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CITY OF WICHITA, KANSAS

Sources and Concentrations of Phosphorus in the Cheney Reservoir Watershed, South-Central Kansas

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Significant Findings

- ***Human-related activities in the predominantly agricultural watershed of Cheney Reservoir have substantial effects on the quality of water in the reservoir.***
- ***Agricultural activities have accounted for 65 percent of the phosphorus transported by streams to Cheney Reservoir, and most of that phosphorus was transported when streamflow consisted predominantly of runoff from agricultural fields.***
- ***On a long-term basis, surface water from five water-quality sampling sites in the watershed exceeded the established goal for phosphorus by about two to five times.***
- ***Substantial reductions in phosphorus concentrations in streams could involve a combination of approaches such as reducing the application of phosphorus in the watershed and more extensive implementation of land-management and agricultural practices to limit its movement to streams.***

Introduction

Phosphorus is a nutrient required by plants for growth and reproduction and often is added to agricultural soils to increase crop yields. However, the agricultural application of phosphorus historically has been greater than crop requirements and has led to a buildup of soil phosphorus (Carpenter and others, 1998). The buildup of soil phosphorus has increased the potential for phosphorus transport to surface water in runoff from agricultural fields (Sharpley and others, 1999).

Excess phosphorus in surface water may contribute to eutrophication (nutrient enrichment) of surface water, particularly lakes and reservoirs. Nutrient enrichment can overstimulate algal production creating algal blooms that may reduce the aesthetic and recreational value of the water, create taste-and-odor problems in drinking water, and, in severe cases, stress or kill aquatic organisms as a result of dissolved oxygen depletion or the release of toxins when algal blooms die (Sharpley, 1995).

The Cheney Reservoir watershed is a 933-square-mile contributing drainage area of Cheney Reservoir located on the North Fork Ninnescah River in an agricultural area of south-central Kansas (fig. 1). The watershed is used almost exclusively for crop and livestock production. Since 1965 when Cheney Reservoir was constructed, the percentage of the watershed used for crop production has averaged about 52 percent annually. Cattle inventories have averaged about 64,000 animals since 1965. Crop production and cattle inventories were estimated from county data presented in Kansas State Board of Agriculture and U.S. Department of Agriculture (1964Ð94) and Kansas Department of Agriculture and U.S. Department of Agriculture (1995Ð97).

The human population in the Cheney Reservoir watershed is less than 4,000, many of whom are associated with the approximately 1,000 farms in the watershed (Cheney

Heimerman Point at Cheney Reservoir, April 2001.

Reservoir Watershed Task Force Committee, written commun., 1996). Populations of the six largest towns in the watershed range from less than 200 to slightly more than 1,200 people (Helyar, 1994). Because of the small population in the watershed, the potential for substantial point-source contamination is small as determined in a previous low-flow investigation (Christensen and Pope, 1997).

Cheney Reservoir is a water-supply source for the city of Wichita and the surrounding area. Currently (2001), the city obtains 60 to 70 percent of its daily water supply for about 350,000 people from Cheney Reservoir (Jerry Blain, city of Wichita Water and Sewer Department, oral commun., 2000). Cheney Reservoir also provides for downstream flood control, wildlife habitat, and recreational opportunities.

In 1996, the U.S. Geological Survey entered into a cooperative study with the city of Wichita to assess the occurrence and transport of selected water-quality constituents, including phosphorus, within the Cheney Reservoir watershed. As part of that study, six surface-water-quality sampling sites were established in the watershed (fig. 1). Sites 1Ð5 were located on the main stem of the North Fork Ninnescah River or its tributary streams. Sampling site 6 was located immediately downstream from the Cheney Reservoir Dam.

Sources of Phosphorus

Because the Cheney Reservoir watershed is used almost exclusively for agricultural purposes, the two major sources of phosphorus are naturally occurring soil phosphorus and phosphorus contributed from agricultural activities (fertilizers and livestock waste). Quantification of these source contributions can provide information related to the extent of agricultural effects on the occurrence of phosphorus in streams of the watershed and the potential to achieve a meaningful reduction in the amount of phosphorus transported to Cheney Reservoir. On the basis of results from a previous investigation conducted during low flow (Christensen and Pope, 1997), point-source discharges (municipal wastewater discharges) probably are not a substantial source of phosphorus to surface water in the Cheney Reservoir watershed.

Historical (1965Ð98) percentages of phosphorus transported into Cheney Reservoir from natural and agricultural sources were calculated by Pope and others (2002) (fig. 2). These calculations were performed on the basis of a comparison between a mean concentration of phosphorus in soil from 43 nonagricultural coring sites, mostly cemeteries, in and near the Cheney Reservoir watershed (fig. 1) and a mean concentration of phosphorus in reservoir bottom sediment. Cemeteries were selected for soil sampling because they represent unique locations where soils have been protected from agricultural enrichment of phosphorus for extended periods. The comparison determined an agricultural-enrichment factor of 2.9 for phosphorus. This enrichment factor indicates that the phosphorus enrichment of watershed soil from agricultural activities has resulted in the transport of 2.9 times

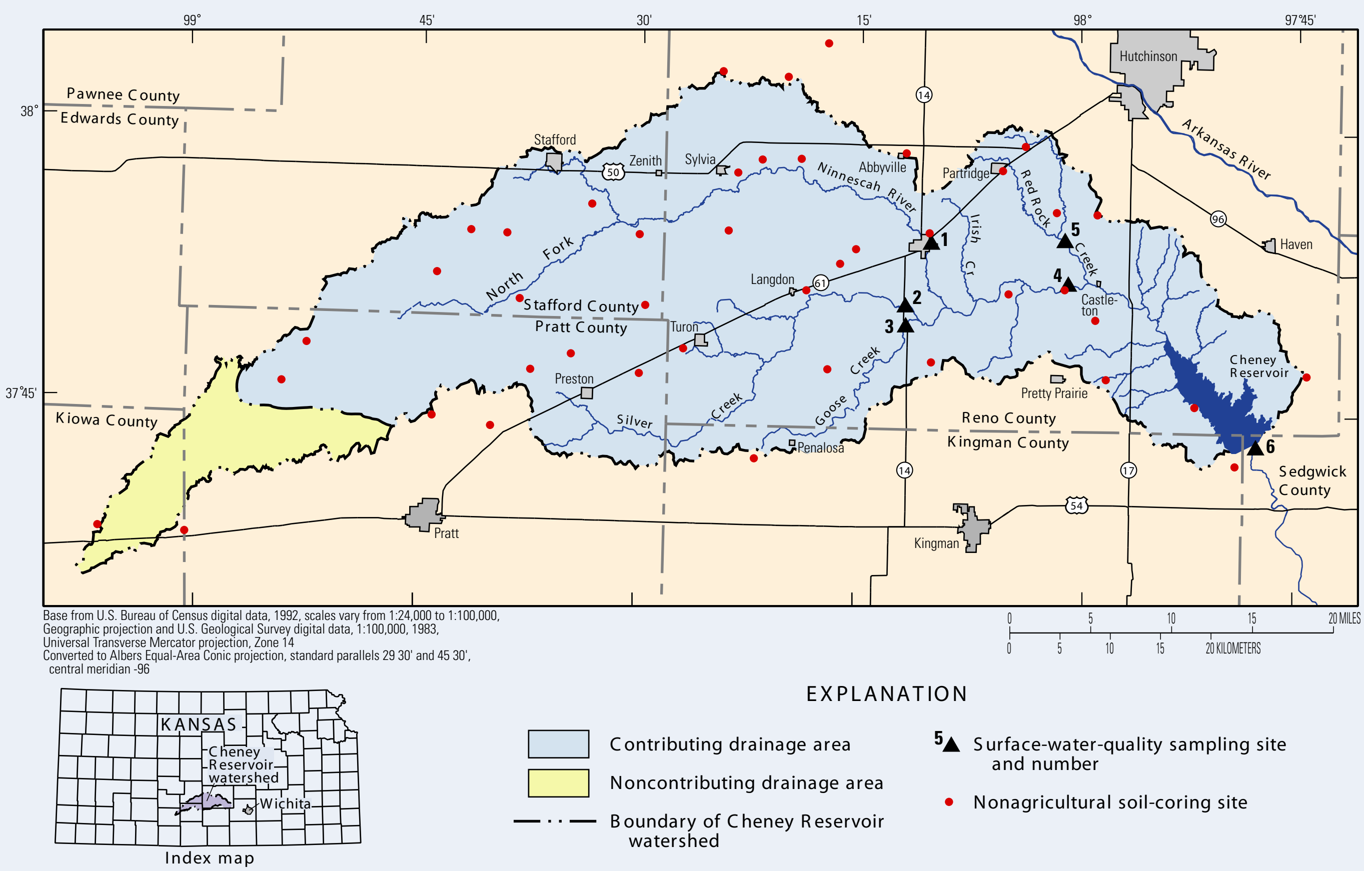

Figure 1. Location of Cheney Reservoir watershed, surface-water-quality sampling sites, and nonagricultural soil-coring sites, south-central Kansas.

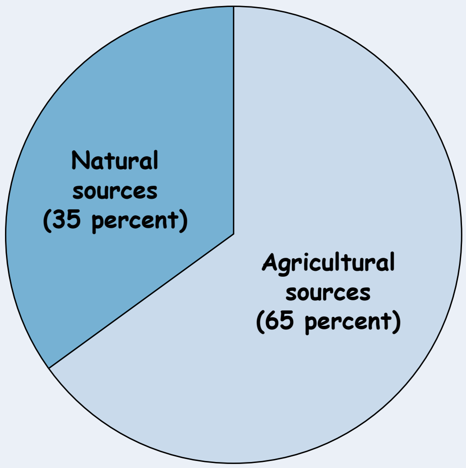

Figure 2. Percentages of phosphorus transported to Cheney Reservoir from natural and agricultural sources, 1965–98.

the amount of phosphorus to Cheney Reservoir than would have been expected under conditions where the watershed soil contained natural concentrations of phosphorus. Reference to phosphorus concentrations (soil or water) in this fact sheet denotes total phosphorus concentrations (suspended plus dissolved in the case of water).

Agricultural activities accounted for 65 percent of the phosphorus transported to Cheney Reservoir between 1965 and 1998 (fig. 2). This percentage is a historical average and may not accurately describe current (2001) conditions. However, this percentage does indicate that changes to agricultural or land-management practices that would mitigate the movement of phosphorus from agricultural fields or changes in phosphorus application and distribution in the watershed have a large potential for reducing the amount of phosphorus transported to Cheney Reservoir.

Concentrations of Phosphorus

Long-term (1997Ð2000) mean concentrations of phosphorus in water (fig. 3) were determined (Milligan and Pope, 2001) for the five surface-water-quality sampling sites upstream from Cheney Reservoir (fig. 1). These mean concentrations were calculated from the analyses of surface-water samples collected during base flow (low flow) and runoff (high flow) (table 1). On average, phosphorus concentrations were 2.0 (sampling site 2) to 4.4 (sampling sites 3 and 5) times larger in samples collected during runoff than in samples collected during base flow. Most phosphorus is transported to Cheney Reservoir during runoff. For example, at sampling site 4 (fig. 1), the main inflow site to Cheney Reservoir, it was estimated that 72 percent of the phosphorus in streamflow at this site during 1997Ð2000 was transported in runoff (Pope and others, 2002). This determination provides additional evidence that nonpoint sources (agricultural sources) are the main contributors of phosphorus in the Cheney Reservoir watershed.

Long-term (1997Ð2000) mean concentrations of phosphorus in water from the five sampling sites upstream from Cheney Reservoir (fig. 3) were 2.3 (sampling site 2) to 5.0 (sampling site 5) times larger than the 0.10-mg/L (milligram per liter) goal established by the Cheney Reservoir Watershed Task Force Committee (written commun., 1996). The 0.10-mg/L goal is the same as that recommended by the U.S. Environmental Protection Agency (1986) for limiting problems associated with nutrient enrichment of lakes and reservoirs.

The differences in long-term mean concentrations of phosphorus among the five sampling sites (fig. 3) probably is the result of a combination of natural and human-related factors. Natural factors may include differences in rainfall, topography, and soil characteristics such as texture (particle size), permeability, and erodibility. Human-related factors include land use, land management, and agricultural practices. Agricultural practices include the extent and magnitude of fertilizer applications and distribution of livestock manure. Little can be done to control the effects of the natural factors, but modifications to the human-related factors may reduce phosphorus inputs to the watershed and limit its movement to surface water.

To estimate how the watershed system might respond to reduced phosphorus inputs, the long-term (1997Ð2000) mean concentrations of phosphorus (fig. 3) were divided by the previously determined 2.9 agricultural-enrichment factor for phosphorus. This calculation, in effect, simulated (estimated) long-term mean phosphorus concentrations in the watershed under natural soil phosphorus conditions. Results of this simulation (fig. 3) indicated that even if soil in the watershed were maintained at natural concentrations of phosphorus, some streams (sampling sites 3 and 5) still would not meet the

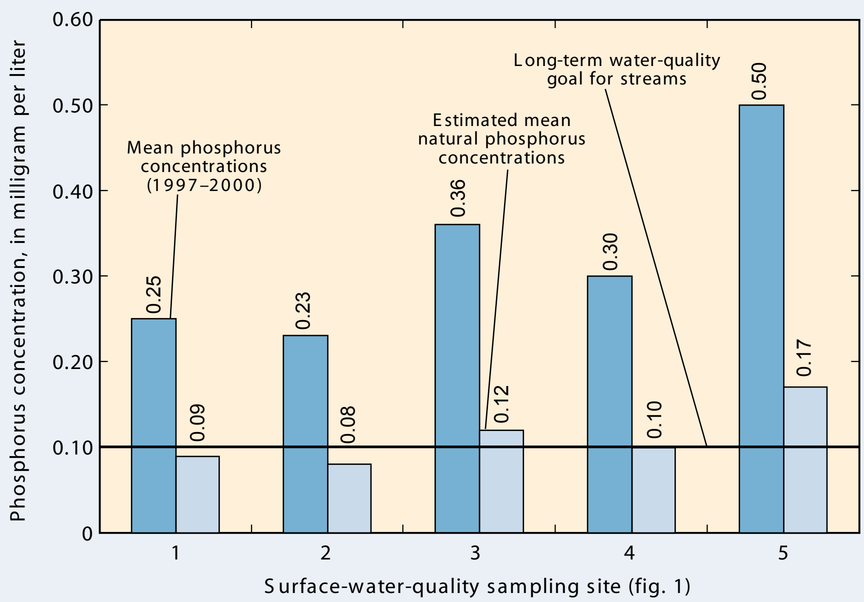

Figure 3. Comparison of mean phosphorus concentrations in water samples from five surface-water-quality sampling sites in Cheney Reservoir watershed to mean concentrations estimated on the basis of an agricultural-enrichment factor of 2.9. The long-term water-quality goal for phosphorus in streams was established by the Cheney Reservoir Watershed Task Force Committee (written commun., 1996).

Table 1. Number of samples analyzed and mean concentrations of total phosphorus in surface water during base-flow, runoff, and long-term streamflow conditions at sampling sites 1–5 in Cheney Reservoir watershed, south-central Kansas, 1997–2000

[Data from Milligan and Pope (2001). N, number of samples analyzed; mg/L, milligram per liter]

Sampling-site number (fig. 1)	Base flow		Runoff		Long term (1997–2000)	
	N	Mean concentration (mg/L)	N	Mean concentration (mg/L)	N	Mean concentration[1] (mg/L)
1	36	0.13	92	0.29	128	0.25
2	38	.14	78	.28	116	.23
3	40	.11	78	.48	118	.36
4	32	.10	85	.38	117	.30
5	37	.14	106	.62	143	.50

[1]Calculated using all available base-flow and runoff analyses.

water-quality goal of 0.10 mg/L. The implication of this finding is that reductions in the agricultural use of phosphorus alone may not provide the water-quality improvement necessary to meet the established phosphorus goal. Instead, it could involve a combination of approaches such as a reduction in use of phosphorus and more extensive implementation of land-management and agricultural practices to mitigate phosphorus loss from agricultural fields and movement to surface water.

Conclusions and Implications

Cheney Reservoir is a water-supply source for about 350,000 people in south-central Kansas and provides for downstream flood control, wildlife habitat, and recreational opportunities. As such, water quality in the reservoir is of great importance. The introduction of excessive amounts of phosphorus in the reservoir can degrade the water quality and result in treated drinking water that is aesthetically objectionable to consumers.

Agricultural activities in the Cheney Reservoir watershed have accounted for 65 percent of the phosphorus transported into Cheney Reservoir. Much of this phosphorus (72 percent) was transported by streams during runoff (high-flow) conditions. The positive implication of this large percentage of human-related phosphorus is that the possibility exists for substantial reductions in phosphorus to Cheney Reservoir through changes in human activities.

Long-term mean concentrations of phosphorus in water from five surface-water-quality sampling sites in the Cheney Reservoir watershed ranged from 0.23 to 0.50 mg/L, about two to five times the established water-quality goal for phosphorus. An estimation of mean concentrations of phosphorus at these sampling sites relative to the watershed with natural (nonagriculturally enriched) soil phosphorus conditions indicated that water from two of the five sampling sites still would not meet the water-quality goal for phosphorus. The implication of this finding is that reductions in the agricultural use or distribution of phosphorus alone may not be sufficient for some streams to meet the water-quality goal. Instead, it could involve a combination of approaches such as reducing phosphorus applications in the watershed and more extensive implementation of practices to inhibit phosphorus movement to streams.

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