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).

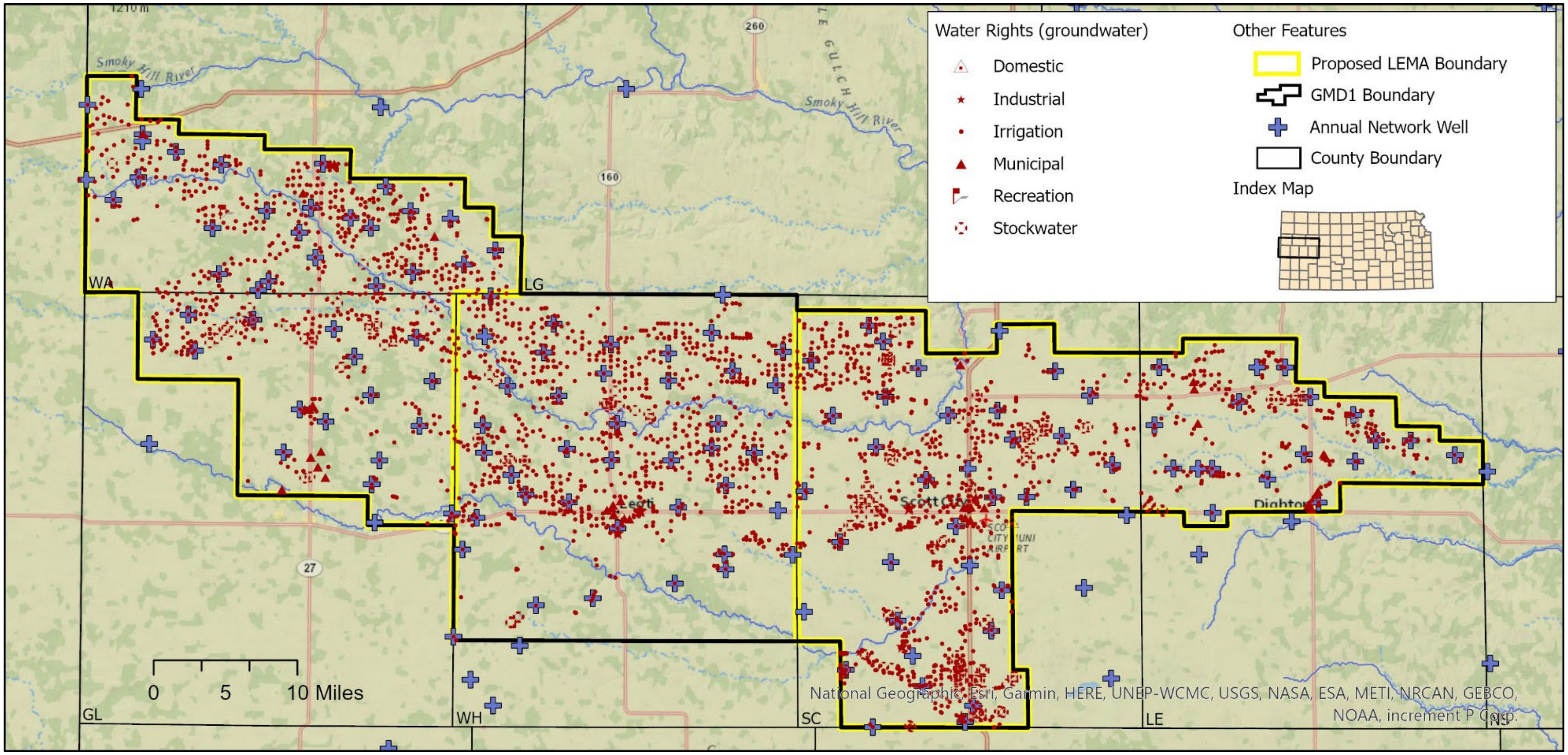

Figure 1. Western Kansas GMD1, annual network wells, and groundwater-based water right wells.

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).

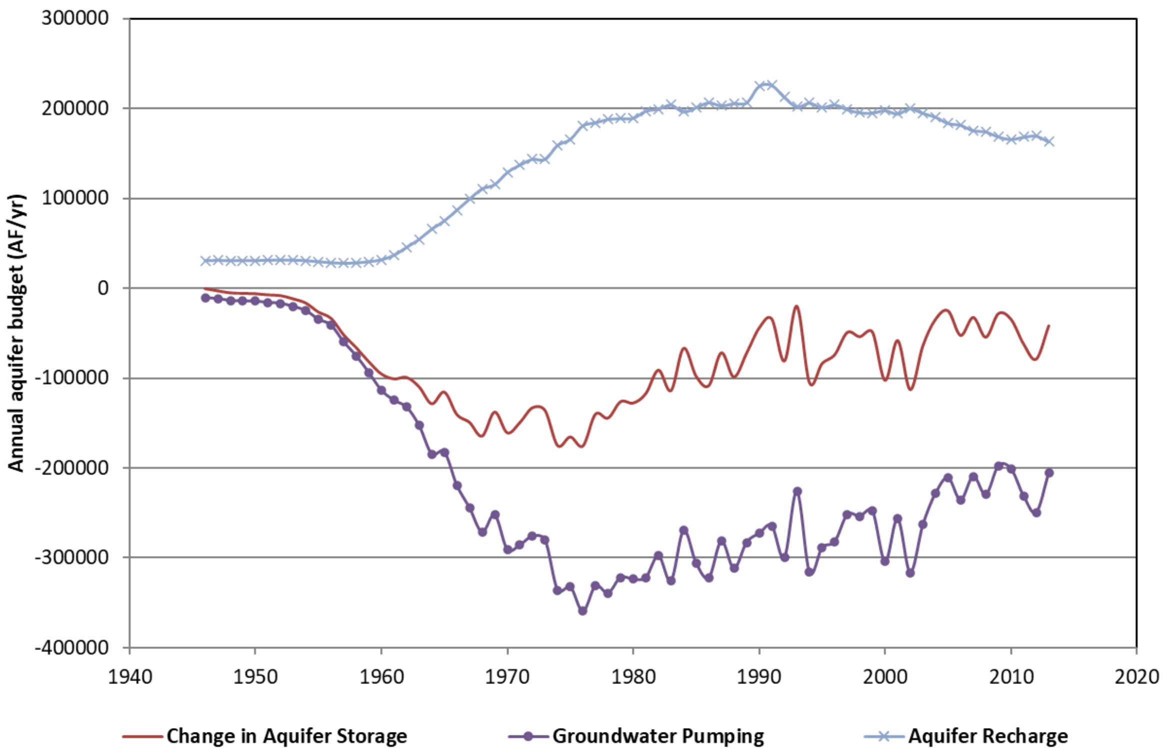

Figure 2. Annual aquifer budget for the active area of the 2020 re-calibrated GMD1 model.

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.

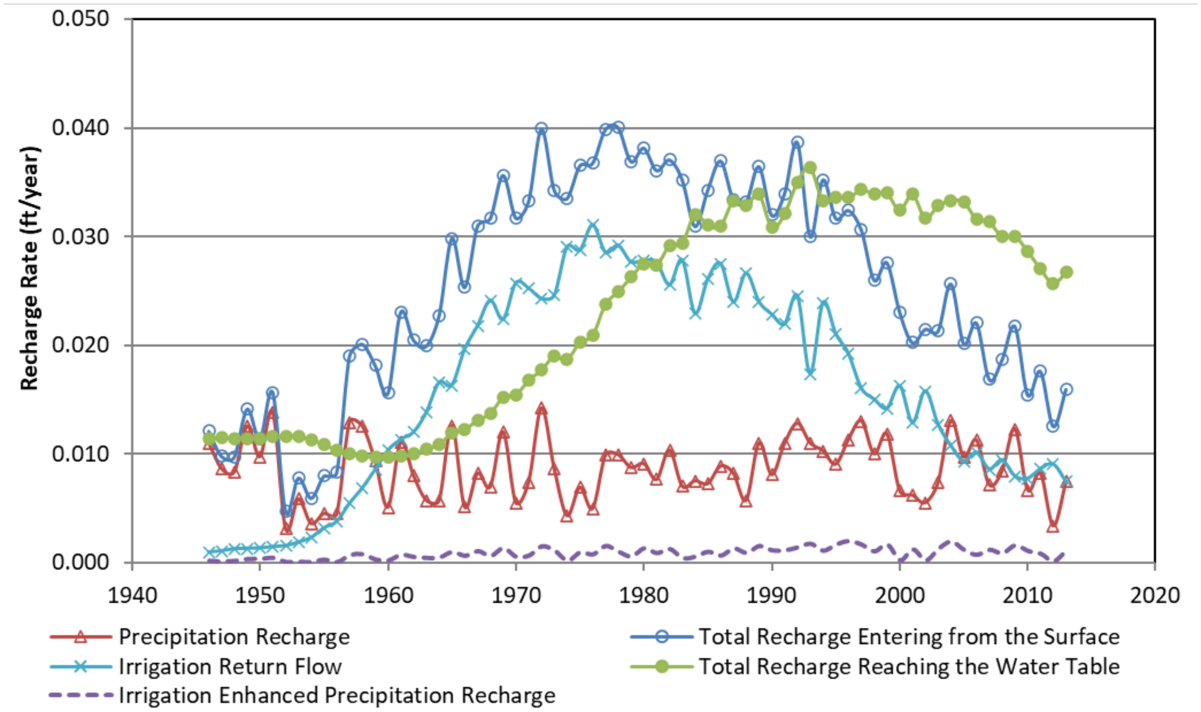

Figure 3. Estimated annual rates of recharge coming from the land surface for the active area of the 2020 re-calibrated GMD1 model.

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.

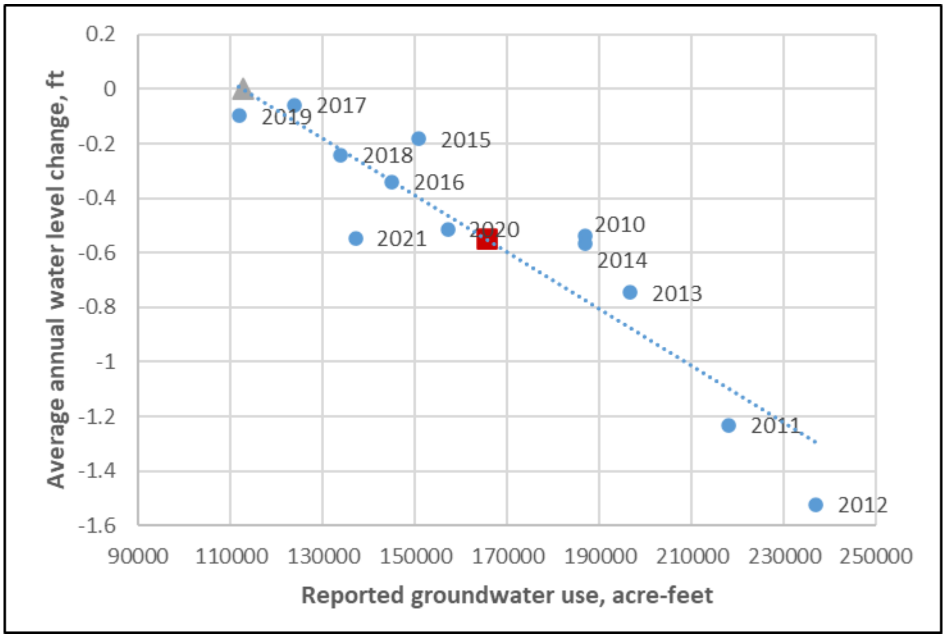

Figure 4. Average annual water-level change versus annual water use from 2010 to 2021 for the GMD1. Dashed line is the best-fit straight line to the plot. Overall average conditions for both water use and water-level change is represented by the maroon square. Water use, under stable water-level conditions,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

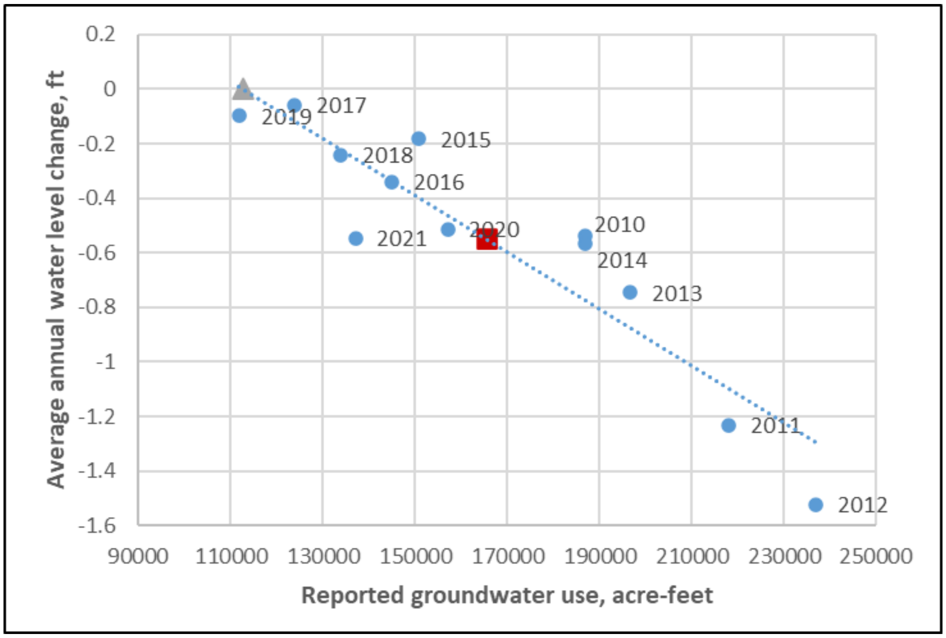

Figure 5. Average annual water-level change versus annual water use from 2010 to 2021 for Wallace County. Dashed line is the best-fit straight line to the plot. Overall average conditions for both water use and water-level change is represented by the maroon square. Water use, under stable water-level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

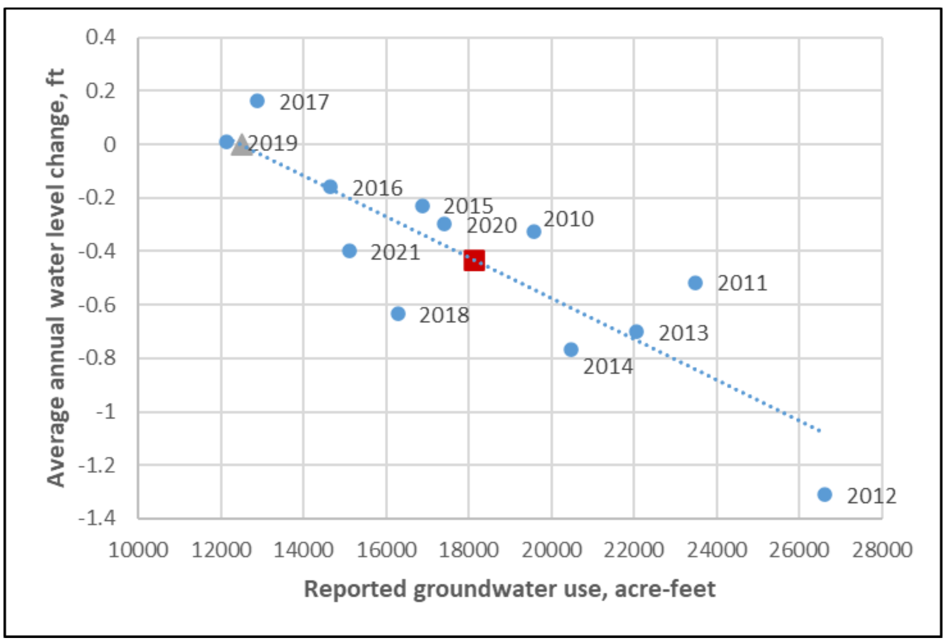

Figure 6. Average annual water-level change versus annual water use from 2010 to 2021 for Greeley County. Dashed line is the best-fit straight line to the plot. Overall average conditions for both water use and water-level change is represented by the maroon square. Water use, under stable water-level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

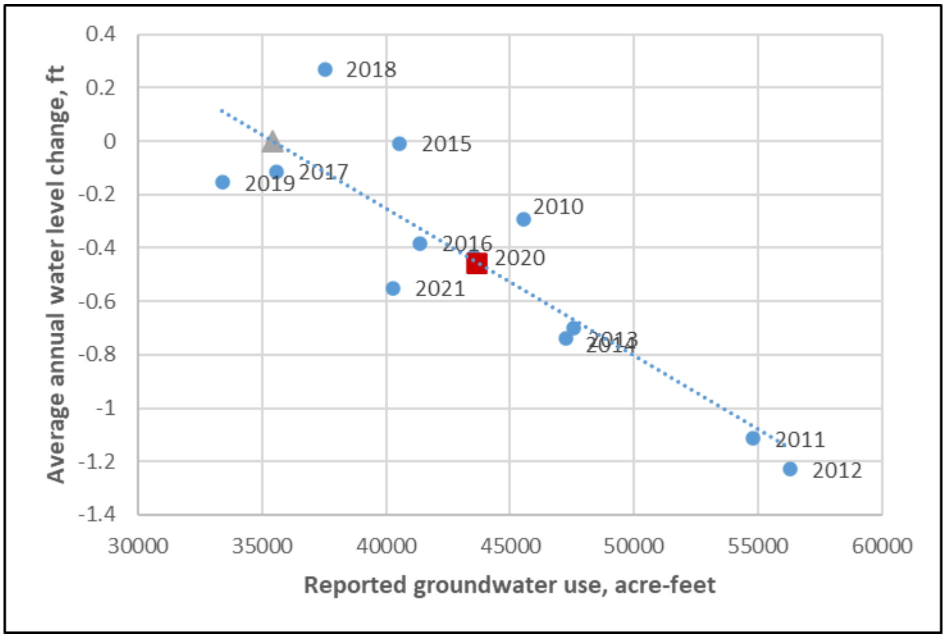

Figure 7. Average annual water-level change versus annual water use from 2010 to 2021 for Scott County. Dashed line is the best-fit straight line to the plot. Overall average conditions for both water use and water-level change is represented by the maroon square. Water use, under stable water-level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

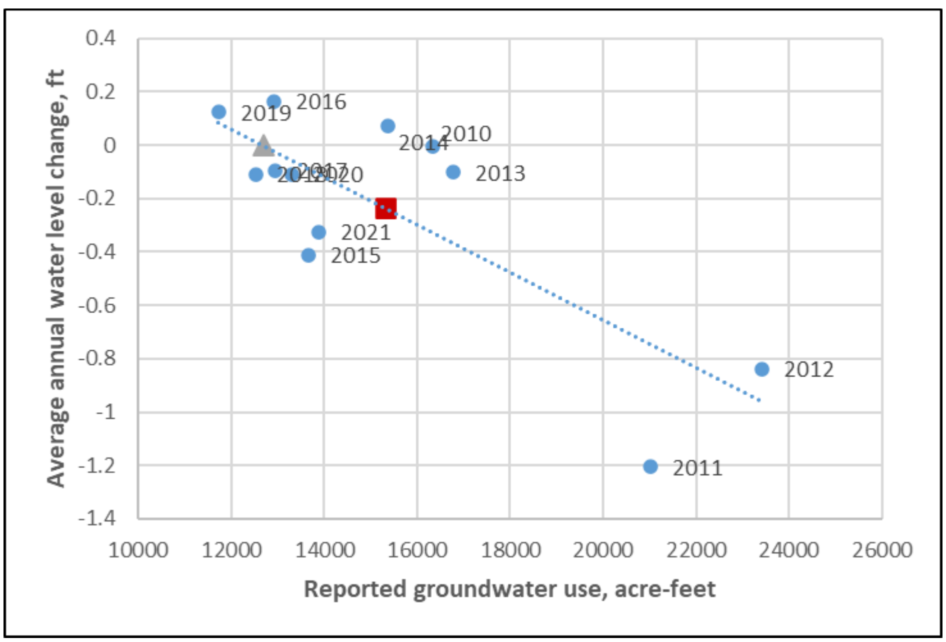

Figure 8. Average annual water-level change versus annual water use from 2010 to 2021 for Lane County. Dashed line is the best-fit straight line to the plot. Overall average conditions for both water use and water-level change is represented by the maroon square. Water use, under stable water-level conditions,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

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