# Extending the Lifespan of the High Plains Aquifer in Kansas

Presentation to
Kansas House Committee on Water
January 19, 2023

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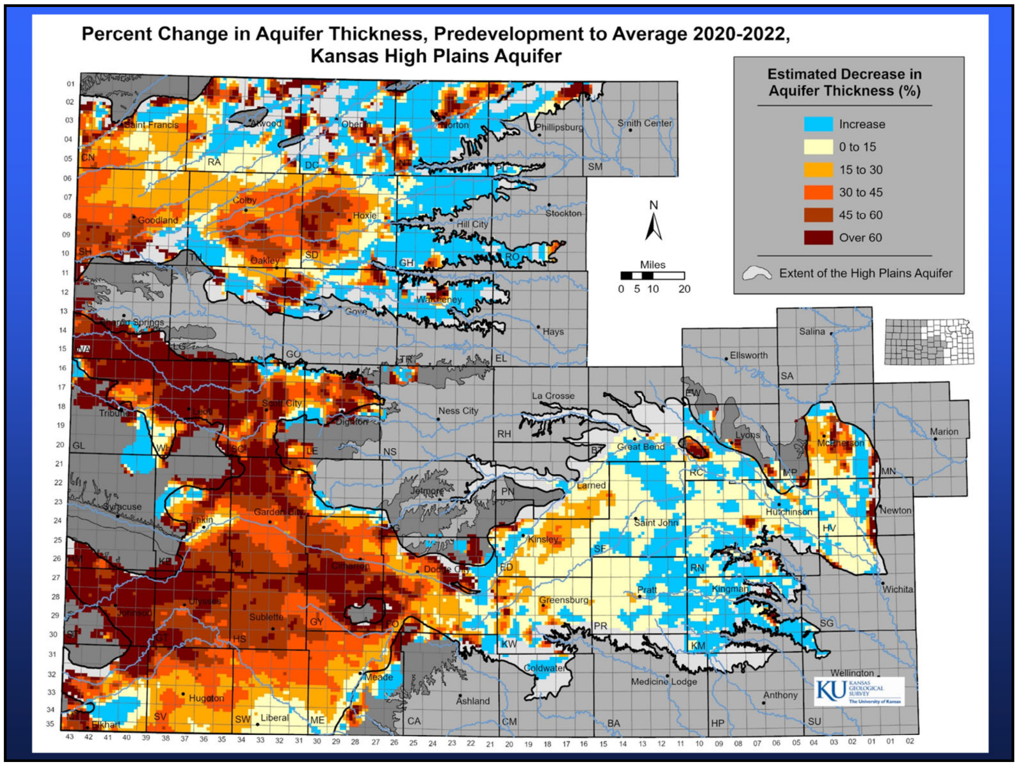
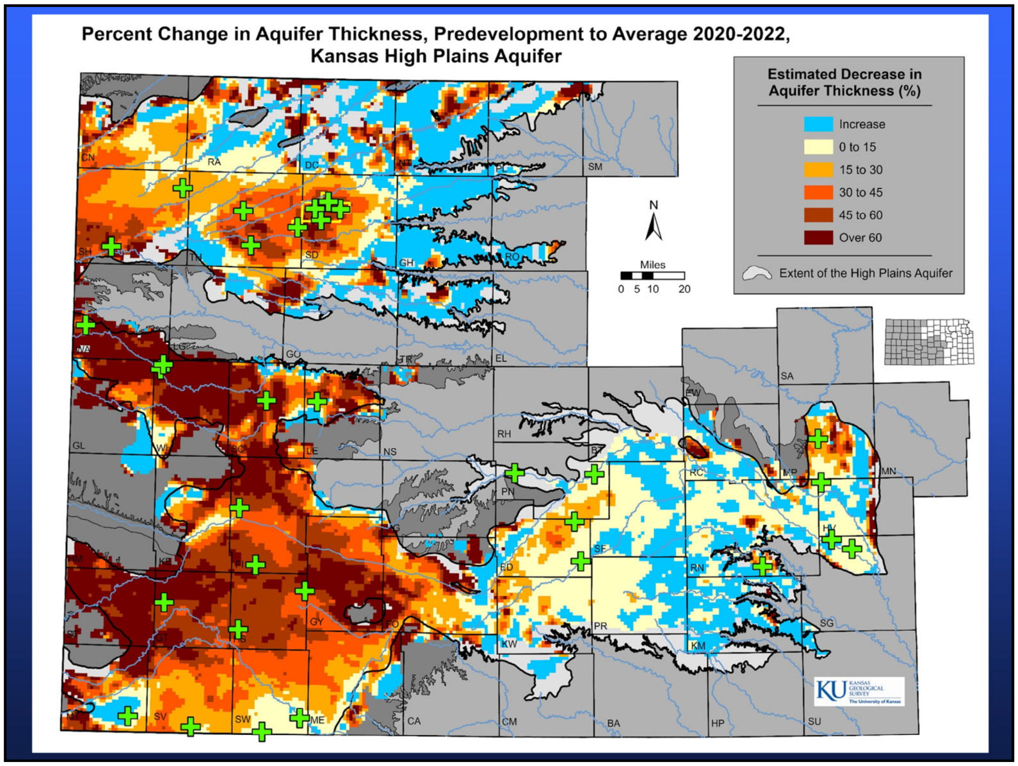
Kansas Geological Survey's briefing to the Kansas Legislature – House Committee on Water, January 19, 2023. The Kansas Geological Survey (KGS) is a research and service unit of the University of Kansas. This presentation is given by Jim Butler (jbutler@ku.edu) and prepared with the assistance of colleagues, Brownie Wilson and Don Whittemore (senior scientist emeritus). Please contact Jim if you have further questions.



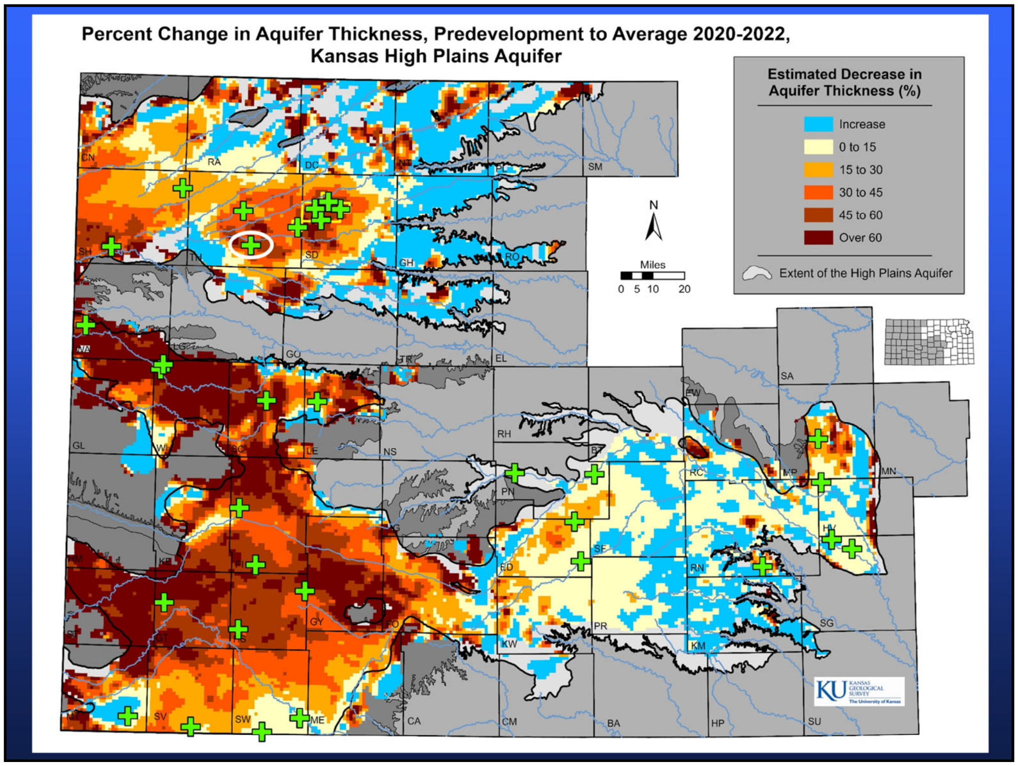

This map is the percent change in aquifer thickness from predevelopment (the period prior to the onset of widespread pumping for irrigated agriculture - late 1940s to mid-1950s) to present (average of 2020-2022 conditions). The semi-arid Ogallala portion of the High Plains Aquifer (HPA) has experienced the greatest decreases in aquifer thickness. These decreases threaten the continued viability of irrigated agriculture; in some areas, over 60% of the aquifer has been lost since predevelopment. The Great Bend Prairie and Equus Bed aquifers in south-central Kansas have had relatively small changes in aquifer thickness over the same period. The blue areas in western Kansas are areas of thin aquifer and of little practical significance.

Continuation of current decline rates will lead to near depletion within a matter of a few to several decades over much of the area in western Kansas. Given the scarcity of surface water in western Kansas, reductions in groundwater pumping are essentially the only means of moderating rates of water-table decline for the next several decades. The key question is how much does pumping need to be reduced to significantly impact the decline rates. The answer to that question requires data on pumping and water-level changes. Kansas is very fortunate to have some of the best data on pumping and water-level changes in the United States, if not the world.

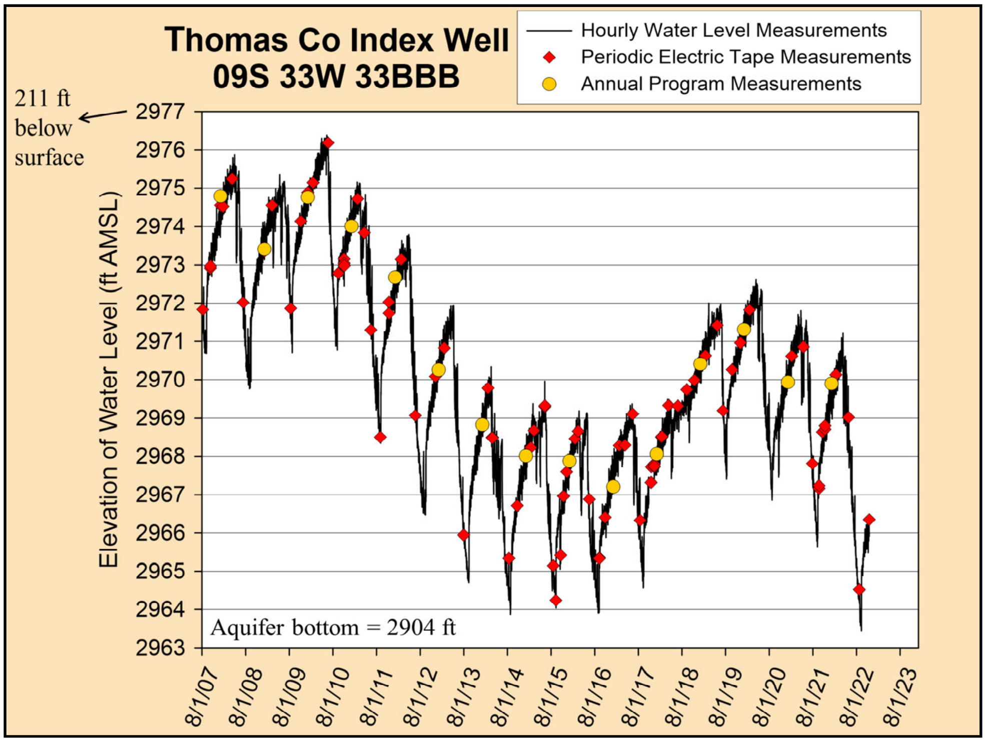



This is the percent change in aquifer thickness map along with the wells of the HPA Index Well Program (green plus signs). The index well network was initiated in the summer of 2007 through the Kansas Water Plan to enhance understanding of conditions in the High Plains aquifer. The network began with the installation of three monitoring wells, each of which had a water-level sensor (hourly measurements) connected to telemetry equipment that allows real-time viewing of water levels on the KGS website. The program has gradually expanded to the present level of 32 sites with 25 wells on telemetry. Data from the remaining wells are posted quarterly on the KGS website. The objective of the program is to maintain the network for the long term, so most wells are screened at or near the bottom of the aquifer. Sites are visited approximately quarterly for downloading and equipment maintenance. We anticipate that we will install another well in south-central Kansas (GMD5) later in the year.

The cluster of wells in Sheridan County and the well in far eastern Thomas County are in the Sheridan-6 Local Enhanced Management Area.

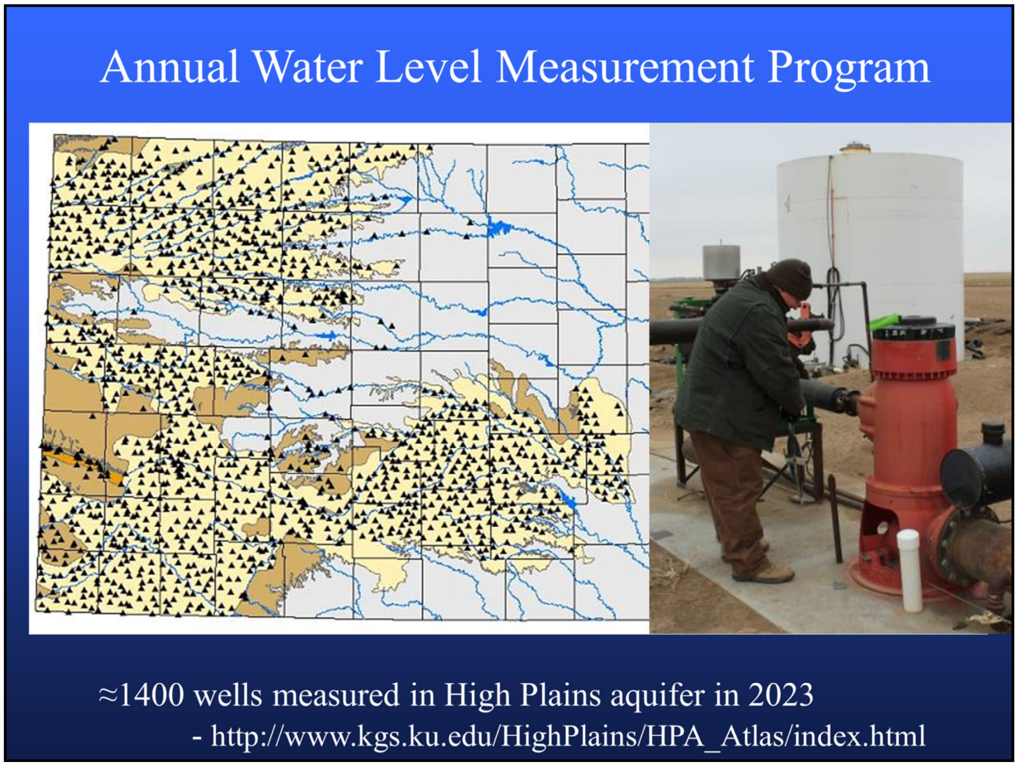



Data from the circled well in Thomas County (Thomas County Index Well) are shown on the next slide.



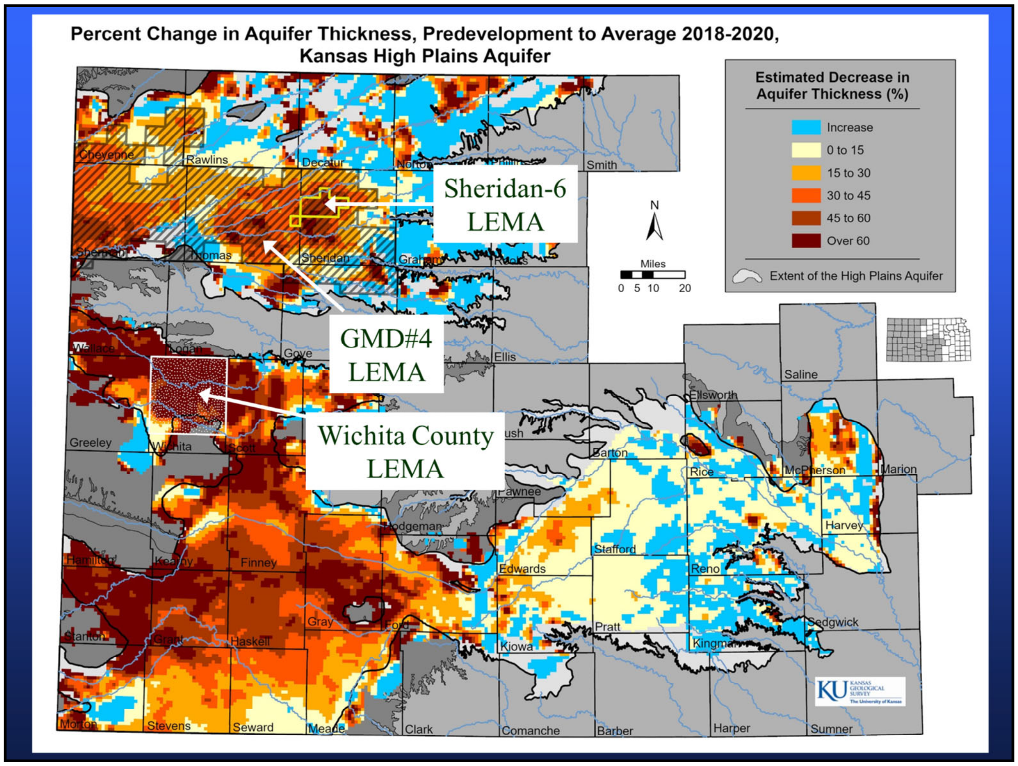

Thomas County Index Well: This is a plot (called a hydrograph) of water level elevation (left y-axis) versus time (in yearly increments) on the x-axis. Monitoring began in August of 2007 and the elevation of the water level in the well has been measured every hour with a sensor in the water column since that time (black line). The yellow circles are the winter water-level measurements taken as part of the annual water-level measurement program (based on the 1/4/23 measurement, the water level decreased 2.64 ft in 2022 – the largest decrease since monitoring began) and the red diamonds are additional manual water-level measurements to make sure the sensor is working correctly. A telemetry unit sends the sensor measurements to the KGS website where they can be viewed and served to the public in near real time.

From such hydrographs, we can get useful information about subsurface conditions and develop insights into how the aquifer might respond to conservation-based pumping reductions. At this well, there were periods during which water levels changed little from year to year (i.e. the flow into the aquifer equals the flow out) – the average annual pumping during those years is the pumping needed to stabilize water levels.



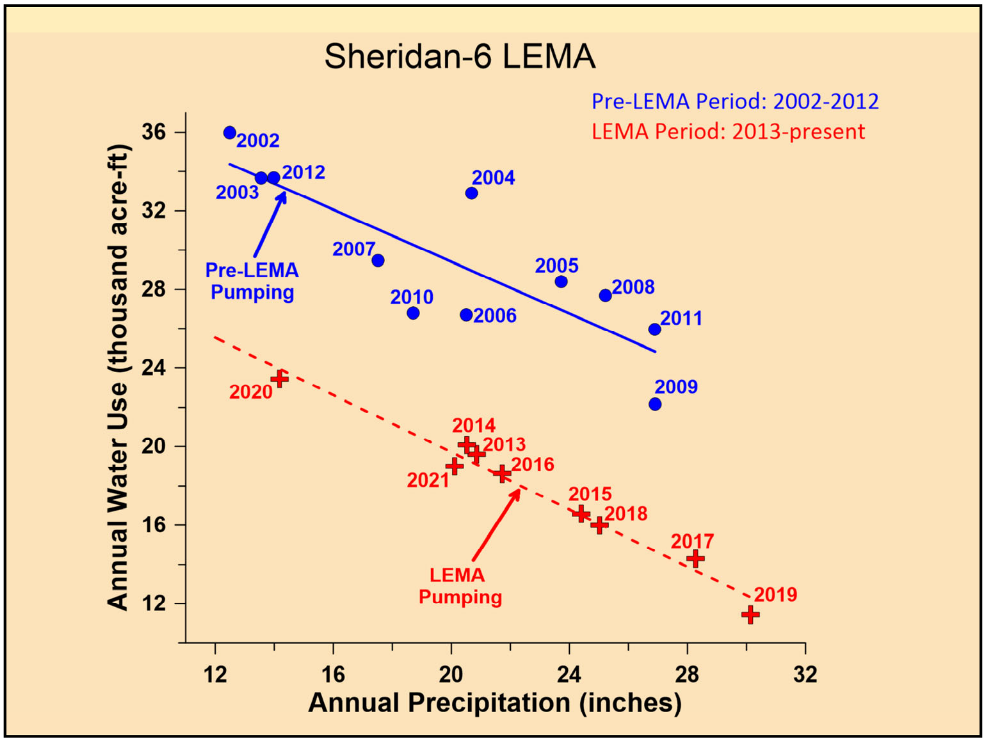

The triangles represent wells included in the Kansas Cooperative Water-Level Measurement Network. Each winter, the KGS and KDA-DWR measure roughly 1400 wells to assess regional trends and conditions in the High Plains aquifer region. The wells are measured in winter, three to four months after cessation of irrigation pumping, to minimize the year-to-year variations in the timing of the end of the irrigation season and the possibility of pumps running when wells are being measured.

These water-level data plus the metering data from the pumping wells enable us to estimate the pumping at which water levels would stabilize across the aquifer.



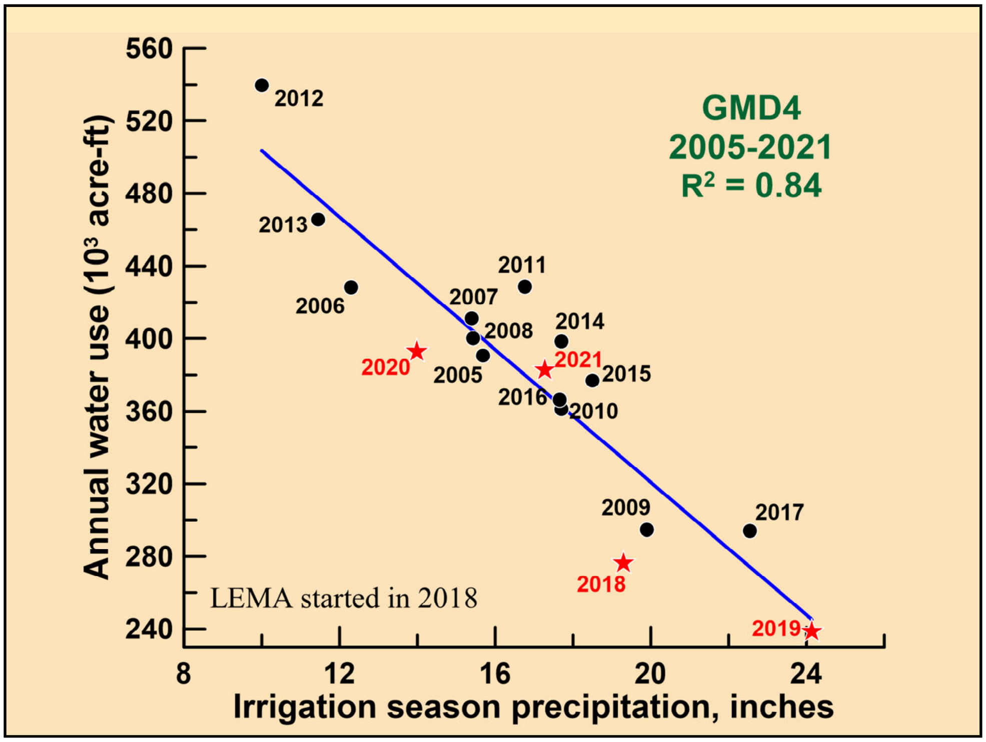

Groundwater reductions must be implemented over a relatively large area to make a significant impact on regional decline rates. Such large-scale reductions require a management framework that makes them possible. In 2012, the Kansas Legislature passed a bill that allowed a new option, the Local Enhanced Management Area (LEMA), for groundwater management in Kansas. The LEMA framework allows the development of locally generated management plans that are then supported by regulatory oversight (KDA-DWR). An additional management option, the Water Conservation Area (WCA), has been developed to further enhance the prospects for large-scale reductions in pumping.

The first LEMA, the Sheridan-6 LEMA was established in 2013 in a 99 square mile area of Sheridan and Thomas counties in GMD#4 in northwest Kansas. The success of the Sheridan-6 LEMA led to the establishment of the GMD#4 district-wide LEMA (over 4,800 square miles) in 2018 and the Wichita County LEMA in a 256 square mile area in west-central Kansas (GMD#1) that began operation in 2021. However, prior to the establishment of the Wichita County LEMA, there was a Water Conservation Area (WCA) in much of the area that began operation in 2017. A fourth LEMA, which covers the remaining four counties in GMD1 (Lane, Scott, Greeley, and Wallace), is currently being considered.



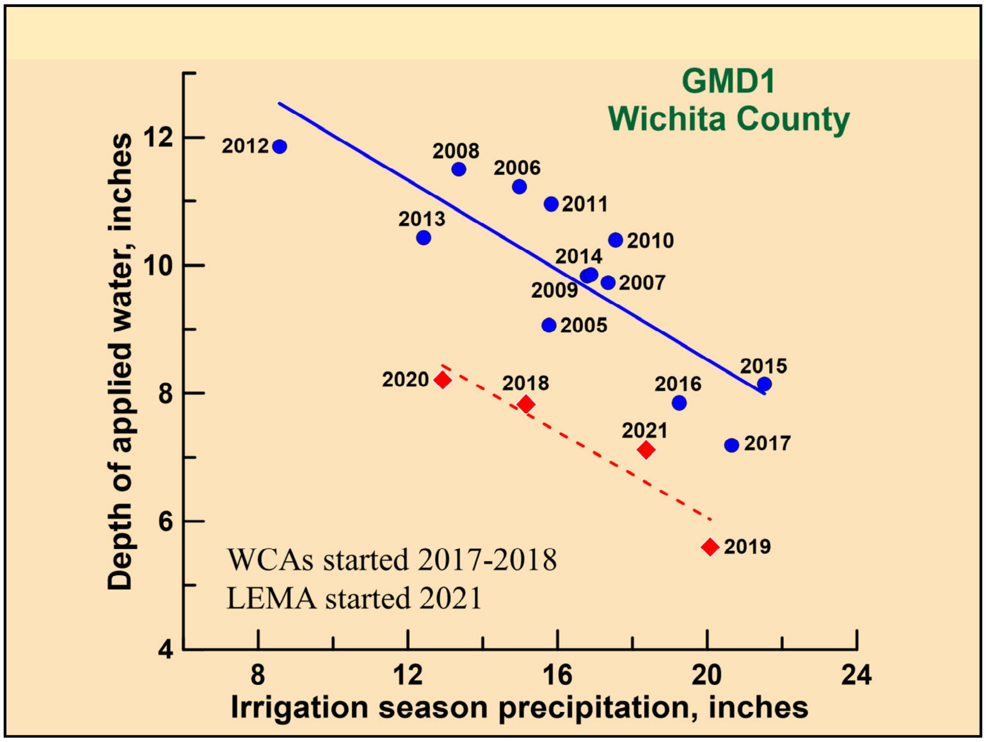

Sheridan-6 LEMA Plot: This is a plot of annual precipitation versus annual water use (pumping) from 2002-2021 using pre-LEMA (2002-2012) and LEMA (2013-2021) data.

The plot demonstrates that significant pumping reductions were achieved during the LEMA period. However, it also reveals that the pre-LEMA period was much drier than the LEMA period. Thus, efforts to quantify how much pumping has been reduced during LEMA operations must control for climatic conditions. After controlling for climatic conditions, estimates of the pumping reduction achieved in the first nine years of the LEMA range from 25-34% depending on the analysis methodology. The tighter fit for the 2013-2021 data may be a reflection of a greater awareness of irrigators, use of soil-moisture sensors, and more intensive monitoring of pumping after the establishment of the LEMA.



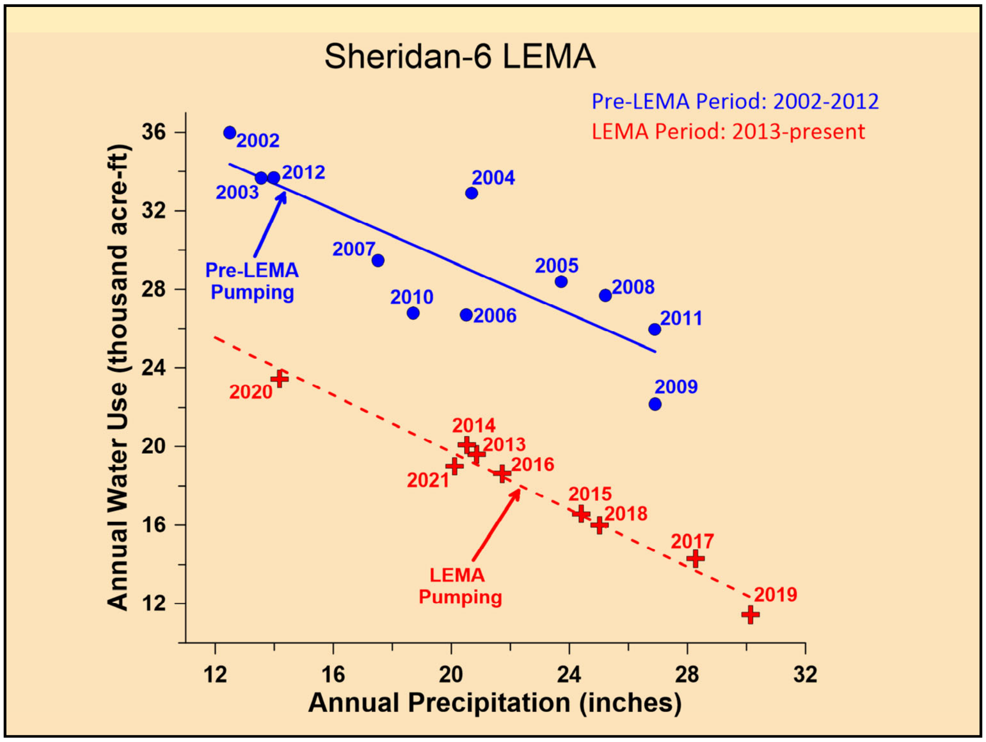

GMD4 LEMA Plot: This is a plot of irrigation season (March-Aug.) precipitation versus annual water use (pumping) from 2005-2021 using pre-LEMA (2005-2017) and LEMA (2018-2021 – red stars) data.

The plot shows little indication of water conservation associated with the LEMA as the initial round of reductions has been modest. The area of the SD-6 LEMA is only about 2% of the total area of GMD4, so the conservation activities in the SD-6 LEMA appear to have had a minimal impact on the scale of the GMD.




Wichita County LEMA Plot: This is a plot of irrigation season (March-Aug.) precipitation versus annual irrigation groundwater use/irrigated area (depth of applied water to irrigated areas) from 2005-2021 using pre-WCAs and LEMA (2002-2017) and WCAs and LEMA (2018-2021) data.

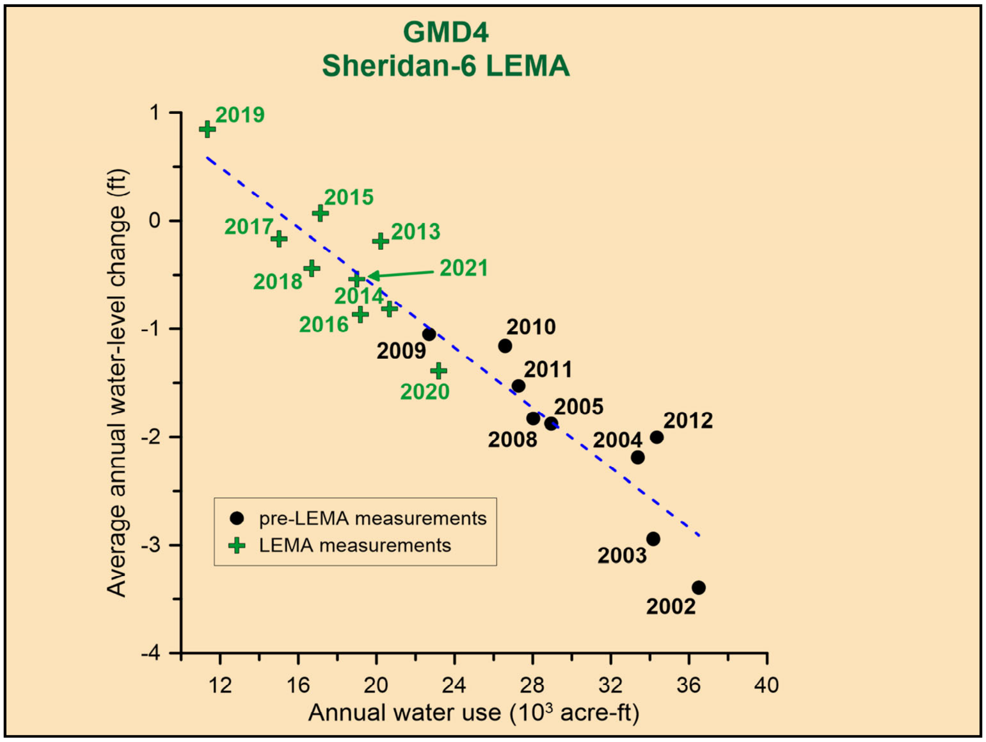
The plot demonstrates that significant improvements in water-use efficiency were achieved during the period since the WCAs became fully operational. The efficiency improvements (26%) combined with a reduction in irrigated area (15%) led to a reduction in water use of approximately 41%. It is too early to assess the impact of the Wichita County LEMA.




There are three major elements that comprise a successful LEMA.

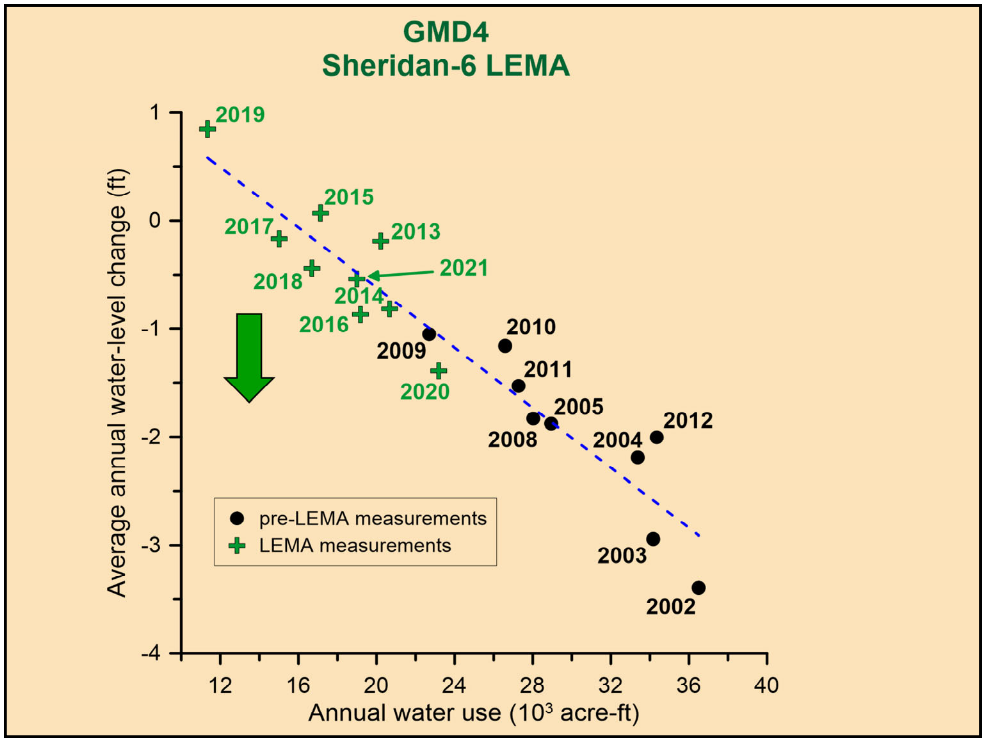
First, there has to been a significant reduction in water use as shown here in the Sheridan-6 LEMA plot. Second, there has to be a significant reduction in the water-level decline rate because that is, ultimately, the purpose of the pumping reductions. Finally, LEMA activities have to be financially viable for the producers.

The next slide illustrates how the producers in the Sheridan-6 LEMA have done in terms of reductions in the water-level decline rate.



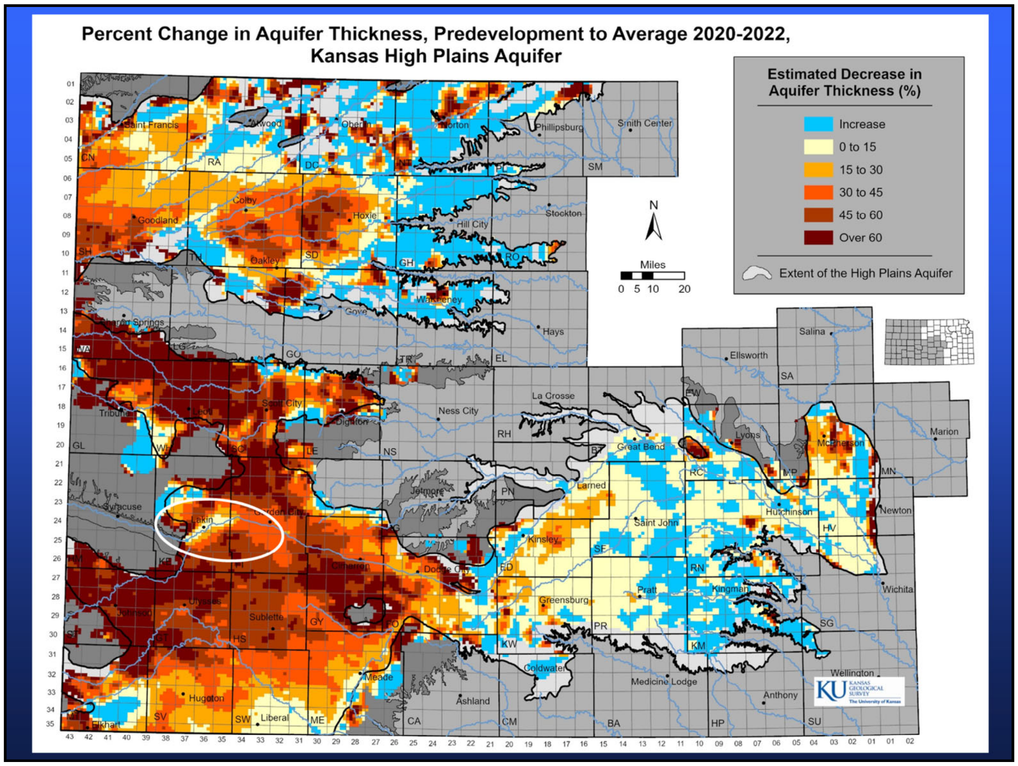

Sheridan-6 LEMA Plot: This is a plot of annual water use (pumping) versus annual water-level change from 2002-2021 using pre-LEMA (2002-2012) and LEMA (2013-2022) data.

The plot demonstrates that the LEMA activities produced a significant reduction in the water-level decline rate. Adjusting for climatic conditions, the decline rate was reduced about 58%. However, water level reductions are still occurring at an average of close to 5 inches/yr. We estimate that another 13% reduction in pumping would be required to stabilize water levels for the next several years to few decades.

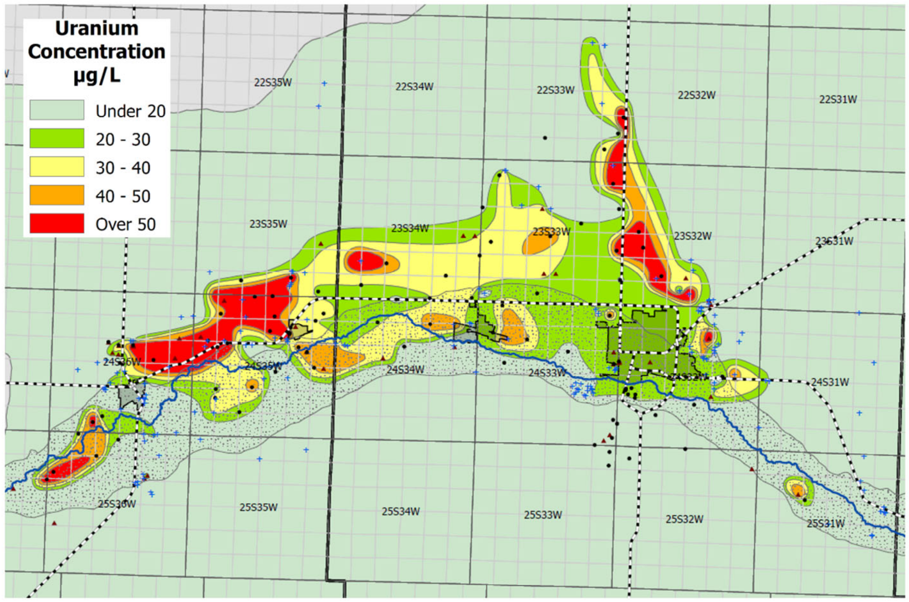



Pumping reductions will eventually diminish the net inflow as the aquifer adjusts to the new conditions. The reduction in net inflow will cause a downward shift in the data points (see green arrow) – in other words, greater drawdown for the same pumping. Thus, further pumping reductions may be necessary. However, we can recognize that condition through continued monitoring.

I am not qualified to assess the economic viability of LEMA activities. However, according to reports from producers and an economic analysis by Bill Golden at KSU, it appears that the producers have been able to implement the reductions without influencing their bottom line.



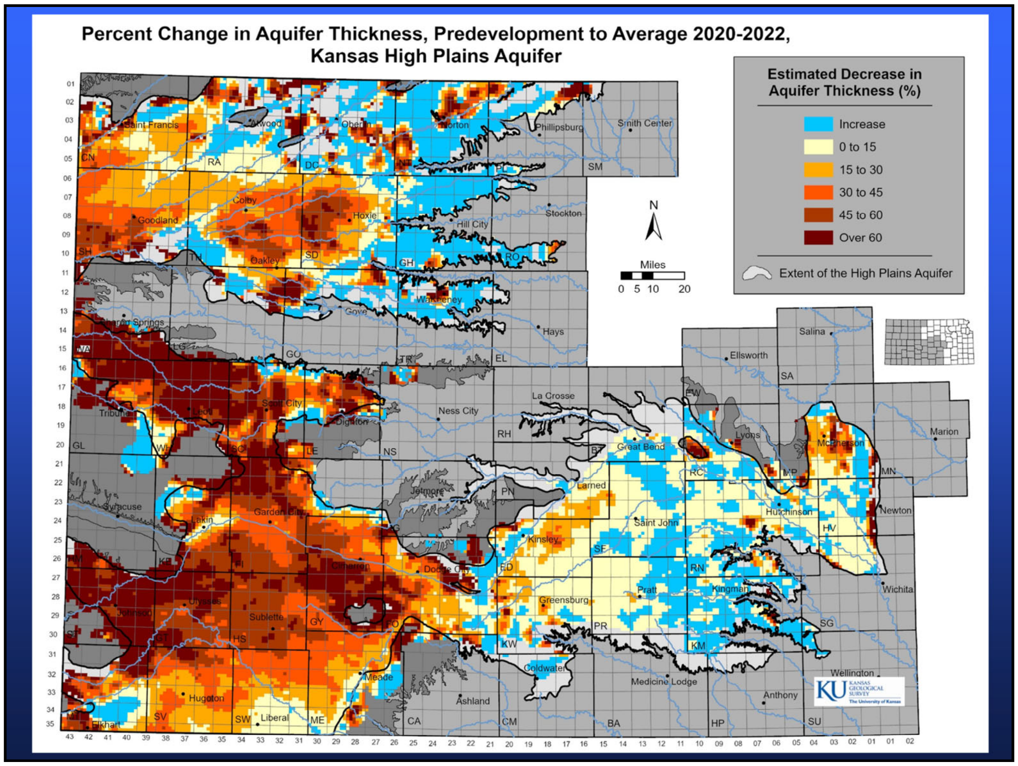

This is the percent change in aquifer thickness map highlighting the portion of the Arkansas River near Garden City. Note that between Lakin and Garden City, the portions of the HPA north of the river appear to have been less affected by pumping than areas away from the river. A major reason is that the river water is recharging the aquifer either directly through the bottom of the river channel or via the network of irrigation canals. The problem is that water is of low quality.



Uranium Concentration in Arkansas River Corridor from Lakin to Garden City.

River water recharge has contaminated the HPA to uranium levels that exceed the MCL for drinking water in a large area north of the Arkansas River and west of Garden City. The area of contamination will only increase with time as saline river water continues to recharge the HPA. This figure shows the results of studies by the KGS and KDHE of uranium levels in groundwater. The maximum contaminant level for uranium is 30 micrograms/liter.

The KGS is finalizing a report on the uranium and sulfate concentrations in this area. That report should be released this February.




Final Comments:

Water Quantity – This map of the percent change in aquifer thickness from predevelopment shows the challenges that we are facing in the High Plains aquifer in western Kansas. Pumping reductions, in coordination with modification of agricultural practices, appear to be the only option over the next several decades for extending the lifespan of this vitally important resource. KGS researchers have developed methods for estimating the impact of pumping reductions on water-level decline rates and those methods are being used to develop LEMAs and WCAs in western Kansas.

Water Quality - The quality of the water of the High Plains aquifer is generally good (total dissolved solids [TDS] of less than 500 mg/l; water with a TDS concentration of less than 1,000 mg/l is considered fresh). Areas of higher TDS concentration are, for the most part, derived from natural sources, although evapotranspiration from surface waters and irrigation activities can increase concentrations to much higher than natural levels as shown in the previous slide. High TDS concentrations in parts of eastern GMD5 and along the Arkansas River valley in GMD2 are derived from saltwater produced by dissolution of salt in the underlying bedrock, whereas small areas of higher TDS concentrations in GMD2 north of the Arkansas River have higher chloride derived from oilfield-brine contamination. High levels of nitrate can be found across the High Plains aquifer; GMDs 2 and 5 are most vulnerable to nitrate contamination because of the shallow depths to water in those areas.

KANSAS GEOLOGICAL SURVEY

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# The High Plains Aquifer

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## Introduction

The High Plains aquifer, which includes the well-known Ogallala aquifer, is the most important water source for much of western and central Kansas (fig. 1), supplying 70% to 80% of the water used by Kansans each day. The majority of water from the High Plains aquifer is used to support irrigated agriculture, but the aquifer's water is also the primary source of supply for the region's cities, industry, and rural domestic uses.

However, large-volume pumping from this aquifer has led to steadily declining water levels in the western portion of the region, and the area faces several critical water-related issues. This Public Information Circular describes the High Plains aquifer, the effect of decades of large-volume pumping, and some responses to water issues in western Kansas.

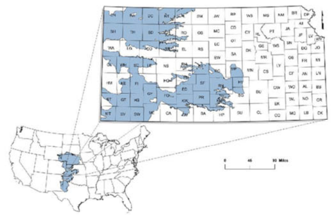

*Figure 1. The High Plains aquifer in Kansas.*

## The High Plains Aquifer Defined

Aquifers are underground deposits of permeable rock or sediments (silts, sands, and gravels) from which water can be pumped in usable quantities. The High Plains aquifer lies beneath parts of eight states in the Great Plains, including about 30,800 square miles of western and central Kansas (fig. 1). It is a regional aquifer system composed of several smaller units that are geologically similar and hydrologically connected—that is, water can move from one aquifer to the other.

Aquifer characteristics are determined in large part by geology. The High Plains aquifer is composed mainly of silt, sand, gravel, and clay—rock debris that washed off the face of the Rocky Mountains and other more local sources over the past several million years. The aquifer varies greatly from place to place: thick in some places, thin in others; permeable (able to transmit water easily) in some places, less so in others. Where the deposits are thick and permeable, water is easily removed and the aquifer can support large volumes of pumping for long periods. In most areas, this water is of good quality.

An important component of the High Plains aquifer is the Ogallala aquifer, found generally in the western third of Kansas. In some locations (such as around Lake Scott State Park in Scott County), the Ogallala Formation crops out at the surface, forming a naturally cemented rock layer called mortarbeds. In the subsurface, the Ogallala consists of sands and gravel interlayered with silt and clay beds that are mostly unconsolidated, or not naturally cemented together.

The south-central extension of the High Plains aquifer is composed of younger sediments that are similar to the Ogallala. These younger sediments, deposited during the Pleistocene Epoch, or Ice Ages, include the Equus Beds aquifer (in McPherson, Reno, Harvey, and Sedgwick counties) and the Great Bend Prairie aquifer (in Stafford, Edwards, Pratt, Kiowa, and other counties). Also lying above the Ogallala Formation are other Pleistocene deposits and other younger deposits in the valleys of modern streams. Where these stream deposits (known as alluvium) are connected to the Ogallala or Pleistocene aquifers, the alluvial aquifers are considered part of the High Plains aquifer (fig. 2).

Beneath the High Plains aquifer is much older, consolidated bedrock, usually limestone, sandstone, or shale. In some places, this bedrock yields enough water to a well to be called an aquifer, and it may be connected to the overlying aquifer. Layers of permeable sandstone in the Dakota Formation, for example, are connected to the High Plains aquifer in parts of southwestern and south-central Kansas. Some layers of the underlying bedrock contain saltwater; where these are directly connected to the High Plains aquifer, they pose a threat to water quality.

## Water Resources in the High Plains Aquifer

Usable water in the High Plains aquifer is in the very small pore spaces between sediment particles. This water (called groundwater) accumulated slowly—

This is the recent revision of the KGS Public Information Circular on the High Plains aquifer. The circular is in the process of being printed and will be provided to the committee by mid-February.


Please contact Jim Butler via phone (785-864-2116) or email (jbutler@ku.edu) if you have further questions.

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