Kentucky Geological Survey
James C. Cobb, State Geologist and Director
University of Kentucky, Lexington

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Report of Investigations 5

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For further information contact:
Manager, Communications and Technology Transfer
Kentucky Geological Survey
228 Mining and Mineral Resources Building
University of Kentucky
Lexington, KY 40506-0107

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The Effect of Turfgrass Maintenance on Surface-Water Quality in a Suburban Watershed, Inner Blue Grass, Kentucky

R. Michael Williams[1], James S. Dinger[1], Andrew J. Powell[2], and Dwayne R. Edwards[3]

Abstract

Nutrients and pesticides applied during routine maintenance or establishment of turfgrass could result in nonpoint-source pollution. Nutrient and pesticide concentrations in water exiting a turfgrass management area in the Sinking Creek watershed, a suburban watershed in the Inner Blue Grass Region of central Kentucky, were monitored. This watershed was selected because it contains multiple land uses: agricultural, residential, and recreational (golf course).

A survey was conducted to determine the extent to which lawn-care products are used in the residential sector of the watershed. For the golf-course portion, the golf-course superintendent recorded chemical application daily.

Runoff from the golf course was sampled in 1993 where the stream exits the golf-course property. Sinking Creek was sampled upstream and downstream of the Tashamingo subdivision from April through October 1996 and January through February 1997. Weekly grab samples and three storm sample sequences (spring, summer, and fall) were analyzed to determine pesticide and nutrient concentrations.

The analysis results revealed that few instances of pesticide concentrations in Sinking Creek exceeded minimum detectable levels and none exceeded the U.S. Environmental Protection Agency drinking-water limits during the sampling period. The herbicide 2,4-D was detected in Sinking Creek at both sample locations. In addition to 2,4-D, the insecticide chlorpyrifos was detected at the golf-course exit. Increases in pesticides and nutrients in Sinking Creek coincided with spring application of turfgrass chemicals in the suburban portion of the watershed. Concentrations of nitrogen and phosphorus were low and similar to what would be expected for the land use.

Background

Homeowners and professional turfgrass managers apply nutrients and pesticides during routine maintenance or establishment of turfgrass, which could result in nonpoint-source pollution. Surface and ground water can become contaminated by rainfall runoff and leaching from treated areas (Harrison and others, 1993). The U.S. Geological Survey (1997) reported that the pesticides most commonly detected in streams are diazinon, chlorpyrifos, and carbaryl, all of which have substantial suburban use for turfgrass management. Nutrient and pesticide loading may be increasing in suburban and urban watersheds as a result of the rapidly growing chemical lawn-care industry (Watsche and Mumma, [1989?]).

The environmental fate of turfgrass pesticides and nutrients has been the subject of many studies published in journals and trade magazines. Rosenthal and Hipp (1993, p. 208) described pesticide and nutrient runoff as

[1]Kentucky Geological Survey, University of Kentucky
[2]Department of Agronomy, University of Kentucky
[3]Biosystems and Agricultural Engineering Department, University of Kentucky

"becoming an increasingly important environmental issue." According to Smith and Bridges (1996, p. 169), "A major concern for the impact of pesticides on the environment is their entrance into the drinking water sources which is facilitated by movement in surface water and ground water from the treated sites."

In laboratory studies designed to measure the movement of pesticides during irrigation, Starrett and others (1996) found that approximately 8 percent of a highly soluble pesticide (metalaxyl) and 0.19 percent of a much less soluble pesticide (pendimethalin) were transported in the leachate below turfgrass-covered, undisturbed soil columns subjected to high levels of irrigation.

Studies of chemical losses in runoff from turf have been lacking, largely because most grassed areas do not produce sufficient runoff for sampling (Harrison and others, 1993). This project was undertaken to evaluate nutrient and pesticide concentrations in water exiting a turfgrass-management area.

Materials and Methods

The Sinking Creek watershed was selected for streamflow sampling because it contains multiple land uses: agricultural, residential, and recreational (golf course) (Fig. 1). The study area covers approximately 2,537 acres, of which the subwatershed containing the golf course covers 516 acres. The residential area surrounding Sinking Creek contains 480 acres, and the agricultural portion of the watershed contains 1,541 acres. The golf course is in a subwatershed of the Sinking Creek watershed. A stream that exits the golf-course subwatershed originates in the golf course and surrounding residential area, and empties into Sinking Creek (Fig. 1).

The Sinking Creek watershed is located in the Inner Blue Grass Region of central Kentucky (Currens and Graham, 1993). The Inner Blue Grass is an upland area where the streams provide normal surface drainage; many karst landforms are present, however, and some of the region has no surface drainage (Thrailkill, 1985). Sinking Creek originates as surface runnels and small springs in the agricultural portion of the watershed, and sinks into a karst formation after passing through the residential neighborhood, known as the Tashamingo subdivision.

In May 1997, a survey was conducted to determine the extent to which lawn-care products are used in the watershed. The survey area included the 58 homes in the watershed, but not a residential area surrounding the golf course. Professional lawn-care companies were contacted by telephone to determine the amounts and kinds of products they used. Many of the homeowners were able to describe the products they used for lawn care, but were unsure of the application rate. Felton and Powell (1994) listed the chemicals used on the golf

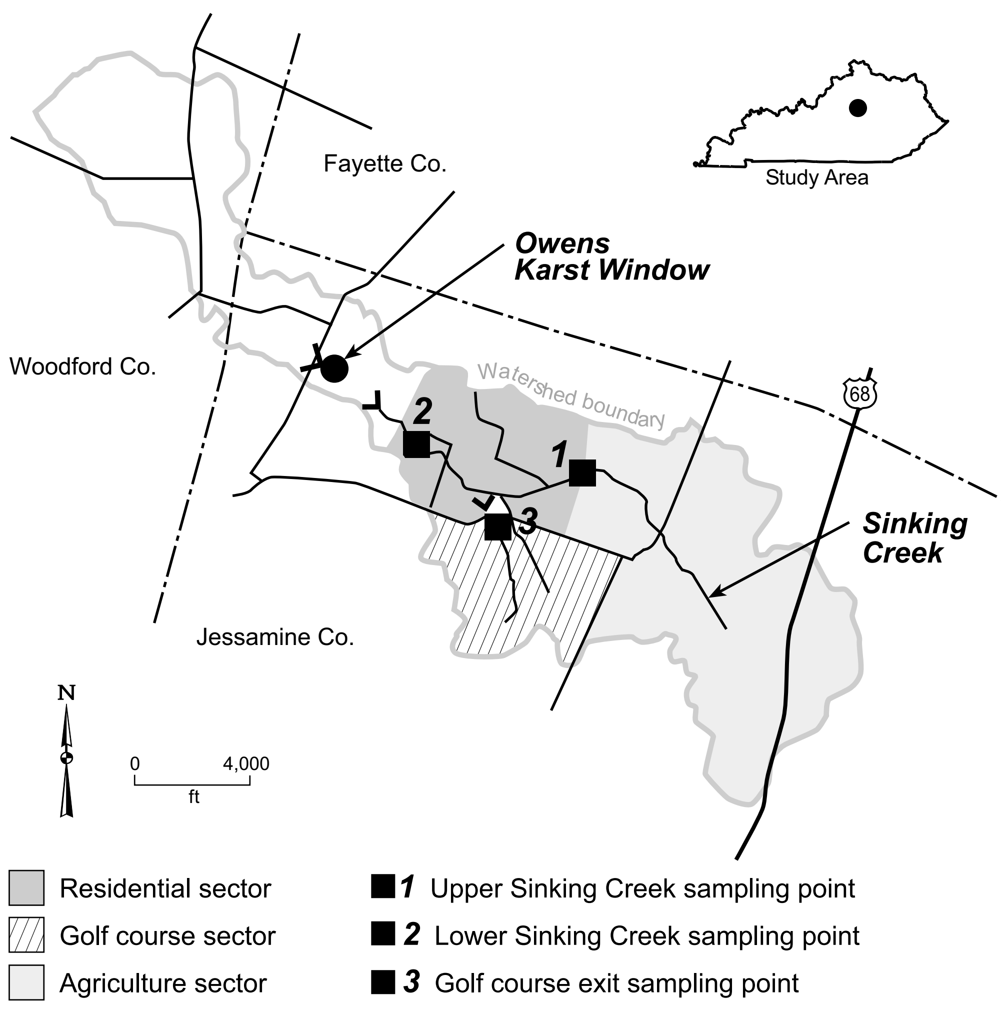

Figure 1. Sinking Creek watershed study area.

course, and the golf-course superintendent recorded chemical application daily.

The golf-course stream monitored by Felton and Powell (1994) collects seepage along the stream bank, occasional overland flow during periods of heavy precipitation, and overflow from a pond on the golf course. The stream was sampled approximately at noon each Monday from April through November 1993. Three-hour sampling intervals began immediately following storms that occurred soon after turf chemical application.

Sinking Creek was sampled upstream (sampling site 1) and downstream (sampling site 2) of the Tashamingo subdivision from April through October 1996 and January through February 1997 (see Figure 1 for locations). During the sampling periods, weekly grab samples and three storm sample sequences (spring, summer, and fall) were analyzed to determine pesticide and nutrient concentrations. Storm samples were taken with automatic samplers. Water level was measured by a pressure transducer in the stream bed, and the automatic samplers were integrated with stage recorders. The samplers were set to activate when a 0.5-in. rise in stream level was detected in response to a storm. Sampling times were preset in an attempt to determine how quickly pesticide and nutrient concentrations responded to rainfall. In general, we expected the concentrations to increase faster on the rising limb of the pollution mass curve than on the falling limb. Consequently, sampling was spaced at shorter intervals at the beginning of each storm.

Samples were analyzed at the Kentucky Geological Survey (KGS) for the herbicide 2,4-D (2,4-dichlorophenoxy acetic acid), the insecticides diazinon and chlorpyrifos, and the fungicide chlorthalonil. Minimum detection levels at KGS for diazinon and chlorpyrifos are 0.2 and 0.15 µg/L, respectively. Immunoassay was used to analyze the water samples for pesticides, and gas chromatography was used to confirm the presence of pesticides when cross-reactivity with other pesticides was suspected. Samples were analyzed for nitrates and phosphorus at the University of Kentucky Department of Agronomy.

Streamflow rates for sites 1 and 2 were calculated from the stage-recorder data using Manning's equation. This equation is an empirical relationship that estimates the streamflow rate as a function of the channel roughness, hydraulic dimensions, and the gradient. Manning's equation is:

$$Q = \frac{1}{n} \times A \times R^{2/3} S^{1/2}$$

where
Q=streamflow rate (m^3/s)
n=Manning's resistance coefficient ($s/m^{1/3}$)
A=flow area (m^2)
R=hydraulic radius (m)
S=channel longitudinal slope (m/m).

The channel gradient is 0.024 percent (U.S. Army Corps of Engineers, 1990). The stream cross section is approximated by a rectangular channel 1.83 m wide for the upper sampling location and 2.44 m wide for the lower sampling location. Manning's resistance coefficient (n), which describes the channel roughness, is estimated at 0.065 for both the upper and lower sections.

Results and Discussion

Results of Pesticide and Nutrient Surveys

Of the 58 residences in the survey area, 52 were contacted. Approximately 33 percent used lawn-care services, 17 percent applied lawn-care products themselves, and the remainder used no lawn-care chemicals. Six professional lawn-care services were operating in the area in 1997.

The most common products used by homeowners, other than fertilizer, were herbicides to control broadleaf weeds and crabgrass. The broadleaf herbicides used in the largest amounts were 2,4-D; MCPP, commonly referred to as mecoprop (2-4chloro-2 methylphenoxy propanoic acid); and dicamba (3,6-dichloro-2-methoxybenzoic acid). Pendimethalin (N-(1-ethylpropyl)-3,4-dimethyl-2,6-dintroaniline) was the herbicide most commonly used by survey participants for control of crabgrass. We assumed that homeowners applied the herbicides at manufacturers' recommended rates. Application rates by the professionals were determined by phone survey. The manufacturers' recommended rates for 2,4-D, MCPP, dicamba, and pendimethalin are 1.0, 0.5, 0.1, and 2.0 lb active ingredient per acre, respectively. Table 1 lists results of the residential survey. The amounts listed are total amounts applied, and application rate is in lb/acre of active ingredients for the treated area, the surveyed area, and the average for the entire watershed.

The results of the survey by Felton and Powell (1994) to determine chemical use at the golf course are listed in Table 2, which shows the total amount of chemical applied from April through November 1993. Because chemicals are not typically applied during the winter (December through March), the amount applied during the study period is representative of the annual load.

Table 1. Results of residential survey on pesticide and nutrient use in 1997.

Pesticide	*Use*	*Total Active Ingredient Applied (lb)*	*Treated Area*	*Surveyed Area*	*Watershed Area*
			(average lb/acre)		
2,4-D	broadleaf herbicide	35.60	0.824	0.367	0.071
MCPP	broadleaf herbicide	19.70	0.456	0.203	0.039
dicamba	broadleaf herbicide	3.40	0.079	0.035	0.007
pendimethalin	crabgrass control	23.30	0.539	0.240	0.047
triclopyr*	broadleaf herbicide	4.20	0.097	0.043	0.008
clopyralid*	broadleaf herbicide	1.43	0.033	0.015	0.003
isofenfos*	insect control	7.00	0.162	0.072	0.014
trifluran*	crabgrass control	1.00	0.023	0.010	0.002
benefin*	crabgrass control	2.00	0.046	0.021	0.004
chlorpyrifos	insect control	2.00	0.046	0.021	0.004
prodiamine*	insect control	0.56	0.013	0.006	0.001
nitrogen	nutrient	3,903	90.35	40.240	7.81
phosphorus	nutrient	1,194	27.65	12.310	2.39

*Used by professionals only

Sampling Results

The sampling results from the golf course in 1993 (sampling point 3, Fig. 1) cannot be directly compared to the present study (sampling points 1 and 2, Fig. 1), but because application of fertilizer at the golf course will not appreciably change from year to year, and because both the golf course and the residential area are underlain by karst, sampling for both land uses can be used to determine the effect of turfgrass maintenance on water quality in a karst terrane. At the golf course, Felton and Powell (1994) detected the pesticides 2,4-D, metalaxyl, and chlorpyrifos at concentrations up to 2.5 µg/L, 0.9 µg/L, and 0.015 µg/L, respectively (Fig. 2). Diazinon was found at concentrations up to 1.4 µg/L (Fig. 2), but the source is presumed to be lawn-care activities in the residential neighborhood surrounding the golf course, because diazinon was not listed as being applied to the golf course (Table 2). Diazinon was found at the golf course consistently in samples taken from August 30 to October 5, 1993, although at much lower concentrations than the peak reported above. Rosenthal and Hipp (1993) observed diazinon

Table 2. Chemicals applied to golf course from April through November 1993 (Felton and Powell, 1994).

Active Ingredient	*Trade Name*	*Amount Applied*	*Typical Rate*	*Type*[1]	*Found*[2]
2,4-D	Trimec	74 gal	0.5 gal/acre	H	Yes
chlorpyrifos	Dursban	NA[3]	66 oz/acre	I	Yes
chlorothalinil	Daconil	49 gal	2 gal/acre	F	No
metalaxyl	Subdue	24 gal	0.5 gal/acre	F	Yes
fenoxaprop-ethyl	Acclaim	2.4 gal	32 oz/acre	H	NC
isoxaben	Gallery	35 gal	1.25 lb/acre	H	NC
MSMA	Daconate	0.9 gal	0.33 gal/acre	H	NC
bensulide	Bensumec	13 gal	3.25 gal/acre	H	NC
dithiopyr	Dimension	48 gal	0.5 gal/acre	H	NC
fluvalinate	Mavrik	16 oz	1.5 oz/1,000 ft^2	I	NC
trichlorfon	Dylox	360 lb	10 lb/acre	I	NC
cyfluthrin	Tempo	23 ml	166 ml/acre	I	NC
iprodine	Chipco	65 gal	0.5–1 gal/acre	F	NC
propamocarb HCL	Banol	42 gal	0.5 gal/acre	F	NC
propiconazole	Banner	9.6 gal	0.39 gal/acre	F	NC
fenzrimol	Broadway	81 gal	1 gal/acre	F	NC
triadimefon	Bayleton	NA	0.33 gal/acre	F	NC
mancozeb	Fore 80	10 lb	14.5 lb/acre	F	NC

[1]H=herbicide, I=insecticide, F=fungicide
[2]Yes=detected in at least one sample, No=not detected, NC=no capability to test for the chemical
[3]NA=application area not available

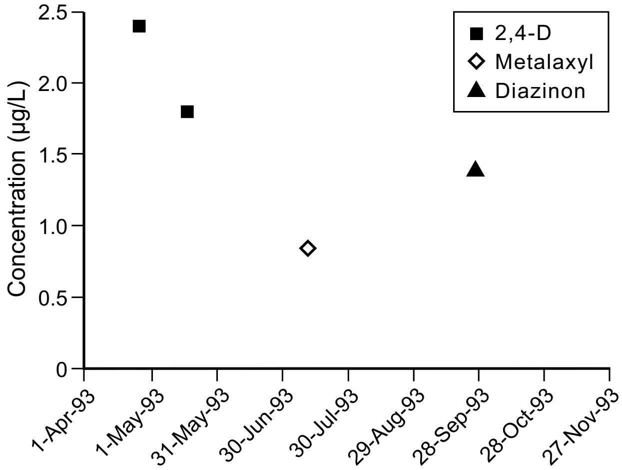

Figure 2. Pesticide concentrations measured at stream exiting golf course (site 3, Fig. 1) (Felton and Powell, 1994).

concentrations of 400 mg/L in surface runoff from turfgrass plot studies.

Water-quality analyses from the Tashamingo subdivision revealed few instances of pesticide concentrations that exceeded minimum detectable levels (MDL) in Sinking Creek (sampling sites 1 and 2, Fig. 1) during the sampling period in 1996 and 1997. Some samples taken following a spring runoff event that were analyzed by immunoassay indicated the possible presence of chlorpyrifos; the levels were below MDL for gas-chromatography detection, however, which suggests possible cross-reactivity with other pesticides. Diazinon is listed on the chlorpyrifos immunoassay kit as a possible cross-reactor. Gas-chromatography analysis did not confirm the presence of diazinon or chlorpyrifos. The herbicide 2,4-D was detected in Sinking Creek at both sampling locations (Figs. 3–4). After the spring application of 2,4-D, no more pesticides were detected.

In response to rainfall on June 6 and 7, 1996 (1.04 in. recorded at Blue Grass Airport in Lexington), the automatic sampler recorded a rise in stream level. During the sampling period, which began at 2300 June 6, 1996, and ended at 0400 June 7, 1996, the average streamflow for the upper and lower sampling locations was 0.8 ft^3/s and 1.5 ft^3/s, respectively. Based on these streamflow rates and the 2,4-D concentrations shown in Figures 3 and 4, the calculated mass flow of 2,4-D for the period averaged 67 g/h and 140 g/h for the upper and lower sampling stations, respectively. The 2,4-D mass flow calculated from the upper sampling station is attributed to runoff from the agricultural portion of the watershed, and the higher 2,4-D mass flow at the lower sampling station is attributed to runoff from the residential and golf course portions of the watershed.

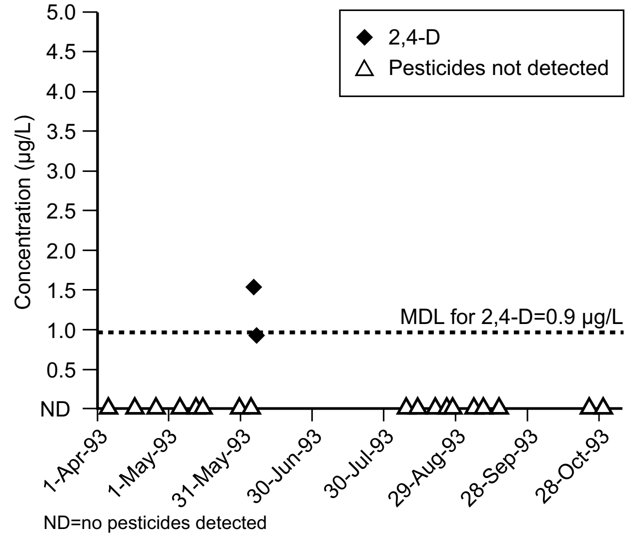

Figure 3. Pesticide concentrations in Sinking Creek, upstream of Tashamingo subdivision (site 1, Fig. 1), 1996.

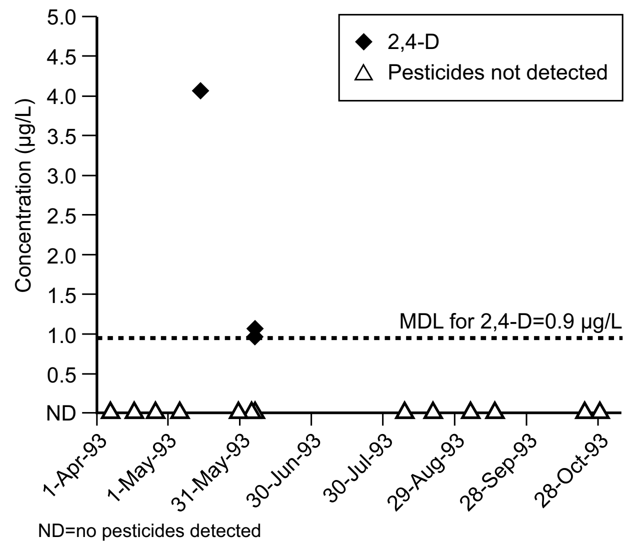

Figure 4. Pesticide concentrations in Sinking Creek, downstream of Tashamingo subdivision (site 2, Fig. 1), 1996.

Measured concentrations of nutrients and pesticides were well below the drinking-water standards established by the U.S. Environmental Protection Agency. Maximum contaminant levels (MCL) for nitrate-nitrogen (NO_3-N) and 2,4-D are 10 mg/L and 70 µg/L, respectively. The MCL's for diazinon, chlorpyrifos, and metalaxyl have not been established.

Concentrations of NO_3-N and phosphorus (as phosphate) found in the streams were low and similar to what would be expected for the land use. Boyer and Pasquarell (1994) reported concentrations of NO_3-N in surface streams in areas with 20 to 40 percent agricultural land to have NO_3-N concentration ranging from 1 to 2 mg/L. Figures 5 and 6 show the concentration of nitrate-nitrogen and phosphate in Sinking Creek throughout the 1996 sampling period. The median upstream concentrations of NO_3-N and phosphate are significantly greater than the median downstream concentrations ($p < 0.05$, Mann-Whitney rank sum test) for the sampling period.

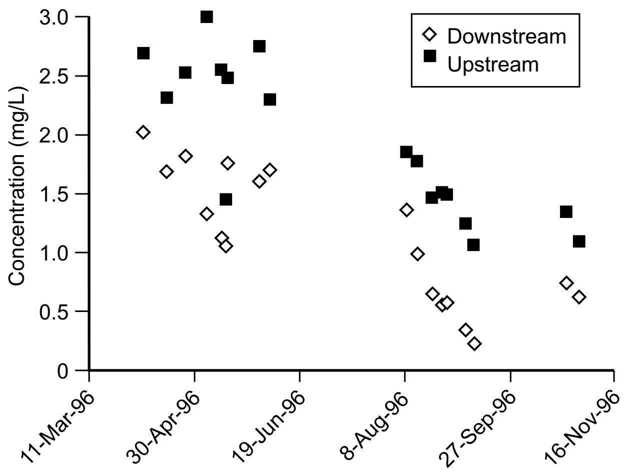

Figure 5. Nitrate-nitrogen concentrations in Sinking Creek, upstream and downstream of Tashamingo subdivision (sites 1 and 2, Fig. 1), 1996.

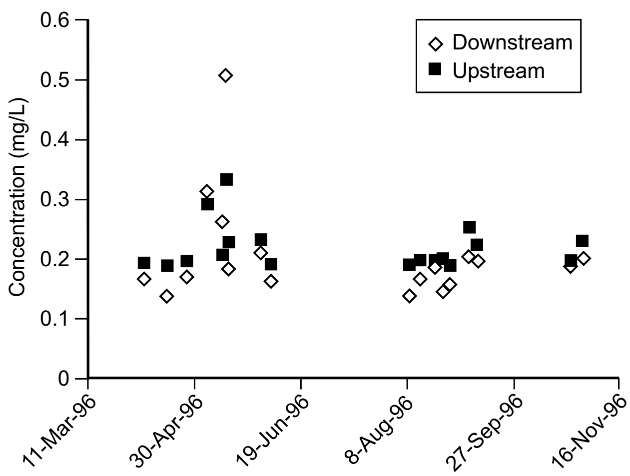

Figure 6. Phosphate concentrations in Sinking Creek, upstream and downstream of Tashamingo subdivision (sites 1 and 2, Fig. 1), 1996.

Figures 7 and 8 show the concentration differences between the upstream and downstream sampling locations for NO_3-N and phosphate during the 1996 sampling period. Figure 9 summarizes the NO_3-N concentration in the stream that exits the golf-course subwatershed during 1993 (Felton and Powell, 1994).

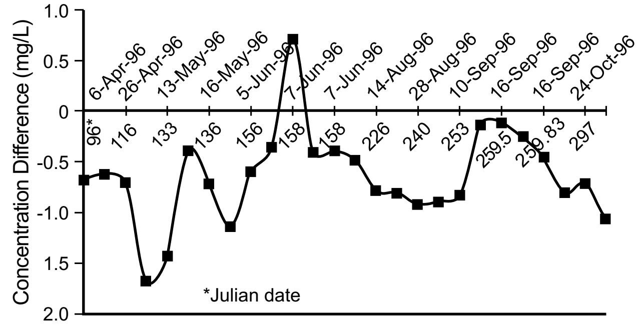

Figure 7. Concentrations of nitrate-nitrogen downstream of Tashamingo subdivision (site 2, Fig. 1) minus concentration of nitrate-nitrogen upstream of Tashamingo subdivision (site 1, Fig. 1), 1996.

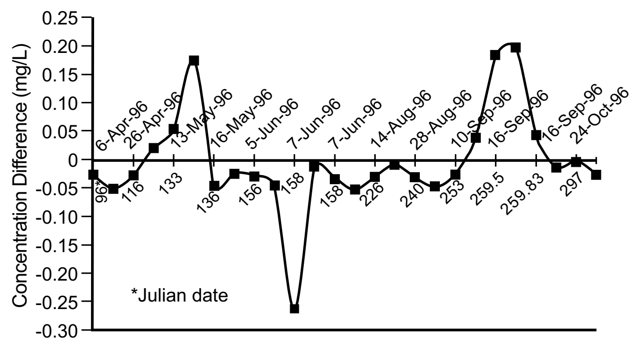

Figure 8. Concentration of phosphate downstream of Tashamingo subdivision (site 2, Fig. 1) minus concentration of phosphate upstream of Tashamingo subdivision (site 1, Fig. 1), 1996.

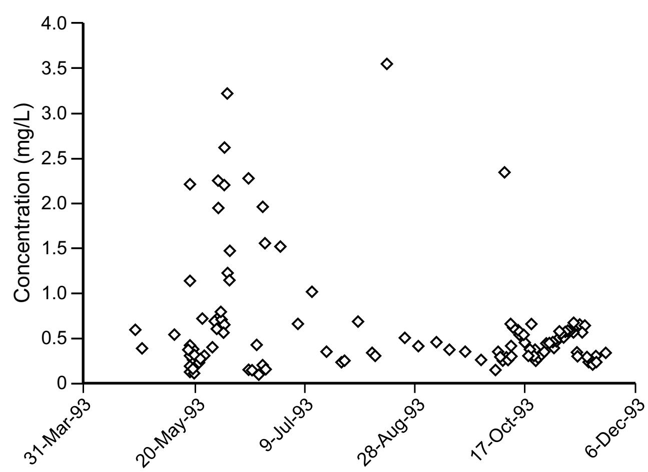

Figure 9. Nitrate-nitrogen concentrations in stream exiting golf course in 1993 (Felton and Powell, 1994).

Comparison of Figures 7 and 9 shows a possible influence of the golf course on Sinking Creek. The higher

NO_3-N concentration at the lower sampling point (site 2) compared to the upper sampling point (site 1) indicates that the residential neighborhood or the golf course may have influenced Sinking Creek. The data for Figure 7 were gathered in 1996 and the data for Figure 9 were gathered in 1993, but the fertilizer application rate at the golf course is unlikely to change appreciably from year to year, and the influence on Sinking Creek would likely be similar in any year.

Figures 10 and 11 and Appendix A show the response of concentrations of phosphate and nitrate in the stream to storms; increases in stage are followed by a decrease in concentration of the nutrients, followed by an increase in nutrient concentration as the stage retreats to base-flow levels. Nutrient concentrations in the streams generally decrease initially because of the dilution by the relatively nutrient-free runoff water. Later, the nutrient concentration increases as the stream stage retreats to base flow, because the runoff at this point contains nutrients dissolved from the soil surface. The dissolution rate of the nutrients determines the time required for the stream concentrations to increase. This is particularly apparent in Figure 10; the phosphate concentration begins to increase even as the stage continues to rise. Figure 11 shows a similar response for nitrate concentration; near the end of the event it is greater than at the beginning, even though the stream stage has nearly doubled.

Conclusions

Application rates recommended by the manufacturers for pesticides or recommended by the University of Kentucky Cooperative Extension Service for nutrients were not exceeded during the period of the survey. The influence of turfgrass maintenance in the suburban portion of the watershed on water quality is small, and the concentrations of nutrients in the stream in that part of the watershed are well below established MCL's. Pesticide and nutrient concentration increases as the stream passes through the suburban neighborhood, however. The increase in pesticides and nutrients in Sinking Creek coincided with spring application of turfgrass chemicals in the suburban portion of the watershed. When properly used, turfgrass chemicals have little impact on surface-water quality.

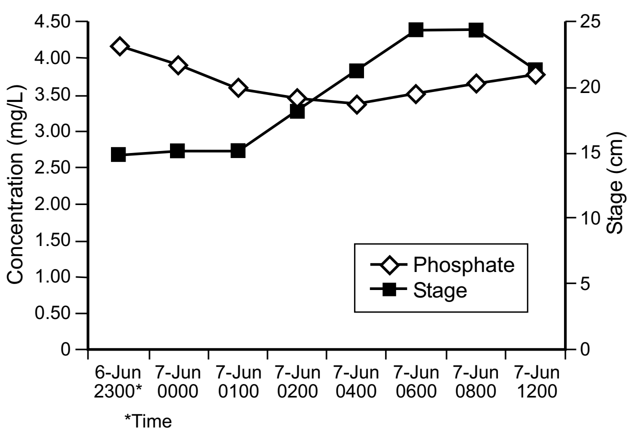

Figure 10. Response of phosphate concentration in Sinking Creek to stage, upstream of Tashamingo subdivision (site 1, Fig. 1) in June 1996. Data gathered by automatic sampler.

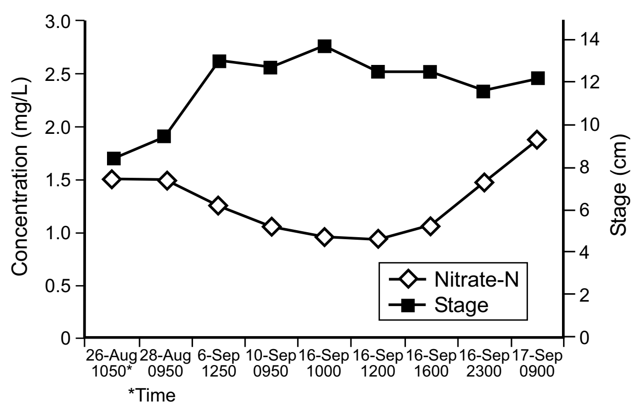

Figure 11. Response of nitrate-nitrogen concentration in Sinking Creek to stage, upstream of Tashamingo subdivision (site 1, Fig. 1) in August and September 1996. Data gathered by automatic sampler.

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APPENDIX A: Response of Concentrations of Phosphate and Nitrate in Sinking Creek to Storms

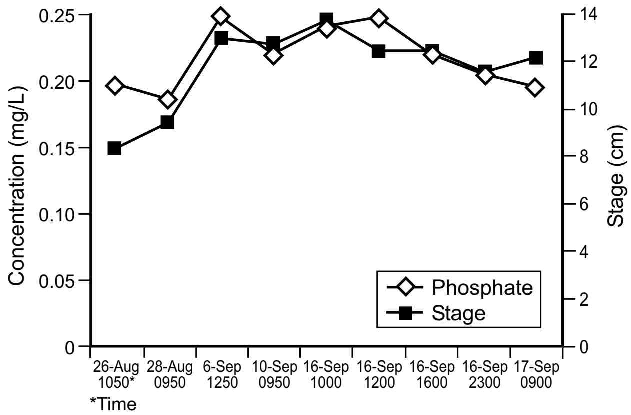

Figure A-1. Response of phosphate concentration in Sinking Creek to stage, upstream of Tashamingo subdivision (site 1, Fig. 1) in August and September 1996. Data gathered by automatic sampler.

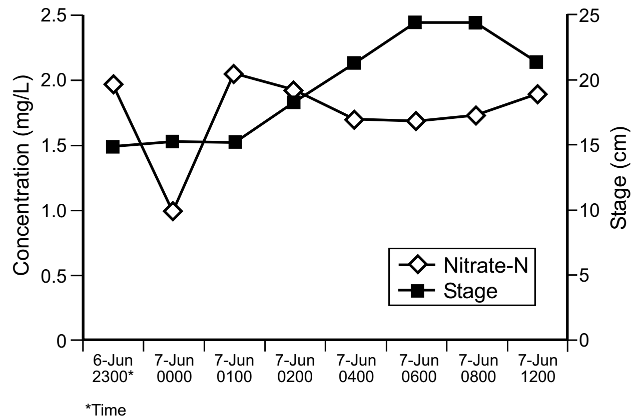

Figure A-2. Response of nitrate-nitrogen concentration in Sinking Creek to stage, upstream of Tashamingo subdivision (site 1, Fig. 1) in June 1996. Data gathered by automatic sampler.

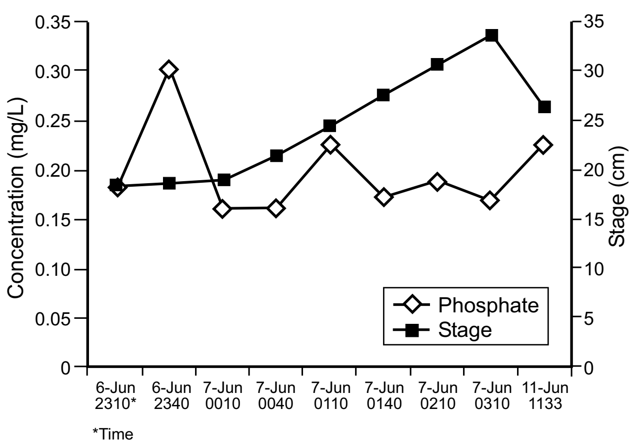

Figure A-3. Response of phosphate concentration in Sinking Creek to stage, downstream of Tashamingo subdivision (site 2, Fig. 1) in June 1996. Data gathered by automatic sampler.

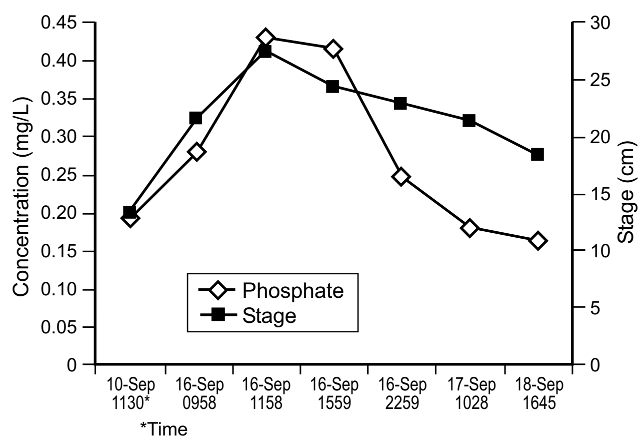

Figure A-4. Response of phosphate concentration in Sinking Creek to stage, downstream of Tashamingo subdivision (site 2, Fig. 1) in September 1996. Data gathered by automatic sampler.

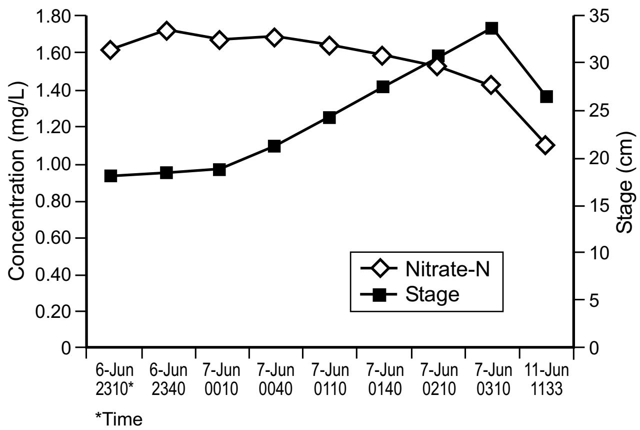

Figure A-5. Response of nitrate-nitrogen concentration in Sinking Creek to stage, downstream of Tashamingo subdivision (site 2, Fig. 1) in June 1996. Data gathered by automatic sampler.

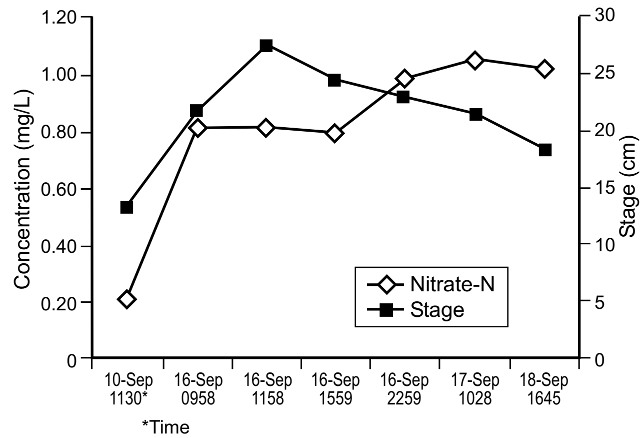

Figure A-6. Response of phosphate concentration in Sinking Creek to stage, downstream of Tashamingo subdivision (site 2, Fig. 1) in September 1996. Data gathered by automatic sampler.

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