U.S. Department of the Interior
U.S. Geological Survey

Fact Sheet 193-96

Study Design and Preliminary Data Analysis for a Streambank Fencing Project in the Mill Creek Basin, Pennsylvania

INTRODUCTION

The Pequea Creek and Mill Creek Basins within Lancaster and Chester Counties in Pennsylvania have been identified as areas needing control of nonpoint-source (NPS) pollution to improve water quality. The two basins are a total of approximately 200 square miles and are primarily underlain by carbonate bedrock. Land use is predominantly agriculture. The most common agricultural NPS pollution-control practices implemented in the Pequea Creek and Mill Creek Basins are barnyard-runoff control and streambank fencing. To provide land managers information on the effectiveness of streambank fencing in controlling NPS pollution, a study is being conducted in two small paired watersheds within the Mill Creek Basin.

PROJECT DESCRIPTION

The objective of the project is:

- *To evaluate the effect of streambank fencing of pasture land on surface- and near-stream ground-water quality within a small watershed underlain by carbonate bedrock.*

To attain the project objective, the hydrology and water quality of the study area needs to be characterized and quantitative relations between paired basins must be developed prior to the implementation of fencing in one of the basins.

The objective of this fact sheet is to describe the study design of the project and to evaluate the effectiveness of the paired-watershed component of the project by presenting preliminary findings.

A cooperative effort between the U.S. Geological Survey (USGS) and the Pennsylvania Department of Environmental Protection (PaDEP), this project supports the study initiative of the U.S. Department of Agriculture within the Pequea and Mill Creeks Hydrologic Unit Area. The project is funded by PaDEP through the National Monitoring Program (NMP) of the U.S. Environmental Protection Agency (USEPA). The NMP stems from Section 319 of the 1987 amendment to the Clean Water Act. The NMP was developed to document the effects of NPS pollution-control measures and associated land-use modifications on water quality (Osmond and others, 1995).

STUDY BASIN

The study area is a 3.2 square-mile watershed (fig.1) within the Mill Creek Basin. Land use in the study area is about 80 percent agricultural; the remaining land uses are either urban, residential, or commercial. Agricultural land in the basin is used primarily for dairy-cow pasture and hay and corn production.

Approximately 12 farming operations are located within the study area. Farmers provide nutrient-application data and information on when the dairy cows are pastured. Cooperation from each farm operation is critical to the objectives of the study.

Two adjacent basins comprise the study area. Basins are similar in land use, climate, topography, and geology. The stream channel will be fenced in pasture areas in one basin (treatment basin), while the other basin (control basin) will not be fenced. The treatment basin, which covers 1.4 square miles and includes 2.8 stream miles, contains about 150 dairy cows. The control basin, which covers 1.8 square miles and includes 2.7 stream miles, contains about 250 dairy cows (fig. 1).

Presently, the majority of dairy cows in both basins have unlimited access to stream channels in pastured areas. Beginning in fall 1996, fencing on the treatment basin will be installed along 1.6 miles of stream channel adjacent to pastures. Fencing will be completed by early spring 1997 (fig. 2). The buffer

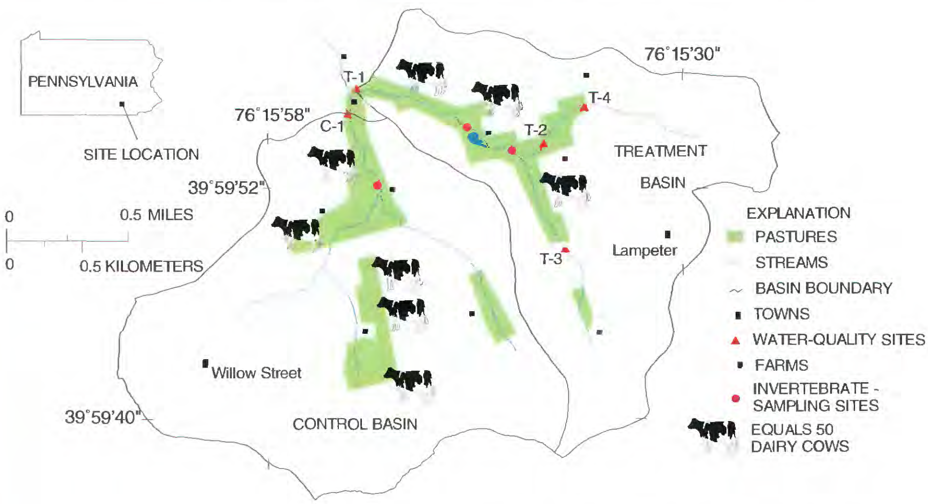


Figure 1. Location of study area and number of dairy cows in the control and treatment basins.

Figure 2. Time line of fence installation along stream channel in pastured areas of treatment and control basins.

strip between the fence and the edge of the stream bank will be 10-12 feet on each side of the stream. Post-fencing data will be collected through the year 2001.

STUDY DESIGN

A study design was developed that documents changes in surface-water and ground-water systems that could result from streambank fencing. This will be accomplished by collecting chemical, physical, and biological data in the study basins.

The primary approach to determine effects of streambank fencing on surface-water quality is a paired-watershed analysis. Secondary approaches to document water-quality changes include collecting pre- and post-fencing data at sites within the treatment basin and monitoring of sites upstream and downstream of fence installation. Ground-water wells were also installed in the treatment basin to document effects of riparian vegetation on shallow ground-water quality.

Surface-water samples are collected every 10 days from April through November (table 1) because this is the time when dairy cows and heifers are pastured. Monthly base-flow samples are collected the remaining part of the year. Stormflow samples are collected throughout the year.

Surface Water

A paired-watershed comparison of water-quality characteristics at the outlets of the treatment (T-1) and control (C-1) basins will be made before and after fence installation in the treatment basin.

Three other surface-water sampling sites are located within the treatment basin. At the most visually degraded site (T-2), which drains 0.36 square miles, data collected before and after fence installation will be compared to data from C-1 to determine changes in water quality (table 2). Upstream of T-1 and T-2, a surface-water site (T-4) was installed to determine the effect of a new (construction began 2 years after initial data collection for the study) residential development on water quality. One site (T-3) is located above most pastured area and will be compared to T-1 in an upstream/downstream design to determine effects of fencing.

Ground Water

The effects of streambank fencing on ground water near the stream is being evaluated at two locations (T1 and T2) within the treatment basin. At each location, four wells were drilled and completed at different depths to monitor water quality and hydraulic head within and outside of the (proposed) fenced riparian buffer strip (table 3).

Table 2. *Description of water-quality sampling sites in study area and use of data in project design*

Sampling site	Description	Data use
C-1	Outlet of control basin	Compare to T-1 and T-2 for paired-watershed analysis
T-1	Outlet of treatment basin	Compare to C-1 for paired-watershed analysis and T-3 for upstream/downstream analysis
T-2	Visually degraded upstream tributary site in treatment basin	Compare to C-1 for paired-watershed analysis
T-3	Upstream site in treatment basin located above most pastured land	Compare to T-1 for upstream/downstream analysis
T-4	Upstream tributary site in treatment basin located downstream of new residential development	Used to characterize effects of new residential development. Changes in water quality may affect T-2 and T-1

Data from water samples collected from wells within the proposed riparian buffer will be statistically compared to data from control wells outside of the buffer to evaluate streambank-fencing effects on ground-water quality. In addi-

Table 1. *Data collection in study area*
[NA, not applicable]

Source	Type of data	Data collected[1]	Sites	Type of sample	Frequency of data collection
Surface water	Chemical and physical	Total and dissolved nutrients, suspended sediment, field measurements	T-1, T-2, T-3, T-4, C-1	Fixed	Every 10 days, April - November; monthly, December - March
		Total and dissolved nutrients, suspended sediment	T-1, T-2, T-4, C-1	Stormflow[2]	15-20 storms per year
	Biological	Fecal streptococcus	T-1, T-2, T-3, T-4, C-1	Base flow	Monthly, January - December
		Benthic macroinvertebrate	T-1, C-1, and upstream sites	Base flow	May and September
	Flow	Discharge	T-1, T-2, T-4, C-1	NA	Continuous
			T-3	NA	Intermittent
Ground water	Chemical	Dissolved nutrients, field measurements, and alkalinity	Nest of 4 wells at T-1, nest of 4 wells at T-2	Fixed	Monthly, January - December
	Biological	Fecal streptococcus			
	Water level	Depth below land surface	Nest of 4 wells at T-1, nest of 4 wells at T-2	NA	Continuous
Agricultural activity	Physical	Number of cows and time in pasture, nutrient applications to farm land	All farms in the treatment and control basins	NA	Continuous
Precipitation	Physical	Quantity	T-1	NA	Continuous

[1] Total nutrients—ammonia plus organic nitrogen, phosphorus; dissolved nutrients—nitrite and nitrate, ammonia, ammonia plus organic nitrogen, phosphorus, orthophosphorus; field measurements—pH, temperature, specific conductance, and dissolved oxygen.

[2] Samples are collected by automatic samplers during the entire storm event. Flow-weighted composite storm samples are submitted for analyses.

tion, samples from the wells will be used to help explain observed changes in base-flow stream quality before and after fencing. Water-level measurements will show the hydraulic potential for ground-water movement toward and away from the stream, which will aid in the interpretation of the stream-chemistry data.

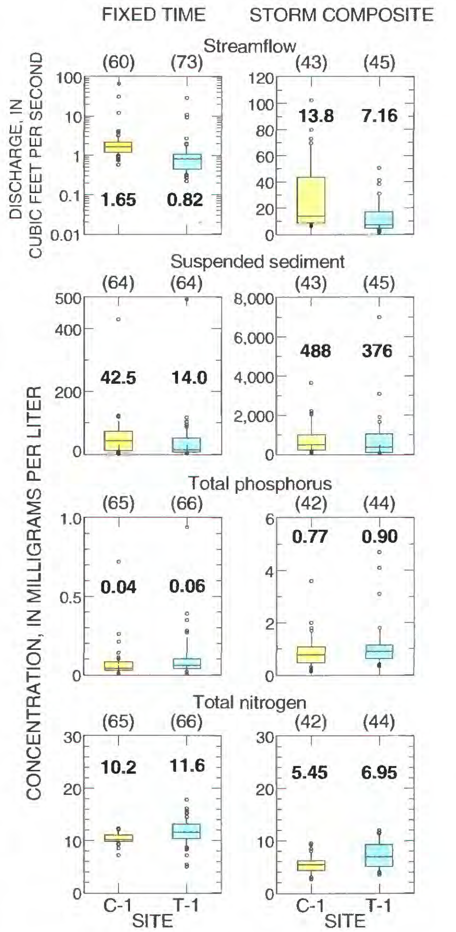
PRELIMINARY DATA ANALYSIS

This section focuses on the paired-watershed approach to the study design. Chemical, physical, and benthic-community data presented here were collected from T-1 and C-1 from June 1993 through December 1995, during the pre-fencing time period.

Chemical and physical data

Data collected at the outlets of control and treatment basins from 1993 to 1995 indicate that concentrations of total nitrogen and phosphorus (fig. 3) in streamflow were similar at T-1 and C-1. Nutrient concentrations from the study area are relatively high compared to concentrations for other water-quality sites within the Chesapeake Bay drainage basin (Langland and others, 1995).

Regression equations will be developed for the pre-fencing period to determine if nutrient and sediment concentrations in streamflow at the outlets of the treatment basin (T-1) are statistically related to those same constituents measured at the outlet of the control basin (C-1). If relations between the two outlets are not significant, there is no chance of detecting a significant change in water quality caused by fencing. If relations are significant, then the likelihood of detecting a change based on a fixed number of samples can be determined. Such pretreatment analysis can



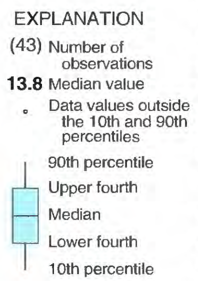


Figure 3. Ranges of discharge and concentrations of nutrients and suspended sediment for fixed-time and storm-composite samples collected from 1993 through 1995 at outlets of control (C-1) and treatment (T-1) basins.

be used to guide post-fencing sampling procedures. At the end of the post-fencing period, analysis of covariance will be applied to the regressions developed for before and after treatment to determine the effect of streambank fencing on water-quality constituents. This procedure is discussed thoroughly by Clausen and Spooner (1993). Regression equations developed for data from storm-composite and fixed-time samples collected from 1993 to 1995 at the outlets of the control and treatment basins for all nutrients listed in table 1 and suspended sediment were significant at an alpha level of 0.05.

As an example, regression equations for both storm-composite and fixed-time samples developed for the concentration of suspended sediment for T-1 against the concentration of suspended sediment for C-1 are shown in figure 4. The higher adjusted R^2 for the storm-composite regression and the actual distribution of data indicate less variation for the storm-composite data relative to the fixed-time data. The lower the variability in pretreatment data, the better the likelihood of detecting significant changes in water quality after the fencing has been installed. Therefore, it appears that there is a better likelihood of detecting a significant change in suspended-sediment concentrations from storm-composite samples than from fixed-time samples collected at the outlets of the treatment and control basins.

- *Based on preliminary analysis of storm-composite and fixed-time data, the streambank fencing project within the Mill Creek Basin can progress forward with fence instal-lation in the fall of 1996. Statistical relations evident between the outlets of the control and treatment basins will allow for the detection of any significant changes in water-quality constituents caused by streambank fencing.*

Benthic-community data

Benthic-macroinvertebrate samples are used to indicate the overall health of the stream. Two metrics of invertebrate community health will be used, the EPT/Chironomidae abundance ratio and taxa richness. The EPT/Chironomidae abundance ratio compares the relative abundance of three orders of aquatic insects (**E**phemeroptera, **P**lecoptera, and **T**richoptera), which require clean water, to a family of aquatic insects (Chironomidae), which is generally tolerant of

Table 3. *Description and use of data for ground-water monitoring wells in treatment basin*

Well depth, in feet below land surface / and open interval, in feet	Description		Data use
	Relative depth of ground-water sampled	Location of well relative to fenced buffer	
Well Nest at T1			
6/1	Shallow	Inside	Comparison to control well before and after fencing
12/1	Shallow	Inside	
8/1	Shallow	Outside	Control well
100/83	Deep	Inside	Characterization of regional ground-water quality and hydraulic head
Well Nest at T2			
6/1	Shallow	Inside	Comparison to control well before and after fencing
7/1	Shallow	Inside	
8/1	Shallow	Outside	Control well
63/43	Deep	Inside	Characterization of regional ground-water quality and hydraulic head

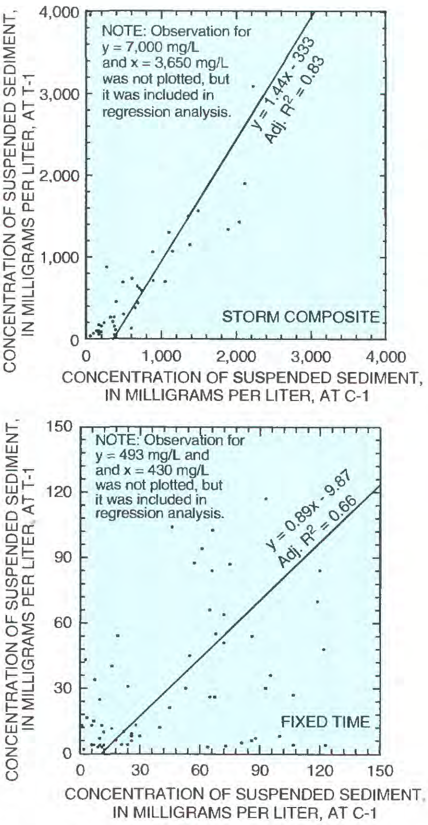


Figure 4. Concentrations of suspended sediment at the outlet of the treatment basin (T-1) as a function of the control basin (C-1) for storm-composite and fixed-time samples collected from 1993 through 1995.

degraded water quality. Thus, the higher the metric score, the better the water quality. Taxa richness is simply the total number of taxa present. Generally, larger taxa richness values denote better water quality (Plafkin and others, 1989).

Water-quality criteria are applied to streams based on the uses designated for that stream. Designated uses for streams in the Pequea Creek and Mill Creek Basins include warm-water fishes, cold-water fishes, trout stocking, and high quality waters (Pennsylvania Department of Environmental Resources, 1994). By comparing the EPT/Chironomidae abundance ratio or the taxa richness score to scores from reference stations, an evaluation is made about the ability of the sampling site to support its designated uses.

For this study, because reference stations are not available, best professional judgment was used to designate levels of stream health. The typical four-tiered classification system based on the level of impact as discussed by Bode and others (1993) was used as a guideline for converting the biological data into terms that are in accordance with NMP guidelines. A fully supported stream would support all the typical uses for that water body. A partially supported stream is somewhat degraded and thus would not support all the typical uses for that water body (U.S. Environmental Protection Agency, 1991).

The metrics used to measure community health indicate that the designated uses within the treatment basin at T-1 are fully supported; however, within the control basin at C-1, the EPT/Chironimide abundance ratio indicates the designated uses are fully supported but threatened (fig. 5).

- *Macroinvertebrate-community metrics indicate that designated uses of the stream are fully supported within the treatment basin at T-1. Therefore, improvements in water quality following streambank fencing will be difficult to document at this site using these metrics as indicators.*

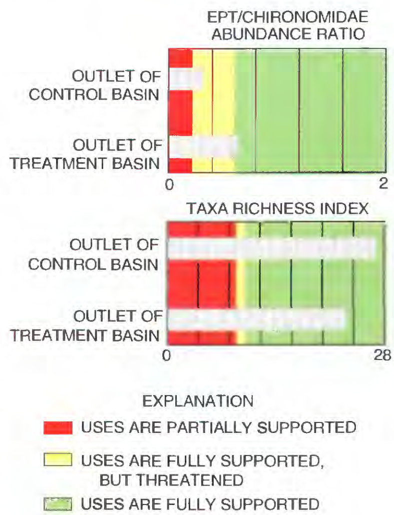


Figure 5. Benthic-macroinvertebrate metrics for samples collected during spring and fall 1994 and 1995 at outlet of control and treatment basins.

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CONTACTS FOR FURTHER INFORMATION

All water-quality and water-quantity data collected for this study are published in the USGS Annual Data Reports for water years 1994 and 1995 for the Susquehanna and Potomac River Basins. If interested in these reports, please contact the following:

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