organisms include the EPT taxa and generally are intolerant of degraded stream quality. Facultative organisms can survive under a wide range of stream conditions. Water quality and habitat conditions at nonimpacted sites are not limiting the

benthic-macroinvertebrate community. Nonimpacted sites include pristine habitats and those receiving inputs that minimally affect the benthic-macroinvertebrate community.

Slightly Impacted: Biological metrics indicate good stream quality. The benthic-macroinvertebrate community is less diverse than at nonimpacted sites but still contains mayflies, caddisflies, and possibly some stoneflies. The community structure typically is dominated by a few taxa including caddisflies, elmids (riffle beetles), and chironomids. Water quality and habitat conditions are having an effect on the benthic-macroinvertebrate community. Slightly impacted sites commonly are receiving some wastewater inputs and (or) agricultural/urban runoff.

Moderately Impacted: Biological metrics indicate fair stream quality. The benthic-macroinvertebrate community is disturbed and noticeably altered from a nonimpacted site. Mayflies and stoneflies are rare, and caddisfly taxa may be limited. The benthic-macroinvertebrate community is dominated by "pollution tolerant" and facultative organisms including chironomids and oligochaetes (aquatic earthworms). One or a few groups usually dominate the community. Water quality and habitat conditions are having a major effect on the benthic-macroinvertebrate community. Moderately impacted sites commonly are receiving heavy wastewater inputs and (or) agricultural/urban runoff.

Severely Impacted: Biological metrics indicate poor stream quality. The benthic-macroinvertebrate community is severely limited with poor diversity. Mayflies, stoneflies, and caddisflies are rare, and the community usually is dominated by "pollution tolerant" organisms such as chironomids and aquatic earthworms. The community may have low numbers of individuals or high numbers of a few taxa. Severely impacted sites commonly are receiving inputs of a toxin or have extremely low concentrations (less than 4.0 mg/L) of dissolved oxygen. Water quality and habitat conditions are having a severe effect on the benthic-macroinvertebrate community. Severely impacted sites commonly are receiving heavy wastewater inputs and agricultural/urban runoff.

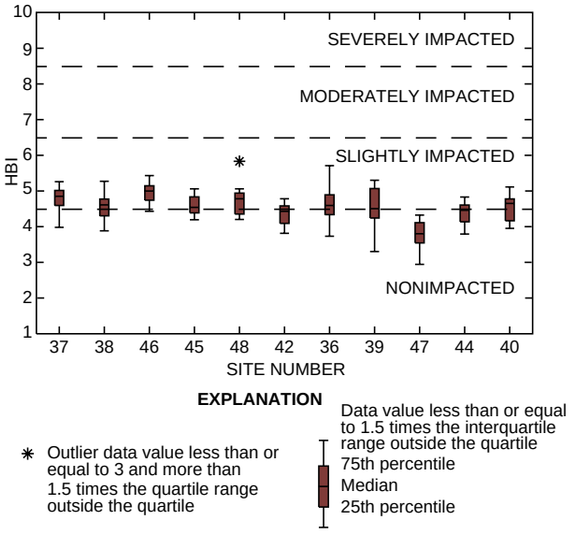

Figure 2. Hilsenhoff's biotic index (HBI) values from sites in the Brandywine Creek Basin, Chester County, Pennsylvania, 1981-97.

STREAM-QUALITY ASSESSMENT

The sites sampled in the Brandywine Creek Basin range in size from Indian Run (site 47), a headwater stream with a drainage area of 4.26 mi^2 (square miles), to the Brandywine Creek at Chadds Ford (site 40), with a drainage area of 291 mi^2. Land use in the basin includes agricultural, forest, suburban, and urban settings. Stream-quality assessments based on calculated biological metrics are presented in table 2 and figure 2.

Table 2. *Designation of water quality and median values of taxa richness, EPT taxa richness, Hilsenhoff's biotic index, and percent EPT for sites in the Brandywine Creek Basin, Chester County, Pennsylvania, 1981-97*

[EPT; Ephemeroptera, Plecoptera, Trichoptera]

U.S. Geological Survey station identification number	Site number	Taxa richness	EPT taxa richness	Hilsenhoff's biotic index	Percent EPT
		West Branch Brandywine Creek			
		Nonimpacted	Nonimpacted	Slightly impacted	
01480434	37	32	19	4.85	63
		Slightly impacted	Nonimpacted	Slightly impacted	
01480640	38	30	13	4.61	61
		Buck Run			
		Slightly impacted	Nonimpacted	Slightly impacted	
01480629	46	25	13	4.99	71
		Doe Run			
		Slightly impacted	Nonimpacted	Slightly impacted	
01480632	45	25	14	4.54	62
		East Branch Brandywine Creek			
		Nonimpacted	Nonimpacted	Slightly impacted	
01480648	48	32	16	4.78	42
		Nonimpacted	Nonimpacted	Nonimpacted	
01480653	42	43	22	4.43	58
		Nonimpacted	Nonimpacted	Slightly impacted	
01480700	36	36	22	4.59	57
		Nonimpacted	Nonimpacted	Nonimpacted	
01480950	39	36	16	4.50	56
		Indian Run			
		Nonimpacted	Nonimpacted	Nonimpacted	
01480656	47	33	21	3.80	55
		West Valley Creek			
		Slightly impacted	Nonimpacted	Nonimpacted	
01480903	44	29	17	4.45	62
		Main Stem Brandywine Creek			
		Nonimpacted	Nonimpacted	Slightly impacted	
01481030	40	32	17	4.65	52

West Branch Brandywine Creek

Sites in the West Branch Brandywine Creek Basin (sites 37, 38, 46, and 45) generally were assessed as slightly impacted on the basis of taxa richness and HBI values (table 2, fig. 2). Although these sites contained numerous EPT taxa, the numbers of EPT taxa were among the lowest of all sites in the Brandywine Creek Basin (fig. 3).

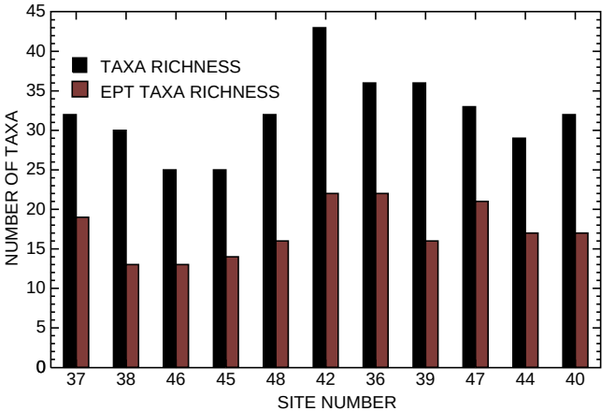

Figure 3. Median values of taxa richness and Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness at sites in the Brandywine Creek Basin, Chester County, Pennsylvania, 1981-97.

Samples of stream-bottom sediment generally contained pesticides below the threshold effect concentration (MacDonald and others, 2000) and were decreasing over time. Field observations noted fairly stable habitat although it was degraded by sedimentation at most sites. Water quality and habitat conditions in the West Branch Brandywine Creek are affected by agricultural and urban runoff and wastewater-treatment discharges that affect the benthic-macroinvertebrate community. Although the benthic-macroinvertebrate samples indicate a slightly impacted community, conditions have improved since 1981 at all four sites.

East Branch Brandywine Creek

Sites 42, 47, and 48 are in the upper East Branch Brandywine Creek Basin and generally were assessed as nonimpacted (table 2, fig. 2). Sites 42 and 47 have benthic-macroinvertebrate communities with large numbers of "pollution sensitive" organisms, low populations of "pollution tolerant" organisms, and stable habitat. Site 42, East Branch Brandywine Creek at Glenmoore, had the highest value of taxa richness and tied for the highest value of EPT taxa richness of any site in the Brandywine Creek Basin (fig. 3).

Sites 36, 39, and 44 are in the lower East Branch Brandywine Creek Basin. These sites were designated as nonimpacted or slightly impacted on the basis of median values of the biological metrics measured (table 2, fig. 2). The benthic-macroinvertebrate communities at all these sites were diverse with large numbers of mayflies, caddisflies, and riffle beetles, which are indicators of good stream quality. Field observations and chemical data indicate stable chemistry and habitat that are supporting stable benthic-macroinvertebrate communities. Samples of stream-bottom sediment generally contained pesticides below the threshold effect concentration (MacDonald and others, 2000).

Main Stem Brandywine Creek

The main stem Brandywine Creek at Chadds Ford (site 40) was designated as nonimpacted on the basis of median values of taxa richness and EPT taxa richness and as slightly impacted on the basis of HBI values (table 2). The benthic-macroinvertebrate community at this site was diverse with large numbers of "pollution sensitive" organisms including mayflies, caddisflies, and riffle beetles, which are indicators of good stream quality. This site receives agricultural and urban runoff and discharges from wastewater treatment plants but supports a benthic-macroinvertebrate community that indicates these inputs are having a minimal effect on the biota.

TRENDS IN BENTHIC-MACROINVERTEBRATE AND CHEMICAL DATA

The Mann-Kendall test was used to detect trends from 1981 through 1997 in HBI values at the sites in the Brandywine Creek Basin (Helsel and Hirsch, 1997). A decreasing trend in HBI indicates improving stream quality, and an increasing trend indicates deteriorating stream quality.

Eight of the 11 sites (sites 37, 38, 46, 45, 36, 39, 44, and 40) had a decreasing trend in HBI values indicating improving stream quality. The trend was statistically significant at sites 46, 36, and 40. Although the decreasing trend in HBI indicates improving stream quality, the sites are designated as slightly impacted. The sites in both the East and West Branches generally had significantly increasing nitrate concentrations and unchanged or decreasing concentrations of ammonia and phosphorus associated with the declining HBI values (fig. 4). This trend of increasing nitrate concentrations and decreasing concentrations of ammonia and phosphorus commonly is the result of upgrades to wastewater treatment plants. The decreased concentrations of ammonia and phosphorus can lead to increased concentrations of dissolved oxygen that result in a healthier biological community as indicated by a decrease in HBI values.

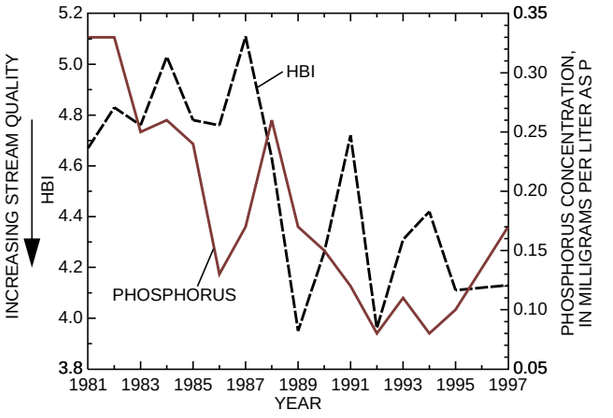

Figure 4. Hilsenhoff's biotic index (HBI) values and phosphorus concentrations from Brandywine Creek near Chadds Ford (site 40), Chester County, Pennsylvania, 1981-97.

The sites on the upper East Branch Brandywine Creek (sites 42, 47, and 48) had insignificant increases in HBI values but generally are designated as nonimpacted. Sites in the lower part of the East Branch Brandywine Creek had lower taxa richness and EPT taxa richness and higher HBI values from 1981 to 1987 than upstream sites. After 1987, sites in the lower East Branch Brandywine Creek had increasing taxa richness and EPT taxa richness, and decreasing HBI values. This trend indicates stream quality in the upper and lower parts of the basin are becoming similar (fig. 5).

Sites 38 and 46 in the West Branch Brandywine Creek Basin show upward trends in EPT taxa richness, indicating improving water quality (fig. 6). Data from the West Branch Brandywine Creek at Wawaset (site 38) indicate improving values of taxa richness and decreasing concentrations of phosphorus (fig. 7). Because phosphorus is nontoxic, the increased taxa richness probably is an indirect result of the decreasing concentrations. Decreasing concentrations of phosphorus result in lower plant and algal growth, which leads to increased concentrations of dissolved oxygen. Invertebrates probably are responding to the improved dissolved-oxygen concentrations (Reif,

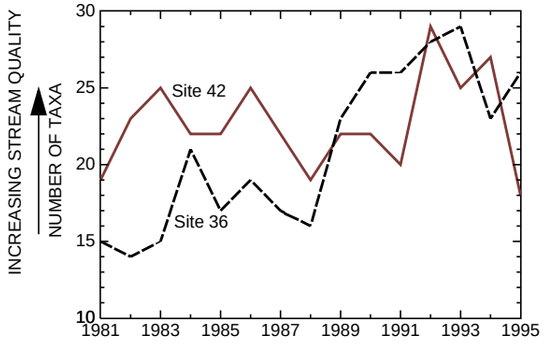

Figure 5. Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness from East Branch Brandywine Creek at Glenmoore (site 42) and East Branch Brandywine Creek near Downingtown (site 36), Chester County, Pennsylvania, 1981-95.

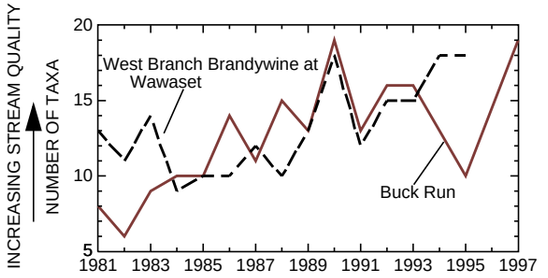

Figure 6. Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness from Buck Run (site 46) and West Branch Brandywine Creek at Wawaset (site 38), Chester County, Pennsylvania, 1981-97.

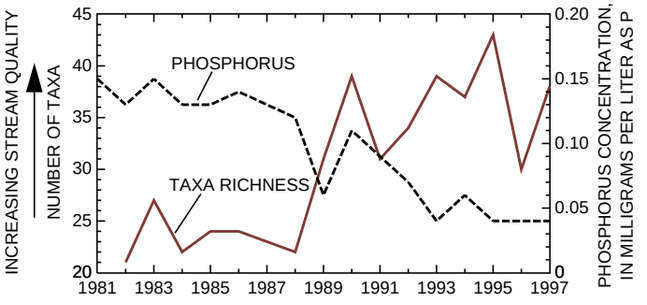

Figure 7. Taxa richness and phosphorus concentrations from West Branch Brandywine Creek at Wawaset (site 38), Chester County, Pennsylvania, 1981-97.

2002). This conclusion is supported by continuously monitored dissolved oxygen concentrations from West Branch Brandywine Creek at Modena. In 1985, dissolved oxygen concentrations lower than 5.0 mg/L were measured on 84 days (Kolva and others, 1987). Ten years later in 1995, no concentrations of dissolved oxygen less than 5.0 mg/L were measured at the same site (Durlin and Schaffstall, 1997).

Brandywine Creek at Chadds Ford, site 40, had a decrease in concentrations of ammonia and phosphorus associated with improved stream quality similar to those measured in the East and West Branch Brandywine Creeks (fig. 4).

SUMMARY

Chemical and benthic-macroinvertebrate data and field observations collected by the U.S. Geological Survey, in cooperation with the Chester County Water Resources Authority between 1981 and 1997 indicate the Brandywine Creek Basin is affected by physical habitat degradation and increasing concentrations of nitrate. Although the sites are slightly impacted, benthic-macroinvertebrate data indicate improved stream quality in the West Branch, the lower East Branch, and the Main Stem Brandywine Creek between 1981 and 1997. The improved stream quality is associated with decreasing concentrations of phosphorus and ammonia in the basin during this time period. The sites sampled in the upper East Branch Brandywine Creek generally were designated as nonimpacted throughout the entire period.

—Andrew G. Reif

REFERENCES CITED

Bode, R.W., 1991, Quality assurance work plan for biological stream monitoring in New York State: New York Department of Environmental Conservation Technical Report, 79 p.

_____1993, 20 year trends in water quality of rivers and streams in New York State on the basis of macroinvertebrate data 1972-1992: New York Department of Environmental Conservation Technical Report, 196 p.

Durlin, R.R., and Schaffstall, W.P., 1997, Water resources data for Pennsylvania, 1995—Volume 1 Delaware River Basin: U.S. Geological Survey Water Data Report PA-95-1, 375 p.

Helsel, D.R., and Hirsch, R.M., 1997, Statistical methods in water resources: New York, Elsevier Science Publishing Co., Inc., 529 p.

Hilsenhoff, W.L. 1982, Using a biotic index to evaluate water quality in streams: Wisconsin Department of Natural Resources Technical Bulletin no. 132, 22 p.

Kolva, J.R., White, T.E., Druther, R.L., and Moleski, Paul, 1987, Water resources data for Pennsylvania, 1985—Volume 1. Delaware River Basin: U.S. Geological Survey Water Data Report PA-85-1, 269 p.

Lium, B.W., 1977, Limnological studies of the major streams in Chester County, Pennsylvania: U.S. Geological Survey Open-File Report 77-462, 37 p.

MacDonald, D.D., Ingersoll, C.G., and Berger, T.A., 2000, Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems: Archives of Environmental Contamination and Toxicology, v. 39, p. 20-31.

Reif, A.G., 1999, Physical, chemical, and biological data for selected streams in Chester County, Pennsylvania, 1981-94: U.S. Geological Survey Open-File Report 99-216, 607 p.

_____2000, Physical, chemical, and biological data for selected streams in Chester County, Pennsylvania, 1995-97: U.S. Geological Survey Open-File Report 00-238, 146 p.

_____2002, Water-quality assessment and trends in biological and water-quality data from selected streams in Chester County, Pennsylvania, 1981-97: U.S. Geological Survey Water-Resources Investigations Report 02-4242, 78 p.

Weber, C.I., ed., 1973, Biological field and laboratory methods for measuring the quality of surface waters and effluents: Cincinnati, Ohio, U.S. Environmental Protection Agency, EPA-670/4-73-001.

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