Title: Measurement and Prediction of Phosphorus Transport from Swine Manure at the Watershed Scale - **NPB #00-022**

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I. Abstract

Livestock production facilities are coming under increased scrutiny with regard to runoff of phosphorus (P) from fields receiving animal manures. Watersheds are not uniform in their surface properties or land use so it is difficult to know how P management on individual fields will affect the quality of surface waters. The objective of this study was to measure and simulate how swine manure management affects P export from a watershed with intensive swine production. Stream water sampling (1-3 week intervals) was conducted for one year at 14 locations within the Tipton Creek watershed in central Iowa. Data on soil and manure P concentrations and amounts were also collected. Geographic Information System (GIS) data layers (topography, soils, land use, and land cover) were prepared to create the input data necessary to run the Agricultural Non-Point Source model (AGNPS).

The average dissolved reactive (DRP) and total phosphorus (TP) concentrations in stream water from 41 sampling dates were 0.14 and 0.21 mg/L, respectively. Total P export from the Tipton Creek watershed from April 1, 2000 to April 1, 2001 was estimated at 10.6 metric tons (11.7 tons) for an average of 0.52 kg of P lost per ha (0.47 lbs P/acre). This loss represents approximately 2.8% of the applied P (fertilizer and manure). Four rainfall events during the 2000 growing season and snowmelt in March 2001 were responsible for the transport of 91% of the P from the watershed. Using animal inventory numbers and standard P excretion values, swine manure was estimated to supply approximately 35% of the land-applied P in the watershed. AGNPS simulations were completed using the 4 storm events from 2000 with an assumed 5% annual increase in swine production and subsequent increase in P application to the soils of Tipton Creek watershed. These simulations indicated that such a production trend, *without any changes in current management*, could result in a 40% increase in P transport from the watershed after 5 years. However, a combination of swine diets with lower P amounts and use of high available-P feedstuffs and/or phytase enzyme have been shown to reduce P excretion by as much as 50%. Adoption of these practices over the next 5 years would likely prevent any increase in P production from swine facilities and potentially reduce P production compared to current levels.

II. Introduction

Livestock production facilities are coming under increased scrutiny with regard to runoff of phosphorus (P) from fields receiving animal manures. Much of the research dealing with P transport from swine manure has been on small-scale research plots. It is difficult to translate these findings to the watershed scale. Unlike research plots, watersheds are not uniform in their surface properties (slope, soil type, nutrient content, drainage, residue cover etc...) or management (crop rotation, tillage system, weed control, fertility program etc...).

One tool to deal with the complex arrangement of surface properties and management systems within watersheds is a computer simulation model. Simulation models allow users to efficiently organize data by location within a watershed, compare simulations of nutrient transport with observations in the field, and predict how changes in application rates or management practices would impact water quality parameters. One model that is specifically designed for use in agricultural watersheds is the Agricultural Non-Point Source (AGNPS) model. A GIS interface for the AGNPS model allows spatial representations of landscape data to be used by the model. Use of the ArcView-AGNPS model provides an opportunity to predict how manure and fertilizer management affect P transport to surface water.

III. Objectives

1) Collect soil, water, and manure data and management information to assess the amount of P from swine manure that is transported out of a watershed with
intensive swine production (Tipton Creek),
2) Compare predictions of P transport using the AGNPS model with water quality data collected within the basin and at the watershed outlet,
3) Predict future trends in P transport by extending current trends in swine production and soil P levels in the Tipton Creek watershed.

IV. Procedures

The Tipton Creek watershed is located in Hardin and Hamilton Counties in central Iowa. It has an area of 202 sq km (77 sq miles) of which 84% is in row crop production (corn and soybeans). There are 26 confined animal feeding operations (swine) in the watershed, most of which are located in the western portion of the basin. Water sampling of Tipton Creek began on May 9, 2000. Fourteen stream sampling locations were chosen to provide a representative sampling of water quality within the watershed. Sample sites include locations upstream from swine production facilities, within the area of concentrated swine production, and on down steam to the watershed outlet. Each location was visited weekly during the growing season unless prevented by inclement weather. A flow monitoring/storm water sampling station was installed at the watershed outlet. This station measured water depth to allow flow (cubic meters per day) calculations that enable P load (kg of P leaving the watershed per day) estimates to be made. Water samples were collected on 41 days and over 350 samples were analyzed for total phosphorus (TP) and dissolved reactive phosphorus (DRP).

Data on soil test P and fertilizer application for over 2000 ha (5000 A) within the Tipton Creek watershed were provided by a local fertilizer dealer. These data indicate that most soils have low to optimum levels of P (~ 20 ppm) and the average fertilizer rate was 21 kg P/ha (18.5 lbs P/A). With 12,165 hectares (30,060 acres) of corn in the watershed, this average rate would require 252 metric tons of P fertilizer (278 tons) per year. The most recent (1999-2000 growing season) fertilizer sales data were obtained for Hardin and Hamilton counties and pro-rated for the Tipton watershed to obtain another estimate of P fertilizer application. This method produced an estimate of 235 metric tons (259 tons) of P fertilizer per year or 19.3 kg P/ha (17.2 lbs P/A). Phosphorus present in swine manure produced in the watershed was estimated from animal census numbers obtained from the Iowa Department of Natural Resources and the 1997 Census of Agriculture. The total amount of P contained in swine manure on an annual basis was estimated as 132 metric tons (145 tons). Thus, it is estimated that approximately 35% of the P applied to cropland in the Tipton Creek watershed was applied in swine manure. Application rate information from swine producers indicate that, if manure was applied to meet the nitrogen (N) demand of corn, the P applied would be from 54 to 89 kg P/ha (60 to 100 lbs P/A). For the AGNPS simulations, a P application rate of 33.6 kg/ha (30 lbs/A) was used for all corn acreage in the watershed.

Input data necessary to run the AGNPS model were collected and assimilated into GIS data layers (topography, soils, land use, and land cover). Figure 1 shows an example of one coverage (land cover). Four rainfall events generated runoff during the 2000 growing season. Each of these events was simulated with the AGNPS model. To project the effect of continued expansion of swine production in the watershed, simulations were completed using the intensities of these storms for 4 years into the future by assuming that swine production will increase at a rate of 5% per year. Model parameters were adjusted to simulate the impact of increased manure application rates and soil P levels on P concentrations and loads at the watershed outlet.

VI. Results

Results of the water quality sampling are summarized in Figures 2 and 3. Figure 2 shows the average concentration of DRP and TP at each site in mg/L (ppm). Figure 3 shows the average concentrations by sampling date for all sites sampled. Sites are numbered beginning from the headwaters of the watershed (TC1). Site SI1 is at a U.S. Geological Survey gaging station on the Southfork of the Iowa River approximately 3.2 km (2 miles) downstream from the last sampling site on Tipton Creek (TC25). The average DRP and TP concentrations were 0.14 and 0.21 mg/L, respectively. The ratio of DRP concentration to TP concentration averaged 0.66, indicating that 66% of the P in the stream water was in the dissolved form. Sites TC5 and TC12 had the highest concentrations of both DRP and TP. TC5 is located near the highest concentration of swine production in the watershed. TC12 is located downstream from a pasture grazed by beef cattle. There is little trend in DRP or TP concentrations over time (Fig. 3).

After combing the flow data with P concentrations, it was estimated that the total P export from the Tipton Creek watershed from April 1, 2000 to April 1, 2001 was 10.6 metric tons (11.7 tons) or an average of 0.52 kg of P lost per ha of watershed area (0.47 lbs P/acre). Four rainfall events during the 2000 growing season and snowmelt in March 2001 were responsible for the transport of 91% of the P from the watershed (Fig. 4). By contrast, P export during baseflow periods averaged only 1 kg/day (2.2 lbs P/day). AGNPS simulations were completed using the 4 storm events from 2000 with an assumed 5% annual increase in swine production and comparable increase in P application to the crop land soils of the watershed. These simulations indicated that this level of increased production for 5 years, *under the current management system*, could result in a 40% increase in P export from Tipton Creek. It should be noted that rainfall in 2000 was far below normal so the number of runoff events and P export reported here is likely low compared to a long-term average.

A holistic approach that incorporates changes in swine feeding, manure storage, and land application is most likely to achieve significant reductions in P transport from swine manure in Tipton Creek. A combination of swine diets with lower P amounts and use of high available-P feedstuffs and/or phytase enzyme have been shown to reduce P excretion by as much as 50%. Adoption of these practices over the next 5 years would likely prevent any increase in P production from swine facilities and potentially reduce P production compared to current levels. Swine manure management strategies should also focus on avoiding land application immediately preceding runoff events and preventing excessive P accumulation in surface soils by matching manure P application with crop removal rates. Better data on manure P availability to crops is needed to help growers optimize the utilization of swine manure as a nutrient source.

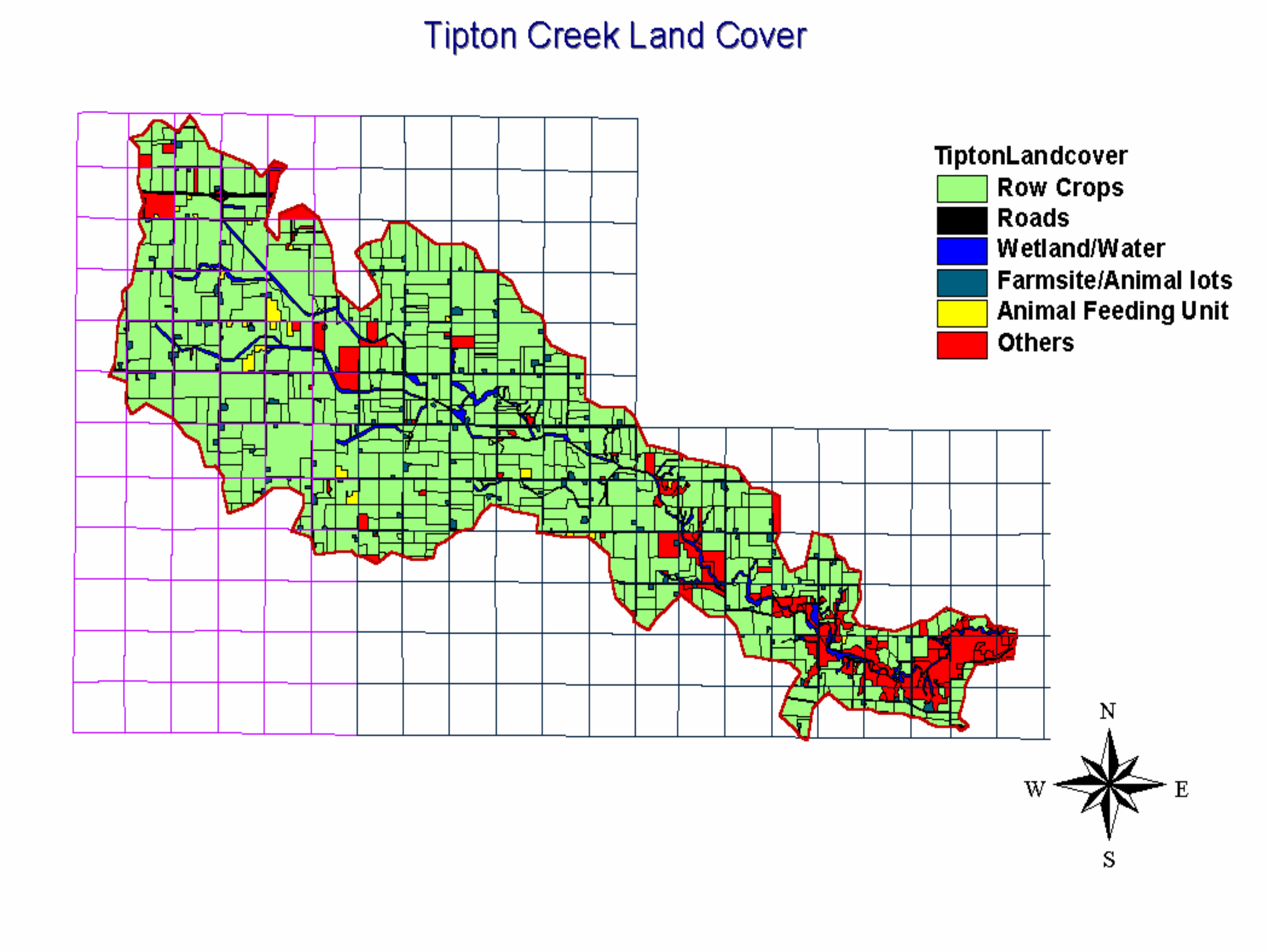
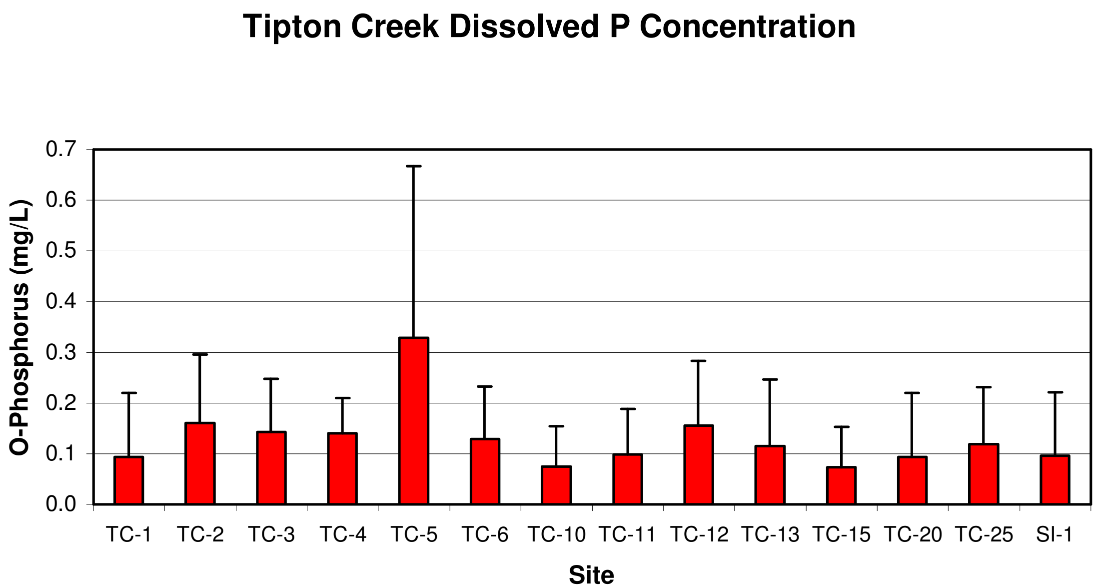


Figure 1. Land cover map for Tipton Creek Watershed. Grid lines represent square miles.



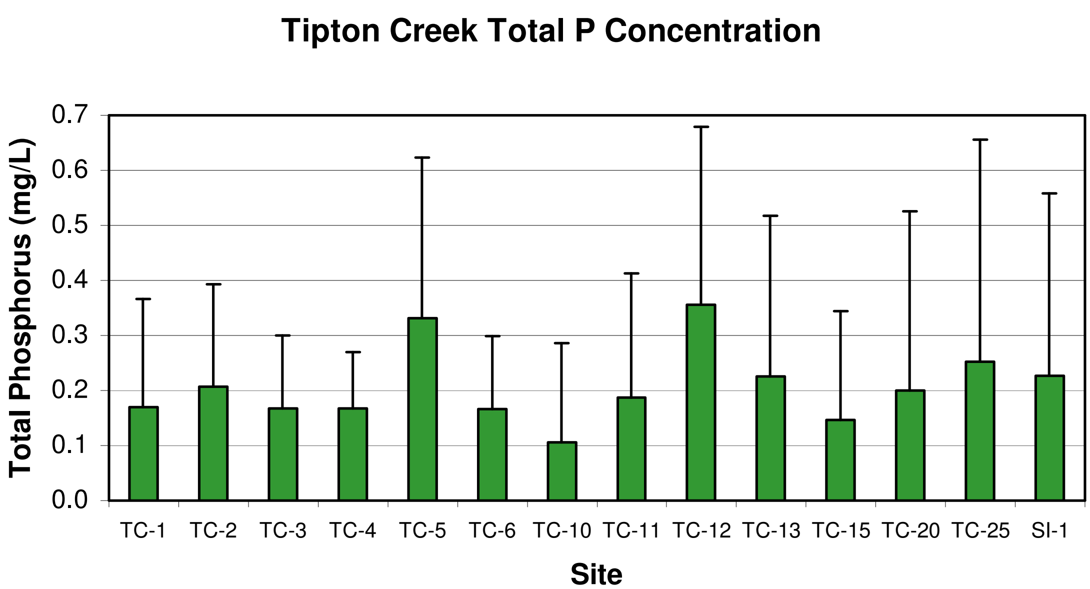
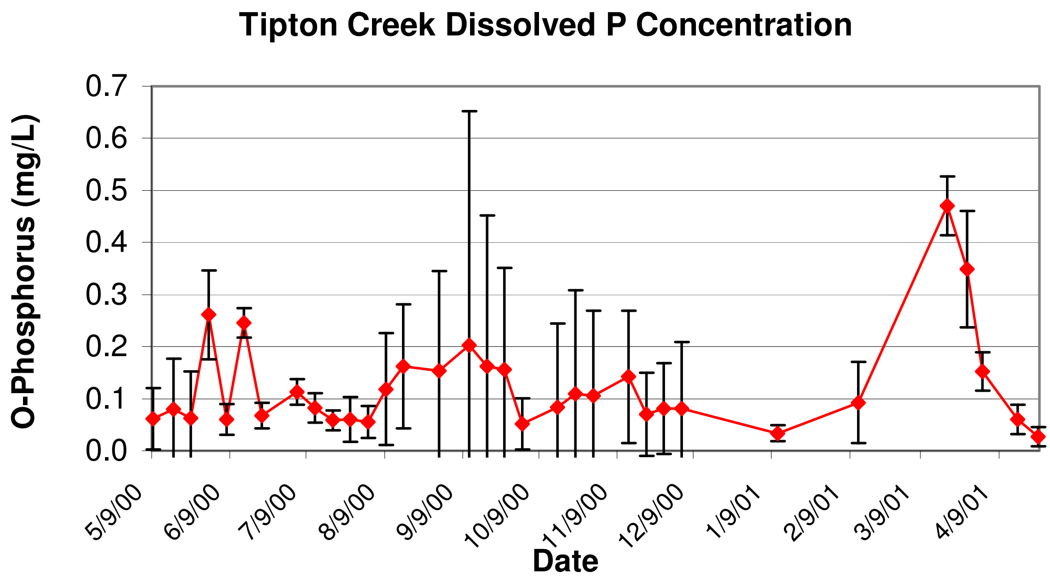


Figure 2. Average dissolved and total phosphorus concentrations in the Tipton Creek watershed by sampling site. Error bars represent one standard deviation from the mean.



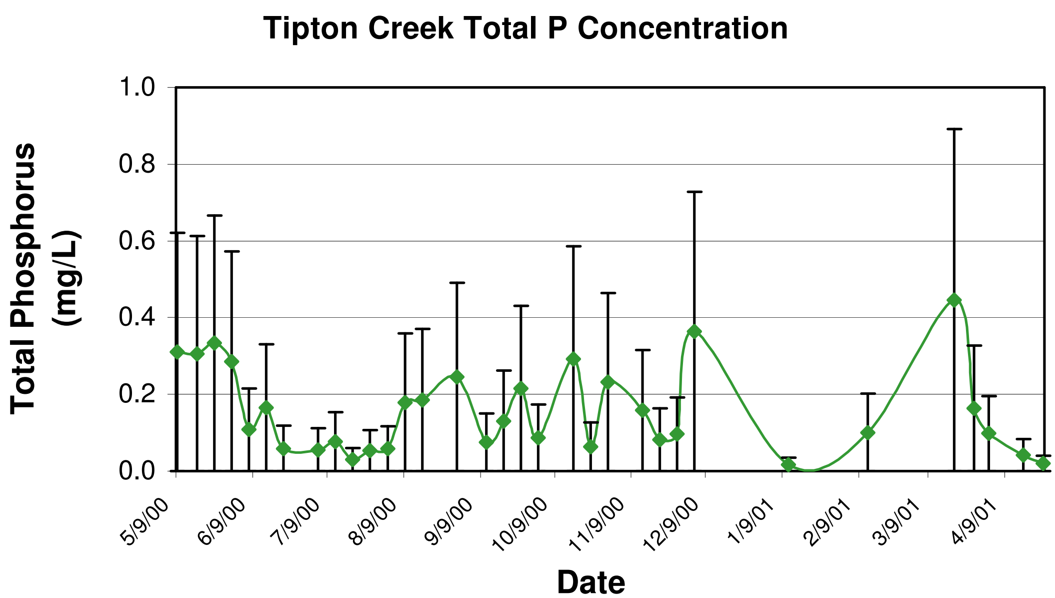


Figure 3. Average dissolved and total phosphorus concentrations in the Tipton Creek watershed by sampling date. Error bars represent one standard deviation from the mean.

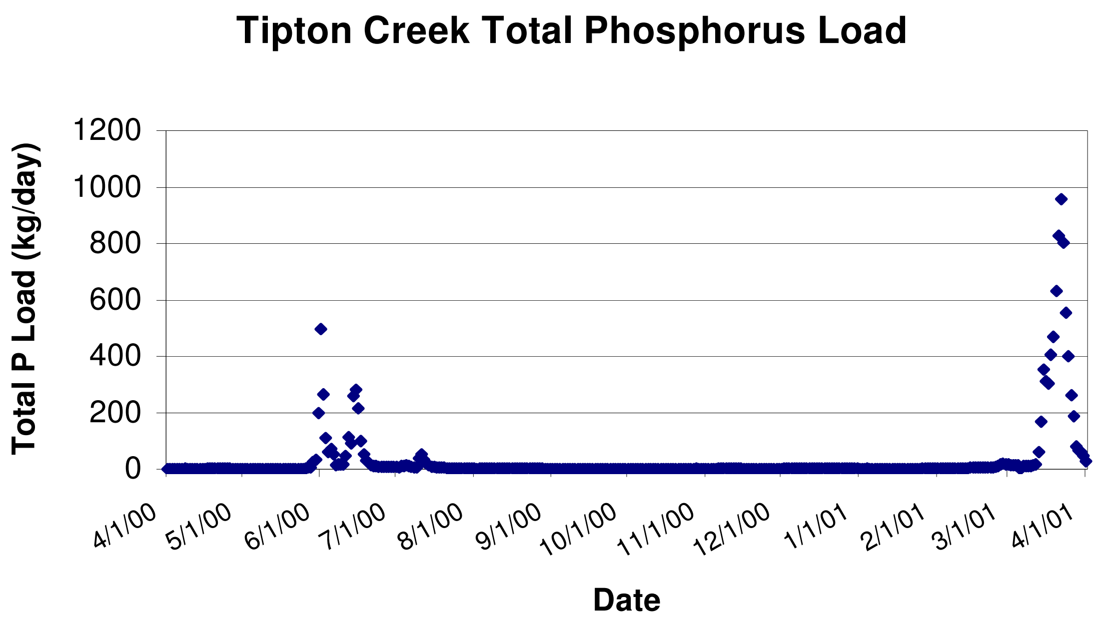


Figure 4. Total phosphorus load at the outlet of the Tipton Creek watershed from April 1, 2000 to April 1, 2001. Ninety-one percent of the P transport occurred during 4 storm events in June/July 2000 and during snowmelt in March 2001.