EXHIBIT A

EXHIBIT B

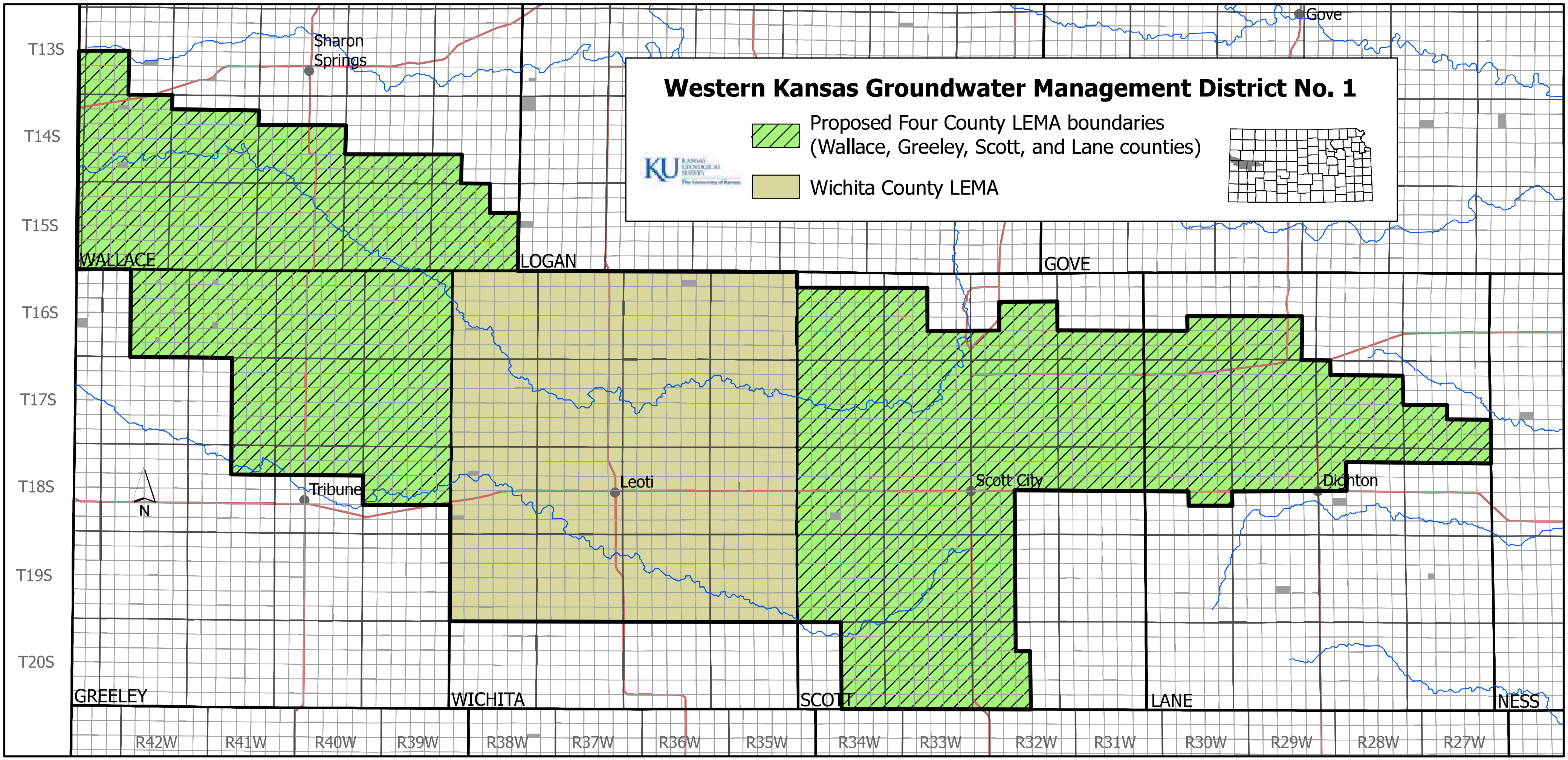

Western Kansas Groundwater Management District No. 1
Proposed Four County LEMA boundaries
(Wallace, Greeley, Scott, and Lane counties)
Wichita County LEMA
Sharon Springs
Gove
Tribune
Leoti
Scott City
Dighton
WALLACE
LOGAN
GOVE
GREELEY
WICHITA
SCOTT
LANE
NESS
N
T13S
T14S
T15S
T16S
T17S
T18S
T19S
T20S
R42W
R41W
R40W
R39W
R38W
R37W
R36W
R35W
R34W
R33W
R32W
R31W
R30W
R29W
R28W
R27W

EXHIBIT C

Wichita County LEMA Annual Review for 2022
January 12, 2023

Introduction and purpose

The Wichita County Local Enhanced Management Area (LEMA), after due consideration through the required processes under the GMD Act, was enacted in 2021 for the five-year period, January 1, 2021, to December 31, 2025, restricting wateruse for all irrigation use, to extend the useful life of the Ogallala Aquifer in the County.

The Wichita County LEMA Plan includes annual review requirements to evaluate how the LEMA is performing, to inform whether the LEMA should continue after 2025, and to assist in determining if changes to the LEMA should be considered for the future. Review requirements specified in the Plan include:

1. Section IV.c. states in part, "*Non-Irrigation Uses – The water use reports of all non-irrigation Water Rights will be reviewed annually by the Board.*"
2. Section VII related to Metering and Monitoring, states the following in sub-section e: "*This metering protocol shall be a specific annual review issue and if discovered to be ineffective, specific adjustments shall be recommended to the Chief Engineer by GMD1.*"
3. Section IX provides for LEMA annual reviews, discussed in more detail below.

Wateruse data for 2021 as well as water level data from the January 2022 water level measurement program conducted by the KDA-DWR and KGS became available during 2022 and are the subject of this first annual review under the LEMA.

This review was developed by District Manager Katie Durham with input and assistance from Mike Meyer of the Division of Water Resources, Brownie Wilson of the KGS, and GMD1's consultant David Barfield.

This review document reviewed by the GMD 1 Board at its regular Board meeting of January 12, 2023.

Background information – Wichita County's Water Conservation Area (WCA)

While the purpose of this annual review is to evaluate the performance of the LEMA and potential future changes to the LEMA, overall wateruse in Wichita County is significantly affected by Wichita County's WCA put in place in 2017. The following summary information is provided as background. More on the WCA can be found on DWR's web page at: https://www.agriculture.ks.gov/divisions-programs/dwr/managing-kansas-water-resources/wca/wichita-county-wca.

The Wichita County WCA is a voluntary program implemented on a countywide basis, the only one of its kind in Kansas. It commits enrollees to a table of reductions over four seven-year periods, with increasing reduction requirements with each successive period. Reduction requirements for the period 2017-2023 are 30 % from the average use for 2009-2015.

There are 25 active consent agreement covering 11,391 acres and projected savings of 2,665 Acre-feet per year (average use of 8770 AF for 2009-15 versus allocations of 6105 AF).

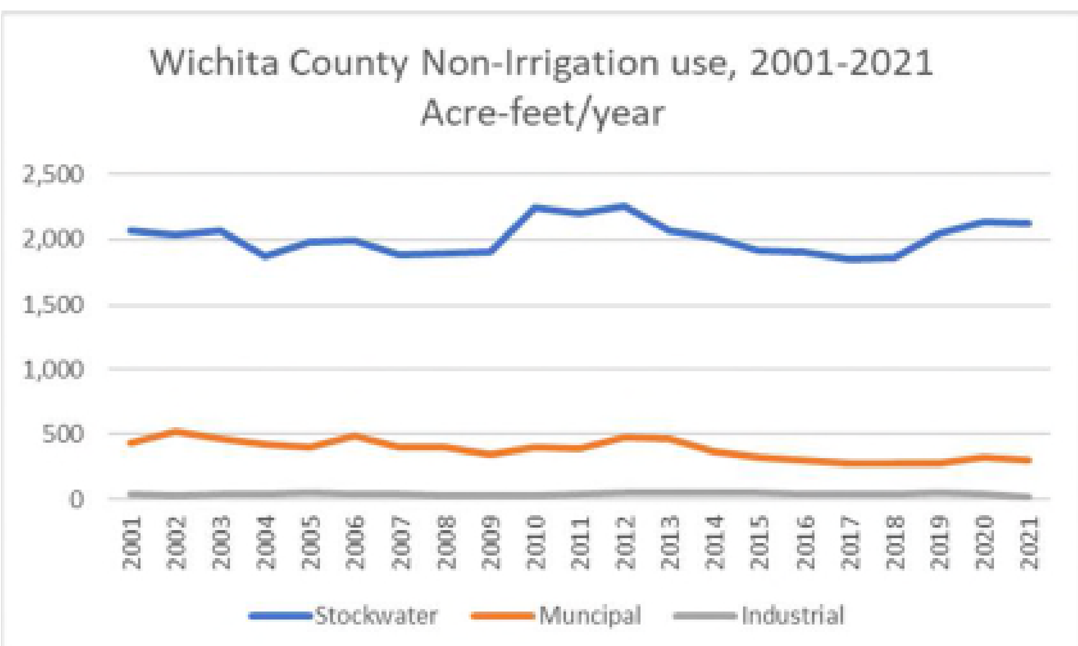
DWR maintains a spreadsheet with a detailed accounting of water use vs. allocation, which we reviewed. Of the 25 active consent agreements, 20 started in 2017, 4 started in 2018, and one started in 2019.

In view of the differing start periods, the most convenient measure of performance of the WCA is to contrast average use under participating water rights for the 2017-2021 period (or 2018 or 2019 according to the start year) with average WCA allocations. Through 2021, the average use totaled 3997 AF/year versus the 6105 AF/year of allocations. Thus, wateruse was 65.5% of the WCA allocations. While the anticipated savings quoted above is 2665 AF/year, actual savings under the WCA from the 2009-2015 average was 4773 AF/year.

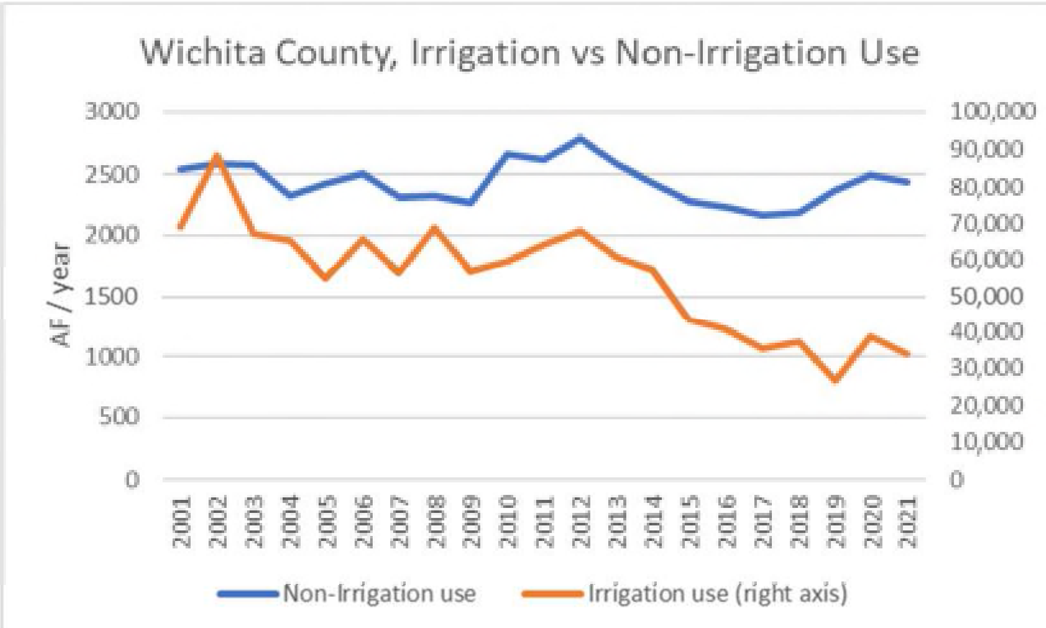
Review of non-irrigation use in 2021

To review the 2021 non-irrigation water use data, 2001-2021 total wateruse data for each non-irrigation use in Wichita County was obtained from the WIMAS application developed and maintained by Kansas Geological Survey (KGS) and the Kansas Department of Agriculture, Division of Water Resources (DWR).

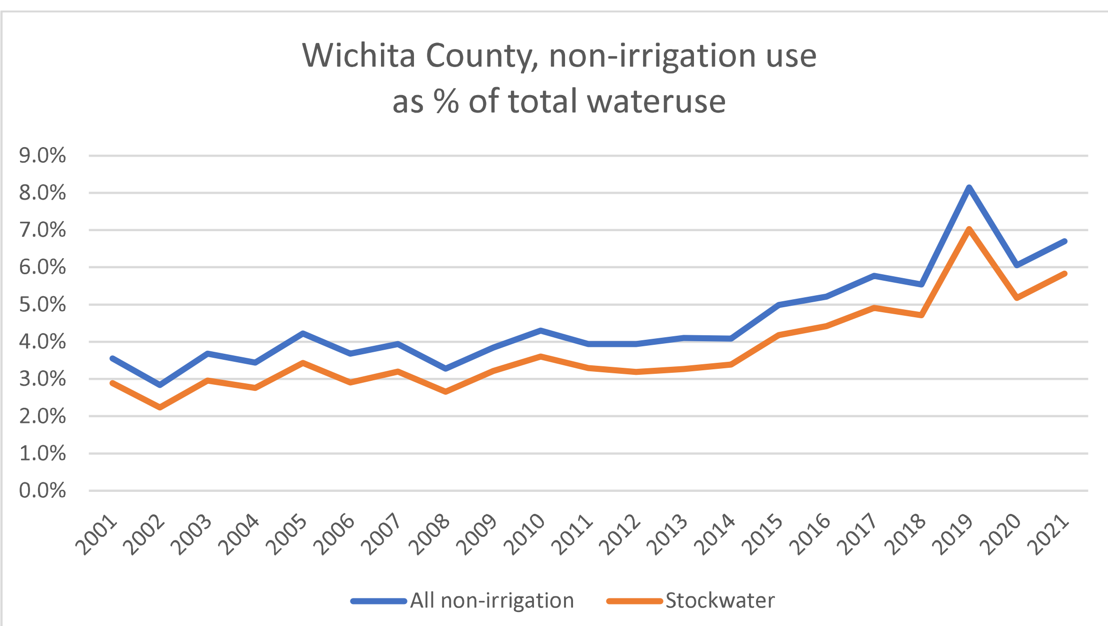
The graph below shows the total wateruse by use made of water for non-irrigation uses in Wichita County, 2001-2021. Stockwater use has been relatively steady to slightly increasing over the period, driven by conversions from irrigation to stockwater use.



The graph below contrasts the trends in total non-irrigation use (using the left axis) versus total irrigation (using the right axis) for the period, with non-irrigation use being relatively stable, while irrigation use is in decline.



Finally, the graph below shows total non-irrigation use and total stockwater use as a percent of total wateruse for the 2001-2021 period. While relatively small, non-irrigation use and stockwater use in particularly, is a growing part of the County's overall use.



<u>Review of Effectiveness of the LEMA's Metering and Monitoring requirements</u>

On December 16, 2022, Katie Durham, Mike Meyer and David Barfield held a call to discuss the effectiveness of the LEMA's Metering and Monitoring requirements. Mike did not have numbers of metering problems or violations, but they continue to occur, with greater significance in LEMAs as individual year wateruse records have implications to all 5 years of the LEMA.

Recommendations for the future:

- We suggest the District undertaken an education program on best practices for regular collecting of wateruse and related data, as such data not only meets the requirement of the LEMA but to also provides producers with valuable operations data, assisting in identifying problems more quickly, thus reducing inefficiencies of wateruse. The District might also want to consider cost-sharing on meter reading technology.
- We discussed the web application that KDA built for GMD 4's LEMA, allowing wateruser to access water use and remaining allocation data. We suggest the District request KDA to assist in building a similar application for the Wichita County LEMA (for its own benefit and as a pilot for the Four County LEMA).

<u>LEMA annual review</u>

The LEMA review section of the Wichita County LEMA Plan has requirement for both annual reviews, and in the fourth year of the LEMA, for a review of the Wichita County LEMA Order of Designation in order to develop recommendations for further LEMA actions.

The LEMA plan states: "*The Board and a member of DWR staff appointed by the Chief Engineer shall comprise the "Review Board" and shall conduct an annual review of the items in subsection (b). The review data shall also be presented at the Annual Meeting of GMD1.*"

With respect to the annual review, of which this is the first, the Plan lists the following items for review: water use data, water table information, economic data as is available, compliance and enforcement issues, any new and preferable enhanced management authorities that become available, and other items deemed pertinent by the Review Board.

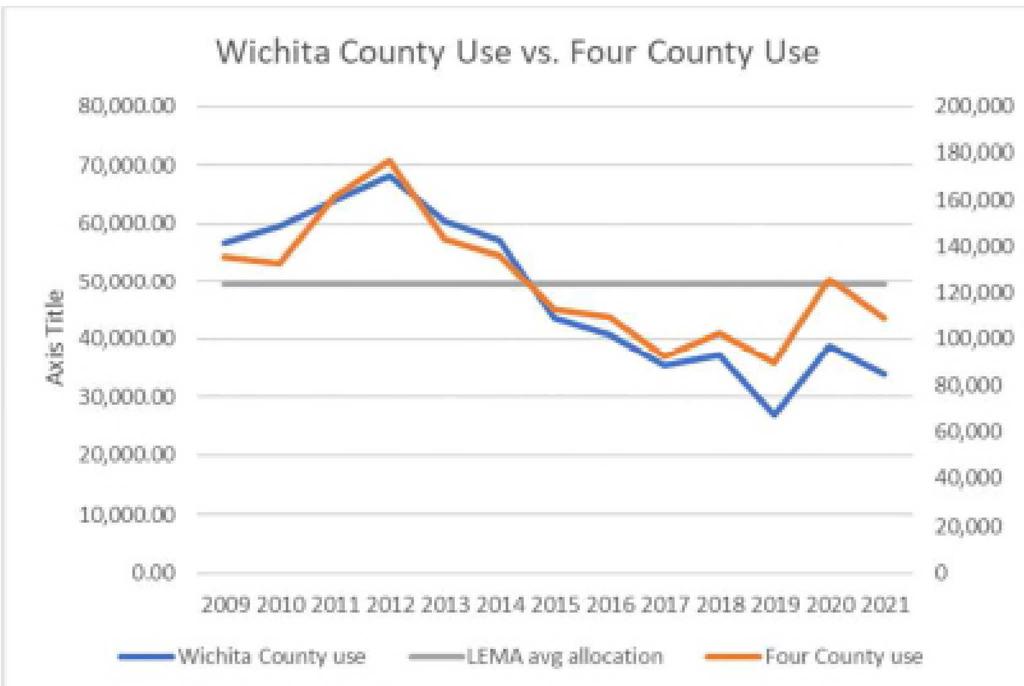
These are each discussed below.

Water use data

With only one year of available data, no detailed review of individual water right's wateruse data was completed. With DWR's assistance, for next year's review, water use data for 2016-2022 could be added to the LEMA's allocation spreadsheet (with its 2009-2015 data organized by water right units) for a more complete review.

For this first year, the following county-wide **review of wateruse** data was completed.

- For each of the District's 5 counties, total wateruse data for the ENTIRE county was down-loaded from KGS's WIMAS application (note: this data includes very limited use outside the GMDs in these counties).
- Summary statistics were developed, averaging the 2009-2015 and 2011-2020 water use for each individual county including Wichita County, as well as the total and average use for the aggregate of the other Four Counties, and then comparing the 2021 use vs. these averages.
- Wichita County's 2021 use was also compared with the average allowable under the LEMA.
- The figure below shows annual total use for Wichita County (using the left axis), the total use of the Four Counties (using the right axis), and the average annual Wichita County LEMA allocations.



This review found the following:

- While all 5 counties use in 2021 was less than the 2009-15 average, Wichita County's reported use was markedly less. Specifically, for the four counties, 2021 wateruse averaged 76.4% of the 2009-2015 average; for Wichita county, its 2021 wateruse was 58.0% of its 2009-2015 average.

- Similarly, while all 5 counties use in 2021 was less than the 2011-20 average, Wichita County's reported use was markedly less. Specifically, for the four counties, 2021 wateruse averaged 87.3% of the 2011-2022 average; for Wichita county, its 2021 wateruse was 71.8% of its 2011-2020 average.

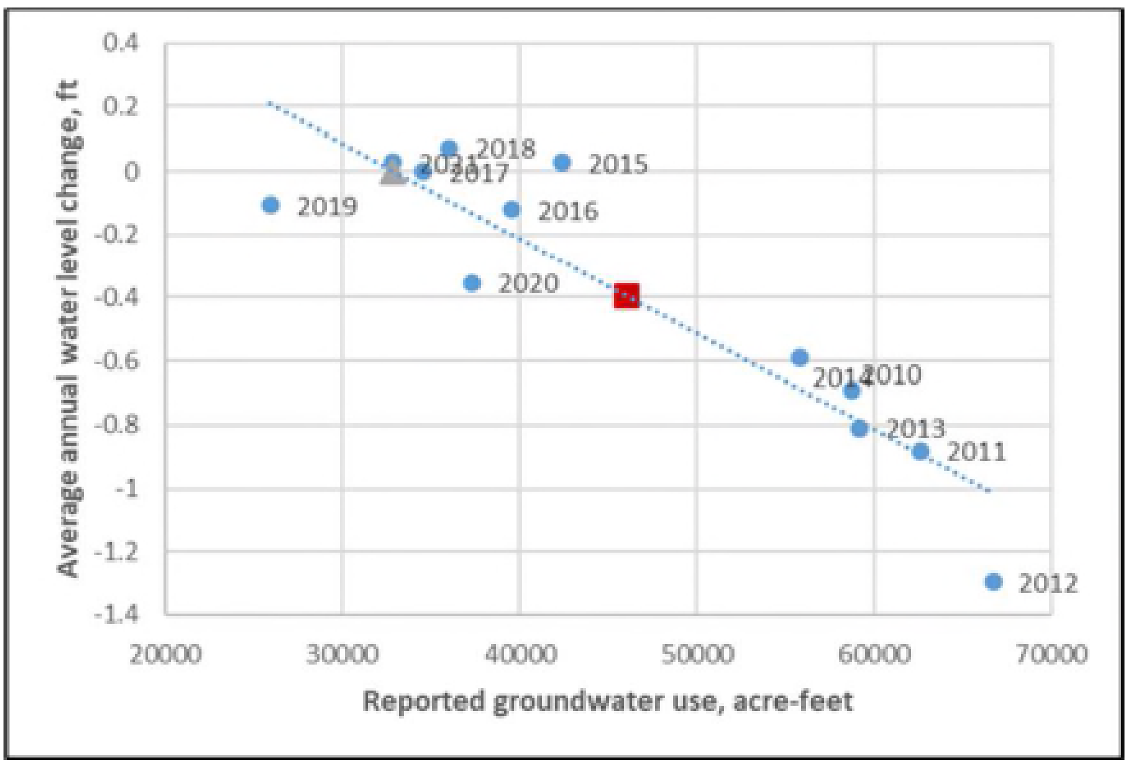
- In addition, Wichita County's 2021 reported wateruse was only 69% of the **average** allowed under the LEMA (the allocation goal was based on 2009-2015 average use, which was on the order of 20% higher in Wichita County, than 2011-2022).

Water table information

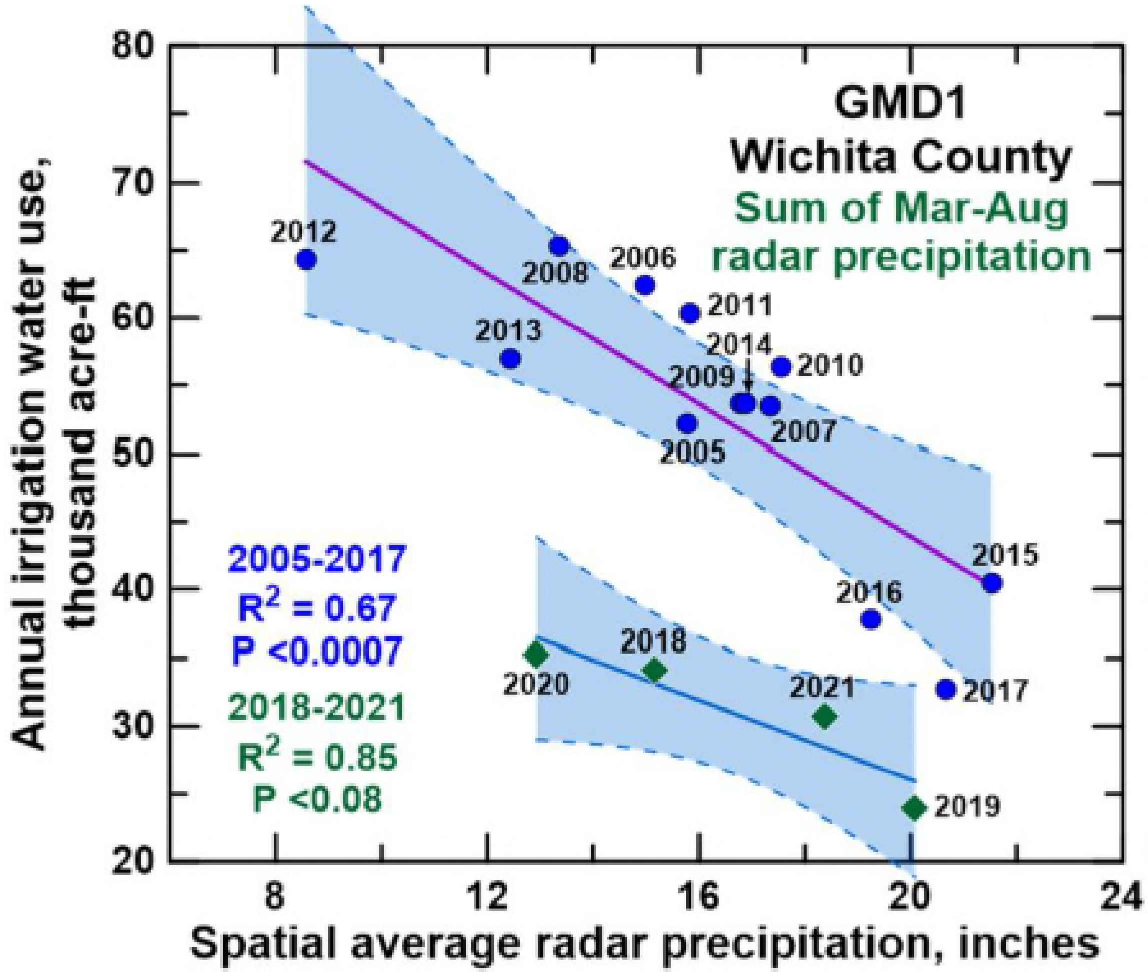
With only one year of data under the LEMA, a review an individual year's water level change is not particularly instructive and was not completed. Next year's review should start providing the individual years' changes and aggregate water level changes for the LEMA period.

The KGS is doing valuable work comparing water level changes to wateruse in the Ogallala-High Plains Aquifer generally, with emphasis in areas of enhanced management. Don Whittemore, on behalf of the KGS, presented a summary of their work at the recent 2022 Governor's Water Conference. He found evidence in both the GMD 4's Sheridan 6 LEMA and in Wichita County of a changing relationships between pumping and annual precipitation.

Below is KGS' "Q-stable" plot for Wichita County, contrasting mean reported pumping with average water level changes from 2010 to 2022.



Below is his summary graph for Wichita County contrasting wateruse with March-August precipitation, for the pre-WCA/LEMA compared with 2018-2021. It shows that wateruse during 2018-2021, under the WCA and LEMA, was substantial lower than previously within similar ranges of precipitation, evidencing changing irrigation management.



Here is Brownie's interpretation of the effect of the markedly reduced pumping of recent years on water level changes, compared to pre-2017 water use and water level declines: "*You can see from the Qstable plot that the water use / water level change points from 2018 to 2021 are all clustered around the lower end of the line relative to the earlier years where you had greater occurrence of higher usage and higher rates of water level declines. The averages in water use from 2018 to 2021 is about 28% relative to the entire period and this has reduced water levels from an average of -0.54 ft a year from 2010 to 2017 to an average of -0.09 ft from 2018 to 2021.*"

Economic data as is available

No economic data was reviewed. The Board should discuss its desire for economic data reviews it desires for future annual reviews.

Compliance and enforcement issues

In our discussion of 12/16/2022, Mike Meyer stated that while compliance and enforcement issues have occurred, they are generally of the nature experienced throughout the Garden City Field Office area and are being handled pursuant to DWR's standard practices.

Any new and preferable enhanced management authorities that become available

Nothing was identified.

Other items deemed pertinent by the Review Board

For discussion by the Board.

Conclusions and Recommendations

While the data is limited after only one year, this first annual review evidences that the LEMA is performing satisfactorily and there wateruse savings are beyond what is required and expected under the Wichita County LEMA Plan.

This review also looked at the performance of the Wichita County WCA, which has more years of record, and found its water savings to be significantly beyond expectations.

For next year's annual review, the Board would request staff, with assistance of DWR and KGS, do the following:

- Work with DWR to update the LEMA's allocation spreadsheet with wateruse from 2016 to current as well as remaining allocation as well as to discuss the potential to develop a web application, similar to GMD 4, to make this information more readily available to waterusers.
- Work with KGS to provide a more complete review of water level change data in the next review.
- Continue to provide information on the performance of the Wichita County Water Conservation Area.

In addition, the Board may wish to develop an education program on best practices for collecting wateruse and related data and consider cost-sharing on meter reading technology.

EXHIBIT D

KU KANSAS GEOLOGICAL SURVEY
The University of Kansas

Written testimony from Brownie Wilson, Kansas Geological Survey.

Submitted to Ronda Hutton, Kansas Department of Agriculture, on October 12, 2022.

RE: Proposed GMD1 Four County LEMA Hearing, October 17, 2022.

My name is Brownie Wilson. I am the Geographic Information Systems (GIS) and Support Services Manager for the Geohydrology Section at the Kansas Geological Survey (KGS). The KGS is a research and service division under the University of Kansas and has been directed by the Kansas Water Plan to provide technical assistance to the three western Groundwater Management Districts (GMDs), the Kansas Water Office (KWO), and the Kansas Department of Agriculture- Division of Water Resources (KDA-DWR) in the assessment, planning, and management of the groundwater resources of western Kansas.

The KGS is involved with Western Kansas GMD#1 (GMD1) through a variety of research projects and data collection efforts. The KGS along with the KDA-DWR actively measures water-levels across GMD1 as part of the State's annual cooperative water-level program (further described below). In addition, the KGS has maintained up to eleven continuously measured observation wells in the area, several of which (known as "Index Wells"), are equipped with telemetry systems to provide real-time water-level data. In 2015, the KGS in cooperation with GMD1 and the KWO completed a numerical groundwater model across the area (Wilson et al., 2015). The model was later recalibrated in 2020 to incorporate new modeling techniques (Liu et al., 2022). The KGS routinely presents its research findings and activities at the district's annual meetings.

At the request of GMD1 in April of 2021, the KGS compared the relationship between observed water-level change and groundwater use in the Ogallala/High Plains aquifer (HPA) for the entire district and the overlying counties of Wallace, Greeley, Wichita, Scott and Lane within the GMD1 boundaries. Results were presented at the 2021 GMD1 annual meeting and again at the 2022 annual meeting along with several county-based LEMA discussion meetings using the latest available data.

The comparison uses a water-balance approach described in Butler et al. (2016), to calculate the reduction in the average annual amount of water use needed to produce, on average, stable water levels over a given area. The approach is data-driven, utilizing only annually collected water-level measurements and annually reported water use estimates. The focus of this study is on GMD1 and its overlying counties in west-central Kansas (fig. 1).

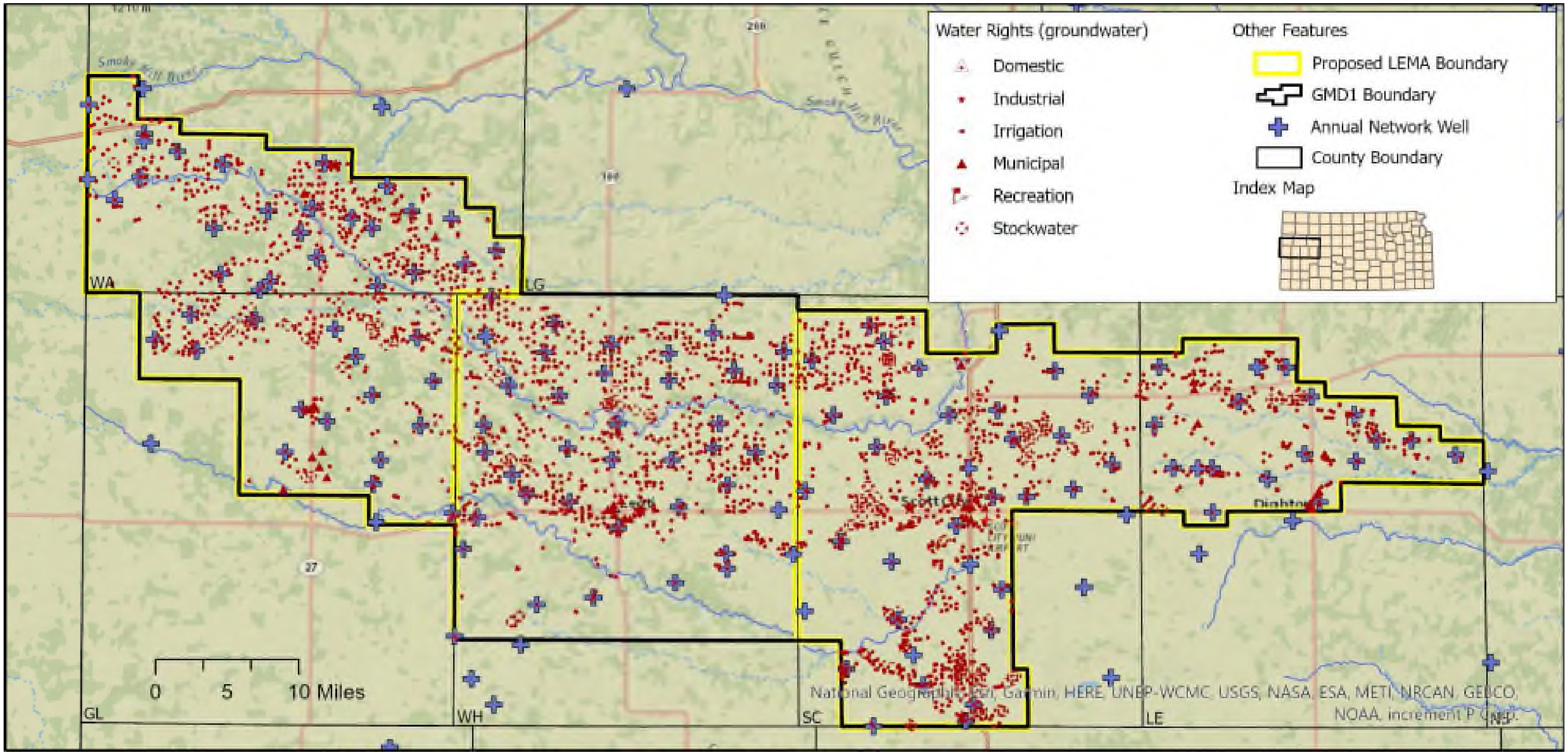


Figure 1. Western Kansas GMD1, annual network wells, and groundwater-based water right wells.

In addition, in support of their spring 2022 county-based meetings to discuss the proposed LEMA plan, GMD1 requested the KGS provide updated maps showing water-level changes since predevelopment to present day. Published as KGS Open-File Report 2022-8 (Woods et al., 2022) the maps are based on interpolated winter water-level measurements taken between 2020 and 2022 combined with estimates of the predevelopment water table and bedrock elevations used by the GMD1 groundwater model. The 2022-8 report maps were submitted separately into the LEMA hearing record.

Aquifer Conditions

The HPA is the primary source of water supply for over 98% of the wells and uses within the district. The thickest portions of the aquifer are found in Wallace County, just south of Weskan, and within a north-south trended trough in Scott County where the present-day thicknesses are near or more than 100 ft (Fross et al., 2012). The eroded bedrock surface at the base of the aquifer has a significant effect on the availability of groundwater resulting in aquifer thickness ranging from zero to over 150 ft within a few miles of each other.

Maps from the 2022-8 report (along with simplified versions used in the proposed LEMA plan) show groundwater declines in GMD1 have been significant. The aquifer thickness has declined, on average, by 63% across the entire district from predevelopment conditions to a 3-year 2020-2022 average of 29 feet. Of the four-counties under the proposed LEMA plan, aquifer thickness from predevelopment to present-day has average declines of 82, 40, 41, and 16 feet in Wallace, Greeley, Scott, and Lane counties, respectively. This represents an 80%, 68%, 53%, and 31% average reduction in the predevelopment aquifer thickness for Wallace, Greeley, Scott, and Lane counties, respectively. Groundwater declines are the result of groundwater usage exceeding the rates of natural inflows into the aquifer.

The numerical groundwater model developed by the KGS in 2015 in cooperation with GMD 1 and the KWO (Wilson et al., 2015) was later re-calibrated in 2020 (Liu et al., 2022) to incorporate specific yield values determined using the water-balance method outlined in Butler et al. (2016) combined with lithologic information, Output from this updated model illustrates the imbalance where groundwater pumping, the largest outflow from the aquifer, is greater than the estimated rates of total recharge, the aquifer's largest inflow component (fig. 2). Groundwater usage continually increased from predevelopment to its highest levels in the mid-1970s, where it was double that of total recharge (further discussed below) and has since been gradually decreasing. This decline in pumping is likely from a combination of reduced well yields from the reduction in aquifer thickness and an improvement in the accuracy of reporting water usage with the increasing adoptions of totalizing flow meters (Whittemore et al., 2018).

Recharge into the aquifer comes from several sources- precipitation, irrigation return flows, enhanced precipitation-based recharge over irrigated fields, and the delayed storage release from de-watered units to name a few. In a pattern similar to pumping, total modeled aquifer recharge increased from predevelopment periods in response to increased rates of irrigation return flows, which is the amount of pumped irrigation water that infiltrates past the root zone of the irrigated crops, eventually returning to the aquifer (fig. 2).

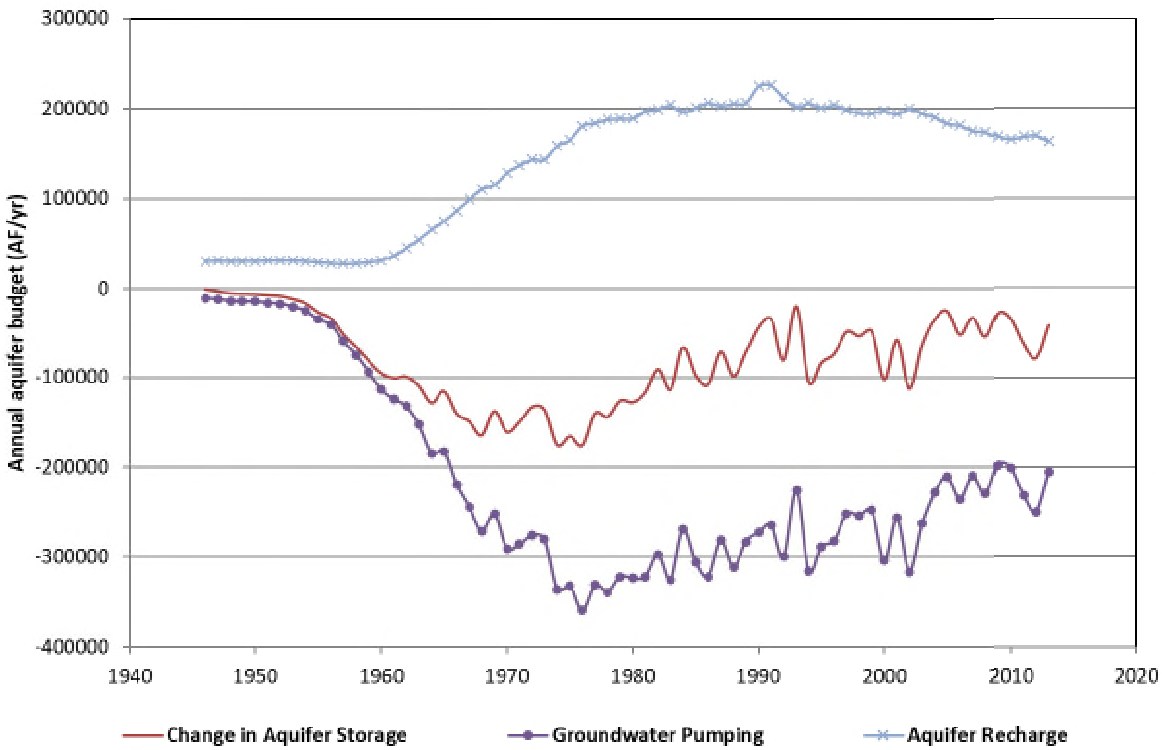


Figure 2. Annual aquifer budget for the active area of the 2020 re-calibrated GMD1 model.

Averages over the last two decades of the model period (1994 to 2013) show pumping to be approximately 25% higher than the annual rates of total recharge over the active area of the model area. During this period, annual pumping demands range from a low of 197,433 acre-feet to a high of 316,263 acre-feet, with an average of 248,923 acre-feet. In comparison, the estimated volume of total recharge ranged from a low of 162,997 acre-feet to a high of 206,371 acre-feet, with an average of 186,492 acre-feet. This difference between pumping and recharge results in losses from aquifer storage each year.

Recharge coming from the land surface (precipitation recharge, enhanced precipitation recharge, and irrigation return flows) is subject to a modeled delay function, typically 9 to 11 years, as it travels through the vadose zone before reaching the water table. Recharge from the surface is estimated to be less than half an inch annually (fig. 3) and will likely decrease slightly, in response to reducing rates of irrigation return flows, over the next decade or two. Of the surface-based recharge components, precipitation-based recharge represents the primary source of new water flowing into the aquifer. Over the last two decades of the modeled period (1994 to 2013), the estimated average amount of water flowing into the aquifer from precipitation and enhanced precipitation-based recharge over irrigated fields averages 27,554 acre-feet each year. In comparison, the average amount of pumping over this period (248,923 acre-feet) is approximately 89% percent higher.

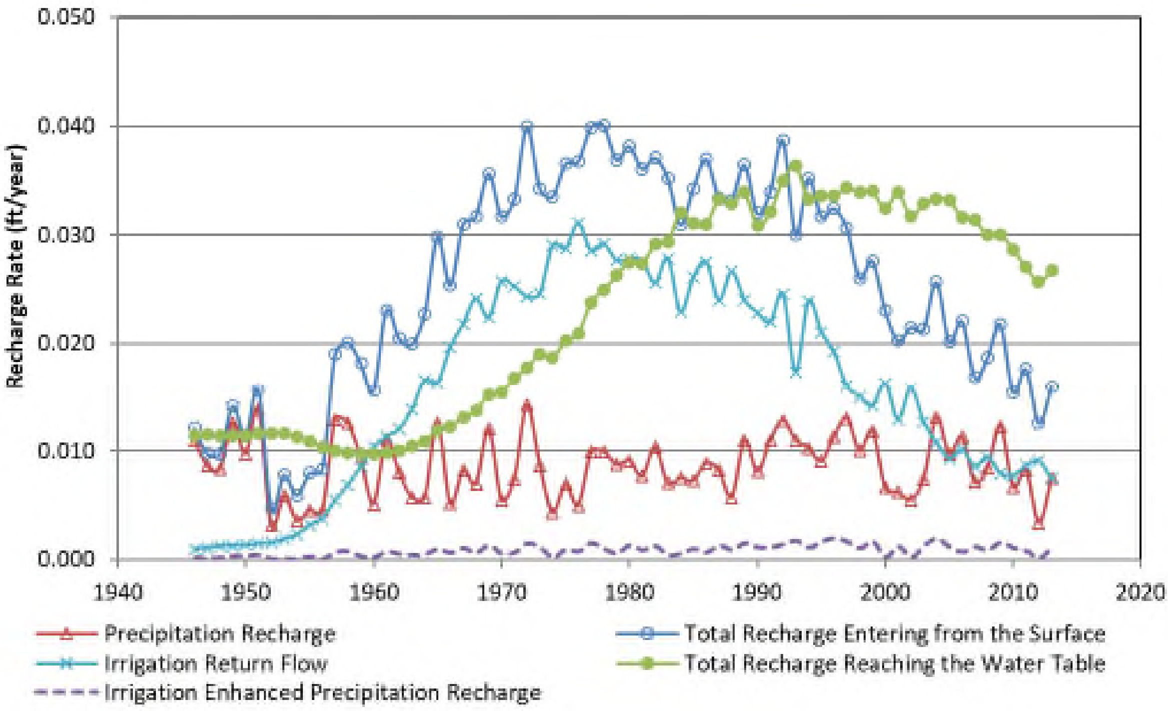


Figure 3. Estimated annual rates of recharge coming from the land surface for the active area of the 2020 re-calibrated GMD1 model.

Water Levels

Each year, the KGS and the KDA-DWR measure the depth-to-water in a network of approximately 1,400 water wells, across the HPA, as part of the state's Cooperative Water Level Program. The network attempts to have a well every 16 square miles and is used to provide regional- to sub-county- scale characterizations of the aquifer.

Customized software developed by the KGS, coupled with Global Positioning System (GPS) data, is used to make sure the same wells are visited each year. The majority of water-level measurements are taken in late December and early January using steel or electric tapes with precisions down to the hundredths of a foot. Measurements are field checked on site at the time of the visit to ensure locational accuracy and that the current measurement is within the historical trend of past measurements. Additional statistical and GIS reviews are conducted later to identify abnormal or anomalous measurements. If deemed necessary, well sites will be re-measured the same day or within a month, depending on the circumstances.

Collected water levels from the Cooperative Water Level Program, along with additional measurements from other local, state, and federal sources, are stored and served online through the KGS' Water Information Storage and Retrieval Database (WIZARD). WIZARD evolved from the U.S. Geological Survey's Ground Water Site Inventory in the mid- 1990s, and today represents the largest repository of depth-to-water measurements in Kansas.

Well site locations in the HPA and their associated water-level measurements were downloaded from WIZARD to estimate the water-table elevations each year from calendar years 2009 to 2022. The well site locations, based on their listed geographic coordinates, were spatially mapped into the ArcGIS software platform, a GIS mapping software. Within GMD1, all of the measured well locations used in this project have been surveyed with hand-held GPS units, which typically have horizontal accuracy ranges of 12 to 40 feet (fig. 1).

The WIZARD database contains codes indicating the status of the site at the time the water level was measured. Most water level measurements across GMD1 are taken in the first week of January and contain blank or null status codes indicating static or near static water level conditions. Past water level measurements that were coded to be “anomalous” from previous statistical and geostatistical reviews were not included in this project along with measurements taken from locations where the well was obstructed, was pumping at the time of the measurement, had recently been pumped, or had nearby sites that were being pumping at the time of the measurements.

The water-level measurements were used to calculate 1-year average winter depth to water for each well site, centered on each calendar year from 2011 to 2021. For example, a well’s 1-year average, winter depth to water for 2019 are based on measurements taken in the months of December 2018, January 2019, February 2019, and March 2019. Given most of the wells are only measured once a year (over 90% of the time in the month of January), the winter averages are typically only composed of a single measurement. However, some wells could be measured 2 or 3 times in a single winter period.

For this testimony, only wells containing computed 1-year, winter average water levels centered on the calendar years from 2010 to 2022 were considered. If a well site was missing a winter average value for one of these target years, it was removed from the data set. Under these selection criteria, 94 well sites were identified across GMD1. The annual change in the water table occurring each year from 2010 to 2021, was computed for each well site.

Groundwater Use

Water use reports can be downloaded from the online Water Information Storage and Retrieval Database (WIMAS) database. These reports are required by law to be submitted annually by water right holders, or their designee, to the KDA-DWR and penalties exist for non-submission or knowingly falsifying them. A quality control program has been in place since 1990 to review the reports and follow up, when necessary, with the water right holders to correct missing or questionable information. A mandatory metered order has been in place in GMD1 since 2012.

Total reported groundwater water usage was summarized for each unique groundwater well within GMD1 and its associated counties from 2010 to 2021. Summaries include all groundwater-based usages and water right types (e.g., Appropriated, Vested, Term, etc.…). Points of diversion for the water rights were spatially mapped into the ArcGIS software platform based on distances from the southeast corner of the public land survey system section they are in or by coordinates from hand-held GPS units with horizonal accuracies ranging from 12 to 40 feet.

Groundwater Use and Water-Level Relationships, GMD1

In Butler et al. (2016), the authors demonstrate how to apply the fundamental concepts of a water balance approach to seasonally pumped aquifers extending over county-scale areas in order to produce linear relationships between annual water use and annual water-level change. From these relationships, the reduction in the average annual water use needed to stabilize areally averaged water levels, defined as Q stable, can be readily calculated.

Figure 4 shows this relationship based on water levels from the annual water level network and groundwater-based water right wells inside GMD1 (fig. 1). Each dot on the plot represents the total amount of groundwater reported used in relation to the average annual water-level change for each year from 2010 to 2021. Over this period, total reported water use ranges from a low of 111,843 acre-feet in 2019 to a high of 236,957 acre-feet in 2012, with an average of 165,434 acre-feet. Water-level declines range from a -0.06 ft in 2017 (change from 2017 to 2018) to -1.52 ft in 2012 (change from 2012 to 2013), with an average annual water level decline of -0.55 feet over the period.

The relationship between reported water use and water level change is statistically significant with an R-squared value of 0.85. This indicates 85 percent of the variation shown in the average water-level change can be explain statistically by variations in the total annual reported water use. Based on this correlation of conditions from 2010 to 2021, a 32% reduction in average annual reported use would allow for stabilized water levels, defined here as a zero change in water levels. Under drought conditions seen in 2012, the reduction needed to stabilize water levels would be 52%.

Water-level trends from continuously recording observations wells across the Kansas HPA suggest these conditions and the computed Q stable values should hold for at least the next decade or two. However, the analysis should be repeated over time as the components that make up the water balance (aquifer inflows and outflows) slowly adjust to new pumping allocations determined by proposed management plans.

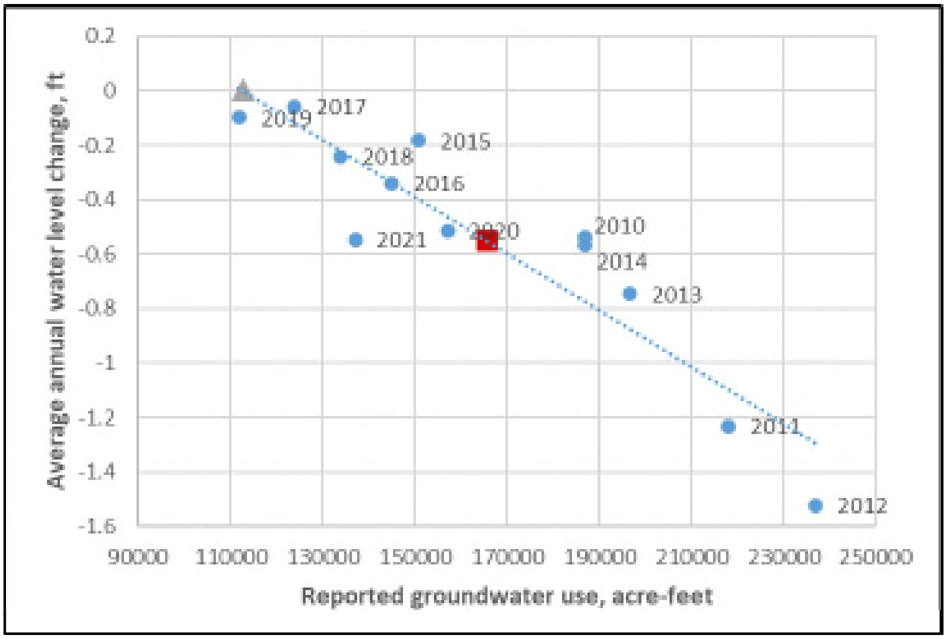


Figure 4. Average annual water-level change versus annual water use from 2010 to 2021 for the GMD1. Dashed line is the best-fit straight line to the plot. Overall average conditions for both water use and water-level change is represented by the maroon square. Water use, under stable water-level conditions, is shown by the olive-colored triangle.

Groundwater Use and Water-Level Relationships, Proposed Four County LEMA

Figures 5 to 8 show the water-level change versus annual water use relationship for each of the county areas within GMD1 listed under the proposed Four County LEMA plan. Each county's R-Square value, average water-level change, average water usage, and percent reduction needed to achieve stabilized water levels, based on conditions from 2010 to 2021, are shown in Table 1. In general, water usage and the percent reductions are the highest in Wallace County and progressively become lower moving south and east. Much of this can be attributed to aquifer conditions (greater water availability in Wallace relative to other areas) and climatic conditions (precipitation increases slightly moving west to east).

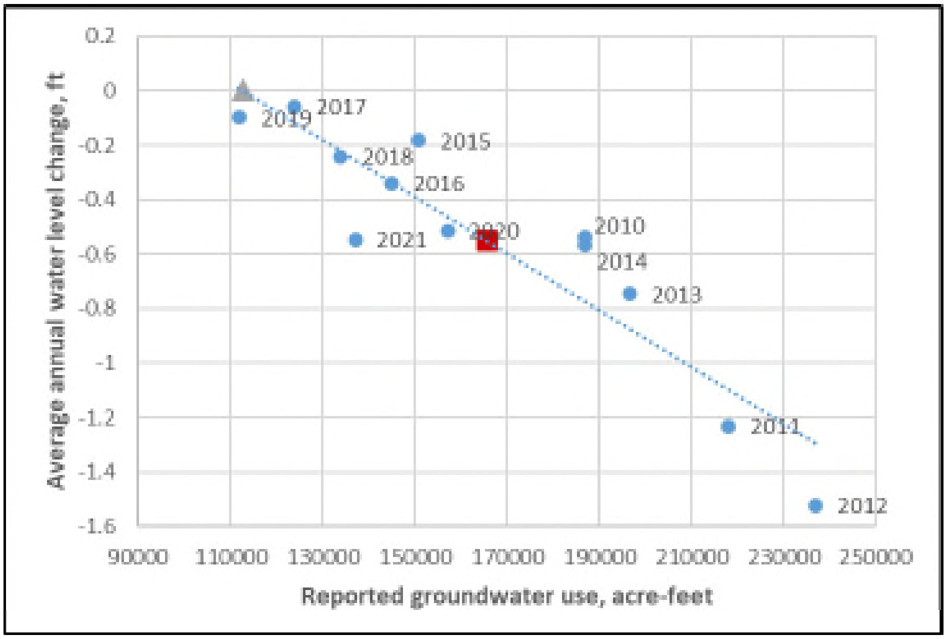


Figure 5. Average annual water-level change versus annual water use from 2010 to 2021 for Wallace County. Dashed line is the best-fit straight line to the plot. Overall average conditions for both water use and water-level change is represented by the maroon square. Water use, under stable water-level conditions, is shown by the olive-colored triangle.

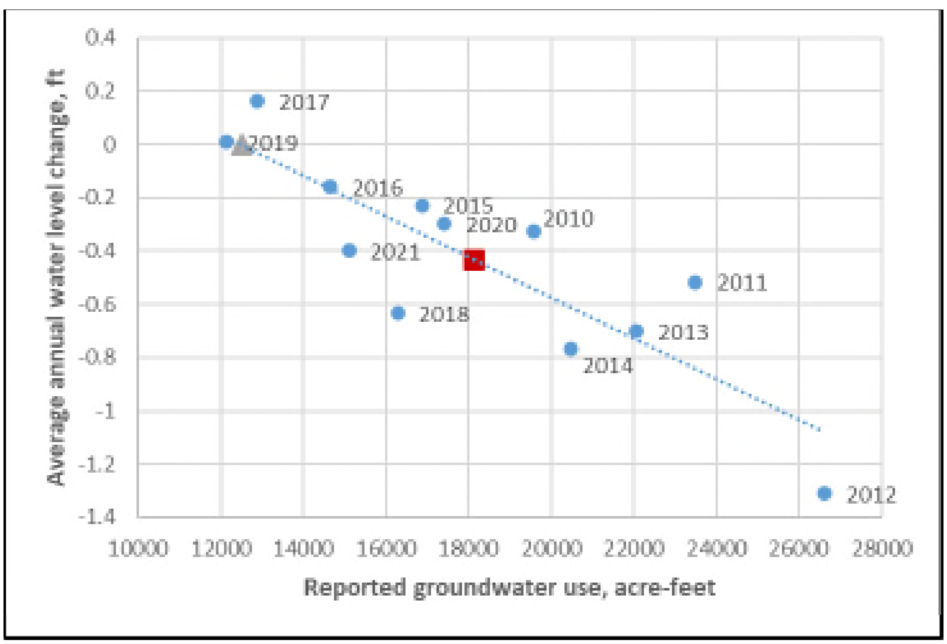


Figure 6. Average annual water-level change versus annual water use from 2010 to 2021 for Greeley County. Dashed line is the best-fit straight line to the plot. Overall average conditions for both water use and water-level change is represented by the maroon square. Water use, under stable water-level conditions, is shown by the olive-colored triangle.

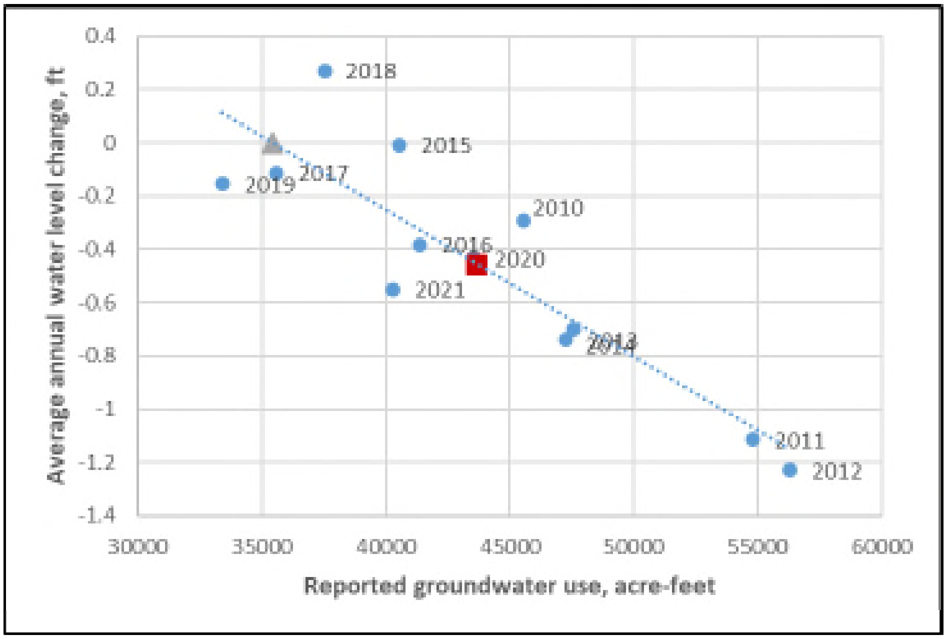


Figure 7. Average annual water-level change versus annual water use from 2010 to 2021 for Scott County. Dashed line is the best-fit straight line to the plot. Overall average conditions for both water use and water-level change is represented by the maroon square. Water use, under stable water-level conditions, is shown by the olive-colored triangle.

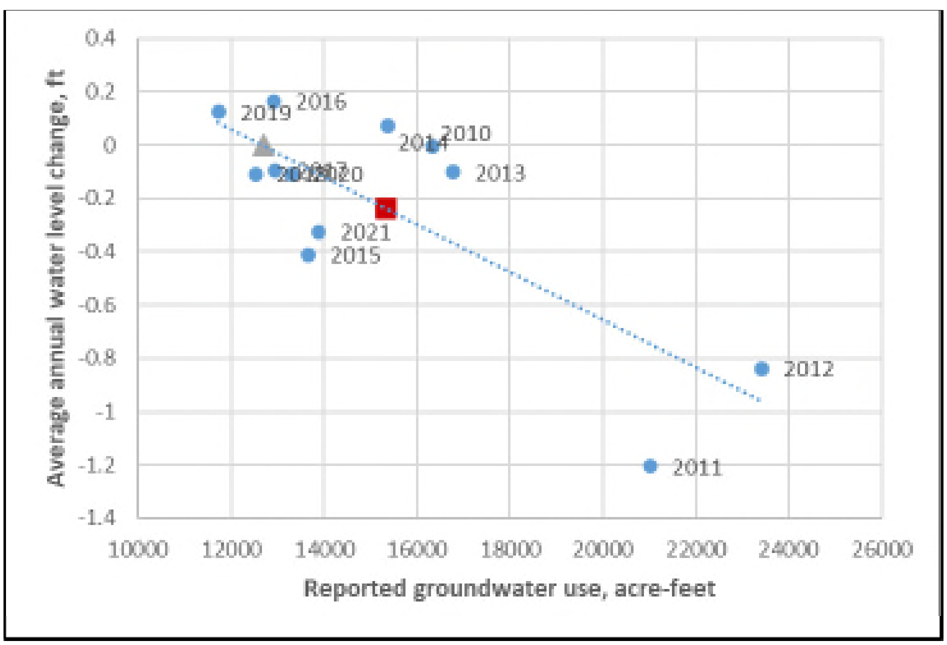


Figure 8. Average annual water-level change versus annual water use from 2010 to 2021 for Lane County. Dashed line is the best-fit straight line to the plot. Overall average conditions for both water use and water-level change is represented by the maroon square. Water use, under stable water-level conditions, is shown by the olive-colored triangle.

Table 1 Water-level change / water use relationships from 2010 to 2021, GMD1 Proposed Four County LEMA					
county	**R Square**	**Average Water-Level Change (ft)**	**Average Reported Groundwater Use (AF)**	**Percent Reduction (average 2010 - 2021)**	**Percent Reduction (Drought 2012)**
Wallace	0.81	-1.25	42,377.44	51%	68%
Greeley	0.74	-0.43	18,127.87	31%	53%
Scott	0.78	-0.45	43,641.70	19%	37%
Lane	0.62	-0.24	15,324.61	17%	46%

References:

Butler, J.J., Jr., D.O. Whittemore, B.B. Wilson, and G.C. Bohling, 2016, A new approach for assessing the future of aquifers supporting irrigated agriculture, Geophys. Res. Lett., v. 43, no. 5, pp. 2004-2010.

Fross, D., Sophocleous M., Wilson B.B., and Butler J.J.Jr., 2012, Kansas High Plains Aquifer Atlas, Kansas Geological Survey. [Available at http://www.kgs.ku.edu/HighPlains/HPA_Atlas/index.html, accessed May, 2022].

Liu, G., Wilson, B. B., Bohling, G. C., Whittemore, D. O., & Butler, J. J., 2022, Estimation of specific yield for regional groundwater models: Pitfalls, ramifications, and a promising path forward. Water Resources Research, 58, e2021WR030761, 14 p.

Whittemore, D. O., Butler, J.J., and Wilson, B. B., 2018, Status of the High Plains Aquifer in Kansas: Kansas Geological Survey, Technical Series 22, 14 p.

Wilson, B. B., Liu, G., Bohling, G. C., Whittemore, D. O., and Butler, J. J., Jr., 2015, West Central Kansas GMD1 Model: Kansas Geological Survey, Open-File Report 2015-33, 137 p.

Woods, J. J., and Wilson, B. B., 2022, Western Kansas GMD1 Maps: Kansas Geological Survey, Open-File Report 2022-8, 5 map set.

EXHIBIT E

EXHIBIT E

Monitoring the Impacts of Sheridan County 6 Local Enhanced Management Area

Final Report for 2013 – 2017

11/15/2018

Dr. Bill Golden

Golden is an assistant professor in the Department of Agricultural Economics at Kansas State University. Liebsch is a graduate student in the Department of Agricultural Economics at Kansas State University. This research was funded in part by the Kansas Water Office under Contract # 15-0112, in part by the U.S.D.A. Ogallala Aquifer Program, and in part by the U.S.D.A. – N.I.F.A. Ogallala Water CAP Project.

IV. Economic Results

As we move into the 21st century, goals for our water resources are gradually changing. Concerns over aquifer decline rates call into question the current allocation of water resources. With increasing frequency, producers and policy makers are asked to decide how to reduce groundwater consumption. Policy makers, producers, and other stakeholders are concerned about the likely negative economic impacts that the agricultural producers might incur as crop water use is reduced. Unfortunately, there is little economic literature and less empirical data that is capable of providing guidance on the likely impacts.

This section of the report reviews economic data collected from irrigated crop producers. These producers generally have irrigated cropland within the boundaries of the LEMA, as well as irrigated cropland outside the boundaries of the LEMA. Producer involvement was strictly voluntary; they reported data directly to GMD #4 who passed the data to the author for analysis. Due to the limited number of participants reporting economic data, the results cannot be considered statistically valid, never the less they are informative. Additionally, rainfall and soil type were not reported by the producers and these variables are important determinants of crop yield. In the following tables 'Cash Flow' was the economic metric reported. Cash Flow was defined as gross revenue (crop price x crop yield) less variable costs of production (fertilizer, seed, herbicide, hired labor etc.). While each producer reported their own crop price, for this analysis, the annual average crop price reported by all producers was used in the cash flow calculation. Land rent and fixed equipment costs were not included in the analysis.

Table 13 summarizes the producer reported data for the 2013 through 2017 crop year. Irrigated corn producers within the LEMA boundary reported using 23.1% less groundwater and yielding 1.2% less corn as compared to irrigated corn producers outside the LEMA boundary. These data are relatively consistent with irrigated crop production functions developed by Kansas State University Research and Extension which exhibit diminishing marginal returns, from the standpoint that using less groundwater typically generates less yield. However, if producers are efficiently using groundwater, outside the LEMA area we would expect a slightly larger yield loss. Somewhat surprisingly, irrigated corn producers within the LEMA boundary reported 4.3% more cash flow than their higher yielding counterparts outside the LEMA. Irrigated soybean producers within the LEMA boundary reported using 1.3% less groundwater and yielding14.9% less soybeans as compared to irrigated soybean producers outside the LEMA boundary. These data are relatively consistent with irrigated crop production functions developed by Kansas State University Research and Extension. Soybean producers within the LEMA boundary reported 12.4% less cash flow than their higher yielding counterparts outside the LEMA. There was only one field of irrigated grain sorghum reported from outside the LEMA boundary. The producers that grew irrigated grain sorghum inside the LEMA boundary applied an average of 4.1 inches per acre, 60.5% less groundwater than their counterpart, yielded 13.8% less grain, but 59.9% more cash flow.

V. Rainfall Data

As previously mentioned, rainfall is a major determinant of groundwater use and crop yield. Figure 13 illustrates the historic annual rainfall for Sheridan County for the years 2000 through 2017. The average for this period was 20.3 inches per year. Both 2013 and 2014 were dryer than normal years, while 2015, 2016, and 2017 were wetter than normal years.

VI. Hydrology Response

The stated purpose of the LEMA legislation was to reduce groundwater consumption in order to conserve the state's water supply and extend the life of the Ogallala Aquifer. While the purpose of this research was to document the observed economic and agronomic changes, it is certainly relevant to comment on the hydrology response to the LEMA. After analyzing the data, Jim Butler, Kansas Geological Survey senior scientist and geohydrology section chief stated that the results indicate that the decline rate within the LEMA has gone from about two feet per year to about 5 inches per year.[3]

VII. Conclusions

The purpose of this report was to provide the methods, assumptions, and estimates of the agronomic and economic impacts associated with groundwater use reductions in the Sheridan #6 LEMA. The reader should note that this is the 'Final Report' and provides information from the five-year study

Relative to their neighbors outside the LEMA boundary, irrigated crop producers within the boundary of the LEMA: reduced total groundwater use by a statistically significant 23.1%, reduced average groundwater use per acre by a statistically significant 16.0%, reduced irrigated crop acreage by a statistically significant 10.9%, reduced irrigated corn acreage by a statistically significant 23.3%, increased irrigated grain sorghum acreage by a statistically significant 335.4%, and increased irrigated wheat acreage by a statistically significant 60.3%.

The economic results are consistent with Golden and Leatherman (2017) and suggests that, given the certainty of groundwater use reductions, producers are able to implement strategies to maintain returns and apply less groundwater. Additional research on the risk associated with reduced groundwater use is needed. The producer-supplied data suggests that producers within the LEMA boundary have been able to reduce groundwater use with minimal impact on cash flow. While we can observe the changes in crop mix and water use, we cannot discern, at this point, exact strategies producers are using to reduce variable expenses and/or adjust cultural practices.

On February 17, 2017, GMD 4, at the request of producers in the Sheridan #6 LEMA, submitted a request to the Division of Water Resources to extend the Sheridan #6 LEMA. On August 24, 2017, the Chief Engineer accepted the extension proposal for the period 2018-2022. This suggests that producers within the Sheridan #6 LEMA believe they can mitigate any negative economic consequences associated with reduced groundwater use and that the benefits of groundwater conservation outweigh the costs.

[3] Source: http://www.kgs.ku.edu/General/News/2017/stabilize.html

EXHIBIT F

EXHIBIT F

The Journal of
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Analysis
& Policy

JRAP 47(2): 176-187.

Impact Analysis of the Walnut Creek Intensive Groundwater Use Control Area

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Abstract: In 1992, an intensive groundwater-use control area (IGUCA) was established in the Walnut Creek Valley in central Kansas. Ex-post quasi-experimental control group analysis suggested that producers were able to mitigate the initial economic losses by maintaining/expanding the production of higher valued crops and by adopting efficient irrigation technologies and practices. It is hypothesized that the 'certainty' of water restrictions diminished the economic impacts. The foreknowledge that water use would be restricted into the foreseeable future allowed producers to develop long-run strategies to mitigate economic damages.

1. Introduction

For the majority of the 20th century, federal and state water policies in the western United States aimed to encourage settlement and develop surface water and groundwater natural resources for use by agriculture. Today, approximately 43 million acres of agricultural land are irrigated in the West. These lands produced 72 percent of crop sales on only 27 percent of the total harvested crop acreage. Irrigated agriculture currently consumes approximately 90 percent of the freshwater resources in the West (Gollehon and Quinby, 2000).

As we move into the 21st century, societal goals for our water resources are gradually changing. Public concerns over aquifer decline rates, diminishing streamflow, decreasing wildlife populations, the desire for more water-oriented recreational facilities, the water needs of an expanding industrial sector, and increased population concentration call into question the current allocation of water resources. With increasing frequency, policy makers are asked to decide how to equitably transfer water rights from the agricultural sector to competing sectors. When these situations, occur policy makers, agricultural producers, and other stakeholders are concerned about the likely negative economic impacts that the agricultural community will incur as water resources are shifted away from the production of irrigated crops, the cost of the policy, and the benefits to the water resource. Unfortunately, there are few case studies capable of providing guidance on the likely impacts.

In 1992, an Intensive Groundwater-Use Control Area (IGUCA) was established in the Walnut Creek Valley in central Kansas. This IGUCA was instituted to address streamflow depletions resulting from excessive withdrawals of groundwater. The Walnut Creek IGUCA stopped the authorization of new water rights and cut back groundwater withdrawals by existing water right holders. The purpose of this project is to provide policy makers, producers, and other stakeholders with a quantitative analysis of the economic impacts associated with transferring water resources from agriculture to other uses or for conservation purposes. This will be accomplished by applying an ex-post case study technique to the Walnut Creek situation. The quasi-experimental control group analysis used in this study can be characterized as a long-run dynamic analysis.

cropland. As reflected in Figure 3 and Table 1, the IGUCA resulted in statistically significant short-run and long-run reductions in annual irrigated acreage. It is possible that idled irrigated acres generated non-irrigated crop revenues. Due to the uncertainty in crop rotation, as noted in Pope (1992), possible nonirrigated crop revenues generated from previously irrigated cropland were not included in this analysis. Had they been included, both the short-run and long-run estimated impacts to crop revenue would be reduced.

4.3. Producer's reaction to water use restrictions

When water-use is restricted, producers of irrigated crops develop and implement strategies to mitigate potential revenue losses (Amossom et al., 2009). Buller (1988) and Wu et al. (1996) suggest that producers will change crop mix by shifting from high water-use crops, such as corn, into crops with lower consumptive use. Taylor and Young (1995) and BBC Research & Consulting et al. (1996) suggest that higher valued, possibly more water intensive crops will remain in production and lower valued crops on marginal land will be the first to be retired. Burness and Brill (2001) and Williams et al. (1996) suggest that in such cases producers will adopt more efficient irrigation technology. Harris and Mapp (1986) and Klocke et al. (2004) suggest that computer-aided technologies and improved irrigation scheduling might provide a solution. Schlegel et al. (2005) report significant water savings with the adoption of a limited irrigation management strategy.

Both alfalfa and corn are considered highly profitable and high water use crops. As a result, it was of interest to analyze how the acreage devoted to these crops varied over time. Data on irrigated crop acreage from WRIS were used to construct a time series for both the Target and Control areas. The econometric models for the difference in the indexed values of irrigated crop acreage, ΔIA_t, follow the same general form as Equation (5), substituting the change in indexed values of irrigated crop acreage for total water use. The model results suggest that the IGUCA resulted in a statistically significant long-run increase in irrigated alfalfa acreage, but no statistically significant change was observed in irrigated corn acreage. While not reported, a reduction in the irrigated acreage devoted to wheat and grain sorghum was observed. These findings are consistent with those suggested by Taylor and Young (1995) and BBC Research & Consulting et al. (1996).

Data on the indexed time trends for acres irrigated with center pivot technology from WRIS were obtained. The econometric models for the difference in the indexed values of acres irrigated with center pivot technology, ΔCPT_t, follows the same general form as Equation (5), substituting the change in indexed values of acres irrigated with center pivot technology for total water use. The model results suggest that the IGUCA resulted in a statistically significant long-run increase in acres irrigated with center pivot technology. While not reported, a similar analysis for acres irrigated with flood technology suggests that the majority of the short-run total irrigated acreage reduction (Figure 3) came from parcels of land irrigated with flood technology. These findings are consistent with those suggested by Burness and Brill (2001) and Williams et al. (1996). Referencing back to Figure 4 and Table 1, statistically significant short-run and long-run reductions in water use per acre were observed. This suggests that producers reduced water use on high water use crops such as corn and alfalfa without experiencing a comparable reduction in revenues. These findings are consistent with those suggested by Schlegel et al. (2005). It is unclear whether computer-aided technologies and improved irrigation scheduling, as suggested by Harris and Mapp (1986) and Klocke et al. (2004), enabled producers to reduce water consumption, as data on these practices are unavailable.

4.4. Impacts on land values and property tax

When irrigated cropland is converted to nonirrigated cropland there may be a change in land values, which may in turn impact local property tax revenues. To determine the IGUCA's impact on land prices, this research relied on a model developed by on Tsoodle et al. (2006). This hedonic appraisal technique allows for the unbiased estimation of the value of irrigated cropland based on the conventional site-specific characteristics of the land as well as hydrological and related characteristics of the water right.

The linear hedonic model for irrigated cropland can be conceptualized as:

$$P = \beta_0 + \sum_{i=1}^{n} \beta_i EV_i + \sum_{i=n+1}^{j} \beta_i BV_i \qquad (7)$$

where P is the logged per acre price for the land sale, EV is a vector of site-specific explanatory variables, and BV is a vector of binary variables representing the year of the sale. The vector of binary variables quantifies the yearly change in land price and will be used to compare the time path of land prices in the control and target areas.

The data in this analysis consists of all 'arms-length transaction' sales of irrigated agricultural land in Kansas between 1986 and 2000. The Property Valuation Division (PVD) of the Kansas Department of Revenue (KDR) collected this information and verified by personal contact the fair market nature of the sale. Kansas statutes require any land transaction to be reported to the KDR. The County Appraiser, using a standardized method, collects this data and provides it to KDR on an annual basis. The data contains information on sales location, sales date, the parcels' agriculture use types, soil mapping unit contained in the parcel, total acres in the parcel, the agricultural tax value, the tax value of all buildings, topographical codes, utility codes, and access codes.

Given Equation 4 and Equation 7, the econometric models for the difference in binary variables, ΔBV_t, can be specified as in Equation (5), substituting the change in the binary variable for total water use. The model results (Table 1) suggest that the IGUCA resulted in no statistically significant short-run or long-run decrease in irrigated cropland values. However, it should be noted that only parcels that were sold as irrigated cropland were in the dataset. While on average there was no difference in observed irrigated land price, this does not imply that some unsold parcels may have experienced a reduction in value or that previously irrigated land that was sold as nonirrigated cropland did not experience a loss.

In 1985, concern over rapidly escalating land prices prompted a shift from fair-market appraisal of agricultural land to use-value appraisal for property tax appraisal purposes in the State of Kansas. These valuations were established for each parcel of land devoted to agricultural use upon the basis of the agricultural income or productivity attributable to the inherent capabilities of such land. In order to stabilize the appraisal process, multi-year averages for acreage, revenue, and costs are incorporated into the process. In 1989 and 1999, major changes were made to the appraisal process. In 1997, those irrigated parcels within the IGUCA boundaries that were classified as having either senior or junior water rights were assessed based on nonirrigated land use values.

County level data from PVD on total agricultural assessed valuations were collected for 1989 through 2005. The econometric models for the difference in the indexed values of total agricultural assessed valuations, $\Delta TAAV_t$, can be specified as:

$$\Delta TAAV_t = \lambda_0 + \lambda_1 D1_t. \tag{8}$$

This model specification includes only one binary variable which takes the value of one for the period 1997 through 2005. The regression results suggest that the IGUCA may not have resulted in a statistically significant increase in total agricultural assessed valuations. The true impact of the reduction in senior and junior water rights assessments may be masked due to the fact that the target area PVD was aggregated at the county level, as opposed to the IGUCA boundaries, and also may have been impacted by the changes in appraisal process that were previously mentioned.

4.5. Impacts on the natural resources

The goal of water conservation policy is obviously to conserve water. While the economic impacts of policy are important to all participants, one metric of success is whether or not the policy actually resulted in a reduction in the primary water usage. Since the implementation policy requires the expenditure of taxpayer dollars, the investment of other state resources, and the financial burdens placed on other stakeholders, it is imperative that research be expended to quantify the impacts on the water resources.

Concerns over the lack of continuous streamflow motivated the 1992 Walnut Creek IGUCA. Pope (1992) reported that the combination of declining streamflows and declining groundwater levels indicated that the hydrologic system was out of balance and that the balance needed to be restored to achieve the goal of sustainability. While this research primarily focuses on the economic impacts associated with the IGUCA, it is nevertheless appropriate to ask whether the IGUCA met its environmental objectives.

Recognizing the hydraulic connectivity between streamflow and the aquifer, the Walnut Creek IGUCA focused on aquifer recovery as the means to restore streamflow. Pope (1992) indicated that the aquifer should be allowed to recharge and be maintained in an essentially full state such that total average annual groundwater withdrawals are limited to the long-term sustainable yield. In order to monitor groundwater elevation changes, the Kansas Department of Agriculture's Division of Water Resources (DWR) began monitoring observation wells within the IGUCA's boundaries. From 1993 to 2008, on average, the groundwater elevation has increased during the observation period (conversely the depth to water has decreased).

The econometric model for depth to groundwater (*DTG*) can be specified as:

$$DTG_t = \lambda_0 + \lambda_1 P_t + \lambda_2 P_t^2 + \lambda_3 D1_t, \tag{9}$$