Proceedings Report, 3rd Annual Total Maximum Daily Load Conference sponsored by: American Society of Agricultural Engineers, Altanta, Georgia, 7-9 March 2005.

EFFECT OF REDUCED EFFLUENT PHOSPHORUS CONCENTRATIONS AT THE ILLINOIS RIVER, NORTHWEST ARKANSAS, 1997–2004

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INTRODUCTION

The focus of this study is the Illinois River Basin in the southwestern portion of the Ozark Plateaus physiographic province (Fenneman, 1938) of northwestern Arkansas and northeastern Oklahoma (Figure 1), which is underlain with cherty limestone of the Springfield Plateau province (Adamski et al., 1995). The Illinois River Basin is about equally divided between the states of Arkansas and Oklahoma where a small impoundment exists on this river near the stateline. Several U.S. Geological Survey (USGS) streamflow and water–quality monitoring stations exist throughout the catchment in Arkansas and Oklahoma. The most notable USGS monitoring station is the Illinois River, South of Siloam Springs (Station No. 07195430) at the Highway 59 bridge crossing the stream in Benton Country, Arkansas. The 1500 km^2 drainage area upstream from this point on the Illinois River has been coined the Illinois River Drainage Area (IRDA) in northwestern Arkansas and is predominately an agricultural catchment with 58, 36 and 6% in pasture, forest and urban land use.

Several municipal facilities discharge into the head waters of the IRDA, including the WWTPs at Fayetteville, Rogers and Springdale. The City of Fayetteville's facility is a tiertiary level treatment plant operating with regard to P management and regulatory effluent limits of 1 mg TP L^{-1} since the mid–1990s. The City of Rogers' facility has advanced secondary treatment capacity and has been voluntarily operating under P management strategies with an effluent limit of 1 mg TP L^{-1} since ca. 1997. The City of Springdale's facility is an advanced secondary system operated using N management in the 1990s and started P based management in late 2002; the facility is currently upgrading and has been attempting to maintain effluent P concentrations less than 1 mg TP L^{-1}. These facilities receive influent from residential, industrial and agricultural sources; the most notable agricultural source is probably poultry processing

facilities. These municipal WWTPs discharge into head water tributaries of the IRDA, including *Mud/Clear Creek* (Fayetteville WWTP), *Osage Creek* (Rogers WWTP), and *Spring Creek* (Springdale WWTP).

At the Illinois River, water column P concentrations and riverine P loads have been under constant evaluation by various state agencies in Arkansas and Oklahoma over the past two decades. In 1992, the U.S. Supreme Court rendered a decision that the U.S. Environmental Protection Agency may require upstream states to meet downstream state water–quality standards with the potential point of regulation being the state borders (Arkansas vs. Oklahoma, 503 U.S. 91; http://laws.findlaw.com/us/503/91.html). Thus, the recent adoption of a TP criterion (0.037 mg L^{-1}; Oklahoma Water Resources Board, 2002) in the Illinois River and other Oklahoma *Scenic Rivers* has brought the sources of P in the IRDA under even closer scrutiny. This TP criterion will be fully implemented in 2012 where TP concentrations should not exceed the 30–day geometric mean concentration of 0.037 mg TP L^{-1}. This standard was based on the 75th percentile TP concentrations from stream draining relatively undeveloped catchments across the U.S.A. (Clark et al., 2000). The promulgation of this water–quality standard has fueled the controversy over elevated stream P concentrations between Arkansas and Oklahoma, and recently the states have been negotiating future water–quality monitoring strategies and implementation procedures of this criterion. Several previous studies have been completed at this catchment describing P concentrations, loads and yields at the Illinois River from 1997 though 2001 (e.g., see Green and Haggard, 2001; Haggard et al., 2003; Pickup et al., 2003).

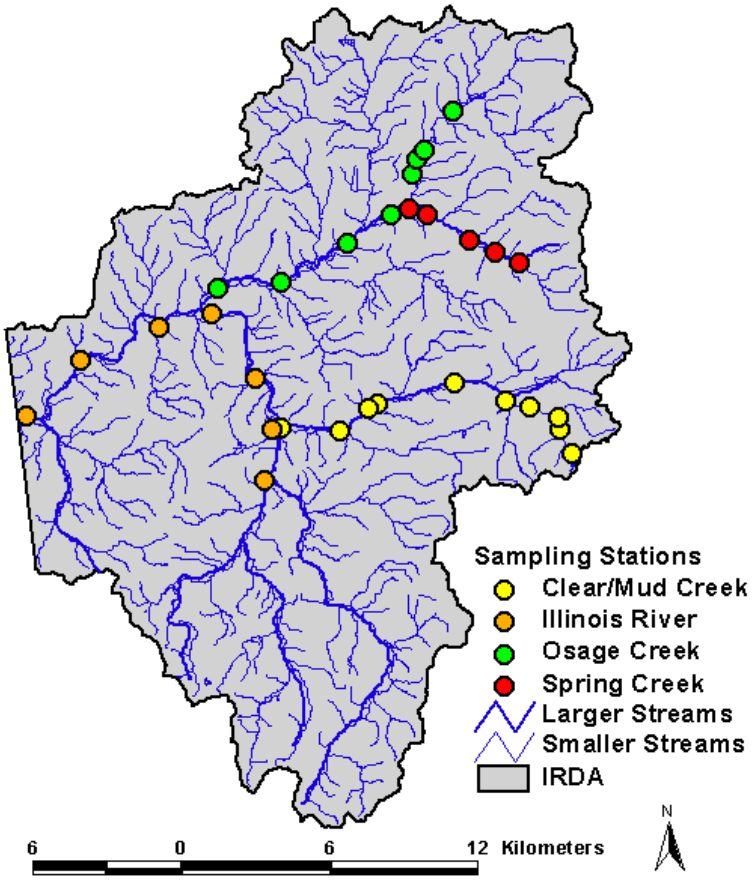

Figure 1. *Water–quality monitoring stations at the Illinois River drainage Area (IRDA) in Northwest Arkansas.*

METHODS

The spatial distribution of dissolved P concentrations was evaluated using multiple water quality monitoring sites from the Illinois River, South of Siloam Springs (USGS Station No. 07195430) upstream to the effluent discharges in Mud/Clear Creeks, Osage Creek and Spring Creeks (Figure 1). Water samples were collected in triplicate from these sites in February, March and April 2002, filtered through a 0.45 μm membrane, stored in a freezer and analyzed

for soluble reactive phosphorus (SRP) using automated ascorbic acid reduction method (APHA, 1998); water samples were collected from the left–center, middle and right–center of the stream channel at each site. A single water sample was collected, filtered (0.45 μm membrane), acidified, frozen and then analyzed for SRP from these sites in August, October, and December 2003 and February, April, June, July, August, September, October and November 2004; a single water sample from the middle of the stream channel was used for economic reasons and because the within site variability in SRP was generally much less than spatial differences. Distance between sites was estimated using the GPS coordinates, digital stream hydrography, and ESRI ArcView software program; the sites are presented using the distance (river km) upstream from the Illinois River, South of Siloam Spring, Arkanas (USGS Station No. 07165430).

RESULTS AND DISCUSSION

In Spring 2002, elevated dissolved P concentrations were easily traced from the Illinois River, South of Siloam Springs, Arkansas (USGS Station No. 07195430), over 45 river km upstream into Osage Creek and then Spring Creek to the City of Springdale's municipal WWTP effluent discharge (Figure 2). Dissolved P concentrations as great as 10 mg SRP L^{-1} were observed on one sampling in March 2002 at Spring Creek, and dissolved P concentrations throughout the IRDA were generally several orders of magnitude greater than concentrations which typically limit periphyton growth in streams (e.g., see Biggs, 2000; Dodds et al., 1997) or that are observed in relatively undeveloped basins (Clarke et al. 2000). The effect of all municipal WWTP effluent discharges was easily observed with this spatial distribution of water–quality monitoring sites, but the effects in Spring Creek were most profound. Thus, we observed a marked longitudinal gradient in dissolved P concentrations was observed at the IRDA during these sampling dates.

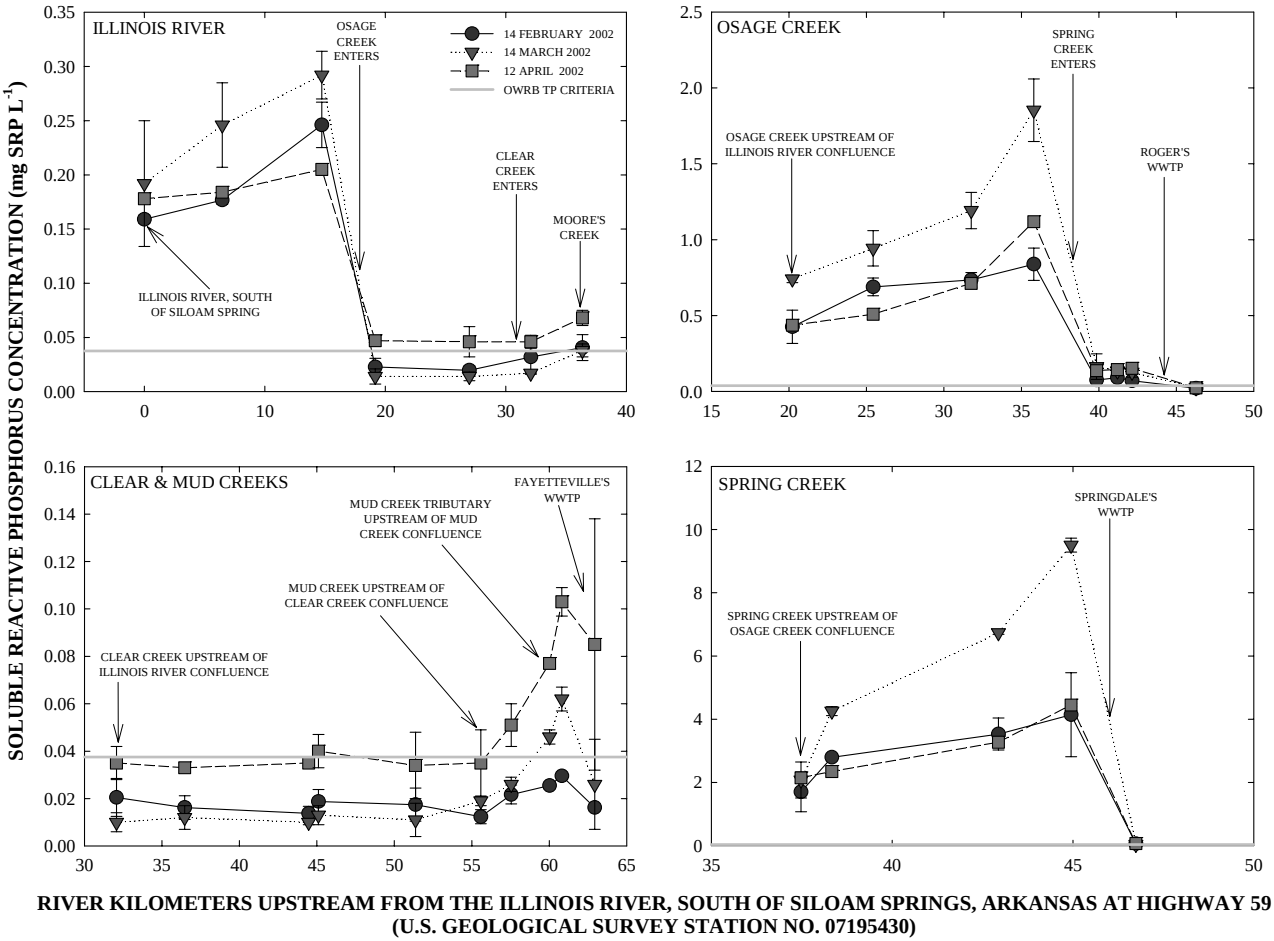

Figure 2. *Longitudinal gradient in dissolved phosphorus concentrations from the Illinois River, South of Siloam Springs, Arkansas (USGS Stations No. 07195430) upstream to headwater streams receiving municipal wastewater treatment plant effluent discharge from the cities of Fayetteville, Rogers and Springdale, Arkansas.*

During Fall 2002, the Springdale municipal WWTP started operating to meet a 1 mg TP L^{-1} limit on effluent concentrations, and with these effluent changes came subsequent changes in dissolved P concentrations in Spring Creek (Ekka et al. 2005); in fact, dissolved P concentrations in Spring Creek are closely tied to the P concentration in the effluent discharge. The effect of reduced effluent P concentrations was profound in Spring Creek from Summer 2003 through Fall 2004. The effect of reduced effluent P concentrations did translate to decreases in dissolved P

concentrations at the stream water–quality monitoring sites downstream from the Springdale WWTP discharge, but dissolved P concentrations were still elevated beyond the Oklahoma *Scenic Rivers* TP criterion (0.037 mg TP L^{-1}). Furthermore, a pronounced gradient in dissolved P concentrations was still observable across the IRDA where concentrations could still be traced from the Illinois River, South of Siloam Springs, Arkansas (USGS Station No. 07195430) upstream over 45 river km into Osage Creek and then Spring Creek (Figure 3).

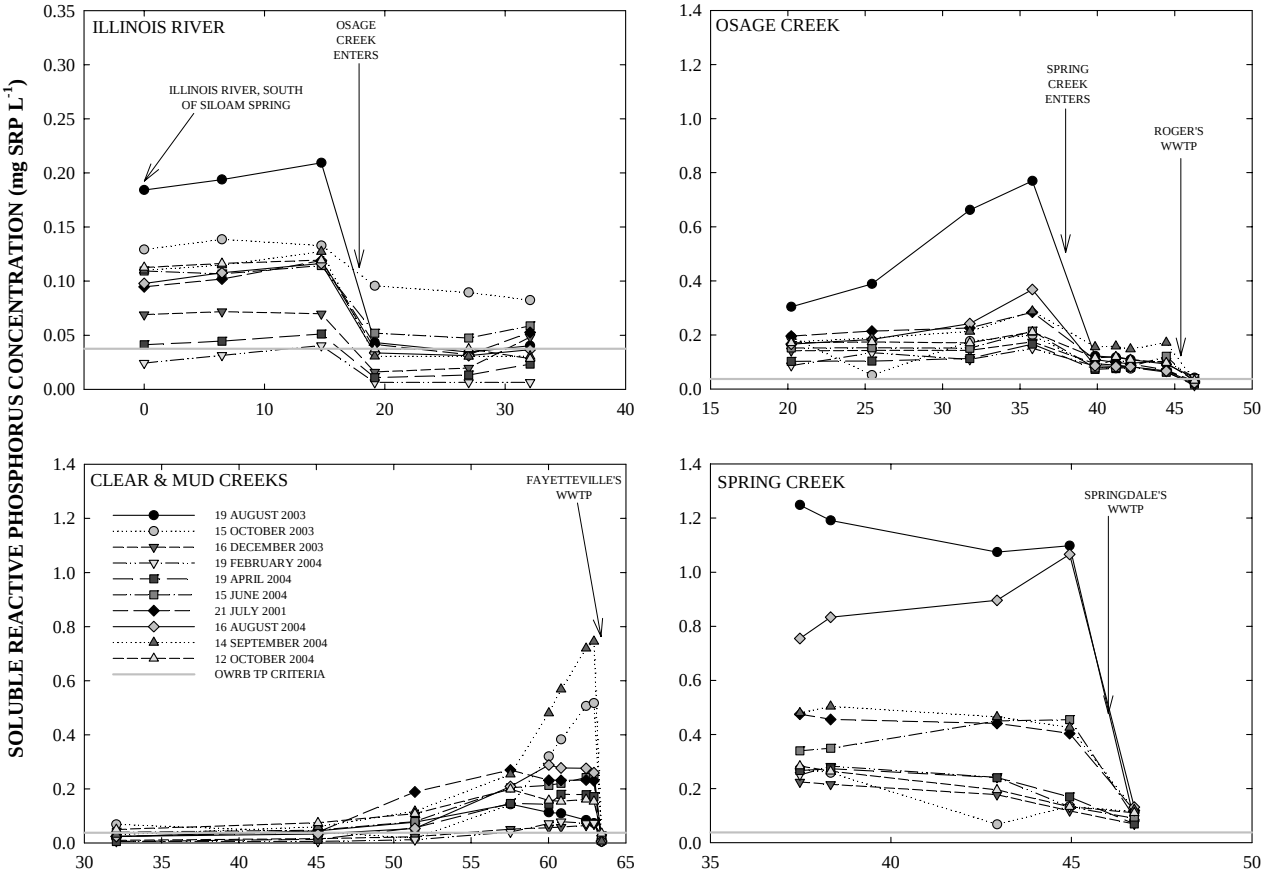

Figure 3. *Longitudinal gradient in dissolved phosphorus concentrations from the Illinois River, South of Siloam Springs, Arkansas (USGS Stations No. 07195430) upstream to headwater streams receiving municipal wastewater treatment plant effluent discharge from the cities of Fayetteville, Rogers and Springdale, Arkansas.*

The effect of reduced effluent P concentrations should be most noticeable in Spring because baseflow discharge and the effects of dilution would be greatest. In fact, dissolved P concentrations at the Illinois River, South of Siloam Springs, Arkansas (USGS Station No. 07195430), were less than the Oklahoma *Scenic Rivers* TP criterion on one sampling date in February 2004, and dissolved P concentrations were close to the criterion in April 2004. So, when we directly compare Spring 2002 with Spring 2004 data collection efforts, we see marked improvements in dissolved P concentrations at the IRDA following the reductions in effluent P concentrations. However, the results observed in Summer 2003 and 2004 show some mechanism of internal P loading exists in the streams draining the IRDA because ambient P concentrations often increase downstream through selected stream reaches (Figure 3). Haggard et al. (2005) observed similar results where P was released from stream sediments when effluent concentrations were low and dissolved P concentrations remained elevated because of these internal sources.

Dissolved P concentrations at the Illinois River, South of Siloam Springs, Arkansas (USGS Station No. 07195430) were generally around 0.10 mg SRP L^{-1} and still almost three times greater than the Oklahoma *Scenic Rivers* TP Criterion (0.037 mg TP L^{-1}). Water–quality monitoring should be continued at the IRDA and should focus on monitoring the long–term recovery of this aquatic system from high effluent P inputs. This spatial distribution of monitoring sites sufficiently captured the marked longitudinal gradient before and after implementation of WWTP P management strategies and showed the effects of reduced effluent P concentrations over a 45 river km reach. It will be interesting to see how dissolved P concentrations are further reduced across the IRDA and if the baseflow concentrations are less than the Oklahoma *Scenic Rivers* TP criterion in the near future.

Acknowledgements

The authors would like to thank all the U.S. Geological Survey hydrologic technicians at the Arkansas Water Resources District Offices, which diligently collected water–quality samples and instantaneous discharge measurements used to maintain the stage–discharge rating curves. The U.S. Geological Survey received funding from the Arkansas Soil and Water Conservation Commission, the Arkansas Department of Environmental Quality, and the Arkansas–Oklahoma River Compact Commission. R. Avery, S. Becton, P. DeLaune, A. Erickson, and S. Williamson diligently collected, processed and analyzed the water–quality samples collected by the USDA–ARS; funding for these efforts was partly contributed by the Arkansas Water Resources Center through a U.S. Geological Survey State Water Resources Research Institute Program.

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