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Using SWAT to enhance watershed-based plans to meet numeric water quality standards

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ABSTRACT

The number of states that have adopted numeric nutrient water-quality standards has increased to 23, up from ten in 1998. One state with both stream and reservoir phosphorus (P) numeric water-quality standards is Oklahoma. There were two primary objectives of this research: (1) determine if Oklahoma was meeting the stream and reservoir numeric water-quality standards in the Illinois River and Eucha–Spavinaw watersheds, respectively and (2) identify various combinations of management practices required to meet the water-quality standards. A Soil and Water Assessment Tool (SWAT) model was developed for each watershed. After runoff and P calibration and validation, each model was used to determine if the numeric water-quality standards were exceeded. Due to recent land management changes in the Eucha–Spavinaw watershed, Oklahoma was meeting the established water quality standard, 0.0168 mg L^{-1} total P in Lake Eucha. Although extensive efforts to reduce P loads have been conducted in the last decade in the Illinois River watershed, a large quantity of P is still reaching the streams and Tenkiller Ferry Lake in the Illinois River watershed. The model was used to identify a combination of potential land management practices in Oklahoma to meet to meet the water-quality standard, 0.037 mg L^{-1} total P, in three of Oklahoma's designated Scenic Rivers: the Illinois River, Barren Fork Creek and Flint Creek. With recent reductions in poultry litter application and improvements in municipal waste water treatment plants, future conservation practices need to focus on cattle production and elevated soil test P. This research illustrated how a watershed model can provide critical information for watershed-based plans to address numeric water-quality standards.

1. Introduction

Excessive nutrients are a major pollutant to many waterbodies worldwide. The United States (US) alone has 7765 waterbodies impaired due to nutrients with over a third on the States' Clean Water Act 303(d) list as a direct result of total phosphorus (P) (USEPA, 2015a). Major P sources include crop and livestock production, wastewater treatment plants (WWTPs) and urbanization. Dissolved and particulate P runoff and erode from overland sources such as agricultural fields, feed lots and urban lawns. Excess P entering streams, lakes and reservoirs can lead to eutrophication, resulting in algal blooms, oxygen depletion and the overall degradation of the water quality (Sims and Sharpley, 2005). Water quality degradation in

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streams and reservoirs has led to an increasing number of states to implement numeric water-quality standards, which can provide a remediation goal for state agencies to develop and implement effective watershed-based plans (USEPA, 2015b). The number of states adopting numeric water quality standards continues to increase; currently 23 states, which is over twice the number in 1998 (USEPA, 2015b).

Oklahoma has both stream, Illinois River watershed (IRW), and reservoir, Eucha–Spavinaw watershed (ESW), numeric water-quality standards. Both watersheds have a long history of poultry and cattle production leading to elevated soil test P, and elevated P in WWTP discharges. Major changes have occurred in the IRW and ESW during the last decade, including increased poultry litter export and upgrades to several WWTPs. Litigation induced changes, along with numerous technical assistance and agricultural cost share programs conducted by state and federal agencies, contributed to the decline in flow-adjusted total P concentrations in the Illinois River near the Oklahoma/Arkansas state line, at Tahlequah, Oklahoma and on the Barren Fork Creek near Eldon, Oklahoma (Scott et al., 2011; Haggard, 2010). In spite of the water-quality improvements in the watersheds, it is unknown if these are sufficient to meet Oklahoma water-quality standards.

The Soil and Water Assessment Tool (SWAT) (Arnold et al., 1998), a watershed-scale hydrological model, has been used worldwide to meet several different types of project needs such as the development of Total Maximum Daily Loads (TMDL) (Borah et al., 2006), modeling climate and land use change (Li et al., 2015) and the effects of conservation practices on water quality (Liu et al., 2014). However, to date the model has only been used by Storm et al. (2010) to aid in the development of a watershed-management plan to meet stream numeric water-quality standards. SWAT predictions have been used as input to reservoir models to evaluate if the water quality standard for a reservoir is exceeded (OWRB, 2008), but to date has not been used without a reservoir model.

The objectives of this research were to estimate P loads originating from the Oklahoma portion of these watersheds and to determine if those loads exceed existing water-quality standards. For this research, loads originating from Arkansas were not considered. If standards were not being met, new management practices were evaluated to reduce P loads. A variety of agricultural-management practices and land-use changes were simulated to determine the necessary changes required to meet the Oklahoma water-quality standards.

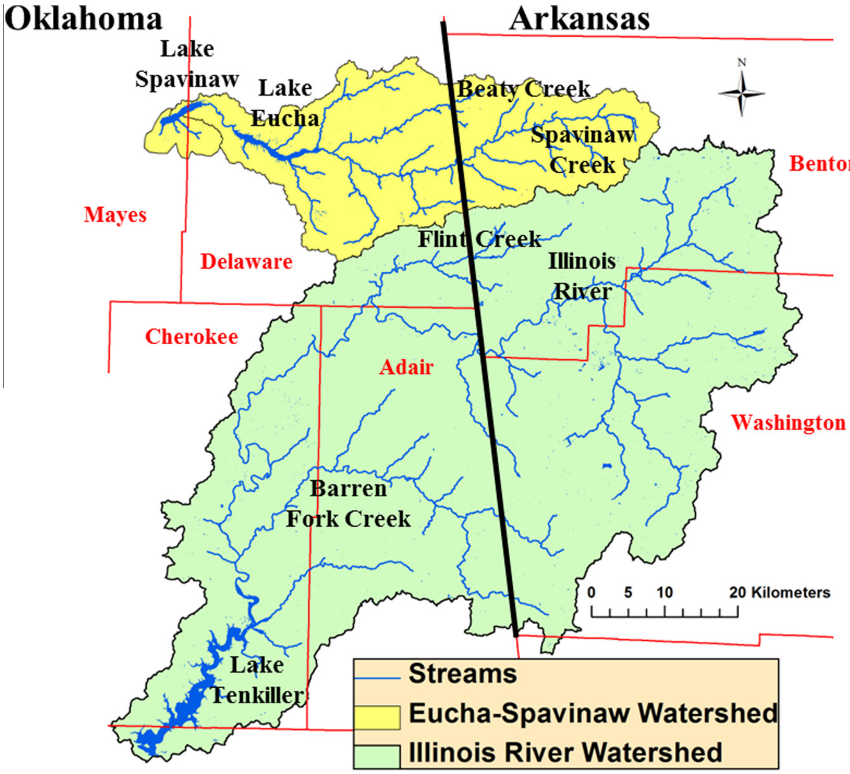

Fig. 1. Illinois River and Eucha–Spavinaw watersheds in northeast Oklahoma and northwest Arkansas showing counties (red), the Oklahoma/Arkansas state line (black) and the major streams and reservoirs. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)