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REDUCING DIFFUSE POLLUTION THROUGH IMPLEMENTATION OF AGRICULTURAL BEST MANAGEMENT PRACTICES: A CASE STUDY

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ABSTRACT

A system of agricultural best management practices (BMPs) was implemented on a 2,100 ha watershed in Duplin County, North Carolina, USA, for the purpose of improving water quality. The BMPs included: Nutrient, pest, and animal waste management; and soil conservation practices. Both surface and ground water were continually analyzed to assess the water quality impacts. Nutrient management plans have been developed for over 80% of the cropland. Pest management plans have been developed for over 60% of the cropland. Over one-half of all plans have been implemented. Poultry mortality composting and improved swine waste management have decreased the potential adverse effects of animal operations. A constructed wetland shows promise as a pre-treatment of swine waste prior to land application.

Stream monitoring shows decreasing amounts of nitrate- and ammonium-nitrogen in the surface waters of the watershed. Ground water monitoring shows relatively high concentrations of nitrate in areas of intensive swine and poultry operations. Ground water monitoring of pesticides reveals low levels of alachlor, atrazine, and metolachlor even though large amounts of these chemicals are used on crops. The successful implementation of agricultural BMPs appears to be having a positive effect on water quality. Both stream and ground water monitoring will be continued for several years to assess more definitively the changes in water quality. Copyright © 1996 IAWQ. Published by Elsevier Science Ltd.

KEYWORDS

Agriculture; animal waste; best management practices(BMPs); diffuse pollution; fertilizers; monitoring; pesticides; water quality.

INTRODUCTION

The Herrings Marsh Run Watershed Project in the state of North Carolina is one of 16 water quality demonstration projects initiated and supported by the U.S. Department of Agriculture (USDA). Demonstration projects are one component of a broader strategy of the USDA Water Quality Initiative designed to "protect ground and surface water from potential contamination by agricultural chemicals and wastes, especially pesticides and nutrients". The Herrings Marsh Run Watershed was selected as a demonstration site based on perceived water quality degradation resulting from agricultural practices. The

North Carolina Division of Environmental Management has designated Herrings Marsh Run as "support threatened" because of biological oxygen demand (BOD), nutrient, and sediment inputs from diffuse sources.

The overall objective of this demonstration project is to encourage accelerated voluntary adoption of management practices and technologies that cost-effectively reduce impacts on surface and ground water and result in documented water quality benefits. The successful accomplishment of this objective depends on the adoption of best management practices (BMPs) by agricultural producers. This paper presents some of the results of BMP implementation and surface/ground water monitoring after five years of project activities.

SETTING

Geology, soils, hydrology

The study watershed is typical of much of the Atlantic Coastal Plain region of the southeastern United States. Soil parent materials are marine and fluvial sediments containing mixed sands and clays. Most of the soils in the watershed are sandy and well drained. The landscape is moderately dissected, consisting of gently undulating uplands and gentle valley slopes.

Two aquifer systems describe the ground water in the project area--the Surficial aquifer and the Cretaceous aquifer. The Surficial aquifer is the saturated portion of the upper layer of sediments, typically 7-17 meters thick. The Surficial aquifer is unconfined, i.e., its upper surface is the water table rather than a confining bed. Thus, it is sometimes called the water table aquifer. Many shallow wells tap the Surficial aquifer, which is particularly vulnerable to contamination.

The Cretaceous aquifer is a grouping of several of the oldest and deepest sedimentary deposits lying directly over the basement rock. The Cretaceous aquifer includes confined aquifers and its thickness is 130 meters or more. This aquifer is the source of deep and productive wells.

Agriculture

The 2,100 ha watershed contains about 1,100 ha of cropland. Major agricultural crops are: Corn (350 ha); soybeans (200 ha); wheat (200 ha); tobacco (100 ha); cotton (100 ha); vegetables, e.g., cucumbers, sweet potatoes (150 ha). The crop diversity gives rise to extensive use of agrichemicals, namely, fertilizers and pesticides. About 50 different chemicals are currently used. Obviously, this use causes concern for water quality.

Swine and poultry production are intensive in the watershed. In fact, such production provides the largest amount of agricultural income to farmers in the watershed. Confined operations are the standard practice. Large amounts of waste are generated by these operations.

Although soil testing is widely accepted and generally practiced by growers in the watershed, careful and precise nutrient management is a relatively new concept. Current annual nutrient use is estimated at 120 mt of nitrogen, 54 mt of phosphorus, and 200 mt of potassium. The animal industry in the project area produces enough waste to supply over one-half of the needed nutrients. Enough fresh manure is generated in the watershed each year to supply about 50 kg/ha of plant-usable nitrogen. Yet, 98% of the nitrogen applied to cropland is supplied in mineral form, e.g., ammonium nitrate.

The sandy soils, fluctuating water table, and intensive crop and livestock operations provide a setting conducive to surface and ground water contamination. Animal wastes from confined swine and poultry operations are potential sources of nitrogen, phosphorus, and organic contaminants. Large amounts of mineral fertilizers in addition to animal manures are used for crop production. Pesticide use is also extensive.

BEST MANAGEMENT PRACTICES (BMPS)

Nutrient management is a major thrust of the project because of the natural setting and the agricultural enterprises described previously. Nutrient management plans have been developed for over 80% of the cropland in the watershed. Recommended nutrient management practices include soil sampling, plant tissue sampling, waste sampling, crediting for nutrients contained in animal manures, calibration of application equipment, and split applications of fertilizers, especially nitrogen.

Pest management plans have been developed for over 60% of the cropland. Improved pesticide management practices include integrated pest management, selection of pesticides to minimize soil and water contamination, proper pesticide application rates, and safe pesticide handling practices.

Waste management planning entails site selection for facilities, crop production, and manure handling, manure collection and treatment systems, and manure handling. Practices for water quality protection emphasize good manure handling and storage, off-site transport of manure, and on-site management of manure as a plant nutrient or feed source.

Innovative waste management practices are being investigated on the project. A constructed wetland systemhas been developed to simulate a natural wetland for removing contaminants from swine wastewater. Alternatives for animal mortality management are also being explored. Composting of poultry mortality is a promising technique. The composting process breaks down organic wastes into stable, safe humus-like materials that can be spread on land.

Producer surveys are being used to track land use and land treatment activities at field and watershed levels. Separate surveys for cropping and animal production systems are used. The BMPs employed in both crop and livestock management are identified and described. Costs of BMP implementation are also recorded for each farm.

The cropping system survey is designed for making nutrient and pesticide recommendations. Soil mapping units and leaching indices are recorded along with soil, plant tissue, and waste analysis results; application rates of nutrients and pesticides and methods of application; tillage practices; and seeding rates. Five-year crop and yield histories are also obtained. The animal system survey tracks production rates, feed consumption, and waste management details for each enterprise.

WATER QUALITY MONITORING

Methodology

Water quality of streams has been monitored using four continuous sampling stations. Ground water data have been obtained from over 100 monitoring wells and private water supply wells. Exact locations of monitoring points was confirmed using global positioning (GPS) technology. Locations of the four continuous monitoring stations for stream discharge and water quality data are shown in Fig. 1. Site 1 is located at the watershed exit. Site 2 is located along a tributary downstream from intensive swine and poultry operations. Site 3, the background site with relatively few potential inputs upstream, is located along the main stream flowing through woodlands. Site 4 is located upstream from Site 1 and monitors the eastern portion of the watershed.

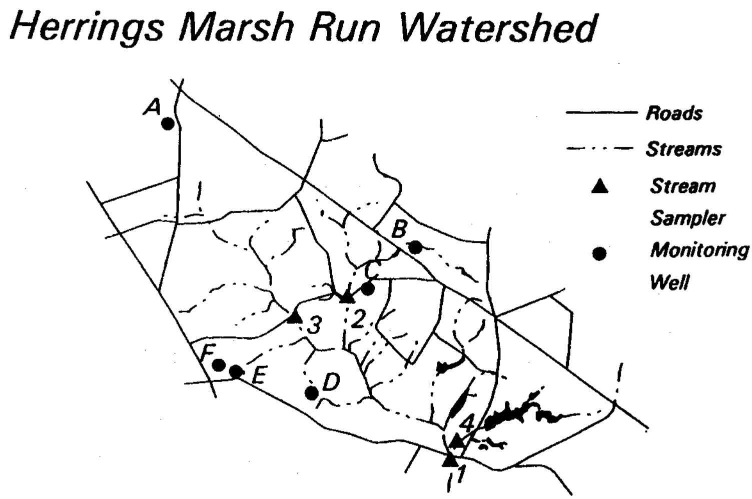

Figure 1. Location of stream water samplers (and gaging stations) and ground water monitering wells in Herrings Marsh Run Watershed.

Sample collection has been continuous from October, 1990, for Sites 1-3. The Site 4 sampler was installed in August, 1991, and sampling has been continuous since. Water samples have been collected hourly and combined into eight-hour composite samples. They are analyzed for nitrate-nitrogen, ammonium-nitrogen, total Kjeldahl nitrogen, ortho-phosphorus, and total phosphorus. Stream discharge is recorded by the U.S. Geological Survey (USGS).

Monitoring wells (Fig. 1) were strategically placed to evaluate impacts of specific land use practices on shallow ground water quality. Well bottoms were placed on an impermeable layer or to a depth of 7.5 m. if an impermeable layer was not found. The wells are monitored monthly for nitrate-nitrogen and selected pesticides. Current well sites include a swine waste irrigation field, pasture field receiving turkey mortality compost, cropped areas for which nutrient and pest management practices are being implemented, and the turkey mortality composter site.

Biological monitoring is conducted annually at Site 2 by the North Carolina Division of Environmental Management (DEM). Benthic macroinvertebrates are collected using the DEM standardized quantitative collection techniques. Aquatic fauna are inventoried, with the primary output consisting of a species list with indications of relative abundance (rare, common, abundant) for each taxon. Unstressed streams have a diversity of species, while stressed streams have relatively few species. Water quality ratings are assigned based on the abundance and characteristics of the most intolerant invertebrate groups. Streams are classified as *Excellent, Good, Good/Fair, and Fair.*

Results

Selected stream monitoring data are shown in Table 1. Mean nitrate-nitrogen concentrations in the surface water leaving the watershed (Site 1) and in a tributary (Site 2) were two-and four-fold higher, respectively, than background concentrations (Site 3). Daily nitrate-nitrogen concentrations at Site 2 sometimes exceeded 10 mg/L during the first year of sampling. Over-application of waste water to fields probably accounted for the elevated nitrate concentrations at this sampling station. Since July, 1991, the maximum nitrate concentration at Site 2 has been 8 mg/L. Over a four-year period, a gradual decrease in nitrate concentrations at both Site 1 and Site 2 has been observed.

Table 1. Mean daily nutrient concentration for four stream monitering stations on Marsh Run

	Station sites			
	1	2	3	4
Concentration	mg/L			
NO_3-N	2.01	5.34	1.18	1.26
PO_4-P	0.14	0.54	0.06	0.07
NH_4-N	0.15	0.42	0.08	0.18

Ammonium-nitrogen concentrations of water leaving the watershed (Site 1) and in the tributary (Site 2) were two- and five-fold higher, respectively, than at the background site (Site 3) over the four-year period of sampling. During the first two years of sampling, ammonium-nitrogen concentrations at Sites 1 and 2 exceeded limits considered harmful to humans (0.5 mg/L) and fish (2.5 mg/L). These high amounts of ammonium-nitrogen indicate that a significant discharge of animal waste into the waterway had occurred. Ammonium-nitrogen levels at Sites 1 and 2 have decreased sharply since February, 1993.

Stream flow data from the USG gaging stations were integrated with the stream monitoring data to calculate the mass loading of nitrate-nitrogen and ammonium-nitrogen. In 1991 and 1992, the mass nitrate-nitrogen leaving the watershed (Site 1) averaged about 30 kg/ha per day. The tributary (Site 2) received about 20 kg/ha per day from its sub-watershed. These levels have decreased slightly with time.

Baseline biological monitoring data indicated a bioclassification of *Fair* at Site 2. Subsequent data have elevated the bioclassification to *Fair/Good.*

Table 2. Mean of monthly nitrate-nitrogen and ammonium-concentrations in groundwater monitering wells located within the demonstration watershed

Farm	**Nitrate -N**		**Ammonium-N**	
	mg/L	Std. Dev.	mg/L	Std. Dev.
A	72.7	64.9	16.5	16.2
B	10.9	6.4	0.25	0.3
C	16.8	4.13	0.27	0.28
D	5.62	5.49	0.29	0.42
E	6.48	1.24	0.28	0.34
F	11.1	8.71	0.44	0.97

A= Continuous Corn, no waste
B= Grassland, swine waste
C= Row crop, no waste
D= Row crop, poultry compost
E= Row crop, poultry litter
F= Poultry compost site

Nitrate-nitrogen concentrations in ground water at six monitored sites are shown in Table 2. The high levels of nitrate at Farm B are likely due to continuous land application of swine wastewater since 1986. The spray field is inadequate to retain all the waste produced by the swine operation which has expanded since its origination. Elevated nitrate-nitrogen concentrations at Site F are possible due to pre-existing contamination from the contiguous poultry houses.

The slightly elevated nitrate-nitrogen concentrations at Sites A and C are likely related to diffuse sources of nitrogen. Sites D and E appear to have appropriate nutrient management since the nitrate-nitrogen concentrations are less than 10 mg/L.

Ground water samples were collected from 92 monitoring wells in 1993 and 1994, and analyzed for alachlor, atrazine, and metolachlor. Immunoassay tests over 18 months showed small detections of the three pesticides in a few wells. The detection frequency appears to follow a seasonal pattern with higher detections found from April to July.

Alachlor was the most frequently detected herbicide, occurring in about 14% of the samples. Most of the wells with detections had alachlor concentrations much less than the maximum contaminant level (MCL). Despite high usage of atrazine, only a small number of wells (5%) had positive immunoassay detections. Metolachlor detections also were low (5%). Although there are heavy applications of herbicides (700–850 kg annually) in the watershed, current pest management BMPs used by local farmers and applicators appear to be satisfactory for maintaining acceptable ground water quality.

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