Charting paths forward for the High Plains aquifer in Kansas

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Kansas Geological Survey
University of Kansas

WRRC Water Webinar
Water Resources Research Center
University of Arizona
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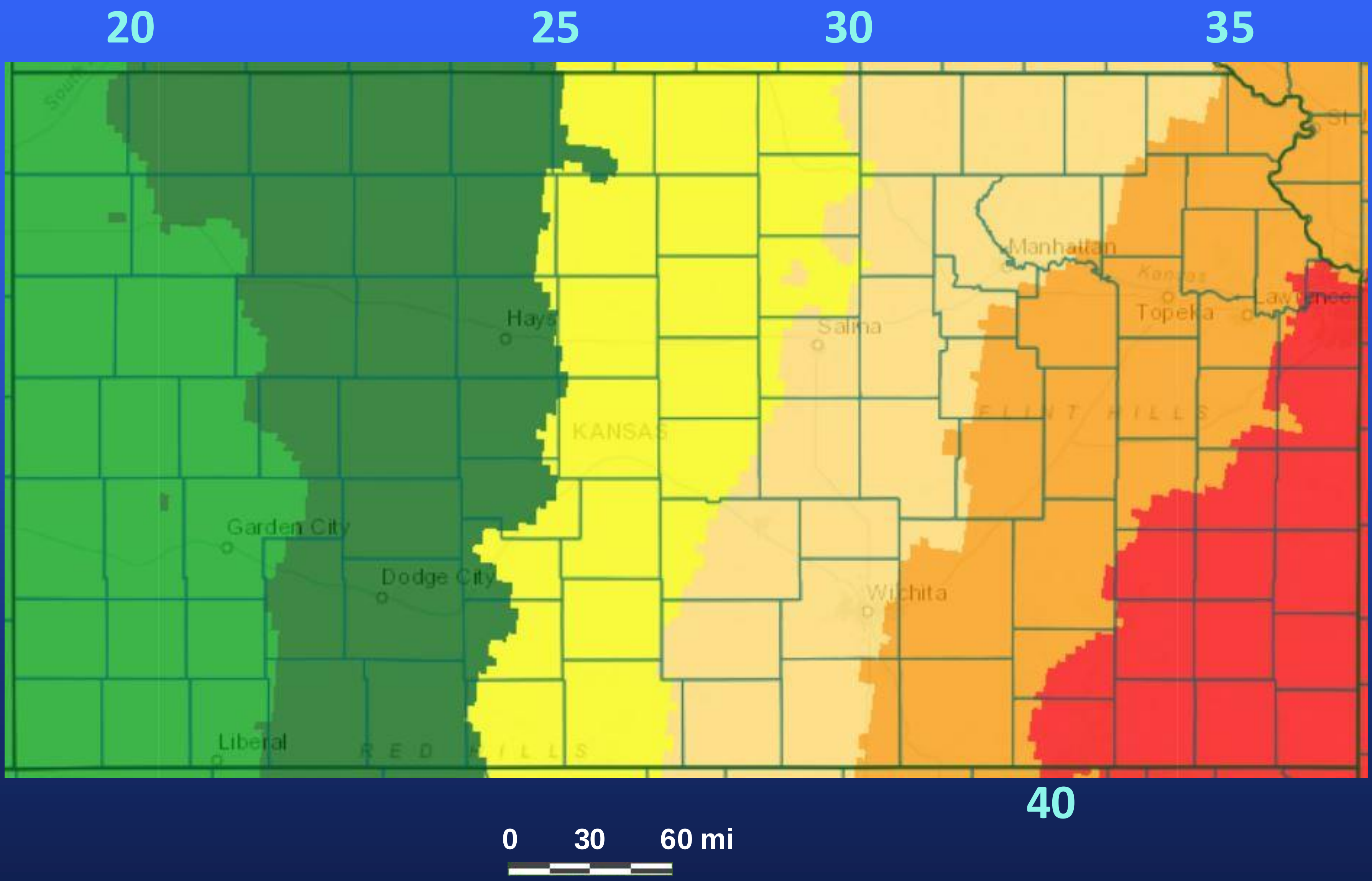
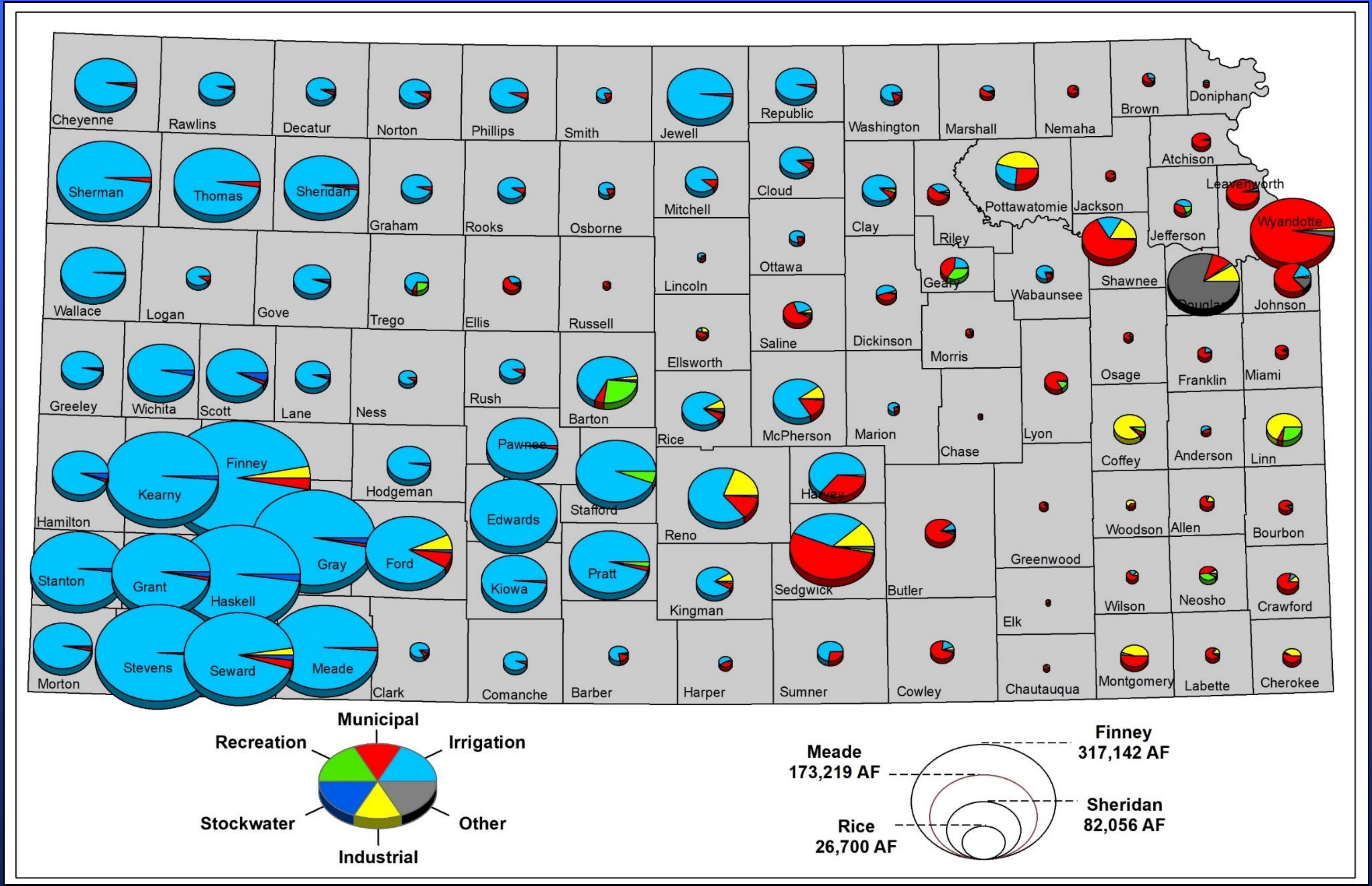
Average Annual Precipitation

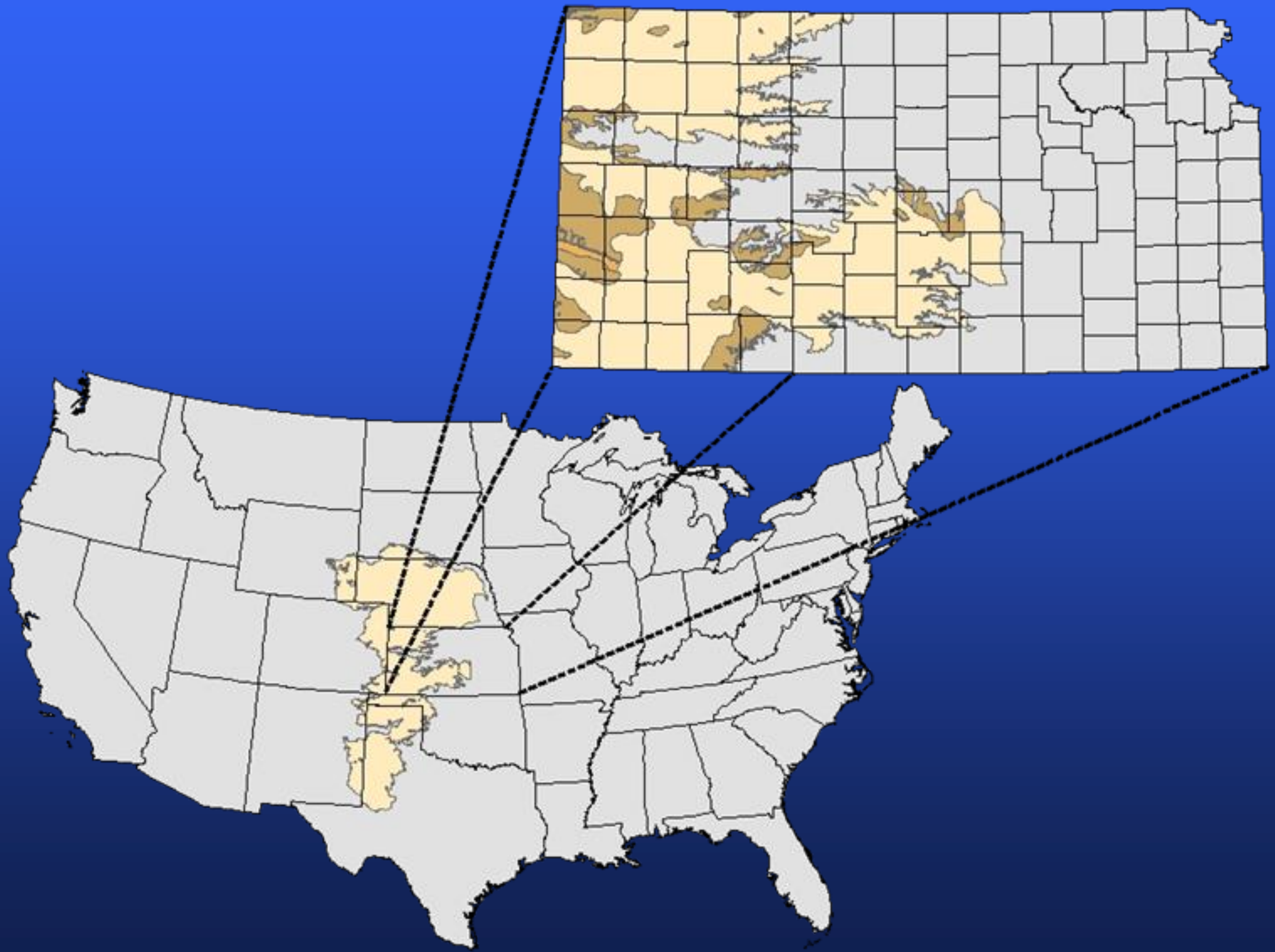
inches



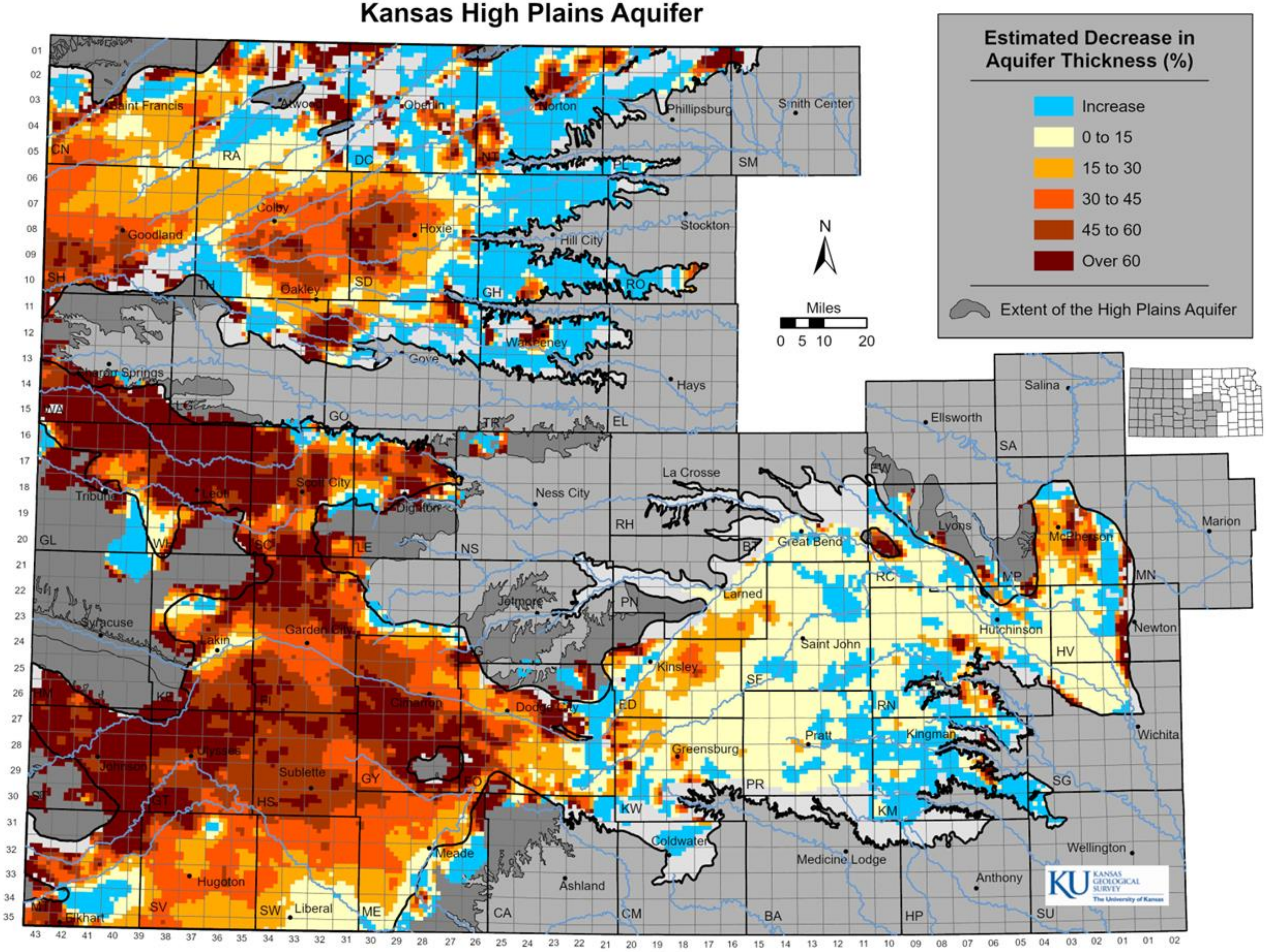
Average Reported Use of Water



The High Plains Aquifer



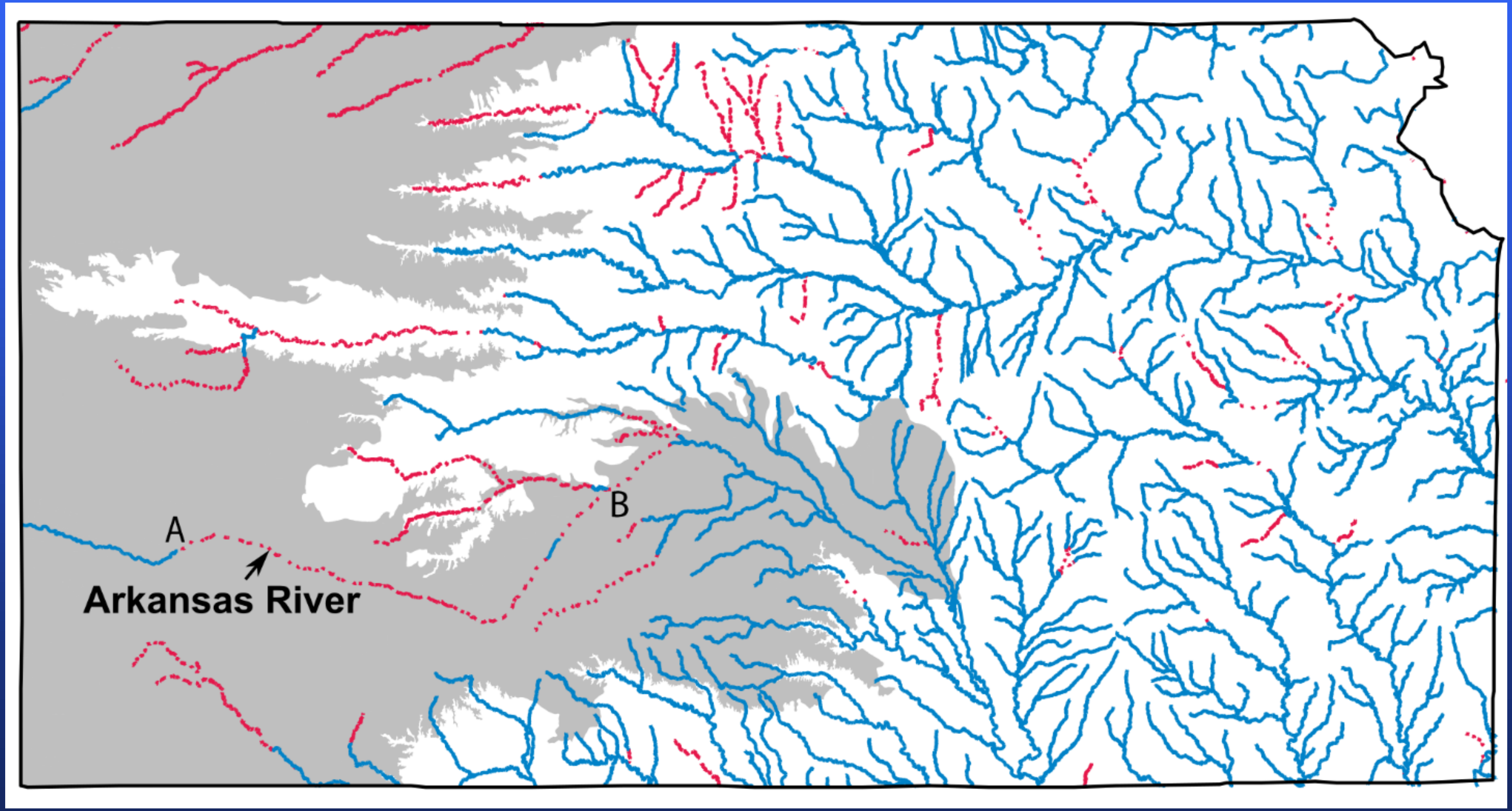
Percent Change in Aquifer Thickness, Predevelopment to Average 2022-2024, Kansas High Plains Aquifer



Major Perennial Streams in Kansas as of 1961

blue line – perennial stream in 1961 and in 2009

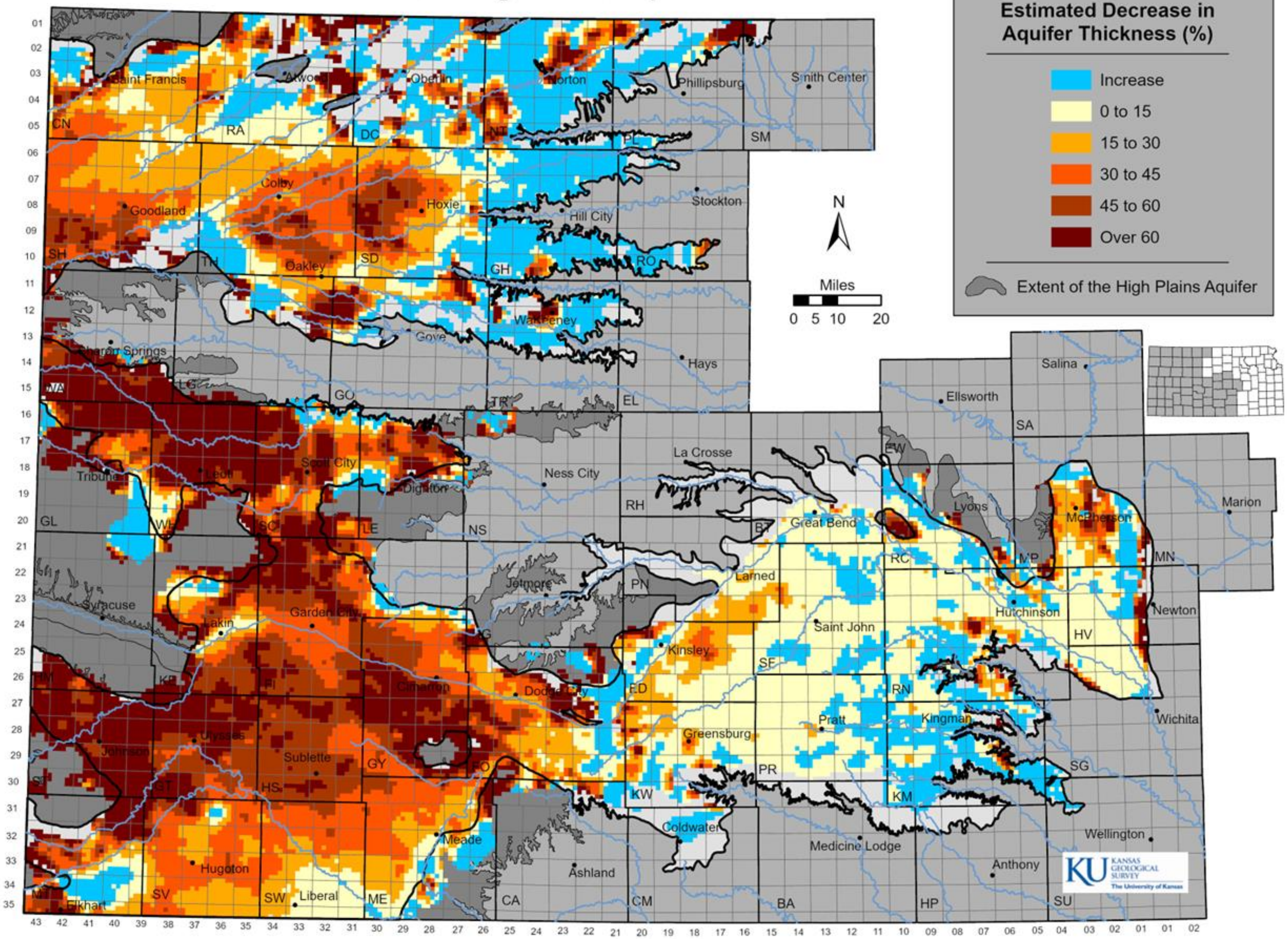
dashed red line – perennial in 1961 but not in 2009

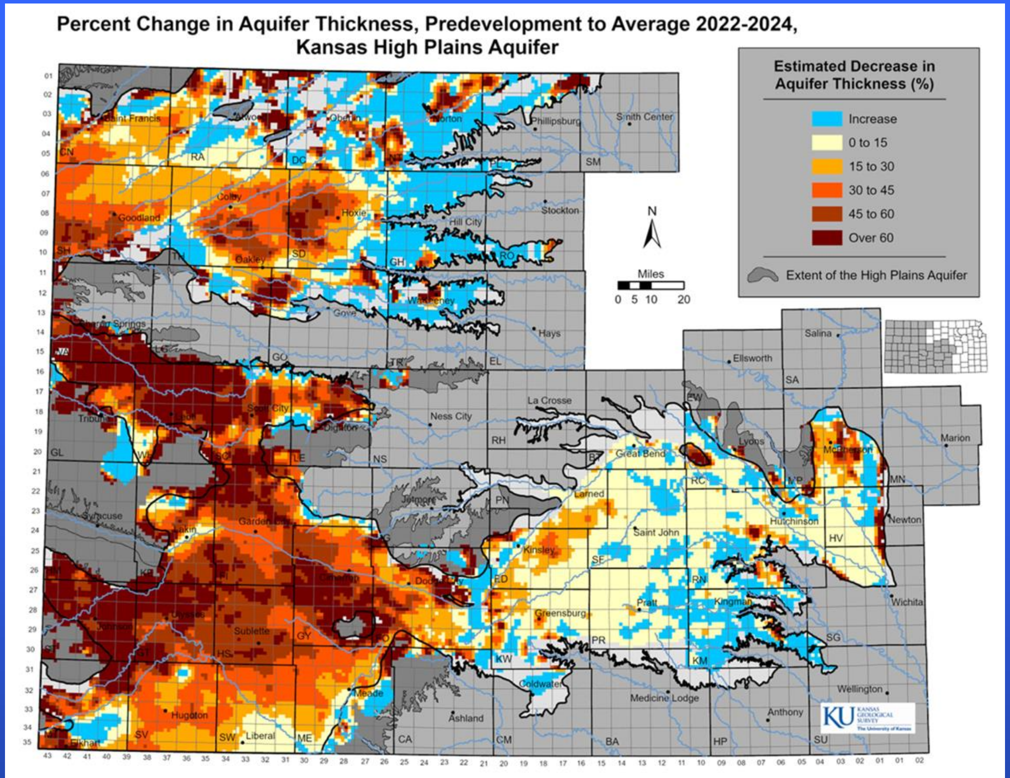


Kansas extends 410 miles east-west at its widest point.

after Zipper et al. (2021)

Percent Change in Aquifer Thickness, Predevelopment to Average 2022-2024, Kansas High Plains Aquifer





1. Replace groundwater with surface water
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- no local source
- long-distance transfers

2. Subsidies for water-efficient equipment
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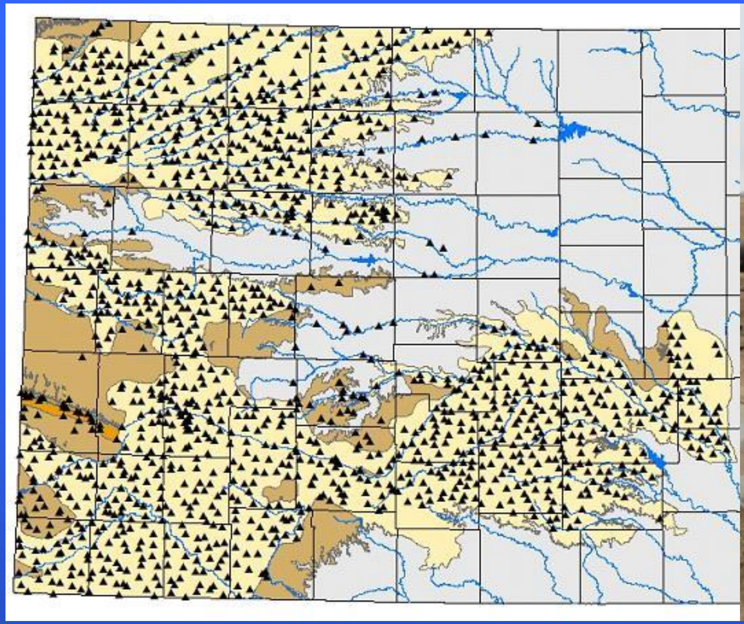
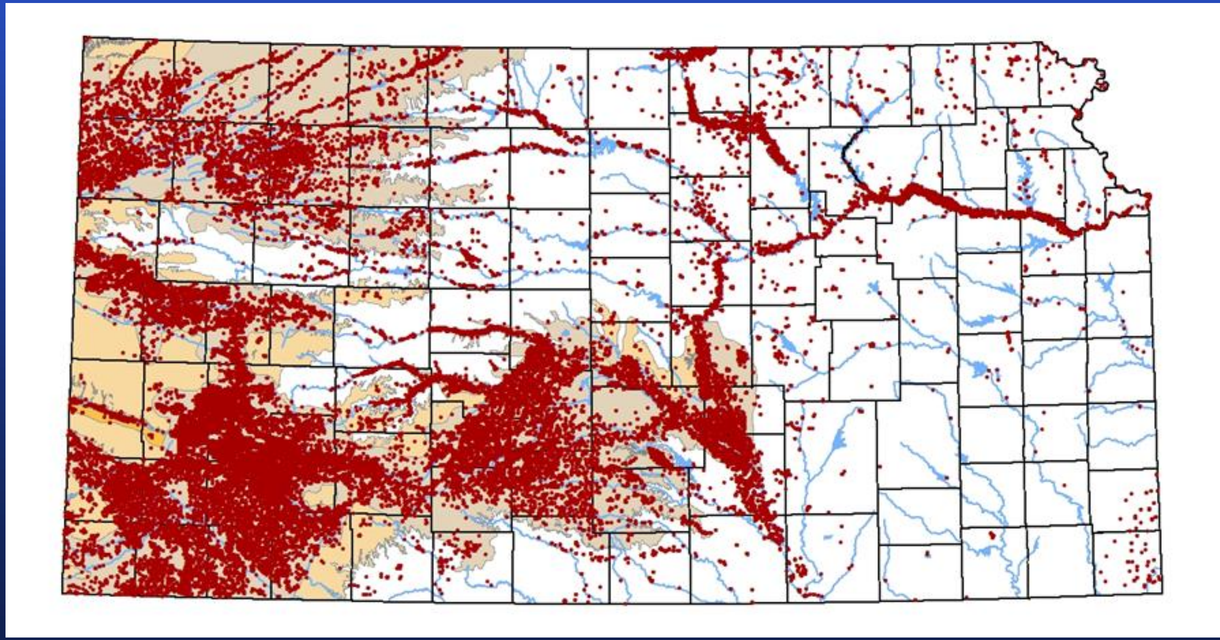
- intuitively appealing
  - but…

3. Pumping reductions with modifications of agricultural practices



Annual Water Level Data

≈1400 wells measured in the Kansas High Plains aquifer in 2024

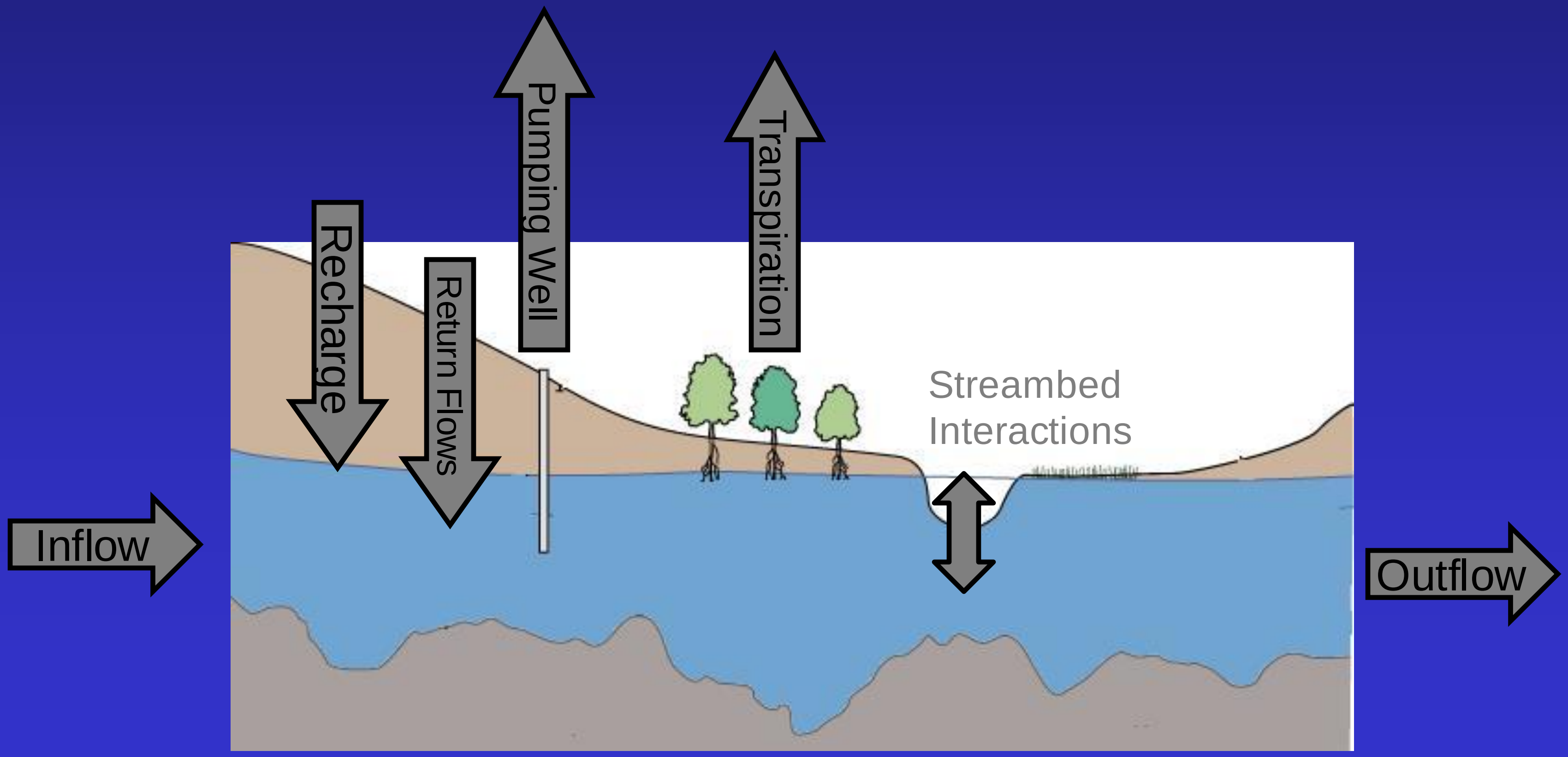


Annual Groundwater Pumping Data

As of 2022, 99+% of the non-domestic pumping wells in the High Plains aquifer in Kansas had totalizing flowmeters.

Aquifer Water Balance

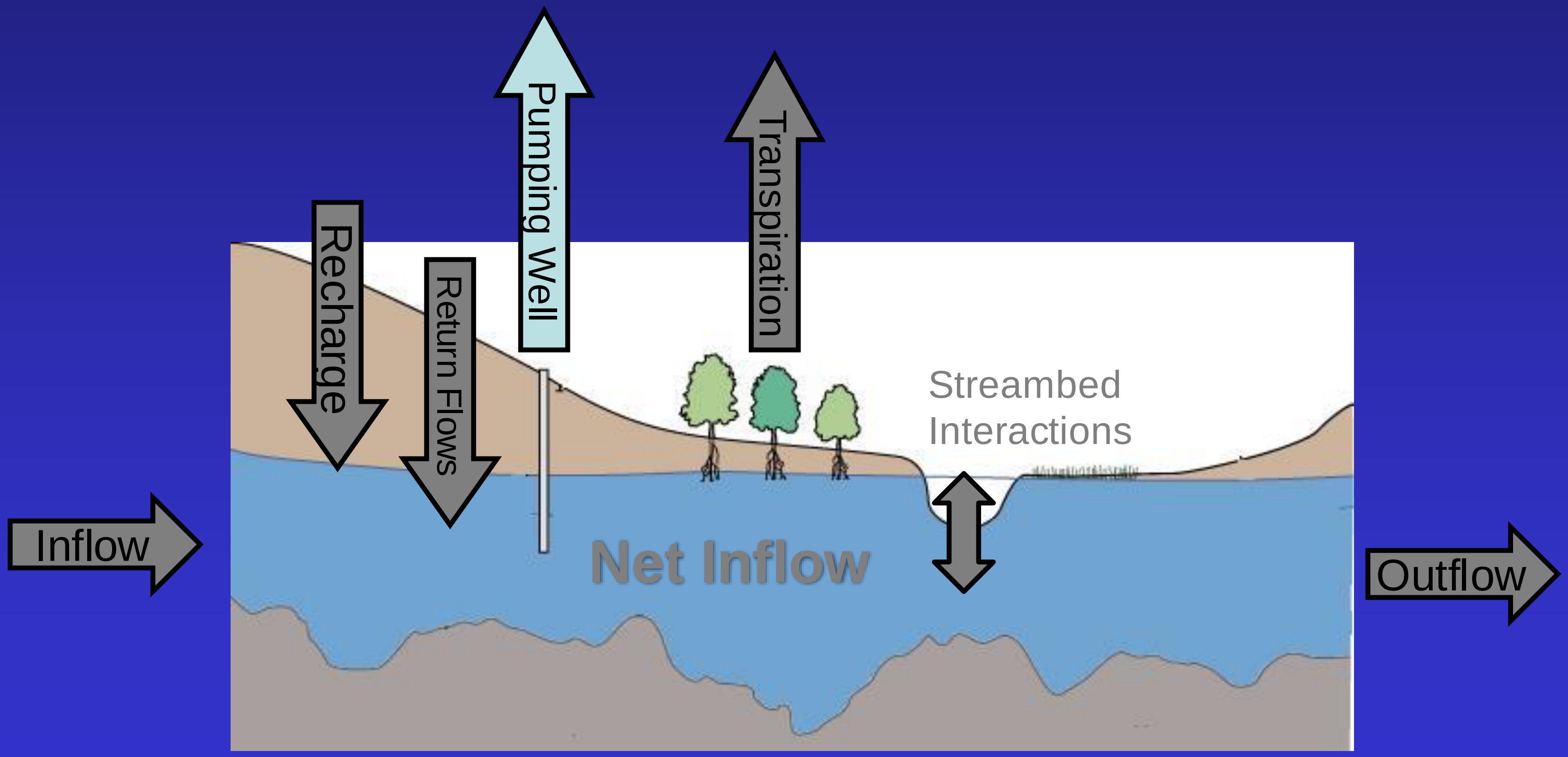
Water Volume Change in Aquifer = Inflows – Outflows

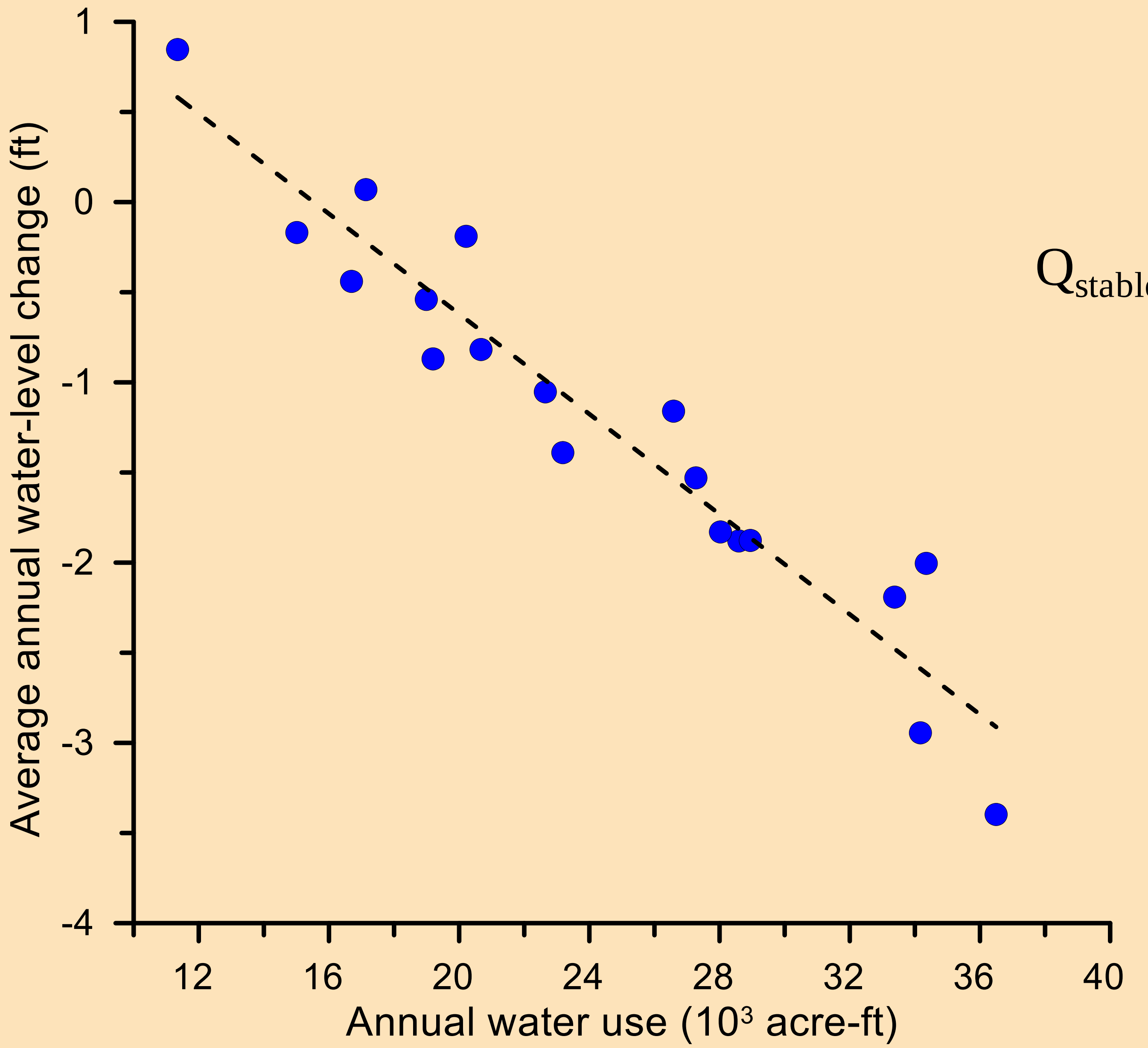


Aquifer Water Balance

Water Volume Change in Aquifer = Net Inflow – Pumping

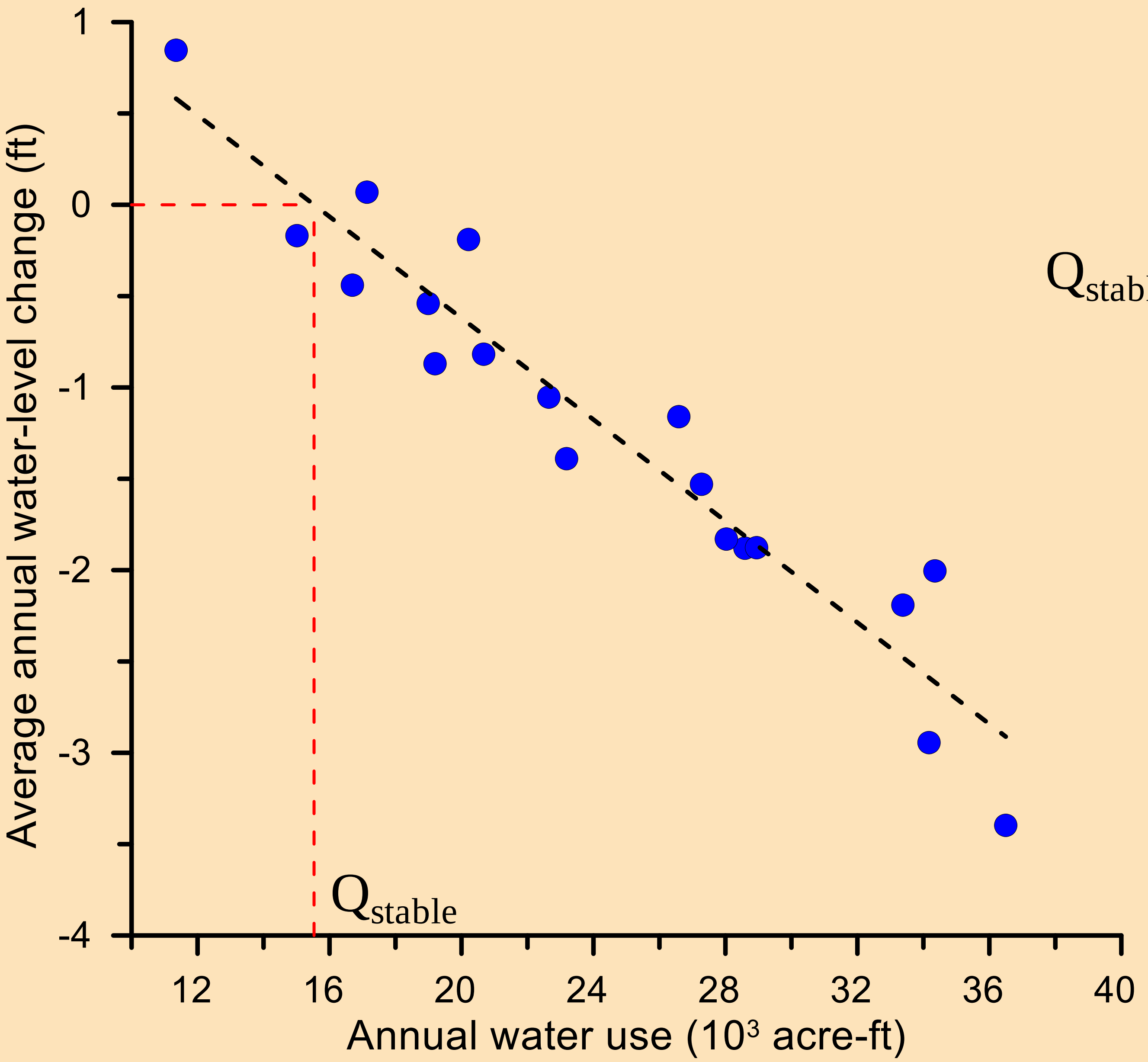
Net Inflow = Pumping at Stable Water Levels = Q_{stable}





Q_{stable} = intercept/slope

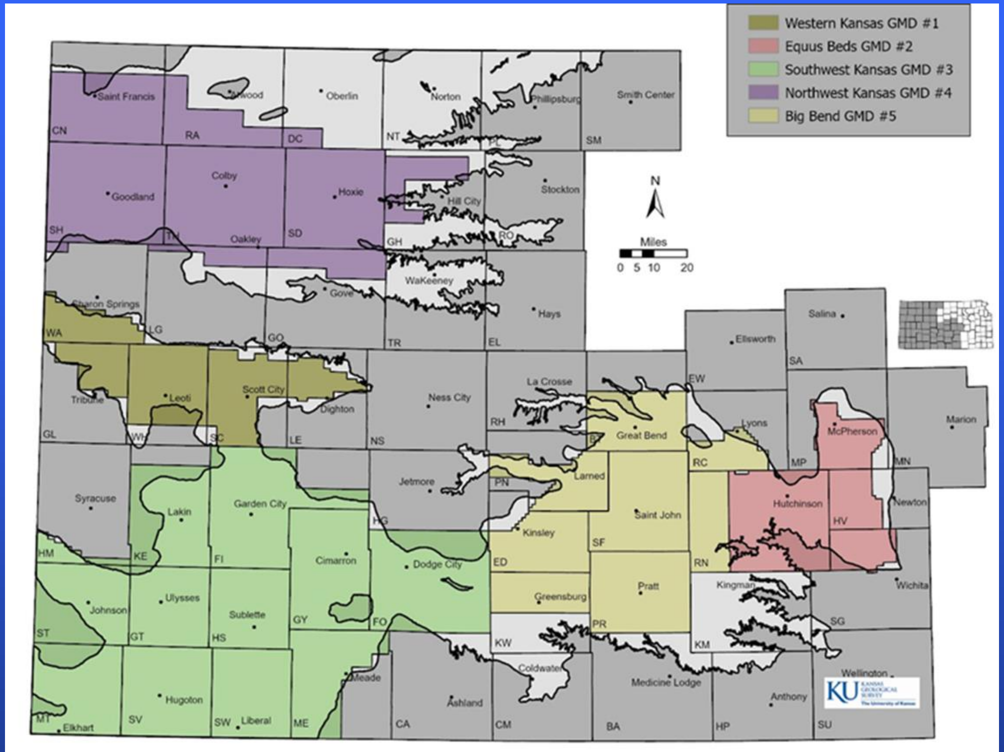
after Butler et al. (2016)



Q_{stable} = intercept/slope

after Butler et al. (2016)

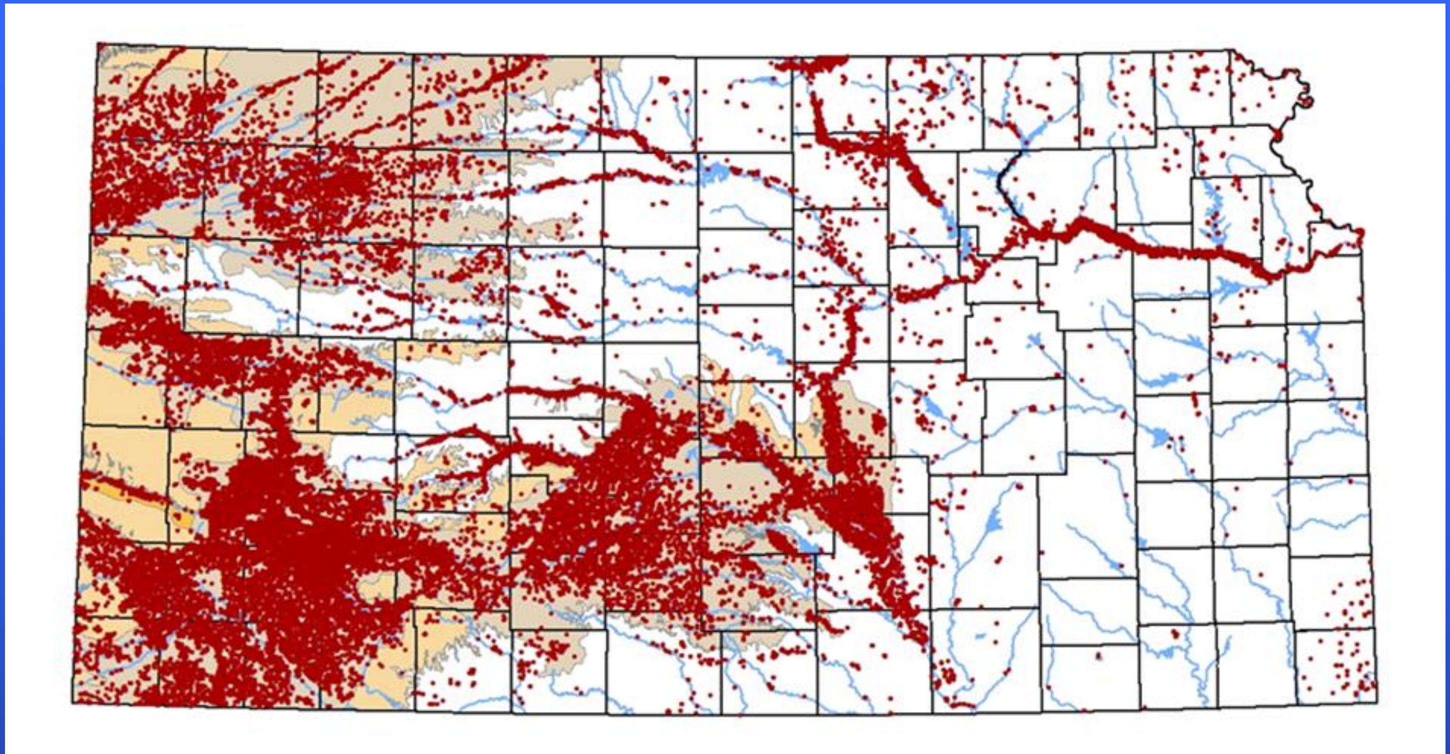
Groundwater Management in Kansas



Lead agency in Kansas – Division of Water Resources (DWR) of the Kansas Department of Agriculture – Chief Engineer

- consider groundwater and surface water as an integrated whole.

Local input via Groundwater Management Districts



Groundwater-based Water Rights in Kansas

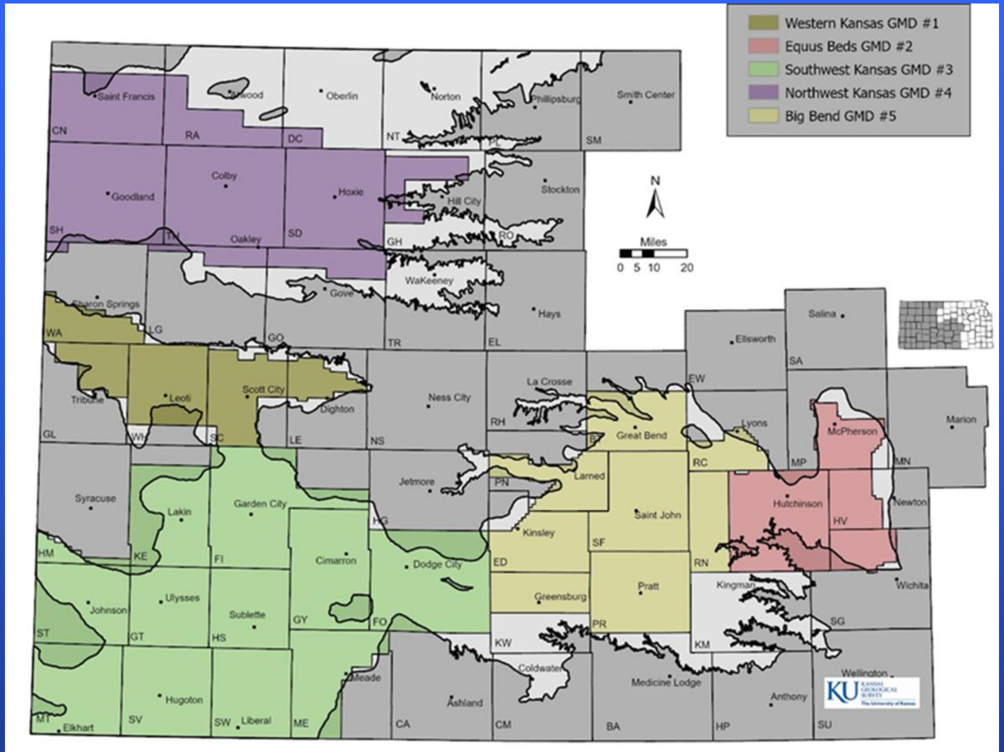
Prior Appropriation Doctrine – first in time, first in right

- cannot impair more senior users
- if so, then….

↓

Water Rights Administration

Groundwater Management in Kansas



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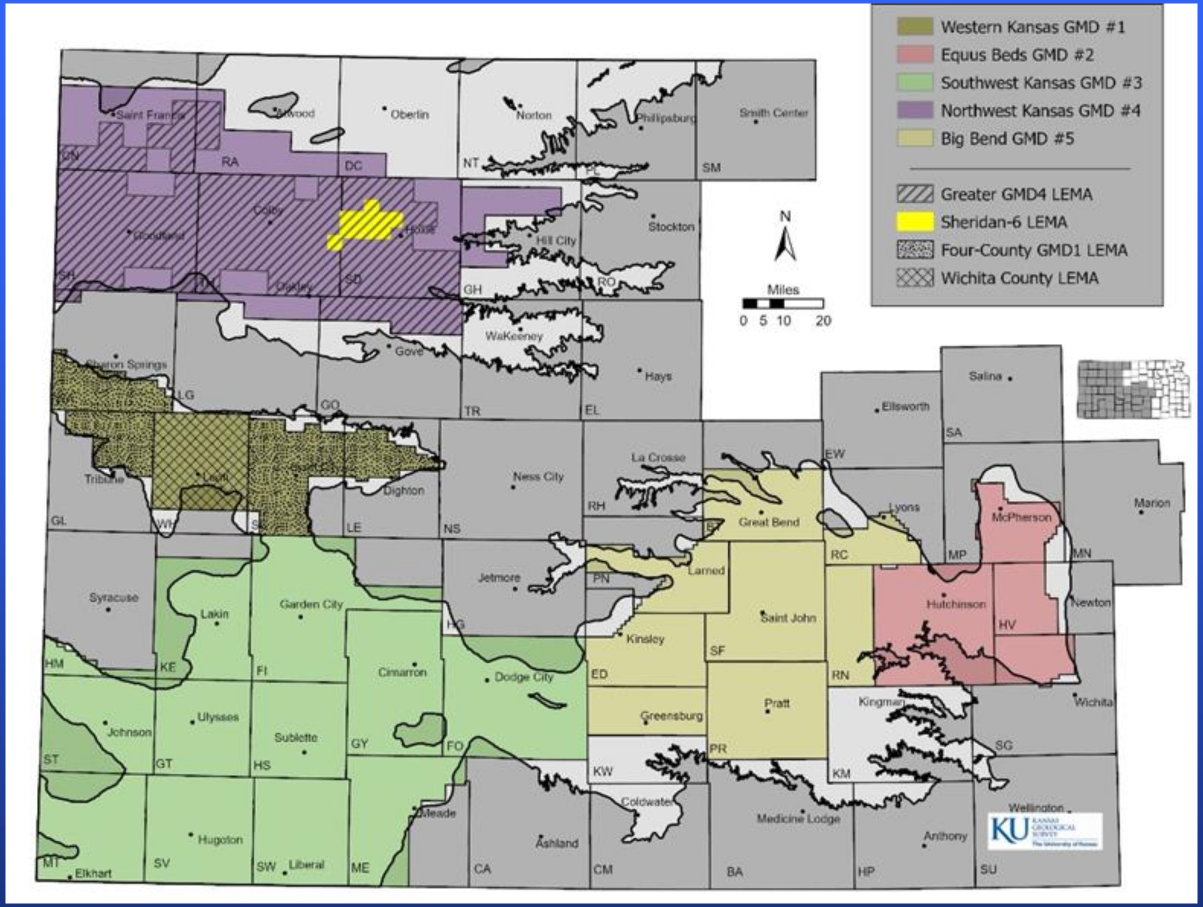
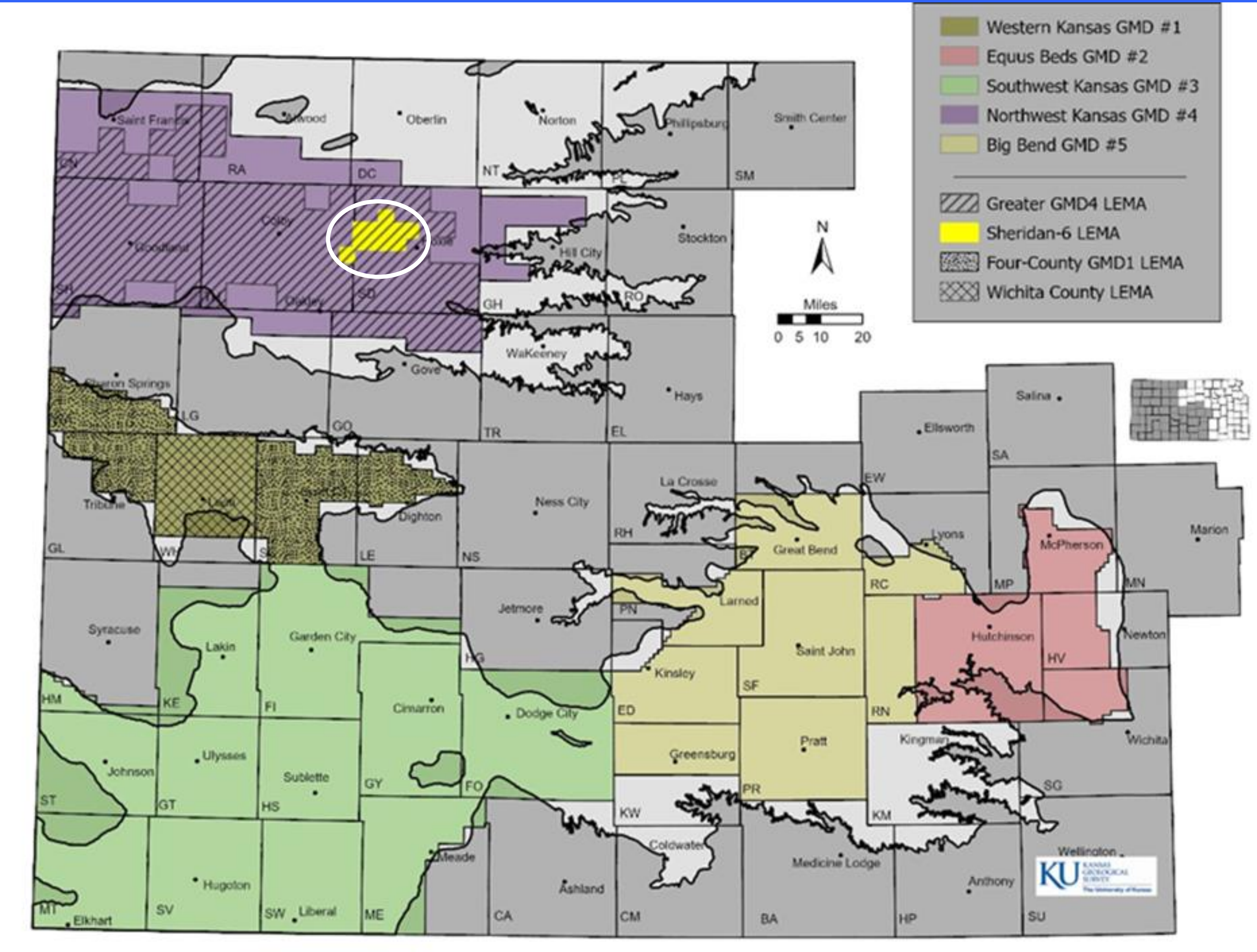
Groundwater Conservation Areas



Local Enhanced Management Area (LEMA) – 2012

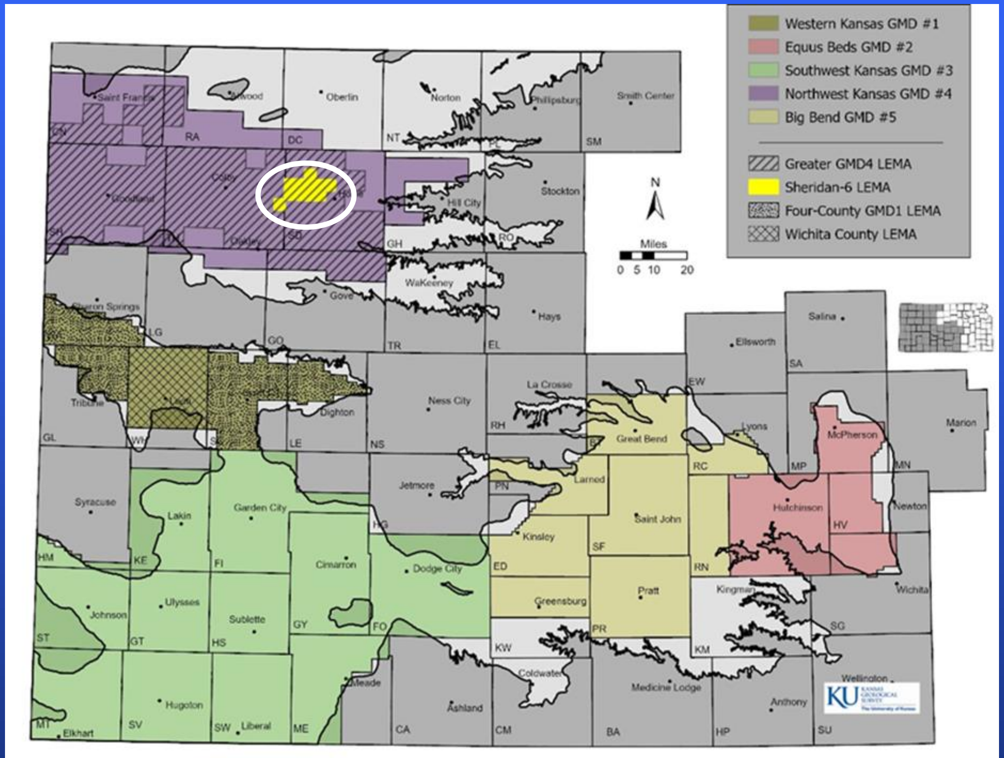
Combination of a grassroots-developed plan with regulatory oversight (binding regulatory order) – Trust, but verify.



Sheridan-6 LEMA

- 99 mi^2
- started in 2013
- 20% reduction in pumping
- five-year periods
- volume of water

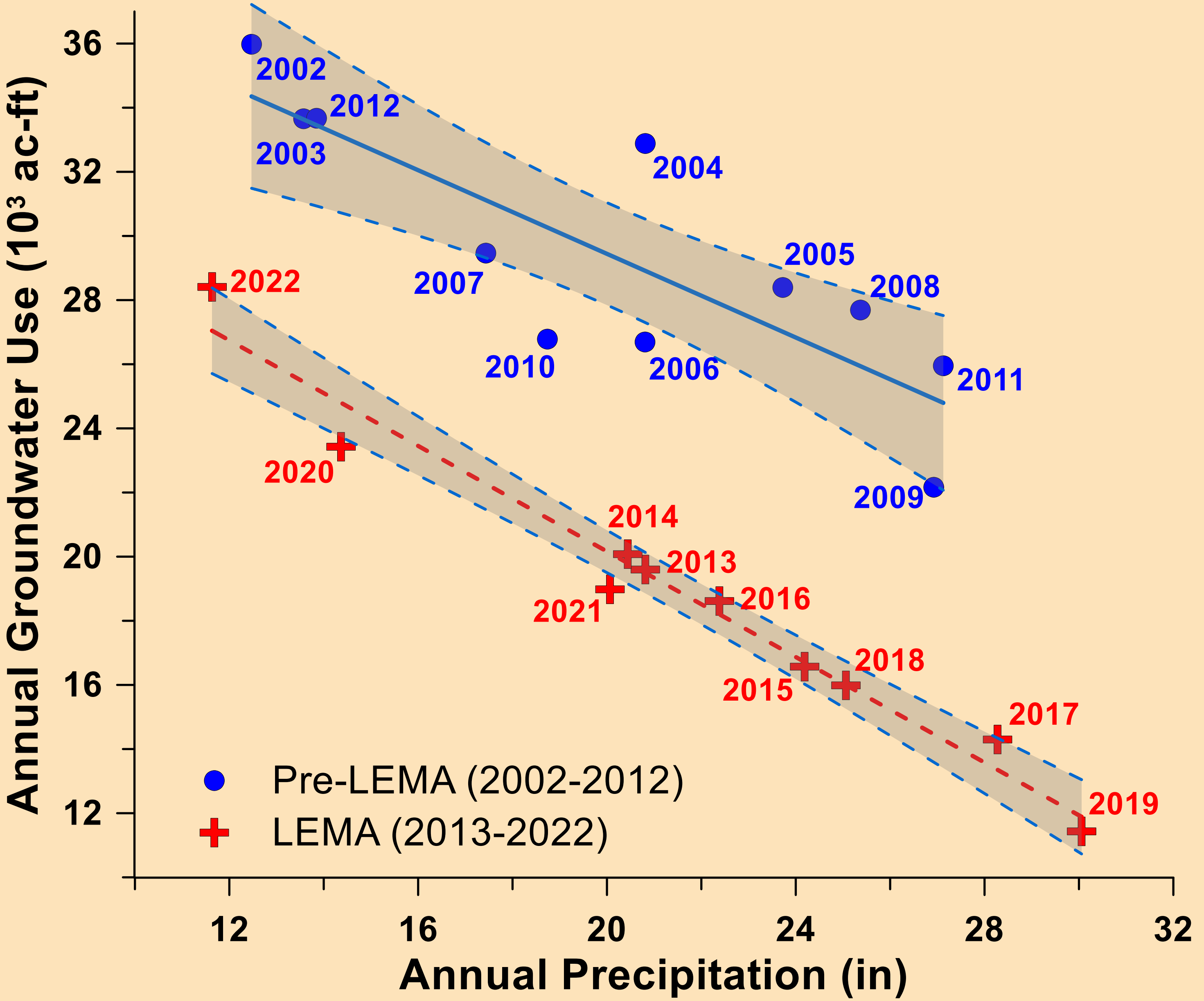
Key Requirements for a Successful Groundwater Conservation Area:



1. **Groundwater pumping must be reduced.**

Sheridan-6 LEMA

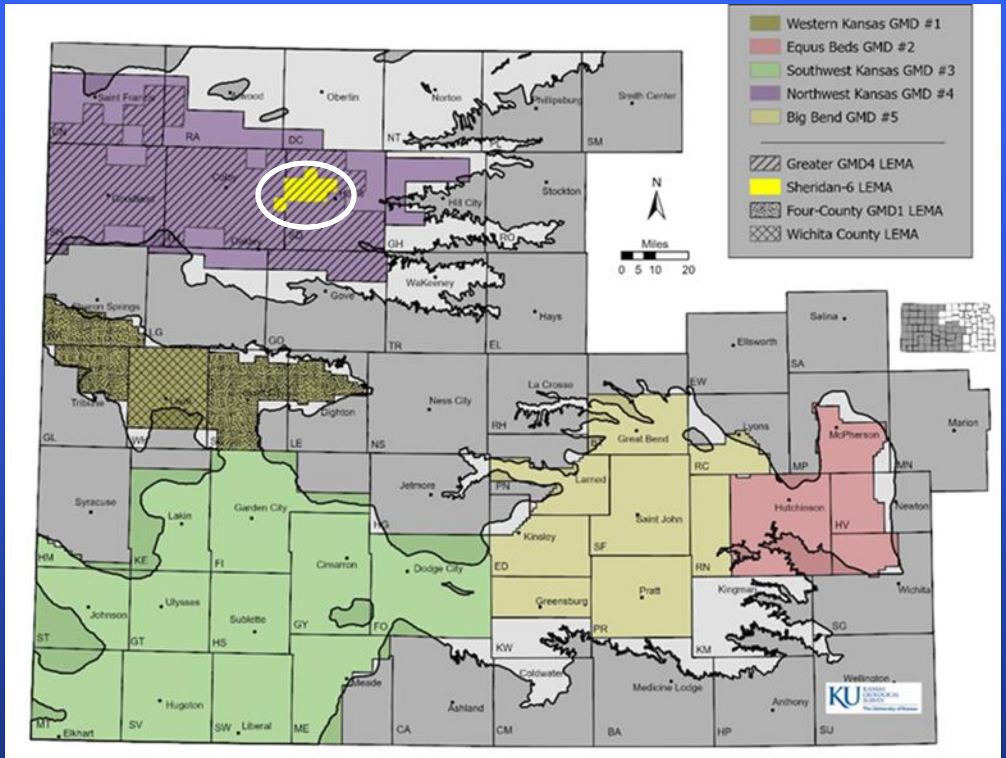
199 pumping wells



≈ 31% reduction in pumping for similar climatic conditions.

after Whittemore et al. (2023)

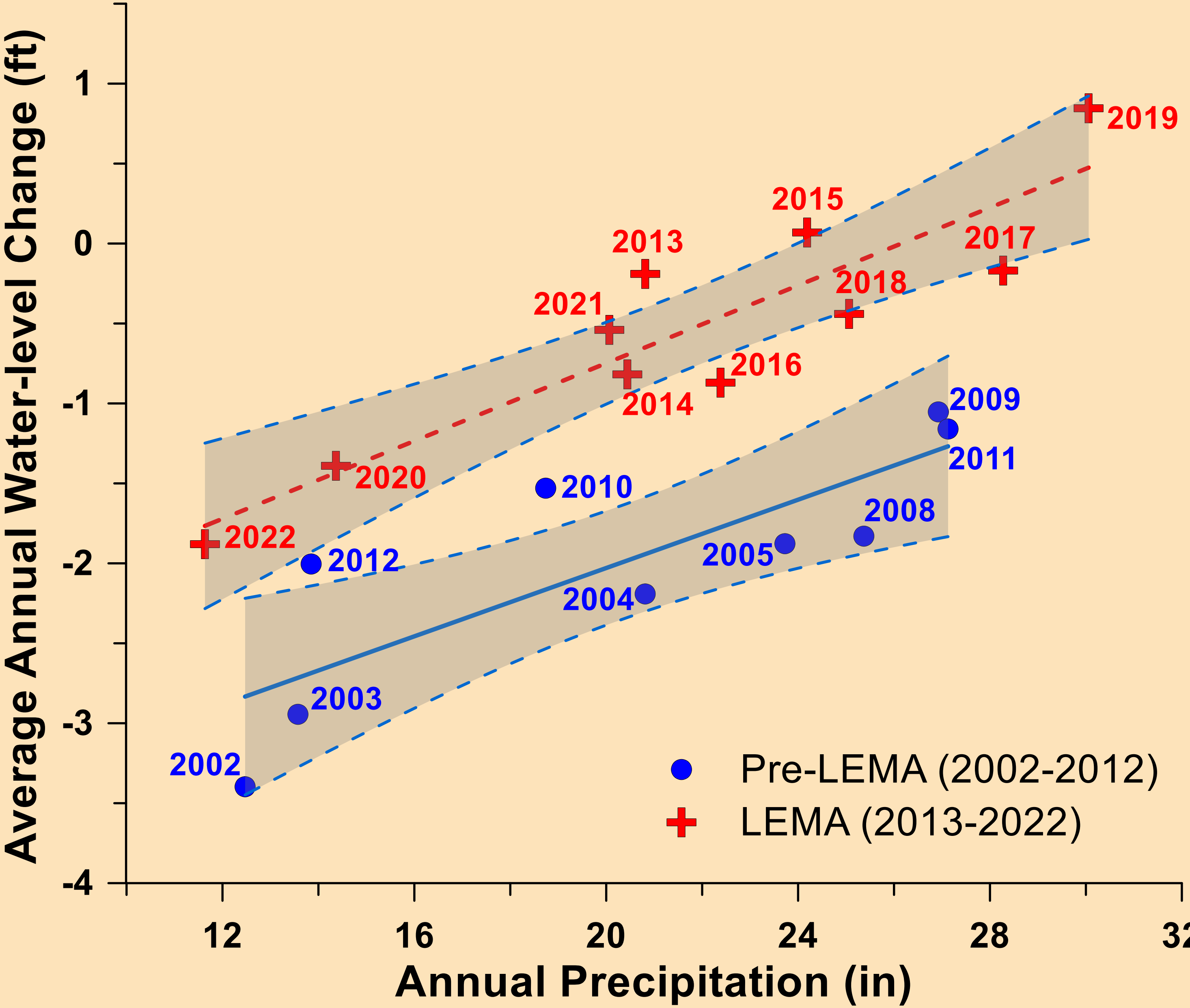
Key Requirements for a Successful Groundwater Conservation Area:



1. Groundwater pumping must be reduced.
2. **Water-level decline rates must be reduced.**

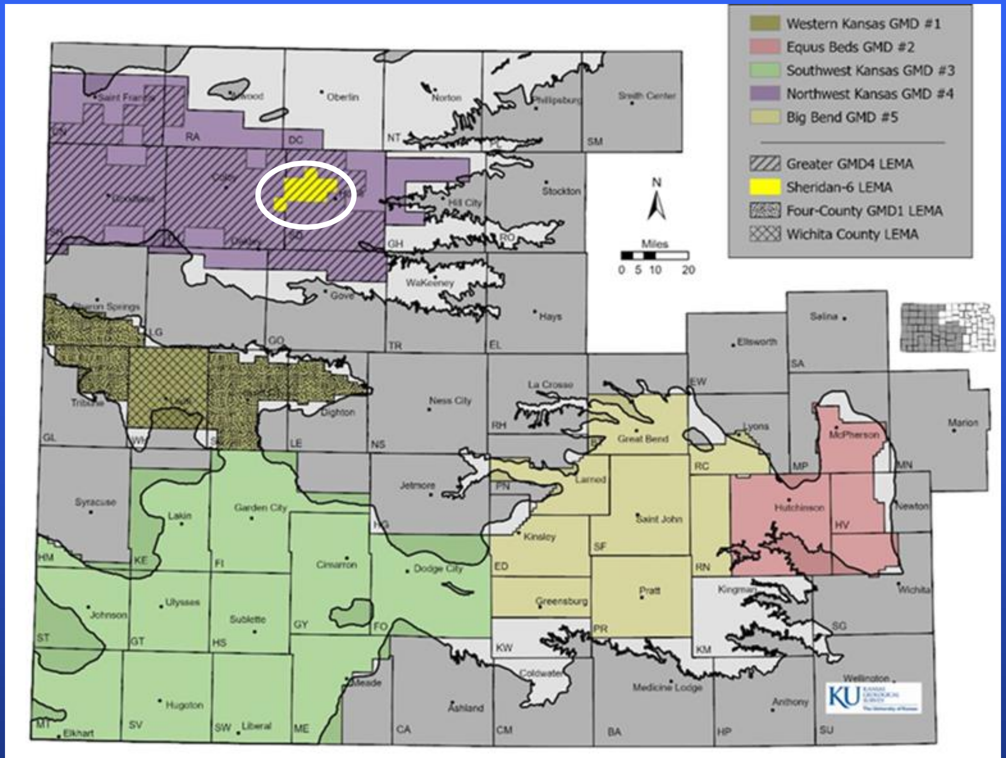
Sheridan-6 LEMA

7 to 11 wells



≈ 62% reduction in water-level decline rate for similar climatic conditions.

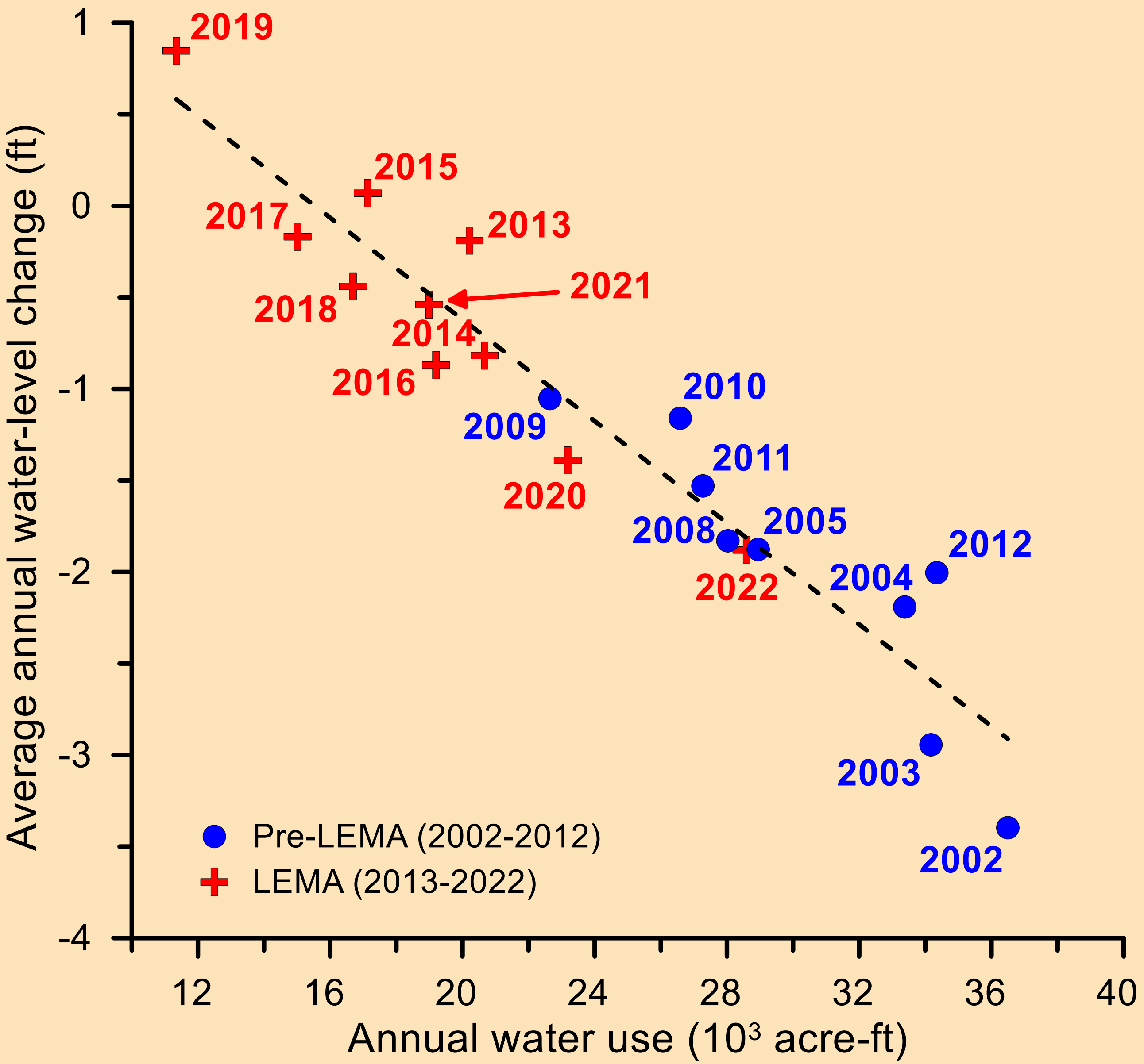
Key Requirements for a Successful Groundwater Conservation Area:



1. Groundwater pumping must be reduced.
2. Water-level decline rates must be reduced.
3. **Must be economically viable.**

Sheridan-6 LEMA

199 pumping wells
7 to 11 observation wells
$R^2 = 0.92$

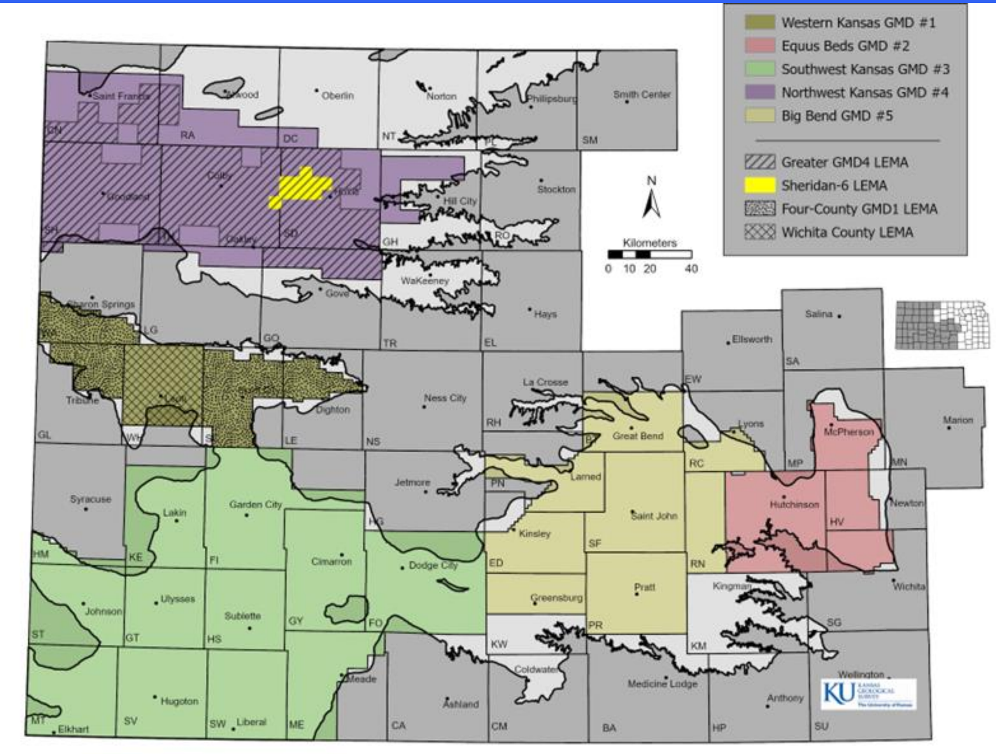


Need to reduce annual pumping by 19% to get to Q_{stable}.

Further pumping reductions will be needed as Net Inflow, and thus Q_{stable}, will decrease with time.

after Butler et al. (2023)

Key Requirements for a Successful Groundwater Conservation Area:



1. **Groundwater pumping must be reduced.**
2. **Water-level decline rates must be reduced.**
3. **Must be economically viable.**

What is the future of the High Plains aquifer in western Kansas?

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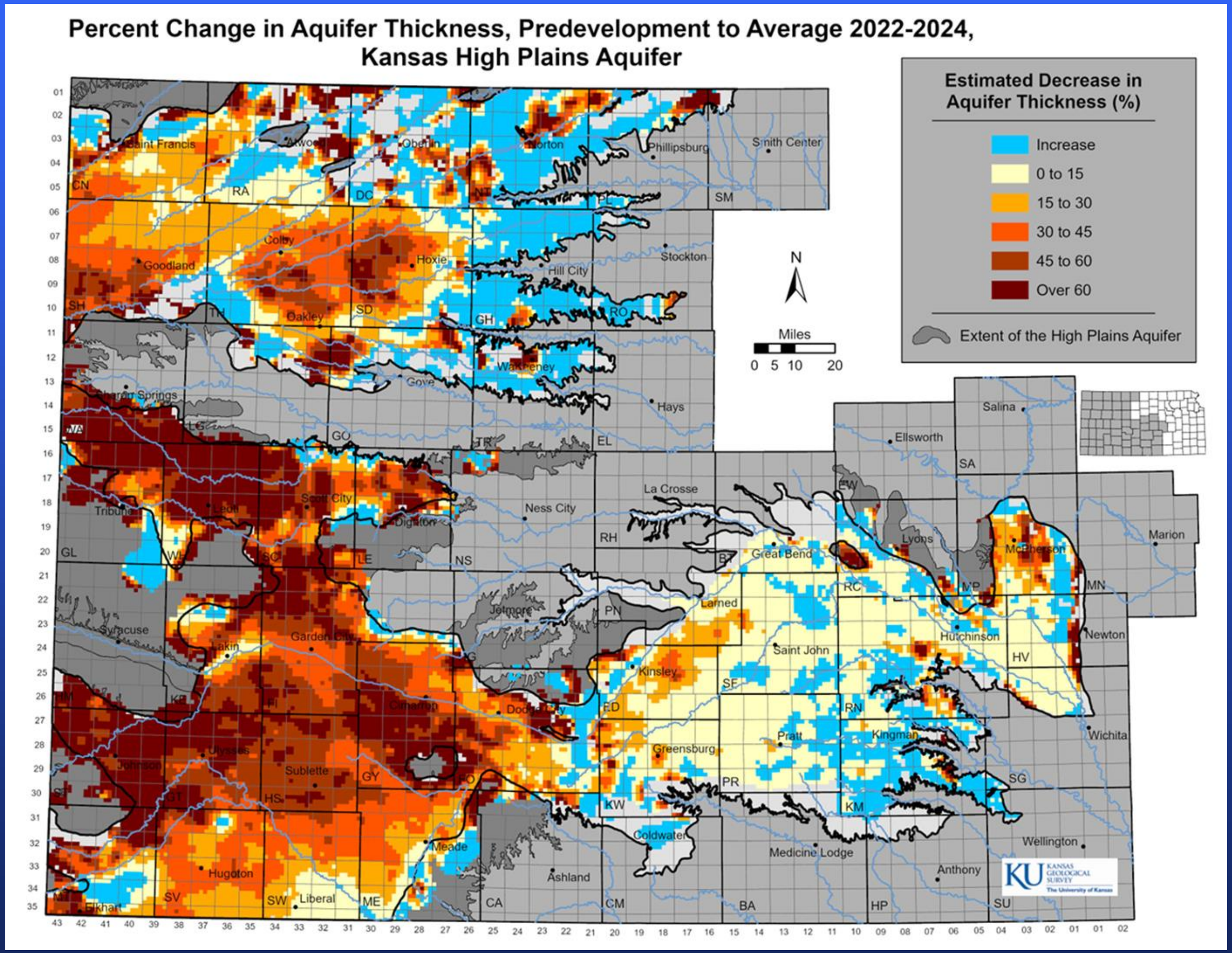
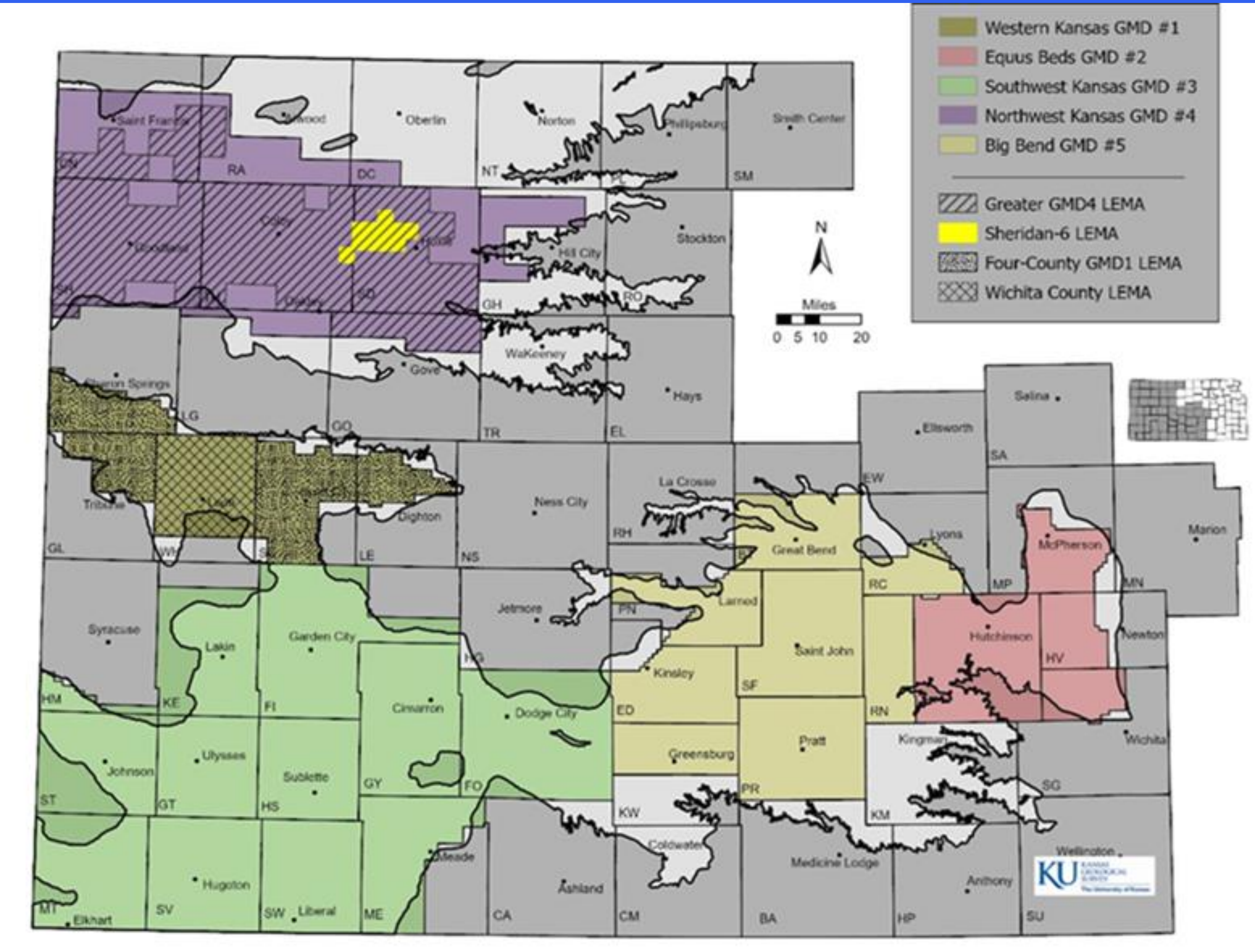


The hour is late,

What is the future of the High Plains aquifer in western Kansas?



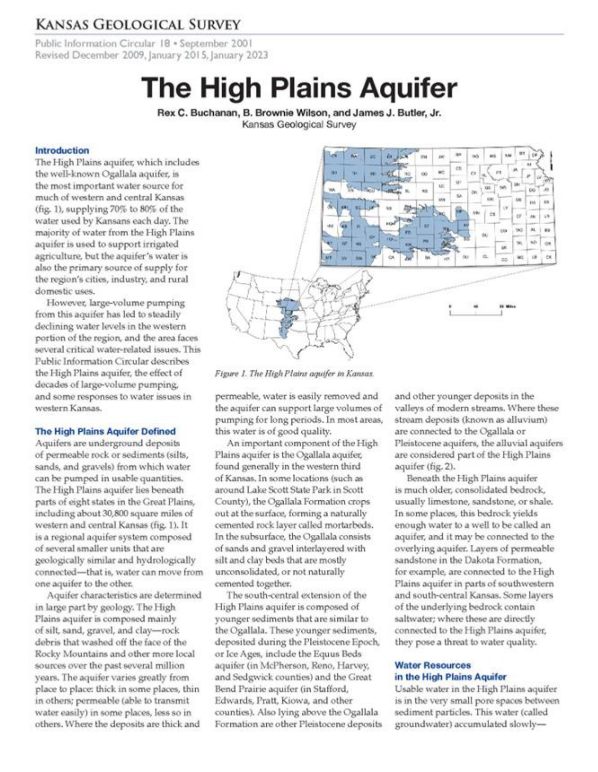
Groundwater conservation areas

Q_{stable}

The hour is late, but all is not lost…

ACKNOWLEDGMENTS

This work was supported, in part, by funding from the Kansas Water Office, the Kansas Water Plan, the U.S. Dept. of Agriculture, and the U.S. National Science Foundation.



KANSAS GEOLOGICAL SURVEY

Public Information Circular 18 • September 2001
Revised December 2009, January 2015, January 2023

The High Plains Aquifer

Rex C. Buchanan, B. Brownie Wilson, and James J. Butler, Jr.
Kansas Geological Survey

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.

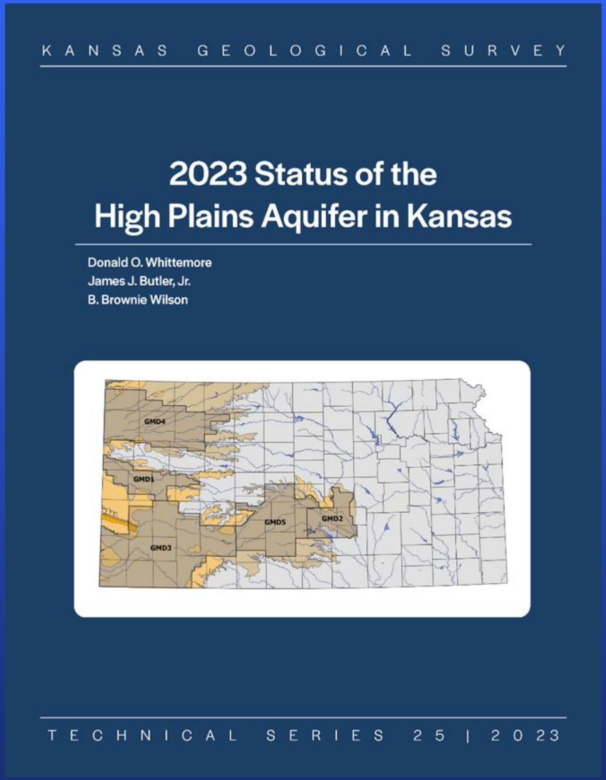
An important component of the High Plains aquifer is the Ogallala aquifer, found generally in the western third of Kansas. In some locations (such as around Lake Scott State Park in Scott County), the Ogallala Formation crops out at the surface, forming a naturally cemented rock layer called mortarbeds. 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—



kgs.ku.edu/high-plains-aquifer

kgs.ku.edu/2023-status-high-plains-aquifer-kansas

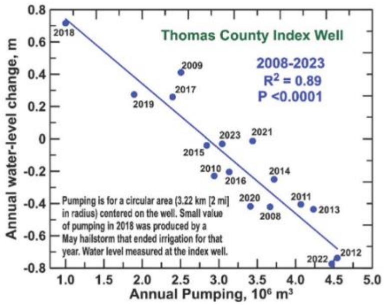
Email: jbutler@ku.edu

Charting Paths Forward for a Heavily Stressed Aquifer

JIM BUTLER, KANSAS GEOLOGICAL SURVEY, UNIVERSITY OF KANSAS

Addressing the depletion of aquifers that support irrigated agriculture and provide drinking water for millions is a global challenge. Like many regional aquifers, the High Plains aquifer (HPA) in western Kansas is under stress produced by decades of intensive pumping for irrigation. The large water-level declines pose an existential threat to the viability of irrigated agriculture and the rural communities that depend on it. There is only one option to reduce that threat in the near-term: pumping reductions in conjunction with modification of agricultural practices. How much reduction is needed is the key question.

An assessment of data from a network of Kansas Geological Survey (KGS) continuously monitored index wells found indications of a steady net inflow to the areas around those wells. Using the KGS database of annual water-level measurements (about 1,400 wells) and annual pumping data (all non-domestic wells are metered), we found strong linear relationships between annual pumping (Q) and water-level change (ΔWL) from the local (Figure) to regional (up to 21,000 km^2) scale, an indication that a steady net inflow is likely a common feature across the Kansas HPA. This led us to develop a method to calculate net inflow from a plot of Q versus ΔWL. If water levels are to be stabilized for the next one to few decades, pumping must be reduced to net inflow (Q_{stable}).



Results from groundwater conservation areas in western Kansas demonstrated the potential of the Q_{stable} framework for broad application. The path to widespread use, however, required us to move far beyond papers in peer-reviewed journals.

In the last decade, we have given numerous presentations to irrigator groups, groundwater managers, legislative committees, and many others. We have also written for non-technical audiences ranging from the general public to theologians. As a result, Q_{stable} is commonly invoked by agricultural groups and legislators in Kansas and is being widely adopted as the target for conservation efforts. Although reductions to Q_{stable} will not attain sustainability in most areas, they will exploit the inertia in unconfined aquifers with deep water tables to buy time to develop longer-term strategies and thus serve as initial steps on a path to more promising conditions in the western Kansas HPA.

Want to showcase hydrology research making a real-world impact? Nominate yourself or a colleague for an upcoming "Science to Solutions" feature by emailing us at agu.hydro.news@gmail.com.

Email: jbutler@ku.edu

Questions??