

Report as of FY2007 for 2006NJ118B: "Integrated Assessment of Economic and Water Quality Impacts of Agricultural Best Management Practices in Upper Cohansey River Watershed"

Publications

- Articles in Refereed Scientific Journals:
 - ◆ Qiu, Z., M.T. Walter, and C. Hall. 2007. Managing Variable Source Pollution in Agricultural Watersheds. *Journal of Soil and Water Conservation*, 62(3): 115-122.
 - ◆ Qiu, Z. 2006. An Integrated Framework for Targeting Best Management Practices in an Agricultural Watershed. *Journal of Soil and Water Conservation*, 61(3):197 (Abstract).
- Conference Proceedings:
 - ◆ Qiu, Z. 2006. An Integrated Framework for Targeting Best Management Practices in an Agricultural Watershed. The 61st Annual International Conference of Soil and Water Conservation Society, Keystone, Colorado, July 22-26, 2006. (Oral Presentation)
 - ◆ Qiu, Z. 2006. Identifying Critical Source Areas in Watersheds for Riparian Buffer Restoration. The 2006 Conference of the Mid-Atlantic Sections of the American Water Resources Association: Stream Restoration and Protection in the Mid-Atlantic Region, NJ School of Conservation, Montclair State University, Branchville, New Jersey, June 14-16, 2006. (Oral Presentation)

Report Follows

Project Summary:

Problem and Research Objectives

Understanding the economic and water quality impacts of agricultural best management practices (BMPs) is becoming increasingly important for achieving the desired water quality standards in watersheds in suburban settings like New Jersey. The goal of this research is to provide a science-based information analysis to policy makers who want to maximize water quality benefits while minimizing economic costs when implementing multiple conservation practices in a watershed. The supporting objectives are (1) to estimate the economic and water quality impacts of various agricultural BMPs being implemented in the Neshanic River watershed; and (2) to evaluate the potential in controlling agricultural pollution to achieve locally defined water quality goals through optimal placement of BMPs in the watershed by integrating the results of the estimated costs and water quality benefits in the first objective with an optimization programming model.

Methodology

A literature review has been conducted on hydrological theories, agro-environmental policies, effectiveness of agricultural BMPs, and modeling to develop innovative ways of managing agricultural nonpoint source pollution. Empirical evaluation of agricultural BMPs in the Neshanic River watershed went two directions. The first was to identify the critical source areas (CSAs) for the placement of conservation buffers, one of the most popular agricultural BMPs by integrating hydrological modeling with geographic information systems to improve its effectiveness. The second was to apply a watershed-scale water quality simulation model Soil and Water Assessment Tool (SWAT) and economic models to evaluating the placement of conservation buffers and other BMPs in the watershed. The Neshanic River watershed is 31 square miles in area with mixed land use in the Raritan River Basin in Hunterdon County, New Jersey. The primary water quality consideration is contamination of phosphorus and fecal coliform in its streams. This non-trout river has over 40% of its drainage area in agricultural land use, which is the highest percentage in the entire Raritan River Basin.

Critical Source Areas (CSAs) for Conservation Buffer Planning

In the previous period, we developed a methodology to identify the CSAs for conservation buffer placement following variable source area hydrology. Three spatial datasets were used to delineate the critical source areas in the watershed: a digital elevation model (DEM), a soil data and a recent land use/cover. In this extended period, we evaluated the cost-effectiveness of three buffer restoration strategies when applied to the Neshanic River watershed by assuming buffer restoration in agricultural lands was supported by the New Jersey Conservation Reserve Enhancement Program (NJCREP). The three strategies included an unconventional strategy of targeting buffer restoration in agricultural CSAs in the watershed and two conventional riparian buffer restoration strategies. The two conventional strategies were restoring buffers in the agricultural lands

within the 177-foot (which is equivalent to the CSA strategies in terms of buffer sizes) and 100-foot (which is most likely being agreed and adopted by local communities) riparian corridors of the streams in the watershed.

NJCREP supports four types of buffer practices, i.e., grass waterway, contour grass strips, filter strips and riparian buffer, in agricultural lands. Site-specific buffer types under each strategy were based on site-specific conditions. The implementation costs including sign-up incentive, installation and maintenance costs, and soil rental costs were based on the average costs of the existing enrolled CREP lands in New Jersey. The environmental benefits of different strategies were evaluated using the runoff potential of all sites measured by the modified topographic index. The cost-effectiveness was measured by the targeted average runoff potential divided by the average implementation costs.

Modeling Water Quality Impacts of Agricultural BMPs using SWAT

SWAT is a continuous, daily time-step process model that simulates the water, nutrient, chemical and sediment movement in a watershed resulting from the interaction of weather, soil properties, stream channel characteristics, land management practice, and crop growth (Arnold et al., 1994). SWAT integrates field-scale BMPs being implemented within a watershed and evaluates their water quality benefits at sub-watershed- and watershed-scales over a long period of time. This model has been widely applied to estimate water quality impacts of BMPs (Fohrer et al., 2002; Santhi, et al., 2002; Tripathi, et al., 2003) and effectiveness of alternative regulatory instruments (Qiu and Prato, 1999; Whittaker et al., 2003). The 2002 landuse data, 10-meter DEM and NRCS Ssurgo soil data and the NJDEP 1995 stream layers were used to set up the SWAT model. The SWAT modeling effort was initially delayed because of the lack of the BMP data. In the interim, we drove through the entire watershed to collect detailed information on agricultural activities, such as crop and livestock productions, in each field within the watershed. We also interviewed farmers and the Hunterdon Soil Conservation District agricultural specialists for detailed crop production practices and BMPs.

Figure 1. The Delineation of Watershed for SWAT Modeling

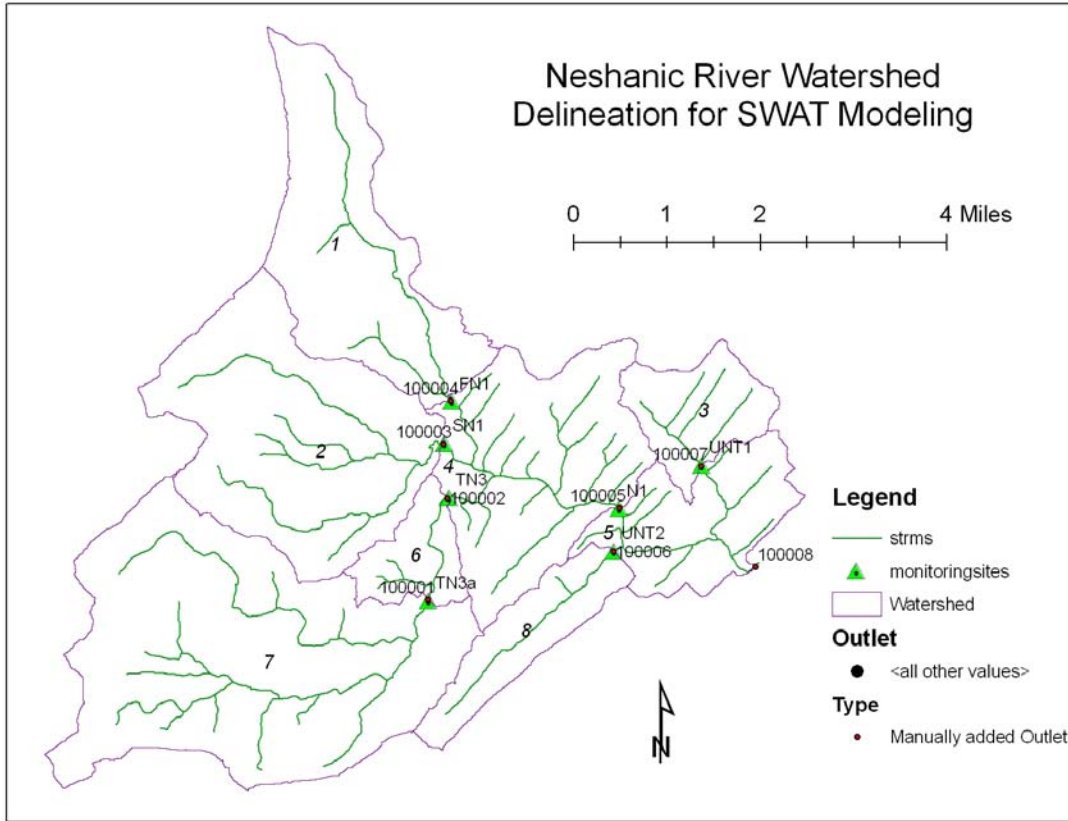


Figure 1. Presentation of the detailed delineation of the watershed for SWAT modeling. The watershed was divided into 8 subwatersheds based on the historical and current water quality monitoring activities in the watershed and each drains to one of those monitoring stations.

Table 1. The area distribution by subbasins in Neshanic River Watershed. Subbasin 7 is the largest, representing about 30 percent of the watershed.

Sub-basin ID	Acres	Percentage
1	2,896	14.84
2	3,819	19.57
3	956	4.90
4	2,851	14.61
5	1,503	7.70
6	651	3.34
7	5,838	29.92
8	997	5.11
Total	19,512	100.00

Table 2. The area distribution of different land uses in Neshanic River watershed

Land Use Type	Acres	Percentage
Residential-High Density --> URHD	93	0.48
Residential-Medium Density --> URMD	207	1.06
Residential-Med/Low Density --> URML	377	1.93
Residential-Low Density --> URLD	4,358	22.34
Commercial --> UCOM	275	1.41
Industrial --> UIDU	486	2.49
Transportation --> UTRN	161	0.83
Water --> WATR	54	0.28
Wetlands-Non-Forested --> WETN	80	0.41
Agricultural Land-Generic --> AGRG	7,926	40.62
Wetlands-Mixed --> WETL	203	1.04
Orchard --> ORCD	111	0.57
Forest-Deciduous --> FRSD	2,983	15.29
Forest-Evergreen --> FRSE	206	1.06
Forest-Mixed --> FRST	904	4.63
Wetlands-Forested --> WETF	1086	5.57

Table 2 gives the area distribution of different land uses in the watershed. Agriculture, low density residential development, and forest are the largest land use categories in the watershed. Since NJDEP didn't give a detailed classification on cropland and pasture, we divided the agricultural lands in each subbasin into the following categories based on the land use activities collected in the watershed.

Table 3. Sub classes of agricultural lands for SWAT Modeling

Sub-class	Percentage
Corn	30
Soybean	15
Timothy	20
Alfalfa	15
Oats	10
Wheat	10

During the basic run of the SWAT model, we also made the following assumptions on the lawn management activities in urban land:

- No nutrients or chemicals applied.

- For low density development, cut lawn twice a month for May, June and July, and once a month for August, September, and October.
- For other urban land use, cut lawn twice a month for May, June, July and August, and three times for September and October.

We also collected the following observed weather data for the Flemington Weather Station, which is just outside of the watershed:

- Rainfall and temperature – 1960-2006
- Others (solar radiation, relative humidity and average wind speed) – 1960-2004

The final SWAT consists of 8 Subbasins and 153 Hydrological Response Units (HRUs). We ran the model for the period from 1/1/1995 to 12/31/2004.

Principal Findings and Significance

Table 4 presents the comparison of the cost-effectiveness of the three strategies. As expected, the CSA strategy was more cost-effective, which was 57 and 51 percent higher than the 177-foot and 100-foot riparian buffer strategies, respectively. Several local conservation initiatives have incorporated the idea of targeting CSAs for agricultural BMPs. For example, a CCPI (Cooperative Conservation Partnership Initiative) grant, funded by the Natural Resource Conservation Service and led by North Jersey Resource Conservation and Development Council (RC&D) with collaborations from New Jersey Institute of Technology and NJWSA, is adopting the innovative CSA strategy to develop a riparian restoration plan for agricultural lands in the Raritan River Basin. The CSA concept is also adopted in the North Jersey RC&D's River-Friendly Farm Certification Program that seeks to promote agricultural best management practices through recognition of those farms that, through good management, help to protect water resources in Raritan River Basin.

Table 4. Cost-effectiveness of three buffer restoration strategies

	Units	CSA Strategy	100-Foot Riparian	177-Foot Riparian
Total Areas	Acres	2,643	1,508	2,654
Agricultural Lands	Acres	692	321	705
Signing Incentive Payments	\$	69,207	32,138	70,475
Installation Costs	\$	1,514,526	926,924	2,032,640
Annual Land Rental Costs	\$	27,698	12,395	26,800
Annual Maintenance Costs	\$	3,045	1,864	4,088
Total Costs	\$	2,044,880	1,172,947	2,566,428
Average costs	\$ per acre	2,955	3,650	3,642
Targeted Runoff Potentials	per acre	500	409	393
Cost-effectiveness		0.169	0.112	0.108

Figure 2 presents the simulated and observed stream flows at the USGS Reaville Station, monitoring station 100006 in Figure 1.

Figure 2. The simulated and observed stream flow in Reaville USGS station

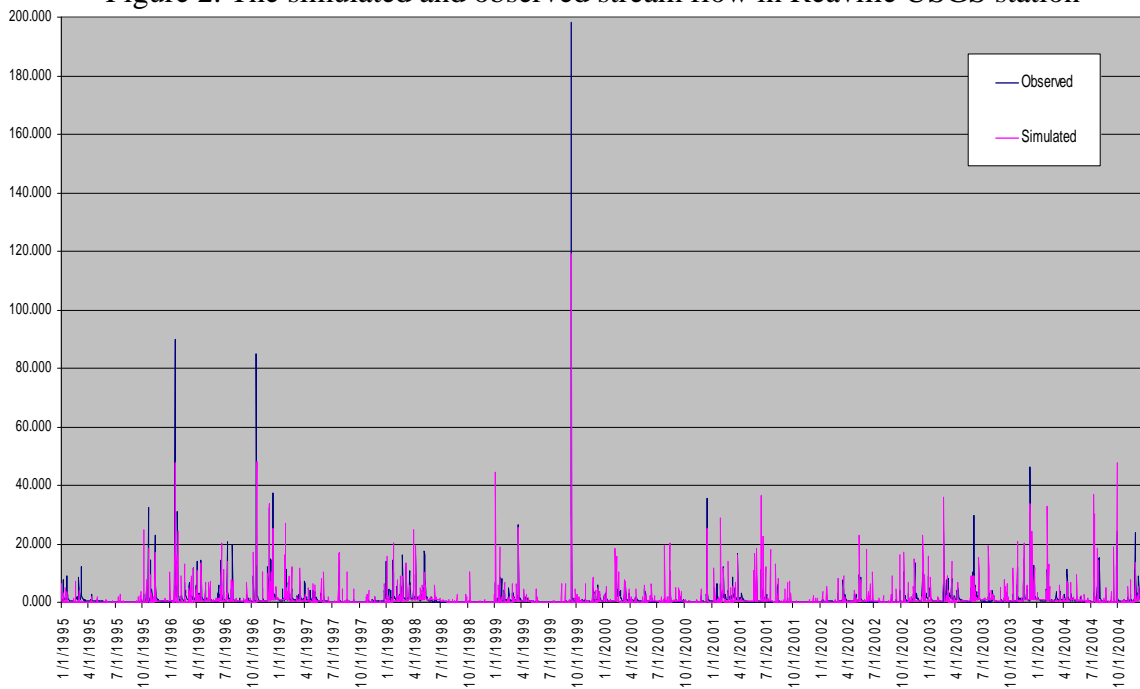


Table 5 compares the simulated crop yields with the Hunterdon County average yield and the farmers' yield goal for each crop. SWAT simulates the crop yield very well.

Table 5. Comparison of the simulated crop yield, Hunterdon County average yield and the Farmers' crop yield goal

Crops	Units	Simulated Yield	County Average	Yield Goal
Corn	Bu/ac	106.84	98.72	95 - 140
Soybean	Bu/ac	32.51	31.75	
Oats	Bu/ac	98.63		72
Wheat	Bu/ac	60.06	48.92	60 - 70
Alfalfa	T/ac	2.89	3.09	
Timothy	T/ac	2.59	1.80	2 - 2.5

We are in the process of refining the subbasin delineation and spatial distribution of crop pattern and crop rotations in the watershed. We are also going to calibrate the model using the observed stream flow and water quality data. The calibrated model will be used to evaluate the water quality impacts of the collected agricultural BMPs, which will then be integrated with the production costs of the farming practices to evaluate the spatial placement of BMPs.

Cited Literature

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- Fohrer, N., D. Moller and N. Sterner. 2002. An interdisciplinary modeling approach to evaluate the effects of land use change. *Phys. Chem. Earth* 27: 655-662.
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