PHOSPHORUS AND SEDIMENT IN HEADWATER STREAMS DRAINING POULTRY OPERATIONS IN THE UPPER ETOWAH RIVER BASIN, GEORGIA

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Abstract. A 1.5-year monitoring program was initiated in January 2005 to support a University of Georgia study aimed at evaluating nutrient trading opportunities for phosphorus (P) in the upper Etowah River basin in Georgia. Twelve first-order streams were instrumented with hydrologic monitoring equipment and automated samplers. Nine streams drain agricultural (AG) watersheds predominated by poultry operations but different in terms of land use history, best management practices, soil test P (STP) concentrations, and other factors. Three streams drain forested (FORS) watersheds. The monitoring program consisted of biweekly grab sampling coupled with stormchasing. From preliminary results, median low-flow and stormflow concentrations of total P (TP) in astreams were 0-1 and 1-3 orders of magnitude greater, respectively, than in FORS streams. The 3 highest median stormflow TP concentrations in AG streams were observed where 3 of the 4 highest STP concentrations were observed. Median low-flow total suspended solids (TSS) concentrations in AG streams were 0-1 order of magnitude greater than in forested streams. Median stormflow concentrations of TSS between the two land use types were within the same order of magnitude. Streamflow, STP, event mean concentrations, and other variables may be important for estimating P loads from agricultural watersheds monitored for the study.

INTRODUCTION

The upper Etowah River flows into Lake Allatoona, a reservoir managed by the U.S. Army Corps of Engineers for water supply, hydropower, recreation, and aquatic life habitat. In 2004, the USEPA established a Total Maximum Daily Load for total phosphorus (TP) in a Lake Allatoona embayment. The Georgia Environmental Protection Division is developing nutrient and chlorophyll *a* criteria for Lake Allatoona and further TMDL development is possible.

Due to a long history of agricultural practices in the Etowah basin plus a rapid increase in urbanization, nonpoint sources of P are assumed to contribute a significant portion of the P load to the upper Etowah River. Poultry-based agriculture has been practiced in the Etowah River basin since the 1940's (McIntyre 1972). A large fraction of the poultry manure generated in the watershed is applied to nearby lands for disposal and crop fertilization.

Results of a nutrient mass balance study by Harned et al. (2004) of the Mobile River basin, which includes the Etowah River, suggest that 62 percent of P transferred to the upper Etowah River above Canton, GA is stored in the basin's soil, sediment, and vegetation compartments. The upper Etowah River is estimated to supply 70-80 percent of the TP load in Lake Allatoona (Dirnberger et al. 1993; Rose 1999).

Recently, small watersheds used for agricultural practices that are not dedicated for long-term research purposes (termed "non-research catchments" by Page et al. (2005)) have been used (i.e. Hively et al. 2005; Page et al. 2005) for P transfer studies.. This paper presents preliminary results from a 1.5 year water quality monitoring project by a University of Georgia (UGA) team that focused on P delivery from 12 first-order watersheds in the upper Etowah River basin.

Objectives

Water quality monitoring, basin-scale watershed modeling, economic analysis, and outreach components all comprise UGA's nutrient trading study. There are 3 objectives of the monitoring component of the study. The first objective is to estimate different metrics and associated uncertainty of P and sediment loads from a cross-section of small agricultural (AG) watersheds in the upper Etowah River basin. The second objective is to estimate the same metrics of P loads from small forested (FORS) watersheds assumed to represent reference conditions. The third objective is to support basin-scale modeling used for exploration of nutrient trading opportunities.

Study Area

All 12 monitored streams in the study are first-order. Eleven streams are perennial and one stream is ephemeral. Drainage areas range from 2.4 to 44 hectares (Table 1). Land use of 9 of the streams' watersheds is AG in nature. The AG watersheds are predominated by poultry operations but differ in terms of livestock management, land use history, best management practices, and other factors (Table 1). The remaining 3 streams are on the Chattahoochee National Forest. The FORS streams are assumed to represent reference conditions.

METHODS

Hydrologic Monitoring

Eleven streams were instrumented with 2-foot aluminum H-flumes (Brakensiek et al. 1979) constructed by R.H. Leathers Company in Athens, GA. The Manning equation is the basis for flow measurement in one stream. ISCO 720 submerged probe modules are used to measuree water level in all streams. Water level is converted to streamflow via programmable ISCO 6700-series autosamplers. Rain gages connected to autosamplers collect rainfall data. All streamflow and rainfall data are recorded at 5-minute intervals. Installation of all hydrologic and water quality monitoring equipment occurred between January and May 2006. Removal of equipment began in November 2006.

Water Quality Monitoring

The water quality monitoring program was based on recommendations of Robertson and Roerish (1999) for load estimation for small streams. Modifications to those recommendations were necessary to accommodate the spatial scale and associated implications for load estimation of the monitored streams. One modification involved how autosamplers were programmed to collect samples during storm events. Other modifications will involve techniques for load estimation.

Every two weeks, field staff collected grab samples from streams and performed routine site maintenance. Most of these biweekly grab (BWG) samples were collected during low flow conditions. A small number of BWG samples were collected on the rising or falling limb of a storm hydrograph.

ISCO autosamplers with 24-bottle configurations collected stormflow samples during storm events. Autosampler programming evolved over the course of the study. Final programming consisted of a two-part program that enabled collection of one composite sample and multiple discrete samples over the storm duration. For each watershed, ISCO sampling intervals for the two program parts were based on the goal of characterizing the event mean concentration (EMC) and intrastorm variability of storm flow resulting from a one-year, 24-hour rain event.

Laboratory analyses for water samples included total P (TP) (or “TP unf” per Haygarth and Edwards 2000); dissolved reactive P (DRP) (or “RP (<0.45 µm)); turbidity; and total suspended solids (TSS) (gravimetric; >0.45 µm). All P analyses were performed by the Analytical Chem istry Laboratory (ACL) in the Institute of Ecology at UGA per standard methods. Laboratory P detection levels ranged between 0.001 and 0.005 milligrams of P of per liter (mg-P/L).

From most storm events that were sampled, only a subset of storm samples was analyzed. Emphasis was placed on analyzing samples collected during larger storms and having equal numbers of samples from rising and falling hydrograph limbs. Composite samples were not generated for every storm event from which discrete samples were selected for analysis.

Soil Sample Collection

Soil P sampling was performed in each of the 12 watersheds during spring 2006. Each soil sample was a composite of discrete soil samples collected to 4-inch depths from an area representing a specific type of land use

Table 1. Characteristics of 12 Watersheds Monitored for Upper Etowah Nutrient Trading Study

Site #	Land Use	Drainage Area (ha)	Number Poultry Houses	Stream Buffer Present	Livestock Grazing		Pond in Watershed on Stream
					Type	Excluded From Channel	
1	FORS	44	na	na	na	na	Yes
2	FORS	28	na	na	na	na	No
3	FORS	31	na	na	na	na	No
4	AG	28	3	No	Cattle	No	No
5[2]	AG	2.8	3	No	Cattle	No	No
6[2]	AG	2.4	3	No	Cattle	Yes	No
7	AG	9.7	3	No	Horses	Yes	No
8	AG	7.3	2	Yes	None	na	No
9	AG	11	9	Partial	Horses + Goats	Yes	Yes
10	AG	19	12	Partial	Cattle	No	No
11	AG	16	2	Partial	Cattle	No	Yes
12[1]	AG	3.2	2	No	Sheep	No	No

[1]Ephemeral stream site [2]Share same farm and poultry houses

and/or land cover within a watershed. All soil P samples were analyzed for Mehlich-1 soil test P (STP) at the UGA Agricultural and Environmental Laboratory.

RESULTS AND DISCUSSION

All data discussed here is preliminary. Surface water quality data is limited to TP and TSS results from discrete samples collected through November 2005.

Hydrologic Conditions

Hydrologic conditions over the monitoring period ranged from the wet spring and summer of 2005 to near-drought conditions of spring and summer 2006. Overall, hydrologic responses in AG watersheds were “flashy.” Times of concentration were on the order of minutes for most storm events. Hydrographs from large storms in AG watersheds typically lasted less than 12 hours. In FORS watersheds, storm hydrographs could persist for 1-2 days or more.

Phosphorus

Median FORS stream TP concentrations in BWG samples ranged from <0.001 to 0.003 µg-P/L. Median AG stream TP concentrations in BWG samples ranged from 0.003 to 0.07 µg-P/L. Figure 1 is a box-whisker plot of FORS and AG stream TP concentrations in BWG samples.

Median FORS TP concentrations in storm samples ranged from 0.004 to 0.01 mg-P/L. Median AG stream TP concentrations ranged from 0.03 to 1.97 mg-P/L. Figure 2 is a box-whisker plot of FORS and AG stream TP concentrations in storm samples. For comparing Figures 1 and 2, note that the y-axes differ by a factor of 10.

Overall, median TP concentrations in AG streams during low flow conditions were zero to 1 order of magnitude higher than in FORS streams, regardless of FORS stream flow regime. During stormflow conditions, median TP concentrations in AG streams were 1 to 3 orders of magnitude times higher than TP in FORS streams.

Soil Test Phosphorus and Stream Phosphorus. Results of soil P sampling from AG and FORS watersheds mirrored differences observed in stream TP concentrations between the two land use types during stormflow conditions. Figure 2 shows ranges of STP concentration (milligrams per kilogram) observed in each watershed. The 3 highest median stream TP concentrations were observed where 3 of the 4 highest STP concentrations were observed. In AG watersheds, the highest STP concentrations were observed at areas in the watershed where poultry litter is applied.

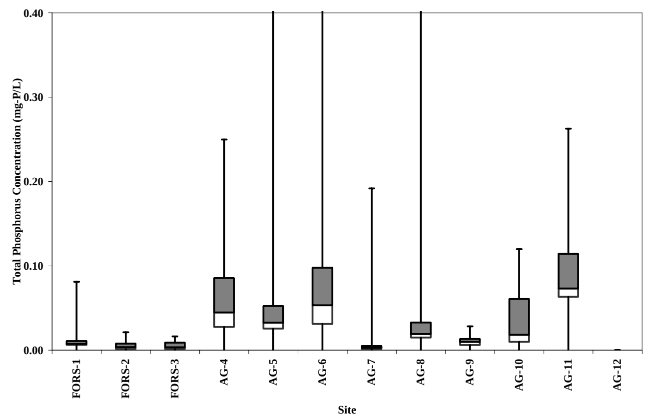

Figure 1. Total phosphorus concentrations observed in biweekly grab samples.

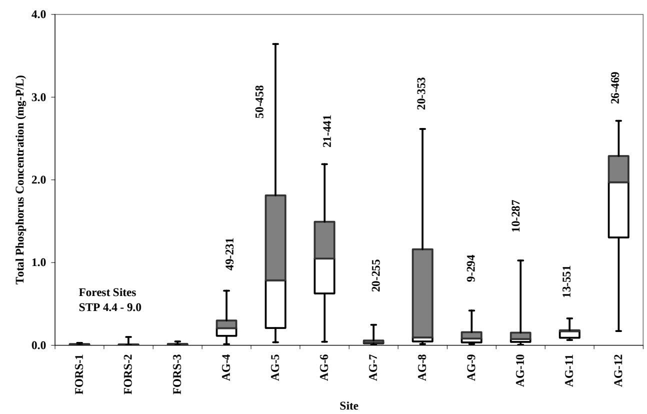

Figure 2. Total phosphorus concentrations observed in storm samples. Ranges of soil test phosphorus (mg/kg) concentrations also shown.

Stream Phosphorus Loads. Preliminary analyses have been performed towards estimation of P loads exported from upper Etowah project streams. Streamflow may be an important independent variable in any regression-based load estimation approach for the study watersheds. Figure 3 is a scatter plot relating stream TP concentration to flow for monitoring data collected from AG Site 5. The trendline shown is a power equation with $y = 0.1132(x)^{0.8966}$ ($R^2 = 0.5756$). Other explanatory variables for estimating P loads will include STP, timing of poultry litter application relative to rainfall, and other factors. Storm EMCs, when available, will be used to estimate storm-specific loads. EMCs will be explored for their utility in calibrating load estimation models.

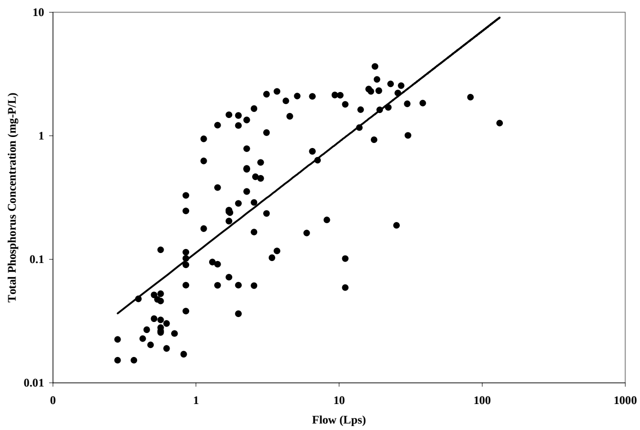

Figure 3. Scatter plot of total phosphorus concentration as function of streamflow observed at Site 5.

Sediment

Median FORS stream TSS concentrations in BWG samples ranged from 3.2 to 8.4 milligrams per liter (mg/L). Median AG stream TSS concentrations in BWG samples ranged from 3.2 to 39 mg/L. Median FORS TSS concentrations in storm samples ranged from 39 to 235 mg/L. Median AG stream TSS concentrations ranged from 18 to 728 mg/L.

Overall, during low-flow conditions which BWG samples typically sampled, TSS concentrations in AG streams were zero to 1 order of magnitude greater than FORS streams. This is similar to what was observed with stream TP. This was not the case for comparisons of storm flow TSS concentrations between the two land use types. The range of median TSS concentrations in AG stream storm flow sample were within the same order of magnitude as FORS streams.

SUMMARY

Preliminary results are presented from a water quality monitoring component of a larger study aimed at exploring options for nutrient trading of P in the upper Etowah River basin. Streamflow, P, and sediment were monitored in 9 AG streams predominated by poultry operations and 3 FORS streams. Median stream TP concentrations in AG streams were 0-1 and 1-3 orders of magnitude greater than FORS streams during low-flow and stormflow conditions, respectively. In terms of TSS, the same trend was observed for low-flow samples, but during stormflow conditions, no order of magnitude differences were observed between the two land uses.

The 3 highest median stormflow TP concentrations in AG streams were observed where 3 of the 4 highest STP concentrations were observed. Streamflow and other variables including STP and EMCs may be important variables for estimating P loads exported from small AG watersheds in the upper Etowah River basin.

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