LANDSCAPE FEATURES USED FOR WATER QUALITY IMPROVEMENT IN A USDA WATER QUALITY DEMONSTRATION PROJECT

by

P. G. Hunt
Soil Scientist
USDA-ARS
Florence, SC

K. C. Stone
Agricultural Engineer
USDA-ARS
Florence, SC

F. J. Humenik
Agricultural Engineer
NC State University
Raleigh, NC

M. E. Johnson
Agricultural Engineer
Clemson University
Florence, SC

A. A. Szögi
Soil Scientist
USDA-ARS
Florence, SC

Written for Presentation at the
1994 International Winter Meeting
Sponsored by ASAE

Atlanta Hilton & Towers
Atlanta, Georgia
December 13-16

Summary:

Nitrogen and phosphorus contamination of stream and ground water is a major concern for agriculture. However, contamination can be minimized by optimal use of agricultural best management practices and wetland landscape features. A restored hardwood riparian zone contiguous to a swine wastewater disposal field lowered the concentration of nitrate-N in ground water, and a 3.3-ha, in-stream wetland reduced nitrate-N in the stream water.

Keywords:

Wetlands, Riparian zones, Nitrogen, Phosphorus

INTRODUCTION

Human population density and agricultural intensity are increasing in the southeastern Coastal Plain. These increases cause more sensitivity to environmental aspects of agriculture. Even though significant progress has been made in the development and implementation of agricultural best management practices (BMPs), nonpoint pollution of surface and ground water by agriculture is a major water quality concern.

Nonpoint pollution of stream and ground water by nitrogen and phosphorus is a particular concern for agriculture, even when BMPs are used, because the production of crops and application of waste are complicated by weather patterns variations, in-field soil variations, and lower-than-target crop yields. Thus, the nutrient assimilative capacity of particular fields and the surrounding landscape features is critically important to water quality. Riparian zones have been shown to have high potential in reducing nutrient loads, particularly NO_3-N before it enters streams (Yates and Sheridan, 1983; Peterjohn and Correll, 1984; Jacobs and Gilliam, 1985; Lowrance et al., 1985; Pinay et al., 1993). Reduction of NO_3-N loads usually occurs by N removal processes as the water flows through the riparian zone. The two main mechanisms for N removal from water in riparian zone systems are denitrification and vegetation uptake (Lowrance, 1992).

A USDA Water Quality Demonstration Project was initiated in 1990 on Herrings Marsh Run watershed (HMR). The watershed, which has multiple wetland landscape features, is located in the Cape Fear River Basin in Duplin County, North Carolina (Fig. 1) . The project is nested inside the Goshen Swamp hydrologic unit study and involves federal, state, and local agencies; agricultural industry; and local land owners.

The application of large quantities of commercial fertilizers, coupled with large quantities of animal waste, caused contaminations of one of the watershed tributaries. We hypothesized that the quality of the stream water could be enhanced by restoration of a hardwood riparian zone near an overloaded swine wastewater treatment field and by creation of an in-stream wetland in the lower reach of the contaminated tributary.

METHODS

Watershed: Stream water sampling and flow gauging stations were initially established at four sites within the HMR watershed (Fig 1) (Stone et al., 1994 and 1995). Station 1 was located at the stream outlet for the watershed. Station 2 (HMR trib.) was located along a tributary near intensive swine and poultry operations, and Station 3 (HMR main) was located on the upper reach of the main channel which flowed through woodlands. Station 4 (HMR trib.) provided information about the eastern part of the watershed. Water samples were collected with automated water samplers at each station. Water samples were analyzed for nitrate-N, ammonia-N, and ortho-phosphate-P, using EPA Methods (US EPA, 1983).

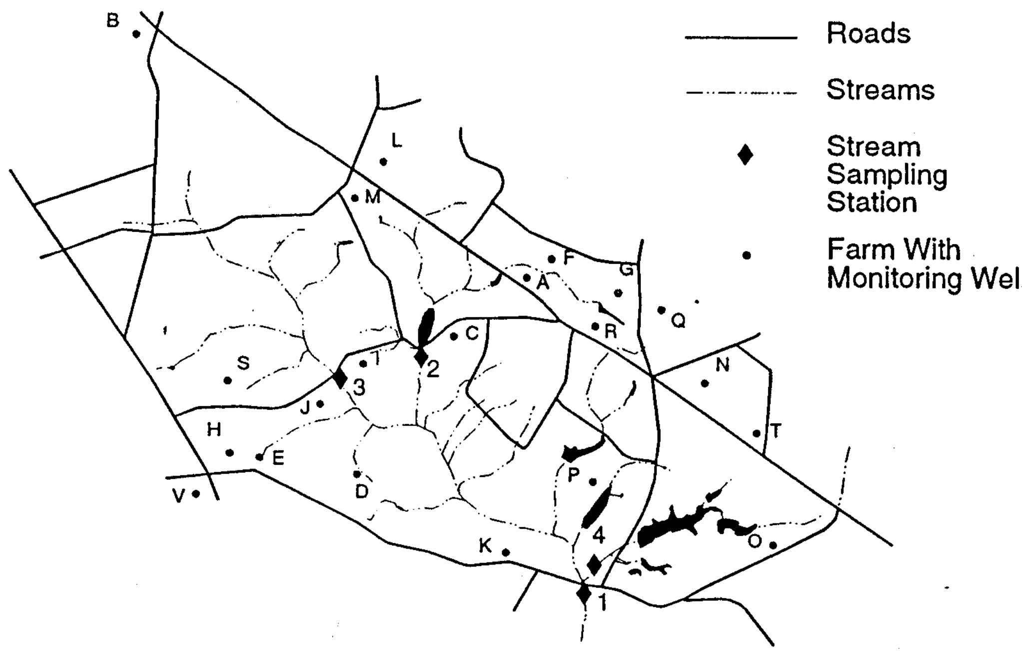

Figure 1. Location of stream sampling stations and farms with ground water monitoring wells on Herrings Marsh Run watershed.

Riparian Zone: An overcut riparian zone of approximately 1.2 ha was contiguous to a 3.7-ha Coastal bermudagrass (*Conodon dactylon* L.) field that continues to be used for swine wastewater treatment (Fig. 1, Farm A). Approximately 2.2 and 1.0 Mg ha^{-1} yr^{-1} of nitrogen and phosphorus, respectively, were applied in swine wastewater. Seedling of five tree species were planted in the riparian zone in March of 1993. Ground water wells were established in the treatment field and the riparian zone in 1991. Point-in-time "grab" samples were collected in the stream near two of the wells in the riparian zone. Denitrification potential in the soil of the spray field and riparian zone was assessed by use of the acetylene blockage method (Smith et al., 1978).

In-stream Wetland: It was hypothesized that a water level control structure and an enhanced wetland would improve water quality (Thomas et al., 1992). A dam with a water control structure was designed in 1993. It would have been sufficient to withstand a 25-yr-frequency storm and meet NC safety requirements for a structure near a highway. However, it was projected to be rather expensive, and beavers had built a dam across the old breach by April of 1993. The wetland area upstream of station 2 was about 3.3 ha when the dam was at approximately 3.1 m above the bottom of the stream bed. The dam initially suffered substantial sidewall erosion, and it was necessary to reinforce the sidewalls and direct the flow over the center of the dam. The structure is stable, and stream water sampling stations have been installed upstream.

RESULTS AND DISCUSSION

Watershed: Mean ammonia-N concentrations at sampling station 2 were higher than those at the watershed outlet (station 1) as well as at sampling stations 3 and 4 (Table 1). During the first month of the sampling, ammonia-N concentrations at the watershed outlet and station 2 exceeded limits considered harmful to humans (0.5 mg L^{-1}) and fish (2.5 mg L^{-1}). These high concentrations of ammonia-N indicated a significant discharge of animal waste into the waterway. The high concentrations of ammonia-N were reduced after the spring of 1992 when an undersized swine lagoon directly up-slope from the wetland at station 2 was enlarged. However, the nitrate concentrations remained high. Overapplication of swine lagoon effluent and undersized, overloaded lagoons were likely contributors to the elevated nitrate-N concentrations in the HMR tributary of station 2. The average mass nitrate-N loads at stations

Table 1. Geometric mean daily nutrient concentrations and mass fluxes over the sampling period for four stream monitoring stations in the Herrings Marsh Run watershed (Stone et al., 1994).

	Stations			
	1	2	3	4
Concentration	mg L^{-1}			
NO_3-N	2.01	5.34	1.18	1.26
NH_3-N	0.15	0.42	0.08	0.18
PO_4-P	0.14	0.20	0.06	0.07
Mass Flux	kg day^{-1}			
NO_3-N	22.17	19.61	3.56	2.18
NH_3-N	2.08	1.34	0.28	0.37
PO_4-P	2.24	0.76	0.17	0.13
Stream Flow	m^3 s^{-1}			
	0.147	0.041	0.034	0.025

1 and 2 were 22 and 20 kg day^{-1}, respectively; but the stream flow rate (0.041 m^3s^{-1}) at station 2 was less than one third the flow at station 1.

Riparian Zone: A significant amount of the nitrate-N at station 2 resulted from an overloaded swine wastewater treatment field. The creek next to the treatment field had mean ammonia-N and nitrate-N concentrations of 4.1 and 8.7 mg L^{-1}, respectively. These stream water concentrations are high, but they are substantially lower than the 13 and 59 mg L^{-1} means of ammonia-N and nitrate-N, respectively, in the shallow ground water of the riparian zone contiguous to the stream, and the riparian zone values were lower than the means of 20 and 83 mg L^{-1} of ammonia-N and nitrate-N in the shallow groundwater of the swine wastewater treatment field. Thus, The nitrate-N and ammonia-N were significantly lowered by the riparian zone. This removal was consistent with the initial denitrification enzyme analyses that indicated significant denitrification potential in the riparian zone, particularly near the creek, and it is consistent with other reports of nitrate transformation in riparian zones (Lowrance, 1992). Tree growth has been excellent, and they represent a significant future sink for nutrients. The land treatment of the swine wastewater was sufficient to remove the phosphate before it reached the shallow groundwater or stream; concentrations of *o*-phosphate-P were < 0.05 mg L^{1-}.

Thus, the concentrations of nitrogen and phosphorus were dramatically lowered, but significant amounts also moved from the wastewater disposal site through the riparian zone to the stream. In such instances, some form of in-stream treatment is desirable, and the need for stream clean-up suggested that an in-stream wetland would be desirable.

In-stream Wetland: Although nutrient management plans and expanded lagoons had been implemented, no significant reduction in nitrate-N was observed until summer 1993 when beavers constructed a dam immediately upstream of sampling station 2. Nitrate-N levels were reduced from approximately 6 mg L^{-1} to 0.5 mg L^{-1} by August of 1993, and they remained low until freezing temperatures occurred in December (Table 2). Nitrate-N concentrations reached about 6 mg L^{-1} in January, but they again started downward in March and were below 1 mg L^{-1} by May of 1994. During the time after the beaver dam was constructed, nitrate-N concentrations in the stream entering the wetland remained similar to the pre-wetland stream concentrations of 5 to 7 mg L^{-1} nitrate-N. Neither ammonia-N nor *o*-phosphate-P were greatly affected by the enhanced wetland. The *o*-phosphate-P concentrations entering and leaving the wetland were generally below 0.20 mg L^{-1}.

Table 2. Mean nitrate-N in stream water of an in-stream wetland in subwatershed 2.

	Time Period			
	Fall 93	Winter 94	Spring 94	Summer 94
	$mg\ L^{-1}$			
In-flow	7.0 (1.1)	6.7 (1.1)	6.3 (1.4)	6.2 (2.0)
Out-flow	0.8 (1.0)	4.9 (0.9)	1.0 (1.1)	0.2 (0.3)

( ) = Standard deviation

SUMMARY

1. At the beginning of the study, stream water at the watershed outlet and a tributary (station 2) had elevated nitrate-N and ammonia-N concentrations.

2. Elevated concentrations of nitrate-N and ammonia-N at station 2 were likely related to swine production in that subwatershed.

3. A riparian zone contiguous to an overloaded swine wastewater treatment field upstream of station 2 lowered ammonia-N and nitrate-N concentrations but did not eliminate nitrogen contamination of stream water.

4. An in-stream wetland enhanced by the construction of a beaver dam significantly lowered the concentrations of nitrate-N at station 2.

ACKNOWLEDGEMENTS

This project received federal funding from U.S. Department of Agriculture, under the North Carolina Herrings Marsh Run Water Quality Demonstration Project, USDA Project No. 90-EWQD-1-9504.

Understanding the Role of Agricultural Landscape Features Function and Position in Achieving Environmental Endpoints, USEPA Project No. CR822270.

REFERENCES

1. Jacobs, T.C., and J.W. Gilliam. 1985b. Riparian losses of nitrate from agricultural drainage waters. J. Environ. Qual. 14:472-478.

2. Lowrance, R., R.A. Leonard, and J. Sheridan. 1985. Managing riparian ecosystems to control nonpoint pollution. J. Soil Water Cons. 40:87-91.

3. Lowrance, R. 1992. Groundwater nitrate and denitrification in a Coastal Plain riparian forest. J. Environ. Qual. 21:401-405.

4. Peterjohn, W.T. and D.L. Correll. 1984. Nutrient dynamics in an agricultural watershed: observations on the role of a riparian forest. Ecology 65:1466-1475.

5. Pinay, G., L. Roques, and A. Fabre. 1993. Spatial and temporal patterns of denitrification in a riparian forest. J. Appl. Ecol. 30:581-591.

6. Smith, S. M., M. K. Firestone, and J. M. Tiedje. 1978. The acetylene inhibition method for short-term measurement of soil denitrification and its evaluation using nitrogen-13. Soil Sci. Soc. Am. J. 42:611-625.

7. Stone, K. C., P. G. Hunt, J. M. Novak, and T. A. Matheny. 1994. Impact of BMP's on stream and ground water quality in a USDA demonstration watershed in the eastern Coastal Plain. pp. 280-286. In Campbell, K. L., W. D. Graham, and A.B. Bottcher (eds.) Proc. of the Second Environmentally Sound Agriculture Conference. ASAE, St. Joseph, MI.

8. Stone, K. C., P. G. Hunt, S. W. Coffey, and T. A. Matheny. 1995. Water quality status of a USDA water quality demonstration project in the eastern Coastal Plain. J. Soil and Water cons. (in press).

9. Thomas, D.L., P.G. Hunt, and J.W. Gilliam. 1992. Water table management for water quality improvement. J. Soil Water Cons. 47:65-70.

10. U.S. EPA. 1983. Methods for chemical analysis of water and wastes. USEPA-600/4-79-020. J. F. Kopp and G. D. McKee (eds.) Environmental Monitoring and Support Lab. Office of Research and Development. Cincinnati, OH.

11. Yates, P. and J.M. Sheridan. 1983. Estimating the effectiveness of vegetated floodplains/wetlands as nitrate-nitrite and orthophosphorus filters. Agric. Ecosys. Environ. 9:303-314