OUTLOOK ON THE HIGH PLAINS AQUIFER: WHAT'S IN STORE FOR IRRIGATED AGRICULTURE?

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ABSTRACT

The High Plains aquifer is the most intensively used aquifer in the United States, providing irrigation for approximately 14 million acres of crop land. The aquifer recharges slowly in the semi-arid environment of the Great Plains, resulting in significant water level declines in parts of Texas, Kansas, Colorado, Oklahoma, New Mexico and Nebraska over the past 40 years. The recent four year drought on the High Plains, coupled with the Republican River settlement, have put increased pressure on irrigators and ground water management districts to reduce withdrawals and use irrigation water more efficiently. Changing cropping systems in response to declining pumping rates will likely result in reduced gross returns and lost revenues to rural communities. High Plains irrigators will need new crop production schemes and management tools to help sustain profitability.

INTRODUCTION

The High Plains aquifer underlies a 111-million acre area (174,000 sq mi) of the Great Plains states of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas and Wyoming. It is one of largest fresh water aquifer systems in the world and is the most intensively used aquifer in the United States, providing 30 percent of the total withdrawals from all aquifers for irrigation (Maupin and Barber, 2005).

The High Plains agricultural economy runs on water from the Ogallala. The crop, livestock and meat processing sectors are the backbone of the regional economy and provide many jobs. Irrigated crops provide feed for livestock, which are part of a large meat packing industry in the region. An estimated 15 million cattle and 4.25 million hogs are raised annually over the aquifer. Approximately 23 percent of the cropland overlying the Ogallala is irrigated, accounting for 94 percent of the total ground-water use on the High Plains (McMahon, 2000). In many rural economies, irrigated crop sales comprise 20% of gross sales for the region. Irrigated agriculture is an important buyer of inputs such as fertilizer, seed and services. Moreover, the relative value of irrigated land compared to dryland generates significant property tax base for rural governments. In a recent study of Colorado's Republican River Basin, every $1 of irrigated crop sales generated an additional 40 cents of economic activity in the local economy (Pritchett et al, 2005).

The Ogallala formation underlies 80% of the High Plains and is the principle geologic unit of the High Plains Aquifer. The maximum saturated thickness is approximately 1,400 feet, with an average of 200 feet of water bearing formation. An estimated 165,000 wells currently pump from the aquifer. The aquifer recharges very slowly in the semi-arid environment of the Great Plains, creating essentially a nonrenewable resource in many areas. Recharge rates vary from 0.024 inches per year in Texas upwards to 6 inches per year in parts of Kansas and Nebraska.

Substantial pumping over the past 40 years has led to water level declines of up to 150 feet and 50% of the saturated thickness in parts of the aquifer. While the rate of decline appears to have slowed in the past two decades due to above average precipitation, the downward trend continues in many areas, threatening the long term viability of an irrigation-based economy.

Large-scale groundwater withdrawal on the High Plains did not begin until after the drought of the 1930s. Advances in well technology beginning in the 1930s made deeper wells feasible and began the era of large-scale Ogallala aquifer development – first in Texas and then moving northward. Irrigation development over the aquifer began expanding rapidly in the 1940s and went from 2.1 million acres in 1949 to 13.7 million acres irrigated in 1980 (McGuire, 2000). Thousands of high capacity wells were drilled annually on the aquifer from the period following World War II to the 1960s. The introduction of center-pivot irrigation systems in the 1960's made irrigation of rolling terrain and sandy soils practical, resulting in more wells and irrigated acres.

Effects of Ground Water Withdrawal

Water level declines started to occur soon after the beginning of extensive irrigation, due to the imbalance between withdrawal and recharge. Water level drops of more than 100 feet declines were reported by 1980. The average water-level change for the entire aquifer from predevelopment to 2000 is a decline of 11.9 feet, with almost no change in Nebraska, S. Dakota and Wyoming to an average decline of 35 feet in Texas (Fig. 1). Water volumes in storage in the aquifer range from an increase of 4 MAF in Nebraska, to a decline of 124 MAF in Texas during the period of predevelopment to 2000 (McGuire, 2004). In general, water level declines have been greatest in the southern part of the aquifer. Texas and western Kansas have suffered the greatest declines in water table levels and saturated thickness.

In 1990, the High Plains aquifer in the eight-state area of the Great Plains contained an estimated 3.27 billion acre-feet of water, of which about 65 percent was located under Nebraska. Texas had about 12 percent and Kansas had 10 percent of the water. About 4 percent was located under Colorado, with 3.5 percent located under Oklahoma. Another 2 percent was under Wyoming and the remaining 3.5 percent of the water was under New Mexico and South Dakota (Table 1). A more recent estimate of the volume of water in the eight-state Great Plains area was 2.98 billion acre feet in storage in 2000, approx 6% less than in 1940 (Maupin and Barber, 2005).

Wells capable of pumping over 2000 gallons per minute were once common on the High Plains and high levels of pumping has resulted in substantial water-level declines in the aquifer, particularly on the fringes of the basin. An estimated 15 MAF of water is withdrawn from the aquifer for irrigation each year, while recharge is some fraction of this amount. In Colorado, Van Slyke and Dass (1999) found that the aquifer is currently being depleted at a rate of 1.5 times the rate of recharge. Annual pumping rates in their study area in northeast Colorado would need to be decreased by approximately 60% to balance recharge and withdrawal.

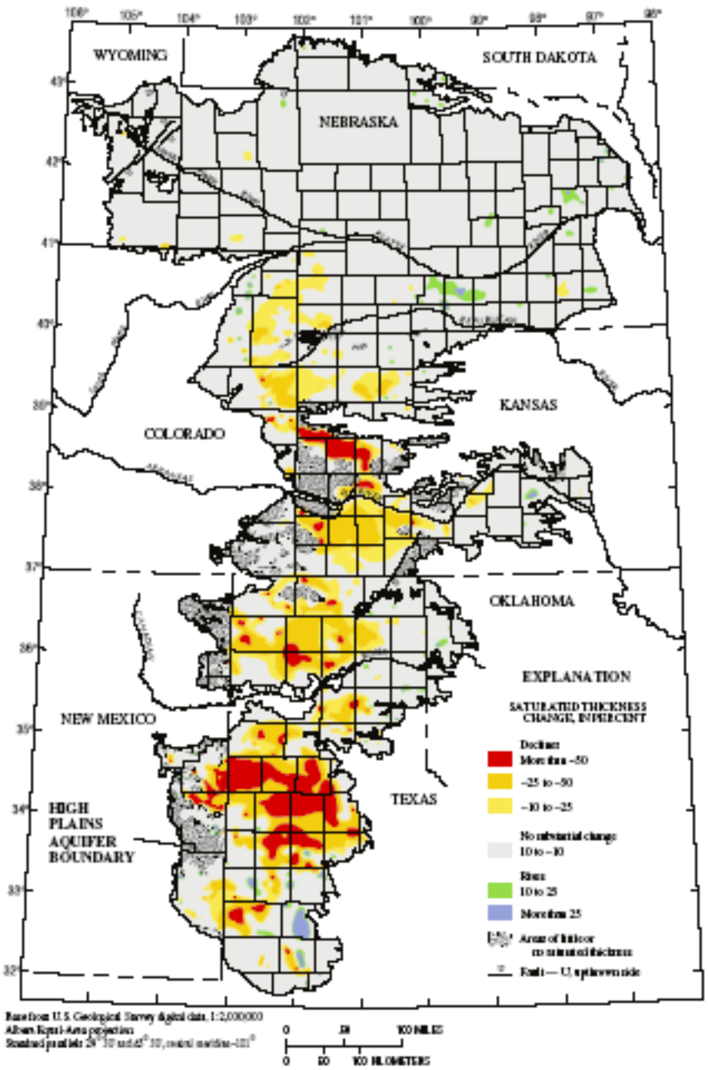

Figure 1. Percent change in saturated thickness of the High Plains aquifer, predevelopment to 2000. From McGuire et al, 2000.

The recent drought of 2001-2005 significantly impacted water levels in areas of the aquifer, with reported declines of nearly four feet per year in parts of Nebraska. During the drought year of 2002–2003, water level declines reported by USGS averaged 1.2 feet across the entire High Plains, representing an 18.9 MAF decline in aquifer (McGuire, 2004). Kansas and Nebraska suffered the greatest average declines with -1.7 and -1.3 feet change respectively. Reports of individual well declines exceeded 20 feet in some areas during the drought.

Because water-level declines in the High Plains aquifer have been large, they have substantially decreased the saturated thickness of the aquifer in some areas. As water levels decline, costs to obtain water increase as a result of the need for deeper wells, larger pumps, and increased energy to lift the water to the surface. As saturated thickness decreases, well yield also decreases and additional wells are required to maintain a constant rate of withdrawal. Reduced well capacity in most areas means lost crop production, as both irrigated acres and crop yields decline. Irrigated acres in Texas from 1964 to 1982 decreased by 44% in areas with reduced saturated thickness (Crosswhite et al., 1990). Reduced well yield means that irrigation is less effective at meeting crop water needs during peak crop water use time periods. Not only do yields decline with aquifer depletions, but yields also become more variable. The lost income and increased variability in income threatens the local economy and the future viability of the agricultural economy on local and regional scales.

Republican River Compact Litigation

In 2001, Kansas, Nebraska and Colorado entered into a year of negotiations to settle disputed claims regarding water allocation and misuse on the Republican River. The negotiated settlement included recognition of the impact of ground water withdrawal on surface water flows in the basin, resulting on a moratorium on new large capacity well drilling in most of the basin upstream of Guide Rock, NE and increased regulation on existing wells (Kansas Water Office, 2005). Compliance with the 2002 settlement under drought conditions presents a very difficult challenge. Colorado and Nebraska have struggled to meet the allocation limits specified by the 2002 settlement in each of the ensuing years and are required to meet compliance on a 5-year running average. 2006 may be a very difficult year for irrigators in the basin as they struggle to make up past water deficits and stay out of the hole for 2006. Currently, both Colorado and Nebraska are looking for ways to reduce pumping and to decommission wells to meet compliance. Farmers in the Lower Republican Basin of Nebraska will receive 33 or 36 inch allocations for 3 years, depending on location (Nebraska DNR, 2004a). In Colorado, the newly formed Republican River Water Conservation District is using an acreage surcharge and federal funds (CREP and EQIP programs) to retire wells in order to reduce irrigated acreage by a targeted 30,000 acres.

State Approaches to High Plains Aquifer Management

The eight Ogallala states all take slightly different approaches to the development and management of the aquifer. Colorado, KS, NM, OK and TX formally recognize that the aquifer is being depleted at rates in excess of recharge. Kansas, NE, WY and CO are taking steps designed to limit water level declines to maintain acceptable levels of ground water discharge to protect surface water systems. Most of the states use a combination of state law and local ground water management districts to regulate the withdrawal and development of the aquifer. While policies of "zero depletion" may sound enticing, the reality acknowledged by most states is that we are harvesting a nonrenewable resource over some agreed upon time frame. Extending the economic life of the aquifer is generally viewed as a more realistic goal.

Table 1. High Plains Aquifer area, distribution, irrigated area, and water level by state.

	CO	KS	NE	NM	OK	SD	TX	WY	Total
Aquifer Area[1] (sq. mi)	14,900	30,500	63,650	9,450	7,350	4,800	35,450	8,000	174,100
% of Aquifer Water under State[2]	4.0	10.0	65.0	1.5	3.5	2.0	12.0	2.0	100.0
Acres Irrigated using the High Plains Aquifer [3]	731,315	2,228,704	6,961,151	312,607	252,198	12,782	3,502,373	286,063	14,287,193
Groundwater Withdrawals for Irrigation[4] (acre-feet per day)	25,683	86,836	216,324	15,281	12,274	522	155,876	8,622	521,418
*Change in Water in Storage from predevelopment to 2003[5] (million acre-feet)	-13.9	-55.6	-11.4	-9.0	-11.4	-0.4	-133.0	-0.5	-235.2
*Change in Water Level from predevelopment to 2003[5] (feet)	-9.9	-18.9	-0.3	-14.4	-13.7	0.2	-36.9	-0.2	-12.6

(1) Ground Water Atlas of the United States, Miller et al., 2002.
(2) McReynolds, D., 2005, The Ogallala Aquifer, High Plains Underground Water Conservation District No. 1, www.hpwd.com/the_ogallala.asp
(3) Qi et al., 2002. Current figures for acres irrigated by state were obtained 12/02/05 from Sharon Qi, USGS.
(4) Maupin and Barber; 2005.
(5) McGuire, 2004.
*Area Weighted Average

Implications for Nutrient Managers, Extension and Research

There is evidence to suggest that irrigation practices are evolving on the High Plains to achieve increased efficiency and decreased gross withdrawals. The future rate of decline and the economic life of the aquifer depend upon a number of difficult to predict factors: the price of corn, livestock production, energy costs, state regulations, federal farm programs, and climate. If the past is any indicator of the future on the High Plains Aquifer, we should anticipate a gradual reduction in pumping rates and acreage, particularly on the fringes of the aquifer and in the Republican River Basin. Producers are likely to change irrigation and farming practices in response to new legislation, federal farm programs and declining water levels by scaling back acreage and adopting conservation measures. These conservation measures will include changes in tillage, irrigation systems, crop rotations, irrigation management, and the inclusion of dryland and limited irrigation practices on previously irrigated lands. As these changes occur, nutrient needs and gross income per acre will decrease accordingly. These shifts will have significant implications for the regional economy and for farmers. Producers will need information on nutrient management under higher residue, lower yielding scenarios. New production schemes, crops and rotations will be necessary for lower water regimes. Tools that facilitate precision application of nutrients in relation to irrigation water availability may help producers sustain profitability. Additionally, nutrient management information relative to both temporary and permanent conversion to dryland systems and perennial grassland is needed to assist farmers making these transitions.

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