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Abstract

The water quality of two small, adjacent watersheds was monitored to determine the effect of land use on nutrient loads and flow-weighted mean concentrations. Poultry litter and liquid swine waste are surface applied as fertilizer to pastures that are used for hay production and beef cattle grazing. The study area is located in northwestern Arkansas, east central Washington County. Cannon Creek, the less influenced watershed (628 hectares), contains 11% pasture; whereas, Shumate Creek, the more influenced watershed (589 hectares), contains 22% pasture and receives approximately four times more land-applied animal waste as fertilizer. The remaining land cover in both watersheds is primarily hardwood forest. Shumate Creek had higher nutrient concentrations and greater nutrient mass transport. Stormflow transports a larger percentage of the nutrient load than baseflow; e.g., during the month of April more than 30% of the total phosphorus (TP) load was transported in less than four days of storm flow at the Shumate Creek site. The total pasture area, the proximity of pastures to streams, and the intensity of pasture management (i.e., the rate and timing of manure applications) are important aspects to consider when monitoring water quality.

Introduction

The water quality of the White River is of special interest since it flows into Beaver Lake, which is the domestic water supply for much of Northwest Arkansas. There is the potential for agricultural non-point source (NPS) pollution due to the agricultural activity in the drainage basin of the White River. The Upper White River Best Management Practice (BMP) Implementation Project is a multi-agency project that was formed in March 1994 to help with the installation and monitoring of agricultural BMPs to help improve water quality. Water quality parameters were measured to monitor the effect of land use on water quality, to evaluate the importance of stormflow when studying water quality, and to determine the effectiveness of the BMPs. Two tributaries of the White River, Shumate Creek and Cannon Creek, were monitored in this study. The two sampling sites are located on the edge of Washington County in Northwest Arkansas, south of Durham and accessed from Arkansas Highway 16. Samples collected at Cannon Creek (Sec. 8, T14N, R28W) represent the less influenced or control site. Shumate Creek (Sec. 32, T15N, R28W) represents the more influenced site and shows the impact of agricultural operations, which are currently implementing best management practices. Non-point source pollution indicators (i.e., increases in phosphorus and nitrate levels) at Shumate Creek should decrease in concentration and/or mass transport as the best management practices are implemented. This statement is consistent with data from five stream monitoring sites collected from September 1991 to April 1994 elsewhere in Northwest Arkansas (Edwards et al., 1994). That particular study observed decreasing trends (from 14 to 75% per year) in average stream flow concentrations of the nitrogen forms, nitrate-nitrogen (NO_3-N) and ammonia-nitrogen (NH_3-N).

The two watersheds are similar in area, soils, relief, and geology. Shumate Creek watershed is 589 hectares and Cannon Creek watershed is 628 hectares. The soils are classified as being deep to shallow, moderately drained to somewhat excessively drained, gently sloping to steep (USDA, 1969). The variability in the soils is contributed to the relief, approximately 259 meters in both basins, which results in different soils on ridges and slopes. Horizontally bedded Pennsylvanian aged sedimentary rocks characterize the geology of both basins. Specifically, the geology is limestone, sandstone, and shale of the Brentwood member of the Bloyd Formation and the Cane Hill and Prairie Grove members of the Hale Formation.

Two important differences between the sub-basins with regard to water quality are the amount of pasture in each and the distribution of the pastures. Shumate Creek, having 22% pasture lands, is more influenced by agricultural practices. Cannon Creek is the less influenced site comprising only 11% pasture. Geographic Information Systems (GIS) land use maps were reviewed for actual percentages of agricultural vs. forested areas in the two drainage basins. Edwards et al. (1996) reported that mean concentrations of dissolved orthophosphate ($P0_4$-P), total phosphorus (TP), and total suspended solids (TSS) were highest for sub-basins with the highest proportions of pastureland use. In addition, the pastures in Shumate Creek basin are along the floodplain; whereas, the pastures in the Cannon Creek basin are on ridge tops with riparian forest along the stream.

Materials and Methods

Data were collected from April 1996 to March 1997. Samples were collected during storm events using Sigma® automated samplers. An increase in stream stage triggers the sampler to begin collecting. Grab samples were taken monthly and following storm events. The samples were then retrieved and delivered within 24 hours to the Arkansas Water Resources Center Water Quality Laboratory, which is certified by the Arkansas Department of Pollution Control and Ecology (ADPC&E) for wastewater and the Louisiana Health Department for drinking water. All samples were analyzed for the following parameters:

Nitrate-nitrogen (NO_3-N)
Ammonia-nitrogen (NH_3-N)
Total phosphorus (TP)
Dissolved orthophosphate (PO_4-P)
Total suspended solids (TSS).

All analyses were performed according to Standard Methods (APHA, 1992).

Loads and flow-weighted mean concentrations were calculated for the water quality parameters that were monitored in the study. Load represents the total mass (kg) of each parameter that is moving by a point in the creek within a given period of time. It was calculated by multiplying the concentration of a parameter by the volume of discharge at the time of the concentration, then summing the results for the month and year. Discharge was recorded every 15 minutes using a pressure transducer to measure stage. Storm and grab sample concentrations were applied to the time interval when collected. Concentrations were applied to each 15-minute discharge reading by extrapolating between the data from storm and grab samples. Estimation of load is useful when evaluating effects on the water quality of Beaver Lake because it represents monthly and/or yearly totals of a substance that are moving into the system and accounts for the effect of discharge.

Flow-weighted mean concentrations were calculated by dividing the monthly load by the monthly discharge. This normalized the concentration for discharge differences that occur between the two watersheds (Fig. 1). Flow-weighted mean concentrations are useful when investigating the effect of land use on the water quality of the two tributaries.

Results and Discussion

Land use (i.e., riparian zones and amount of land-applied animal waste) in the drainage basins of Shumate and Cannon Creeks has impacted water quality. Shumate Creek has more agricultural use in its drainage basin and approximately four times more land-applied animal waste than Cannon Creek. Data indicated higher loads and flow-weighted mean concentrations in Shumate for most parameters. In several Buffalo River tributaries, nitrate concentrations were found to be related to percent pasture, as well as specific pasture management (Mott, 1997). The flow-weighted mean concentrations of nutrients, which are indicators of pollution from animal waste, were two to four times higher in Shumate Creek than Cannon Creek, (Fig. 2-4). For example, in May 1996 the flow-weighted mean concentration of nitrate-nitrogen was 0.3 mg/L at Cannon Creek and 1.25 mg/L at Shumate Creek. The mean concentration of nitrate-nitrogen for a pristine upper Buffalo River site varied from 0.04 mg/L during baseflow to 0.01 mg/L during stormflow (calculated from the National Buffalo River Database, 1998). This verifies that the intense agricultural practices in the watershed of Shumate Creek are affecting its water quality.

Stormflow is responsible for transporting a considerable percentage of total loads. Increased discharge corresponds with increased loads and substantially higher concentrations. For example, during an April 1996 storm at Shumate watershed, TSS concentrations increased from approxi-

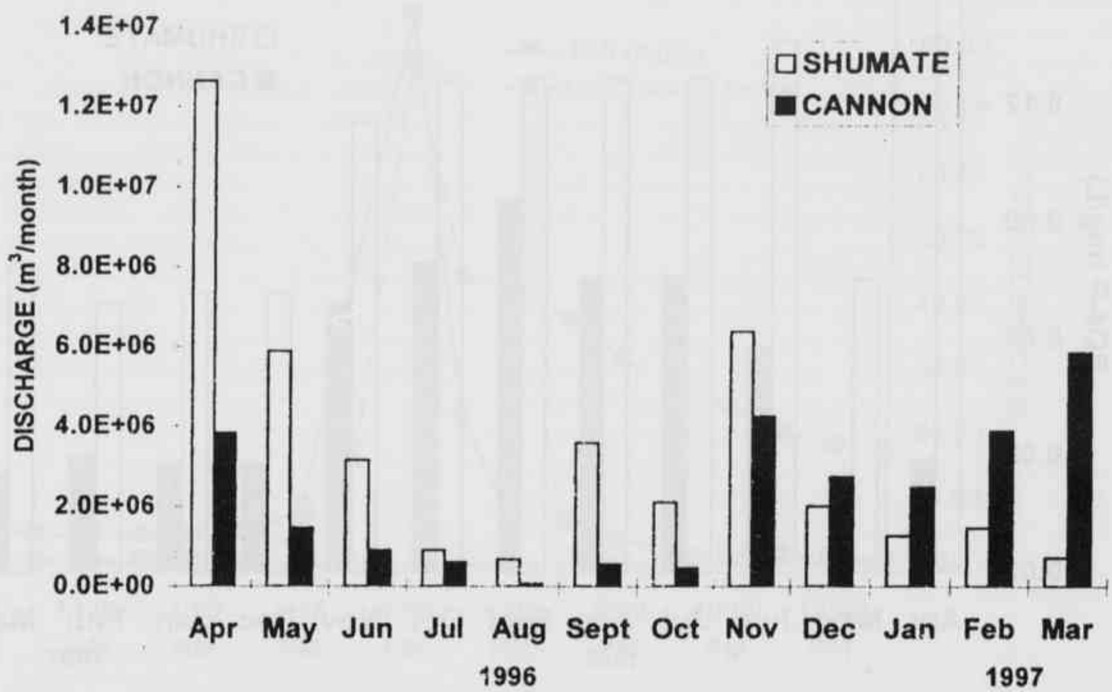

Fig. 1. Discharge for Shumate and Cannon Creeks.

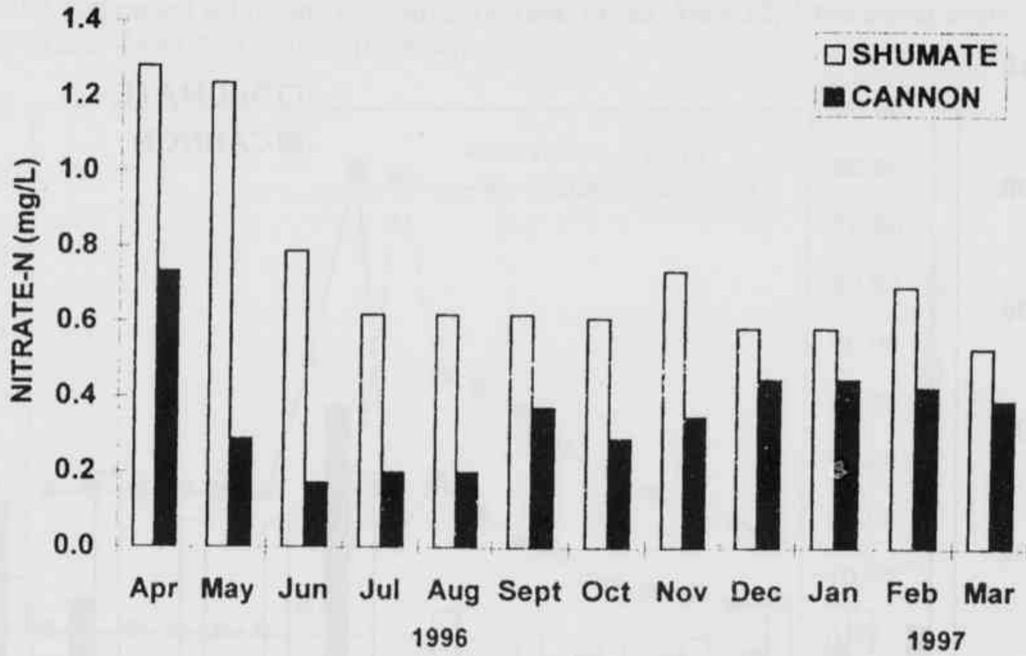

Fig. 2. Flow-weighted mean concentrations of nitrate-nitrogen in Shumate and Cannon Creeks.

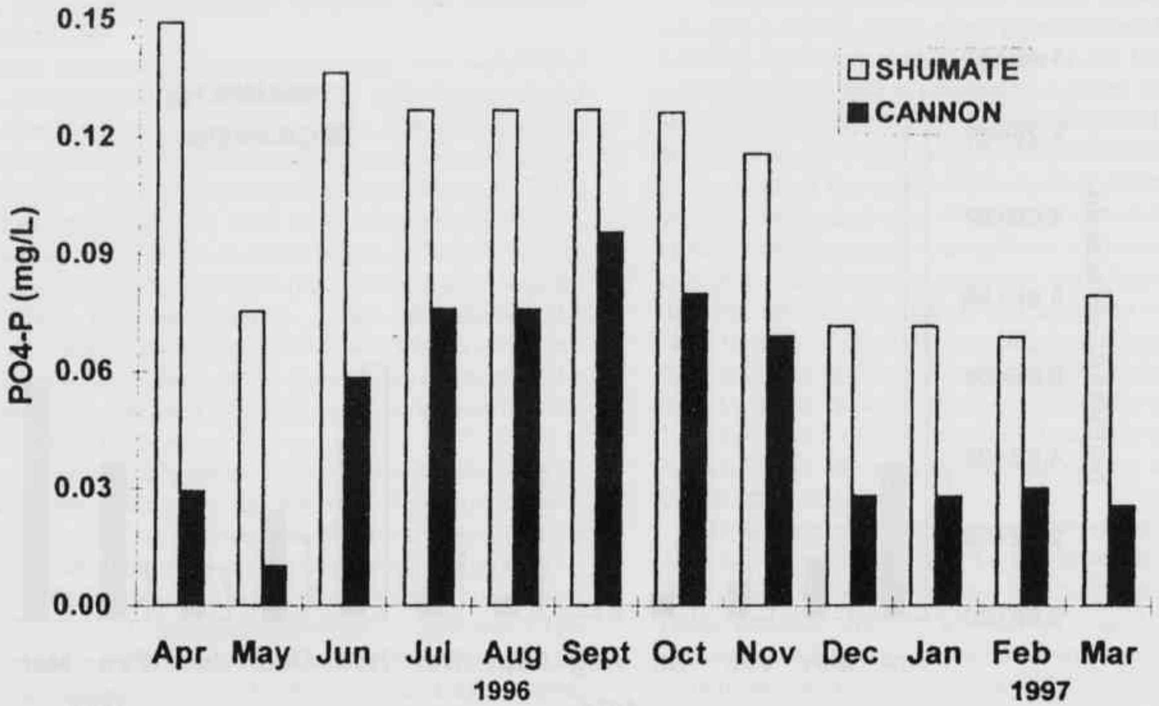

Fig. 3. Flow-weighted mean concentrations of dissolved orthophosphate in Shumate and Cannon Creeks.

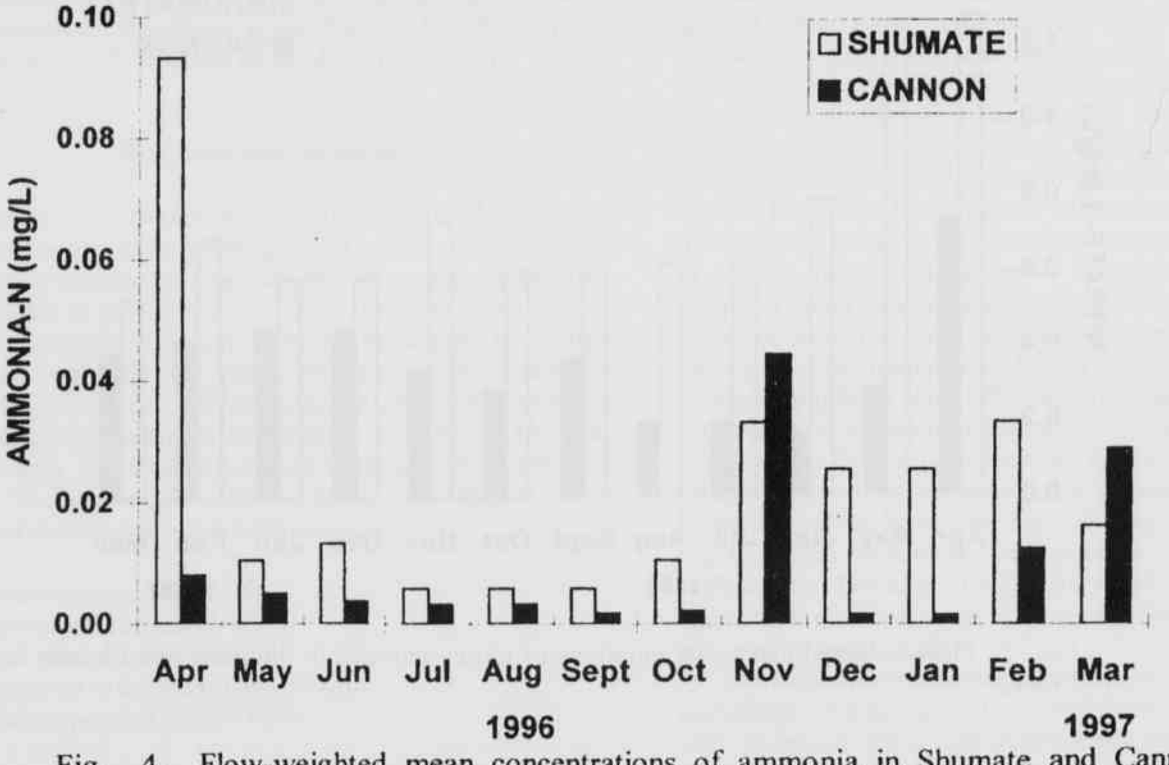

Fig. 4. Flow-weighted mean concentrations of ammonia in Shumate and Cannon Creeks.

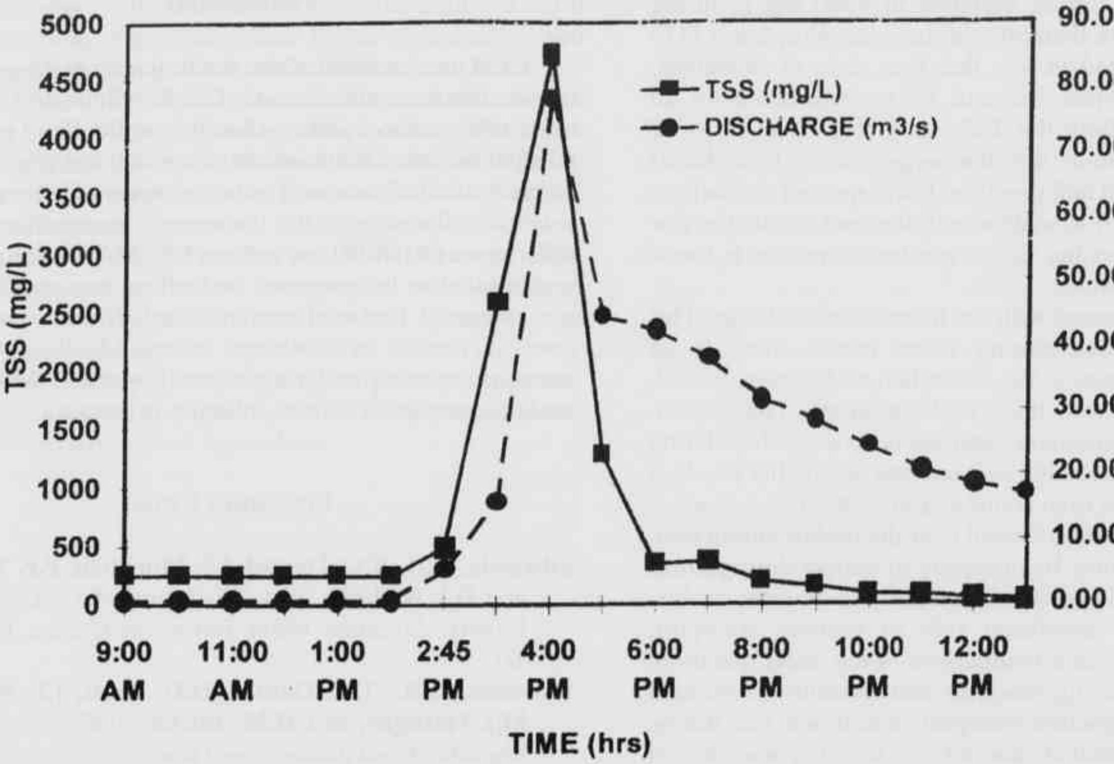

Fig. 5. Total suspended solids and discharge vs. time for an April 12, 1996 storm event at Shumate Creek. Note TSS mimics the discharge.

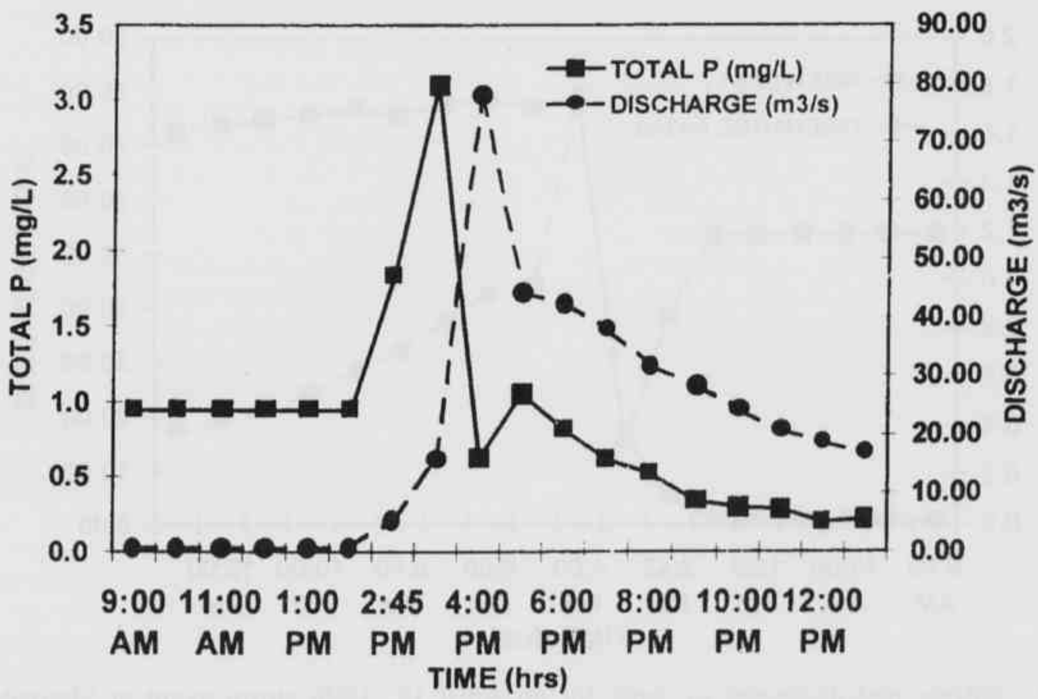

Fig. 6. Total phosphorus and discharge vs. time for and April 12, 1996 storm event at Shumate Creek. Note TP mimics the discharge.

mately 250 mg/L during baseflow to 4500 mg/L during stormflow and more than 30% of the total phosphorus (TP) load was transported in less that four days of stormflow. Figures 5 and 6 depict TSS and TP concentrations for an individual storm. Both the TSS curve (Fig. 5) and the TP curve (Fig. 6) mimic the discharge curve. Phosphorus adheres to sediment and therefore is transported similarly to TSS. Nitrate (Fig. 7) is soluble and does not mimic the discharge curve suggesting that a portion of nitrate is transported by ground water.

Load also increased with the increase in discharge. This is an indication that during storm events there is an increased erosion rate in the watershed and excessive loading of sediments (Mott, 1997) to the tributary. The concentrations of most parameters increased considerably during stormflow. Spring and fall rainy seasons had higher levels of selected parameters than summer and winter dry periods.

Although the data collected over the twelve-month period indicate that it may be necessary to sample during storm events to obtain an accurate representation of water quality, baseflow plays a significant role in nutrient transport. Owens et al. (1991) in a comparison of the water quality of four watersheds during baseflow and stormflow, indicated that although the greatest transport of nutrients was during stormflow, a substantial amount, 25 to 50%, was moved during baseflow. Therefore, it is important to sample during both stormflow and baseflow to obtain the most accurate information.

Conclusions

Land use has affected the water quality of these two tributaries, Shumate and Cannon Creeks. Shumate Creek had more total pasture, pastures located on the flood plain with no riparian zone, more intensive agricultural practices, and higher nutrient loads and concentrations. There were also seasonal influences on the loads and concentrations due to differences in rainfall, as well as times when animal waste was applied to the pastures. Stormflow transported a large percentage of the total nutrient load. Nutrient concentrations increased as discharge increased. It is therefore necessary to sample during stormflow and baseflow when studying non-point source pollution in streams.

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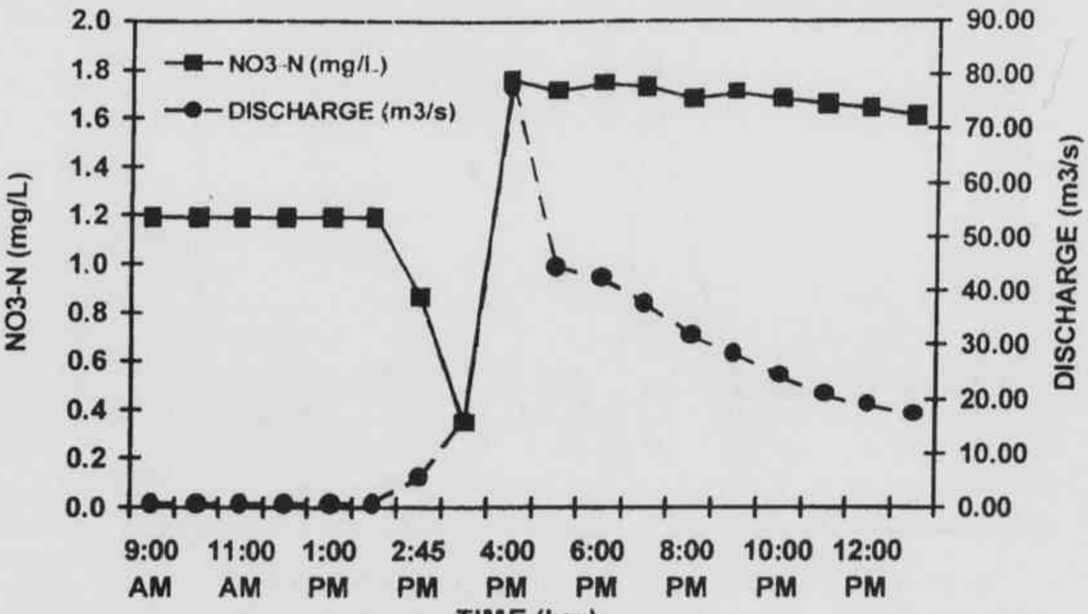

Fig. 7. Nitrate and discharge vs. time for an April 12, 1996 storm event at Shumate Creek. Note NO3-N doesn't mimic the discharge.

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