Hydrologic and Nutrient Modeling within an Agricultural Watershed in Southeast Kansas

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Summary

Access to safe, clean water is important to support society. Agricultural watersheds are often contaminated due to agricultural activities. Identification of specific factors contributing to impairment of water bodies is important to target remediation efforts. This research is designed to explore water quality within the Middle Neosho Watershed in southeastern Kansas to make more informed decisions in potential corrective actions.

Introduction

Most of the water in the Grand Lakes Watershed originates from Kansas. As such, the agricultural activities of Kansas create potential problems with our southern neighbors due to contamination of water from sediments and nutrients. The Middle Neosho Watershed (MNW) is the major watershed that drains from southeast Kansas into the Grand Lakes Watershed. The watershed is primarily agricultural, with production of cows on pasture, row crops, and small grains. The soils of the area are potentially productive silt loams, but are prone to erosion due to annual rainfall amounts in excess of 40 inches per year and agricultural activity.

Our research is designed to improve agronomic production and reduce negative environmental impacts from farming operations. We want to identify what agricultural practices are actual sources of sediments and nutrients in waterways, and develop improved production methods that keep these valuable resources on the field. Loss of sediment from production fields reduces the productive capacity of the land, limiting crop yields. Loss of nutrients applied to crop acres represents a negative investment for producers.

Experimental Procedures

One watershed within the Middle Neosho Watershed was selected for study. The Cherry Creek Watershed is a major contributor to the Neosho River, and drains approximately 218,000 ac in southeastern Kansas. A watershed model, developed in Hydrological Simulation Program Fortran (HSPF), was designed for simulation of non-point source watershed hydrology and water quality for the Cherry Creek Watershed. Simulation results indicate runoff, sediment load, and nutrient and pesticide concentrations, along with time-series of water quantity and quality, at watershed outlets. The model was calibrated and validated with in-stream water quality measurements of nitrate, total ammonia, and orthophosphate from the Kansas Department of Health and Environment and U.S. Geological Survey gage stations.

Results and Discussion

The simulation model performed well in simulating hydrology within the Cherry Creek Watershed. Nutrient measurements reported for the stream that were below the Minimum Quantifiable Limit hampered precise simulation of nutrient changes, although simulated values were acceptable. The calibrated model was used to estimate the probability that nutrient levels would exceed established Total Maximum Daily Load exiting the watershed. Although nutrient runoff from agricultural watersheds is anticipated to be a major contributor to elevated stream nutrient loads, this study showed minimal contamination from Cherry Creek.

Overall, nitrate (NO_3) concentrations in Cherry Creek were low (Table 1). Total ammonia (TAM) concentrations simulated by the model were lower than NO_3 levels. The probability that NO_3 would exceed safe drinking water levels set by the EPA (10 mg/L) is minimal (less than 0.01%). The probability that nitrate will exceed the lower water quality criteria set for aquatic ecosystem health (0.98 mg/L or lower) is only 8.1%. The potential toxicity levels for total ammonia were even lower in Cherry Creek. However, the probability that orthophosphate (PO_4) levels will exceed the minimum standards is more than 25%.

The low level of nitrogenous compounds (NO_3 and TAM) in Cherry Creek Watershed is surprising for an agricultural watershed, indicating that other factors may be contributing to the low levels of dissolved oxygen in the stream. However, the elevated PO_4 levels indicate animal manures from either cattle grazing on pasture or applied poultry litter may be contributing to water impairments.

Acknowledgements

This research was funded in part by a grant from CONICYT, and from an International Incentive Grant from the Kansas State University College International Advisory Council.

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Table 1. Nutrient impairment levels and probability of exceedance for Cherry Creek Watershed. After Alarcon and Sassenrath, 2016

Constituent	Concentration	Associated risk	Contaminant source	Probability of exceedance
NO_3	10.00 mg/L	Infants younger than six months of age could become seriously ill and die. Symptoms: shortness of breath and blue-baby syndrome. (EPA, 2016)	Runoff from fertilizer use; leaking from septic tanks, sewage; erosion of natural deposits.	Less than 0.01%
NO_3	0.98 mg/L	Eutrophic Macroinvertebrate communities are likely at > 0.98mg/L. (MCEA, 2010).	Runoff from fertilizer use; leaking from septic tanks, sewage; erosion of natural deposits.	8.1%
TAM	Less than 1 mg/L	Impairment of aquatic life: toxicity may result if high ammonia levels (e.g., TAM > 1 mg/L) are present (MCEA, 2013).	Major evacuative product of animals; can percolate into groundwater; TAM converts to nitrate	1.65%
TAM	1.24 mg/L at pH 6.5 to 8.3, and temperature from 32 to 86°F	pH- and temperature-dependent chronic aquatic life criteria for total ammonia early life stages of fish present. (KDHE, 2015)	Main evacuative product of animals; can percolate into groundwater. TAM converts to nitrate	0.83%
PO_4	0.05 mg/L	0.08 to 0.10 mg/l may trigger periodic blooms; long-term eutrophication preventable if total P and orthophosphate levels are below 0.5 mg/l and 0.05 mg/l, respectively (Dunne and Leopold, 1978).	Natural processes. Main man-made sources include: sewage, runoff from agricultural sites, and lawn fertilizers.	28.8%