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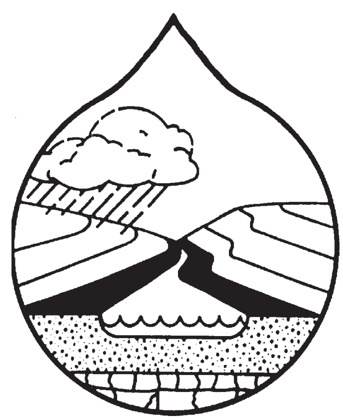
Section 319
National Nonpoint Source Monitoring Program (NNPSMP) Projects

2011 Summary Report



Prepared by: NCSU Water Quality Group

For: U.S. Environmental Protection Agency
Nonpoint Source Management Program
Section 319(h) of the Clean Water Act

2011 SUMMARY REPORT

SECTION 319
National Nonpoint Source Monitoring Program (NNPSMP) Projects

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Disclaimer

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Background

Section 319 was added to the Clean Water Act (CWA) in 1987 to establish a national program to address nonpoint sources of water pollution in recognition that it is the leading cause of water quality degradation in the United States. Agriculture, forestry, construction, and urban activities are some of the leading nonpoint sources of pollution. As rainfall and snowmelt move over the land, they pick up pollutants, carry them, and deposit them into ground water and waterbodies such as lakes, rivers, streams, wetlands, and coastal waters. Section 319(h) specifically authorizes EPA to award grants to states with approved Nonpoint Source Management Programs. The funds are to be used to implement programs and projects designed to reduce nonpoint source pollution. As required by section 319(h), the state's Nonpoint Source Management Program describes the state program for nonpoint source management and serves as the basis for how funds are spent. In addition, a variety of other funding sources are available under the CWA (e.g., sections 106, 320, and 604(b) and the State Revolving Fund) or through other federal agencies (e.g., Environmental Quality Incentive Program [EQIP] funds from U.S. Department of Agriculture).

Every year section 319 funds are allocated to each state according to a national allocation formula based on the total annual appropriation for the section 319 grant program. The allocation formula is contained in Appendix G of EPA's *1997 Nonpoint Source Guidance* (USEPA, 1996).

Since 1999 section 319(h) funds have been awarded to state nonpoint source agencies in two categories—incremental funds and base funds. ***Incremental funds***, a $100 million portion that EPA has designated for the development and implementation of watershed-based plans that are designed to restore impaired waters that have been listed by States as impaired under Section 303(d) of the Clean Water Act. ***Base funds***, funds other than incremental funds, are used to provide staffing and support to manage and implement the state Nonpoint Source Management Program. Base funds help in implementing projects to identify and address nonpoint source problems and threats, as well as funding activities that involve specific waterbodies in that state or statewide or regional projects. A portion of these funds (up to 20 percent) may be used for planning and assessment activities such as conducting assessments, developing TMDLs, and creating programs to solve nonpoint source problems. EPA periodically issues supplemental grant guidelines that identify priority activities to be funded with section 319 incremental and base funds. The 2003 supplemental grant guidelines added a requirement on the use of incremental funds for watershed-based planning. Watershed-based plans that are developed or implemented with Section 319 funds to address impaired (CWA Section 303(d)-listed) waters must include nine elements (see a through i below).

Comparison of 319 NMP Reporting and the Required Nine Elements of Watershed Plans

The following table compares the nine required elements of watershed plans eligible for implementation funding with 319 grants with how each element is addressed in the reporting format of the 319 National Monitoring Program (NMP). It should be noted that the purposes of most 319 projects and the 319 NMP are different and that this accounts for some of the differences. Most of the nine elements required in watershed-based plans for 319 grant projects were included in the 319 NMP project report format, with the exception of "interim, measurable milestones" and "criteria that can be used to determine whether loading reductions are being achieved over time." Also, note that the information included in the project summary reports contained in this *2006 Summary Report* were not consistent with respect to level of detail and the type of information included due to the variety of management strategies addressed.

Required Elements of Watershed Plans that are Eligible for Implementation Funding with 319 Grants	Elements of the National Monitoring Program Project Reports
a. An identification of the **causes and sources** or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this watershed-based plan (and to achieve any other watershed goals identified in the watershed-based plan), as discussed in item (b) immediately below. Sources that need to be controlled should be identified at the significant subcategory level with estimates of the extent to which they are present in the watershed (e.g., X numbers of dairy cattle feedlots needing upgrading, including a rough estimate of the number of cattle per facility; Y acres of row crops needing improved nutrient management or sediment control; or Z linear miles of eroded streambank needing remediation).	This information can be found in the **pollutant sources** section. The sources presented in various example reports, however, were not always identified at the "significant subcategory level" and did not include "estimates of the extent to which they were present in the watershed." Sometimes only a very general list of sources was provided (e.g., cropland, pasture, shoreline, and streambanks).
b. An estimate of the **load reductions expected** for the management measures described under paragraph (c) below (recognizing the natural variability and the difficulty in precisely predicting the performance of management measures over time). Estimates should be provided at the same level as in item (a) above (e.g., the total load reduction expected for dairy cattle feedlots; row crops; or eroded streambanks).	Load reductions were described in the **water quality objectives** section, although they were reported as percent reductions of particular pollutants rather than load reductions. In most cases, the percent reductions were not linked to the sources listed in the pollutant sources section; rather they were presented as general pollutant reductions for the entire study area (e.g., the goal of the project was to reduce sediment delivery into Sycamore Creek by 52%).
c. A description of the **NPS management measures** that will need to be implemented to achieve the load reductions estimated under paragraph (b) above (as well as to achieve other watershed goals identified in this watershed-based plan), and an identification (using a map or a description) of the critical areas in which those measures will be needed to implement this plan.	Information about management practices to be implemented is included in the **nonpoint source control strategy** section. However, these management practices are not presented in the context of the nonpoint source management measures as presented in the 1993 CZARA 6217 guidance. The level of technical detail varied significantly in the 319 NMP project summary reports.
d. An estimate of the amounts of **technical and financial assistance needed**, associated costs, and/or the sources and authorities that will be relied upon, to implement this plan. As sources of funding, States should consider the use of their Section 319 programs, State Revolving Funds, USDA's Environmental Quality Incentives Program and Conservation Reserve Program, and other relevant Federal, State, local and private funds that may be available to assist in implementing this plan.	The **project budget** section contains a breakdown of costs for different parts of the project. The format of the budget estimates differs among projects, with some projects showing a timeline of costs to be incurred and others breaking down costs by funding source.
e. An **information/education component** that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the NPS management measures that will be implemented.	The **information, education, and publicity** section includes information about how each 319 NMP project will be advertised to or used by the public.

Required Elements of Watershed Plans that are Eligible for Implementation Funding with 319 Grants	Elements of the National Monitoring Program Project Reports
f. A **schedule** for implementing the NPS management measures identified in this plan that is reasonably expeditious.	The **project schedule** section describes the timeline of the project and is presented in a tabular format that includes each monitoring site, pre-BMP monitoring, BMP installation, and post-BMP monitoring. This section does not contain a description of the steps taken to implement the management practices.
g. A description of **interim, measurable milestones** for determining whether NPS management measures or other control actions are being implemented.	Interim milestones are not included in the format. However, the purpose of 319 NMP projects is to assess the effectiveness of specific management strategies over time not to assure that the project watershed achieves specific water quality objectives.
h. **A set of criteria** that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards and, if not, the criteria for determining whether this watershed-based plan needs to be revised or, if a NPS TMDL has been established, whether the NPS TMDL needs to be revised.	Criteria for determining whether load reductions were achieved are not included. The 319 NMP projects focus on direct measures of water quality changes after land treatment rather than using indicators or other proxies.
i. A **monitoring component** to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item (h) immediately above.	The **water quality monitoring** section provides substantial detail about how changes will be monitored prior to and after BMP implementation.

Chapter 1

Introduction

Monitoring of both land treatment and water quality is the best way to document the effectiveness of nonpoint source pollution control efforts. The purposes of the United States Environmental Protection Agency (USEPA) Section 319 National Monitoring Program (NMP) are to provide credible documentation of the feasibility of controlling nonpoint sources, and to improve the technical understanding of nonpoint source pollution and the effectiveness of nonpoint source control technology and approaches. These objectives are to be achieved through intensive monitoring and evaluation of a subset of watershed projects funded under Section 319 (USEPA, 1991).

The Section 319 NMP projects comprise a small subset of nonpoint source pollution control projects funded under Section 319 of the Clean Water Act as amended in 1987. The development of NMP projects has largely been accomplished through negotiations among States, USEPA Regions, and USEPA Headquarters.

The selection criteria used by USEPA for Section 319 NMP projects are primarily based on the components listed below. In addition to the specific criteria, emphasis is placed on projects that have a high probability of documenting water quality improvements from nonpoint source controls over a 5- to 10-year period.

- Documentation of the water quality problem, which includes identification of the pollutants of primary concern, the sources of those pollutants, and the impact on designated uses of the water resources.
- Comprehensive watershed description.
- Well-defined critical area that encompasses the major sources of pollution being delivered to the impaired water resource. Delineation of a critical area should be based on the primary pollutants causing the impairment, the sources of the pollutants, and the delivery system of the pollutants to the impaired water resource.
- A watershed implementation plan that uses appropriate best management practice (BMP) systems. A system of BMPs is a combination of individual BMPs designed to reduce a specific nonpoint source problem in a given location. These BMP systems should address the primary pollutants of concern and should be installed and utilized on the critical area.
- Quantitative and realistic water quality and land treatment objectives and goals.
- High level of expected implementation and landowner participation.
- Clearly defined nonpoint source monitoring program objectives.
- Water quality and land treatment monitoring designs that have a high probability of documenting changes in water quality that are associated with the implementation of land treatment.
- Well-established institutional arrangements and multi-year, up-front funding for project planning and implementation.
- Effective and ongoing information and education programs.
- Effective technology transfer mechanisms.

Minimum tracking and reporting requirements for land treatment and surface water quality monitoring have been established by USEPA for the NMP projects (USEPA, 1991). These requirements (see Appendix 1) were set forth based upon past efforts (e.g. Rural Clean Water Program) to evaluate the effectiveness of watershed projects.

USEPA developed a software package, the NonPoint Source Management System (NPSMS), to help the 319 National Monitoring Program projects track and report land management and water quality information (Dressing and Hill, 1996). NPSMS has three data files: 1) a Management File for information regarding water quality problems within the project area and plans to address those problems; 2) a Monitoring Plan File for the monitoring designs, stations, and parameters; and 3) an Annual Report File for annual implementation and water quality data. NPSMS version 4.2 is currently used by National Monitoring Program projects, operating in a Windows^{TM} environment. (USEPA, 1996a).

This publication is an annual report on 28 Section 319 NMP projects approved as of November 1, 2010. Project profiles (Chapter 2) were prepared by the North Carolina State University (NCSU) Water Quality Group under the USEPA contract entitled National Nonpoint Source Watershed Project Studies. Profiles have been reviewed and edited by personnel associated with each project.

The 27 surface water monitoring projects selected as Section 319 NMP projects are Lightwood Knot Creek (Alabama), Oak Creek Canyon (Arizona), Morro Bay (California), Jordan Cove Urban Watershed (Connecticut), Kickapoo Creek (Illinois), Lake Pittsfield (Illinois), Waukegan River (Illinois), Sny Magill Watershed (Iowa), Walnut Creek (Iowa), Corsica River Watershed, (Maryland), Warner Creek Watershed (Maryland), Eagle River (Michigan), Sycamore Creek Watershed (Michigan), Whitewater River Watershed (Minnesota), Elm Creek Watershed (Nebraska), New York City Watershed (New York), Long Creek Watershed (North Carolina), Peacheater Creek (Oklahoma), Upper Grande Ronde Basin (Oregon), Pequea and Mill Creek Watershed (Pennsylvania), Stroud Preserve Watersheds (Pennsylvania), Swatara Creek Watershed (Pennsylvania), Villanova University Stormwater Best Management Practice (Pennsylvania), Bad River (South Dakota), Lake Champlain Basin Watersheds (Vermont), Totten and Eld Inlet (Washington), and Otter Creek (Wisconsin). Snake River Plain, Idaho, is a pilot ground water project.

Five of the projects focus on urban or mining sources, while the others primarily address agricultural sources. Nearly all of the projects address river or stream problems, while several projects are intended to directly benefit a lake, estuary, or bay. One of the projects is focused on ground water protection. The progress made by these projects will be showcased in this report.

Each project profile includes a project overview, project background, project design, and maps showing the location of the project in the state and the location of water quality monitoring stations. In the project background section, water resources are identified and water quality and project area characteristics are described. The project design section outlines the water quality monitoring program and nonpoint source control strategy. Project budgets and project contacts are also presented.

The Appendices include the minimum reporting requirements for Section 319 NMP projects (Appendix I), a list of abbreviations (Appendix II), and a glossary of terms (Appendix III) used in the project profiles. A list of project documents and other relevant publications for each project is included in Appendix IV.

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Dressing, S.A. and J. Hill. 1996. Nonpoint Source Management System Software: A Tool for Tracking Water Quality and Land Treatment. IN: *Proceedings Watershed '96 Moving Ahead Together Technical Conference and Exposition.* Water Environment Federation, Alexandria, VA, p. 560-562.

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Chapter 2

Section 319
National Monitoring Program
Project Profiles

This chapter contains a profile of each of the Section 319 National Monitoring Program projects approved as of November 1, 2010, arranged in alphabetical order by state.

Each profile begins with a brief project overview , followed by detailed information about the project, including water resource description; project area characteristics; information, education, and publicity; nonpoint source control strategy; water quality monitoring program information; total project budget; impact of other federal and state programs; other pertinent information; and project contacts.

Sources used in preparation of the profiles include project documents and review comments made by project coordinators and staff.

Project budgets have been compiled from the best and most recent information available.

Abbreviations used in the budget tables are as follows:

Proj Mgt .... Project Management
I&E .... Information and Education
LT .... Land Treatment
WQ Monit .... Water Quality Monitoring
NA .... Information Not Available

A list of project documents and other relevant publications for each project may be found in Appendix IV.

Alabama

Lightwood Knot Creek
Section 319
National Monitoring Program Project

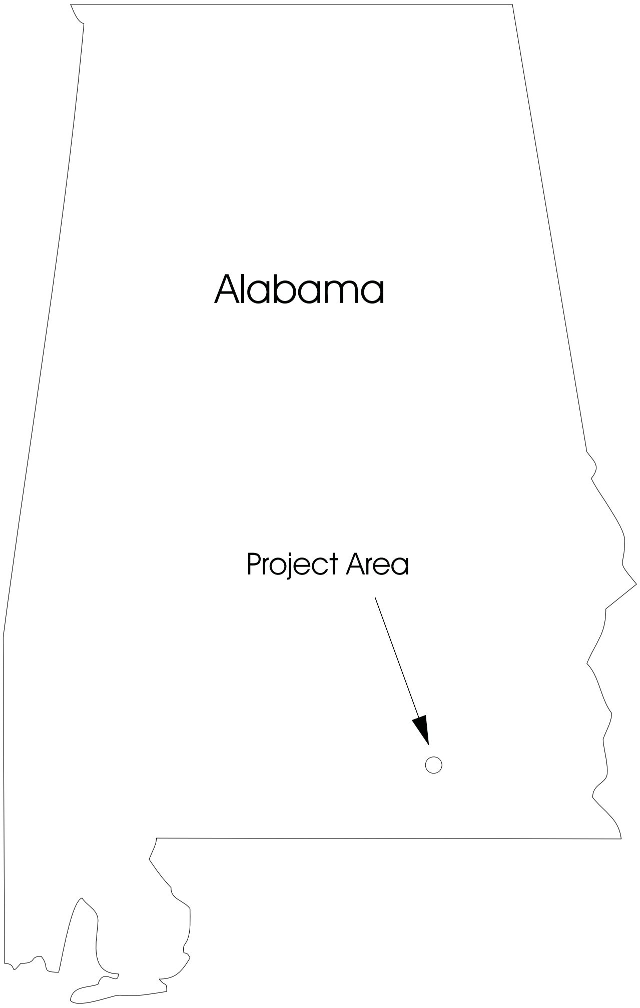

Figure 1: Lightwood Knot Creek (Alabama) Project Location

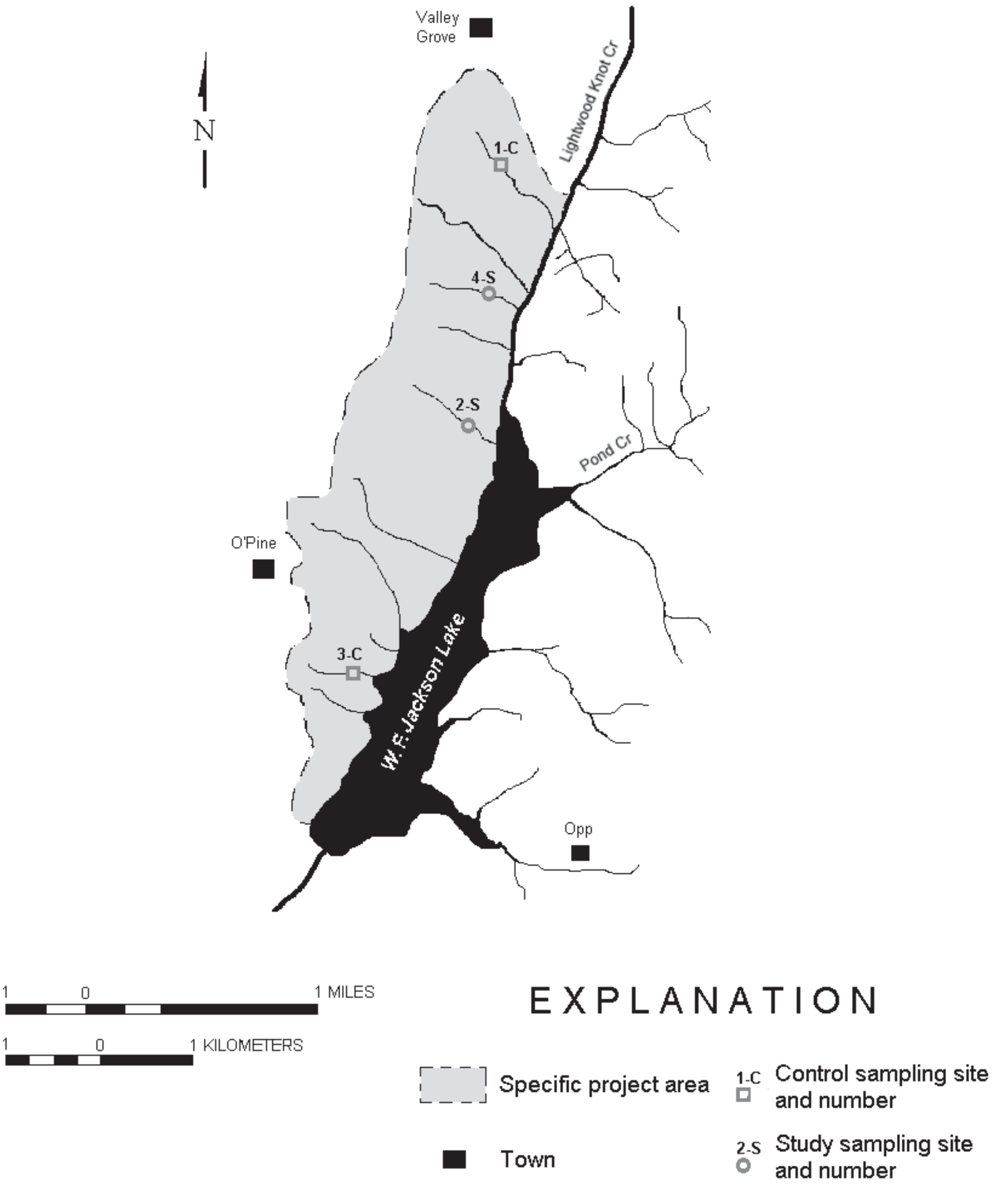

Figure 2: Water Quality Monitoring Stations for Lightwood Knot Creek (Alabama) Watershed

PROJECT OVERVIEW

Lightwood Knot Creek is a tributary of the 1,100-acre W.F. Jackson Lake in Southeastern Alabama (Figure 1). Jackson Lake was constructed for recreational uses in 1987. The 47,300-acre watershed is approximately half forested and half in agriculture. Pasture, hayland, cropland, and poultry production are the dominant agricultural land uses.

Erosion in the Lightwood Knot Creek watershed and resulting sedimentation of Jackson Lake and disposal of animal wastes are major water quality problems. Numerous areas have been identified as sources of sediment. Types of erosion occurring include sheet, rill, ephemeral, and erosion along unpaved roads. Nutrients and bacteria from cattle and poultry operations are also sources of pollution.

Land treatment began after three years of baseline monitoring. Erosion control practices implemented include runoff and sediment control structures, critical area planting, cover and green manure crops, and pasture and hayland management. For animal waste management, practices include poultry litter storage, litter and dead poultry composting and prescribed waste utilization.

The Geological Survey of Alabama conducted physical, chemical, and biological monitoring at two sets of paired watersheds. Each of the sets of watersheds had a control and treatment watershed. These watersheds were small, ranging from 75 to 240 acres. Monitoring was conducted weekly for all parameters (see Water Quality Monitoring section below) from April through August. Only inorganic and physical parameters were monitored for the remainder of the year.

The project is completed. Pre-BMP monitoring and installation of BMPs were completed in September 1999, post BMP monitoring and statistical analyses were completed in September 2002. The final report is dated 2002.

PROJECT DESCRIPTION

Project Area

The Lightwood Knot watershed draining into Jackson Lake covers 47,300 acres. Jackson Lake is 1,100 acres in size.

Relevant Hydrologic, Geologic, and Meteorologic Factors

Soils consist of a thin sandy loam topsoil and a sandy clay subsoil with a depth of six feet. Coastal plain sediments of the Tertiary aged Lisbon and Tallahatta Formations crop out in the project subwatersheds. Average annual rainfall is 56 inches and average annual runoff is 23 inches.

Land Use

Land Use	Percent
Crop	23
Pasture/hay	26
Forest	47
Residential	2
Lake	2
Total	100

Water Resource and Size

Water resources of concern are Lightwood Knot Creek and other tributary streams to Jackson Lake, a reservoir created in 1987. Four branches of Lightwood Knot Creek were monitored in this study Median seven-day low flow of these branches, sustained by ground water seepage, is approximately 0.32 cubic feet per second per square mile of watershed.

Water Uses and Impairments

Lightwood Knot Creek and Jackson Lake are used for recreation. Disposal of animal wastes and sedimentation of tributaries and the lake are primary concerns. Excessive sediment impairs aquatic life habitat, increases bridge maintenance costs, increases flooding potential, and reduces the capacity of Jackson Lake. Elevated levels of nitrogen and phosphorus and elevated fecal bacteria counts have been found in Lightwood Knot tributaries.

Pollutant Sources

Pollutant sources varied from agricultural fields and roads to confined animal operations. Numerous areas were identified for erosion control BMPs. There were 6 poultry operations that were potential sources of nonpoint source pollution.

Pre-Project Water Quality

Very little background water quality information was available; however, tributary sampling in July of 1994 provided some indication of pre-project water quality. Turbidity ranged from 41 to 55 NTU. Total nitrogen ranged from 0.8 to 5.0 mg/L and total phosphorus ranged from 0.03 to 0.51 mg/L. Fecal coliform and fecal streptococcus ranged from approximately 500 to nearly 9,000 counts per 100 ml.

Water Quality Objectives

The main objective of the project was to achieve and document water quality improvements in the treatment subwatersheds through the implementation of BMPs.

Project Time Frame

1996 to 2002

PROJECT DESIGN

Nonpoint Source Control Strategy

Land treatment began during the summer of 1999. BMPs were constructed to control erosion and sedimentation in the 4-S watershed. Erosion control practices included runoff and sediment control structures, floodplain fencing, critical area repair and planting, cover and green manure crops, and pasture and hayland management.

Animal waste management practices were designed and implemented to limit nonpoint sources of pollution. These included poultry litter storage, mortality composting, and floodplain fencing and rotational cattle feeding.

Project Schedule

Management Unit	Pre-BMP Monitoring Dates	BMP Installed	Date Installed/ Established	Post-BMP Monitoring Dates
Sites 1-C, 2-S, 3-C, and 4-S*	Spring 1996 – June 1999	All BMPs installed September 1999	June-September 1999	Fall 1999 – Fall 2002

* C denotes a control watershed: S denotes a study (treatment) watershed

Water Quality Monitoring

Two paired watershed studies were conducted on tributaries of Lightwood Knot Creek (Figure 2). There were two control watersheds and two treatment watersheds. No BMPs were installed in the treatment watersheds while the three-year baseline monitoring was being conducted. No additional BMPs were installed in the control watersheds until the monitoring study was completed (approximately seven years).

Variables Measured

Biological

Aquatic habitat assessment and biotic indexing
Fecal coliform (FC)
Fecal streptococcus (FS)

Chemical

Aluminum (Al)
Ammonia (NH3)
Antimony (Sb)
Arsenic (As)
Barium (Ba)
Beryllium (Be)
Biochemical oxygen demand (BOD)
Boron (B)
Cadmium (Cd)
Calcium (Ca)
Chemical oxygen demand (COD)
Chloride (Cl)
Chromium (Cr)
Copper (Cu)
Iron (Fe)
Lead (Pb)
Magnesium (Mg)
Manganese (Ma)
Nickel (Ni)
Nitrite (NO2)
Nitrate + nitrite (N03+ N02)
Orthophosphate (OP)

pH
Selenium (Se)
Silica (Si)
Silver (Ag)
Sulfate ($SO4^-$)
Tin (Sn)
Total dissolved phosphorus (TDP)
Total dissolved solids (TDS)
Total Kjeldahl nitrogen (TKN)
Total suspended solids (TSS)
Turbidity
Zinc (Zn)

Covariates

Bedload sediment
Discharge
Precipitation
Specific conductance

Sampling Scheme

Samples were taken daily and composited for all parameters from April through August. Total dissolved solids, total suspended solids, and covariates were monitored weekly during the remainder of the year.

Surface water quality monitoring at four project sites was initiated on April 1, 1996. Stream discharge, water level, specific conductance, and temperature data were recorded at 15-minute intervals. Water samples were collected every 24 hours from April to September and every 8 hours from three to six storm event samples per week. Water samples were analyzed for more than 30 constituents including metals and nutrients. Continuous bedload sediment volumes were monitored for all four streams and continuous rainfall data were collected at two sites. Because of the required short holding time for samples used for bacteria and biochemical oxygen demand analyses, these samples were collected as weekly grab samples from April to September. Best management practices installation was completed in September 1999 in the two treatment watersheds. No additional BMPs were installed in the control watersheds until the monitoring study was completed (approximately seven years).

Monitoring Scheme for the Lightwood Knot Creek Section 319 National Monitoring Program Project

Design	Sites or Activities	Primary Parameters	Covariates	Frequency of WQ Sampling	Frequency of Habitat/Biological Assessment	Duration
Two paired watersheds	Tributary subwatersheds	P NH_3 $N0_2$ $N0_3 + N0_2$ DO TDS Turbidity TSS FC FS pH Conductivity	Discharge Precipitation Sediment Conductance	Variable Weekly Daily 15-minute event	2 times per year	7 years

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

All chemical monitoring results collected during the Lightwood Knot Creek 319 National Monitoring Project were entered into the USEPA STORET database and the Alabama Department of Environmental Management's database. Biological data were stored in the USEPA BIOS database.

NPSMS Data Summary

The project intended to track water quality parameters and land use activities with the Nonpoint Source Management System (NPSMS) software.

Final Results

Due to drought, flood, and beaver activity, the data from the 3-C and 4-S watersheds received most of the analytical evaluation related to statistical determinations of water quality change for the pre- and post-treatment periods. Average concentrations of nitrate for the Pre-BMP period (April 96-June 99) were 2.47mg/L at site 3-C, and 2.30 mg/L at site 4-S. Average concentrations of nitrate for the Post-BMP period (Sept 99-Sept 02) were 1.68 mg/L at site 3-C, and 0.62 mg/L at site 4-S.

Average fecal coliform counts for the pre-treatment period (April 96-June 99) for the 3-C and 4-S watersheds were 1,352 and 1,420 colonies per 100 milliliters (col./100 ml), respectively. Average fecal coliform counts for the post-treatment period (Sept 99-Sept 02) were 1,279 and 1,121 col./100 ml, respectively. Average fecal streptococcus counts for the pre-treatment period (April 96-June 99) for the 3-C and 4-S watersheds were 7,381 and 6,903 col./100 ml, respectively. Average fecal streptococcus counts for the post-treatment period (Sept 99-Sept 02) were 4,160 and 3,101 col./100 ml, respectively

Sedimentation rates for the pre-treatment period (April 96-June 99) for the 3-C and 4-S watersheds were 2.2 and 13.4 tons of suspended sediment per year, respectively. Post-treatment period (Sept 99-Sept 02) rates were 5 and 11.1 tons of suspended sediment per year, respectively. Bedload sedimentation rates for the pre-treatment period (April 96-June 99) for the 3-C and 4-S watersheds were 2.7 and 460 tons of per year, respectively. Post-treatment period (Sept 99-Sept 02) rates were 2.9 and 165.4 tons per year, respectively.

Statistical analyses for calibration of paired watersheds were performed after 20 months of monitoring. Nine of eleven parameters were calibrated to detect a change of less than 10% in the log-transformed data for both pairs of watersheds.

Results of statistical analyses of paired watershed data indicated a 71% reduction of nitrate, a 92% reduction in bedload sediment, and an 11% reduction in fecal coliform bacteria in the 4-S watershed. Regression analysis indicated an 18% increase in suspended solids load for the 4-S watershed during the post-treatment period. This increase was not caused by increased erosion but was attributed to a dramatic increase in iron bacteria (iron hydroxide) in the stream resulting from stabilization of the stream bed and reductions of bedload sediment. Also, fecal streptococcus bacteria increased by 14 % in the 4-S watershed during the post-treatment period. This increase was caused by a design flaw in the constructed cattle crossing that encouraged cattle to stop while crossing the stream.

INFORMATION, EDUCATION, AND PUBLICITY

A program of educational outreach and information distribution was initiated in April, 1996.

Numerous presentations, field tours, and demonstrations have occurred since initiation of the project. A tour of the Lightwood Knot Creek Project watersheds was conducted by GSA and NRCS to promote environmental awareness and ongoing water quality improvement efforts to local and state officials. Several mayors, state legislators, and the Speaker of the Alabama House of Representatives were in attendance.

A brochure about the project and nonpoint source pollution was produced by the Geological Survey of Alabama. The brochure describes, for the general public, the nature and purpose of the project, and some of the preliminary results.

TOTAL PROJECT BUDGET

The estimated budget for the Lightwood Knot Creek Section 319 National Monitoring Program project for the life of the project is:

Project Element	Funding Source ($)			
	Federal	State	Local	Sum
Proj Mgt	120,693	59,305	NA	179,998
I & E	NA	NA	NA	NA
L T	100,000	NA	NA	100,000
WQ Monit	544,307	715,695	NA	1,270,002
TOTALS	775,000	775,000	NA	1,550,000

Source: Geological Survey of Alabama, 1995

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

In 1994, a Water Quality Incentive Project (WQIP) was approved for the Yellow River basin. The project included funding for BMPs in the Lightwood Knot Creek watershed to improve erosion control and implementation of animal waste management practices. However, WQIP funding is no longer available for the project.

The Lightwood Knot Creek watershed is being targeted for funding for water quality improvement projects under the Environmental Quality Incentives Program (EQIP). However, no funding of projects has been applied specifically to the National Monitoring Program Project watersheds.

The Natural Resources Conservation Service distributed more than 1.4 million dollars in Covington County, Alabama through the Emergency Watershed Protection Act for roadside repairs performed after March and September 1998 floods. The Farm Service Agency distributed more than 1 million dollars for pond and field repairs performed as a result of the flooding. A significant portion of this funding was spent in the Lightwood Knot Creek watershed.

Methodologies developed for the Lightwood Knot Creek project for monitoring nonpoint source impacts on surface-water quality are now being used state-wide to assess impacts on other water bodies.

OTHER PERTINENT INFORMATION

Surface-water quality and discharge data collected during the pre and post BMP monitoring indicated close interaction between surface and ground water in the project area. The data indicated that shallow, nonpoint source contaminated ground water may be a major source of surface-water contamination, particularly during periods of low flow. Nitrate concentrations of more than 20 mg/L were documented from analyses of ground water samples collected in the project subwatersheds.

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Arizona

Oak Creek Canyon
Section 319
National Monitoring Program Project

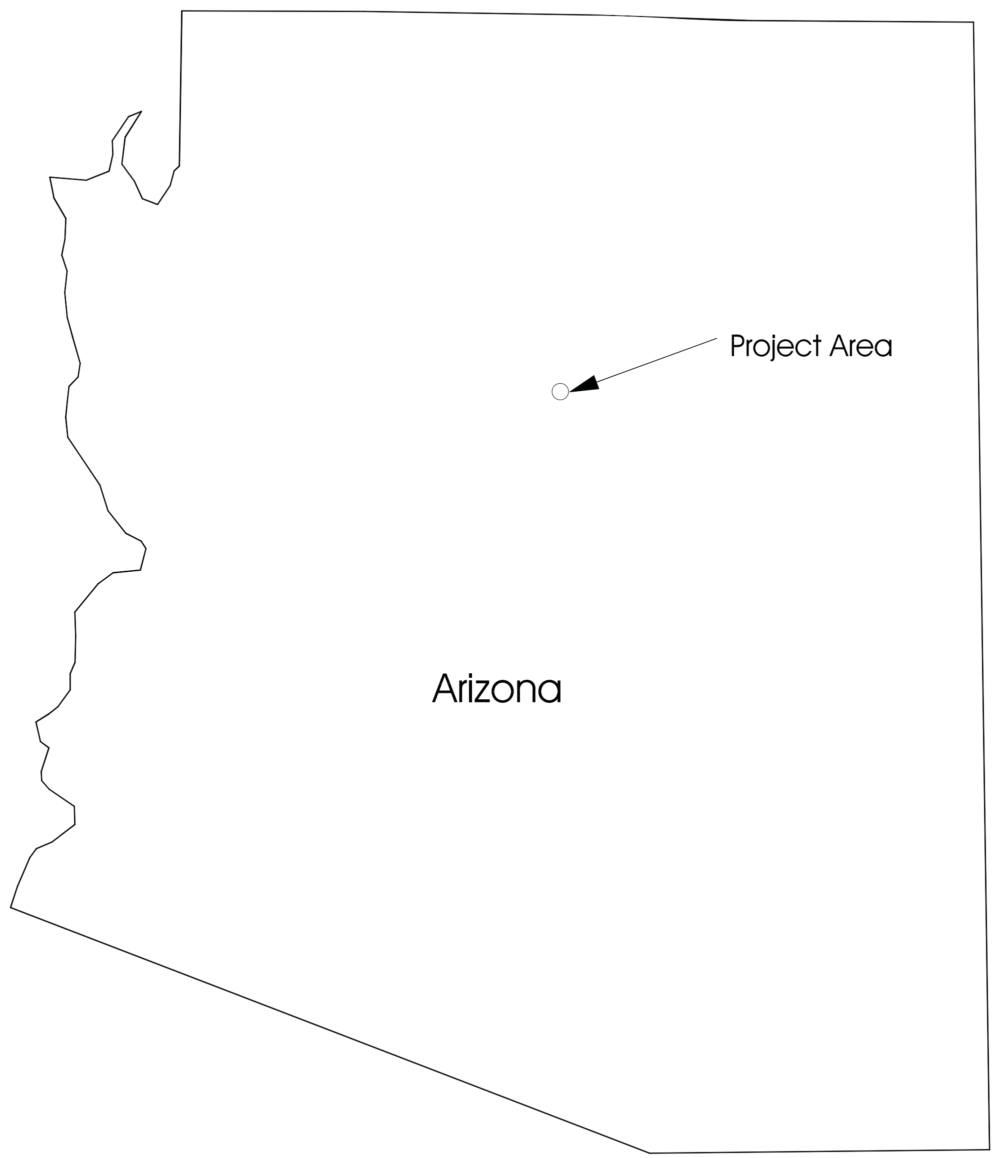

Figure 3: Oak Creek Canyon (Arizona) Project Location

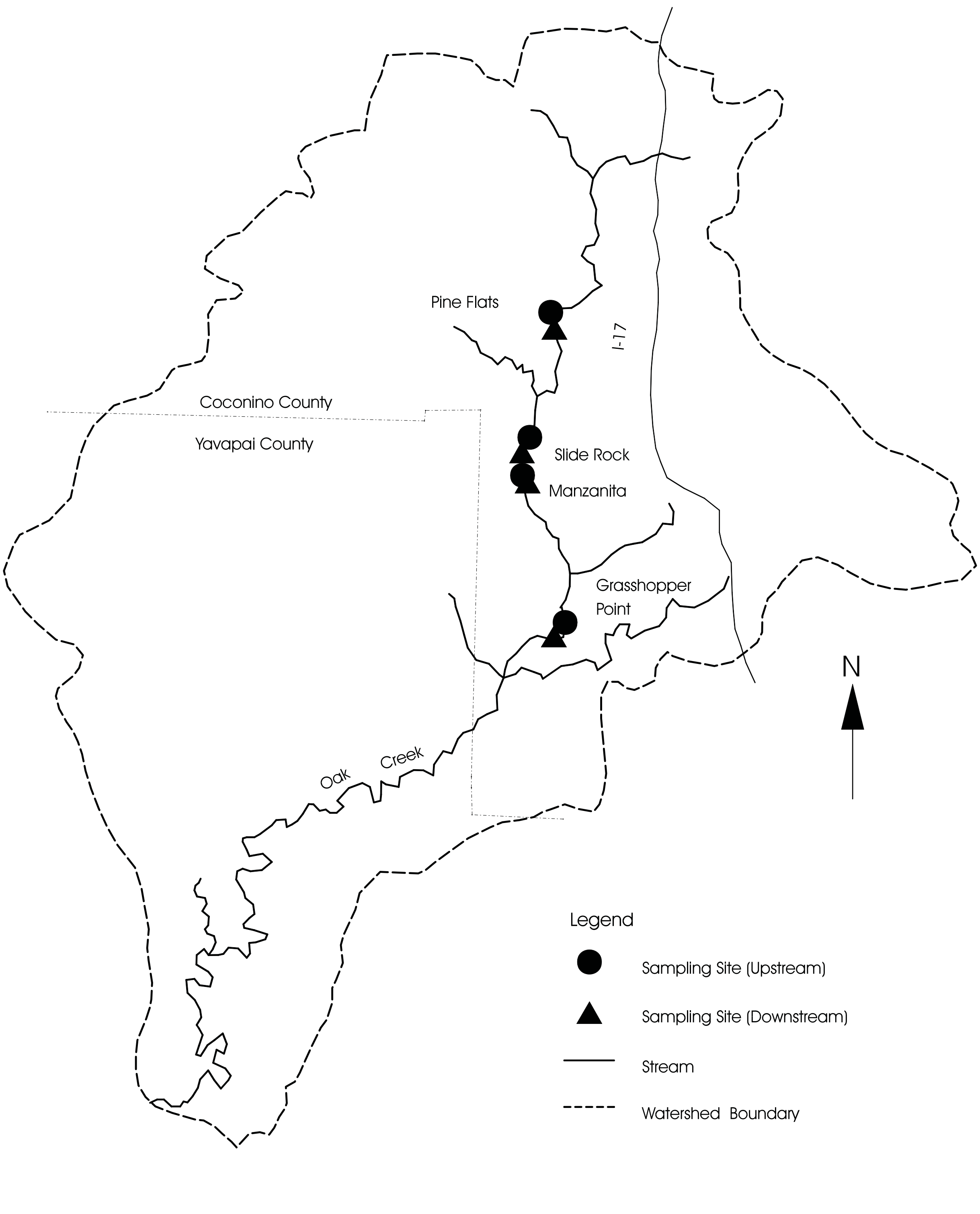

Figure 4: Water Quality Monitoring Stations for Oak Creek Canyon (Arizona)

PROJECT OVERVIEW

Oak Creek flows through the southern rim of the Colorado Plateau (Figure 3). The Oak Creek Canyon National Monitoring Project focused exclusively on that segment of water located in the canyon portion of Oak Creek, a 13-mile steep-walled area of the creek that extends from the Mogollon Rim to the city limits of Sedona. Although the Oak Creek Canyon watershed encompasses 5,833 acres, only 907 primarily recreational acres were considered to impact the water quality of Oak Creek within the Canyon.

The Oak Creek Section 319 National Monitoring Program Project focused on the implementation and documentation of integrated best management practice (BMP) systems for two locations: Slide Rock State Park and Pine Flats Campground. The eleven-acre Slide Rock State Park was used by more than 350,000 swimmers and sunbathers each season and Pine Flats Campground accommodated approximately 10,000 campers each season. Recreational use at both locations was thought to be the source of high fecal coliform and nutrient levels in Oak Creek.

The BMPs implemented at Slide Rock State Park and Pine Flats Campground included enhanced restroom facilities, better litter control through more intense monitoring by state park officials of park visitors, and the promotion of visitor compliance with park and campground regulations on use of facilities, littering, and waste disposal.

A modified nested upstream/downstream water quality monitoring design was used to evaluate the effectiveness of BMPs for improving water quality at Slide Rock State Park. Grasshopper Point, a managed water recreation area similar to Slide Rock State Park, served as the control. Water quality monitoring stations were located upstream and downstream of swimming areas at both Slide Rock (treatment) and Grasshopper Point (control). A similar monitoring design was also used for Pine Flats Campground and Manzanita Campground. Pine Flats Campground was the treatment site, while Manzanita served as the control site. Monitoring stations were upstream/downstream of campground sites. For these two studies, grab samples were taken weekly during the tourist season (May 15 through September 15) and monthly from November through April for four years. The Oak Creek National Monitoring Program Project has terminated as of June 30, 1998.

PROJECT BACKGROUND

Project Area

The entire Oak Creek watershed contains 300,000 acres. The project area, Oak Creek Canyon, encompasses 5,833 acres. However, the critical area comprises only 907 acres.

Relevant Hydrologic, Geologic, and Meteorologic Factors

Flow in Oak Creek ranges from an average 13 cfs, in the higher Oak Creek Canyon area, to 60 cfs at its confluence with the Verde River.

Annual precipitation in the Oak Creek watershed varies from a six-inch average in the Verde Valley to 20 inches per year on the higher elevations of the Mogollon rim. The majority of rainfall occurs during July and August of the monsoon season (July 4 to September 15). Summer rainfall storm events are short and intense in nature (rarely lasting for more than a half-hour) and are separated by long dry periods. In a normal summer season, over twenty rainfall events occur.

Perennial flow in Oak Creek is sustained by ground water, the main source of which is the regional Coconino Aquifer. The majority of aquifers in the Oak Creek watershed are confined or artesian. Within the Oak Creek watershed, ground water flow is generally to the south, paralleling topography toward the low-lying valley floor.

Land Use

Land Use	Acres	%
Road	55	6
Campground and Parking Lots	123	14
Business and Residential	245	27
Floodplain	290	32
Undeveloped	194	21
TOTAL	907	100

Source: *The Oak Creek 319(h) Demonstration Project National Monitoring Program Work Plan*, 1994

Water Resource Type and Size

Oak Creek cuts deep into the southern rim of the Colorado Plateau. It drops approximately 2,700 feet from its source along the Mogollon Rim to its convergence with the Verde River. The Creek averages about 13 cubic feet per second (cfs) at the study area, but increases to 60 cfs downstream at its confluence with the Verde River.

The study sites for this project were located in Oak Creek Canyon. Steep canyons and rapid water flows characterize this portion of the watershed with sharp drops forming waterfalls and deep, cold pools. Oak Creek Canyon is the primary recreational area in the watershed.

Water Uses and Impairments

Designated beneficial uses of Oak Creek include full body contact (primarily in Oak Creek Canyon), cold water fishery and wildlife habitat (primarily Oak Creek Canyon), drinking water (along the entire course), agriculture (the lower third), and livestock watering (lower third).

Oak Creek was designated as a Unique Water by the Arizona State Legislature in 1991 on the basis of 1) its popularity and accessibility as a water recreation resource; 2) its aesthetic, cultural, educational, and scientific importance; and 3) its importance as an agricultural and domestic drinking water resource in the Verde Valley. Two other criteria were considered in the designation: 1) Oak Creek Canyon is susceptible to irreparable or irretrievable loss due to the ecological fragility of its location and 2) it is a surface water segment that can be managed as a unique water. Management considerations must include technical feasibility and the availability of management resources.

Indicator bacteria and excess nutrients pose the most serious and pressing current threats to Oak Creek water quality. Oak Creek water quality is impaired by high fecal coliform levels associated with the campgrounds and day-use swimming areas; bacteriological impairments coincide with peak recreational use from May through September. Residential septic systems, and natural and grazing animal populations may also contribute to water quality impairments.

Pollutant Sources

Pollutants in Oak Creek addressed in this study were believed to originate mainly from swimmers, campers, residences and animals in the watershed. Poor sanitation practices by recreational users and lack of adequate restroom facilities were initially cited as major sources of bacteria. Sediment fecal coliform analysis at one time suggested that the correlation between number of recreational users and high FC counts was a function of contaminated sediments being resuspended by recreational activity. Genotyping *Escherichia coli* isolates using Amplified Fragment Length Polymorphism (AFLP) (ADEQ Grant Agreement Number 99-0006) was performed to determine the source(s) of bacteria contamination. However, firm determination of the source(s) of the bacteria was never made.

Pre-Project Water Quality

Water Recreation and Camping Areas

Human pathogens (protozoa, bacteria, and viruses) contaminate the Canyon segment of Oak Creek. Most of the attention has focused upon Slide Rock State Park and Grasshopper Point, the two managed "swimming holes" in the area. Fecal coliform counts peak in the summer during the height of the tourist season. The seasonal deterioration of bacteriological water quality has been observed since 1973 by the AZ Department of Public Health and subsequent state and federal agency studies confirmed these results.

Fecal Coliform Levels During the Tourist Season (1993)

Date	Fecal Coliform Count (cfu/100 ml)
July	434
August	393
June	61
September	54

Water Quality Objectives

Water Recreation Project Objectives

- A 50% reduction in fecal coliform
- A 20% reduction in nutrients, particularly ammonia

Camping Project Objectives

- A 50% reduction in fecal coliforms
- A 20% reduction in nutrients

Project Time Frame

1994 to 1998

PROJECT DESIGN

Nonpoint Source Control Strategy

Slide Rock and Grasshopper Point (Water Recreation Project)

Slide Rock State Park and the US Forest Service improved the access and ambience of the restroom facilities located at the Slide Rock swimming area. Public education programs promoting compliance with park regulations, including use of restroom facilities, were conducted. Based on casual observation, the rate of use has increased significantly over pre-improvement days. The USFS also replaced the old vault toilets at Grasshopper Point and constructed composting toilets. These have been well received by the public. At both swimming facilities, trash removal has improved with regular walks throughout the recreation area by staff of both the Park and the USFS. Control of visitor numbers was improved by parking restrictions on the adjacent state highway.

Pine Flats and Manzanita (Campgrounds Project)

The nonpoint source control strategy for the campground project targeted the upstream site of Pine Flats. Best management practices implemented at Pine Flats were designed to reduce pollutants associated with human use of campground facilities. The BMPs implemented include enforcement of a clean zone between the creek and the campground and promotion of the use of the existing restroom facilities. Direct contact by park personnel with visitors and the addition of more visible signs helped accomplish these goals.

Project Schedule

Site Name	Pre-BMP Monitoring	BMP Installation	Post-BMP Monitoring	BMP(s) Installed
Pine Flats Campground	May 1994 – Jan 1996	January 1996	Feb 1996 – March 1997	Educational Outreach
Slide Rock State Park	May 1994 – Jan 1996	Oct – Jan 1995-6	Feb 1996 – March 1997	Restroom improvements, trail improvement, post and cable installation on roadside to reduce parking, improve foot bridge, development of and posting of an operations and management strategy
Manzanita Campground	May 1994 – Jan 1996	Control Site	Feb 1996 – March 1997	Control Site for Pine Flats Campground
Grasshopper Point	May 1994 – Jan 1996	Control Site	Feb 1996 – March 1997	Control Site for Slide Rock State Park

Water Quality Monitoring

The water recreation project, which was a modified nested upstream/downstream monitoring design (Figure 4), was designed to document the change in water quality as a result of the application of BMPs. The swimming sites at Slide Rock State Park (treatment site) and Grasshopper Point (the control site) were compared. Water quality monitoring stations were located above and below each swimming area.

The camping area project also used an upstream/downstream monitoring design. Water quality monitoring stations were installed above and below both the camping area at Pine Flats (treatment site) and the site at Manzanita (control site).

The two-year BMP implementation phase entailed sampling protocols identical to those instituted in the calibration and project sampling phase. The objective of this monitoring phase was to demonstrate the extent to which land treatment reduced nonpoint source pollution.

Variables Measured

Biological (Critical Parameters)

Fecal coliform (FC) (water column and stream sediments)

Chemical and Others (Critical Parameters)

Ammonia (NH_3)
Nitrate (NO_3)
Phosphate (PO_4^-)

Covariates (Noncritical Parameters)

Water temperature
Stream flow
Number of users of the sites
Weekly precipitation
Alkalinity
Calcium (Ca^{2+})
Chloride (Cl^-)
Conductivity
Dissolved oxygen (DO)
Magnesium (Mg^{2+})
pH
Potassium (K^+)
Sodium (Na^+)

Sampling Scheme

Grab samples were collected weekly from May 15 through September 15 and monthly from November through April. Samples were taken in the deepest part of the stream at each sampling site.

The monitoring scheme for the projects is presented as follows.

Monitoring Scheme for the Oak Creek Section 319 National Monitoring Program Project

Design	Activity/Sites*	Critical Monitoring Parameters	Noncritical Covariates	Frequency	Time	Duration
Upstream/ downstream	**Water Recreation** Slide Rock (T) Grasshopper Point (C) **Camping** Pine Flats (T) Manzanita (C)	FC NH_3/NH_4^+ NO_3^- PO_4^{3-} BOD	Alkalinity Ca^{2+} Cl^- Conductivity DO Mg^{2+} pH K^+ Rainfall Na^+ Streamflow Visitor count Water temperature	9/15-5/15 monthly 5/15-9/15 weekly	10 am – 5 pm Saturdays	2 years pre-BMP 2 years BMP

* T = the treatment site; C = the control site

Modifications Since Project Start

The Slide Rock State Park parking lot study has been discontinued.

Progress To Date

The Oak CreekTask Force implemented the following BMPs:

Slide Rock State Park

- Enhanced access and ambience of restroom facilities
- Social strategies promoting compliance with Park regulations, including use of restroom facilities
- Preparation of kiosk warning swimmers of potential dangers of elevated bacteria counts
- Reduction in number of Park visitors by parking restrictions on State Hwy 89A

Pine Flats Campground

- Improved garbage collection
- Visitor education program

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

The project team submitted all raw data for storage in ST ORET and reported the project results in USEPA's Nonpoint Source Management System (NPSMS) software.

NPSMS Data Summary

Submitted to EPAS.

Final Results

The BMPs implemented at Slide Rock and Pine Flats resulted in limited improvement to the water quality of Oak Creek. It is important to locate the source of pollution so that appropriate measures can be taken to control the problem. However, identifying fecal coliform sources proved dificult. Slide Rock visitors are, undoubtedly, a source of pollution (i.e., discarding dirty diapers in the water and defecating in the water or on land nearby). However, visitor behavior cannot account for the cyclical nature of elevated bacteria in this area. High bacteria levels approaching the current water quality standard of 800 cfu/100 ml historically and during this project are typically detected during the July 15 to September 15 "monsoon season". If visitors were the sole source of elevated fecal pollution, then high levels should have occurred between Memorial Day and July 4, when visitor counts are as high as during the monsoon season. This has not occurred; therefore, there must be one or more other sources of fecal coliform.

Although efforts continue to identify the exact bacterial sources, it appears there are virtually no water quality violations in Oak Creek until the sediment plumes have been reinstated after the spring thaw and high water levels. Once the sediments are contaminated, agitation of the sediments by either high flows or recreational users nearly always results in closure of the recreation areas. This loading of the sediments generally occurs at the end of June and beginning of July, resulting in closures early in July.

Genotyping of *E. coli* populations in Oak Creek by Northern Arizona University using amplified fragment length polymorphism (AFLP) helped to differentiate between human and animal sources of pollution.and revealed additional contributions to the fecal loading of Oak Creek. These included the tracking of a fecal plume from residences along the creek and sediment interstitial loading. Most importantly, by employing a watershed approach to water quality monitoring, the project determined that natural animal populations are responsible for a larger proportion of the fecal pollution in Oak Creek than humans are. Therefore, BMPs designed to address the historical misconception that recreational users are solely responsible for polluting Oak Creek cannot be expected to improve water quality. An important unidentified sediment reservoir of fecal pollution still remains in the upper reaches of Oak Creek Canyon. The success of the project in developing a high throughput method for bacterial genotyping and the development of an *E. coli* strain collection for the Oak Creek Watershed will facilitate future investigation of the pollution problems of Oak Creek.

INFORMATION, EDUCATION, AND PUBLICITY

Numerous organizations and individuals perceived themselves as “owners” of Oak Creek Canyon. It was in the best interest of the Oak Creek National Monitoring Program project to fully involve these groups and individuals in informational and educational activities.

The Oak Creek Advisory Committee, which was formed in 1992, involved federal, state, and local government agencies and private organizations such as Keep Sedona Beautiful and the Northern Audubon Society as well as several homeowner organizations. The committee met monthly to keep participants informed of current project activities and results, gain insights into areas of concern, and learn about the BMPs that are being implemented as part of the 319 National Monitoring Program.

Progress Toward Meeting Goals

With respect to the proposed Public Education Campaign for the Oak Creek Canyon Section 319 National Monitoring Program project, the following events have transpired:

- The U.S. Forest Service prepared a Public Education Plan for Slide Rock State Park and hired a public education specialist to continue and expand the public education effort.
- The Arizona State Parks staff has developed bi-lingual brochures and a three stage alert signage system, posted daily at the park, for the visitors.
- The USFS volunteer organization, Friends of the Forest, in conjunction with Slide Rock State Park, have developed and implemented an educational program aimed at school children and their parents that visit the recreational area. Programs were held for all of the elementary schools within a one-hour drive of Sedona and with a school from Tucson, AZ. In addition, road signs are being installed throughout the canyon alerting visitors to use toilets and take care of the creek. Messages were developed by the school children who participated in the education program. Finally, a promotional Public Announcement slide was produced by the Friends of the Forest. This “Help Keep Oak Creek Unique” slide will be shown before every movie in every movie theater in Northern Arizona during the intensive recreational use period.

TOTAL PROJECT BUDGET

The estimated budget for the Oak Creek Canyon Section 319 National Monitoring Program project for the life of the project was:

Funding Source ($)			
Federal	**State**	**Local**	**Total**
330,000	87,000	288,000	705,000

The Arizona Department of Environmental Quality decided not to fund the Oak Creek Canyon National Monitoring Program project after the funding from Region IX of the U.S. Environmental Protection Agency was discontinued (Spring, 1998).

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

The Oak Creek Section 319 National Monitoring Program project complemented several other programs (federal, state, and local) located in the Verde Valley:

- The U.S. Geological Survey initiated a comprehensive water use/water quality study focusing on the north-central Arizona region extending from the City of Phoenix to the Verde Valley.
- The Verde Watershed Watch Program, a 319(h)-funded program run by Northern Arizona University. The program was designed to train students and teachers from seven high schools (located within the river basin) in macroinvertebrate and water chemistry sampling to evaluate the effects of BMP implementation.
- The Arizona Department of Environmental Quality established theVerde Nonpoint Source Management Zone in the state.
- The Colorado Plateau Biological Survey established a major riparian study project focusing on the Beaver Creek/MontezumaWells area of theVerde Valley.

OTHER PERTINENT INFORMATION

None.

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California

Morro Bay Watershed
Section 319
National Monitoring Program Project

Figure 5: Morro Bay (California) Watershed Project Location

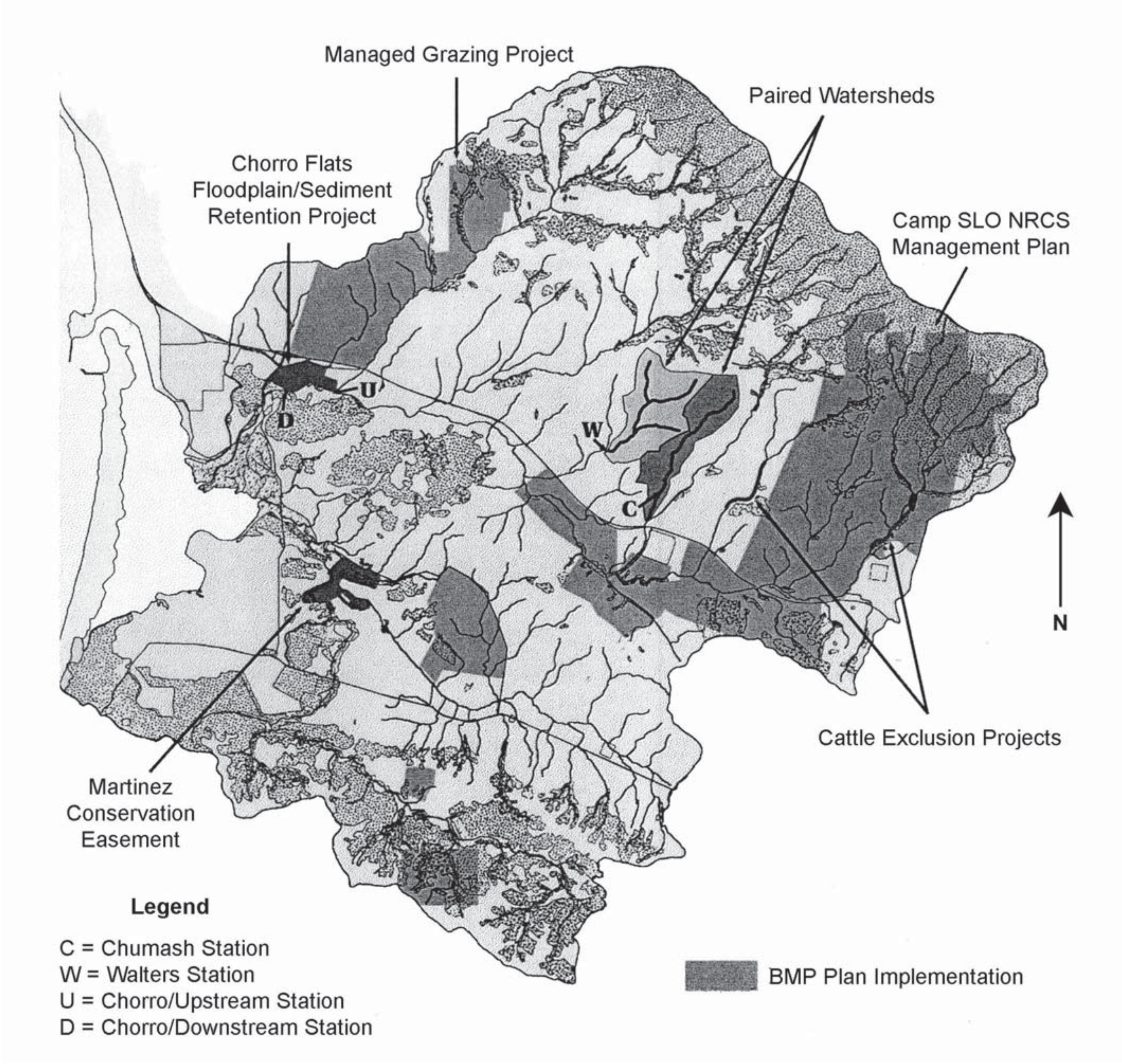

Figure 6: Paired Watersheds and other Projects in Morro Bay (California)

PROJECT OVERVIEW

The Morro Bay watershed is located on the central coast of California, 237 miles south of San Francisco in San Luis Obispo County (Figure 5). This 76-square mile watershed is an important biological and economic resource. Two creeks, Los Osos and Chorro, drain the watershed into the Bay. Included within the watershed boundaries are two urban areas, prime agricultural and grazing lands, and a wide variety of natural habitats that support a diversity of animal and plant species. Morro Bay estuary is considered to be one of the least altered estuaries on the California coast. Heavy development activities, caused by an expanding population in San Luis Obispo County, have placed increased pressures on water resources in the watershed.

Various nonpoint source pollutants, including sediment, bacteria, nutrients, and organic chemicals, are entering streams in the area and threatening beneficial uses of the streams and estuary. The primary pollutant of concern is sediment. According to recent studies, upland areas contribute the largest portion of sediment, and Chorro Creek contributes twice as much sediment to the Bay as does Los Osos Creek. At present rates of sedimentation, Morro Bay could be lost as an open water estuary within 300 years unless remedial action is undertaken. The main objective of the Morro Bay Nonpoint Source Pollution and Treatment Measure Evaluation Program, of which the Morro Bay Watershed Section 319 National Monitoring Program project was a subset, is to reduce the quantity of sediment entering Morro Bay.

The U.S. Environmental Protection Agency (USEPA) Section 319 National Monitoring Program project for the Morro Bay watershed was developed to characterize the sedimentation rate and other water quality conditions in a portion of Chorro Creek, to evaluate the effectiveness of several best management practice (BMP) systems in improving water quality and habitat quality, and to evaluate the overall water quality at select sites in the Morro Bay watershed.

The focus of the Morro Bay Watershed Section 319 National Monitoring Program project was a paired watershed study on two subwatersheds of Chorro Creek (Chumash and Walters Creeks). The purpose of the project was to evaluate the effectiveness of a BMP system in improving water quality (Figure 6). BMP system effectiveness was evaluated for sites outside the paired watershed. These projects included a managed grazing system on the Maino Ranch, two cattle exclusion projects (Dairy Creek and Chorro Creek), and a flood plain sediment retention project. In addition, water and habitat quality samples taken throughout the Morro Bay watershed have documented the changes in water quality during the life of the project.

The project was completed on Sept. 30, 2002. The Final Report, dated Aug. 31, 2003, is available through the Central Coast Regional Water Quality Central Board.

PROJECT BACKGROUND

Project Area

The Morro Bay watershed drains an area of 48,450 acres into the Morro Bay estuary on the central coast of California. The Bay is approximately 4 miles long and 1.75 miles wide at its maximum width. The project area was located in the northeast portion of the Morro Bay watershed.

Relevant Hydrologic, Geologic, and Meteorologic Factors

Morro Bay was formed during the last 10,000 to 15,000 years (NRCS, 1989a). A post-glacial rise in sea level of several hundred feet resulted in a submergence of the confluence of Chorro and Los Osos creeks (Haltiner, 1988). A series of creeks that originate in the steeper hillslopes to the east of the Bay drain westward into Chorro and Los Osos creeks, which drain into the Bay. The 400-acre salt marsh has developed in the central portion of the Bay in the delta of the two creeks. A shallow ground water system is also present underneath the project area.

The geology of the watershed is highly varied, consisting of complex igneous, sedimentary, and metamorphic rock. Over fifty diverse soils, ranging from fine sands to heavy clays, have been mapped in the area. Soils in the upper watershed are predominantly coarse-textured, shallow, and weakly developed. Deeper medium- or fine-textured soils are typically found in valley bottoms or on gently rolling hills. Earthquake activity and intense rain events increase landslide potential and severity in sensitive areas.

The climate of the watershed is Mediterranean: cool, wet winters and warm, dry summers. The area receives about 95% of its 18-inch average annual precipitation between the months of November and April. The mean air temperature ranges from around 45 degrees F in January to 65 degrees F in July, with prevailing winds from the northwest averaging about 15 to 20 miles per hour.

Land Use

Approximately 60% of the land in the watershed is classified as rangeland. Typical rangeland operations consist of approximately 1,000 acres of highly productive grasslands supporting cow-calf enterprises. Brushlands make up another 19% of the watershed area. Agricultural crops (truck, field, and grain crops), woodlands, and urban areas encompass approximately equal amounts of the landscape in the watershed.

Land Use	Acres	%
Agricultural Crops	3,149	7
Woodland	3,093	7
Urban	3,389	8
Brushland	8,319	19
Rangeland	26,162	59
Total	44,112	100

Source: NRCS, 1989a Water Resource Type and Size

Water Resource Type and Size

The total drainage basin of the Morro Bay watershed is approximately 48,450 acres. The 319 project monitoring effort was focused on the Chorro Creek watershed. Chorro Creek and its tributaries originate along the southern flank of Cuesta Ridge, at elevations of approximately 2,700 feet. Currently three stream gauges are present in the Chorro Creek watershed: one each on the San Luisito, San Bernardo, and Chorro creeks. The San Bernardo gauge became inoperable in 1996; a new gauge has yet to be installed. Annual discharge is highly variable, ranging from approximately 2,000 to over 20,000 acre-feet, and averaging about 5,600 acre-feet. Flow in tributaries is intermittent in dry years and may disappear in all but the uppermost areas of the watershed.

Water Uses and Impairments

In spite of the intermittent nature of these creeks, both Chorro and Los Osos creeks are considered cold-water resources, supporting anadromous fisheries (steelhead trout).

Morro Bay is one of the few relatively intact natural estuaries on the Pacific Coast of North America. The beneficial uses of Morro Bay include recreation, industry, navigation, marine life habitat, shellfish harvesting, commercial and sport fishing, wildlife habitat, and rare and endangered species habitat.

A number of fish species (including anadromous fish, which use the Bay during a part of their life cycle) have been negatively affected by the increased amount of sediment in the streams and the Bay. Sedimentation in anadromous fish streams reduces the carrying capacity of the stream for steelhead and other fish species by reducing macroinvertebrate productivity, spawning habitat, and egg and larval survival rates, and increasing gill abrasion and stress on adult fish. Trout are still found in both streams, but ocean-run fish have been greatly reduced. However, several reports of sitings have occurred in the past years. The Tidewater Goby, a federally endangered brackish-water fish, was eliminated from the mouths of both Chorro and Los Osos creeks, most likely as a result of sedimentation of pool habitat in combination with excessive water diversion.

Accelerated sedimentation has also resulted in significant economic losses to the oyster industry in the Bay. Approximately 100 acres of oyster beds have been lost due to excessive sedimentation. Additionally, fecal coliform bacteria carried by streams to the Bay have had a negative impact on the shellfish industry, resulting in periodic closures of the area to shellfish harvesting (NRCS, 1992). Due to continually elevated levels of total and fecal coliform, the California Department of Health Services has reclassified the Bay from “conditional” to “restricted.” Reclassification to “restricted” requires changes in harvesting practices, which have cost prohibitive for existing operations and have resulted in closure of a significant portion of the growing area. Elevated fecal coliform counts have been detected in water quality samples taken from several locations in the watershed and the Bay.

Pollutant Sources

It has been estimated that 50% or more of the sediment entering the Bay results from human activities. Sheet and rill erosion account for over 63% of the sediment reaching Morro Bay (NRCS, 1989b). An NRCS Erosion and Sediment Study identified sources of sediment to the Bay, which include activities on rangeland, cropland, and urban lands (NRCS, 1989b). The greatest contribution of sediment to the Bay originates from upland brushlands (37%) because of the land’s steepness, parent material, lack of undercover, and wildfire potential. Rangelands are the second largest source of sediment entering into streams (12%). Cattle grazing has damaged riparian areas by removing vegetation and breaking down bank stability. The unvegetated streambanks, as well as overgrazed uplands, have resulted in accelerated erosion. Other watershed sources that contribute to sediment transport into Morro Bay include abandoned mines, poorly maintained roads, agricultural croplands, streambank erosion, and urban activities.

The Morro Bay watershed is listed as “impaired” by sediment, nutrients, organics, and bacteria. NMP data have been used to develop Total Maximum Daily Loads for Chorro Creek, Los Osos Creek, and the Morro Bay estuary. The Total Maximum Daily Loads (TMDLs) identify the sources, determine the loading capacity of the waterbodies, and reduce pollutant loading so that beneficial uses are protected. TMDLs for sediment and bacteria have recently been adopted, and efforts to develop TMDLs for nutrients and organics are currently underway.

The Morro Bay National Estuary Program conducted a Sediment Loading and Stream Flow Study to evaluate the sediment contributions from the creeks that feed the bay. The results of this study indicate that the majority of the sediments being transported to Morro Bay from Los Osos Creek and Chorro Creek are fines (silts and clays). The average annual loading is estimated at 70,000 tons per year. Los Osos creek is expected to contribute only 14% of the total average annual loading and 86% is from Chorro Creek (Tetra Tech, 1998). The event and even-interval data collected for the Morro Bay National Monitoring Program were used as the foundation for this study and numerical models.

Pre-Project Water Quality

Morro Bay and the two creeks that flow into the estuary (Chorro Creek and Los Osos Creek) are listed as “impaired waters” due to siltation, metals, organics, nutrients, and pathogens by the State of California (Central Coast Regional Water Quality Control Board, 1993). Studies conducted within the watershed have identified sedimentation as a serious threat in the watershed and estuary. Results of a U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Hydrologic

Unit Areas (HUA) project study show that the rate of sedimentation has increased tenfold during the last 100 years (NRCS, 1989b). Recent studies indicate that the estuary has lost 25% of its tidal volume in the last century as a result of accelerated sedimentation, and has filled in with an average of two feet of sediment since 1935 (Haltiner, 1988). NRCS estimated the current quantity of sediment delivered to Morro Bay to be 45,500 tons per year (NRCS, 1989b).

Water Quality Objectives

The overall goal of the Section 319 National Monitoring Program project was to evaluate improvements in water quality resulting from implementation of BMPs. The following objectives were identified for this project:

- Identify sources, types, and amounts of nonpoint source pollutants (see the list of parameters that will be monitored under Water Quality Monitoring), originating in paired watersheds in the Chorro Creek watershed (Chumash and Walters creeks).
- Determine stream flow/sediment load relationships in the paired watersheds.
- Evaluate the effectiveness of improving water quality in one of the paired subwatersheds (Chumash Creek) of a BMP system.
- Evaluate the effectiveness of several BMP systems in improving water or habitat quality at selected Morro Bay watershed locations, including a managed grazing project, cattle exclusion projects, and a flood plain sediment retention project.
- Monitor overall water quality in the Morro Bay watershed to identify problem areas for future work, detect improvements or changes, and contribute to the water quality database for watershed locations.
- Develop a geographic information system (GIS) database to be used for this project and in future water quality monitoring efforts.

The goals for these projects were to achieve:

- A 34% decrease in sediment yield from the sediment retention project
- A 66% reduction in sediment yield from the cattle exclusion project
- A 30% reduction in sediment as a result of the managed grazing project

Project Time Frame

The project began on September 1, 1992. Funding in the amount of $200,000 (from 91-92 and 92-93) was provided on September 1, 1992. Two years of pre-implementation data collection and equipment installation (93-94 and 94-95) were funded for the project. Sampling during 95-96 was ultimately also included in the pre-BMP period, because changes to the land resulting from BMP installation were minimal and water quality data showed little change from past years. The first and second year of post-implementation sampling was conducted during 96-97 and 97-98. Additional funding was obtained to extend the storm water monitoring at Chumash and Walters Creeks for an additional year. The project was completed on September 30, 2002. A Final Report is available through the Central Coast Regional Water Quality Control Board.

PROJECT DESIGN

Nonpoint Source Control Strategy

In the paired watershed, a BMP system was used to reduce nonpoint source pollutants. Cal Poly was responsible for implementing the BMP system on Chumash Creek, which is one of the streams in the paired watershed, while Walters Creek serves as the control. The implemented BMPs include 1) fencing the riparian corridor, 2) creating smaller pastures for better management of cattle-grazing activities, 3) providing appropriate water distribution to each of these smaller pastures, 4) stabilizing and revegetating portions of the streambank, 5) installing water bars and culverts on farm roads where needed, and 6) removing and stabilizing a failed on-stream stock pond. The project team established a goal of a 50% reduction in sediment following BMP implementation.

The NRCS has designed several BMP systems in the Morro Bay watershed. Three of these systems were evaluated for their effect on water and habitat quality:

- A flood plain sediment retention project was developed at Chorro Flats to retain sediment (sediment retention project)
- A riparian area along Dairy Creek, a tributary of Chorro Creek, and a reach along Chorro Creek downstream of the Chorro Reservoir, was fenced and revegetated (cattle exclusion project)
- Fences and watering systems were installed to allow rotational grazing of pastures on the 1,400-acre Maino ranch (managed grazing project)

Project Schedule

Site	Pre-BMP Monitoring	BMP Installation	Post-BMP Monitoring
Chumash/Walters Creek	1993-1996	1994-1997	1996-2001
Chorro Flats	1993-1995	1997	1998-2000
Upper Chorro Creek	1993-1995	1994	1995-2001
Dairy Creek	1993-1995	1994	1995-2001
Maino Ranch	1993	1994	1995-2000

Water Quality Monitoring

Two watersheds were selected for a paired watershed study. Chumash Creek (400 acres) and Walters Creek (480 acres) both drain into Chorro Creek. The watersheds of the two creeks have similar soils, vegetative cover, elevation, slope, and land use activities. The property surrounding the two creeks is under the management of Cal Poly. Because the rangeland treated is owned by Cal Poly, project personnel were able to ensure continuity and consistency of land management practices.

The paired watershed monitoring plan entailed three specific monitoring techniques: stream flow/climatic monitoring, water quality monitoring, and biological/habitat monitoring. The calibration period (the period during which the two watersheds were monitored to establish statistical relationships between them) was completed during the first two years of the project (1994/95 and 1995/96). Beginning in 1995/96, a BMP system of fences, watering troughs, and other improvements were installed in one of the watersheds (Chumash Creek). The other watershed, Walters Creek served as the control. 1996-2001 served as the post-BMP monitoring period.

Other systems of BMPs were established at different locations in the Morro Bay watershed. These projects include a managed grazing system on the Maino Ranch, cattle exclusion projects on Dairy Creek and Chorro Creek, and a flood plain sediment retention project on Chorro Creek. Water quality was monitored using upstream/downstream and single station designs to evaluate these systems. An upstream/downstream design was adopted to monitor the water quality effect of a flood plain sediment retention project and a cattle exclusion project. A single station design on a subdrainage was used to evaluate changes in water quality from implementation of a managed grazing program. Changes in channel profile rangeland composition and benthic invertebrate composition were also part of the monitoring design at these sites.

In addition to BMP effectiveness monitoring, ongoing water quality sampling was conducted at selected sites throughout the Morro Bay watershed to document long-term changes and to prioritize problem areas in need of further restoration efforts. The Morro Bay Volunteer Monitoring Program has taken over the watershed-wide monitoring now that the NMP project has come to an end.

Variables Measured

Biological

Total and fecal coliform (FC)
Riparian vegetation
Upland rangeland vegetation
In-stream benthic invertebrates

Chemical and other

Nitrate (NO_3)
Phosphate (PO_4^{3-})
Conductivity
pH
Dissolved oxygen (DO)

Physical

Temperature
Suspended solids (SS) (total filterable solids)
Turbidity
Cross-sectional stream profile/morphology

Covariates

Precipitation
Stream flow
Evaporation
Animal units

Sampling Scheme

In the paired watershed, SS samples were collected during storm events using automated sampling equipment set at even intervals (30-minute). The water collected from each individual sample were analyzed for SS, turbidity, and conductivity. Streamflow and climatic data were also collected for hydrologic response of watersheds. Flow is measured at 5-minute intervals during events. Weekly grab samples were taken for at least 20 weeks during the rainy season, starting on November 15 of each year or after the first runoff event.

The samples from the paired watershed stations were analyzed for SS, turbidity, NO_3, PO_4^{3-}, total and fecal coliform, and other physical parameters.

The Dairy Creek cattle exclusion reaches were analyzed for SS, turbidity, nutrients, total and fecal coliform, and other physical parameters.

Suspended sediment and turbidity were monitored at the Chorro Flats sediment retention area.

In addition, year-round samples for pH, DO, turbidity, temperature, and total and fecal coliform were conducted every two weeks at several additional sampling sites throughout the Morro Bay Watershed.

Monitoring Scheme for the Morro Bay Watershed Section 319 National Monitoring Program Project

Design	Sites or Activities	Primary Parameters	Covariates	Frequency for WQ Sampling	Frequency for Vegetation Sampling	Duration
Paired	Chumash Creek[T] and Walters Creek [C]	Total & FC Riparian vegetation SS Turbidity NO_3^- PO_4^{3-} Conductivity pH DO	Precipitation Stream flow Evaporation Animal units	Start after first run-off and weekly grab samples thereafter for 20 weeks. Storm event based monitoring (every 30 minutes).	Vegetation transects twice per year. RBA once per year. Cross-sectional profiles once per year (cross-sections).	2 yrs pre-BMP 2 yrs BMP 4 yrs post-BMP
Upstream/ downstream	Chorro Flats Sediment Retention Project	SS Turbidity Sediment deposition	Precipitation Stream flow Evaporation Animal units	Storm event monitoring (hourly)	March & Sept. aerial photography in 1st, 5th, & 10th year. RBA once per year. Cross-sections.	4 yrs pre-BMP 1 yr BMP 4 yrs post-BMP
Upstream/ downstream	Chorro Creek Cattle Exclusion Project	SS Turbidity FC NO_3^- PO_4^{3-} Physical parameters	Precipitation Stream flow Evaporation Animal units	Weekly during rainy season starting around Nov. 15.	March & Sept. aerial photography in 1st, 5th, & 10th year. RBA once per year. Cross-sections.	2 yrs pre-BMP 1/2 yr BMP 6 yrs post-BMP
Upstream/ downstream	Dairy Creeks Cattle Exclusion Project	SS Turbidity FC NO_3^- PO_4^{3-} Physical parameters	Precipitation Stream flow Evaporation Animal units	Weekly during rainy season starting around Nov. 15.	March & Sept. aerial photography in 1st, 5th, & 10th year. RBA once per year. Cross-sections.	2 yrs pre-BMP 1/2 yr BMP 6 yrs post-BMP
Single downstream	Maino Ranch Managed Grazing Project	SS Turbidity FC Riparian vegetation	Precipitation Stream flow Evaporation Animal units	Weekly during the rainy season.	March & Sept. aerial photography in 1st, 5th, & 10th year. Vegetation transects twice per year. RBA once per year. Cross-sections.	0-1 yr pre-BMP 8 yrs post-BMP

[T]Treatment watershed
[C]Control watershed

Land Treatment Monitoring

On both the paired watershed and the Maino property, four permanent vegetation transects were monitored two times each year to sample upland and riparian vegetation and document changes during the life of the project. Aerial photography was used to document large-scale vegetative trends.

Cross-sectioned stream channel profiles were conducted once each year to document stream channel shape, substrate particle size, and streambank vegetation. Rapid BioAssessment (RBA) was used as a tool to assess water and habitat quality of sites throughout the Chorro and Los Osos Watersheds. Samples were collected during April and May at a number of sites, including several upstream-downstream pairs. The Morro Bay Volunteer Monitoring Program has continued habitat monitoring at selected sites throughout the watershed.

Modifications Since Project Start

Modifications have been made to sediment analysis techniques at the paired watersheds and other locations since project inception. During the first year, evaporation was used to process suspended sediment samples; however, dissolved solids are high in this watershed and contribute significantly to the total weight of the samples. As a result, total filterable solids were determined for the majority of the project duration. A relationship between conductivity and dissolved solids was developed to convert past years' data to filterable solids. Conductivity was no longer measured for each suspended sediment sample during event monitoring as it was not proved to be of significant interest. Composite samples from event monitoring were no longer analyzed for total N, total P, or pH. Grab sampling continues unchanged for nitrate, phosphate, conductivity, turbidity, dissolved oxygen, and water temperature for the duration of the project.

Monitoring of Chorro Flats as part of the NMP project, included an upstream-downstream evaluation of water quality (suspended sediment and turbidity) including an even-interval and storm-event sampling regime, stream profiling, benthic macroinvertebrate analysis, and a qualitative evaluation of riparian and wetland re-establishment. The success of the event-based sampling was compromised by a lack of adequate flow data combined with sampling effectiveness in a high discharge stream, and the lack of a consistent relationship between the upstream and downstream stations. The RCD efforts partially funded by another Clean Water Act Section 319 (h) grant to monitor the effectiveness of the sediment floodplain proved to be more successful. These methods included the use of topographic surveys to record sediment deposition.

The winter rainy seasons varied dramatically during the project period. The winter of 1993-1994 was relatively dry, with only two runoff events. In contrast, the 1994-1995 rainy season was characterized by above average precipitation and periods of flooding. The 1995-96, 1996-97, 1998-99, and 1999-2000 winters were more representative of normal rainfall events and streamflow levels in the watershed, while the 1997-98 winter was a very heavy rainfall year as "El Nino" flow levels were evident throughout the watershed. Sediment, turbidity, and flow data from storm events were collected.

Even interval grab sampling was obtained, with sampling conducted once every two weeks. During the rainy season (20 weeks beginning after the first runoff event), grab samples were collected once per week. Although the study design requires even-interval sampling year round, this is not feasible in several locations (including the paired watersheds) because the flow becomes intermittent or ceases entirely during summer months.

In August, 1994, the "Highway 41 Fire" burned a significant portion (7,524 acres) of the upper Chorro Creek watershed and its tributaries. The paired watersheds, Chorro, Chumash, and Walters, were not burned. Above average precipitation and several periods of widespread flooding during the 1994-95 winter, following the wildfires, resulted in significant erosion and sediment loading throughout the watershed. Modifications occurred at Chorro Flats due to emergency post-fire concerns. An existing level breech was widened so that the flood plain could serve as a sediment deposition area.

Progress to Date

Public presentations about the Morro Bay 319 National Monitoring Program project were regularly made to groups such as Friends of the Estuary, Cal Poly State University (Cal Poly), Cuesta Community College, and the Morro Bay National Estuary Program (MBNEP). The data collected as part of the National Monitoring Program provided a foundation for the development and implementation of the MBNEP's Comprehensive Conservation and Management Plan.

Paired Watershed Study: Funding was acquired through CWA 319(h) for implementation of improvements on the paired watershed. A Technical Advisory Committee was formed and expanded its focus to include monitoring projects throughout the entire Morro Bay watershed. Implementation for land improvements on the Chumash Creek watershed included construction of riparian pastures, additional upland pastures, installation of watering troughs, culvert improvements, and revegetation and stabilization of portions of the corridor. Removal and stabilization of an on-stream stock pond was completed in 1997.

Flood Plain Sediment Retention Project: The Chorro Flats project obtained funding ($960,000) for implementation of the Flood Plain Restoration Project. Construction of the project and revegetation was completed in 1997.

Cattle Exclusion Projects: Dairy Creek and Chorro Creek fencing for riparian exclusion was completed in the summer of 1995.

Managed Grazing Project: In 1994, the Maino Ranch completed installation of watering devices and fencing, and the land is being managed as planned in a timed grazing project.

The Morro Bay National Monitoring Program hosted the 7th Annual National Nonpoint Source Monitoring Workshop that took place September 12 -17, 1999. The purpose of this nationwide workshop was to bring together approximately 200 water quality specialists to share information on such topics as overall effectiveness of Best Management Practices (BMPs) on water quality, effective monitoring techniques, and statistical analysis of watershed data.

National Monitoring Program data was used to develop Total Maximum Daily Loads in the watershed. Water quality data collected at the paired watersheds were used to develop numerical models of sediment loading in the watershed. Additionally, nutrient data was used to identify concentrations in the various tributaries in the watershed and the percent reductions needed at these locations to achieve water quality targets.

Cal Poly has developed a website for the NMP project that features the BMP projects, photos, monitoring methods, and results. The Regional Board will be hosting the NMP website on their website in the future as well.

A brochure (fact sheet) was created as part of the NMP grant. The MBNEP has offered to print and mail the color brochure to interested agricultural entities locally and region-wide.

Additional efforts are also underway for continued BMP implementation. Cal Poly is seeking to implement BMPs on Walters Creek in order to duplicate the significant water quality improvements found at Chumash Creek. Funding has been acquired through the MBNEP to implement BMPs, funding is being sought to continue the monitoring on both. The new study will implement a more extensive set of BMPs that seek to answer the question of whether the maximum benefit to water quality has been achieved on Chumash Creek and also determine whether the water quality of Walters Creek can be improved beyond that of Chumash Creek.

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

The program made significant progress in data storage, management, and analysis. Ten years of photographs and field data were archived at the Regional Board. Data management was coordinated with the Central Coast Ambient Monitoring Program. Much of the water quality data for the NMP was entered into STORET previously. The expanded dataset will be entered as soon as "version two" of the software becomes available. The data generated as part of the project will be made available along with the NMP Final Report. Data handling was greatly improved and streamlined, data storage was provided for on a web site, and data analysis detected changes resulting from BMPs.

A Quality Assurance Project Plan, for project water quality sampling and analysis, was developed by the Central Coast Regional Water Quality Control Board. The plan was used to assure the reliability and accuracy of sampling, data recording, and analytical measurements. It is available at the Central Coast Regional Water Quality Control Board.

GIS data layers that have been entered (using ARC/INFO) include sample site locations, streams, flood zones, ground water basins, geology, soils, vegetation, land use, and topography. Data analysis indicated that Chumash and Walters Creek were well paired and that sufficient baseline data were collected.

Statisticians were added to the team during the last year and have performed additional detailed analysis of the storm water data. Initial analysis of data focused on determining minimum-detectable change and comparing even interval data results to event data. The data was examined in a variety of ways, including simple creek-to-creek regressions, regressions of flow-weighted pollutant parameters, double mass curves, regressions of flux- and time-weighted averages of event data, multiple +/- tests, non-parametric ranking, time-series plots, and flow-averaging.

Additional funding was obtained in FY 2000-02 to conduct further statistical analyses using the even-interval water quality data. In order to better understand the temporal relationships between the paired watersheds and the effectiveness of the BMPs, two regression models were developed. These include a repeated measures linear regression model and a repeated measures binary logistic model.

Final Results

Data analysis for the Morro Bay NMP project focused on evaluating the effectiveness of the range-land BMPs. Results indicate that water quality sampling has been effective at detecting improvements at various locations where BMPs were implemented.

Paired Watershed Study

Two subwatersheds in the Chorro Creek watershed, both on Cal Poly cattle rangelands, were selected for monitoring over a ten-year period. Chumash Creek watershed (400 acres) and Walters Creek watershed (480 acres) are as similar as possible in size, geomorphology, geology, soils, climate, vegetative cover, and land use. They share a common divide, and are managed as cattle rangeland.

Cal Poly owns the land encompassed by Walters and Chumash watersheds. Chumash and Walters Creeks run through Cal Poly's Escuela Ranch, which is a cow-calf operation with approximately 150 cows grazing both creeks' watersheds, plus Pennington Creek watershed (not included in the paired watershed study). The BMPs fell within four categories of rangeland management practices: livestock fencing and water development, streambank stabilization, road improvement, and grazing management. Numerous findings were documented as a result of implementing BMPS at the paired watersheds. If implementing BMPs improved water quality on an already well-managed land, then it would help improve water quality on other, more traditional ranches. These are summarized below.

Storm-event Flow and Water Quality Findings

Examination of paired hydrographs from 1995 through 2001 revealed interesting trends. In the period of 1995 through 1998, the timing of peak flow in Walters and Chumash was approximately equal. Beginning early in 1999, peak flow of Chumash lagged behind that of Walters, by 30 minutes to 1 hour. This was most noticeable early in each post-BMP season. We hypothesize this was due to increased interception of water by plants, and increased infiltration in the Chumash watershed, as vegetation increased on streambanks and in the watershed.

As of the 2000-01 season, the complete data set contained 82 events that included paired data on turbidity, and 80 events that included paired data on sediment. Significant declines in turbidity and sediment in Chumash Creek were found, as a result of implementing BMPs. Improvements have leveled off, or plateaued, beginning with the 1999-2000 sampling season. We hypothesize that the plateau occurred because fast-growing stream channel vegetation has reached its maximum protective affect, and slow-growing vegetation (such as sycamores and oaks) has not yet reached a stage of maturity where it is having a quantifiable affect on water quality.

Year-round Water Quality Findings

Results of even-interval water quality monitoring indicate that BMPs significantly lowered water temperature at Chumash Creek.

Fecal coliform bacteria did not improve at Chumash Creek post-BMP. The number of fecal coliform bacteria exceeding the threshold (200MPN) did not significantly change during the entire study period. This is possibly due to grazing practices in the upper Chumash watershed or an increase in birds and wildlife.

Nitrate exceeded the threshold value (0.300 mg/L) more often at Chumash Creek than at Walters Creek. The increase in nitrate-nitrogen at Chumash Creek was most notable in spring and summer and is thought to be indicative of early riparian succession.

Dissolved oxygen significantly decreased at Chumash Creek, but remained at a mean concentration of 8.15 PPM, and was less variable than in pre-BMP conditions. It should be noted that nitrate and dissolved oxygen values were still within the typical range of other creeks in the Morro Bay watershed.

Even-interval turbidity samples also exceeded a low threshold value (7 NTUs) more often at Chumash Creek than at Walters Creek post-BMP. This may be due to an increase in vegetation and algae at Chumash Creek year-round. Significant reductions in turbidity as a result of BMP implementation have been detected, however, in storm events data. It is expected that turbidity collected during storm events (rather than year-round) would be more likely to decrease as a result of BMPs, as most sediment is transported during storm events.

Rangeland Findings

Rangeland parameters in the paired watershed showed improvement, particularly bare ground and species diversity. Results were not statistically significant. The Cal Poly staff believes that if monitoring was to have been continued, or especially if pre-BMP monitoring had begun earlier, statistical verification of observations would have been achieved.

During the sixth year of monitoring, it was noted that the BMPs implemented in Chumash watershed seem to have resulted in an increase in residual vegetation that is harvested by cattle during the dry season. Supplemental feed costs have decreased, and we hypothesized that the grazing practices in Chumash watershed contributed to the increase in vegetation and decrease in supplemental feed costs.

Stream channel improvements were noted. These included proliferation of streambank and channel bottom herbaceous and woody vegetation, and healing of cattle trails and streambank erosion scars. The improvements were not systematically revealed by the Pfankuch monitoring method, but become strikingly apparent via photodocumentation, when pre-BMP photos are compared to post-BMP.

One of the most significant findings of a long-term study are the lesson's learned. As discussed, changes were detected due to BMP implementation at Chumash Creek, particularly significant reductions in sediment and turbidity during storm events and improvements in water temperature year-round. This is particularly meaningful because the Cal Poly ranches have been well-managed and get more rest than a typical working ranch. If implementing BMPs improved water quality on an already well-managed land, then it would help improve water quality on other, more traditional ranches. And, there are additional benefits to the system (such as more docile cattle, and more time for observation of health of the cows and calves). A preferred experimental design would have maintained two separate watersheds, with each containing its own identical, randomly selected herd of cattle, but this was not a part of the initial study design. In this design, supplemental feed would be differentially determined between watersheds, and the water quality and rangeland results would be more easily transferable to other ranches. Additionally, body condition scores of the cows could be estimated throughout the year, and impact of BMP implementation on seasonal forage availability would be determined empirically. Another limitation is that the original design of the study did not plan for determination of the effects of BMP implementation on productivity of the rangeland as it relates to grazing animals. Therefore, effects of the BMPs on feed costs were dampened by the increased availability of feed in all three of the watersheds. As forage availability increased in the Chumash (treatment) watershed, the energy availability increased in the remaining two watersheds as the cattle acquired a greater level of nutrient intake in each. These considerations are included in the future plans for evaluating improvements on Walters Creek.

Dairy Creek

Dairy Creek, tributary to Chorro Creek, runs through El Chorro Regional Park, and is the site of a cattle exclusion project. NRCS partnered with San Luis Obispo County Parks Department fencing and revegetating the mile long riparian corridor through the park. Improvements to the lower mile of creek were completed during the summer of 1994, with the remaining upper half-mile of creek fenced during the summer of 1995.

BMPs did not significantly affect air temperature, fecal coliform bacteria, nitrates, ortho-phosphates, and turbidity (10 NTUs). BMPs significantly improved water temperature dissolved oxygen and total coliform. Fecal coliform bacteria improved in samples taken at the DAU site when compared to the samples taken at the DAM site, possibly due to the gaps in the cattle exclusion fencing to provide water access to cattle.

Chorro Creek

Cattle exclusion fencing was installed along the riparian corridor of upper Chorro Creek in 1994. Chorro Creek Dam and Chorro Valley Culvert are the upper and lower sampling stations of a cattle exclusion area on the Camp San Luis Military Reservation.

Fecal coliform has significantly decreased at the BMP treatment site CVC as a result of BMP implementation. Water temperature and dissolved oxygen have also significantly improved post-BMP implementation at CVC. The significant reduction in fecal coliform at this BMP evaluation project is most likely due to the fact that there is no cattle access to the creek via water gaps or riparian pasture.

Maino Ranch

The Maino Ranch is located at the intersection of Highway one and San Bernardo Creek Road in the Morro Bay watershed. The Maino Ranch is a privately owned, 1850 acre ranch located in the Morro Bay watershed within San Luis Obispo County California.

Trends in vegetative species and water quality were detected from rangeland monitoring, but these findings may be more associated with natural phenomena such as soil properties or rainfall. Changes following the implementation of BMPs were observed by the land owner, John Maino, including an increase in biodiversity and in perennial vegetation.

Chorro Flats

Chorro Flats, located near the mouth of Chorro Creek, is the site of a floodplain restoration and sediment retention project and was acquired by the Coastal San Luis Resources Conservation

District. The project was completed during the summer of 1997. Where the creek was channeled and levied, the project reestablished an active floodplain, riparian corridor, and overflow channels. The majority of the creek flow is now using the newly created main channel.

Monitoring of Chorro Flats as part of the NMP project, included an upstream-downstream evaluation of water quality (suspended sediment and turbidity) including an even-interval and storm-event sampling regime, stream profiling, benthic macroinvertebrate analysis, and a qualitative evaluation of riparian and wetland re-establishment. The success of the event-based sampling was compromised by a lack of adequate flow data combined with sampling effectiveness in a high discharge stream, and the lack of a consistent relationship between the upstream and downstream stations.

The RCD efforts partially funded by another Clean Water Act Section 319 (h) grant to monitor the effectiveness of the sediment floodplain proved to be more successful. Results from the Chorro Flats Enhancement Project Final Report prepared for the Regional Board indicate that approximately 23% of the total load, and 85% of the bed-load, from Chorro Creek between 1992 and 1998 was captured on Chorro Flats. The current estimate for sediment load from the watershed is more than twice the estimate used in 1993. Based on the annual sediment load, and the 23% trapping efficiency, it is expected that the Chorro Flats site will fill in 26 years.

Watershed-Wide Characterization

In addition to the water quality data collected at the BMP evaluation sites, data was also collected from several other locations throughout the Chorro Creek and Los Osos Creek watersheds during 1993-2001. These sampling stations were used to collect watershed-wide data for use in targeting and prioritizing areas for BMP implementation and to monitor various projects that are already occurring throughout the watershed.

Elevated percent saturation, exceeding values indicative of supersaturated conditions were found at numerous sites. Additionally, elevated nitrate (NO_3^--N) and phosphate (PO_4^--P) concentrations were found throughout the watershed. Elevated fecal coliform concentrations were also found. Elevated turbidity levels were found, particularly during the high winter flow periods following the Highway-41 Fire. Mean concentrations, however, were typically low throughout the watershed. Index of Biological Integrity scores were evaluated throughout the watershed, and the least disturbed sites received higher scores than the more impacted sites.

The Friends of the Estuary's Volunteer Monitoring Program is continuing much of the watershed-wide water and habitat quality assessment as part of another 319 (h) grant with the assistance of the Morro Bay National Estuary Program. Implementation efforts are underway by numerous organizations in the watershed. These actions are expected to improve water and habitat quality conditions throughout the Morro Bay watershed.

Overall MBNMP Conclusions

Results of statistical analyses indicate significant positive changes in water quality, including decreased suspended sediment, decreased turbidity, decreased water temperature, stabilized levels of dissolved oxygen, and decreases in fecal coliform as a result of the BMPs implemented at different project sites. Rangeland characteristics such as forage species composition and production improved and supplemental feed costs appear to have decreased following BMP implementation.

These data provided a basis for Total Maximum Daily Load (TMDL) development and self-determined nonpoint source implementation in the watershed. The project provided baseline values to establish the framework for a local Volunteer Monitoring Program and a regionally-scaled ambient monitoring program. The Morro Bay NMP is part of a continued effort to evaluate long-term effects of BMP implementation on California rangelands and water quality.

PROJECT BUDGET

This NMP project was conducted as a partnership between the Regional Water Quality Control Board (RWQCB) and Cal Poly State University. The RWQCB evaluated the effectiveness of BMPs, through the collection and analysis of even interval water quality sampling data, habitat evaluations, stream channel profiles, and rapid bioassessment. The RWQCB subcontracted to California Polytechnic State University (Cal Poly), to measure water quality and streamflow during storm events, to document quality assurance of recorded vs. observed data, to compare data from Chumash and Walters Creeks, to conduct habitat sampling, and to maintain sampling and recording equipment. The estimated budget for the Morro Bay Watershed Section 319 National Monitoring Program project for the two-year period of FY00-02 is $100,000, with 50% of the funding allocated to the Regional Water Quality Control Board (RWQCB) and 50% to Cal Poly State University. Project management includes contract management, personnel, data analysis, interpretation, and reporting. Matching funds have been made available in the past through the Coastal Conservancy. For the duration of the project, Cal Poly acquired $120,000 in Agricultural Resource Initiative grant funds to extend data collection and analysis to 2002. Matching funds have also been provided by the Total Maximum Daily Load Program, the Morro Bay National Estuary Program, the Central Coast Ambient Monitoring Program, and from the RWQCB general laboratory funds.

The ten-year project received a total of 1,000,000 from Section 319 (h) funds, with additional matching state monies. The last year of funding for the project was used over a two year period in order to write up the final results. The final two-year budget for the Morro Bay Section 319 National Monitoring Program project for the period of 00-02 was as follows:

	Funding Source ($)		
Project Element	**Federal**	**State**	**Sum**
Project Management	37,859	28,198	66,048
Information & Education	13,541	7,979	21,520
Land Treatment	0	0	0
WQ Monitoring	48,600	61,468	110,068
TOTAL	$100,000	$97,635	$197,635

Source: Katie McNeill (Personal Communication), 2001.

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

The California Assembly Bill 640 became law in January, 1995. The law establishes Morro Bay as the first “State Estuary,” and mandates that a comprehensive management plan be developed for the bay and its watershed by locally involved agencies, organizations, and the general public.

On July 6, 1995, Morro Bay was accepted into the National Estuary Program (NEP). This “National Estuary” designation provides 1.3 million from USEPA dollars for planning over a three year period. Ongoing efforts have been made by the MBNEP to create the foundation for this “grass-roots” planning process. Stakeholders in the watershed have met continuously during the last several years to discuss pollution sources in the watershed and estuary and to explore management measures which could be implemented. A Comprehensive Conservation and Management Plan (CCMP) that identifies strategies for reducing pollutants such as sediment and bacteria was developed by MBNEP staff through input from numerous community and interested agencies in the watershed. A significant amount of funding ($4,000,000) was acquired for implementation of the CCMP. The Draft CCMP is currently undergoing public review and is expected to be revised and approved in early 2000. In addition to the USEPA 319 National Monitoring Program project being led by the California Central Coast Regional Water Quality Control Board, several other agencies are involved in various water quality activities in the watershed. The California Coastal Conservancy contracted with the Coastal San Luis Resource Conservation District in 1987 to inventory the sediment sources to the estuary, to quantify the rates of sedimentation, and to develop a watershed enhancement plan to address these problems. The Coastal Conservancy then provided $400,000 for cost share for BMP implementation by landowners. USDA funding was obtained for technical assistance in the watershed ($140,000/year), Cooperative Extension adult and youth watershed education programs ($100,000/year), and cost share for farmers and ranchers ($100,000/year) for five years. An NRCS range conservationist was hired with 319(h) funds ($163,000) to manage the range and farm land improvement program. The Coastal San Luis Resource Conservation District has developed a program titled Project Clear Water to assist ranchers and farmers in implemented BMPs on their property. Cooperative Extension received a grant to conduct detailed monitoring on a rangeland management project in the watershed. The California National Guard, a major landowner in the watershed, contracted with the NRCS ($40,000) to develop a management plan for grazing and road management on the base. State funding from the Coastal Conservancy and the Department of Transportation was used to purchase a $1.45 million parcel of agricultural land on Chorro Creek, just upstream of the Morro Bay delta, which was restored as a functioning flood plain. Additional lands have recently been acquired through the Department of Fish and Game, the Trust for Public Land, and the MBNEP. Without the cooperation of many of these agencies and their financial resources, the Section 319 project would be unable to implement BMPs or educate landowners about nonpoint source pollution.

The Central Coast Regional Water Quality Board conducted a study of the abandoned mines in the watershed with USEPA 205(j) funds. The Board also obtained a USEPA Near Coastal Waters grant to develop a watershed work plan, incorporate new USEPA nonpoint source management measures into an overall basin plan, and develop guidance packages for the various agencies charged with responsibility for water quality in the watershed.

The Department of Fish and Game Wildlife Conservation Board provided funding ($48,000) for steelhead habitat enhancement on portions of Chorro Creek. The State Department of Parks and Recreation funded studies on exotic plant invasions in the delta as a result of sedimentation. The California Coastal Commission used Morro Bay as a model watershed in development of a pilot study for a nonpoint source management plan pursuant to Section 6217 of the Federal Coastal Zone Management Act Reauthorization Amendments of 1990.

The Friends of the Estuary at Morro Bay, working in conjunction with the Morro Bay National Estuary Program received a 319 (h) grant from the State Water Resources Control Board to continue the Volunteer Monitoring Program. The volunteer monitors have been collecting water quality and habitat data at established NMP sites since Fall, 2001.

Waterbodies within the Morro Bay watershed are listed as "impaired" by sediment, nutrients, organics, and bacteria. As such, Total Maximum Daily Loads (TMDLs) are required to identify the sources, determine the loading capacity of the waterbodies, and reduce pollutant loading so that beneficial uses are protected. NMP data have been used to develop Total Maximum Daily Loads for Chorro Creek, Los Osos Creek, and the Morro Bay estuary. TMDLs for sediment and bacteria have recently been adopted, and efforts to develop TMDLs for nutrients and organics are currently underway.

OTHER PERTINENT INFORMATION

In addition to state and federal support, the Morro Bay watershed receives tremendous support from local citizen groups. The Friends of the Estuary, a citizen advocacy group, is invaluable in its political support of Morro Bay. The Bay Foundation, a nonprofit group dedicated to Bay research, funded a $45,000 study on the freshwater influences on Morro Bay, developed a library collection on the Bay and watershed at the local community college, and is actively cooperating with the Morro Bay Section 319 National Monitoring Program project to develop a watershed GIS database. The Bay Foundation also recently purchased satellite photographs of the watershed, which will prove useful for long-term restoration efforts. The Bay Foundation co-wrote the nomination to the National Estuary Program along with the Regional Board. The National Estuary Program just completed four Technical Studies that heavily utilized data collected by the National Monitoring Program to develop several pollutant loading and tidal circulation models. The National Estuary Program, Friends of the Estuary, and the Bay Foundation of Morro Bay are cooperating to implement a volunteer monitoring program for the Bay itself. Ongoing volunteer efforts that have been invaluable for the National Monitoring Program include water quality and habitat monitoring.

PROJECT CONTACTS

Morro Bay NMP project website: *http://www.swrcb.ca.gov/rwqcb3/WMI/MorroBay/*

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Connecticut

Jordan Cove Urban Watershed
Section 319
National Monitoring Program Project

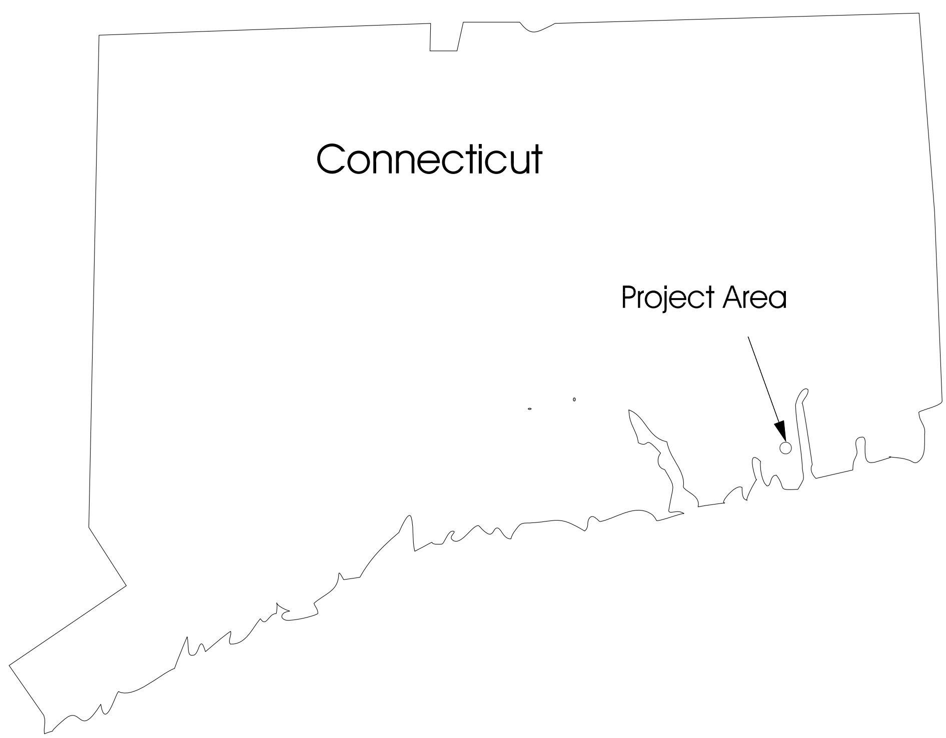
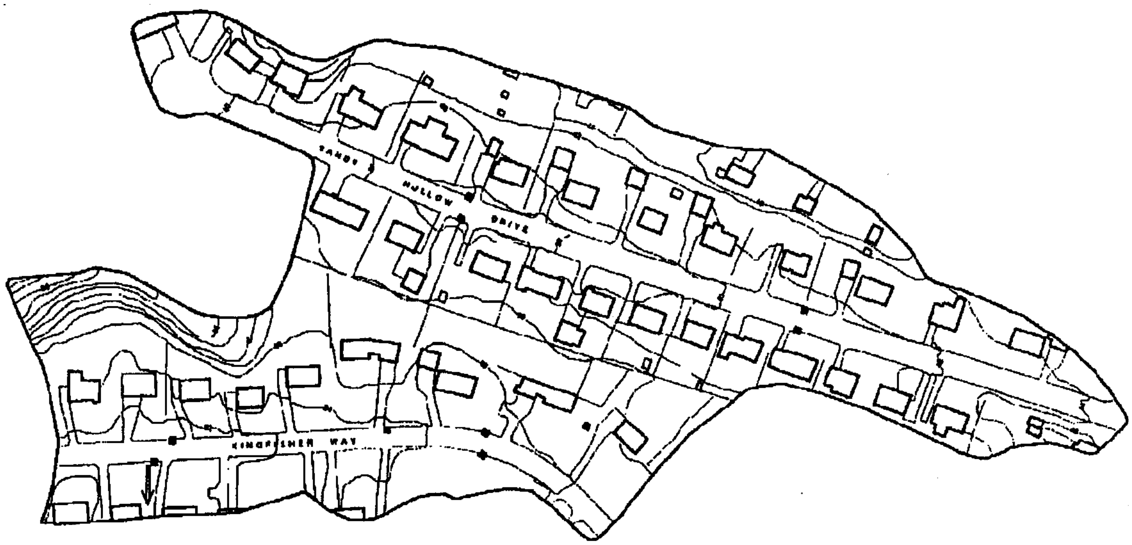
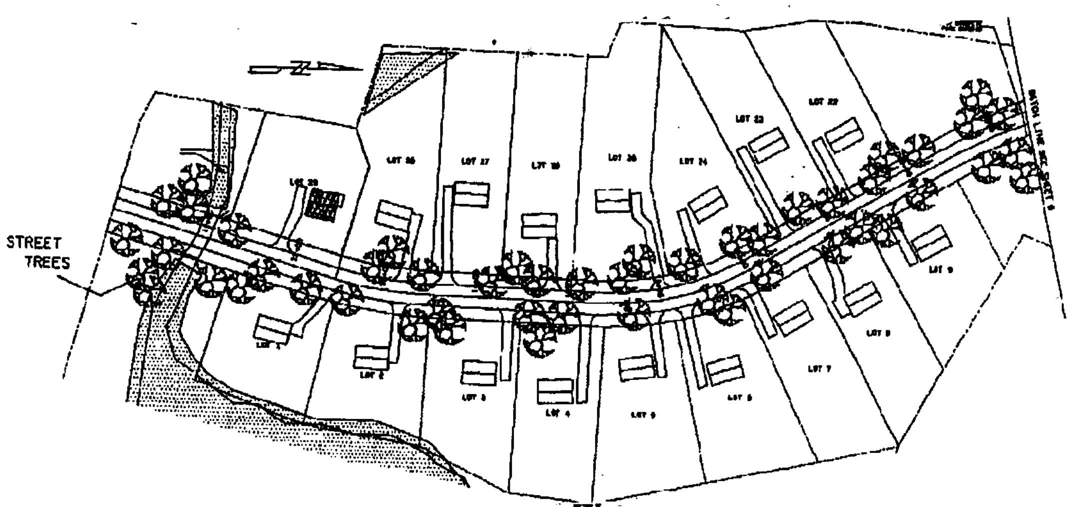


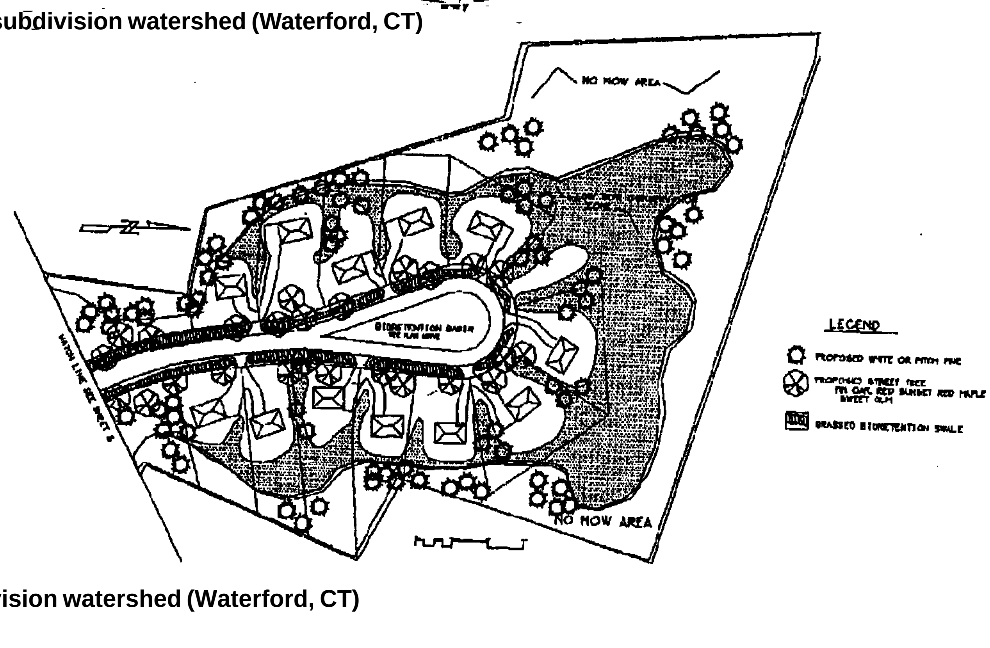
Figure 7: Jordan Cove Urban Watershed (Connecticut) Project Location



Existing residential control watershed with contours (Waterford, CT)



Traditional subdivision watershed (Waterford, CT)



BMP subdivision watershed (Waterford, CT)

Figure 8: Water Quality Monitoring Stations for Jordan Cove Urban Watershed (Connecticut)

PROJECT OVERVIEW

The Jordan Cove watershed is located along the north or Connecticut side of the Long Island Sound (Figure 7). Jordan Cove is a small estuary fed by Jordan Brook; the estuary empties into Long Island Sound. Water quality sampling had indicated that the Cove did not meet bacteriological standards for shellfish growing and sediment sampling had revealed high concentrations (>20 ppm) of arsenic. Also, short-term monitoring of bottom waters had documented depressed levels of dissolved oxygen.

Land use in the 4,846-acre Jordan Brook watershed is mostly forests and wetlands (74%) along with some urban (19%), and agricultural (7%) uses. The project was located in a residential section of the watershed. The project plan was to develop a 10.6-acre area following traditional subdivision requirements and another 6.9-acre area of housing using best management practices (BMPs).A third drainage area consisting of 43 lots on 13.9 acres, which was developed in 1988, was used as a control.

The project incorporated the paired watershed monitoring design for the three study areas. Monitoring included precipitation, air temperature, and grab and storm-event sampling for solids, nutrients, metals, fecal coliform, and biochemical oxygen demand (BOD).Additionally, monitoring of selected individual BMPs was conducted.

The 10-year project is completed. Monitoring concluded in June 2005. The 2007 Final Report is on the web: http://www.jordancove.uconn.edu/jordan_cove/publications/final_report.pdf.

PROJECT BACKGROUND

Project Area

The project was located within the Town of Waterford, CT near Long Island Sound. The two developments designated as treatment watersheds together covered about 17.5 acres and the residential control watershed was approximately 13.9 acres.

Relevant Hydrological, Geological, and Meteorologic Factors

The average annual precipitation was 49.8 inches, including 35 inches of snowfall. Soils on the study areas were mapped as Canton and Charlton, which are well-drained soils (hydrologic soil group B). The surficial geology is glacial till and stratified drift. Bedrock is composed of gneiss originating from Avelonia. Bedrock is typically at a depth greater than 60 inches and the water table is located below six feet.

Land Use

Land use in the area to be developed using traditional requirements was poultry farming; the area designated for development using BMPs was a closed-out gravel pit. The control drainage area of 13.9 acres had 43 residential lots, ranging in size from 15,000 square feet to 20,000 square feet, which were developed in 1988. The traditional watershed had 15 developed 0.3 acre lots. The BMP watershed had 12 developed lots. Imperviousness in the traditional watershed increased from 4 to 11%.

Water Resource Type and Size

Water resources of concern were Jordan Brook, Jordan Cove estuary, and Long Island Sound. The cove is a long and narrow estuary consisting of a 390-acre inner cove and an 100-acre outer cove. Because the project sampled only overland runoff, no water resource was monitored.

Water Uses and Impairments

The Jordan Cove estuary did not meet bacteriological standards for shellfish growing. Sediment sampling had revealed high concentrations (>20 ppm) of arsenic.

Pollutant Sources

Primary pollutant sources were construction and later urban runoff from residences.

Pre-Project Water Quality

Semi-annual sampling at eight locations along Jordan Brook had documented average concentrations of total phosphorus less than 0.03 mg/l and nitrate less than 1 mg/l.Water samples from inner Jordan Cove have had fecal coliform counts with a geometric mean ranging from 26 to 154 cfu/100ml.

Water Quality Objectives

Retain sediment on site during construction and reduce nitrogen, bacteria, and phosphorus export by 65, 85, and 40 percent, respectively. Maintain post-development runoff peak rate and volume and total suspended solids load to pre-development levels.

Project Time Frame

1996 to 2005

PROJECT DESIGN

Nonpoint Source Control Strategy

The management practices were applied to the BMP treatment drainage area only and varied with two time phases. The first phase was during construction (18 months). During this phase, nonstructural practices such as phased grading, immediate seeding of stockpiled topsoil, maintenance of a vegetated open space perimeter, and immediate temporary seeding of proposed lawn areas and structural practices, including sediment detention basins and sediment detention swales, was employed.

Post-construction practices included implementation of fertilizer and pesticide management plans, animal (pets) waste management, and plant waste pick-up. Structural practices such as grassed swales, detention basins, roof runoff rain gardens, pervious access road and driveways, and the minimization of impervious surfaces were used. The goal was to implement BMPs on 100% of the lots in the BMP study area.

Project Schedule

Site	Calibration	Construction	Post-Construction
BMP	1/96-3/99	3/99-8/02	8/02-6/05
Traditional	8/96-10/97	10/97-6/03	6/03-6/05
Control	11/95	N/A	

Water Quality Monitoring

The study design was the paired watershed approach using one control and two treatment watersheds. The calibration period was about two years, during which time land use management remained unchanged. The treatment period included two phases: an 18-month construction phase and a long-term post implementation monitoring phase.

Variables Measured

Biological

Fecal coliform (FC)

Chemical and Other

Total suspended solids (TSS)
Total phosphorus (TP)
Total Kjeldahl nitrogen (TKN)
Ammonia (NH_3)
Nitrate + nitrite (NO_3 + NO_2)
Biochemical oxygen demand (BOD)
Copper (Cu), lead (Pb), and zinc (Zn)

Covariates

Runoff
Precipitation
Air temperature

Sampling Scheme

Flow-weighted composite samples were collected during storm-events and analyzed for solids and nutrients. Bacteria and BOD analyses were conducted on grab samples collected manually when flow was occurring during weekly visits to the site. Portions of storm samples were saved and combined into a monthly composite sample that were analyzed for metals.

Monitoring Scheme for the Jordan Cove Urban Watershed 319 National Monitoring Program Project

Design	Sites or Activities	Primary Parameters	Covariates	Frequency of WQ Sampling	Frequency of Habitat/Biological Assessment	Duration
Paired	BMP watershed	TSS	Rainfall	Storm-event		2-3 yr calibration
	Traditional watershed	TP	Air temperature			3-5 yr construction
	Control watershed	TKN	Runoff			3 yr post-BMP
		NH_3				
		NO_3+NO_2				

Land Treatment Monitoring

In addition to annual household surveys, weekly observations were made of earth-moving and construction activities in the traditional and BMP watersheds.

Modifications Since Project Start

In August 1996, Monitoring Station 544 at the traditional site was abandoned and replaced with Monitoring Station 545 at a different location at the site. This resulted from the concern that water quality at the old station location (Sta. 544) may be contaminated with high organic nitrogen and total phosphorus associated with past chicken house cleaning practices. In May 1998, the station was moved again to sample exports from the traditional site which now largely leave via a paved street. The new station sampled the stormwater sewer For 2 months in Spring 1998, monitoring was halted in the traditional watershed as the station was connected to the stormwater sewer which was being constructed at the same time. The BMP station was bermed off in June through July 1999 and received no flow.

Progress to Date

Tradition Watershed: Construction was complete in the traditional watershed.

BMP Watershed: BMPs installed during construction included earthen berms, temporary seeding, bioretention cul-de-sac, swales, and access road using pervious concrete pavers. Twelve homes with residential rain gardens were constructed. Two replicates of three driveway types were constructed and monitored. The three driveway treatments were asphalt, concrete paver, and crushed stone. Water quality monitoring was completed June 2005.

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

Quarterly and annual reports were prepared and submitted according to Section 319 National Monitoring Program procedures.

NPSMS Data Summary

STATION TYPE: CONTROL/504 **STUDY TYPE:** Paired

CHEMICAL PARAMETERS

Season Parameter Name	QUARTILE VALUES -75-	-50-	-25-		Counts/ 1997	1998
BOD (MG/L)	6.4	2.0	1.7	Highest		
				High	1	2
				Low		
				Lowest	1	2
NITROGEN, AMMONIA, TOTAL (MG/L)	.47	.19	.06	Highest	21	15
				High	6	6
				Low	7	4
				Lowest	1	7
NITROGEN, KJELDAHL, TOTAL (MG/L)	1.9	1.2	.6	Highest	10	15
				High	9	6
				Low	13	5
				Lowest	2	5
PHOSPHORUS, TOTAL (MG/L)	.353	.183	.103	Highest	8	6
				High	4	7
				Low	4	8
				Lowest	18	10
FECAL COLIFORM (CFU/100ML)	110	37	4	Highest	1	1
				High		
				Low	1	1
				Lowest		
COPPER, TOTAL (MG/L)	.018	.011	.006	Highest	2	2

				High	1	6
				Low	4	4
				Lowest	5	0
LEAD, TOTAL (MG/L)	.013	.009	.005	Highest	1	2
				High	3	5
				Low	2	1
				Lowest	6	4
ZINC, TOTAL (MG/L)	.061	.035	.013	Highest	4	7
				High	3	5
				Low	2	
				Lowest	3	
NITRATE + NITRATE (MG/L)	.5	.3	.1	Highest	23	12
				High	13	4
				Low		8
				Lowest		10
TOTAL SUSPENDED SOLIDS (MG/L)	67.2	29.5	12.0	Highest	6	7
				High	4	7
				Low	11	11
				Lowest	10	9

STATION TYPE: TRADITIONAL/545

CHEMICAL PARAMETERS

Season Parameter Name	QUARTILE VALUES -75-	-50-	-25-		Counts/ 1997	1998
BOD (MG/L)				Highest		
				High		
				Low		
				Lowest		
NITROGEN, AMMONIA, TOTAL (MG/L)	.26	.15	.03	Highest	2	6
				High		3
				Low		8
				Lowest		2
NITROGEN, KJELDAHL, TOTAL (MG/L)	7.2	5.7	4.6	Highest		
				High		
				Low	1	1
				Lowest		19
PHOSPHORUS, TOTAL (MG/L)	3.288	2.902	1.461	Highest		
				High		1
				Low	1	2
				Lowest	1	17
FECAL COLIFORM (CFU/100ML)				Highest		
				High		
				Low		
				Lowest		
COPPER, TOTAL (MG/L)	.034	.018	.011	Highest		2
				High		3
				Low		1
				Lowest	2	1
LEAD, TOTAL (MG/L)	.035	.023	.013	Highest		
				High	1	3
				Low		2
				Lowest	1	2
ZINC, TOTAL (MG/L)	.100	.090	.077	Highest		5
				High		
				Low		
				Lowest	2	2
NITRATE + NITRATE (MG/L)	.32	.17	.1	Highest	1	18
				High		
				Low		
				Lowest	1	1
TOTAL SUSPENDED SOLIDS (MG/L)	353	257	93	Highest		4
				High		1
				Low		4
				Lowest	1	11

STATION TYPE: BMP/537 **STUDY TYPE:** Paired

CHEMICAL PARAMETERS

Season Parameter Name	QUARTILE VALUES -75-	-50-	-25-		Counts/ 1997	1998
BOD, (MG/L)				Highest	2	0
				High		2

				Low		2
				Lowest		3
NITROGEN, AMMONIA,TOTAL (MG/L)	.36	.10	.005	Highest	10	5
				High	7	0
				Low	8	6
				Lowest		11
NITROGEN, KJELDAHL,TOTAL (MG/L)	1.85	.70	.40	Highest	2	6
				High	12	10
				Low	10	3
				Lowest		3
PHOSPHORUS, TOTAL (MG/L)	.093	.025	.009	Highest	6	2
				High	3	11
				Low	9	6
				Lowest	6	3
FECAL COLIFORM (CFU/100ML)	330	20	7	Highest	2	1
				High		3
				Low		
				Lowest		1
COPPER, TOTAL (MG/L)	.013	.009	.003	Highest	1	
				High	1	4
				Low	7	2
				Lowest		
LEAD, TOTAL (MG/L)	.006	.004	.003	Highest	1	2
				High		1
				Low	1	
				Lowest	7	3
ZINC, TOTAL (MG/L)	.074	.044	.034	Highest	2	4
				High	2	1
				Low	1	1
				Lowest	4	
NITRATE + NITRA TE (MG/L)	.4	.2	.1	Highest	13	2
				High	5	2
				Low	4	5
				Lowest	2	13
TOTAL SUSPENDED SOLID (MG/L)	8.9	5	3	Highest	5	3
				High	7	5
				Low	1	5
				Lowest	12	9

Final Results

Calibration Period

Concentrations of pollutants in runoff from the existing residential control were somewhat lower when compared to event mean concentrations from the Nationwide Urban Runoff Program. Runoff from the BMP site exhibited lower concentrations of most water quality variables than the control site.

Calibration for flow were conducted between the control and BMP watershed. In order to develop the regression between runoff from the two sites, hydrograph separation of stormflow and baseflow was necessary for the BMP site due to the ground water inputs. The regression between the two sites was significant ($F=83.0$, $p=<0.001$, $R^2=0.62$). The median runoff from the existing residential control was about 10 times that from the BMP site. Significant ($p=0.05$) calibration regressions were established for TSS, TP, BOD, FC, Cu, and Pb concentrations; and the mass export of NH_3, TKN, TSS, and TP. Calibration of the control and traditional sites has been completed.

Construction Period

During the construction period on the traditional watershed, no samples were collected until May 1998 even though the construction period began October 1997. The lack of runoff occurred because construction activities, including silt fence installation, divided the watershed into smaller pieces.

In the traditional watershed, weekly flow (34,930%) and peak discharge significantly ($p<0.05$) increased due to land development. Concentrations of TKN decreased 63% and TP increased 51% ($p<0.05$). TSS, nitrate, ammonia, copper, lead, and zinc concentrations did not change. Mass export (kg/ha/yr) increased for NO_3-N (7,525%), NH_3-N (1,958%), TKN (6,928%), TP (9,914%), and TSS

(11,620%) ($p<0.05$) in accord with the increases of flow . Export of copper (19,412%), lead (3,644%), and zinc (7,208%) also increased ($p<0.05$) during the construction period. These results suggest that hydrologic response, rather than erosion and sediment, is the cause of increased pollutant export from this construction site. Changes in geomorphic land forms likely influenced the hydrologic response at this site.

In the BMP watershed during construction weekly stormflow decreased ($p<0.05$) by 97% and peak discharge also decreased. The earthen berm, basement excavations and permeable fill all contributed to the runoff. However, concentrations of TSS (1,575%), TP (3,870%), NH_3-N (414%), TKN (256%) increased ($p<0.05$) in runoff. The mass export (kg/ha/yr) of TSS and TP also increased. Fertilization influenced N and P results. Time plots suggest that activities early in the construction period produced peak concentrations of TSS, N and P.

The results suggest a trade-off between traditional construction practices and low-impact development (LID). Stormflow increased during traditional construction but decreased during LID construction. However, increased erosion and nutrient concentrations occurred during LID construction, as compared to traditional construction, perhaps due to the lack of an impervious road.

Post-Construction Period

BMP Watershed: The volume of stormwater runoff from the BMP Watershed decreased during the construction period and continued to decrease by 74% during the post-construction period. Peak flow did not change significantly from predevelopment conditions which was a goal. During the post-construction period, the peak discharge actually declined by 27% based on the calibration prediction. Following construction, TSS, TP, NO_3 and TKN concentrations were higher than predicted by calibration. Exports generally declined in the post-construction period, except for TP and TSS which increased. Metals export declined following construction.

Traditional Watershed: The volume of stormwater runoff increased 600 times during the post-construction period; peak discharge increased 30 times. Concentrations of TKN, TP, TSS and BOD have all declined compared to calibration but mass exports of all pollutants have increased from 65 to 76,361% depending on the pollutant, except Pb.

Driveway Study

Stormwater runoff was significantly different among each driveway type; the order of decreasing runoff was asphalt>paver>stone. Average infiltration rates were 0, 11.2 and 9.0 cm/hr fro asphalt, paver, and crushed stone driveways, respectively. Both paver and crushed stone driveways reduced stormwater runoff as compared to asphalt driveways. Runoff from paver driveways contained significantly lower concentrations of all pollutants measured than runoff from asphalt driveways. However, runoff from crushed stone driveways was similar in concentrations to runof from asphalt driveways, except for TP concentrations, which were lower in runoff from crushed stone driveways than runoff from asphalt driveways. The mass export of measured pollutants followed the relative differences in stormwater runoff, rather than differences in concentrations.

Lawn Nutrient Study

NO_3-N desorbed from AEM strips, soil water NO_3-N concentrations and plant reflectance all indicate that the BMP lawns being monitored have lower values than the non-BMP lawns. Soil P concentrations in the BMP watershed were ranked medium during the study.

Household Survey

The survey of residents in the three watersheds revealed little differences among their behaviors. BMP residents mulch their leaves and mow their own lawns compared to the control watershed. No differences in fertilizer habits were observed. There were also no differences in behaviors across years within each watershed.

Conclusions and Recommendations

The BMPs used were able to keep runoff volume and peak at predevelopment levels, which was a project goal. Reduced N and P export goals were also met but TSS export goals were not met. For future projects, cluster designs, LID-based regulations and stormwater disconnects are recommended. Future construction projects should control compaction, maximize undisturbed soils, and use on-site supervision. Earthen berms were an effective BMP. Sediment control for swales and following soil test recommendations are important. Following construction, maintenance of bioretention areas, infiltrating pavers, turf dams, and appropriate grass mixes is needed. Further study is needed of groundwater effects, behavioral social indicators, the economics of LID, and soil testing.

INFORMATION, EDUCATION, AND PUBLICITY

Each household in the three study watersheds were surveyed annually for the purpose of obtaining survey information related to factors influencing nutrient and bacteria losses. Interaction during these visits helped answer questions about residents' habits that affect nutrient and bacteria deposition and educated residents about reducing nonpoint source pollution.

TOTAL PROJECT BUDGET

The estimated budget for several elements of the Jordan Cove Urban Watershed National Monitoring Program project for the life of the project was:

Project Element	Funding Source ($)			
	Federal	State	Local	Sum
Proj Mgt	48,400	NA	6,600	55,000
I & E	NA	NA	NA	NA
L T	151,882	NA	106,675	258,557
WQ Monit	779,718	540,058	NA	1,319,776
TOTALS	980,000	540,058	113,275	1,633,333

Source: Jack Clausen, Personal Communication (2007)

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

Unknown.

OTHER PERTINENT INFORMATION

None.

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Idaho

Eastern Snake River Plain
Section 319
National Monitoring Program Project

Figure 9: Eastern Snake River Plain (Idaho) Demonstration Project Area Location

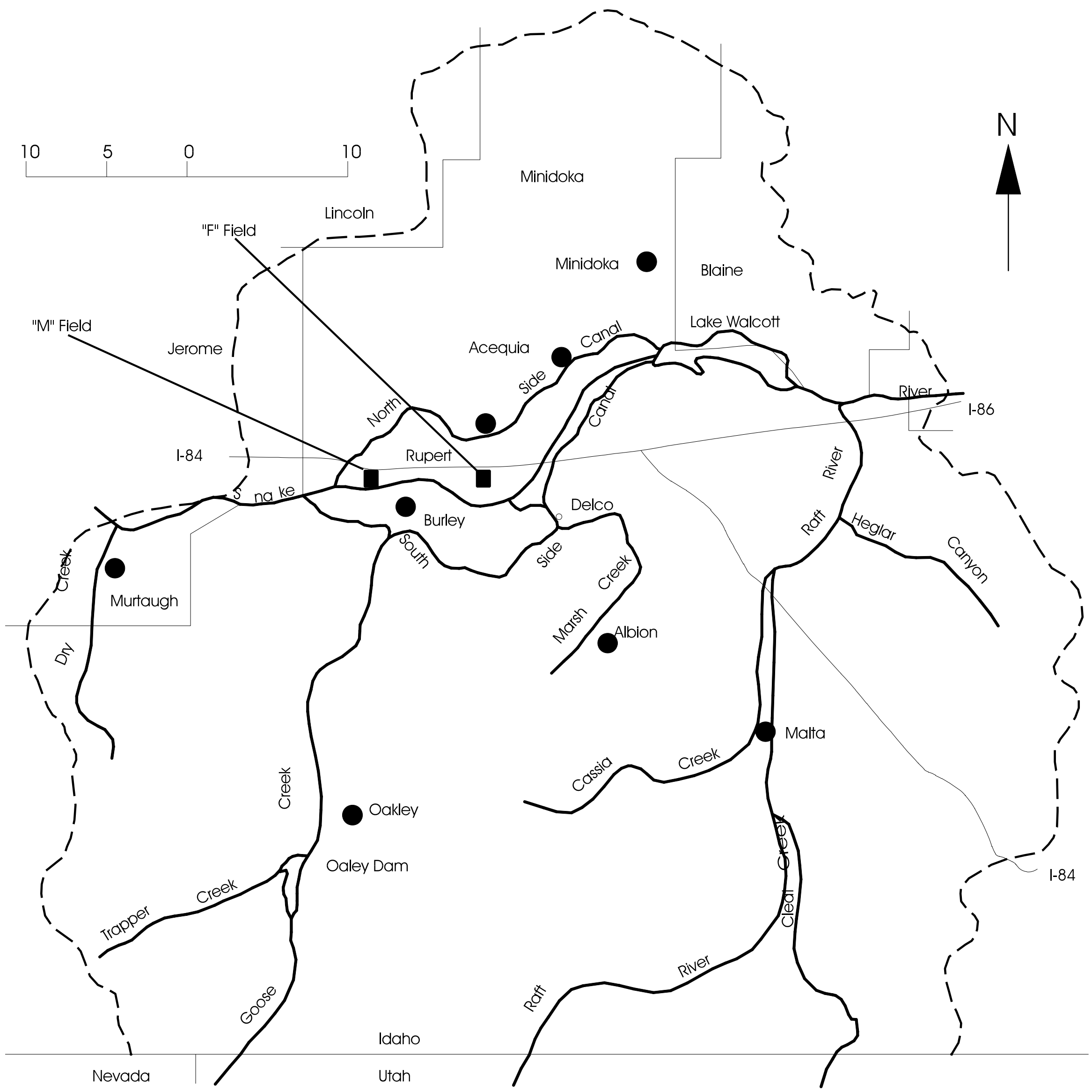

Figure 10: Eastern Snake River Plain (Idaho) USDA Demonstration Project Area

PROJECT OVERVIEW

The Idaho Eastern Snake River Plain is located in south-central Idaho in an area dominated by irrigated agricultural land (Figure 9). The Eastern Snake River Plain aquifer system, which provided much of the drinking water for approximately 40,000 people living in the project area, underlies about 9,600 square miles of basaltic desert terrain. The aquifer also serves as an important source of irrigation water. In 1990, this aquifer was designated by the U.S. Environmental Protection Agency (USEPA) as a sole source aquifer.

The objective of a seven-year United States Department of Agriculture (USDA) Demonstration Project within the Eastern Snake River Plain (1,946,700 acres) (Figure 10) was to reduce adverse agricultural impacts on ground water quality through coordinated implementation of nutrient and irrigation water management. As part of the project, two paired-field monitoring networks (constructed to evaluate best management practices (BMPs) for nutrient and irrigation water management effects) were funded under Section 319 of the Clean Water Act.

The monitoring portion of the project has been completed. Data analysis and findings have been completed. The project has been terminated as of 1999.

PROJECT BACKGROUND

Project Area

The USDA Demonstration Project encompasses over 1,946,000 acres. The ground water quality monitoring activities are limited to a 30,000-acre area of south Minidoka County. The 319 National Monitoring Program project consists of two sets of paired five-acre plots (a total of four five-acre plots) located in this 30,000-acre area (Fields “M” and “F,” see Figure 10). The paired fields were located in the eastern and western portions of the area to illustrate BMP effects in differing soil textures. The “M” field soils are silty loams. The “F” field soils are fairly clean, fine to medium sands. Due to the differences in soils and the traditional irrigation methods employed on these fields (flood on “M” and furrow on “F”), the “M” field has a relatively lower spatial variability of existing water quality than the “F” field. The “F” field also shows greater influences of water and nutrient movement from adjacent fields.

Relevant Hydrologic, Geologic, and Meteorologic Factors

The average annual rainfall is between 8 and 12 inches. Soils in the demonstration area have been formed as a result of wind and water deposition. Stratified loamy alluvial deposits and sandy wind deposits cover a permeable layer of basalt. These soils are predominantly level, moderately deep, and well drained.

Shallow and deep water aquifers are found within the project area. Both study fields are situated over shallow aquifers that extend from a depth of about 3 - 7 feet below the land surface to as much as 25 - 35 feet below the land surface.

Land Use

Within the 30,000 acre monitored area, 99% of the land is irrigated. Local irrigation systems vary from the historical practice of flood irrigation to more modern techniques of sprinkler irrigation. Of the irrigated cropland, at least 85% is in sprinkler irrigation and the remaining 15% is in furrow. A diversity of crops are grown in the area: beans, wheat, barley, potatoes, sugar beets, alfalfa, and commercial seed. Confined animal feeding operations (CAFOs) are also located in the project area.

Water Resource Type and Size

In the intensely irrigated areas overlying the Eastern Snake River Plain aquifer, shallow, unconfined ground water systems have developed primarily from irrigation water recharge. Domestic water is often supplied by the shallow systems. Within the project area, the general flow direction of the shallow ground water system is toward the north from the river; however, localized flow patterns due to irrigation practices and pumping effects are very common. This ground water system is very vulnerable to contamination because of the 1) proximity of the shallow system to ground surface, 2) intensive land use overlying the system, and 3) dominant recharge source (irrigation water) of the ground water.

Water Uses and Impairments

Many diverse crops are produced throughout the Eastern Snake River Plain region. Excessive irrigation, a common practice in the area, creates the potential for nitrate and pesticide leaching and/or runoff. Irrigation return flows drain to local creeks which dissect the area. Ground water monitoring indicates the presence of elevated nitrate levels in the shallow aquifer underlying the project area.

As far back as 1938, elevated nitrate concentrations were documented in the deep regional ground water system underlying the county. Ground water nitrate concentrations exceeding the EPA drinking water standard began to be reported in the 1980s. Increasing trends in ground water nitrate concentrations in shallow ground water were observed from 1985 to 1995. Elevated nitrate concentrations in the ground water impairs the use of the shallow aquifer as a source of drinking water. Low-level pesticide concentrations in the ground water have been detected in domestic wells and are of concern in the project area. Both nitrate and potential pesticide concentrations threaten the present and future use of the aquifer system for domestic water use.

Pollutant Sources

Within the USDA project area, there are over 1,500 farms with an average size of 520 acres. Nutrient addition to irrigated crops is intensive. A 1990 USGS study estimated that 93 percent of N inputs in the Snake River Basin come from livestock manure, fertilizer, and legume crops. Heavy nitrogen application and excessive irrigation are the primary causes of water quality problems in the shallow aquifer system. In addition, over 80 different agrochemicals have been used within the project area. Excessive irrigation may cause some leaching of these pesticides into ground water (Idaho Eastern Snake River Plain Water Quality Demonstration Project, 1991).

Pre-Project Water Quality

Ground water data collected and analyzed within the project area indicate the widespread occurrence of nitrate concentrations that exceed state and federal drinking water standards. In a study conducted from May through October 1991, 195 samples taken from 54 area wells were analyzed for nitrate. Average nitrate concentrations were around 6.5 milligrams per liter (mg/l), with a maximum of 28 mg/l. The federal Maximum Contaminant Level (MCL) for nitrate concentrations of 10 mg/l was exceeded in 16 % of the wells at least once during the sampling period. Five percent of the wells yielded samples that continuously exceeded the MCL during the sampling period.

Ninety-eight samples collected from the same 54 wells were analyzed for the presence of 107 pesticide compounds. Fourteen of the 54 wells yielded samples with at least one detectable pesticide present, but all concentrations measured were below the federal Safe Drinking Water MCL or Health Advisory for that compound. Even though the well water currently meets MCL standards, pesticide concentrations are still believed to be a future concern for the Eastern Snake River Plain Aquifer.

Water Quality Objectives

The overall USDA Demonstration Project objective was to decrease nitrate and pesticide concentrations through the adoption of BMPs on agricultural lands.

Specific project objectives for the USEPA 319 National Monitoring Program project were to:

- Evaluate the effects of irrigation water management on nitrate-nitrogen leaching to a shallow unconfined aquifer. A paired-field study, referred to as “M” (Figure 10), will allow a comparison of ground water quality conditions between two sprinkler irrigation set durations; 24-hour control and 12-hour “BMP.”
- Evaluate the effects of crop rotation on nitrate-nitrogen leaching to a shallow unconfined aquifer. A paired-field study, referred to as “F” (Figure 10), will allow a comparison of the amount of nitrogen leached to ground water as a result of growing beans after alfalfa, a practice that generates nitrogen, and the amount of nitrogen leached to ground water as a result of growing grain after alfalfa, a practice that utilizes excess nitrogen in the soil.

Source: James Osiensky (Personal communication), 1993; Osiensky, J.L. et al. 1993. Ground Water Monitoring Technical Completion Report. Dept. of Geological Sciences, U. of Idaho, Moscow, ID.

Project Time Frame

October 1991 to October 1998

PROJECT DESIGN

Nonpoint Source Control Strategy

The 319 NMP project took place within a larger Idaho Snake River Plain USDA Demonstration Project. The nonpoint source control strategy for the USDA Demonstration Project focused on nitrogen, pesticide, and irrigation water management practices that will reduce the amount of nutrients and pesticides reaching surface water and leaching into the ground water. BMP strategies in the Demo project included fertilizer management, pesticide management, and irrigation water management.

The nonpoint source control strategy for the 319 National Monitoring Program project focused on evaluating BMPs on two test fields.

- The BMP implemented on the "F" field consisted of nutrient management through crop rotation; half of the field continued a traditional alfalfa-beans rotation, while the treatment half initiated a USDA-recommended alfalfa-grain rotation.
- The BMP implemented on the "M" field consisted of nutrient management through reduced irrigation water application, promoting increased nutrient residence time in the soil.

Project Schedule

Site	Pre-BMP Monitoring	BMP Installation	Post-BMP Monitoring
Forgeon Field	1995-1996	5/97	6/97-1998
Moncur Field	1992-4/96	5/96	6/96-1998

Water Quality Monitoring

The 319 National Monitoring Program portion of the USDA Demonstration Project incorporated two paired-field networks consisting of a total of 24 constructed wells. Of the 12 wells on each paired field, 8 wells were centrally located "permanent" wells and 4 were peripheral "temporary" wells. Wells were installed to a depth of 11 feet and extended 4 to 6 feet below the seasonal water table.

Variables Measured

Biological

None

Chemical and Other

Nitrate (NO3)
pH
Temperature
Conductivity
Dissolved oxygen (DO)
Total dissolved solids (TDS)
Total Kjeldahl nitrogen (TKN) and Ammonium (NH+4)
Organic scans for pesticide

Covariates

Precipitation
Crop
Soil texture
Nutrient content of the irrigation water

Monitoring Scheme for the Eastern Snake River Plain Section 319 National Monitoring Program Project

Design	Site	Primary Parameters	Covariates	Frequency of WQ Sampling	Duration
Paired field	"M" field	NO_3 pH Temperature Conductivity DO TDS TKN NH^+_4 Pesticides	Precipitation Irrigation water amt. Nutrient content of the irrigation water Water table elev Soil texture Crop	Monthly for primary pollutants except Pesticides (sampled) and Nitrogen (quarterly)	4 yrs pre-BMP 1 yr BMP 2 yrs post-BMP semiannually)
Paired field	"F" field	NO_3 pH Temperature Conductivity DO TDS TKN NH^+_4 Pesticides	Precipitation Irrigation water amt. Nutrient content of the irrigation water Water table elev Soil texture Crop		4 yrs pre-BMP 1 yr BMP 2 yrs post-BMP

Sampling Scheme

A number of covariate monitoring activities have been undertaken by some of the other agencies participating in the project. In addition, vadose zone suction lysimeters were used to monitor NO3 transport. Well monitoring consisted of monthly grab samples. Chemical and other parameters were analyzed monthly, except for NH+4 and TKN, which were analyzed quarterly, and organics, which were analyzed semiannually.

Hydrogeologic variability within and across fields required that a geostatistical approach be developed to evaluate nitrate concentration distribution and BMP effects. Geostatistically-derived maps based on Gaussian simulation and trend surface analysis were compared using a spatial map subtraction technique to evaluate net nitrate changes at each demonstration field.

Land Treatment Monitoring

Land treatment monitoring consisted of field visits and communication with producers and project personnel.

Modifications Since Project Start

The design of the project changed since its inception. Originally, the objective of the "M" paired field was to determine the effect of irrigation water management on nitrate-nitrogen leaching into the ground water. One side of the field was to have a sprinkler irrigation system, while the other side was to have furrow irrigation. However, cost share negotiations with the "M" field land owner for project participation led to implementation of the same irrigation water supply system (sprinkler irrigation) in both the BMP test field and the control field.

The type of crops produced and the production methods employed during baseline monitoring changed during the experimental design. The original objective of the "F" paired field was to compare water quality conditions under different cropping regimes (beans after alfalfa vs. wheat after alfalfa). However, scheduled crop rotations were changed to meet commodity market demands on the "F" field. In 1994, potatoes were planted, and in 1995 alfalfa was reestablished. Due to the changes in experimental design, the duration of the monitoring project was extended in order to re-establish baseline water quality data.

The scope of work was increased significantly since the project inception in 1992. The changes were required to facilitate evaluation of the effects of spatial variability within the two paired fields. In addition to the original ground water sample collection scheme for the 12 wells in each field, soil water and additional ground water samples were collected. Geostatistically-based soil water and ground water sampling programs were initiated. Soil water samples, taken with suction lysimeters (soil water samplers), were collected monthly during the growing season at both the "F" and "M" paired fields. Permanent, pressure-vacuum lysimeters (12 inch length) were installed to a depth of one meter below land surface at the "F" field. A seasonal (removed and replaced each growing season) sampling network that includes both vacuum lysimeters (24 inch length) and pressure-vacuum lysimeters (12 inch length) was installed in the "M" field. These lysimeters were installed at a depth of 0.5 meters below land surface. The soil water sampling program provided important information for the interpretation of spatial and temporal variability of the ground water samples collected from in-field monitoring wells.

Twenty-three lysimeters were installed in the "F" field during June, 1994. Six lysimeters were installed in the "M" field during July, 1994. The areal distribution of lysimeters installed in 1994 was based on grain size analyses of soil samples collected in the "F" and "M" fields.

Nitrate samples were collected from the lysimeters for the months of July, August, September, and October, 1994. Basic univariate statistics were computed and a preliminary geostatistical analysis was conducted. Based on these results, the following modifications to the sampling plan were implemented for the 1995 growing season:

- Reduced the length of the shortest lags (distance between samplers)
- Increased the overall number of short lags produced by the sampling configuration
- Included a greater number of the original soil sample locations as lysimeter installation locations

An additional 13 lysimeters were installed in 1995 in the "F" field in addition to Airstone groundwater point samplers at all 36 lysimeter locations. Nineteen lysimters were added to the "M" field network in 1995.

Total Kjeldahl nitrogen was detected in a few wells during the first three years of the project but did not appear to correlate with the nitrate concentrations measured. Nitrate was chosen as the primary constituent of interest as the indicator parameter for evaluation of BMP effectiveness.

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

The Idaho Division of Environmental Quality entered raw water quality data in the USEPA STORET system. Data were also entered into the USDA Water Quality Project's Central Data Base, and the Idaho Environmental Data Management System. Because this is a ground water project, the NonPoint Source Management System (NPSMS) software had limited utility.

This project used geostatistical analysis to evaluate the influence of land use activities on ground water quality. Geostatistics is the branch of applied statistics that focuses on the characterization of spatial dependence of attributes that vary in value over space (or time) and the use of that dependence to predict values at unsampled locations. The usefulness of a geostatistical analysis is dependent upon the adequate characterization of the spatial dependence and of the parameter of interest in the given environment. The degree to which spatial dependence is characterized is a function of the configuration of the sampling locations. Thus, a geostatistic investigation centers around designing an areal distribution of sampling locations which ensures that spatial dependence of the parameter of interest can be recognized if it exists. Geostatistical factors, which must be considered in the design of a sampling plan, include the number of samples and the magnitude and density of separation distances provided by a given configuration.

NPSMS Data Summary

Not applicable.

Final Results

At the F site, data suggest that the BMP effects were detectable in groundwater. Probabilistic evaluation suggested a high probability that the crop rotation BMP used at the F field had a positive effect on the ground water quality (reduced nitrate).

- Leaching of nitrate to the ground water in the field was a function of irrigation-precipitation amounts with an approximate 1 to 2 month time lag between increased irrigation-precipitation amounts and increased levels of ground water nitrate.

- The rate and amount of nitrate leached to the ground water in the field were dependent upon the properties of the subsoils. Higher ground water nitrate concentrations were observed in the shallow aquifer within the sandy subsoils area of the field following increased irrigation with an approximate 1 to 2 month time lag.

- The rate and amount of nitrate leached to the ground water in the field were dependent upon the crop grown. Higher ground water nitrate concentrations and higher net nitrate increases were observed in the control half of the field under beans. Lower ground water nitrate concentrations and lower net nitrate increases were observed in the treatment half of the field under grain. These results suggested that the crop rotation BMP implemented at the F field for one year had a positive effect on the ground water quality.

- Crop type had a significant effect on soil water nitrate concentrations during the growing season. Comparatively high soil water nitrate concentrations and larger net nitrate increases occurred under beans compared to low soil water nitrate concentrations and smaller net nitrate increases under grain. This result is significant from the standpoint of reducing the nonpoint source of soil nitrate available to leach to the ground water over time.

- The positive effects of growing grain for a single season were relatively short term. Net changes in the distribution of nitrate in the ground water apparently reversed from July to August 1998, one year after BMP implementation. Crop rotation BMPs must be used on a regular basis to improve the long-term ground water quality significantly in the area.

- Following the crop of potatoes by two years of alfalfa significantly reduced the amount of residual nitrate in the soil water and effectively reduced nitrate concentrations in the shallow ground water.

- Education of farmers on the significance of crop rotation BMPs and work to increase farmer acceptance of BMPs should continue. Results from this study suggest the crop rotation BMP had a positive influence on the soil water and ground water quality.

A reversed trend in net ground water concentrations was observed over the BMP period on the "M" field. These results suggested that irrigation amounts probably influence leaching of nitrate to the ground water.and that the irrigation water management BMP had a positive influence on the ground water quality.

Monthly sampling of monitoring wells in the M field have shown no significant increases in ground water nitrate after the planting of potatoes or sugar beets, even though both crops required large amounts of fertilizer. The low variance in ground water nitrate concentrations and lack of significant increases in nitrate concentrations after the growing season for crops requiring heavy fertilization suggest that fertilizer applications over a one year period had very little effect on ground water nitrate concentrations in the M field under sprinkler irrigation. The greatest changes in ground water nitrate concentrations were measured under furrow irrigation. Conversion from furrow to sprinkler irrigation of the fine grained (silty) soils in the M field reduced the leaching of nitrate to the ground water over the period of the investigation. Conversion to sprinkler irrigation is probably the best management practice to reduce ground water nitrate concentrations in fields with predominantly fine grained (silty) soils.

Source: Osiensky, J.L. et al. 1993. Ground Water Monitoring Technical Completion Report. Dept. of Geological Sciences, U. of Idaho, Moscow, ID.

INFORMATION, EDUCATION, AND PUBLICITY

Information, Education and Publicity (I & E) for the Snake River Section 319 National Monitoring Program project was included in the Snake River Plain Demonstration Project I & E program.

Two Eastern Snake River Plain Demonstration Project brochures have been published. One brochure, targeting the local public, was designed to provide a general explanation of the project. The second explains results from the nitrate sampling of the project area.

The USDA Demonstration Project staff provided the I&E program for this project. University articles were produced on the demonstration project, and project information was disseminated through university and producer conferences. Presentations on the project were also made to the public through local and regional outlets, such as the American Association of Retired Persons, Future Farmers of America, local and regional agricultural producers, local irrigation districts and canal companies, industry representatives, industry supply vendors, and primary and secondary education institutions. In addition, a public information workshop was held annually within the project area for project participants, cooperators, and interested individuals.

Cooperating farm operations that implemented improved management practices for water quality were marked by project display boards to maximize exposure to the local population. These operations weree also visited during the numerous project organized field trips.

Information was also disseminated through local and regional television and radio programs and newspaper articles.

TOTAL PROJECT BUDGET

Funds budgeted to the State for the Eastern Snake River Plain Section 319 National Monitoring Program project for the period of FY92–98 was approximately $500,000. This figure includes Section 319(h) funds utilized after the National Monitoring Program project monies were suspended, as well as funds provided by the Idaho Division of Environmental Quality and the Idaho Department of Agriculture for additional water quality monitoring.

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

None.

OTHER PERTINENT INFORMATION

The Eastern Snake River Plain Demonstration Project was led by the USDA Natural Resources Conservation Service (NRCS), the University of Idaho Cooperative Extension Service (CES), and the USDA Farm Service Agency (FSA). In addition to the three lead agencies, this project involved an extensive state and federal interagency cooperative effort. Numerous agencies, including the Idaho Division of Environmental Quality, the University of Idaho Water Resource Research Institute, the USDA Agricultural Research Service, the Idaho Department of Water Resources, the U.S. Geological Survey, and the Idaho Department of Agriculture, took on various project tasks.

The Idaho Department of Environmental Quality and the Idaho Water Resource Research Institute were responsible for the 319 National Monitoring Program portion of the project.

An institutional advantage of this project was that the NRCS and the CES are located in the same office.

Three local Soil and Water Conservation Districts, East Cassia, West Cassia, and Minidoka, as well as the Minidoka and Cassia County FSA, county committees, and the Cassia County Farm Bureau made up the USDA Demonstration Project Steering Committee.

A regional well monitoring network consisting of existing domestic sandpoint (driven) wells was established within the Demonstration Project Area. The regional network was intended to augment the paired-field data and provide a means to document the influence of the Demonstration Project on the quality of the area's shallow ground water system. This network consists of 25 wells which have been monitored for nitrogen-nitrate concentrations on a quarterly basis for an average of 12 sampling events.

During implementation of the regional domestic well water quality monitoring portion of the USDA project, agricultural chemicals and nitrate-nitrogen were detected at levels of concern and measured in samples collected from domestic wells. In addition, limited sampling and analysis of ground water drainage systems, irrigation return flows, and injection wells identified nutrients and pesticides in certain surface water bodies within the project area. Nitrate-nitrogen concentrations in subsurface tile drain effluent as high as 8 mg/l were measured. The herbicides MCPA and 2,4-D were detected in return flow irrigation water entering into an injection well. The 2,4-D was measured at levels greater than the allowable Safe Drinking Water MCL of 70 ppb.

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Illinois

Kickapoo Creek
Section 319
National Monitoring Program Project

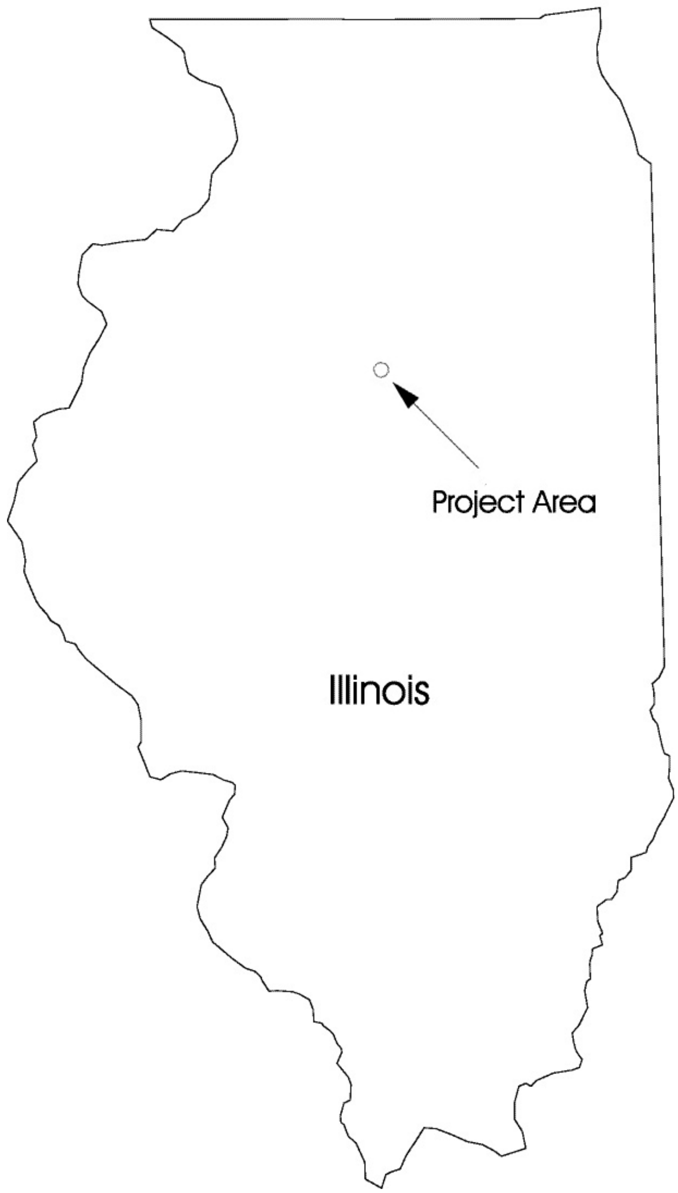

Figure 1: Kickapoo Creek (Illinois) Location

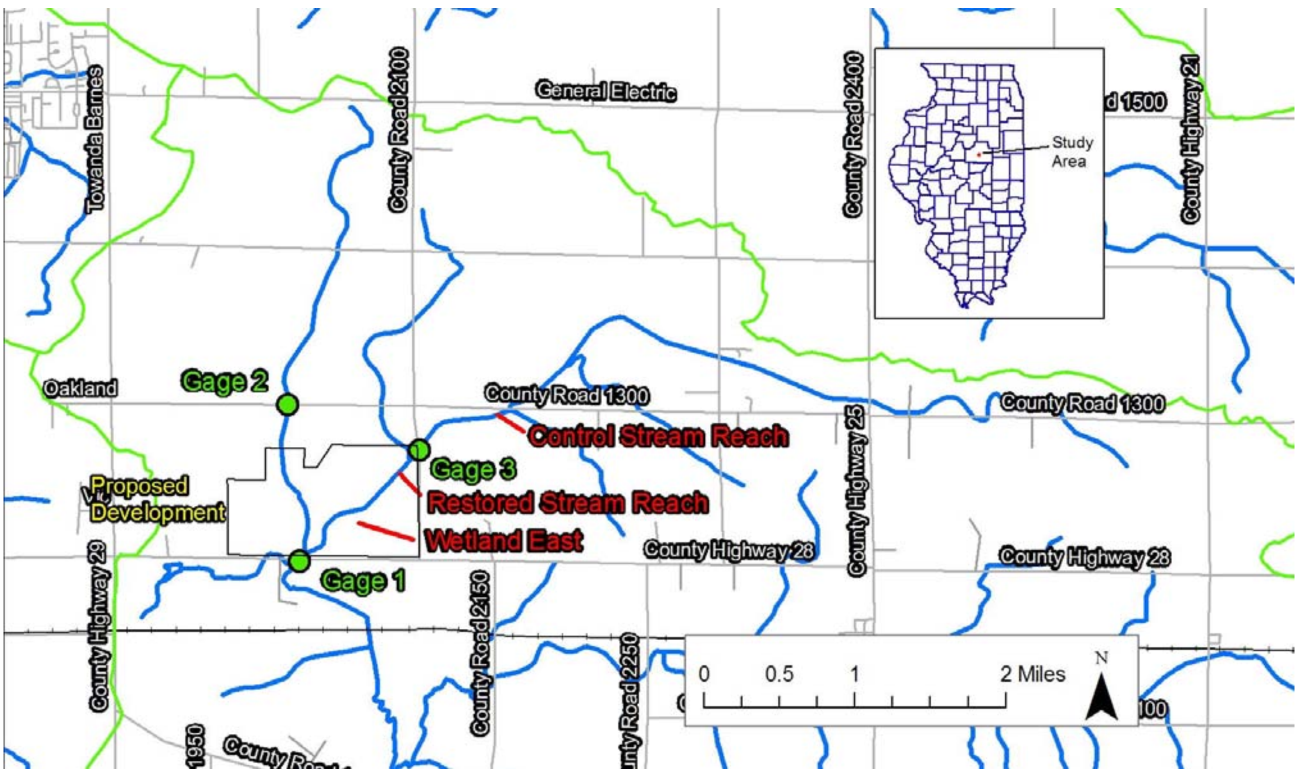

Figure 2: Kickapoo Creek Watershed Monitoring Network

PROJECT OVERVIEW

With Section 319 funding from the Illinois EPA and additional funding from other federal, state, and local partners, the City of Bloomington is developing wetland detention within a natural stream design for The Grove Residential Development in central Illinois. Runoff from the 460-ac (186-ha) Grove Development will be captured in large shallow wetland basins to manage both quantity and quality of stormwater runoff.

Stream restoration will convert two miles (3 km) of agricultural drainage ditches in the East and West Branches of Kickapoo Creek into meandering stream channels within an 80-ac (32-ha) park. New wetland basins will be created within the meander bends throughout the park to reduce stormwater runoff rates. The park landscape will maximize the enhancement of native wetland, riparian and aquatic species for the parks trail system.

Present sediment transport capacity in the restored stream segments will be maintained in order to prevent the loss of wetland plant communities and instream habitat resulting from excessive sediment deposition.

Monitoring will be conducted according to an essentially upstream/downstream design. Fish and macroinvertebrates will be monitored in the restored reach and in an upstream control reach. Sediment and nutrient concentrations and loads will be measured at stations upstream and downstream of the development area and at a third control station on the West branch of Kickapoo Creek. Effectiveness of created wetlands will be assessed by monitoring the concentration and loads of nutrients entering the wetland vegetation and the concentrations and loads entering the stream. Detailed monitoring of the vegetation community in the riparian plantings within the restoration area will contribute to better understanding of vegetation management in river restoration elsewhere in the state and region.

The project is currently in its first year of monitoring and is expected to continue through 2015.

PROJECT BACKGROUND

Project Area

The project area is located in the City of Bloomington, Illinois and includes 14.8 mi^2 (38.3 km^2) or 9,472 ac (3,833 ha) of watershed area. At the USGS upstream gages, the West Branch of Kickapoo Creek drains about 3.8 mi^2 (9.8 km^2) and the East Branch of Kickapoo Creek drains about 7.3 mi^2 (20.7 km^2). A 460 ac (186 ha) residential development is planned for the area above the confluence of the North Branch and East Branch.

Relevant Hydrologic, Geologic and Meteorological Factors

The average annual rainfall of the area is about 44 in (112 cm). The 2-yr flood discharge of Kickapoo Creek is 700 ft^3/s (20 m^3/s) and the 100-yr flood discharge is 3,380 ft^3/s (93 m^3/s). The project is located in the Wisconsin glacial moraine within the Bloomington Ridged Plain. The Eureka and Normal moraines form adjacent low ridges that direct runoff. Peoria Loess soils (loam and clay loam) overlay the glacial till.

Land use

More than 90% of land (about 8,000 ac or 3,200 ha) is in corn and soybeans; there are no livestock operations in the project area. Existing and planned residential development comprises about 750 ac (304 ha).

Water resource and size

Kickapoo Creek is essentially a system of second and third order drainage ditches. The stream has been channelized entirely, receives extensive tile drain discharge, and is surrounded by row crops grown to the top of the bank.

Water use and present impairments

Documented water quality impairments include the stream fishery, sedimentation, instream habitat, and loss of channel stability and natural stream geomorphology. Nutrient and sediment pollution have not been documented within the project area, but have been reported downstream. The Illinois Department of Public Health has issued a fish advisory for PCBs along Kickapoo Creek. Several segments of the main stem of Kickapoo Creek are on the 303(d) list. Causes of impairment have been identified as fecal coliform bacteria, sediment, phosphorus, and dissolved oxygen.

Extensive residential development is expected to threaten water resources in the future due to increased rates of runoff, construction erosion, increased nutrients from housing infrastructure, and landscaping.

Pollutant sources

Sources of nutrients and sediments within the monitored area have not been specifically identified but row crops, stream channelization, and new housing development are the presumed sources. Sediment and nutrients from construction site erosion and yard landscaping from 750 acres of existing and newly initiated housing developments are anticipated to be significant problems.

Pre-project water quality

Pre-project water quality data do not exist for the project area. Pre-treatment fishery data collection began in the summer of 2006 and wass scheduled for completion in summer of 2009. Stream water quality impairments will be assessed in late 2007, after the first year of water quality sampling that began in October 2006 at the USGS stream gages.

Water quality objectives

The overall goal of the project is to restore Kickapoo Creek and its adjacent wet prairie floodplain as a stormwater detention system for the residential development. The 80-ac (32-ha) restoration will transform a channelized agricultural ditch into two miles (3.2 km) of naturalized stream channel; adjacent wet prairie will capture the runoff from the streets and homes before entering the stream. Specific water quality objectives include:

- Restore the stream fishery to an IBI score of 38 – 40;
- Restore and maintain high-quality instream and riparian habitats;
- Maintain efficient sediment transport through the system; and
- Evaluate the erosion control practices approved by the City of Bloomington as applied to the construction site.

Additional objectives for the monitoring project include:

- Document the biological enhancement that results from stream and floodplain restoration from a channelized system dominated by row crops and invasive species to a naturalized floodplain system;

- Document the condition of both reaches of Kickapoo Creek before residential development begins on the East branch; and
- Determine the effectiveness of floodplain restoration to capture and treat runoff from residential development.

Project time frame

October, 2007 to October, 2015, with two additional years of monitoring possible.

PROJECT DESIGN

Nonpoint source control strategy

The principal nonpoint source control strategy is to construct a natural meandering stream channel with associated floodplain wetlands based upon sediment transport capacity and instream habitat enhancements. Stream restoration will convert two miles (3.2 km) of previously managed agricultural drainage ditches in the East and West Branches of Kickapoo Creek into meandering stream channels within an 80 ac (32 ha) linear park. Wetlands will be created within the meander bends throughout the park to reduce stormwater runoff rates from the Grove residential development. The park landscape will maximize the enhancement of native wetland, riparian and aquatic species for the parks trail system. The sediment transport capacity in the restored stream segments will be maintained in order to prevent the loss of wetland plant communities and instream habitat to excessive deposition of sediment from the upstream row crop area of the watershed.

During construction of the residential development, runoff and erosion controls will include silt fences, rock check dams, sediment basins, wide buffer strips, and reseeding. Runoff from the completed residential development will be captured in large shallow wetland basins created from the sediment basins used to trap runoff and sediment during the construction period so that runoff from a 100-yr rain event will be reduced to the flows resulting from a 3-yr rain event. Wetland basins will also provide treatment for sediment and nutrients in runoff from the proposed development area.

Project Schedule

		Pre-Restoration		Post-Restoration
Monitoring	**2006**	**2007**	**2008**	**2009-2012**
Fishery	X	X	X	X
Macroinvertebrate —		X	X	X
Stream Gaging	X	X	X	X
Wetland Gaging	N/A	N/A	X	X
Physical Habitat	X	X	X	X
Floodplain Vegetation —		X	X	X
Construction Site	N/A X		X	X

Pre-restoration monitoring will extend into late 2008. Restoration of the East Branch will be completed in winter 2008/2009. Post-restoration monitoring will begin in 2009. Residential construction will begin in 2009.

Water Quality Monitoring

The monitoring project consists of two phases. Phase 1 monitoring determines the effectiveness of stream restoration on stream fisheries in the restored stream segments, sediment transport through the restored stream segments, construction erosion controls, and reduction of stream bank erosion by revegetation. Phase 2 monitoring will evaluate the effectiveness of floodplain wetland restoration in capturing residential runoff after the housing development has been constructed and will address discharge, nutrient, and sediment reduction in the stormwater runoff by the constructed wetlands by monitoring the concentration and loads of nutrients entering the wetland vegetation and the concentrations and loads entering the stream.

Variables measured

Biological

Stream fisheries IBI (June and September, streams only)
Macroinvertebrates (late summer, streams only)
Stream habitat, and geomorphology (late summer, streams only),

Chemical and other

Suspended sediment concentration and load (base flows and flood events)
Nutrient concentrations and loads (base flows and flood events)
Total P
Soluble P
Total N
Ammonia N
Nitrite+Nitrate N
Dissolved oxygen, pH, temperature, and specific conductance
Discharge

Covariates

Precipitation
Sediment particle size distribution
Floodplain and riparian vegetation surveys (summer)
Construction activities

Sampling Scheme

The fish population will be monitored in the restoration reach and in a control reach upstream of the proposed development area twice per year, in June and September. Monitoring procedures will employ electrofishing, following standardized Illinois Department of Natural Resources stream sampling protocol. The upstream reference site will reflect the changes over time as compared to the changes at the downstream treatment area.

Macroinvertebrate sampling will be performed by the Illinois EPA at the upstream control and downstream treatment sites on the East Branch during the late summer. The IEPA staff will use a 20-jab multi-habitat methodology.

Three sites are established for chemistry sampling and discharge measurements on the two upstream tributaries and on the main channel below the channel constriction. Streamflow will be measured continuously at these sites by USGS methods. Baseflow water chemistry will be characterized with bi-monthly sediment and nutrient grab samples, and stage-weighted event sampling will be conducted for storms. Dissolved oxygen, pH, temperature, and specific conductance will be determined concurrent with grab sampling upstream and monitored continuously *in-situ* at the downstream gaging station.

Additional gaging stations will be positioned in the waterway above and below a restored wetland to monitor discharge and nutrient load into and out of the wetland. Wetland sampling will document the concentration and loading of nutrients and salts entering the floodplain vegetation and the extent of wetland effectiveness in reducing the rate of stormwater runoff and pollutant concentrations entering the stream.

During Phase 1, vegetation monitoring of the floodplain will determine species composition and area of coverage for major species to ensure that the stream restoration meets project objectives. Qualitative and quantitative vegetation sampling will be conducted in the stream corridor in the restoration reach and control reach using a floristic quality assessment (FQA) to characterize the overall floristic integrity of the site. Quantitative vegetation sampling will be performed in conjunction with qualitative sampling to provide reproducible and consistent data collection for estimates of species' presence, frequency, relative density and cover.

Land treatment monitoring

Erosion sources from construction activities will be documented with photography during stream sampling events and after storm events. Construction activities will be tracked by photography twice monthly, with the GPS locations imbedded on the film. Infrastructure installations such as roads and sewers, housing excavations, and stream/wetland excavations will also be tracked via photography.

Modification since project started

Construction site monitoring has been expanded since project inception.

Progress to date

Two upstream and one downstream USGS gaging and automated sampling stations have been established, with real time uplink to the web. As of September, 2007, project staff have:

- Completed 1 year of discharge, sediment, and nutrient monitoring;
- Completed 2 years of fishery data collection at 6 sites representing upstream controls and downstream treatment;
- Completed stream geomorphology and floodplain vegetation surveys;
- Conducted detailed surveys of floodplain and channel dimensions for 14,000 ft (4,267 m) of channel;
- Performed particle size distribution analysis of stream bed and stream bank materials at 17 locations in the watershed;
- Located and documented stream erosional and depositional features throughout the watershed;
- Conducted floodplain borings to determine subsurface soil characteristics and erosion potential to determine bank stabilization requirements in the stream meanders to be constructed along two miles of floodplain;
- Conducted a GIS analysis of the watershed to identify locations of soils with high runoff rates and greater erosion potential; and
- Estimated annual sediment yield from sheet and rill erosion in upper Kickapoo Creek watershed

DATA MANAGEMENT AND ANALYSIS

The USGS will maintain the streamflow and water quality data in the standard USGS databases. Data will be provided in spreadsheet format on a CD to the IEPA for entry into STORET.

Fisheries data will be evaluated by the Illinois Department of Natural Resources using the revised Index of Biotic Integrity for Illinois, multiple fish population metrics, and standard statistical measures. Macroinvertebrate data will be evaluated using the Macroinvertebrate Index of Biotic Integrity that was designed to be sensitive primarily to nonpoint/habitat related disturbances. Illinois Environmental Protection Agency field staff use macroinvertebrate data to assess community structure and determine the relative quality of a stream compared to reference conditions.

Anova, regression analysis, and t-tests will be used to compare sediment and nutrient loadings at the stream and wetland gaging stations. Nutrient loadings will be based upon the discharge and nutrient concentrations of stormwater flows into and out of the wetland basins. Reductions in stormwater discharge rates, sediment loadings, and nutrient loadings will determine wetland effectiveness.

INFORMATION, EDUCATION, AND PUBLICITY

Both the Bloomington Park District and local environmental groups including Friends of Kickapoo Creek have requested annual reports on the project status and are actively involved in restoration and protection activities.

Radio interviews on local public radio were broadcast on May 10, 2007.

Project staff made a presentation on stream and floodplain restoration to Bloomington Park District staff and to Friends of Kickapoo Creek Partnership on May 23, 2007.

A project kickoff event with state and local media is scheduled for Oct. 2007.

TOTAL BUDGET

Item	Federal	Local
Restoration of streams(2 miles) and adjacent floodplains	$1,900,000	$1,266,667
4 years of stream and wetland gaging and vegetation monitoring (2006-2009) [1]	$550,000	$366,667

[1] Future years of monitoring scope and costs will be determined after review the first 4 years of data collection

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

The US Fish and Wildlife Service and the Illinois DNR have contributed $430,000 to the stream restoration project through the Wildlife Habitat Restoration Program.

OTHER PERTINENT INFORMATION

The six developers donated 80 acres of park lands with associated park trails and educational center to the Bloomington Park District, representing an assessed value of $1,760,000.

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Lake Pittsfield
Section 319
National Monitoring Program Project

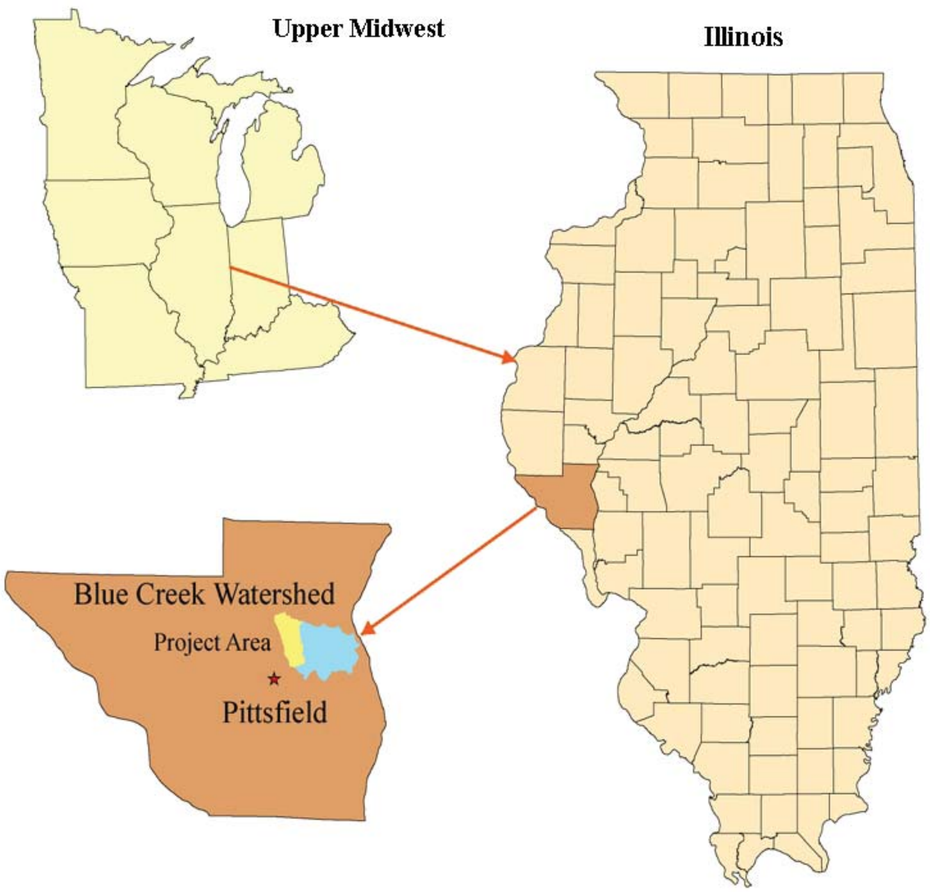

Figure 11: Location of the Lake Pittsf eld Project in the Blue Creek Watershed of Pike County, Illinois

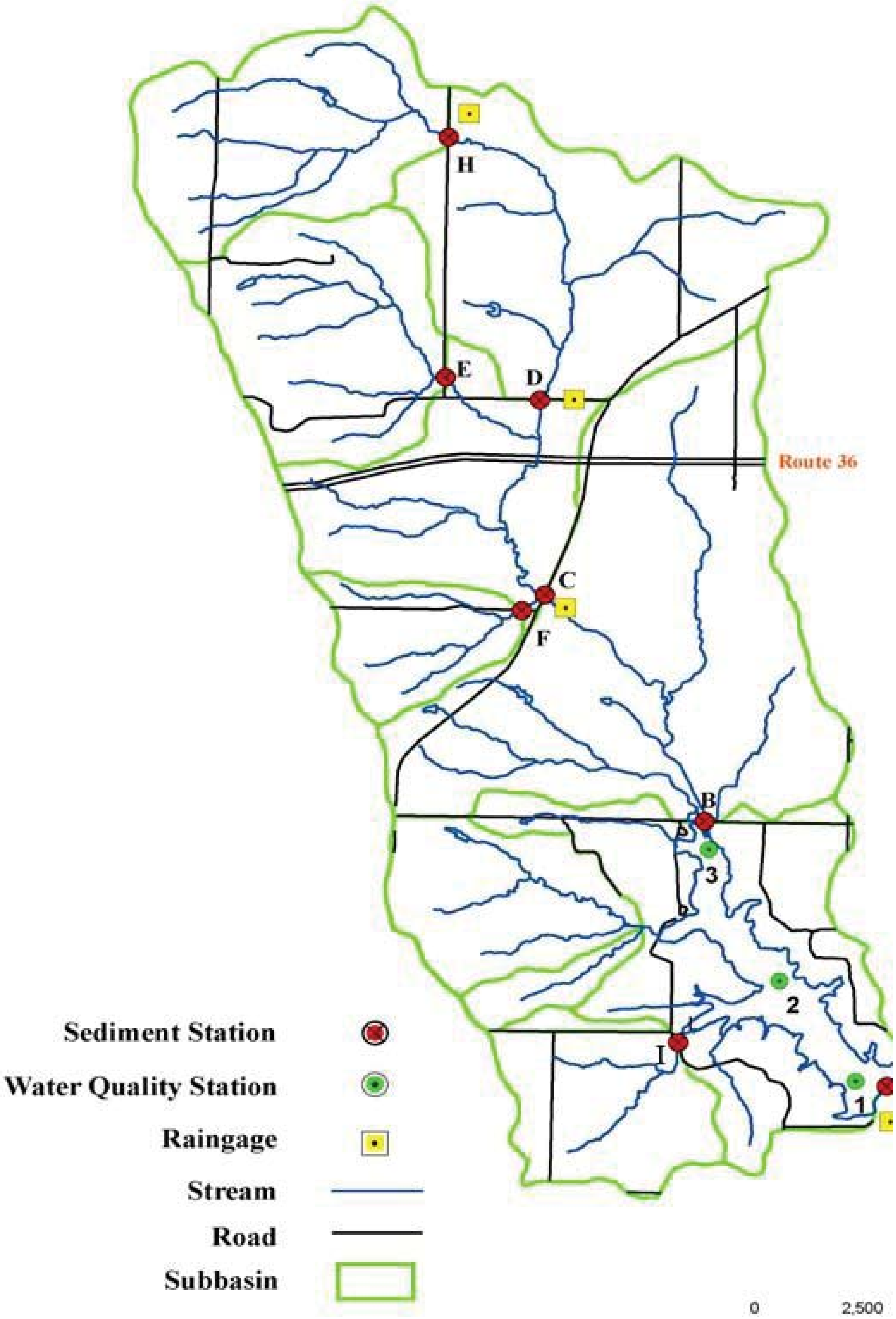

Figure 12: Monitoring Network in the Blue Creek Watershed above Lake Pittsf eld

PROJECT OVERVIEW

Lake Pittsfield was constructed in 1961 to serve as both a flood control structure and a public water supply for the city of Pittsfield, a western Illinois community of approximately 4,000 people. The project area consists of 6,956 acres of the Blue Creek watershed that directly drains into Lake Pittsfield. Agricultural production consists primarily of row crops (corn and soybeans), and small livestock operations: hog production, generally on open lots, and some cattle on pasture.

Sedimentation is the major water quality problem in Lake Pittsfield. Sediment from farming operations, gullies, and shoreline erosion has decreased the surface area of Lake Pittsfield from 262 acres to 219.6 acres in the last 33 years. Other water quality problems are excessive nutrients and atrazine contamination. The lake is classified as hypereutrophic, a condition caused by excess nutrients.

The major land treatment strategy is to reduce sediment transport into Lake Pittsfield by constructing settling basins throughout the watershed, including a large basin at the upper end of Lake Pittsfield. Water Quality Incentive Project (WQIP) money, provided through the United States Department of Agriculture (USDA) Farm Service Agency (FSA), was used to fund conservation tillage, integrated crop management, livestock exclusion, filter strips, and wildlife habitat management. An information and education program on the implementation of best management practices (BMPs) used to control sediment, fertilizer, and pesticides were conducted by the Pike County Soil and Water Conservation District (SWCD).

The Illinois State Water Survey (ISWS) conducted the Lake Pittsfield Section 319 National Monitoring Program project in order to evaluate the effectiveness of the settling basins. Water quality monitoring consists of storm event tributary sampling, lake water quality monitoring, and lake sedimentation rate monitoring.

Land-based data was used by the ISWS to develop watershed maps of sediment sources using a geographic information system (GIS). The data for the different GIS layers consist of streams, land uses, soils, roads, subwatersheds, topography, and border line of the lake.

Monitoring ended in August 2004. Results are included in the 2009 Final Report and highlights are summarized in NWQEP NOTES #129 (September 2008) at http/ncsu.edu/waterquality.

PROJECT BACKGROUND

Project Area

The 6,956-acre Blue Creek watershed that drains into Lake Pittsfield is located in western Illinois (Figure 11). The terrain is rolling with many narrow forested draws in the lower portion of the watershed. The topography of the upper portion of the watershed is mild and the draws are generally grassed.

Relevant Hydrologic, Geologic, and Meteorologic Factors

The area surrounding Lake Pittsfield receives approximately 39.5 inches of rainfall per year, most of which falls in the spring, summer, and early fall. Soils are primarily loess derived. Soils in the upper portion of the watershed developed under prairie vegetation, while those in the middle and lower portions of the watershed were developed under forest vegetation.

Land Use

Some sediment-reducing BMPs are currently being used by area farmers as a result of a program (Special Water Quality Project) that was started in 1979. Pike County SWCD personnel encouraged the use of terraces, no-till cultivation, contour plowing, and water control structures. Many terraces were constructed and most farmers adopted contour plowing. Table 1 shows that agriculture is the dominate land use in the Blue Creek watershed above Lake Pittsf eld.

Table 1: Land Use of the Blue Creek watershed above Lake Pittsf eld

Land Use	Acres	%
Agricultural	3350.5	48
Forest/Shrub	1505.1	21
Pasture/Rangeland	1374.9	20
Residential	132.4	2
Reservoir/Farm Ponds	258.7	4
Roads/Construction	137.1	2
Park	197.5	3
TOTAL	6956.2	100

Source: Illinois Environmental Protection Agency. 1993. Springf eld, IL.

Water Resource Type and Size

Lake Pittsf eld is a 219.6-acre lake located near the city of Pittsf eld in Pike County (western Illinois) (Figure 11).

Water Uses and Impairments

Lake Pittsf eld serves as the primary drinking water source for the city of Pittsf eld. Secondarily, the lake is used for recreational purposes (f shing and boating). Sedimentation, which has decreased storage capacity in Lake Pittsf eld, is the primary water quality impairment. Lake eutrophication and occasional concentrations of atrazine above the 3 ppb Maximum Contaminant Level (MCL) also impair lake uses.

Pollutant Sources

Cropland, pasture, shoreline, and streambanks

Pre-Project Water Quality

Lake sedimentation studies have been conducted four times (1974, 1979, 1985, and 1992). Almost 15% of Lake Pittsf eld's volume was lost in its f rst 13 years (Table 2). An additional 10% of the lake's volume was lost in the next 18 years (1974 to 1992), suggesting that the rate of sedimentation has slowed. The majority of the lake volume that has been lost is at the Blue Creek inlet into the lake, which is in the northern portion of the lake.

Table 2: Lake Pittsf eld Sedimentation Studies

Year of Survey	Lake Age (Years)	Lake Volume		Sediment Volume		Original Volume
		ac-ft	MG	ac-ft	MG	Lose (%)
1961		3563	1161			
1974	13.5	3069	1000	494	161	13.9
1979	18.3	2865	933	697	227	19.6
1985	24.3	2760	899	803	262	22.5
1992	31.5	2679	873	884	288	24.8
2004	43.5	2839	926	748	244	21.0

Source: Illinois Environmental Protection Agency, 1993; Illinois State Water Survey, 2005

Long-term water quality monitoring data demonstrated that the lake has been, and continues to be, hypereutrophic. In 1993, Lake Pittsf eld's water quality was found to exceed the Illinois Pollution Control Board's general use water quality standards for total phosphorus (0.05 mg/l). Total phosphorus standards of 0.05 mg/l were exceeded in 70% of the samples taken. The 0.3 mg/l standard for inorganic nitrogen was exceeded in 60% of the water samples. Water quality samples collected in 1979 had similar concentrations in terms of phosphorus and nitrogen.

In 2004, a partial sedimentation survey was conducted to def ne the baseline condition for post-dredge lake volume. An estimate of the volume of dredged material from the lake was based on the observed extent of the dredging, 2004 average depth of water, the dredged area, and the 1992 depth determined by survey transects within the dredged area. The estimated area of dredging was 16.6 acres. The estimated volume of the removed sediment was 136 ac-ft and the average depth of sediment removal was 8.2 feet. Dredging restored the lake volume loss from 24.8% to 21% which is just under the volume loss of the 1985 sedimentation survey (Table 2).

Water Quality Objectives

The objectives of the project are to

- reduce sediment loads into Lake Pittsf eld
- evaluate the effectiveness of sediment retention basins.

Project Time Frame

Initial water quality funding began in 1992 as a 319 Watershed Project. In 1994, the project was approved for the Section 319 National Monitoring Program and continued up through the 2004 seasonal sampling events. This allowed monitoring for a period of nine years after the installation of sediment retention basins.

March 1, 1993 to September 30, 1995 (Watershed)

September 1, 1992 to 1994 (Monitoring Strategy)

PROJECT DESIGN

Nonpoint Source Control Strategy

The nonpoint source control strategy is based on reducing off-site sediment movement and limiting the transport of sediment into the water resource of Lake Pittsf eld.

In 1995 Section 319(h) funds were used to build 29 small (approximately two acres each) sediment retention basins. These basins are used to limit the transport of sediment into Lake Pittsf eld. In addition, a large sediment retention basin (SRB) capable of trapping over 90% of the sediment entering Lake Pittsf eld at the upper end was built above station B in 1996 by utilizing Section 319(h) funds.

Funds from the Water Quality Incentive Program were used to encourage the adoption of BMPs that reduce the off-site movement of sediment, fertilizer, and pesticides. These BMPs include conservation tillage, integrated crop management, livestock exclusion, f lter strips, and wildlife habitat management.

Section 314 Clean Lakes Program funds were used to build shoreline stabilization BMPs in order to reduce shoreline erosion. Areas where rip rap existed were reinforced and new rip rap was installed along the eroded shoreline.

In 1998, a series of 12 rock grade controls (Newbury weirs) were constructed above sampling station D on Blue Creek to stabilize the streambed and recreate pool and riff e sequences. The rock grade controls helped slow erosion occurring from streambanks and a large mass wasting upstream of station D. Re-vegetation (tree planting and seeding) was also conducted on the streambanks and the mass wasting in conjunction with the installation of rock grade controls. Table 3 outlines the pre and post BMP monitoring dates covering the basins and the rock grade controls.

A Phase II Section 314 Clean Lakes Program was conducted for the Illinois EPA utilizing Section 314 funding in 1999-2000 which evaluated the effectiveness of the restoration measures implemented within Lake Pittsf eld and its watershed from 1989-1999. The restoration measures implemented were recommended under a Phase I Diagnostic - Feasibility Study of Lake Pittsf eld, completed in 1989 through Section 314 funding, and included but was not limited to watershed treatments, upland watershed best management practices, shoreline stabilization practices, thermal destratif cation, algal treatment and dredging (sediment removal). An additional 3,000 linear feet of shoreline stabilization practices were implemented in 2002 on Lake Pittsf eld utilizing Section 319 funding to address eroded shoreline.

Table 3: Project Schedule

Site	Pre-BMP Monitoring	BMP Installation	Post-BMP Monitoring
Subwatershed D	11/92-12/94	1995	1996-1998
Subwatershed C	11/92-12/94	1995	1996-2004
Subwatershed B	11/92-06/96	Fall 96	2/97-12/04
Subwatershed D	12/92-12/97	1998	1998-2004

Water Quality Monitoring

Storm sampling was conducted at four stations on the main channel of Blue Creek which feeds into Lake Pittsf eld. Three storm monitoring stations on tributaries of Blue Creek and a station located at the outf ow of Lake Pittsf eld were monitored up to 1995. Monthly ambient lake monitoring was conducted at three water quality stations within Lake Pittsf eld. Trend monitoring was also done at the three lake stations. The variables used at these monitoring stations are listed in table 4. Lake sedimentation studies were conducted before dredging and a post-dredge baseline condition has been established.

Variables Measured

Table 4: List of Variables Measured within Lake Pittsf eld and its Watershed

Chemical and other (Lake)	**Chemical and other (Stream)**	**Biological**	**Covariates**
Total phosphorus (TP)	Total suspended solids (TSS)	None	Rainfall
Dissolved phosphorus (DP)			
Total Kjeldahl nitrogen (TKN)			
Nitrate + nitrite (NO3 + NO2)			
Ammonia nitrogen (NH3+ NH4+)			
Total suspended solids (TSS)			
Volatile suspended solids (VSS)			
pH			
Total alkalinity			
Phenolphthalein alkalinity			
Specif c conductivity			
Water temperature			
Dissolved oxygen (DO)			
Atrazine (started in 1999)			

Sampling Scheme

Storm sampling has been conducted at four stations located at stations B, C, D, and H on Blue Creek (Figure 2). These stations were equipped with ISCO automatic samplers and manual DH-59 depth-integrated samplers. A pressure transducer triggers sampling as the stream rises. The samplers measure stream height. In addition, the streams were checked manually with a gauge during f ood events to determine the stage of the stream. During these f ood events, the stream was rated to determine f ow in cubic feet per second. Stream stage was then correlated with f ow in order to construct a stream discharge curve. Water samples were analyzed to determine sediment loads. From 1992 to 1995 three stations located on tributaries to Blue Creek (stations E, F, and I) were sampled with manual DH-59 depth-integrated samplers and grab samples while taking f ow measurements with a Marsh-McBirney Flowmate 2000 f owmeter. Grab Samples were taken at station A at the outf ow of the dam. Rain gauges have been placed near sampling sites A, C, D, and H (Figure 12).

Three lake sampling stations had been established in the shallowest portion of the lake, the middle of the lake, and the deepest part of the lake (Figure 2). Water quality grab samples were taken monthly from April through October starting in October of 1992 through August of 1995. In-situ observations were done at 2-foot intervals at these stations for Secchi disk transparency, temperature and dissolved oxygen prof les. In addition, water chemistry samples were taken from the surface of all three lake stations, as well as the lowest depth at the deepest station, and were analyzed for the chemical constituents listed in table 5.

Table 5: Monitoring Scheme for the Lake Pittsf eld Section 319 National Monitoring Program Project

Design	Sites or Activities	Primary Parameters	Covariates	Frequency	Duration
Before/After	Stations B, C	TSS	Rainfall	During storms	11 yrs
pre-BMP	D & H				2 yr
post-BMP					9 yrs
Single	Lake stations	Secchi disk transparency	Rainfall	Monthly,	2 yrs
pre-BMP	Stations 1, 2, & 3	DO		April	1 yr
		OP		through October	
		TP			
		Ammonia nitrogen (NH3 + NH4+)			
		TKN			
		NO3 + NO2			
		TSS			
		VSS			
		pH			
		Total alkalinity			
		Phenolphthalein alkalinity			
		Specif c conductivity			
		Water temperature			
		Air temperature			
		DO			
		Atrazine			
Lake Sedimentation Study		Lake depth		Prior to dredging	
Shoreline erosion Severity Survey				Once	

Land Treatment Monitoring

Table 6 shows the extent and installation dates of the Water and Sediment Control Basins (WASCOBs). Excluded from the table is the large Sediment Retention Basin (SRB) built 300 feet above station B in 1996. The watershed above the SRB includes the subwatersheds of stations B, C, and D totaling 4984 acres which is 71.7% of the entire watershed above Lake Pittsf eld.

Table 6: Summary of Water and Sediment Control Basin Installation

Subwatershed	Subwatershed acres	Watershed above WASCOBs, %	No. of	Installation Dates WASCOBS
A	1551	34	7	8/25/94 to 9/08/95
B	1661	13.4	4	8/13/94 to 9/23/95
I	421	69	4	7/29/94 to 9/26/95
C	1567	41	7	8/17/94 to 9/30/95
D	1756	45	7	7/27/94 to 9/06/95

Modifications During Project

The contract for building sediment basins was extended to August 20, 1996, due to design modif cation and the permit process for the large sediment basin.

Nonpoint source national monitoring during the spring season was included at monitoring sites B and C, which includes 2 years of pre-BMP data, 1 year during BMP implementation, and 8 years of sampling after BMP implementation.

Progress to Date

A total of 29 sediment basins and the large SRB have been completed. It is estimated that the basins in the C and D subwatersheds are reducing sediment delivery by 68-61% respectively. The large SRB is estimated to be reducing sediment delivery entering directly into Lake Pittsf eld from the entire watershed by 91%. A series of rock grade controls (Newbury weirs) have been installed throughout 3,000 feet of stream channel upstream of station D. All WQIP projects have been implemented.

A Phase II Section 314 Clean Lakes Program was conducted for the Illinois EPA utilizing Section 314 funding in 1999-2000 to evaluate the effectiveness of the restoration measures implemented at Lake Pittsf eld from 1989 to1999. Addition 3,000 linear feet of shoreline stabilization practices on Lake Pittsf eld utilizing Section 319 funding to address eroded shoreline were installed in 2002 to help reduce the amount of in-lake sedimentation sources and to provide enhanced wildlife habitat, while also providing NPS education to the local community.

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

The water quality monitoring data are entered into a database and then loaded into the USEPA (U.S. Environmental Protection Agency) water quality data base, STORET. Data are also stored and analyzed with the USEPA Nonpoint Source Management System (NPSMS) software. Table 7 contains sediment yield data for the larger subwatersheds in the project.

NPSMS Data Summary

Table 7: Summary of Data Collected from Subwatersheds B and C

PERIOD: Spring Season, 1994
STATION TYPE: Upstream Station — **PRIMARY CODE:** Station C
CHEMICAL PARAMETERS

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	
-25-STREAM, INSTANTANEOUS, CFS	S	cfs	8.4	3.9	2.4
INSTANTANEOUS YIELD	S	lbs/sec	.017	.004	.002
PRECIPITATION, TOTAL	S	in/day	.2	0	0
SEDIMENT, PARTICLE SIZE FRACT. < .0625 MM % dry wgt.	S	mg/L	49	24	10

STATION TYPE: Downstream Station — **PRIMARY CODE:** Station B

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FLOW, STREAM, INSTANTANEOUS, CFS	S	cfs	9.5 4	.5	2.4
INSTANTANEOUS YIELD	S	lbs/sec	.024	.022	.007
PRECIPITATION, TOTAL	S	in/day	0	0	0
SEDIMENT, PARTICLE SIZE FRACT. < .0625 MM % dry wgt.	S	mg/L	133	69	40

Table 7: Continued

PERIOD: Spring Season, 1995
STATION TYPE: Upstream Station **PRIMARY CODE:** Station C
CHEMICAL PARAMETERS

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FLOW, STREAM, INSTANTANEOUS, CFS	S	cfs	6.3	3.6	2.8
INSTANTANEOUS YIELD	S	lbs/sec	0.025	0.005	0.002
PRECIPITATION, TOTAL	S	in/day	0.05	0.00	0.00
SEDIMENT, PARTICLE SIZE FRACT. < .0625 MM % dry wgt.	S	mg/L	60	27	14

STATION TYPE: Downstream Station **PRIMARY CODE:** Station B

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FLOW, STREAM, INSTANTANEOUS, CFS	S	cfs	8.9	5.0	3.0
INSTANTANEOUS YIELD	S	lbs/sec	0.081	0.023	0.008
PRECIPITATION, TOTAL	S	in/day	0.08	0.00	0.00
SEDIMENT, PARTICLE SIZE FRACT. < .0625 MM % dry wgt.	S	mg/L	112	64	44

PERIOD: Spring Season, 1997
STATION TYPE: Upstream Station **PRIMARY CODE:** Station C
CHEMICAL PARAMETERS

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FLOW, STREAM, INSTANTANEOUS, CFS	S	cfs	2.5	1.9	1.5
INSTANTANEOUS YIELD	S	lbs/sec	0.03	0.002	0.001
PRECIPITATION, TOTAL	S	in/day	0.00	0.00	0.00
SEDIMENT, PARTICLE SIZE FRACT. < .0625 MM % dry wgt.	S	mg/L	22	17	13

STATION TYPE: Downstream Station **PRIMARY CODE:** Station B

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50--25-FLOW,	
STREAM, INSTANTANEOUS, CFS	S	cfs	4.9	4.4	3.6
INSTANTANEOUS YIELD	S	lbs/sec	0.007	0.005	0.003
PRECIPITATION, TOTAL	S		in/day		0.00
0.00 0.00					
SEDIMENT, PARTICLE SIZE FRACT.	S		mg/L		27
19	12	< .0625 MM % dry wgt.			

PERIOD: Spring Season, 1998
STATION TYPE: Upstream Station **PRIMARY CODE:** Station C
CHEMICAL PARAMETERS

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FLOW, STREAM, INSTANTANEOUS, CFS	S	cfs	6.4	4.2	2.4
INSTANTANEOUS YIELD	S	lbs/sec	0.012	0.004	0.002
PRECIPITATION, TOTAL	S	in/day	0.05	0.00	0.00
SEDIMENT, PARTICLE SIZE FRACT. < .0625 MM % dry wgt.	S	mg/L	40	20	13

STATION TYPE: Downstream Station **PRIMARY CODE:** Station B

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FLOW, STREAM, INSTANTANEOUS, CFS	S	cfs	18.4	9.1	6.7
INSTANTANEOUS YIELD	S		lbs/sec	0.035	0.015
0.010					
PRECIPITATION, TOTAL	S		in/day		0.00
0.00 0.00					
SEDIMENT, PARTICLE SIZE FRACT.	S		mg/L		52
30	18	< .0625 MM % dry wgt.			

PERIOD: Spring Season, 1999

STATION TYPE: Upstream Station | **PRIMARY CODE:** Station C

CHEMICAL PARAMETERS

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FLOW, STREAM, INSTANTANEOUS, CFS	S	cfs	5.2	3.0	2.2
INSTANTANEOUS YIELD	S	lbs/sec	0.007	0.003	0.002
PRECIPITATION, TOTAL	S	in/day	0.09	0.00	0.00
SEDIMENT, PARTICLE SIZE FRACT. < .0625 MM % dry wgt.	S	mg/L	36	17	10

STATION TYPE: Downstream Station | **PRIMARY CODE:** Station B

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FLOW, STREAM, INSTANTANEOUS, CFS	S	cfs	14.3	6.0	3.7
INSTANTANEOUS YIELD	S	lbs/sec	0.039	0.010	0.004
PRECIPITATION, TOTAL	S	in/day	0.38	0.00	0.00
SEDIMENT, PARTICLE SIZE FRACT. < .0625 MM % dry wgt.	S	mg/L	41	30	19

PERIOD: Spring Season, 2000

STATION TYPE: Upstream Station | **PRIMARY CODE:** Station C

CHEMICAL PARAMETERS

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FLOW, STREAM, INSTANTANEOUS, CFS	S	cfs	0.4	0.1	0.1
INSTANTANEOUS YIELD	S	lbs/sec	0.003	0.000	0.000
PRECIPITATION, TOTAL	S	in/day	0.310.00	0.00	
SEDIMENT, PARTICLE SIZE FRACT. < .0625 mm, % dry wgt.	S	mg/L	120	59	18

STATION TYPE: Downstream Station | **PRIMARY CODE:** Station B

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FLOW, STREAM, INSTANTANEOUS, CFS	S	cfs	4.5	0.1	0.0
INSTANTANEOUS YIELD	S		lbs/sec	0.008	0.010
0.000					
PRECIPITATION, TOTAL	S	in/day	0.41	0.000.00	
SEDIMENT, PARTICLE SIZE FRACT. < .0625 mm, % dry wgt.	S	mg/L	110	30	19

PERIOD: Spring Season, 2001

STATION TYPE: Upstream Station | **PRIMARY CODE:** Station C

CHEMICAL PARAMETERS

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FLOW, STREAM, INSTANTANEOUS, CFS	S	cfs	3.5	2.1	0.9
INSTANTANEOUS YIELD	S	lbs/sec	0.006	0.002	0.001
PRECIPITATION, TOTAL	S	in/day	0.070.00	0.00	
SEDIMENT, PARTICLE SIZE FRACT. < .0625 mm, % dry wgt.	S	mg/L	29	16	10

STATION TYPE: Downstream Station | **PRIMARY CODE:** Station B

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FLOW, STREAM, INSTANTANEOUS, CFS	S	cfs	10.5	4.6	1.6
INSTANTANEOUS YIELD	S		lbs/sec	0.020	0.009
0.001					
PRECIPITATION, TOTAL	S	in/day	0.07	0.000.00	
SEDIMENT, PARTICLE SIZE FRACT. < .0625 mm, % dry wgt.	S	mg/L	56	25	19

Table 7: Continued

PERIOD: Spring Season, 2002
STATION TYPE: Upstream Station **PRIMARY CODE:** Station C
CHEMICAL PARAMETERS

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FLOW, STREAM, INSTANTANEOUS, CFS	S	cfs	5.9	2.5	1.8
INSTANTANEOUS YIELD	S	lbs/sec	0.020	0.002	0.001
PRECIPITATION, TOTAL	S	in/day	0.140.00	0.00	
SEDIMENT, PARTICLE SIZE FRACT. < .0625 mm, % dry wgt.	S	mg/L	56	15	10

STATION TYPE: Downstream Station **PRIMARY CODE:** Station B

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FLOW, STREAM, INSTANTANEOUS, CFS	S	cfs	19.2	6.9	3.0
INSTANTANEOUS YIELD	S		lbs/sec	0.025	0.009
0.002					
PRECIPITATION, TOTAL	S	in/day	0.07	0.000.00	
SEDIMENT, PARTICLE SIZE FRACT. < .0625 mm, % dry wgt.	S	mg/L	32	16	10

PERIOD: Spring Season, 2003
STATION TYPE: Upstream Station **PRIMARY CODE:** Station C
CHEMICAL PARAMETERS

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FLOW, STREAM, INSTANTANEOUS, CFS	S	cfs	5.6	3.4	1.5
INSTANTANEOUS YIELD	S	lbs/sec	0.013	0.004	0.002
PRECIPITATION, TOTAL	S	in/day	0.01	0.00	0.00
SEDIMENT, PARTICLE SIZE FRACT.	S	mg/L	50	30	
18					
< .0625 mm, % dry wgt.					

STATION TYPE: Downstream Station **PRIMARY CODE:** Station B

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FLOW, STREAM, INSTANTANEOUS, CFS	S	cfs	16.3	10.6	7.2
INSTANTANEOUS YIELD	S	lbs/sec	0.020	0.009	0.005
PRECIPITATION, TOTAL	S	in/day	0.00	0.00	0.00
SEDIMENT, PARTICLE SIZE FRACT. < .0625 mm, % dry wgt.	S	mg/L	26	13	10

PERIOD: Spring Season, 2004
STATION TYPE: Upstream Station **PRIMARY CODE:** Station C
CHEMICAL PARAMETERS

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FLOW, STREAM, INSTANTANEOUS, CFS	S	cfs	3.3	2.4	1.3
INSTANTANEOUS YIELD	S	lbs/sec	0.002	0.002	0.001
PRECIPITATION, TOTAL	S	in/day	0.03	0.00	0.00
SEDIMENT, PARTICLE SIZE FRACT.	S	mg/L	26	14	
6					
< .0625 mm, % dry wgt.					

STATION TYPE: Downstream Station **PRIMARY CODE:** Station B

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FLOW, STREAM, INSTANTANEOUS, CFS	S	cfs	20.7	14.5	10.9
INSTANTANEOUS YIELD	S	lbs/sec	0.012	0.007	0.005
PRECIPITATION, TOTAL	S	in/day	0.04	0.00	0.00
SEDIMENT, PARTICLE SIZE FRACT. < .0625 mm, % dry wgt.	S	mg/L	12	8	5

Final Results

The non-glaciated C watershed with limited rowcrop agriculture had the highest sediment yields, which decreased after basin construction. Subwatershed D, which is glaciated and has greater row crop agriculture, had higher sediment yields after basin construction. Streambank erosion sites were evident and resulted from streambank incision. Tabulations of mass wasting at specif c bank erosion sites indicate the increased sediment concentrations resulted from channel erosion upstream of sampling station D. Upstream of station B a large sediment basin was constructed in 1996. Results of the installation of the basin showed that sediment yields dropped from 4.35 tons per acre-ft of stream f ow to 0.26 tons/ac-ft of stream f ow. This represents a decrease in concentration from 3,197 mg/L to 189 mg/L entering into Lake Pittsf eld. Figure (3) illustrates all events sampled at station B and shows the reduction of tons of sediment entering Lake Pittsf eld.

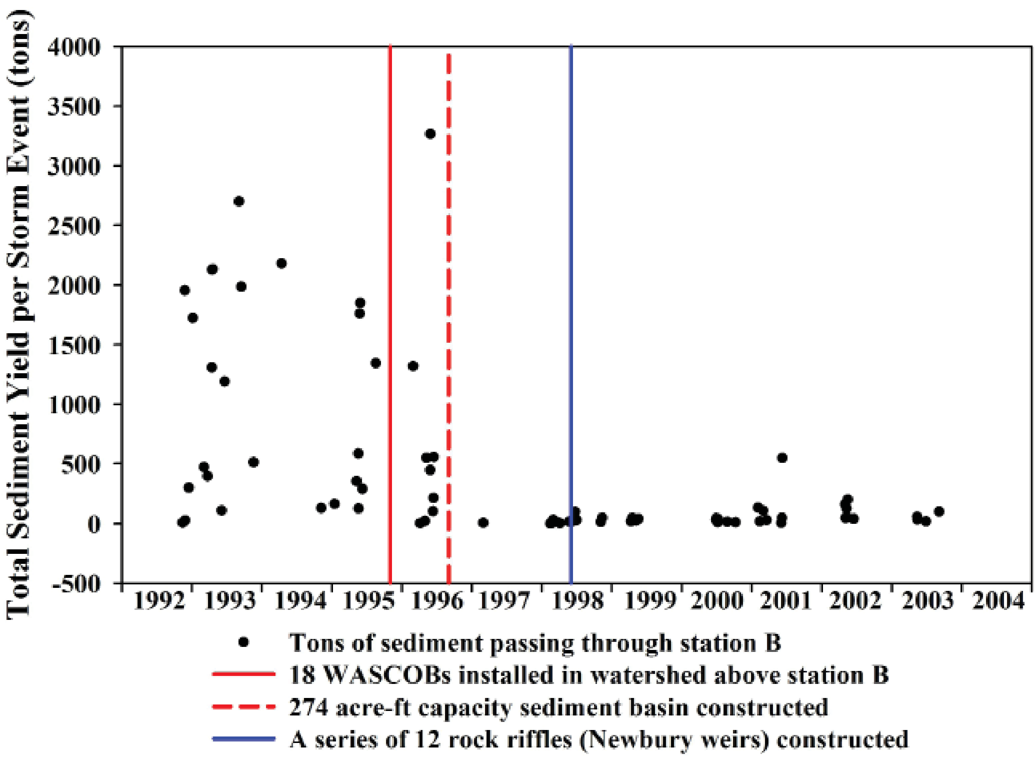

Figure 13: Total sediment yield, monitoring station B, 1992-2003. The number of WASCOBs cited represents the cumulative number constructed above the monitoring station

Project data were also statistically analyzed in two stages. Preliminary data (1992-1998) were analyzed by Grabow (1999), while ISWS project staff conducted subsequent analysis on complete project data (1992 to 2003). Grabow (1999) f rst evaluated discrete changes in sediment yield, then gradual changes and lastly year-by-year changes. To analyze discrete changes in sediment yield, Grabow (1999) conducted multiple regression analysis on data from 1992-1998 using the variables 'period', 'season' and 'discharge'. The variable 'period' def ned data from 1992 to 1996 as being pre-BMP, while data from 1997-1998 was def ned as post-BMP. Sediment yield per storm event was the dependent variable. Storm water discharge, period and season (winter/spring and summer/fall) were explanatory variables. Grabow (1999) used the nonparametric Kendall's tau-b (Kendall, 1938) to corroborate f ndings from the test for gradual change in sediment yield from storm events from 1992 to 1998. Analysis of Covariance (ANCOVA) was used to detect differences in sediment yield between specif c years. The data were log transformed due to the skewness of the data.

Multiple regression analysis was also used to analyze updated data covering 1992 to 2003 consistent with Grabow's (1999) methodology. As before, the variables 'season,' 'discharge,' and 'period' where used as explanatory variables, with the 'period' variable redef ned as pre-BMP (1992–1996) and post-BMP (1997-2003). Storm event sediment yield was the dependent variable. Storm water discharge, period and season (winter/spring and summer/fall) were explanatory variables. Statistical tests and results are summarized in Table 8. Kendall tau b and ANCOVA results for gradual and yearly change in sediment yield from storm events from 1992 to 2003 will be published elsewhere. All statistical analyses were done using appropriate SAS procedures (SAS Institute 2001). The impact of potential differences in the intensity of individual storm events was not examined in this study and could affect conclusions presented here regarding trends in erosion and sediment yield. The authors are in the process of investigating this issue.

Table 8. Summary of Findings by Station

Station		Analysis Method[3]		
	Period covered	**Pre/Post Ye**	**arly**	**Gradual**
B	1992-1998 90	% reduction	1997 and 1998 lower than all previous years	Significant trend, reduction from 330 to 70 kg at avg flow (79% reduction)
	1992-2003 91	% reduction	--	--
C	1992-1998 45	% reduction	1998 lower than 1993, 1994 and 1996	No significant trend over period covered
	1992-2003	67.8% reduction	-- --	
D[2]	1992-1998 48	% reduction	1998 lower than 1993 and 1996, higher than 1992. 1996 higher than all other years	No significant trend over period covered
	1992-2003 61	% reduction	--	--

[1]Sediment yield and reductions based on average flow
[2] No data collected in 1997
[3] All statistical results presented are significant at $\alpha=0.05$

INFORMATION, EDUCATION, AND PUBLICITY

Information and education activities were conducted by a private organization (Farm Bureau) and the Pike County S&WCD. Two public meetings were held to inform producers about the goals of the project. Articles pertaining to the project have appeared in the local newspapers.

The Illinois State Water Survey will produce two educational/informational productions at the end of the Lake Pittsf eld National Monitoring Strategy. These two productions will include a f nal videotape production and a f nal project report documenting the entire aspects of the Lake Pittsf eld National Monitoring Strategy. The f nal videotape was produced and the f nal project report is being created and should be complete on or before January of 2009.

TOTAL PROJECT BUDGET

The estimated budget for the Lake Pittsf eld Section 319 National Monitoring Program project for the period of FY 92-04 is summarized in table 9.

Table 9: Summary of the Lake Pittsf eld Section 319 National Monitoring Program Project

Project Element	Funding Source ($)			
Federal		State	Local	Sum
Proj Mgt	NA	NA	NA	NA
I&E NA		NA	NA	NA
LT [319(h)]	689,000	459,333	NA	1,148,333
WQ Monit	617,934	NA	223,332	841,266
Cultural Practices (WQIP)	32,000	NA	NA	32,000
Dredge/Shoreline/ 132,1 Aeration (314 Clean Lakes)	10	NA	132,110	264,220
TOTALS 1,471,044		459,333	355,442	2,285,819

Source: State of Illinois, 1993; State of Illinois, 1992; Gary Eicken (Personal Communication), 2000, Scott Tomkins (Personal Communication), 2001; Scott Tomkins (Personal Communication), 2002; Scott Tomkins (Personal Communication), 2003; Scott Tomkins (Personal Communication); 2004; Scott Tomkins (Personal Communication); 2005; Scott Tomkins (Personal Communication)

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

In 1979, the Pike County SWCD began a Special Water Quality Project that encouraged the implementation of terraces, no-till cultivation, contour plowing, and water control structures. This project was instrumental, along with drier weather conditions, in reducing soil erosion from an average of 5.8 tons per acre to 3.3 tons per acre (a 45% decrease) from 1979 to 1994.

In the fall of 1997, funding was designated from the Illinois EPA and the Illinois Department of Agriculture for the construction of a series of rock grade controls (Newbury weirs) located on Blue Creek upstream of station D. The construction of these rock grade controls was completed in May of 1998. The construction of the weirs has helped to reduce channel erosion and sedimentation by slowing the incision process occurring upstream of station D.

Section 314 funds have been used to install sediment-reducing shoreline BMPs and one destratif er (aerator) in Lake Pittsf eld to increase oxygen concentrations throughout the lake, thereby increasing f sh habitat. The lake was dredged in April of 1999 in an effort to reclaim the original capacity of the lake.

OTHER PERTINENT INFORMATION

Many organizations have combined resources and personnel in order to protect Lake Pittsf eld from agricultural nonpoint source pollution. These organizations are listed below:

- USDA FSA
- City of Pittsf eld
- Farm Bureau
- U.S. Environmental Protection Agency

- Illinois Environmental Protection Agency
- Illinois State Water Survey
- Landowners
- Pike County Soil and Water Conservation District
- Illinois Department of Agriculture

PROJECT CONTACTS

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Illinois

Waukegan River
Section 319
National Monitoring Program Project

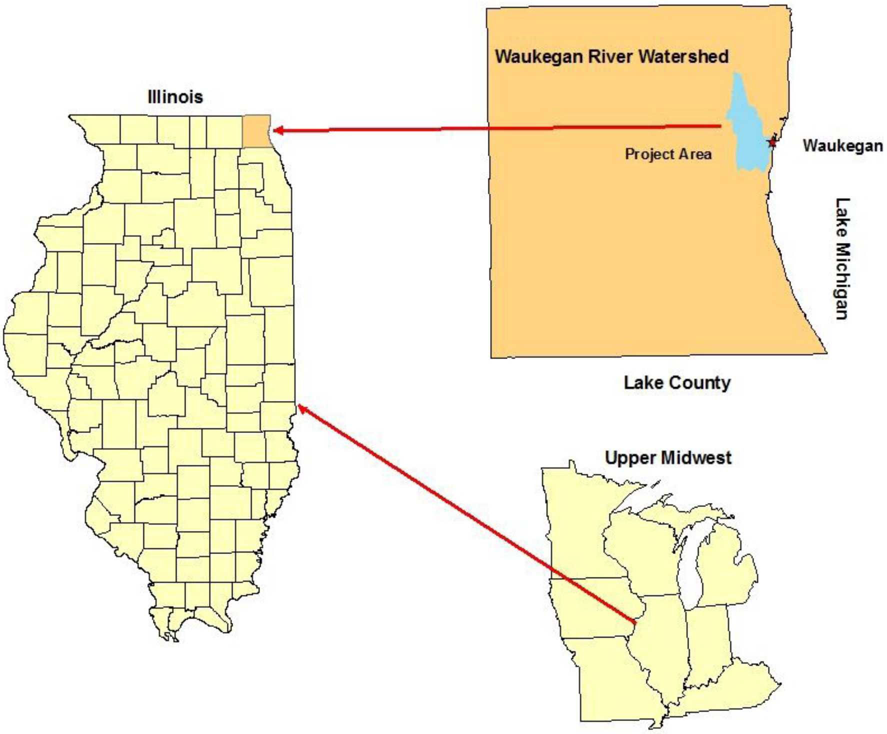

Figure 13: Location of the Waukegan River Project in the Waukegan River Watershed of Lake County, Illinois

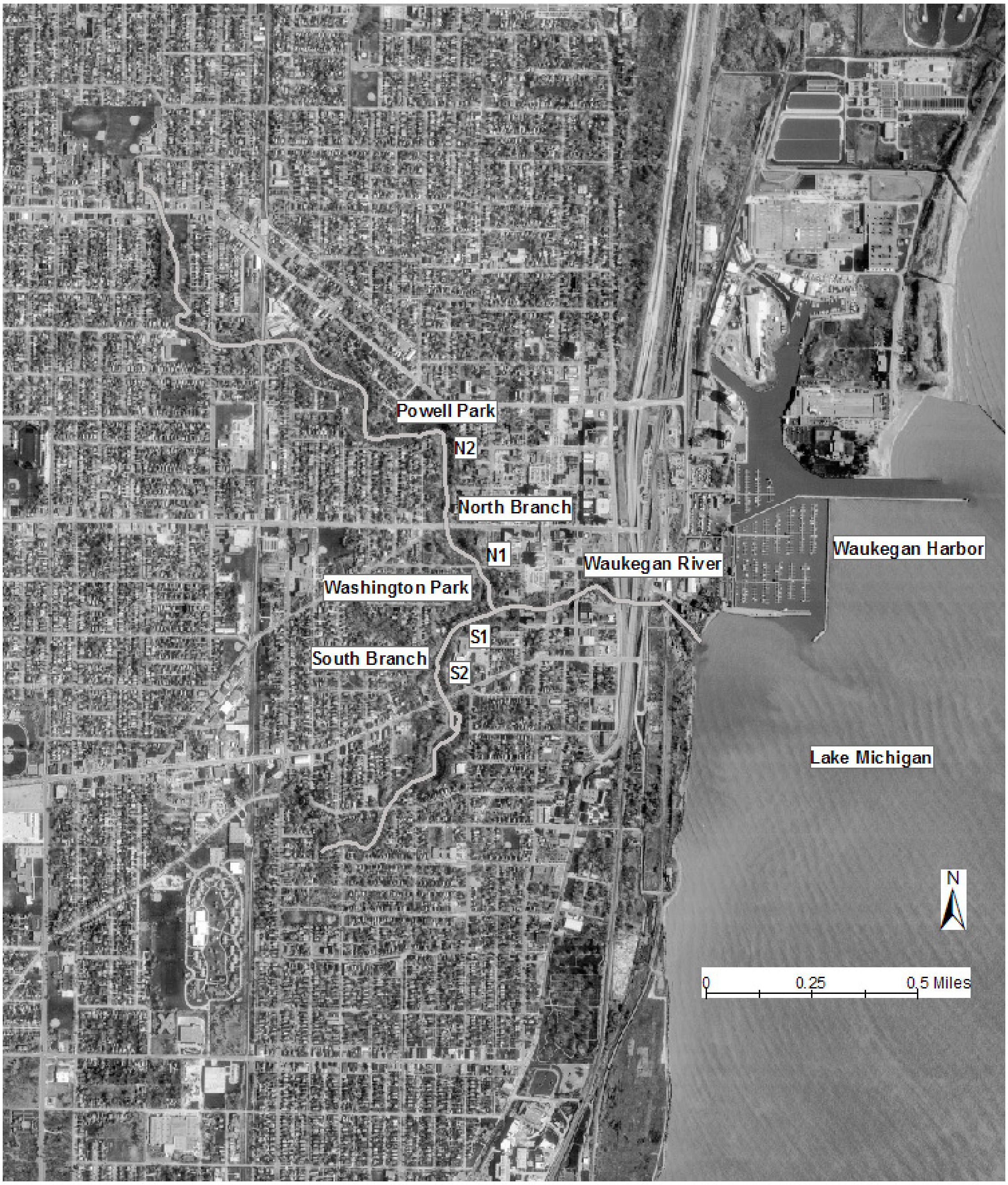

Figure 14: Monitoring Locations in the Waukegan River Watershed

PROJECT OVERVIEW

The Waukegan River watershed is located about 35 miles north of Chicago (Figure 1). The project locations for the Waukegan River Section 319 National Monitoring Program project are located in Washington and Powell Parks in the City of Waukegan, Illinois (Figure 2). The watershed is 12.5 miles long and contains 7,397 acres, with major land uses consisting of single and multi-family dwellings (35.0 %), transportation (24.4 %), public and private open space (11.8 %) (Table 1). Washington Park is situated in an area that represents the most urbanized reach of the river and is located at the confluence of the North Branch and the South Branch about 1/2 mile upstream from the river mouth on Lake Michigan. Powell Park is located on the North Branch 1 mile from the river mouth and within a residential area. Most of the watershed was urbanized prior to any requirements for stormwater detention. Therefore, there is little control over stormwater quantity or quality, resulting in flashy runoff rates and heavy stormwater pollutant loads. Water quality concerns also include cross-connections between sanitary and storm sewers, potential sanitary sewer overflows during wet weather, severe streambank erosion, channel downcutting, and artificial lining.

Erosion control methods used to repair the eroding stream channels included vegetative stabilization (dogwoods, willows, and grasses) combined with structural stabilization (Lunkers, fiber rolls, A-jacks, and stone). A series of pool-and-riffle complexes were created by constructing six rock grade control structures (Newbury Weirs) from granite boulders in a reach covering 1000 feet of the South Branch starting at the confluence and two structures in a reach covering 300 feet of the North Branch in Washington Park.

The Waukegan River Section 319 National Monitoring Program project is being used to demonstrate the effectiveness of stream restoration techniques implemented on the Waukegan River. The stream habitat and urban fisheries were surveyed before implementation of the stream restoration techniques. The in-stream habitat and stream fisheries were also surveyed to provide post-implementation data. The monitoring strategy included macroinvertebrate sampling, physical habitat monitoring, and fisheries monitoring during the spring, summer, and fall cycles of the project period.

This project has demonstrated that biotechnical streambank stabilization techniques are more cost-effective than traditional armoring approaches in reducing erosion and also provide additional water quality and in-stream habitat benefits. It has been shown that rock grade control structures (Newbury Weirs) that mimic natural pool and riffles add to the in-stream physical diversity which in turn leads to increased biodiversity. In addition to enhancing habitat, pool and riffle structures are effective in reducing erosion of the streambed, improving stream stability and increasing water aeration. Currently, the project is in the post-BMP monitoring phase, with monitoring completed in October 2006. Data analysis and Final Report preparation activities have begun. The Final Report is expected to be completed on or before June 2009.

PROJECT BACKGROUND

Project Area

The project area consists of four stations located within two city parks of Waukegan, IL (Figure 2). Stations located in Washington Park are S1 and S2 on the South Branch of the Waukegan River and station N1 on the North Branch. Station N2 is located in Powell Park on the North Branch. The parks are situated within an older, highly urbanized area of the city.

Relevant Hydrologic, Geologic, and Meteorological Factors

The Waukegan River falls from 730 msl to 580 msl, with the steepest lands located in Washington and Powell Parks. Information from the Midwestern Regional Climate Center indicates that the Waukegan River watershed has a mean annual of 32.82 inches of precipitation.

Land Use

The 7,397 acre watershed of the Waukegan River is largely urbanized, with over 80% of the City of Waukegan lying within the watershed boundaries. As of the 2000 census there were 87,901 people living in Waukegan with a population density of 1,475.0/km2 (3,819.8/mi2). Because this is an older town, there are very few stormwater detention basins.

Table 1: Land Use of the Waukegan River Watershed

Land Use	**Acres**	**%**
Agricultural	6.9	0.1
Disturbed Land	139.1	1.9
Forest and Grassland	495.9	6.7
Government and Institutional	449.0	6.0
Industrial	204.3	2.8
Multi-Family	169.8	2.3
Office	1.2	0.0
Public and Private Open Space	872.8	11.8
Retail/Commercial	482.1	6.5
Single Family	2416.8	32.7
Transportation	1801.9	24.4
Utility and Waste Facilities	161.6	2.2
Water	28.3	0.4
Wetlands	167.1	2.2
TOTAL	7396.8	100

Source: Lake County Planning, Building and Development, 2000, (Waukegan River Watershed Plan, 2007).

Water Resource Type and Size

The Waukegan River Section 319 National Monitoring Program project is located in the northeastern corner of Illinois (Figure 1). The length of the Waukegan River/Ravine main channel and tributaries, which drain predominantly urban areas in Waukegan, IL, is approximately 12.5 miles. Discharge of the Waukegan River is into Lake Michigan, just east of the downtown area and only 6,000 feet from the City's fresh water intake.

Water Uses and Impairments

As an urban stream, stormwater has caused severe channel erosion. The primary pollutant of concern is sediment. Severe bank erosion, due to unstable stream channels and high velocity runoff, is increasing nonpoint source pollution loads into Lake Michigan, breaking smaller sewer lines that were buried in the stream and endangering other sewer lines. In addition to the physical destruction, aquatic habitat has been impaired due to the lack of water depth in pools, limited cobble substrates, and limited stream aeration.

Pollutant Sources

High volume of runoff from impervious surfaces is degrading the urban streams within the Waukegan watershed. The steepest lands, and therefore the most eroded, are located in Washington and Powell Parks along the Lake Michigan bluffs.

Pre-Project Water Quality

Aquatic resources were limited by shallow pool depth and high summer water temperatures. Fine silts filled both pools and runs to the extent that little rock substrates were visible.

Water Quality Objectives

The purpose of the project is to restore the stream banks for the Waukegan River in Washington Park and Powell Park, which have become a source of urban nonpoint source pollution and a danger to the public. The detrimental effects of stormwater runoff will be reduced or mitigated.

Project Time Frame

The project was initially funded in 1994 as a 319 Watershed Project. Monitoring began in 1994 and was officially approved in 1996 as a Section 319 National Monitoring Program project. Monitoring activities concluded in October of 2006. This allowed for ten years of post-BMP implementation.

PROJECT DESIGN

Nonpoint Source Control Strategy

Biotechnical stream restoration techniques (a combined vegetative and structural approach) were selected to demonstrate how these techniques can be more cost-effective than traditional engineered approaches in reducing erosion, enhancing habitat and stabilizing the stream.

Projects on the North Branch of the Waukegan River

Lunkers and a-jacks were installed in Powell Park. Lunkers with stone were installed in Washington In May of 1992 Lunkers and A-jacks were installed at station N2 in Powell Park. In September of 1992 Lunkers with stone and A-jacks were installed at station N1in Washington Park. Willows, dogwoods, and grasses were planted on the stream banks where lunkers were installed. In January of 1996 two Newbury Weirs were constructed at station N1. Two sampling stations, N1 and N2 (Figure 2), are utilized for background data collection, but were not part of the Section 319 National Monitoring Program project.

Projects on the South Branch of the Waukegan River

In September of 1994, lunkers, a-jacks, stone, dogwoods, willows, and grasses were used to stabilize a severe bank erosion site at station S1on the South Branch of the Waukegan River. Smaller bank erosion sites were stabilized with coir coconut fiber rolls, willows, and grasses. Because the original bank stabilization efforts did not significantly increase stream depth, in January of 1996, a series of six pool-and-riffle complexes were created by the construction of rock grade control structures (Newbury Weirs) from granite boulders in a 1000 foot reach of the South Branch beginning at the confluence. Station S2 did not have any projects installed and was utilized as control. Both station S1 and S2 were primary sampling stations.

Water Quality Monitoring

Variables Measured

Biological parameters are measured during the spring, summer, and fall cycles of the project period. Flow is measured continuously.

Biological

Fish samples
Macroinvertebrates
Habitat

Chemical and Other

None

Covariates

Dissolved oxygen (DO)
Temperature
Flow

Sampling Scheme

The stream was divided into an upstream untreated reference site designated as station S2 and a severely eroding downstream treated area designated as station S1. With this design, urban water quality will affect both the control (S2) and the rehabilitated station (S1) uniformly. At each location fish, macoinvertebrates, and habitat were sampled during the spring, summer, and fall seasons. Sampling was also conducted at stations N1 and N2 on the North Branch as additional reference (Figure 2).

The scoring used for each category to measure stream health were the Index of Biotic Integrity (IBI) for fish, the Macroinvertebrate Biotic Index (MBI) for aquatic insects, and Potential Index of Biotic Integrity (PIBI) for habitat. Major criteria used to determine stream health include percentage of fish species and number of individuals for the IBI; the number of individuals in each taxon and a tolerance value for each taxon for MBI; and. percentage of substrate types, percent of pool, and the average width for the PIBI.

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

Water quality data are stored and maintained in the USEPA NonPoint Source Management System (NPSMS) databases.

Findings to Date

The biological sampling since 1994 indicates that the number of fish species and abundance in the South Branch had improved after the construction of lunkers and rock grade control structures (Newbury Weirs).The IBI rose sharply from a limited aquatic resource into the moderate category after construction (Figure 3). Both N1 and S1where lunkers and Newbury Weirs were applied averaged higher IBI scores and fish population with more fish species than the untreated control at S2 or the N2 bank armored site from 1996 through 2006.

Documented fish kills occurred in 1998 and 1999 impacting the South Branch. The fish kills were observed at very low flow conditions with no turbidity present in the water column. Fish kills were not observed during sampling event activities after 1999. After the 1996 peak IBI scores continued to decline. Tolerant fish species dominated the fish population at all four stations which helped drive down the IBI scores. The Mottled Sculpin was the only intolerant species caught during the entire period making up less than one percent of the total catch. Coho Salmon had the highest overall percent of intermediate species. The occurrence of this non-native species was influenced by annual spring stocking of Lake Michigan. Eighty percent of the Coho Salmon were caught during the spring sampling period. Table 2 shows the percent of the total catch of fish species for each station over the thirteen year period.

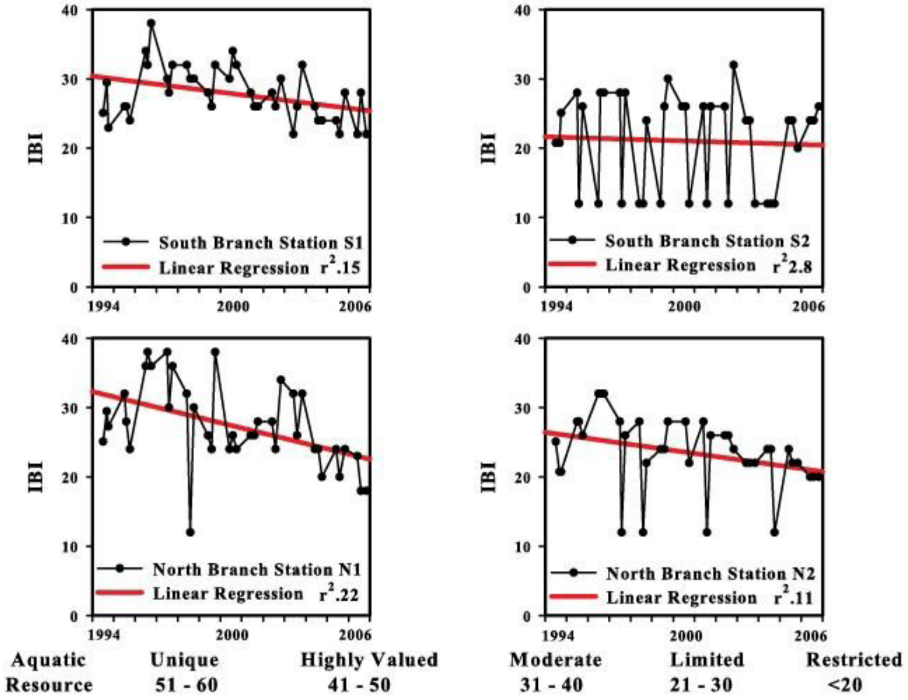

Figure 3: IBI Scores from Monitoring stations in the Waukegan River Watershed

Table 2: Percent of the Total Fish Caught during the Project Period in the Waukegan River Watershed

Fish Species Common Name	Tolerance	Native Status	Station	Station S1 %	Station S2 %	Station N1 %	Station N2 %
Green Sunfish	Tolerant	Native		38.0	13.4	15.2	48.8
Mosquitofish	Tolerant	Native		8.4	37.6	1.6	0.5
Threespine Stickleback	Intermediate	Non-Native		12.2	31.1	43.5	1.2
Fathead Minnow	Tolerant	Native		12.8	8.7	7.5	9.2
White Sucker	Tolerant	Native		8.5	2.2	6.4	23.7
Goldfish	Tolerant	Non-Native		0.9	0.0	0.9	3.7
Bluegill	Tolerant	Native		1.5	0.2	4.6	2.9
Coho Salmon	Intermediate	Non-Native		0.9	4.3	1.5	2.5
Longnose Dace	Intermediate	Native		4.0	0.2	1.6	0.0
Largemouth Bass	Tolerant	Native		3.5	0.7	1.6	0.0
Golden Shiner	Tolerant	Native		2.4	0.7	1.6	0.0
Carp	Tolerant	Non-Native		1.8	0.0	1.1	1.9
Number of remaining species <1% & percent				(12) 5.1%	(3) 0.9%	(13) 12.9%	(8) 5.6%

Macroinvertebrate Biotic Index scores progressed into a poor stream condition following a similar pattern to the IBI scores (Figure 4). Some individual scores at station S1 and S2 on the South Branch jumped into the very poor stream condition category. Station S2 had MBI scores that dropped into a fair stream condition after restoration in 1996 and persisted up to 2001where they began to move back into a poor stream condition. The station N1 restoration site also had MBI scores in the fair stream condition category during and after stream restoration from 1995 through 2001where the scores began to creep into a poor stream condition. Station N2 maintained better quality scores throughout the project period with the exception of 2004 and 2006 having poor stream conditions.

Pollutant associated species Chironomidae (Bloodworms or Midge fly larvae), OLIGOCHAETA (Aquatic Earthworms), and Caecidotea (Pillbugs or Sowbugs) dominated the overall population of collected species (Table 3). The average taxa richness for the thirteen year period at station N2, N1, and S2 were 8 (poor) while station S1 averaged a 10 (fair). An overall average of the EPT (Ephemeroptera + Plecoptera + Trichoptera) taxa richness for stations N1 and N2 were in a fair category with a score of 3 where 23% of the 39 sampled dates at station N1fell into the fair, good or excellent category's and 13% of the sampled dates at station N2 were in the fair, good or excellent categories while the remaining percents fell into the poor or very poor category. At Stations S1 and S2 the overall average EPT taxa richness score was under a 1(very poor) where 8% of the sampled dates at both stations fell into the fair, good or excellent categories.

Examaning the functional feeding designations of the species collected revealed that gatherer/collectors averaged 87% of the population of all stations while 6% were predators and 4% were scrapers with the remaining percent made up of filter/collectors, omnivores, and shredders. Generalists, such as collectors and filterers, have a broader range of acceptable food materials than specialists (scrapers, piercers,and shredders) (Cummins and Klug 1979), and thus are more tolerant to pollution that might alter availability of certain food.

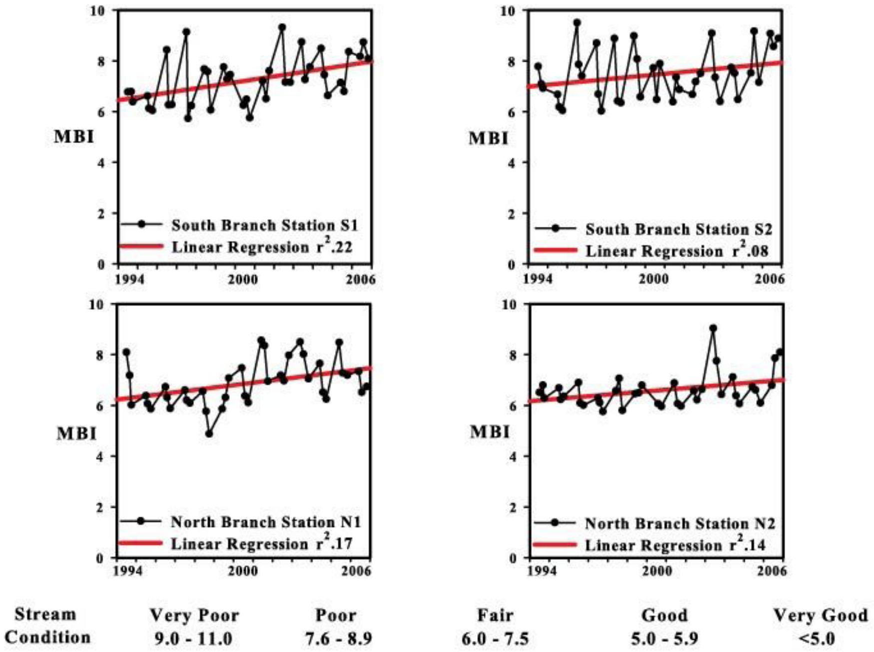

Figure 4: MBI Scores from Monitoring stations in the Waukegan River Watershed

Table 3: Percent of the Total Benthic Sampled during the Project Period in the Waukegan River Watershed

Taxon	Functional Feeding	Tolerance	S1 %	S2 %	N1 %	N2 %
Chironomidae	Gatherer/Collector	6	39.29	37.12	24.42	24.17
OLIGOCHAETA	Gatherer/Collector	10	30.02	27.83	16.35	9.00
Caecidotea intermedius	Gatherer/Collector	6	4.57	1.67	35.83	25.42
Caecidotea	Gatherer/Collector	6	9.30	15.82	12.16	29.17
Physella	Scraper	9	4.42	6.46	1.76	3.23
Erpobdellidae	Predator	8	3.48	2.55	2.76	2.13
Gammarus	Omnivore	3	0.89	0.41	3.19	1.91
Glossiphoniidae	Predator	8	0.76	1.01	0.83	1.85
Ischnura	Predator	6	2.08	1.34	0.05	0.01
Crangonyx	Gatherer/Collector	4	0.03	0.68	0.39	0.94
TURBELLARIA	Predator	6	0.41	1.29	0.03	0.49
Hydropsyche	Filter/Collector	5	0.19	0.22	0.74	0.70
Number of remaining		--	(55)	(45)	(25)	(30)
taxa & percent			4.56	3.60	1.49	0.98

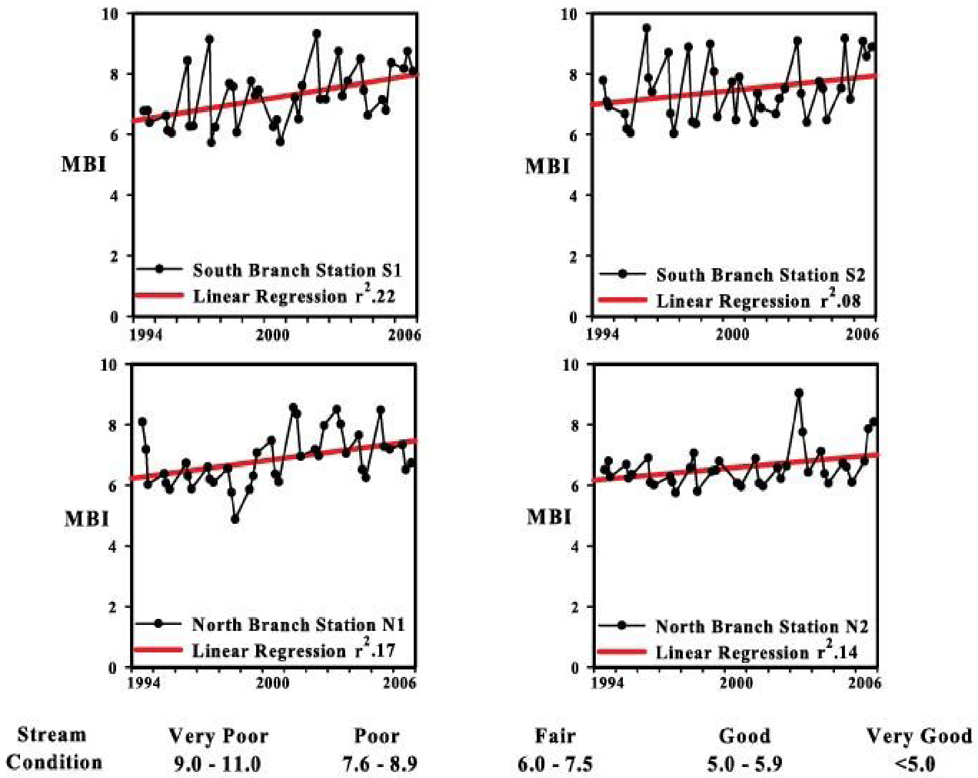

Figure 5: PIBI Scores from Monitoring stations in the Waukegan River Watershed

At treated stations S1 and N1the PIBI scores continued to climb into the highly valued category driven by the increase in the percent of pool and a decrease in the percent of silt-mud (Figure 5). The untreated station S2 also shows a slight improvement that is driven by natural changes in the percent of pool. The station N2 bank armored project scores stay fairly consistent where an increase in the percent of claypan substrate due to scour is driving the scores down. At all stations the PIBI scores remain in the moderate to highly valued aquatic resource category.

INFORMATION, EDUCATION, AND PUBLICITY

Station S1on the South Branch of the Waukegan River in Washington Park served as a training site for a streambank restoration class held during the Second National Nonpoint Source Watershed Monitoring Workshop. Senior personnel from the city's Public Works Department and the Waukegan Park District were taken through the restoration and stabilization process before and during construction. Workshop members participated in both the restoration installation and the fish monitoring activities.

A field manual of urban stream restoration and video of the biotechnical streambank restoration activities have been developed to highlight the biotechnical techniques that were used in the restoration.

An updated videotape production was developed describing the biotechnical stream stabilization techniques, the monitoring program, and the physical and biological enhancements achieved.

The Illinois State Water Survey will produce two educational/informational productions at the end of the Waukegan River National Monitoring Strategy. These two productions include a completed final videotape production and a final project report which is currently being developed to document the entire aspects of the Waukegan River National Monitoring Strategy. The final videotape was produced and the final project report is being created and should be completed on or before June 2009.

TOTAL PROJECT BUDGET

The estimated budget for the Waukegan River Section 319 National Monitoring Program project for the period of FY 92-06 is shown in table 4.

Table 4: Estimated budget for the Waukegan River Section 319 National Monitoring Program

Project Element	**Funding Source ($)**			
	Federal	**State**	**Local**	**Sum**
Proj Mgt	59,895	24,597	NA	84,492
I&E	2,023	677	NA	2,700
LT [319(h)]	227,218	NA	275,320	502,538
WQ Monit	163,047	96,842	NA	259,889
TOTALS	452,183	122,116	275,320	849,619

Source: Illinois Environmental Protection Agency (Personal Communication, 2000), Illinois Environmental Protection Agency (Personal Communication, 2001), Illinois Environmental Protection Agency (Personal Communication, 2003), Illinois Environmental Protection Agency (Personal Communication, 2004), Illinois Environmental Protection Agency (Personal Communication, 2005), Illinois Environmental Protection Agency (Personal Communication, 2006)

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

Further restoration activities on the South Branch of the Waukegan River included two projects in the Waukegan Park District's Washington and Roosevelt Parks. The Waukegan River Wetland Restoration Project that was started in 1998 to improved a degraded ½ acre wetland adjacent to the Waukegan River in Washington Park. The intent of this project was to reestablish the natural function of the wetland and to reduce nonpoint source pollution impacts. The project also included the stabilization of 300 feet of eroding streambank on the Waukegan River using bioengineering techniques in Washington Park. An interpretive observation station was constructed that overlooked the wetland site to inform the public about the project, the Waukegan River National Monitoring Project, Waukegan River Watershed and nonpoint source pollution.

The Roosevelt Park and Waukegan River Restoration Project begun in 2002 to address erosion and poor water quality conditions present in the Waukegan Park District's Roosevelt Park. The goals of this project will be addressed in two phases. The first phase will include the design and installation of an interpretive signage and pathway, stream restoration and wetland retrofit of the existing Roosevelt Park sediment basin on the South Branch of the Waukegan River. The proposed second phase will include the "daylighting" of Illinois Route 120 (Belvidere Street) stormwater culvert to connect Washington and Roosevelt Parks and stream corridor restoration on the South Branch of the Waukegan River in Washington Park. While the stream corridor restoration portion of the second phase was accomplished, the "daylighting" efforts for Illinois Route 120 did not proceed forward due to the lack of local/state funding availability. These stream and wetland restoration efforts will help improve water quality, create wildlife habitat and provide for environmental educational opportunities.

Waukegan River Watershed planning initiative begun in 2005 with a local advisory group to facilitate the work with local stakeholders to develop a comprehensive watershed plan. This plan included the selection of a watershed coordinator, formation of stakeholder and technical planning committees, stakeholder workshops, watershed data evaluation and resource inventory, and proposed Action Plan to improve water quality and to identify and reduce pollutants while protecting, restoring and enhancing the natural habitat and aesthetics.

This planning effort brought together the general public, governmental entities, local businesses, educational institutions and homeowners in the Waukegan River Watershed to improve the quality of life for their community. The results of the present planning efforts were the creation of the Waukegan River Watershed Plan in December of 2007 through the input of all the involved stakeholders.

OTHER PERTINENT INFORMATION

Participating agencies and organizations:

- U.S. Environmental Protection Agency
- Illinois Environmental Protection Agency
- Illinois Department of Natural Resources
- Illinois State Water Survey
- Private Contractor
- University of Illinois at Champaign—Urbana
- Waukegan Park District
- Waukegan Public Works Department

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Iowa

Sny Magill
Section 319
National Monitoring Program Project

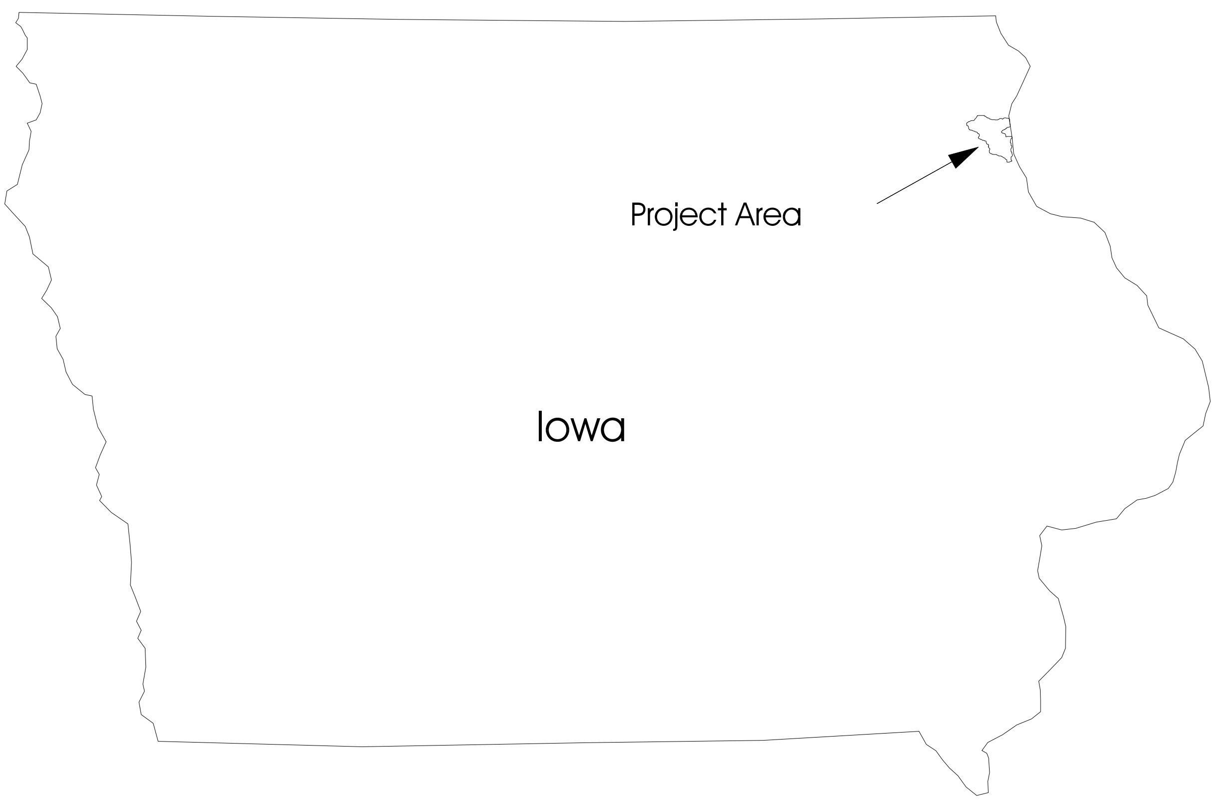

Figure 15: Sny Magill and Bloody Run (Iowa) Watershed Project Locations

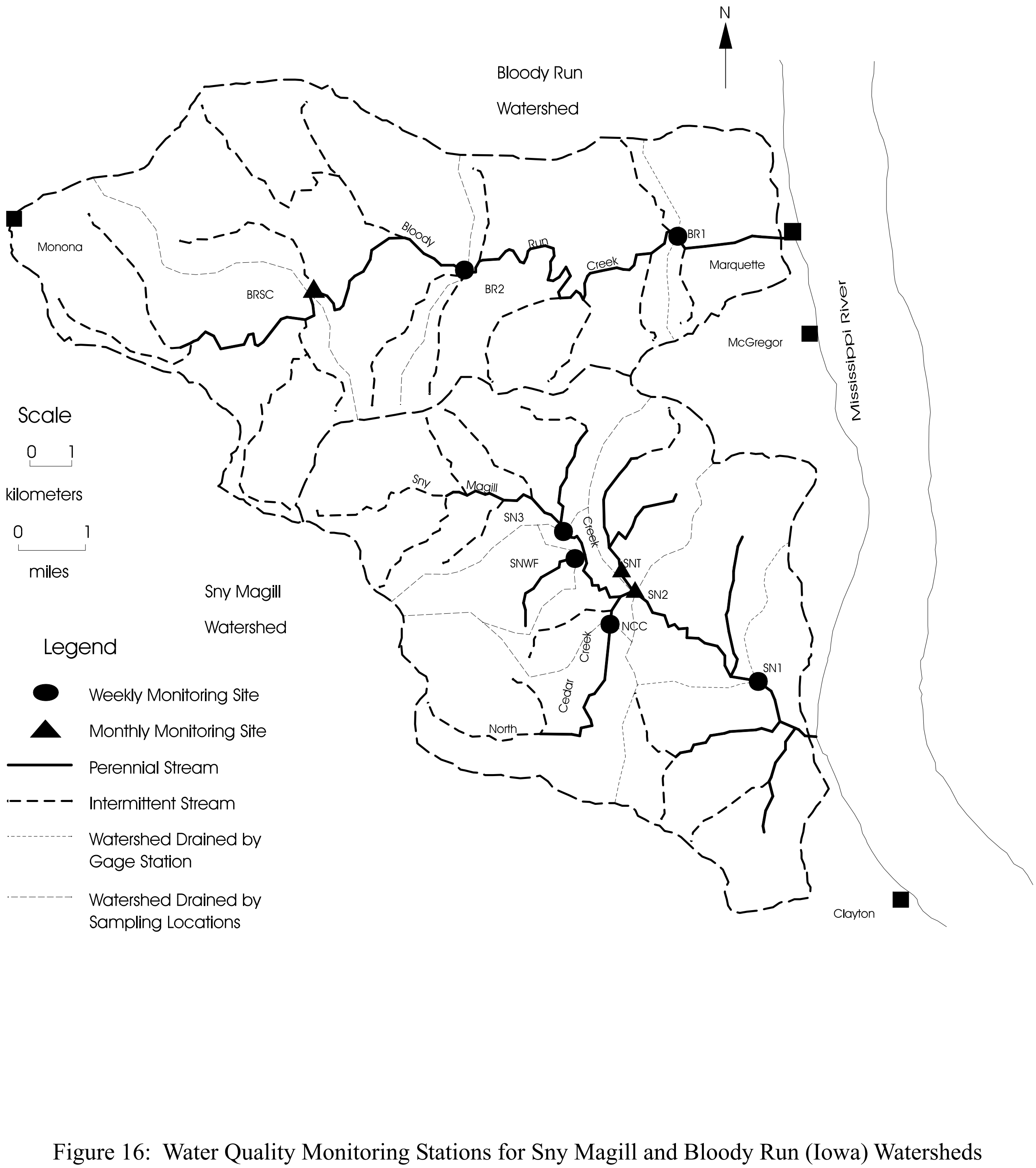

Figure 16: Water Quality Monitoring Stations for Sny Magill and Bloody Run (Iowa) Watersheds

PROJECT OVERVIEW

The Sny Magill Watershed Section 319 National Monitoring Program project was an interagency effort designed to monitor and assess improvements in water quality (reductions in sedimentation) resulting from the implementation of two U.S. Department of Agriculture (USDA) land treatment projects in the watershed: the Sny Magill Hydrologic Unit Area (HUA) and the North Cedar Creek Water Quality Special Project (WQSP). Project areas included Sny Magill Creek and North Cedar Creek basins (henceforth referred to as the Sny Magill watershed) (Figure 16). Sny Magill and North Cedar creeks are Class "B" cold water streams located in northeastern Iowa (Figure 15). North Cedar Creek is a tributary of Sny Magill Creek. The creeks, managed for "put and take" trout fishing by the Iowa Department of Natural Resources (IDNR), are two of the more widely used recreational fishing streams in the state.

The entire Sny Magill watershed is agricultural, with no industrial or urban areas. No significant point sources of pollution exist in the watershed. Land use consists primarily of row crop, cover crop, pasture, and forest. There are about 95 producers in the watershed, with farms averaging 250 acres in size.

Water quality problems in the stream result primarily from agricultural nonpoint source pollution; sediment is the primary pollutant. Nutrients, pesticides, and animal waste are also of concern.

Two USDA land treatment projects implemented in the watershed supported voluntary changes in farm management practices, resulting in improved water quality. The State of Iowa, through the Iowa Department of Agriculture and Land Stewardship (IDALS) and the IDNR, agreed to work through the local Clayton County Soil and Water Conservation District (SWCD) to provide funds for the best management practice (BMP) implementation. Sediment control measures, water and sediment control basins, animal waste management systems, stream corridor management improvements, and bank stabilization demonstrations were implemented to reduce agricultural nonpoint source pollution. A long-term goal of 50% reduction in sediment delivery to Sny Magill Creek was established.

A paired watershed approach was used with the Bloody Run Creek watershed serving as the comparison watershed (Figure 16). Subbasins within the Sny Magill watershed were compared using upstream/downstream stations.

Primary monitoring sites were equipped with U.S. Geological Survey (USGS) stream gauges to measure discharge and suspended sediment in both Sny Magill and Bloody Run creeks. Primary sites, and several other sites, were sampled for chemical and physical water quality parameters on a weekly to monthly basis. Annual habitat assessments were conducted along stretches of both stream corridors. Biomonitoring of macroinvertebrates occured on a bimonthly basis, and annual fisheries survey were conducted.

The project completed post-BMP monitoring on September 30, 2001. The final report was completed in May, 2005.

PROJECT DESCRIPTION

Project Area

The watershed drains an area of 22,780 acres directly into the Upper Mississippi River Wildlife and Fish Refuge and part of Effigy Mounds National Monument. Sny Magill Creek is the sixth most widely used recreational trout fishing stream in Iowa.

Relevant Hydrologic, Geologic, and Meteorologic Factors

Average yearly rainfall in the area is 30.6 inches.

The watershed is characterized by narrow, gently sloping uplands that break into steep slopes with abundant rock outcrops. Up to 550 feet of relief occurs across the watershed. The landscape is mantled with approximately 10-20 feet of loess, overlying thin remnants of glacial till on upland interfluves, which in turn overlie Paleozoic-age bedrock formations. The bedrock over much of the area is Ordovician Galena Group rock, which composes the Galena aquifer, an important source of ground water and also drinking water in the area. Some sinkholes and small springs have developed in the Ordovician-age limestone and dolomite.

About 80% of discharge for both Sny Magill and Bloody Run is composed of ground water, which provides the cold water characteristic of the creeks. Hence, ground water quality is also important in the overall water resource management considerations for area streams.

The stream bottom of Sny Magill and its tributaries is primarily rock and gravel with frequent riffle areas. Along the lower reach of the creek where the gradient is less steep, the stream bottom is generally silty. The upstream areas have been degraded by sediment deposition.

Land use information for the Sny Magill watershed was compiled from 1:24,000 scale color infrared aerial photographs taken September 20, 1991. The land treatment is being tracked using the USDA Natural Resources Conservation Service's CAMPS and GRASS data management systems. The information is also summarized in annual reports as required by the Sny Magill Hydrologic Unit Area project. The land treatment information has been successfully transferred and linked by tract number to other available Geographic Information System coverages for the Sny Magill watershed.

Land Use

The entire watershed is agricultural, with no industrial or urban areas. No significant point sources exist in the watershed. Sixty-five percent of the cropland is corn, with the rest primarily in oats and alfalfa in rotation with corn. There are about 95 producers in the watershed, with farm sizes averaging 250 acres.

Land use is variable on the alluvial plain of Sny Magill Creek, ranging from row cropped areas, to pasture and forest, to areas with an improved riparian right-of-way where the IDNR owns and manages the land in the immediate stream corridor. The IDNR owns approximately 1,800 acres of stream corridor along approximately eight miles of the length of Sny Magill and North Cedar creeks. Some of the land within the corridor is used for pasture and cropping through management contracts with the IDNR.

Row crop acreage planted to corn has increased substantially over the past 20 years. Land use changes in the watershed have paralleled the changes elsewhere in Clayton County, with increases in row crop acreage and fertilizer and chemical use, and attendant increases in erosion, runoff, and nutrient concentrations. U.S. Forest Service data show a 4% decline in woodland between 1974 and 1982. Much of this conversion to more erosive row crop acreage occurred without adequate installation of soil conservation practices.

Land Use	Sny Magill		Bloody Run	
	Acres	%	Acres	%
Row crop	5,842	25.9	9,344	38.6
Cover crop, pasture	5,400	23.9	6,909	28.5
Forest, forested pasture	11,034	48.9	7,171	29.6
Farmstead	263	1.2	415	1.7
Other	28	0.1	376	1.6

TOTALS	22,567	100	24,215	100

Source: Bettis et al., 1994

Water Resource Type and Size

Sny Magill and North Cedar creeks are Class "B" cold water streams located in northeastern Iowa.

Water Uses and Impairments

Sny Magill and North Cedar creeks are managed for "put and take" trout fishing by the IDNR and are two of the more widely used streams for recreational fishing in Iowa. Sny Magill Creek ranks sixth in the state for angler usage. The creek drains into backwaters and wetlands of the Mississippi River. These backwaters are heavily used for fishing and also serve as an important nursery area for juvenile and young largemouth bass.

The creeks are designated by the state as "high quality waters" to be protected against degradation of water quality. Only 17 streams in the state have received this special designation. The state's Nonpoint Source Assessment Report indicates that the present classifications of the creeks as protected for wildlife, fish, and semiaquatic life and secondary aquatic usage are only partially supported. The report cites impairment of water quality primarily by nonpoint agricultural pollutants, particularly sediment, animal wastes, nutrients, and pesticides. No significant point sources of pollution exist within the Sny Magill watershed.

Pollutant Sources

Sediment — cropland erosion, streambank erosion, gully erosion, animal grazing
Nutrients — animal waste from livestock facilities (cattle), pasture, and grazed woodland; commercial fertilizers; crop rotations
Pesticides — cropland, brush cleaning

Pre-Project Water Quality

Water quality evaluations conducted by the University Hygienic Laboratory (UHL) in 1976 and 1978 during summer low-flow periods in Sny Magill and Bloody Run creeks showed elevated water temperatures and fecal coliform levels (from animal wastes) in Sny Magill Creek. Downstream declines in nutrients were related to algal growth and in-stream consumption. An inventory of macroinvertebrate communities was conducted in several reaches of the streams (Geary, 1977; Prill and Meierhoff, 1979).

Assessments of North Cedar Creek during the 1980s by IDNR and the USDA Natural Resources Conservation Service (NRCS) located areas where sediment covered the gravel and bedrock substrata of the streams, decreasing the depth of existing pools, increasing turbidity, and degrading aquatic habitat. Animal waste decomposition increases biochemical oxygen demand (BOD) in the streams to levels that are unsuitable for trout survival at times of high water temperature and low stream flows. The IDNR has identified these as the most important factors contributing to the failure of brook trout to establish a viable population (Seigley et al., 1992).

Several reports summarize pre-project water quality studies conducted in the two watersheds (i.e., water quality, including available data from STORET – Seigley and Hallberg, 1994; habitat assessment – Wilton, 1994; benthic biomonitoring – Schueller et al., 1994, and Birmingham and Kennedy, 1994; fish assessment – Wunder and Stahl, 1994; and Hallberg and others, 1994) and provide perspectives on water quality monitoring in northeast Iowa.

Water Quality Objectives

Primary objectives of the Sny Magill Watershed Project were:

- Reduce sediment delivery to Sny Magill Creek by 50%;
- Reduce manure runoff to Sny Magill Creek by helping producers implement 30 animal manure management sytems;
- Accelerate adoption of refined crop and manure management practices that reduce agricultural pollution potential in the watershed; and
- Develop a series of demonstrations to educatethe watershed's producers and the public at large about water quality issues and provide additional data and learning experience for the participating agencies.

Additional objectives of the broader HUA and WQSP projects included:

- To quantitatively document the significance of water quality improvements resulting from the implementation of the Sny Magill HUA Project and North Cedar Creek WQSP;
- To develop the protocols and procedures for a collaborative interagency program to fulfill the U.S. Environmental Protection Agency (USEPA) standards for Nonpoint Source Monitoring and Reporting Requirements for Watershed Implementation Projects;
- To refine monitoring protocols to define water quality impacts and the effectiveness of particular management practices;
- To develop Iowa's capacity for utilization of rapid habitat and biologic monitoring;
- To use water quality and habitat monitoring data interactively with implementation programs to aid targeting of BMPs, and for public education to expand awareness of the need for nonpoint source pollution prevention by farmers; and
- To provide Iowa and the USEPA with needed documentation for measures of success of nonpoint source control implementation (Seigley et al., 1992).

Project Time Frame

1991 to 2001

PROJECT DESIGN

Nonpoint Source Control Strategy

From 1988 through 1999, three separate projects installed many different BMPs in the Sny Magill Watershed. The first project was the North Cedar Creek Agricultural Conservation Program. This USDA program ran from 1988 to 1994 and focused only on the 3,220 acres of the North Cedar Creek Watershed. Most of the BMPs applied in the watershed under this program were structural, including terraces, tile outlets, grade stabilization structures, and animal waste structures. When the project ended in 1994, the Sny Magill Creek Watershed project continued the effort to install BMPs in the North Cedar Creek Watershed and work with landowners.

A large project – the Sny Magill Hydrologic Unit Area (HUA) project – began in 1991 and continued to 1999, covering 19,560 acres (86%) of the Sny Magill watershed. The remainder of the watershed is included in the WQST, which began in 1988 and was completed in 1994. These projects provided technical advice, cost sharing assistance, and educational programs to assist farmers in the watershed in implementing voluntary changes in farm management practices that would result in improved water quality in Sny Magill Creek.

Over the course of the HUA project, conservation plans were developed for all highly erodible (HEL) acres in the watershed and conservation plans were fully implemented on 4,174 acres, or 40% of the HEL acres in the project area. Structural practices, such as terracing and a few animal waste systems were implemented, as well as a variety of management practices such as crop residue management and contour stripcropping. Extension staff assisted farmers with farmstead assessment

Site Name	Pre-BMP Monitoring Dates	BMPs Installed	Date Installed/ Established	Post-BMP Monitoring Dates
Sny Magill Treatment Watershed	October 1991– September 1992	Waste storage facility, conserv. cover, conserv. crop rotation, conserv. tillage, contour farming, critical area planting, residue mngmt., sediment basin, windbreak, field border, grade stabil., grass waterway, use exclusion, pasture and hayland mngmt., planned grazing systems, proper grazing use, streambank protect., stripcropping, nutrient mngmt., pesticide mngmt., terraces, subsurface drainage, tree and shrub establish., underground outlet, wildlife habitat mngmt., forest stand improv.	Various from 1991 through 1998	October 19 September 2
Bloody Run Control Watershed	October 1991 - September 1992	None to date	N/A	October 1999 - September 2001

(Source: Bettis et al., 1994)

and with ICM, in the hope of reducing fertilizer and pesticide inputs by at least 25% while maintaining production levels. Over 80% of the 98 landowners in the Sny Magill Watershed participated in the HUA project.

Project Schedule

Water Quality Monitoring

The Sny Magill watershed was amenable to documentation of water quality responses to land treatment. The cold water stream has a high baseflow element that provides year-round discharge, minimizing potential missing data problems. These conditions also make possible analysis of both runoff and ground water contributions to the water quality conditions. Because of the intimate linkage of ground and surface water in the region, the watershed has a very responsive hydrologic system and should be relatively sensitive to the changes induced through the land treatment implementation programs.

A paired watershed study compares Sny Magill watershed to the (control) Bloody Run Creek watershed (adjacent to the north and draining 24,064 acres). Watershed size, ground water hydrogeology, and surface hydrology are similar; both watersheds receive baseflow from the Ordovician Galena aquifer. The watersheds share surface and ground water divides, and their proximity to one another minimizes rainfall variation. However, the large size of the two watersheds creates significant challenges in conducting a true paired watershed study. Land treatment and land use changes were kept to a minimum in the Bloody Run Creek watershed throughout the project period and for the first two years of water quality monitoring in the Sny Magill watershed.

Within the Sny Magill watershed, subbasins are compared using upstream/downstream stations.

Variables Measured

Biological

Fecal coliform (FC)
Habitat assessment
Fisheries survey
Benthic macroinvertebrates

Chemical and Other

Suspended sediment (SS)
Nitrogen (N)-series (NO3+NO2-N, NH4-N, Organic-N)
Chloride
Total phosphorus (TP)
Immunoassay for triazine herbicides
Water temperature
Conductivity
Dissolved oxygen (DO)
Turbidity

Covariates

Stream discharge
Precipitation

Sampling Scheme

Primary monitoring sites (SN1, BR1) (Figure 16) were established on both Sny Magill and Bloody Run creeks. The sites were equipped with USGS stream gauges to provide continuous stage measurements and daily discharge measurements. Suspended sediment samples were collected daily by local observers and weekly by water quality monitoring personnel when significant rainfall events occurred.

Monthly measurements of stream discharge were made at seven supplemental sites (NCC, SN2, SNT, SNWF, SN3, BRSC, and BR2) (Figure 16).

Baseline data were collected during the summer of 1991. A report documenting these data was published (Seigley and Hallberg, 1994). The monitoring program, as described below, began in October of 1991.

Weekly grab sampling was conducted at the primary surface water sites (SN1, BR1) for fecal coliform bacteria, N-series (NO3 +NO2-N, NH4-N, Organic-N), chloride, TP, BOD, and immunoassay for triazine herbicides.

Four secondary sites were monitored weekly (three on Sny Magill: SN3, SNWF, and NCC; and one on Bloody Run: BR2). Grab sampling was conducted for fecal coliform, partial N-series (NO3 + NO2-N, NH4-N), and chloride.

Three additional sites were monitored on a monthly basis (two on Sny Magill: SN2, SNT; and one on Bloody Run: BRSC). These were grab sampled for FC, partial N-series, and chloride.

Temperature, conductivity, DO, and turbidity were measured at all sites when sampling occured.

An annual fish assessment was conducted at six sites in Sny Magill and Bloody Run watersheds during the fall of each year. The sample date was selected to minimize stocked trout numbers, to minimize angler interference with fish sampling personnel, and to sample the streams under baseflow conditions. Two backpack-mounted stream electrofishing units were used to sample a 300-foot stream reach of mixed pool-riffle habitat at each site.

An annual habitat assessment, designed to characterize stream habitat conditions, occured in the fall under low-flow, baseflow conditions at eight water-quality sites. Instream and streamside habitat variables were measured and observed at ten regularly spaced, cross-sectional stream transects within a 100-foot stream reach. Each stream reach included two or three sets of pools and riffles.

Modifications Since Project Started

Originally, site BRSC was monitored weekly and site BR2 was monitored monthly. However, after one water-year of sampling, the invertebrate biomonitoring group requested (in March of 1992) that the sites be switched. Thus, since October 1, 1992, BRSC was monitored monthly and BR2 was monitored weekly.

Statistical analysis required an extension of the pre-BMP period from the initial one-year (WY 1992) to three (WY 1992-94). This was due to an insufficient time to develop a significant relationship between parameters in the two streams. In addition to the pre/post model, a gradual change model was also used to define changes in water quality. Continual BMP implementation in the watershed throughout all ten years of the project made it impossible to strictly define distinct

Monitoring Scheme for the Sny Magill and Bloody Run Watershed Section 319 National Monitoring Program Project

Design	Sites	Primary Parameters	Covariates	Frequency of WQ Sampling	Frequency of Habitat/Biological Assessment	Duration
Paired watershed with upstream/ downstream stations (for each creek)	Sny Magill[T] and Bloody Run[C]	Habitat assessment Fishery survey Benthic macro-invertebrates SS Nitrogen series Chloride TP* BOD* Triazine herbicides* Water temperature Conductivity DO Turbidity FC	Stream discharge (daily at sites SN1 & BR1; monthly at sites NCC, SN2, SNT, SNWF, SN3, BRSC, BR2) Stage (continuous at SN1, BR1) Precipitation	Weekly (for SN1, BR1, SN3, SNWF, NCC, BR2) Monthly (for SN2, SNT, BRSC)	Habitat and fisheries data collected annually. Macroinvertebrate data collected every two months.	1 yr pre-BMP 7 yrs BMP 2 yrs post-BMP

[T]Treatment watershed
[C]Control watershed
* These parameters are only sampled at sites SN1 and BR1

calibration and treatment periods. Therefore, the monitoring design was amended to include a gradual change multiple regression analysis.

Analysis for nitrate-N was discontinued after WY 1996; analysis for anion fluoride, bromide, and sulfate was discontinued after WY 1997.

Progress to Date

Following the completion of all the land treatment projects, the following nonpoint source pollution controls were completed in North Cedar Creek and Sny Magill Creek watersheds:

- 392,765 feet of terraces
- 97 grade stabilization structures
- 62 water and sediment control basins
- 1,140 feet of streambank protection
- 1,907 acres of contouring
- 26,700 feet of field borders
- 2 agricultural waste structures
- The more effective use of nitrogen, phosphorus, and pesticides on 6,723 acres in the Sny Magill watershed

Five streambank stabilization demonstrations that utilize soil bioengineering technologies were constructed. One site took into account angler accessibility issues. A pool and riffle sequence was installed in 1999.

In 1998, a total of four cooperators enrolled 1,393 acres in the Nutrient and Pest Management Incentive Education Program. This program, developed in the fall of 1994, promotes nutrient and pest management through participant education and implementation, rather than relying on the private sector for crop management services.

Based on USLE estimates, sediment delivery has been reduced by 50.7% (Tisl and Palas, 1998).

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

Data was stored and maintained by the Iowa Department of Natural Resources-Geological Survey. The U.S. Geological Survey data were entered into the WATSTORE database and all other water quality data were entered into STORET. In addition, data were added to Iowa's STORET water quality database (http://wqm.igsb.uiowa.edu/storet/), and also entered into the USEPA's Nonpoint Source Management System (NPSMS) software.

The USEPA nonpoint source monitoring and reporting requirements for watershed implementation grants have been completed for the data from Water Years 1992, 1993, and 1994. Technical reports on data from water years 1992 and 1993 (Seigley et al., 1994), water year 1994 (Seigley et al., 1996), and water years 1995 through 1998 (Langel et al., 2001), and 1999 through 2001 (Liu et al., 2003) have been completed.

NPSMS Data Summary

Monitoring Station Parameters Report (WY92)

STATION TYPE: BR1 (Control Station)

<u>CHEMICAL PARAMETERS</u>

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		275	85	10
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	28	24	20
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		<0.1	<0.1	<0.1
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		0.4	0.2	<0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		0.2	0.1	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.05	0	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		14	10	5
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		5.8	4.8	4.3

STATION TYPE: SN1 (Treatment Station)

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		300	110	20
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	18	15	13
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		<0.1	<0.1	<0.1
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		0.2	0.2	<0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		0.1	<0.1	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.03	0	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		15	10	5
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		2.3	1.9	1.5

Monitoring Station Parameters Report (WY93)

STATION TYPE: BR1 (Control Station)

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		1025	85	<10
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	45	35	20
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		<0.1	<0.1	<0.1
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		0.4	0.3	<0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		0.3	0.2	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.07	0	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		13	8	5
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		6.4	5.6	5.2

STATION TYPE: SN1 (Treatment Station)

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		530	80	20
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	47	31	13
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		<0.1	<0.1	<0.1
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		0.4	0.2	<0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		0.3	0.1	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.07	0	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		13	8	4
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		3.0	2.4	2.2

Monitoring Station Parameters Report (WY94)

STATION TYPE: BR1 (Control Station)

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		215	60	<10
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	26	20	13
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		0.2	0.1	<0.1
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		0.2	0.1	<0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		0.1	<0.1	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.01	0	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		16	11	6
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		6.5	5.8	5.1

STATION TYPE: SN1 (Treatment Station)

Parm	Reporting	QUARTILE VALUES

Parameter Name	Type	Units	-75-	-50-	-25-
FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		210	43	10
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	21	14	10
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		0.2	0.1	<0.1
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		0.2	0.1	<0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		0.1	<0.1	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.01	0	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		17	11	5
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		3.3	3.0	2.5

Monitoring Station Parameters Report (WY95)

STATION TYPE: BR1 (Control Station)

	Parm	Reporting	QUARTILE VALUES		
Parameter Name	**Type**	**Units**	**-75-**	**-50-**	**-25-**
FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		218	65	10
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	26	23	19
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		<0.1	<0.1	<0.1
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		0.3	0.2	<0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		<0.1	<0.1	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.02	0	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		16	11	4
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		5.9	5.5	5.1

STATION TYPE: SN1 (Treatment Station)

	Parm	Reporting	QUARTILE VALUES		
Parameter Name	**Type**	**Units**	**-75-**	**-50-**	**-25-**
FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		220	115	18
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	24	16	12
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		<0.1	<0.1	<0.1
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		0.3	0.2	0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		<0.1	<0.1	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.01	0	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		17	11	3
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		2.7	2.4	2.1

Monitoring Station Parameters Report (WY96)

STATION TYPE: BR1 (Control Station)

	Parm	Reporting	QUARTILE VALUES		
Parameter Name	**Type**	**Units**	**-75-**	**-50-**	**-25-**
FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		70	21	<10
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	22	18	16
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		<0.1	<0.1	<0.1
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		0.3	0.2	<0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		<0.1	<0.1	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.01	0	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		14	10	5
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		5.7	5.3	5.0

STATION TYPE: SN1 (Treatment Station)

	Parm	Reporting	QUARTILE VALUES		
Parameter Name	**Type**	**Units**	**-75-**	**-50-**	**-25-**
FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		158	48	10
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	19	14	11
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		<0.1	<0.1	<0.1
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		0.3	0.2	<0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		<0.1	<0.1	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.01	0	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		15	9	3
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		2.6	2.4	2.2

Monitoring Station Parameters Report (WY97)

STATION TYPE: BR1 (Control Station)

	Parm	Reporting	QUARTILE VALUES		
Parameter Name	**Type**	**Units**	**-75-**	**-50-**	**-25-**

FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		100	30	<10
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	17	15	13
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		<0.1	<0.1	<0.1
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		0.2	0.1	<0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		<0.1	<0.1	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.02	0	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		14	10	4
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		5.5	4.9	4.5

STATION TYPE: SN1 (Treatment Station)

	Parm	Reporting	QUARTILE VALUES		
Parameter Name	**Type**	**Units**	**-75-**	**-50-**	**-25-**
FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		200	20	<10
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	15	13	11
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		<0.1	<0.1	<0.1
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		0.3	0.1	0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		<0.1	<0.1	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.02	0	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		15	10	2
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		2.6	2.4	2.2

Monitoring Station Parameters Report (WY98)

STATION TYPE: BR1 (Control Station)

	Parm	Reporting	QUARTILE VALUES		
Parameter Name	**Type**	**Units**	**-75-**	**-50-**	**-25-**
FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		320	32	<10
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	13	12	11
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		<0.1	<0.1	<0.1
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		0.3	0.1	<0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		<0.1	<0.1	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.03	0.01	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		16	11	5
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		6.7	5.6	5.2

STATION TYPE: SN1 (Treatment Station)

	Parm	Reporting	QUARTILE VALUES		
Parameter Name	**Type**	**Units**	**-75-**	**-50-**	**-25-**
FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		340	55	10
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	21	17	11
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		<0.1	<0.1	<0.1
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		0.3	0.2	<0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		<0.1	<0.1	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.03	0	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		16	10	4
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		3.1	2.7	2.6

Monitoring Station Parameters Report (WY99)

STATION TYPE: BR1 (Control Station)

	Parm	Reporting	QUARTILE VALUES		
Parameter Name	**Type**	**Units**	**-75-**	**-50-**	**-25-**
FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		500	82	10
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	33	25	21
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		<0.1	<0.1	<0.1
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		<0.1	<0.1	<0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		<0.1	<0.1	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.02	0	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		15	11	6
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		9.6	8.6	7.6

STATION TYPE: SN1 (Treatment Station)

	Parm	Reporting	QUARTILE VALUES		
Parameter Name	**Type**	**Units**	**-75-**	**-50-**	**-25-**
FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		305	100	15
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	32	21	18
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		<0.1	<0.1	<0.1

NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		0.3	0.2	<0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		<0.1	<0.1	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.03	0	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		15	10	5
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		3.8	3.5	3.4

Monitoring Station Parameters Report (WY00)

STATION TYPE: BR1 (Control Station)

	Parm	Reporting	QUARTILE VALUES		
Parameter Name	**Type**	**Units**	**-75-**	**-50-**	**-25-**
FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		255	30	10
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	23	20	17
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		<0.1	<0.1	<0.1
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		0.3	0.1	<0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		0.1	<0.1	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.02	0	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		15	10	7
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		7.0	6.6	6.2

STATION TYPE: SN1 (Treatment Station)

	Parm	Reporting	QUARTILE VALUES		
Parameter Name	**Type**	**Units**	**-75-**	**-50-**	**-25-**
FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		343	30	<10
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	19	16	14
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		<0.1	<0.1	<0.1
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		0.3	0.1	<0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		0.1	<0.1	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.01	0	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		16	10	5
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		3.5	3.3	3.1

Monitoring Station Parameters Report (WY01)

STATION TYPE: BR1 (Control Station)

	Parm	Reporting	QUARTILE VALUES		
Parameter Name	**Type**	**Units**	**-75-**	**-50-**	**-25-**
FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		255	60	<10
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	26	20	13
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		<0.1	<0.1	<0.1
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		0.5	0.2	<0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		0.1	<0.1	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.02	0	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		16	11	5
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		7.2	6.8	6.5

STATION TYPE: SN1 (Treatment Station)

<u>CHEMICAL PARAMETERS</u>

	Parm	Reporting	QUARTILE VALUES		
Parameter Name	**Type**	**Units**	**-75-**	**-50-**	**-25-**
FECAL COLIFORM, MEMBR FILTER, M-FC BROTH, 44.5 C	S		240	100	10
FLOW, STREAM, MEAN DAILY, CFS	S	CFS	21	14	10
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	S		<0.1	<0.1	<0.1
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	S		0.3	0.1	<0.1
PHOSPHORUS, TOTAL (MG/L AS P)	S		0.1	<0.1	<0.1
PRECIPITATION, TOTAL (INCHES PER DAY)	S		0.03	0	0
TEMPERATURE, WATER (DEGREES CENTIGRADE)	S		16	10	2
NITROGEN, NITRITE + NITRATE, TOTAL (MG/L as N)	S		3.5	3.3	3.1

Final Results

Water Quality Changes

Overall, a large decrease in turbidity and slight decrease in suspended sediment were observed in Sny Magill Creek, suggesting that BMP implementation can measurably improve water quality, even in a relatively healthy trout stream. Temperature in Sny Magill decreased slightly, likely due to improved riparian cover. Dissolved oxygen levels increased significantly and are close to saturation. The significant increase in discharge and nitrate-nitrite-N, however, indicates that there were other effects associated with BMP implementation that are not fully understood.

Table 4. Overall changes in water quality for Sny Magill sites when compared to their Bloody Run monitoring site.

Location	Discharge		Sediment		Turbidity		NOx		Fecal Coliform		Temperature		DO	
	P/P	Grad.	P/P	Grad.	P/P	Grad.	P/P	Grad.	P/P	Grad.	P/P	Grad.	P/P	Grad.
SN1	↑ 8%	↑ 12%	↓ 7%	NS	↓ 41%	↓ 46%	↑ 15%	↑ 39%	↓ 12%	NS	↓ 4%	↓ 5%	↑ 11%	↑ 16%
SN2	-	-	-	-	↓ 34%	↓ 24%	↑ 26%	↑ 43%	NS	NS	↑ 10%	↑ 17%	↑ 2%	↑ 26%
SN3	-	-	-	-	NS	NS	↑ 39%	↑ 37%	↑ 192%	↑ 464%	↓ 1%	NS	↑ 28%	↑ 36%

P/P = Pre/Post model; Grad. = Gradual Change model; NS = Not Significant

Benthic Macroinvertebrates

Based on results of biomonitoring, no dramatic changes were observed in the benthic communities of either watershed during the monitoring period. Though some metrics show statistically significant trends toward improving water quality, they are weak and other results indicate a significant trend toward declining water quality. Therefore, water quality changes in the study area based on benthic macroinvertebrate monitoring cannot be directly linked to land treatment changes.

Fish Assessment

Habitat assessments indicated monitoring sites with similar drainage areas had similar habitat characteristics for most years and that BMP implementation had little or no significant influence on stream habitat in Sny Magill. Sampled fish communities remained relatively constant through the project and were typical of Iowa coldwater streams. Although not conclusive, the results of the fish assessment and fish Index of Biotic Integrity (IBI) studies have shown that the environmental quality of. Sny Magill Creek has slowly improved during recent years. A return of the slimy sculpin to Sny Magill Creek may have ndicated an improvement in stream quality.

Source: Fields, et al. 2005. Sny Magill Nonpoint Source Pollution Monitoring Project: Final Report. Iowa Geological Survey, Technical Information Series 48, http://www.igsb.uiowa.edu/gsbpubs/pdf/TIS-48.pdf

Lessons Learned

Installed BMP’s such as tiled terraces and sediment catchment basins significantly decreased turbidity levels and sediment concentrations in the stream. However, these same practices might have lead to increased discharge and nitrate+nitrite-N concentrations. Tiles and tiled terraces transfer surface water and shallow groundwater directly to the stream channel before evaporation and transpiration. Water flowing in the tiles also mobilizes water soluble nutrients such as NOx, which could lead to increased concentrations in the stream.

Having an adequate (2+ yrs) pre-BMP monitoring period is essential to properly establish a calibration relationship between the treatment and control streams.

The lag time between initial BMP installation and measured changes in stream water quality might take many years, perhaps even decades. This is especially true of watersheds that are highly groundwater dependent, or that have significant pre-existing sediment deposits in the stream system.

Results from the Sny Magill Watershed Section 319 National Monitoring Program project have influenced and aided subsequent projects: including the Walnut Creek Watershed Restoration and Water Quality Monitoring Project in Iowa, and the Sny Magill Watershed Monitoring Project, which used both data and results in its modeling and final report.

INFORMATION, EDUCATION, AND PUBLICITY

Information was disseminated through newsletters, field days, special meetings, press/media releases, surveys of watershed project participants, and at meetings at the local, state, and national level. Information about the project is also available via the internet (www.igsb.uiowa.edu/inforsch/sny/sny.htm).

Media outreach was conducted primarily by the communications specialist for the Sny Magill project. Various other personnel involved in the land treatment and water quality monitoring components also assist in these efforts.

- The media outreach program has included preparation of demonstration plot brochures, press releases, booklets for the “self-guided” tours of the watershed, and articles for local newspapers. Water Watch, a bimonthly newsletter published by the Extension Service, is disseminated to over 1,665 subscribers. Article topics have included upcoming field days, field demonstration results, water quality monitoring results, riparian buffer activities, and streambank stabilization efforts.
- Numerous field days were held at plot sites in and around the watershed.
- Efforts and activities in the Sny Magill watershed were the focus of a field trip that was held in conjunction with the Sixth National Nonpoint-Source Monitoring Workshop (September 1998, Cedar Rapids, IA).

TOTAL PROJECT BUDGET

Estimated budget for the Sny Magill Watershed Section 319 National Monitoring Program project for the period FY91-01:

Project Element	**Funding Source ($)**			
	Federal	**State**	**Local**	**Sum**
I&E	445,000	233,550	NA	678,550
LT (cost share)	374,000	333,634	NA	707,634
LT (technical assist.)	874,000	NA	NA	874,000
WQ Monit	1,133,910	NA	NA	994,958
TOTALS	2,826,910	567,184	NA	3,394,094

* from Section 319 National Monitoring Program funds

Funding restrictions in the Sny Magill HUA for FY94 affected cost-share funding to assist cooperating producers in installing BMPs. The HUA was able to operate in FY94 on limited funding that remained from previous years. The project applied for alternate funding to meet the unmet needs of producers to install BMPs. Funding for BMP implementation for 1995 through 1998 was provided by the Iowa Department of Agriculture and Land Stewardship – Division of Soil Conservation and the Iowa Department of Natural Resources.

Federal funding from the Agricultural Conservation Program to encourage BMP implementation was lost in 1993; however, applications for alternative funding sources were filed in 1994. Funding for sediment reducing practices, such as terraces, was secured through the Iowa Department of Agriculture and Land Stewardship, Division of Soil Conservation, for Fiscal Years 1995-1998. An application for funding was filed through the USEPA Section 319(h) Program for animal manure structures, Integrated Crop Management (ICM), and streambank stabilization practices. The USEPA Section 319(h) funding became available in 1995, and continued through 1998. Extended funding for the Sny Magill Hydrologic Unit Area was requested and received through 1999.

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

Please refer to the section entitled Nonpoint Source Control Strategy.

OTHER PERTINENT INFORMATION

Agencies participating in the Sny Magill Section 319 National Monitoring Program project are listed below:

- Clayton County USDA Farm Service Agency Committee
- Iowa State University Extension
- Iowa Department of Agriculture and Land Stewardship
- Iowa Department of Natural Resources
- Natural Resources Conservation Service
- University Hygienic Laboratory
- U.S. Forest Service
- U.S. Fish and Wildlife Service
- U.S. Geological Survey
- U.S. National Park Service
- U.S. Environmental Protection Agency

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Iowa

Walnut Creek
Section 319
National Monitoring Program Project

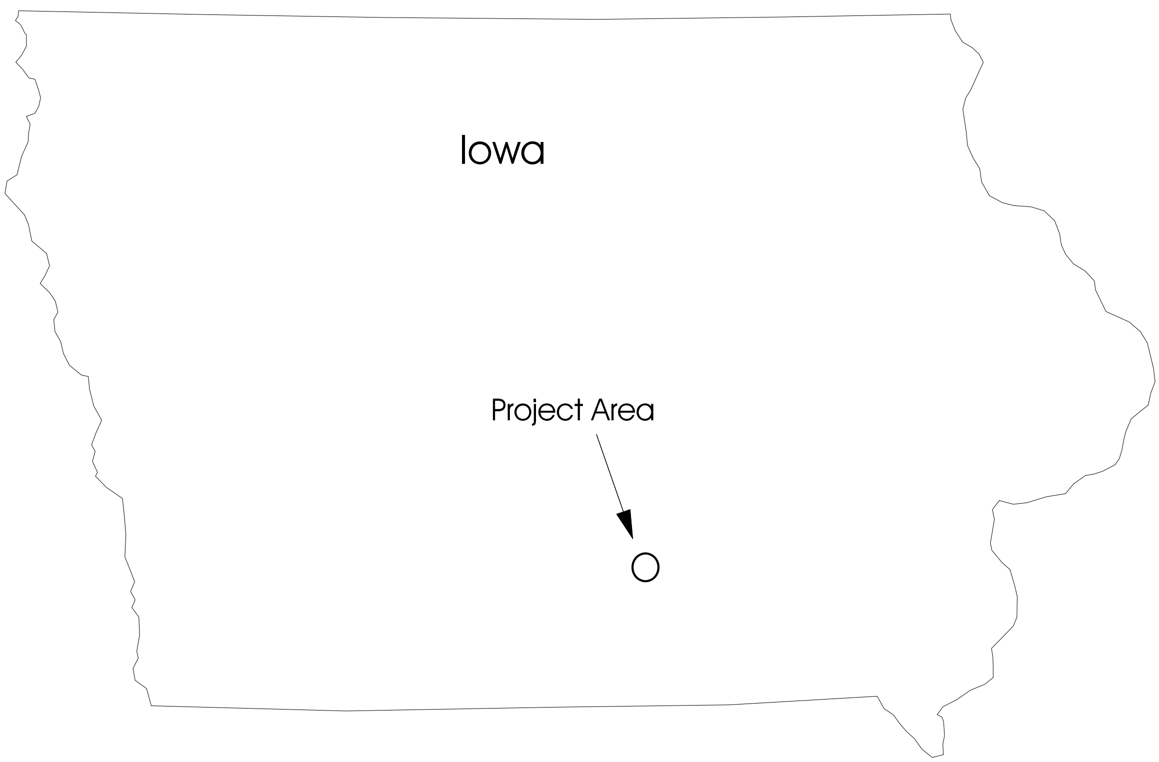

Figure 17: Walnut Creek (Section 319) Project Location

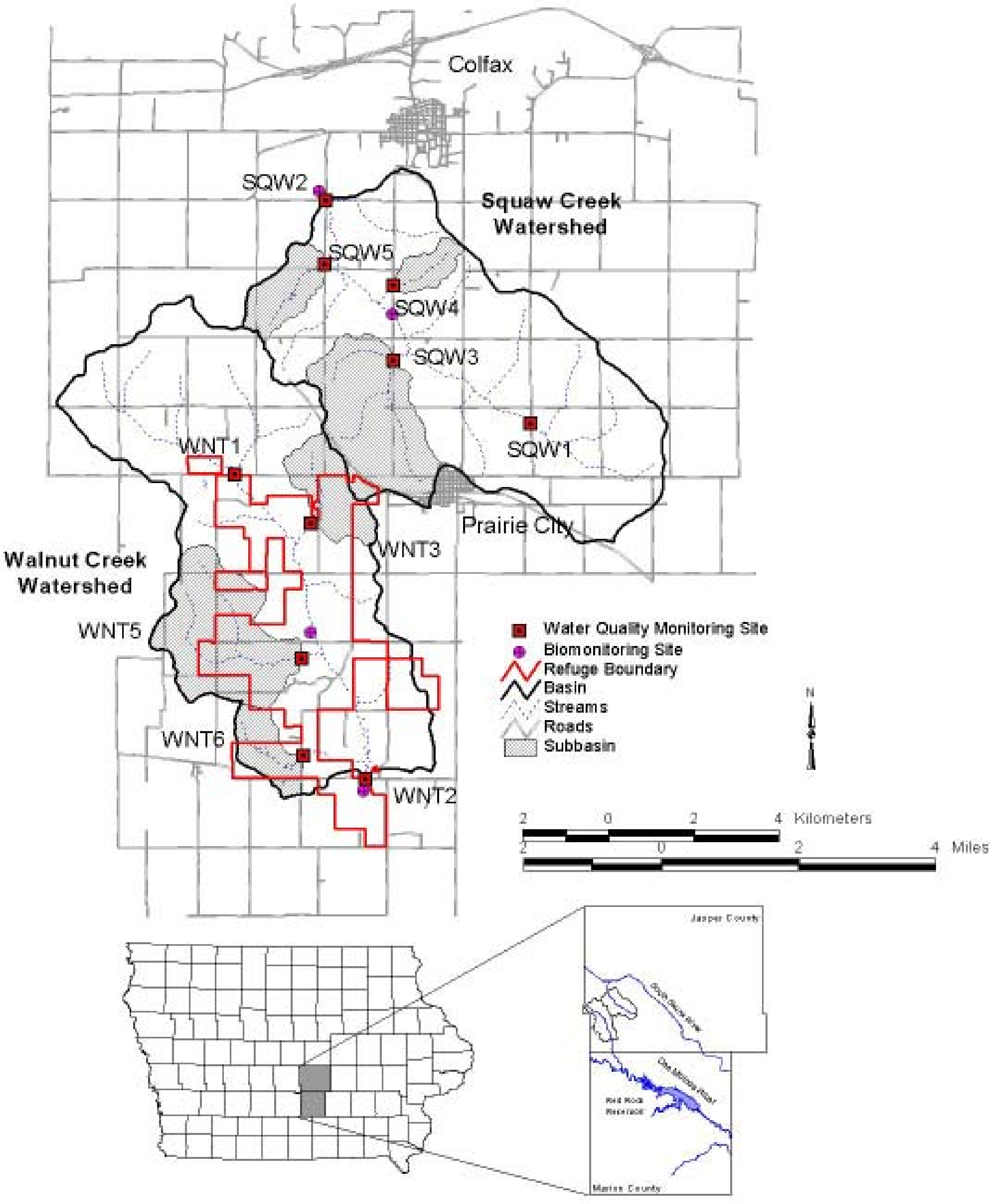

Figure 18: Water Quality Monitoring Stations for Walnut Creek (Iowa)

PROJECT OVERVIEW

The Walnut Creek Watershed Restoration and Water Quality Monitoring Project conducted between 1995 and 2005 was designed as a nonpoint source monitoring program in relation to the watershed habitat restoration and agricultural management changes implemented by the U.S. Fish and Wildlife Service (USFWS) at Neal Smith National Wildlife Refuge and Prairie Learning Center (WNT) in central Iowa. The watershed is being restored from row crop to native prairie.

There were two components to the land use changes being implemented by USFWS: ecosystem resources restoration to prairie/savanna and mandatory (contractual) use of improved agricultural management practices on farmlands prior to conversion. The majority of the Refuge area is being seeded to tall-grass prairie with savanna components where applicable. In the riparian areas, 100 foot-wide vegetative filter strips will be seeded along all of the streams in the Refuge that are not allowed to revert to wetlands. Riparian and upland wetlands will also be restored or allowed to revert to wetlands by the elimination of tile lines.

The USFWS management team also controls cropland management within the WNT Refuge. Farming is done on a contractual, cash-rent basis, with various management measures specified; some are flexible, some more prescriptive. The measures include soil conservation practices; nutrient management through soil testing, yield goals, and nutrient credit records; and integrated pest management. Crop scouting for pest management is mandatory for all farms on Refuge lands, as are no-till production methods. Insecticide use is highly restricted and herbicide use is also controlled in order to minimize adverse impacts on non-target plants and animals.

The project utilized a paired watershed approach as well as an upstream/downstream assessment. The treatment watershed is Walnut Creek, the paired site is Squaw Creek. Both watersheds are primarily agricultural dominated by row crop, mainly corn and soybeans. Although no specific water quality objectives have been set for this project, the intent of the USFWS is to restore the area to pre-settlement conditions, circa 1840. In general, the decrease in active row crop agriculture should lead to reductions in nutrients and pesticides in Walnut Creek.

Three gaging stations for flow and sediment were established, two on Walnut Creek and one on Squaw Creek. Both creeks were monitored for biological and chemical parameters. Both the main creek and several tributaries are included in the sampling scheme.

The Walnut Creek monitoring project was completed on September 30, 2005. A final report for the project was completed in April 2006 and is available online at http://www.igsb.uiowa.edu/gsbpubs/pdf/tis-49.pdf.

PROJECT BACKGROUND

Project Area

The project area, located in central Iowa (Figure 18), consists of a total of 24,570 acres. The Walnut Creek Basin is the treatment watershed (12,860 acres) and the Squaw Creek Basin (11,710) is the control watershed (Figure 18). Both creeks have been channelized in part. Both are characterized by silty bottoms and high, often vertical, banks. Deposition of up to 4 feet of post-settlement alluvium is not uncommon.

Relevant Hydrologic, Geologic, and Meteorological Factors

The total project area is located in the Southern Iowa Drift Plain, an area characterized by steeply rolling hills and well-developed drainage. Dominant soils are silty clay loams, silt loams, or clay loams formed in loess and till. Average annual rainfall for the project area is approximately 32 inches. Both creeks have been extensively channelized and are incised into their valleys. Two to six feet of post-settlement alluvium is present in both valleys. Stream gradients in the main stem vary from 0.01 to 0.002. Basin characteristics of Walnut and Squaw creek watersheds are very similar:

Basin Characteristics	Walnut Creek	Squaw Creek
Total Drainage Area (sq mi)	20.142	18.305
Slope Class:		
A (0-2%)	19.9	19.7
B (2-5%)	26.2	26.7
C (5-9%)	24.4	25.0
D (9-14%)	24.5	22.2
E (14-18%)	5.0	6.5
Basin Length (mi)	7.772	6.667
Basin Perimeter (mi)	23.342	19.947
Average Basin Slope (ft/mi)	10.963	10.981
Basin Relief (ft)	168	191
Relative Relief (ft/mi)	7.197	9.575
Main Channel Length (mi)	9.082	7.605
Total Stream Length (mi)	26.479	26.111
Main Channel Slope (ft/mi)	11.304	12.623
Main Channel Sinuosity Ratio	1.169	1.141
Stream Density (mi/sq mi)	1.315	1.426
Number of First Order Streams (FOS)	12	13
Drainage Frequency (FOS/sq mi)	0.596	0.710

Land Use

In 1990, land use in both Walnut and Squaw Creek watersheds was dominated by row crops of corn and soybeans, with 69.4 percent row crop in Walnut Creek and 71.4 percent in Squaw Creek. From 1990 to 2005, major changes in land cover occurred in both watersheds. Squaw Creek showed an increasing trend of row crop land use whereas row crop in Walnut Creek significantly decreased. In Squaw Creek, a 9.2 percent increase in row crop area from 1990 to 2005 was likely due to the passage of the Freedom to Farm Act in 1996 that appeared to have substantially increased row crop production. Lands previously categorized as grasslands enrolled in the Conservation Reserve Program (CRP) were converted to row crop production. This trend was particularly evident in two monitored subbasins (SQW4 and SQW5) where the row crop percentage increased by 26 and 29 percent. In Walnut Creek watershed, row crop land use decreased from 69.4 to 54.5 percent between 1992 to 2005 as a result of prairie restoration by the USFWS at the Neal Smith refuge. From 1992 to 2005, an average of approximately 222 acres of prairie were planted each year. As of 2005, 3,023 acres of land in Walnut Creek watershed were planted in native prairie, representing 23.5 percent of the watershed. In the subbasins, restored prairie accounted for 14.3 to 45.9 percent of the land area. In Squaw Creek, nitrogen applications increased 12.8% over 1990 N applications whereas nitrogen applications in the Walnut Creek watershed decreased 21.4%. Pesticide applications in Walnut Creek watershed were reduced by nearly 28 percent compared to levels in 1990.

Water Resource Type and Size

Walnut Creek and Squaw Creek are warmwater streams located in central Iowa.

Water Uses and Impairments

Walnut Creek and Squaw Creek are designated under the general use category. No designated use classification has been assigned to Walnut Creek.

Walnut Creek drains into a segment of the Des Moines River that is classified as Not Supporting its designated uses in the Iowa Department of Natural Resources' (IDNR) water quality assessments; Squaw Creek and the Skunk River are classified as Partially Supporting. Assessments in this area cite agricultural nonpoint source as the principal concern.

Walnut and Squaw creeks are affected by many agricultural nonpoint source water pollutants, including sediment, nutrients, pesticides, and animal waste. Water quality in these streams is typical for many of Iowa's small warmwater streams: water quality varies significantly with changes in discharge and runoff. Streambank erosion has contributed to significant sedimentation in the creeks.

Pollutant Sources

Sediment — streambank erosion, cropland erosion, gully erosion, animal grazing
Nutrients — crop fertilizers, manure
Pesticides — cropland

Pre-Project Water Quality

Three pre-project water quality studies were completed. The US Fish and Wildlife Service collected data during the pre-implementation period in 1991. The Tri-State Monitoring Project collected data in the Walnut Creek basin from 1992 to 1994. Two sets of storm event samples were collected in 1995.

In 1991, nitrate-nitrogen concentrations ranged from 14 to 19 mg/l with a mean of 16. Atrazine concentrations were from 0.24 to 1.2 ug/l. The Tri-State data were similar, with nitrogen from 5 to 44 mg/l, averaging 14.5 mg/l and atrazine from 0.1 to 2.7 ug/l. The event sampling in 1994 had fewer samples, but nitrogen ranged from 2.1 to 11.0 mg/l (avg. 6.1) in Walnut Creek and from 0.1 to 20 (avg. 10.0) in the tributaries. Atrazine in the main stem of Walnut Creek ranged from <0.1 to 0.3 ug/l and was higher in the tributaries (up to 3.1 ug/l).

Primary biological productivity is low and the condition of the fish community is poor.

Water Quality Objectives

Maintain or exceed water quality criteria for general use waters. The long-term goal of the US Fish and Wildlife Service is to restore this area to pre-settlement conditions.

Project Time Frame

April, 1995 to September, 2005

PROJECT DESIGN

Nonpoint Source Control Strategy

In general, best management practices (BMPs) for row crop production include specific erosion control measures along with nutrient and pesticide management. In the Walnut Creek watershed, the primary land treatment activity was removal of cropland from production by converting it to native tall grass prairie. Wetlands and riparian zones were also restored. Limited nutrient and pesticide management was expected for the remainder of the Walnut Creek watershed.

Project Schedule

Management Unit	Pre-BMP Monitoring Dates	BMP Installed	Date Installed/ Established	Post-BMP Monitoring Dates
Squaw Creek (control)	June 1991 – September 1994	None	None	June 1994 – Current
Walnut Creek (treatment) 2005	May 1991 – September 1994	Restoration of prairie/ savanna; Improved management practices (filter strips, no till, restricted pesticide use)	1992 – Current	June 1994 – September

Water Quality Monitoring

A paired monitoring design was used (Figure 18). For the paired watershed design, the outlets of Walnut Creek (treatment) and Squaw Creek (control) watersheds were monitored. Each watershed had stations upstream and downstream in order to differentiate natural processes from land use changes. Gradual changes in water quality were compared to evaluate land treatment effectiveness.

Parameters Measured

Biological

Fecal coliform (FC)
Macroinvertebrates
Fisheries

Chemical and Other

Chloride (Cl)
Common herbicides
Dissolved oxygen (DO)
Nitrate (NO_3)
pH
Specific conductivity
Sulfate (SO_4^-)
Turbidity

Covariates

Precipitation
Water Discharge

Sampling Scheme

The outlets at Walnut and Squaw Creeks were gaged, as was an upstream station on the main stem of Walnut Creek. At these three stations, water discharge and SS were monitored daily, and data compiled for storm event statistical evaluation.

Ten stations were monitored biweekly to monthly in March through September. Four stations were sampled once in August, October, December, and February.

Modifications Since Project Start

The number of chemical parameters measured had been reduced. Chemical parameters that showed little variability or were not detected during five years of monitoring were not retained for future chemical monitoring.

Monitoring Scheme for the Walnut Creek Section 319 National Monitoring Program Project

Design	Sites or Activities	Primary Parameters	Covariates	Frequency of WQ Sampling	Frequency of Habitat/Biological Assessment	Duration
Paired	Walnut Creek[T] Squaw Creek[C]	NO_3 Pesticides Turbidity SS	Precipitation Water Discharge	Biweekly/ Monthly; Storm events	Habitat/fisheries annually; Macroinv. bimonthly	Unknown
Upstream/ Downstream	Walnut Creek[T]	NO_3 Pesticides Turbidity SS	Precipitation Water Discharge	Biweekly/ Monthly; Storm events	Habitat/fisheries annually; Macroinv. bimonthly	Unknown

T = Treament watershed
C = Control watershed

Progress To Date

The monitoring project was completed in September 2005. Water quality monitoring data from the project will be available on STORET at http://wqm.igsb.uiowa.edu/iastoret/. Flow and suspended sediment measurements are available for downloading from the USGS at http://waterdata.usgs.gov/ia/nwis/sw.

DATA MANAGEMENT AND ANALYSIS

All United States Geological Survey (USGS) data are reported in WATSTORE, the USGS national database. The project used Arcview for tracking and quantifying land use changes. Statistical analyses on water quality data for trend detection were completed as deemed necessary. Water quality parameters and land use activities were tracked using Nonpoint Source Management System (NPSMS) software. Data management and reporting was handled by the Iowa Department of Natural Resources Geological Survey Bureau (IDNR-GSB) and follows the Nonpoint Source Monitoring and Reporting Requirements for Watershed Implementation Grants. All water quality data are entered into STORET.

NPSMS Data Summary

Not available.

Final Results

Suspended Sediment

Suspended sediment concentrations and loads varied widely during the 10-year monitoring period. Total annual sediment export ranged from 3,706 to 18,367 tons in Walnut Creek and from 893 to 20,456 tons in Squaw Creek, with higher average annual loss higher in Walnut Creek (8,384 tons) than Squaw Creek (8,044 tons). Sediment transport through Walnut and Squaw creek watersheds was very flashy, evidenced by most of the annual suspended sediment load occurring during intermittent high flow events. While single day discharge events typically accounted for six to eight percent of the annual discharge, single day suspended sediment loads accounted for 25 to 37 percent of annual sediment total. The pattern of rapid conveyance of discharge and sediment loads is typical of incised channels. Greatest sediment transport typically occurred in May and June of each year, when on average these months accounted for 59.2 and 68.2% of the total annual load in Walnut and Squaw Creek watersheds, respectively. Annual sediment loss was similar in both watersheds, averaging 0.69 and 0.65 tons/acre, respectively, with annual sediment yield significantly related to annual discharge.

Suspended sediment concentrations were similar in Walnut Creek and Squaw Creek, with average and median values of 104.1 and 46.0 mg/l at WNT2 and 90.1 and 42.7 mg/l at SQW2, respectively. Suspended sediment concentrations most commonly ranged between 20-50 mg/l, with concentrations within this range approximately 35 to 39 percent of the time. Trends in daily sediment concentrations and loads were mixed and reflected the variable nature of sediment transport. One regression model indicated a decreasing trend in sediment concentrations and loads over time was observed at WNT2 whereas another model indicated an increase over time. A GIS-based RUSLE model suggested that prairie reconstruction in Walnut Creek watershed reduced sheet and rill erosion by more than 50% compared to Squaw Creek. Field mapping suggested that streambank erosion contributes greatly to sediment export in Walnut Creek (up to 50% of total) compared to Squaw Creek (14% of total).

Nitrate

Nitrate concentrations have ranged between <0.5 to 14 mg/l at the Walnut Creek outlet (WNT2) and 2.1 to 15 mg/l at the downstream Squaw Creek outlet (SQW2). Mean nitrate concentrations were 1.7 mg/l higher at SQW2 than WNT2, and highest at the upstream monitoring sites in both watersheds, averaging 11.2 mg/l at WNT1 and 12.4 mg/l at SQW1. Monthly nitrate concentrations exhibited clear seasonality, with higher concentrations occurring during May, June and July. Both Walnut and Squaw Creek watersheds have shown a similar temporal pattern of detection, with higher concentrations observed in the spring and early summer months coinciding with periods of application, greater precipitation and higher stream flow. Total export of nitrate from Walnut Creek (WNT2) was lower than Squaw Creek (SQW2) averaging 22.0 and 26.1 kg/ha, respectively. The average flow-weighted concentration of nitrate was 8.6 mg/l in Squaw Creek and 10.4 mg/l in upper Walnut Creek but was 4.9 mg/l in lower Walnut Creek.

During the 10-year project, nitrate concentrations significantly decreased in Walnut Creek watershed, both at the watershed outlet and in monitored subbasins. At the Walnut Creek outlet (WNT2), the trend analysis indicated that nitrate concentrations decreased 0.119 mg/l/year or 1.2 mg/l over 10 years when the Squaw Control watershed was utilized as a covariate. Nitrate concentrations decreased 3.4, 1.2 and 2.7 mg/l at WNT3, WNT5 and WNT6 subbasins, respectively. Nitrate concentrations increased 1.9 mg/l over 10 years in the downstream Squaw station SQW2 and 1.1 mg/l over 10 years in the upstream Squaw station SQW1. All subbasins in the Squaw Creek increased in nitrate concentrations, with subbasins SQW4 and SQW5 having quite dramatic increases. Over the 10-year monitoring program, nitrate in surface water in SQW4 and SQW5 subbasins increased 11.6 and 8.0 mg/l, respectively.

Pesticides

Atrazine and DEA were the most commonly detected herbicides in both watersheds with detection frequencies greater than 70 percent. Acetochlor was occasionally detected (up to 27 percent) whereas alachlor and metolachlor were rarely detectable (less than 5%). Cyanazine detections were also rare during the last five years of the project. Concentrations of atrazine often exceeded 1 ug/L during high streamflows in late spring/early summer; however, overall median concentrations of atrazine and DEA were less than 0.3 ug/l. May and June accounted for approximately 80 percent of the export load of atrazine, and the period of April through July accounted for 96 percent of the annual atrazine load. Statistical changes in herbicide concentrations over time were mixed, since both decreasing and increasing trends were observed. Sites WNT3 and SQW2 had decreasing trends in atrazine concentration with respect to time whereas sites WNT5, WNT6, and SQW5 had increasing trends in DEA concentration with respect to time. Other sites had no herbicide trends over time.

Fecal Coliform Bacteria

Fecal coliform bacteria were detected frequently above the EPA water quality standard of 200 count/100 ml in both watersheds. Elevated detections were occasionally observed at all monitored watersheds with highest fecal coliform counts occurring at any time between May and October during high stream flow periods associated with rainfall runoff. No changes in fecal coliform concentrations were observed during the 10-year monitoring project at downstream Walnut Creek (WNT2). Increases in fecal coliform concentrations were noted in two Walnut subbasins.

Phosphorus

Phosphorus (P) monitoring began in Water Year 2001 and thus five years of monitoring data were available for project reporting. Annually, median P concentrations were consistent, ranging between 0.14 to 0.2 mg/l at SQW2 and 0.17 to 0.2 mg/l at WNT2 for water years 2001 to 2005. The range in annual median P concentrations varied between 0.06 to 0.2 mg/l at all sites. Phosphorus did not change in any of the main stem streams in either Walnut Creek or Squaw Creek. The only statistically significant trend in phosphorus was an increase in the SQW3 subbasin and a decreasing trend in SQW5. Lack of phosphorus concentration trends in five years of monitoring in the watersheds was not unexpected given the episodic transport and variability in P concentrations detected in water.

Biomonitoring

Quantitative collections from Squaw Creek and Walnut Creek had poor macroinvertebrate colonization during the project. Taxa richness metrics for Walnut Creek initially showed consistent improvement until 2001 after which metrics have steadily declined to lower levels than project inception. The metric measures of community balance showed similar positive trends with values decreasing until 2002, after which values have increased to levels at or higher than project inception levels. However, many of the positive changes in the macroinvertebrate community appeared to be driven by the habitat modification (addition of coarse substrate for a bridge crossing) that occurred at the Walnut Creek sampling site. Metric means were calculated for both streams. Data did not show consistent trends in either watershed. Except for 2001 when large differences were evident, patterns of the four quantitative metrics have been similar between Walnut Creek and Squaw Creek.

Thirty-one species of fish from eight families were collected from Walnut Creek and twenty-two species of fish from six families were collected from Squaw Creek since 1995. The fish community in both streams was dominated by minnows and most of the minnow species collected are considered abundant to common in Iowa streams. Walnut Creek FIBIs ranged from 15 in 1995 to 40 in 1996 and 2002 whereas FIBI scores for Squaw Creek ranged from 21 in 2000 to 38 in 1997. FIBI scores for Walnut or Squaw Creek did not show any visual improvement or decline since 1995. Most FIBIs calculated for Walnut Creek and Squaw Creek were considered fair.

INFORMATION, EDUCATION, AND PUBLICITY

The WNT's educational commitment and resources will allow for educational and demonstration activities far beyond the scope of those that could typically be accomplished by 319 projects. Of particular note, the linkages between land use changes and water quality improvements will be an integral part of these educational efforts. In addition, existing curriculum creates opportunities for interested visitors to acquire, enter, and interpret hydrologic and water quality data from the watershed. Both streamside and visitor center-based activities and educational stations are planned. Information presentations could readily be tailored to school, environmental, or agricultural interest groups. The Neal Smith NWR hosts thousands of visitors annually.

USFWS will utilize the WNT as a demonstration area for landscape restoration projects. Information will be disseminated to visitors and invited groups, the public (through published reports), and the news media. Of broader interest, the project is also serving as a demonstration site for riparian restoration and small wetland restoration. Having a linked water quality evaluation program makes these demonstrations more effective for general use and translation to a broader audience.

Progress To Date

The Neal Smith NWR Prairie Learning Center opened in the spring of 1997. Tours have been done for a variety of different groups, including students from grade school through college; scientists from several institutions, including Iowa and several other states and counties; Iowa and U.S. legislators; and members of the farming community and general public.

In September 1998, the Walnut Creek watershed was a field trip tour stop for the 6th National Nonpoint-Source Monitoring Workshop. Formal oral and/or poster presentations have been given at several meetings around the Midwest both to scientific groups and to the general public.

Information on the project is contained on the IDNR-GSB web page as well as a web page maintained by the USFWS. Several contacts have been made via this avenue.

During the school year, approximately 150 school children participate in environmental education activities presented by refuge staff each week day. Improvement in water quality is part of one of the displays at the center.

TOTAL PROJECT BUDGET

The estimated budget for the Walnut Creek Section 319 National Monitoring Program project for 1995 through 2005 was:

Project Element	Funding Source ($)			
	Federal*	USFWS	State	Sum
Proj Mgt	249,200	NA	113,196	362,396
I & E	13,000	NA	1,000	14,000
L T	NA	500,000	NA	500,000
WQ Monit	772,500	NA	29,800	802,300
TOTALS	1,034,700	500,000	143,996	1,678,696

*from Section 319 NMP funds
Source: Keith Schilling, 2000 (personal communication)

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

None.

OTHER PERTINENT INFORMATION

Participating Agencies and Organizations:

- Iowa Department of Natural Resources
- U.S. Fish and Wildlife Service
- U.S. Geological Survey — Water Resources Division
- University of Iowa Hygienic Laboratory
- Farm Service Agency
- Iowa Department of Natural Resources — Environmental Protection Division
- U.S. Environmental Protection Agency

PROJECT CONTACTS

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Maryland

Corsica River Watershed
Section 319
National Monitoring Program Project

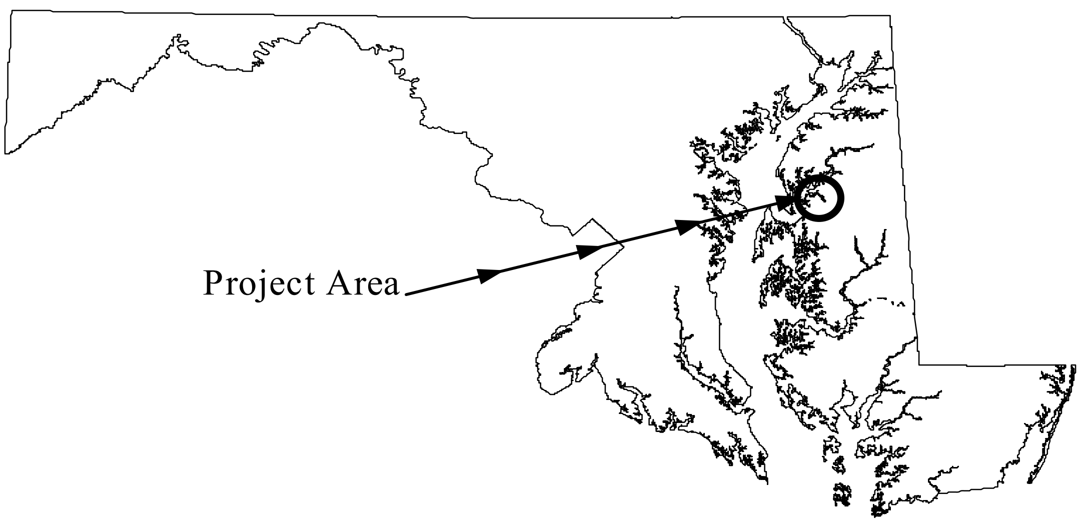
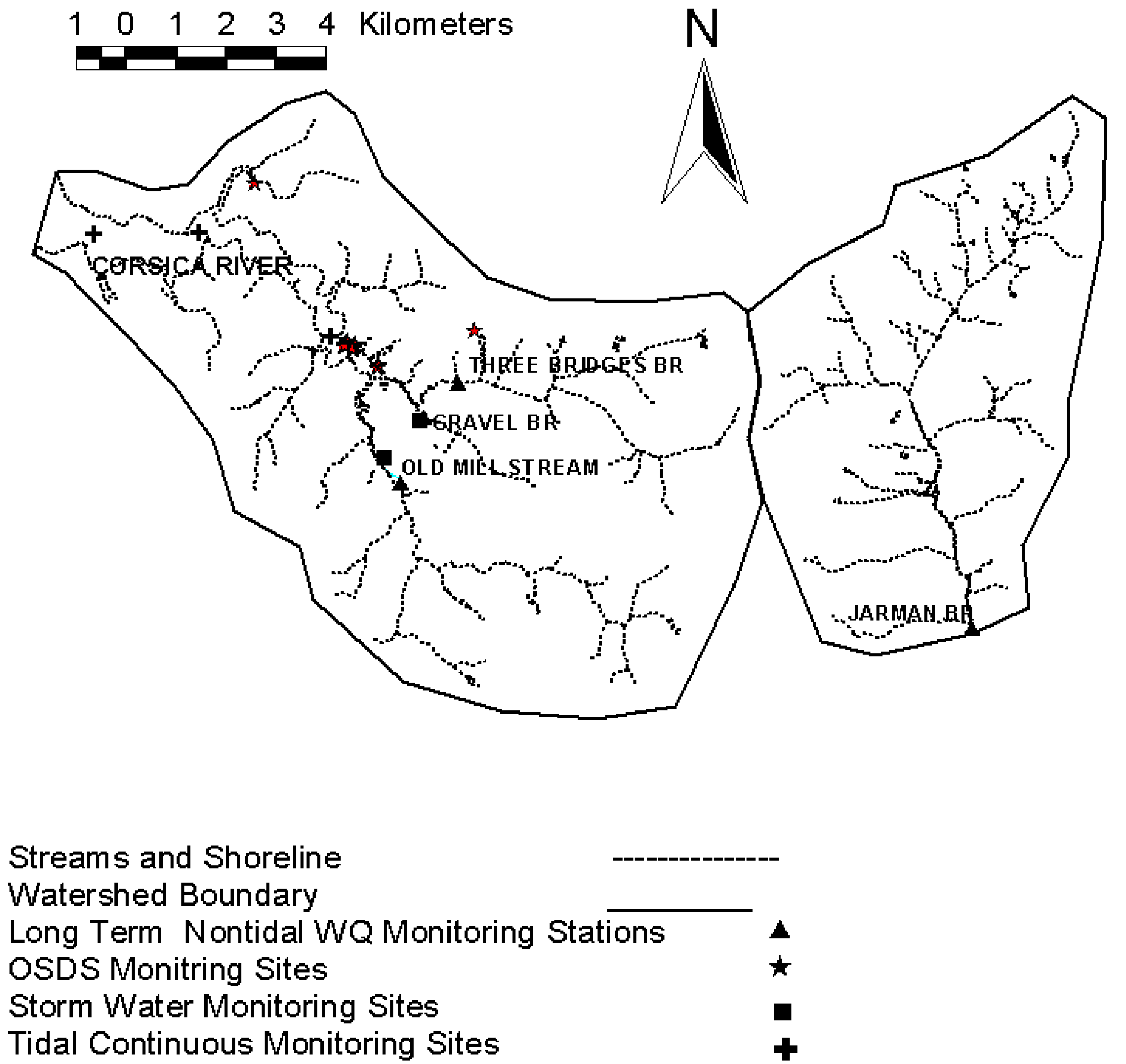


Figure 19: Corsica River Watershed (Maryland) Project Location



Corsica River Watershed (treatment) and adjoining Jarman Branch (control).

PROJECT OVERVIEW

The Corsica River Watershed Restoration Project is the restoration of a 24,000 acre watershed, leading to estuarine water quality that meets all water use and quality criteria noted in the State's Integrated 305(b)/303(d) Report. The overarching monitoring objective is to demonstrate the response of non-tidal and estuarine surface water nutrient loads, and by extension the TMDL end points of dissolved oxygen and phytoplankton (chlorophyll *a*) levels, to watershed management decisions and associated implementation activities. Implementation activities are not prescribed or mandated, but based on the market place and life style changes. Specific monitoring objectives include documenting tidal and non-tidal surface water nutrient concentrations and loads, effectiveness of cover crops, effectiveness of nitrogen removing onsite sewage disposal systems, and effectiveness of urban stormwater management retrofits. This project is unique for the State of Maryland. It is the first time that five major state agencies, the Departments of Environment (MDE), Natural Resources (DNR), Agriculture (MDA), Transportation (MDOT), and Planning (MDP), have collaborated on funding, implementation, and monitoring in an attempt to remove a Chesapeake Bay sub-watershed from the 303d list of impaired waters. Further collaboration and partnerships with the University of Maryland, local county and town governments, and local environmental and citizen groups have made this a very all-encompassing work group. Management plan implementation activities have begun. Initial non-tidal nutrient loading analysis has been completed for the first six-month period of flow record to establish a benchmark for future comparisons. Depressed dissolved oxygen and elevated chlorophyll levels continue to impact the tidal portion of the river.

PROJECT BACKGROUND

Project Area

Corsica River watershed @ 24,000 acres (treatment)

Jarman Branch watershed @ 12,000 acres (control)

Relevant Hydrologic, Geologic, and Meteorologic Factors

The project area is in the upper portion of Maryland's Eastern Shore of the Chesapeake Bay (Queen Anne's Co.). There is an estuarine tidal portion of the watershed that has salinities ranging from 5 to 15 parts per thousand, and a tidal range of 18 to 24 inches. The upland free flowing portion of the watershed is gently rolling coastal plain hills with maximum relief of approximately 60 feet. Approximately 67% of the watershed is prime loamy agricultural soils and about 20% is hydric soil. All other soils amount to about 13% of the watershed. There is no exposed bedrock in these watersheds. Wetlands identified by Maryland Department of Natural Resources (DNR) comprise less than 0.5% of the landscape.

Annual average rainfall is on the order of 40 to 42 inches per year. Average annual temperature is approximately 55^{o}F and there are approximately 220 frost-free growing days.

Land Use

Land use in the 24,000+ acre Corsica River watershed is approximately 16,000 acres (64%) agricultural, 6,700 acres (28%) forest/scrub shrub and 1,700 acres (7%) developed. The Jarman Branch watershed has 8,259 acres (68%) as cropland, approximately 1,450 acres (12%) as upland forests, and upland and wooded wetlands total 1,650 acres (14%).

Water Resource Type and Size

The Corsica River is a tidal tributary to the Chester River, and the Chester River is a tidal tributary of the Chesapeake Bay. The tidal portion of the Corsica River covers approximately 1,200 acres of open water. The tributary streams to the Corsica range from first to third order. The largest, Old Mill Stream Branch, is approximately 10 feet wide with a discharge ranging from 1 to 600 cubic feet per second. USGS currently gauges Three Bridges Branch. Jarman Branch is a third order stream with discharges ranging from 2 to 1,200 cubic feet second.

Water Uses and Impairments

The tidal and free flowing portion of the Corsica watershed are classified as suitable for water contact recreation and fishing with some restrictions as noted below.

A Total Maximum Daily Load (TMDL) approved for both nitrogen and phosphorus in the tidal portion of the Corsica River sets load limits for both nutrients. The low flow TMDL for nitrogen is 1379 lbs/month, and the low flow TMDL for phosphorus is 202 lbs/month. These TMDLs apply during the period May 1 – October 31, and will be implemented through NPDES permits. The annual TMDL for nitrogen is 287,670 lbs/yr, and the annual TMDL for phosphorus load is 22,244 lbs/yr. Although the TMDL sets nutrient goals, no nutrient criteria have been established for fresh or estuarine waters. In lieu of nutrient criteria, chlorophyl *a* concentrations in the estuary are used as a surrogate measure of nutrients, with a goal of 50 micrograms per liter to meet the estuarine water clarity goal and satisfy the TMDL.

A TMDL has also been written for bacteria in the tidal portion of the river. Fecal coliform concentrations in portions of the Corsica River are high enough to trigger shellfish harvesting regulations. The tidal waters closest to Centreville are “restricted” which means that no harvesting of oysters and clams is allowed at any time. No restrictions have been placed on water contact recreation or fishing.

The tidal portion of the Corsica River also suffers from legacy polychlorinated biphenyls (PCBs) and dieldrin. A TMDL has not been written for these substances at this time. The PCBs and dieldrin are associated with toxic and carcinogenic effects in humans. Since there is a risk that health problems could occur in people who eat these local fish too frequently, fish consumption advisories were issued in late 2001 and an update to the advisory was issued by MDE in January, 2003.

Several of the free flowing tributaries have been noted as being biologically impaired and put on the 303d list of impaired waters.

Pollutant Sources

Nonpoint sources of pollution are row crop agricultural activities, stream bank erosion, and pet waste.

Pre-Project Water Quality

Nutrient concentrations vary between the three major tributaries, but have remained relatively constant over the past 10 to 15 years as noted below.

	TN mg/L	TP mg/L
Jarman Br	3 – 6	.02 - .45
Old Mill Stream	3 – 6	.04 - .16

Gravel Branch	2 – 5	.03 - .27
Three Bridges Br	1 – 5	.04 - .43
Corsica tidal	.5 – 2	

Water Quality Objectives

The overall goal of this project is to work in an appropriate size watershed where, given sufficient resources, the State, County and local governments could demonstrate the ability to implement sufficient point and non-point source management activities to significantly improve habitat and water quality for living resources and maintain those improvements. To this end, the State's overall water quality management goal for the Corsica River watershed is to meet all specific water use and quality criteria noted in the State's Integrated 305(b)/303(d) Report. This task can be broken into four subcategories:

- Address tidal Corsica River TMDL for nitrogen and phosphorus designed to meet dissolved oxygen and water clarity standards for Use II - Shallow and Open Water uses. The low flow TMDL for nitrogen is 1379 lbs/month, and the low flow TMDL for phosphorus is 202 lbs/month. These TMDLs apply during the period May 1 – October 31, and will be implemented through NPDES permits. The annual TMDL for nitrogen is 287,670 lbs/yr, and the annual TMDL for phosphorus load is 22,244 lbs/yr.
- Address the sediment impairment in the tidal Corsica River and reduce suspended sediment levels to meet Use II - Shallow Water criteria for water clarity due to excess turbidity.
- Address the bacterial impairment in the tidal Corsica River and reduce bacterial levels to meet Use II - Shellfish Harvesting criteria and minimize any human-source bacteria levels that would limit shellfish harvesting in available waters (excepting permanently-closed WWTP discharge safety zone).
- Address the biological impairments in the non-tidal waters of the Corsica River watershed to meet Use I (water contact recreation) criteria and improve necessary water and habitat quality issues so that aquatic life communities will meet reference conditions.

The Corsica Watershed Project is a pilot program designed to develop best business and management practices and implement the processes, partnerships, assessment, and implementation tools needed to meet that threshold for restoring a single sub-watershed of the Chesapeake Bay to its designated uses.

The direct goals will be:

- Demonstrate the impact of a comprehensive watershed restoration program on non-tidal surface water nutrient and sediment concentrations and loads.
- Demonstrate effectiveness of cover crops at reducing soil pore and shallow ground water nutrient concentrations under agricultural fields.
- Demonstrate effectiveness of onsite sewage disposal systems with nitrogen removal technology at reducing nutrient concentrations delivered to ground water.
- Demonstrate effectiveness of urban storm water management retrofits at reducing nutrient and sediment loads discharged to surface waters.
- Demonstrate the response of estuarine phytoplankton (chlorophyll A) to changes in non-tidal surface water nutrient loads.

Project Time Frame

July, 2005 to July, 2010 (estimated)

PROJECT DESIGN

Activity	Pre-BMP	BMP Implementation*	Post-BMP
Outlet monitoring	7/05 – 9/07	Cover crops 9/07 – indefinite	9/07 – 9/10
Nutrient Synoptic Surveys	7/05 – 9/07	Cover crops 9/07 – indefinite	9/07 – 9/10
Subsurface nitrate	7/04 – 7/06	Cover crops 9/07 – indefinite	9/07 – 9/10
Urban stormwater	7/06 – 7/08	Wetland retrofit 7/08 – 10/08	10/08 – 9/10
Onsite sewage	7/06 – 1/08	Denitrifying OSDS 1/08 – 3/08	3/08 – 9/10
Estuarine monitoring	7/05 – 9/07	NA	9/07 – 9/10

Project Schedule

*As noted, the BMP implementation consists of a number of different activities. The timing for the cover crop implementation is open ended because this is an ongoing program with no specific end date. The goal of the cover crop program is to maintain a minimum of 4,000 acres per year in grass or small grain cover crops in perpetuity within the watershed. Sign-up for, and actual planting of cover crops is voluntary and subject to commodity market fluctuations and weather. The estuarine monitoring looks at the cumulative effect of all implementation activities within the watershed.

Nonpoint Source Control Strategy

The Corsica River Watershed Project was envisioned as the test of a management process. We are attempting to shift from the current and generally ineffective scattershot approach to watershed restoration to a coordinated life style changing program that results in significant water quality, habitat, and living resource improvements. BMP implementation is critical to program success, and monitoring is critical to determining if success has been achieved. In the context of the Chesapeake Bay restoration, the Corsica River Watershed Project is a test of a watershed management process that will further our understanding of, and ability to, limit non-point source pollution. Because this is a test of the management process more than any individual implementation activity, the market place and life style changes will dictate timing and extent of BMP implementation. The monitoring was begun in July 2005 prior to any significant implementation activities over and above ‘business as usual.’

Water Quality Monitoring

The non-tidal baseflow and storm flow monitoring will be a paired watershed trend study. The three major tributaries to the Corsica - Three Bridges Branch, Gravel Branch, and Old Mill Stream Branch -will be paired against Jarman Branch, an adjacent watershed in the Tuckahoe/Choptank watershed. Three Bridges Branch, Old Mill Stream Branch and Jarman Branch watersheds are similar in size (@ 8,000 to 10,000 acres) and dominated by agricultural land use. Although Gravel Branch is considerably smaller at approximately 1,000 to 1,500 acres, a calibration period of sufficient length to establish a relationship should allow for appropriate comparisons. A 10-year nutrient discharge monitoring, and land treatment history in the Jarman Branch watershed was a prime consideration when choosing it as the pairing watershed. Jarman Branch had over 99% of the watershed under nutrient management plans in 1995, with BMP implementations being tracked by the county Soil Conservation District. During this 10 year period, there was limited nutrient sampling from the Corsica tributaries being sampled for the current study. While implementation activities will not be discouraged or prohibited in the Jarman Branch watershed, past experience has shown that 'business as usual' does not produce the level of implementation required to significantly effect nutrient exports from this watershed.

The nutrient synoptic survey will be a trend study (means separation, Kolmogorov/Smirnov) providing an ongoing systematic assessment of dry weather base flow nutrient concentrations and yields from up to 43 subwatersheds throughout the Corsica non-tidal watershed.

Tracking changes in subsurface nitrate levels of agricultural land with and without cover crops will be a trend study (means separation, Kolmogorov/Smirnov) providing an ongoing systematic assessment of nitrate leaching rates and nitrate concentrations in shallow groundwater throughout the Corsica River watershed.

The urban stormwater monitoring has been planned as a combined before/after and upstream/downstream monitoring study. The before/after aspect will monitor improvements to housekeeping (street sweeping, pet management, etc.), while the upstream/downstream portion will look at the effectiveness of storm water wetland retrofits.

The onsite sewage disposal system study will be a paired study with three treatment sites and three control sites.

The estuarine monitoring will be a trend study of nutrient, chlorophyll *a*, and sediment concentrations as they relate to documented loads delivered from non-tidal streams (means separation, Kolmogorov/Smirnov).

Variables Measured

Chemical and Other

Non-tidal

Total phosphorus
Orthophosphate
Total nitrogen
Total dissolved nitrogen
Nitrate+nitrite
Ammonia
Total suspended solids

Tidal

Chlorophyll
Water temperature
Specific conductance
Salinity
Dissolved oxygen
Turbidity (NTU)
Fluorescence
Total chlorophyll (used to estimate chlorophyll *a*)
pH

Depth
Total dissolved nitrogen
Particulate nitrogen
Nitrite
Nitrite+nitrate
Ammonium
Total dissolved phosphorus
Particulate phosphorus
Orthophosphate
Dissolved organic carbon
Particulate carbon
Silicic acid
Total suspended solids
Volatile suspended solids
Particulate inorganic phosphorus

Covariates

Precipitation
Discharge

Sampling Scheme

Non-tidal

Project 1. Base and storm flow water quality samples will be collected at the three Corsica tributary sites using ISCO©, Inc. automated samplers and flow meters. Flow weighted composite samples will be collected. Weighting criteria will be set based on a rating curve established for each stream. To define the relationship between dissolved and total nutrient concentrations, grab samples for whole and filtered water will be collected weekly just below the water surface at mid-stream at all stations including Jarman Branch. Filtered samples will be filtered through a 0.47 micron pore size Whatman 934/AH filter.

Project 2. Synoptic nutrient samples will be collected at approximately forty-five sites throughout the Corsica watershed. Sampling will be conducted during a base flow period of high ground water recharge in February and a period of minimal ground water recharge in August. Surface water grab samples will be collected just below the water surface at mid-stream at all sites. A stream discharge measurement will be taken at the time of sampling.

Project 3. The primary field activity for assessment of changes in nitrate leaching rates and nitrate concentrations in shallow groundwater will be the collection of soil cores from cropland throughout the Corsica River watershed. At each sampling site 5 cm diameter cores will be collected from the soil surface to approximately 0.5 m below the water table in 15 cm increments. Three cores will be collected in each field and GPS coordinates will be established for each sampling site. In addition to soil coring, edge-of-field well nests will be established at four sites in the watershed to track changes in groundwater nitrate concentrations leaving crop fields. These wells will be sampled quarterly at a minimum. Wells will be sampled using standard techniques and all samples will be analyzed for nitrate, sulfate, and chloride.

Project 4. Automated sampling equipment has been installed at storm water outfalls to Gravel Branch and Old Mill Stream Branch to capture first flush and composite storm flows to these tributaries. Stormwater discharge volumes will be calculated using a Mannings equation, or a V-notch weir, and the recorded stage heights at the pipe outfall. Samples will be collected from 12 to 16 storms per year beginning at least one year prior to storm water retrofit installation and continuing for one year after completion. After retrofit, samples will be collected from both retrofit inflow and outflow. At a minimum, samples will be analyzed for total nitrogen, total phosphorus and total suspended solids. Screening of initial samples will be done to identify other potential constituents that could be considered as contributing to existing water quality problems.

Project 5. This project chose two of the 30 proposed retrofit sites, and one traditional OSDS with no planned upgrade. Two new homes with nitrogen reducing OSDSs installed as original equipment are still planned, but are currently unavailable due to real estate market changes. Three off site controls have been established in areas unimpacted by septic effluent, one adjacent to agricultural land, a second in forest, and a third on an undeveloped subdivision lot. An array of 4 to 6 shallow wells will be installed within and down gradient of each drain field to monitor the nutrient (NO_2, NO_3, NH_4, PO_4 and TDN) concentrations being discharged to the shallow ground water. Control sites have three wells. Samples are collected every four weeks from each test site.

Estuarine
Project 6. The Corsica River will be monitored using monthly water quality mapping cruises, two continuous monitoring sites, a vertical water quality profiler and fixed station grab sampling. The two continuous monitoring sampling stations are chosen to be representative of the Corsica's up-stream and downstream conditions, with two instruments deployed at the downstream station (sur-face and bottom). The continuous monitoring will be conducted year round at three sites within the estuarine portion of the Corsica at both the surface and bottom. Each continuous monitoring station deploy YSI© 6600-EDS sondes in the water column. At each station, one instrument will be floating 1 meter below the surface while a second instrument will be fixed 0.3 meters above the bottom. The monitoring sondes record nine water quality parameters every 15 minutes; water temperature, specific conductance, salinity, dissolved oxygen, turbidity (NTU), fluorescence and total chlorophyll (used to estimate chlorophyll *a*), pH and depth. During bi-weekly site visits for instrument replace-ment a discrete water sample will be collected for chlorophyll, turbidity and TSS calibration of sonde and a full suite of nutrients (total dissolved nitrogen, particulate nitrogen, nitrite, nitrite + nitrate, ammonium, total dissolved phosphorus, particulate phosphorus, orthophosphate, dissolved organic carbon, particulate carbon, silicic acid, total suspended solids, volatile suspended solids, and particu-late inorganic phosphorus). In addition, secchi depth and photosynthetic active radiation (PAR) measurements are taken at calibration stations to calculate light attenuation (Kd). Water quality mapping (DataFlow) is a shipboard system of geospatial equipment and water quality probes that measure water quality parameters from a flow-through stream of water collected near the water's surface. The water quality mapping system samples water at approximate 0.5-m below the surface. Each water quality measurement is associated with a date, time, water depth, and GPS coordinate (NAD83).

Land Treatment Monitoring

BMP implementation on agricultural land is tracked by the local Soil Conservation District Office. Other urban and suburban implementation activities are tracked by direct observation and local contacts on a monthly basis.

Progress to Date

Implementation activities as of July, 2007 include increases in cover crop acreage from <10% of available crop land to > 50% of available crop land, and installation of 15 urban/suburban rain gardens. No significant changes have been noted in nutrient export to the estuary or changes in chlorophyll concentrations.

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

Primary data management was done using in-house spreadsheets in MS Excel. Data transfer to EPA Storet will be on an annual basis. A data summary is unavailable at this time.

INFORMATION, EDUCATION, AND PUBLICITY

Technical transfer will be through several avenues. Quarterly and annual progress and data reports are part of the 319(h) grant requirement, as is submission of data to the EPA storet system. A comprehensive annual report compiled by DNR and Maryland Department of the Environment (MDE) with input from other participating agencies and organizations will detail all watershed activities and results associated with the project. Additionally, a web site dedicated to the Corsica River restoration will be established and maintained by the Maryland Department of Natural Resources with periodic postings on activities and progress, and of data and analysis. An existing website (http://mddnr.chesapeakebay.net/eyesonthebay) will have near time data from the continuous estuarine monitoring. Data, results, and analysis will also be presented at public and professional forums such as the National Non-point Source Workshop and the Maryland Water Monitoring Council Workshop. A major assumption of this project is that the implementation methods and lessons learned for watershed restoration would be transferable to other impaired Chesapeake Bay watersheds.

Stakeholder representatives from local and regional environmental groups, watershed associations, river keepers, etc., local and county government, and agency personnel attend monthly implementers/progress meetings. A synopsis of past months activities is provided and future plans discussed at each meeting. This forum can provide data useful for program goal and strategy corrections and refinements with associated refinements to the various monitoring programs.

Other local communications initiatives will design and conduct a comprehensive outreach and education plan to target every resident in the watershed with particular focus on the residents of the Town of Centreville. Landowners will be targeted for increased technical assistance in the design and installation of best management practices (BMP's) that emphasize nutrient and sediment control throughout the urban landscape including innovative household water conservation and stormwater management, household and pet waste management strategies, street trees, and stream buffers. Tools for providing outreach and education support, which focus on sustainable site design and "Bay Scapes" for homeowners, will include educational programming distributed on DVDs, guidance materials, and workshops for developers.

PROJECT BUDGET

Implementation Activity	Current 05 Annual $$ Level	Total Activity Cost (5 year budget)
SCD support/Extension service support	$63,448	$634,480
Cover Crops	$164,550	$700,000
Small Grain Enhancement	$50,000	$250,000
Maryland Agricultural Cost Share	$14,900	$74,500
Buffers, Forest Cover and Conservation Landscaping Incentive payments (15-yr rental)	$1,700	$48,450
Buffer establishment	$22,000	$220,000
Horse Pasture Management	$40,000	$350,000
Point Source ENR	$0	$1,100,000
MDE, TARSA Project Coord 1 FTE	$0	$223,580
Stormwater Management	$260,500	$3,440,080
Homeowner pollution reduction	$40,000	$90,000

Septic Retrofits	$0	$255,000
Urban Forest Buffers	$0	$220,000
Urban Wetlands	$0	$1,000,000
SAV	$0	$160,000
Oysters	$400,000	$900,000
Stream Restoration	$0	$2,000,000
Project Coordination	$0	$750,000
SAV Monitoring	$0	$132,500
Tidal Water Quality Monitoring	$0	$551,725
Tidal Water Quality Monitoring Project Analysis	$0	$331,000
Oyster Monitoring	$16,000	$80,000
Imagery and data acquisition for implementation and progress tracking	$0	$632,750
Flow monitoring	$0	$50,000
Cropland conversion loading analysis	$56,300	$148,900
Soil Pore nitrogen and shallow ground water sampling under cover crops	$96,000	$264,000
Shallow ground water sampling adjacent to OSDS	$44,000	$212,000
Nontidal water quality sampling	$189,000	$910,000
Nontidal project analysis	$55,000	$300,000
Living resources and habitat monitoring	$80,740	$472,580
Bacterial Source tracking	$0	$75,000
updated 8/22/05	$1,594,138	$16,576,545

All estimates in current dollars

*Funding sources are federal, state, and local.

Focus	Responsible agency	Sampling type	Intensity	Parameters
Shellfish harvesting waters M	DE	tidewater surface grabs bacteria 2	sites biweekly	Enterococcus, insitu temp, pH, cond, D.O.
Oysters	DNR	population estimates	annual	Quality and quantity
Bacteria	MDE	Bacterial source tracking	watershed wide, seasonal	Scat, insitu temp, pH, cond, D.O.
SAV	DNR	population estimates/surveys	seasonal	Areal coverage, species
Centreville STP, spray irrigation	MES* /MDE	ground and surface water	monthly 7 sites	nutrients
Nontidal Biological	MDE/DNR	benthos, fish	every other yr	IBIs
Nontidal habitat	MDE	assessment	every other yr	quantitative measurements
Tidal/ anadromous fisheries	DNR	stock assessment	annual	species presence
Fish passage blockage removal	DNR	fish community	annual	species presence
Wetland/riparian restoration D	NR	assessment	annual	quantitative measurements

* Maryland Environmental Service

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

Additional Monitoring Activities Planned or Ongoing in the Corsica River Watershed

USDA agricultural BMP cost share programs are a significant part of the Corsica Watershed restoration program. USGS actively maintains a gauge at Three Bridges Branch. The US Fish and Wildlife Service and Maryland DNR Heritage have interest in the watershed due to the presence of a globally rare, threatened, endangered species. The MDE TMDL and 303(d) Programs have an interest in this watershed project.

OTHER PERTINENT INFORMATION

None.

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Maryland

Warner Creek Watershed
Section 319
National Monitoring Program Project

Figure 21: Warner Creek (Maryland) Watershed Project Location

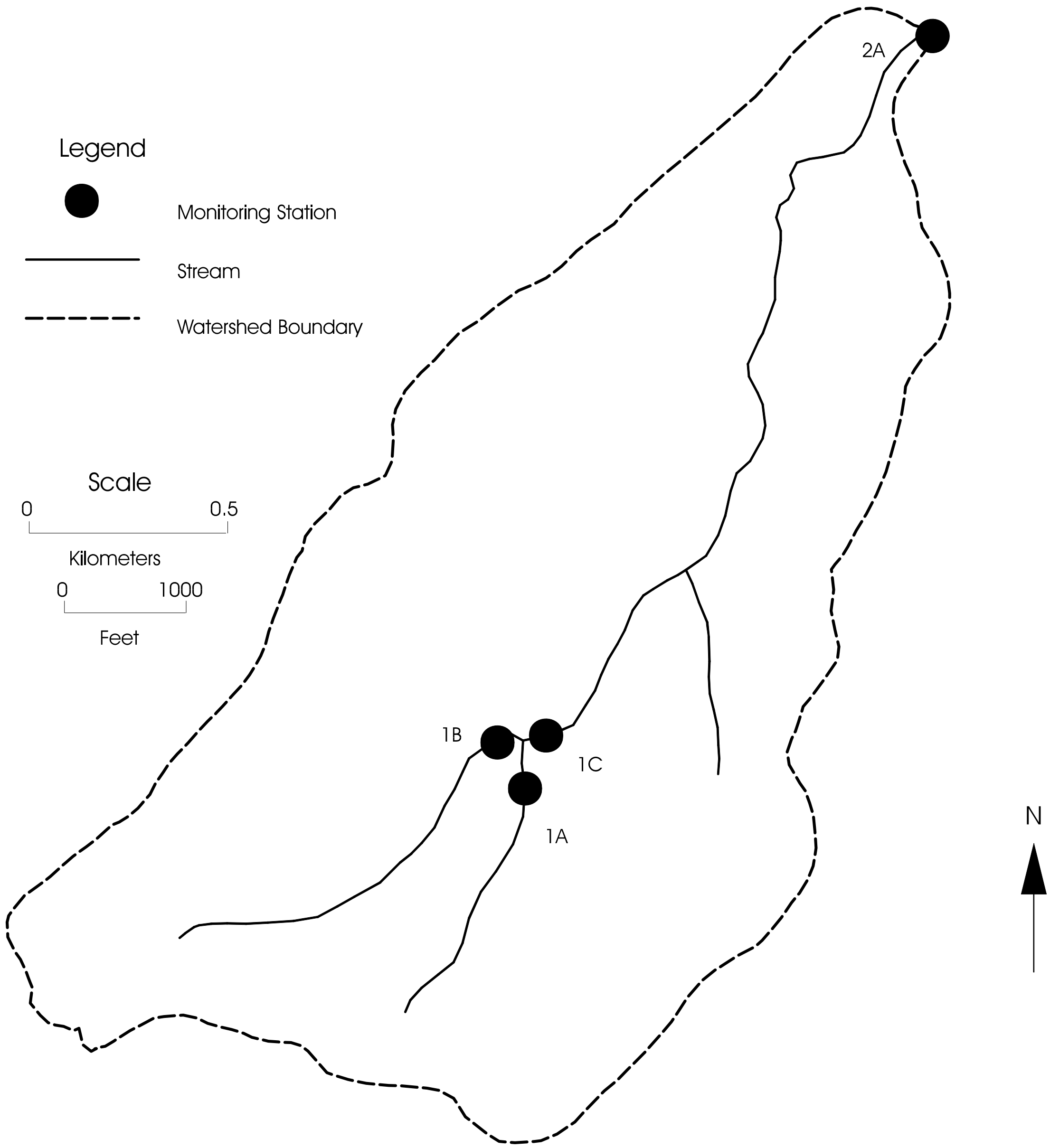

Figure 22: Water Quality Monitoring Stations for Warner Creek (Maryland) Watershed

PROJECT OVERVIEW

The Warner Creek watershed is located in the Piedmont physiographic region of northcentral Maryland (Figure 21). Land use in the 830-acre watershed is almost exclusively agricultural, primarily beef and dairy production and associated activities.

Agricultural activities related to dairy production are believed to be the major nonpoint source of pollutants to the small stream draining the watershed. A headwater subwatershed, in which the primary agricultural activity is dairy farming (treatment), was compared to another subwatershed, in which the primary agricultural activity is beef production (control).

Proposed land treatment for the treatment watershed included conversion of cropland to pasture, installation of watering systems, fencing to exclude livestock from tributary streams, and the proper use of newly constructed manure slurry storage tanks.

Water quality monitoring involved both paired watershed and upstream/downstream experimental designs. Sampling occured at the outlets of the paired watersheds (stations 1A and 1B) and at the upstream/downstream stations (1C and 2A) on a bi-weekly basis (Figure 22). Storm-event sampling by an automatic sampler occured at station 2A. Water samples were analyzed for sediment, nitrogen, and phosphorus.

Warner Creek is a subtributary of the Monocacy River basin. Monitoring data were used to evaluate the suitability of a modified version of the CREAMS and/or SWAT model for its use in the larger Monocacy River basin and elsewhere in Maryland.

Many of the BMPs in the treatment subwatershed (IB) were implemented. Post-implementation monitoring terminated December, 2003.

PROJECT BACKGROUND

Project Area

Approximately 830 acres.

Relevant Hydrologic, Geologic, and Meteorologic Factors

The watershed is in the Piedmont physiographic province. Geologically, bedrock in this area has been metamorphosed. Upland soils in the watershed belong to the Penn silt loam series with an average slope of three to eight percent. Average annual rainfall near the watershed is 44-46 inches.

Land Use

The land use in the upper portion of the watershed monitored by stations 1A, 1B, and 1C (Fig 20), is a mixture of dairy, beef, pasture, and cropland. The branch of the upper portion of the watershed, subwatershed 1A, does not have any dairy operation and that makes it very distinct from subwatershed 1B. The dominant surface cover in the upper portion of the watershed is pasture. This subwatershed (1C, sum of 1A and 1B) occupies about 324 acres. The rest of the watershed toward the downstream section (subwatershed 2A) is also under dairy, beef, pasture, and cropland. The area under subwatershed 2A is about 506 acres.

Water Resource Type and Size

Warner Creek is a small stream with a drainage area of about 830 acres, all of which are included in the study area. Its average discharge is 30 gallons per minute. Warner Creek drains into a tributary that drains into the Monocacy River basin.

Water Uses and Impairments

Other than aquatic life support, no specific uses or impairments are listed for Warner Creek. However, the watershed is characteristic of the region and impairment of Chesapeake Bay for recreation and aquatic life support by excessive nutrient loads from land runoff is a significant regional issue.

Pollutant Sources

The major sources of pollutants are thought to be the dairy operations and the associated cropland. Pastures in which cows have unlimited access to the tributary streams also contribute significant amounts of pollutants.

Pre-Project Water Quality

Seven weeks of pre-project water quality monitoring at four stations yielded the following data:

Nitrate (mg/l)	Nitrite (mg/l)	Ammonia (mg/l)	TKN (mg/l)	TKP (mg/l)	Orthophosphorus (mg/l)
3.3-6.7	.01-.05	0-23.0	0-73.0	0-6.7	0-3.6

Source: Shirmohammadi and Magette, 1993

Water Quality Objectives

The objectives of the project were to

- develop and validate a hydrologic and water quality model capable of predicting the effects of agricultural best management practices (BMPs) on water quality, both at the field and basin scale;
- collect water quality data for use in the validation of the basin-scale hydrologic and water quality model; and
- apply the validated model to illustrate relationships between agricultural BMPs and watershed water quality in support of the USDA Monocacy River Demonstration Project.

Project Time Frame

Preliminary work on the project began in May 1993; however, the project was not approved until June, 1995.

PROJECT DESIGN

Nonpoint Source Control Strategy

Upstream/Downstream Study Area (1C and 2A):
Best management practices planned for this area included construction of watering systems for animals, fencing animals from streams, and the proper use of newly constructed manure slurry storage tanks. Conversion of cropland to pasture was also anticipated in this area.

Most of the planned BMPs for subwatershed 2A were installed in 1992 and 1993. These BMPs included conversion of cropland to pasture, installation of a watering trough(s) for the animals, fencing out the animals from the streams, and the use of the newly constructed slurry storage tanks for farms on the eastern and western portions of subwatershed 2A. The cost-shared contracts were signed in March 1995 and implementation began in July 1995. Most of the BMP implementation in this portion of the watershed was completed.

Monitoring stations for this project were carefully selected to isolate areas where a major NPS pollution problem existed that would be addressed with an individual BMP (or category of BMPs). For this project, the BMP consisted of a manure management system (two farmers have already installed a 520,000 gallons Slurry Storage system in their respective farms). Integral to such a system was a nutrient management plan that met USDA-SCS FOTG standards, as well as Cooperative Extension Service guidelines, and Maryland Department of Agriculture specifications.

BMP adoption is a voluntary process in Maryland, as it is across the U.S. The adoption process is enhanced, however, by efforts of Soil Conservation District and Cooperative Extension Service personnel. Because the Monocacy watershed, where this project was located, was a major BMP demonstration project, BMP adoption was promoted to an even greater degree.

As elsewhere, Conservation planning by the local Soil Conservation District (SCD) formed the basis of voluntary adoption in the project area. Conservation planning involved a farmstead assessment of potential and actual NPS pollution problems. Conservation plans to address such problems were written by the SCD for farms in the project area. However, implementation of these plans and the BMPs they specify was entirely voluntary and it was not possible to mandate implementation. As an example, two major farmers in the watershed have installed the Slurry Storage System (each with 620,000 gallons capacity) in their farm for managing manure as was promoted and cost-shared by SCD and USDA—Agricultural Stabilization and Conservation Service (ASCS)—in 1993. Conservation plans and BMPs proposed for the critical pollution area of the watershed, subwatershed 1B, were installed in Summer and Fall of 1995.

Impacts of nonpoint sources to ground water, and to surface water via ground water, were generally assessed by both the monitoring and modeling aspects of this project. It is beyond the scope and funding of the project to attempt a more rigorous examination of these potential impacts.

Paired Watershed (1A and 1B):
The implementation of BMPs in the treatment (1B) watershed began in July 1995. Installed BMPs included waste storage structure, nutrient management, loafing at runoff management, stream crossing, water trough, livestock exclusion fencing, and critical area seeding. Additional BMPs including conservation cropping and tillage systems, crop residue, and cover crop management, interceptions/diversions around milking parlor, silage stack and loafing were installed later.

Water Quality Monitoring

The water quality monitoring component incorporated two designs:

- Upstream/downstream on Warner Creek
- Paired watersheds in the uppermost areas of the watershed

Parameters Measured

Chemical and Other

Ammonia (NH_3)
Total Kjeldahl nitrogen (TKN)
Nitrate + nitrite (NO_3+NO_2)
Nitrite (NO_2)
Orthophosphorus (OP)

Total Kjeldahl phosphorus (TKP)
Sediment

Covariates

Rainfall
Discharge: instantaneous (1A, 1B and 1C) continuous (2A)

Sampling Scheme

Upstream/Downstream Study Area (1C and 2A) (Figure 20)
Type: grab (1C and 2A); automated storm event (2A)
Frequency and season: weekly from February to June and biweekly for the remainder of the year (1993 through 1995) and biweekly since 1996.

Paired Watershed (1A and 1B) (Figure 20)
Type: grab (1A and 1B)
Frequency and season: weekly from February to June and biweekly for the remainder of the year

Four additional sampling stations were added between sites 1C and 2A to further define nutrient levels in Warner Creek.

Monitoring Scheme for the Warner Creek Watershed Section 319 National Monitoring Program Project

Design	Sites or Activities	Primary Parameters	Covariates	Frequency of WQ Sampling	Frequency of Habitat/Biological Assessment	Duration
Paired		NH_3, $NO_2 + NO_3$ TKN, O P, TKP, Sediment	Rainfall discharge	Weekly Feb. to June and bi-weekly the remainder of the year (1993-1995)		3 yrs. pre-BMP 1 yrs. BMP 1 yrs. post-BMP
Upstream/ Downstream	Warner Creek	TKN, NO_3+NO_2 NO_2 O P T K P Sediment	Discharge pH	biweekly since 1996		

Land Treatment Monitoring

Land use information for 1991,1992, and 1993 was compiled using information from the Soil Conservation District Office in Frederick, Maryland. Land use tracking has been performed on about 2/3 of the watershed and it will be performed for the entire watershed. Land use data was collected on each tract of land and for every field identified by a number on the aerial photos obtained from USDA-ASCS office. For each field, data such as a crop type, tillage, and acreage was recorded. Land use data have been entered into the GIS database and overlaid on topographic and soils data on the same coordinate system. BMP implementation by management area was also tracked.

The focus of much of the land treatment effort was in the drainage area to monitoring site 1B as this site had the highest loading of nitrogen and phosphorus. In 1996, an animal waste storage system, roof runoff management system, and partial fencing along a stream channel were installed; however high nutrient export from the area continued. In 2001, the landowner installed a retention pit for milkhouse waste, interceptor tiles for silage effluent, and 9.5 acres of riparian corridor (40 ft. on either side) along stream channels.

Modifications Since Project Started

Biweekly sampling frequency was increased to weekly sampling during the wet season. Data for 1996, 1997, and portion of 1998 are in the FFY97 Annual Report (Table 3).

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

Testing of the SWAT model against monitoring data indicated that it showed good promise for predicting hydrologic and water quality response.

Monitoring data are stored and analyzed at the University of Maryland. In addition, some project data were reported using the Nonpoint Source Management System (NPSMS) software.

Project Findings

Water quality data indicate that despite long term monitoring, unusual climatic and hydrologic conditions similar to the conditions in 2003 can result in unstable watershed responses. For instance, mean nitrate-N concentrations in all four monitoring stations were unusually high (about 250 mg/L) compared to previous years with 4-8 mg/L. These high means were the consequence of wet conditions during and after hurricane Elizabeth (September 19, 2003). It is hypothesized that several storms including hurricane Elizabeth caused groundwater level to rise to near root zone area in the watershed where there may have been the abundance of nitrate-N, thus resulting in discharge of high amount of this constituent via subsurface flow into the stream.

Monitoring results documented that 70% of the total nitrate-N discharging from the watershed was carried by subsurface flow. Pollutant load reductions resulting from BMP implementation in 1996 could not be documented. Because the timing of BMP implementation could not be adequately controlled, the project was unable to isolate distinct pre-treatment and post-treatment water quality data. Thus, the project was unable to document the impacts of BMPs primarily because the statistical analyses required for paired-watershed and upstream-downstream studies could not be carried out. The primary success of the project was in calibrating and validating the SWAT model for broader use in Maryland nonpoint source projects, including TMDLs.

INFORMATION, EDUCATION, AND PUBLICITY

The project drew support from University of Maryland Cooperative Extension Service (CES) agents, the Natural Resources Conservation Service (NRCS) and Frederick Soil Conservation District offices in Frederick, Maryland, and project specialists located in the Monocacy River Water Quality Demonstration offices, several of whom have established lines of communication between watershed farmers and the local personnel of the relevant USDA agencies. Education and public awareness was conducted through the CES in the form of tours, press releases, scientific articles, and oral presentations.

TOTAL PROJECT BUDGET

Project Element	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Monitoring						
Personnel	$41,600	$32,500	$45,000	$49,000	$62,500	$67,000
Equipment	10,000	3,000	NA	NA	NA	NA
Other	26,733	35,938	37,140	34,190	39,725	39,626
TOTALS	78,333	71,438	82,140	83,190	102,225	106,626

Source: FFY94 Work Plan (6/23/94).

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

The USDA Monocacy River Demonstration Watershed Project facilitated the dissemination of information gained from the project and helped provide cost-share funds for implementing BMPs.

OTHER PERTINENT INFORMATION

Other aspects of this project dealt with the calibration and validation of the SWAT model with the measured hydrologic and water quality data. Overall results indicated that SWAT is an excellent model to be used for annual simulation of hydrologic and water quality response of mixed land use watersheds. However, its use for shorter time intervals such as daily or even monthly intervals has shortcomings. It was concluded that the SWAT model can provide an excellent management guidance on a long term basis regarding land use impacts on hydrology and water quality. Long term monitoring studies such as the one conducted in this project are very helpful in compiling proper data-base that can help to validate models such as SWAT that are being recommended for TMDL analysis by US-EPA.

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Michigan

Eagle River
Section 319
National Monitoring Program Project

Figure 21: Eagle River (Michigan) Project Location

Figure 22: Eagle River Stamp Snad Restoration Project Location

PROJECT OVERVIEW

The Eagle River Section 319 National Monitoring Program project is located in Keweenaw County in Michigan's western Upper Peninsula (Figure 1). The Eagle River is a small, largely undeveloped watershed that drains into Lake Superior at the small town of Eagle River. Land use consists mainly of conifer and hardwood forest and wetlands.

Native copper and silver have been mined in Michigan's Keweenaw Peninsula since the late 19th century. Copper was historically recovered from the parent rock by "stamping"- crushing the rock using steam-driven stamp heads followed by sluicing the crushed rock to separate out the native metals from the waste rock or stamp sands. During the mining period approximately 500 million tons of stamp sands were discharged directly into Lake Superior or into its tributaries from Keweenaw Peninsula milling operations. Between the 1840s and 1890s, several copper mines discharged stamp sands into both the East Branch and West Branch of the Eagle River, forming deposits up to 6 feet thick. A century and a half of water and wind erosion has transported stamp sands throughout the watershed, forming major deposits wherever the stream gradient is low enough for sediment deposition. For these reasons, an 8.5 mile reach of the Eagle River is currently on Michigan's 303(d) list for poor macroinvertebrate communities and elevated water column copper concentrations that exceed Michigan water quality standards.

This project proposes to reduce copper loadings to the Eagle River by restoring the stream channel flowing through two stamp sand deposits in the headwaters of the East Branch of the river, known as Central Mine sites #1 and #2, and stabilizing upland stamp sand deposits.

Project monitoring will employ a before-after control-impact design and include analysis of water chemistry (including total copper), sediment copper concentration, benthic macroinvertebrates, habitat characteristics, and geomorphic assessments. Pre-BMP monitoring occurred in 2006 and 2007, construction will occur in 2009, and post-BMP monitoring will continue through 2021.

PROJECT BACKGROUND

Project Area

The Eagle River watershed, in Keweenaw County on the Keweenaw Peninsula in Michigan's Upper Peninsula, is 21.2 square miles in size.

Project Hydrologic, Geologic, and Meteorologic Factors

The surficial geology of most of the watershed consists of glacial till (sand and gravel), more than 150 feet thick in some locations. Exposed basalt bedrock occurs mostly in the ridges and cliffs that parallel the Lake Superior shore. The basalt bedrock contains the copper ores that were the origin of the stamp sands.

Average annual precipitation is approximately 34 inches, which includes an average of 219 inches of snow. "Lake effect" precipitation is common, especially in late autumn and early winter. The major annual runoff event is often spring snowmelt.

Land Use

The Eagle River watershed is largely undeveloped; 88 percent of the area is forest, 8 percent is wetland, 2 percent is urban, and 2 percent is "other" (primarily roads and stamp sand deposits). Population data for the watershed are not available, but it is wholly within Keweenaw County, which had a population of only 2,301 in 2000.

Water Resource Type and Size

The Eagle River watershed drains into Lake Superior at the town of Eagle River. Watershed headwaters are predominantly wetlands, beaver ponds, and beaver meadows. Stream channels are predominantly small (less than 20 feet wide and 5 feet deep), and alternate between low-gradient, meandering channels that flow through wetlands, and higher-gradient, comparatively straight channels that flow over gravel and cobble riffles. The project reach consists of two low-gradient channels that are separated by a shorter, higher gradient reach in which stamp sand deposition is minimal.

Water Uses and Impairments

The Eagle River is a cold-water stream. The stream reach addressed in this project is small and shallow, and not a significant fishery resource. The Eagle River is not used as a drinking water source by any of the villages within its watershed (Central, Phoenix, or Eagle River).

An 8.5 mile reach of the Eagle River is currently on Michigan's 303(d) list for poor macroinvertebrate communities and elevated water column copper concentrations that exceed Michigan water quality standards.

Pollutant Sources

"Stamp sand" copper mining wastes, described above, are believed to be the primary source of copper to the Eagle River. Because adjacent streams with similar geologies but lacking stamp sand deposits do not exhibit high aqueous copper concentrations, groundwater transport of copper leached from underground copper deposits is not thought to be a significant source.

Pre-Project Water Quality and Ecological Objectives

Several previous studies of water quality and instream characteristics have been performed:

- Macroinvertebrate, instream habitat, and water chemistry surveys performed by the State of Michigan, in 1992, 1996, 2001, and 2006.
- Monitoring performed in 2006 by the Houghton/Keweenaw Conservation District during development of a Section 319-funded watershed management plan. This includes limited monitoring of:
    - Macroinvertebrates and fish using Michigan Department of Environmental Quality (MDEQ) sampling procedures
    - Riparian vegetation
    - Water chemistry, including aqueous copper concentrations
    - Channel geomorphology (cross-channel transects, pebble counts, sediment grain size analysis)
    - Stream flow

These studies documented that:

- Instream habitat and macroinvertebrate communities are impacted by the stamp sands.
- Aqueous concentrations of copper exceed State ambient water quality standards.
- More than a century after the stamp sands were deposited, riparian vegetation is still lacking. This impacts instream biological communities and increases stamp sand loadings to the stream.

Water Quality Objectives

The objective of this project is to reduce aqueous copper concentrations and improve instream habitat quality such that the East Branch of the Eagle River can be removed from Michigan's 303(d) list.

Project Time Frame

1997-2021

PROJECT DESIGN

Nonpoint Source Control Strategy

Both Central Mine stamp sand sites, and the upstream reach including the headwaters of the East Branch of the Eagle River, are owned by the Keweenaw County Road Commission. Significant land use changes upstream or adjacent to the project location, including development or timber harvest, are not expected during the life of the project.

The pollution control strategy has four major components:

1. Relocate portions of the stamp sand deposits away from the stream channel, reducing transport of these materials into the channel, reducing the thickness of the deposits, and decreasing the distance from the riparian zone surface to the groundwater table.
2. Use principles of natural channel design to create a stable, self-sustaining stream channel that will reduce stream bank erosion and provide better instream habitat.
3. Take advantage of the natural revegetation propensity of thin, moist stamp sand deposits to create a stable vegetated riparian zone and stream banks.
4. Actively revegetate upland areas where natural revegetation is improbable.Project Schedule

- Pre-BMP monitoring = 2007
- BMP construction = 2009
- Post-BMP monitoring = 2010, 2011, 2013, 2016, and 2021

Post-BMP monitoring in 2011, 2016, and 2021 will take advantage of MDEQ's 5-year rotating watershed monitoring schedule.

Water Quality Monitoring

A before-after control-impact (BACI) study design will be employed to assess the effectiveness of the stamp sand stabilization/channel restoration activities. Two different control streams will be used; see below.

Variables Measured

Biological
Benthic macroinvertebrates
Riparian vegetation

Chemical

Water chemistry, including total copper, hardness, pH, and total organic carbon
Sediment copper concentrations

Physical

Instream habitat characteristics
Geomorphic measurements, including cross-channel transects, longitudinal profiles, bank erosion hazard index, and pebble counts

Covariates and Misc.

Flow
Referenced photo points

Sampling Scheme

A variety of chemical, biological and physical variables will be monitored. Preliminary plans are outlined in Table 1.

Two different control streams will be used in this project:

- Buffalo Creek, for water chemistry, sediment chemistry, and riparian vegetation.
- The West Branch of the Eagle River, for benthic macroinvertebrates, instream habitat, riparian vegetation, and geomorphic measurements.

Buffalo Creek is a tributary to the East Branch of the Eagle River, entering it less than 0.5 miles downstream of the Central Mine #2 stamp sand deposit. The control site on the West Branch of the Eagle River is approximately 6 miles west of the Central Mine stamp sand deposits.

Table 1. Sampling Scheme Outline

Monitoring Activity	Sampling Sites	Sampling Frequency*
Benthic macroinvertebrates & instream habitat	A total of 5 reaches within the project area, plus a control stream	Annual
Riparian vegetation	Both banks at a total of 5 sites bracketing and within the project area, plus a control stream	Annual
Water chemistry	A total of 4 sites bracketing and within the project area, plus a control stream	Pre-BMP = 10 samples in a 12 month period; post-BMP = to be determined, based on statistical analysis of the pre-BMP data
Sediment chemistry	A total of 5 reaches within the project area, plus a control stream	Annual
Geomorphic measurements	Longitudinal profiles, cross-channel transects, bank erosion hazard index, & pebble counts in 5 reaches within the project area, plus a control stream	Annual
Monumented photo points	Numerous	Annual, minimum

* Annual refers to the pre-construction monitoring in 2007 and the post-construction monitoring scheduled through 2021.

The effectiveness of the remedial activities will be judged using the data collected by the monitoring activities described above. Evaluation criteria for each of the monitoring activities are outlined in Table 2.

Modifications Since Project Started

None

Progress to Date

As of June 2008, the majority of the pre-BMP sampling had been completed, including sediment and macroinvertebrate sampling, instream habitat and riparian vegetation observations, channel geomorphology measurements, and photo points. Water chemistry sampling should be completed by the end of July 2008.

Data Management and Analysis

Data Management and Storage

Data collected for the project will be maintained by MDEQ and appropriate water and sediment chemistry data will be loaded into EPA's STORET database.

Information, Education, and Publicity

Documentation of progress will be ongoing, and will be distributed to interested groups, both local and national.

Table 2. Evaluation Criteria for the Monitoring Activities.

Monitoring Activity	Evaluation Criteria
Benthic macroinvertebrates & instream habitat	MDEQ's P51 sampling protocol has scoring procedures for macroinvertebrates and instream habitat; recovery of macroinvertebrate community and instream habitat over time
Riparian vegetation	Plant community development (stamp sand deposits currently devoid of vegetation)
Water chemistry	Decrease in aqueous copper concentrations over time, & Michigan ambient water quality standards
Sediment chemistry	Decrease in sediment copper concentrations over time, & Michigan sediment quality guidelines
Geomorphic measurements	Interstation comparisons; changes over time; consistency of stable channel over time
Referenced photo points	Visible change over time

TOTAL PROJECT BUDGET

The total project budget is $ 430,366. Pre- and post-construction monitoring activities will be funded with Clean Michigan Initiative funds, and staff will be funded by the MDEQ's Section 319 grant.

IMPACTOF OTHER FEDERAL AND STATE PROGRAMS

Staff from the Houghton/Keweenaw Conservation District and NRCS will play prominent roles in the construction phase of this project:

· Houghton/Keweenaw Conservation District staff will be primarily responsible for the financial aspects of the project and overall project administration.

· NRCS staff will have the lead responsibility for project design (including the natural channel design), and construction oversight.

There is also an on-going total maximum daily load study in several Keweenaw Peninsula streams, conducted by the MDEQ-Water Bureau, whose data may contribute to this study.

Other Pertinent Information

None.

PROJECT CONTACTS

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Michigan

Sycamore Creek Watershed
Section 319
National Monitoring Program Project

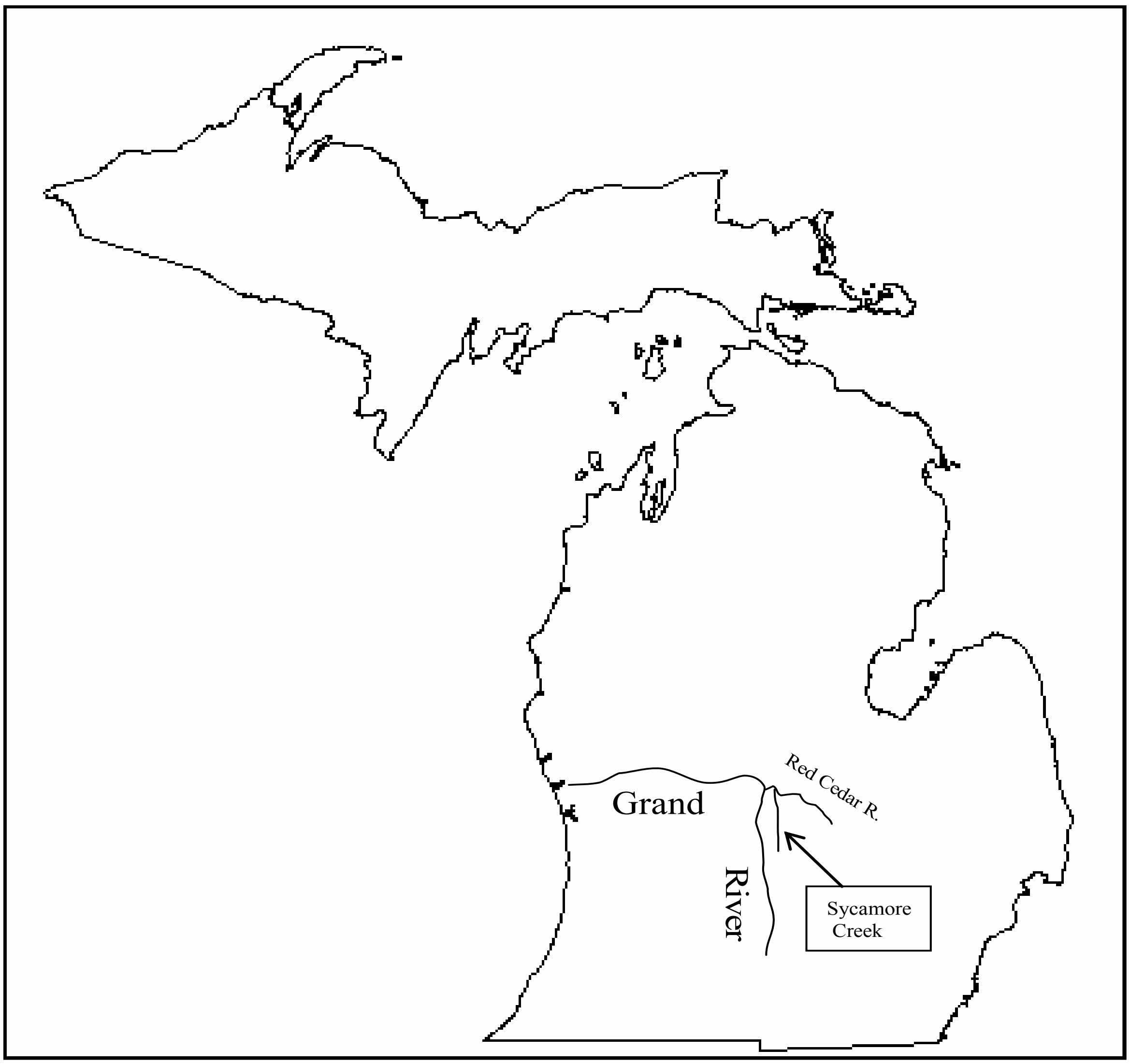

Figure 23: Sycamore Creek (Michigan) Project Location

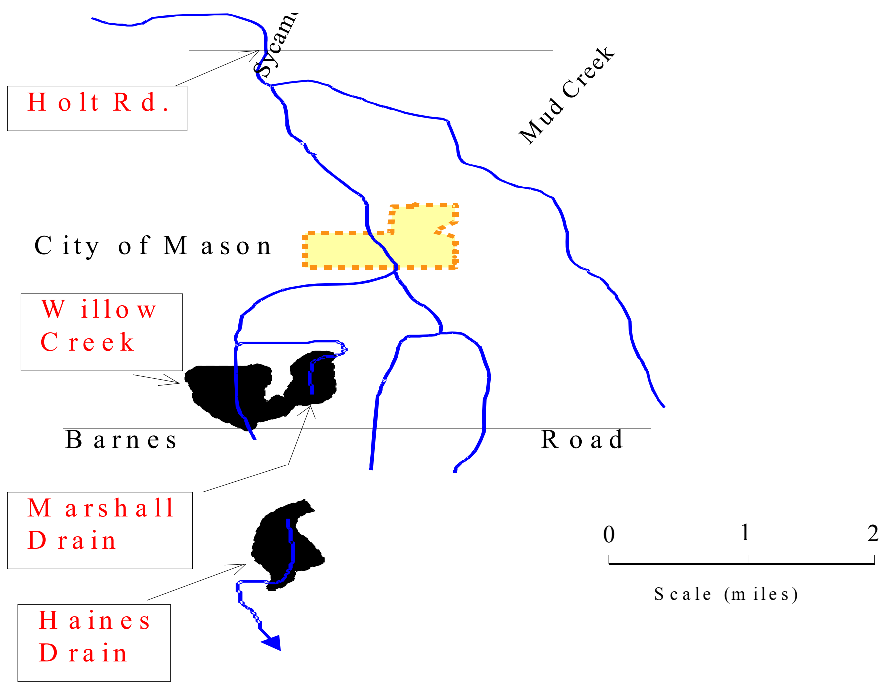

Figure 24: Paired Water Quality Monitoring Stations for the Sycamore Creek (Michigan) Watershed

PROJECT OVERVIEW

Sycamore Creek is located in southcentral Michigan (Ingham County) (Figure 23). The creek has a drainage area of 67,740 acres, which includes the towns of Holt and Mason, and part of the city of Lansing. The major commodities produced in this primarily agricultural county are corn, wheat, soybeans, and some livestock. Sycamore Creek is a tributary to the Red Cedar River, which flows into the Grand River. The Grand River discharges into Lake Michigan.

The major pollutants of Sycamore Creek are sediment, phosphorus, nitrogen, and agricultural pesticides. Sediment deposits are adversely affecting fish and macroinvertebrate habitat and are depleting oxygen in the water column. Sycamore Creek has been selected for monitoring, not because of any unique characteristics, but rather because it is representative of creeks throughout lower Michigan.

Water quality monitoring occured in three subwatersheds: Haines Drain, Willow Creek, and Marshall Drain (Figure 24). The Haines subwatershed, where best management practices (BMPs) were installed, served as the control and is outside the Sycamore Creek watershed. Stormflow and baseflow water quality samples from each watershed were collected from March through July of each project year. Water was sampled for turbidity, total suspended solids, chemical oxygen demand (COD), nitrogen (N), and phosphorus (P).

Land treatment consisted primarily of sediment and nutrient-reducing BMPs on cropland, pastureland, and hayland. BMP Implementation was funded as part of the U.S. Department of Agriculture (USDA) Sycamore Creek Hydrologic Unit Area (HUA) project.

The Sycamore Creek Watershed NMP Project has terminated as of October, 1999.

PROJECT BACKGROUND

Project Area

The project, located in southcentral Michigan, encompasses 67,740 acres.

Relevant Hydrologic, Geologic, and Meteorologic Factors

The geology of the watershed consists of till plains, moraines, and eskers (glacially deposited gravel and sand that form ridges 30 to 40 feet in height). The Mason Esker and associated loamy sand and sandy loam soil areas are the major ground water recharge areas in Ingham County. Eskers are the predominant geologic feature near the stream. These grade into moraines that are approximately one-half to one mile in width. The moraines have sandy loam textures with slopes of 6 -18%. The moraines grade into till plains. Interspersed within the area, in depressional areas and drainageways, are organic soils.

Land Use

Approximately 50% of the land in this primarily agricultural watershed is used for crops, forage, and livestock, but is experiencing a substantial increase in urban and suburban development.

Crop and residue cover are recorded on a 10-acre cell basis in each of the three monitored subwatersheds.

Land Use	Acres	(%)
Agricultural	35,453	52
Forest	8,017	12
Residential	9,336	14

Business/Industrial	2,562	4
Idle	6,381	10
Wetlands	2,324	3
Transportation	1,349	2
Open land	826	1
Gravel pits and wells	806	1
Water	359	0.5
Other	325	0.5
Total	67,738	100

Source: NRCS/CES/FSA, 1990

Water Resource Type and Size

Sycamore Creek is a tributary of the Red Cedar River. The Red Cedar River flows into the Grand River, which flows into Lake Michigan.

Water Uses and Impairments

Sycamore Creek is designated through Michigan State Water Quality Standards for warmwater fish, body contact recreation, and navigation. Currently the pollutant levels in the creek are greater than prescribed standards. In particular, dissolved oxygen levels (the minimum standard level is 5 milligram per liter) are below the minimum standard, primarily because of sediment but also, in some cases, nutrients (Suppnick, 1992).

The primary pollutant is sediment. Widespread aquatic habitat destruction from sedimentation has been documented. Nutrients (nitrogen and phosphorus) are secondary pollutants. Pesticides may be polluting ground water; however, evidence of contamination by pesticides is currently lacking. Low levels of dissolved oxygen in the creek are a result of excess plant growth and organic matter associated with the sediment.

Sycamore Creek was chosen for monitoring because of its central location in the state, its demonstrated water quality problems, and because it was considered representative of many southern Michigan agricultural watersheds.

Pollutant Sources

Agricultural fields, streambanks, and urban areas, are the most significant sources of sediment in the watershed.

Pre-Project Water Quality

Sediment and Phosphorus Content of Sycamore Creek Under Routine (dry) and Storm (wet) Flow Conditions

Dry P mg/l	Wet P mg/l	Dry Sediment mg/l	Wet Sediment mg/l
0.01-0.09	0.04-0.71	4-28	6-348

Source: NRCS/CES/FSA, 1990

A biological investigation of Sycamore Creek, conducted in 1989, revealed an impaired fish and macroinvertebrate community. Fish and macroinvertebrate numbers were low, suggesting lack of available habitat.

Channelization of Sycamore Creek is causing unstable flow discharge, significant bank-slumping, and erosion at sites that have been dredged.

Water Quality Objectives

The water quality objective was to reduce the impact of agricultural nonpoint source pollutants on surface and ground water of Sycamore Creek.

The goal of the project was to reduce sediment delivery into Sycamore Creek by 52%, a reduction projected to solve the Creek's dissolved oxygen problem according to the TMDL analysis.

Project Time Frame

1993-1999

PROJECT DESIGN

Nonpoint Source Control Strategy

The Sycamore Creek U.S. Environmental Protection Agency (USEPA) Section 319 National Monitoring Program project was nested within the Sycamore Creek HUA project. The nonpoint source control strategy included: 1) identification and prioritization of significant nonpoint sources of water quality contamination in the watershed and 2) promotion of the adoption of BMPs that significantly reduce the affects of agriculture on surface water and ground water quality.

Critical areas for targeting BMPs were agricultural fields (cropland, hayland, or pasture) within one-half mile of a stream. Priority areas for streambank stabilization were defined as those locations where bank undercutting, coupled with bare channel banks and ground water seepage, were visibly contributing to the sediment load. Priority areas were chosen by the ICDC and consultants based on observations during several field visits.

Cropland BMPs included conservation tillage, conservation cropping sequence, crop residue use, pest management, nutrient management, waste utilization, critical area planting, and erosion control structures. Hayland BMPs consisted of conservation cropping sequence, conservation tillage, pest management, nutrient management, pasture/hayland management, and pasture/hayland planting. BMPs utilized on pastureland were conservation cropping sequence, conservation tillage, pasture/hayland management, pasture/hayland planting, fencing, waste utilization, filter strips, and critical area planting. The following practices were eligible for ACP funding:

- No till
- Permanent vegetative cover establishment
- Diversions
- Cropland protective cover
- Permanent vegetative cover on critical areas
- Sediment retention erosion or water control structure
- Sod waterways
- Integrated crop management
- Critical area planting
- Pest management
- Nutrient management

Streambank stabilization BMPs were also implemented. Measures were selected based on their effectiveness in reducing ground water seepage and slope instability. The techniques chosen for implementation on Willow Creek included brush mattresses, live fascines, fiber rolls, biolunkers, riprap, underdrain, slope reduction, vegetative plantings, tree/branch revetments, current deflectors, and rock cascades.

The Ingham County Drain Commission (ICDC) received an implementation grant under Section 319 of the Clean Water Act for the installation of streambank stabilization in Willow Creek (Figure 22). Innovative and environmentally sensitive techniques for streambank stabilization were selected to minimize the sediment load in Willow Creek.

Project Schedule

Site	Pre-BMP Monitoring	BMP Installation	Post-BMP Monitoring
Haines Drain	1990-95	1996	1997
Willow Creek	1990-95 1996		1997
Marshall Drain	1990-92	1993-94	1995-97

Water Quality Monitoring

A paired watershed design was used to document water quality changes in Sycamore Creek. Two subwatersheds within the project, Willow Creek and Marshall Drain, were compared to a control subwatershed, Haines Drain, that lies outside the boundaries of the project (Figure 22). BMPs were installed in the Haines Drain prior to the commencement of water quality monitoring in 1990.

Variables Measured

Biological

None

Chemical and Other

Total suspended solids (TSS)
Turbidity
Total phosphorus (TP)
Total Kjeldahl nitrogen (TKN)
Nitrate + nitrite (NO_3 + NO_2)
Chemical oxygen demand (COD)
Orthophosphate (OP)
Ammonia (NH_3)

Covariates

Rainfall
Flow
Erosion-intensity index

Sampling Scheme

A ~20-week sampling period was defined from snowmelt (approximately March) through the development of crop canopy (approximately July).

Samples were collected every one to two hours during storm events over the sampling period. For each location and storm, six to twelve samples were selected for analysis. Automatic stormwater samplers equipped with liquid level actuators were used.

Weekly grab samples were also taken for trend determination. Sampling began in March when the ground thaws and continued for the next 20 weeks.

A continuous record of river stage was obtained with Isco model 2870 flow meters. The river stage converted to a continuous flow record using a stage discharge relationship which was periodically updated by field staff of the Land and Water Management Division of the Michigan Department of Environmental Quality.

One recording rain gauge is installed in each agricultural subwatershed (Figure 22).

Monitoring Scheme for the Sycamore Creek Section 319 National Monitoring Program Project

Design	Sites	Primary Parameters	Covariates	Frequency of WQ Sampling	Duration
Three-way paired	Willow Creek[T]	TSS	Rainfall flow	Weekly for 20	6 yrs pre-BMP
		Turbidity	Erosion-intensity	samples starting	1 yr BMP
	Haines Drain[C]	TP	index	after snow melt	1 yr post-BMP
		TKN			
	Marshall Drain[T]	$NO_3 + NO_2$		Storm sampling	3 yrs pre-BMP
		OP		until canopy closure)	2 yr post-BMP
		NH_3			

[T] Treatment watersheds
[C] Control watershed

Land Treatment Monitoring

Land use and tillage practices were recorded annually by NRCS staff. A 10-acre grid was superimposed on a USGS topographic map for each subwatershed as a template for storing land use data in a spreadsheet. Practice installation and the effect on water quality was tracked using the database ADSWQ (Automatic Data System for Water Quality). The EPIC model (Erosion Productivity Index Calculator) was used to estimate changes in edge-of-field delivery of sediment, nutrients, and bottom of root zone delivery of nutrients resulting from BMP implementation.

Variables Measured

Land use was tracked on a 10-acre cell basis. Categories were crops and tillage practice, woods, residential, and mining (sand and gravel).

Modifications Since Project Start

Prior to 1993, weekly grab samples were not collected, but occasional grab samples during base flow were collected.

The Willow Creek and Marshall Drain subwatersheds were selected among all subwatersheds in the Sycamore Creek watershed because they contained the highest sediment loads and the largest percentage of erodible land within one-quarter mile of a channel.

An additional station was added in 1995 at the United States Geological Survey (USGS) gauging station at Holt Road. Sampling was conducted year round using a flow stratified strategy. The monitoring data from this station was used to determine the annual load of pollutants near the mouth of the stream and to compare these loads with various models for estimating pollutant loads in the watershed. Automatic sampling equipment was used to collect samples and the USGS flow data was used to determine loads. The parameters tested for were the same as the other three stations.

For purposes of data analysis, the experimental design was changed from a paired watershed to a before/after design. This was due to the fact that the control watershed was subject to land use changes. Accordingly, the control watershed was analyzed as a treatment watershed.

DATA MANAGEMENT AND ANALYSIS

Preliminary exploratory analysis included a linear regression of control values versus treatment values for storm loads, storm event mean concentrations, storm rainfall amounts, storm runoff volume, and storm runoff coefficients. Storm loads were also compared to the AGNPS model for the first two years of data. Land use and cover data were recorded each year on a 10 acre grid scale.

NPSMS Data Summary

Summaries of quartile data from 1990 through 1993 are presented in the table below. These summaries include all data including storm event data for 1990-1993, base flow grab samples for 1990-1992, and weekly sampling in 1993. Differences can be seen among the watersheds, for example, stable flow and NO2+NO3 levels in Willow Creek compared to the other stations and the higher flows in Haines Drain compared to the other stations.

Monitoring Station Parameters Report

CHEMICAL PARAMETERS

STATION NAME: Haines Drain (Control; 848 acres) **YEAR:** 1990

Parameter Name	Reporting Units	N	QUARTILE VALUES -75-	-50-	-25-
FLOW,CFS	cfs	85	8	6	2
SUSPENDED SOLIDS	mg/l	84	38	15	7
TOTAL PHOSPHORUS	mg/l	84	0.196	0.107	0.048
$NO_3 + NO_2$	mg/l	84	3.8	3.5	2.9
COD	mg/l	84	35.5	29	22

STATION NAME: Haines Drain (Control; 848 acres) **YEAR:** 1991

Parameter Name	Reporting Units	N	QUARTILE VALUES -75-	-50-	-25-
FLOW,CFS	cfs	44	8	5	4
SUSPENDED SOLIDS	mg/l	43	147	46	20
TOTAL PHOSPHORUS	mg/l	45	0.64	0.34	0.178
$NO_3 + NO_2$	mg/l	45	36.	3. 3	3
COD	mg/l	15	55	36	29

STATION NAME: Haines Drain (Control; 848 acres) **YEAR:** 1992

Parameter Name	Reporting Units	N	QUARTILE VALUES -75-	-50-	-25-
FLOW,CFS	cfs	31	14	6	0.9
SUSPENDED SOLIDS	mg/l	31	270	95	24
TOTAL PHOSPHORUS	mg/l	31	0.8	0.47	0.126
$NO_3 + NO_2$	mg/l	31	4.2	3.4	2.9
COD	mg/l	31	59	37	20

STATION NAME: Haines Drain (Control; 848 acres) **YEAR:** 1993

Parameter Name	Reporting Units	N	QUARTILE VALUES -75-	-50-	-25-
FLOW,CFS	cfs	67	8.3	2	1
SUSPENDED SOLIDS	mg/l	66	91	45	15
TOTAL PHOSPHORUS	mg/l	67	0.48	0.24	0.105
$NO_3 + NO_2$	mg/l	66	7.4	2.9	1.82
COD	mg/l	66	45	31	23

STATION NAME: Marshall Drain (Treatment; 422 acres) **YEAR:** 1990

Parameter Name	Reporting Units	N	QUARTILE VALUES -75-	-50-	-25-
FLOW,CFS	cfs	44	0.5	0.4	0.2
SUSPENDED SOLIDS	mg/l	44	98.5	29	16.5
TOTAL PHOSPHORUS	mg/l	44	0.059	0.04	0.029
$NO_3 + NO_2$	mg/l	36	5.8	2.55	1.9
COD	mg/l	44	19	16	14

STATION NAME: Marshall Drain (Treatment; 422 acres) **YEAR:** 1991

Parameter Name	Reporting Units	N	QUARTILE VALUES -75-	-50-	-25-
FLOW,CFS	cfs	40	2	1	0.8
SUSPENDED SOLIDS	mg/l	39	115	29	17
TOTAL PHOSPHORUS	mg/l	41	0.35	0.118	0.062
$NO_3 + NO_2$	mg/l	41	7.5	6.4	5
COD	mg/l	23	40	31	17

STATION NAME: Marshall Drain (Treatment; 422 acres) **YEAR:** 1992

Parameter Name	Reporting Units	N	QUARTILEVALUES -75-	-50-	-25-
FLOW,CFS	cfs	23	5	0.9	0.3
SUSPENDED SOLIDS	mg/l	23	100	30	7
TOTAL PHOSPHORUS	mg/l	23	0.4	0.152	0.046
$NO_3 + NO_2$	mg/l	23	6.2	4.8	2.4
COD	mg/l	23	49	26	16

STATION NAME: Marshall Drain (Treatment; 422 acres) **YEAR:** 1993

Parameter Name	Reporting Units	N	QUARTILE VALUES -75-	-50-	-25-
FLOW,CFS	cfs	52	4.87	0.57	0.32
SUSPENDED SOLIDS	mg/l	52	60	26	7
TOTAL PHOSPHORUS	mg/l	52	0.27	0.177	0.06
$NO_3 + NO_2$	mg/l	51	12	3.9	3
COD	mg/l	52	32	22	12

STATION NAME: Willow Creek (Treatment; 1087 acres) **YEAR:** 1990

Parameter Name	Reporting Units	N	QUARTILE VALUES -75-	-50-	-25-
FLOW,CFS	cfs	83	5	4	3
SUSPENDED SOLIDS	mg/l	82	44	32	18
TOTAL PHOSPHORUS	mg/l	83	0.075	0.055	0.036
$NO_3 + NO_2$	mg/l	83	2.7	2.4	2.1
COD	mg/l	83	31	24	18

STATION NAME: Willow Creek (Treatment; 1087 acres) **YEAR:** 1991

Parameter Name	Reporting Units	N	QUARTILE VALUES -75-	-50-	-25-
FLOW,CFS	cfs	47	4	4	3
SUSPENDED SOLIDS	mg/l	47	197	80	44
TOTAL PHOSPHORUS	mg/l	50	0.36	0.137	0.066
$NO_3 + NO_2$	mg/l	50	3	2.3	2.3
COD	mg/l	21	67	51	32

STATION NAME: Willow Creek (Treatment; 1087 acres) **YEAR:** 1992

Parameter Name	Reporting Units	N	QUARTILE VALUES -75-	-50-	-25-
FLOW,CFS	cfs	37	6	4	3
SUSPENDED SOLIDS	mg/l	37	150	70	28
TOTAL PHOSPHORUS	mg/l	37	0.26	0.135	0.052
$NO_3 + NO_2$	mg/l	37	3.5	1.94	1.75
COD	mg/l	37	82	45	27

STATION NAME: Willow Creek (Treatment; 1087 acres)	YEAR: 1993				
	Reporting		QUARTILE VALUES		
Parameter Name	Units	N	-75-	-50-	-25-
FLOW,CFS	cfs	74	7.36	4.98	4.14
SUSPENDED SOLIDS	mg/l	74	130	80	40
TOTAL PHOSPHORUS	mg/l	73	0.21	0.128	0.069
$NO_3 + NO_2$	mg/l	72	2.5	2.2	1.9
COD	mg/l	74	76	49	33

Final Results

Data analysis was performed to detect changes or trends in water quality in the treatment watersheds and the control watershed. Because the control watershed (Haines Drain) had changing land use, and therefore was not a control watershed, analysis for change was performed on all three watersheds using streamflow as an explanatory variable.

A statistically significant reduction in sediment and total phosphorus load occurred in Willow Creek storm runoff over the eight years of monitoring. These reductions were 60% and 57% for total suspended solids and total phosphorus respectively. This water quality improvement was correlated with the percent of land in no-till.

No reductions were found in Haines Drain or Marshall Drain even though they had a greater increase in no-till land than did Willow Creek. This suggests that land management factors affecting the riparian zone may have an equal or greater effect on suspended sediment loads in these Grand River tributaries than no-till. The stream bank stabilization program implemented in Willow Creek may be responsible for the reduction in sediment and total phosphorus observed there. The adoption of no-till farming alone may not, therefore, accomplish major reductions in suspended solids loads, but when coupled with streambank erosion control, can result in significant reduction in sediment loads.

Weekly grab samples from Willow Creek indicated a downward trend in nitrate and nitrite concentration declining from an average of 2.3 mg/l in 1990 to 1.73 mg/l in 1997. This was a statistically significant difference and accounted for seasonal variation and streamflow. This trend may reflect adoption of soil testing and reduced nitrogen application as a result of the USDA water quality program.

Haines Drain exhibited an increase in nitrate and nitrite from an average of 2.8 mg/l in 1990 to 4.07 mg/l in 1997 after adjustment for seasonal variation and streamflow. The cause of this increase is unknown, but could be changes in fertilizer use or changes in cropping patterns.

One of the subwatersheds (Haines Drain) produced significantly more surface runoff and suspended solids load than did either of the other two subwatersheds., despite having similar soils and land use and lower average field slope. Because loading models frequently use these factors to estimate relative watershed loadings, this finding suggests that application of models to target nonpoint source control measures may need to be supplemented with stream monitoring data to verify results.

INFORMATION, EDUCATION, AND PUBLICITY

The Ingham County Cooperative Extension Service (CES) is responsible for all information and education (I&E) activities within the watershed. These I&E activities have been developed and were implemented as part of the Sycamore Creek HUA project. Activities included public awareness campaigns, conservation tours, media events such as news releases and radio shows, display setups, workshops, short courses, farmer-targeted newsletters, homeowner-targeted newsletters, on-farm demonstrations, meetings, and presentations. Ingham County CES assists producers with nutrient management plans and integrated pest management.

1994 activities included:

- Ten on-farm demonstrations
- One watershed tour
- One watershed winter meeting
- Monthly newsletters for area farmers
- One homeowners' newsletter
- Twenty-five farm plans for nutrient and pesticide management

TOTAL PROJECT BUDGET

The estimated budget for the Sycamore Creek Watershed Section 319 National Monitoring Program project for the life of the project is:

Project Element	Funding Source: ($)			
	Federal	State	Local	Sum
Project Mgt	129,370	122,000	3,130	254,500
I & E	159,900	NA	9,935	169,835
LT	1,078,300	NA	500,751	1,579,051
WQ Monit	285,000	222,000	NA	507,000
TOTALS	1,652,570	344,000	513,816	2,510,386

Source: John Suppnick (Personal Communication), 1993

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

The funds for the 319 National Monitoring Program project provided for the water quality monitoring in the HUA project area. The county Farm Service Agency Committee agreed to use Agricultural Conservation Program (ACP) funds for land treatment (erosion control, water quality improvement, and agricultural waste management).

OTHER PERTINENT INFORMATION

Agencies involved in this project are as follows:

- USDA – Natural Resources Conservation Service (NRCS)
- Farm Service Agency (FSA)
- Michigan State University Extension – Ingham County
- Ingham County Health Department (Environmental Division)
- Ingham Conservation District

- Landowners within the Sycamore Creek watershed
- Michigan Department of Environmental Quality

PROJECT CONTACTS

Land Treatment

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Minnesota

Whitewater River Watershed
Section 319
National Monitoring Program Project

Figure 25: Whitewater River (Minnesota) Watershed Project Location

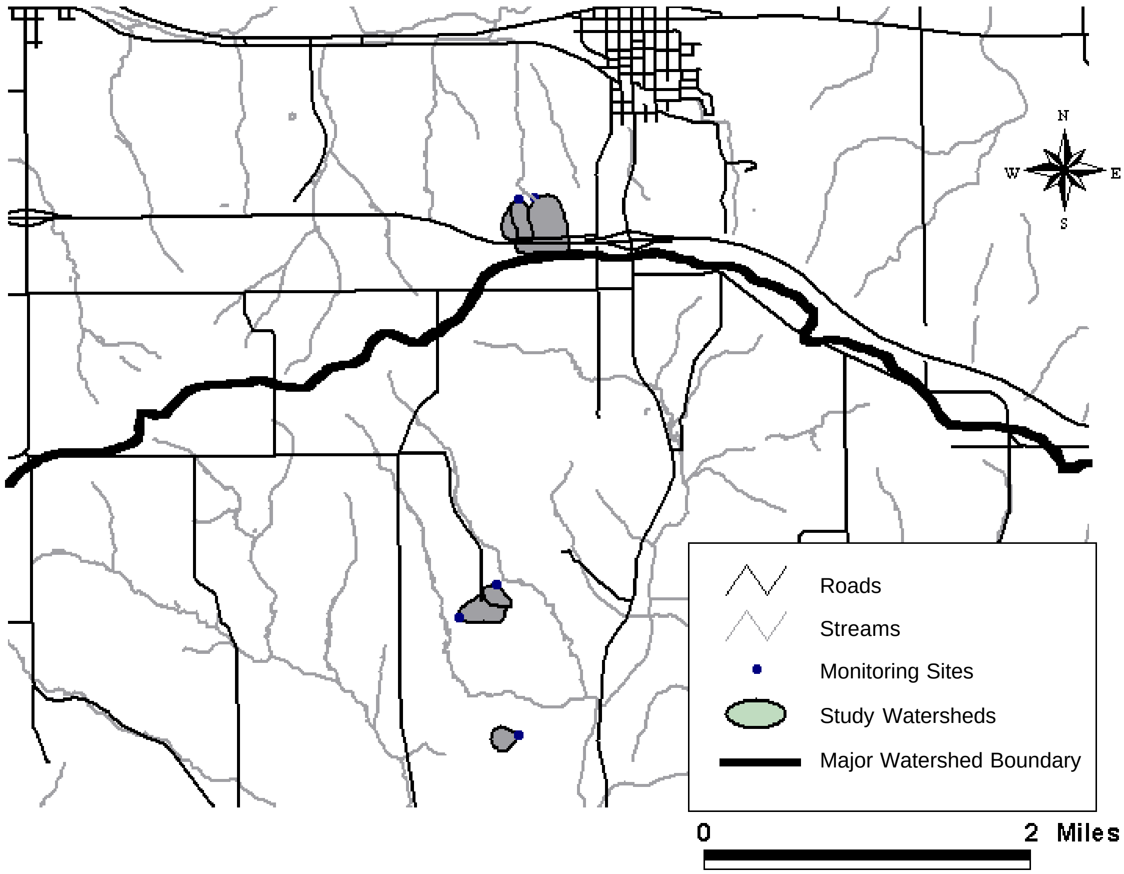

Figure 26: Watersheds monitored for physical and chemical variables as part of the paired-watershed monitoring component of the NMP project.

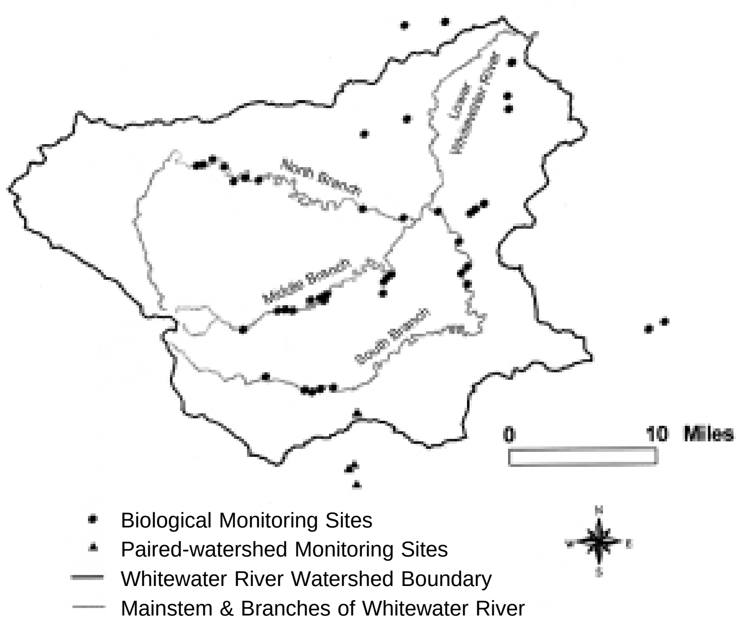

Figure 27: Monitoring site locations in and around the Whitewater River NMP project.

PROJECT OVERVIEW

The Whitewater River Watershed Section 319 National Monitoring Program (NMP) project is located in southeastern Minnesota (Figure 25). The NMP project is a small component of an overall watershed project involving several local, state, and federal agencies and organizations with various sources of funding for the Whitewater River and its tributaries.

The Whitewater River is a tributary to the Mississippi River at Weaver Bottoms, a nationally significant waterfowl staging area that is threatened by the pollutants delivered in the river. The Whitewater River watershed is 205,000 acres in size. Three main subwatersheds (South, Middle, and North Branches) drain gently rolling to steeply sloped karst topography. Land use in the watershed consists of approximately 58 percent cropland, 8 percent pastureland, 13 percent woodland, 14 percent wetland and designated wildlife management areas, and 7 percent other land. Significant portions of the river are classified as wild or semi-wild trout waters. The overall project evolved from a pilot project on the Middle Branch that identified intensively cultivated fields, long unprotected slopes, and inadequate feedlot, pasture, and forestry management as significant problems. These problems have resulted in impairments of the aquatic life (cold and warm water fisheries) and recreation designated uses of the river and its tributaries.

The Whitewater River NMP project was established to evaluate the effectiveness of various best management practices (BMPs) using NMP guidance that encouraged the use of paired-watershed monitoring designs and biological monitoring in streams. There are two components to the project. One component involved a multiple paired-watershed monitoring design incorporating physical and chemical monitoring of five small watersheds (Figures 26 and 27). The second component involved a biological monitoring effort at several sites throughout the watershed (Figure 27). The monitoring design for the biological monitoring involved the development of a cold-water Index of Biotic Integrity and an overall assessment of stream conditions to be followed with a before-and-after treatment comparison.

The physical and chemical monitoring of the five small watersheds was conducted using various methods. Continuous recording equipment was used at the five H-flume monitoring sites to measure stream flow, temperature, and specific conductivity. An automated weather station collected various climate data at one site. Water samples were collected by hand and with automatic samplers during the project period. Water samples were analyzed for a suite of cations and anions, total suspended solids, and total phosphorus. Monitoring for the NMP project was initiated in 1996 and was completed in 2006; however, two sites are still being operated in the hopes of continuing the small watershed research.

The biological monitoring consisted of annual stream assessments at between 15 and 42 stream sites for up to seven years with a series of special studies in the last three years of the project. The assessments included the use of physical habitat, benthic macroinvertebrate, and fish surveys to assess watershed condition, generate baseline data to evaluate changes in the watershed, and provide comparisons of BMPs with conventional agricultural practices. Sampling was initially conducted in the lower cold water portions of the three branches of the Whitewater River and their tributaries, along with cold water streams in nearby watersheds to gauge the relative condition of the watershed. Sampling was then extended into the upper warm water portions of the watershed, where there is more agricultural and urban land uses, to examine BMP and conventional sites, as well as riparian buffer types.

BMPs were implemented in two ways. The automated monitoring site paired watersheds selected as treatment sites incorporated BMPs using individual landowner interest. The study design had to be adapted with the introduction of a small grazing-based dairy in place of the row crops present previously. Implementation for the biological component of the monitoring project relied on the watershed implementation plan of the overall watershed project.

The NMP project completed its last year of monitoring in 2006. Post-BMP monitoring in one set of paired-watersheds was constrained by delays in the completion of a managed intensive grazing plan begun in 2003. Use of a tillage treatment in the other set of paired-watersheds began in 2001. Biological monitoring was revised for the last two years of monitoring to provide an intensive transect of sampling sites along one branch of the Whitewater River and a survey of stream pools being filled with fine sediment given few changes in IBI scores at the sites located throughout the watershed in the previous years of monitoring.

Work on the paired-watershed data focused on its use in developing the Gridded Surface Subsurface Hydrologic Analysis (GSHHA) model for comparison of the one set of the paired-watersheds. There is interest in further monitoring and modeling the hydraulic characteristics of the paired-watershed sites to better understand the watershed processes affecting water movement and pollutant transport in the karst watersheds, but funding has not been obtained. Monitoring has been continued in 2007 with some remaining funding, but no samples have been collected to date due to drought conditions.

Progress on overall project analysis, evaluation, and reporting was not completed in the past year. The final report for the NMP project will be completed by June 2009.

PROJECT BACKGROUND

Project Area

The Whitewater River watershed is located between the cities of Rochester and Winona, Minnesota, and is 205,000 acres in size. The drainage areas of the five paired-watershed monitoring sites range from 12 to 60 acres. The drainage areas of the biological monitoring sites range in size from about 2,500 to 50,000 acres.

Relevant Hydrological, Geological, and Meteorological Factors

The Whitewater River Watershed consists of four major subwatersheds: the South Branch, Middle Branch, North Branch, and Lower (mainstem) Whitewater River. The landscape ranges from gently rolling hills to steep bluffs with rock outcrops. The predominant soils are silt loams, which overlay bedrock formations of sedimentary sandstones, shales, and dolomites. Given the dolomite (limestone) formations, the terrain is largely characterized as incipient (poorly developed) karst.

The average annual precipitation in the watershed is between 30 and 32 inches. Approximately 60 percent of this precipitation falls during the growing season. The average growing season is 150 days. The average daily minimum and maximum temperatures of 2 and 82 degrees Fahrenheit occur in January and July, respectively.

Land Use

Land use in the watershed consists of 58 percent cropland, 13 percent woodland, 8 percent pasture land, 14 percent wetland and 7 percent other land. Dairy and beef farms were predominate in the past; however, recent trends in the farm economy have shown a shift from dairy to cash crop production. The watershed also includes 2 state parks, a state wildlife management area, and a trout hatchery.

Water Resource Type and Size

The Whitewater River and its tributaries range from first- to third-order streams. Stream flows are largely influenced by springs originating from the various bedrock aquifers that are intersected by the river and its tributaries. The Whitewater River outlets to the Mississippi River at Weaver Bottoms, a nationally significant waterfowl staging area that is threatened by the pollutants delivered in the river.

The five paired-watershed monitoring sites are located on first-order streams that originate from springs and/or seeps from the Galena Dolomite aquifer. The presence of the springs (and the geologic formations causing the springs) was a primary factor in selecting the sites for the project.

Water Uses and Impairments

The designated uses identified by Minnesota's water quality standards for the Whitewater River and its tributaries are for aquatic life and recreation. Specifically, eight segments of these streams are classified as cold water fisheries. The remaining segments of the river and its tributaries are classified as cool and warm water fisheries. All of the waters are classified for all recreational uses, including swimming. Three reaches in the watershed were listed as impaired for turbidity and/or fecal coliform bacteria in Minnesota's 1998 303(d) List. Four other reaches were added to the 2002 303(d) List.

In addition to the impairments associated with water quality standards, the primary water quality problems of concern in the Whitewater River watershed include elevated water temperatures, sediment, low dissolved oxygen concentrations, flow, and habitat. Water temperatures, sedimentation and turbidity, dissolved oxygen, and habitat are primary issues of concern for the river's trout fishery. Sediment transport through the watershed is a major concern for the Weaver Bottoms area of the Mississippi River. Other pollutants of concern include nutrients and pesticides.

The paired-watershed component of the project is focusing on water temperature, flow, total suspended solids, and several cations and anions (including nutrients) to evaluate changes in water quality with the implementation of BMPs. Fecal coliform bacteria will also be measured, with the addition of the dairy cows to the farm. The biological monitoring component of the project is focusing on fish, invertebrate, and habitat variables to evaluate changes in water quality

Pollutant Sources

Pollutant sources include both point and nonpoint sources. Several small wastewater treatment facilities are located in the watershed; however, the primary sources of concern are nonpoint sources. The nonpoint sources include streambank erosion, degraded riparian areas, runoff and erosion from crop land, feedlot runoff, animal waste on crop land and pastures, and livestock access to streams.

Pre-Project Water Quality

No historical data exists for the paired-watershed and the biological monitoring sites of the NMP project.

Data collected in various watershed monitoring efforts has shown elevated sediment and nutrient concentrations, degraded stream habitats, increased water temperatures, potential low dissolved oxygen conditions, and turbidity and fecal coliform bacteria levels that often exceed water quality standards. Commonly used pesticides have been detected frequently at the two Minnesota Department of Agriculture surface water monitoring program sites in the watershed.

Water Quality Objectives

The overall goals of the Whitewater River Watershed NMP project are:

1. To provide the information needed for use in evaluating the effectiveness of best management practices (BMPs) implementation, and

2. To provide long-term monitoring for continuing evaluation of the pollution problems and solutions in the Whitewater River Watershed Project.

Specific objectives for the project are:

1. To evaluate surface and ground water interactions present in the five small paired-watershed study areas.
2. To detect improvement in the quality of water from a treatment watershed as compared to the quality of water from a control watershed using a paired-watershed monitoring design in the five H-flume sites. Variables to be evaluated include amount of runoff; peak flows; base flows; and total suspended solids, nitrate-nitrogen, phosphorus, and chloride concentrations and loads.
3. To characterize and evaluate the biological conditions of the Whitewater River and its tributaries as they relate to watershed hydrology, land use, land cover, geology, and location.
4. To evaluate the effect of BMP implementation on water quality using biological monitoring at a watershed scale larger than the paired-watershed study. Efforts will involve a reference stream monitoring design and a paired-watershed monitoring design. Variables to be evaluated include macroinvertebrate, fish, and stream habitat indices.
5. To evaluate the degree to which BMPs are implemented in treatment watersheds versus control watersheds.

Project Time Frame

Biological monitoring and the small paired-watershed monitoring following NMP guidelines began in 1994 and 1996, respectively. The project was approved as a NMP project in 2001. Project monitoring ended in 2006; however, two small watershed sites have continued to be operated in 2007 with the hope of obtaining funding for further research.

PROJECT DESIGN

Nonpoint Source Control Strategy

The project was designed to evaluate the effectiveness of various BMPs in two settings.

The first setting involved five small watersheds in which cropland management practices were to be compared using a paired-watershed design. BMPs were selected by the landowners or operators. One watershed was enrolled in the Conservation Reserve Program (CRP) until fall, 1997, when it was tilled for conversion back to a corn-soybean rotation with a small portion seeded to alfalfa. Three watersheds contain a grass buffer between the crop land and the springs and streams. A series of paired-watershed control and treatment evaluations were to be made. The first involved a “reverse” treatment given the conversion of CRP back to cropland in one watershed. Other treatments to be evaluated included the use of no-till planting, addition of a small grain to a corn-soybean rotation, and the use of managed intensive grazing.

The second setting involved the biological monitoring of several sites in and around theWhitewater River watershed. Implementation of nonpoint source BMPs occurred through the overall watershed project’s implementation efforts utilizing P.L. 566 and Minnesota Clean Water Partnership funds. Practices targeted for use included several land treatment practices (i.e., conservation tillage, use of cover crops, critical area plantings, diversions, field borders, grade stabilization structures, livestock exclusion, contour farming, etc.), planned grazing systems, nutrient and pesticide management plans, forestry BMPs, waste management systems, and stream filters and bufers.

Water Quality Monitoring

Project Schedule

Paired Watershed Monitoring	Pre-BMP Monitoring Dates	BMPs Implemented	Dates BMPs Installed/Established	Post-BMP Monitoring Dates
Treatment #1				
Finley East	1997-2001	Addition of small grain/alfalfa to crop rotation	2002 (incomplete)	2002 – 2003
Finley West	1997-2001			2002 – 2003
Treatment #2				
Finley East	1997 – 2002	Managed intensive grazing	2003 (incomplete)	2003 – 2006
Finley West	1997 - 2002			2003 – 2006
Treatment #3				
CRP	1996 – 1997	"Reverse" treatment – CRP converted back to crop land	1998	1998 – 2005
CSP	1996 – 1997			1998 – 2001
ORG	1996 - 1997			1998 – 2005
Treatment #4				
CRP	1996 – 2001			2002 - 2005
CSP				
ORG	1996 - 2001	"Zone" Conservation Tillage	2002	2002 - 2005

Biological Monitoring

Biological monitoring conducted one time yearly: 1996 – 2002 and 2004 – 2006.

Water quality monitoring consists of two components. One component involved a paired-watershed monitoring design incorporating physical and chemical monitoring of five small watersheds. The second component involved a biological monitoring effort at several sites throughout the watershed.

Variables Measured

Biological

Fish
Macroinvertebrates
Habitat
Fecal coliform bacteria

Chemical

Temperature
Total suspended solids

Nitrate-nitrogen
Nitrite-nitrogen
Total phosphorus
Conductivity
pH
Chloride
Oxygen-18
Deuterium

Covariates
Precipitation (continuous)
Discharge (continuous)

Sampling Scheme

A multiple paired-watershed monitoring design was used for physical and chemical variables in five small watersheds. Continuous recording equipment were used at the five H-flume monitoring sites to measure stream flow, temperature, and specific conductivity. An automated weather station collected various climate data at one site. Water samples have been collected by hand and with automatic samplers. The sampling frequency was increased in 1999 in an effort to better characterize the hydrology of the watersheds (source(s) and pathways of the water).

Biological monitoring has been conducted for several years at 15 to 42 stream sites within the project area since 1994. The assessments include the use of physical habitat, benthic macroinvertebrate, and fish surveys. Sampling was initially conducted in the lower cold water portions of the three branches of the Whitewater River and their tributaries, along with cold water streams in nearby watersheds to gauge the relative condition of the watershed. Sampling was extended into the upper warm water portions of the watershed. Physical habitat measurements included water depth, mean water column velocity, substrate type, substrate embeddedness, and cover with a quantitative measurement of bank

Monitoring Scheme for the Whitewater River Watershed Section 319 National Monitoring Program Project

Design	Sites or Activities	Primary Parameters	Covariates	Frequency of WQ Sampling	Frequency of Habitat/Biological Assessment	Duration
Multiple paired-watershed	Finley East Finley West	Temperature Nitrate-N TP TSS Conductivity Cations Anions Fecal coliform bacteria	Precipitations Discharge (both continuous)	Continuous temperature & conductivity Weekly and flow-interval event sampling or other variables		Variable-depending on treatment: 1 - 5 yrs pre-BMP 1 yr BMP 3 - 4 yrs post-BMP
Biological-Reference & Before/After	Within watershed: North Br. (9) Middle Br. (9) South Br. (9) Trout Run (2) Trout Run trib. (1) South Br. trib. (1) Trout Valley Cr. (3) Beaver Cr. (2) Outside watershed: Garvin Brook (2) East Indian Cr. (2) (#) - number of sites	Fish Macro-invertebrates Habitat			Once per year	1994-2005

erosion along each bank. Fish habitat ratings were calculated using the procedures of Simonson et al. (1994). Macroinvertebrates were sampled using the Rapid Bioassessment Protocol III as described by Plafkin et al. (1989). Fish sampling was conducted with a backpack electrofisher The fish assemblage at all sites were assessed with the Index of Biotic Integrity (IBI) recommended by Plafkin et al. (1989), using regional modifications for cold water (Mundahl and Simon, 1998) and warm water (Lyons, 1992) streams.

Land Treatment Monitoring

Land use and management information was to be obtained with the assistance of the landowners, county soil and water conservation district staff, and/or Whitewater River Joint Powers Board staff. The identification and selection of management practices to be used on the paired-watershed treatment watersheds was also to be made with the assistance of these people. The watershed assessment needs for the biological monitoring portion of the project were more extensive than the assessment needs for the small automated monitoring sites. Analysis of the data collected will be completed with a geographic information system (GIS).

Modifications Since Project Start

Significant delays occurred in initiating the paired-watershed monitoring component of this project. The initial plan to conduct paired-watershed monitoring on two perennial streams with watersheds greater than 5,000 acres to allow biological, physical, and chemical monitoring at the same sites proved to be too difficult. The reasons for this difficulty were two-fold. One, the proposed paired-watershed sites were determined to not be representative of each other given that extensive habitat restoration work had been completed in the control watershed stream. Two, the likelihood of detecting significant changes in water quality as a result of BMP implementation was determined to be low given the large watersheds and the large amount of BMPs that would have to be implemented in a relatively short time.

The next plan for paired-watershed monitoring focused on two watersheds in the one thousand- acre size range to increase the likelihood of obtaining sufficient BMP implementation in the treatment watershed to detect a water quality change. Monitoring at these sites would have been limited to runoff event sampling due to the ephemeral nature of the streams at these locations. Biological sampling was proposed on two streams below the proposed control watershed. A miscommunication between project staff resulted in initial monitoring site work prior to the landowner giving his permission to establish the monitoring site. This mistake resulted in the need to change monitoring sites again.

The third plan for paired-watershed monitoring involved the selection of the second plan's biological monitoring sites as the primary paired-watershed monitoring sites. These sites, again, presented an opportunity to conduct biological, physical, and chemical monitoring at the same sites. The problem that developed at these sites, in terms of not being suitable for paired-watershed monitoring, resulted from the findings of the first round of biological sampling conducted on the two streams. The findings indicated that not only were the two streams very similar to each other in terms of fisheries, benthic macroinvertebrates, and habitat, but that the streams ranked among the best trout streams in the whole Whitewater River watershed. With both streams being in such good condition, the ability to detect a significant change in water quality would, again, be dificult. So, new paired-watersheds needed to be located one more time.

Following these project delays, two small watersheds were selected for physical and chemical monitoring using a paired-watershed approach. Monitoring sites were constructed in 1996 with full monitoring beginning in April 1997. Monitoring is also being completed at three previously established sites in an adjacent watershed given their proximity and similarities to the Whitewater sites. The paired-watershed monitoring sites in the Whitewater River watershed were selected for the project given their small size, proximity and similar land use (pasture and crop land) combined with the farmer's interest in expanding his use of rotational grazing. Initial paired-watershed treatment plans involved the expansion of rotational grazing onto the crop land acreage in the treatment watershed; however, these plans were altered when the farmer sold his dairy herd and the management of the land reverted to his father. Treatment plans were delayed given that the landowner used good conservation tillage practices. The addition of small grain (oats) and alfalfa to the crop rotation in the treatment watershed in 2002 was an initial treatment BMP; however, management of the farm again changed with the reintroduction of a dairy herd to the farm by the landowner's granddaughter. Efforts were then made to compare grazing management techniques; however, land management delays again resulted in a poor treatment setting.

Efforts were made to adapt the monitoring sites to allow monitoring through the winter, but these efforts were not successful.

Progress to Date

Water quality data has been collected for several years through the Whitewater 319 Monitoring Project. The physical and chemical data collected from the paired-watershed monitoring sites was sufficient to provide adequate calibration period relationships between the following pairings of the study sites: Finley East and Finley West and CRP and Corn-Soybean sites. Pairing the Organic Site with either the CRP or Corn-Soybean Sites may be more difficult. The ability to pair the Finley sites with the other three sites has not been explored yet. Data is also available to evaluate the effects of a reverse treatment given a change in land use from CRP enrollment to annual cropping in 1998.

The initiation of BMP treatment practices in the small paired-watersheds has been delayed due to landowner issues. While these delays have limited the progress toward completing the project, they have also resulted in a longer calibration period. The implementation of BMPs in the treatment watersheds began in 2001 and 2002. Monitoring will be continued through 2006 to obtain the necessary treatment period data.

The biological monitoring data base that has been developed through this project is quite extensive. In addition to characterizing the biological quality of the streams in the Whitewater River watershed, it has been used to develop and refine the biological metrics used in assessing the quality of cold water streams throughout Minnesota. Use of the data to evaluate the effectiveness of BMPs in the watershed is just beginning. Detailed land use data is present and will be incorporated into the data analyses. It was hoped that a paired-watershed design could be established for both a warm water and a cold water set of streams, but the design was not pursued.

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

Data management is completed using two spreadsheet systems. The small paired-watershed monitoring data is managed by the University of Minnesota Department of Biosystems and Agricultural Engineering. The biological monitoring data is managed by the Winona State University Department of Biology. The Nonpoint Source Management System (NPSMS) will be used to report data to EPA. Data will also be entered into STORET.

Data analysis will be performed using both parametric and nonparametric statistical methods.

NPSMS Data Summary

Data has not been entered into NPSMS as of July, 2007.

Findings to Date

The physical and chemical monitoring at the five paired-watershed sites resulted in calibration-period regression relationships that appear to be significant for several variables. Figure 26 provides an example of the calibration period regression observed for the Finley East and West watersheds. Detailed analyses of the data began in 2004.

The biological monitoring has shown that most stream sites had fair to good fish habitat ratings. Fish assemblage assessment using two indices of biotic integrity (IBI) indicated that most cold water sites rated fair to good, but most warm water sites rated poor to very poor. Cold water IBI scores were more erratic from year to year at poorer-quality cold water sites than at better-quality cold water sites. Invertebrate assemblage assessments rated most sites throughout the watershed as having moderate impairment. Figure 27 provides a summary of the cold-water IBI scores recorded in the watershed.

To date, only a simple assessment of land use types versus the biological monitoring metrics has been made. Land use type was only identified by visual observation near the monitoring sites as conventional or BMP. There was no observable effect on the instream habitat variables due to these two land use types at the monitoring sites in the Whitewater watershed; however, the percent fines and embeddedness measures did show strong tendencies to be higher at stream sites adjacent to conventional land use than at sites adjacent to BMP land uses. Detailed land use information is available and will be incorporated into the data assessments in the coming year.

Based on similarities in land use and watershed size, there is a potential for the use of a paired-watershed evaluation of BMP effectiveness via the biological monitoring data at selected sites. The drainage areas of these sites are approximately 10,000 acres and 10,000 to 30,000 for cold water and warm water sites, respectively.

INFORMATION, EDUCATION, AND PUBLICITY

Paired-watershed monitoring activities have been discussed informally with the three landowners in the five small watersheds. Information on the paired-watershed and biological monitoring activities has been presented to the Whitewater Watershed Joint Powers Board (WWJPB) and its overall project committees.

Project papers have been presented at the National Nonpoint Source Monitoring workshops.

A fact sheet describing the NMP project was completed by the MPCA as part of its documentation of Section 319 and state Clean Water Partnership project successes.

PROJECT BUDGET

CWA Section 319 funds were first received for the monitoring project in federal fiscal year (FFY) 1993. Funds have subsequently been received each funding cycle, except FFY 2000, through FFY 2003 for a total grant amount of $513,425. All funds were used for monitoring-related project elements.

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

The overall watershed project has received diagnostic study and implementation project funding from the Minnesota Clean Water Partnership (CWP) Program and the USDA P.L. 566 Program. The project has worked hard to incorporate and integrate the project activities of these programs, as well as the activities of other local, state, and federal organizations. The implementation plan was developed by the Whitewater Joint Powers Board following extensive input from a citizens' advisory committee. Additional funding and support has been received from the Minnesota Board of Water and Soil Resources, the Legislative Commission on Natural Resources, the Minnesota Department of Natural Resources, the U.S. Fish and Wildlife Service, and private sources including Land O'Lakes and the McKnight Foundation.

A pilot turbidity TMDL project was initiated in the watershed in large part due to the extensive biological monitoring information available through this "long-term" monitoring project. While the TMDL program has placed increased attention on fecal coliform bacteria and turbidity given their presence on the 1998 303(d) List, the watershed data has been an important resource in the development of regional focused TMDLs. A regional TMDL titled, "Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota," was completed September 2002. A regional TMDL effort to address the turbidity listings in the Lower Mississippi River Basin resulted in the completion of the report, "Phase I Report for Lower Mississippi River Basin Regional Data Sediment Evaluation". Information from the Whitewater project played an important role in this effort.

OTHER PERTINENT INFORMATION

None.

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Nebraska

Elm Creek Watershed
Section 319
National Monitoring Program Project

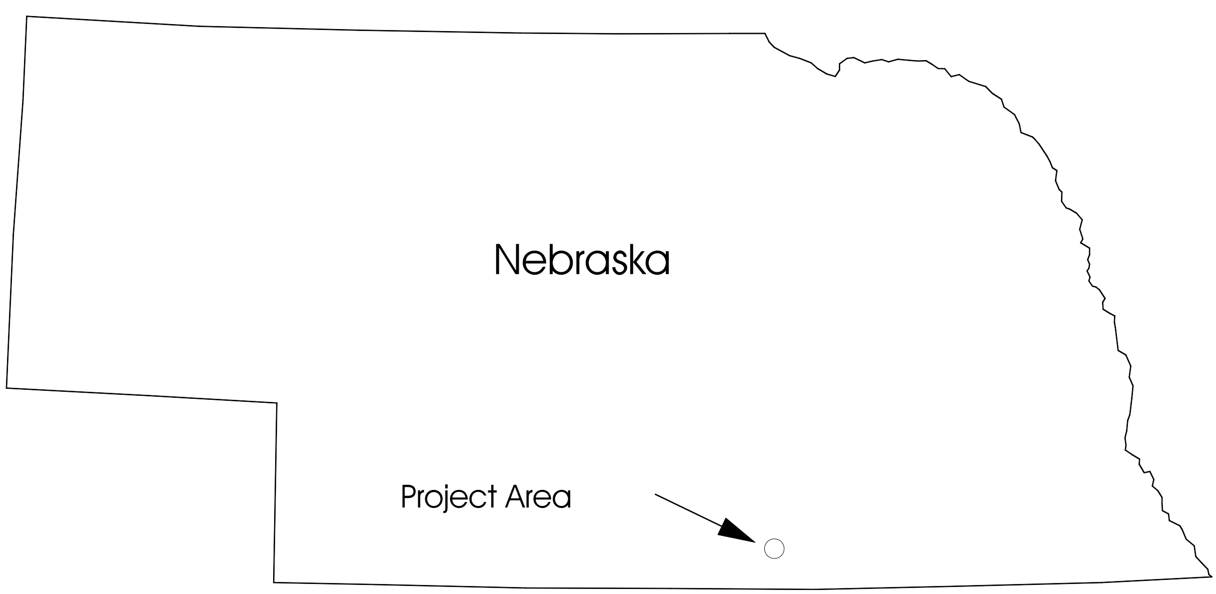

Figure 28: Elm Creek (Nebraska) Watershed Project Location

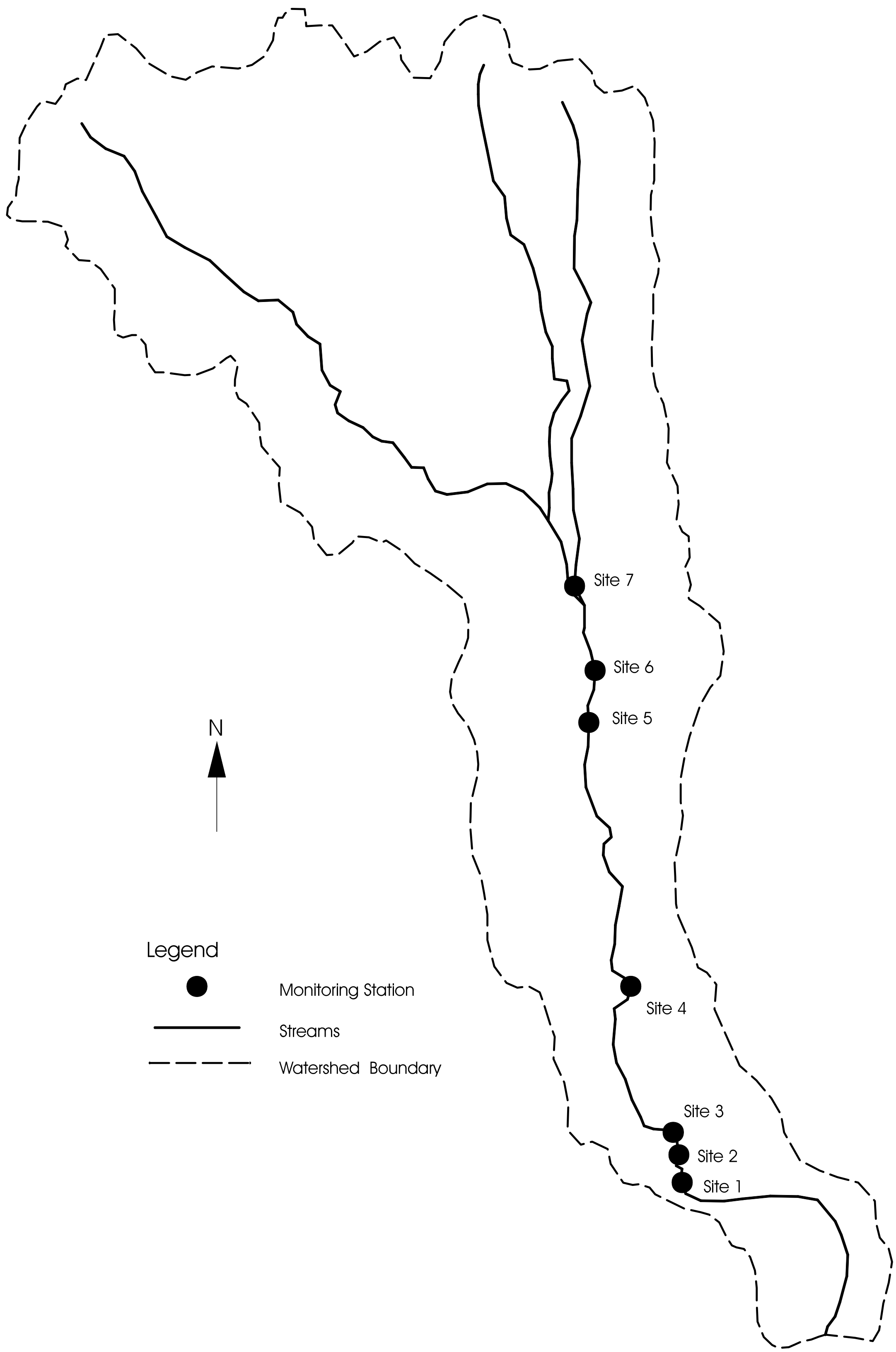

Figure 29: Water Quality Monitoring Stations for Elm Creek (Nebraska) Watershed

PROJECT OVERVIEW

Elm Creek is located in south central Nebraska, near the Kansas border within Webster County, NE (Figure 28). Elm Creek is a tributary to the Republican River. The creek flows in a southerly direction through agricultural lands of rolling hills and gently sloping uplands. The creek has a drainage area of 35,800 acres, consisting mainly of dryland crops of wheat and sorghum and pasture/rangelands with some areas of irrigated corn production.

A primary water use of Elm Creek is recreation, particularly as a coldwater trout stream. Loss of riparian area vegetation and streambank erosion have increased water temperatures, stream sediment aggregation, and high peak flows, thus impairing aquatic life by destroying habitat, which reduces the creek's recreational use due to lowered trout productivity.

Land treatment for creek remediation includes non-conventional best management practices (BMPs) such as streambank stabilization and livestock exclusion, water quality and runoff control structures, water quality land treatment such as tree planting and permanent vegetative cover, and conventional water quality management practices (see section on Nonpoint Source Control Strategy). Many of these BMPs were funded as part of an U.S. Department of Agriculture (USDA) Hydrologic Unit Area (HUA) project, which ended September 30, 1997. Water quality monitoring included an upstream/ downstream design as well as a single station downstream design for trend detection. Grab samples were collected weekly from March through September to provide water quality data. Additional biological and habitat data were also collected on a seasonal basis.

Post project water quality monitoring and implementation of "best management practices" for the Elm Creek project concluded in late 1999.

PROJECT BACKGROUND

Project Area

The project area, in south central Nebraska, consists of 35,800 acres of rolling hills, gently sloping uplands, and moderately steep slopes.

Relevant Hydrologic, Geologic, and Meteorologic Factors

The Elm Creek watershed, which receives 25.9 inches of rainfall per year, lies in a sub-humid ecological region. Seventy-five percent of this rainfall occurs between April and September. The average temperature is 52 degrees Fahrenheit with averages of 25 degrees in January and 79 degrees in July.

The soils are derived from loess and the predominant soil types are highly erosive.

The base flow in Elm Creek is derived from a combination of ground and surface water sources.

Land Use

Wheat and sorghum are the primary dryland crops produced. Corn is the primary irrigated crop. Range and pasture dominate the more steeply sloping lands.

Land Use	Acres	%
Agricultural		
Dryland	14,630	42
Irrigated	2,680	7
Pasture/Range	16,170	44
Forest	650	2
Other	1,670	5
Total	35,800	100

Source: Elm Creek Project, 1992

Water Resource Type and Size

Elm Creek flows through cropland and pasture/range into the Republican River Flow in the creek is dominated by inflow springs. The average discharge of Elm Creek is 21.4 cubic feet per second and the drainage area is 56 square miles.

Water Uses and Impairments

Elm Creek is valued as a coldwater aquatic life stream, as an agricultural water supply source, and for its aesthetic appeal. It is one of only two coldwater habitat streams in south central Nebraska. Sedimentation, increased water temperatures, and peak flows are impairing aquatic life by destroying stream habitat of the macroinvertebrates and trout. Problems arise when pulses of sediment generated by storm events arrive at the lower reaches of the channel. Gravel beds are covered, water temperatures raised, and the streambed widens. These negative impacts on the stream result from farming practices that cause excessive erosion, loss of riparian area vegetation, streambank erosion, and overland water flow.

Pollutant Sources

Sources of nonpoint pollutants included streambank erosion, sheet and rill erosion, gully erosion, irrigation return flows, cattle access, and cropland runoff.

Pre-Project Water Quality

A thorough water quality analysis of Elm Creek conducted in the early 1980s indicated that the water quality of Elm Creek was very good under base-flow conditions.There was, however, short-term degradation of water quality following storm events. In addition, water temperatures measured during the summer of 1980 regularly exceeded 20^{o} C and approached levels lethal to salmonids. The coldwater habitat use assignment of Elm Creek appeared to be attainable if it was not impaired by nonpoint source (NPS) pollution, particularly sedimentation and scouring of streambank vegetation during storm events.

The Agricultural Non-Point Source Pollution Model (AGNPS) estimated that 8,009 tons of sediment was delivered into the Elm Creek project area during a 10-year 24-hour storm with an peak flow of 2,854 cfs.

An inventory of sediment pollution sources was conducted in a nine-mile stretch of Elm Creek.

Streambank Erosion:	
Severe	3.1 miles
Moderate	1.4 miles
Slight	0.4 miles

Gullies/Overfalls:
Greater than 5 feet – 5 sites
Less than 5 feet – 43 sites

Adjacent Cropland Filter Strip Potential – 8.3 miles

Grazing Damage – 3.5 miles

Tree Snags/Debris Jams – 24 sites

Water Quality Objectives

The NPS management objective in the Elm Creek watershed was to implement appropriate and feasible NPS pollution control measures for the protection and enhancement of water quality in Elm Creek by reducing runoff, sediment, pesticides, fertilizers, and animal waste reaching the creek.

Project goals were to:

- Reduce sediment load in Elm Creek by 50 percent
- Reduce maximum summer water temperature
- Reduce in-stream sedimentation
- Reduce peak flows by 30 percent
- Improve in-stream aquatic habitat

Project Time Frame

Monitoring activities began in April 1992 and continued through the fall of 1999.

The project was approved under the Section 319 National Monitoring Program in 1992.

PROJECT DESIGN

Nonpoint Source Control Strategy

Pre-BMP implementation period was from 1981 to 1992. Most of the BMPs were installed by 1994, but some practices continued to be installed through 1997.

Four types of structural and non-structural BMPs were implemented throughout the Elm Creek watershed. These BMPs have been divided into four BMP types. The Elm Creek Hydrologic Unit Area project funded most BMPs.

Non-conventional
Vegetative Filter Strips
Permanent Vegetative Cover on
Critical Areas
Streambank Stabilization, including the
use of lunkers to stabilize the toe
Livestock Access & Exclusion
Ground Water Recharge
Abandoned Well Plugging
Trickle Flow Outlets
Sediment Barriers
Grade Stabilization

Water Quality & Runoff Control Structures

Water Quality Land Treatment
Tree Planting
Permanent Vegetative Cover
Terraces
Stripcropping

Conventional Water Quality Management Programs
Irrigation Management
Conservation Tillage
Range Management
Integrated Pest Management

Non-conventional BMPs were funded under the Section 319 National Monitoring Program. Other BMPs were funded with 75% cost share funds from the HUA project. Finally, selected BMPs were cost shared at 100% [75% from the Section 319 National Monitoring Program and 25% from Lower Republican Natural Resource District (LRNRD)]. The number and types of BMPs implemented was totally dependent on voluntary farmer participation.

Water Quality Monitoring

Upstream/downstream: The two sampling sites (sites 2 & 5) were located two miles apart (Figure 24)

The downstream station (site 5) was also used for trend monitoring.

Variables Measured

Biological
Macroinvertebrates
Fish collection
Creel survey

Chemical and Other
Water temperature
Dissolved oxygen (DO)
Substrate samples (% Gravel, % Fines)
Total suspended solids (TSS)
Atrazine/Alachlor
Stream morphological characteristics (width, depth, velocity) and habitat
Water temperature (June – September)

Explanatory Variables (Covariates)
Stream discharge (United States Geological Survey gauging station)
Monthly precipitation collected near Red Cloud, NE.

Sampling Scheme

Qualitative and quantitative macroinvertebrate sampling spring, summer, fall, and winter (sites 2 and 5).

Fish collections spring and fall (sites 2,3, &5).

Creel survey (passive).

DO (sites 2, 5): Weekly grab samples from April through September. Monthly samples from October through March.

Substrate samples spring and fall at sites 2, 4, and 5.

TSS (sites 2,5): Weekly grab samples from April through September and monthly samples, October through March. Selected runoff samples are collected April through September.

Stream morphological characteristics (width, depth, velocity) and habitat: spring/summer (sites 2, 5).

Continuous recording thermograph (hourly water temperatures for at least 60% of the period June through September and at least 80% of the period July through August) (sites 2, 5).

Monitoring Scheme for the Elm Creek Section 319 National Monitoring Program Project

Design	Sites	Primary Parameters	Covariates	Frequency of WQ Sampling	Frequency of Habitat/Biological Assessment	Duration
Upstream/	2, 5	Macroinvertebrate	Stream		2 times/yr	0 yrs pre-BMP
downstream		survey	discharge		spring & fall	5 yrs BMP
	1, 2, 3, 4, 5, 6	Fish survey			passive	3 yrs post-BMP
Single		Creel survey				
downstream	2, 5	Water temperature				
	2, 4, 5	Substrate samples		Spring & fall		
	2, 5	DO		Weekly (April-Sept.) &		
	2, 5	TSS		monthly (Oct.-March)		
	2, 5	Stream morphological		Spring		
	2, 5	characteristics		Spring/summer		
	2, 5	Water temperature				

Land Treatment Monitoring

Land use was inventoried. Cropping patterns and BMP implementation were tracked over the life of the HUA project. Tracking was based on the 40-acre grid system used for AGNPS modeling.

Field Surveys were conducted to determine the extent of conservation tillage and residue cover

Modifications Since Project Start

Land use in the project area changed from rangeland to cropland due to sodbusting. Total estimated acreage sodbusted during the project period of 1990-1997 is over 1,000 acres.

Artificial salmonid redds (live egg baskets) were initially used to monitor trout reproduction. However, the redds have been discontinued because initial monitoring results indicate substrates are not suitable for salmonid spawning because of the high fines content.

Plans to place a recording rain gauge in the Elm Creek watershed have been cancelled because of the variability associated with its large size. For the same reason, the volunteer network for recording rainfall amounts has also been discontinued.

As originally proposed, land use and BMP implementation were to be tracked based on a 40-acre grid system of the Agricultural Nonpoint Source (AGNPS) model. This scheme was to be used since a pre-project inventory of current land uses had been completed by the Natural Resource Conservation Service (NRCS) to run the AGNPS model. The goal was to then rerun the model with updated land use and BMP implementation data. However, once the Section 319 and HUA projects were initiated, staff quickly realized that annual tracking of land use changes and BMP implementation on a 40-acre basis in such a large watershed could not be accomplished with the resources available.

Disruption of stream hydrology in the upper reaches of the watershed occurred due to railroad construction and stream modification activities in July 1996. The Burlington Northern and Santa Fe railroad upgraded a track that runs approximately parallel to Elm Creek. Concurrently, they removed the riparian vegetation, realigned, and channelized a section of Elm Creek above of Monitoring Station 5, just above wildlife management area. They also constructed a 10-foot high rock dike along the west side of the stream for a linear length of approximately 0.75 miles about 0.5 miles above Monitoring Station 5. The result was an inability of the stream to effectively utilize its floodplain area, downstream streambank instability, and downstream stream bedload scouring.

Land Treatment Progress to Date

Conservation tillage was used on seventy-five percent of crop acres by 1997, up from forty percent (3,850 acres) in 1990.

178 cooperators installed installation of erosion or sediment control practices.

Significant strides were made in implementing NPS control measures throughout the watershed (see following table). It is estimated by NRCS that (Elm Creek Water Quality Report, 9/87):

- Gully erosion was reduced, saving 7,897 tons of soil per year
- Ephemeral erosion was reduced, saving 4,999 tons of soil per year
- Sheet and rill erosion was reduced, saving 24,995 tons of soil per year
- Total soil savings of 37,891 tons per year

Installation of Erosion Control Practices in the Elm Creek Watershed (9-30-97).

NRCS PRACTICE/ACTIVITY NUMBER AND CODE	#UNITS	INSTALLED
Conservation Cropping Sequence (328)	acres	7,822
Reside Mgt. - Conservation Tillage (329)	acres	7,290
Contour Farming (330)	acres	3,200
Critical Area Planting (342)	acres	115
Crop Residue Use- seasonal (344)	acres	532
Dam, Multiple Purpose	number	2
Sediment Basin (350)	number	1
Deferred Grazing (352)	acres	169
Dike (356)	feet	1,609
Diversion (362)	feet	6,323
Pond (378)	number	40
Windbreak/Shelterbelt Establishment (380)	feet	9,080
Fencing (382)	feet	61,400
Field Border (386)	feet	35,952
Filter Strip (393)	acres	5
Grade Stabilization Structure (410)	number	13
Grassed Waterway (412)	acres	14
Irrigation System-Sprinkler, Meter (442)	number	21
Irrigation System-Surface, Meter (443)	number	9
Irrigation Water Conveyance Pipeline (430EE)	feet	3,150
Irrigation Water Management (449)	acres	2,619

NRCS PRACTICE/ACTIVITY NUMBER AND CODE (cont'd)	#UNITS	INSTALLED
Livestock Exclusion (472)	acres	318
Mulching (484)	acres	4
Pasture and Hayland Management (510)	acres	339
Pasture and Hayland Planting (512)	acres	105
Pipeline (516)	feet	2,732
Proper Grazing Use (528)	acres	4,587
Range Seeding (550)	acres	214
Planned Grazing System (556)	acres	2,700
Streambank Protection/Habitat Restoration	feet	800
Stripcropping – Contour (585)	acres	2
Nutrient Management – Irrigated (590)	acres	2,141
Nutrient Management – Dryland (590)	acres	924
Pest Management – Irrigated (595)	acres	2,115
Pest Management – Dryland (595)	acres	924
Terrace (600)	feet	208,701
Tree Planting (612)	acres	4
Trough or Tank (614)	number	13
Underground Outlet (620)	feet	3,536
Water & Sediment Control Basin (638)	number	7
Well (642)	number	10
Wildlife Upland Habitat Management (645)	acres	295

Source: Elm Creek Water Quality Project. SCREC 98/4. 9/97.

In 1992, the Nebraska Game and Parks Commission (NGPC) installed cedar tree revetments on a stream segment to reduce stream bank erosion and provided additional trout habitat. In the spring of 1996, 'lunker' structures were placed in the same site to stabilize the toe of the streambank. In the fall of 1996, to partially mitigate habitat destruction by the local railroad project, additional habitat improvements were installed by NGPC and NDEQ (lunkers, double wing deflectors, and boulder/ rock clusters).

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

Ambient water quality data are entered into USEPA STORET. Biological data are stored in USEPA BIOS. Other data are stored and analyzed using Microsoft Excel 5.0 spreadsheet program and USEPA NonPoint Source Management System (NPSMS). Water quality data are being analyzed using SAS statistical software. These data were managed by the Nebraska Department of Environmental Quality (NDEQ).

Data assessment and reporting consisted of quarterly activity reports, and yearly interim reports focusing on BMP implementation.

NPSMS Data Summary

ANNUAL REPORT WQ PARAMETER FREQUENCIES

YEAR: 1995
STATION TYPE: Upstream Station

CHEMICAL PARAMETERS

	QUARTILE VALUES							
Parameter Name	**-75-**	**-50-**	**-25-**	**Counts/Season:**	**1**	**2**	**3**	**4**
FLOW, STREAM, INSTANTANEOUS, CFS	13.3	12.0	10.7	Highest	6	5	0	0
				High	1	0	0	0
				Low	1	0	0	0
				Lowest	7	1	0	0
OXYGEN, DISSOLVED (METER)	8.7	7.75	6.9	Highest	6	5	0	0
				High	10	1	0	0
				Low	8	0	0	0
				Lowest	1	0	0	0
SUSPENDED SOLIDS, TOTAL	51.0	16.5	2.0	Highest	3	1	0	0
				High	2	0	0	0
				Low	20	5	0	0
				Lowest	0	0	0	0
TEMPERATURE, WATER (DEGREE CENTIGRADE)	15.7	14.3	11.5	Highest	4	0	0	0
				High	6	0	0	0
				Low	9	0	0	0
				Lowest	6	5	0	0

BIOLOGICAL PARAMETERS (Non-Chemical)

		INDICES						
Parameter Name	**Fully**	**Threatened**	**Partially**	**Scores/Values**	**1**	**2**	**3**	**4**
INDEX OF BIOLOGICAL INTEGRITY	30	—	22		29	—	29	—
INVERTEBRATE COMMUNITY INDEX	31	—	17		18	30	—	32
TROUT HABITAT QUALITY INDEX	—	—	—		—	—	4.1	—

STATION TYPE: Downstream Station

CHEMICAL PARAMETERS

	QUARTILE VALUES							
Parameter Name	**-75-**	**-50-**	**-25-**	**Counts/Season:**	**1**	**2**	**3**	**4**
FLOW, STREAM, INSTANTANEOUS, CFS	13.3	12.0	10.7	Highest	6	5	0	0
				High	1	0	0	0
				Low	1	0	0	0
				Lowest	7	1	0	0
OXYGEN, DISSOLVED (METER)	9.9	8.85	8.5	Highest	6	5	0	0
				High	9	1	0	0
				Low	6	0	0	0
				Lowest	4	0	0	0
SUSPENDED SOLIDS, TOTAL	65.3	20.75	6.0	Highest	4	0	0	0
				High	10	2	0	0
				Low	10	3	0	0
				Lowest	1	1	0	0
TEMPERATURE, WATER (DEGREE CENTIGRADE)	16.6	14.8	11.2	Highest	8	0	0	0
				High	3	0	0	0
				Low	8	0	0	0
				Lowest	6	6	0	0

BIOLOGICAL PARAMETERS (Non-Chemical)

		INDICES						
Parameter Name	**Fully**	**Threatened**	**Partially**	**Scores/Values**	**1**	**2**	**3**	**4**
INDEX OF BIOLOGICAL INTEGRITY	30	—	22		35	—	31	—
INVERTEBRATE COMMUNITY INDEX	31	—	17		28	26	32	32
TROUT HABITAT QUALITY INDEX	—	—	—		—	—	2.2	—

Quartile data for all chemical and physicochemical parameters indicate water quality conditions were relatively good. The values presented reflected water quality under baseflow conditions, but not necessarily impacts caused by runoff events. After heavy rainfall events, the stream is often subject to high flows and the associated NPS pollutants seemingly have only a short-term degrading impact on the in-stream chemical and physiochemical water quality. However, long-lasting impacts not reflected in the data are the scouring and sedimentation resulting from these events that impair designated aquatic life uses.

Project Findings

Monitoring results indicated that overall water quality of Elm Creek is excellent under base flow conditions, but continues to be degraded under runoff conditions. Monitoring data failed to show much, if any, improvement in water quality due to the implementation of nonpoint source control measures.

Water temperature data did not indicate a significant reduction in maximum summer levels as a result of implementing nonpoint source management measures. Although it appears that periods of elevated water temperatures are relatively short in duration, periods of warmer temperatures brought about by runoff events or low flow would most likely be lethal to salmonids.

No significant reductions in maximum suspended solids concentrations were observed as a result of implementing BMPs. It is likely that as long as Elm Creek is subject to high floes, suspended solids concentrations will continue to be high.

Significant reductions in peak streamflow did not result from project implementation. Maximum precipitation levels during the post-project monitoring period were lower than during the pre-project period, but discharge peaks were still quite high.

No significant changes in stream substrate composition or condition were documented over the project. There is no indication that the percent fines in the stream substrate decreased as a result of nonpoint source controls. Given the sandy nature of Elm Creek's substrate, it is unlikely that it could ever support salmonid spawning to a great extent.

The *fish and macroinvertebrate* communities fluctuate in response to habitat degradation caused during runoff events. Trout stocked in Elm Creek appear to do quite well under base flow conditions, but after heavy runoff events few, if any, were ever collected. It is theorized that they get flushed downstream, or the warmer, turbid water forces them to migrate or induces death.

Although monitoring was conducted successfully, a few problems were encountered. Preliminary evaluation of the project monitoring design (upstream-downstream and single downstream) and water quality data suggests that the large size of the watershed above the upstream monitoring station (approximately 31,142 acres) inhibits documentation of water quality improvements due to land treatment implementation. More specifically, this problem can be attributed to the variability associated with regional and watershed conditions. The majority of non-structural BMPs recommended by the NRCS implemented in the Elm Creek watershed are designed only to control runoff from one-in-ten year storm events. When such storm events occur in the watershed, water quality (including in-stream habitat) remains good. However, with such a large watershed area above the perennial stream reach (which starts within a mile above the upstream monitoring station), even slightly larger storm events generally contribute to high flows, which degrade water and habitat quality, making it difficult to detect improvements.

Increased streambank erosion and decreased biological habitat has been observed at Site 5 due to recent railroad construction and stream modification activities.

Post project water quality monitoring and implementation of "best management practices" for the Elm Creek project concluded in late 1999. An interim water quality assessment was included in a report published by the University of Nebraska Cooperative Extension in 1998.

INFORMATION, EDUCATION, AND PUBLICITY

Information and education (I&E) activities have been developed and were implemented as part of the Elm Creek HUA Project. The University of Nebraska and Cooperative Extension in Webster County were in charge of I&E activities. I&E activities include newsletters, an NPS video, slide shows, programs, questionnaires, fact sheets, demonstration sites, field days, and meetings.

The process of addressing nonpoint source issues in the Elm Creek watershed through information and education activities was coordinated by the University of Nebraska Cooperative Extension as part of the USDA HUA effort. In addition to those activities listed below, a newsletter promoting implementation of NPS pollution prevention practices was developed and delivered to owners/ operators in the watershed.

I&E activities implemented in the Elm Creek watershed included the following:

- Several producers agreed to host field days and BMP demonstration plots.
- A no-till drill was made available for rent at $8.00 per acre in order to encourage no-till practices.
- Videotapes on no-till crop planting practices and on rotational grazing were completed.
- Two newsletters were produced for the project. A quarterly newsletter was sent to all landowners and operators in the project area and included articles on BMPs, cost share funds available, and updates on project progress and upcoming events. The second newsletter was an irrigation-scheduling newsletter. This monthly newsletter gave updates on pests, and crop-irrigation needs based upon an automated weather station.
- An end-of-season survey indicated that irrigators were saving a total of about $18,000 from reduced irrigation water and pesticide applications.
- A series of educational programs have been held to provide producers with background information to encourage the adoption of BMPs. Other program topics included new tools for pasture production, rotational grazing tour, and a prescribed burn workshop.
- An eco-farming clinic was held where no-till drills were demonstrated. Topics of discussion for the program included winter wheat production and weed control, diseases, cultivar selection, insect control, and soil fertility.
- Sixteen demonstration plots exhibiting various BMPs were used as an educational tool. Practices being demonstrated include: fertilizer management, integrated crop management - irrigated, integrated crop management - dryland, no-till milo production, no-till winter wheat drilling, ridge-till, gravity irrigation, pivot irrigation, range management, plugging an abandoned well, permanent cover, conservation tillage wheat production, terraces, cedar revetments for streambank protection, and sediment retention basin restoration.
- Youth programs on conserving and managing natural resources were given to 1,000 participants each years at the Earth Jamboree.
- Webster County 4-H clubs participated in tree planting days.
- Numerous news stories, articles, meeting announcements and updates have been published in local newspapers.

TOTAL PROJECT BUDGET

The estimated budget for the Elm Creek Watershed Section 319 National Monitoring Program project for the life of the project is:

Project Element	Funding Source ($) Federal HUA/WQIP	319	State	Local	Sum
Proj Mgt	0	11,200	0	0	11,200
I&E	0	0	0	3,400	3,400
Reports	0	6,300	0	0	6,300
LT	260,000	115,000	0	101,600	476,600
WQ Initiative Program (WQIP)	30,000	0	0	0	30,000
WQ Monit	0	100,000	0	15,000	115,000
Post-Project Monit	0	30,000	0	0	30,000
TOTALS	290,000	262,500	0	120,000	672,500

Source: Elm Creek Project, 1991

Time frame for funding sources:

- Section 319(h) funds in the amount of $30,000 have been secured to continue post-BMP implementation monitoring activities for an additional three years (1999)
- Local/Section 319 — April, 1992 to October, 1996
- HUA — May, 1990 to October, 1997 (The HUA project was scheduled to end in September, 1995, but has received a three year extension)
- WQIP — Contracts were written for cropping years 1992, 1993, and 1994. All funds were allocated in 1992
- Final report — December, 2003

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

The Elm Creek Watershed Section 319 National Monitoring Program project provided the water quality monitoring for the area HUA project. USDA program funding was used for approved, conventional BMPs.

OTHER PERTINENT INFORMATION

The HUA activities were jointly administered by the University of Nebraska Cooperative Extension and the USDA NRCS. Employees of these two agencies work with local landowners, Farm Service Agency (FSA) personnel, personnel of the Nebraska Department of Environmental Quality (NDEQ), Nebraska Game and Parks Commission, and personnel of the Lower Republican Natural Resource District (LRNRD). Section 319 National Monitoring Program project activities are administered by the NDEQ.

Agencies or groups involved in the project are listed below.

- USDA FSA
- Landowners
- Lower Republican Natural Resources District:
Monitoring
- Little Blue Natural Resources District

- Nebraska Game and Parks Commission
- USDA NRCS
- Nebraska Department of Environmental Quality
- Nebraska Natural Resources Commission
- U.S. Geological Survey
- University of Nebraska Cooperative Extension
- U.S. Environmental Protection Agency
- Webster County Conservation Foundation (WCCF)
- Future Farmers of America Chapters and 4-H Clubs
- Center for Semi-Arid Agroforestry and Nebraska Forest Service
- Webster County Board of Commissioners

PROJECT CONTACTS

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New York

New York City Watershed
Section 319
National Monitoring Program Project

Figure 30: New York City Watershed (New York) Project Location

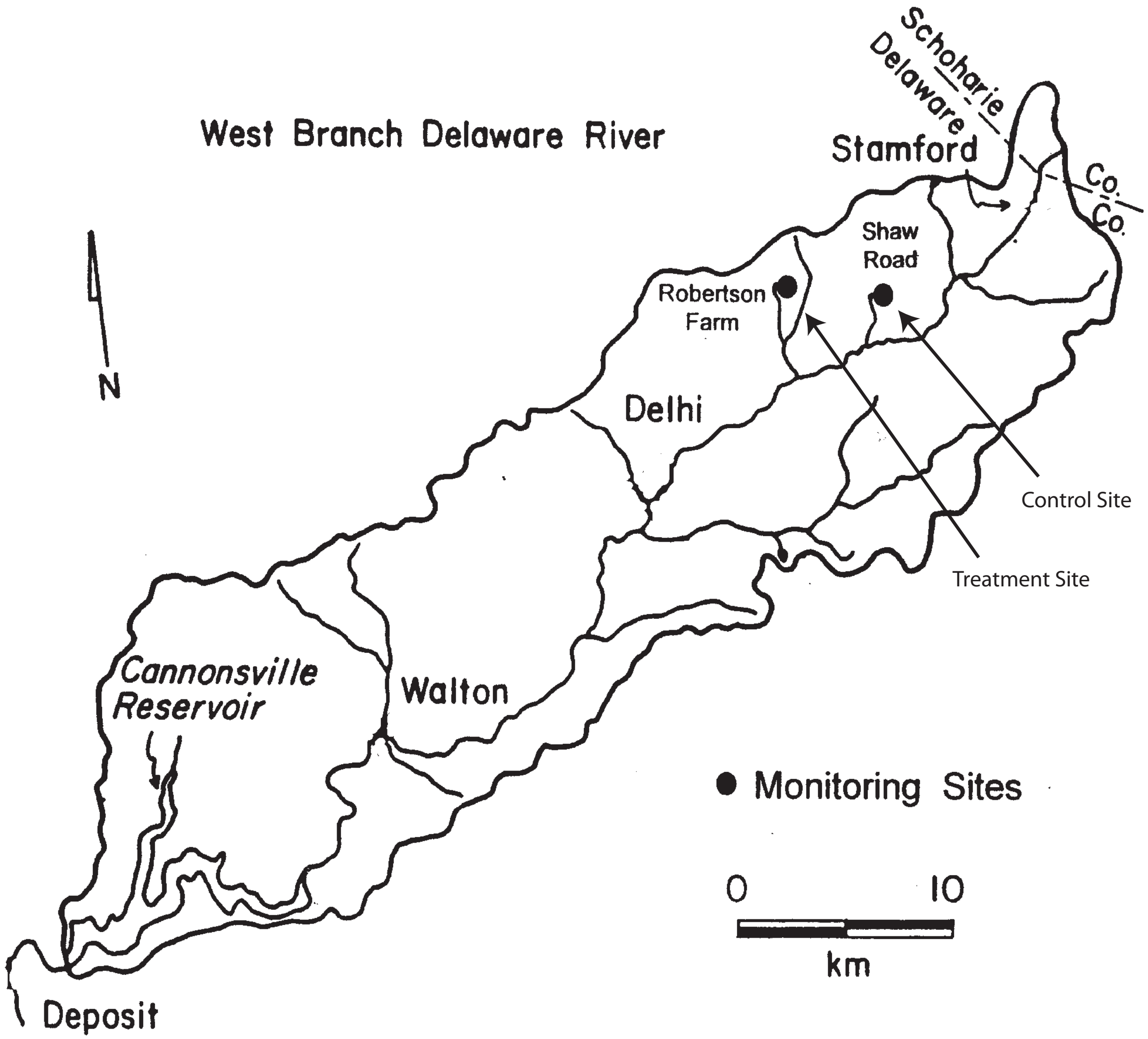


Figure 31: Water Quality Monitoring Stations for New York City Watershed (New York)

PROJECT OVERVIEW

New York City's three major systems of drinking water supply, the Catskill, Delaware, and Croton, are located to the north and northeast of the City within a 125-mile radius, and provide water for 9 million people. The total watershed area is 1,950 square miles, covering 8 New York counties and containing 19 surface water reservoirs. A major land use in the Catskill/Delaware portion of the watershed is agriculture; the approximately 350 farms located there are predominantly dairy and livestock enterprises.

The 1989 federal Surface Water Treatment Rule (SWTR) requires filtration for most water supply systems that draw water from surface sources. The SWTR provided for a waiver of the filtration requirement if the water supplier could meet certain objective and subjective criteria. As outlined in the SWTR, issues of concern fall into several categories: coliform bacteria, enteric viruses, *Giardia* sp., *Cryptosporidium* sp., turbidity, disinfection by-products, and watershed control. The City was able to demonstrate that the Catskill/Delaware supply met the objective criteria: (1) the source water met the turbidity and fecal coliform standards of the SWTR, (2) there were no source-related violations of the Coliform Rule, and (3) there were no waterborne disease outbreaks in the City. The subjective criteria of the SWTR required the City to demonstrate through ownership or agreements with landowners that it could control human activities in the watershed which might have an adverse impact on the microbiological quality of the source water. To demonstrate its eligibility for a filtration waiver, the NYC Department of Environmental Protection (DEP) advanced a program to assess and address water quality threats in the Catskill/Delaware system. This program has provided the basis for a series of waivers from the filtration requirements of the SWTR (January 1993; December 1993; January 1997; May 1997). The most recent waiver, issued in July 2007 for 10 years, is based on commitments by the City to provide $300 million for land acquisition, build a UV disinfection plant for the Catskill/Delaware supply, and continue to fund wastewater infrastructure initiatives, including residential septic system rehabilitation and maintenance programs, a new program for commercial septic systems, upgrades to existing wastewater plants, completion of ongoing projects for new wastewater treatment plants, three new community wastewater treatment projects, and two new sewer extension projects. The City will still be required to build a filtration plant by 2011 to treat water from the Croton system.

Based upon information collected through its extensive monitoring and research efforts, DEP designed a comprehensive watershed protection strategy, which focused on implementing both protective (antidegradation) and remedial (specific actions taken to reduce pollution generation from identified sources) initiatives. DEP's assessment efforts pointed to several key potential sources of pollutants: waterfowl on the reservoirs; wastewater treatment plants dischaging into watershed streams; failing septic systems; the approximately 350 farms located throughout the watershed; and stormwater runoff from development.

The NYC Watershed Agricultural Program (WAP), a voluntary incentive-based program, was established to implement the agricultural nonpoint source portion of the management program. Whole Farm Planning (WFP) was adopted by the WAP as the primary means of protecting NYC water supplies from farm-related nonpoint source pollution, as well as maintaining a viable agricultural community in the watershed. Beginning in 1993, ten demonstration farms in five counties were selected on which to develop, test and demonstrate the WFP method. Ultimately the WAP intended to have 85% of the farms within the watershed participating in WFP by 1997, a goal which has been met. While many of the Whole Farm plans for these farms have been completed, installation of the recommended practices is ongoing.

The New York State Department of Environmental Conservation (DEC) began studying one of the demonstration farms, the R. Farm, in 1993 in an effort to quantitatively evaluate the WFP approach for water quality protection and improvement. This study was later accepted into the Section 319 National Monitoring Program in June 1997.

The R. Farm, which is representative of upland agriculture in this hilly area is located in the West Branch of the Delaware River (WBDR) watershed where most of the dairy agriculture of the entire NYC watershed occurs. The WBDR, a class C[T] stream, is the primary tributary of Cannonsville Reservoir, which is used for NYC drinking water downstream water level maintenance, and trout fishing. Cannonsville Reservoir has had a long history of eutrophication problems due to excess loading of phosphorus from the WBDR associated primarily with dairy agriculture and point source discharges. Major sources of nonpoint phosphorus include land application of manure, barnyard runoff and overfertilization of cropland.

The project incorporated a paired watershed monitoring design, with the R. Farm as the treatment watershed and a forested watershed as the control. Monitoring included measurement of streamflow, precipitation, phosphorus, nitrogen, organic carbon, suspended sediment, pathogens and macroinvertebrates. In addition, records of farm activities before and after BMP implementation were kept.

The treatment and control sites were monitored for 2 years from June 1993 through May 1995, prior to BMP implementation at the treatment site in 1995-1996. Monitoring resumed in late 1996 and was originally scheduled to continue for 5 years. Another five years were added to the evaluation period for a total of ten years. The project ended in October 2006. The last three years of data will also be used to compare loadings from an upland to those of a monitored lowland farm in the Cannnonsville watershed. The final report is expected by December 2007.

PROJECT BACKGROUND

Project Area

The project consisted of two sites located in the Town of Kortright, Delaware County, New York, on tributaries to the WBDR. The treatment watershed is 396 acres (Fig. 1). The control watershed is 213 acres (Fig. 2).

Relevant Hydrologic, Geologic and Meteorological Factors

The WBDR watershed lies in the northwestern Catskill section of the Appalachian Plateau. The topography is rolling to mountainous; tributaries occupy steep-sided valleys, and the river's main stem occupies a broader valley. Elevation ranges from 1150 to 3315 feet above mean sea level. The average annual precipitation in the WBDR watershed is 40 inches; average annual temperature is 46°F. The climate is characterized as humid continental. Watershed geology consists of consolidated sedimentary bedrock overlain by unconsolidated glacial till and stratified deposits of clay, sand and gravel. Many soils in the WBDR basin are classified as highly erodible, are severely or very severely limited in their use for cultivation due to stoniness, excessive slope or wetness, and range from somewhat excessively drained to poorly drained.

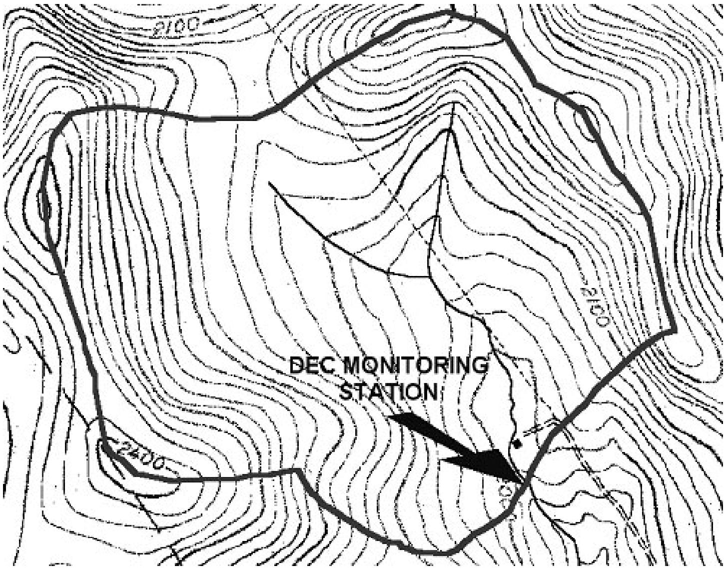
Land Use

The WBDR watershed covers an area of 350 mi^2 and comprises about 80% of Cannonsville Reservoir's total drainage area. Land use is approximately 73% forested, 25% agriculture and 2% urban/industrial.

Land use in the treatment watershed is improved pasture and hay: (25%); corn rotation (7%); unimproved pasture (13%), deciduous forest (53%) and impermeable (2%). At the beginning of the study, the farm had 70 dairy animals and 40 replacements, but has since increased herd size by about 15-20%. As is typical of upland dairy farms in the Catskills region, the barn is located in the valley bottom, close to a central stream. Intensively managed fields, which tend to be situated on the lower slopes of the watershed, include improved pasture, hay, and a rotation of tilled corn. Barnyards, roads, and farm infrastructure create impermeable surfaces, much of which is near the stream. During the grazing season (mid-May to end of October) cows must cross through or over streams and saturated areas to reach pasture.

The control watershed is comprised of forest land, abandoned field returning to forest, and shrub land. Several weekend residences and one permanent residence are located within the control watershed. In 2000, a landowner in the control watershed fenced an area and imported a small domestic deer herd.

Figure 1. Farm watershed.



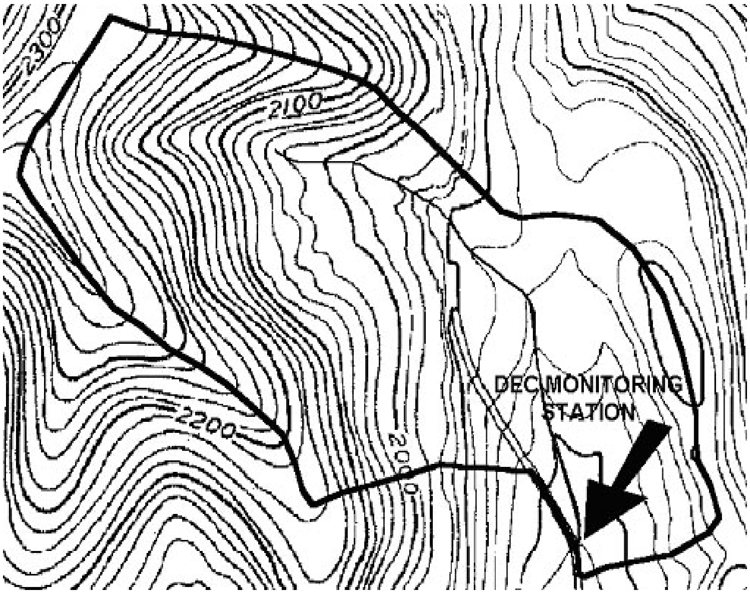


Figure 2. Control watershed.

Water Resource Type and Size

The study streams are small, first-order permanent streams that drain to theWBDR. Under baseflow conditions, they are generally 1-3 feet wide at the monitoring sites, but may increase to 15-20 feet wide during runoff events. Average annual stream discharge at the treatment site has ranged from 0.65 to 1.33 cfs during the study, while at the control it has ranged from 0.32 to 0.72 cfs.

The WBDR itself winds about a 50-mile course to the Cannonsville Reservoir and has an average annual discharge of 580 cfs. The reservoir has a total capacity of about 100 billion gallons and a surface area of about 5000 acres.

Water Uses and Impairments

The two study streams are the headwaters of tributaries that are classified C(T) or C(TS). However, they are too small to have been identified as having use impairments. It is unlikely that trout species travel as far upstream as the monitoring sites due to the shallowness and increased temperature of the water at those locations in the summer.

The WBDR is a highly regarded trout fishing resource in the county. Upstream of the reservoir, it has no use impairments. Cannonsville Reservoir is classified AA(T). It is used for NYC drinking water, trout fishing and maintenance of downstream river and temperature levels through hypolimnetic releases. However, throughout most of its history, eutrophication has impaired the designated uses of Cannonsville Reservoir for drinking water and trout survival and propagation. NYC uses Cannonsville less frequently for drinking water due to aesthetics problems associated with summer algal blooms. Higher temperatures in the epilimnion combined with hypoxia in the hypolimnion create difficult conditions for cold-water fish species. While the current water quality of the reservoir is sufficient to meet the filtration avoidance criteria, there is a continual threat of waterborne pathogens such as *Cryptosporidium* and *Giardia*, as well as sediment, entering and degrading the drinking water supply.

Pollutant Sources

In 1993 at the beginning of the study, the four largest municipal wastewater treatment plants in the WBDR watershed, along with dairy agriculture, were the primary pollutant sources in the Cannonsville basin. Point source phosphorus concentrations were in the 3 – 5 mg/L range. Major sources of nonpoint phosphorus included animal waste and fertilizers. Sources of the parasitic protozoa *Cryptosporidium* and *Giardia* were livestock, sewage, and wildlife.

By the end of the study, the four wastewater facilities had been upgraded to the highest levels of treatment such that phosphorus concentrations are now typically less than 20 ug/L in the effluent and removal of protozoan cysts is enhanced through use of microfiltration. Nearly all of the farms in the watershed have been improved through implementation of agricultural BMPs.

Pre-Project Water Quality

Event-based monitoring of the WBDR in the early 1980s, and again from 1991 to the present, has revealed that nonpoint sources typically contribute 70-80% of the annual load of dissolved phosphorus, which largely drives phytoplankton production in the Cannonsville Reservoir

Nutrient and sediment loadings from agriculture versus forested land are predictably unequal as illustrated by the results of the pre-implementation monitoring at the treatment and control sites (see Tables 4a and b). Estimated load rates from the agricultural portion of the treatment watershed, which is two-thirds forested, were considerably higher than those calculated for the entire watershed.

Water Quality Objectives

The main objective of this project was to test the ability of the WFP process to: a) correctly identify significant sources of on-farm pollution; and b) recommend and implement cost-effective management practices that will substantially reduce pollutant losses from those sources. This was done by quantifying reductions in nutrient and sediment loadings from the farm due to implementation of the Whole Farm Plan, and associating these reductions with specific changes made in management on the farm. In addition, modeling of the farm landscape, both temporally and spatially, has been accomplished in another effort to relate management decisions to changes seen in water quality over time.

Data have been used to test and calibrate watershed models that can predict the net effect on water quality after those farms in the WBDR watershed participating in the WAP complete BMP implementation. Ultimately, this is expected to produce estimates of changes in pollutant loads delivered to Cannonsville Reservoir as a result of this program.

Project Time Frame

1993-2006

PROJECT DESIGN

Paired Watershed

Although this study utilized a paired watershed approach (e.g., Wilm, 1949; Reinhardt; 1967, Clausen and Spooner, 1993; Galeone 1999), it differed from the traditional design in that the two watersheds were not alike in their land use. A non-farm control was selected because it was expected that no significant changes would be made in the watershed during the study period. In contrast, working farms often change operations during the course of a long-term study, or may go out of business altogether and, thus, may not provide the consistent control necessary for describing natural environmental variability. Located in Delaware County within five miles of each other at the headwaters of tributaries that drain to the WBDR, the two watersheds are similar in size, elevation, and soil conditions. The farm watershed was monitored before and after BMP implementation to assess changes in water quality. The non-farm site was monitored concurrently and provided control for with inter-annual and seasonal hydrologic variability. This design also enable an assessment of the degree to which water quality from the farm might approach “background” water quality after BMP implementation.

The treatment watershed is 396 acres (160 ha) and consists almost entirely of the R. farm itself (Fig. 1). The farm is situated at the headwaters of a small tributary that drains to Wright Brook, which then drains to the WBDR. Watershed elevation at the farm site ranges between 2400 ft. and 1800 ft. above sea level. Pollutant problem areas identified on the farm prior to WFP implementation included surface spreading of manure, particularly on snow and frozen ground, barnyard runoff, high soil phosphorus levels on certain crop fields, uncontrolled livestock access to stream, milkhouse waste discharged into the stream, silage leachate draining near the stream from an "ag bag", and sediment losses from farm roads and eroding stream banks. Further assessment of the farm in more recent years has identified importation of animal feed as an additional source of excess phosphorus on the farm.

At the control site, the watershed encompasses 213 acres (86 ha) (Fig. 2). Elevation ranges between 2380 ft. and 1760 ft. above sea level. Small modifications were made by a landowner in this watershed in 1997 which involved collection of overland runoff and diversion into a pipe emptying to the road ditch. This likely did not change the amount of runoff reaching the monitoring station as the flow pattern was previously spread out over the road, but eventually reached the ditch.

The treatment and control sites were monitored for two years, from June 1993 to May 1995, prior to implementation of any practices. The BMPs recommended in the farm’s Whole Farm Plan were then installed at the treatment site (Table 1). These practices were, for the most part, completed by the fall of 1996 and totaled nearly $300,000 in cost. However, additional BMPs have been installed at this farm since the initial round (see below: Modifications Since Start).

Table 1. Best management practices (BMPs) implemented on the farm watershed in Phase 1.

Near-barn improvements:
Installation of manure storage lagoon
Barnyard improvement including outside water management
Filter area established for barnyard runoff
Stream corridor relocated away from barnyard
Grazing cows excluded from stream/swale areas
Milkhouse washwater diverted from stream discharge to manure storage
Relocation of silage storage bag away from stream
Improvement of stream crossings and roadways
Watershed scale improvements:
Access roads constructed to allow manure spreading on upper slopes
Distributed manure spreading according to nutrient management plan
Fencing improvements to support rotational grazing
Spring development to supply drinking water away from the stream
Diversion ditches to improve field drainage
Subsurface drainage to reduce field saturation
Contour strip cropping to reduce erosion
Crop rotation to reduce erosion

Post-implementation monitoring began in November 1996 and continued for 10 years. Comparison of before and after water quality from the farm, with reference to the control site to account for natural inter-annual variability, was used to document effectiveness of WFP practices. Detailed records of farm activities, such as location and amount of manure spreading and fertilizer used, were kept in order to relate changes in water quality to changes in farm practices.

Water Quality Monitoring

Sampling Scheme

Automated monitoring stations were installed on the tributaries of the farm and control sites. Streamflow and precipitation were continuously recorded by data-loggers which trigger automatic sample collection during runoff events upon rise in stream stage and/or onset of precipitation. Frequency of sample collection over the course of the event varied, depending on rate of stream rise or fall, up to a maximum of one every 10 minutes. Samples were also collected on a routine basis during base-flow periods at least one per week. All were analyzed for nutrients (3 forms each of phosphorus and nitrogen), organic carbon and suspended sediment. Streamflow volumes and nutrient and sediment loads were calculated. Sampling for macroinvertebrates was first conducted at both sites in July 1996 prior to completion of BMP implementation. Post-implementation bioassessment monitoring was performed once a year during the summer season through 2001.

Variables Measured

Biological

Macroinvertebrates

Chemical and Other

Particulate phosphorus (PP)
Total dissolved phosphorus (TDP)
Soluble reactive phosphorus (SRP)
Nitrate + nitrite (NO_x)
Total ammonia ($T\text{-}NH_3$)
Total Kjeldahl nitrogen (TKN)
Total organic carbon (TOC)
Total suspended solids (TSS)

Alkalinity
pH

Covariates

Runoff
Precipitation

Monitoring Scheme for the New York City Watershed 319 National Monitoring Program Project

Design	Sites or Activities	Primary Parameters	Covariates	Frequency of WQ Sampling	Frequency of Biological/Habitat Assessment	Duration
Paired	BMP farm Site Control non-ag Site	PP TDP SRP NOx T-NH3 TKN TOC TSS pH Alkalinity	Rainfall Runoff	Once/wk at low flow Storm event up to once every 10 min.	Once a year in July	2yr pre-BMP 1 ½ yr BMP installation 9yr post-BMP

Land Treatment Monitoring

The farm operator at the treatment site kept daily records of manure placement and quantity by field before and after BMP implementation. Manure analysis was performed several times. Soil test P has been compared by field before and after as well. Other record keeping included usage of commercial fertilizer and pesticides, and herd rotation in grazing paddocks.

Modifications Since Project Start

Original plans called for all BMPs to be installed within one year. However, due to the extent of treatment on this farm, startup of post-implementation monitoring was delayed by about 5 months until November 1996 when the practices listed in Table 1 were completed. After several years of monitoring, a former machine shed used as a shelter area for dry cows and heifers was identified as a high contributing source area. Located just upstream of the monitoring station, a cattle path led from it down a steep, eroded slope through the stream and up the opposite bank to a pasture area. In late summer of 2001, a stream crossing was constructed to exclude the cows, and the banks were repaired and revegetated.

In January 2001, this farm was selected for participation in a pilot program of precision feeding to reduce phosphorus importation on dairy farms from purchased feed. Feeds and homegrown forages were analyzed for their protein, carbohydrate and mineral contents and the nutritional needs of the herd were determined using the *cu*NMPS (Cornell University Nutrient Management Planning System) software. Diets were adjusted and as a result, phosphorus imported onto the farm in purchased feed was reduced by 30%. This directly translated into a 30% reduction in phosphorus excreted by the cow (Cerosaletti et.al, 2004).

Installation of a spring development and remote watering system was performed in 2001 on the farm, resulting in less cattle traffic in and around the stream.

It was expected that additional improvements to water quality would result from the new management practices described above. Thus, post-implementation sampling was extended from 5 to 10 years in order to observe the effects of these more recent farm management improvements. To differentiate between the two treatment phases, the post-implementation period was split into Phase 1: initial round of BMPs, and Phase 2: initial round plus BMPs since April 2001. This start date for Phase 2 represents the time manure produced under the precision feeding program and stored in the manure lagoon would first be applied to the farm's fields. Analysis of data, therefore, focuses on changes in water quality between the Pre-BMP period and Phase 1, and changes between Phase 1 and Phase 2.

In summer of 2002 (Post-6), there was a failure of the manure storage system and a portion of the lagoon contents back-flowed through the barn eventually reaching the stream. The spill was largely cleaned up within a few days, but enough manure remained in the stream bed and near-stream areas to produce elevated nutrient concentrations during the next several runoff events.

Progress to Date

The study is completed. Data have been analyzed for the two-year pre-implementation phase and ten-year post-implementation phase.

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

Water quality data were stored in Microsoft Excel workbooks. Data analysis was conducted using Excel, Statistica and S-Plus statistical software.

NPSMS Data Summary

Not available

Findings to Date

Water Quality Results

Table 2 shows the dates corresponding to each monitoring year and the number of samples collected during these periods. Over 1,300 samples were collected during the two Pre years and about 5,900 during the ten Post years. The bulk of samples each year were collected during runoff events. The number of samples collected in a year generally varied directly with amount of runoff produced (also see Table 4a).

Stream water nutrient and sediment concentrations at the farm were typically three to twenty times higher than at the control site during events (Table 3), reflecting the more intensive land use and presence of livestock. As one of the objectives of the study was to determine if farm runoff quality could be improved enough to approach background water quality, given the amount of BMP implementation that occurred, it is apparent from the comparison in Table 3 that concentrations of pollutants in farm runoff were still elevated considerably after treatment compared to control levels.

Annual runoff and loads of nutrients and sediment were substantially greater at the farm site than at the control site (Tables 4a and 4b). The more intensive land use and somewhat greater watershed area of the farm site are obvious factors that contribute to this result. Source track-down studies revealed that much of the load leaving the farm was generated on the most intensively utilized portion of the farm consisting of the farmstead area and fields spread with manure.

Runoff varied somewhat over the twelve years due to variations in precipitation amounts and timing (Table 4a). Annual loads were variable at the farm, less so at the control, and tended to be smaller in years with less runoff. Simple comparison of annual farm pre- and post BMP loads did not indicate clear patterns of pollutant reductions with the exception of TDP loads, which were consistently lower throughout the post-BMP period regardless of the amount of annual runoff produced (Fig. 3). As a large amount of loading at both sites occurred during runoff events, and there appeared to be seasonal factors that strongly affected event losses, we focused on events in detail to better determine effects.

Table 2. **Study periods and number of samples collected during study.**

	Period	Farm	Control	Total
Pre-1	6/1/93 – 5/31/94	468 331 79		9
Pre-2	6/1/94 – 5/31/95	315 212 52		7
Post-1	11/1/96 – 10/31/97	416	232	648
Post-2	11/1/97 – 10/31/98	483	262	745
Post-3	11/1/98 – 10/31/99	273	191	464
Post-4	11/1/99 – 10/31/00	403	275	678
Post-5	11/1/00 – 10/31/01	206	137	343
Post-6	11/1/01 – 10/31/02	305	162	467
Post-7	11/1/02 – 10/31/03	299	209	508
Post-8	11/1/03 – 10/31/04	475	291	766
Post-9	11/1/04 – 10/31/05	387	204	591
Post-10	11/1/05 – 10/31/06	443	282	725
Total		4,475	2,788	7,263

Table 3. Average event concentrations computed as event load divided by event flow volume for each of the three study phases at the farm (F) and control (C) sites. Concentrations in ug/L except for TSS, which is in mg/L.

	PP		**TDP**		**T-NH_3**		**NOX**		**TSS**	
	F	**C**	**F**	**C**	**F**	**C**	**F**	**C**	**F**	**C**
Pre-BMP	202	35	94	12	197	10 607	147		85.2	23.3
Phase 1	234 5	1	81	13 122		11	795	132	97.2	30.9
Phase 2	219 6	5	79	13	102	16	530	65	105.6	44.3

Analysis of Events

Throughout the study, runoff events accounted for a substantial portion of the annual loading of most analytes. Typically, 75 – 95% of the annual loads of particulate fractions such as PP and TSS were delivered during event periods. Dissolved analytes, such as TDP and NOX, tended to have 45 – 75% of the annual load associated with runoff periods. Runoff events delivered a greater percentage of annual loads at the farm site than at the control. On average, more of the annual loading was delivered during events in the post-BMP period than during the pre-BMP period at both the farm and control sites, although this disparity was more apparent at the farm.

Table 4a. Annual runoff (cm) and loads (kg·ha^{-1}) of phosphorus and sediment at farm and control sites.

	Runoff		PP		TDP		TSS	
	Farm	**Control**	**Farm**	**Control**	**Farm**	**Control**	**Farm**	**Control**
Pre-1	70.4	59.9	0.57	0.08	0.47	0.05	217	45
Pre-2	52.7	49.4	0.61	0.10	0.49	0.04	231	61
Post-1	60.1	55.1	0.79	0.14	0.20	0.05	343	76
Post-2	60.7	54.2	0.70	0.13	0.27	0.05	298	75
Post-3	36.3	36.2	0.29	0.12	0.22	0.04	108	74
Post-4	70.2	53.9	1.04	0.12	0.42	0.05	384	70
Post-5	38.4	32.1	0.33	0.08	0.29	0.03	135	37
Post-6[a]	39.2	35.4	0.58	0.05	0.20	0.03	253	30
Post-7	74.1	51.0	0.54	0.07	0.42	0.05	211	47
Post-8	66.5	71.4	0.93	0.24	0.38	0.08	453	154
Post-9	59.1	62.0	0.61	0.27	0.33	0.06	314	166
Post-10								

[a] Farm values calculated with manure spill load removed from the analysis.

Table 4b. Annual runoff (cm) and loads of nitrogen and organic carbon (kg·ha^{-1}) at farm and control sites*.

	NH_3-N		NOX-N		TKN-N		TOC	
	Farm	**Control**	**Farm**	**Control**	**Farm**	**Control**	**Farm**	**Control**
Pre-1	1.04	0.04	3.77	0.76	2.72	0.77	29.1	14.8
Pre-2	0.50	0.05	2.23	0.48	1.99	0.91	30.0	14.9
Post-1	0.36	0.05	3.47	0.62	2.63	1.09	25.2	17.3
Post-2	0.44	0.03	4.87	0.55	3.16	1.47	29.0	18.6
Post-3	0.25	0.04	2.43	0.60	1.69	0.93	16.5	13.2
Post-4	0.64	0.05	3.76	0.47	4.51	1.18	33.3	16.6
Post-5	0.48	0.03	3.77	0.33	2.38	0.74	15.1	8.7
Post-6[a]	0.28	0.05	1.88	0.29	2.93	0.88	20.3	10.8
Post-7	0.72	0.11	4.27	0.35	4.62	1.26	35.3	16.0

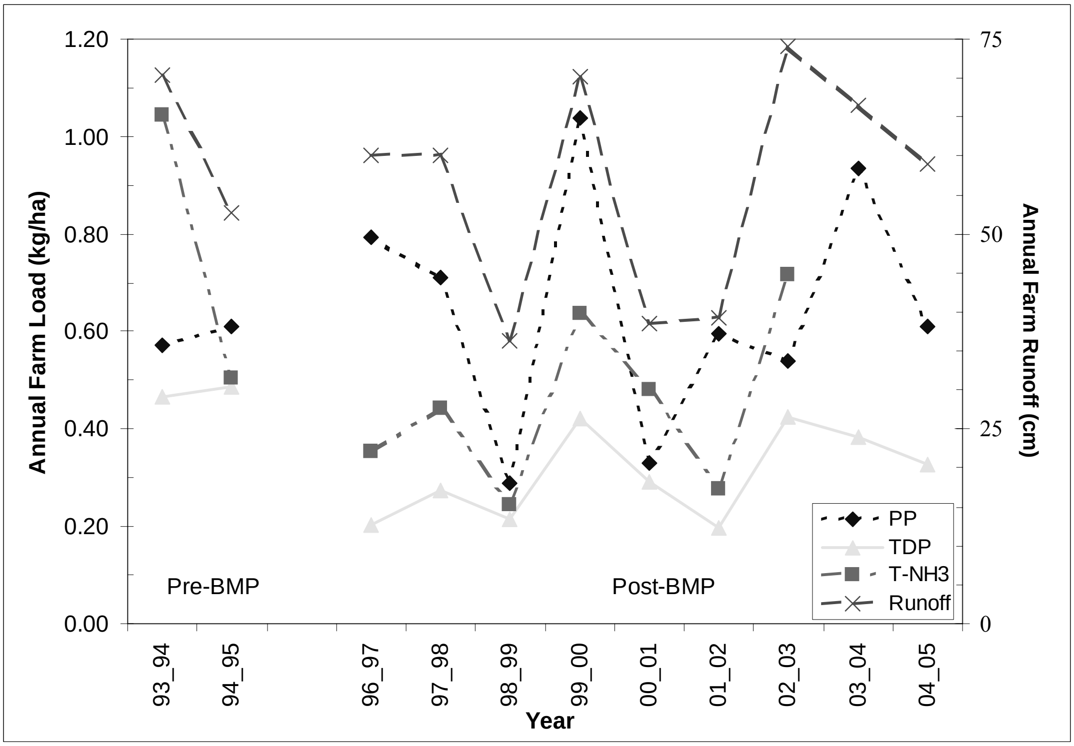
* Sampling for nitrogen and carbon was discontinued after Post-7.
[a] Farm values calculated with manure spill load removed from the analysis.

Table 5. Seasonal definitions, with the number of matched events that occurred in each season and in the full year, for the pre-BMP, Phase 1 and Phase 2 post-BMP periods.

	Number of Matched Events			
Season	Pre-BMP[†]	Phase 1[‡]	Phase 2[§]	Total
Winter (16 December–13 April)	33	70	33	136
Spring (14 April–15 June)	12	33	27	72
Summer (16 June–30 September)	17	35	48	100
Fall (1 October–15 December)	12	29	28	69
Full year	74	167	136	377

[†] June 1993 – May 1995
[‡] November 1996 – April 2001
[§] May 2001 – October 2005

Figure 3. Annual farm loads of selected analytes during the eleven study years. PP = particulate phosphorus, TDP = total dissolved phosphorus, T-NH_3 = total ammonia.



Annual event runoff at the study sites was roughly comparable (farm: 14–36 cm; control: 8–27 cm) although the farm site was always higher in a given year, perhaps due to the greater amount of impermeable area and the greater tendency of summer storms to either occur at the farm or result in measurable runoff at the farm. In the pre-BMP period, event flow accounted for 35% of total stream discharge at the farm and 28% at the control site; in the entire post-BMP period, event flow averaged 46% of the total at the farm and 34% at the control. The remainder of stream discharge occurred as baseflow.

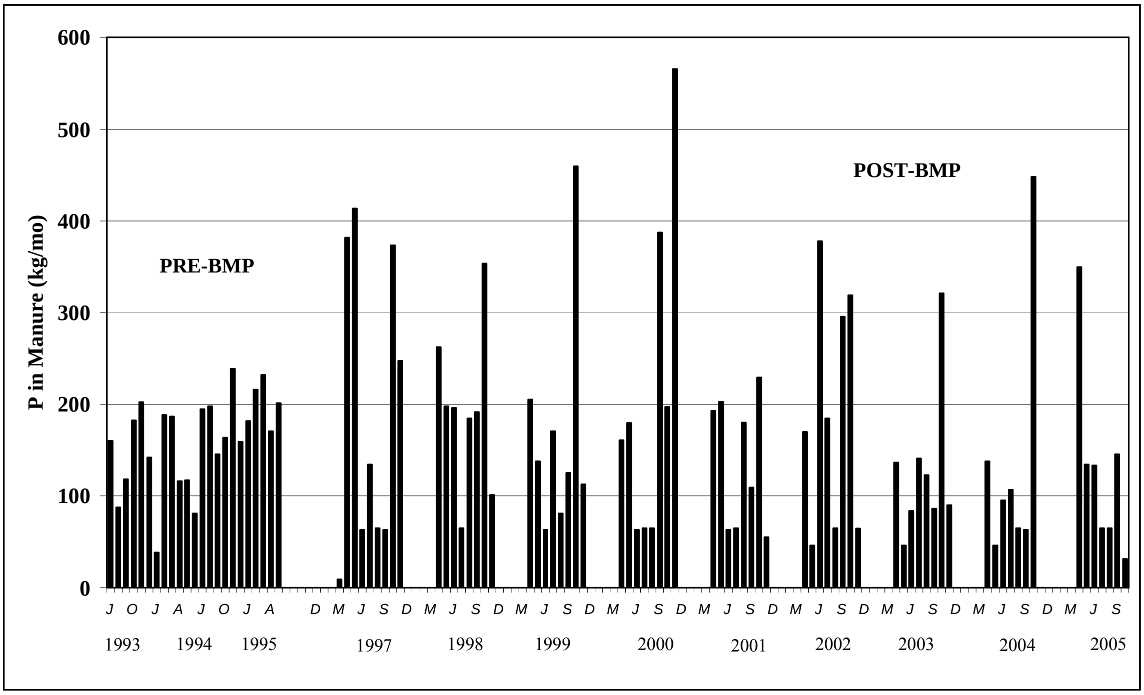
Over the course of the study, 486 runoff events were observed and sampled. One hundred and eight of these events were removed from the analysis because they were unmatched (event at farm but not at control: n=87; or vice-versa: n=21). Unmatched events occurred mainly when event size was small, so analysis of seasonal loading trends for the farm watershed was not affected by their removal. One additional event (28 Jan. 1994) was deleted because of a suspected laboratory error. The resulting dataset includes 74 events in the PRE-BMP period, 167 events in Phase 1 of the POST-BMP period, and 136 events in Phase 2 (Table 5). Data were grouped (Table 5) to reflect seasonal variation in both land application of manure, (considered a primary source of nutrients on the farm) following BMP implementation and hydrologic runoff processes (wet versus dry periods). Manure in the PRE-BMP period was daily spread, while in the POST-BMP period, manure was stored from mid-December to about mid-April and then spread heavily in spring and fall and less heavily in summer. Figure 4, which shows the monthly P contained in both land-applied manure and manure deposited by pastured cows, illustrates this change in spreading pattern. Approximate begin and end dates for the dry period and timing of manure spreading were used to define seasonal date ranges.

Statistical Model to Evaluate Event Loads

The following discussion of the statistical analysis is based on Bishop et al. (2005). A complete discussion of the development of the statistical model may be found there.

USEPA recommends an analysis of covariance (ANCOVA) model for paired watershed data analysis, using matched event loads from control and treatment watersheds to determine effects of

Figure 4. Monthly P in manure applied on the farm watershed from spreading and pastured cows. One load manure = 4.6 kg P.



BMPs (USEPA 1993, 1997a, 1997b). In addition to event load at the control site, several available covariates were employed during this study to explain variability in pollutant losses from the treatment watershed due to effects of hydrologic and watershed parameters. These included the ratio of event flow volumes at the farm and control sites, farm event instantaneous peak flow, and farm event average flow rate. The control event load reflects local characteristics of rainfall, runoff production, and pollutant loading processes in the absence of farm management practices, while the farm watershed variables represent the treatment effect, along with runoff production and pollutant loading processes associated with the farm landscape. All of these variables can be considered for use as covariates in an ANCOVA model evaluating post-treatment changes in farm event pollutant loads, as long as they did not change in response to the BMP treatments. Variation in farm event pollutant loads that is not explained by the combined covariates can be attributed to pre-treatment versus post-treatment effects, represented by an indicator variable, k, or to unexplained error, ε.

The natural log transformation was employed to normalize the distribution of event magnitude, as is common practice (Cohn et al., 1989; USEPA, 1997b). The complete multivariate regression model, which was applied to both the seasonal and full-year dataset, is written as:

$$\ln(Pf_i) = a + b\ln(Pnf_i) + c\ln(Qf_i/Qnf_i) + d\ln(peak\ Qf_i) + e\ln(QRf_i) + fk_i + gk_i[\ln(Pnf_i) - m] + \varepsilon_i \qquad [1]$$

where ln is the natural logarithm, i is the event index, Pf_i is the farm event load for the pollutant of interest for event i, Pnf_i is the matched nonfarm event load for the pollutant of interest for event i, Qf_i is the farm event flow volume for event i, Qnf_i is the matched nonfarm event flow volume for event i, peak Qf_i is the farm instantaneous peak flow rate for event i, QRf_i is the average farm flow rate (volume/duration) for event i, k_i is the BMP treatment index variable, m is the average of $\ln(Pnf_j)$ during the post-BMP period, and ε_i is the residual error, assumed to be independently distributed. For simplicity in the following text, the interaction term $k_i[\ln(Pnf_i) - m]$ is denoted as $k\ln Pnf$. Interpretation and discussion of these model terms are given below.

1. *a*: The intercept accounts for differences in watershed area and land use, as well as the greater magnitude of pollutant losses from the farm site. The farm watershed (160 ha) is 1.9 times the size of the nonfarm watershed (86 ha).

2. $\ln(Pnf_i)$: Event loads from the nonfarm watershed reflect background environmental factors, including event magnitude, antecedent soil moisture, rainfall intensity, and seasonal variation in watershed hydrological processes.

3. $\ln(Qf_i/Qnf_i)$: This flow ratio term accounts for imbalances in matched-event precipitation between the two study watersheds (amount and intensity, and subsequent variation in runoff volume) that make $\ln(Pnf_i)$ a less than perfect predictor of $\ln(Pf_i)$. Because event loads and flows are highly correlated (load is the product of flow and concentration), and it is the imbalance that is likely to be important, the farm and nonfarm flow variables were combined into a single covariate (Qf/Qnf), thereby reducing multi-collinearity.

4. $\ln(peak\ Qf_i)$: This term represents environmental processes affecting farm load that vary with event magnitude, yet are not captured by the control watershed variables because of differences between the farm and nonfarm landscape. For example, sediment loading from impermeable near-stream areas, which are more prevalent on the farm, is expected to correlate with event peak flow

5. $\ln(QRf_i)$: The average farm event flow rate is an indicator of event intensity. Again, particulate detachment and transport processes at the farm and control watersheds should respond differently under differing runoff intensities, due to the greater percentage of impermeable and unvegetated areas in the farm landscape.

6. k_i: The coefficient *f* associated with this BMP treatment index variable describes the log-change in farm event loads between the pre- and post-treatment periods (k = 0 for the pre-BMP period; k = 1 for the post-BMP period).

$k\ln Pnf$: This interaction term allows for a change in regression slope between the pre- and post-BMP periods. The term was made orthogonal to the BMP treatment index variable by subtracting *m* from $\ln(Pnf)$, where *m* is the average value of $\ln(Pnf)$ over the post-BMP period. Consequently, addition of this interaction term to the model had relatively little effect on the coefficient of *k*. Significance of the $k\ln Pnf$ term would indicate that the BMPs performed differently under high- versus low-flow events, in which case analysis of treatment effects becomes more complex as load reductions would then vary with event magnitude.

The treatment period interaction covariate $k\ln Pnf$, which was included in the model to allow for PRE- vs. POST-BMP changes in the regression slope, was not significant in most of the seasonal and full-year analyses. In those cases it was dropped from the model prior to calculation of treatment effects. Significance of the $k \cdot \ln P_{nf}$ term may point to seasons or situations where the BMPs are performing differently under high- versus low-flow events.

The use of the flow ratio term $\ln(Qf/Qnf)$ as an explanatory covariate is only valid if the BMPs are assumed to have no effect on the relationship between precipitation and runoff production at the farm site. This assumption was tested using the model:

$$\ln(Qf_i) = a + b\ln(Qnf_i) + f\,k_i + \varepsilon_i \qquad [2]$$

The analysis found no significant pre- vs. post-treatment differences in the matched watershed flow relationship for any season, nor for the full-year (*f* not significant at a = 5%). Overall, adoption of BMPs did not seem to produce significant changes in the relationship of farm runoff volume and precipitation characteristics, and $\ln(Qf/Qnf)$ could therefore be safely used as a predictor variable.

For each seasonal and full-year dataset, the full multivariate model was fit and non-significant terms were subsequently dropped. Confidence intervals (CI_{95}) for reductions in event loads were calculated. For most cases where $k\ln Pnf$ was not significant, the analysis was based upon the multivariate model:

$$\ln(Pf_i) = a + b\ln(Pnf_i) + c\ln(Qf_i/Qnf_i) + d\ln(peakQf_i) + e\ln(QRf_i) + f\,k_i + \varepsilon_i \qquad [3]$$

Differences in pre- vs. post-BMP event P loading were based on a one-sided t test on the *f* coefficient in Eq. [2] using a 5% significance level.

Model Results

BMP Treatment Effects: Comparing Pre-BMP to Phase 1 Post-BMP Event Loads

The magnitude of Phase 1 post-BMP event load reductions, as well as 95% confidence intervals (CI_{95}), were computed for all analytes (Table 6). When data from the full-year were analyzed without separation into seasons, all analytes, with the exception of NOX and TKN, showed significant reductions ($p < 0.05$) in event loads after implementation of Phase 1 BMPs. Reductions ranged from 22% in TOC loads to 41% in TDP loads. NOX loads actually increased when compared to pre-BMP levels and TKN loads were essentially unchanged. Seasonally, most analytes showed significant reductions in winter and summer. No significant changes in fall event loads were noted for any analytes. Spring event loads were similarly unaffected with the exception of a 38% reduction in TDP.

Table 6. Percent reductions event loads between pre-BMP and Phase 1 post-BMP, and between Phase 1 with Phase 2 post-BMP *. Negative values indicate increase in event loads.

	Full Year	Summer	Fall	Winter	Spring
PP					
Pre vs. Phase1	**34** (17/48)†	**44** (13/64)	5‡	**33** (17/46) 24	‡
Phase 1 vs. Phase 2	16‡	**33** (5/53)	**40** (5/62)	**-32** (-4/-66)¶ 36	‡
TDP					
Pre vs. Phase1	**41** (32/48)	**51** (31/65)	6‡	**43** (32/52)	**38** (12/58)
Phase 1 vs. Phase 2	**14** (4/30)	**32** (13/47)	11‡ -3	‡	8‡
TSS					
Pre vs. Phase1	**28** (8/44)	35‡ -7	‡	**26** (3/43)	24‡
Phase 1 vs. Phase 2	17‡	**36** (3/58)	**41** (3/65)	**-68** (-28/-119)¶ 34	‡
T-NH_3					
Pre vs. Phase1	**33** (17/46)	**54** (22/73)	-17‡	**36** (13/53)	19‡
Phase 1 vs. Phase 2	**43** (28/54)	**55** (20/74)	38‡ 28	‡ 26	‡
NOX					
Pre vs. Phase1	**-20** (-4/-38)	6‡ -2	1‡	**-22** (-1/-47)	-40‡
Phase 1 vs. Phase 2	**26** (12/37)	**53** (32/67)	20†	**-33** (-3/-72)	**45** (24/60)
TKN					
Pre vs. Phase1	-1‡ -1	2‡ -9	‡ 18	‡ -4	8‡
Phase 1 vs. Phase 2	-5‡ 27	‡ 15	‡	**-27** (-3/-56)	-12‡
TOC					
Pre vs. Phase1	**22** (13/29)	**30** (7/46)	18‡	**23** (16/29)	15‡
Phase 1 vs. Phase 2	1‡ 20	‡ 0		0	-1‡

* Phase 2 ended on October 31, 2005 for PP, TDP and TSS. It ended on October 31, 2003 for the remaining parameters.

† Percent reduction (bold) and 95% confidence interval (CI_L / CI_U).

‡ Indicates non-significant ($p > 0.05$) change.

¶ Interaction term (see Bishop et al. 2005) is significant indicating BMPs may perform differently under high- versus low-flow conditions.

BMP Treatment Effects: Comparing Phase 1 to Phase 2 Post-BMP Event Loads

By comparing event loading in Phase 1 to Phase 2, it was determined that additional reductions occurred after the second round of practices were installed on the farm for some analytes (Table 6). In Phase 2 TDP and T-NH3 decreased 14% and 43%, respectively, relative to loading in Phase 1. NOX decreased by about the same percentage it increased between the pre-BMP period and Phase 1, and thus, was essentially unchanged from the beginning of the study Seasonally, reductions in summer loads were noted for PP, TDP, TSS, T-NH3 and NOX. PP and TSS showed significant decreases in fall loads but corresponding increases in winter loads. NOX and TKN both increased significantly in winter when compared to Phase 1. It is unclear why winter event loads of these analytes would increase in Phase 2 as manure spreading in November, which is expected to have the most influence on winter loadings, appears somewhat reduced from 2001 to 2005 when compared to the Phase 1 years (Fig. 4). It remains to be determined if some other aspect of farm management changed in Phase 2 that would contribute to winter increases.

Seasonal Differences in Event Loading and BMP Performance

Summer (15 June–30 September)

BMPs implemented on the farm appeared to be most effective with respect to summer season event loads.. After Phase 1, TDP and PP summer event loads were reduced by 51% and 44%, respectively, and after Phase 2, by 33% and 32%, respectively (Table 6). Total NH_3 summer event loads exhibited >50% reductions after each phase of BMPs. Significant reductions after Phase 2 were also observed in TSS and NOX. In the dry summertime, upper watershed slopes did not usually saturate, and nutrient and sediment loads were produced mainly from near-stream, impermeable, and slope-break sources. BMPs that would operate mostly in these areas included Phase 1 and 2 exclusion of cows from the stream corridor, relocation of the silage storage bag away from the stream bank, implementation of rotational grazing, improved pasture management, Phase 2 remediation of the dry cow loafing area and stream crossing improvement, and somewhat reduced manure spreading during summer months (Fig. 4).

Fall (1 October–14 December)

Significant event load reductions after Phase 1 were not observed during the fall season for any analytes (Table 6). Increased fall manure spreading in the post-BMP period (Fig. 4) when the farmer emptied the manure storage lagoon in preparation for the winter may have offset any P and N reductions attributable to other BMPs implemented on the farm. At this time of year there is little crop growth to utilize nutrients added to the soil, thus manure applied to the land would be expected to be available for loss during runoff events. The fall reductions observed after Phase 2 in PP (40%) and TSS (41%) may be somewhat attributable to the protection and re-vegetation of the dry cow loafing area near the stream, practices that would be expected to reduce losses of particulate fractions.

Winter (15 December–13 April)

Reductions in winter P and organic carbon event loads in the Phase 1 post-BMP period were most likely largely attributable to storage of manure and minimal spreading from mid-December to mid-April. Sediment reductions may be linked to decreased farm vehicle traffic and farm road disturbance associated with extremely reduced manure spreading. Decreases in winter ammonia-N loads appeared to be largely offset by increases in nitrate-N loading, and suggest a transformation of N forms through nitrification. In the pre-BMP period, fresh surface-applied manure in cold weather would tend to retain N as ammonia, instead of being converted to nitrate, a process which occurs in the soil under warmer conditions. Low volatilization rates in winter would act to preserve ammonia as well. The reduction in ammonia loading observed after BMPs is likely due to the lack of fresh manure being applied daily to snow and frozen ground and subjected to runoff processes. Increases in nitrate event loads may be related to conversion of the ammonia contained in the large amounts of manure applied in the fall, when the storage was emptied, to nitrate in the soil. This nitrate could have still been available for loss during winter runoff events, N being more mobile in the soil than P. In addition, a portion of the ammonia in fall-applied manure was no doubt lost through volatilization during agitation of the storage, and subsequent spreading on fields. Thus, unlike P, winter loads of N appear unaffected by the BMPs installed in either Phase 1 or Phase 2.

Spring (14 April–14 June)

Spring TDP event loads were reduced by 38% in the Phase 1 post-BMP period, while PP, TSS, T-NH_3 and TOC event loads showed nonsignificant ($p > 0.05$) reductions ranging from 15 – 24%. Manure was heavily surface-applied in the spring months (Fig. 4) to empty the storage after winter, with some being incorporated into the soil during tillage. Losses from manure-spread fields and increased sediment availability resulting from spring tillage and increased farm trafic would potentially mask clear-cut reductions in sediment and nutrient loadings. It is encouraging thatTDP, the most important nutrient contributing to eutrophication, was significantly reduced in springtime as a result of the Phase 1 BMPs. This may be a result of barnyard water management practices, improved field drainage, and manure spreading schedules that more evenly distributed manure over the farm. All of these practices may be expected to reduce event loadings of dissolved nutrients, but not necessarily the particulate fractions. Phase 2 BMPs did not appear to have a significant effect on spring event loadings, except for NOX, which was reduced by 45%. However, as NOX exhibited a non-significant increase of 40% after Phase 1 BMPs, the overall change in nitrate event loading from the pre-BMP period may be considered negligible.

Baseflow(Non-event) Reductions

Annual Loads

When compared to the pre-BMP period, the amount of stream discharge occurring annually as baseflow in the entire post-BMP period was, on average, 24% less at the farm and 16% less at the control site. Some of the farm reduction in baseflow may be due to the absence of the daily milkhouse waste discharge into the stream after BMP implementation. Annual farm baseflow loads of PP, TDP, TSS, and T-NH_3 were reduced by 50% or more, greater amounts than what could be explained simply by reductions in baseflow discharge. In contrast, at the control site, load reductions tended to be about the same as or less than the reduction in baseflow, although some parameters increased slightly. As observed during event periods, baseflow loads of NOX and TKN did not appear to decrease after implementation of management practices.

Analysis of Baseflow Concentrations

While there appeared to be differences in annual baseflow farm loads between the pre- and post-BMP periods, due to the confounding effects of interannual variability it made more sense to examine baseflow sample concentrations for any significant changes during the study period.

In the pre-BMP period, there were 125 baseflow samples collected; in Phase 1, there were 178 samples; in Phase 2 there were 255 for P forms and sediment, and 141 for N forms and TOC. Concentrations were analyzed both for the full year and seasonally.

When comparing Phase 1 post-BMP to the pre-BMP period, baseflow concentrations of all three forms of P and T-NH_3 were significantly reduced in the full year and in all seasons;TSS was significantly reduced in the full year and spring season; NOX was significantly reduced in the summer season, and significantly increased in the winter and spring seasons; andTKN significantly increased in the full year, fall and spring seasons (Table 7). Changes in mean baseflow concentrations between Phase 1 and Phase 2 of the post-BMP period included significant reductions in full-year TSS, summer TDP, TSS and NOX, and fall PP and TSS. Significant increases in full-year TKN and TOC, summer T-NH_3 and TKN, winter SRP and TKN, and spring T-NH3 were also observed between Phase 1 and Phase 2 baseflow concentrations.

Table 7. Overall percent reductions calculated from differences in full-year baseflow geometric mean concentrations among the three study periods. Negative value indicates an increase in concentration.

	% Reduction and 95% Confidence Interval	
	Pre-BMP vs. Phase 1	Phase 1 vs. Phase 2
PP	**51** (39/58)† -	
TDP	**60** (51/66)	-
TSS	**16** (3/28)	**22** (13/30)
NOX	-	**35** (22/46)
T-NH_3	**68** (61/74)	-
TKN	**-15** (-2/-28)	**-28** (-15/-42)
TOC	-	**-16** (-7/-26)

† Percent reduction (bold) and 95% confidence interval (CI_L / CI_U.

The significant reductions observed in post-BMP baseflow concentrations of P, sediment and ammonia would be expected to result in proportionally reduced baseflow loads. Pollutants in baseflow are typically derived from point discharges, leaching from field soils in subsurface flow, release from disturbed stream banks and resuspended bed sediments, and direct activity by cattle in the stream. For dissolved analytes, much of the reduction may be attributed to the elimination of the daily milkhouse waste discharge to the stream as well as decreased manure deposition in the stream. The reductions in particulate forms are likely due to the exclusion of livestock from the stream and associated reductions in direct manure deposition, stream bank erosion, and sediment resuspension and transport.

Although the farm baseflow concentrations were reduced over the course of the study they still remain quite elevated when compared to those measured at the control site. Average annual baseflow concentrations computed as baseflow load divided by baseflow volume are shown in Table 8. As observed with event periods, it appears that BMPs may be able to reduce farm losses to varying degrees, but for most pollutants they are unlikely to ever control these losses to the point where the quality of water from intensively used agricultural land begins to approach that from forested, non-farm areas. Baseflow concentrations of TDP, T-NH_3 and NOX were all still considerably higher in Phase 1 and 2, although PP and TSS did approach the magnitude of those observed at the control site after practice implementation (Table 8).

Table 8. Average baseflow concentrations computed as baseflow load divided by baseflow flow volume for each of the three study phases at the farm (F) and control (C) sites. Concentrations in ug/L except for TSS, which is in mg/L.

	PP		TDP		T-NH_3		NOX		TSS	
	F	C	F	C	F	C	F	C	F	C
Pre-BMP	37	8 68	7		86 7		420	99	9.4	4.1
Phase 1	21	10	27 7		42 6		568	96	6.0	4.9
Phase 2	18 10		35	8	66	14	503	55	4.6	4.6

Total Farm Reductions

The overall effect of BMPs on the farm may be estimated by adding the event reductions to the baseflow reductions. Table 8 shows the fraction of annual post-BMP loads delivered during events and baseflow periods, significant reductions ($p<0.05$) after Phase 1 and Phase 2 BMPs for both event and baseflow loads, and the combined effect of these reductions on the total annual loading. Loads of ammonia and dissolved P exhibited the greatest reductions, 64% and 53% respectively, as a result of the BMPs implemented under Whole Farm Planning. Farm losses reduced by 50% or more can be considered to be quite substantial and would be expected to have positive effects on receiving water bodies if also achievable on other farms in the watershed. Particulate P and sediment losses were reduced by 36% and 28%, respectively. While not as large as the decreases in ammonia and TDP, these reductions may help reduce eutrophication, turbidity and sedimentation in receiving water bodies. In the case of Cannonsville Reservoir, agriculture has been estimated to be responsible for 60-70% of the TP load; thus measures that reduce contributions from this source by a third to a half would be significant. Reductions in NOX of 23% and TOC of 5% were smaller, and TKN increased by 17%. These differences would be expected to have little effect on receiving waters.

Phosphorus. Certain changes in farm practices occurring in the post-BMP period may have counteracted the effect of BMPs to some degree. These included a gradual increase in herd size of about 30% and intensified use by cows of the streamside loafing yard in Phase 1 that created a concentrated nutrient-loading source area not far upstream of the monitoring station. In addition, none of the Phase 1 BMPs altered either the amount of P imported onto the farm as feed or fertilizer or the amount exported as products. Therefore, as the mass balance of P on the farm did not change appreciably during the first four years of the post-BMP period, presumably any reductions observed in stream losses of P resulted from more of it being retained on the farm. This outcome has the potential of accelerating net accumulation of P in the farm soils and eventually raising soil-P levels to the point of saturation of soil-P binding capacity. Studies indicate this saturation point represents a threshold of soil-P above which TDP concentrations in runoff can increase sharply (e.g., Beauchemin and Simard 1999; McDowell and Sharpley 2001), an effect that, in the absence of measures to reduce P inputs, would be expected to lead to increased loss of dissolved P from the farm in the future.

Beginning in 2001, the second phase of BMPs implemented on the farm not only corrected the concentrated nutrient source area but also addressed the P imbalance on the farm. The farm watershed P mass balance was improved with institution of a precision feeding program that lowered imports of dietary P by an average of 25% and reduced excretion of P in manure by 33% (Cerosaletti et al. 2004). Reductions of this magnitude in the amount of manure P applied to the farm soils should slow the rate of soil P accumulation and continue to reduce losses of P in runoff waters. The observed Phase 2 reductions in TDP and PP (Table 6) may be somewhat attributable to the institution of precision feeding, although, seasonally, reductions due to this practice would be expected to be associated more with runoff losses during fall and spring, when most of the manure is now spread, not in summer when the greatest reductions in both TDP and PP actually occurred.

Our study was somewhat unusual in its characterization of the changes in water quality from a single farm and may not be directly comparable to findings from other BMP effectiveness studies that monitored larger watersheds. Brannan et al.. (2000), however, demonstrated reductions of 35% in PP loading and 4% in TDP loading in a 10-year evaluation of improved animal waste practices (including manure storage, spreading schedules, and stream fencing) implemented in a 331-ha Virginia watershed containing two dairy farms. In the same study, the authors reported PP load reductions of 70%, but TDP load increases of 117% in a nearby 462-ha agricultural watershed composed mostly of cropland that received BMPs including nutrient management plans based on N needs, and field erosion control practices. Conversion of organic P to inorganic P in the manure storage and application of manure at rates based on N needs of crops, which typically result in overfertilization of P, were suggested as factors that could explain the ineffectiveness of the program in reducing TDP loads. The BMPs evaluated in our study produced overall PP reductions comparable with those Brannan et al. (2000) reported for the first watershed and about half of that observed in the second watershed, but were much more successful in reducing TDP loading. Findings of Brannan et al. (2000) may constitute evidence of the eventual P saturation of soil and subsequent release of dissolved P in runoff that is postulated to occur when conservation and nutrient management practices are implemented in the absence of efforts to improve whole-farm mass balance of P.

Nitrogen. The effects of the BMPs implemented under the Whole Farm Planning program on N losses were mixed. The two main components of N in manure are organic N and ammonia (Collins et al. 1995). In fresh manure, the inorganic portion is commonly in the form of ammonium. Storage of manure, especially in slurry form, generally results in conversion of organic N to ammonium through ammonification (Brannan et al. 2000). Loss to the atmosphere can occur through volatilization of ammonia N from either the storage or from surface-applied manure. Ammonia N is converted to nitrate by soil bacteria when manure is incorporated into the soil. If application is in excess of crop needs, nitrate can be quickly lost in surface and subsurface runoff. While manure storage has the benefit of producing more plant-available N by transforming organic N to inorganic forms, if crop needs are small or absent at time of application, as they are in the fall season when the storage is emptied, there is more potential for loss to the environment. This may explain the apparent increases seen in NOX loading after Phase 1. Ammonia loadings decreased, presumably through loss to the atmosphere and conversion to nitrate, and nitrates increased due to excess amounts in relation to plant needs. Brannan et al. (2000) reported results similar to ours in that reductions in ammonia concentrations of 30% - 70% were measured in their three study watersheds and nitrate loading showed the smallest reductions as a result of BMPs.

INFORMATION, EDUCATION AND PUBLICITY

Tours conducted by the Watershed Agricultural Council have included stops at the R. farm to view the WFP practices and monitoring station. Numerous publications, including newsletters, have been prepared to disseminate information on the WAP. Workshops on WFP plan preparation and in-service training sessions have been held and a printed WFP guide and environmental audit procedure have been developed. The website for the WAP and its activities can be accessed at http://www.nycwatershed.org/.

TOTAL PROJECT BUDGET

NRCS provided consulting and design services for the BMPs. NYSDEC project personnel are funded through the state. The majority of funds to pay for both the BMPs and the monitoring comes from NYC Department of Environmental Protection. There was also local input in the form of the farmers' time in helping to prepare the Whole Farm Plans and those that serve on the Watershed Agricultural Council. Approximate costs are as follows:

Monitoring	
Installation of stations:	~$85,000
Operation of stations:	$5,000/year
Analytical services:	$60,000/year
Personnel:	~$150,000/year
Misc.:	$8,000/year
BMPs:	~$350,000+

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

Unknown

OTHER PERTINENT INFORMATION

None.

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North Carolina

Long Creek Watershed
Section 319
National Monitoring Program Project

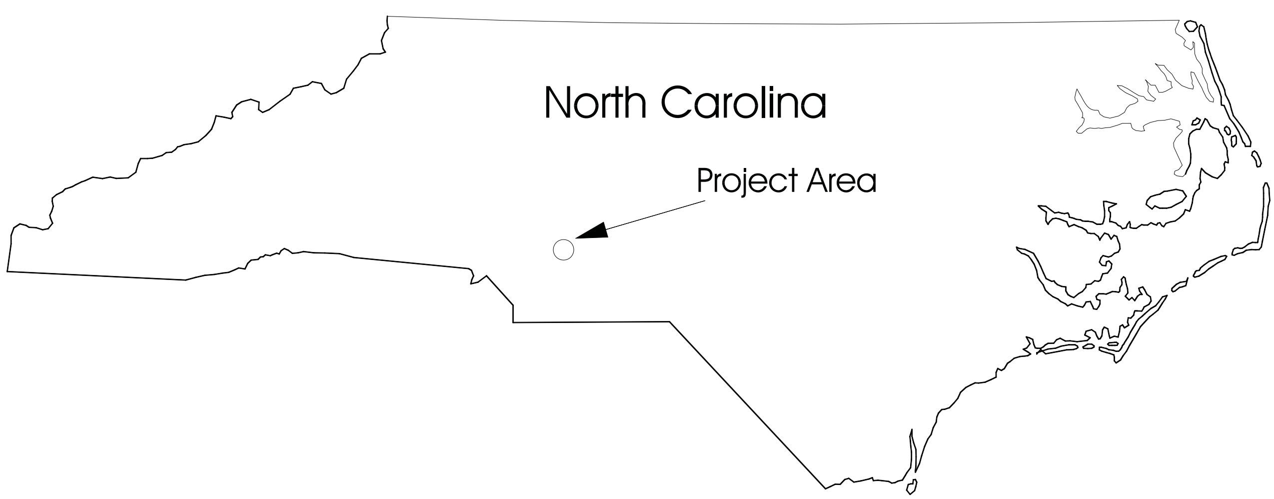

Figure 32: Long Creek (North Carolina) Watershed Project Location

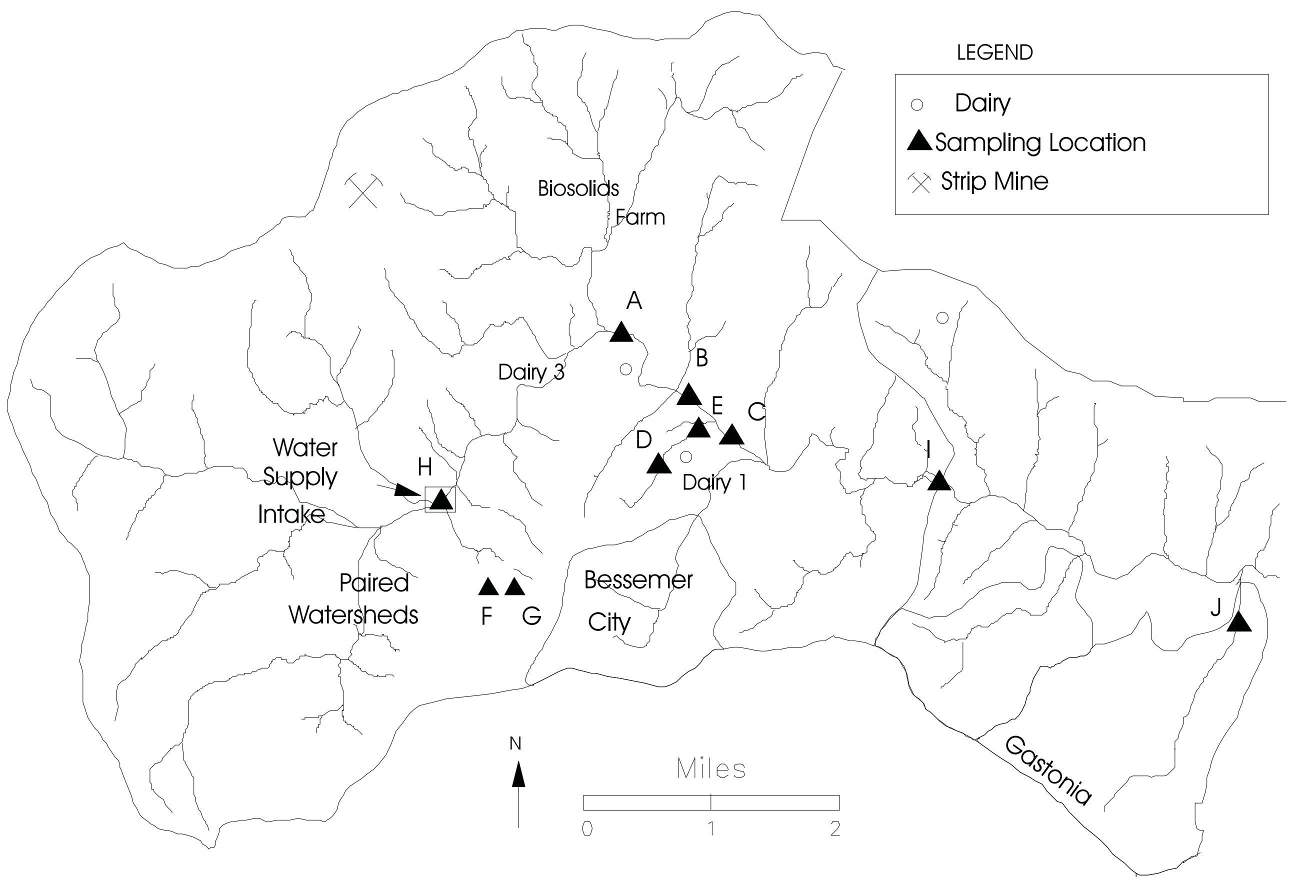

Figure 33: Water Quality Monitoring Stations for Long Creek (North Carolina) Watershed

PROJECT OVERVIEW

The Long Creek Watershed Section 319 National Monitoring Program project (28,480 acres), located in the southwestern Piedmont of North Carolina, consists of an area of mixed agricultural and urban/ industrial land use (Figure 32). Long Creek is a perennial stream that serves as the primary water supply for Bessemer City, a municipality with a population of about 4,888 people (1994 estimate).

Agricultural activities related to crop and dairy production were believed to be the major nonpoint sources of pollutants to Long Creek. Sediment from eroding cropland was the major problem in the upper third of the watershed. At the start of the project, the water supply intake pool had to be dredged quarterly to maintain adequate storage volume, by the end of the project the frequency of dredging had been reduced to less than once per year. Below the intake, Long Creek is impaired primarily by bacteria and nutrients from urban areas and animal-holding facilities.

Below the intake, land treatment involved implementing a comprehensive nutrient management plan on a large dairy farm. Fencing was installed on four farms to exclude livestock from small streams. Stable stream crossings were also installed. More than 340 practices were implemented in the watershed. Land treatment and land use tracking was based on a combination of voluntary farmer record-keeping and frequent farm visits by extension personnel. Data was stored and managed in a geographic information system (GIS).

Water quality monitoring included a single-station, before-and-after-land treatment design near the Bessemer City water intake (Figure 33), upstream and downstream stations above and below an unnamed tributary on Long Creek (B and C), stations upstream and downstream of a dairy farmstead on an unnamed tributary to Long Creek (D and E), and monitoring stations on paired watersheds at a cropland runoff site (F and G). Storm-event and weekly grab samples were collected at various sites to provide the chemical and hydrologic data needed to assess the effectiveness of the land treatment program.

Post-BMP monitoring ended April 2001. The final report was completed in November, 2001.

PROJECT BACKGROUND

Project Area

About 44.5 square miles or 28,480 acres

Relevant Hydrologic, Geologic, and Meteorologic Factors

The average annual rainfall is about 43 inches. The watershed geology is typical of the western Piedmont, with a saprolite layer of varying thickness overlaying fractured igneous and metamorphic rock. Soils in the study area are well drained and have a loamy surface layer underlain by a clay subsoil.

Land Use

Land Use	Acres	%
Agricultural	6,975	24
Forest	15,289	54
Residential	3,985	14
Business/Industrial	1,842	6
Mining	516	2
Total	28,607	100

Source: Jennings et al., 1992

Water Resource Type and Size

The study area encompasses approximately seven miles of Long Creek (North Carolina stream classification index # 11-129-16). Annual mean discharges at the outlet of the study area (I) range between 17 and 59 cubic feet per second over a 40 year period of record.

Water Uses and Impairments

Long Creek is the primary water supply for Bessemer City Water quality impairments include high sediment, bacteria, and nutrient levels. The stream channel near the water supply intake in the headwaters area requires frequent dredging due to sediment deposition. The section of Long Creek from the Bessemer City water supply intake to near the watershed outlet sampling station (Figure 30) is listed as support-threatened by the North Carolina Nonpoint Source Management Program. Biological (macroinvertebrate) habitat is degraded in this section due to the presence of fecal coliform, excessive sediment, and nutrient loading from agricultural and urban nonpoint sources.

Pollutant Sources

Pollutants probably originate mainly from urban and residential areas and rural agricultural areas which include the following dairy farms:

Dairy Name	Cows (#)	Feedlot Drainage
Dairy 4	125	Open lot into holding pond
Dairy 3	85	Open lot across pasture
Dairy 1	400	Under roof and open lot into holding pond

Pre-Project Water Quality

Water quality parameters change with time and location along Long Creek, but generally are close to the following averages:

Fecal Coliform #/100ml	BOD (mg/l)	TSS (mg/l)	TKN (mg/l)	NO_3-N (mg/l)	TP (mg/l)
2100	2	14	0.35	0.41	<0.17

Note: These average values were computed from the analyses of twelve monthly grab samples taken from three locations along Long Creek.

Water Quality Objectives

The objectives of the project were to quantify the effects of nonpoint source pollution controls on:

- Bacteria, sediment, and nutrient loadings to a stream from a working dairy farm;
- Sediment and nutrient loss from a field with a long history of manure application; and
- Sediment loads from the water supply watershed (goal is to reduce sediment yield by 60%).

In addition, biological monitoring of streams attempted to show improvements in biological habitat associated with the implementation of nonpoint source pollution controls.

Project Time Frame

January, 1993 to September, 2001

PROJECT DESIGN

Nonpoint Source Control Strategy

Water Supply Watershed (site H):
Bessemer City purchased 13 acres of cropland immediately upstream of the intake with the intention of implementing runoff and erosion controls. Also, to comply with the North Carolina Water Supply Watershed Protection Act, land use requirements were implemented on land within one-half mile of and draining to the intake. Less strict requirements such as the conservation provisions of the Food Security Act were implemented in the remainder of the watershed.

Up/downstream of Dairy 1 Tributary on Long Creek (sites B and C):
In addition to the BMPs planned for the Dairy 1 farmstead, the control strategy was to design and implement a comprehensive nutrient management plan on the land between the sampling stations.

Dairy 1 Farmstead (sites D and E):
A larger waste storage structure was constructed. Improved pasture management, livestock exclusion from the unnamed tributary, and stream bank stabilization between sites D and E have been implemented. A fenceline feeding system that channels runoff to a waste holding pond was constructed.

Paired Cropland Watersheds (sites F and G):
The control strategy on the paired watersheds involved implementing improved nutrient management on the treatment watershed while continuing current nutrient management and cropping practices on the control watershed. Nutrient management was implemented on the treatment watershed.The number and types of BMPs implemented depended on voluntary farmer participation.

Project Schedule

Site Pr	e-BMP Monitoring	BMP Installation	Post-BMP Monitoring
D & E	8/94-2/96	2/96	3/96-3/01

Water Quality Monitoring

The water quality monitoring effort incorporated the following designs:

- Single downstream station at water supply intake and watershed outlet
- Upstream/downstream design on Long Creek and unnamed tributary
- Paired watersheds on Dairy 1 cropland

Parameters Measured

Biological

Percent canopy and aufwuchs (organisms growing on aquatic plants)

Invertebrate EPT taxa richness and abundance: ephemeroptera, plecoptera, trichoptera, coleoptera, odonata, megaloptera, diptera, oligochaeta, crustacea, mollusca, and other taxa

Bacteria: Fecal coliform (FC) and fecal streptococci (FS)

Chemical and Other

Total suspended solids (TSS)
Total solids (TS)
Dissolved oxygen (DO)
Biochemical oxygen demand (BOD) (1991-92)
pH (1993-1997) & temperature
Conductivity
Nitrate + nitrite (NO_3 + NO_2)
Total Kjeldahl nitrogen (TKN)
Total phosphorus (TP)

Physical stream indicators: width, depth and bank erosion

Covariates

Rainfall, humidity, solar radiation, air temperature, and wind speed
Discharge rate of Long Creek and a tributary
Rainfall at paired watersheds and Dairy 1 farmstead

Sampling Scheme

Water Supply Watershed (Figure 30):
Type: grab (site H)
Frequency and season: weekly from December through May and monthly for the remainder of the year for TS, TSS, FC, FS, temperature, conductivity, DO, pathogens, pH, and turbidity

Upstream/downstream of Dairy 1 Tributary on Long Creek (Figure 30):
Type: grab and storm event (sites B and C)
Frequency and season: weekly from December through May and monthly for the remainder of the year for FC and FS, temperature, pH, conductivity, turbidity, DO, TSS, TP, TKN, and NO_2+NO_3

Annual biological survey for sensitive species at station C only

Dairy 1 Farmstead Storm Event:
Type: grab (sites D and E)
Frequency and season: weekly all year for FC and FS, temperature, pH, conductivity, DO, TSS, TS, TKN, NO_2+NO_3, and TP; storm events for TSS, TS, TKN, NO_2+NO_3, TP, and pathogens

Paired Cropland Watersheds (Figure 30):
Type: storm event (sites F and G)
Frequency and season: stage-activated storm event for runoff, TS, TKN, NO_2+NO_3, and TP

Single Downstream Station at Watershed Outlet (Figure 30):
Type: grab (site I)
Frequency and season: weekly from December through May and monthly for the rest of the year for temperature, pH, conductivity, turbidity, DO, TSS, TP, TS, TKN, NO_2+NO_3, and FC and FS; annual biological for sensitive species

Monitoring Scheme for the Long Creek Section 319 National Monitoring Program Project

Design	Sites or Activities	Primary Parameters	Covariates	Frequency of WQ Sampling	Frequency of Habitat/Biological Assessment	Duration
Single downstream	Water supply watershed	TS TSS FC FS Pathogens	Discharge (weekly)	Weekly (Dec.-May) Monthly	Annually	2 yrs pre-BMP 6 yrs BMP
Upstream/ downstream	Long Creek	TP $NO_3 + NO_2$ TKN TSS FS & FC	Discharge (weekly)	Weekly	Annually (downstream)	2 yrs pre-BMP 4 yrs BMP 2 yrs post-BMP
Upstream/ downstream	Dairy 1 Farmstead	TP $NO_3 + NO_2$ TS TSS FC FS Pathogens	Discharge (continuous) Rainfall Water table	Weekly and storm event		2 yrs pre-BMP 4 yrs post-BMP
Paired	Paired cropland watersheds	TP $NO_3 + NO_2$ TS TKN	Discharge (continuous) Rainfall Water table	Storm event		2 yrs pre-BMP 6 yrs post-BMP
Single downstream	Watershed outlet	TP $NO_3 + NO_2$ TKN TSS FC FS	Discharge (continuous)	Weekly (Dec.-May) Monthly (June-Nov.)	Annually	2 yrs pre-BMP 6 yrs BMP

Modifications Since Project Start

Dairy 2 went out of business and was purchased by the city of Gastonia for conversion to a biosolids application area.

In May – June, 1994, four monitoring wells were installed at the paired watersheds to gain a better understanding of ground water movement. Ten wells were installed between Sites D and E in July, 1996, and have been sampled monthly for nutrients, bacteria, and metals. Approximately 16 wells above Site B were also installed on a Biosolids Application site.

Also, storm-event sampling (Site J) on a small stream draining an urban subwatershed was added. Assessment monitoring for the pathogens *cryptosporidium* and *giardia* was initiated at several locations in the overall Long Creek watershed. The monitoring began in April, 1996 and included collecting grab samples at 12 locations within the watershed. Samples from three current sites, as well as additional sites, were collected and analyzed for indicator organisms such as E. coli, clostridium perfringens, and coliphages and the pathogens *giardia* and *cryptosporidium*.

Sampling at sites A, B,C, and J ceased on March 31, 2001 and sampling at sites D, E, H, and I stopped in July, 2001.

Progress To Date

Farm plans for more than 20 farms within the watershed were developed. Twenty-five Water Quality Incentive Project (WQIP) applications were submitted by landowners in the Long Creek watershed. Eight plans were prepared representing more than $50,000 of BMP installations to control nonpoint source pollution on these sites.

Water Supply Watershed (site H):
A land use survey of the agricultural portion of the water supply watershed was completed.These data were used by the North Carolina Division of Soil and Water Conservation (DSWC) to develop a Watershed Management Plan. Along with developing the plan, DSWC staff used data from 1984 and 1994 to estimate erosion and sediment delivery rates in the watershed. The comparison indicated a 52% reduction in estimated annual erosion and a 51% reduction in sediment delivery to stream channels. However, visual inspection of the watershed tributaries indicates that considerable work remains in controlling stream channel erosion.

A watering system and a stream crossing were installed at a beef farm and fencing was planned on a dairy farm to exclude cows from tributary streams.

Dairy 1 Farmstead (sites D and E):
The Conservation District and the landowner completed the installation of a Waste Holding Pond in September, 1993. North Carolina Agriculture Cost Share Funds were utilized for this project. In addition, an underground main and hydrant with a stationary gun for applying waste efluent on the pasture/hayland areas was installed in July, 1994.

A solid waste storage structure was completed in July, 1993. A watering system was installed in the pastures of the watershed. Fencing for cattle exclusion between monitoring sites D and E was completed and the streamside buffers were planted in pine and hardwood trees. Grass was planted on severely eroding streambanks.

Beginning in June, 1998, the Dec through May sampling scheme at sites A, B, C, H, & I was extended to the whole year thereby replacing the June through November scheme.

DATA MANAGEMENT AND ANALYSIS

Data are stored locally at the county Extension Service office. The data are also stored and analyzed at North Carolina State University using the U.S. Environmental Protection Agency's (USEPA) NonPoint Source Management System software. The North Carolina Division of Water Quality will also store the water quality data in the USEPA STORET system. Data will be shared among all participating agencies for use in their data bases. Data analysis involved performing statistical tests for detection of long term-trends in water quality.

NPSMS Data Summary

STATION TYPE: Upstream Station **PRIMARY CODE:** Site B **YEAR:** 1994

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	3600	1700	810
Fecal Streptoccoci 9230C	U	CFU/100ML	3700	1400	270
Nitrate + Nitrite (353.1 EPA, 1983)	U	MG/L	.53	.49	.45
Nitrogen, Kjeldahl, Total (MG/L as N)	S		.30	.22	.15
Phosphorus, Total (MG/L as P)	S		.30	.18	.10
Total Suspended Solids (2540C 17th SMEWWW)	U	MG/L	8	5.0	4.0

STATION TYPE: Downstream Station **PRIMARY CODE:** Site C **YEAR:** 1994

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	3400	1350	940
Fecal Streptoccoci 9230C	U	CFU/100ML	4150	1650	495
Nitrate + Nitrite (353.1 EPA, 1983)	U	MG/L	.56	.51	.46
Nitrogen, Kjeldahl, Total (MG/L as N)	S		.35	.22	1.7
Phosphorus, Total (MG/L as P)	S		.29	.2	.13
Total Suspended Solids (2540C 17th SMEWWW)	U	MG/L	11	7	3

STATION TYPE: Upstream Station **PRIMARY CODE:** Site D **YEAR:** 1994

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	81000	31000	7700
Fecal Streptoccoci 9230C	U	CFU/100ML	28000	10000	2600
Flow, Stream, Daily mean, (CFS)	S	CFS	0.08	0.05	0.04
Nitrate + Nitrite (353.1 EPA, 1983)	U	MG/L	2.7	2.085	1.405
Nitrogen, Kjeldahl, Total (MG/L as N)	S		3.2	1.3	.615
Phosphorus, Total (MG/L as P)	S		.745	.45	.285
Total Solids (Residue) 2540B (17th SMEWWW)	U	MG/L	145	102	90
Total Suspended Solids (2540C 17th SMEWWW)	U	MG/L	44.5	12.5	2

STATION TYPE: Downstream Station **PRIMARY CODE:** Site E **YEAR:** 1994

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	485000	60000	21000
Fecal Streptoccoci 9230C	U	CFU/100ML	215000	42500	8150
Flow, Stream, Daily mean (CFS)	S	CFS	0.15	0.10	0.08
Nitrate + Nitrite (353.1 EPA, 1983)	U	MG/L	3.275	1.925	1.28
Nitrogen, Kjeldahl, Total (MG/L as N)	S		12.00	2.80	1.65
Phosphorus, Total (MG/L as P)	S		2.865	.815	.59
Total Solids (Residue) 2540B (17th SMEWWW)	U	MG/L	309	139	114
Total Suspended Solids	U	MG/L	71.5	13	3

STATION TYPE: Upstream Station **PRIMARY CODE:** Site H **YEAR:** 1994

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	910	630	270
Fecal Streptoccoci 9230C	U	CFU/100ML	1300	360	100
Total Solids (Residue) 2540B (17th SMEWWW)	U	MG/L	75	68	61
Total Suspended Solids (2540C 17th SMEWWW)	U	MG/L	8	5	3

STATION TYPE: Upstream Station **PRIMARY CODE:** Site B **YEAR:** 1995 (2)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform,	S	CFU/100ML	9	9	9	6
Nitrogen, Kjeldahl, Total (MG/L as N)	S		3	8	6	16
Phosphorus, Total (MG/L as P)	S		22	6	4	1
Total Suspended Solids	U	MG/L	8	3	14	8

STATION TYPE: Downstream Station **PRIMARY CODE:** Site C **YEAR:** 1995 (2)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	7	5	13	8
Nitrogen, Kjeldahl, Total (MG/L as N)	S		3	6	16	8
Phosphorus, Total (MG/L as P)	S		24	5	3	1
Total Suspended Solids (2540C 17th SMEWWW)	U	MG/L	4	15	6	8

STATION TYPE: Upstream Station **PRIMARY CODE:** Site D **YEAR:** 1995 (2)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	7	3	13	8
Fecal Streptoccoci 9230C	U	CFU/100ML	11	20	24	5
Flow, Stream, Daily mean, CFS	S	CFS	91	91	92	91
Nitrogen, Kjeldahl, Total (MG/L as N)	S		19	23	9	1
Phosphorus, Total (MG/L as P)	S		29	16	5	2
Total Solids (Residue) 2540B (17th SMEWWW)	U	MG/L	21	14	11	6
Total Suspended Solids (2540C 17th SMEWWW)	U	MG/L	9	33	7	3

STATION TYPE: Downstream Station **PRIMARY CODE:** Site E **YEAR:** 1995 (2)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	19	10	8	15
Fecal Streptoccoci 9230C	U	CFU/100ML	11	17	17	7
Flow, Stream, Daily mean (CFS)	S	CFS	91	91	92	91
Nitrogen, Kjeldahl, Total (MG/L as N)	S		31	6	14	1
Phosphorus, Total (MG/L as P)	S		29	8	13	2
Total Solids (Residue) 2540B (17th SMEWWW)	U	MG/L	25	12	10	5
Total Suspended Solids	U	MG/L	13	21	12	6

STATION TYPE: Upstream Station **PRIMARY CODE:** Site H **YEAR:** 1995 (2)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	3	12	8	5
Fecal Streptoccoci 9230C	U	CFU/100ML	7	7	9	5
Total Solids (Residue) 2540B (17th SMEWWW)	U	MG/L	16	6	3	7
Total Suspended Solids (2540C 17th SMEWWW)	U	MG/L	8	8	11	5

STATION TYPE: Upstream Station **PRIMARY CODE:** Site B **YEAR:** 1996 (3)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform,	S	CFU/100ML	9	7	9	6
Nitrogen, Kjeldahl, Total (MG/L as N)	S		6	7	9	7
Phosphorus, Total (MG/L as P)	S		27	3	0	1
Total Suspended Solids	U	MG/L	8	5	5	13

STATION TYPE: Downstream Station **PRIMARY CODE:** Site C **YEAR:** 1996 (3)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	14	3	7	7
Nitrogen, Kjeldahl, Total (MG/L as N)	S		7	1	11	12
Phosphorus, Total (MG/L as P)	S		27	3	0	1
Total Suspended Solids (2540C 17th SMEWWW)	U	MG/L	7	10	4	10

STATION TYPE: Upstream Station **PRIMARY CODE:** Site D **YEAR:** 1996 (3)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	4	27	12	8
Fecal Streptoccoci 9230C	U	CFU/100ML	10	23	11	7
Flow, Stream, Daily mean, CFS	S	CFS	85	26	57	196
Nitrogen, Kjeldahl, Total (MG/L as N)	S		26	17	7	2
Phosphorus, Total (MG/L as P)	S		43	7	0	2
Total Solids (Residue) 2540B (17th SMEWWW)	U	MG/L	29	6	11	6
Total Suspended Solids (2540C 17th SMEWWW)	U	MG/L	15	29	4	4

STATION TYPE: Downstream Station **PRIMARY CODE:** Site E **YEAR:** 1996 (3)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	6	8	9	29
Fecal Streptoccoci 9230C	U	CFU/100ML	4	7	9	32
Flow, Stream, daily mean (CFS)	S	CFS	55	73	113	125
Nitrogen, Kjeldahl, Total (MG/L as N)	S		21	6	15	10
Phosphorus, Total (MG/L as P)	S		23	3	16	10
Total Solids (Residue) 2540B (17th SMEWWW)	U	MG/L	13	13	15	11
Total Suspended Solids	U	MG/L	9	19	11	13

STATION TYPE: Upstream Station **PRIMARY CODE:** Site H **YEAR:** 1996 (3)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	6	10	2	13
Fecal Streptoccoci 9230C	U	CFU/100ML	5	9	4	13
Total Solids (Residue) 2540B (17th SMEWWW)	U	MG/L	13	3	6	9
Total Suspended Solids (2540C 17th SMEWWW)	U	MG/L	9	6	7	9

STATION TYPE: Upstream Station **PRIMARY CODE:** Site B **YEAR:** 1997 (4)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform,	S	CFU/100ML	12	12	6	3
Nitrogen, Kjeldahl, Total (MG/L as N)	S		4	4	11	14
Phosphorus, Total (MG/L as P)	S		32	0	0	1
Total Suspended Solids	U	MG/L	10	2	9	11

STATION TYPE: Downstream Station **PRIMARY CODE:** Site C **YEAR:** 1997 (4)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	10	7	10	6
Nitrogen, Kjeldahl, Total (MG/L as N)	S		3	4	14	12
Phosphorus, Total (MG/L as P)	S		32	0	0	1
Total Suspended Solids (2540C 17th SMEWWW)	U	MG/L	7	11	6	9

STATION TYPE: Upstream Station **PRIMARY CODE:** Site D **YEAR:** 1997 (4)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	3	33	13	1
Fecal Streptoccoci 9230C	U	CFU/100ML	9	20	13	7
Flow, Stream, Daily Mean (CFS)	S	CFS	123	44	109	89
Nitrogen, Kjeldahl, Total (MG/L as N)	S		33	13	3	1
Phosphorus, Total (MG/L as P)	S		44	3	2	1
Total Solids (Residue) 2540B (17th SMEWWW)	U	MG/L	24	11	12	3
Total Suspended Solids (2540C 17th SMEWWW)	U	MG/L	21	22	6	1

STATION TYPE: Downstream Station **PRIMARY CODE:** Site E **YEAR:** 1997 (4)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	14	24	7	5
Fecal Streptoccoci 9230C	U	CFU/100ML	12	24	3	10
Flow, Stream, Daily Mean (CFS)	S	CFS	252	33	27	54
Nitrogen, Kjeldahl, Total (MG/L as N)	S		44	3	3	0
Phosphorus, Total (MG/L as P)	S		42	3	3	2
Total Solids (Residue) 2540B (17th SMEWWW)	U	MG/L	21	9	8	2
Total Suspended Solids	U	MG/L	33	12	4	1

STATION TYPE: Upstream Station **PRIMARY CODE:** Site H **YEAR:** 1997 (4)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	3	14	5	12
Fecal Streptoccoci 9230C	U	CFU/100ML	3	7	13	10
Total Solids (Residue) 2540B (17th SMEWWW)	U	MG/L	9	4	2	3
Total Suspended Solids (2540C 17th SMEWWW)	U	MG/L	7	10	6	11

STATION TYPE: Downstream Station **PRIMARY CODE:** Site E **YEAR:** 1998 (5)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	20	22	3	5
Fecal Streptoccoci 9230C	U	CFU/100ML	19	19	5	6
Flow, Stream, Daily mean (CFS)	S	CFS	192	62	44	66
Nitrogen, Kjeldahl, Total (MG/L as N)	S		44	3	5	0
Phosphorus, Total (MG/L as P)	S		44	2	1	5
Total Solids (Residue) 2540B (17th SMEWWW)	U	MG/L	28	14	5	5
Total Suspended Solids	U	MG/L	33	13	3	3

STATION TYPE: Upstream Station **PRIMARY CODE:** Site H **YEAR:** 1998 (5)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	15	11	2	8
Fecal Streptoccoci 9230C	U	CFU/100ML	8	14	6	6
Total Solids (Residue) 2540B (17th SMEWWW)	U	MG/L	29	8	5	8
Total Suspended Solids (2540C 17th SMEWWW)	U	MG/L	9	16	8	7

STATION TYPE: Upstream Station **PRIMARY CODE:** Site B **YEAR:** 1998 (5)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform,	S	CFU/100ML	25	4	0	6
Nitrogen, Kjeldahl, Total (MG/L as N)	S		5	13	7	11
Phosphorus, Total (MG/L as P)	S		29	2	3	2
Total Suspended Solids	U	MG/L	14	5	7	9

STATION TYPE: Downstream Station **PRIMARY CODE:** Site C **YEAR:** 1998 (5)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	22	4	1	8
Nitrogen, Kjeldahl, Total (MG/L as N)	S		9	5	14	8
Phosphorus, Total (MG/L as P)	S		28	2	4	2
Total Suspended Solids (2540C 17th SMEWWW)	U	MG/L	7	13	7	8

STATION TYPE: Upstream Station **PRIMARY CODE:** Site D **YEAR:** 1998 (5)

Chemical Parameters

Parameter Name	Parm Type	Reporting Units	QUARTILE COUNTS 1	2	3	4
Fecal Coliform, Membr Filter, M-FC Broth, 44.5 C	S	CFU/100ML	11	31	5	3
Fecal Streptoccoci 9230C	U	CFU/100ML	13	25	7	4
Flow, Stream, Daily mean, CFS	S	CFS	123	42	95	105
Nitrogen, Kjeldahl, Total (MG/L as N)	S		40	7	2	3
Phosphorus, Total (MG/L as P)	S		43	3	1	5
Total Solids (Residue) 2540B (17th SMEWWW)	U	MG/L	27	8	11	6
Total Suspended Solids (2540C 17th SMEWWW)	U	MG/L	25	17	6	4

Final Results

At the start of the project in 1993, headwater tributaries were contributing significant amounts of sediment to Long Creek. In addition to sediment, tributary streams further downstream were supplying elevated levels of nutrients and bacteria to Long Creek such that Long Creek was considered degraded and of poor water quality for aquatic life support by the time it emptied into the South Fork of the Catawba River. At the start of the project, a coordinated program to monitor water quality throughout key areas of the watershed was initiated. Shortly thereafter a concerted efort, which included information and education activities and enhanced cost share availability to implement BMPs in the watershed was begun and continued for several years.The implementation of BMPs and land use changes resulted in considerable and statistically significant decreases in total phosphorus and bacteria levels in Long Creek during the 8 years of the project.

More than 350 BMPs to treat runoff from 10,000 acres of pasture and cropland were implemented in the watershed. Animal waste management systems were installed to properly handle and apply 7,732,000 gallons of animal waste from four dairy operations.

The implementation of primarily erosion control practices and the conversion of some land from row crop to tree production in the headwaters or water supply watershed of Long Creek resulted in a decrease in the frequency of dredging around the water supply intake for Bessemer City. Prior to 1996, the stream channel required dredging of deposited sediment three to four times per year, but after, the need for dredging decreased to less than once per year.

The implementation of BMPs and changes in land use in the watershed resulted in 75 and 70% decreases in median annual total phosphorus and fecal coliform levels at three downstream monitoring sites on Long Creek.

The closure of the surface mining operation and subsequent draining of several large tailings ponds coincided with decreases in suspended sediment and fecal coliform levels at three monitoring sites on Long Creek.

The installation of livestock exclusion fencing and riparian buffer establishment in the pasture of a large dairy operation resulted in 43, 75, 74, 85% reductions in weekly nitrate+nitrite, total Kjeldahl nitrogen, total phosphorus, and suspended sediment loads from the stream draining the pasture. Fecal coliform and streptococci levels decrease 90 and 80%, respectively following livestock exclusion. Statistical analyses suggested that all the reductions were significant except for nitrate+nitrite.

Monthly sampling of 10 monitoring wells in a dairy pasture documented elevated levels of nitrogen and phosphorus species in ground water beneath heavily use areas of the pasture. Wells along a transect in the riparian buffer show that the buffer was effective at nitrogen removal from ground water, but was not effective at phosphorus removal.

Annual sampling has documented that the abundance and diversity of the macroinvertebrate community at several sites in Long Creek has been increasing indicating an improving trend in water quality.

Monitoring of a small wetland, constructed along an urban stream, documented decreases in the concentrations of petroleum-related polycyclic aromatic hydrocarbons (PAHs) as water from the stream passed through the wetland. However, the wetland had little effect on combustion-related PAHs.

Sampling of cropland soil, stream banks, and stream beds indicated that cropland had considerably higher total phosphorus levels than stream bank or bed material. Storm sampling of two tributaries and Long Creek itself showed that, on average, the phosphorus burden in suspended sediment was an order of magnitude greater than for bedload sediment.

At least 1.5 years of background or pre-treatment water quality monitoring is required to document the effectiveness of nonpoint source controls; however, the start of a project and the initiation of monitoring often prompts landowners to implement improved management practices. Therefore, a concerted effort to explain the timeline of the study must be spent prior to the start of monitoring.

INFORMATION, EDUCATION, AND PUBLICITY

Cooperative Extension Service (CES) personnel conducted public meetings and media campaigns to inform the general public, elected officials, community leaders, and school children about the project and water quality in general. In addition, project personnel made many one-to-one visits to cooperating and non-cooperating farmers in the watershed to inform them of project activities and address any questions or concerns they had.

An education plan developed for Gaston County included activities in the Long Creek watershed. Also, a Stream Watch group had been formed to 1) educate other watershed residents and 2) conduct quality monitoring by volunteers. Project overviews were presented at state, local, regional, and international water-related conferences.

The Gaston County Conservation District is continuing an extensive natural resources education outreach program to local schools. Eighty-five percent of schools (100% of elementary and junior high schools) located in the Long Creek watershed participate in District programs.

The information and education effort was expanded to an urban watershed that is drained by Kaglor Branch. Streambank stabilization practices and a stormwater wetland were installed in an urban park near the outlet of the Kaglor watershed. A boardwalk to facilitate viewing of various features of the wetland is in place and educational displays along the boardwalk were planned.

TOTAL PROJECT BUDGET

The estimated budget for the Long Creek Watershed National Monitoring Program project for the life of the project is:

Project Element	Funding Source ($)			
	Federal	State	Local	Sum
Proj Mgt	340,300	147,360	98,240	585,900
I & E	0	20,000	80,000	100,000
L T	0	370,000	80,000	450,000
WQ Monit	561,186	0	12,000	573,186
TOTALS	901,486	537,360	270,240	1,709,086

Source: Jennings et al., 1992

A 319(h) grant has been awarded to provide cost share for BMP implementation.

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

State and probably federal United States Department of Agriculture (USDA) - Agricultural Conservation Program cost share programs will be essential for the implementation of BMPs. The provisions of the North Carolina Water Supply Watershed Protection Act (see section below) and the threat of additional regulation will motivate dairy farmers to implement animal waste management and erosion control BMPs.

OTHER PERTINENT INFORMATION

The North Carolina Water Supply Watershed Protection Act, as applied to this class of watershed, requires that 1) agricultural activities within one-half mile of and draining to a water intake maintain at least a 10-foot vegetated buffer or equivalent control and 2) animal operations of more than 100 animal units use BMPs as determined by the North Carolina Soil and Water Conservation Commission. Other regulations in the Act apply to activities such as forestry, transportation, residential development, and sludge application.

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Oklahoma

Peacheater Creek
Section 319
National Monitoring Program Project

Figure 34: Peacheater Creek (Oklahoma) Project Location

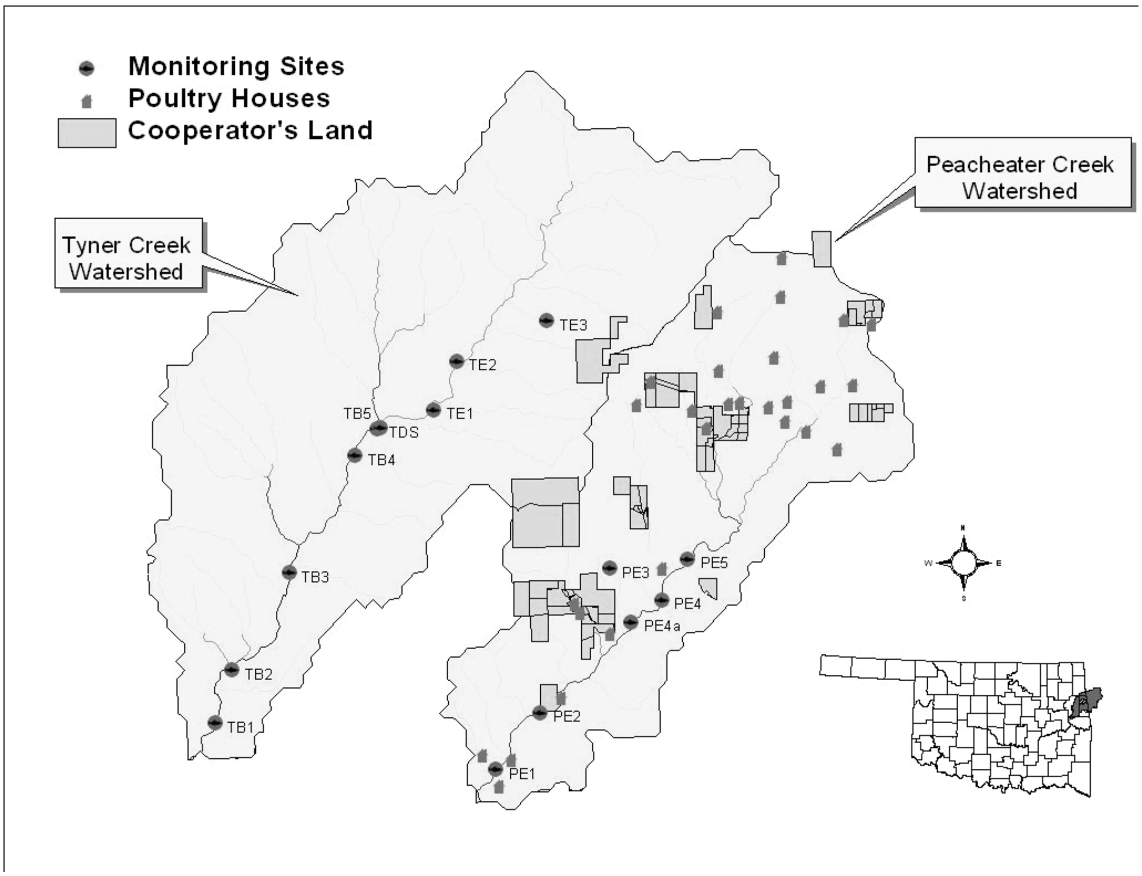


Figure 35: Water Quality Monitoring Stations for Peacheater Creek (Oklahoma) Watershed

PROJECT OVERVIEW

Peacheater Creek is located in eastern Oklahoma (Figure 34). The watershed is primarily pastureland and forestland with little cropland or rangeland. There are 65 poultry houses (locations of complexes or single houses shown in Figure 35), four dairies, and numerous beef cattle producers in the watershed. Cattle traffic and forestry activities are known to be major contributors to streambank erosion. Streambank erosion was quantified to estimate loads of sediment, total nitrogen, and total phosphorus contributed to each stream. Large gravel bars generated from streambank erosion impair fish and macroinvertebrate habitat quality. Baseflow monitoring shows intermittent high nutrient levels contribute to creek eutrophication. Impacts downstream of Peacheater Creek include streambank erosion, habitat degradation, nuisance periphyton growth in Baron Fork and the Illinois River, and phytoplankton blooms and summer hypolimnetic anoxia in Lake Tenkiller.

The project team has completed an extensive natural resource and stream corridor inventory. Data from the inventory were digitized and mapped in a geographic information system. A distributed parameter watershed model was used to determine critical areas for treatment. Critical areas included pasturelands, riparian areas, and dairies. Nutrient management planning was completed to improve poultry and dairy waste utilization on cropland and pastureland.

Chemical, biological and habitat monitoring was completed for tributaries and the main stem stream. The project was designed as a paired watershed study comparing Peacheater Creek to Tyner Creek watershed, the control watershed. The program compared water quality data collected in the two streams before (preimplementation) and after (post-implementation) the implementation of best management practices. Sufficient data were collected to develop statistically significant relationships between the two watersheds using water quality variables. This pre-implementation calibration enabled a post-implementation comparison that linked improvements in water quality to implementation of best management practices as opposed to differences in weather patterns between the two periods.

Following calibration, implementation of best management practices began in 2000 to address the animal waste and erosion issues in the watershed. Implementation was challenged by several factors including drought, poor economic returns, and in some cases, resistance to the program. Despite these challenges, installation of practices was completed in the winter of 2002.

Post-BMP implementation monitoring, which began in January 2003, was completed in August 2005. Results indicated significant improvements in water quality due to the implementation of the project. The final project report is expected to be finalized in September 2007. Upon approval, the final report will be available from the Oklahoma Conservation Commission Website at: www.ok.gov/okcc/Agency_Divisions/Water_Quality_Division/WQ_Reports/WQ_Project_Reports/WQ_Reports:_Watershed_Specific.html.

PROJECT BACKGROUND

Project Area

The Peacheater Creek watershed area is 16,209 acres. The creek is a tributary of Baron Fork, a tributary of the Illinois River, which is impounded to form Lake Tenkiller.

Relevant Hydrological, Geological, and Meteorological Factors

Average baseflow for Upper Tyner and Peacheater Creeks is 2-13 cubic feet per second. Rocks in the project area are chert rubble. Surface rocks are from the Boone Formation, the Osage Series, and of the Mississippian Age. Geology in the basin is karstic.

Project area soils are generally gravelly silt loams with high infiltration rates.Typical slopes in the floodplains range from 2-5%. A large portion of the watershed is steeply sloped land (15-40% slopes).

Land Use

Peacheater Creek has 65 poultry houses, four dairies and 176 private residences. Upper Tyner Creek has 19 poultry houses, three dairies, and 150 private residences. The 65 poultry houses in the Peacheater Creek watershed have a total capacity of approximately 1,290,000 birds. Five broods a year are produced for a total annual population of approximately 6,450,000 birds. Types of poultry grown in the watershed include broilers, layers, pullets, and breeder hens. In addition, at least 1,200 beef cattle graze in the watershed.

The percentage of land use by major categories in Peacheater Creek is:

Land Use	%
Forest land	36
Grassed pastureland	14
Brushy pastureland	40
Cropland	3
Rangeland	7
TOTAL	100

Water Resource Type and Size

Water resources of concern are the Illinois River and Lake Tenkiller, a downstream impoundment of the river. The project water resource is Peacheater Creek, a fourth order stream, with baseflow ranging from 5 to 10 cubic feet per second. Peacheater Creek flows into Baron Fork, a tributary of the Illinois River upstream of Lake Tenkiller. The Illinois River is classified as a State Scenic River in Oklahoma.

Water Uses and Impairments

Beneficial uses for Peacheater Creek include recreation and aquatic life support. Such use of Peacheater Creek is threatened by nutrient enrichment and loss of in-stream habitat.The Illinois River has been degraded by stream bank erosion, loss of habitat, reduced water clarity, and nuisance periphyton growth. Lake Tenkiller experiences phytoplankton blooms and summer hypolimnetic anoxia which threatens the fishery, water supply, and recreational resource. Peacheater has been recommended for listing for impaired primary body contact recreation use based on Enterococcus concentrations in Oklahoma's 2006 Integrated Report.

Pollutant Sources

Primary sources of pollution are suspected to include poultry houses, the distribution of poultry litter, dairies, and other livestock activities in the treatment and control watersheds (Peacheater Creek and Tyner Creek Watersheds). Other sources of nutrients could include septic systems of private residents.

The gravel which degrades in-stream habitat is also a pollutant. Its primary source is believed to be streambank erosion. This streambank erosion is largely due to riparian degradation or removal. Forestry activities and other clearing on steep slopes are an important secondary source of gravel.

Pre-Project Water Quality

Baseflow monitoring for both Peacheater Creek and Tyner Creek for 1990-1992 indicated high dissolved oxygen levels (generally well above 6 mg/1), suggesting little concern about oxygen demanding pollutants. Turbidity was very low, with all samples collected less than 8 NTU. Specific conductivities ranged from 120 to 183mS/cm. Nitrate-nitrogen concentrations for Peacheater Creek ranged from 0.82 mg/l to 3.4 mg/l. Nitrate-nitrogen levels near 3 mg/l may be considered elevated if significantly above background for the area. Total Kjeldahl nitrogen (TKN) levels ranged from the detection limit of 0.2 mg/l to 1.5 mg/l. Eleven of the thirty TKN observations were equal to or greater than 0.3 mg/l, which is sufficient organic nitrogen to promote eutrophication. Generally, TKN concentrations for Tyner Creek were lower than Peacheater Creek. Three of the thirty baseflow samples showed total phosphorus (TP) levels above 0.05 mg/l, which may be considered a minimum level for eutrophication. Storm sample TP concentrations are elevated. Storm sample TN concentrations are similar to baseflow concentrations.

Both Peacheater and Tyner Creeks have sections of poor in-stream habitat. Large chert gravel bars cover expansive portions of the streambed in Peacheater Creek. These gravel bars continue to grow and shift following major runoff events. The gravel covers natural geologic and vegetative substrates reducing habitat quality for macroinvertebrates and fish. Peacheater Creek has extensive streambank erosion due to cattle traffic and forestry activities. The streambank erosion is believed to be further accelerated by the destabilization of the stream channel by the growing bed load.

Evaluation of the chemical, habitat, and biological data suggests that streambank erosion and bedload may be more problematic for Peacheater and Tyner Creeks than nutrient loading. It appears that although nutrient loading translates to water quality problems downstream, the most significant problems in Peacheater and Tyner are related to sedimentation. In other words, although nutrient concentrations are significantly above background levels, lack of available habitat due to bedloads which sometimes result in entirely subsurface flow is a more significant problem than periphyton growth and dissolved oxygen concentrations.

Water Quality Objectives

Restore recreational and aquatic life beneficial uses in Peacheater Creek and minimize eutrophication impacts on the Illinois River and Lake Tenkiller.

Project Time Frame

1995 to 2005. The Section 319 NMP project approval date was October, 1995.

PROJECT DESIGN

Nonpoint Source Control Strategy

Land treatment implemented through the project was designed to 1) reduce nutrient loading to the Illinois River system and Tenkiller Lake and 2) restore streambanks with the objective of improving pool depth and reducing gravel loading in the system. Implementation of land treatment was delayed by design until the calibration phase was finalized.

Eleven landowners participated in the project. Two were dairy producers, three combined dairy and poultry, two had poultry houses and beef cattle, and four had beef cattle. Acreage included in the program totaled 3,643 of the total 16,209 or twenty-two percent of the watershed.

All the operating dairies have animal waste management plans. A total of four waste management systems, including waste storage structures, were completed. Eight planned grazing systems were implemented. Three heavy use areas were installed to reduce sediment and nutrient runoff from feeding and loafing areas. Travel and or feeding lanes were installed at two dairies.

One hundred percent of the poultry producers have current Conservation Plans that include animal waste plans. Fifteen mortality composters were recommended and five were installed through the program. One litter storage building was installed. The conservation plans recommend planned grazing systems, buffer zones adjacent to streams, watering facilities, critical area vegetation, and riparian area establishment that exclude livestock access to the streams. The animal waste plans made recommendations on the amount of animal waste that could be applied to the soil according to the soil and litter test. Poultry producers in the watershed established one new buffer, four riparian buffer zones, four new pastures and installed 20 cross-fences for pasture management, and completed litter transport to farms where soil tests indicate litter spreading is allowable.

Twelve alternative water sources were installed, either ponds or freeze-proof tanks. The purpose of these alternative sources was to replace fenced off original water sources, or in the absence of fences, to encourage livestock to stay out of the creek, thereby protecting riparian areas. In addition, three ponds were fenced to restrict livestock access and prevent fouling.

One septic tank was installed to reduce NPS pollution from onsite wastewater Although the exact percentage of watershed residents with inadequate onsite wastewaters systems is unknown, previous projects in similar watersheds suggest that as many as 70% of watershed residents have inadequate, or nonexistent onsite wastewater systems.

The land treatment and monitoring plan is summarized:

Project Schedule

Site	Pre-BMP	BMP Installation	Post-BMP	BMPs
Peacheater Creek[T]	12/95 – 8/98	3/99 – 12/02	1/03-9/05	Nutrient management (w/ respect to poultry litter), streambank stabilization
Tyner Creek[C]	12/95 – 8/98		1/03-9/05	

[T]Treatment watershed
[C]Control watershed

Water Quality Monitoring

The monitoring design for the Peacheater Creek 319 National Monitoring Program project was a paired watershed design. Peacheater Creek watershed treatment was paired withTyner Creek watershed (control) (Figure 33). Water quality monitoring occurred at each watershed outlet. Habitat and biological monitoring occurred in both streams at appropriate locations.

Variables Measured

Biological

Periphyton productivity
Fisheries survey
Macroinvertebrate survey
Intensive and extensive habitat assessment
Bank erosion and bank soil sampling

Chemical
Dissolved oxygen (DO)
Specific conductance (SC)
pH
Alkalinity
Turbidity
Total Kjeldahl nitrogen (TKN)
Nitrate + nitrite nitrogen (NO2 and N03)
Total phosphorus (TP) and ortho-phosphorus (oP)
Total suspended solids (TSS)
Sulfate
Chloride
Hardness

Covariates (Explanatory Variables)
Stream discharge
Precipitation

Sampling Scheme

Pre-implementation monitoring consisted of chemical, biological, and habitat monitoring begun in December 1995 on Peacheater and Tyner Creeks. Chemical variables were monitored monthly from July through January, weekly during February through June, and during storm events for a duration of 20 weeks. Storm event monitoring was stage-activated and samples were taken continuously over the hydrograph. Concentration samples were flow-weighted composites.

Biological monitoring varied considerably with assemblage being sampled. Periphyton productivity was measured in the summer and the winter. Macroinvertebrates were monitored twice per year: once in the summer and once in the winter. Fish were intensively monitored every other year. Pool dwelling fish were inventoried quarterly. Future frequency will be determined by variance of parameters. Extensive habitat, based on transects every 100 meters over the stream length was monitored on alternate years. Bank erosion and bank soil sampling were monitored on alternate years. Permanent transects have been established to monitor channel morphology and streambank erosion.

Post-implementation monitoring to document effects of BMP installation on water quality was conducted from January 2003 through August 2005. The post-implementation monitoring program was identical to pre-implementation monitoring with regard to site location, parameters measured, and frequency of monitoring events. Post-implementation monitoring continued for a minimum of two years or until such time sufficient data was collected to verify whether a change in water quality had occurred.

Land Treatment Monitoring

BMP implementation was tracked by measurement and record of structural controls put in place to control nutrient and sediment in the watershed and by estimate of the pounds of manure managed or removed and these effects on nutrient budgets in the watershed.

Modifications Since Project Start

Since commencing the project, interactions with landowners in the Peacheater Creek watershed revealed considerable resistance and even hostility towards interaction by any outside source, especially governmental. Landowners in a majority of the critical areas of the watershed (mainly riparian areas) were particularly resistant. Consideration was given to switching implementation activities to the Tyner Creek watershed, leaving Peacheater as the control. Though the original intent was to focus implementation in the most impaired of the two watersheds and thus bring about the most dramatic improvement, local opposition threatened this design. Initial contacts with landowners in theTyner Creek watershed revealed much lower resistance to outside aid.

A public meeting was held January 26, 1996 in the Peacheater Creek Watershed to inform watershed landowners about the results of the monitoring and the problems the results suggested. Every landowner residing in the watershed attended (over 60 people). The project team then spoke about planned implementation practices and cost-share rates offered to correct some of the problems. Landowners were encouraged to respond with what they felt were the problems in the watershed and whether they approved of the actions the project team was proposing. Based on the outcome of this meeting, it was decided the Peacheater Creek would remain as the Implementation Watershed.

Monitoring Scheme for the Peacheater Creek Section 319 National Monitoring Program Project

Design	Sites or Activities	Primary Parameters	Covariates	Frequency of WQ Sampling	Frequency of Habitat/Biological Assessment	Duration
Paired	Tyner Creek[C] Peacheater Creek[T]	Periphyton productivity Fisheries survey Macroinvertebrate survey Stream habitat quality Bank erosion	Stream discharge Precipitation		Summer / winter Alternate years Summer / winter As needed Alternate years	2 yrs. pre-BMP 2 yrs. post-BMP
		Turbidity DO TKN $NO_3 + NO_2$ TP and OP TSS		Monthly Storm event		

[C]Control watershed
[T]Treatment watershed

Land Treatment Progress to Date

The implementation of BMPs was completed in 2002, although contracts to maintain practices extended through 2004. Eleven landowners participated in the program. The following is a breakdown of the practices planned and implemented.

PRACTICE	PLANNED	COMPLETED
Cross Fencing for Pasture Management	27,170 ft.	13,598 ft.
Pond Excavation	5 ponds totaling 7,250 yd^3	2 ponds totaling 1,496 yd^3
Fence Pond	2,900 ft.	400 ft.
Fencing Around Pond	2,900 ft.	400 ft.
Buffer Strip	27.52 acres	7 acres
Buffer Strip/Filter Strip Fencing	4,400 ft	1,800 ft.
Freeze Proof Tanks- Alternate Water Source	14	14
Lagoon Excavation	3 totaling 3,548 yd^3	3 totaling 2,953 yd^3
Fence Lagoon	1,000 ft.	0 ft.
Pasture Management Incentives	902 ac -	433 ac
Heavy Use Protection	4 -	3
Lane Fencing	4,000 ft.	2,560 ft.
Poultry Litter Storage Facility	2 -	2
Septic Systems	2 -	1
Nutrient Management	405 acres	94 acres
Proper Waste Utilization	418 acres	259* acres
Riparian Areas	61 ac -	49 ac
Riparian Fencing	5,900 ft.	4,000 ft.

*management of these 259 acres resulted in removal of at least 22,921 pounds of phosphorus from the watershed.

Implementation was completed in December 2002, although incentive payments continued through December 2004. Eleven producers participated in the program, and over seventy practices were put in place. Although approximately 35% of the watershed landowners participated in the program, only 66% of practices originally planned were implemented. Landowners cited economics as the primary factor leading to the failure to install planned practices.


Figure 34.

Failure to install originally planned practices led to unobligated monies but a lack of willing landowners. Therefore, landowner needs were evaluated to come up with practices that would solve landowner problems and protect water quality. The solution was winter feeding areas (Figure 34). Through installation of these feeding areas, landowners had a facility to feed livestock in a healthier, less wasteful, more convenient area. At the same time, cattle were encouraged to concentrate in an area farther away from the stream where waste products could be collected and disposed of more appropriately.

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

Chemical variables will be entered into the U.S. Environmental Protection Agency (USEPA) STORET system, the Oklahoma Conservation Commission (OCC) Water Quality Data Base and OCC office library. Biological variables will be entered into the OCC Water Quality Data Base, the collections stored at the OCC, and archived in the BIOS data base.

The OCC will prepare data and summary statistics for entry into the USEPA Nonpoint Management System Software (NPSMS).

Final Results

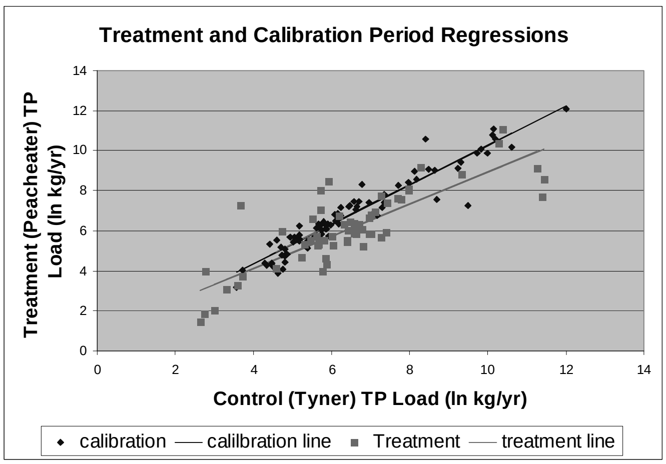
The pre-implementation monitoring verified that Peacheater and Tyner Creeks have similar habitat, water quality, and biological communities. A statistically significant relationship has been defined between water quality analysis for Tyner and Peacheater Creeks. This relationship is based on USEPA requirements for paired watershed studies and signifies completion of the calibration phase of the project. The creeks respond similarly to disturbances such as high flow events. Both creeks have elevated nutrient concentrations and phosphorus is the primary nutrient of concern. Both creeks also have problems with riparian destruction which are resulting in bank erosion and increased bedload. The creeks are literally filling in with gravel from the cherty soils. This bedload is highly mobile during storm events which further exacerbates the bank erosion problem, causing more bank erosion and making it difficult for stabilizing vegetation to develop. Streambank erosion contributes significantly to the total nutrient load of the creeks. Although anthropogenic influences are more intensive in the Peacheater Creek watershed, overall landuse is still very similar between watersheds.

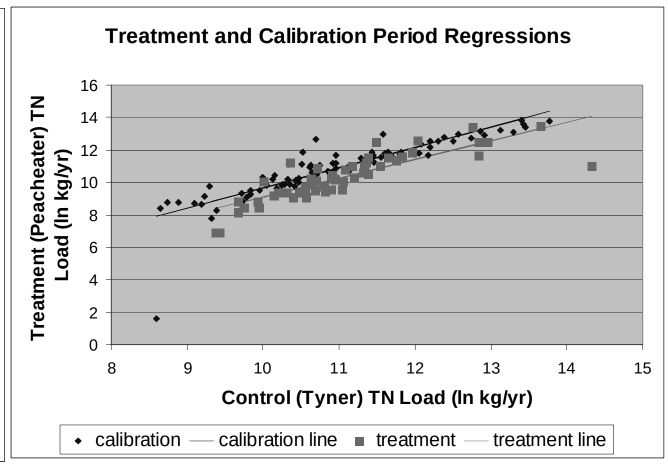
During the course of the project and often as a result of the problems encountered, several lessons have been learned that can be incorporated into future projects. These include:

- The most significant water quality problems may be different from those initially suspected.

- Insure that a reasonable number of landowners, particularly those in critical areas or with large holdings, are receptive to the program before you begin.
- Prevent partial implementation of recommended practices. Consider an “all or nothing” clause for contracts.
- Select practices that protect water quality, but that also meet the specific needs of landowners- be flexible.
- Develop a means of effective communication among all the people involved in the project.

Two years of post-implementation monitoring began in 2003 in order to document water quality changes due to installation of best management practices. Analysis of results indicated statistically significant reductions in total phosphorus loading (66%) (Figure 35), total phosphorus concentration (10%), nitrate concentrations (23%), nitrite concentration (54%), and total nitrogen loading (57%) (Figure 36), due to the implementation of practices. Analysis also suggested a significant increase in dissolved oxygen concentrations (3%). Impacts of these water quality changes were more significant during baseflow conditions than highflow conditions.

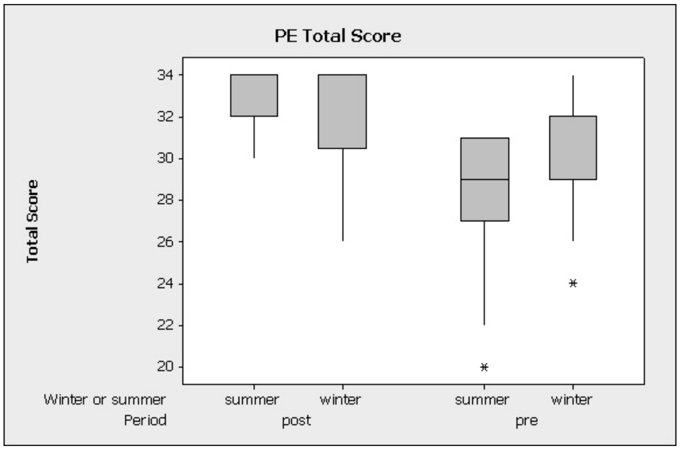


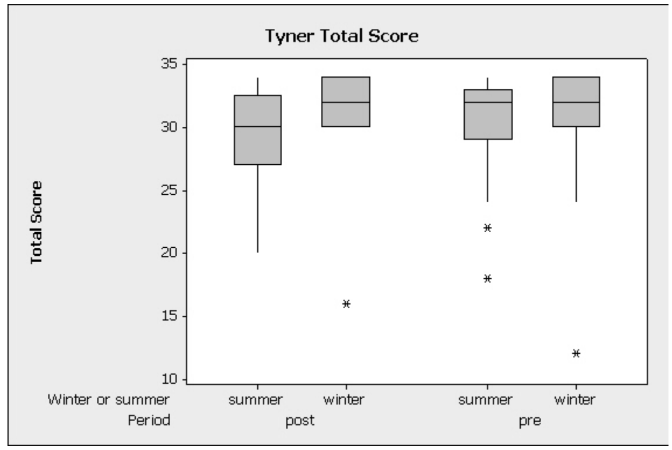


Comparison of habitat and fish community metrics and scores did not indicate any significant diferences between pre- and post-implementation overall scores; however, comparison of individual metrics suggested that bank stability and bank vegetation may have been increased in Peacheater following implementation. However, canopy cover in Peacheater may have decreased following implementation. The cause of this decrease is not immediately evident based on examination of aerial photographs from the two periods of record.

The increased bank stability and bank vegetation evident in habitat scores is further supported by bank erosion studies which document significantly less bank erosion and mutrient loading due to bank erosion during the post-implementation period.

The effects of these improvements were also evident upon analysis of the benthic macroinvertebrate community. Although overall health of the community was well in line with reference streams for the area, post-implementation summer benthic community total score improved significantly in Peacheater Creek, but did not change in Tyner Creek. The summer community is often the poorer of the two indexing periods; therefore it is important that the summer community was improved, but also significant that it was improved to a level equal to that of the winter community





INFORMATION, EDUCATION, AND PUBLICITY

Several methods were used to educate the general public and agricultural community about pollution control and water quality management. A primary concern in the watershed was animal waste and nutrient management. Producer meetings were used to provide updates on regulations for concentrated animal feeding operations, which include egg laying poultry operations and various types of poultry for flesh production. Records on waste clean-out operations and litter applications were recommended. Cooperative Extension Service and the US Department of Agriculture Natural Resources Conservation Service worked together to promote the proper use of waste holding ponds for dairies in the watershed. Soil nutrient sampling was provided free-of-charge to identify fields with excessive phosphorus levels. Litter testing was also available for broiler and laying operations. Litter application demonstrations are used to illustrate nutrient management principles on bermuda grass and fescue.

Rainfall simulator studies and demonstrations have been held to show effects of animal waste best management practices (BMPs) on water quality. The effect of nutrient application rate and filter strips was demonstrated during a summer field day. Future rainfall simulator study demonstrations are planned.

A 4-H Day camp for three days has been completed annually to provide water quality education. An inner tubing excursion was used to show the extent and effect of stream bank erosion on stream habitat quality. Youth camp participants also tested the chemical quality of Peacheater Creek using portable kits. Resource Fairs for students were held in 2000 and another scheduled for 2001.

TOTAL PROJECT BUDGET

The estimated budget for the Peacheater Creek National Monitoring Program project for the life of the project is:

Project Element	Funding Source ($)			
	Federal	State	Local	Sum
WQ Monitoring	250,000	166,667	NA	416,667
Flow Monitoring	100,000	66,670	NA	166,670
Implementation	108,000	72,000	NA	180,000
Post Implementation Monitoring	19,000	12,667	NA	31,667
TOTALS	477,000	318,004	NA	795,004

Source: Phillip Moershel (Personal Communication), 1996

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

This project compliments a larger program to improve the water quality of the Illinois River and Lake Tenkiller. An effort to establish a Total Maximum Daily Load (TMDL) for the system is nearing completion, which may build upon the results in Peacheater Creek. The TMDL will recommend significant nonpoint source reductions for the watershed. Successes and failures in the Peacheater watershed will guide the larger watershed implementation efforts.

The USDA Natural Resources Conservation Service (NRCS) is an important partner in State Programs to reduce Nonpoint Source Pollution. The NRCS implemented additional practices in the watershed through the EQIP program. Also through this program, 96 producers with poultry, dairy cattle, or beef cattle operations have developed waste management plans for their operations. As a result, it was estimated that over 63% of producers in the watershed reduced their waste application rates and/or quit applying waste to unsuitable areas.

OTHER PERTINENT INFORMATION

None.

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Oregon

Upper Grande Ronde Basin
Section 319
National Monitoring Program Project

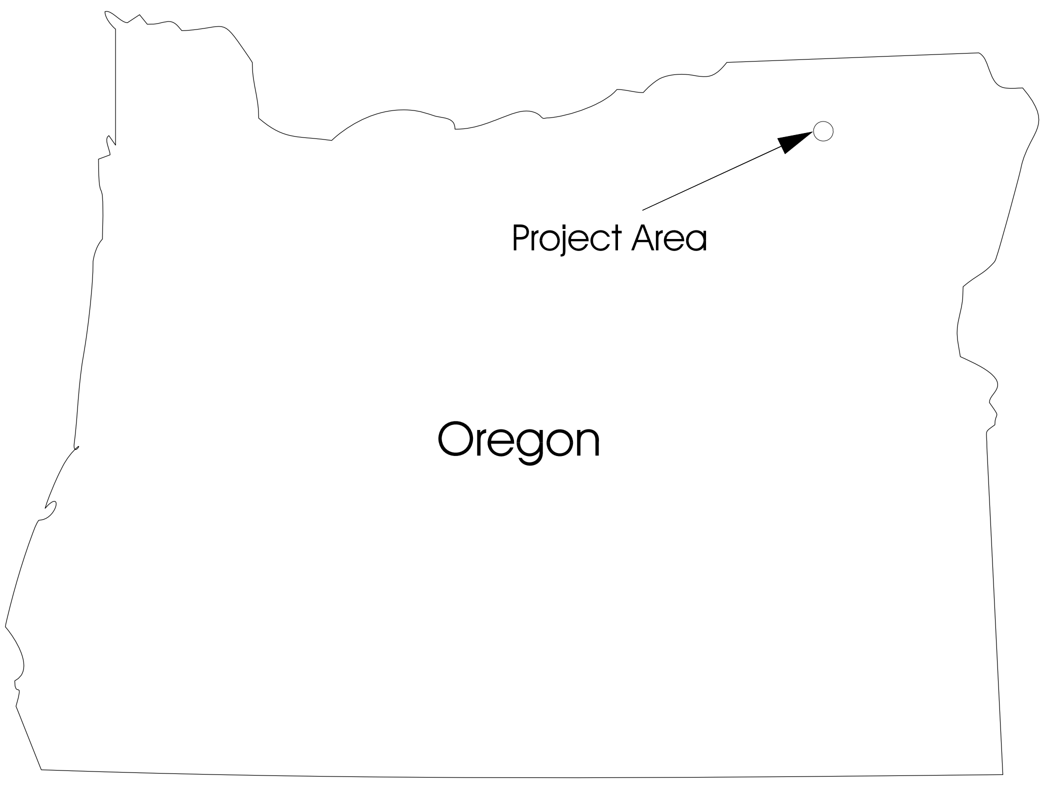

Figure 36: Upper Grande Ronde Basin (Oregon) Project Location

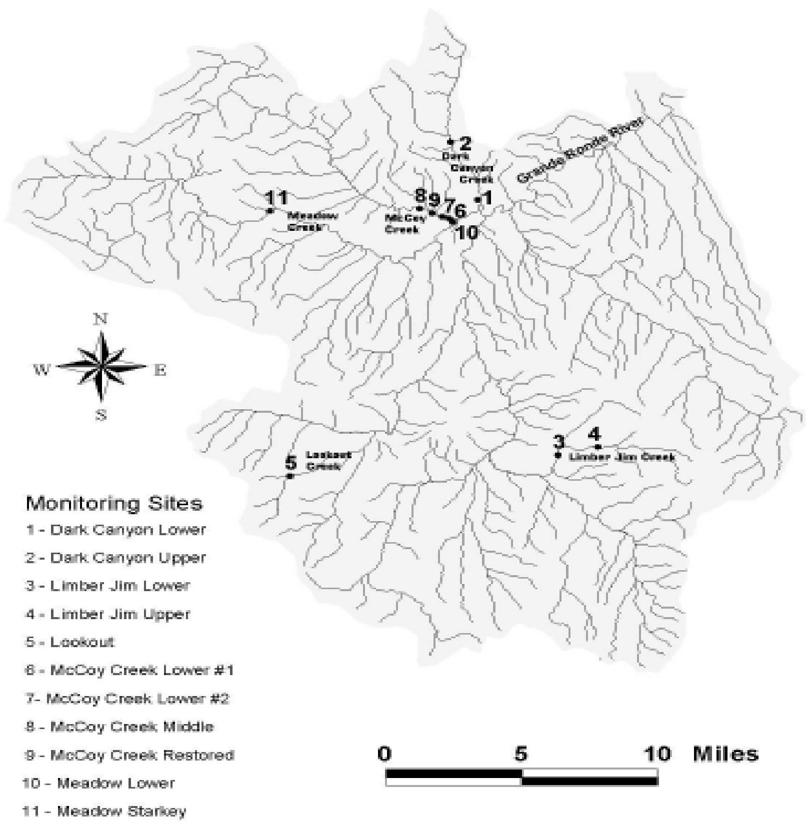

Figure 37: Biological and Water Quality Monitoring Stations in Selected Watersheds within the Upper Grande Ronde Sub-basin (Oregon)

PROJECT OVERVIEW

The Upper Grande Ronde Basin (695 square miles) is located in the Columbia Intermontane Central Mountains of northeast Oregon (Figure 36). The Grande Ronde River traverses primarily forest and grazing lands draining into the Snake River, a major tributary of the Columbia River. The study area is included in the ceded lands of the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), and is a culturally significant area.

The watershed has historically been important for anadromous fish production, but from about 1970 to the present fish numbers have been declining. Land use activities, such as grazing, timber harvest, road construction, and mining, have been cited as contributing to fish and other aquatic species' habitat degradation (Bach, 1995).

Water temperature and loss of physical habitat have been identified by the US Forest Service (USFS) as the most important factors affecting spring Chinook salmon and steelhead populations (Hafele, 1996). An important cause of increased stream temperature is the loss of riparian vegetation. It has been estimated that land use activities have reduced stream shading from a potential of 80% to a total of 28% (Hafele, 1996). As a result of these and other water quality violations (primarily pH), the Grande Ronde has been listed by the Oregon Department of Environmental Quality (ODEQ) as water quality limited.

From 1993 through 2005, ODEQ conducted a water quality monitoring program has been conducted by ODEQ to evaluate the basin's biological communities and the physical and chemical factors that affect them. This monitoring project was part of the US Environmental Protection Agency (USEPA) Section 319 National Monitoring Program. The monitoring effort targeted five subbasins within the Upper Grande Ronde Basin. Water quality monitoring was based on a paired watershed design for two highly impacted basins, while other basins represented a range of less impacted control sites. Additionally, an upstream/downstream approach was used to evaluate changing land use along individual streams. The major monitoring components included habitat, macroinvertebrates, fish and water quality. Significant measures of success were reduction in maximum summer temperatures, improved habitat for aquatic life, and increased biotic index scores for fish and macroinvertebrates. Restoration work was focused on McCoy Creek, a tributary of Meadow Creek.

The Upper Grande Ronde Basin 319 National Monitoring Program project has evolved from local, state, and tribal cooperation. In 1995, a watershed assessment was completed by ODEQ under the Oregon Watershed Health Program (Bach, 1995). In 2000 ODEQ developed Total Maximum Daily Load (TMDL) waste load allocations for the basin and is now implementing the management plan for the TMDL. The USFS has developed a restoration plan for anadromous fish in the Upper Grande Ronde Basin and identified desired future conditions (Hafele, 1996). Stream habitat restoration activities aimed at improving habitat conditions have been implemented on McCoy Creek in cooperation with the landowner and CTUIR.

The project wrapped up seven years of post-BMP monitoring in 2005. The final project report has been completed (Whitney, 2007). Other technical reports have been published using project results and are available on-line at http://wwwdeq.state.or.us/lab/techrpts/bioreports.htm. Future monitoring at five year intervals may be conducted for long term tracking of restoration effectiveness.

PROJECT BACKGROUND

Project Area

The Upper Grande Ronde Basin Monitoring Project consists of ten study sites in five subbasins located within the Blue Mountain ecoregion (Omernick, 1987). The total area of the Upper Basin is approximately 695mi^2 (1,800 km^2), with 1,000 mi (1,609 km) of stream (Bach, 1995).

Relevant Hydrologic, Geologic, and Meteorological Factors

The study region is characterized by a semi-arid climate and rugged mountains in the headwater areas. Temperature and precipitation vary with elevation, which ranges from approximately 2,300 to 7,800 ft (700 to 2,380 m) The climate is characterized by warm, dry summers and cold, moist winters. At elevations above 5,000 ft (1,524 m), average annual precipitation is greater than 50 in (127 cm), and usually occurs as snow (Bach, 1995).

Slopes vary throughout the basin, with relatively gentle slopes in the valley and steeper slopes (as high as 90% in some areas) in the upper parts of the watershed (Bach, 1995). The combination of slope, rainfall, and snowpack can lead to large runoff events in the mid and upper elevations.

Land Use

Approximately 60% of the land in the Grande Ronde Basin is devoted to forestry, while approximately 36% is agricultural. Land use activities such as grazing, timber harvesting, road construction, and livestock practices have been cited as causes for beneficial use impairment. Land ownership in the Upper Basin is approximately 53% private and 47% federal. The only two land use/cover types present in the study subbasins are range and evergreen forest.

Water Resource Type and Size

The total drainage area of the Upper Grande Ronde Basin is approximately 695 mi^2 (1,800 km^2 with a stream density of 1.44 mi/mi^2)(1.12 km/km^2). Eleven sites from five subbasins located in the upper southwest portion of the watershed were selected for this monitoring project.

McCoy Creek	55.3 mi^2 (143.4 km^2)	paired basin (4 sites)
Dark Canyon Creek	18.8 mi^2 (48.7 km^2)	paired basin (2 sites)
Meadow Creek	56.2 mi^2 (145.6 km^2)	paired basin (2 sites)
Lookout Creek	15 mi^2 (38.8 km^2)	single site (1 site)
Limber Jim Creek	18.8 mi^2 (48.7 km^2)	paired basin (2 sites)

Water Uses and Impairments

The designated beneficial uses of concern in the basin include anadromous populations of spring/summer Chinook salmon, summer steelhead, and resident populations of bull trout.

Important beneficial uses of the streams that drain the watershed include cold water fish migration, spawning, and rearing; domestic and agricultural water supply; primary and secondary contact recreation; and wildlife habitat.

Reduced fish populations of spring chinook and steelhead, as well as impaired aquatic life (macroinvertebrates), are the main beneficial uses impaired in the Upper Grande Ronde Basin. Spring Chinook adult populations dropped from 12,200 individuals in 1957 to less than 400 in 1989 (USFS, 1992). Water quality has been documented as severely impaired for excessive sedimentation and high water temperatures. Riparian vegetation has been classed as moderate to severely degraded throughout the watershed (DEQ, 1988). Also, large pool habitat has declined by 59% since 1941 (Everest & Sedell, 1991). Restoration work is designed to lower water temperature and increase habitat for native salmonids.

Pollutant Sources

The major sources of nonpoint source temperature pollution are loss of riparian habitat through historic grazing practices and channel modifications.

Pre-Project Water Quality

Most water chemistry violations (mostly pH) in the Grande Ronde Basin have been shown to occur in the main stem of the Grande Ronde. Water chemistry results for 1993-95 documented no significant water chemistry problems for the ten study sites based on sixteen parameters.

Monitoring of habitat conditions indicated that Lookout Creek has the most stable and highest quality habitat with Dark Canyon Creek the lowest. Habitat conditions in McCoy Creek showed impaired conditions at the two lower sites and moderately impaired at the upper site. Lower McCoy Creek was characterized by channelized banks, little riparian vegetation, and shallow pools and riffles, and was the target of the stream restoration efforts.

Water temperature has been identified as a significant factor affecting both water quality and biological communities in the Grande Ronde. Temperature in the basin has been characterized by placing continuous recording thermographs at the top and bottom of each stream reach selected for bioassessment. For the Grande Ronde Basin, the water temperature standard is based on the 7-day maximum mean and should not exceed 17.8°C for cold water species when salmonids are not spawning; water temperature should not exceed 12.8°C during salmonid spawning and incubation. The 17.8°C temperature maximum applies to the study sites during July, August and September. This maximum temperature is typically exceeded at all sites except Upper Limber Jim Creek. The sites on McCoy Creek, Dark Canyon Creek and Meadow Creek generally exceeded the standard throughout the sampling period (Whitney, 1999).

Water Quality Objectives

Project objectives were:

- To improve salmonid and aquatic macroinvertebrate communities in McCoy Creek by restoring habitat quality and lowering stream temperatures.
- To quantitatively document a cause-and-effect relationship between improved habitat, lower water temperatures and improved salmonid and macroinvertebrate communities.

Differences in fish and macroinvertebrate communities and pre-project water quality results suggested that the above objectives were feasible. The results of snorkel surveys for fish completed during the summers of 1994 through 1997 showed two interesting factors:

- Rainbow trout were present in all streams, including Meadow and McCoy Creeks, where summer temperatures exceed 25°C, well above the acceptable range for trout. Temperature measurements indicate a 5°C gradient was present in pools as shallow as 18 inches. These areas of temperature refugia may be critical for fish survival under the temperature conditions of streams like Meadow and McCoy Creeks. Pool temperature stratification studies conducted in 1996 confirmed the presence of temperature refugia in pools over two feet in depth.
- Fish communities at Meadow and McCoy creeks were dominated by warm water red-sided shiner and dace. These species were scarce or completely absent at the other study sites, presumably because of cooler water temperatures. It is expected that fish communities will shift from one dominated by red-sided shiner and dace to one dominated by trout in the McCoy reaches if water temperatures can be lowered by restoration work.

Macroinvertebrate results from 1993, 1994, and 1995 show a similar pattern to the fish surveys and temperature results. It is expected then that if temperatures in McCoy Creek can be improved through habitat restoration, the macroinvertebrate and fish communities will respond favorably and that these responses can be measured.

Project Time Frame

1993 to 2007

PROJECT DESIGN

Nonpoint Source Control Strategies

The nonpoint source treatment implemented in the study area consisted of stream channel and riparian restoration on the lower reach of McCoy Creek. This site is located on a private ranch on the lower mile and a half of McCoy Creek. Lower McCoy Creek is characterized by channelized banks, little riparian vegetation, and shallow pools and riffles. In 1968 and again in 1977 the lower two miles of McCoy Creek were channelized, straightened, and relocated to drain wetlands and maximize grazing land. These actions produced a wide, shallow channel and resulted in near elimination of out of bank stream flow and a significant decrease in meadow storage capacity and connectivity with cool ground water. The focus of restoration was to reverse the adverse effects of channelization.

Riparian fencing has been in place on lower McCoy Creek since 1988; however, response of the stream channel to livestock exclusion was limited. Channel restoration was initially implemented in July, 1997 when a half mile section of the channelized creek was reintroduced into its historic meandering wet meadow channel in the upper meadow area to redevelop meanders, better pool quality, and more habitat complexity. A second phase was completed in September 2002, with the diversion of an additional 1.2 mile (1.9 km) section of channelized creek into a constructed meandering channel in the lower meadow area. In addition, a new bridge and culvert were constructed at a road crossing in October, 2001. This work was accomplished by extensive riparian planting and the creation of off-channel pond habitats. The working hypothesis was that restoring wet meadow conditions and improving riparian vegetation cover would result in cooler stream temperatures and improved fish habitat within the restoration area.

A number of study reaches were involved in restoration and evaluation:

Study Reach	Sample Period	Study Design Type	Treatment
McCoy Creek Middle	1993-2005	Upstream, Before and After Treatment	Cattle excluded by fencing beginning in 1988. Forested habitat feeding into McCoy Meadows area.
McCoy Creek Lower #1 and #2	1993-2001	Down Stream, Before and After Phase 1 Treatment	Channelized with cattle excluded by fencing beginning in 1988. Diverted to Phase 2 reconstructed channel in 2002.
McCoy Creek Restored	1997-2005	Treated – Phase 1 Restoration	Section of historic meandering channel restored by diverting water from adjacent channelized section in 1997.
McCoy Creek Lower Reconstructed	2003-2005	Treated – Phase 2 Restoration	Reconstructed meandering channel. This section replaced McCoy Creek Lower #1 and #2 in 2002. Cattle remained excluded.
Dark Canyon Creek Lower	1993-2003	Control – Before and After Treatments	Cattle grazing with no riparian fencing. Cattle used the active stream channel.
Meadow Creek Lower	1993-2005	Control – Before and After Treatments	Located in McCoy Meadows – Cattle excluded by fencing beginning in 1988.
Limber Jim Creek Lower	1993-2005	Reference – Before and After Treatments	Open meadow habitat in a sub-basin with grazing excluded and minimal human disturbance.

Water Quality Monitoring

To assess the effectiveness of restoration efforts on McCoy Creek, a sampling design was implemented that included paired watersheds (USEPA, 1993), upstream and downstream monitoring, and reference sites. In addition to restoration effectiveness monitoring, this study offered the opportunity to assess stream conditions relative to different land use practices. Altogether thirteen study reaches were selected on wadeable streams in five sub-basins of the upper Grande Ronde River The reaches represented a range of conditions related to habitat type, land use, and management practices. Reach elevations ranged from 3,300 to 4,700 ft (1,006 to 1,432 m). The least disturbed reaches occurred in subbasins with minimal or no grazing at higher elevations.The remaining reaches were located in sub-basins with varying levels of grazing use.

The paired watershed design compared monitoring results between treated and untreated subbasins before, during, and after treatment (restoration). McCoy Creek was the treatment sub-basin, and Dark Canyon Creek was the control . Dark Canyon Creek was selected because it was located in close proximity to McCoy Creek, and was similar in elevation and size. Both McCoy Creek and Dark Canyon Creek have histories of grazing and degraded habitat.The Dark Canyon sub-basin has been used for cattle grazing with no riparian fencing or other improvements.This use was unchanged throughout the duration of the study.

Several other study reaches were monitored. The Meadow Creek Lower study reach also provided a set of control data. This reach was located in McCoy Creek Meadows, just upstream from the McCoy Creek confluence. Lower Meadow Creek was fenced for livestock exclusion in 1988, as was Lower McCoy Creek. This remained unchanged throughout the duration of the study. For upstream (above restoration) and downstream (below restoration) comparisons, the McCoy Creek Middle site and the McCoy Creek Lower #1 and #2 sites bracketed the upper and lower boundaries of the restored (Phase 1) section of McCoy Creek. The Middle site remained unchanged through the study period, but the creek was diverted away from the Lower sites in 2002 during the Phase 2 channel reconstruction. Data from McCoy lower 1 and 2 sites represent conditions in the meadow area before phase 1 and phase 2 channel restoration.

Limber Jim and Lookout Creek sites provide data from least disturbed reaches and set reference benchmarks by which to evaluate the effects of land use and expected benefits of restoration. The Limber Jim Creek Lower Reach was the best available choice for reference comparisons because it was protected from grazing and located in meadow habitat similar to the McCoy Creek restoration area.

Variables Measured

Biological

Habitat
Macroinvertebrates
Fish

Chemical and Other

Continuous water temperature
Specific conductivity
Alkalinity
Dissolved oxygen (DO)
pH
Ammonia (NH_3)
Biochemical oxygen demand (BOD)
Total organic carbon (TOC)
Turbidity

Covariates

Continuous air temperature
Discharge
Precipitation (from nearby climate station)
Shading and solar input
Time of travel
Slope or gradient
Width/depth measurements

Sampling Scheme

Water quality monitoring was generally conducted between early April and early October. Air and water temperature were measured continuously at each site throughout the monitoring season. Water quality, habitat, and macroinvertebrate surveys were conducted three times and fish snorkel surveys were done once during each monitoring season in late July or early August in the period of peak stream temperatures. The methods used for identifying sites were based on a modified Hankin and Reeves procedure (Hafele, 1996). The habitat and macroinvertebrate assessment procedures followed Oregon's biomonitoring protocols.

Water quality, habitat, and macroinvertebrate samples were collected spring, summer, and fall each year. The spring sampling has proved to be problematic. Restrictions due to snowpack and high water levels have resulted in incomplete sampling, and results show that summer and fall samples identify differences between sites better than spring samples. For these reasons, spring sampling for these variables were discontinued. The schedules for fish surveys and continuous temperature monitoring remained unchanged.

In addition to the scheduled snorkel surveys, a more intensive fish and habitat survey was completed on lower McCoy Creek in August, 2001. This survey was designed to better define the relationships between pool depth, water temperature, and the spatial distribution of salmonid species. The section surveyed was replaced by the second reconstructed section of McCoy Creek in July 2002. A similar survey was conducted on the new reconstructed section in July 2003, and again in July 2005. The data collected were useful in assessing the benefits of this new channel reconstruction.

Time of travel data, used in temperature modeling, were collected during the 1996 monitoring season and will be collected again after restoration work is completed. Pool volumes and detailed temperature refugia measurements were collected during the 1996 monitoring season. Photo and video images taken at all study sites during summer low flows documented habitat conditions before and after restoration.

Monitoring Scheme for the Upper Grande Basin Watershed 319 National Monitoring Program Project

Design	Sites or Activities	Primary Parameters	Covariates	Frequency of WQ Sampling	Frequency of Biological/Habitat Assessment	Duration
Paired Upstream/ downstream	McCoy Creek Dark Canyon Creek	Habitat Macroinvertebrate Fish Water temperature Water Chemistry	Air temperature Discharge Precipitation	3 times yearly	3 times yearly (fish once per year)	4 years pre-BMP 1 yr BMP 5 yr post-BMP

Land Treatment Monitoring

The channel restoration work on McCoy Creek has been extensively documented. Photo points have been established and before and after photos have been taken. Habitat condition including vegetation, channel form, gradient, cover, and pool quality have been collected in the restored reach along with all other monitored parameters (water quality, continuous temperature, macroinvertebrates, and fish). Besides monitoring work by DEQ, the CTUIR and the Oregon Dept. of Fish and Wildlife have also collected data concerning vegetation and fish populations in the restored channel reach.

Modifications Since Project Start

The number of sites and sampling frequency were modified as the study progressed. The McCoy Creek Upper site was dropped early in the project (July, 1994) because it was found to be dry during the summer season. Sampling of the Dark Canyon Creek Monitoring at the upper site was terminated in April, 1998 because of access difficulties. Sampling of the Dark Canyon Creek Lower site ended in September, 2003 because of access problems. In 2002, the spring season was dropped monitoring at all study reaches, while continuous temperature and annual fish surveys continued as usual.This decision was based on several factors: First, the spring monitoring runs often resulted in incomplete data; High flows prohibited or limited complete instream sampling, and snow sometimes blocked access to higher elevation sites. Second, preliminary analyses showed spring data did not discriminate well between sites compared to summer and fall results. In 2005, monitoring frequency was reduced to a fall sample at five key sites, which were the McCoy Creek sites, Meadow Creek Lower, and Limber Jim Creek14 Lower. The annual fish survey and continuous temperature monitoring were conducted as usual at these sites, and additional temperature and biological replicate sampling were done in 2005.

Progress to Date

A half-mile section of McCoy Creek was reintroduced into its historic meandering channel in July 1997, with accompanying vegetation planting and wetland reclamation and development in the abandoned channelized section. Additional planting and fence relocation was completed between 1999 and 2001. Construction of a new bridge to accommodate McCoy Creek at the previously constricted McIntyre Road crossing was completed in October 2001. In conjunction with the bridge construction, an additional half-mile section of meandering channel was constructed in the meadow area below the bridge. Water was diverted from the existing channel into this newly constructed section in August of 2002. At that time, temperature monitoring equipment was installed. Monitoring of water quality, habitat, macroinvertebrates, and fish began on this new section in July 2003. DEQ, in cooperation with BLM and US Forest Service, completed Proper Functioning Condition (PFC) assessments on the McCoy Creek reaches and its paired watersheds in 1998. PFC is used widely in the West as a quick assessment tool to determine a stream's channel stability and identify management practices that need changing to improve channel conditions. The extensive data set of water quality, habitat and aquatic biota collected for this project provides a unique opportunity to compare PFC assessments with more intensive monitoring techniques.

The project has been completed and a final report published in June, 2007.

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

Field and laboratory water chemistry test results and continuous water temperature data were reviewed and stored in the DEQ Laboratory Storage and Retrieval (LASAR) database. Habitat, macroinvertebrate, and fish data were entered into a separate ACCESS database managed by the DEQ Watershed Assessment Section. Supplemental monitoring results and data were managed separately by the project leader.

STATISTICA software was used for data analysis and graphing.

NPSMS Data Summary

Currently unavailable.

Final Results

This project demonstrated that channel restoration can improve habitat and water quality for sensitive aquatic species, including rainbow trout. However, recovery may not be apparent using traditional water column measurements.

Results showed a clear response in stream conditions relative to land use practices and an overall improvement in McCoy Creek as a result of the channel restoration efforts. Sites with minimal land use disturbance were associated with higher quality habitat, and were characterized by narrower, deeper channels with more shade, cooler water temperatures, and better water quality when compared to sites with histories of land use such as livestock grazing and channelization. Macroinvertebrate assemblages at the sites with minimal use compared more closely to regional reference site expectations, and these sites were populated primarily by rainbow trout, while sites with heavier use were populated by more tolerant fish species.

Fish results from Dark Canyon Creek, where habitat was poor but water temperature was cool due to extensive cool ground water influx, demonstrated the importance of water temperature as it affected fish species composition. Results from all sites showed that numbers of rainbow trout declined sharply when yearly seven day average water temperatures exceeded 23^{o}C, and that areas of cool water refuge became important for trout survival as temperatures increased.

Although there was an apparent gradual improvement in McCoy Creek after livestock fencing was in place, the healing process was slow. Habitat quality remained poor. The channel remained simplified, shallow and wide, with little riparian vegetation providing cover and shade. Water temperatures were high, and little cool water refuge was available for trout survival. However, following the 1997 phase 1 and the 2002 phase 2 channel restoration efforts, improvements were clearly achieved. Water quality improved following restoration. Habitat was clearly improved; the narrower, deeper channel and elevated water table renewed wet meadow functionality and created more areas of complex habitat and cool water refuge for fish and other aquatic life.

While chemistry and habitat results clearly showed improvement in McCoy Creek following restoration, temperature, macroinvertebrate, and fish results were more ambiguous. Reach scale temperature data from well mixed water column measurements did not show overall improvement in the combined years following restoration; however, sub-reach scale profiles showed improvement in cool water habitat associated with pools and ground water influx. Additionally, temperature decreased over time in the phase 1 restored reach, while temperatures increased in non-restored reaches and in the study control reach during the same time period. The macroinvertebrate response to restoration was an increase in abundance and taxa richness; however, the assemblage was changing or adjusting over the initial 3 to 5 years following restoration, so it was difficult to determine if the response was simply due to colonization of new habitat or an indication of improvement. Fish assemblage composition did not change notably in McCoy Creek following restoration; however, the number of trout in the phase 1 restored section increased progressively over time.

Results from this study suggest the following conclusions:

- Livestock exclusion by itself may not result in improved habitat and recovery of sensitive aquatic life if stream channel conditions and habitat remain degraded

- Restoration of meandering wet meadow channels can improve habitat and benefit sensitive aquatic life in a relatively short time frame (2-5 years).

- Water temperature and areas of temperature refuge can be critical to the survival of salmonids through summer rearing periods.

- Improvements may not be detected using reach scale water column temperature measurements. Smaller scale quantification of thermal refugia may be more appropriate.

- Macroinvertebrate assemblages responded to habitat and water quality conditions and showed improving trends following restoration. Due to initial colonization of new habitat, however macroinvertebrates may require 2-5 years to establish a stable assemblage.

INFORMATION, EDUCATION, AND PUBLICITY

There has been little quantitative documentation of the effects of habitat restoration on stream temperatures and aquatic communities. The Upper Grande Ronde Basin Monitoring project will provide useful information on the effects of channel and riparian restoration on fish and macroinvertebrate habitat improvement for areas elsewhere in the basin. This project will also enhance interagency coordination among other agencies and watershed councils which have expressed interest in restoration work. Interagency cooperation is reflected by the involvement in this project of Oregon Department of Fish and Wildlife (ODF&W), NRCS, local Soil and Water Conservation Districts (SWCD), USFS, USEPA, and the CTUIR.

Education and outreach efforts are occurring primarily through tours of the project area. Tours have been conducted by the Confederated Tribes of the Umatilla, the local Soil & Water Conservation District (SWCD), and DEQ. Tour participants have included other private landowners and state and federal agency personnel. There is not a newsletter designed to specifically cover this project, though it has been discussed in the local newspaper and at board meetings of the Grande Ronde Model Watershed Board. The Model Watershed Board is funded to oversee and coordinate restoration work in the Grande Ronde Basin.

The following are reports written using data from the upper Grande Ronde Basin Section 319 National Monitoring Program Project. These reports are posted on the Oregon Department of Environmental Quality website: *http://www.deq.state.or.us*. Navigate to Laboratory, Technical Reports, Biomonitoring Technical Reports:

Bio 2000-01 Grande Ronde National Monitoring Program Project Temperature Monitoring Summary Report

Bio 2000-06 Grande Ronde Section 319 National Monitoring Program Project Fish Survey Report 1994-1999

Bio - 006 Analysis of Macroinvertebrate Data from the Grande Ronde Long Term NPS Project 1993-1996

Bio - 012 Multivariate Analysis of Fish and Environmental Factors in the Grande Ronde Basin of Northeastern Oregon

TOTAL PROJECT BUDGET

The estimated budget for the Upper Grande Ronde National Monitoring Project for the life of the project is based on 10 years of funding, with seven years completed (1993–1999):

Project Element	Funding Source ($)				
	Federal	State	Local	Tribal	Total
Proj Mgt	230,000	92,000	NA	NA	322,000
I&E	NA	NA	NA	NA	NA
LT	185,000	NA	NA	70,000	255,000
WQ Monit	470,000	188,000	NA	NA	658,000
TOTALS	885,000	280,000	NA	70,000	1,235,000

Source: Rick Hafele, personal communication (1996).

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

The Upper Grande Ronde Basin Monitoring Project is a major component of the Grande Ronde Watershed Enhancement Project, a cooperative effort between ODEQ, EPA, NRCS and Union County SWCD.

The National Marine Fisheries Service (NMFS) listed the Snake River spring/summer Chinook salmon as an endangered species under the Endangered Species Act (ESA) in August 1994. The US Fish and Wildlife Service determined the Bull trout to be warranted for ESA listing in February 1995. Bull trout are also on the Oregon sensitive species list. Snake River summer steelhead have also been listed as threatened by NMFS, and are classified as a stock of concern by the Oregon Department of Fish and Wildlife, and sensitive by the USFS.

OTHER PERTINENT INFORMATION

The project final report has been completed.

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Pennsylvania

Pequea and Mill Creek Watershed
Section 319
National Monitoring Program Project

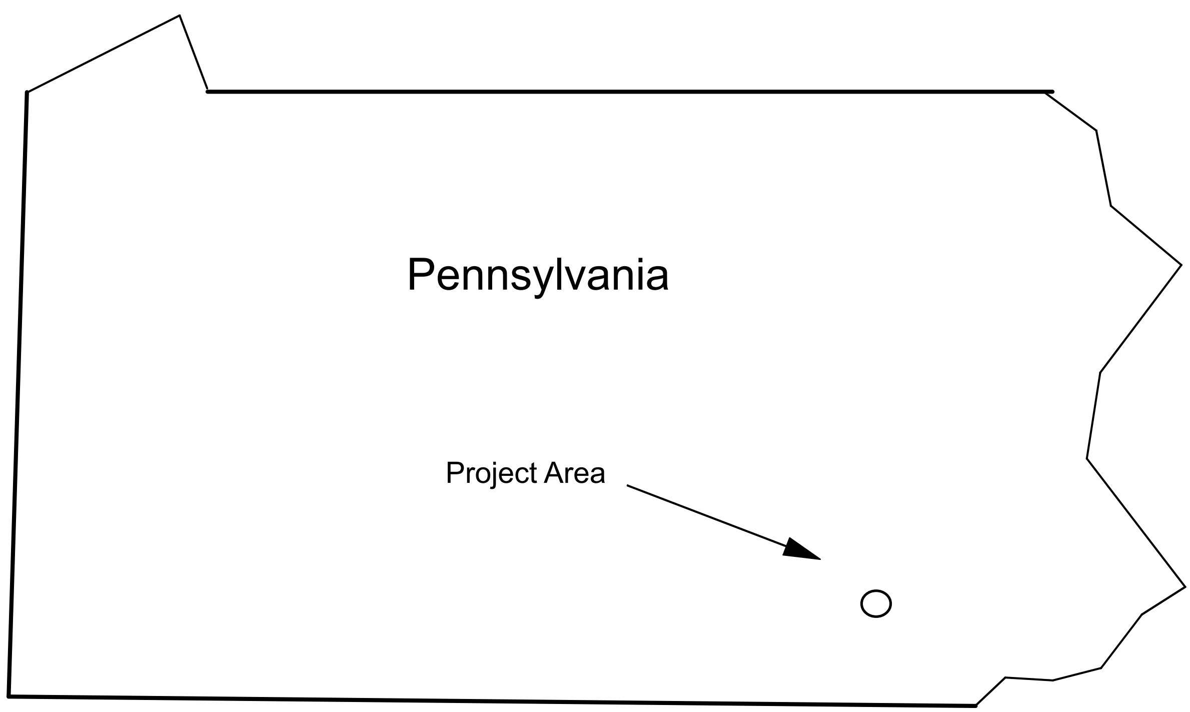

Figure 38: Pequea and Mill Creek (Pennsylvania) Watershed Project Location

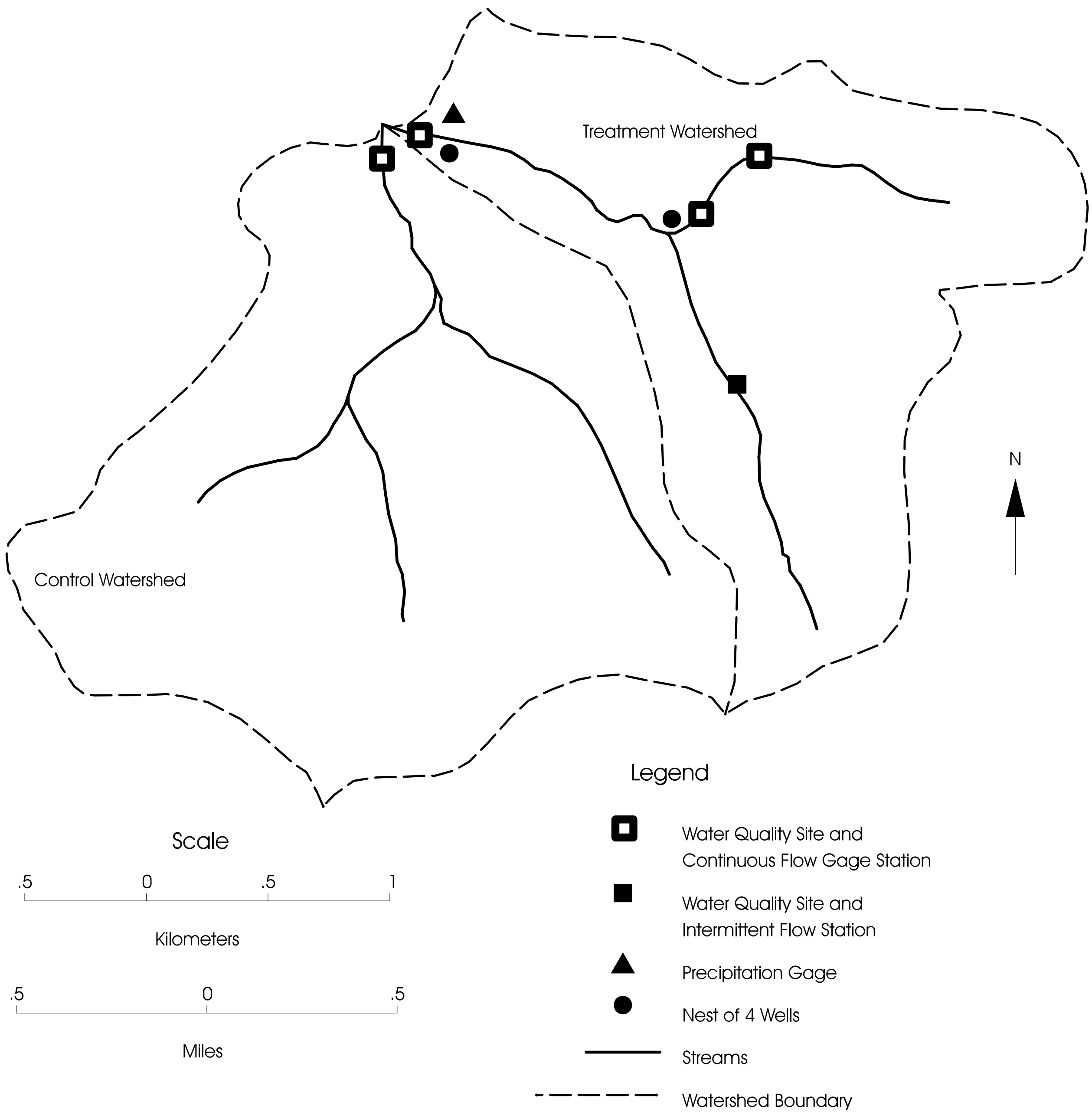

Figure 39: Water Quality Monitoring Stations for Pequea and Mill Creek (Pennsylvania) Watershed

PROJECT OVERVIEW

The Big Spring Run is a spring-fed stream located in the Mill Creek Watershed of southcentral Pennsylvania (Figure 38). Its primary uses are livestock watering, aquatic life support, and fish and wildlife support. In addition, receiving streams are used for recreation and public drinking water supply. Stream uses such as recreation and drinking water supply are impaired by elevated bacteria and nutrient concentrations.

Uncontrolled access of about 200 dairy cows and heifers to each of the two watershed streams is considered to be a major source of pollutants. Pastures adjacent to streams and upgradient cropland also are thought to contribute significant amounts of nonpoint source pollutants. Therefore, land treatment was to focus on streambank fencing to exclude livestock from streams, except for cattle crossings, which were also to be used for drinking water access for the cattle. This was to allow a natural riparian buffer to become established, stabilizing streambanks and potentially filtering pollutants from pasture runoff.

Water quality monitoring was based on a paired and upstream-downstream watershed design in which the proposed nonpoint source control was to implement livestock exclusion fencing on nearly 100 percent of the stream miles in the treatment subwatershed (Figure 39). Grab samples were collected approximately every 10 days at the outlet of each paired subwatershed and at upstream sites in the treatment subwatershed from April through November. Storm event, ground water, biological, and other monitoring were conducted to help document the effectiveness of fencing in the treatment subwatershed.

Livestock exclusion fencing was completed in the treatment watershed in July, 1997. Water quality sampling in the study area was discontinued in July 2001.

The final report and summary fact sheet have been completed. Copies of both reports are available on the internet and in hard copy.

PROJECT BACKGROUND

Project Area

Total area is 3.2 square miles (mi^2); Control = 1.8 mi^2; Treatment = 1.4 mi^2

Relevant Hydrologic, Geologic, and Meteorologic Factors

The average annual precipitation is 43 inches. The watershed geology consists of deep well-drained silt-loam soils underlain by carbonate rock. About five percent of each subwatershed is underlain by noncarbonate rock.

Land Use

Type	**Control Watershed**		**Treatment Watershed**	
	Acres	%	Acres	%
Agricultural	922	80	762	85
Urban	150	13	116	13
Commercial	80	7	18	2
Total	1152	100	896	100

Water Resource Type and Size

The study area encompasses about 2.8 and 2.7 miles of tributary streams in the treatment and control subwatersheds, respectively. Annual mean discharges for 1994–2000 water years were 1.69 and 2.92 cfs at the outlets of the treatment (T-1) and control (C-1) subwatersheds, respectively.

Water Uses and Impairments

The subwatershed streams have relatively high nutrient and fecal coliform and streptococcus concentrations that contribute to use impairments of receiving waters.

Pollutant Sources

The primary source of pollutants was believed to be pastured dairy cows and heifers with uncontrolled access to stream and streambanks, along with the application of nutrients to croplands used for silage corn and soybean production. At the beginning of the project, about 200-400 animals were pastured in each of the treatment and control watersheds. The PA Department of Environmental Protection estimated that grazing animals deposit an average of 40 pounds of nitrogen and 8 pounds of phosphorus annually per animal. Other (commercial, urban, and septic) sources of pollutants were considered insignificant.

Pre-Project Water Quality

Onetime baseflow grab sampling at four and seven locations in the control and treatment subwatershed are presented in tabular form:

	Fecal coliform (mg/l)	TP (mg/l)	OP (mg/l)	NH_3+Organic N (mg/l)	NO_3+NO_2
Treatment	1,100-38,000	.06-.25	.03-.15	.3-1.6	10-18
Control	10,000	.02-.04	.01-.03	.1-.3	4-12

Water Quality Objectives

The overall objective was 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.

Project Time Frame

September, 1993 to June 2001 (field work); report preparation and printing complete by winter 2006.

Modifications Since Project Started

A new residential community was developed in the treatment subwatershed directly upstream of site T-4.

PROJECT DESIGN

Nonpoint Source Control Strategy

The control strategy involved installing streambank fencing on nearly 100 percent of the pasture land adjacent to the stream draining the treatment subwatershed. All of the farmers in this watershed had agreed to install fencing. A stabilizing vegetative buffer naturally developed soon after the fencing was installed.

Project Schedule

Surface-water site	Basin Sta	tion type	Pre-BMP monitoring interval (MM/YY)	Date of BMP installation	Post-BMP monitoring interval
C-1	Control	Continuous	09/93 – 06/97		07/97 - 06/01
C1-2	Control	Benthic	05/96 – 05/97		09/97 – 05/01
T-1	Treatment	Continuous	09/93 – 06/97	04/97 – 06/97	07/97 - 06/01
T1-3	Treatment	Benthic	09/93 - 05/97	04/97 – 06/97	09/97 – 05/01
T-2	Treatment	Continuous	10/93 – 06/97	04/97 – 06/97	07/97 - 06/01
T2-3	Treatment	Benthic	09/93 - 05/97	04/97 – 06/97	09/97 – 05/01
T-3	Treatment	Low flow	10/93 – 06/97	04/97 – 06/97	07/97 - 06/01
T-4	Treatment	Continuous	10/93 – 06/97	04/97 – 06/97	07/97 - 06/01

Station Type
Continuous – Low-flow and stormflow water-quality sampling, and continuous discharge.

Benthic – Only sampled for macroinvertebrates and water quality twice a year, in May and September

Low flow – Sampled on fixed, grab sample interval. No storm sampling was conducted, and no continuous recorder was present.

Water Quality Monitoring

The water quality monitoring effort was based on paired watershed and upstream-downstream experimental designs (Figure 36).

Parameters Measured

Biological

Habitat survey
Benthic invertebrate monitoring
Algal mass
Fecal streptococcus (FS) (only during base flow)

Chemical and Other

pH
Temperature
Specific Conductance
Dissolved Oxygen
Turbidity
Suspended sediment (SS)
Total and dissolved ammonia (NH_3) plus organic nitrogen
Dissolved ammonia (NH_3)
Dissolved nitrate + nitrite (NO_3 + NO_2)
Dissolved nitrite (NO_2)
Total and dissolved phosphorus (TP and DP)
Dissolved orthophosphate (OP)

Covariates

Continuous streamflow
Continuous precipitation
Ground water level

Sampling Scheme

Continuous Streamflow Sites (T-1, T-2, T-4, C-1):
Type: grab and storm event composite
Frequency and season: grab approximately every 10 days fromApril through November. Monthly grab December through March. Fifteen to 30 composite storm flow samples per year were collected at each site.

Partial Streamflow Site (T-3):
Type: grab
Frequency and season: approximately every 10 days fromApril through November. Monthly grab December through March.

Ground Water (8 wells):
Type: grab
Frequency and season: The six shallow wells were sampled monthly and analyzed for fecal streptococcus. On a quarterly basis, all eight wells were sampled, including two deeper wells completed in bedrock. Analysis includes dissolved NO_2, $NO_3 + NO_2$, NH_3, ammonia plus organic nitrogen, and phosphorus.

Habitat, benthic invertebrate, and algal mass surveys were conducted twice per year, during May and September, at the outlet of each subwatershed (T-1 and C-1), at two points upstream (T1-3 and T2-3) in the treatment subwatershed, and at one point upstream (C1-2) in the control subwatershed.

Continuous discharge was recorded at watershed outlets and two tributary sites and partial discharge at four upstream sites. Continuous precipitation amount was recorded at one site.Additionally, ground water level was continuously monitored in seven wells.

Monitoring Scheme for the Pequea and Mill Creek Section 319 National Monitoring Program Project

Design	Sites or Activities	Primary Parameters	Covariates	Frequency of WQ Sampling	Frequency of Habitat/Biological Assessment	Duration
Paired watershed	Treatment and control watershed	Habitat and benthic invertebrate survey Algal mass SS Total organic nitrogen NH_3, OP, FS $NO_3 + NO_2$ NO_2, TP, DP, TP	Discharge Precipitation	Sampling every 10 days (Apr.-Nov.) Monthly sampling from Dec. to March	May and September of each year (at sites T-1, T1-3, T2-3, C-1, and C1-2	4 yrs pre-BMP 4 yrs post-BMP
Upstream-Downstream	Treatment watershed		Discharge Precipitation Ground-water level and quality	Storm event samples (15-30 per year) (at sites T-1, T-2, T-4, and C-1)		

Modifications Since Project Start

Additional biological, chemical , and continuous discharge monitoring sites were added to the treatment watershed to make an upstream-downstream design.

A new biological site was added upstream in the control subwatershed. A new continuous monitoring station and water quality site was added to the treatment subwatershed to document effects of a new residential development upstream of pasture land.

Piezometers were installed at two locations in the treatment basin (T-1 and T-2) and one location in the control basin (C-1) during 1999. They were located near and within the stream channel to determine the altitudes of hydraulic heads in the shallow ground water near the stream channel. This was used to estimate potential shallow ground-water flow directions. Nitrogen isotope and age-dating samples were collected in the piezometers, shallow ground-water wells, and stream sites in order to develop an understanding of the interaction between ground water and surface water at the sites.

Progress To Date

Streambank fencing in pastured areas of the treatment basin was completed in July, 1997. Several stable stream crossings for cattle were also installed.

DATA MANAGEMENT AND ANALYSIS

Data were stored and maintained locally by U.S. Geological Survey (USGS) and entered into the USGS WATSTORE database. The following data were collected during the critical season (April through November). Data for 2001 were collected from April through June (termination of data collection).

NPSMS Data Summary

DATA TYPE: Fixed Time
STATION TYPE: CONTROL (C-1) **STUDY TYPE:** Paired
CHEMICAL PARAMETERS

Parameter Name	QUARTILE VALUES -75-	-50-	-25-	Counts/Season	1996	1997	1998	1999	2000	2001
TEMPERATURE, WATER (CENTIGRADE)	15.9	15.2	12.5	Highest	5	5	7	8	2	0
				High	20	1	2	1	2	1
				Low	10	10	5	7	12	4
				Lowest	6	7	7	8	7	4
PRECIPITATION, TOTAL (INCHES PER DAY)	0.64	.31	.11	Highest	21	8	11	12	15	3
				High	15	10	12	9	16	9
				Low	15	24	16	24	28	8
				Lowest	35	40	32	12	43	4
FLOW, STREAM, INSTANTANEOUS, CFS	2.2	1.8	1.4	Highest	18	1	8	1	7	3
				High	4	3	2	1	4	3
				Low	1	3	2	6	4	2
				Lowest	0	16	10	16	8	1
TURBIDITY, HACH TURBIDIMETER	9	6.1	3.5	Highest	6	8	6	3	0	5
				High	3	6	4	2	3	3
				Low	5	5	7	3	7	1
				Lowest	9	4	5	16	11	0
SPECIFIC CONDUCTANCE	700	691	682.5	Highest	5	5	0	10	15	9
				High	5	0	0	1	1	0
				Low	5	2	0	1	1	0
				Lowest	8	15	21	12	6	0
OXYGEN, DISSOLVED	10.8	10.1	9.4	Highest	7	8	8	9	10	3
				High	4	2	4	2	8	3
				Low	8	6	4	5	1	1
				Lowest	4	4	5	7	4	2

PH (STANDARD UNITS)	7.86	7.75	7.5	Highest	3	2	2	4	5	1
				High	3	4	4	3	6	1
				Low	12	8	8	9	11	4
				Lowest	5	9	7	8	1	3
NITROGEN, AMMONIA, DISSOLVED	0.05	0.04	0.02	Highest	4	5	8	6	0	0
				High	4	3	4	2	3	0
				Low	14	7	8	9	7	8
				Lowest	1	8	2	7	13	1
NITROGEN, NITRITE, DISSOLVED	0.04	0.03	0.02	Highest	8	11	5	10	5	3
				High	4	6	8	3	3	2
				Low	9	3	7	5	5	2
				Lowest	2	3	2	6	10	2
NITROGEN, AMMONIA+ORGANIC, DISSOLVED	0.30	<0.20	<0.20	Highest	4	2	6	9	3	0
				High	6	7	8	6	8	4
				Low	13	14	8	0	0	0
				Lowest	0	0	0	9	12	5
NITROGEN, AMMONIA+ORGANIC, TOTAL	0.40	0.30	<0.20	Highest	5	4	6	7	2	0
				High	1	1	4	5	5	2
				Low	7	6	9	8	11	7
				Lowest	10	12	3	4	5	0
NITROGEN, NITRITE+NITRATE, DISSOLVED	10	10	9.7	Highest	15	20	10	2	1	1
				High	3	0	0	0	0	0
				Low	2	1	3	1	1	1
				Lowest	3	2	9	21	21	7
PHOSPHORUS, TOTAL (MG/L)	0.08	0.04	0.03	Highest	4	2	8	3	0	0
				High	6	6	7	5	8	4
				Low	5	5	2	9	7	2
				Lowest	8	10	5	7	8	3

	QUARTILE VALUES				1996	1997	1998	1999	2000	2001
Parameter Name	**-75-**	**-50-**	**-25-**		**Counts/Season**					
PHOSPHORUS, DISSOLVED ORTHOPHOSPHATE	0.04	0.03	0.02	Highest	3	4	9	-	0	0
				High	5	2	2	-	0	0
				Low	6	3	5	-	1	1
				Lowest	9	14	5	-	0	1
PHOSPHORUS, DISSOLVED	0.03	0.03	0.02	Highest	6	5	13	7	10	2
				High	7	0	0	1	0	0
				Low	7	12	5	7	7	4
				Lowest	3	6	4	9	6	3
STREPTOCOCCI, FECAL, KF AGAR	5720	3580	2190	Highest	4	1	0	2	0	0
				High	0	1	1	1	0	0
				Low	3	2	2	1	0	0
				Lowest	1	4	5	4	8	3
SUSPENDED SEDIMENT	107	84	20	Highest	2	1	0	0	0	0
				High	0	1	0	0	0	0
				Low	8	13	14	5	4	1
				Lowest	1 1	8	8	19	19	8

DATA TYPE: Fixed Time
STATION TYPE: STUDY (T-1)
CHEMICAL PARAMETERS

	QUARTILE VALUES				1996	1997	1998	1999	2000	2001
Parameter Name	**-75-**	**-50-**	**-25-**		**Counts/Season**					
TEMPERATURE, WATER (CENTIGRADE)	20.5	18.7	13	Highest	0	2	4	6	0	0
				High	4	4	3	2	2	0
				Low	12	8	7	9	13	5
				Lowest	7	9	7	7	8	4
PRECIPITATION, TOTAL (INCHES PER DAY)	0.64	.31	.11	Highest	21	8	11	12	15	3
				High	15	10	12	9	16	9
				Low	15	24	16	24	28	8
				Lowest	35	40	32	12	43	4
FLOW, STREAM, INSTANTANEOUS, CFS	1.5	.9	.6	Highest	18	1	8	1	3	1
				High	5	6	3	2	8	5
				Low	0	4	2	7	4	3
				Lowest	0	12	9	14	8	0
TURBIDITY, HACH TURBIDIMETER	7	4	3	Highest	8	6	4	1	4	1
				High	5	6	2	4	5	7
				Low	5	2	5	4	3	1
				Lowest	5	9	11	15	9	0
SPECIFIC CONDUCTANCE	680	640	609	Highest	3	0	0	9	13	8
				High	10	4	2	4	7	0
				Low	5	6	4	4	0	1
				Lowest	5	12	15	7	2	0

OXYGEN, DISSOLVED	12.4	11.4	9.8	Highest	3	6	2	4	3	1
				High	4	1	1	3	3	1
				Low	4	5	8	5	10	3
				Lowest	12	9	8	12	7	4
PH (STANDARD UNITS)	8	7.84	7.67	Highest	0	2	4	4	5	0
				High	3	2	7	1	6	1
				Low	4	6	1	5	6	0
				Lowest	16	13	8	14	6	8
NITROGEN, AMMONIA, DISSOLVED	0.06	0.035	0.03	Highest	7	3	5	5	0	0
				High	9	6	4	4	5	1
				Low	1	3	3	5	0	0
				Lowest	6	11	10	10	18	8
NITROGEN, NITRITE, DISSOLVED	0.07	0.06	0.05	Highest	11	8	3	3	1	0
				High	3	3	3	3	1	0
				Low	3	2	1	2	1	2
				Lowest	6	10	15	15	20	7
NITROGEN, AMMONIA+ORGANIC, DISSOLVED	0.42	0.3	0.2	Highest	4	4	8	9	2	0
				High	7	2	7	7	6	3
				Low	8	14	6	8	11	6
				Lowest	4	3	1	0	4	0
NITROGEN, AMMONIA+ORGANIC, TOTAL	0.7	0.55	0.38	Highest	3	2	5	4	0	0
				High	1	0	4	3	0	0
				Low	7	6	4	10	7	6
				Lowest	12	15	9	7	16	3
NITROGEN, NITRITE+NITRATE, DISSOLVED	12.2	11	9.4	Highest	3	0	0	0	0	0
				High	12	4	0	0	0	0
				Low	4	8	4	3	2	0
				Lowest	4	11	18	20	21	9

QUARTILE VALUES					1996	1997	1998	1999	2000	2001
Parameter Name	**-75-**	**-50-**	**-25-**		**Counts/Season**					
PHOSPHORUS, TOTAL (MG/L)	0.1	0.06	0.04	Highest	3	2	6	13	6	0
				High	1	1	7	6	10	0
				Low	3	7	6	3	3	3
				Lowest	16	13	3	2	4	6
PHOSPHORUS, DISSOLVED ORTHOPHOSPHATE	0.06	0.025	0.02	Highest	3	3	7	-	0	0
				High	4	6	6	-	1	0
				Low	6	2	1	-	0	1
				Lowest	10	12	7	-	0	1
PHOSPHORUS, DISSOLVED	0.05	0.025	0.02	Highest	3	4	11	17	17	0
				High	4	5	4	5	2	2
				Low	7	3	1	0	1	2
				Lowest	9	11	6	1	3	5
STREPTOCOCCI, FECAL, KF AGAR	98320	10880	1710	Highest	0	0	0	0	0	0
				High	1	0	0	1	0	0
				Low	6	4	2	3	2	1
				Lowest	1	4	6	4	6	2
SUSPENDED SEDIMENT	54	26	6	Highest	2	3	1	0	0	1
				High	4	5	2	1	0	0
				Low	13	8	10	15	14	6
				Lowest	2	7	9	8	9	2

DATA TYPE: Storm **STUDY TYPE:** Paired

STATION TYPE: CONTROL (C-1)

CHEMICAL PARAMETERS

QUARTILE VALUES					1996	1997	1998	1999	2000	2001
Parameter Name	**75-**	**-50-**	**-25-**		**Counts/Season**					
FLOW, STREAM, MEAN DAILY	23.14	13.38	9.39	Highest	8	4	0	3	4	1
				High	3	2	5	5	3	0
				Low	5	3	1	5	2	1
				Lowest	0	10	4	3	3	3
NITROGEN, AMMONIA, DISSO	.355	.255	.145	Highest	0	0	3	2	4	0
				High	1	2	0	3	1	0
				Low	6	5	11	5	4	2
				Lowest	9	8	0	6	3	3
NITROGEN, NITRITE, DISSOLV	.095	.075	.055	Highest	2	2	3	2	1	2
				High	1	0	2	3	3	0
				Low	3	3	6	2	4	3
				Lowest	10	10	3	9	4	0

NITROGEN, AMMONIA+ORGANIC,DISS	1.05	1	.75	Highest	2	2	4	4	5	1
				High	1	2	0	0	1	0
				Low	5	2	6	6	3	2
				Lowest	8	9	3	6	3	2
NITROGEN, AMMONIA+ORGANIC,TOTAL	2.95	2.3	1.9	Highest	0	3	1	4	6	1
				High	0	0	4	4	2	2
				Low	4	2	2	3	1	0
				Lowest	12	10	7	4	3	2
NITROGEN, NITRITE+NITRAT	4.05	3.6	2 .65	Highest	6	2	5	0	2	1
				High	1	1	2	2	2	1
				Low	4	5	2	5	4	2
				Lowest	5	7	5	9	4	1
PHOSPHORUS, TOTAL (MG/L)	1.3	.825	.57	Highest	0	0	1	3	6	1
				High	5	4	4	4	1	0
				Low	3	0	2	2	0	0
				Lowest	8	11	7	7	5	4
PHOSPHORUS, DISSOLVED	.54	.32	.21	Highest	4	0	0	1	1	0
				High	3	1	3	2	3	1
				Low	4	2	4	4	1	0
				Lowest	5	12	7	9	7	4
SUSPENDED SEDIMENT	718	501.5	347.5	Highest	6	1	5	2	6	1
				High	2	4	2	3	1	0
				Low	1	1	1	0	0	0
				Lowest	6	9	6	11	5	4

DATA TYPE: Storm **STUDY TYPE:** Paired

STATION TYPE: STUDY (T-1)

CHEMICAL PARAMETERS

Parameter Name	QUARTILE VALUES -75-	-50-	-25-	COUNTS/SEASON	1996	1997	1998	1999	2000	2001
FLOW, STREAM, MEAN DAILY	15.58	5.37	4.41	Highest	7	0	2	1	2	1
				High	6	4	7	7	3	1
				Low	3	1	1	2	3	1
				Lowest	0	9	4	4	2	2
NITROGEN, AMMONIA, DISSO	.46	.26	.13	Highest	2	1	2	1	0	0
				High	4	5	6	6	5	0
				Low	8	5	3	3	2	3
				Lowest	2	3	3	4	3	2
NITROGEN, NITRITE, DISSOLV	.17	.1	.06	Highest	0	2	0	2	2	0
				High	5	3	5	4	1	3
				Low	8	8	5	6	4	2
				Lowest	3	1	4	2	3	0
NITROGEN, AMMONIA+ORGANIC, DISS	1.6	1.2	.9	Highest	2	2	3	3	3	0
				High	3	7	4	3	2	1
				Low	8	3	6	3	3	3
				Lowest	3	2	1	5	2	1
NITROGEN, AMMONIA+ORGANIC, TOTAL	3.2	2.3	1.9	Highest	1	2	3	3	4	1
				High	2	4	3	7	3	1
				Low	2	2	1	0	0	1
				Lowest	11	6	7	3	3	2
NITROGEN, NITRITE+NITRATE	7	5.9	2.6	Highest	2	1	2	0	0	0
				High	1	3	1	3	2	1
				Low	10	5	8	9	6	4
				Lowest	3	5	3	2	2	0
PHOSPHORUS, TOTAL (MG/L)	1.5	1.1	.73	Highest	1	1	2	2	4	1
				High	0	0	1	4	1	0
				Low	5	4	4	4	1	0
				Lowest	10	9	7	4	4	4
PHOSPHORUS, DISSOLVED	.76	.59	.38	Highest	1	1	0	0	2	0
				High	2	1	3	1	1	0
				Low	4	4	2	6	0	2
				Lowest	9	8	9	6	7	3
SUSPENDED SEDIMENT	735	376	125	Highest	6	0	0	0	2	1
				High	4	0	5	2	3	0
				Low	4	5	3	8	1	2
				Lowest	1	9	6	4	4	2

DATA TYPE: Bio/Habitat **STUDY TYPE:** Paired

STATION TYPE: CONTROL (C-1)

BIOLOGICAL PARAMETERS (Non-Chemical)				1996	1997	1998	1999	2000	2001
		INDICES				**Scores/Values**			
Parameter Name	**Fully**	**Threatened**	**Partially**						
HILSENHOFF BIOTIC INDEX	0-6.5	6.51-8.5	8.51-10	5.62	6.33	5.69	6.75	6.50	5.04
TAXA RICHNESS	20	11	10	21	21.5	24	18.5	22	24
EPT INDEX	6	4	1	2	3.5	3	1.5	3	3
PERCENT DOMINANT TAXA	20	35	50	25.9	29.8	25.0	39.4	38.0	35.0
SCRAPERS/FILTER COLLECT	.8	.4	.2	.081	.031	.098	.012	.078	.096

STATION TYPE: STUDY (T-1)

BIOLOGICAL PARAMETERS (Non-Chemical)				1996	1997	1998	1999	2000	2001
		INDICES				**Scores/Values**			
Parameter Name	**Fully**	**Threatened**	**Partially**						
HILSENHOFF BIOTIC INDEX	0-6.5	6.51-8.5	8.51-10	5.92	6.43	5.91	7.15	6.28	5.65
TAXA RICHNESS	20	11	10	26	26.0	30	23.5	24	29
EPT INDEX	6	4	1	3	2.5	5	2	2	1
PERCENT DOMINANT TAXA	20	35	50	25.2	35.2	22.4	32.9	20.6	31.3
SCRAPERS/FILTER COLLECT	.8	.4	.2	.072	.053	.325	.096	.211	.32

**Note that for years 1996-2000, index values are average for data collected in May and September of that year. Data for year 2001 are only for May sample collection.

Final Results

Field data were collected for about eight years, with four years of calibration data and four years of post-treatment data. Major differences in annual precipitation occurred from the pre- to post-treatment period, with approximately 5 inches more per year occurring during the pre-treatment period. This caused significant decreases to occur from the pre- to post-treatment period in nutrient and suspended sediment yields for both sites at the outlet of the treatment (T-1) and control (C-1) basins due to decreased stream discharge. This highlights the importance of paired analysis in order to detect changes in water quality caused by BMP implementation.
Paired relations between T-1 and C-1 were developed for fixed-time and storm samples using analysis of covariance. These results were combined in order to quantify an overall effect of streambank fencing on water quality during the post-treatment period.The combined results indicated that T-1 (relative to C-1) showed yield reductions in total nitrogen (19 percent), nitrate (18 percent), ammonia (36 percent), dissolved ammonia plus organic nitrogen (20 percent), total ammonia plus organic nitrogen (26 percent), and suspended sediment (37 percent). The yield of dissolved phosphorus at T-1 increased by 19 percent, and this was mainly attributed to increased subsurface movement of dissolved phosphorus in the upper parts of the treatment basin. However, there was a more substantial reduction in the yield of suspended phosphorus, thus there was a significant reduction at T-1 in the yield of total phosphorus (14 percent).

Benthic-macroinvertebrate data collected (in both May and September of each year) at T-1 and C-1 showed improvement at T-1 relative to C-1 for three metrics, the Hilsenhoff Biotic Index, taxa richness, and percent dominant taxa. Physical characteristics of the stream that affect benthic-macroinvertebrate communities also showed improved conditions at T-1. Improvement was detected in the pool/riffle or run/bend ratio (improvement in this ratio indicated that riffles and bends were becoming more common than straight runs or uniform depth reaches) and bank stability. September sampling indicated improvements at T-1 in bottom substrate and scour, and better velocity to depth ratios (improvement in this indicated an increase in flow and depth variability in the channel, thus creating a more varied habitat).

Results from this study indicated streambank fencing resulted in decreases in stream N-species, total-P, and suspended-sediment con-centrations and yields at the outlet of the treatment basin relative to untreated sites; however, dissolved-P concentrations and yields increased. It is not possible to determine what the effects of fencing would be on dissolved P if an upgradient field was not acting as a source. These results indicate that nutrient management, in conjunction with streambank fencing, is important in helping to control nutrient loadings to streams in this agricultural setting.

Benthic-macroinvertebrate data indicated streambank fencing had a positive influence on benthic macroinvertebrates and their habitat. More improvement was detected at the outlet of the treatment basin than the upstream sites. Biological metrics indicated that fencing caused improvement. Probably the most important biological metric, taxa richness, indicated a greater number of benthic-macroinvertebrate taxa at treated relative to control sites after fencing. Results indicated fencing improved shallow ground-water quality (for the well nest in a stream-gaining area), as noted by decreased concentrations of N species and fecal streptococcus counts. This improvement only occurred at the well nest for which the ground-water flow path was from the shallow ground-water system through the subsurface zone below the fenced area and into the stream (a gaining stream reach).

This study indicated that a small buffer width (5 to 12 ft) can have a positive influence on surface-water quality, benthic mac-roinvertebrates, and near-stream shallow ground-water quality. However, results showed that streambank fencing in itself can not alleviate excessive nutrient inputs that are transported through subsurface zones into the stream system. Overland runoff processes that move suspended sediment to the stream were controlled (or reduced) to some extent by the vegetative buffer established inside the fenced area.

Copies of the final project report and 4-page factsheet summarizing project results may be obtained by contacting Dan Galeone at the address given below. Both the final report and the factsheet are available in printed form and on the internet.

INFORMATION, EDUCATION, AND PUBLICITY

The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) has had an important role in the information and education (I&E) programs in the Pequea and Mill Creek watershed. NRCS provided an employee to gather nutrient management data in the watershed. The Lancaster County Conservation District and the Pennsylvania State University Cooperative Extension Service maintained active I&E programs in the area. Also, as part of the USDA-funded Pequea-Mill Creeks Hydrologic Unit Area (HUA), the landowners in the watersheds were to be targeted for additional educational programs.

The study watersheds have been used for numerous field tours. In 2003 and 2004, high school students from Annapolis, MD collected benthic-macroinvertebrate and water quality samples. Project personnel helped with the sampling, provided data from the fencing study for comparative purposes, and helped the students understand how their results were reflective of agricultural watersheds.

Progress Towards Meeting Goals

The Pennsylvania State University Cooperative Extension Service has produced an educational video which includes information about the project and participating farmers.

TOTAL PROJECT BUDGET

Project Element	Funding Required									
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Personnel	$91,980	$67,656	$90,097	$94,207	$98,424	$92,472	$86,382	$93,614	$75,438	$2,348
Equipment and Supplies	$5,600	$5,020	$4,000	$4,000	$5,000	$4,000	$4,000	$3,040	$200	$0
Contracted Services	$14,200	$6,200	$7,380	$6,181	$8,875	$9,070	$8,800	$10,288	$0	$0
USGS (lab and gauging)	$38,800	$40,770	$30,500	$31,057	$27,900	$30,240	$23,928	$32,375	$0	$0
USGS Overhead	$139,834	$109,214	$121,393	$119,614	$112,133	$107,842	$98,942	$109,498	$74,634	$2,496
Other	$2,000	$3,000	$4,000	$10,241	$11,920	$13,040	$5,158	$2,634	$1,260	$2,092
TOTAL*	$292,404	$231,860	$257,370	$265,300	$264,252	$256,664	$227,210	$251,450	$151,532	$6,936

*50% of total funds are USGS matching funds, except for 2003, when only 43% of total funds were USGS match.
** Total funding for 1993 was $236,300.

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

The Chesapeake Bay Program, which has set a goal of a 40% reduction in annual loads of total ammonia plus organic nitrogen and total phosphorus to the Bay, has had a significant impact on the project. The Bay Program has provided 100% cost-share money to help landowners install streambank fencing.

OTHER PERTINENT INFORMATION

Water quality monitoring for the project was discontinued in July 2001. Thus, for this project, four years of pre-treatment and four years of post-treatment data were collected to document the effectiveness of streambank fencing in reducing the load of nutrients and suspended sediment to receiving streams.

PROJECT CONTACTS

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Pennsylvania

Stroud Preserve Watershed
Section 319
National Monitoring Program Project

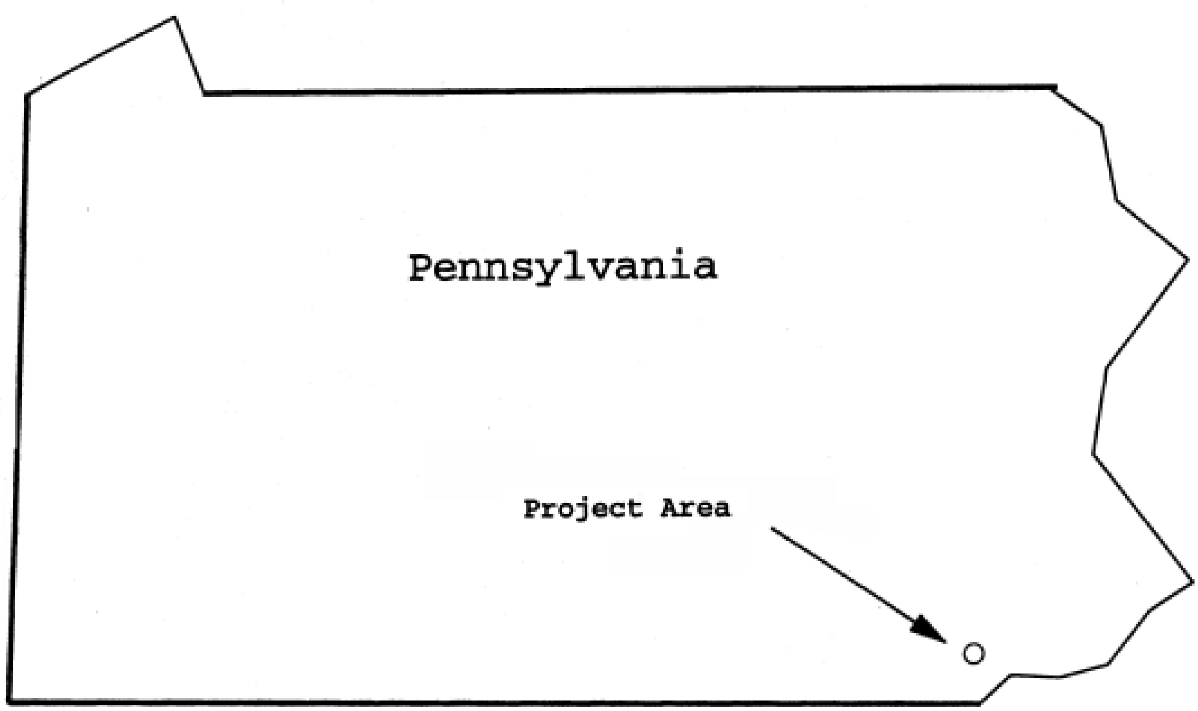

Figure 40: Stroud Preserve (Pennsylvania) Watershed Project Location

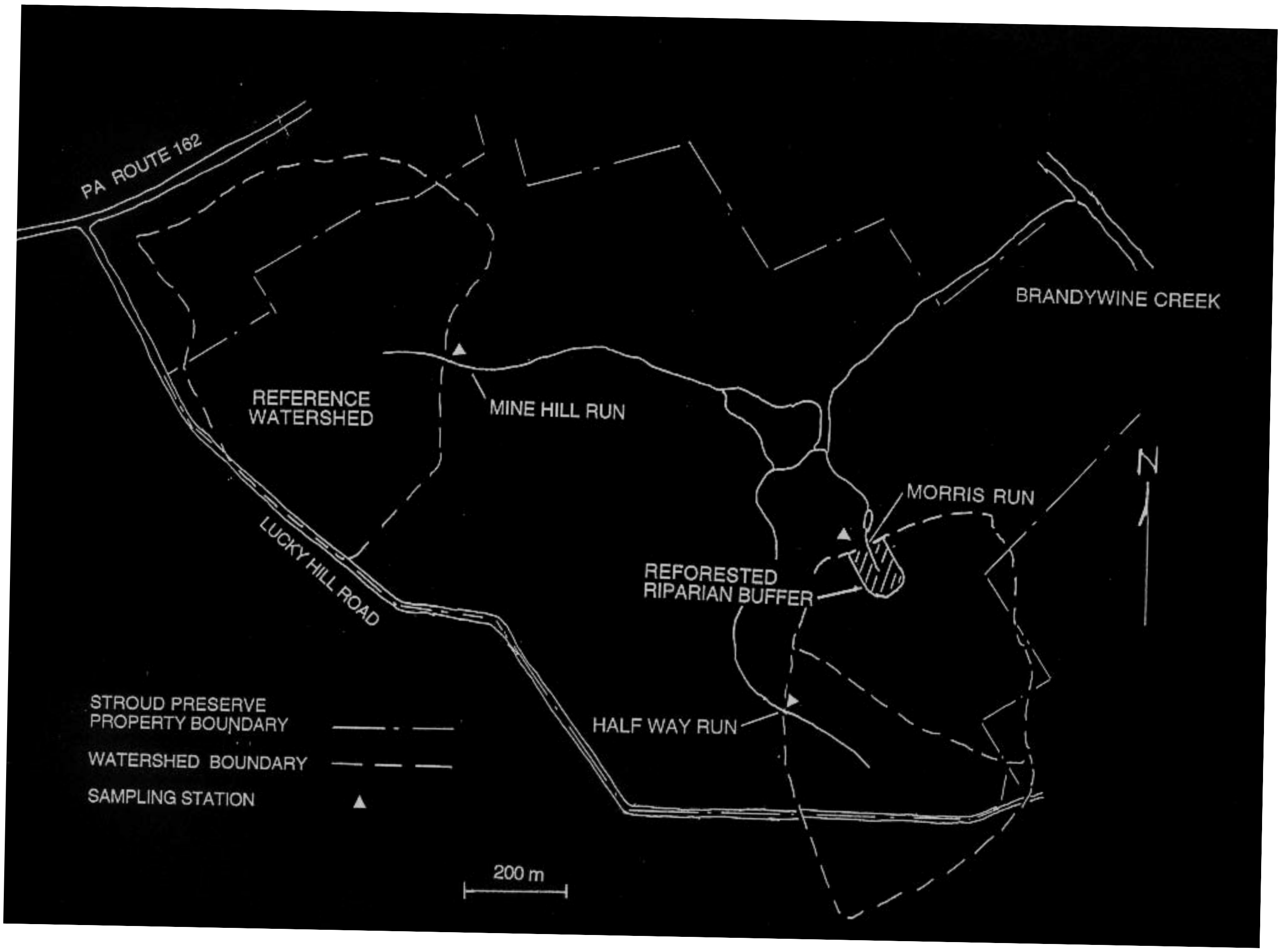

Figure 41: Sampling Stations and Boundaries for Stroud Preserve (Pennsylvania) Watershed

PROJECT OVERVIEW

The Stroud Preserve riparian reforestation project is a demonstration of the three-zone Riparian Forest Buffer System (RFBS) developed by the U.S.D.A. Forest Service. Initiated in 1992, the project involves three experimental agricultural watersheds in the Stroud Preserve, a southeastern Pennsylvania farm protected by conservation easements. The streams are in the drainage of the Brandywine River, which flows into the Delaware Estuary. Prior to 1992, all three watersheds were primarily in crop production (maize, soybeans, hay) under a soil conservation plan including contouring and crop rotation. Water quality was compromised by elevated nutrients and suspended sediments.

The primary objectives of this project are to: (1) evaluate the non-point source reductions of the RFBS in the relatively high-relief terrain of the Mid-Atlantic Piedmont, (2) assess the time required after reforestation to achieve significant mitigation, and (3) establish specific guidelines for planting and managing forest buffers zones in the mid-Atlantic region.

The RFBS consists of: Zone 1, a streamside strip (~5 m) of permanent woody vegetation for stream habitat protection; Zone 2, an 18-20 m strip of managed forest upslope from Zone 2; and Zone 3, a 6-10 m wide grass filter strip. The RFBS was established between 1992 and 1994 in a 16-ha watershed (Morris Run) that is primarily in row crop production. Zone 1 included existing streambank trees; Zone 2 was converted from hay and crops to hardwood seedlings; and a level-lip spreader (to disperse concentrated overland flow) was constructed in Zone 3. A second treatment watershed (Half Way Run) was taken out of agricultural production and reforested in its entirety. The third watershed (Mine Hill Run) is being maintained in agricultural production comparable to that of Morris Run, as a long-term reference watershed.

The monitoring design uses paired watersheds supplemented by mass balance estimates of nutrient removal by the riparian forest buffer**.** Water quality monitoring for nutrients and suspended solids includes grab samples collected every 14 days from all three streams, intensive sampling storm runof eight times a year (Morris Run and Mine Hill Run), sampling of overland flow (Morris Run), and quarterly sampling of groundwater (Morris Run).

Post-BMP monitoring was completed in March 2007. Data analysis is underway. A final project report will be completed by December 2007.

PROJECT BACKGROUND

Project Area

The project is being carried out within the Stroud Preserve, a 197-hectare tract in Chester County, Pennsylvania that is held in conservation easements that assure control over land-use in perpetuity. The area of the riparian forest buffer system is approximately 1 hectare of the 16.2 ha of the Morris Run watershed. The location of the sampling station at Morris Run is 39º56' 41" N, 75º39’13"W.

Relevant Hydrologic, Geologic, and Meteorological Factors

The average annual precipitation is 115 mm (45 inches). Soils on the Preserve are mainly typic hapludults, but those in the riparian areas are aquic fragiudults. A weathered rock or saprolyte extends to a typical depth of 5-7 m with a bedrock consisting mainly of fractured schist. Slopes average about 10%.

Land Use

All but a few hectares of the Morris Run watershed are maintained in contoured strips under a crop rotation program established by the U.S.D.A. Natural Resources Conservation Service (NRCS). The primary crops are maize, soybeans, and hay (alfalfa). Records are being kept of all fertilizer applications, and of crop yields.

Most of the watershed of Mine Hill Run, the reference watershed, is planted in alfalfa, maize, and soybeans, also under NRCS conservation tillage. A sparsely forested, brushy zone extends 50-200 m from the stream. Land use in this watershed is being maintained without alteration.

The Half Way Run Watershed was in production for row crops and hay prior to 1992 when it was reforested with hardwood seedlings.

Water Resource Type and Size

Morris Run, Mine Hill Run, and Half Way Run are perennial headwater streams in watersheds of 16.2, 36.1, and 15.1 hectares, respectively. They flow into the Brandywine River, which has a 750-km^2 watershed, and is a tributary to the Delaware Estuary.

Water Uses and Impairments

The Brandywine River provides varied water supply and recreational uses and is classified for warm water and migratory fishes in its lower reaches, trout stocking and cold water fishes in various upper reaches. Agricultural sources contribute to elevated nutrient concentrations and sediment loads.

Pollutant Sources

Agricultural fertilizers and atmospheric deposition are the primary sources for elevated exports of nitrogen from the basins. Erosion from tilled fields is the primary source of sediment export. Both erosion and fertilization contribute to elevated phosphorus exports.

Pre-Project Water Quality

Grab samples taken in August 1991 yielded the following:

	Morris Run	**Half Way Run**
Nitrate-N (mg/L)	3.6	2.7
Ammonia-N (mg/L)	0.10	0.05
Dissolved Orthophosphate-P (mg/L)	.029	0.020

Water Quality Objectives

Primary objectives of this project are to: 1) demonstrate the effectiveness of riparian reforestation, when used in conjunction with sound nutrient management and erosion control practices on uplands, in reducing non-point source pollution from agricultural sources and 2) to establish specific guidelines for planting and managing forest buffers zones in the mid-Atlantic region.

Project Time Frame

Initiation of routine water chemistry sampling: Jan 1992
Planting of riparian zone in hardwood seedlings: Apr 1992
Installation of level spreader: May 1994
NMP Monitoring Project: Apr 1997-Mar 2007

PROJECT DESIGN

Nonpoint Source Control Strategy

A riparian forest buffer system was established in Morris Run (the treatment watershed) inApril of 1992, in accordance with the specification published by the U.S.D.A. Forest Service (Welsch 1991, Publication NA-PR-07-91). Seedlings of Sugar Maple, Red Oak, Tulip Poplar, White Ash, Black Walnut, and Trembling Aspen were planted in a zone extending 23 meters (75 feet) from the stream bank on each side and upslope from its source. Prior to the planting, the buffer area consisted of mowed grass, some tilled area, and a narrow riparian strip (3-10 m) of hardwood trees and brush. Maintenance of the riparian buffer includes replacement of mortality (drought and deer damage), use of tree-tubes and wire tree protectors, and annual application of glyphosate around each tree.

An additional 6 meters (minimum) beyond the reforested buffer is maintained as grassland, representing "Zone 3" of the Riparian Buffer specification. In accordance with this specification, the grassland zone was contoured in late May 1994 to form a level-lip spreader, designed by the NRCS. The purpose of the spreader is to intercept surface runoff, which is delivered to the buffer via grassed waterways, and to release the runoff to the forested buffer as dispersed sheet flow in order to minimize erosion within the buffer.

Other nonpoint source control measures applicable to both the treatment and control watersheds include contoured strips, waterways, and crop rotations in accordance with a soil conservation plan developed by the NRCS.

Project Schedule

Site Pr	e-BMP Monitoring	BMP Implementation	Post-BMP Monitoring
Morris Run (Treatment)	1992-~1998 (onset of significant tree growth	Zone 2 Reforestation: 1992 Zone 3 Level Spreader: 1994	~1999-2007 (Transition from pre-post defined by forest maturation
Mine Hill Run (Reference)	As for Morris Run	No implementation--reference	As for Morris Run

Water Quality Monitoring

The monitoring program is based on a paired watershed design. Although the riparian forest buffer was established in the first year of monitoring, the first several years (prior to rapid tree growth) serve as a calibration period to establish the pre-implementation comparison between the treatment and reference watersheds. To supplement the paired watershed design, nutrient and sediment retention by the riparian buffer are estimated by mass balance, using data from groundwater monitoring wells and overland flow collectors.

Parameters Measured

Biological
None

Chemical and other
Suspended solids (SS)
Volatile Solids
Dissolved nitrate+nitrite

Dissolved ammonia
Dissolved organic nitrogen, (discontinued 4/02)
Total phosphorus
Total dissolved phosphorus, (discontinued 4/02)
Dissolved orthophosphate
Dissolved organic carbon, (discontinued 4/02)
Chloride
pH
Conductivity

Covariates
Precipitation
Streamflow
Groundwater level
Streamwater temperature
Basal area of woody vegetation within riparian zone

Sampling Scheme

Streamwater samples are collected every 14 days throughout the year from all three streams. Discharge is continuously monitored at all three streams using v-notch weirs. Intensive sampling of streamwater during runoff events is conducted eight times annually from Morris Run and Mine Hill Run. Groundwater is sampled quarterly from 27 monitoring wells. Overland flow in Morris Run watershed is collected from four events annually.

Modifications Since Project Start

The monitoring program described above was implemented 1 April 1997, when the project was accepted for the National Monitoring Program. The monitoring program prior to 1 April 1997 differed from the current program in the following respects: Between January 1992 and 1 April 1997, regular grab samples from all three streams were taken for nitrate, dissolved ammonium, dissolved orthophosphate, conductivity, and pH, at a frequency of 18-24 times per year. Particulate phosphorus and total dissolved phosphorus were sampled regularly from October 1993 through September 1994. Dissolved organic nitrogen was not sampled regularly prior to April 1997. Sampling for suspended solids began in late 1993 for Morris Run and Half Way Run, and March 1995 in Mine Hill Run. Seven runoff events were sampled in Morris Run between November 1993 and June 1995 in Morris Run.

Beginning in March 1999, the target rate for sampling runoff during storm events (rainfall > 20 mm) was increased from four per year to eight per year, while the number of samples analyzed from each event was reduced from ten to four.

As of April 2002, monitoring intensity was reduced because tree growth and canopy closure has been slower than expected and further effects of reforestation may not be apparent until substantially more tree growth occurs. Monitoring continues at a level sufficient to detect an impact on baseflow water chemistry when it occurs. Intensive sampling of stormwater exports and overland flow, however, will be suspended until the riparian forest has matured sufficiently to expect measurable effects on these processes. It is anticipated that such maturation will require two to four years and that monitoring of stormflow and overland should resume at that time.

Also in April 2002, analyses for the following constituents was discontinued: dissolved organic carbon (DOC), total dissolved phosphorus (TDP), and dissolved organic nitrogen (DON). Ammonium analyses of groundwater samples was also discontinued, but ammonium analyses of surface water samples will continue.

In April 2005, sampling of stream water and overland flow during storms was reinstated in response to a rapid increase in tree growth that occurred between 2001 and 2005. Five storm events were captured during 2005 including one overland flow event.

Progress To Date

Reforestation of the riparian area was initiated and completed in 1991 and the level-lip spreader was installed in 1994. Tree growth during the first seven years, 1992-1999, was lower than anticipated, attributable to both drought and deer-damage. As of 1998 woody basal area within the reforested buffer was 0.15 m2 ha-1 or <1% of the expected (mature forest) basal area of 20-60 m^2 $ha^{-1.}$ Beginning in 1998, aggressive measures were instituted to assure vigorous forest development.These included annual herbicide (glyphosate) treatment of each tree, installation of 5-foot plastic tree protectors (in place of 4-foot protectors) and wire mesh tree enclosures, application of deer repellants, and the planting of relatively mature trees to replace mortality, especially into critical remaining gaps. Since 1999, tree growth has been rapid. Woody basal area increased to 0.65 m2/ha in 2001 and 2.49 m2/ha in 2005. Canopy closure by the 2005 growing season was 67%.

DATA MANAGEMENT AND ANALYSIS

Data are entered, verified, stored, and analyzed using the SAS Information System. Data will also be entered into the USEPA STORET system and the NonPoint Source Management System.

Data analysis includes:

(1) comparisons of concentrations and annual exports of nitrogen, phosphorus, and suspended solids from each of the three watersheds, testing the hypothesis that these parameters are reduced by riparian reforestation;

(2) mass-balance estimates of nitrogen, phosphorus, and sediment retention within the reforested riparian buffer.

NPSMS Data Summary

	STATION TYPE: Control			STATION TYPE: Treatment		
	STATION NAME: Mine Hill Run			STATION NAME: Morris Run		
	Quartile Values					
Parameter Name	_25_	_50_	_75_	_25_	_50_	_75_
Total Suspended Solids (mg/L)	9.98	13.14	15.70	1.28	2.12	4.51
Nitrate + Nitrite (mg/L as N)	3.20	3.40	3.76	4.15	4.30	4.69
Nitrogen, Ammonia (mg/L)	0.01	0.014	0.017	0.007	0.009	0.015
Phosphorus, Total (mg/L)	0.036	0.041	0.051	0.027	0.03	0.047
Phosphorus, Dissolved (mg/L)	0.019	0.022	0.028	0.024	0.027	0.032
Phosphorus, Dissolved Orthophosphate (mg/L)	0.016	0.019	0.026	0.022	0.025	0.032
pH (Standard Units)	7.14	7.24	7.30	6.50	6.56	6.67
Flow, Stream, Instantaneous (L/s)	1.43	2.17	3.86	0.87	1.14	1.65

Quartile values generated from samples collected 01Apr97 to 31Mar98

	Quartile Counts							
YEAR: 1992	1	2	3	4	1	2	3	4
Nitrate + Nitrite	23	0	0	0	23	0	0	0
Nitrogen, Ammonia	12	1	0	10	15	0	1	7
Phosphorus, Total	1	0	0	0	1	0	0	0
Phosphorus, Dissolved Orthophosphate	1	0	3	18	1	1	5	15
pH (Standard Units)	1	0	0	22	0	0	0	23
	Quartile Counts							
YEAR: 1993	1	2	3	4	1	2	3	4
Nitrate + Nitrite	16	0	0	0	18	0	0	0
Nitrogen, Ammonia	13	0	0	3	18	0	0	0
Phosphorus, Dissolved Orthophosphate	0	0	3	13	0	2	7	9
pH	0	0	0	15	0	0	0	18

		Quartile Counts						
YEAR: 1994	1	2	3	4	1	2	3	4
Nitrate +Nitrite	23	0	0	0	20	0	0	0
Nitrogen, Ammonia	18	0	0	5	18	0	0	2
Phosphorus, Total	0	0	1	0	0	0	10	4
Phosphorus, Dissolved	1	0	1	0	2	1	5	6
Phosphorus, Dissolved Orthophosphate	1	0	6	16	0	0	8	12
pH	0	0	0	21	0	0	0	19
		Quartile Counts						
YEAR: 1995	1	2	3	4	1	2	3	4
Total Suspended Solids	7	2	3	6	5	5	12	1
Nitrate + Nitrite	24	0	0	0	23	0	0	0
Nitrogen, Ammonia	23	0	0	1	21	0	0	2
Phosphorus, Dissolved Orthophosphate	0	1	11	12	5	1	5	12
pH	0	1	0	23	0	0	0	23
		Quartile Counts						
YEAR: 1996	1	2	3	4	1	2	3	4
Total Suspended Solids	14	0	2	2	4	1	8	5
Nitrate + Nitrite	12	6	0	0	17	0	0	1
Nitrogen, Ammonia	18	0	0	0	17	0	0	1
Phosphorus, Dissolved Orthophosphate	0	1	7	10	0	0	6	12
pH	0	0	1	16	0	0	0	17
		Quartile Counts						
YEAR: 1997	1	2	3	4	1	2	3	4
Total Suspended Solids	6	8	4	5	6	8	7	3
Nitrate + Nitrite	3	6	7	8	3	8	5	8
Nitrogen, Ammonia	9	3	5	7	9	4	4	7
Phosphorus, Total	4	5	5	6	6	5	6	3
Phosphorus, Dissolved	5	3	4	8	5	6	5	4
Phosphorus, Dissolved Orthophosphate	5	2	8	9	3	6	9	6
pH	2	6	4	12	6	6	4	8
Flow, Stream, Instantaneous (L/s)	6	5	4	8	4	6	4	10
		Quartile Counts						
YEAR: 1998	1	2	3	4	1	2	3	4
Total Suspended Solids	10	5	2	7	4	1	9	11
Nitrate + Nitrite	5	2	8	9	7	0	5	13
Nitrogen, Ammonia	12	8	2	2	11	6	6	2
Phosphorus, Total	6	7	7	4	4	2	13	6
Phosphorus, Dissolved	4	6	7	7	5	9	5	6
Phosphorus, Dissolved Orthophosphate	2	5	9	8	6	2	11	6
pH	12	3	2	7	7	7	8	3
Flow, Stream, Instantaneous (L/s)	6	4	9	5	10	5	5	5
		Quartile Counts						
YEAR: 1999	1	2	3	4	1	2	3	4
Total Suspended Solids	20	2	2	2	3	2	12	9
Nitrate + Nitrite	2	5	9	9	7	1	9	8
Nitrogen, Ammonia	9	5	2	9	6	5	10	4
Phosphorus, Total	16	1	4	4	0	3	14	8
Phosphorus, Dissolved	7	5	5	8	3	3	8	11
Phosphorus, Dissolved Orthophosphate	4	6	7	8	0	3	12	10
pH	14	3	1	8	8	6	6	6
Flow, Stream, Instantaneous (L/s)	8	8	9	1	13	8	2	3
		Quartile Counts						
YEAR: 2000	1	2	3	4	1	2	3	4
Total Suspended Solids	19	5	1	1	6	3	8	8
Nitrate + Nitrite	1	0	4	21	2	2	12	10
Nitrogen, Ammonia	6	12	1	7	4	5	15	2
Phosphorus, Total	12	5	9	0	6	1	16	3
Phosphorus, Dissolved	0	8	8	10	4	8	9	5
Phosphorus, Dissolved Orthophosphate	1	1	14	10	1	8	13	4
pH	12	7	2	5	4	3	10	9
Flow, Stream, Instantaneous (L/s)	0	9	10	7	3	10	3	9
		Quartile Counts						
YEAR: 2001	1	2	3	4	1	2	3	4
Total Suspended Solids	19	0	2	5	2	7	13	4
Nitrate +Nitrite	1	1	7	17	1	0	2	23
Nitrogen, Ammonia	7	8	4	7	4	4	13	5
Phosphorus, Total	15	2	3	6	4	8	13	1
Phosphorus, Dissolved	3	8	4	11	7	6	11	2
Phosphorus, Dissolved Orthophosphate	0	3	12	11	2	7	14	3
pH	0	1	1	24	0	0	5	21
Flow, Stream, Instantaneous (L/s)	10	4	10	2	13	2	9	2

	Quartile Counts							
YEAR: 2002	1	2	3	4	1	2	3	4
Total Suspended Solids	17	0	2	7	9	4	3	4
Nitrate + Nitrite	8	9	9	0	1	1	1	19
Nitrogen, Ammonia	2	3	6	15	1	3	6	12
Phosphorus, Total	13	1	4	8	4	3	12	3
Phosphorus, Dissolved	12	3	6	5	12	7	1	2
Phosphorus, Dissolved Orthophosphate	5	0	9	12	4	2	10	6
pH	0	0	0	26	0	2	8	12
Flow, Stream, Instantaneous (L/s)	17	8	0	1	25	1	0	0
	Quartile Counts							
YEAR: 2003	1	2	3	4	1	2	3	4
Total Suspended Solids	22	4	0	0	8	8	7	3
Nitrate + Nitrite	3	2	7	14	7	2	13	4
Nitrogen, Ammonia	10	7	3	6	11	7	5	3
Phosphorus, Total	22	4	0	0	3	3	17	3
Phosphorus, Dissolved	26	0	0	0	26	0	0	0
Phosphorus, Dissolved Orthophosphate	2	4	16	4	1	2	15	8
pH	12	6	3	5	0	0	2	24
Flow, Stream, Instantaneous (L/s)	2	2	7	15	3	0	2	21
	Quartile Counts							
YEAR: 2004	1	2	3	4	1	2	3	4
Total Suspended Solids	25	1	0	1	6	4	8	9
Nitrate + Nitrite	2	0	13	12	6	8	11	2
Nitrogen, Ammonia	11	6	3	7	16	5	5	1
Phosphorus, Total	22	4	0	1	5	5	13	4
Phosphorus, Dissolved	27	0	0	0	27	0	0	0
Phosphorus, Dissolved Orthophosphate	0	4	16	7	4	2	15	6
pH	8	5	8	6	0	1	3	23
Flow, Stream, Instantaneous (L/s)	0	0	7	20	1	1	2	23
	Quartile Counts							
YEAR: 2005	1	2	3	4	1	2	3	4
Total Suspended Solids	25	3	0	16	1	2	7	34
Nitrate + Nitrite	24	7	10	3	45	0	0	0
Nitrogen, Ammonia	12	11	7	14	17	9	9	10
Phosphorus, Total	15	3	8	18	5	2	17	21
Phosphorus, Dissolved	44	0	0	0	45	0	0	0
Phosphorus, Dissolved Orthophosphate	0	2	10	32	2	7	14	22
pH	16	4	6	18	0	0	0	46
Flow, Stream, Instantaneous (L/s)	1	8	7	28	4	2	4	34

Findings to Date

Streamwater nitrate concentration in the stream draining the RFBS declined for the first three years after planting, both absolutely and relative to the reference stream. This decline was apparently a response to cessation of near-stream fertilizer application because it occurred prior to significant tree growth. Over the next six years, streamwater nitrate in both streams trended upward, but the increase was somewhat greater in the stream draining the RFBS. This trend was paralleled by increases in groundwater nitrate in the cultivated field upslope of the buffer, and so apparently reflected higher nitrate inputs to the cultivated fields. In 2002, however, two-to-three years after the rapid tree growth began, streamwater nitrate draining the RFBS began a precipitous decline so that by 2005 the concentration in streamwater draining the RFBS was lower, relative to the reference stream, than at any time during the study The timing of the decline strongly suggests that this represents a response to the tree growth. However, upslope groundwater concentrations also declined in 2004 and 2005 complicating interpretation of the recent trend. Based on mass balance estimates, the RFBS has, since 1994, removed an annual average of 70 kg of nitrogen per hectare of riparian buffer, or between 8 and 36% of upslope inputs of subsurface nitrate. However, because of the large fluctuations in upslope inputs no clear temporal trends in nitrate removal can be established.

Based on overland flow sampling between 1997 and 2001, the riparian buffer (including the level spreader) removed an average of 55% of the sediment transported from the cultivated field or approximately 2500 kg per year per hectare of riparian buffer. During this same period, streamwater exports of sediments also declined by about 50% relative to the reference stream. Measurements of overland transport and sediment export were temporarily suspended in 2002 pending further tree growth, but resumed in 2005. Results from 2005 were inconclusive because few storms occurred.

INFORMATION, EDUCATION, AND PUBLICITY

The project targets both professionals involved in development of nonpoint source control strategies and the public at large. Results will be made available to professionals through scientific papers prepared for refereed publication, presentations and meetings and symposia, a brochure and the annual reports. In addition, the project receives considerable exposure through the Stroud Water Research Center's educational program, which reaches thousands of students and adults annually

Progress Towards Meeting Goals

Two theses have been completed as part of this project:

Watts, S. "Organic matter decomposition, N mineralization and denitrification in organic and mineral soils of two riparian ecosystems," Ph.D. Thesis, Rutgers University, 1997.

Alberts, S. "Reduction of total suspended sediment concentration in agricultural runoff by a vegetative buffer strip in Chester County, Pennsylvania" M.S. Thesis, West Chester University, 2000.

The following manuscript is in preparation:

Watts, S. H., S. S. Seitzinger, and J. D. Newbold. In preparation. Nitrogen removal rates within mixed hardwood riparian ecosystems Manuscript for submission to Journal of Environmental Quality

A brochure describing the project and results-to-date was completed in September 2006.

TOTAL PROJECT BUDGET

For time period 1 April 1, 1997 to March 31, 2007:

	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Personnel	$44,042	$47,475	$48,899	$50,366	$51,877
Travel	1,100	1,133	1,167	1,202	1,238
Equipment	15,370	0	0	0	0
Materials & Supplies	4,000	4,400	4,532	4,668	4,808
Administrative (telephone, copies, postage)	250	258	265	273	281
Contractual Services Water Chemistry Analysis	28,342	29,192	30,068	30,970	31,899
TOTAL DIRECT COSTS	$93,104	$82,458	$84,931	$87,479	$90,104

	Year 6	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Personnel	$30,306	$31,516	$32,777	$41,308	$44,756
Travel	1,000	1,040	1,082	3,000	3,120
Equipment	2,174	2,261	2,351	3,500	3,600
Contractual Services (Water Chemistry Analysis)	7,670	7,977	8,296	21,514	22,375
Total direct costs	$41,150	$42,794	$44,506	$69,322	73,891
Indirect costs	22,221	23,109	24,033	37,434	39,701
TOTAL PROJECT COST	63,371	65,903	68,539	106,756	103,592

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

The project has received financial support for various periods since 1991 from the USDA Forest Service, the Pennsylvania State Bureau of Forestry, and the Chesapeake Bay Program. Technical assistance has been provided by the U.S.D.A. Forest Service, the Pennsylvania State Bureau of Forestry, and the USDA Natural Resource Conservation Service.

OTHER PERTINENT INFORMATION

None

PROJECT CONTACTS

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Pennsylvania

Swatara Creek
Section 319
National Monitoring Program Project

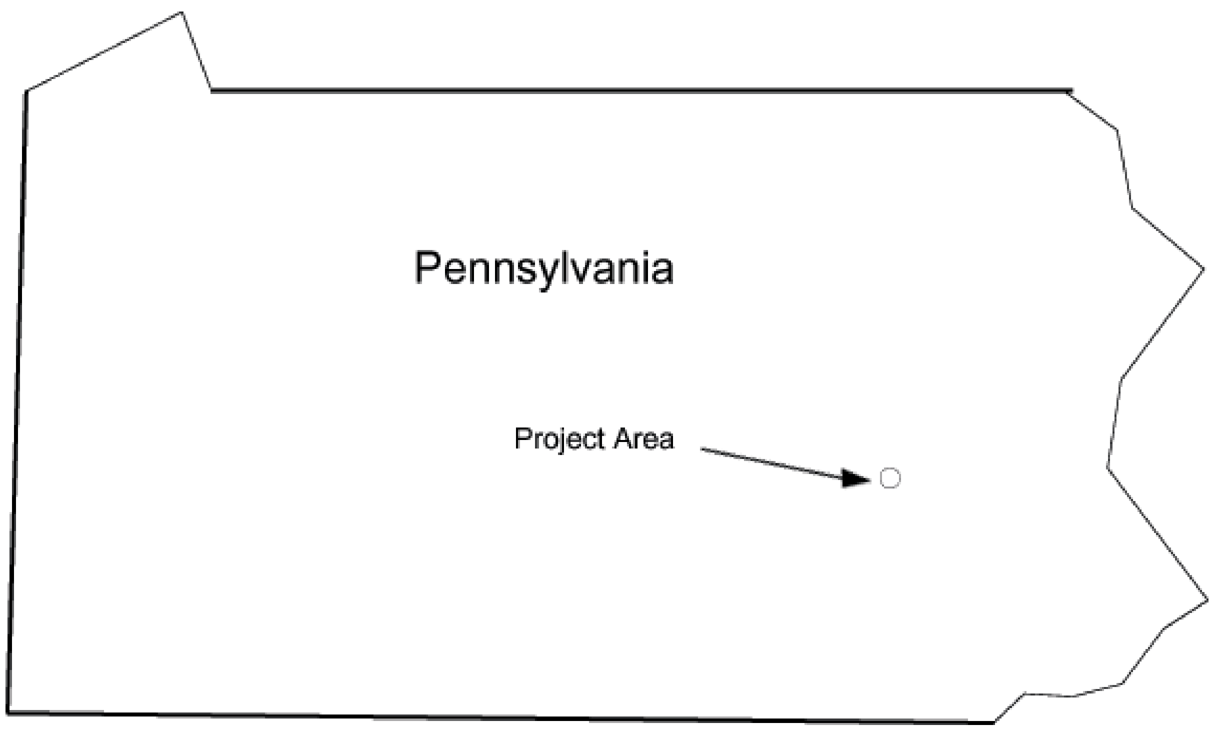

Figure 42: Swatara Creek (Pennsylvania) Watershed Project Location

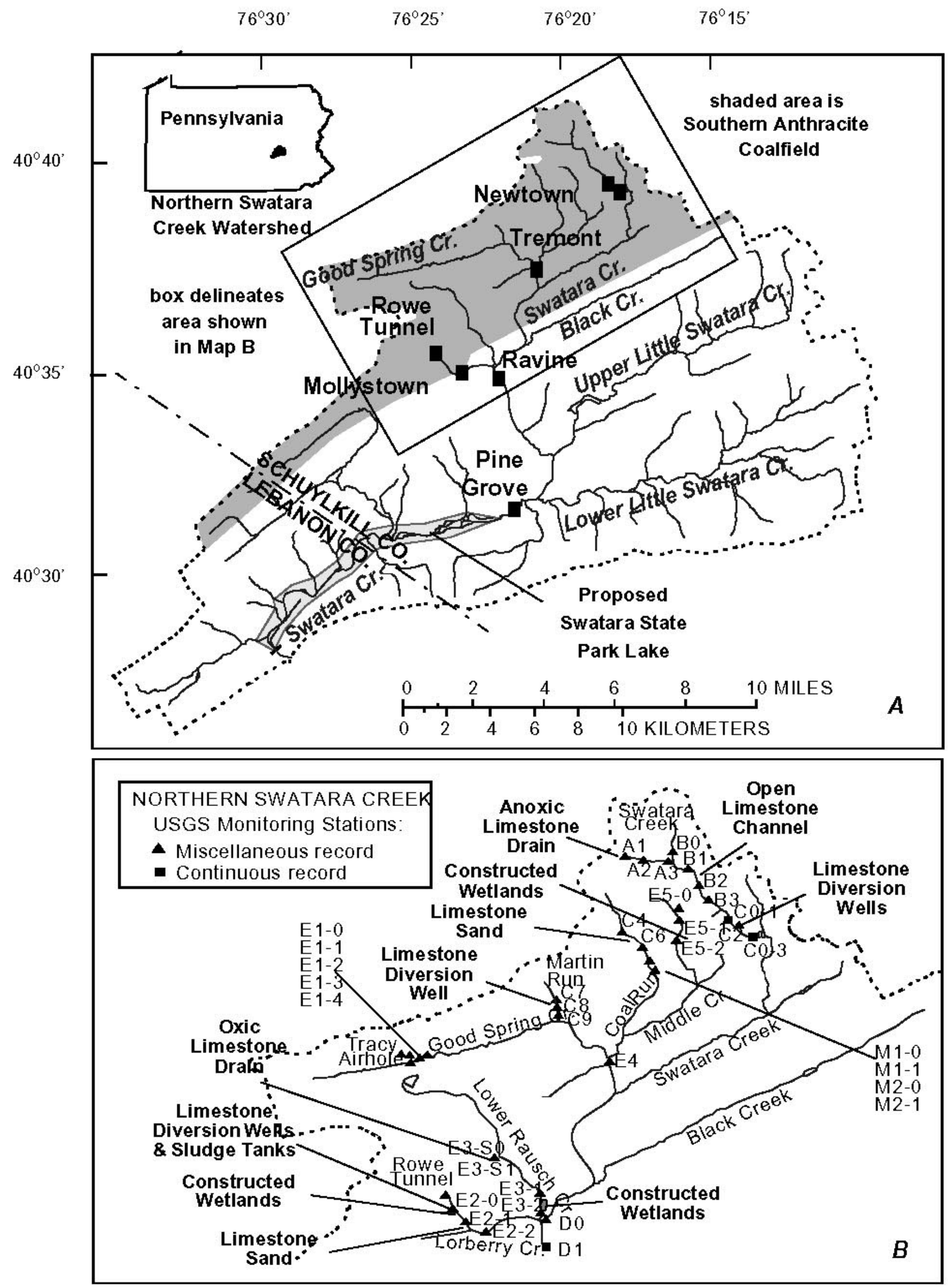

Figure 43. Water-quality and streamflow monitoring sites in the Swatara Creek Basin, Schuylkill County, Pennsylvania: A, continuous monitoring stations on Lorberry and Swatara Creeks; B, CMD treatment systems within the Southern Anthracite Coalfield, above Ravine, and bimonthly monitoring sites in Swatara Creek, Good Spring, Lorberry Creek, and Lower Rausch Creek subbasins.

PROJECT OVERVIEW

Coal mine drainage (CMD) from abandoned mines has affected more than 2,400 miles of streams and associated ground water in Pennsylvania. Approximately half the discharges from bituminous and anthracite coal mines in Pennsylvania are acidic, having pH <5 and acidity > alkalinity. Acidic CMD typically contains elevated concentrations of dissolved sulfate (SO_4^{2-}), dissolved and particulate iron (Fe), and other metals produced by the oxidation of pyrite (FeS_2). Elevated concentrations of sulfate and metals in mine drainage and receiving streams make the water unfit for most uses. Losses of surface water to and CMD from abandoned anthracite mines within the northern 43 mi^2 of the 576-mi^2 Swatara Creek Basin (Fig. 42) degrade the aquatic ecosystem and impair uses of Swatara Creek to its mouth on the Susquehanna River 70 mi downstream from the mined area. Consequently, the Swatara Creek Basin is designated as a “high priority watershed” for reducing nonpoint-source pollution.

To neutralize the acidic CMD and reduce the transport of dissolved metals in the Swatara Creek watershed, innovative passive-treatment systems are being implemented and monitored in the 43 mi^2 northern Swatara Creek Basin. These treatments systems include limestone-sand dosing, open limestone channels, anoxic and oxic limestone drains, limestone diversion wells, and limestone and/or compost-based wetlands. The performance of these new and existing treatment systems is being evaluated using upstream/downstream and before/after monitoring schemes.

The project is currently in the post-BMP monitoring phase. Limestone drains constructed to treat CMD from the Orchard Discharge (1995), Buck Mtn. Discharge (1997), and Hegins Discharge (2000) (fig. 43) and limestone diversion wells constructed on Swatara Creek (1995), Martin Run (1997), and Lorberry Creek (1998) in the Swatara Creek Basin, have had significant effects on the mitigation of acidic baseflow and stormflow and on the restoration of aquatic quality to Swatara Creek. Additionally, recently constructed wetlands in the Lower Rausch Creek (1997) and Lorberry Creek (2002) subbasins in the Swatara Creek watershed (Fig. 43) potentially will reduce the transport of metals to Swatara Creek. However, the long-term performance of these treatment systems and continued recovery of the aquatic ecosystem are uncertain. Data collected to date on treatment system performance have been used to plan modifications of several treatment systems. The project has been extended to 2007.

PROJECT BACKGROUND

Project Area

The 43-mi^2 northern Swatara Creek watershed, upstream from Ravine, Pa., is located in Schuylkill County, Pennsylvania (Fig. 42).

Relevant Hydrologic, Geologic, and Meteorologic Factors

The northern Swatara Creek watershed drains the Southern Anthracite Field in the Ridge and Valley Physiographic Province. The watershed is underlain by siliciclastic bedrock of the Llewellen and Pottsville Groups. The ridges are held up by quartzite sandstone and conglomerate, whereas mostly softer rocks, including shale and siltstone with some interbeds of sandstone and anthracite, underlie the hillslopes and valleys. The mining of coal has had a significant effect on the watershed hydrology, affecting both the flow and quality of surface and ground water.

Average annual rainfall for the watershed area is approximately 44 in/yr, with approximately 33 in/yr of snowfall.

Land Use

Current land use in the 43-mi^2 project area is classified as 86.6 percent forested and 4.9 percent agricultural, with only 6.4 percent classified as barren, mined; however, the land-use classification for this extensively mined area is misleading because underground mines extend beneath much of the surface and "natural" reforestation conceals large tracts of unreclaimed spoil. Agricultural development predominates downstream from the mined area. For example, land use in the 116-mi^2 area of the Swatara Creek Basin upstream from Pine Grove, which is 11 km downstream from Ravine, is classified as 69.7 percent forested, 25.0 percent agricultural, and 2.4 percent barren, mined.

Water Resource Type and Size

The northern Swatara Creek watershed contains approximately 37 miles of streams that will discharge to a proposed water-supply reservoir located in Swatara State Park. The proposed 775-acre reservoir will support recreational activities as well, including boating, fishing, and swimming. The water quality of source streams must be improved for the proposed reservoir to support all its designated uses.

Water Uses and Impairments

The streams of the northern Swatara Creek watershed are classified as cold-water streams. The Pennsylvania Fish and Boat Commission manage some of the streams as put-and-take trout waters. Additionally, the proposed reservoir to be constructed within Swatara State Park will support recreational activities including boating, fishing, and swimming.

CMD is considered to be the leading cause of degraded water quality in the project area. Acidity and high levels of sulfates and metals have created conditions that are toxic to some aquatic organisms. Recent efforts have been undertaken by the Pennsylvania Department of Environmental Protection (PaDEP), Bureau of Mining and Reclamation (BMR) to develop a watershed remediation plan. The goal of this plan is to improve water quality and restore the streams to recreational and fishable waters.

Pollutant Sources

CMD is the primary nonpoint source of pollution in the northern Swatara Creek basin; other sources are negligible. Although several surface and underground anthracite mines presently are active, most mines in the Swatara Creek Basin were abandoned before 1960. Barren, steep banks of spoil and culm and fine coal debris in siltation basins are sources of sediment (suspended solids), sulfate, iron, aluminum, and other metals in water that infiltrates or runs off the surface during storms. The abandoned underground mines have flooded and have collapsed locally causing subsidence. Surface flow is diverted through subsidence pits, fractures, and mine openings to the underground mines where the water becomes contaminated with acidity, sulfate, and metals. In downstream reaches, the contaminated water resurges as CMD contaminating Swatara Creek and its tributaries, while contributing substantially to baseflow.

A substantial proportion of the total streamflow originates as CMD. This source is most important during baseflow conditions. In contrast, during stormflow conditions, as much as 95 percent of the total streamflow for Swatara Creek at Ravine originates as surface runoff. The surface runoff typically has lower pH and lower concentrations of dissolved solids than the baseflow at Ravine.

Plans for pollution control have recently been implemented for one of the largest sources of water, the Rowe Tunnel Discharge, to reduce transport of acidity and loads of iron and aluminum from Rowe Tunnel, averaging 290 and 30 pounds per day, respectively.

Pre-Project Water Quality

Water quality data collected at 49 stations by BMR, Skelly and Loy Engineering Consultants, and the Northern Swatara Creek Watershed Association (NCSWA) volunteers from previous investigations were used to help document stream conditions and identify problem areas prior to installation of passive treatment systems. Data from these previous investigations included analysis of typical CMD; metals, major ions, acidity, and alkalinity.

The data indicated that a substantial proportion of the total streamflow originates as CMD. The investigations also revealed that the majority of the aluminum load to the stream originates from the eastern areas of the watershed upstream from Route 209 near Newtown (sites A, B, and C, Fig. 40) and the majority of the iron load originates from western areas of the watershed, including the Rowe Tunnel and Tracy Airhole which are significant sources of water to Lorberry Creek and Good Spring Creek, respectively.

Water Quality Objectives

The objectives of the project are:

- Design, install, and evaluate the performance of innovative passive-treatment systems for neutralization of CMD and removal of iron from an anthracite mine-tunnel discharge feeding a 4.01 mi^2 subbasin.
- Evaluate the long-term effects on stream water quality from a combination of limestone passive-treatment systems designed to neutralize CMD and remove aluminum in a 2.8 mi^2 subbasin.
- Determine the long-term cumulative effects of a variety of CMD treatments on stream water quality resulting from the remediation of approximately 25 miles (67 percent) of degraded streams in the coalfields of the 43 mi^2 northern Swatara Creek watershed.

Project Time Frame

1998-2001
2002-2007 (extension)

PROJECT DESIGN

Nonpoint Source Control Strategy

Downstream monitoring is critical in evaluating the overall success of watershed-scale implementation of NPS pollution controls within the Swatara Creek watershed. Each passive treatment system has different advantages and disadvantages; however, all suffer from possible complications associated with variability in flow rates, chemistry of the CMD and stream water, and from uncertainties about efficiency and longevity of the treatments. An evaluation of chemical and physical factors affecting reactions within passive treatment systems is needed to resolve uncertainties about the optimum designs and appropriate uses of these systems.

During 1996, BMR and volunteers constructed five limestone based passive-treatment systems with technical assistance from the USGS to begin the cleanup of several major pollution sources in the Swatara Creek headwaters. These treatment systems included limestone sand dosing, open limestone channels, limestone drains, and limestone diversion wells. Limestone sand dosing and open limestone channels are the simplest treatment systems where limestone fragments are added directly to the stream channel semiannually or less frequently. Slow dissolution rates, armoring, burial, and transport of limestone from the channel during high flows are concerns. A limestone drain is another relatively simple treatment method, which involves the burial of limestone in airtight trenches that intercept acidic discharge water. Keeping carbon dioxide within the drain can enhance limestone dissolution and alkalinity production. Furthermore, keeping oxygen out of contact with the discharge water minimizes the potential for oxidation of dissolved iron and the consequent precipitation of solid iron hydroxide [$Fe(OH)_3$], which could armor the limestone and clog the drains. In a limestone diversion well, acidic water is diverted from upstream points and the hydraulic force of the piped flow is deflected upward through limestone fragments inside 4-ft diameter “wells.” Hydraulic churning abrades the limestone forming fine particles and preventing the buildup of hydroxide armoring.

Samples will be taken at baseflow and stormflow conditions to determine the effectiveness of the limestone treatment systems. These treatments intend to raise the pH and alkalinity, facilitating the precipitation of dissolved iron, aluminum, and associated metals. Results from the characterization of Lorberry Creek and a dosing field test will be used to design an innovative passive-treatment system to neutralize the CMD and reduce the iron loads. A combination of underground and above ground treatment alternatives will be considered. The combination will include physical, chemical, and biological treatments. Examples of underground treatments that may be considered include fly ash or limestone injection and aeration; while above ground treatments may include diversion wells, settling ponds, wetlands, clarifiers, and biological treatment.

On the basis of the testing described above, an innovative semi-passive treatment system involving limestone diversion wells, a hydraulically powered auger and hopper for caustic chemical delivery and a 4-cell wetland were designed and installed in 2001-2002 below the Rowe Tunnel on Lorberry Creek. Monitoring and testing of various caustic reagents and delivery rates are ongoing to determine its optimal configuration.

Project Schedule

Management Unit	Pre-BMP Monitoring Dates	BMP Implementation	Post-BMP Monitoring Dates	BMPs
Watershed Area E (Lorberry Creek)	1993-May 1995 1993-Mar. 1999	Feb. 1995-ongoing Mar. 1999-Dec. 2001	Mar. 1996-Mar. 2007 Mar. 2001-Mar. 2007	Limestone sand dosing, Diversion wells, Limestone drains, Wetlands

Water Quality Monitoring

Combinations of upstream-downstream and before-after sampling schemes are being utilized within the northern Swatara Creek watershed. Within stream reaches where passive treatment systems have been established, upstream and downstream monitoring stations have been installed to evaluate the effectiveness of these treatment alternatives. Monitoring stations have also been established on streams within the project area where treatment systems will be implemented in the future. Samples collected from these stations before the implementation of BMPs will be used to assess existing water quality conditions and determine appropriate treatment designs. After treatment systems have been installed, samples will continue to be collected to assess changes in water quality over time due to BMP implementation.

Variables Measured

Biological

Fish surveys
Benthic macroinvertebrates

Chemical and Others

Acidity
Alkalinity
Aluminum
Calcium
Chloride
Dissolved oxygen (DO)
Iron
Magnesium
Manganese
Nickel
pH
Potassium
Sodium
Solids, suspended
Specific Conductance
Sulfate, as SO_4
Zinc

Covariates

Redox potential
Temperature
Streamflow or discharge rate

Sampling Scheme

Three USGS streamflow gages, Swatara Creek at Ravine (D1, Fig. 41), Swatara Creek at Pine Grove (D2, Fig. 41), and Swatara Creek at Newtown (C3, Fig. 41) are used as continuous streamflow and water-quality monitoring stations on the main stem of Swatara Creek. Two additional gages on Lorberry Creek at Mollystown (E2, Fig. 41) and below Rowe Tunnel (E-244, Fig. 41) also are equipped for continuous streamflow and water-quality monitoring. These stations are sampled periodically by the USGS to document and evaluate both the efficiency of a combination of limestone passive-treatment systems, and the long-term water quality changes in the Swatara Creek watershed that result from upstream coal-mine discharges and CMD cleanup.

Within the first year of monitoring on Lorberry Creek (March 1998 - February 1999), water-quality data will be collected monthly. During this same period, fish and benthic macroinvertebrate data will be collected annually upstream (E1, Fig. 41) and downstream (E2, Fig. 41) of surrounding lands that potentially could be utilized for passive treatments. Continuous water-quality monitors also will be installed near E2 (Fig. 41) to correlate water-quality and flow measured at a continuous streamflow record gaging station operated by OSM at the Rowe Tunnel entrance. Once the characterization of Lorberry Creek is complete in March 1999, a treatment system (based upon the acid and iron loads and iron oxidation rate) will be implemented in Lorberry Creek upstream from the junction with Swatara Creek.

Beginning in October 1998, base-flow and high-flow water-quality samples were collected using manual methods at four of the ungaged monitoring stations (A3, B3, C6, and C9, Fig. 41) established during the existing program and quarterly at three new synoptic stations where CMD treatment is expected under other current and proposed 319 projects. The samples will be used to determine system performance under variable flow conditions and to evaluate the long-term treatment efects on water-quality of a combination of limestone passive-treatment systems.

Water quality samples will be collected monthly for base flow, quarterly for stormflow, and annually for biological data at the downstream gages (D1 and C3, Fig. 41) as part of this proposed project. Sampling will determine the long-term cumulative effects from a variety of treatments of CMD discharges from degraded streams in the coalfields of the northern Swatara Creek subbasin. Stormflow samples will be collected using automatic pumping samplers.Annual load and trends in transport of suspended sediments, sulfate, metals, and nutrients will be estimated using a multivariate regression model. Data for continuous water-quality and flow records at stations D1 and C3 (Fig. 41) will be compared with data for synoptic base-flow and high-flow samples to verify that samples represent the range of flow and water-quality conditions. Statistical methods will be used to characterize the flow and water-quality data and to determine intercorrelations among the hydrological and chemical variables.

Concurrent with water-quality sampling, measurements of streamflow, temperature, pH, specific conductance (SC), dissolved oxygen (DO), redox potential (Eh), acidity, and alkalinity will be conducted by USGS. Water-quality samples will be analyzed for major ions and metals in filtered and whole-water fractions by the PaDEP Bureau of Laboratories facility in Harrisburg (1996-2001) and the USDOE Laboratory in Pittsburgh (2001-2007). In addition to the synoptic sampling, flow rates, temperature, pH, and SC, at two stream gages (D1 and C3, Fig. 41) will be monitored continuously by the USGS during the three years after BMP implementation (1998-2000). Statistical correlations will determine if SC and pH can be used as surrogates for laboratory chemical measurements of sulfate, metals, acidity, and alkalinity.

Land Treatment Monitoring

Changes in land-use over the project duration are not expected to be significant.

Sampling Scheme

Changes in land-use over the project will be assessed by considering available aerial photography and digital orthophotoquads in conjunction with information from the PaDEP about completed land-reclamation and coal-mining projects.

Monitoring Scheme for the Swatara Creek Section 319 National Monitoring Program Project

Design	Sites or Activities	Primary Parameters	Covariates	Frequency of Water Quality Sampling	Frequency of Biological Assessment	Duration
Upstream/ Downstream	E (Lorberry Creek)	SS, Fe, Al, SO_4, fish survey, benthic macroinvertebrates	Discharge Precipitation	Storm sampling, Monthly grab, Continuous temperature, SC, pH	Yearly for benthic macro-invertebrates and fish surveys	2 yrs pre-BMP 1 yr BMP 3 yrs post-BMP

Modifications Since Project Start

For 2003-2007, laboratory services will be provided by a commercial laboratory and administered by Schuylkill Conservation District. The commercial laboratory schedule excludes most trace elements, but includes major metals associated with mine drainage.

Progress to Date

The testing of innovative passive-treatment systems began in March 1996 with assistance from the U.S. Department of Energy (USDOE) and PaDEP. Water-quality and flow data will be collected monthly and biological data annually at stations E1 and E2 (Figure 2) throughout the project to monitor the effectiveness of the treatment system(s) for the removal of dissolved and suspended metals, and rates of removal over variable flows.

Limestone sand, which can dissolve rapidly because of its small size (<1/8 inch), was dumped into Coal Run (14 tons) between stations C4 and C6 (Fig. 41) on September 4, 1996, and into Lorberry Creek (150 tons) below station E2 (Fig. 41) on February 13-14, 1997. An open limestone channel was constructed within a 110-ft long segment of Swatara Creek at station B2 (Fig. 41) on March 21, 1997. A total of 44 tons of sand-size fragments and 70 tons of larger fragments (1-4 inches) were installed as a series of alternating berms extending part way across the 15-ft-wide channel from opposite sides of the stream.

Limestone drains were constructed on March 15, 1995, at station E3 (Fig. 41) to treat a small acidic discharge (10-30 gpm, oxic inflow; 44 tons limestone) along Lower Rausch Creek. On May 21, 1997, limestone drains were constructed at station A1 (Fig. 41) to treat a larger discharge (50-200 gpm, anoxic inflow; 400 tons limestone) at the headwaters of Swatara Creek. On June 10-27, 2000, a large, oxic limestone drain was constructed on Hegins Run at station H1 (Fig. 41) to treat a large, low-pH, high aluminum discharge (100-500 gpm; 900 tons limestone). These larger systems were designed on the basis of results for the smaller system where pH increased from 3.5 to 6.5 through the drain during the < 3-hour residence time.

On November 14, 1995, a pair of diversion wells was installed to treat water diverted from Swatara Creek at station C2 (Fig. 40). On July 13, 1997, a single diversion well was installed to treat water from Martin Run at station C8 (Fig. 41). In December 1998, a pair of diversion wells was installed on Lorberry Creek below Rowe Tunnel. Approximately 1 ton of limestone is consumed weekly by each operating diversion well. Diversion wells can be installed in series to treat large flows, but must be maintained by frequent refilling with fresh limestone. Furthermore, the diversion wells only add alkalinity and increase pH, facilitating the precipitation of dissolved metals; however, they do not remove particulate iron and other metals.

In December 1997, near the mouth of Lower Rausch Creek at station E3 (Fig. 41), a 3-acre compost-limestone based wetland was constructed to remove iron from near-neutral streamflow. In December 2001, near the confluence of Stumps Run and Lorberry Creek at station E2 (fig. 41), a 3-acre wetland was constructed to remove iron from treated water exiting two limestone diversion wells below the Rowe Tunnel discharge. In addition, a large hydraulically powered hopper has been installed to deliver hydrated lime, waste lime, or other alkalinity-producing materials and supplement alkalinity production by diversion wells needed for iron oxidation and particle removal. Ongoing tests conducted since 2002 coupled with monitoring at the wetlands and along Lorberry Creek are being conducted to determine optimal operating conditions for the hopper delivery of reagents, the removal of iron by the wetlands, and the corresponding effects on quality of Lorberry Creek and Swatara Creek.

In fall of 2005, the limestone drains at the headwaters of Swatara Creek and Hegins Run were enlarged with the addition of 100 and 200 respectively. Futhermore, to retain carbon dioxide and promote greater rates of limestone dissolution, the Hegins drain was covered with geotextile and compost. Additionally, in summer of 2007, the limestone drain at station E3 was reconstructed as a downflow cell with flushing pipes and a settling basin to manage the accumulation of metal rich solids.

In July of 2007, stage, temperature, and water-quality recording devices were removed from all continuous gage sites as the sites were decommissioned at the conclusion of planned monitoring. Only the staff plates were left in place.

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

Data collected for the project will be maintained in the USGS NWIS data base. The water-quality and streamflow data will be published annually in the USGS Water Resources Data Report.

NPSMS Data Summary

Updates to the Nonpoint Source Management System (NPSMS) will be provided annually to the U.S. Environmental Protection Agency and a two or three page annual progress summary will be provided to PaDEP.

Findings to Date

Preliminary results indicate that the constructed treatment systems function well during baseflow conditions. The anoxic limestone drain (A1 in Fig. 41) near the headwaters of Swatara Creek has the greatest benefit, producing significant improvement in pH and alkalinity that are measurable several miles downstream. The diversion wells have greatest potential to treat stormflow, which generally is more acidic than baseflow, however, these systems require maintenance to ensure that they contain sufficient limestone through the duration of a stormflow event and that they do not become clogged with leaves and other debris. At near-neutral pH, the transport of dissolved iron, aluminum, and trace metals including cobalt, copper, lead, and zinc typically is attenuated owing to precipitation and adsorption. Wetlands installed at various locations on tributaries and at CMD sources have demonstrated their effectiveness at reducing metals transport to the main stem of Swatara Creek. Nevertheless, substantial transport of dissolved and suspended metals persists in Swatara Creek because of the long-term accumulation of $Fe(OH)_3$, $Al(OH)_3$, and associated materials within the streambed during baseflow, and the scour and transport of accumulated metal-rich streambed deposits during the rising stage of stormflow events.

At Ravine, immediately downstream of the mined area, annual minimum values of pH have increased from acidic to near-neutral over the study period, and the fish community has rebounded from nonexistent in 1990 to 25 species in 2002. Despite continued maintenance of near-neutral water quality, recent fish surveys in 2003-2006 demonstrated wide variations in species abundance and numbers largely in response to flow conditions; fewer species and numbers of fish were found during high-water conditions following large flow events in 2004 and 2005. An increased abundance of benthic macroinvertebrate taxa that are intolerant of pollution indicates water quality improved from fair in 1994 to very good in 1999 and 2000.

INFORMATION, EDUCATION AND PUBLICITY

The project will document: 1) the surface-water quality of Swatara Creek and its tributaries within and downstream from the southern anthracite coalfield, 2) aquatic habitat recovery and biological diversity in reaches downstream from treatment, and 3) the operational performance of the treatment systems. Knowledge about factors affecting the performance of passive treatment systems in CMD environments will help in designing cost-effective treatment systems for a variety of situations. The information and technology will be immediately transferable to groups such as the Eastern Coalition for Abandoned Mine Reclamation. This group would benefit from the fact that several treatment scenarios and a wide range of flow-rate and water-quality conditions will be studied at Swatara Creek that are applicable to other watersheds in the anthracite region. Project results also will be applicable to natural and man-made hydrologic systems in which limestone is an important reactant, particularly with respect to neutralization of acidic surface water or ground water.

Documentation of progress is ongoing, and will be distributed to interested groups, local and national. Information of particular interest to local groups includes the methodology used in improving surface-water quality within the watershed (degree of success with treatment systems), remediation of aquatic habitat and biological diversity both within and downstream of the affected area, and the project's extensive degree of flow-rate and water-quality studies. Preliminary results will be presented annually at the National Monitoring Program workshop. Data will be published annually, interpretive reports will be published as journal articles and presented at regional and national meetings, and a final interpretive report will be published in 2007.

TOTAL PROJECT BUDGET

The estimated total cost of the project for 1999-2002 is $670,000 (see previous years NMP Summary Reports for this project for budget details). The estimated total cost of the project for 2003-2007 is $967,340. The USGS and PaDEP will share costs. Laboratory services will be provided by USDOE.

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

The Schuylkill County Conservation District (SCCD) has been the main coordinator in constructing the abatement measures for the mine drainage pollution, as well as nutrient management and stream-bank stabilization in the farming areas. The SCCD has helped local citizens organize the Northern Swatara Creek Watershed Association (NSCWA) to implement passive-treatment and surface-stabilization projects to clean up the coal-mine pollution in the northern portion of the watershed.The Swatara Creek Watershed Association, a separate organization, has worked hand-in-hand with the Concerned Citizens for Clean Water, and has focused its efforts in the past in Lebanon County and the lower part of the watershed. Other local groups assisting with the project include Schuylkill County fishing and sportsman's groups, and, in particular, the county's Waste Management Coordinator, who has been instrumental in seeking funding for stream improvement projects.

Local industries have been supportive of the project. Coal companies and limestone quarries have donated supplies and services in the cleanup effort.

PROJECT TASK	FEDERAL FISCAL YEAR					TOTAL
	FY2003 F	Y2004 F	Y2005 F	Y2006 F	Y2007	
Project Management	$8,088	$5,731	$6,014	$6,311	$6,623	$32,767
Maintenance of Gages	$38,807	$33,774	$34,948	$36,181	$23,238	$166,948
Lorberry Monitoring/Data Mgt.	$43,403	$45,398	$47,492	$49,691	$27,035	$213,019
N.Swatara Monitoring/Data Mgt.	$22,369	$23,447	$24,577	$25,765	$21,289	$117,447
Lorberry Lab Analysis	$22,313	$23,428	$24,600	$25,830	$14,231	$110,402
N.Swatara Lab Analysis	$10,756	$11,294	$11,859	$12,452	$9,764	$56,125
Annual Ecological Surveys	$5,695	$5,972	$6,264	$6,570	$6,892	$31,393
Annual Data Report	$10,391	$10,910	$11,456	$12,028	$12,630	$57,415
Presentations, Interim & Final Report	$19,966	$27,867	$40,367	$30,551	$63,073	$181,824
TOTAL: $181,	788	$187,821	$207,577	$205,379	$184,775	$967,340
Contributions:						
USGS $55,0	00	$57,750	$60,638	$63,669	$66,853	$303,910
PaDEP $104,	475	$106,643	$122,339	$115,880	$103,691	$553,028
USDOE $22,3	13	$23,428	$24,600	$25,830	$14,231	$110,402

OTHER PERTINENT INFORMATION

None.

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Villanova University Stormwater Best Management Practice
Section 319
National Monitoring Program Project

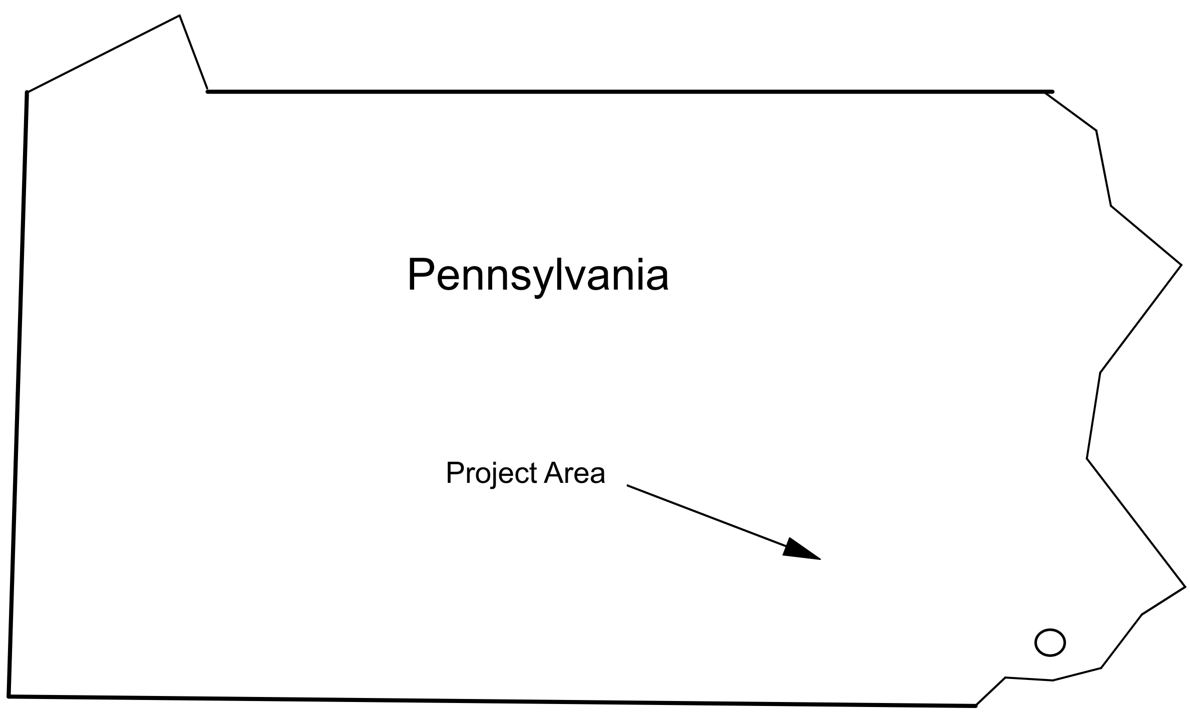
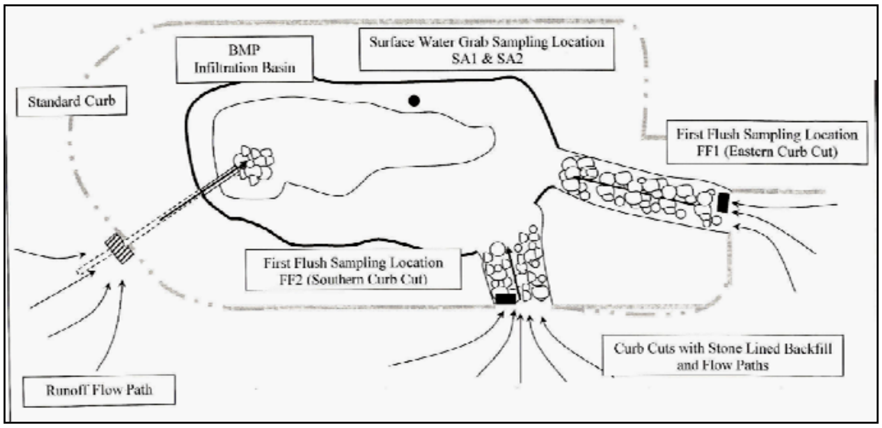


Figure 44: Villanova University Stormwater Best Management Practice (BMP) Monitoring Project.



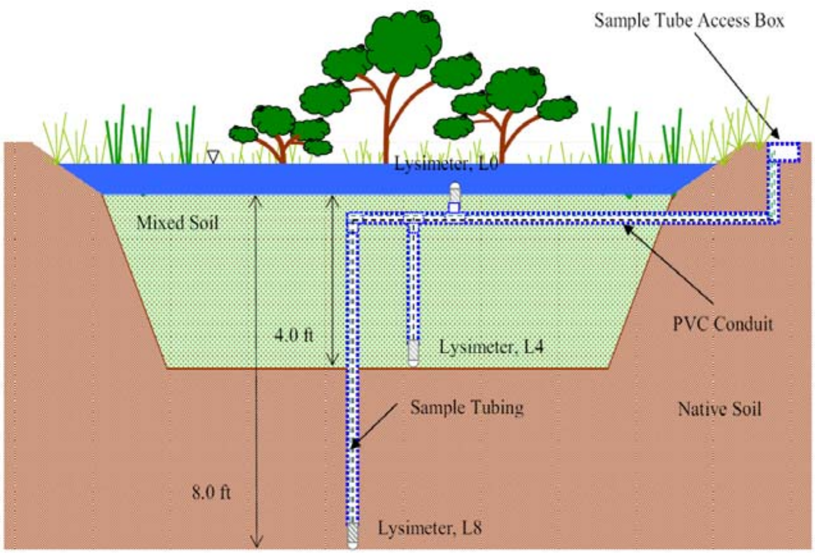


Figure 45a. Bioinfiltration Rain Garden (formally called Bioinfiltration Traffic Island)- Monitoring Setup.

(top) Schematic of surface sampling locations (Ermillo, 2005)

(bottom) Diagram of subsurface lysimeters sampling locations

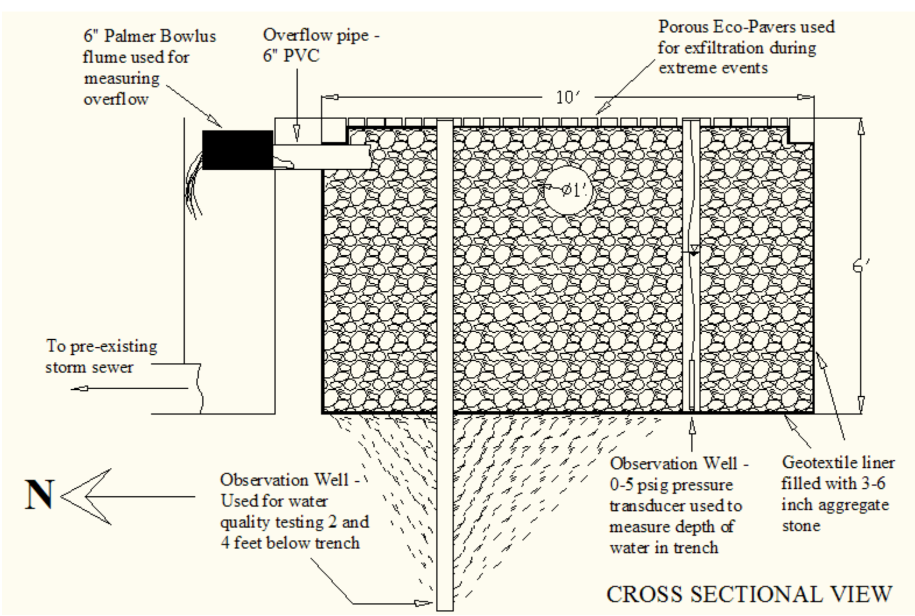


Figure 45b. Diagram of the infiltration trench cross with subsurface monitoring locations

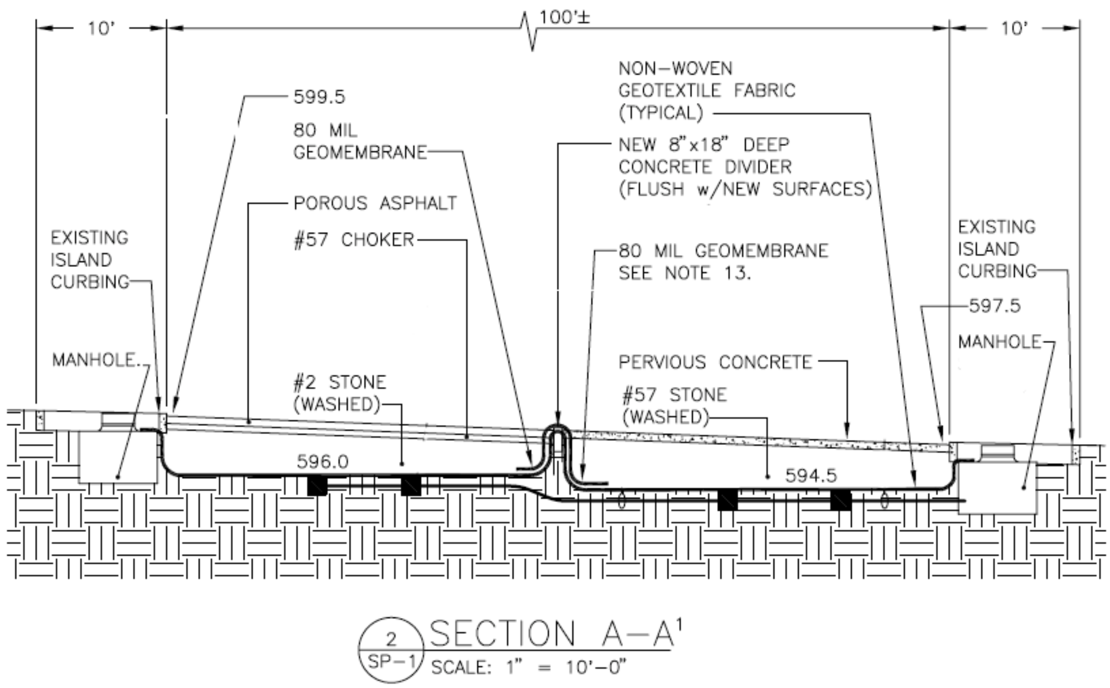


Figure 45c. (top) Diagram of the Pervious Concrete/ Porous Asphalt (PCPA)

(bottom) Photograph of the GKY First Flush Sampler, a passive stormwater sampler that can hold up to 5 L of water.

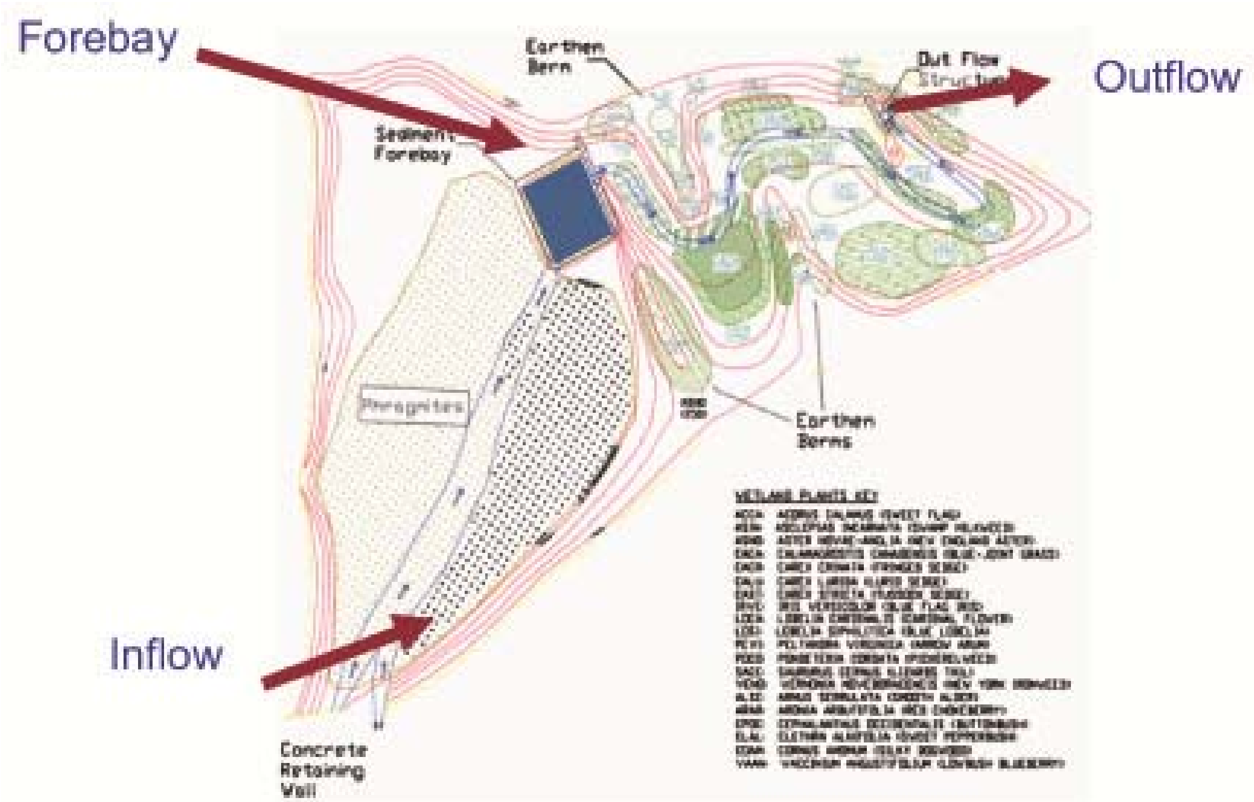


Figure 46. Stormwter Wetland - Monitoring Setup

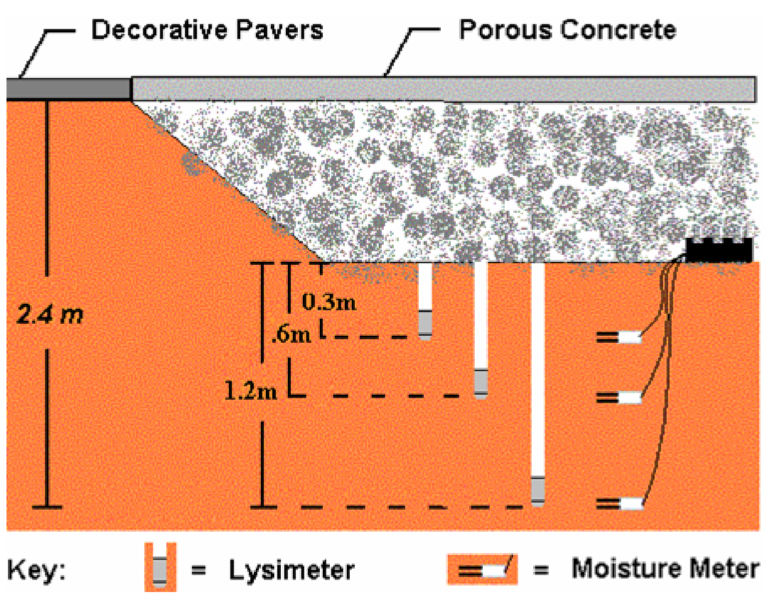


Figure 47. Porous Concrete –Cross Section of Monitoring Instrumentation (Kwiatkowski 2003)

PROJECT OVERVIEW

This project was accepted into the U.S. EPA NNPSMP in 2003. The goals of the EPA National Nonpoint Source Monitoring Program (NNPSMP) project and the Villanova University Stormwater Best Management Practice Park Research and Demonstration Park are:

1) To improve our understanding of nonpoint source pollution;

2) To scientifically evaluate the effectiveness of watershed technologies designed to control nonpoint source pollution; and

3) To export results and lessons learned to the stormwater community

During the last decade there has been a dramatic shift in the practice of stormwater management. The field has moved away from a single-minded flood prevention approach to one that embraces both water quality and quantity. A new suite of control measures termed Best Management Practices (BMPs) using on-site infiltration and treatment approaches have been developed to treat various forms of water pollution including runoff volume and peak flows from urban stormwater. These practices are still evolving, as recognized by the National Academies report entitled Urban Stormwater Management in the United States (National Research Council 2008).

Recognizing the need for research and public education, Villanova University, in collaboration with the Pennsylvania Department of Environmental Protection (PaDEP), formed the Villanova Urban Stormwater Partnership (VUSP) in 2002 and created a Stormwater Best Management Practice Research and Demonstration Park on its campus near Philadelphia, PA.

Since 1999, VUSP has constructed and monitored multiple innovative BMP devices including a stormwater wetland, bioinfiltration and bioretention rain gardens, pervious concrete/ porous asphalt installations, an infiltration trench, and a green roof. Other practices on campus include both wet and dry ponds, rain barrels, a bioswale and a seepage pit estimated to have been built in the 1890s.

By monitoring wet weather flows and pollution entering and exiting each BMP, the effectiveness of these technologies can be measured and evaluated. As the research ends on a specific site, a new one is brought on line. Each site is instrumented to facilitate study of runoff volume, peak flow and quality.

PROJECT BACKGROUND

Project Area

Bioinfiltration Traffic Island	Watershed – 0.53 hectares
Infiltration Trench	Watershed – 0.16 hectares
Pervious Concrete / Porous Asphalt	Watershed - 0.07hectares
Porous Concrete	Watershed - 0.52 hectares

Relevant Hydrologic, Geologic, and Meteorologic Factors

All BMPs are in the Philadelphia region. Rainfall is approximately 114 centimeters per year, with about 50% of the total volume falling in storms less then 2.5 cm. The soils are underlain by undisturbed sandy silt.

Land Use

Bioinfiltration Traffic Island - The watershed includes a student parking lot, roadway and lawn areas. It is approximately 50% impervious..

Infiltration Trench - The watershed consists of an elevated parking deck. It is 100% impervious.

Pervious Concrete / Porous Asphalt – Faculty / Staff Parking area – 100% impervious

Water Resources of Concern

All sites are built to mitigate the effects of urban stormwater runoff on the area streams and groundwater. This includes water quality, baseflow recharge, and stream bank protection. The Bioinfiltration Traffic Island is at the headwaters of the Darby Creek Watershed, while the other sites are in the headwaters of Mill Creek, which eventually reaches the Schuylkill River.

Water Uses and Impairments

Both Darby and Mill Creeks are degraded and listed on the 303d list, with urban runoff listed as the cause. Note that urban runoff is rated as the Nation's third highest leading source of water pollution (EPA, 1998 and 2002b). The EPA Region III website lists stormwater as the second highest cause of stream impairment as measured by river miles.

Pollutant Sources

Unlike many types of polluted water, stormwater typically is characterized by rapidly changing and widely fluctuating flows; in some instances high flow periods are accompanied by high concentrations of pollutants, leading to exceptionally elevated short-term loads to receiving waters. In addition to suspended solids, nitrogen and phosphorus, stormwater runoff may contain elevated concentrations of lead and zinc, which also have the potential to affect receiving waters adversely.

Pre-Project Water Quality

For this project, inflow to the stormwater BMP sites is treated as the pre-project water quality.

Water Quality Objectives

All projects are developed to mitigate the effects of urban runoff. The infiltration projects are designed to remove the first flush and infiltrate it into the ground, thus recharging baseflow and treating the first flush, as well as reducing volumes and peak flows.

Project Time Frame

The project time frame is to monitor most sites for six to ten years. Initial monitoring for water quality and quantity for the Bioinfiltration Traffic Island commenced October 1, 2003. During this first year of monitoring, it was discovered that sampling from the traffic island bowl and the porous concrete rock bed did not adequately represent the inflow conditions so first flush samplers were installed for both these practices. It was also discovered that unexpected extremely large levels of chloride increased the minimum detection level of the laboratory instruments for dissolved nutrients. These issues have been addressed through development of new laboratory techniques and purchase of new equipment.. Multiple wells were added to the Bioinfiltration site to facilitate monitoring of Groundwater.. The Infiltration Trench monitoring started in August 2004. One problem on the site is small rainfall events overflow the site and are difficult to monitor. Therefore an overflow weir and an automated sampler were added to the project during July/August of 2006. It was also determined that the grab sampler was not properly categorizing the inflows, so a composite sampler was added and previous inflow data was discarded. Sampling on the Pervious Concrete / Porous Asphalt site initiated in 2008.

Due to the experiences with these sites, the startup work is termed the "Initial Monitoring Period." Note that as all the original sampling locations are continued, the data collected during this first year will be used in analysis.

PROJECT DESIGN

Nonpoint Source Control Strategy

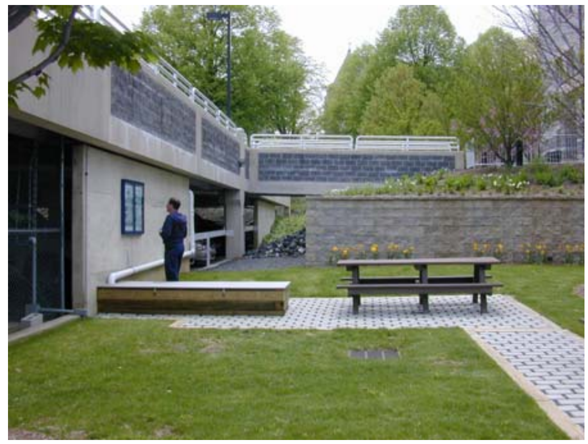
"Green Infrastructure" infiltration BMPs have been the focus of much research at Villanova University (VU). Each of the sites described below has been under study since construction. Websites for each stormwater BMP project can be viewed through the following link: http://www.villanova.edu/ vusp.

The control strategy is to assess flow volumes, rates and pollutant loads for wet weather flows entering and exiting the BMPs. The inflow and outflow of individual BMPs are examined. The BMPs considered to be part of the NNPSMP are summarized below.

Bioinfiltration Rain Garden (BRG) (formally called Bioinfiltration Traffic Island). (PA Growing Greener Grant, constructed summer 2001). This bioinfiltration BMP (previously termed Bioinifiltration Traffic Island) was created by retrofitting an existing traffic island on Villanova's campus as shown in Figure 2. The facility intercepts runoff from a highly impervious (50%) student parking area and road (0.53 ha) that previously would be collected by inlets and delivered through culverts to a dry detention basin. The BMP is designed to control runoff from smaller storms (1- 3 cm) through capture and infiltration of the first flush. Capture of these small storms treats more than 80% of the annual rainfall, thus improving water quality, reducing downstream bank erosion and maintaining baseflow.

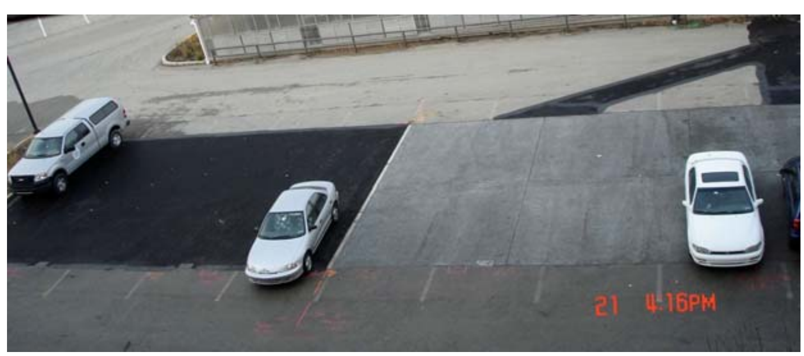
VU Bioinfiltration Rain Garden BMP (photo bottom taken 2007)

Infiltration Trench (IT). (319 Grant – Constructed August 2004). The project is designed to capture runoff from an elevated parking deck and then infiltrate it through a rock bed into the ground. The project presents some unique possibilities. As the water is piped through storm drains to the site, filtration devices can be used and tested at this site. This BMP has a very large drainage area to infiltration area ratio to stress the capacity of the BMP. It is designed to capture approximately the first 0.6 cm of runoff from an elevated parking deck (0.16 ha) and infiltrate it through a rock bed into the ground. The rock bed has a surface area of approximately 7.2 m2, and is 3 m deep (under the influent box and picnic table - see photo). Overflow from the trench first exits through a pipe at the surface to the inlet pictured (far left of Figure 3). During extreme events, if the overflow pipe is full, any additional runoff exits through the porous pavers placed above the infiltration trench (Figure 3). Of the demonstration sites under study, this site is the only one with a 100% impervious drainage area. The drainage area receives continuous use by faculty and staff vehicles.



VU Infiltration Trench, (left) completion of trench excavation with geotextile fabric lining (note locations of the two monitoring wells) (right) completed infiltration trench (2005)

Pervious Concrete / Porous Asphalt (PCPA). (EPA Section 319 grant, National Ready-Mixed Concrete Association – Prince Georges County, constructed October 2007). This BMP captures runoff from a campus parking area, passes the flow through either a pervious concrete or porous asphalt surface course, and infiltrates it through a rock bed into the ground. The site, formerly a standard asphalt paved area, is located behind Mendel Hall at the Villanova campus. The site consists of an infiltration bed overlain by a 15.2 x 9.1 m pervious concrete surface and an adjacent, equally sized porous asphalt surface. The site receives continuous use by faculty and staff vehicles. The site is designed to capture and infiltrate storms of up to five cm of rainfall. From these events there is no runoff from the site. The pervious pavements receive water solely from parking areas. The infiltration beds are level and range from 0.9 to 1.5 m deep and are filled with washed stone, with approximately 40% void space. In extreme events when the capacity of the storage beds is exceeded, flows are permitted to exit the site and flow out to the original storm sewer system. This overflow eventually makes its way to a stormwater wetland. The project presents some unique possibilities, to include comparing the performance from both a hydrologic and environmental view of the technologies. Hydrocarbon testing was in 2008.



VU Pervious Concrete / Porous Asphalt BMP

VU Stormwater Wetland Outlet (2004)

Stormwater Wetland. (EPA Section 319 grant, NOAA Coastal Zone Program grant, construction 1998). An existing stormwater detention basin on Villanova University property was converted into an extended detention Stormwater Wetland BMP (Center for Watershed Protection, 1996) using the design concepts presented in the Pennsylvania Handbook of Best Management Practices for Developing Areas (PACD, 1998). The wetland was designed to treat water quality and to reduce erosive peak flows from runoff from large parking lots, university buildings and dormitories, roadways and train tracks. The watershed draining to the wetland is approximately 40% impervious. The project has been published in EPA 319 Success Stories Part III (EPA, 2002a). Some limited unfunded flow studies was conducted at this site prior to 2005; additional monitoring was conducted after 2005 under a NOAA Coastal Zone Program grant. Monitoring has ended.

Porous Concrete Demonstration Site PaDEP 319 grant, construction 2002) The creation of a porous concrete infiltration facility was in an existing central paved area on the Villanova University campus.. Rock beds underlie three large paved areas, with porous concrete strips (the darkest gray edging around the white concrete) surrounding the beds. The rock beds capture runoff directly from the surrounding roof drains and also from drainage through the porous concrete strips. This site was first built in 2002, but the initial concrete pour failed. The surface was replaced in the summer of 2003, but again some material problems reemerged which were addressed through replacement of some of the surfaces in October 2004. Similar to the concept of the Bioinfiltration Traffic Island, runoff from the site and surrounding buildings (approximately 64% impervious) are captured and infiltrated, decreasing the flows and pollution to a high priority stream segment on the 303(d) list. The site has a much higher capacity then the Bioinfiltration Traffic Island as it overlies the large rock holding beds.

(left) Construction of porous concrete infiltration beds with #4 baffle stone in place.
(middle) Runoff being infiltrated by porous concrete.
(right) Porous Concrete Demonstration Site.

Project Schedule

Site	Monitoring TimeframeStatus	Initial Monitoring Phase	Notes
Bio-Infiltration Traffic Island	Monitoring Underway 10/01/04-09/30/14	10/01/03-09/30/04	IMP - added first flush samplers + bowl lysimeter. GW Well added 2006 Additional GW Wells added 2007
Infiltration Trench	12/01/04-09/30/10	09/01/04-09/30/05	2006 added Automated inflow sampler Overflow Weir
Pervious Concrete / Porous Asphalt	1/1/2009- 9/1/2013	1/1/2008-12/31/2008	Constructed Oct 2007
Stormwater Wetland	Monitoring concluded Baseflow monitoring 6/1/04-9/30/10 Wet weather monitoring 2/1/05-9/30/10	2005-2008	Constructed 1998
Porous Concrete	Monitoring concluded 10/1/04-9/30/10	10/1/03-9/30/04	Construction 2002

Water Quality Monitoring

Variables Measured

pH
Conductivity
Total Suspended Solids (surface samples)
Dissolved Solids (depending on volume collected)
Chlorides
Nutrients - N, P (Dissolved - Various Forms)
Metals - Various (Dissolved - Various Forms)
Hydrocarbons (start 2008)

This list is adjusted based upon what is found at the site and the direction of the research governing board. Note that some of these tests are only applicable to the surface or ground water samples (currently, spectrophometry, ion chromatography, and atomic adsorption equipment is in use - QAPP plan is in place).Unexpected extreme values of high chlorides from road salt interfered with the nitrates, nitrites, and orthophosphate HPLC analysis for the first several years. A new analysis technique was developed to address this situation.

The samples are analyzed in Villanova University’s Civil and Environmental Engineering Water Resources Laboratory, beginning within 30 minutes of sample collection; all analyses are typically completed within 24 hours of sample collection. Any samples not analyzed within 24 hours are preserved according to appropriate protocols established for each analysis.

Sampling / Flow Monitoring Scheme

See figures 45, 46, and 47 for sampling locations.

Infiltration Sites – Each site has rain gages, water sampling devices, and flow or level recorders as appropriate. Pressure transducers are also used to measure the depth of water in the rock beds or surface bowls. First flush samplers are used to capture runoff inflow for water quality testing. Flow leaving the site is split into infiltration and overflow for large storm events. As sampling is conducted from the vadose zone, soil lysimeters were used to collect water samples under the beds (treated as a composite sample). Note that only dissolved fractions are collected from the vadose zone samples and that the sample size is limited, occasionally limiting the number of tests performed.

Lysimeters were used to measure subsurface flow. Lysimeters work by overcoming soil water tension or negative pressure created by capillary forces. By creating a vacuum or negative pressure greater than the soil suction holding the water within the capillary spaces, a hydraulic gradient is established for the water to flow through the porous ceramic cup into the sampler.

Bioinfiltration Rain Garden (formally Bioinfiltration Traffic Island) – A level detector is used to measure the rate of infiltration from the surface bowl, and outflow is measured using a weir in the culvert leaving the site. Soil moisture meters and lysimeters have been placed under the bed. For the past year, inflow water samples for quality analysis were taken from the water bowl above the bed. As considerable removal in the stone beds leading to this BMP has been observed, "first flush" flow samplers have been installed to better represent the inflows to the site. These devices are installed to capture water samples where the runoff enters the site through curb cuts. Ground water quality (outflow) is measured using lysimeters located at the bottom of the made soil (multiple depths and locations). Surface water outflow (only large storms) grab samples are taken from the bowl. A well was added to the site in 2006 to learn more about the site interaction with the groundwater. In 2007 several more were drilled, and pressure transducers with conductivity meters were added to allow for study of the groundwater hydrology from both the hydrology and environmental perspective. More specifically:

<u>Stormwater quantity</u>: The bioinfiltration rain garden has been equipped to accept runoff entering the system via two inlets (north and south), and from a culvert that intercepts runoff from an adjacent culvert.

- Rainfall is measured in 5-minute intervals with a tipping bucket rain gage.
- Overflow is measured through use of a combination V notch weir / pressure transducer.
- Depth within the bowl is measured directly, initially using an ultrasonic level recorder and later a pressure transducer.

  Inflow is determined from a calibrated hydrologic model using all data mentioned previously.
- Multiple Pressure Transducers are installed in surrounding wells. This arrangement is still preliminary.

<u>Stormwater quality</u>: Surface runoff and sub-surface vadose zone samples are collected for approximately 12-18 storms/year.

- Two first-flush samplers catch the first two L of direct runoff from the impervious surface and the grass area adjacent to the basin.
- Initially, a grab sample was collected of surface water during the storm event, with a second sample collected at the conclusion of rainfall, if ponding had occurred. This has been replaced by an automated composite sampler.
- A composite grab sample is taken from the outflow weir.
- Lysimeters are located at depths of 0, 1.2, and 2.4 m beneath the surface. The sample is

extracted from the soil through the use of a pressure-vacuum soil water sampler.

- Grab samples have been taken of the groundwater from surrounding wells. These samples are part of another project that is still at a preliminary stage.

Sample locations for the Bioinfiltration Rain Garden:

- "first flush #1" (FF1) – located on the perimeter of the basin. Assumed to collect the first segment of runoff from the surrounding landscape to the south and east of the basin
- "first flush #2" (FF2) – located on the perimeter of the basin. Assumed to collect the first segment of runoff from the surrounding landscape to the north of the basin.
- "grab sample 1" (GS1) – Sample taken during the rain storm from the ponded water within the basin. Assumed to represent surface water inflow into the site.
- "grab sample 2" (GS2) – Sample taken once the rain has ended from the ponded water within the basin – Assumed to represent outflow leaving the site as either surface water if the depth is above the weir or infiltration into the ground.
- "L0" – lysimeter located at ground level within the drainage bowl. Assumed to represent water infiltrating into the bed.
- "L4" – lysimeter located within the bowl approximately 4 feet beneath the ground surface.
- "L8" – lysimeter located within the bowl approximately 8 feet beneath the ground surface.

Infiltration Trench – As the site is unique in categorizing the nonpoint pollutant contribution of a paved area, this site is treated differently. A rain gage is on site, and runoff inflow is measured using a pressure transducer and V-notch weir. An automated sampler has been added to measure the inflow water quality at the V notch weir. Pressure transducers and soil lysimeters are used to evaluate the depth within the rock bed, volume of infiltration (outflow), and pollutant loadings (Outflow). An overflow weir was added to improve outflow measurements for larger storm events. Again, as the overflow outflows are essentially untreated, the outflow surface water quality is considered the same as the inflow. More specifically:

Stormwater Quantity: The infiltration trench has been equipped to measure and sample runoff entering the system, storage within the system, and overflow. All data are recorded continuously and downloaded weekly.

- Rainfall is measured in 1-minute intervals using a tipping bucket rain gage.
- Runoff entering the site is measured using two V-notch type weirs with corresponding pressure transducers.
- Depth of runoff stored in the rock bed is measured using a pressure transducer.
- Overflow is measured using a manufactured weir and a pressure transducer.

Stormwater Quality: Event-based samples of surface runoff and soil moisture are collected from an average of 12-18 storms/ year.

- An autosampler takes rainfall-weighted discrete samples of surface water inflow.
- Lysimeters are located at 0.6 and 1.2 m depths beneath the surface to extract vadose zone water samples.
- A grab sample co collector is used to capture overflow water quality samples.

Sample locations for the Infiltration Trench:

- "In" – Sequential samples entering the BMP. Samples are taken after ¼", ½" and 1" of runoff.

- “Overflow” – Grab Sample of overflow from the Infiltration Trench - captures the first segment of overflow.
- “L2” lysimeter located approximately 2 feet below the bottom of the bed.
- “L4” lysimeter located approximately 4 feet below the bottom of the bed

Pervious Concrete / Porous Asphalt — Inflow water quality is measured using first flush and lysimeters for both the asphalt and concrete sections. Overflow outflow (large storms only) from each site is measured at weirs in and overflow structure adjacent to the rock bed. Composite water samples for quality measurement of the surface water overflows are taken through a port in the rock bed. More specifically:

Note: Sampling was reduced in 2009 to focus on flow and temperature following conclusion of the water quality study. Notes below are on the original instrumentation.

<u>Stormwater Quantity</u>: The PC/PA has been equipped to monitor runoff entering the system through the porous surface. These flows are correlated to the rainfall amounts measured by a rain gage located on site. The site is further equipped to measure ponded depths and potential overflow. All data are recorded continuously in a data logger.

- Rainfall is measured in 10-minute intervals using a tipping bucket rain gage.
- Pressure transducers that measure the depth in 5 minute intervals are used to measure depths in each rock bed. They are also used in conjunction with a V-notch weir to measure any overflow.

<u>Stormwater Quality</u>: Precipitation event data are collected for surface runoff and sub-surface soil moisture. On average, 12 to 18 storms are sampled yearly.

- Two first-flush samplers catch the first two L of direct runoff from the impervious surfaces upstream of each pervious surface.
- Grab samples of runoff stored in the rock bed are collected following the storm.
- Lysimeters located at 0.15, 0.30, and 0.46 m beneath the surface extract samples from the soil through the use of porous ceramic cups placed under suction during a storm event and pressure after completion using a pressurevacuum soil water sampler.
- The project used Sigma 900 autosamplers capable of taking up to 24 discrete water samples or one composite sample per storm event. To get a consistent sampling routine, the automated samplers are triggered through the data logger through rainfall or depth of water in the BMP. A consistent sampling protocol is established for each site.
- First flush samples were collected using the GKY First Flush Sampler, a passive stormwater sampler that can hold up to 5 L of water (Figure 9). The lid of each sampler is constructed with 5 sampling ports, each of which can be plugged to control the rate at which collected runoff enters the sampler. Plastic flaps on the underside of each port function as closing mechanisms, preventing additional water from entering the sampler once it has reached its capacity. Each sampler is fitted with a 5 L removable plastic container and lid to permit sample transport.

Porous Concrete— Inflow water quality is measured using first flush and lysimeters. Two sets of six soil moisture meters and lysimeters were placed both under and adjacent to the bed at two locations. These were to determine the outflow groundwater quality and quantity. Overflow outflow (large storms only) from each site is measured at weirs in and overflow structure adjacent to the rock bed. Composite water samples for quality measurement of the surface water overflows are taken through a port in the rock bed.

Stormwater Wetland - Both wet weather and baseflow events are included in the monitoring program for this BMP. As the great majority of the inflow is piped to the wetlands through culverts, flow is measured using Sigma Corporation flowmeters. These units measure both velocity and level within the culvert at the inflow and outflow of the BMP (five minute intervals). A rain gage is connected to the flow meter to record the intensity and pattern of the storm. To measure quality, multiple discrete samples are taken during the storm events using automated samplers. Samples are taken at the inflow, the sediment forebay, and the outlet. Probes connected to the flowmeters continuously measure dissolved oxygen, pH, temperature and conductivity. Bimonthly baseflow samples are analyzed for these parameters plus fecal coliform and *E coli*.

Modifications Since Project Start

2005 - “First Flush” samplers were added to the Bioinfiltration Traffic Island and Pervious Concrete and a gutter flow collection device was added to the Pervious Concrete site in 2004.

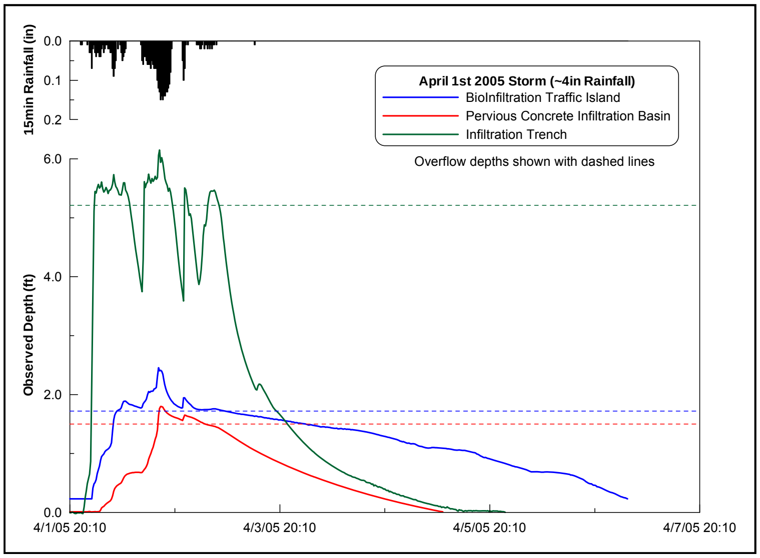
2006 - A groundwater well was added to the Bioinfiltration Site, and an overflow weir and an automated sampler was added to the infiltration Trench.

2007 Additional Groundwater Wells added to the Bioinfiltration Site. Second weir added to the Infiltration Trench inflow.

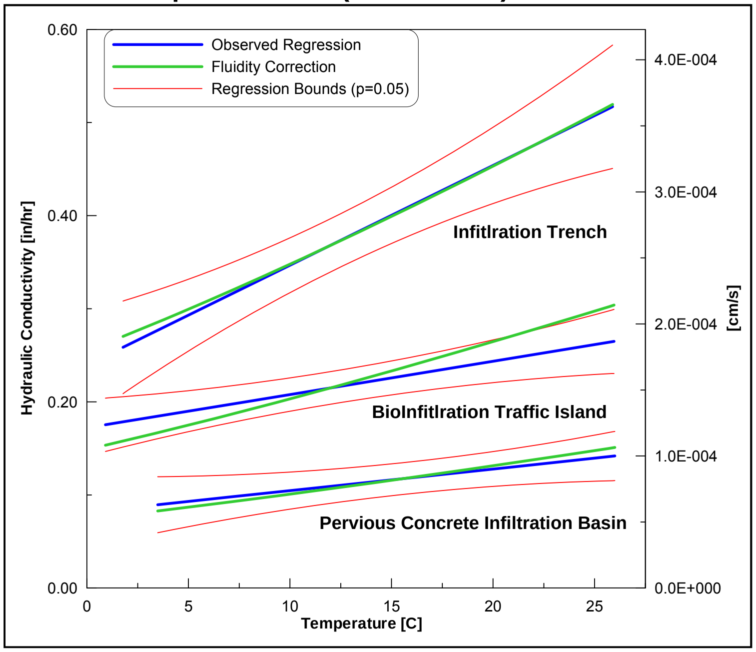
DATA MANAGEMENT AND ANALYSIS

Data has been submitted to the ASCE / EPA Stormwater BMP database and are the focus of numerous student masters theses and dissertation. available through the VUSP website. Multiple Journal articles have been published with more under review.

Flow Example – Infiltration Sites.



BMP Volume performance (Emerson 08)



Overlay of linear regressions for all three infiltration BMPs (Emerson 08)

Water Quality / Quantity Findings To Date

Each of the green infrastructure BMPs is monitored for both quality and flow. Research results are used to further our understanding of how each BMP performs from both a surface and subsurface water perspective. Data from the Bioinfiltration Rain Garden are presented in depth, with selected examples of data from the other sites.

Bioinfiltration Rain Garden (Previously known as the Bioinfiltration Traffic Island). The surface water results of pollutants and flows entering and exiting the BRG from a surface water perspective are presented in Tables 1 and 2. Table 1 is a record of all storm events sampled, while Table 2 presents results from 2008 to allow comparison of the removal percentages for that individual year to that of the complete record.

Note the significant reduction of surface water pollutants achieved through bioinfiltration. It is interesting to observe how much higher the TSS removal is than that of the flow volume. The surface water capture is underrepresented in this report as storms less then 6.3 mm are not included in the statistics, and these storms would be completely captured. The comparison of 2008 to the long term record is used to further our understanding of the volume and pollutant removal of the site as it ages. It appears that the site is increasing in pollutant removal effec tiveness, but that has not as of yet been proven statistically. The exception is TDS / Chlorides / Cadmium, which are skewed due to snow melt operations for 2008. We will learn more as results from 2009 and 2010 are incorporated in the data base, as laboratory detection limits have improved.

Table 1. Bioinfiltration Rain Garden – Surface Flow Performance 2003-2008

Bioinfiltration Rain Garden Surface Water Analysis				
Lifetime Totals				
	# of Storms	Inflow	Outflow	Removal Efficiency
Water Quantity (Measured Events)	253	14,548,858 L	7,297,715 L	49.8%
Total Suspended Solids (TSS)	74	410 kg	10 kg	97.5%
Total Dissolved Solids (TDS)	76	408 kg	94 kg	76.9%
Total Nitrogen (TN) as N	41	2848 g	287 g	89.9%
Total Kjeldahl Nitrogen (TKN) as N	1	0 g	0 g	NA
NO2 as N	51	162 g	21 g	87.0%
NO3 as N	55	1226 g	142 g	88.4%
Total Phosphorus (TP) as P	70	2844 g	2073 g	27.1%
Phosphate (PO4) as P	51	254 g	75 g	70.3%
Chloride (CHL)	62	257 kg	4 kg	98.5%
Total Cadmium	25	2243 mg	222 mg	90.1%
Total Chromium	38	42337 mg	14698 mg	65.3%
Total Lead	41	44428 mg	6580 mg	85.2%

Note: Smaller storms less then 6.3 mm are not included.

Table 2. Bioinfiltration Rain Garden – Surface Flow Performance 2008

Bioinfiltration Rain Garden Surface Water Analysis					
2008					
	# of Storms	Inflow	Outflow	Removal Efficiency	Change in Removal Efficiency vs. long-term
Water Quantity (All Recorded Events > 0.25")	38	-	-	-	"+/-
Water Quantity (Measured Events)	29	1,501,589 L	706,432 L	53.0%	3.1%
Total Suspended Solids (TSS)	14	49 kg	3 kg	94.7%	-2.8%
Total Dissolved Solids (TDS)	15	62 kg	23 kg	62.4%	-14.5%
Total Nitrogen as N	12	310 g	17 g	94.5%	4.6%
Total Kjeldahl Nitrogen as N	1	0 g	0 g	-	
NO2 as N	10	72 g	3 g	95.3%	8.3%
NO3 as N	10	11 g	0 g	99.3%	10.8%
Total Phosphorus (TP) as P	11	127 g	12 g	90.6%	63.5%
Phosphate (PO4) as P	10	50 g	2 g	96.2%	25.8%
Chloride (CHL)	10	7 kg	2 kg	72.2%	-26.3%
Total Cadmium	8	1,244 mg	180 mg	85.5%	-4.6%
Total Chromium	5	30,186 mg	8,248 mg	72.7%	7.4%
Total Lead	8	37,233 mg	3,893 mg	89.5%	4.4%

Note: Smaller storms less then 6.3 mm are not included.

The subsurface results (Table 3) are presented as concentrations (mg/L) of each pollutant as measured at the 0, 1.2, and 2.4 m level. As it is not yet known how much of the captured volumes are infiltrated versus evapotranspired, we are unable to estimate mass loadings.

Note that while TDS, conductivity, TN, and Chloride increase as the stormwater moves through the soil, the pollutants are slightly reduced.

While the pollutant reduction as percent effectiveness is a useful index of BMP performance, an advantage of long-term monitoring is the ability to study the behavior of the BMP based upon a larger data set, especially the more infrequent larger events. Figures 45a1 and 45a2 present analysis from the bioinfiltration rain garden with respect to flow volume and peak flow. In Figure 10, the relationship between inflow and outflow volume is bilinear, with smaller rainfall events being completely infiltrated or evapotranspired. Note that the x intercept of 41.6 m3 represents the average inflow volume that is removed completely with no surface outflows. Based on the regression model, this volume is removed from larger events as well.

Figure 45a2 presents a similar look at the effect of the bioinfiltration BMP on peak flows. While the relationship between inflow and outflow peaks are not as linear as for volume, a clear reduction in peaks is evident.

Extended monitoring allows the researcher to examine the record in new ways to more fully understand the characteristics of the technology under investigation. Figures 45a3 and 45a4present the TSS and TDS results using a probabilistic approach. For each rainfall event, the inflow and outflow TSS or TDS mass values are sorted and assigned probabilities based on the cumulative distribution of observed data in order to understand their significance. For ex ample, it can be stated that a 40% chance exists of the inflow carrying a TSS load of 1 kg, but only an 11% chance of 1 kg of TSS exported in the outflow. Or there is a 15% chance of having less than 10 kg entering, with approximately 0.16 kg leaving at the same probability level.

Table 3. Bioinfiltration Raingarden Vadose Zone Sampling 2008. Concentrations at 0, 25, 50, 75, and 100 percent levels refer to quantiles from cumulative frequency distribution of observed values.

BioInfiltration Traffic Island Groundwater Analysis - Concentrations at Soil Surface							
2008							
Water Quantity	Detection Limit	Num. of Storms	Concentration				
			0% (Min)	25%	50%	75%	100% (Max)
TDS (mg/l)	-	8	53	74	107	385	1445
pH	-	11	4.18	5.96	6.56	6.90	7.33
Conductivity (µS/cm)	-	11	54	68	81	95	135
TN (mg/l) as N	1.7 mg/l	10	0.85	0.85	1.28	2.05	2.40
NO2 (mg/l) as N	0.005 mg/l	9	0.03	0.52	0.74	1.19	4.22
NO3 (mg/l) as N	0.01 mg/l	9	0.00	0.00	0.03	0.21	0.44
TP (mg/l) as P	0.06 mg/l	10	0.14	0.19	0.26	0.48	0.95
PO4 (mg/l) as P	0.01 mg/l	9	0.01	0.02	0.03	0.07	0.94
CHL (mg/l)	0.5 mg/l	9	0.3	9.2	26.7	65.2	407.8
Dissolved Cadmium (µg/l)	0.1 µg/l	4	0.05	0.05	0.14	0.31	0.58
Dissolved Lead (µg/l)	0.5 µg/l	3	0.25	0.33	0.42	1.05	1.68
				*Non-detects are reported as half of the detection limit			

BioInfiltration Traffic Island Groundwater Analysis - Concentrations at 4 feet							
2008							
Water Quantity	Detection Limit	Num. of Storms	Concentration				
			0% (Min)	25%	50%	75%	100% (Max)
TDS (mg/l)	-	10	6	197	237	455	1344
pH	-	11	6.22	6.42	6.70	6.78	7.33
Conductivity (µS/cm)	-	11	330	339	349	397	774
TN (mg/l) as N	1.7 mg/l	12	0.85	0.85	0.85	0.85	1.90
NO2 (mg/l) as N	0.005 mg/l	10	0.03	0.22	0.53	0.83	1.29
NO3 (mg/l) as N	0.01 mg/l	10	0.01	0.01	0.14	0.64	2.12
TP (mg/l) as P	0.06 mg/l	11	0.07	0.17	0.20	0.23	0.34
PO4 (mg/l) as P	0.01 mg/l	10	0.01	0.01	0.03	0.11	0.80
CHL (mg/l)	0.5 mg/l	10	35.6	155.8	292.2	380.5	625.5
Dissolved Cadmium (µg/l)	0.1 µg/l	7	0.05	0.05	0.05	0.05	0.22
Dissolved Lead (µg/l)	0.5 µg/l	7	0.25	0.25	0.25	0.25	0.25
				*Non-detects are reported as half of the detection limit			

BioInfiltration Traffic Island Groundwater Analysis - Concentrations at 8 feet							
2008							
Water Quantity	Detection Limit	Num. of Storms	Concentration				
			0% (Min)	25%	50%	75%	100% (Max)
TDS (mg/l)	-	15	35	209	262	487	8659
pH	-	12	5.97	6.54	6.83	6.99	7.58
Conductivity (µS/cm)	-	12	80	313	383	421	476
TN (mg/l) as N	1.7 mg/l	12	0.85	0.85	0.85	0.85	3.50
NO2 (mg/l) as N	0.005 mg/l	10	0.03	0.24	0.53	0.86	1.19
NO3 (mg/l) as N	0.01 mg/l	10	0.01	0.01	0.02	0.38	1.08
TP (mg/l) as P	0.06 mg/l	11	0.03	0.15	0.19	0.29	0.44
PO4 (mg/l) as P	0.01 mg/l	10	0.00	0.01	0.02	0.04	0.70
CHL (mg/l)	0.5 mg/l	10	34.5	170.5	258.0	354.9	654.8
Dissolved Cadmium (µg/l)	0.1 µg/l	8	0.05	0.05	0.05	0.05	0.05
Dissolved Lead (µg/l)	0.5 µg/l	7	0.25	0.25	0.25	0.25	1.33
				*Non-detects are reported as half of the detection limit			

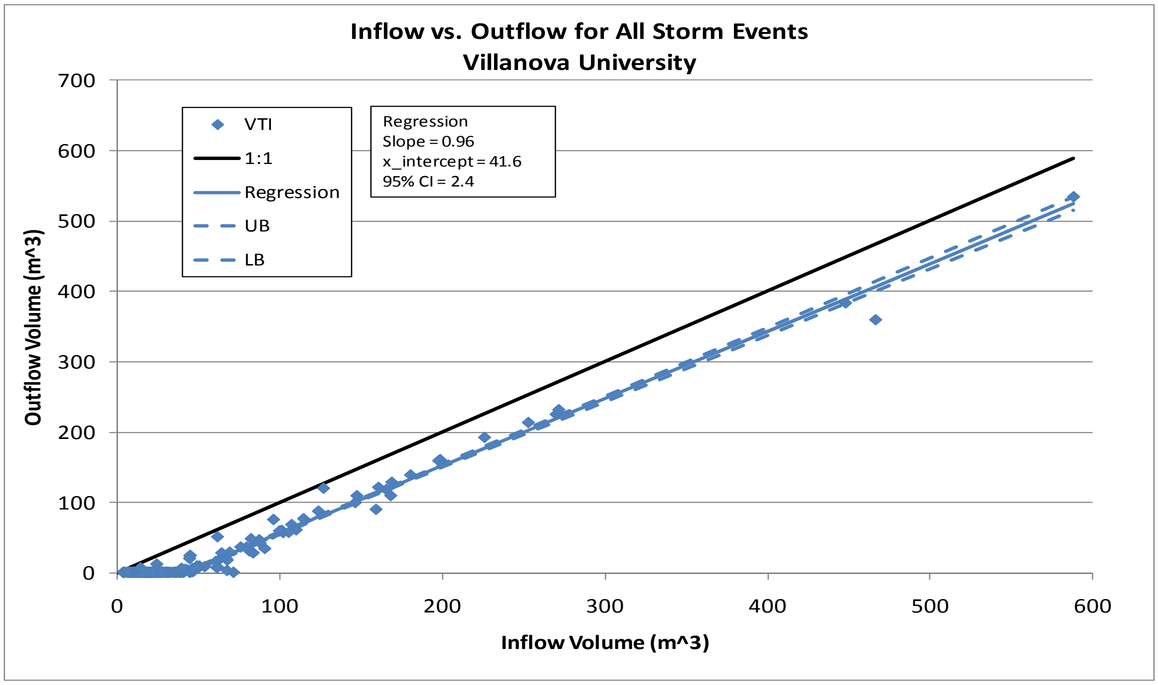


Figure 45a1. Plot of volume inflow / outflow relationship for Bioinfiltration Rain Garden.

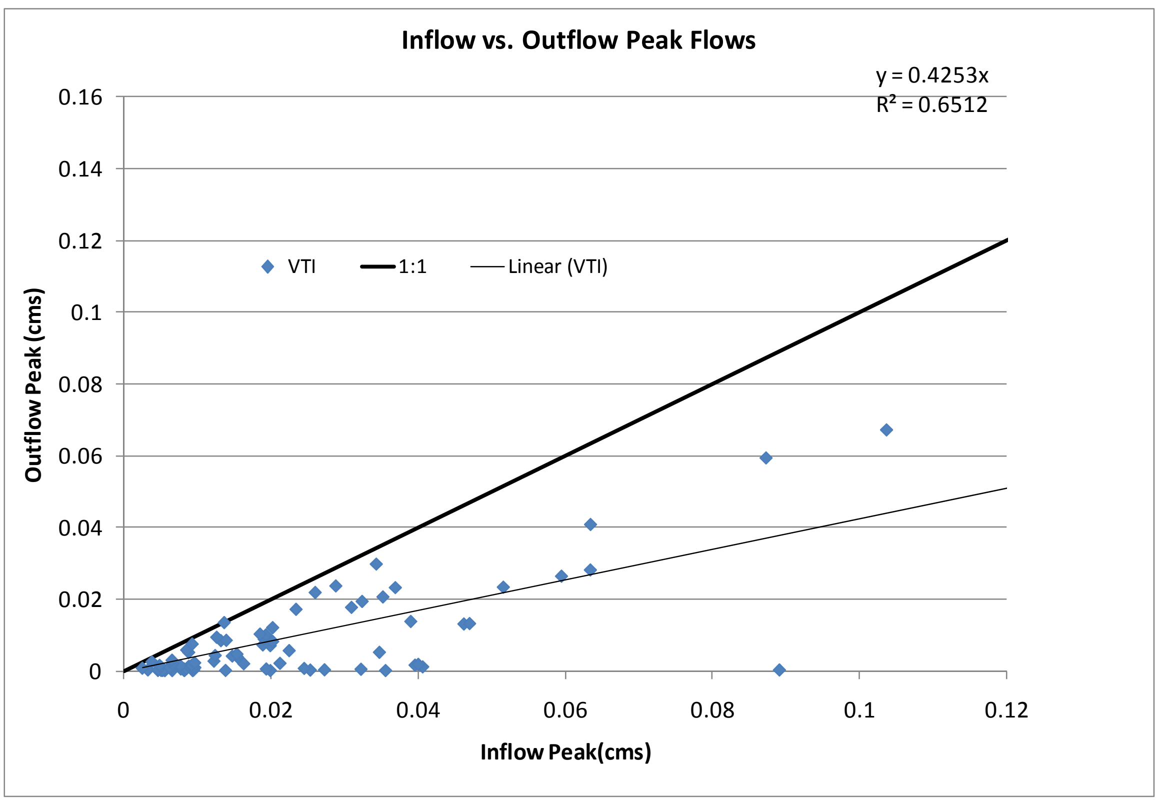


Figure 45a2. Plot of flow inflow / outflow relationship for Bioinfiltration Rain Garden.

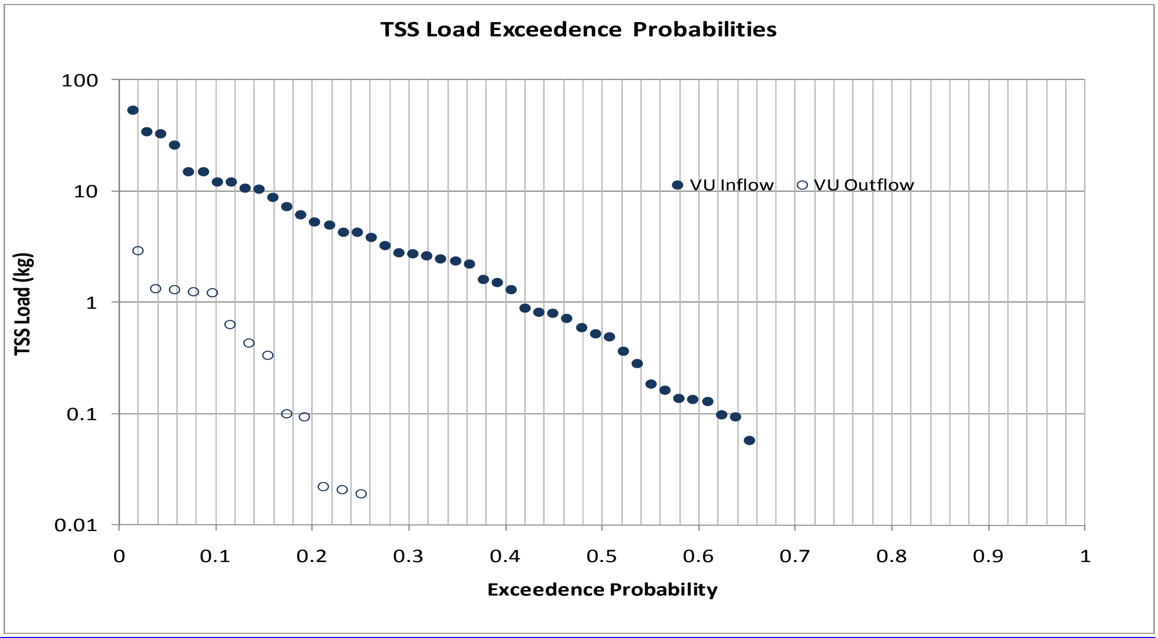


Figure 45a3. TSS exceedence probability plot for the Bioinfiltration Rain Garden.

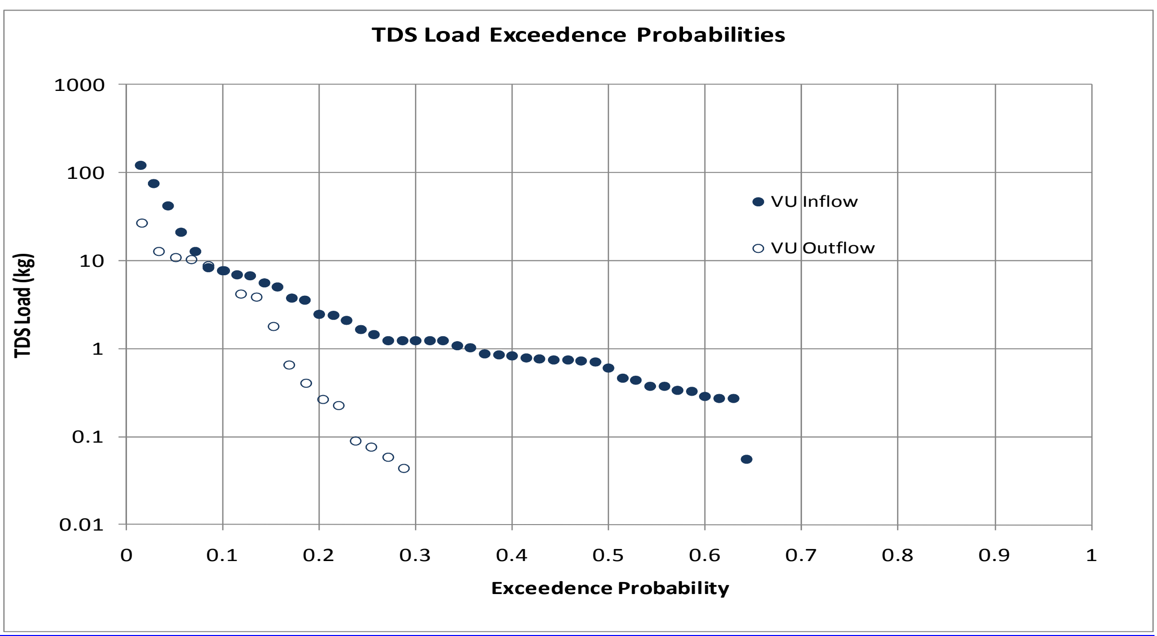


Figure 45a4. TDS exceedence probability plot for the Bioinfiltration Rain Garden.

Infiltration Trench. While no statistical change in performance over seven years was found for the Bioinfiltration Rain Garden (Emerson and Traver 2008) the same is not the case for the infiltration trench. Note in Figure 45b1 the rapid decrease in infiltration rate. We have concluded that the TSS entering the infiltration trench has been compressed at the bottom, and all current infiltration occurs through the side wall accounting for the reduction in volume removal. The influence of temperature is also depicted on this graph. The blue diamonds represent the ground temperature. Note the change in percolation rates with higher ground temperature, likely due to the temperature effect on water viscosity. This seldom reported property is seen on all infiltration sites under study (Heasom et al. 2006, Braga et al. 2007, Emerson and Traver 2008).

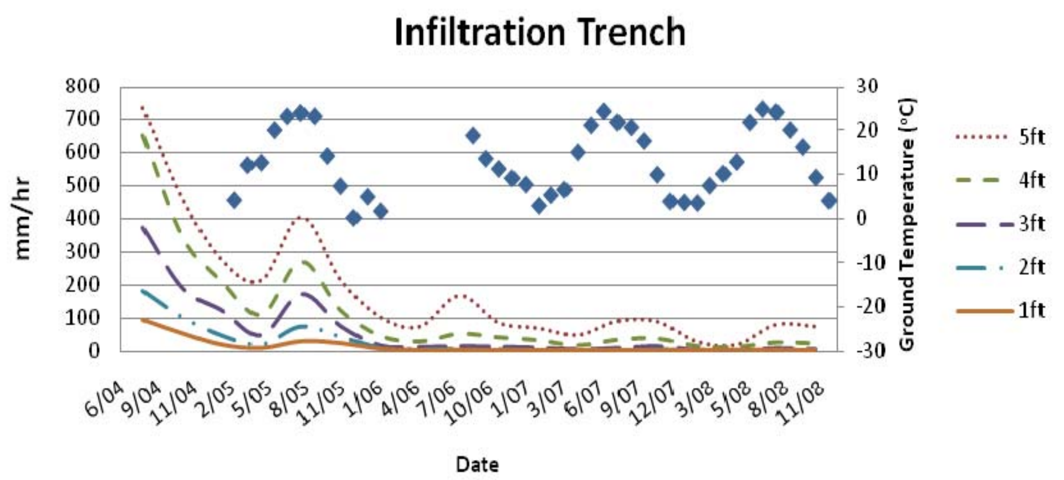


Figure 45b1. Plot of infiltration rates over time for the infiltration trench.

Pervious Concrete – Porous Asphalt. Research on the Pervious Concrete – Porous Asphalt site has shown a significant benefit in the reduction of thermal pollution (Fig. 45c1). The surface temperatures of A (asphalt) and C (concrete) reflect the temperatures of the air. Runoff is clearly heated by the surface (Porous Asphalt (PA) and Pervious Concrete (PC)). However, the runoff entering the bed is quickly cooled as shown by the almost constant bed temperature.

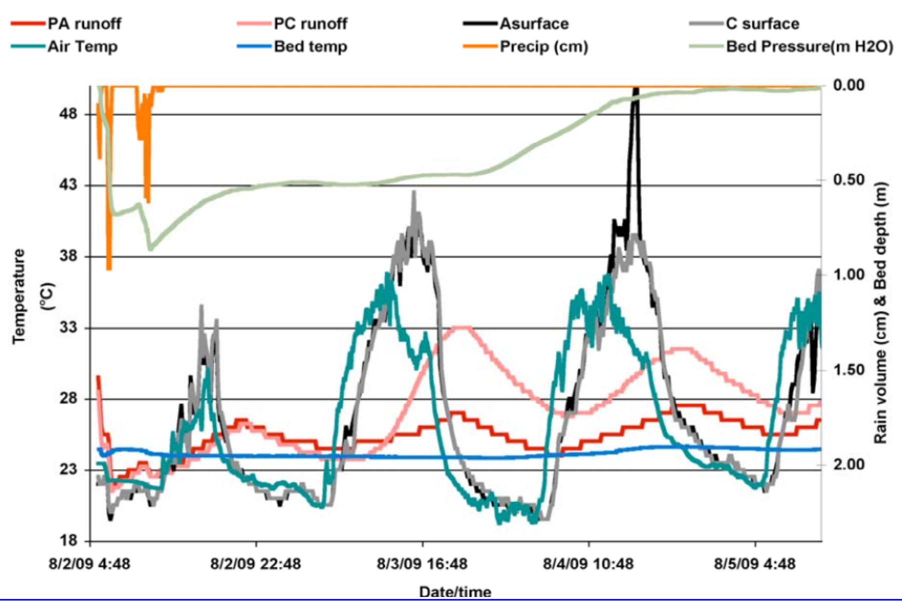


Figure 45c1. Plot of storm event temperature for the Pervious Concrete – Porous Asphalt site.

Green Infrastructure Project Findings Year 1-7 (through 2011)

The advantage of conducting long-term investigation into multiple BMPs has been the ability to track performance changes over time and to contrast performance of different BMP types. Further, additional research grants from CICEET and the Pennsylvania Growing Greener program among others has allowed us to perform expanded analysis beyond that funded by the EPA National Nonpoint Source Monitoring Program. This research work coupled with our day to day experiences have led to the following findings:

Proof of Concept: Results from constructing, operating, and monitoring green infrastructure infiltration BMPs have proven that these devices are effective in removing pollutants and runoff volume from the surface stream.

Effectiveness of Small Storm Capture: The efficiency of designing for small storms has been proven. Results from both the infiltration trench and bioinfiltration raingarden have shown that because the majority of the region's rainfall is produced by smaller storms, BMPs designed for smaller storms are extremely effective in reducing runoff volume and capturing surface pollutants in regions with similar climates.

Variability of Infiltration Rate: Results from all three sites have shown that the rate of infiltration during a specific storm is extremely variable, and dependent on season, temperature, soil moisture, and rainfall pattern. Note that on a yearly basis, this variation has not interfered with performance, but must be considered when conducting municipal inspection / monitoring programs.

Longevity: A study based on the results of this project has shown that there is no statistical reduction in performance for the bioinfiltration rain garden after 7 years, or from the pervious concrete site after 4 years (Emerson and Traver 2008). As long as the site is protected from large sediment loads (i.e., from upstream erosion) there is every expectation that these sites will remain effective for a very long time.

Longevity is achieved through proper design, construction, and siting (characteristics of the drainage area). For the bioinfiltration BMP, freeze - thaw, soil processes and root systems are aiding in maintaining the infiltration capacity. For the pervious concrete site, the lack of suspended sediments in the rooftop runoff, the filtering through the pervious concrete, and the large surface area support its longevity. Conversely, a considerable change in performance has been seen at the infiltration trench due to the theorized clogging of the bottom layer. It should be noted that the ratio of drainage area to the infiltration trench greatly exceeds that of "normal" sites. Using the drainage area sizing recommendations of the Pennsylvania BMP manual, the infiltration trench has experienced a pollutant load equivalent to 80 years during its 5-year lifetime.

Robustness of Green Infrastructure: Continuing performance of the Villanova University stormwater BMPs with minimal maintenance demonstrates the robustness of green infrastructure practices, as long as the systems are sited, designed, and constructed appropriately. After six years, no major maintenance has been required of the bioinfiltration sites, and only street sweeping for the porous concrete/porous asphalt site.

Variation in Pollutant Loading Rate / First Flush: Runoff from different contributing areas has been found to vary considerably in quality. For example, roof runoff from taller buildings has been found to be remarkably free of TSS, which makes it an ideal candidate for infiltration. In contrast, runoff from the parking deck has delivered extremely high pollutant loads to the infiltration trench. Clearly pretreatment devices would extend the life of infiltration BMPs in high loading areas.

Raingarden Volume Removal Repeatability and Predictability: Analysis of data from bioretention / bioinfiltration raingardens at Villanova University, NC State University, and the University of Maryland show repeatability of performance of volume reduction. These results will lead to new design criteria and regulatory approaches

INFORMATION, EDUCATION, AND PUBLICITY

Educational signage has been installed at each BMP site to enhance the learning experience and a website has been created to facilitate technology transfer. The experiences gained through the construction, operation, monitoring, and evaluation of these sites form the basis for the outreach and education component of the Research and Demonstration Park.

Technical Transfer is a prime mission of the VUSP. This task is approached through on-campus symposium's, speaking engagements, publications, tours of the BMP research and demonstration park, and the VUSP website. Every two years the VUSP coordinates the Commonwealth of Pennsylvania Stormwater Management Symposium. This is a two-day event with featured speakers, paper sessions and BMP tours. Additionally, it has been projected live over the internet and the presentations are available through the VUSP website. Prior to the symposium, a workshop for municipal officials is held. Note the symposium is run entirely from attendance fees and no grant monies are used. Faculty and students are also frequent participants at many area seminars. These engagements include everything from national EWRI / AWRA conferences to regional and community organizations. On the off year of the October Symposium, a one-day seminar with invited speakers on stormwater topics is held. Attendance at these events is usually around 150. In 2011, the Villanova project hosted the Annual NPS Monitoring Workshop in conjunction with a national LID Symposium. Attendance exceeded 700.

Many many many visitors have toured the BMP Research and Demonstration Park. Many organizations (AWRA, EWRI, IECA, etc.) have held national conferences in Philadelphia and have included tours of the BMP park. Local watershed groups have also visited the park, as well as many Villanova University classes. Each BMP has an educational sign to help passersby (as well as a website devoted to the BMP).

The VUSP website is a significant tool for outreach (http://www3.villanova.edu/VUSP/). Within the website there are links to every BMP that has been built at the park (and some offsite) with a description, design information, streaming videos, and lessons learned. These sites are updated continuously as results from our studies continue. The website also includes a site for presentations and an interactive database with links to information on all aspects of stormwater BMPs. This structure has been a major emphasis of the VUSP and directly supports all project areas listed previously.

TOTAL PROJECT BUDGET

Note: several of these grants had differing starting dates, this is an estimate.

Financial support for the construction and monitoring of the BMPs has come from a variety of sources. Construction has been funded through the Pennsylvania Section 319 Nonpoint Source program, the Pennsylvania Growing Greener I and II programs, and Villanova University Facilities Department. Monitoring has been supported by EPA Section 319 NMP, along with funds from the William Penn Foundation, Pennsylvania Growing Greener, the VUSP corporate partners, the NOAA Coastal Zone Program, EPA Region III 104B3, and several targeted EPA grants. A project comparing bioretention sites across multiple universities, including Villanova University, is underway, funded by the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET). Public and private partners are listed at the projects web site: http://www3.villanova.edu/VUSP/.

Year 1: 1 Oct 2003 – 1 Oct 2004
VUSP – PaDep Growing Greener $170,000
NMP – PaDep (319 Funds) $ 53,933
NMP – PaDep (319 Funds) $ 11,733

Year 2: 1 Oct 2004 – 1 Oct 2005
EPA Region III – 104b.3. funds $160,000
NMP – PaDep (319 Funds) $ 56,630

Year 3: Oct 2005 – 1 Oct 2006
TVSSI - William Penn Foundation $70,070
NMP – PaDep (319 Funds) $ 58,561
VUSP - PaDep Growing Greener $175,000

Year 4: Oct 2006 – 1 Oct 2007.
TVSSI - William Penn Foundation $93,507 NMP – PaDep (319 Funds) $ 61,000
VUSP Corporate Donations and Carry Over from previous year.

Year 5: Oct 2007 – 1 Oct 2008.
NMP – PaDep (319 Funds) $ 63,990Note Several other Non PaDEP grants and corporate donations aid this research
Note PC/ PA funds not included

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

N/A

OTHER PERTINENT INFORMATION

Mission Statement:

The mission of the Villanova Urban Stormwater Partnership (http://www.villanova.edu/VUSP) is: "to advance the evolving field of sustainable stormwater management and to foster the development of public and private partnerships through research on innovative stormwater Best Management Practices, directed studies, technology transfer and education.". The approaches to meet this mission are:

- Research and directed studies to emphasize comprehensive watershed stormwater management planning, implementation, and evaluation.
- Technology transfer to provide tools, guidance and education for the professional.
- Partnerships to promote cooperation amongst the private, public and academic sectors

In 2011, the LID-MARC (Low Impact Development - Mid-Atlantic Research Consortium) was formed between the Villanova Urban Stormwater Partnership in the Civil Engineering Department at Villanova University, Stormwater Engineering Group in the Department of Biological and Agricultural Engineering at NC State University, and Department of Civil and Environmental Engineering at the University of Maryland. LID-MARC's mission is to " Provide research-based recommendations to government and industry on LID stormwater practices, including bioretention and bioinfiltration. Work conducted by the partnership will range from the fundamental to the applied practical and will be able to focus on a variety of land uses and climate conditions found among the Mid-Atlantic States. (http://www.bae.ncsu.edu/stormwater/LID-MARC/, accessed 12/29/11)

PROJECT CONTACTS

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South Dakota

Bad River
Section 319
National Monitoring Program Project

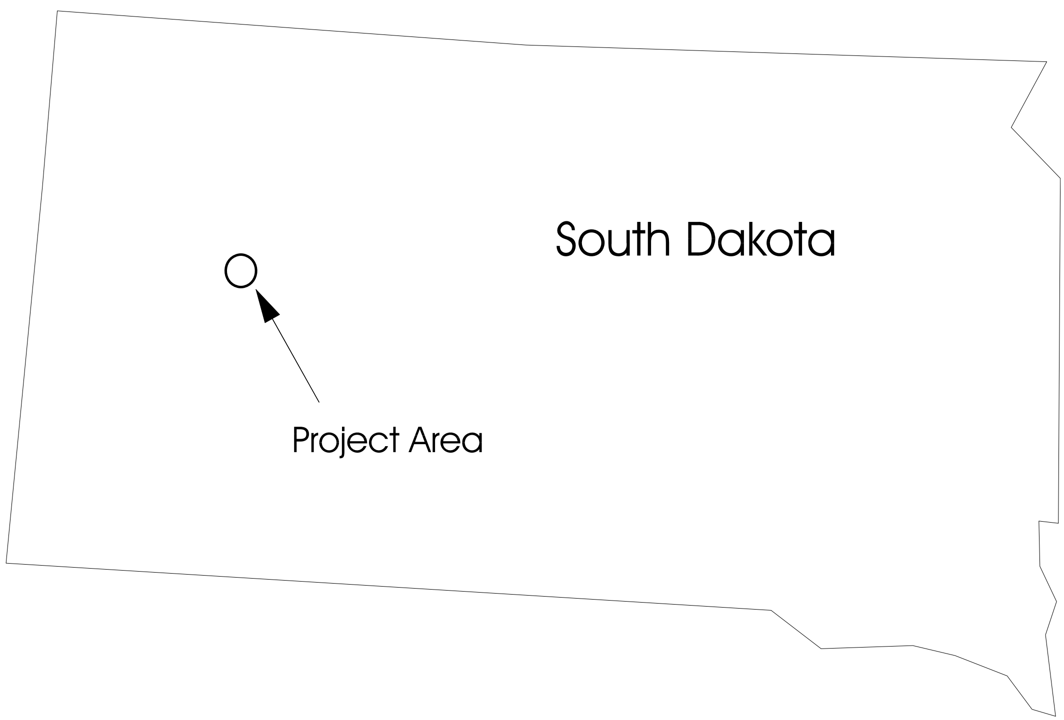
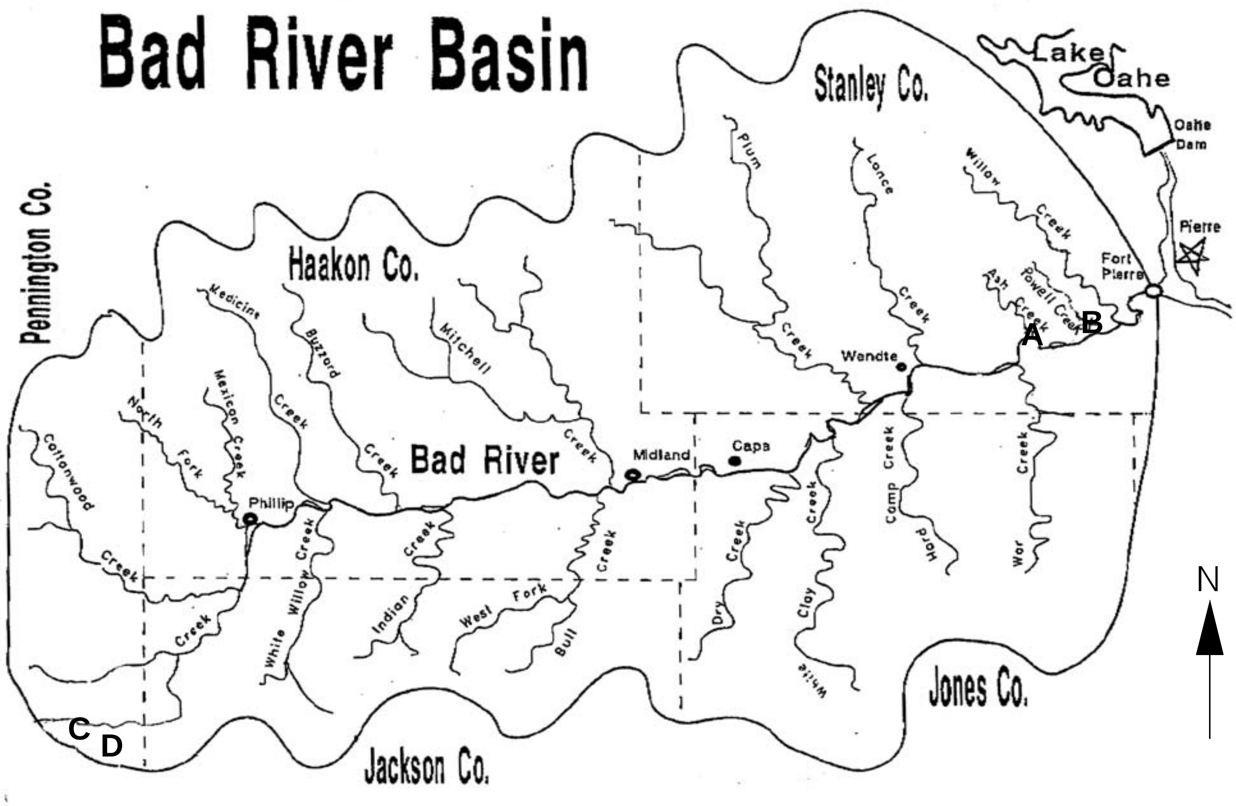


Figure 48: Bad River (South Dakota) Project Location



Legend

- Watershed Boundary
- County Boundary
- ● Cities and Towns
- **A** Ash Creek Monitoring Site (Control)
- **B** Powell Creek Monitoring Site (Treatment)
- **C** Whitewater North Monitoring Site (Treatment)
- **D** Whitewater South Monitoring Site (Control)

Figure 49: Water Quality Monitoring Stations for Bad River (South Dakota)

PROJECT OVERVIEW

The Bad River watershed, located in west central South Dakota (Figure 48), consists entirely of rolling prairie rangeland. Livestock grazing and dryland wheat farming are the main land uses of the watershed. The Bad River joins with the Missouri River at its mouth, near Ft. Pierre, South Dakota. Soil erosion, primarily from poor grazing management and poorly maintained riparian areas, is causing excessive sedimentation to the main channel of the Missouri River. This has impaired recreation due to loss of depth in the Missouri Channel. Loss of channel depth below the dam for the Oahe Reservoir on the Missouri River, located 10 miles upstream from the mouth of the Bad River, has impaired the hydropower generation of Oahe Dam during winter months. This, in turn, causes flooding in the cities of Pierre and Ft. Pierre.

The Bad River Section 319 National Monitoring Program project, by using a two-paired watershed design, will determine the effectiveness of best management practices (BMPs). The rangeland, cropland and riparian areas in the treatment watersheds (Powell Creek in the eastern part of the Bad River watershed and Whitewater North Creek in the western part of the watershed) will be treated with appropriate BMPs, such as fencing, rotational grazing, alternative feeding and watering stations, and vegetation plantings. All land uses will be monitored regularly and the information will be tracked by the use of a Geographic Information System (GIS) database.

Sampling for this project is complete, and analysis of the data is ongoing. A final report will be submitted in December of 2007.

PROJECT BACKGROUND

Project Area

The drainage area of the Bad River is located in west-central South Dakota (Figure 49) and covers 3,209 square miles of mostly rangeland. The rolling topography of fine textured, deep, shale-derived soils allows for significant soil erosion when rangeland and cropland is not properly managed. The project area supports an abundance of wildlife including mule deer, pronghorn antelope, porcupines, bobcats, prairie grouse, and numerous other species.

Relevant Hydrologic, Geologic, and Meteorologic Factors

This area of South Dakota receives, on average, 15-16 inches of rainfall per year. Most of the precipitation is derived from thunderstorm events during the spring and summer, although snowmelt produces significant runoff. On average there are four storms in the year that produce enough rainfall that runoff occurs in the tributaries. Runoff usually lasts for four to five days per storm event.

Land Use

The land use in the watershed is primarily agricultural and consists of 75% rangeland and 25% dryland wheat farming. A large portion of the upper end of the Bad River watershed is owned by the U.S. Forest Service. Rotational grazing practices have been implemented on the federal rangeland and also on many private ranches.

Water Resource Type and Size

The Bad River watershed encompasses 3,209 square miles of western rangeland. The small streams that feed the main channel are ephemeral as are the upper reaches of the Bad River itself. The Bad River enters the Missouri in the town of Ft. Pierre in Stanley County, South Dakota.

Water Uses and Impairments

The official beneficial uses of the Bad River include the following:

- Warmwater marginal fish life propagation waters
- Limited contact recreation waters
- Wildlife propagation and stock watering waters
- Irrigation waters

The main impairment to the Bad River is excess sediment from eroded soils in poorly managed rangeland and riparian areas. The load of sediment from the Bad River creates a problem in the Missouri near the mouth of the Bad River. Loss of channel capacity and water clarity impacts on sport fishing are problems on the Missouri in the Pierre area due to the Bad River sediment.

Pollutant Sources

Soil erosion, primarily from rangeland and riparian areas, is the primary source of the stream sediment.

Pre-Project Water Quality

There is no existing water quality data from the paired watersheds of the Bad River National Monitoring Project.

Water Quality Objectives

The main objective of the project was to document water quality improvements in the treatment subwatersheds due to the implementation of BMPs.

Project Time Frame

1996-2006

PROJECT DESIGN

Nonpoint Source Control Strategy

A two-paired watershed design was implemented for this project, with one pair located in the eastern part of the Bad River watershed (A and B — Figure 47), and the other pair in the western part (C and D — Figure 47), at a higher elevation than the east. The nonpoint source pollution control strategies vary for the different subwatershed that are being treated.

Powell Creek, located in the eastern part of the watershed and comprised of 11,221 acres, was to be the lower treatment subwatershed, while Ash Creek, with 13,702 acres, was to be the lower control. Best management practices that were expected for the Powell Creek subwatershed included riparian management (cross-fencing, dam construction, and alternative feed and watering sites) and rangeland management (rotational grazing). Due to changes in ownership and the farm program, the analysis of Ash and Powell may require some changes. Both watersheds have received a great deal of conservation work on them resulting in two treatments and no controls. Comparisons of the two will be made on a before and after basis for the conservation practices.

In the western part of the watershed, Whitewater North Creek (6,780 acres) served as the higher treatment subwatershed while Whitewater South Creek (6,605 acres) will be the higher control. In 2000, BMPs were implemented in the Whitewater North Creek Implementation Project. This $64,570 project implemented sediment traps, and exclusion area, drop and check structures, timber and rock barbs, and managed grazing.

Project Schedule

Site Pr	e-BMP Monitoring	BMP Installation	Post-BMP Monitoring
Whitewater North Creek	1998	1999	2000-2006
Powell/Ash Creek	1998	1999	2000-2006

Water Quality Monitoring

The Bad River Section 319 National Monitoring Project uses a paired watershed monitoring design, with two pairs as part of the protocol. Two subwatersheds have been identified in the eastern part of the watershed (Ash and Powell Creeks) and two in the western portion (Whitewater North and Whitewater South) (Figure 47).

Variables Measured

Biological

N/A

Chemical and Other

Total suspended sediment

Covariates

Stream discharge
Rainfall: amount, duration, intensity
range condition

Sampling Scheme

Because the streams in this area are ephemeral, monitoring is storm-event driven. Storm event occurrence, rainfall amounts, and rainfall intensity are compared with the hydrologic discharge and sediment loads. Complete hydrologic and sediment loads will be calculated on each storm event. Storm samples will be flow integrated. Twenty-four-hour composite samples are collected and analyzed for the duration of flow of each storm event.

During snowmelt in the spring, two 24-hour composite samples are collected during the first week of snowmelt with one sample collected per week thereafter. This is done until runoff ceases.

Land Treatment Monitoring

Rangeland was monitored by measuring range condition and vegetative cover during the project period. Natural Resources Conservation Service (NRCS) personnel rated the range condition using the *NRCS South Dakota Technical Guide* range site descriptions. The Robel Pole method was used to determine vegetative cover at permanent transects located within each subwatershed (Ash Creek — 21 transects, Powell Creek — 13 transects, Whitewater North — 10 transects, and Whitewater South — 9 transects). The Robel Pole measurements were taken 3 times per transect per year. This information was entered into the GIS.

Monitoring Scheme for the Bad River Section 319 National Monitoring Program Project

Design	Sites or Activities	Primary Parameters	Covariates	Frequency of WQ Sampling	Duration
Paired	Whitewater North Creek[T]	TSS	Stream discharge	During spring	2 yr pre-BMP
Watershed	Whitewater South Creek[C]			snowmelt	1 yr BMP
Pow	ell Creek[T]		Rainfall	Storm event	6-7 yr post-BMP
	Ash Creek[C]				

[T]Treatment
[C]Control

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

All data collected during the Bad River 319 National Monitoring program will be entered into a relational database, Microsoft Access. Files will be backed up daily and the water quality data will also be stored in the U.S. Environmental Protection Agency's STORET database. The U.S. Environmental Protection Agency (EPA) NonPoint Source Management System (NPSMS) software will be used to track and report data to EPA.

A GIS map will be constructed for the Bad River watershed. The GIS will allow cropland and rangeland BMP tracking throughout the life of the project. Other information, such as rangeland and riparian conditions will be entered into the system.

Statistical comparisons of sediment load to rainfall intensity will be determined by regression analysis at all four subwatersheds. The effectiveness of implementing watershed BMPs will be tested through regression and/or correlation analyses.

INFORMATION, EDUCATION AND PUBLICITY

As part of the Bad River Phase III implementation project, meetings were held with the ranch communities to explain the project. The Upper Bad River Task Force, a group comprised of ranchers and agency personnel committed to improving water quality in the Bad River watershed, met to discuss nonpoint source pollution control strategies. As the project progressed, newspaper articles and brochures were used to highlight project activities.

PROJECT BUDGET

Project Element	Funding Source ($) Federal	State	Local	Sum
LT	154,428	2,000	NA	156,428
WQ Monit	148,978	18,300	NA	167,278
TOTALS	303,406	20,300	NA	323,706

Source: Bad River National Monitoring Project Workplan, 1996

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

Section 319 watershed funds were used in the Bad River watershed to implement BMPs under the Whitewater Creek North and Bad River Phase III projects. This watershed was also given priority status for funding under the U.S. Department of Agriculture EQUIP (Environmental Quality Incentive Program). Matching funds were provided by the State of South Dakota and participating private ranchers.

OTHER PERTINENT INFORMATION

Project contributors are listed below:

- Private Landowners
- Natural Resources Conservation Service
- South Dakota Department of Environment and Natural Resources
- Upper Bad River Task Force
- Stanley County Conservation District
- East Pennington Conservation District
- U.S. Forest Service

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Vermont

Lake Champlain Basin Watersheds
Section 319
National Monitoring Program Project

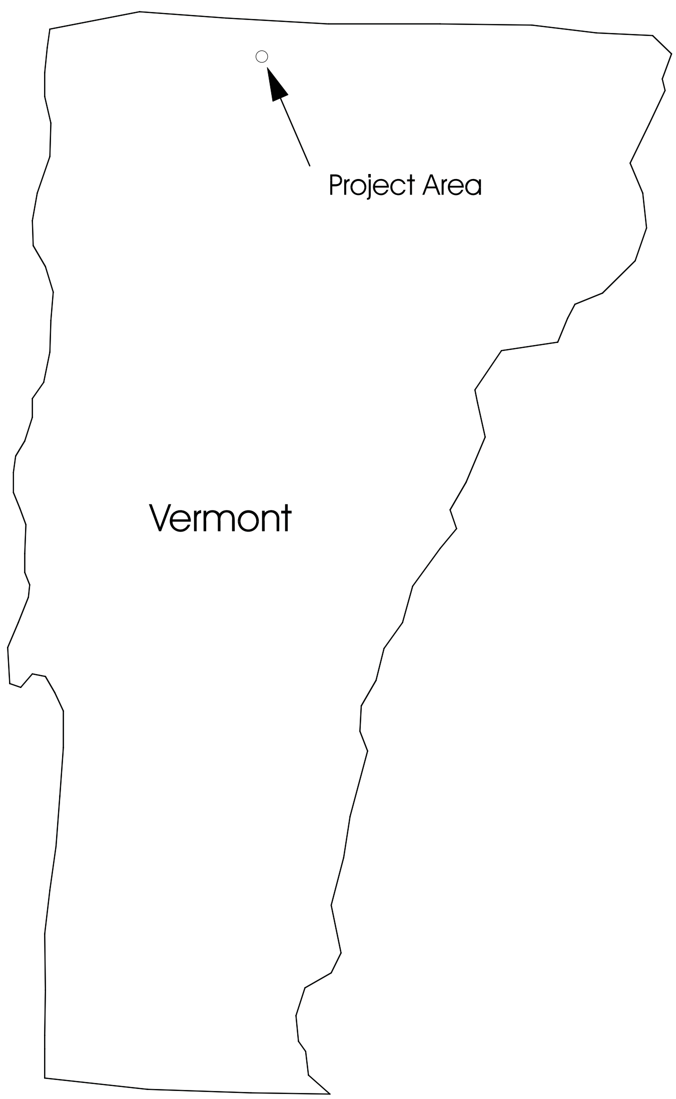

Figure 50: Lake Champlain Basin (Vermont) Watersheds Project Location

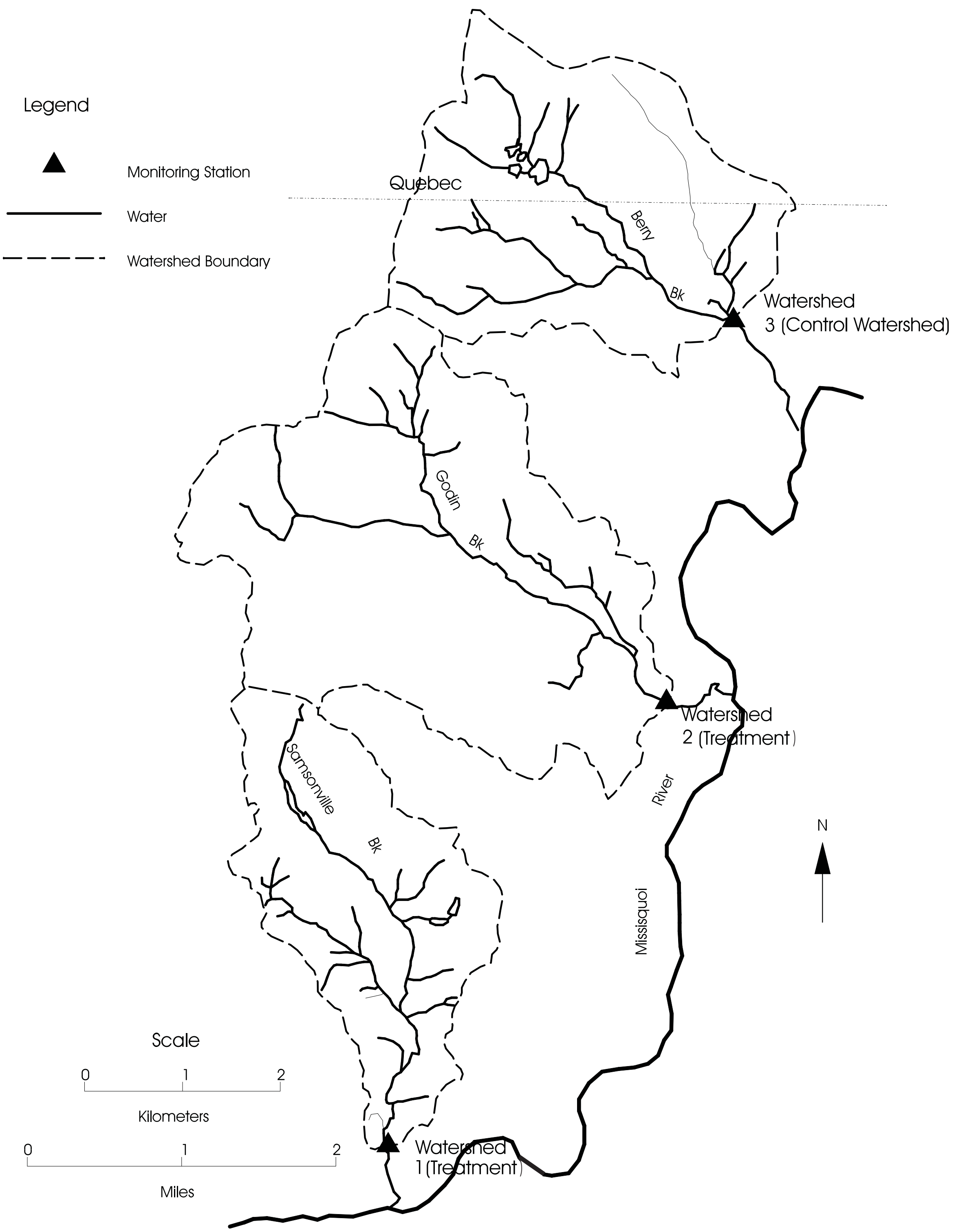

Figure 51: Water Quality Monitoring Stations for Lake Champlain Basin (Vermont) Watersheds

PROJECT OVERVIEW

The Lake Champlain Basin Watersheds Section 319 National Monitoring Program project (also known as the Lake Champlain Agricultural Watersheds Best Management Practice Implementation and Effectiveness Monitoring Project) is located in northcentral Vermont in an area of transition between the lowlands of the Champlain Valley and the foothills of the Green Mountains (Figure 50). Agricultural activity, primarily dairy farming, is the major land use in this area of Vermont.

The streams in these project watersheds drain into the Missisquoi River, a major tributary of Lake Champlain. The designated uses of many of the streams in this region are impaired by agricultural nonpoint source pollution. The pollutants responsible for the water quality impairment are nutrients, particularly phosphorus, *E. coli*, fecal streptococcus, fecal coliform bacteria, and organic matter. The source of most of the agricultural nonpoint source pollution is the manure generated from area dairy farms, livestock activity within streams and riparian areas, and crop production. The Missisquoi River has the second largest discharge of water and contributes the greatest nonpoint source load of phosphorus to Lake Champlain.

The Lake Champlain Basin Watersheds 319 National Monitoring Program project was designed to evaluate a set of treatments to control the pollutants generated by agricultural activities, focusing on grazing management and riparian restoration. A system of best management practices (BMPs) has been implemented to exclude livestock from selected critical areas of streams and to protect stream crossings, streambanks, and riparian zones. Individual BMPs included fencing, minimization of livestock crossing areas in streams, strengthening of necessary crossings, watering systems, and streambank stabilization through bioengineering techniques.

The water quality monitoring program was based on a three-way paired design: one control watershed and two treatment watersheds receiving similar BMP systems at different intensities (Figure 51). The watersheds have been monitored during a three-year calibration period prior to BMP implementation. Implementation has occurred and post-treatment monitoring continued for three years.

Biological, chemical, and covariates were monitored during all three monitoring phases. Fish, macroinvertebrates, fecal streptococcus, fecal coliform, and *E. coli* bacteria are the monitored biological parameters. The chemical parameters monitored were total phosphorus, total Kjeldahl nitrogen, total suspended solids, dissolved oxygen, conductivity, and temperature. Two covariates, precipitation and continuous discharge, were also monitored.

Nutrients and suspended sediment were monitored in a flow-proportional weekly composite sample. Bacteria grab samples were collected twice weekly, with concurrent in-situ measurements of temperature, dissolved oxygen, and conductivity. Macroinvertebrate and fish communities were sampled annually. Invertebrate and fish monitoring were also conducted at an unimpaired local reference site. The project has been completed, with the Final Report dated June 2001.

PROJECT BACKGROUND

Project Area

1705 ac (WS 1) + 3513 ac (WS 2) + 2358 ac (WS 3) = 7576 ac

Relevant Hydrologic, Geologic, and Meteorologic Factors

The project area is in northcentral Vermont (Franklin County) in an area of transition between the lowlands of the Champlain Valley and the foothills of the Green Mountains. Average annual precipitation is about 41 inches; average annual temperature is about 42°F. Frost-free growing season averages 118 days.

Most of the watershed soils are till soils, loamy soils of widely variable drainage characteristics. There are significant areas of somewhat poorly drained silt/clay soils in the lower portions of the watersheds.

Land Use

The three watersheds are generally similar in land use:

	WS1		WS2		WS3	
Land Use	Acres	%	Acres	%	Acres	%
Corn/hay	275	16	824	24	443	19
Pasture/ hay-pasture	137	8	530	15	231	10
Forest	1153	68	1908	54	1443	61
Other	140	8	250	7	242	10

Source: 2000 FSA aerial photography, farmer interviews, ground-truthing

Water Resource Type and Size

The study streams are small second- or third-order permanent streams that drain to the Missisquoi River, a major tributary of Lake Champlain. The streams are generally 10-15 feet wide at the monitoring stations. Historical stream flow data do not exist for these streams; discharge has ranged from 0.1 to over 300 cubic feet per second (cfs) since May, 1994.

Water Uses and Impairments

These particular small watersheds were selected to represent agricultural watersheds in the Lake Champlain Basin, where streams often violate state water quality criteria (Clausen and Meals, 1989; Meals, 1990; Vermont RCWP Coordinating Committee, 1991) and contribute nutrient concentrations and areal loads that generally exceed average values reported from across the United States (Omernik, 1977) and in the Great Lakes Region (PLUARG, 1978).

Because of their size, the study streams themselves are subject to very limited use for agricultural purposes (livestock watering) and recreation (swimming and fishing). No historical data exist to document support or nonsupport of these or other uses. Project data indicate that Vermont water quality (bacteriological) criteria for body contact recreation are consistently violated in these streams. Biological data for fish and macroinvertebrates indicate moderate to severe impact by nutrients and organic matter.

The receiving waters for these streams—the Missisquoi River and Lake Champlain—have very high recreational use that is being impaired by agricultural runoff (Vermont Agency of Natural Resources, 1994). The Missisquoi River is the second largest tributary to Lake Champlain in terms of discharge (mean flow =1450 cfs) and contributes the highest annual nonpoint source phosphorus load to Lake Champlain among the major tributary watersheds (75.1 mt/yr) (VT and NY Departments of Environmental Conservation, 1994). Lake Champlain currently fails to meet state water quality standards for phosphorus, primarily due to excessive nonpoint source loads (Vermont Agency of Natural Resources, 1994). About 66% of the nonpoint source phosphorus load to Lake Champlain is attributed to agricultural land (Meals and Budd, 1998).

Pollutant Sources

Nonpoint sources of pollutants are streambanks, degraded riparian zones, and dairy-related agricultural activities, such as field-spread and pasture-deposited manure and livestock access. Some agricultural point sources such as milkhouse waste or corn silage leachate are thought to exist.

Pre-Project Water Quality

No historical physical/chemical data exist for the study streams. Pretreatment monitoring data showed the following ranges:

E. coli (#/100 ml)	Fecal Coliform (#/100 ml)	Fecal Strep. (#/100 ml)
1 – 108,000	2 – 122,000	2 – 110,000
TP (mg/l)	**TKN (mg/l)**	**TSS (mg/l)**
0.02 – 1.57	< 0.20 – 3.59	1 – 585

Water Quality Objectives

The overall goal of the project is a quantitative assessment of the effectiveness of livestock/grazing management practices focused on the riparian zone in reducing concentrations and loads of nutrients, bacteria, and sediment from small agricultural watersheds. Major water quality objectives are to 1) document changes in sediment, nutrient, and bacteria concentrations and loads due to treatment at the watershed outlets and 2) evaluate response of stream biota to treatment.

Project Time Frame

September 1993 to November 2000

PROJECT DESIGN

Nonpoint Source Control Strategy

The project tested a suite of practices that treat and protect the stream and riparian zone. In both treatment watersheds, work concentrated on selective exclusion of livestock from the streams, creation of a protected riparian zone, improvement or elimination of heavily used livestock stream crossings, and revegetation of degraded streambanks. The treatment required fencing, watering systems, reducing the number of livestock crossing areas, bridging or strengthening necessary crossing areas, and streambank erosion control through willow planting and other bioengineering techniques.

During the pretreatment monitoring period, treatment needs were assessed, specific plans and specifications developed, and agreements with landowners pursued. The project and/or its partners provided 100% cost support for cooperating landowners. Agricultural management activity—both routine and treatment implementation—is monitored by farmer record-keeping and annual interviews.

Some work was done, as necessary, on agricultural point sources when such pollutant sources were identified.

Project Schedule

Site	Pre-BMP	BMP Implementation	Post-BMP
WS-1	5/94-5/97	6/97-11/97	11/97-11/00
WS-2	5/94-5/97	6/97-11/97	11/97-11/00
WS-3	5/94-5/97	N/A	11/97-11/00

Water Quality Monitoring

The study was based on a paired-watershed design, with a control watershed and two treatment watersheds (Figure 44). The design called for three years of calibration monitoring, one year of implementation monitoring, and three years of post-treatment monitoring.

Variables Measured

Biological

E. coli bacteria (EC)
Fecal coliform bacteria (FC)
Fecal streptococcus bacteria (FS)
Macroinvertebrates
Fish

Chemical and Other

Total phosphorus (TP)
Total Kjeldahl nitrogen (TKN)
Total suspended solids (TSS)
Dissolved oxygen (DO)
Conductivity
Temperature

Covariates

Precipitation (continuous)
Discharge (continuous)

Sampling Scheme

Automated sampling stations were located at three watershed outlets for continuous recording of streamflow, automatic flow-proportional sampling, and weekly composite samples for sediment and nutrients. Twice-weekly grab samples for bacteria were collected. Concurrent in-stream measurement of temperature, dissolved oxygen, and conductivity occurred at grab samples collection. Three precipitation gauges were installed. All monitoring systems operated year-round.

The macroinvertebrate community at each site and a fourth "background reference" site were sampled annually using a kick net/timed effort technique. Methods and analysis followed USEPA's Rapid Bioassessment Protocols (Protocol III). Fish were sampled annually by electroshocking and evaluated according to Rapid Bioassessment Protocols Protocol V.

Physical habitat assessments were performed during each sampling run.

Monitoring Scheme for the Lake Champlain Basin Watersheds Section 319 National Monitoring Program Project

Design	Site or Activities	Primary Parameters	Covariates	Frequency of WQ Sampling	Frequency of Biological Assessment	Duration
Three-way paired watershed	WS1-Samsonville Brook[T] WS2-Godin Brook[T] WS3-Berry Brook[C]	E Coli FC FS Macroinvertebrates Fish survey TP TKN TSS DO Conductivity Temperature	Precipitation Discharge (continuous)	TP, TKN, TSS—weekly composite from continuous flow-proportional sampling. Bacteria, temperature, DO and conductivity—twice weekly	Fish and Macroinverte-brates sampled once per year	3 yrs pre-BMP 1 yr BMP 3 yrs post-BMP

[T]Treatment watershed
[C]Control watershed

Land Treatment Monitoring

Land use monitoring included farmer record-keeping, annual farmer interviews, and examination of annual FSA crop compliance aerial photography. Land treatment tracking was accomplished by at least weekly inspections of installed treatments. Additional details were included in the Project Final Report (2001).

Modifications Since Project Started

Problems with funding and personnel shifts delayed the start of treatment implementation by approximately one year resulting in extension of pre-treatment monitoring and reduction of planned post-treatment monitoring. In 1996, the project timetable was revised to reflect a three-year calibration period (1994–1996), one year of implementation (1997), and two years of post-treatment monitoring (1998–2000). In 1999, the active monitoring period was extended through November 2000 to provide three years of post-treatment monitoring.

The nonpoint source control strategy and design have been changed due to changes in agricultural operations in WS1. The original project design called for the implementation of intensive grazing management in WS1 as a means to minimize the time spent by livestock in or near the streamcourse without resorting to complete exclusion. However, since the beginning of the project, one farmer in WS1 ceased operations, one changed his management to complete confinement, and another was determined to have no riparian pasture. Moreover, the owner of the large dairy operation immediately above the monitoring station has implemented full rotational grazing on his own. Thus, opportunities for implementing the planned treatment were essentially eliminated. After additional field surveys and discussions with the Project Advisory Committee, the Principal Investigator requested approval from EPA Region I for a change in treatment design. Approval was granted in June, 1997.

Under the modified strategy, WS1 has received the same style of treatments as WS2, i.e. livestock exclusion, crossing protection, and streambank stabilization. Thus, WS1 can be viewed as a replicate of WS2 with respect to treatment. Because the level of treatment differed in WS1 compared to WS2, the opportunity existed to evaluate thresholds and degrees of water quality response to varying levels of treatment.

While no changes to the monitoring program design have occurred, changes in the TKN analysis within the Vermont Department of Environmental Conservation laboratory required rejection of TKN data generated prior to April, 1996. TKN analysis continues to be conducted.

Fish community sampling has been reduced from semi-annual to annual. In May 1997, one precipitation gauge was moved about 300 meters at a landowner's request.

Progress to Date

The water quality monitoring component of the project became operational in May, 1994 and operated successfully to meet project goals. A severe drought and elevated temperatures during June and July, 1995, and a series of major floods in summer, 1997, and winter, 1998, interfered slightly with chemical and physical monitoring, and may have had some lasting influence on biological communities in the monitored streams. Analysis of calibration period water quality data (May 1994 – May 1997) confirmed that statistical conditions for acceptable calibration between the control and treatment watersheds were met with respect to physical and chemical variables.

Following a baseline inventory and new aerial videography in 1995, land use/agricultural activity has been conducted through annual farmer recordkeeping, annual interviews, and windshield surveys.

The process of identifying specific treatment needs and designs and negotiating agreements with landowners began in the fall of 1995. However, project difficulties and changes noted earlier delayed this process significantly. Under renewed initiatives, agreements were signed with eight watershed landowners in the spring of 1997 and implementation is underway. As of the end of 1997, installed practices included more than 8,800 feet of riparian fence, elimination of three livestock crossings, a culvert livestock crossing, three armored livestock crossings, and a livestock bridge. In addition, several thousand feet of streambank have been protected with brushrolls and tree revetments and willow plants. Significant assistance has been given by the Vermont Youth Conservation Corps, the Missisquoi River Basin Association, and local volunteers.

After full BMP implementation, the following levels of treatment were achieved in the treatment watersheds:

	WS 1	WS 2
Total stream length (m)	10,382	24,776
Pasture stream length (m)	1,481	8,150
Treated stream length (m)	726	2,283
Stream length treated (%)	7%	9%
Pasture stream length treated (%)	49%	28%
Livestock grazing on treated pasture (%)	96 – 97%	15 – 23%
Pasture area draining to treated stream (%)	42%	32%

BMP implementation was completed in November, 1997. Except for repair of winter/spring flood damage, no additional land treatments are planned. Water quality and land treatment monitoring continues to be conducted as described in the recent Comprehensive Calibration Period Project Report.

As of the end of the treatment implementation period, a total of $39,713 had been spent on land treatment, of which $18,759 were project funds, $4,166 were landowner contributions, and $16,788 were contributed by other agencies and volunteer groups. Subsequent maintenance of installed practices required expenditure of an additional $3,500.

Analysis of post-treatment water quality data suggests that bacteria counts, phosphorus concentration, and phosphorus export declined significantly in one or both of the treated watersheds with respect to the control watershed. Installed treatments continue to perform well with relatively little maintenance.

Land use changes in the two treatment watersheds caused some problems in 1999. In WS1, runoff and severe erosion from cleared land had increased TSS load to Samsonville Brook in 1998. An NRCS-designed diversion was installed in August 1999 to correct this problem. Visual inspection of the diversion over the remainder of the field season and water quality data indicated that the problems have been corrected.

In WS2, major expansion and mismanagement of a large farm operation in the center of the watershed continued to have major impact on water quality observed in that watershed. Elevated sediment, nutrient and bacteria levels resulting from this disturbance effectively negated the effects of land treatment in the final project year.

The principal impediment to project progress was funding, both mechanism and quantity. While in principle, Section 319 National Monitoring Program funding was intended to be set up for the entire project period, this was not the case in this project. The requirement to renew funding each year caused significant problems, including accounting confusion over fiscal vs. project vs. monitoring "years," inefficient expenditure of staff time, and, most importantly, difficulty in accounting for and documenting required match. This was a particular problem in the implementation budget, since actual implementation (and associated match) did not take place until project year 4, while funds were allocated in project years 1, 2, and 3 budgets. Budgeting over the entire project lifetime would have substantially alleviated these problems.

The other financial impediment to the project involved significant increases in charges for sample analysis by the state Department of Environmental Conservation (DEC) laboratory. These costs increased dramatically (on the order of $11,000–$16,500 per year) since the first funding year and, with no corresponding increase in overall funding, other budget categories had to be cut. In the last three budget years, this required elimination of all nonsignificant principal investigator support, limiting available time commitment to the project. The increase in analytical costs also reduced the previous match contributions from DEC. Annual funding from U.S. Environmental Protection Agency (USEPA), however, has been essentially level and nonnegotiable for the last three years. Some flexibility in funding, such as increasing USEPA funding to cover such cost increases, would be helpful. The project was significantly under-funded in FY 1997, resulting in a five-month suspension of project activities except for basic water quality monitoring. This problem was been corrected.

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

Primary data management was done using an in-house spreadsheet system. The USEPA Nonpoint Source Management System (NPSMS) software was not used to track and report data to USEPA because it was never upgraded to handle three watersheds. Requisite data entry into STORET was accomplished through annual file transfer. Water quality data were compiled and reported for quarterly project advisory committee meetings, including basic plots and univariate statistics. For annual reports, data were analyzed on a water-year basis.

Data analysis was performed using both parametric and nonparametric statistical procedures in standard statistical software.

NPSMS Data Summary

Monitoring Station Parameters Report

DATE: 08/04/98 PERIOD: calibration period, 5/94 - 9/97

STATION TYPE: Treatment Watershed #1 (Samsonville Brook)

CHEMICAL PARAMETERS

	Reporting	QUARTILE VALUES		
Parameter Name	**Units**	**-75-**	**-50-**	**-25-**
CONDUCTANCE	uS/CM	113	88	70
E. COLI	CFU/100ML	418	96	22
FECAL COLIFORM	CFU/100ML	440	77	28
FECAL STREPTOCOCCUS	CFU/100ML	1611	362	55
FLOW, STREAM, WEEKLY MEAN	CFS	7.7	2.4	1.0
OXYGEN, DISSOLVED	MG/L	14.8	12.1	9.8
PRECIPITATION, TOTAL	IN/WEEK	1.02	0.54	0.20
NITROGEN, TOTAL KJELDAHL[1]	MG/L	.80	.50	0.37
PHOSPHORUS, TOTAL	MG/L	0.166	0.090	0.052
TEMPERATURE, WATER	oC	16.5	7.7	0.7
TOTAL SUSPENDED SOLIDS	MG/L	68.5	28.0	12.8

STATION TYPE: Treatment Watershed #2 (Godin Brook)

CHEMICAL PARAMETERS

	Reporting	QUARTILE VALUES		
Parameter Name	**Units**	**-75-**	**-50-**	**-25-**
CONDUCTANCE	uS/CM	135	105	87
E. COLI	CFU/100ML	3950	515	40
FECAL COLIFORM	CFU/100ML	4500	455	58
FECAL STREPTOCOCCUS	CFU/100ML	1951	538	70
FLOW, STREAM, WEEKLY MEAN	CFS	14.9	6.0	3.1
OXYGEN, DISSOLVED	MG/L	14.8	12.0	10.1
PRECIPITATION, TOTAL	IN/WEEK	1.00	0.47	0.18
NITROGEN, TOTAL KJELDAHL[1]	MG/L	.93	0.50	0.35
PHOSPHORUS, TOTAL	MG/L	0.199	0.102	0.039
TEMPERATURE, WATER	oC	16.5	7.9	0.7
TOTAL SUSPENDED SOLIDS	MG/L	43.4	18.6	5.1

STATION TYPE: Control Watershed (Berry Brook)

CHEMICAL PARAMETERS

	Reporting	QUARTILE VALUES		
Parameter Name	**Units**	**-75-**	**-50-**	**-25-**
CONDUCTANCE	uS/CM	125	107	87
E. COLI	CFU/100ML	4175	550	36
FECAL COLIFORM	CFU/100ML	3875	510	39
FECAL STREPTOCOCCUS	CFU/100ML	1464	442	65
FLOW, STREAM, WEEKLY MEAN	CFS	13.7	7.1	3.9
OXYGEN, DISSOLVED	MG/L	14.3	11.3	9.6
PRECIPITATION, TOTAL	IN/WEEK	0.97	0.50	0.18
NITROGEN, TOTAL KJELDAHL[1]	MG/L	0.65	0.50	0.32
PHOSPHORUS, TOTAL	MG/L	0.174	0.084	0.052
TEMPERATURE, WATER	oC	16.1	8.0	0.9
TOTAL SUSPENDED SOLIDS	MG/L	35.1	16.5	6.7

[1] TKN Data 4/96 - 9/97 only

Monitoring Station Parameters Report

DATE: 07/09/01 PERIOD: 10/97 – 9/00 (Treatment Period)

STATION TYPE: Treatment Watershed #1 (Samsonville Brook)

CHEMICAL PARAMETERS

Parameter Name	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
CONDUCTANCE	uS/CM	105	85	64
E. COLI	CFU/100ML	235	68	10
FECAL COLIFORM	CFU/100ML	258	74	11
FECAL STREPTOCOCCUS	CFU/100ML	1125	237	38
FLOW, STREAM, WEEKLY MEAN	CFS	10.2	4.1	1.5
OXYGEN, DISSOLVED	MG/L	14.6	12.5	10.0
PRECIPITATION, TOTAL	IN/WEEK	0.90	0.52	0.18
NITROGEN, TOTAL KJELDAHL[1]	MG/L	0.65	0.54	0.39
PHOSPHORUS, TOTAL	MG/L	0.126	0.072	0.042
TEMPERATURE, WATER	oC	15.8	7.2	1.0
TOTAL SUSPENDED SOLIDS	MG/L	34.0	15.2	6.7

STATION TYPE: Treatment Watershed #2 (Godin Brook)

CHEMICAL PARAMETERS

Parameter Name	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
CONDUCTANCE	uS/CM	143	120	94
E. COLI	CFU/100ML	1653	201	18
FECAL COLIFORM	CFU/100ML	2113	253	24
FECAL STREPTOCOCCUS	CFU/100ML	1838	400	58
FLOW, STREAM, WEEKLY MEAN	CFS	13.8	5.6	2.8
OXYGEN, DISSOLVED	MG/L	14.5	12.0	9.9
PRECIPITATION, TOTAL	IN/WEEK	0.98	0.62	0.22
NITROGEN, TOTAL KJELDAHL[1]	MG/L	0.83	0.60	0.42
PHOSPHORUS, TOTAL	MG/L	0.170	0.104	0.058
TEMPERATURE, WATER	oC	16.8	8.3	1.0
TOTAL SUSPENDED SOLIDS	MG/L	31.5	18.3	7.5

STATION TYPE: Control Watershed (Berry Brook)

CHEMICAL PARAMETERS

Parameter Name	Reporting Units	QUARTILE VALUES -75-	-50-	-25-
CONDUCTANCE	uS/CM	132	115	92
E. COLI	CFU/100ML	3175	311	28
FECAL COLIFORM	CFU/100ML	4850	373	45
FECAL STREPTOCOCCUS	CFU/100ML	1430	438	70
FLOW, STREAM, WEEKLY MEAN	CFS	15.0	7.5	3.8
OXYGEN, DISSOLVED	MG/L	14.2	11.6	9.4
PRECIPITATION, TOTAL	IN/WEEK	0.86	0.54	0.20
NITROGEN, TOTAL KJELDAHL	MG/L	0.58	0.43	0.31
PHOSPHORUS, TOTAL	MG/L	0.124	0.073	0.40
TEMPERATURE, WATER	oC	16.2	8.4	1.3
TOTAL SUSPENDED SOLIDS	MG/L	23.8	9.9	4.4

Final Results

Analysis of calibration period physical and chemical monitoring data indicated that conditions for acceptable calibration between the control and treatment watersheds were met. Significant regression relationships were found to exist between watershed pairs for all parameters of interest. For all physical and chemical variables, the calibration period was adequate to detect reasonable changes following treatment. Residual errors around the regressions were small enough to allow determination for changes of 24% or less in response to treatment. TKN data collected since April, 1996, yielded acceptable calibration. Therefore, data collected during the calibration phase appeared to be adequate for the project to proceed into the treatment period.

The fish and macroinvertebrate assemblages indicated degraded conditions in the treatment watersheds over the calibration period due to nutrient enrichment and sedimentation.The impaired control section supported a biological community indicative of severe, intermittent stress resulting from improper manure and corn silage management upstream.Although mildly impacted by local non-agricultural activities, the reference control stream supports the healthiest biological community

Analysis of three years of post-treatment data showed significant water quality response to treatment. In WS 1, mean TP, TKN, and TSS concentrations were reduced by 15%, 12%, and 34%, respectively. Indicator bacteria counts declined by 29% - 38%. Over the entire treatment period, TP export was reduced 49%, TKN export 38%, and TSS 28%. Similar water quality changes were observed in WS 2 over the first two years of treatment, but impacts from the farm expansion reversed those improvements.

The macroinvertebrate community in Samsonville Brook (WS 1) responded significantly to treatment, with BioIndex values meeting Vermont Water Quality Biocriteria in the second and third post-treatment year. Improvements noted in Godin Brook (WS 2) after two years of treatment were reversed in the final year due to catastrophic sedimentation from the farm expansion.

Copies of the Final Project Report may be obtained by contacting Rick Hopkins at the address given below.

INFORMATION, EDUCATION, AND PUBLICITY

Pre-project activity included letters to all watershed agricultural landowners followed by small "kitchen table" meetings with farmers in each watershed.The purpose of these meetings was to assess landowner interest and acceptance of the project.

Two articles concerning the project were published in the weekly county newspaper

In July 1994, a monitoring station "open-house" was held to present the project, monitoring hardware, and some early monitoring results.

The first annual winter lunch meeting was held in February 1995, where watershed farmers discussed the project and heard a talk by a local farmer engaged in rotational grazing.A second such meeting was held in April, 1996, a third in February, 1998, and a fourth in March, 1999

A semi-annual project newsletter initiated in summer, 1995, was distributed to watershed farmers and other interested parties. In addition, a feature story on the project has been published in the monthly magazine of a regional environmental advocacy group.

The project included a Project Advisory Committee with representatives from United States Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS), Extension, Vermont Dept. of Agriculture, Vermont Dept. of Environmental Conservation, Vermont Natural Resources Conservation Council, U.S. Fish and Wildlife Service, the Vermont Pasturelands Outreach Program, and a watershed dairy farmer. The committee met quarterly to review progress and assist in program direction.

Information and education efforts during the pretreatment calibration phase focused on laying the groundwork for treatment by presenting demonstrations and information concerning grazing management and livestock access control. Additional contact with farmers occurs through routine collection of agricultural management data. Current information efforts are devoted to keeping watershed farmers and other residents informed of project activities and findings.

A vigorous communication strategy was undertaken to publicize final project results. Activities included:

- A newsletter to watershed landowners
- A presentation to local farmers and the Missisquoi River BasinAssociation
- Final meeting of the ProjectAdvisory Committee
- Presentation to the Lake Champlain Basin ProgramTechnical Advisory Committee
- Presentation to USDA-NRCS State Office staff
- Publication of articles in local environmental advocacy periodicals
- Publication of Final Project Report
- Presentation to USEPA Region I staff
- Presentation to New England region state nonpoint source management agencies
- Paper presented at International Water Association Diffuse Pollution/Watershed Management Conference
- Paper presented at 9th National Nonpoint Source Monitoring Workshop, August, 2001

The project is documented on: http://wwwanr.state.vt.us/dec/waterq/VT319Watershed.htm

PROJECT BUDGET

The estimated budget for the Lake Champlain BasinWatersheds National Monitoring Program project for years 1–5 is shown in the following table.

Vermont NMP – Approximate Budget Breakdown

Project Element	Federal*	Federal**	State	University	Other+	Total
Land treatment (FFY92 – 96)	121,093	9,200	3,388	21,918	54,981	210,580
WQ monitoring (FFY1991 – 2000)	738,255	-	209,137@	134,773@	-	987,464
Total	859,348	9,200	212,525@	156,691@	54,981	**1,292,745@**

Table Notes:
* Includes funding from Clean Water Act Section 319 and Section 104b3
** Includes cost share funds from USF & WS and USDA-NRCS
\+ Represents potential labor and/or materials needed to be provided by farmers and/or volunteers.
In 1997, some $4,166 and $7,588 were contributed to the project by landowners and other volunteers, respectively.
In 1998, 1999, and 2000 field seasons, an unquantified amount of in-kind was contributed by landowners associated with inspection and maintenance of installed practices.
@ Amounts shown are incorrect since non-federal match requirements associated with FFY00 funds are not finalized.

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

The project area was within the area of the Lake Champlain Basin Program (a program modeled after the Chesapeake Bay Program), directed toward the management of Lake Champlain and its watershed. Considerable effort on agricultural nonpoint source control is associated with this program, including funding for pollution control/prevention demonstration projects.

Additionally, the state of Vermont's phosphorus management strategy calls for targeted reductions of phosphorus loads from selected subbasins of Lake Champlain.

The U.S. Fish and Wildlife Service (USF&WS) was an active participant in the project. Two watershed landowners have agreements with the USF&WS *Partners for Wildlife* riparian zone restoration program. NRCS rendered valuable assistance in engineering design and streambank restoration. The onset of the new USDA EQUIP program, however, severely curtailed the availability of staff time to assist in the project. The Vermont Youth Conservation Corps Franklin County crew donated three days of labor in streambank stabilization. The Missisquoi River Basin Association, a citizens group, organized several days of volunteer labor, and employees of Ben & Jerry's Homemade donated substantial field work.

OTHER PERTINENT INFORMATION

None.

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Washington

Totten and Eld Inlet
Section 319
National Monitoring Program Project

Figure 52: Totten and Eld Inlet (Washington) Project Location

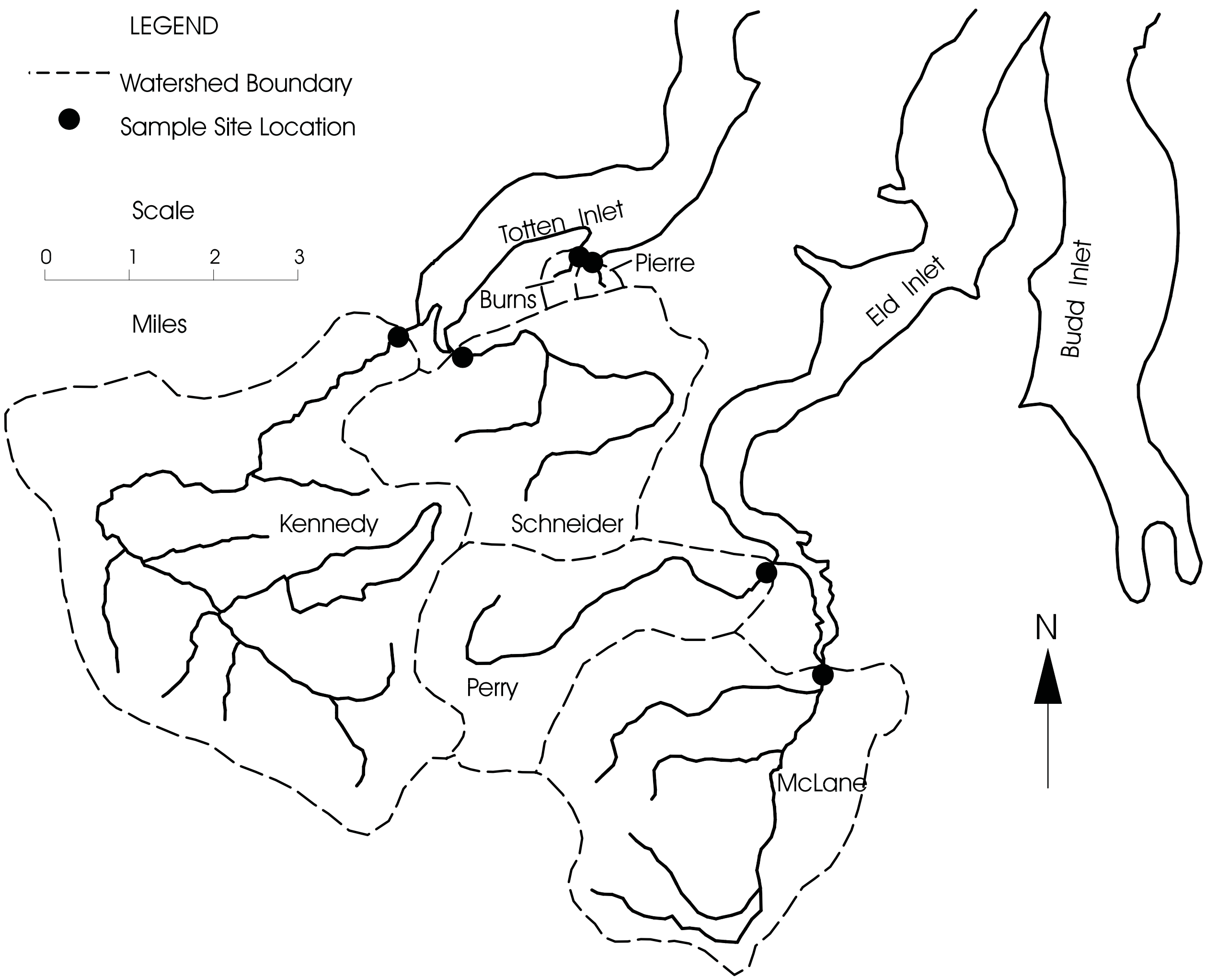

Figure 53: Water Quality Monitoring Stations for Totten and Eld Inlet (Washington)

PROJECT OVERVIEW

Totten and Eld Inlets are located in southern Puget Sound (Figure 52). These adjacent inlets are exceptional shellfish production areas. The rural nature of the area makes it an attractive place in which to live. Consequently, stream corridors and shoreline areas have experienced considerable urban, suburban, and rural growth in the past decade. Located in the area are many recreational, noncommercial farms that keep various livestock. Both upland and lowland areas have highly productive forest lands.

The most significant nonpoint source pollution problem in these inlets is bacterial contamination affecting shellfish production. Totten Inlet is currently classified by the Department of Health (DOH) as an 'approved' shellfish harvest area but is considered threatened due to bacterial non-point-source pollution. Eld Inlet is currently classified by DOH as 'approved' for shellfish harvest, except for the extreme southern-most portion which was reclassified from 'conditionally approved' to 'unclassified' several years ago, and remains so at this time. A designation of 'unclassified' means shellfish may not be commercially harvested, although this may not be an issue if an area is not otherwise (independent of pollution concerns) suitable for shellfish growing or harvest. The southern DOH 'approved' portion of Eld Inlet had been classified 'conditional' (shellfish could not be harvested for 3 days following rain events greater than 1.25 inches in 24 hours) until early 1998. Eld Inlet is still threatened due to bacterial non-point-source pollution sources. As with Totten Inlet, the major sources of fecal coliform (FC) bacteria are on-site wastewater treatment systems and livestock-keeping practices along stream corridors and marine shorelines.

The Totten and Eld Inlet Clean Water Projects evolved from the combined efforts and resources of local and state government. Watershed action plans were completed in 1989 for both Totten and Eld Inlet. While a significant level of public involvement and planning occurred, material resources for implementing on-the-ground best management practices (BMPs) were scarce. In 1993, revenue from property assessments and grants provided funds for local government to implement remedial actions in targeted areas within these watersheds. The goal of the remedial efforts was to minimize the impacts of nonpoint source pollution by implementing farm plans on priority farm sites and identifying and repairing failing on-site wastewater treatment systems. In part, these eforts have been hampered by a shift in political climate from regulatory/mandatory compliance to voluntary eforts. Grant-funded BMP efforts lasted into 1999 for the four Totten-Inlet sub-basins, and into 2000 for the two Eld-Inlet sub-basins.

In 1992, a water quality monitoring program was initiated to evaluate the effectiveness of remedial land treatment practices on water quality. The monitoring effort was formalized in 1995 into a U.S. Environmental Protection Agency (USEPA) Section 319 National Monitoring Program (NMP) project. The monitoring effort targeted six sub-basins within the larger Totten and Eld Inlet watersheds. The goal of the water quality monitoring program was to monitor water quality over time to measure the effectiveness of watershed-based land management programs. A paired watershed design was used for two sub-basins while a single site approach was used for four sub-basins. Water quality monitoring was conducted from mid-November to mid-April on a weekly basis for at least 21 consecutive weeks each year. Fecal coliform bacteria, suspended solids, turbidity, flow, and precipitation were the main parameters of interest. Farm-plan BMP implementation was tracked via information provided by the Conservation Districts. Washington State NMP staff did not have control over any aspect of BMP design, implementation, or monitoring.

The project post-BMP monitoring period concluded as of spring, 2002. A final report was published July 2003, and is available at *http://www.ecy.wa.gov/biblio/0303010.html*.

PROJECT BACKGROUND

Project Area

The Totten and Eld Inlets Section 319 National Monitoring Program project area consists of six sub-basins within the Totten and Eld Inlets. The Totten watershed is approximately 44,300 acres and the Eld Inlet watershed is approximately 22,900 acres.

Relevant Hydrologic, Geologic, and Meteorologic Factors

The topography of the project area includes the rugged Black Hills area southwest of the city of Olympia, upland prairies, fresh and estuarine wetlands, high and low gradient stream reaches, and rolling hills. Pleistocene glacial activity was the most recent major land-forming process.

The predominant soil type is glacial till, generally consisting of compact silts and clays.

Wet, mild winters and warm, dry summers are characteristic of the Puget Sound region.The climate and precipitation of the project area are similar. Rainfall ranges from about 50 to 60 inches per year, depending on elevation and longitude. The precipitation received in the area usually occurs mostly between October and April.

Land Use

Land Use	Totten/Little Skookum Inlet % Land Use	Eld Inlet % Land Use
Forest	82.0%	63.0%
Residential	4.3%	6.3%
Agriculture	5.0%	5.1%
Public Use	0.3%	5.1%
Undeveloped	7.5%	19.8%
Other	0.9%	0.7%

Water Resource Type and Size

Totten and Eld Inlets are estuaries separated by peninsulas in southern Puget Sound. The total drainage basin for the two inlets is approximately 67,200 acres. Six sub-basins have been selected for this monitoring project. They are as follows:

Totten Inlet		
Burns	82-acre	single site
Kennedy	13,046-acre	paired site
Pierre	65-acre	single site
Schneider	4,588-acre	paired site
Eld Inlet		
McLane	7,425-acre	single site
Perry	3,857-acre	single site

Water Uses and Impairments

Important beneficial uses of the Totten and Eld Inlet marine waters include shellfish culturing, finfish migration and rearing, wildlife habitat, and primary and secondary contact recreation.

Important beneficial uses of the freshwater streams that drain into the Totten and Eld Inlets include finfish migration, spawning, and rearing; domestic and agricultural water supply; primary and secondary contact recreation; and wildlife habitat.

The most significant non-point-source pollution problem in these inlets is bacterial contamination affecting shellfish production.

Pollutant Sources

Sources of fecal coliform bacteria are failing on-site wastewater treatment systems, and livestock-keeping practices along stream corridors and marine shorelines. Wet season (October-April) soil saturation hampers the ability of many on-site systems to operate correctly. Saturated soils and stormwater runoff also contribute to water quality problems associated with overgrazed pastures, manure-contaminated runoff, and livestock access to streams. The major source of pollution in the monitoring sub-basins is considered to be animal-keeping practices. Livestock common to these farms include horses, beef cattle, llamas, donkeys, goats, sheep, and chickens. Animal types and numbers from inventories were converted to animal units (1AU = 1,000 lbs animal weight) in order to estimate the wet season animal population for each basin. Estimates are based on conservation district surveys --primarily windshield surveys, except the 2002 survey, which was conducted by Ecology.

Animal unit surveys by sub-basin and period

	1989	1992-93	1996	1996-97	2002
BUR	9.2	8.2	6.5	7.7	10.8
KND	9.9			1	5
MCL	112	89.7		142	46.5
PIE		2	2	5	1
PRY	56.1	77.8	59.8	44.3	5.7
SHN		35	56.2	93	69.6

Water Quality Standards

Kennedy, Schneider, Burns, and Pierre creeks are designated by the state as class AA streams. The class AA water quality standard for fecal coliform (FC) bacteria requires that the geometric mean value (GMV) not exceed 50 colony-forming units per 100 milliliters (cfu/100ml) and that not more than 10% of samples exceed 100 cfu/100 ml. McLane and Perry creeks are class A streams, allowing a GMV no greater than 100 cfu/100ml, and no more than 10% of the samples may exceed 200 cfu/100ml.

Pre-Project Water Quality

During the pre-BMP calibration period, Kennedy Creek (the control) did not exceed the fecal coliform water quality standard; Schneider exceeded three out of three years; McLane and Perry each exceeded one out of two years; and Burns and Pierre exceeded three out of three years. These results are based on entire wet-season calculations.

Post-Calibration Period Water Quality

Kennedy Creek did not exceed fecal coliform water quality standards from the calibration period through 2002. Perry did not exceed through the study except for the last wet-season. McLane exceeded one year after calibration and before BMP grant issue, and then again the last wet-season. Schneider exceeded three years; one excursion took place after the onset of BMP grants, and the other two took place well into the grants. Burns and Pierre creeks exceeded water quality standards all years. These results are based on entire wet-season calculations; analysis of moving-averages and of data outside the project sampling window yielded more water quality exceedances.

Comparison of Fecal Coliform data to water quality standards

Geometric Means for Wet Seasons (cfu/100ml)

Site	Class	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02
Kennedy	AA	5	5	5	5	9	7	8	4	4	8
Schneider	AA	23	15	21	11	8	12	19	15	10	19
McLane	A	37	24	36	24	17	32	80	30	41	43
Perry	A	14	8	17	12	6	10	11	8	10	25
Pierre	AA	**52**	**81**	**405**	**115**	**124**	**53**	**89**	**53**	45	45
Burns	AA	**95**	**222**	**227**	**80**	**62**	**110**	**311**	**237**	**266**	**109**

Percent of Samples Exceeding WQ Standard Part 2

Site	Class	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02
Kennedy	AA	0	0	0	0	0	0	4	0	0	0
Schneider	AA	**17**	9	**17**	4	0	9	**13**	4	**13**	9
McLane	A	4	4	4	4	0	9	4	9	9	**22**
Perry	A	0	0	4	0	0	0	0	0	0	**17**
Pierre	AA	**22**	**50**	**91**	**57**	**45**	**17**	**39**	**17**	**14**	**17**
Burns	AA	**35**	**75**	**79**	**30**	**32**	**39**	**83**	**70**	**74**	**39**

Bold values indicate violations of water quality standards:

Class AA Standard
Part 1 - geometric mean value (GMV) shall not exceed 50 colonies/100Ml
Part 2 - not more than 10% of the samples used for calculating the GMV shall exceed 100 colonies/100mL

Class A Standard
Part 1 - geometric mean value (GMV) shall not exceed 100 colonies/100mL
Part 2 - not more than 10% of the samples used for calculating the GMV shall exceed 200 colonies/100mL

Looking at five week moving averages for the same period, water quality violations occurred with higher frequency as indicated below. This table summarizes violations of part 1 or part 2 of the standards.

Wet Seasons with 5-week moving-average water quality violations

Site	Class	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02
Kennedy	AA							X			
Schneider	AA	X	X	X	X		X	X	X	X	X
McLane	A	X	X	X			X	X	X	X	X
Perry	A			X							X
Pierre	AA	X	X	X	X	X	X	X	X	X	X
Burns	AA	X	X	X	X	X	X	X	X	X	X

Sampling was extended before and after the regular NMP sampling-window for the 1998-1999 and later seasons. Water quality fecal coliform standards were exceeded during these dry-seasons through summer 2001.

Water Quality Objectives

Pierre Creek

- reduce median fecal coliform concentration by 69% (reduce to 10 cfu/100ml)

Burns Creek

- reduce median fecal coliform concentration by 63% (reduce to 20 cfu/100 ml)

Schneider Creek

- reduce median fecal coliform concentration by 50% (reduce to 10 cfu/100 ml)

McLane Creek

- reduce median fecal coliform concentration by 44% (reduce to 22 cfu/100 ml)

Project Time Frame

1993 through 2002

PROJECT DESIGN

Nonpoint Source Control Strategy

The nonpoint source treatment in the project area was designed to reduce the amount of nonpoint source pollution via repair of failing on-site wastewater treatment systems and implementation of farm plans on priority farm sites. Priority farm sites are those farms that potentially threaten the quality of receiving waters due to a variety of physical and managerial properties such as closeness to stream, numbers of animals, and lack of pollution prevention practices. The nonpoint source control strategy involved surveying all potential pollution sources in critical areas, estimating the water quality impact, and finally, planning and implementing corrective actions.

Resource management plans (farm plans) were developed cooperatively by landowners and local conservation districts. The farm planning process identified potential water quality impacts and recommended BMPs to mitigate those impacts. Conservation district staff and each landowner discussed implementation costs and schedules of BMPs and cost-share opportunities. The landowner then chose what he or she was willing to implement and agreed to implement the plan as funding allowed. Specific BMPs most likely to be employed for nonpoint source control in project watersheds include pasture and grazing management, stream fencing, stream buffer zones, rainwater and runoff management, livestock density reduction, and animal waste management. Monies from the Farm Service Agency, State Revolving Fund, U.S. Fish and Wildlife Service, and other sources were sought for cost-share or low interest loan contracts.

Voluntary participation (prompted by education/outreach activities and local ordinances) was anticipated to be the major mechanism for implementation of farm plans. Farm owners whose operations had deleterious effects on water quality and who did not comply with local ordinances were to become involved in a formal compliance procedure, which was outlined by a memorandum of agreement between the Ecology Water Quality Program and each conservation district.

Project Schedule

Sites or Activities	Pre-BMP	BMP Implementation	Post-BMP
Burns 198	8-1993	1993-1995	1995-2002
Pierre 198	6-1990	1989-1993	1993-2002
Perry 198	3-1989	1989-2000	2000-2002
McLane 198	3-1989	1988-2000	2000-2002
Kennedy	No BMPs designed; monitoring 1986-2002		
Schneider 198	8-1993	1993-1995	1995-2002

TYPE AND NUMBER OF BMPs IMPLEMENTED IN STUDY SUB-BASINS

BMP#	BMP Description	Units	Burns	McLane	Pierre	Perry	Schneider
312	Waste Management	each					
313	Waste Storage	each	2	1			1
322	Channel Vegetation	acres		2			
342	Critical Area Planting	acres					2
344	Crop Residue Use	acres	23				
352	Deferred Grazing	acres	19.1	24.5			
382	Fencing	feet	2000	14401	50	1499	9952
393	Filter Strip	acres	1.5	12	0.5	4	33
395	Fish Stream Improvement	feet		7194		220	6200
412	Grassed Waterway	acres	6				
430	Irrigation Pipeline	feet		271			
472	Use Exclusion	each	17.2	53.5	3	4	79
490	Forest Site Preparation	acres					427
510	Pasture & Hayland Mgmt	each		134			127
512	Pasture & Hayland Planting	acres	9.6	25			
516	Pipeline	feet	890	495			
528	Prescribed Grazing	acres	34.1	11	3		110
530	Proper Woodland Management	each					
556	Planned Grazing System	acres	22.5	28			
558	Roof Runoff Management	each	3	3		2	
561	Heavy Use Area Protection	acres		3.25			
575	Livestock Crossing	each		1			30
580	Streambank Protection	acres		2550			2000
590	Nutrient Management	acres	41.6	42			110
612	Tree/Shrub Establishment	acres	15				
614	Trough	each	4	17		6	
633	Waste Utilization	acres		38.5			111
644	Wildlife Wetland Habitat Mgmt	acres		5			
645	Wildlife Upland Habitat Mgmt	acres	51	287			600
654	Forest Harvest Trails	acres					427
660	Tree/Shrub Pruning	acres					427
666	Forest Stand Improvement	acres					427
	Total BMP units installed		3139.6	25598.75	56.5	1735	21063
	Total BMP units planned		3164.8	32557.8	61.5	17234	21367.1
	Percent of BMP units installed		99.2%	78.6%	91.9%	10.1%	98.6%
	Uncertain BMP units installed		0	1777.75	0	2736	0
	Percent of BMP units installed including uncertain BMPs		99.2%	84.1%	91.9%	25.9%	98.6%

Water Quality Monitoring

A paired watershed approach was used for the Kennedy/Schneider sub-basins to document the change in water quality as a result of BMP implementation. Kennedy was a background (control) sub-basin, while Schneider was the treatment sub-basin (Figure 51).A single site approach was applied to Burns, Pierre, Perry and McLane sub-basins (Figure 51).

Variables Measured

Biological
Fecal coliform (FC)

Covariates
Conductivity
Daily precipitation
Flow
Temperature
Total suspended solids (TSS)
Turbidity

Water quality monitoring was conducted from early November through mid-April. Grab samples were collected on a weekly schedule (usually Tuesdays) for at least 21 consecutive weeks each year of the project. During 1994, some additional samples were collected each season during runoff events at each site. The sample sites are located near the mouth of each stream.

The Puget Sound Protocols for freshwater and general quality assurance/quality control (Tetra Tech, 1986) were followed for water sample collection, identification, preservation, storage, and transport. Replicate samples (two samples taken from the same location at nearly the same time) for at least 10% of the total number of laboratory samples were taken and analyzed each week. All sample sites are represented every sampling season.

Environmental monitoring data prior to November 1992 were collected by Thurston County under a different sampling scheme than that used for NMP monitoring.

Monitoring Scheme for the Totten and Eld Inlet Section 319 National Monitoring Program Project

Design	Sites or Activities	Primary Parameters	Covariates	Frequency of Primary Parameter Sampling	Duration
Single downstream	Burns Pierre Perry McLane	FC	Conductivity Daily precipitation Flow Temperature TSS Turbidity	Weekly (Nov. to mid-April)	Schneider Burns Pierre: 1 yr. pre-BMP 3 yrs BMP 3+yrs post-BMP Perry:
Paired watershed	Kennedy/ Schneider	FC			3 yrs pre-BMP 3 yrs BMP 2 yrs post-BMP McLane: 1 yr pre-BMP 5 yrs BMP 2 yrs post-BMP

Land Treatment Monitoring

Land treatment monitoring was expected of the county and conservation district. Grant requirements for monitoring and reporting were lacking or incomplete, so data have been difficult to obtain, and are incomplete.

Modifications Since Project Started

During the 1993-1994 sampling-year of the project, a Washington State Supreme Court decision was issued declaring that under existing law, administrative search warrants could not be used for inspection programs; as this was later deemed to apply to on-site sanitary surveys. Thurston County modified its administrative code in 1995 to allow such warrants, but early in 1996, on advice from legal counsel, the Board of Health decided not to proceed with search warrants. Consequently, participation dropped from 93% during 1992-1993 to 72% during 1995-1996 (Hofstad et al., 1996). Voluntary participation in the 1996-97 survey in Schneider basin was low, with only 36% of homeowners allowing their on-site wastewater systems to be inspected.

Voluntary participation in the farm plan development was also less than expected. Ten of 22 priority farms in the Schneider, Burns, and Pierre sub-basins developed farm plans. Five of these farm plans resulted from some level of pressure by the local health department. Originally, owners whose operations had deleterious effects on water quality and who did not comply with local ordinances were to become involved in a formal compliance procedure, which was to be outlined by a memorandum of agreement (MOA) between the Ecology Water Quality Program and the conservation district. However, there is some debate as to the interpretation of the MOA requirement, and the extent to which the drafted MOA met the intent of the original language. Regardless, no known formal compliance procedures have been activated via the MOA. It is uncertain if farm planning for the remaining 12 priority farms in Schneider sub-basin will occur. Farm planning and implementation in McLane and Perry sub-basins continued until June 30, 2000 via a state to conservation district grant extension.

Changes have occurred in the definition of pre- and post-BMP sampling periods for each sub-basin as BMP grants have been extended and additional BMP implementation data has become available.

The 1998-99 and later sampling seasons were each started a month early, and extended a month past the usual cutoff dates, then into the summer, although at a reduced sampling frequency. Fecal coliform loading has been added to analysis for all years.

Enterococci were added to the analysis suite for the 2000-01 sampling season.

Progress To Date

Three on-site wastewater treatment systems were inspected in Burns and Pierre sub-basins in 1994. In Schneider sub-basin, 12 of a targeted 33 On-site Sewage Systems (OSSS) were surveyed in 1997; 21 of the 33 homeowners chose not to participate in the survey. No on-site wastewater treatment system surveys were scheduled for the McLane or Perry basins during this project. About 120 OSSS in the Summit Lake drainage area, in the Kennedy sub-basin, were also inspected and remedial actions were undertaken. However, it is unlikely that remedial actions will affect bacteria levels at the Kennedy Creek monitoring site, because in-lake bacterial levels have historically been at or below detection limits.

About 180 of 234 planned agricultural BMPs were implemented on 30 sites in Schneider, McLane, Perry, Burns, and Pierre sub-basins between 1986 and 1997. These pollution controls were installed on noncommercial farms that keep various types of livestock. About 61% of these controls were installed from 1993 and 1997, while about 39% were installed from 1986 to 1992. Most farm planning and BMP installation activities in the Totten basins ended in 1997; Eld basin grant-funding for BMPs concluded mid-2000.

Within each sub-basin, the average number of BMPs planned per farm ranged from 7.8 to 10.5 while the average number of BMPs implemented per farm ranged from 5.0 to 8.7. The number of individual practices installed per farm ranged from 1 to 14. The most frequently applied BMPs included fencing, prescribed grazing, filter strips, livestock exclusion, nutrient management, and watering troughs. Other commonly employed practices included roof runoff management and fish stream improvement.

The completeness or rate of implementation of a farm plan is defined as the percentage of planned BMPs actually implemented. Over half of farm operators signed their farm plans symbolizing some level of commitment to implementing the farm plan. For all sub-basins, 53% of farms implemented all of their planned BMPs, while 30% of farms had implementation rates of less than 60%. For the remaining farms, the completeness of farm plan implementation was better than 70%.

For Burns and Pierre sub-basins, all priority farms entered the farm planning process. In Schneider sub-basin, 24% of the priority farms entered the farm planning process. Several prioritizations were done in McLane and Perry sub-basins, and 33% to 52% of priority farms entered the farm planning process depending on which prioritization scheme is considered.

Reporting for work completed under the last state-issued BMP grant in Eld Inlet (McLane and Perry creeks) has been obtained. It will take considerable time and effort to extract the needed data.

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

Water quality data were stored and managed in spreadsheets and later transferred to Ecology's Environmental Information Management (EIM) data base. As funding allows, Ecology is committed to transferring data from EIM to USEPA's STORET. Data evaluation and analysis strategies included the following:

- Determining statistically significant temporal trends in water quality by comparison of 95% Confidence Interval about seasonal medians using notched boxplots (single site approach); linear regression of monthly or seasonal medians over time, and the significance of slope tested to indicate a decreasing trend of FC concentrations over time (single site approach); change in linear relationship of FC concentrations between paired basins (paired watershed approach); comparison of frequencies of water quality standards violations between years; and comparison of the 95% Confidence Interval about the median of pre- and post-BMP data sets. This approach uses historical data from 1986–1992 (n=4 per season); these data were collected by the Thurston County Environmental Health Division. Ecology started weekly wet-season sampling November, 1992.
- Determining temporal trends in BMP implementation by bar graph of BMPs (individual or grouped) implemented over time and plot of cumulative histogram of BMPs implemented over time (individual measures or groups of measures).
- Evaluating combined water quality and BMP trends by linear regression of FC as a function of BMPs (individually or grouped) such as livestock management, acres treated, farm plans implemented, and stream-bank protected; and graphical expression of water quality and BMP information plotted over the same time scale (e.g. seasonal median FC values with cumulative histogram of fully implemented farm plans).

NPSMS Data Summary

Burns Creek FCMF cfu/100ml — **Percentiles**

	n	75	50	25
92-93	23	190	54	36
93-94	24	390	180	106
94-95	24	340	200	94
95-96	23	230	53	32
96-97	22	150	65	21
97-98	23	160	91	44
98-99	24	880	205	123
99-00	23	650	250	76
00-01	23	638	170	96
01-02	23	320	61	25

Pierre Creek FCMF cfu/100ml — **Percentiles**

	n	75	50	25
92-93	23	96	32	18
93-94	22	150	80	30
94-95	23	830	460	270
95-96	23	210	120	84
96-97	22	273	98	63
97-98	23	79	52	27
98-99	23	150	85	53
99-00	23	91	57	35
00-01	21	59	36	28
01-02	23	91	45	15

Kennedy Creek FCMF cfu/100ml — **Percentiles**

	n	75	50	25
92-93	23	11	5	2
93-94	24	16	6	1
94-95	23	18	4	1
95-96	23	14	5	1
96-97	22	30	12	3
97-98	23	10	7	3
98-99	24	17	8	3
99-00	23	18	3	1
00-01	23	14	5	1
01-02	23	31	8	3

Schneider Creek FCMF cfu/100ml — **Percentiles**

	n	75	50	25
92-93	23	56	20	8
93-94	23	31	13	7
94-95	23	38	17	7
95-96	23	26	12	6
96-97	22	22	12	2
97-98	23	22	11	5
98-99	24	66	16	6
99-00	23	31	14	10
00-01	23	36	9	3
01-02	23	48	20	7

McLane Creek FCMF cfu/100ml **Percentiles**

	n	75	50	25
92-93	23	64	39	25
93-94	23	49	20	12
94-95	23	92	35	20
95-96	23	44	22	14
96-97	22	37	26	11
97-98	23	88	25	15
98-99	24	110	83	61
99-00	23	56	30	14
00-01	23	120	70	14
01-02	23	212	38	19

Perry Creek FCMF cfu/100ml **Percentiles**

	n	75	50	25
92-93	23	31	10	7
93-94	24	28	6	3
94-95	23	32	14	5
95-96	23	44	11	4
96-97	22	17	8	4
97-98	23	21	10	3
98-99	24	37	12	5
99-00	23	29	12	4
00-01	23	26	10	4
01-02	23	51	24	7

Final Results

Pre- and post-BMP periods were defined by examining available farm and BMP implementation data (see the following table). For the paired-watershed analysis, Kennedy data were paired according to pre- and post-BMP period data for Schneider. Two approaches were used to evaluate water quality: comparison of pre- and post-BMP median FC concentrations. Pre-treatment (calibration) periods varied depending on sub-basin; post (treatment) periods are 1999-2002. Univariate statistical tests are used for before/after streams, and regression is used for the paired watershed (Kennedy-Schneider).

Pre- and Post-BMP Periods in Study Sub-Basins

Basin	Pre-BMP period	Post-BMP period
Kennedy	none	none
Schneider	1988-1993, 5 seasons	1995-2002, 7 seasons
McLane	1986-1988, 2 seasons	2000-2003, 3 seasons
Perry	1986-1989, 3 seasons	2000-2003, 3 seasons
Burns	1989-1993, 4 seasons	1996-2002, 6 seasons
Pierre	1986-1989, 3 seasons	1993-2002, 8 seasons

The next table summarizes the results of the pre- and post-BMP comparison of the median FC concentration. These results use the past three years as the post-period in all cases.

Median FC Concentrations from Pre- and Post-BMP Periods

Basin	Pre-BMP median FC and (n)	Post-BMP median FC and (n)	Change Direction
McLane	30 (7)	35 (71)	increase
Perry	5 (10)	13 (71)	increase
Schneider	25 (39)	13 (71)	decrease
Burns	84 (35)	205 (71)	increase
Pierre	25 (11)	47 (69)	increase

For the paired-watershed analysis with Kennedy and Schneider, pre- and post-BMP period, regression outputs were examined after Zar (1984), EPA (1993), and Grabow et al. (1998). The slopes of these regressions were not significantly different while the y-intercepts were different. The difference in intercepts, rather than slopes, indicates a parallel shift in the regression equation. This shift in the regression represents a 46% decrease from the pre-BMP period. There is some possibility that changes in loading at Schneider result from the presence or absence of livestock as a consequence of land ownership changes at one site, and not as a result of BMPs at that site.

Early results of linear regression analyses showed that flow and Antecedent Precipitation Index (API) correlated poorly with FC. API slope, TSS, and turbidity correlate more strongly with FC but were generally inconsistent among the stations or between years. Results suggest that the hydrologic characteristics in the study basins will make poor covariates of FC data for use in trends analyses or pre-and post-BMP comparisons.

Analysis for the entire project period is complete. For the ten-year monitoring period, the FC trend was up significantly (*a*=0.05) at McLane, and down at all other streams, but significantly only at Pierre. The FC loading trend was up significantly at McLane, and up, but not significantly, at Schneider and Kennedy. The trend was down, but not significantly, at the other streams. Incorporating historical data back to 1983, the FC trend was up significantly at McLane, and down at all other streams, but significantly only at Perry. Post pollution-control FC levels - both concentrations and loadings - have fluctuated considerably from year to year. Significant improvement occurred at Schneider and Perry after BMPs were installed; but in all cases where significant improvement occurred for at least one two-year averaged period, the average of the last monitoring period (2000-2002) is higher than the prior low value. All streams violated state water quality standards for FC at some time during the study after best management practices were implemented; Burns and Pierre violated the standards every year of the study. McLane contributes as much FC loading to marine waters as the other five streams combined.

Linking water quality changes to BMPs and grant programs					
	Burns	Pierre	McLane	Perry	Schneider
1. Has there been significant improvement?	No	No	No	Yes	Yes
2. Is the improvement continuing or at least holding?	n/a	n/a	n/a	Maybe	Maybe
3. Can improvement be linked to improvements in land treatment?	n/a	n/a	n/a	Maybe	Yes, qualified
4. Are the land treatment changes and grant programs connected?	Yes	Partially	Partially	Partially	Yes

INFORMATION, EDUCATION, AND PUBLICITY

There are a variety of educational and informational resources within the project counties (Thurston and Mason counties) that address land and water stewardship. Local and state initiatives over past years have resulted in stewardship activities that cover the spectrum of personal commitment activities, including awareness, learning, experience, and personal action programs. Many educators involved with these activities share ideas, resources, and programs through a stewardship-focused Regional Education Team.

A Section 319 Clean Water Act grant funded a watershed resident survey in August, 1994. The survey explored public awareness and opinions regarding water quality and environmental issues. The survey targeted the Totten and Eld Inlet watersheds in southern Puget Sound, as well as northern Puget Sound watersheds in Whatcom, Skagit, and Snohomish counties. Approximately 1300 residents responded to the mail survey. The survey was designed to help state and local governments evaluate levels of public awareness and effectiveness of current educational programs, and determine where educational efforts, and efforts to involve the public, should be directed (Elway Research, 1994).

The objective of the state's public involvement and education component has been to participate in and lend support to established public information and education activities addressing environmental stewardship in the project areas and in the larger South Puget Sound area.

TOTAL PROJECT BUDGET

The estimated budget for the Totten and Eld Inlet National Monitoring Program project for the period of FY 1993–2003 (ten years):

Project Element	Funding Source ($)			
	Federal	State	Local	Total
Proj Mgt	NA	NA	NA	NA
I&E, LT, & OSSS	NA	1,411,000	462,000	1,873,000
WQ Monit	537,708	358,472	NA	896,181
TOTALS	537,708	1,769,472	462,000	2,769,180

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

In response to increased and persistent closures of shellfish harvest areas and threats to close additional areas, state and local groups developed the Shellfish Protection Initiative (SPI). This program provided $3 million from State Referendum 39 funds for implementing BMPs in targeted watersheds. The Totten Basin, a targeted watershed, received $1.3 million in grant funds as part of the SPI. Eld Inlet, although not selected as an SPI project, received $260,000 from the SPI program to augment ongoing nonpoint source control efforts in specific areas. In addition, $331,000 was targeted for farm planning and implementation activities in the Eld watershed from 1996 to 1999. The Eld watershed grant was later extended another year through Spring of 2000.

An identified issue was that there is no institution charged with or mechanism in place for tracking maintenance of BMPs. This lack impedes the ability to correlate BMP implementation with any water quality changes.

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Wisconsin

Otter Creek
Section 319
National Monitoring Program Project

Figure 54: Otter Creek (Wisconsin) Project Location

Figure 55: Water Quality Monitoring Stations for Otter Creek (Wisconsin)

PROJECT OVERVIEW

The Otter Creek Section 319 National Monitoring Program project is in east central Wisconsin (Figure 54), with a project area of 9.5 square miles. Otter Creek drains into the Sheboygan River, which then drains into Lake Michigan. Land use mainly consists of dairies and croplands.

Otter Creek has a warmwater forage fishery. The fish community is degraded by lack of cover, disturbed streambanks, and siltation. Fecal coliform levels frequently exceed the state standard of 400 counts per 100 ml, and dissolved oxygen often drops below 2 mg/l during runoff events. Fifteen percent of all water oxygen concentration samples fall below the state standard of 5 mg/L. Otter Creek delivers high concentrations of phosphorus and fecal coliform to the Sheboygan River. These pollutants then travel to the near shore waters of Lake Michigan, which serves as a water supply for municipal use and also supports recreational fisheries.

Streambed sediments originating from cropland erosion, eroding streambanks, and overgrazed dairy pastures are reducing the reproductive potential for a high quality fishery with abundant forage fish. Otter Creek is further degraded by total phosphorus and fecal coliform export from dairy barnyards, pastures, cropland, and alfalfa fields.

Critical area criteria are being used to reduce phosphorus and sediment loading to project area streams. Eight of the nine dairy operations in the project area were classified as critical; two of the eight critical dairy operations spread enough manure that their cropland was classified as critical. Streambank critical areas are the 6,200 feet of streambank trampled by cattle.

Land treatment design is based on the pollutant type and the source of the pollutant. Upland fields were treated with cropland erosion control practices to reduce sediment loss. Streambanks have been fenced to limit cattle access, and barnyard structural practices have been installed to reduce nutrient runoff into Otter Creek. Post-BMP monitoring was completed in Summer, 2002. The final project report was completed in 2005.

PROJECT BACKGROUND

Project Area

The Otter Creek watershed area is about 9.5 square miles. The Meeme River watershed is the control watershed, with an area of about 16 square miles.

Project Hydrologic, Geologic, and Meteorologic Factors

Average annual precipitation is 29 inches. Fifteen inches of rain falls during the growing season between May and September. About 42 inches of snow (five inches of equivalent rain) falls during a typical winter.

The topography of the watershed ranges from rolling hills to nearly level. The soils are clay loams or silty clay loams that have poor infiltration and poor percolation but high fertility. Soils are glacial drift underlain by Niagara dolomite.

Land Use

Land Use	%
Agricultural	75
Forest	14
Wetland	6
Other*	5
Total	100

*Includes pasture, grazed woodlot, residential, water, and roads
Source: Corsi et al., 2005

Water Resource Type and Size

Otter Creek is 4.2 miles long with an average gradient of .0047 ft/ft or 25 ft/mile (Figure 53). The creek flows into and out of a small spring-fed lake called Gerber Lake.

Water Uses and Impairments

Otter Creek is used for fishing and for secondary body contact recreation. The fishery is impaired by degraded habitat, while contact recreation is impaired by high fecal coliform counts. Both uses are also impaired by eutrophic conditions.

Pollutant Sources

There are eight critical dairy operations that serve as important pollutant sources. Trampled streambanks and cropland and pastureland receiving dairy manure are also critical sources. Some critical area cropland is in need of erosion control practice installation.

Modifications Since Project Started

None.

Pre-Project Water Quality

The Otter Creek project area is part of the larger Sheboygan River watershed, identified as a Priority Watershed in 1985. The watershed is characterized by streambank degradation due to cattle traffic. Excessive phosphorus, fecal coliform, and sediment runoff originate from manure spreading and cropland. Fisheries are impaired because of degraded aquatic habitat that limits reproduction. Recreation is limited by degraded fisheries and highly eutrophic and organically enriched stream waters.

Water Quality Objectives

The Otter Creek project water quality objectives are as follows:

- Increase the numbers of intolerant fish species by improving the fish habitat and water quality
- Improve the recreational uses by reducing the bacteria levels.
- Reduce the loading of pollutants to the Sheboygan River and Lake Michigan by installation of best management practices (BMPs) in the Otter Creek watershed.
- Improve the wildlife habitat by restoring riparian vegetation.

Project Time Frame

Spring, 1994 through Spring, 2003

PROJECT DESIGN

Nonpoint Source Control Strategy

Streambank erosion and cattle exclusion practices included shoreline and streambank fencing and stabilization; barnyard management included barnyard runoff management and manure storage facilities; and cropland practices included grassed waterways, reduced tillage, and nutrient and pesticide management.

The Sheboygan County Land Conservation Department obtained funds through a private organization, “Pheasants Forever,” to plant and maintain vegetative buffers on 19.8 acres of riparian land for 10 years.

Nine thousand, two hundred feet of streambank fencing have been installed, as well as a significant change in cropping practices to reduce upland soil erosion.

Project Schedule

Management Unit	Pre-BMP Monitoring Dates	BMP Installed	Date Installed/ Established	Post-BMP Monitoring Dates
Otter Creek Watershed	A USGS monitoring station has been collecting water quality data on Otter Creek since 1990. Water quality monitoring funded through the 319 Program began in April 1994. Pre-BMP 1990-1993.	Animal waste utilization, Streambank stabilization, Runoff diversions, Conservation tillage, Clean-water diversions, Barnyard runoff controls, Cattle crossings, Streambank fencing	Majority of BMPs were installed between Oct. 1993- Sept. 1997	Oct. 1999-Sept. 2002
Upstream-downstream monitoring study, within the Otter Creek Watershed	April 1994 – October 1995	Clean-water diversions, Barnyard runoff controls, Filter strip, Cattle crossing, Streambank fencing	October 1995 – November 1995	April 1996 – June 1997

Water Quality Monitoring

Two monitoring studies were conducted in the Otter Creek National Monitoring Program project. They initially included a paired watershed study and an above and below study Because of significant changes in the control watershed (MR1) that prevented a paired watershed analysis, the data collected at the Otter Creek outlet station (OC1) were evaluated as a on Otter Creek single-watershed before-/ after- design.

Six sampling sites on Otter Creek are shown in Figure 53.The main site on Otter Creek was an outlet station that served as the site for the single station before and after monitoring site. Four fish and habitat monitoring stations are indicated by the numbered dots in Figure 53.The above and below watershed study was conducted using two mainstem sites located above and below a critical area dairy, approximately coinciding with the biological monitoring stations numbered 3 and 2 in Figure 53.

The before-/after- watershed study was used to assess the overall impact of best management practices on water quality. The treatment watershed is 9.5 square miles and was monitored at station OC1. Biological, bacterial, and chemical parameters were monitored; precipitation, along with precipitation and water discharge covariates.

The above and below study of a single dairy that implemented barnyard runoff control structures has been completed. Data on the pollutant loads from the barnyard prior to BMPs are reported in USGS Fact Sheets FS-221-95 and FS-051-98. Findings on this before and after – above and below study were presented at the 1997 National 319 Conference.

Variables Measured

Biological

Fisheries survey
Macroinvertebrate survey
Habitat assessment
Fecal coliform (FC)*

Chemical

Total phosphorus (TP)*
Dissolved phosphorus (DP)
Total Kjeldahl nitrogen (TKN)
Ammonia (NH_3)*
Nitrogen series ($N0_2$-N and $N0_3$-N)
Total suspended solids (TSS)*
Dissolved oxygen (DO)*
pH

*monitored throughout entire project

Covariates

Stream discharge
Precipitation

Sampling Scheme

The schedule for chemical grab sampling and biological and habitat monitoring varied by station and by year. Chemical grab sampling occurred at a time characterized as midsummer-fall for 1990 and 1994 and during spring-midsummer in 1991.

Fisheries monitoring included sampling fish species, frequencies, and biomass. Fisheries data were summarized and interpreted based on the Index of Biotic Integrity (Lyons, 1992). Macroinvertebrate monitoring criteria included macroinvertebrate species or genera and numbers. Macroinvertebrate data were summarized and interpreted using the Hilsenhoff Biotic Index (Hilsenhoff , 1987). Habitat parameters included riparian buffer width, bank erosion, pool area, stream width to depth ratio, riffle-to-riffle or bend-to-bend rating, percent fine sediments, and cover for fish. Habitat information was rated using the fish habitat rating system established for Wisconsin streams by Simonson et al. (1994).

Grab and event-flow samples were used for water chemistry monitoring. Parameters sampled included TP, FC, DO, and TSS.

The following table provides details on the original sampling design for the paired study, the upstream/downstream, and the single downstream station. The monitoring sites are listed for reference. The primary covariates are very similar for each study except for methods used for macroinvertebrates. The frequency of sampling, the covariates, and the duration of each study are also listed.

The before and after – above and below component of the project has been completed. Automated event flow sampling has been discontinued on Otter Creek.

Monitoring Scheme for the Otter Creek Section 319 National Monitoring Program Project

Design	Sites or Activities	Primary Parameters	Covariates	Frequency of Primary Parameter Sampling	Duration
Paired watershed design	Otter Creek[T] OC1 Meeme River[C] MR1	Fisheries index Macroinvertebrates[H] Habitat FC TP DP TKN NH_3 NO_3 NO_2 TSS DO	Precipitation Discharge	Annually Annually Annually 30 samples per monitoring season; weekly April-Oct.	1990-2002
Upstream/ downstream	Above Dairy[C] OC4 Below Dairy[T] OC2	Fisheries index Macroinvertebrates[F] Habitat Same bacterial & chemical parameters as paired watershed study	Precipitation Discharge	Annually Annually Annually 30 samples per monitoring season; weekly April-Oct.; periodic storm event sampling	1994-1997
Single downstream	Otter Creek OC1	Fisheries index Macroinvertebrates[F] Habitat Same bacterial & chemical parameters as paired watershed study	Precipitation Discharge	30 samples per monitoring season for nutrients only	1990-2002

[T] = Treatment Area
[C] = Control Area
[H] = Hilsenhoff Biotic Index level; kick samples
[F] = Family level; kick samples

DATA MANAGEMENT AND ANALYSIS

Data Management and Storage

All water chemistry data were entered into the Wisconsin Department of Natural Resources (DNR) data management system, WATSTORE (the U.S. Geological Survey national database), U.S. Environmental Protection Agency's Nonpoint Source Management System software (NPSMS), and STORET.

Project Findings

Before/after watershed study. Targeted and implemented land treatment in the Otter Creek Watershed is summarized in the table below. Upland erosion control BMPs included change in crop rotation, reduced tillage, critical area stabilization, grass waterways, and pasture management; tons of sediment controlled were estimated by the RUSLE.

Management practice	Targeted	Implemented
Animal waste management		
Manure storage (#)	4	3
Barnyard runoff (#)	8	8
Milkhouse wastewater treatment (#)	0	2
Streambank protection		
Streambank protection (feet)	6,600	6,220
Fencing (feet)	9,200	9,200
Grade stabilization (#)	4	4
Buffer strips (acres)	0	19.8
Upland management		
Nutrient management (acres)	1,130	1,570
Upland erosion BMPs (tons of sediment)	505	276

Under base-flow conditions, reductions between pre- and post-BMP periods were detected in median concentrations for total suspended solids (TSS) and BOD_5 but not for total phosphorus (TP) or dissolved ammonia nitrogen. Fecal coliform counts during base-flow increased over the study period.

Annual reductions in rainfall storm loads between the pre-and post-BMP periods during the non-vegetative season (Nov through May) were observed for TSS (58%), TP (48%) and dissolved ammonia nitrogen (41%). Differences in rainfall storm loads of these three constituents for the vegetative season (June through October) were not detected. On an annual basis, TSS storm loads were reduced by 58% and dissolved ammonia nitrogen loads were reduced by 41% during the post-BMP period.

Habitat was improved for stream segments that had either natural riparian buffer or where streambank fencing was installed, but not at the station where the riparian area was pasture and no streambank fencing was installed. Biomonitoring results also suggest that BMP implementation in Otter Creek substantially modified fish community structure, but the overall community quality was not improved.

The Sheboygan County Land and Water Conservation Department felt that the most effective BMPs for TSS reduction were the buffer strips, which provide an area for solids to settle before reaching the stream, and streambank fencing that allows for growth of vegetation on the streambank, reducing streambank erosion. The most effective BMPs for nutrient reduction were believed to be streambank fencing that reduced the number of livestock in the stream, barnyard-runoff control systems, manure-storage facilities, and milk house wastewater treatment systems.

The final report on this portion of the project is published as Corsi, et al. 2005. Effects of Best-Management Practices in Otter Creek in the Sheboygan River Priority Watershed, Wisconsin, 1990-2002. Scientific Investigations Report 2005-5009, U.S. Geological Survey, U.S. Department of the Interior and is available at: http://water.usgs.gov/pubs/sir/2005/5009

Upstream/downstream study. A comparison of upstream and downstream loads after the barnyard BMPs were implemented indicates that the BMP systems improved water quality. Post-BMP pollutant loads contributed by the barnyard were significantly lower than pre-BMP loads for:

suspended solids (85%), total phosphorus (85%), ammonia (94%), BOD (83%), and fecal coliform (81%) were statistically lower. The final report on this portion of the project is published as Stuntebeck and Bannerman. 1998. *Effectiveness of Barnyard Best Management Practices in Wisconsin*. USGS Fact Sheet FS-051-98. U.S. Geological Survey, U.S. Department of the Interior and is available at http://wi.water.usgs.gov/pubs/FS-051-98/.

INFORMATION, EDUCATION, AND PUBLICITY

The Sheboygan County Land Conservation Department developed and implemented an effective educational program to reach project dairymen. Project personnel achieved a high level of participation through education, technical assistance, effective communication, and cost-share assistance.

- Watershed tours are held for landowners.
- Watershed newsletters are sent biannually to landowners.
- Annual watershed advisory committee meetings are held.
- Small group tours of BMP installation sites are given for landowners considering installing BMPs.

TOTAL PROJECT BUDGET

Funds through the state of Wisconsin Nonpoint Source Program were used to fund cost-share practices. The estimated budget for the Otter Creek National Monitoring Program project for the period FY00 is:

Project Element	Funding Source($)			
	Federal	State	Local	Total
Proj Mgt	NA	5,000	NA	5,000
LT	NA	NA	NA	NA
I&E	NA	5,000	NA	5,000
WQ Monit	25,000	NA	NA	25,000
TOTALS	25,000	10,000	NA	35,000

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

State grants were provided to cover the cost of land treatment technical assistance and information and educational support.

OTHER PERTINENT INFORMATION

Cooperating agencies included the Wisconsin Department of Natural Resources, Department of Agriculture, Trade, and Consumer Protection, Sheboygan County Land Conservation Department, and the U.S. Geological Survey.

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Appendices

Appendix I

Minimum Reporting Requirements For Section 319 National Monitoring Program Projects

The United States Environmental Protection Agency (USEPA) has developed the NonPoint Source Management System (NPSMS) software to support the required annual reporting of water quality and implementation data for Section 319 National Monitoring Program projects (USEPA, 1991). The software tracks nonpoint source control measure implementation with respect to the pollutants causing the water quality problem.

Currently, NPSMS can accept and track the following information (USEPA, 1991):

Management Area Description:

- State, USEPA Region, and lead agency.
- Watershed management area description (management area name, management area identification, participating agencies, area description narrative).
- 305(b) waterbody name and identification.
- Designated use support for the waterbody.
- Major pollutants causing water quality problems in waterbody and relative source contributions from point, nonpoint, and background sources.

Best Management Practices (BMPs) and Nonpoint Source Pollution Control Measures:

- Best management practices (BMP name, reporting units, indication whether the life of the practice is annual or multi-year).
- Land treatment implementation goals for management area.
- Pollutant sources causing impaired uses that are controlled by each BMP. Each control practice must be linked directly to the control of one or more sources of pollutants causing impaired uses.

Funding Information:

- Annual contributions from each funding source and use of funding for each management area.

Water Quality Monitoring Plan:

- Choice of monitoring approach (chemical/physical or biological/habitat).
- Monitoring design and monitoring station identification (paired watersheds, upstream-downstream, reference site for biological/habitat monitoring, single downstream station). The paired watershed approach is recommended; the single downstream station is discouraged.
- Drainage area and land use for each water quality monitoring station.
- Delineation of monitoring year, seasons, and monitoring program duration.
- Parameters measured (parameter name; indication if the parameter is a covariate; STORET, BIOSTORET, or 305(b) Waterbody System code; reporting units).
- Quartile values for chemical/physical parameters. Quartile values are established cutoffs based on historical or first-year data for each season and monitoring station.
- Maximum potential and reasonable attainment scores for biological monitoring parameters. Indices scores that correspond to full, threatened, and partial use supports are required.
- Monitoring frequency. Chemical/physical monitoring, with associated covariates, must be performed with at least 20 evenly-spaced grab samples in each season. Fishery surveys must be performed at least one to three times per year. Benthic macroinvertebrates must be performed at least once per season, with at least one to three replicates or composites per sample. Habitat monitoring and bioassays must be performed at least once per season.

Annual Reporting:

- The NPSMS software is used to report annual summary information. The raw chemical/physical and biological/habitat data are required to be entered into STORET and BIOSTORET, respectively.
- Annual chemical/physical and covariates. The frequency count for each quartile is reported for each monitoring station, season, and parameter.
- Annual biological/habitat and covariates. The scores for each monitoring station and season are reported.
- Implementation tracking in the watershed and/or subwatersheds that constitute the drainage areas for each monitoring station. Implementation reported corresponds to active practices in the reporting year and includes practices with a one-year life span and practices previously installed and still being maintained.

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Appendix II

Abbreviations

ACP	Agricultural Conservation Program
ADSWQ	Automatic Data System for Water Quality
Ag	Silver
AGNPS	Agricultural Nonpoint Source Pollution Model
Al	Aluminum
ANSWERS	Areal Nonpoint Source Watershed Environment Response Simulation
API	Antecedent Precipitation Index
As	Arsenic
ASCS	Agricultural Stabilization and Conservation Service, USDA
B	Boron
Ba	Barium
Be	Beryllium
BMPs	Best Management Practices
BIBI	Biological Index of Biotic Integrity
BIOS	USEPA Natural Biological Data Management System
BOD	Biochemical Oxygen Demand
Ca	Calcium
Cal Poly	California Polytechnic State University
Cd	Cadmium
CES	Cooperative Extension Service, USDA
cfs	Cubic Feet per Second
cfu	Colony Forming Units
Cl	Chloride
COD	Chemical Oxygen Demand
Cr	Chromium
CREAMS	Chemicals, Runoff, and Erosion from Agricultural Management Systems Model

CTUIR	Confederated Tribes of the Umatilla Indian Reservation
Cu	Copper
DEC	Department of Environmental Conservation
DO	Dissolved Oxygen
DP	Dissolved Phosphorus
DNR	Department of Natural Resources
DSWC	Division of Soil and Water Conservation
DWQ	Division of Water Quality
EPIC	Erosion Productivity Index Calculator
FC	Fecal Coliform
Fe	Iron
FS	Fecal Streptococcus
FSA	Farm Service Agency (USDA)
GIS	Geographic Information System
GMV	Geometric Mean Value
GRASS	Geographic Resources Analysis Support System
HBI	Hilsenhoff Biotic Index
HEL	Highly Erodible Land
HUA	Hydrologic Unit Area
I&E	Information and Education Programs
IBI	Index of Biotic Integrity
ICM	Integrated Crop Management
IDNR	Iowa Department of Natural Resources
IDNR-GSB	Iowa Department of Natural Resources Geological Survey Bureau
ISU-CES	Iowa State University Cooperative Extension Service
ISUE	Iowa State University Extension
K	Potassium
LRNRD	Lower Republican Natural Resource District
LT	Land Treatment
Ma	Manganese
MCL	Maximum Contaminant Level
Mg	Magnesium
Mg/l	Milligrams Per Liter
N	Nitrogen
Na	Sodium
NA	Information Not Available
NCSU	North Carolina State University

NDEQ	Nebraska Department of Environmental Quality
NEP	National Estuary Program
NH_3	Ammonia-Nitrogen
NH^+_4	Ammonium-Nitrogen
Ni	Nickel
NMP	National Monitoring Program
NO_2	Nitrite-Nitrogen
NO_3	Nitrate-Nitrogen
NPS	Nonpoint Source
NPSMS	NonPoint Source Management System
NRCS	Natural Resources Conservation Service (USDA)
NTU	Nephelometric Turbidity Units
OCC	Oklahoma Conservation Commission
OP	Orthophosphate
OSSS	On-site Sewage System
P	Phosphorus
Pb	Lead
Proj Mgt	Project Management
QA/QC	Quality Assurance/Quality Control
RCWP	Rural Clean Water Program
Se	Selenium
Section 319	Section 319 of the Water Quality Act of 1987
Si	Silica
Sn	Tin
SO_4^-	Sulfate
SPI	Shellfish Protection Initiative
SS	Suspended Solids
STORET	USEPA STOrage and RETrieval Data Base for Water Quality
TDP	Total Dissolved Phosphorus
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
TP	Total Phosphorus
TS	Total Solids
TSS	Total Suspended Solids
Ug/l	Micrograms Per Liter

UHL	University Hygienic Laboratory (Iowa)
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geologic Survey (U.S. Department of the Interior)
VSS	Volatile Suspended Solids
WATSTORE	USGS Water Data Storage System
WCCF	Webster County Conservation Foundation
WQ	Water Quality
WQIP	Water Quality Incentive Project
WQ Monit	Water Quality Monitoring
WQSP	Water Quality Special Project
Zn	Zinc

Appendix III

Glossary of Terms

***AGNPS** (Agricultural Nonpoint Source Pollution Model)* — an event-based, watershed-scale model developed to simulate runoff, sediment, chemical oxygen demand, and nutrient transport in surface runoff from ungauged agricultural watersheds.

***Animal unit** (AU)* — One mature cow weighing 454 kg or the equivalent. For instance, a dairy cow is 1.4 AU because it weighs almost 1.5 times a mature beef cow. The animal units of smaller animals than beef cows is less than one: pigs = 0.4 AU and chickens = 0.033 AU.

Anadromous — Fish that return to their natal fresh water streams to spawn. Once hatched, these fish swim to the ocean and remain in salt water until sexual maturity.

Artificial redds — An artificial egg basket fabricated of extruded PVC netting and placed in a constructed egg pocket.Artificial redds are used to measure the development of fertilized fish eggs to the alevin stage (newly hatched fish).

Alachlor — Herbicide (trade name Lasso) that is used to control most annual grasses and certain broadleaf weeds and yellow nutsedge in corn, soybeans, peanuts, cotton, woody fruits, and certain ornamentals.

Atrazine — Herbicide (trade name Atrex, Gesa prim, or Primatol) that is widely used for control of broadleaf and grassy weeds in corn, sorghum, sugar cane, macadamia orchards, pineapple, and turf grass sod.

Autocorrelation — The correlation between adjacent observations in time or space.

Bedload — Sediment or other material that slides, rolls, or bounces along a stream or channel bed of flowing water.

Before-after design — A term referring to monitoring designs that require collection of data before and after BMP implementation.

Beneficial uses — Desirable uses of a water resource such as recreation (fishing, boating, swimming) and water supply.

***Best management practices** (BMPs)* — Management or structural practices designed to reduce the quantities of pollutants — such as sediment, nitrogen, phosphorus, bacteria, and pesticides — that are washed by rain and snow melt from farms into nearby surface waters, such as lakes, creeks, streams, rivers, and estuaries. Agricultural BMPs can include fairly simple changes in practices such as fencing cows out of streams (to keep animal waste out of streams), planting grass in gullies where water flows off a planted field (to reduce the amount of sediment that runoff water picks up as it flows to rivers and lakes), and reducing the amount of plowing in fields where row crops are planted (in order to reduce soil erosion and loss of nitrogen and phosphorus from fertilizers applied to the crop land). BMPs can also involve building structures, such as large animal waste storage tanks that allow farmers to choose when to spread manure on their fields as opposed to having to spread it based on the volume of manure accumulated.

BMP system — A combination of individual BMPs into a “system” that functions to reduce the same pollutant.

***Biochemical oxygen demand** (BOD)* — Quantitative measure of the strength of contamination by organic carbon materials.

***Chemical oxygen demand** (COD)* — Quantitative measure of the strength of contamination by organic and inorganic carbon materials.

Cost sharing — The practice of allocating project funds to pay a percentage of the cost of constructing or implementing a BMP. The remainder of the costs are paid by the producer.

County ASC Committee — County Agricultural Stabilization and Conservation Committee: a county-level committee, consisting of three elected members of the farming community in a particular county, responsible for prioritizing and approving practices to be cost shared and for overseeing dissemination of cost-share funds by the local USDA-Agricultural Stabilization and Conservation Service office.

Covariance — A measure of the relationship between two variables whose values are observed at the same time.

Covariate — The parameter which is related to another parameter.

Critical area — Area or source of nonpoint source pollutants identified in the project area as having the most significant impact on the impaired use of the receiving waters.

Demonstration project — A project designed to install or implement pollution control practices primarily for educational or promotional purposes. These projects often involve no (or very limited) evaluations of the effectiveness of the control practices.

Designated use — Uses specified in terms of water quality standards for each water body or segment.

Drainage area — An area of land that drains to one point.

Ecoregion — A physical region that is defined by its ecology, which includes meteorological factors, elevation, plant and animal speciation, landscape position, and soils.

EPIC *(Erosion Productivity Index Calculator)* — A mechanistic computer model that calculates erosion from field-size watersheds.

Erosion — Wearing away of rock or soil by the gradual detachment of soil or rock fragments by water, wind, ice, and other mechanical or chemical forces.

Eskers **—** Glacially deposited gravel and sand that form ridges 30 to 40 feet in height.

Explanatory variables — Explanatory variables, such as climatic, hydrological, land use, or additional water quality variables, that change over time and could affect the water quality variables related to the primary pollutant(s) of concern or the use impairment being measured. Specific examples of explanatory variables are season, precipitation, streamflow, ground water table depth, salinity, pH, animal units, cropping patterns, and impervious land surface.

Fecal coliform *(FC)* — Colon bacteria that are released in fecal material. Specifically, this group comprises all of the aerobic and facultative anaerobic, gram-negative, nonspore-forming, rod-shaped bacteria that ferment lactose with gas formation within 48 hours at 35 degrees Celsius.

Fertilizer management — A BMP designed to minimize the contamination of surface and ground water by limiting the amount of nutrients (usually nitrogen) applied to the soil to no more than the crop is expected to use. This may involve changing fertilizer application techniques, placement, rate, and timing.

Geographic information systems *(GIS)* — Computer programs linking features commonly seen on maps (such as roads, town boundaries, water bodies) with related information not usually presented on maps, such as type of road surface, population, type of agriculture, type of vegetation, or water quality information. A GIS is a unique information system in which individual observations can be spatially referenced to each other.

Goal — A narrowly focused measurable or quantitative milestone used to assess progress toward attainment of an objective.

Interfluve — A flat area between streams.

Land treatment — The whole range of BMPs implemented to control or reduce NPS pollution.

Loading — The influx of pollutants to a selected water body.

Macroinvertebrate — Any non-vertebrate organism that is large enough to be seen without the aid of a microscope.

Mechanistic — Step-by-step path from cause to effect with ability to make linkages at each step.

Moraine — Glacial till (materials deposited directly by ice) which is generally irregularly deposited.

Nitrogen — An element occurring in manure and chemical fertilizer that is essential to the growth and development of plants, but which, in excess, can cause water to become polluted and threaten aquatic animals.

Nonpoint source (NPS) pollution — Pollution originating from diffuse areas (land surface or atmosphere) having no well-defined source.

Nonpoint source pollution controls — General phrase used to refer to all methods employed to control or reduce nonpoint source pollution.

NonPoint Source Management System *(NPSMS)* — A software system designed to facilitate information tracking and reporting for the USEPA 319 National Monitoring Program.

Objective — A focus and overall framework or purpose for a project or other endeavor, which may be further defined by one or more goals.

Paired watershed design — In this design, two watersheds with similar physical characteristics and, ideally, land use are monitored for one to two years to establish pollutant-runoff response relationships for each watershed. Following this initial calibration period, one of the watersheds receives treatment while the other (control) watershed does not. Monitoring of both watersheds continues for one to three years. This experimental design accounts for many factors that may affect the response to treatment; as a result, the treatment effect alone can be isolated.

Parameter — A quantity or constant whose value varies with the circumstances of its application.

Pesticide management — A BMP designed to minimize contamination of soil, water, air, and nontarget organisms by controlling the amount, type, placement, method, and timing of pesticide application necessary for crop production.

Phenolphthalein alkalinity — A measure of the bicarbonate content.

Phosphorus — An element occurring in animal manure and chemical fertilizer that is essential to the growth and development of plants, but which, in excess, can cause water to become polluted and threaten aquatic animals.

Post-BMP implementation — The period of use and/or adherence to the BMP

Pre-BMP implementation — The period prior to the use of a BMP.

Runoff — The portion of rainfall or snow melt that drains off the land into ditches and streams.

Sediment — Particles and/or clumps of particles of sand, clay, silt, and plant or animal matter carried in water.

Sedimentation — Deposition of sediment.

Single-station design — A water quality monitoring design that utilizes one station at a point downstream from the area of BMP implementation to monitor changes in water quality.

Subbasins — One of several basins that form a watershed.

Substrate sampling — Sampling of streambeds to determine the percent of fine particled material and the percent of gravel.

Subwatershed — A drainage area within the project watershed. It can be as small as a single field or as large as almost the whole project area.

Tailwater management — The practice of collecting runoff, "tailwater," from irrigated fields. Tailwater is reused to irrigate crops.

Targeting — The process of prioritizing pollutant sources for treatment with BMPs or a specific BMP to maximize the water quality benefit from the implemented BMPs.

Total alkalinity — A measure of the titratable bases, primarily carbonate, bicarbonate, and hydroxide.

Total Kjeldahl nitrogen *(TKN)* — An oxidative procedure that converts organic nitrogen forms to ammonia by digestion with an acid, catalyst, and heat.

Total Kjeldahl phosphorus *(TKP)* — An oxidative procedure that converts organic phosphorus forms to phosphate by digestion with an acid, catalyst, and heat.

Tracking — Documenting/recording the location and timing of BMP implementation.

Turbidity — A unit of measurement quantifying the degree to which light traveling through a water column is scattered by the suspended organic (including algae) and inorganic particles. The scattering of light increases with a greater suspended load. Turbidity is commonly measured in Nephelometric Turbidity Units (NTU), but may also be measured in Jackson Turbidity Units (JTU).

Upstream/downstream design — A water quality monitoring design that utilizes two water quality monitoring sites. One station is placed directly upstream from the area where the implementation will occur and the second is placed directly downstream from that area.

Vadose zone — The part of the soil solum that is generally unsaturated.

Variable — A water quality constituent (for example, total phosphorus pollutant concentration) or other measured factors (such as stream flow, rainfall).

Watershed — The area of land from which rainfall (and/or snow melt) drains into a stream or other water body Watersheds are also sometimes referred to as drainage basins. Ridges of higher ground generally form the boundaries between watersheds. At these boundaries, rain falling on one side flows toward the low point of one watershed, while rain falling on the other side of the boundary flows toward the low point of a different watershed**.**

Appendix IV

Project Documents and Other Relevant Publications

This appendix contains publication references for the Section 319 National Monitoring Program projects. Project document lists appear in alphabetical order by state.

This list is preceded by general information on the 319 National Monitoring Program, including publications pertaining to data analysis and National Monitoring Program project highlights, successes and recommendations.

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Appendix V

Matrix for Section 319 National Monitoring Program Projects

PROJECT	BASIN SIZE	IMPAIRMENT(S)	POLLUTANT(S)
Alabama: Lightwood Knot Creek	68 mi^2	(Lake Jackson and tributaries) ◆Recreation ◆Aquatic life support	◆Sediment ◆Nutrients (N & P) ◆Bacteria
Arizona: Oak Creek Canyon	9 mi^2	◆Primary contact recreation ◆Aquatic life support ◆Drinking water supply	◆Bacteria ◆Nutrients (N)
California: Morro Bay Watershed	76 mi^2	◆Estuarine and fresh water habitat ◆Shellfish harvesting ◆Recreation	◆Sediment ◆Nutrients ◆Bacteria ◆Metals
Connecticut: Jordan Cove Watershed	<1 mi^2	◆Jordan Cove: shellfish harvesting ◆Long Island Sound: habitat, recreation	◆Sediment ◆Fecal coliform ◆Nutrients (N) ◆Metals
Idaho: Eastern Snake River Plain	47 mi^2 (ground water monitoring) 20 acres (test fields)	◆Drinking water supply (ground water)	◆Nitrate
Illinois: Lake Pittsfield	11 mi^2	◆Drinking water supply ◆Recreation	◆Sediment ◆Nutrients
Illinois: Waukegan River	12 mi^2	◆Aquatic life support	◆Peak stormwater flows ◆Sediment ◆Loss of physical habitat
Iowa: Sny Magill Watershed	36 mi^2	◆Recreation ◆Aquatic life support	◆Sediment ◆Nutrients ◆Animal waste ◆Pesticides
Iowa: Walnut Creek	38 mi^2	◆Aquatic life support (Mississippi River and Gulf of Mexico)	◆Sediment ◆Nutrients (nitrate ◆Herbicides
Maryland: Warner Creek Watershed	1mi^2	◆Aquatic life support (Monocacy River and Chesapeake Bay)	◆Sediment ◆Nitrogen ◆Phosphorus

POLLUTANT SOURCE(S)	WATER QUALITY OBJECTIVES	WATER QUALITY MONITORING DESIGN
◆Agricultural fields ◆Poultry operations	◆Control erosion ◆Reduce nutrient loading to streams	Paired watershed 2 paired sites - 2 control / 2 treatment
◆Recreational users ◆Aquatic sediments ◆Septic systems ◆Natural/background ◆Unknown	◆Reduce fecal coliform by 50% ◆Reduce nutrient levels (NH_3) 20%	Upstream / downstream
◆Cropland and rangeland ◆Urban areas and roads ◆Unstable streambanks ◆Abandoned mines	◆Evaluate effectiveness of several BMP systems ◆30% to 66% reduction in sediment yield	◆Paired watershed 1 control / 1 treatment ◆3 upstream/downstream ◆1 single downstream site
◆Urban runoff ◆Construction	◆Demonstrate water quantity/quality benefits of urban/residential BMPs ◆Maintain post-development peak runoff rate and volume at pre-development rates ◆Reduce N 65%, P 40%, FC 85%	◆Paired watershed: 1 control/ 2 treatment ◆Two treatment periods: construction and post-construction
Irrigated cropland: ◆Excessive irrigation ◆Excessive N inputs	Evaluate nitrate-reducing BMPs at the field scale ◆Evaluate effects of irrigation water management on nitrate leaching to shallow ground water ◆Evaluate effects of crop rotation on nitrate leaching to shallow ground water	◆Paired fields 2 control / 2 treatment
◆Cropland ◆Streambanks/channels ◆Small livestock operations	◆Reduce sediment loads to lake ◆Evaluate effectiveness of sediment retention basins	Before/After: ◆4 subwatershed stations ◆3 in-lake stations
◆Urban impervious surfaces ◆Streambank erosion	◆Restore streambanks ◆Reduce or mitigate effects of stormwater on aquatic habitat ◆Restore stream fishery	◆Upstream / downstream
◆Cropland ◆Livestock facilities ◆Streambank erosion	◆Reduce sediment loads by 50% ◆Reduce N, P, pesticide loads by 25% ◆Decrease streambank erosion rates ◆Implement 30 animal manure management systems	◆Paired watershed: 1 control / 1 treatment ◆Upstream/downstream in subbasins
◆Cropland ◆Streambank erosion	◆Demonstrate/evaluate prairie restoration as BMP for water quality ◆Reduce nitrate, phosphorus, herbicide and sediment loads	◆Paired watershed/trend analysis 1 control/ 1 treatment ◆Upstream / downstream subbasin stations
◆Dairy operations ◆Animal waste ◆Cropland ◆Pasture	◆Collect WQ data to develop and calibrate a SWAT model application to predict effects of BMPs on water quality in MD ◆Illustrate relationships between BMPs and WQ	◆Paired watershed 1 control / 1 treatment ◆Upstream/downstream

PROJECT	SAMPLING SCHEME	PRIMARY WATER QUALITY VARIABLES
Alabama: Lightwood Knot Creek	◆Discharge monitored continuously ◆Weekly composites April - September ◆Weekly grab samples for bacteria ◆Biological monitoring 2 times/year	◆Physical: turbidity, TSS, bedload, TDS, conductance ◆Chemical: TP, OP, NH_3, NO_3 ◆Biological: fecal bacteria, macroinvertebrates, habitat
Arizona: Oak Creek Canyon	◆Weekly grab samples during recreation season (May - Sept.) ◆Monthly grab samples Nov-April	FC, NO_3, NH_3, TN, OP
California: Morro Bay Watershed	◆Event/baseflow automated ◆Even interval grab sampling ◆Annual biomonitoring ◆Stream channel transects, vegetation monitoring	SS, turbidity, NO_3, PO_4, fecal coliform Macroinvertebrates, habitat Riparian and rangeland vegetation
Connecticut: Jordan Cove Urban Watershed	◆Storm event (automated, flow-proportional composites) ◆Grab samples (bacteria, BOD) ◆Monthly composites (metals)	Flow, TSS, TP, TKN, NH_3, NO_2 + NO_3, FC BOD, Cu, Pb, Zn
Idaho: Eastern Snake River Plain	◆Monthly ground water grab samples ◆Growing season soil water samples ◆Geospatial/geostatistical analysis used to address hydrogeologic variability of fields	NO_3-N, NO_4-N, TKN, TDS, DO, organic pesticides
Illinois: Lake Pittsfield	◆Storm event sampling (automated) at subwatershed outlets ◆Monthly grab sampling (April - October) in Lake	Subwatersheds: TSS Lake: TSS, VSS, SS, TO, OP, DP, NH_3-N, NO_2+NO_3-N, TKN
Illinois: Waukegan River	◆Seasonal biomonitoring ◆Continuous flow ◆Flow, temperature, DO	◆Fish (IBI) ◆Macroinvertebrates (MBI) ◆Habitat (PBI)
Iowa: Sny Magill Watershed	◆Continuous stage, daily Q and SS ◆Weekly grab samples ◆Annual habitat fisheries assessment ◆Bi-monthly macroinvertebrates	Q, turbidity, SS, TP, N series, DO, fecal coliform, herbicides
Iowa: Walnut Creek	◆Flow, SS monitored daily at watershed outlets ◆Storm event and Biweekly/monthly sampling ◆Annual habitat and fishery survey	Flow, turbidity, SS, P, NO_3, NH_3, BOD, herbicides, Macroinvertebrates, fish
Maryland: Warner Creek Watershed	◆Paired watersheds: grabs weekly (Feb-June) and bi-weekly ◆Upstream/downstream: automated storm samplings; grabs weekly (Feb-June) and bi-weekly	TKN, NH_3, NO_3 + NO_2, NO_3, TP, OP, sediment

BMPs	MAJOR COOPERATING INSTITUTIONS	PROJECT TIME FRAME
◆Runoff and sediment control structures ◆Critical area planning ◆Cover and green manure crops ◆Pasture and hayland management ◆Poultry litter storage / waste management	◆Geological Survey of Alabama ◆Alabama Dept. of Environmental Management ◆USDA NRCS ◆Covington County Extension	1996-2002 Final Report 2002
◆Enhance rest room/shower facilities ◆Public education/signage ◆Enforce litter laws ◆Upgrade septic systems	◆Arizona Dept. of Environmental Quality ◆Northern Arizona University ◆Arizona State Parks	1994-1998 Final Report 1998
◆Livestock exclusion ◆Riparian pasture development ◆Rotational grazing ◆Floodplain restoration/sediment retention	◆Central Coast Regional Water Quality Control Board ◆California Polytechnic State University ◆USDA NRCS	1993-2002 Final Report 2003
◆Phased grading ◆Vegetation management ◆Sediment retention basins/ grassed swales ◆Rain gardens ◆Pervious paving ◆Post-construction maintenance practices	◆University of Connecticut ◆Aqua Solutions, L.L.C. ◆Connecticut DEP ◆Connecticut Cooperative Extension ◆USDA-NRCS	1996-2006 annual reports published
◆Irrigation water management ◆Crop rotation ◆Fertilizer management ◆Pesticide management	◆ID Division of Environmental Quality ◆U. of Idaho Cooperative Extension ◆Boise State University ◆USDA NRCS	1991 - 1998 annual reports published under Demo Project
◆Sediment retention basins/WASCOBs ◆Stream channel stabilization ◆Conservation tillage ◆Integrated crop management ◆Livestock exclusion ◆Filter strips	◆IL State Water Survey ◆IL Environmental Protection Agency ◆Pike Co. Soil and Water Conservation District	1992-1994 annual reports
◆Biotechnical streambank restoration (vegetative + structural) ◆Stream restoration - pool & riffle complexes ◆Waukegan Park District	◆IL Environmental Protection Agency ◆IL State Water Survey ◆IL Department of Natural Resources	1992 -2004 annual reports
◆Structural erosion control practices ◆Integrated crop management ◆Water and sediment control structures ◆Animal waste management systems ◆Grazing management ◆Education and assistance	◆IA DNR-Geologic Survey ◆IA State University Extension ◆USDA NRCS (larger Hydrologic Unit Area and WQ Special Projects	1991-2001 Final Report 2004
◆Conversion of cropland to native prairie ◆Restoration of wetlands and riparian zones ◆Required nutrient management and pest management on remaining cropland	◆IA DNR-Geological Survey ◆US Fish and Wildlife Service 1996	1995 - 2005 Final Report 2006
◆Conversion of cropland to pasture ◆Watering systems ◆Livestock exclusion fencing ◆Manure storage and management ◆Nutrient management	◆MD Department of Natural Resources ◆U. of Maryland Agricultural Engineering ◆USDA-NRCS, CES (Monocacy Demo Project)	1993 - 2003 annual reports

PROJECT	BASIN SIZE	IMPAIRMENT(S)	POLLUTANTS
Michigan: Sycamore Creek Watershed	106 mi^2	◆Aquatic life support ◆Recreation ◆Urban areas	◆Sediment ◆Nutrients ◆BOD
Minnesota: White Water River Watershed	320 mi^2	◆Aquatic life support ◆Recreation	◆Turbidity/sediment ◆Fecal coliform ◆Temperature
Nebraska: Elm Creek Watershed	56 mi^2	◆Aquatic life support (coldwater trout fishery)	◆Sediment ◆Increased water temperature ◆Increased peak flows
New York: New York City Watershed	1 mi^2	◆Drinking water ◆Aquatic life support	◆Phosphorus ◆Sediment ◆Bacteria/pathogens
North Carolina: Long Creek Watershed	44 mi^2	◆Aquatic life support ◆Drinking water	◆Sediment ◆Bacteria ◆Nutrients
Oklahoma: Peacheater Creek	25 mi^2	◆Recreation ◆Aquatic life support	◆Nutrients ◆Loss of habitat ◆Reduced water clarity ◆Periphyton growth ◆Eutrophication (downstream lake)
Oregon: Upper Grande Ronde Basin	695 mi^2	◆Aquatic life support (cold water fish, macroinvertebrates ◆Water supply ◆Recreation	◆Water temperature ◆Loss of physical habitat ◆Loss of riparian vegetation
Pennsylvania: Pequea and Mill Creek Watersheds	3 mi^2	◆Aquatic life support ◆Wildlife habitat ◆Agricultural water supply	◆Bacteria ◆Sediment ◆Nutrients ◆Organic matter

POLLUTANT SOURCE(S)	WATER QUALITY OBJECTIVES	WATER QUALITY MONITORING DESIGN
◆Cropland ◆Livestock access ◆Streambanks	◆Reduce impacts of agricultural nps pollutants on surface and ground water quality ◆Reduce sediment in Sycamore Creek by 52%	◆Paired watershed 1 control/2 treatments
◆Streambank erosion ◆Degraded riparian areas ◆Cropland/pasture ◆Feedlot runoff ◆Livestock access to streams	◆Evaluate effectiveness of BMP implementation implementation on water quality	◆Paired watershed 1 control/multiple treatments
◆Cropland ◆Rangeland ◆Streambank erosion ◆Irrigation return flows	◆Reduce sediment load in Elm Creek by 50% ◆Reduce summer max. water temperature ◆Reduce instream sedimentation ◆Reduce peak flows ◆Improve aquatic habitat	◆Upstream/downstream ◆Single downstream station
Dairy operations: ◆Animal waste ◆Cropland ◆Pasture	◆Test ability of Whole Farm Planning process to correctly identify on-farm pollution sources ◆Quantify reductions in pollutant loading due to implementation of BMPs under Whole Farm Planning	◆Paired watershed 1 control / 1 treatment
◆Cropland ◆Dairy operations ◆Pastures ◆Streambank erosion ◆Urbanization	Quantify the effects of BMPs on: ◆Pollutant loads from dairy farm ◆Cropland sediment/nutrient losses ◆Aquatic biota ◆Reduce sediment yield from water supply watershed by 60%	◆Paired watershed 1 control / 1 treatment ◆Upstream/downstream ◆Single downstream station
◆Poultry houses ◆Land application of litter ◆Dairies & other livestock ◆Streambank erosion ◆Poor riparian management	◆Restore recreation and aquatic life support ◆Minimize eutrophication impacts on downstream lake	◆Paired watershed 1 control / 1 treatment
◆Grazing practices ◆Channel modification ◆Mining ◆Road construction ◆Logging	◆Improve salmonid and aquatic macroinvertebrate communities ◆Quantitatively document a cause & effect relationship between improved habitat, lower water temperatures, & improved salmonid & macroinvertebrate communities	◆Paired watershed 1 control / 1 treatment ◆Upstream/downstream ◆3 Single stations
◆Livestock access to streams ◆Degraded riparian zones	Evaluate effects of streambank fencing on surface and near-stream ground water quality	◆Paired watershed 1 control / 1 treatment ◆Upstream/downstream

PROJECT	SAMPLING SCHEME	PRIMARY WATER QUALITY VARIABLES
Michigan: Sycamore Creek Watershed	◆Automated storm events (Mar. - July) ◆Weekly grab samples (Mar. - July) ◆Automated flow-proportional sampling year-round at watershed outlet	◆Turbidity, TSS, TP, OP, TKN, NH_3, NO_2+NO_3, COD
Minnesota Whitewater River Watershed	◆Automated event and weekly chemistry ◆Annual biomonitoring	Temperature, TSS, TP, NO_3, fecal coliform, macroinvertebrates, fish, and habitat
Nebraska: Elm Creek Watershed	◆Grab sampling: weekly (April - Sept.), monthly (Oct. - March) ◆Seasonal biomonitoring, habitat assessment	Temperature, DO, TSS, macroinvertebrates, fish, stream morphology, substrate, habitat
New York: New York City Watershed	◆Automated storm event sampling ◆Weekly grabs during base flow ◆Twice/monthl pathogens ◆Annual biomonitoring	TSS, TP, SRP, TDP, PP, TKN, NH_3-N, NO_2+NO_3-N, TOC, pH, *Cryptosporidium, Giardia,* macroinvertebrates
North Carolina: Long Creek Watershed	◆Grab sampling: weekly (Dec. - May), monthly (June - Nov.) ◆Automated storm event sampling ◆Annual biological survey	TS, TSS, TP, TKN, NO_2+NO_3-N, DO FC, FS, macroinvertebrates, aufwuchs
Oklahoma: Peacheater Creek	◆Grab sampling: weekly (July - Jan.), monthly (Feb. - June) ◆Automated storm event sampling ◆Biomonitoring: 2x/yr (periphyton and macroinvertebrates), annual to biennial (fish and habitat)	Turbidity, TSS, TP, OP, TKN, NO_2+NO_3-N, Periphyton, macroinvertebrates, fish habitat, bank erosion
Oregon: Upper Grande Ronde Basin	April - October monitoring season: ◆Continuous water temperature ◆Water chemistry, habitat, biomonitoring 3x/year	Water temperature, DO, turbidity, BOD NH_3, macroinvertebrates, fish, habitat
Pennsylvania: Pequea and Mill Creek Watersheds	◆Continuous flow measurement ◆Paired watersheds: grab samples every 10 d (Apr. - Nov.), monthly (Dec. - Mar.) ◆Upstream/downstream: automated storm even sampling ◆Biomonitoring 2x/yr	SS, NH_3, NO_2+NO_3, organic N, TP, OP, habitat, macroinvertebrates

BMPs	MAJOR COOPERATING INSTITUTIONS	PROJECT TIME FRAME
◆Reduced tillage ◆Cropland protective cover ◆Diversions ◆Water and sediment control structures ◆Streambank stabilization	◆Ingham Co. Soil Conservation District ◆MI Dept. of Natural Resources ◆MSU Extension - Ingham Co. ◆USDA-NRCS	1993 - 1997 annual reports
◆No-till/conservation tillage ◆Grazing management ◆Livestock exclusion ◆Nutrient and pest management ◆Stream buffers	◆MN Pollution Control Agency ◆Whitewater River Watershed Project ◆University of Minnesota ◆Winona State University	1994 - 2006
◆Filter strips ◆Streambank stabilization ◆Vegetative cover ◆Livestock exclusion/range management ◆Conservation tillage ◆Irrigation management	◆NE Department of Environmental Quality ◆USDA NRCS (HUA Project) ◆Webster County Cooperative Extension	1992 - 1996 annual HUA reports
◆Manure storage/management ◆Barnyard runoff management ◆Milkhouse waste diversion ◆Livestock exclusion ◆Cropland erosion control ◆Nutrient management	◆NY State Dept. Env. Cons. ◆NY City Dept. Env. Protection ◆NYS Watershed Agricultural Council ◆Delaware County Soil and Water Cons. District ◆USDA-NRCS	1993 - 2006
◆Cropland erosion controls ◆Nutrient management ◆Waste storage structures ◆Livestock exclusion/pasture management	◆Gaston Co. Cooperative Extension ◆NCSU Water Quality Group ◆NC DNR Div. of Water Quality ◆NC Cooperative Extension	1993-2001 Final Report 2002
◆Riparian buffers, fencing ◆Planned grazing/pasture management ◆Animal waste management, structures ◆Watering facilities ◆Critical area vegetation ◆Nutrient management	◆OK Conservation Commission ◆Co. Conservation Districts ◆Co. Extension Service ◆OK State University ◆USDA NRCS	1995-2005 Implementation Report 2005
◆Stream channel diversion/restoration ◆Streambank stabilization ◆Riparian revegetation	◆OR Dept. Environmental Quality ◆Local SWCDs ◆Confederated Tribes of Umatilla Indian Reservation (CTUIR) ◆US Forest Service ◆USDA NRCS	1993-2006 annual and periodic reports
◆Streambank fencing on all pasture land adjacent to stream	◆PA DEP Bureau of Land and Water Conservation ◆USGS ◆USDA NRCS ◆Lancaster Conservation District ◆PSU Cooperative Extension	1993 - 2001 Final Report 2005

PROJECT	BASIN SIZE	IMPAIRMENT(S)	POLLUTANT(S)
Pennsylvania: Stroud Preserve Watershed	0.3 mi^2	Regional WQ impairments: ◆Recreation ◆Aquatic life support	◆Nutrients ◆Sediment
Pennsylvania: Swatara Creek Watershed	43 mi^2	◆Aquatic life support ◆Recreation ◆Metals	◆Acidity ◆Sulfates
Pennsylvania: Villanova University Stormwater BMPs	<0.5 mi^2	Regional stormwater issues, e.g., ◆Aquatic life support ◆Recreation ◆Water Supply	◆Flow ◆Sediment ◆Nutrients ◆Bacteria ◆Metals
South Dakota: Bad River	3,209 mi^2	◆Aquatic life support ◆Recreation ◆Irrigation	◆Sediment ◆Loss of channel capacity ◆Loss of water clarity
Vermont: Lake Champlain Basin Agricultural Watersheds	12 mi^2	◆Aquatic life support ◆Recreation ◆Downstream impacts to Lake Champlain (Eutrophication)	◆Nutrients (P) ◆Bacteria ◆Organic matter
Washington: Totten and Eld Inlet	105 mi^2	◆Shellfish harvesting	◆Bacteria
Wisconsin: Otter Creek	26 mi^2	◆Aquatic life support ◆Recreation ◆Downstream impacts to Sheboygan River and lake Michigan	◆Nutrients (P) ◆Bacteria ◆Sediment ◆Loss of habitat

POLLUTANT SOURCE(S)	WATER QUALITY OBJECTIVES	WATER QUALITY MONITORING DESIGN
◆Cropland ◆Fertilizers ◆Atmospheric deposition	◆Evaluate nps pollutant reduction by riparian forest buffer ◆Assess time required to achieve significant pollution reductions ◆Establish specific guidelines for development and management of rfb in mid-Atlantic region	◆Paired watershed 1 control/1 treatment
Coal mine drainage	◆Evaluate performance of innovative passive treatment systems for neutralizing coalmine drainage and iron removal ◆Evaluate long-term effects on stream water quality	◆Upstream/downstream ◆Single station before/ after
Urban stormwater, i.e. impervious surfaces	◆Test and evaluate performance of individual stormwater BMPs to reduce peak flows and treat water quality	◆Input/output from BMPs
◆Cropland ◆Rangeland ◆Grazing practices ◆Hydropower generation	Document water quality improvements achieved through implementation of riparian and rangeland management BMPs	◆Paired watershed 1 control / 1 treatment ◆Before/after
◆Livestock access to streams ◆Degraded streambanks and riparian zones ◆Dairy operations ◆Cropland	Assess effectiveness of livestock exclusion/ riparian restoration: ◆Document changes in nutrients, bacteria, and sediment concentrations and loads ◆Evaluate response of stream biota	◆Paired watershed 1 control / 2 treatment
◆Livestock operations in stream corridors ◆Failing on-site wastewater treatment systems	◆Reopen restricted shellfish areas and protect threatened shellfish areas ◆Reduce median FC levels in tributary streams by 44-69%	◆Paired watershed 1 control / 1 treatment ◆Watershed outlet trend stations
◆Dairy operations ◆Cropland ◆Streambank erosion	◆Increase numbers of pollution-intolerant fish species ◆Improve recreational uses ◆Reduce pollutant loading to the Sheboygan River and Lake Michigan	◆Paired watershed 1 control / 1 treatment ◆Above/below ◆Watershed outlet station

PROJECT	SAMPLING SCHEME	PRIMARY WATER QUALITY VARIABLES
Pennsylvania: Stroud Preserve Watershed	◆Grab samples 2x/month ◆Storm events 8x/year ◆Overland flow 4x/yr ◆Groundwater quarterly	SS, dissolved N, dissolved P, Dissolved Organic Carbon, Chloride, conductivity
Pennsylvania: Swatara Creek Watershed	◆Continuous flow, pH, temperature ◆Storm event sampling	pH, acidity, alkalinity, DO, SS, TP, TN, NH_3, NO_2+NO_3, metals, fish, macroinvertebrates
Pennsylvania: Villanova University Stormwater BMPs	◆Automated storm event monitoring for infiltration BMPs ◆Automated event monitoring and grab sampling of baseflow for stormwater wetland	Flow, temperature, turbidity, TSS dissolved P, N, metals, FC
South Dakota: Bad River	◆Automated storm event monitoring ◆24-hr composites during spring snowmelt period (daily to weekly)	Flow, TSS
Vermont: Lake Champlain Basin Agricultural Watersheds	◆Continuous flow measurement ◆Automated flow proportional composite samples (weekly) ◆Grab sampling (2x/week) ◆Annual biomonitoring	TSS, turbidity, TP, TKN, *E. coli*, FC, FS, macroinvertebrates, fish
Washington: Totten and Eld Inlet	◆Grab sampling: weekly (Nov. - April), ◆Storm event sampling (6x/yr)	FC, TSS, turbidity
Wisconsin: Otter Creek	Monitoring season: April - October ◆Grab sampling ~ weekly ◆Storm event monitoring ◆Annual biomonitoring	TP, dissolved P, TKN, NH_3, NO_2+NO_3, TSS, turbidity, FC, fish, macroinvertebrates, habitat

BMPs	MAJOR COOPERATING INSTITUTIONS	PROJECT TIME FRAME
◆Three-zone riparian forest buffer	◆Stroud Water Research Center ◆PA Dept. Environ. Protection ◆Chesapeake Bay Program ◆USDA NRCS ◆USDA Forest Service	1992 - 2007
◆Limestone sand dosing ◆Open limestone channels ◆Diversion wells ◆Limestone drains	◆USGS ◆PA DEP Bureau of Mining and Reclamation ◆Schuylkill Co. Cons. Dist. ◆Northern Swatara Creek Watershed Association	1998 - 2007 periodic reports
◆Bio-infiltration traffic island ◆Porous concrete infiltration ◆Infiltration trench ◆Stormwater wetland	◆Villanova University Urban Stormwater Partnership ◆PA DEP	2003 - 2010 periodic reports
◆Riparian management ◆Rangeland/grazing management	◆SD Dept. of Environment and Natural Resources ◆USDA-NRCS ◆Upper Bad River Task Force ◆East Pennington Conservation District	1996 - 2006
◆Livestock exclusion ◆Bio-engineering streambank stabilization	◆Univ. of VT School of Natural Resources ◆VT Dept. Environ. Cons. ◆USDA NRCS ◆USDA FWS	1994-2000 Final Report 2001
◆Pasture/grazing management ◆Stream fencing ◆Riparian buffers ◆Animal waste management ◆Runoff management ◆Repair failing on-site wastewater systems	◆WA Dept. of Ecology ◆Thurston Co. Env. Health Serv. ◆Thurston Cons. District ◆USDA NRCS	1993 - 2002 Final Report 2003
◆Streambank stabilization ◆Livestock fencing ◆Barnyard runoff management ◆Reduced tillage ◆Nutrient and pesticide management	◆WI Dept. Natural Resources ◆USGS ◆Sheboygan Co. Land Conservation Dept. ◆UW Extension	1994 - 2003 Final Report 2005