First Report on the Five Year Review of Water Availability
East James Management Unit of the Tulare Aquifer
September 17, 2020

The Water Management Board deemed the East James management unit of the Tulare aquifer as fully appropriated in 2013. In 2014, the South Dakota Legislature provided a process for administering fully appropriated aquifers by placing into law SDCL 46-2A-7 through 46-2A-7.7. These laws provide a process to 1) notice a determination that a groundwater source is fully appropriated; 2) accept and hold applications for future consideration; 3) create a priority list for future appropriations if unappropriated water becomes available; and 4) conduct a review at least once every five years to determine whether unappropriated water is available. At the time of this report, there are 14 applications to appropriate water on hold for this aquifer management unit and they total 26.27 cubic feet per second (cfs) for the irrigation of 1,893 acres. This report is an assessment of the availability of unappropriated water in the East James management unit of the Tulare aquifer to satisfy the five-year review requirements for fully appropriated aquifers.

AQUIFER: East James management unit of the Tulare aquifer (T:EJ)

HYDROGEOLOGY

The Tulare aquifer is a Quaternary aged system of interconnected sand and gravel layers that were deposited as outwash by meltwater from receding glaciers (Howells and Stephens, 1968). The East James management unit of the Tulare aquifer is a buried aquifer generally lying immediately above the bedrock (basal) (Hedges et al., 1982). The glacial deposits that created the Tulare aquifer were deposited on top of an existing erosional surface that had exposed the Cretaceous aged Pierre Shale, Niobrara Formation, and in the buried deeply incised bedrock valleys, the Codell Sandstone member of the Carlisle Shale (Howells and Stephens, 1968). Hedges et al. (1982) identified 23,200 acres of Tulare: East James aquifer in Beadle County and over 100,700 acres of Tulare: East James aquifer in Spink County. The specific yield of the aquifer was estimated to be 0.15 by Hedges et al. (1982) and the aquifer was estimated to contain over 608,000 acre-feet of recoverable water in storage. Goodman (2006) refined the estimated areal extent of the Tulare: East James aquifer by using the areal extent calculated for Spink County by Goodman (1984) and the areal extent calculated for Beadle County by Hedges et al. (1982). Buhler (2012) further refined the estimated areal extent of the Tulare: East James aquifer to 123,578 acres.

Using the aquifer area estimated by Buhler (2012), 123,578 acres, and an estimated average saturated thickness of 37 feet (Hamilton and Howells, 1996), the estimated amount of recoverable water in storage is approximately 686,000 acre-feet. Buhler's (2012) analysis also determined that approximately 22,477 acres of the Tulare: East James aquifer were under unconfined conditions in September 2011, showing that at that time, the Tulare: East James aquifer was generally under confined conditions. Hedges et al. (1982) had found that the aquifer was more unconfined than confined and classified the aquifer as generally being unconfined. The static water level in the Tulare: East James aquifer has ranged from 50 feet below ground surface to rising above ground surface (Water Rights, 2020b). In the southern portion of the Tulare: East James aquifer, the direction of groundwater flow is generally from the east to the west, towards the James River. In the northern portion of the Tulare: East James aquifer, the direction of groundwater flow is generally towards Timber Creek and towards the James River.

South Dakota Codified Law 46-2A-9
Pursuant to SDCL 46-2A-9, a permit to appropriate water may be issued only if there is a reasonable probability that there is unappropriated water available for the applicant's proposed use, that the proposed diversion can be developed without unlawful impairment of existing rights and that the proposed use is a beneficial use and in the public interest.

WATER AVAILABILITY
The probability of unappropriated water available from an aquifer can be evaluated by considering SDCL 46-6-3.1, which requires "No application to appropriate groundwater may be approved if, according to the best information reasonably available, it is probable that the quantity of water withdrawn annually from a groundwater source will exceed the quantity of the average estimated annual recharge of water to the groundwater source."

The availability of unappropriated water from the Tulare: East James aquifer was last evaluated in 2012 and was based upon observation well data and through consideration of a hydrologic budget for the aquifer (Buhler, 2012). This report will reevaluate the availability of unappropriated water from the Tulare: East James aquifer based upon additional years of observation well data and the development of a hydrologic budget for the aquifer.

Observation Well Data
In determining the availability of unappropriated water, South Dakota Administrative Rule 74:02:05:07 requires the Water Management Board to rely on the record of observation well measurements in addition to other data, to determine that the quantity of water withdrawn annually from the aquifer does not exceed the estimated average annual recharge to the aquifer. The analysis of observation well data provides a means of assessing the aquifer and provides the best reasonably available information to evaluate the balance between withdrawals from and recharge to the Tulare: East James aquifer.

The Water Rights Program monitors 33 observation wells completed in the Tulare: East James aquifer (Water Rights, 2020b). Hydrographs for four of these observation wells are shown in Figures 2-5, and hydrographs for all 33 are included in Appendix B. The four selected hydrographs are representative of the Tulare: East James aquifer and show that the aquifer readily responds to climatic conditions, with rising water levels during wet years and declining water levels during dry years.

The response of the aquifer as recorded by the observation well measurements can provide insight into the balance of withdrawals to recharge for an aquifer. If discharge (natural and from well withdrawals) from an aquifer is exceeding the recharge to an aquifer, a steady, continual decline of the water level or artesian pressure is expected. In observation wells that show the influence of well withdrawals, a seasonal decline should be observed followed by a return to the pre-pumping water level. If the withdrawals across the entirety of the aquifer are unevenly distributed, the configuration of the potentiometric surface may change to show the effect of these withdrawals. The effects of climate can mask some of these signals for how the aquifer responds to pumping.

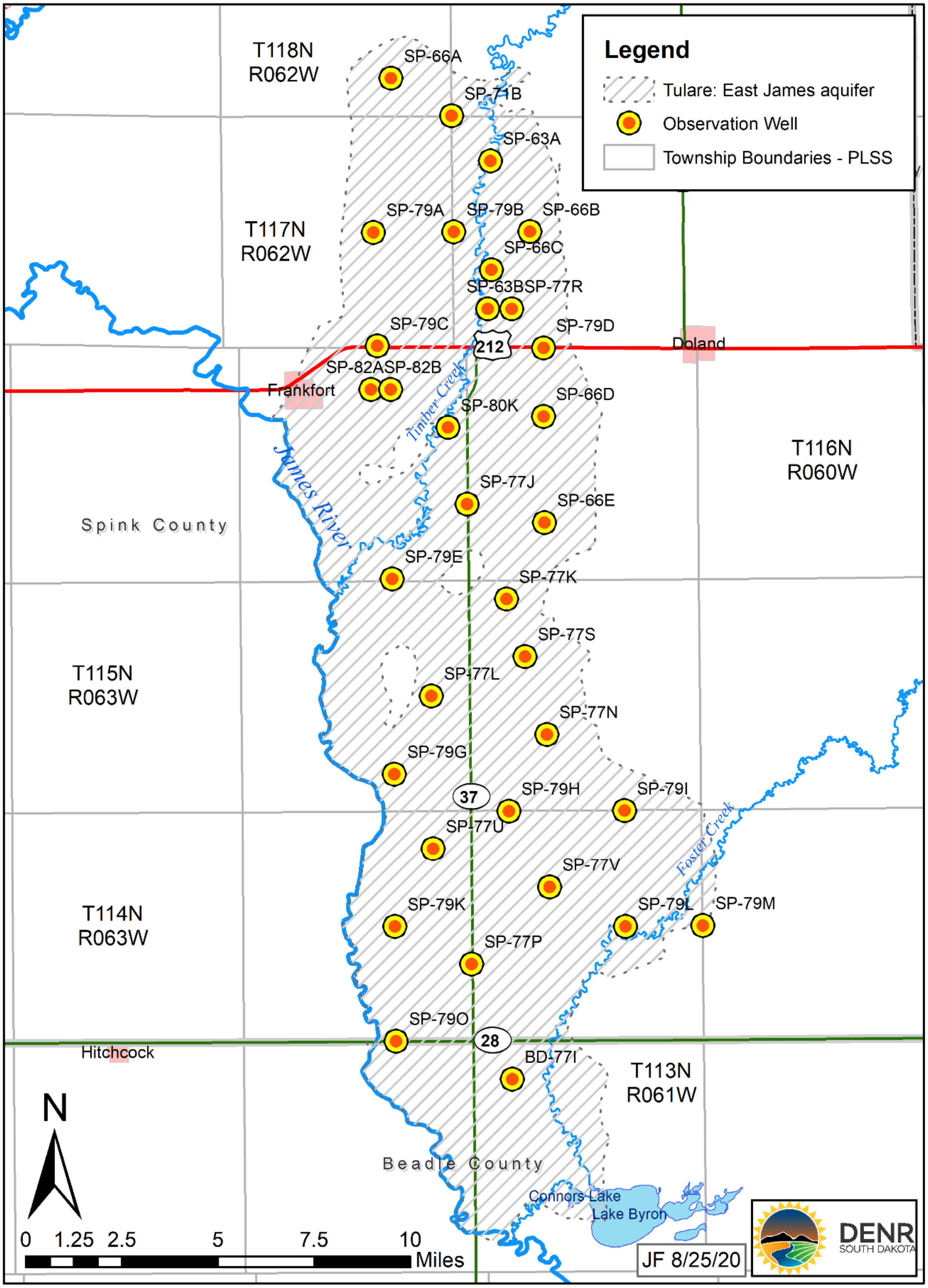

Figure 1. Map of the East James management unit of the Tulare Aquifer showing the location of observation wells in the Tulare: East James aquifer (Modified from Buhler, 2012; Water Rights, 2020c)

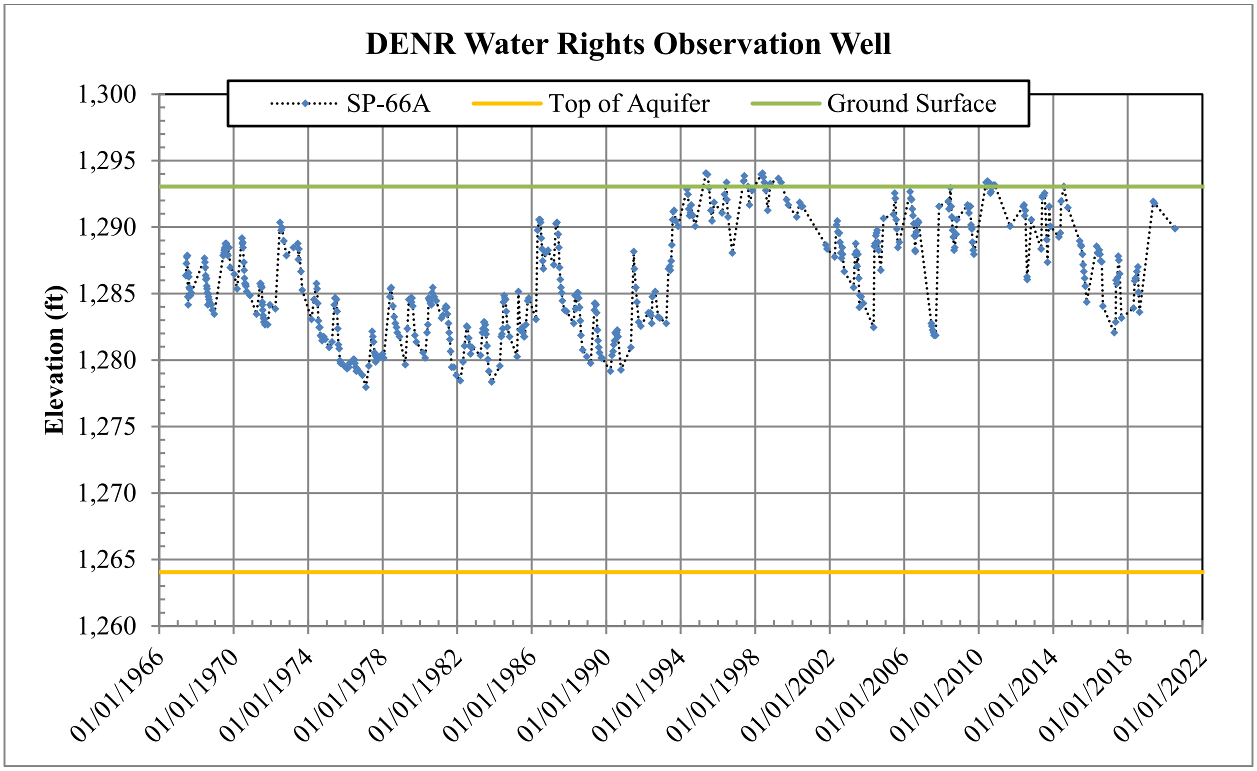

Figure 2. Hydrograph of DENR-Water Rights' observation well SP-66A. (see Figure 1 for location)

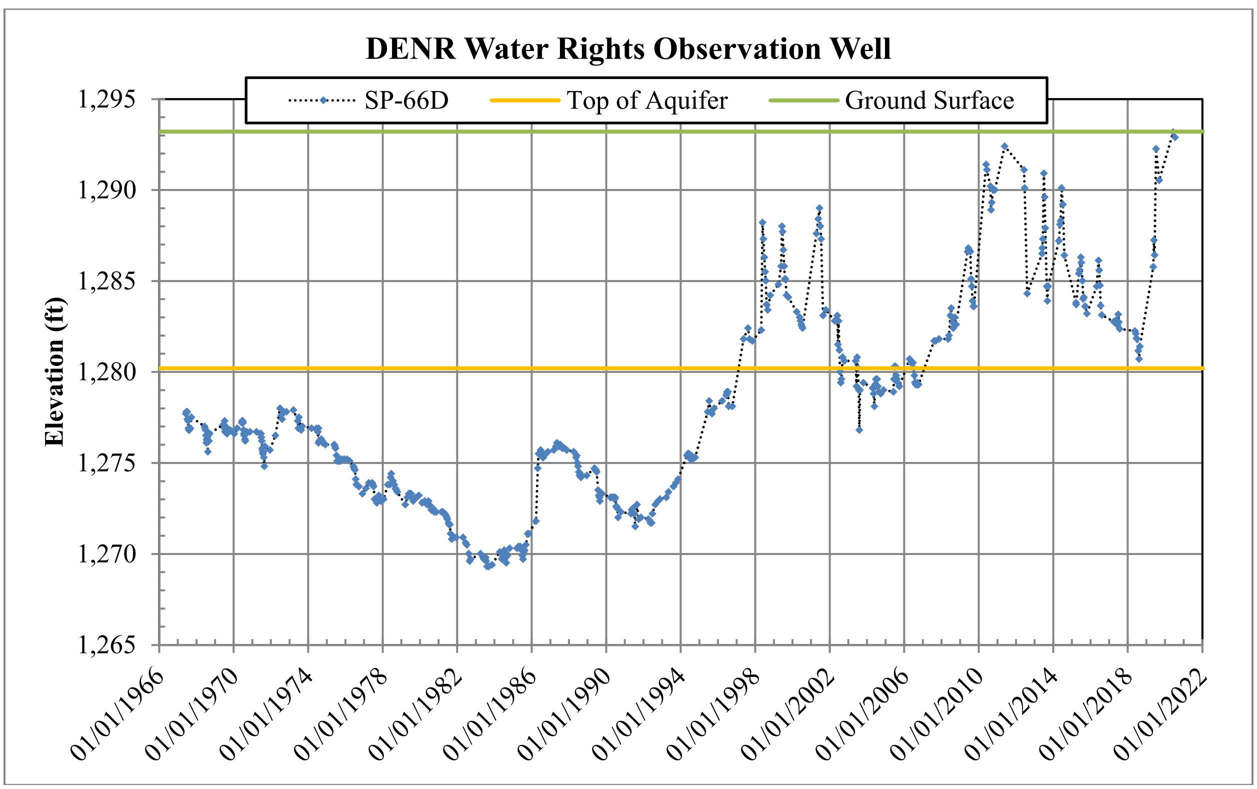

Figure 3. Hydrograph of DENR-Water Rights' observation well SP-66D (see Figure 1 for location)

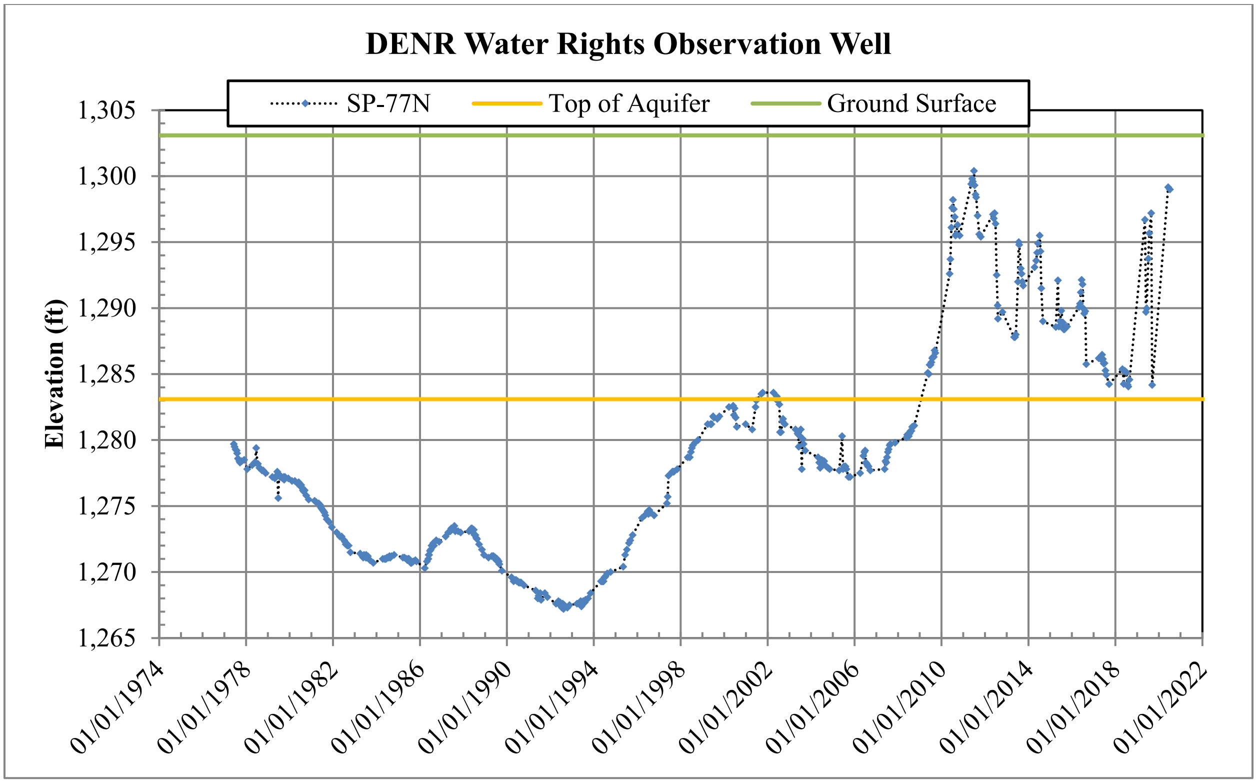

Figure 4. Hydrograph of DENR-Water Rights' observation well SP-77N (see Figure 1 for location)

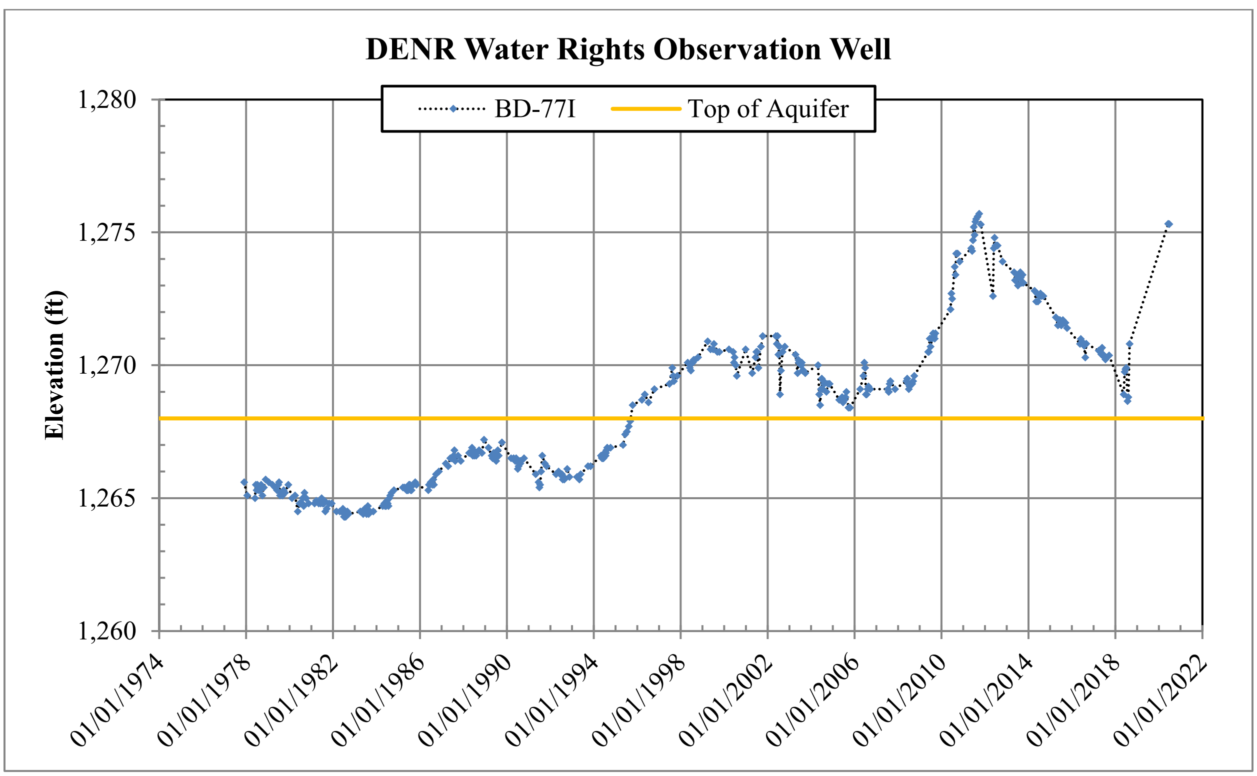

Figure 5. Hydrograph of DENR-Water Rights' observation well BD-77I, ground surface elevation estimated at 1,296 ft NGVD29 (see Figure 1 for location)

Observation well water level trends:
When the discharge (natural and from well withdrawals) exceeds the recharge of an aquifer, a declining water level is an indicator. Conversely, a rising water level in an aquifer is an indicator that the recharge is exceeding the discharge (natural and well withdrawals) of an aquifer. An equation for this relationship is:

$$\Delta S = R - D$$

Where: ΔS = change in the volume of water in storage in the aquifer
R= Recharge
D= Discharge

The observation well data for the Tulare: East James aquifer has documented upward trending water levels throughout the aquifer (Water Rights, 2020b). The average slope of linear trend lines for the 32 observation well hydrographs over each well's period of record (up to the end of 2019) has been +0.000637 feet per day (+0.233 feet per year). Observation Well SP-63A was removed from this analysis due to the well no longer accurately showing the water level in the aquifer. Buhler's analysis (2012) refined the period of analysis to encompass 1980 through July 2, 2012 and excluded observation wells SP-82A and SP-82B due to not having a complete set of data. That analysis found the average slope of the linear trend line for all observation well hydrographs to be +0.0008844 feet per day (+0.323 feet per year). In the time since Buhler's analysis up to the end of 2019, the average slope of the linear trend line for the 32 observation well hydrographs has been -0.001123 feet per day (-0.410 feet per year). The time period of 1980 through 2019 saw an average slope of +0.000762 feet per day (+0.278 feet per year). The 1980 through 2019 time period trendline analysis included 30 observation wells and excluded observation wells SP-63A, SP-82A, and SP-82B. This type of analysis does not account for any errors introduced by including data from observation wells that are influenced by well withdrawals and the year to year variability of those withdrawals or an observation well changing between unconfined and confined behaviors. Observation wells that are under unconfined conditions show the change in storage within the aquifer, while observation wells that are under confined conditions show the change in hydrostatic pressure.

Over the period of record, the upward trend of the water levels indicates recharge to the Tulare: East James aquifer has likely been greater than the total of the discharges from the aquifer. However, given the decrease in the average slope of the linear trend line since Buhler's analysis (July 3, 2012 through 2019), the reduction in trendline slope from the previous trendline analysis, and appropriations that have started placing water to beneficial use since then, the observation well water level trend is indicating that discharge may have exceeded the recharge of the aquifer over the July 2012 through 2019 time period.

Quantifying the change in volume of water stored in the Tulare: East James aquifer is possible through analysis of observation wells that have remained unconfined throughout their period of record. The response of the aquifer when an observation well is under confined conditions is only reflective of the head pressure at that location and does not directly show changes in the volume of water in the aquifer. The hydrographs for observation wells SP-66D, SP-77N, and BD-77I as shown in Figures 3, 4, and 5, visually show how the observed water level changes between unconfined and confined conditions. Observation well SP-77N was under unconfined conditions between 1977 and 2009, and then transitioned to confined conditions when the water level started rising above the top of the aquifer in 2009.

Continuing the methodology used by Buhler (2012), the same seven observation wells were used to analyze the Tulare: East James aquifer. These wells were chosen by Buhler because they are located in portions of the aquifer that remained unconfined for their entire period of record and the wells were determined to accurately reflect aquifer conditions. The time period used for this updated analysis was 1980-2019 to allow each observation well to have the same number of water years on record. The water year runs from October 1 to September 30 and the values used in this analysis are interpolated values for October 1 that were obtained using the two adjacent readings on the observation well hydrograph, unless a reading was recorded on October 1. For example, the 1980 water year water level change is the interpolated Oct. 1, 1980, reading minus the interpolated Oct. 1, 1979, reading. The results of the analysis are shown in Table 1.

Buhler (2012) analyzed the average annual water level change from 1980-2011. Buhler's (2012) analysis showed an increase in average annual water level of 0.31 feet per year. This increase indicated that the annual recharge to the aquifer exceeded discharge by an average of 1,045 acre-feet per year for the period of 1980-2011 (Buhler, 2012). In the time since Buhler's report (2012), the average annual water level change has seen a decline of 0.19 feet per year (2012-2019), resulting in the average annual water level change being lowered to show an increase of 0.21 feet per year from 1980 to 2019. Assuming the same area of unconfined aquifer and specific yield as Buhler's report (2012), the average annual change in volume has been reduced to 708 acre-feet per year. The average annual change in volume over the period of record (40 years) has been reduced by 337 acre-feet in a period of 8 years, which is a relatively quick change for the entire period of record. This method of estimating a volume of water is approximate as the unconfined area of the aquifer is not static and changes as the elevation of the water changes. This method also assumes that all variables relating to the use of the water are static and does not take into consideration any recent changes that would affect the use of water going into the future.

Over the period of record, the observation well data indicates that the average annual recharge to the aquifer has exceeded the average annual discharge from the aquifer. In the time since Buhler's report (2012), the observation well data indicates that the average annual recharge to the aquifer has been insufficient to supply the average annual discharge from the aquifer. These two conclusions differ and suggest that additional data is needed to determine if the most recent set of appropriations from the Tulare: East James aquifer brought the aquifer up to being fully appropriated, or if there is additional unappropriated water available from the aquifer.

Table 1. Water Level change in feet by water year for select unconfined observation wells with averages calculated for specific time periods (Water Rights, 2020b)

Water Year	SP-77J	SP-77P	SP-79G	SP-79H	SP-79K	SP-79O	SP-80K	Average
1980	-0.4	-0.3	-2.0	-0.8	-0.5	-0.1	-0.7	-0.7
1981	-1.0	-0.4	-1.2	-1.0	-0.3	-0.3	-1.0	-0.7
1982	-0.8	-0.5	0.4	-0.6	-0.3	0.3	-1.4	-0.4
1983	-0.7	0.0	0.9	-0.3	0.0	0.2	-0.9	-0.1
1984	0.7	0.7	1.4	0.8	0.7	0.8	-0.2	0.7
1985	0.4	0.0	-0.4	0.1	-0.1	-0.5	-0.1	-0.1
1986	1.6	0.6	2.1	1.7	1.1	1.0	1.0	1.3
1987	0.5	0.2	-0.5	0.1	-0.4	-0.7	0.5	0.0
1988	-0.7	-0.1	-1.6	-0.6	-0.2	-0.2	-0.4	-0.6
1989	-0.9	-0.2	-0.6	-0.6	-0.2	0.0	-1.1	-0.5
1990	-0.9	-0.4	-0.4	-0.4	-0.4	-0.3	-1.1	-0.5
1991	-0.5	-0.2	0.6	-0.2	-0.1	0.1	-0.7	-0.1
1992	-0.4	-0.4	-0.2	-0.2	-0.1	-0.2	0.1	-0.2
1993	0.5	0.3	2.1	0.6	0.5	1.3	1.4	1.0
1994	0.4	0.4	1.1	1.3	0.4	-0.2	-0.2	0.5
1995	1.5	1.7	1.5	1.6	2.4	1.1	1.3	1.6
1996	1.1	1.1	-0.7	0.4	-0.5	-0.6	0.5	0.2
1997	1.9	1.6	2.8	2.1	1.9	1.0	2.1	1.9
1998	1.8	0.8	-0.4	0.9	0.2	-0.7	1.5	0.6
1999	1.9	0.5	0.0	0.9	0.2	-0.3	0.7	0.6
2000	-0.7	-0.7	-1.1	-0.2	-0.9	-1.5	0.0	-0.7
2001	1.6	1.8	1.2	1.6	2.2	1.9	0.5	1.5
2002	-1.1	-0.1	-1.6	-0.8	-1.0	-1.0	-0.5	-0.9
2003	-1.1	-0.8	-2.0	-1.5	-0.8	-0.3	-0.6	-1.0
2004	-0.8	-0.8	-0.1	-0.9	-0.6	-0.2	-0.2	-0.5
2005	-0.4	-0.6	0.1	-0.9	-0.2	0.1	-0.5	-0.3
2006	-0.4	0.6	0.3	1.1	0.4	0.1	-0.2	0.3
2007	0.4	0.4	1.7	1.5	0.8	0.7	0.8	0.9
2008	0.2	0.2	0.2	0.7	-0.2	-0.2	0.6	0.2
2009	1.0	1.5	2.7	1.9	1.3	0.5	0.5	1.4
2010	2.6	3.8	2.5	4.9	4.2	1.4	2.0	3.1
2011	3.4	2.3	1.5	1.9	1.0	-0.1	1.4	1.6
2012	-0.1	-0.7	-3.6	-3.4	-2.3	-1.2	-1.1	-1.8
2013	1.0	-1.1	0.2	1.0	-0.4	0.0	0.9	0.2
2014	1.9	-0.8	-0.8	-0.6	-1.0	-0.6	0.4	-0.2
2015	-0.7	-1.3	-0.3	-2.0	-0.9	-0.2	-0.3	-0.8
2016	-0.5	-0.9	-1.3	-1.1	-0.6	0.0	-1.0	-0.8
2017	-1.0	-0.7	0.4	-1.1	-0.6	-0.1	0.3	-0.4
2018	-0.4	-0.6	-0.7	-0.5	0.2	0.0	-1.2	-0.5
2019	2.3	2.1	3.5	3.7	4.3	1.5	1.9	2.8
Average from 1980-2019	*0.34*	*0.22*	*0.19*	*0.28*	*0.23*	*0.06*	*0.13*	*0.21*
Average from 1980-2011, time period of Buhler (2012)	*0.34*	*0.40*	*0.32*	*0.47*	*0.33*	*0.10*	*0.17*	*0.30*
Average from 1986-2005, time period of Goodman (2006)	*0.27*	*0.24*	*0.11*	*0.25*	*0.18*	*0.01*	*0.23*	*0.18*
Average from 2006-2019	*0.69*	*0.33*	*0.44*	*0.56*	*0.45*	*0.13*	*0.36*	*0.42*
Average from 2012-2019	*0.30*	*-0.51*	*-0.34*	*-0.50*	*-0.16*	*-0.08*	*-0.01*	*-0.19*
Average from 2015-2018	*-0.68*	*-0.88*	*-0.51*	*-1.18*	*-0.47*	*-0.07*	*-0.52*	*-0.62*
Average from 2015-2019	*-0.08*	*-0.29*	*0.29*	*-0.21*	*0.49*	*0.24*	*-0.03*	*0.06*

Potentiometric Surface:

The potentiometric surface of an aquifer is a snapshot of the water level in the aquifer at a selected time. The potentiometric surface will show high water levels as a result of wetter periods of time and lower water levels during drier times and/or increased periods of withdrawals. An analysis of the potentiometric surface does not provide a clear indication of whether there is unappropriated water available or how much may be available. The potentiometric surface data can show whether there are significant stressors on the aquifer, in other words, if the recharge is able to keep up with the withdrawals from the aquifer. These stressors would show up as a significant change in the general shape/configuration of the potentiometric surface. If there are areas of the aquifer that are showing signs of stress, it is an indicator that the aquifer is over-appropriated. The stressors may be caused by very significant increases in withdrawals in an area over a short period of time, or may be more subtle, such as a slight increase in the withdrawals that cumulatively over the course of 10, 15, 20 years exceed the recharge to the local area. The potentiometric surface of the aquifer would be able to show these stressors because the area that is being stressed is creating a steeper hill for the groundwater to flow down.

The potentiometric surface of the Tulare: East James aquifer was estimated from observation well data for three time periods (Magstadt, 2020). These time periods are May 1981, May 2012, and June 2020. These dates were chosen for comparison of the configuration of the potentiometric surface with the potentiometric surfaces calculated by Buhler (2012). Maps showing the contour lines for these potentiometric surfaces are shown in Figure 6.

The potentiometric surface contours shown in Figure 6 show that water levels were generally lower in May 1981 than they were in May 2012. The potentiometric surface contours also show that the water levels were similar in May 2012 and June 2020. The potentiometric surface contour lines generally follow the same shapes for all three dates, indicating that the configuration of the potentiometric surface has not changed significantly over time. The configuration of the potentiometric surface of the aquifer over time is showing that the well withdrawals have not been affecting the general direction of groundwater flow, indicating that the aquifer has not been stressed by withdrawals. It is unknown what the pre-development configuration of the potentiometric surface was.

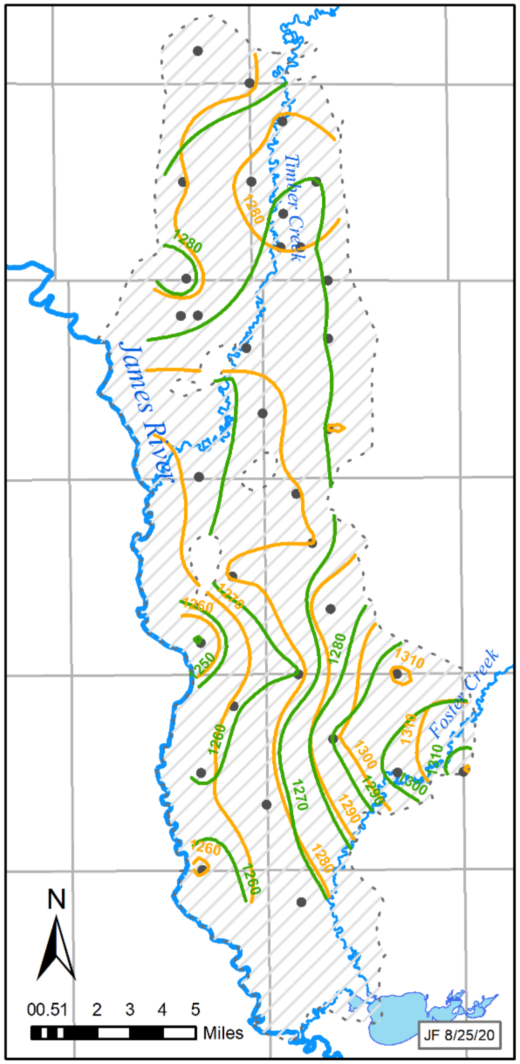

Figure 6a. Potentiometric surface contours of the Tulare: East James aquifer for May 1981 (Green) and May 2012 (Yellow)

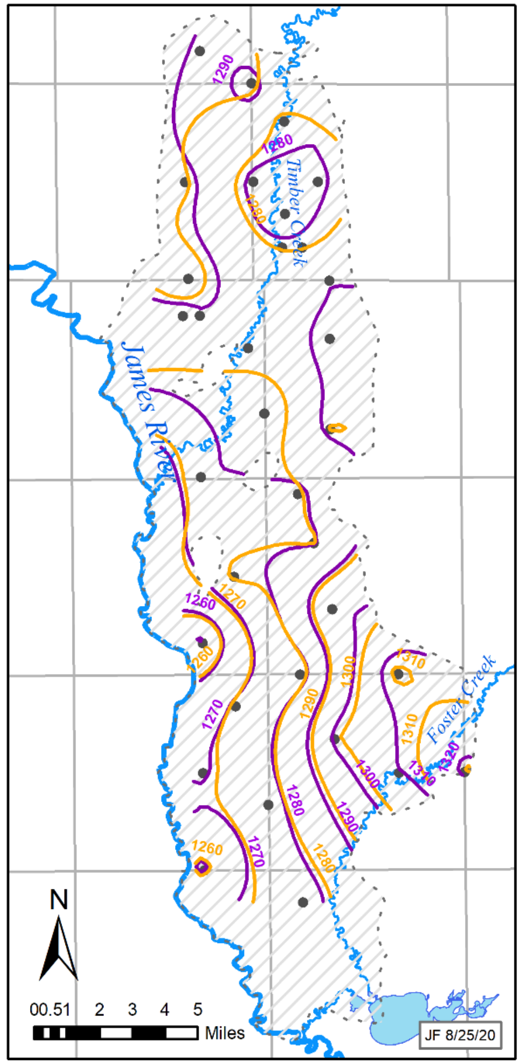

Figure 6b. Potentiometric surface contours of the Tulare: East James aquifer for May 2012 (Yellow) and June 2020 (Purple)

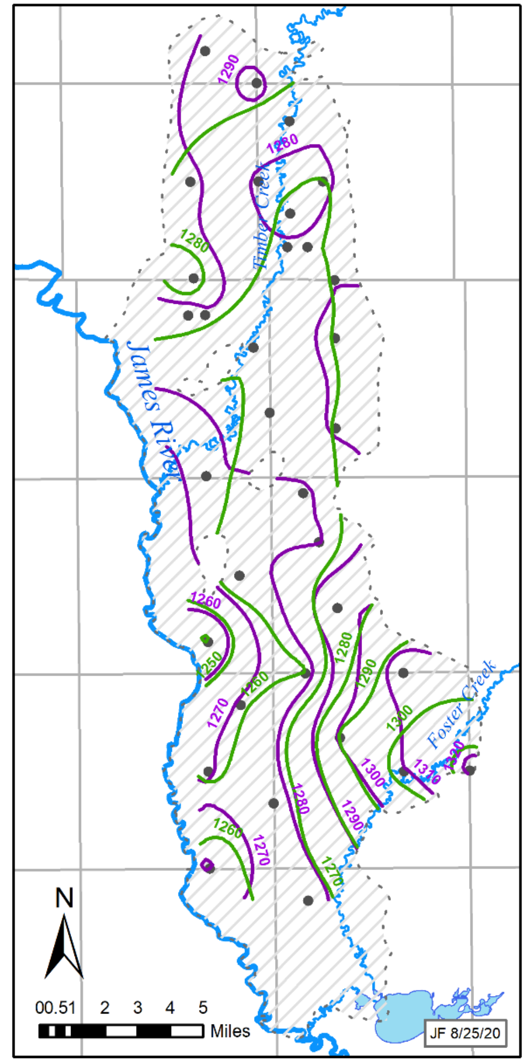

Figure 6c. Potentiometric surface contours of the Tulare: East James aquifer for May 1981 (Green) and June 2020 (Purple)

Hydrologic Budget

Recharge

Recharge to the Tulare: East James aquifer occurs primarily through infiltration of precipitation where the aquifer is at or near the surface. Recharge from precipitation varies by season, by year, and by location (Hamilton and Howells, 1996). Recharge could also occur from rivers and streams if they are hydraulically connected to the aquifer and if the potentiometric surface of the aquifer was lower than the stage of streams and rivers. Previous reports indicate that Timber Creek and its tributaries provide recharge to the Tulare: East James aquifer (Goodman, 1984; Buhler, 2012); however, in the area of Timber Creek the potentiometric surface slopes towards Timber Creek. The slope direction of the potentiometric surface could indicate that any recharge occurring from Timber Creek is minimal and that it primarily functions as a place of discharge from the aquifer.

Recharge Estimates:

Previous Estimates:

Recharge to the Tulare: East James has been estimated through a variety of methods. Hedges et al. (1985) used data from 18 observation wells to determine the recharge rate to the unconfined portion of the Tulare: East James is 2.5 inches per year. A regional flow-net analysis of the Tulare: East James aquifer was also performed by Hedges et al. (1985) and found the estimated recharge rate was 0.72 inches per year. It is unknown what the confined and unconfined areas were for these analyses. Buhler (2012) estimated the confined and unconfined areas for his analysis, the estimated unconfined area is 22,477 acres and the estimated confined area is 101,101 acres. Using the areas as determined by Buhler (2012) would result in the observation well analysis by Hedges et al. (1985) to have an estimated average annual recharge of 4,683 acre-feet and the regional flow-net analysis by Hedges et al. (1985) would produce an estimated average annual recharge of 7,415 acre-feet.

A numerical groundwater flow model (Kuiper, 1984) estimated that the average recharge to the Tulare: East James is 0.76 inches per year. Applying this recharge rate across the 167 square miles of the model results in an estimated recharge rate of 6,800 acre-ft per year (Kuiper, 1984). This model used cells that measured 1 mile by 1 mile and compared the response of the aquifer in the model to observation well data from 1968 to 1978 and irrigation questionnaire data from 1978. Estimated recharge in the model was varied throughout the model domain, including 37 square miles where there was no calculated recharge to the aquifer. These 37 square miles are concentrated in T115N-R61W, T115N-R62W, T114N-R61W, and T114N-R62W. The model domain did not include Beadle County, and 13 square miles along the James River were included in both model areas A (Tulare: Western Spink Hitchcock) and B (Tulare: East James).

In previous Water Management Board decisions, the Water Management Board has relied upon the 0.76 inches of recharge per year calculated from Kuiper's (1984) results. While this recharge rate has been applied over the entirety of Tulare: East James aquifer, resulting in an estimated average annual recharge of 7,950 acre-feet per year (Goodman, 2003), the modeled recharge rate is not reflective of the current area of the aquifer. The boundaries that were used in the development of the model are not consistent with the currently accepted boundaries of the Tulare: East James aquifer. After the model was developed, aquifer boundaries were delineated in this area by Hedges et al. (1982). Subsequently, a portion of the model is currently identified as being part of the Altamont aquifer or not part of an identified aquifer (Hedges et al., 1982). If the 16 square miles and associated recharge of the Altamont aquifer and the area not identified as an aquifer within the model boundary are removed by simply subtracting the cells, the recharge rate within the remainder of the model becomes 0.738 inches per year. It is also unknown what the estimated recharge rates are outside of the model boundary and depending upon the characteristics of the aquifer in those areas, the recharge rate could range from 0 to over an inch per year. There are approximately 48 square miles of the Tulare: East James aquifer that were not included within the boundaries of Kuiper's model. It is not clear if the removal or addition of the various portions of the management unit as currently mapped compared to the modeled area would have affected the estimated recharge rate found to best fit the observation well data used by Kuiper (1984). As each cell in the model had several input values, changing the extent of the model and adding or removing cells would result in the adjustment of values in other cells to best fit the model output to the observed water elevation data. It is unknown if the estimated average recharge rate would increase or decrease to account for a change in the model extent.

It is unknown how the addition of 48 square miles of recharge to the model and the removal from the model of 16 square miles of recharge that are not part of the aquifer would affect the modeled behavior of the aquifer at the observation wells and how the modeled recharge to the aquifer would change.

Buhler (2012) performed a simple regional flow net analysis. This analysis was used to confirm the reasonableness of the average annual recharge estimate from Kuiper (1984). This simple regional flow net analysis is only applicable to the year 2011 and does not provide an estimated average annual recharge rate. The simple regional flow net analysis estimated the recharge rate for 2011 was 0.80 inches per year and showed that Kuiper's average annual recharge estimate was reasonable (Buhler, 2012).

Given the uncertainty involved with applying Kuiper's estimated average annual recharge to the entirety of the Tulare: East James aquifer, it is difficult to determine the estimated average annual recharge to the entire aquifer. The 6,800 acre-feet of recharge per year as calculated by Kuiper (1984) is the best information reasonably available for quantifying the estimated average annual recharge to the Tulare: East James aquifer.

Discharge

Discharge from the Tulare: East James aquifer occurs through well withdrawals, evapotranspiration from areas where the aquifer is near the land surface, outflow to the James River, and possible outflow to Timber Creek and its tributaries.

Domestic water use:

Buhler (2012) identified 55 domestic water supply wells on file with the DENR-Water Rights Program that appear to be completed into the Tulare: East James aquifer. In the time since 2012, four domestic wells have been completed into the Tulare: East James aquifer (Water Rights, 2020d). The volume of water used by domestic wells was estimated based upon the average rural use for the rural water system in the area (Buhler, 2012). The 2012 estimated domestic use was 7,000 gallons per month per tap per month, which equated to an estimated average annual use from domestic wells of 14 acre-feet per year (Buhler, 2012). The addition of 4 domestic wells raises the estimated average annual use by domestic wells to approximately 15 acre-feet per year. The actual quantity of water these domestic wells withdraw is unknown; this is the best available and reasonable estimate of domestic water use from the Tulare: East James aquifer.

Appropriative water use:
As of June 17, 2020, there is a total of 94 Licensed or Permitted Water Rights appropriating water from the Tulare: East James aquifer (Water Rights, 2020c). The appropriative water use from the Tulare: East James aquifer is used entirely for irrigation of crops. Figure 7 shows how the number of acres authorized for irrigation at the start of each irrigation season (April 1) has changed from 1979 to 2020 and the reported irrigation data for 1979 and 1983 through 2019. The irrigation questionnaires from 1980 through 1982 could not be located, so those years were not included in any calculations. Authorized acres are the acres approved to be irrigated under an existing water right, and the status of the water right could be permitted or licensed. Irrigated acres are the acres indicated as irrigated on the irrigation questionnaire by the irrigator. The annual irrigation summaries have the reported use for the 1980-1982 time period; however the number of acres that were irrigated are not included on the summaries, and it is impossible to investigate any anomalous data.

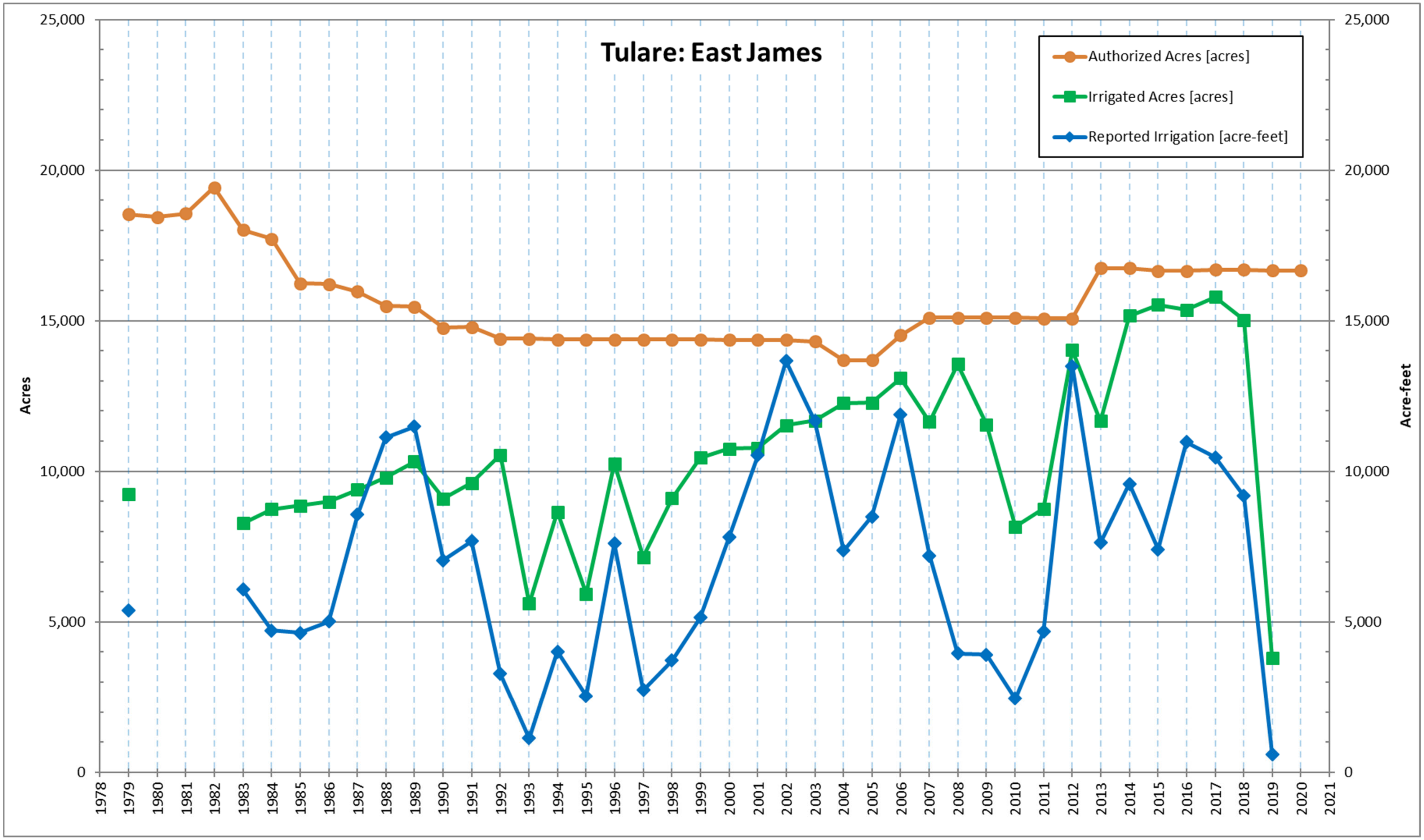

Figure 7. Acres authorized for Irrigation, Irrigated Acres and Reported Irrigation from the Tulare: East James aquifer (Water Rights, 2020c)

Table 2. Irrigation development from the Tulare: East James aquifer (* data not available), (modified from Buhler, 2012; Mathiowetz, 2012; Water Rights, 2020a; Water Rights, 2020c)

Year	Permits with Acres	Authorized Acres [acres]	Irrigated Acres [acres]	Utilization Rate (Irrigated Acres/Authorized Acres Percentage)	Reported Irrigation [acre-feet]	Average Application Rate for Irrigated Acres [inches]
1979	89	18,529.7	9,231.00	49.82	5,388.25	7.00
1980	91	18,436.7	*	*	*	*
1981	94	18,552.7	*	*	*	*
1982	99	19,420.7	*	*	*	*
1983	95	18,014.7	8,281.50	45.97	6,078.64	8.81
1984	91	17,711.7	8,740.00	49.35	4,718.44	6.48
1985	86	16,245.9	8,863.00	54.56	4,638.54	6.28
1986	86	16,212.7	8,993.00	55.47	5,009.57	6.68
1987	84	15,972.7	9,385.00	58.76	8,565.77	10.95
1988	81	15,492.7	9,793.50	63.21	11,130.45	13.64
1989	81	15,468.7	10,317.80	66.70	11,491.67	13.37
1990	78	14,759.0	9,094.00	61.62	7,041.01	9.29
1991	79	14,787.0	9,612.60	65.01	7,676.99	9.58
1992	78	14,403.0	10,540.80	73.18	3,277.58	3.73
1993	78	14,403.0	5,614.00	38.98	1,122.85	2.40
1994	77	14,375.0	8,647.00	60.15	4,013.98	5.57
1995	77	14,375.0	5,928.00	41.24	2,537.21	5.14
1996	77	14,375.0	10,252.00	71.32	7,602.08	8.90
1997	77	14,375.0	7,150.00	49.74	2,736.47	4.59
1998	77	14,375.0	9,110.80	63.38	3,717.80	4.90
1999	77	14,375.0	10,454.80	72.73	5,136.78	5.90
2000	77	14,369.0	10,745.80	74.78	7,807.48	8.72
2001	77	14,369.0	10,772.00	74.97	10,529.00	11.73
2002	77	14,369.0	11,528.80	80.23	13,668.09	14.23
2003	75	14,313.0	11,678.80	81.60	11,666.06	11.99
2004	75	13,688.0	12,259.00	89.56	7,372.58	7.22
2005	75	13,685.0	12,273.40	89.69	8,491.16	8.30
2006	80	14,523.0	13,096.80	90.18	11,889.10	10.89
2007	83	15,099.0	11,648.40	77.15	7,204.13	7.42
2008	83	15,099.0	13,555.00	89.77	3,948.88	3.50
2009	82	15,099.0	11,547.30	76.48	3,908.42	4.06
2010	82	15,099.0	8,161.20	54.05	2,449.76	3.60
2011	82	15,071.0	8,753.00	58.08	4,675.06	6.41
2012	82	15,071.0	14,030.70	93.10	13,494.16	11.54
2013	92	16,812.0	11,666.40	69.67	7,626.45	7.84
2014	93	16,812.0	15,160.11	90.53	9,580.27	7.58
2015	90	16,727.0	15,532.40	93.23	7,407.94	5.72
2016	90	16,727.0	15,363.10	92.21	10,971.52	8.57
2017	91	16,699.0	15,792.00	94.57	10,463.75	7.95
2018	91	16,699.0	15,017.30	89.93	9,179.74	7.34
2019	90	16,674.0	3,809.00	22.84	603.47	1.90
2020	90	16,674.0	*	*	*	*
MAX.		*19,420.70*	*15,792.00*	*94.57*	*13,668.09*	*14.23*
MIN.		*13,685.00*	*3,809.00*	*22.84*	*603.47*	*1.90*
AVE.		*15,674.74*	*10,589.46*	*69.01*	*6,968.98*	*7.62*

Using the available reported pumping data from 1979 through 2019 and the estimated annual domestic use, the total well withdrawal from the aquifer is expected to average less than 7,000 acre-feet/year. This total withdrawal from the Tulare: East James aquifer due to pumping is around 1.02% of the estimated recoverable water in storage in the aquifer (7,000 acre-feet pumped per year versus 685,857 acre-feet of recoverable water in storage).

In light of the recent development that occurred as a result of appropriations made in 2012, it is no longer appropriate to consider the entire period of record for determining the estimated average annual withdrawals. Table 3 shows the averages of Table 2 for many different periods of time to include data for comparison from previous reports and methodologies, the effect of a dry year (2012) and the effect of a very wet year (2019). The time periods that have the break between the years of 1979 and 1983 are effectively continuous time periods for all columns, except for the average authorized acres, as demonstrated in the first two rows of data.

Table 3. Averages of data in Table 2 for select time periods.

Period	Average Authorized Acres [acres]	Average Irrigated Acres [acres]	Average Utilization Rate	Average Reported Irrigation [acre-feet]	Average Application Rate for Irrigated Acres [inches]
1979-2019	15,647.1	10,589.5	69.0	6,969.0	7.62
1979, 1983-2019	15,398.0	10,589.5	69.0	6,969.0	7.62
1979-2011	15,437.7	9,867.6	65.9	6,516.5	7.71
1979, 1983-2012	15,100.2	10,001.9	66.8	6,741.5	7.83
1979, 1983-2018	15,367.1	10,772.7	70.3	7,141.0	7.78
1986-2005	14,627.1	9,707.6	66.6	7,029.7	8.34
2000-2019	15,350.2	12,119.5	79.1	8,146.9	7.83
2012-2018	16,506.7	14,651.7	88.8	9,817.7	8.08
2012-2019	16,527.6	13,296.4	80.6	8,665.9	7.31
2013-2018	16,746.0	14,755.2	88.1	9,204.9	7.50
2013-2019	16,735.7	13,191.5	78.8	7,976.2	6.70
2015-2018	16,713.0	15,426.2	92.3	9,505.7	7.39
2015-2019	16,705.2	13,102.8	78.4	7,725.3	6.30

Examination of the average application rate for the time period of Buhler's (2012) report, 1979-2011, shows that the average application rate has been adjusted slightly from Buhler's calculated 7.68 inches to 7.71 inches. This is due to corrections of the underlying water right and irrigation questionnaire data, either from data entry errors, missing irrigation questionnaire data that was not included in Buhler's (2012) dataset, and from resolving instances where the irrigator submitted data for multiple permits and some values were double counted or not counted at all. The application rate could still change slightly due to corrections in the water right data, locating missing irrigation questionnaire files, identifying when systems were constructed, considering suspensions, and upon further review of the irrigation questionnaires that cover several pivots and/or have been amended, incorporated, or reissued.

In the time since Buhler's report (2012), the average application rate has varied due to climatic conditions. The time period of 2012-2018 has an average application rate of 8.08 inches, but with the wet year of 2019, the average application rate dropped to 7.31 inches for the time period of 2012-2019. The year of 2012 was dry and saw a high average application rate, the effect of this can be seen by comparing the average application rates between the time periods of 1979-2011 and 1979, 1983-2012; 2012-2018 and 2013-2018; and 2012-2019 and 2013-2019. For the entire period of record, 1979 through 2019, the average application rate has been 7.62 inches.

In Buhler's (2012) report, the average annual withdrawals were calculated by averaging the irrigation questionnaire summary reports for the years 1979-2011 and adding the estimated domestic use. Table 4 shows the data from the irrigation questionnaire summary reports. The data from the irrigation questionnaire summary reports is currently the best information reasonably available to determine how much water has been used by irrigation from an aquifer. These summaries have never been revised to reflect updated data or to correct water sources. There are minor differences between the values in Table 2 and Table 4 for the number of permits and the reported irrigation due to more recent data being represented in Table 2.

Table 4. Annual Summary of Reported Irrigation from the Tulare: East James aquifer (Water Rights, 1980-2020)

Year	Number of Permits Reported	Reported Irrigation [acre-feet]
1979	81	5,321.00
1980	82	7,348.00
1981	92	12,935.00
1982	80	6,873.68
1983	82	5,951.32
1984	81	4,236.80
1985	79	4,251.00
1986	80	4,940.00
1987	76	8,481.00
1988	75	11,106.20
1989	76	11,281.50
1990	75	6,928.00
1991	76	7,890.10
1992	76	3,224.40
1993	75	1,089.00
1994	76	3,897.29
1995	75	2,932.31
1996	75	7,389.13
1997	75	2,676.00
1998	75	3,475.85
1999	75	5,011.51
2000	75	7,690.37

2001	77	10,287.41
2002	78	13,668.09
2003	75	11,864.48
2004	77	7,372.58
2005	79	8,491.16
2006	84	11,746.21
2007	86	7,204.13
2008	85	3,900.71
2009	87	3,908.42
2010	88	2,414.41
2011	87	4,675.06
2012	88	13,441.82
2013	99	7,717.08
2014	94	9,837.12
2015	93	7,489.18
2016	92	11,048.27
2017	93	10,506.72
2018	93	9,210.26
2019	92	603.47
MAX.		*13,668.09*
MIN.		*603.47*
AVE.		*7,080.88*

Balance of Recharge to Discharge

In applying SDCL 46-6-3.1, the Sixth Judicial Circuit Court of South Dakota ruled in 2005 that if the Water Management Board uses average annual recharge, then it should also use average annual withdrawals to determine if unappropriated water is available from an aquifer (Hines v. Department of Environment and Natural Resources, 2005). This ruling resulted in additional water being appropriated from the Tulare: East James aquifer even though the Water Management Board had previously recognized that water use exceeded the estimated average annual recharge.

The first set of new appropriations were permitted in 2006 and were based upon an average annual recharge of 7,950 acre-feet per year and the average use for the previous 20 years (1986-2005) of 6,981 acre-feet per year (Goodman, 2006). The 20-year period used in this calculation was chosen based upon the end date of the allowed construction period of a permit (5 years are allowed for construction) and when the previously approved water rights were permitted. The average irrigation application rate over the previous 20 years had been calculated as 8.2 inches per year. It was determined that an additional 969 acre-feet per year were available for appropriation, and that based upon the average irrigation application rate, 1,420 acres per year could have been irrigated during the previous 20 years. Water right permits were issued for the irrigation of an additional 1,411 acres, including the water right permit approved by the Sixth Judicial Circuit Court of South Dakota.

The second set of new appropriations were permitted in 2012 and were based upon an average annual recharge of 7,950 acre-feet per year and the average annual use over the entire period of record (1979-2011) of 6,700 acre-feet per year as reported in the annual irrigation summaries (Buhler, 2012). The average irrigation application rate over the period of 1979-2011 was calculated as 7.68 inches per year, excluding the years of 1980-1982 due to missing data (Buhler, 2012). It was determined that an additional 1,761 acres could have been irrigated over the period of record. Water right permits were issued for the irrigation of 1,759 acres.

There is no mention in Buhler's 2012 report of how the recently developed permits that were approved in 2006 affected the average annual use over the entire period of record or if the use due to the recent permits would be accurately reflected in a calculation for the entire period of record. Table 5 shows the permits that have been approved since 2005 for the irrigation of "new" acres, acres that were not previously authorized under an existing water right, and when they placed their appropriated water to beneficial use.

Table 5. Water right permits approving new acres since 2005 (Water Rights, 2020c)

Permit No.	Year Approved	Year water placed to beneficial use
6431-3	2005	2012
6655-3	2006	2006
6656-3	2006	2006
6676-3	2006	2007
6711-3	2006	2007
6712-3	2006	2009
6713-3	2006	2013
7295-3	2012	2013
7316-3	2012	2013
7348-3	2012	2014
7364-3	2012	2014
7365-3	2012	2014
7366-3	2012	2014
7367-3	2012	2014
7368-3	2012	2015
7369-3	2012	2015
7370-3	2012	2014

If the same methodology is used as Goodman's report (2006), the estimated average annual use since the time that the most recent permits placed their water to beneficial use (2015-2019) would be 7,725 acre-feet per year. Given the short period of time since the last appropriations were approved in 2012, anomalously wet or dry years can skew the analysis of short time periods. One such anomalous year is the wet year of 2019, as evidenced in Table 2 by having the smallest amount of reported irrigation, the fewest irrigated acres, and the lowest application rate over the period of record. Excluding 2019, the estimated average annual use for irrigation over 2015-2018 is 9,506 acre-feet per year. The estimated average annual recharge from

Kuiper's report (1984) that was applied over the entirety of the Tulare: East James aquifer is 7,950 acre-feet per year. Depending upon whether the wet year of 2019 is included in this balance, the volume of water available for appropriation ranges from 225 acre-feet per year, to being over-appropriated by 1,556 acre-feet per year.

If the same methodology is used as Buhler's report (2012), the estimated average annual use over the entire period of record would be 7,081 acre-feet per year. The estimated average annual recharge from Kuiper's report (1984) that was applied over the entirety of the Tulare: East James aquifer is 7,950 acre-feet per year. This would suggest that there are 869 acre-feet per year that could be appropriated. This volume of water, however, is not available for appropriation as this volume of water was already accounted for in Buhler's 2012 report and is merely showing that there has not been enough time elapsed to properly reflect the usage by new appropriations in the average annual calculations. In the time since Buhler's report, 2012-2019, the average annual reported use is 8,666 acre-feet per year.

A metric other than the total withdrawals over the entire period of record should be utilized to prevent over-appropriation of water from the Tulare: East James aquifer as a result of the 5-year reviews. For example, using Buhler's (2012) methodology repeatedly, if the existing data from 1979-2019 is used, and the years of 2020 through 2024 (5 years) pump an average of 10,000 acre-feet per year, the estimated average annual use over the entire period would rise to 7,398 acre-feet per year. At the end of that 5-year period, there would be an additional 551 acre-feet of water which could be appropriated as a result of the 5-year review because the estimated average annual use is still below the estimated average annual recharge of 7,950 acre-feet. If the next 5-year period pumps an average of 10,500 acre-feet per year, the estimated average annual use over the entire period would rise to 7,702 acre-feet per year. At the end of this 5-year period, there would be an additional 248 acre-feet of water which could be appropriated. If the next 5-year period pumps an average of 10,750 acre-feet per year, the estimated average annual use over the entire period of record would rise to 7,974 acre-feet per year. By the end of this 5-year period, the aquifer would be over-appropriated, and no additional acre-feet were appropriated. After an additional 5 years averaging 10,750 acre-feet of withdrawals per year, the estimated average annual use over the entire period of record would continue rising to 8,202 acre-feet per year. Repeated use of this methodology will result in the aquifer being over-appropriated in the future.

Figure 7 shows the number of irrigated acres approaching the number of authorized acres, indicating that irrigation practices have changed in the area of the Tulare: East James aquifer. These changes may be due to climate, modern farming practices, crop prices, the production of ethanol, and the consolidation, relocation, and transference of irrigation water rights. Appendix A contains an approximate timeline of events regarding Water Rights in the Tulare: East James aquifer, including the amending and transferring of acres to other lands.

Use of the average application rate and the utilization of acres would be a better determination of the estimated average annual use when the number of authorized acres has not remained constant. The application rate is the reported use divided by the number of irrigated acres and the utilization of acres is the number of irrigated acres divided by the number of authorized acres. The average application rate would account for factors regarding the climate over time, allowing for consideration of both dry and wet periods. The average utilization of acres would account for factors regarding farming practices, this could be looked at on a shorter period to allow for recent changes to be in effect.

As of the beginning of the 2020 irrigation season, there are 16,674 acres authorized for irrigation. Applying the average application rate (1979, 1983-2019) of 7.62 inches over the authorized acres results in an estimated average annual use of 10,588 acre-feet of water. While it is impossible for the average percentage of irrigated acres to authorized acres to ever reach 100% over the entire period of record, 6 out of the 8 years (2012-2019) since Buhler's (2012) report have exceeded 89% utilization of authorized acres with the maximum utilization reaching 94.6% in 2017. The utilization rate of authorized acres and the estimated average annual use using the average application rate of 7.62 inches for authorized acres is calculated in Table 6.

Table 6. Utilization Rate of Authorized Acres and Estimated Average Annual Use calculated using 16,674 authorized acres and the application rate of 7.62 inches

Average Utilization Rate of Authorized Acres	Estimated Average Annual Use [acre-feet per year]
100%	10,588
65.9% (1979-2011)	6,977
69% (1979-2019)	7,306
79% (2000-2019)	8,365
89% (exceeded by 6 out of 8 previous years)	9,423
94.6% (2017)	10,016
92.3% (2015-2018)	9,773
78.4% (2015-2019)	8,301

Kuiper's model estimated the recharge to the aquifer to best simulate the observed observation well hydrographs over the period of 1968 to 1978. It is unknown how well this model fits the last 42 years of observation well data. Kuiper's model estimated the average annual recharge to the Tulare: East James aquifer to be 6,800 acre-feet per year, within the boundaries of the model. Given the currently identified boundaries of the Tulare: East James aquifer and the mismatch to the model boundaries, it is impossible to assume that a spatially variable recharge rate can be averaged out across the model area and then applied to areas outside of the model boundaries to include the entire aquifer area. In the past Water Management Board decisions regarding the Tulare: East James aquifer, the average annual recharge rate of Kuiper's model has been improperly applied over the entirety of the Tulare: East James aquifer. The estimated average annual recharge is unknown for the currently identified boundaries of the Tulare: East James aquifer; however the 6,800 acre-feet as modeled by Kuiper (1984) is the best reasonably available estimate of the average annual recharge to the Tulare: East James aquifer.

Given the uncertainties involved with the estimated average annual recharge model, the recharge to the Tulare: East James aquifer is likely to exceed the 6,800 acre-feet as calculated by Kuiper (1984), however it is unknown by how much. It is unknown if the estimated average annual recharge rate of 7,950 acre-feet per year as used in past reports is above or below the actual recharge rate. Using the average application rate of 7.62 inches over the period of record and the current authorized acreage, the estimated average annual use for irrigation withdrawals using the average utilization rate for the time period of 2015-2019 is 8,301 acre-feet per year. Excluding the abnormally wet year of 2019, the average utilization rate for the time period of 2015-2018 likely better reflects the expected usage of the Tulare: East James for the current authorized acreage. The estimated average annual use for irrigation withdrawals from the Tulare: East James aquifer for the time period of 2015-2018 is 9,773 acre-feet per year. The estimated average annual use for domestic use is 15 acre-feet per year. Whether or not the abnormally wet year of 2019 is used to estimate the average annual use, the estimated average annual use exceeds both of the estimated average annual recharge estimates. Based upon the estimated average annual use exceeding the estimated average annual recharge, there is no unappropriated water available from the Tulare: East James aquifer.

CONCLUSIONS

1. The Tulare: East James aquifer is a glacial outwash aquifer that is generally found under confined conditions and buried under a layer of glacial till.

2. The best information currently available indicates that the Tulare: East James aquifer underlies approximately 123,578 acres of Spink and Beadle Counties.

3. The SD DENR-Water Rights Program observation well data documents that over the period of record the potentiometric surface of the Tulare: East James aquifer has averaged an upward trend.

4. The SD DENR-Water Rights Program observation well data documents that in the time period since Buhler's analysis, the potentiometric surface of the Tulare: East James aquifer has averaged a downward trend.

5. The SD DENR-Water Rights Program observation well data documents that over the period of record the configuration of the potentiometric surface of the Tulare: East James aquifer has not changed significantly with time or increased development. The elevation of the potentiometric surface has changed throughout time, however the direction of groundwater flow has not been significantly affected by withdrawals.

6. The estimated average annual recharge to the Tulare: East James aquifer was estimated as 6,800 acre-feet per year by Kuiper's model. The estimated average annual recharge is likely to exceed this number due to additional area in Beadle County that was not accounted for by Kuiper, however it is unknown by how much.

7. Kuiper's recharge rate was based upon 11 years of observation well data between 1968 and 1978. 15 observation wells have been drilled into the Tulare: East James aquifer since 1978 and there are 42 additional years of observation well data since 1978.

8. It is improper to assume the spatially variable recharge rate found in Kuiper's model can be averaged across the model domain and then applied to areas outside of the model. The current best estimated average annual recharge to the Tulare: East James aquifer is 6,800 acre-feet per year.

9. The Tulare: East James aquifer currently has 94 permitted or licensed water rights appropriating water. These 94 water rights currently authorize the irrigation of 16,674 acres.

10. All water right permits approved since 2005 have placed their water to beneficial use as of the 2015 irrigation season.

11. Excluding the anomalously wet year of 2019, the authorized acres saw a utilization rate of 92.3% over the years of 2015-2018. Including the anomalously wet year of 2019, the authorized acres saw a utilization rate of 78.4% over the years of 2015-2019.

12. The application rate on irrigated acres over the period of record (1979,1983-2019) is 7.62 inches.

13. Assuming current irrigation trends continue, the estimated average annual use from the Tulare: East James aquifer is 9,773 acre-feet per year at 92.3% utilization of authorized acres. At 78.4% utilization of authorized acres, the estimated average annual use from the Tulare: East James aquifer is 8,301 acre-feet per year.

14. Based upon the downward trend observed in the observation well analysis since Buhler's analysis (2012-2019) and the hydrologic budget showing that the estimated average annual withdrawal exceeds the estimated average annual recharge, there is not a reasonable probability that unappropriated water is available from the Tulare: East James aquifer.

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REFERENCES

Buhler, K.A., 2012. Report to the Chief Engineer on Water Permit Application Nos. 7295-3, 7316-3, 7348-3, 7364-3, 7365-3, 7366-3, 7367-3, 7368-3, 7369-3, and 7370-3, August 23, 2012: SD DENR-Water Rights Program, Joe Foss Bldg., Pierre, South Dakota.

Goodman, J.A., 1984. Report on Applications No. 5009-3 Duane Muxen, No. 3178A-3 M.J.T. Inc., and No. 2235A-3 Gary D. Wipf. SD DENR-Water Rights Program, Joe Foss Bldg., Pierre, South Dakota.

Goodman, J.A., 2003. Report on Water Permit Application No. 6445-3 for Spink Colony. SD DENR-Water Rights Program, Joe Foss Bldg., Pierre, South Dakota.

Goodman, J.A., 2006. Report on Water Permit Application No. 6655-3 for Oscar, Inc. SD DENR-Water Rights Program, Joe Foss Bldg., Pierre, South Dakota.

Hamilton L.J., and Howells, L.W. 1996. Water Resources of Spink County, South Dakota. Water-Resources Investigations Report 96-4056. U.S. Geological Survey.

Hedges, L.S., Allen, J. and Holly, D.E. 1985. Evaluation of Ground-Water Resources Eastern South Dakota and Upper Big Sioux River, South Dakota, and Iowa. Task 7: Ground-Water Recharge. U.S. Army Corps of Engineers Contract DACW 45-80-C-0185.

Hedges, L.S., Burch, S. L., Iles, D. L., Barari, R. A., and Schoon, R. A. 1982. Evaluation of Ground-Water Resources Eastern South Dakota and Upper Big Sioux River, South Dakota, and Iowa. Task 1: Bedrock Topography and Distribution, Task 2: Extent of Aquifers, Task 3: Ground-Water Storage, Task 4: Computerized Data Base, Final Report. U.S. Army Corps of Engineers Contract DACW 45-80-C-0185.

Hines, Phillip W. v. Department of Environment and Natural Resources (South Dakota Water Management Board), Sixth Judicial Court of South Dakota, Case: HU04-37 concerning Water Permit Application #6431-3. Memorandum Decision issued April 29, 2005, Judgement, Findings of Fact, and Conclusion of Law filed June 7, 2005.

Howells, L.W., and Stephens, J.C., 1968. Geology and Water Resources of Beadle County, South Dakota; Part II: Water Resources. South Dakota Geological Survey Bulletin 18. Vermillion, SD.

Kuiper, L.K. 1984. Appraisal of the Water Resources of the Eastern Part of the Tulare Aquifer, Beadle, Hand, and Spink Counties, South Dakota. Water-Resources Investigations Report 84-4078. U.S. Geological Survey.

Magstadt, T. 2020. Unpublished data. SD DENR-Water Rights Program, Joe Foss Bldg., Pierre, South Dakota.

Mathiowetz, A.W. 2012. Unpublished data. SD DENR-Water Rights Program, Joe Foss Bldg., Pierre, South Dakota.

Water Rights. 1980-2020. 1979-2019 Irrigation Summaries by Aquifer: SD DENR-Water Rights Program, Joe Foss Bldg., Pierre, South Dakota.

Water Rights. 2020a. Irrigation Questionnaire Database. SD DENR-Water Rights Program, Joe Foss Bldg., Pierre, South Dakota.

Water Rights. 2020b. Observation Well Files. SD DENR-Water Rights Program, Joe Foss Bldg., Pierre, South Dakota.

Water Rights. 2020c. Water Right Files. SD DENR-Water Rights Program, Joe Foss Bldg., Pierre, South Dakota.

Water Rights. 2020d. Well Completion Report Database. SD DENR-Water Rights Program, Joe Foss Bldg., Pierre, South Dakota.

Appendix A: Approximate Timeline of Water Right Activity in the East James Management Unit of the Tulare Aquifer since the year 2000.

Date	Water Right	Action	Water Right Status	Change in Authorized Acres
02/22/2000	1033A-3	Result of Licensing Inspection	LC	-6
03/07/2001	3391-3	Denied due to approval of 6242-3 (same piece of land)	DN	
03/07/2001	4376-3	Incorporated into Water Right 6242-3, 0 acres remain	IL	
03/07/2001	6242-3	Permit approved by WMB, denied the deferred application 3391-3 and transferred 138 of 138 acres from Water Right 4376-3	PE	0
01/02/2002	6287-3	Date Received, Recommended for Denial, Denied by WMB 5-01-02	DN	
02/25/2002	6242-3	Incorporated into Water Right 6242A-3, 0 acres remain	IL	
02/25/2002	6242A-3	Water Right 6242-3 amended, moved 138 of 138 acres	PE	
09/25/2002	4612-3	Incorporated into Water Right 4612A-3, 0 acres remain	IL	
09/25/2002	4612A-3	Water Right 4612-3 amended, moved 132 of 132 acres	PE	
12/04/2002	970-3	Portion Cancelled by WMB for forfeiture, License Reissued for 132 acres	LC	-180
03/05/2003	6341-3	Permit approved by WMB, additional diversion point, no additional acres	PE	0
03/13/2003	3490-3	Incorporated into Water Right 5280-3	IL	
03/13/2003	3490-3A	Incorporated into Water Right 5280-3	IL	
03/13/2003	4772-3	Incorporated into Water Right 5280-3	IL	
03/13/2003	5280-3	Result of Licensing Inspection, Incorporated 3490-3, 3490-3A, 4772-3	LC	-56
05/07/2003	2729-3	Incorporated into Water Right 2729A-3, 0 acres remain once 2729A-3 system is used	IL	
05/07/2003	2729A-3	Water Right 2729-3 amended, moved 120 of 120 acres	PE	
10/07/2003	6445-3	Date Received, Recommended for Denial, Denied by WMB 7-07-04	DN	
12/03/2003	3466-3	Cancelled by WMB for forfeiture	CA	-91
12/03/2003	4586-3	100 acres transferred to 6382-3, License reissued	LC	0
12/03/2003	6382-3	Permit approved by WMB, moved 100 acres from 4586-3	PE	0
03/03/2004	1504-3	Incorporated into Water Rights 1504A-3 and 1504B-3, 218 acres remain	IL	
03/03/2004	1504A-3	Water Right 1504-3 amended, moved 16 of 370 acres	PE	

03/03/2004	1504B-3	Water Right 1504-3 amended, moved 136 of 370 acres	PE	
03/03/2004	3467-3	Cancelled by WMB for forfeiture	CA	-136
05/12/2004	1504-3	Remaining 218 acres cancelled by WMB	CA	-218
06/28/2004	3268-3	Incorporated into Water Right 3268A-3, 3 acres remain	IL	
06/28/2004	3268A-3	Water Right 3268-3 amended, moved 110 of 113 acres	PE	
06/07/2005	6431-3	Approved by 6th Judicial Circuit Court (Hines vs. SD DENR)	PE	91
06/20/2005	3268A-3	Incorporated into Water Right 3268B-3, 0 acres remain	IL	
06/20/2005	3268B-3	Water Right 3268A-3 amended, moved 113 of 113 acres	PE	
09/30/2005	4612A-3	Result of Licensing Inspection	LC	0
12/07/2005	4586-3	Incorporated into Water Right 4586A-3, 0 acres remain	IL	
12/07/2005	4586A-3	Water Right 4586-3 amended, moved 264 of 264 acres	PE	
04/07/2006	6715-3	Date Received, Recommended for Denial, Denied by WMB 10-11-06	DN	
04/24/2006	6728-3	Date Received, Recommended for Denial, Denied by WMB 10-11-06	DN	
05/03/2006	4586B-3	Date Received, Recommended for Denial, Withdrawn 8-25-06	WI	
05/30/2006	6720-3	Date Received, Recommended for Denial, Withdrawn 8-25-06	WI	
07/12/2006	6655-3	Permit approved by WMB	PE	160
07/12/2006	6656-3	Permit approved by WMB	LC	320
07/12/2006	6675-3	Permit approved by WMB, additional diversion rate, no change in acres due to same acres as 6382-3	LC	0
07/12/2006	6676-3	Permit approved by WMB	LC	264
08/25/2006	6721-3	Date Received, Recommended for Denial, Withdrawn 8-25-06	WI	
09/25/2006	3268B-3	Incorporated into Water Right 3268C-3, 0 acres remain	IL	
09/25/2006	3268C-3	Water Right 3268B-3 amended, moved 113 of 113 acres	PE	
10/11/2006	6711-3	Permit approved by WMB, amended by 6711A-3 prior to issuance	PE	304
10/11/2006	6712-3	Permit approved by WMB	PE	136
10/11/2006	6713-3	Permit approved by WMB	PE	136
03/08/2007	6831-3	Date Received, Recommended for Denial, Withdrawn 5-31-07	WI	
03/26/2007	4195-3	Incorporated into Water Right 4195A-3, 0 acres remain	IL	
03/26/2007	4195A-3	Water Right 4195-3 amended, moved 272 of 272 acres	PE	
04/30/2007	6711A-3	Water Right 6711-3 amended, moved 304 of 304 acres	PE	

05/16/2008	4753-3	Incorporated into Water Right 6341-3, 0 acres remain	IL	
05/16/2008	6341-3	Result of Licensing Inspection, Incorporated 4753-3	LC	0
04/27/2009	6712-3	Incorporated into Water Right 6712A-3, 0 acres remain	IL	
04/27/2009	6712A-3	Water Right 6712-3 amended, moved 136 of 136 acres	PE	
06/08/2009	3175-3	Incorporated into Water Right 3175A-3, 0 acres remain	IL	
06/08/2009	3175A-3	Water Right 3175-3 amended, , moved 132 of 132 acres	PE	
05/28/2010	6431-3	Incorporated into Water Right 6431A-3, 0 acres remain	IL	
05/28/2010	6431A-3	Water Right 6431-3 amended, moved 91 of 91 acres	PE	
06/01/2010	2208-3	Incorporated into Water Right 2208A-3, 28 acres remain with no diversion rate	IL	
06/01/2010	2208A-3	Water Right 2208-3 amended, moved 132 of 160 acres	PE	
05/09/2011	6713-3	Cancelled by WMB upon approval of 7235-3, authorized acres stayed the same	CA	-136
05/09/2011	7235-3	Permit approved by WMB, qualification canceled Water Right 6713-3 at the same time	PE	136
06/11/2012	1724-3	Incorporated into Water Right 1724A-3, 0 acres remain	IL	
06/11/2012	1724A-3	Water Right 1724-3 amended, moved 128 of 128 acres	PE	
10/25/2012	7480-3	Date Received, Recommended for Denial, Withdrawn 1-30-13	WI	
10/25/2012	7481-3	Date Received, Recommended for Denial, Withdrawn 1-30-13	WI	
10/25/2012	7482-3	Date Received, Recommended for Denial, Withdrawn 1-30-13	WI	
10/25/2012	7483-3	Date Received, Recommended for Denial, Withdrawn 1-30-13	WI	
10/25/2012	7484-3	Date Received, Recommended for Denial, Withdrawn 1-30-13	WI	
12/06/2012	7295-3	Permit approved by WMB	PE	120
12/06/2012	7316-3	Permit approved by WMB	PE	272
12/06/2012	7348-3	Permit approved by WMB	PE	440
12/06/2012	7364-3	Permit approved by WMB	PE	135
12/06/2012	7365-3	Permit approved by WMB	PE	132
12/06/2012	7366-3	Permit approved by WMB	PE	132
12/06/2012	7367-3	Permit approved by WMB	PE	132
12/06/2012	7368-3	Permit approved by WMB	PE	132
12/06/2012	7369-3	Permit approved by WMB	PE	132
12/06/2012	7370-3	Permit approved by WMB	PE	132
12/06/2012	7545-3	Date Received, Recommended for Denial, Withdrawn 1-30-13	WI	

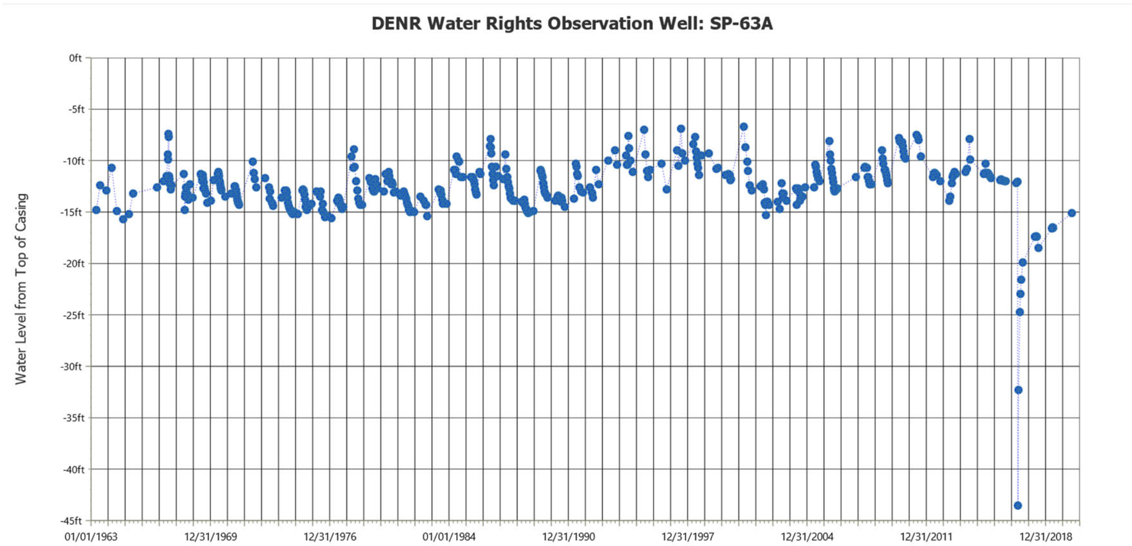
12/06/2012	7546-3	Date Received, Recommended for Denial, Withdrawn 1-30-13	WI	
12/06/2012	7547-3	Date Received, Recommended for Denial, Withdrawn 1-30-13	WI	
12/06/2012	7548-3	Date Received, Recommended for Denial, Withdrawn 1-30-13	WI	
01/11/2013	7641-3	Date Received, Recommended for Denial, Withdrawn 4-12-13	WI	
02/08/2013	7728-3	Date Received, Recommended for Denial, Withdrawn 5-17-13	WI	
02/08/2013	7729-3	Date Received, Recommended for Denial, Withdrawn 5-17-13	WI	
02/08/2013	7760-3	Date Received, Recommended for Denial, Withdrawn 5-17-13	WI	
02/08/2013	7761-3	Date Received, Recommended for Denial, Withdrawn 5-17-13	WI	
02/08/2013	7762-3	Date Received, Recommended for Denial, Withdrawn 5-17-13	WI	
02/08/2013	7763-3	Date Received, Recommended for Denial, Withdrawn 5-17-13	WI	
02/08/2013	7764-3	Date Received, Recommended for Denial, Withdrawn 5-17-13	WI	
02/08/2013	7766-3	Date Received, Recommended for Denial, Withdrawn 5-17-13	WI	
02/08/2013	7875-3	Date Received, Recommended for Denial, Denied by WMB 7-08-15	DN	
02/08/2013	7876-3	Date Received, Recommended for Denial, Denied by WMB 7-08-15	DN	
02/08/2013	7877-3	Date Received, Recommended for Denial, Denied by WMB 7-08-15	DN	
02/08/2013	7879-3	Date Received, Recommended for Denial, Denied by WMB 7-08-15	DN	
02/08/2013	7880-3	Date Received, Recommended for Denial, Denied by WMB 7-08-15	DN	
02/08/2013	7881-3	Date Received, Recommended for Denial, Denied by WMB 7-08-15	DN	
02/08/2013	7882-3	Date Received, Recommended for Denial, Denied by WMB 7-08-15	DN	
02/08/2013	7883-3	Date Received, Recommended for Denial, Denied by WMB 7-08-15	DN	
02/08/2013	7884-3	Date Received, Recommended for Denial, Denied by WMB 7-08-15	DN	
02/09/2013	7878-3	Date Received, Recommended for Denial, Denied by WMB 7-08-15	DN	
02/25/2013	7747-3	Date Received, Recommended for Denial, Denied by WMB 10-03-13	DN	
02/28/2013	7730-3	Date Received, Recommended for Denial, Withdrawn 5-17-13	WI	
02/28/2013	7765-3	Date Received, Recommended for Denial, Withdrawn 5-17-13	WI	
02/28/2013	7767-3	Date Received, Recommended for Denial, Withdrawn 5-17-13	WI	
03/11/2013	1201-3	Incorporated into Water Right 1201A-3, remaining 18 acres cancelled upon IL	IL	-18
03/11/2013	1201A-3	Water Right 1201-3 amended, moved 122 of 140 acres	PE	
03/26/2013	7810-3	Date Received, Recommended for Denial, Withdrawn 6-13-13	WI	
04/11/2013	7826-3	Date Received, Recommended for Denial, Withdrawn 5-17-13	WI	

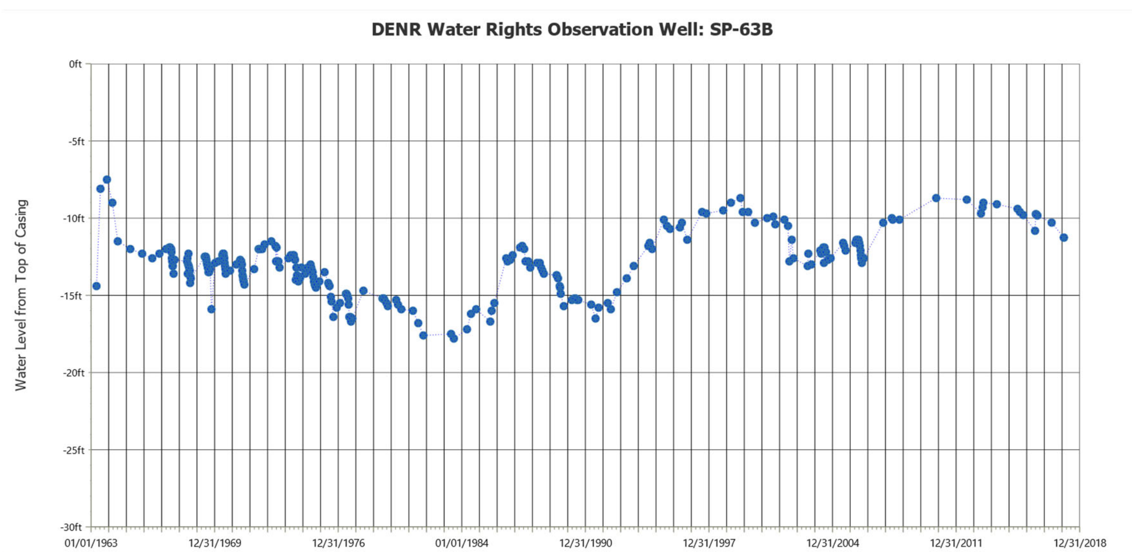
04/15/2013	4586A-3	Incorporated into Water Right 4586C-3, 132 acres remain	PE	
04/15/2013	4586C-3	Water Right 4586A-3 amended, moved 132 of 264 acres	PE	
06/03/2013	7235-3	Incorporated into Water Right 7235A-3, 0 acres remain	IL	
06/03/2013	7235A-3	Water Right 7235-3 amended, moved 136 of 136 acres	PE	
09/13/2013	7903-3	Date Received, Recommended for Denial, Withdrawn 12-13-13	WI	
12/16/2013	7934-3	Date Received, Recommended for Denial, Withdrawn 3-04-14	WI	
04/18/2014	8003-3	Date Received, Recommended for Denial, Withdrawn 7-08-14	WI	
06/27/2014	8032-3	Date Received, Recommended for Denial, Denied by WMB 7-08-15	DN	
07/07/2014	1504A-3	Result of Licensing Inspection, Incorporated all 120 acres of Water Right 2729A-3	LC	0
07/07/2014	2729A-3	Incorporated into Water Right 1504A-3, 0 acres remain	IL	
07/07/2014	6242A-3	Result of Licensing Inspection	LC	0
09/04/2014	6382-3	Incorporated into Water Right 6675-3, 0 acres remain	IL	
09/04/2014	6675-3	Result of Licensing Inspection, Incorporated 6382-3	LC	0
09/04/2014	6676-3	Result of Licensing Inspection	LC	0
09/24/2014	1504B-3	Result of Licensing Inspection	LC	0
09/24/2014	6656-3	Result of Licensing Inspection	LC	-50
09/24/2014	6711A-3	Result of Licensing Inspection	LC	-34
09/24/2014	6712A-3	Result of Licensing Inspection	LC	-1
10/22/2014	2729-3	Cancelled by WMB upon use of the system approved by 2729A-3	CA	0
02/25/2015	8082-3	Number 14 of 14 in the Random Selection Priority List	HD	
02/25/2015	8086-3	Number 5 of 14 in the Random Selection Priority List	HD	
02/25/2015	8087-3	Number 7 of 14 in the Random Selection Priority List	HD	
02/25/2015	8088-3	Number 1 of 14 in the Random Selection Priority List	HD	
02/25/2015	8089-3	Number 10 of 14 in the Random Selection Priority List	HD	
02/25/2015	8090-3	Number 2 of 14 in the Random Selection Priority List	HD	
02/25/2015	8112-3	Number 4 of 14 in the Random Selection Priority List	HD	
02/25/2015	8113-3	Number 8 of 14 in the Random Selection Priority List	HD	
02/25/2015	8114-3	Number 11 of 14 in the Random Selection Priority List	HD	
02/25/2015	8115-3	Number 12 of 14 in the Random Selection Priority List	HD	
02/25/2015	8116-3	Number 3 of 14 in the Random Selection Priority List	HD	

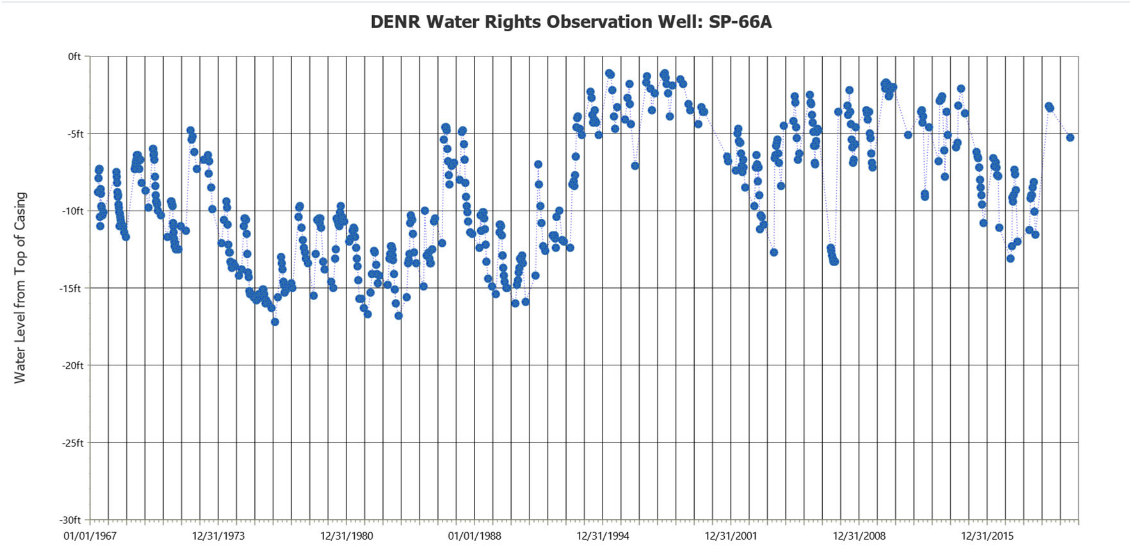
02/25/2015	8117-3	Number 6 of 14 in the Random Selection Priority List	HD	
02/25/2015	8119-3	Number 9 of 14 in the Random Selection Priority List	HD	
02/25/2015	8140-3	Number 13 of 14 in the Random Selection Priority List	HD	
05/07/2015	3268C-3	Incorporated into Water Right 7369A-3, 0 acres remain	IL	
05/07/2015	6431A-3	Incorporated into Water Right 7369B-3, 0 acres remain	IL	
05/07/2015	7368-3	Incorporated into Water Right 7369C-3, 0 acres remain	IL	
05/07/2015	7369-3	Incorporated into Water Right 7369A-3, 7369B-3, 7369C-3, 0 acres remain	IL	
05/07/2015	7369A-3	Water Right 7369-3 amended, moved 45 of 132 acres, Incorporated Water Right 3268C-3 (113 acres)	PE	0
05/07/2015	7369B-3	Water Right 7369-3 amended, moved 61 of 132 acres, Incorporated Water Right 6431A-3 (91 acres)	PE	0
05/07/2015	7369C-3	Water Right 7369-3 amended, moved 26 of 132 acres, Incorporated Water Right 7368-3 (132 acres)	PE	0
10/14/2015	7369-3	Remaining diversion rate cancelled by WMB, all acres and partial diversion rate had been transferred to other permits	CA	0
02/23/2016	7364-3	Result of Licensing Inspection	LC	0
02/24/2016	1201A-3	Result of Licensing Inspection	LC	0
02/24/2016	1724A-3	Result of Licensing Inspection	LC	0
07/22/2016	4195A-3	Result of Licensing Inspection	LC	0
08/17/2016	4586A-3	Incorporated into Water Right 4586C-3, 0 acres remain	IL	
08/17/2016	4586C-3	Result of Licensing Inspection, Incorporated 4586-3 and 4586A-3	LC	0
10/11/2016	6655-3	Result of Licensing Inspection	LC	-28
10/11/2016	7316-3	Result of Licensing Inspection	LC	0
05/08/2017	7348-3	Transferred 66 of 440 acres to 7348A-3, 374 acres remain	PE	0
05/08/2017	7348A-3	Water Right 7348-3 amended, moved 66 of 440 acres	PE	
06/21/2017	1722-3	Ownership Change, 160 acres to 1722A-3 and 80 acres to 1722B-3	OC	
06/21/2017	1722A-3	Ownership Change, took 160 acres of 240 acres	LC	
06/21/2017	1722B-3	Ownership Change, took 80 acres of 240 acres	LC	
01/28/2019	1358-3	Incorporated into Water Right 1358B-3, 25 acres remain	IL	
01/28/2019	1358B-3	Water Right 1358-3 amended, moved 135 of 160 acres	PE	

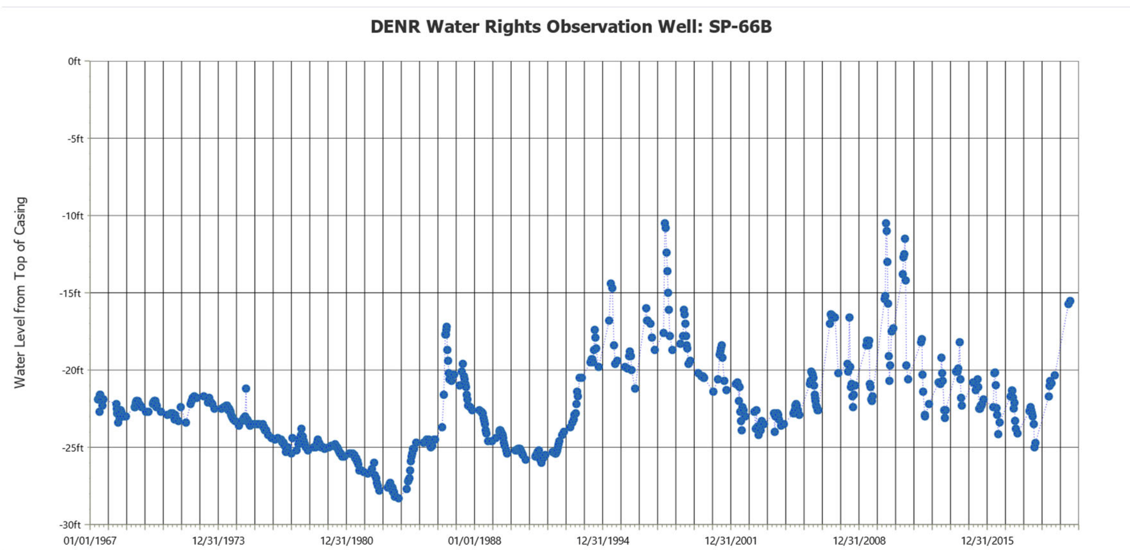
05/08/2019	1358-3	Remaining 25 acres cancelled by WMB	CA	-25
05/22/2019	2208A-3	Result of Licensing Inspection, Incorporated 2208-3 (28 acres remained), 3175-3 (0 acres), 3175A-3 (132 acres)	LC	-28
05/22/2019	3175A-3	Incorporated into Water Right 2208A-3, 0 acres remain	IL	
02/24/2020	7295-3	Result of Licensing Inspection	LC	0
02/28/2020	7348-3	Result of Licensing Inspection	LC	0
02/28/2020	7348A-3	Result of Licensing Inspection	LC	0
03/03/2020	7367-3	Result of Licensing Inspection	LC	0

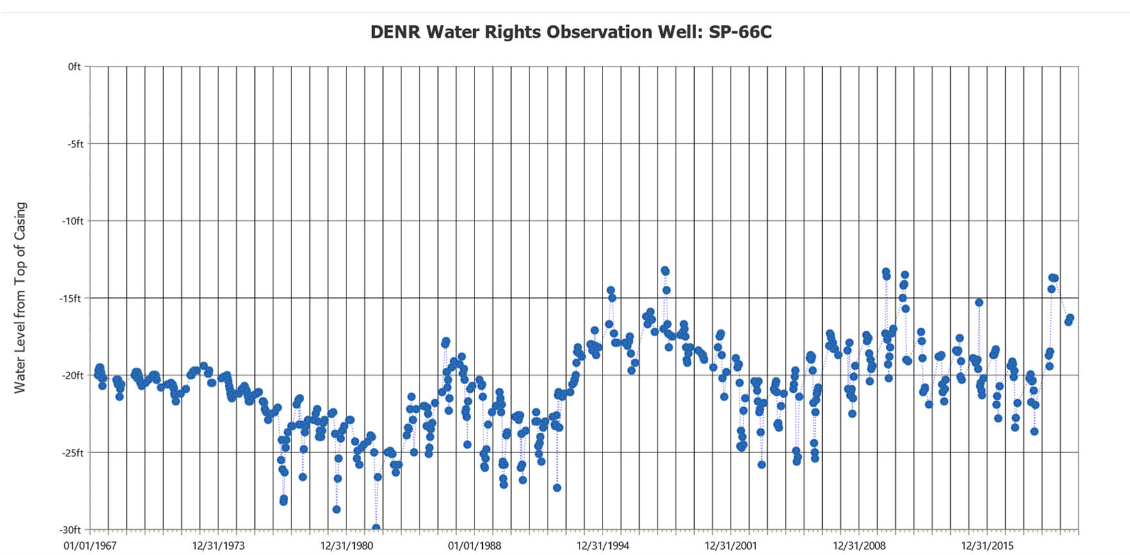
Appendix B: SD DENR-Water Rights Program Tulare: East James aquifer observation well hydrographs (Water Rights, 2020b).

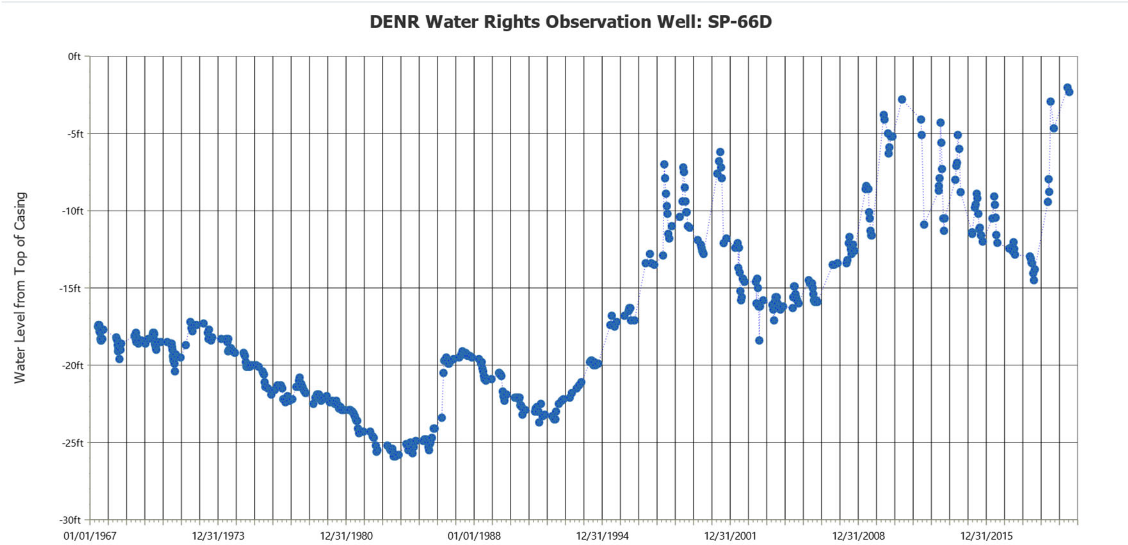


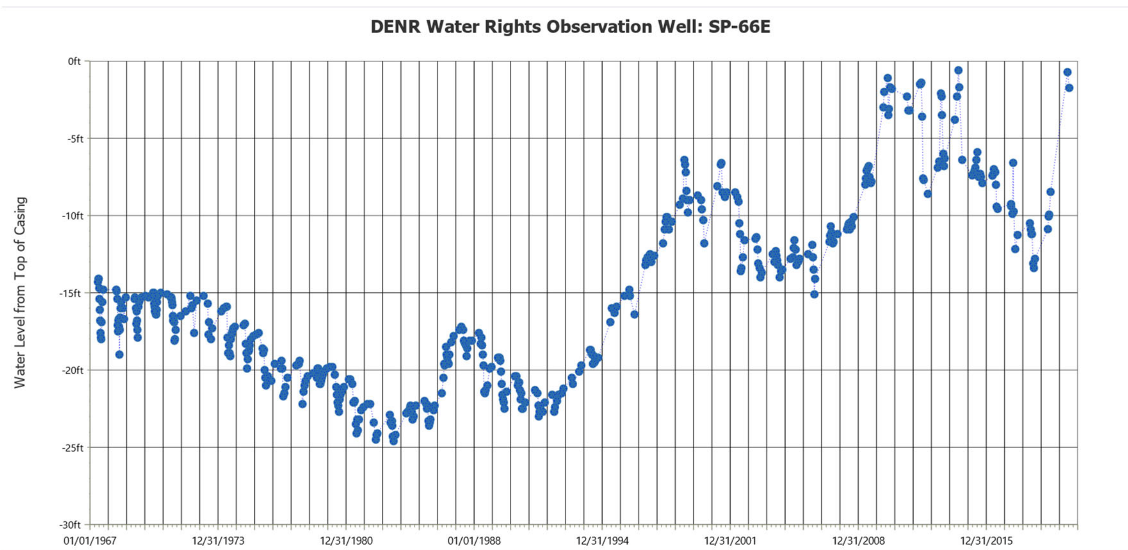


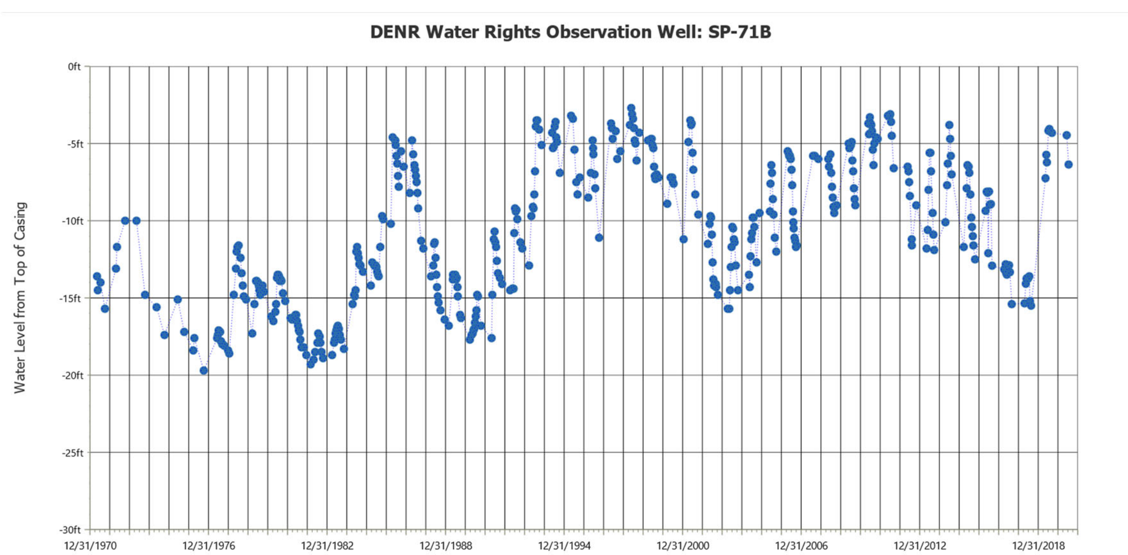

DENR Water Rights Observation Well: SP-66A
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
01/01/1967
12/31/1973
12/31/1980
01/01/1988
12/31/1994
12/31/2001
12/31/2008
12/31/2015

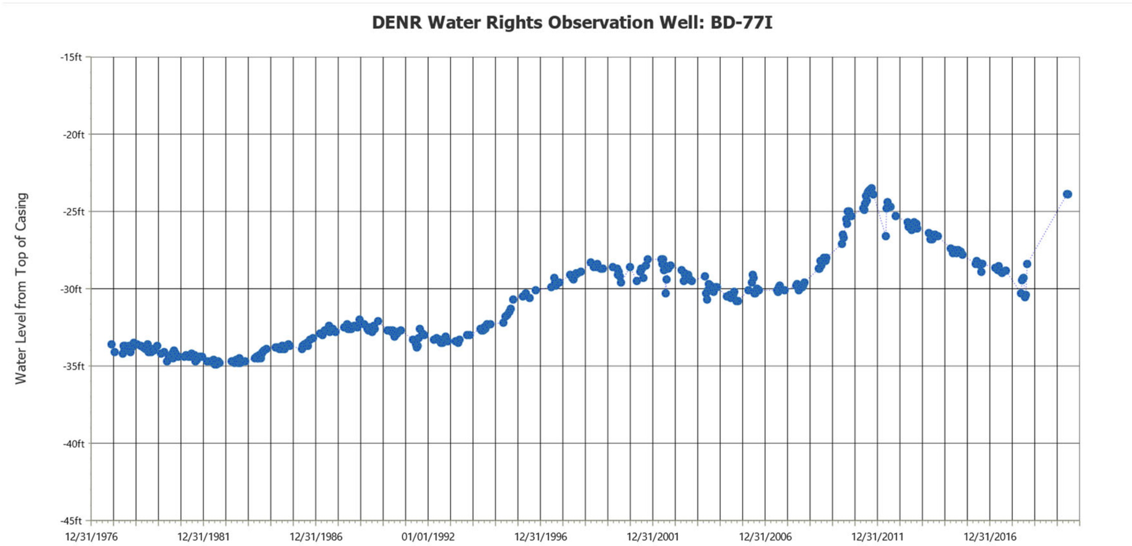

DENR Water Rights Observation Well: SP-66B
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
01/01/1967
12/31/1973
12/31/1980
01/01/1988
12/31/1994
12/31/2001
12/31/2008
12/31/2015

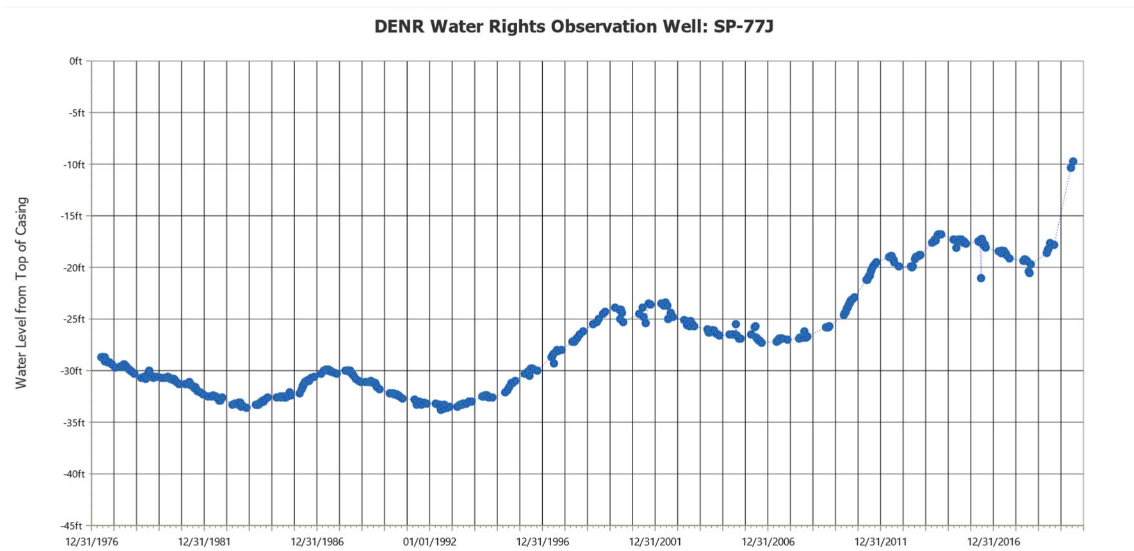

DENR Water Rights Observation Well: SP-66C
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
01/01/1967
12/31/1973
12/31/1980
01/01/1988
12/31/1994
12/31/2001
12/31/2008
12/31/2015


DENR Water Rights Observation Well: SP-66D
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
01/01/1967
12/31/1973
12/31/1980
01/01/1988
12/31/1994
12/31/2001
12/31/2008
12/31/2015


DENR Water Rights Observation Well: SP-66E
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
01/01/1967
12/31/1973
12/31/1980
01/01/1988
12/31/1994
12/31/2001
12/31/2008
12/31/2015


DENR Water Rights Observation Well: SP-71B
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
12/31/1970
12/31/1976
12/31/1982
12/31/1988
12/31/1994
12/31/2000
12/31/2006
12/31/2012
12/31/2018


DENR Water Rights Observation Well: BD-77I
Water Level from Top of Casing
-15ft
-20ft
-25ft
-30ft
-35ft
-40ft
-45ft
12/31/1976
12/31/1981
12/31/1986
01/01/1992
12/31/1996
12/31/2001
12/31/2006
12/31/2011
12/31/2016


DENR Water Rights Observation Well: SP-77J
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
-35ft
-40ft
-45ft
12/31/1976
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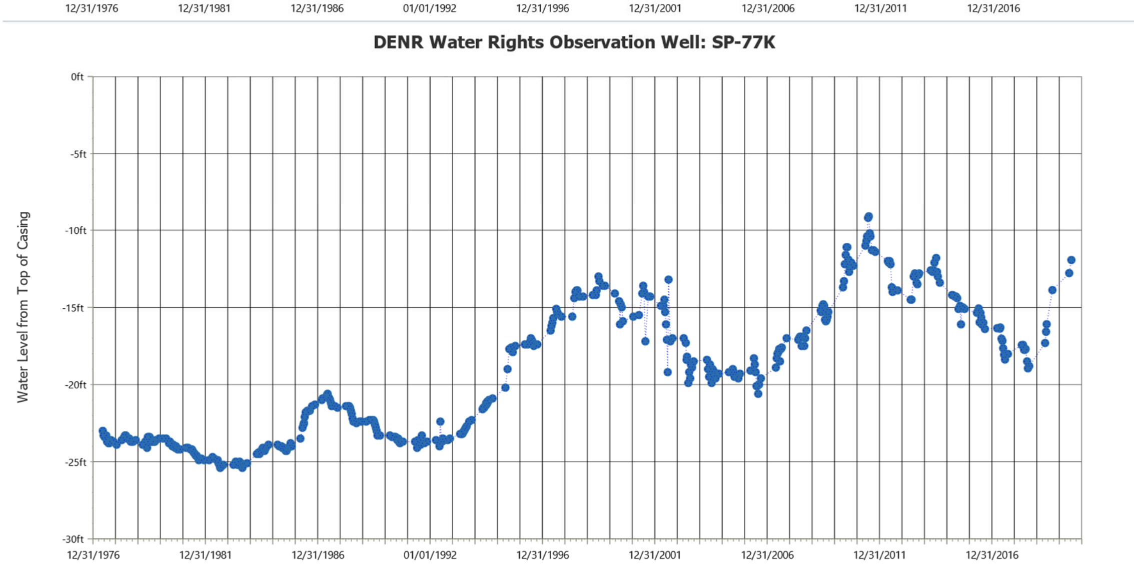
12/31/2011
12/31/2016


DENR Water Rights Observation Well: SP-77K
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
12/31/1976
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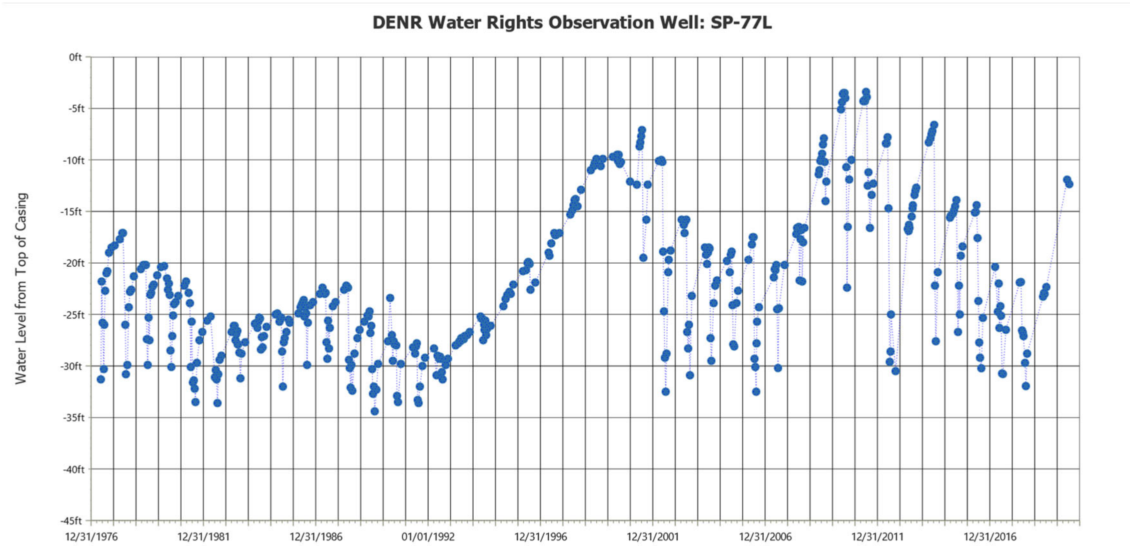
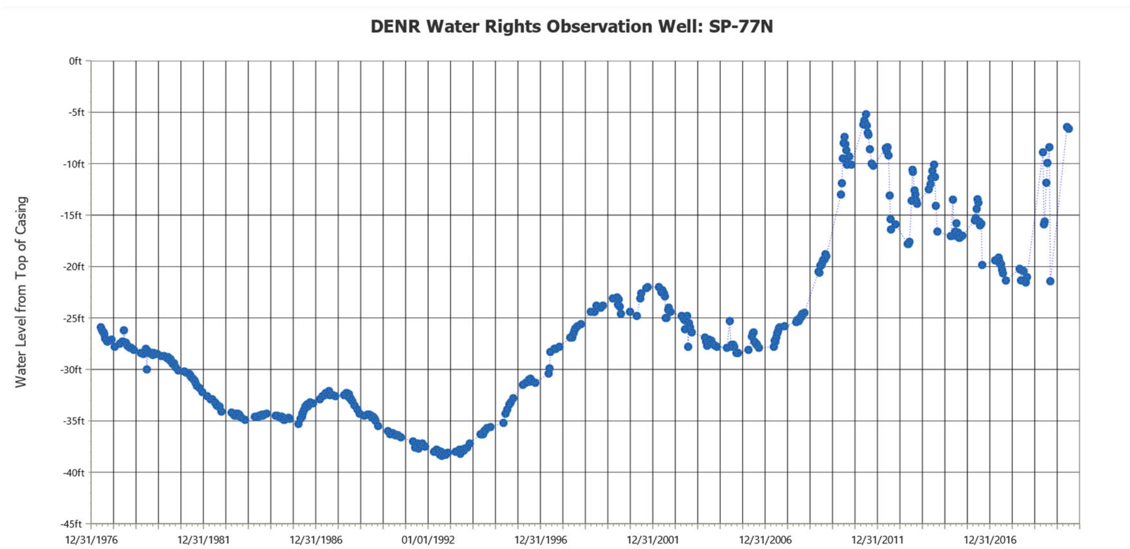
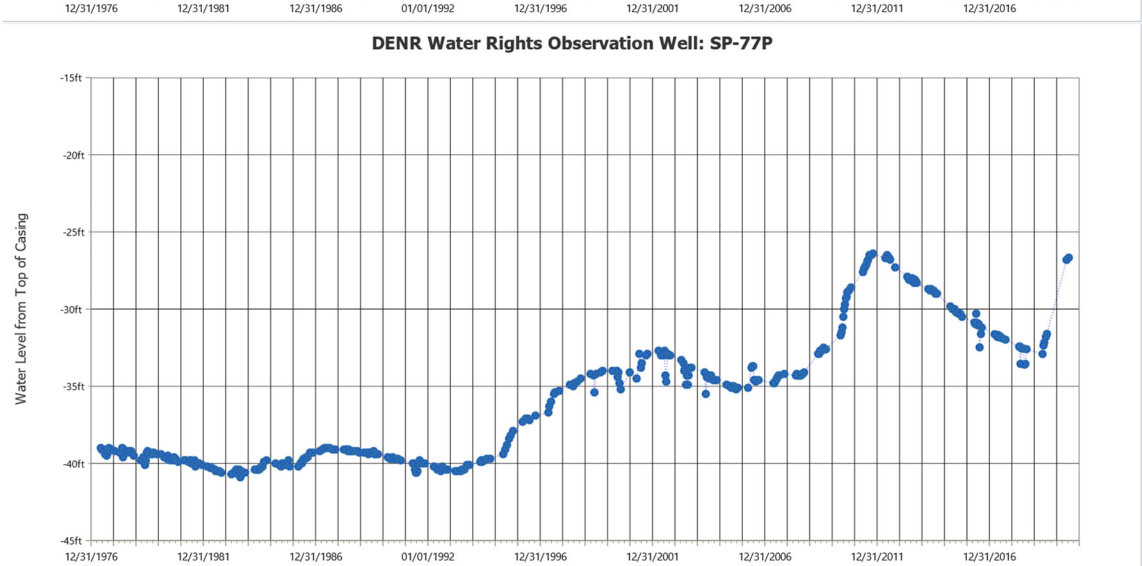
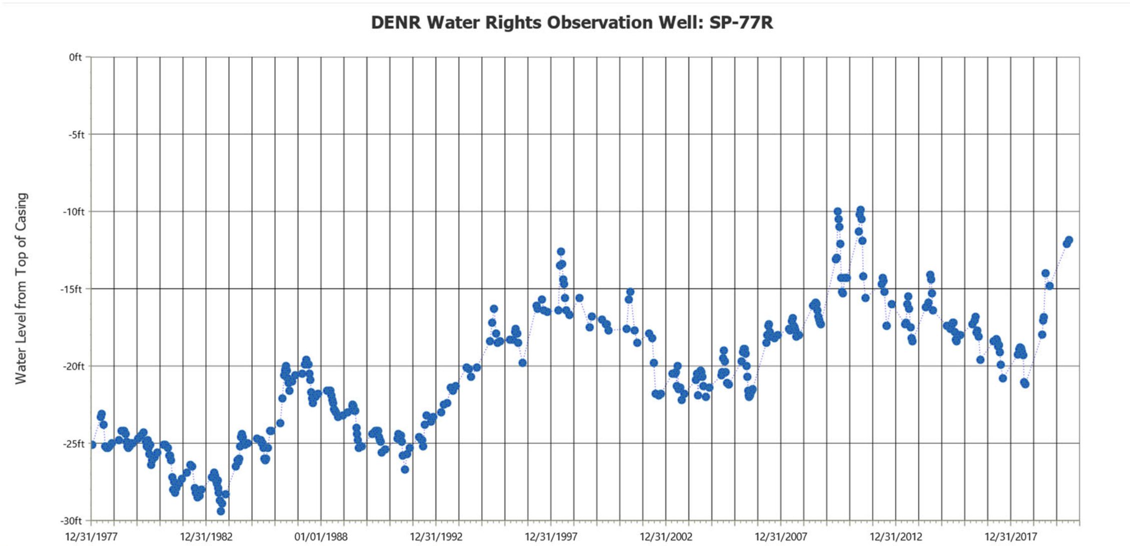
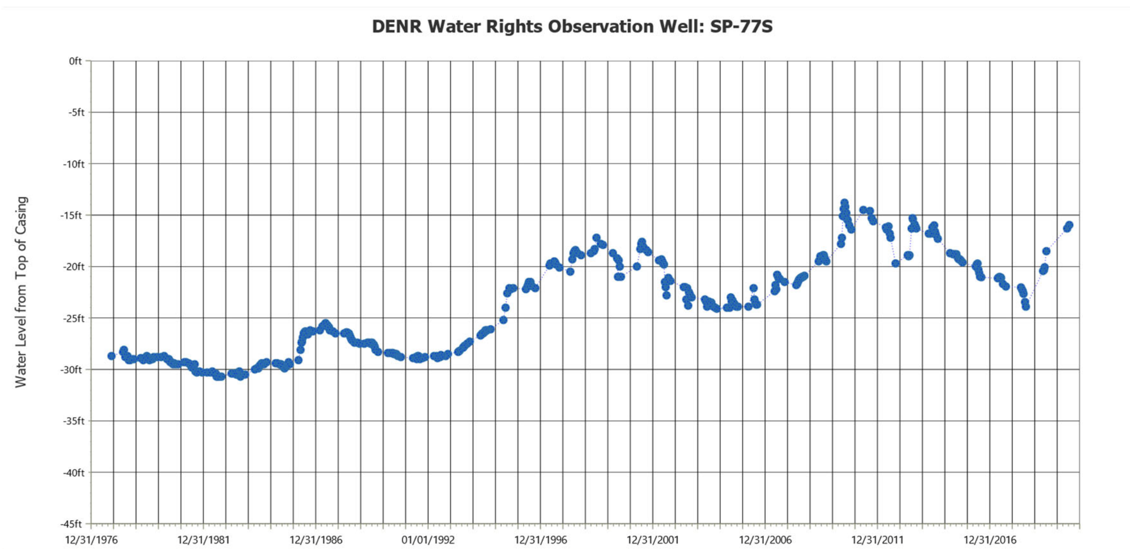
12/31/1986
01/01/1992
12/31/1996
12/31/2001
12/31/2006
12/31/2011
12/31/2016

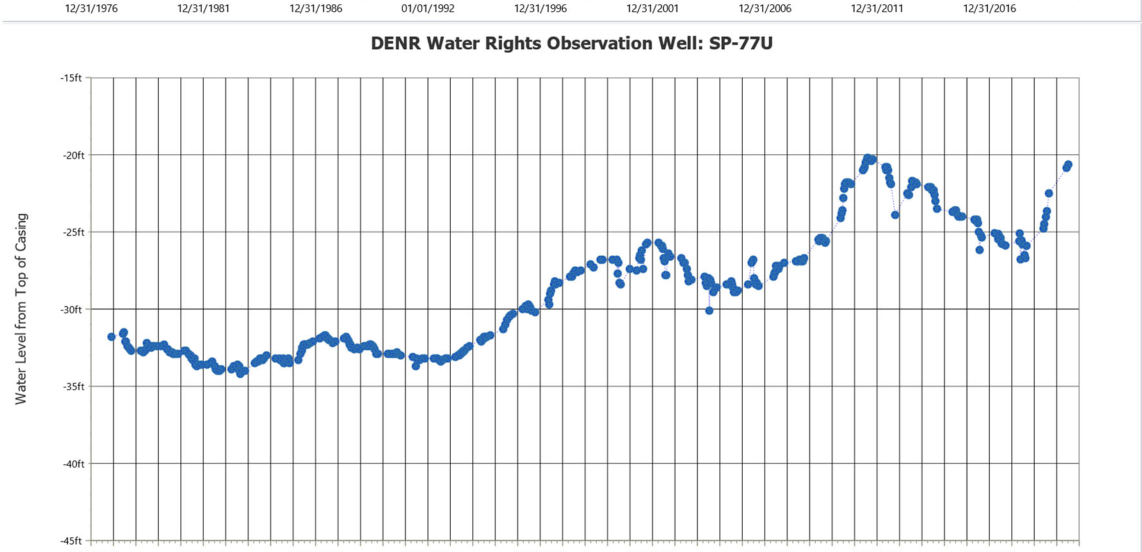

DENR Water Rights Observation Well: SP-77L
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
-35ft
-40ft
-45ft
12/31/1976
12/31/1981
12/31/1986
01/01/1992
12/31/1996
12/31/2001
12/31/2006
12/31/2011
12/31/2016

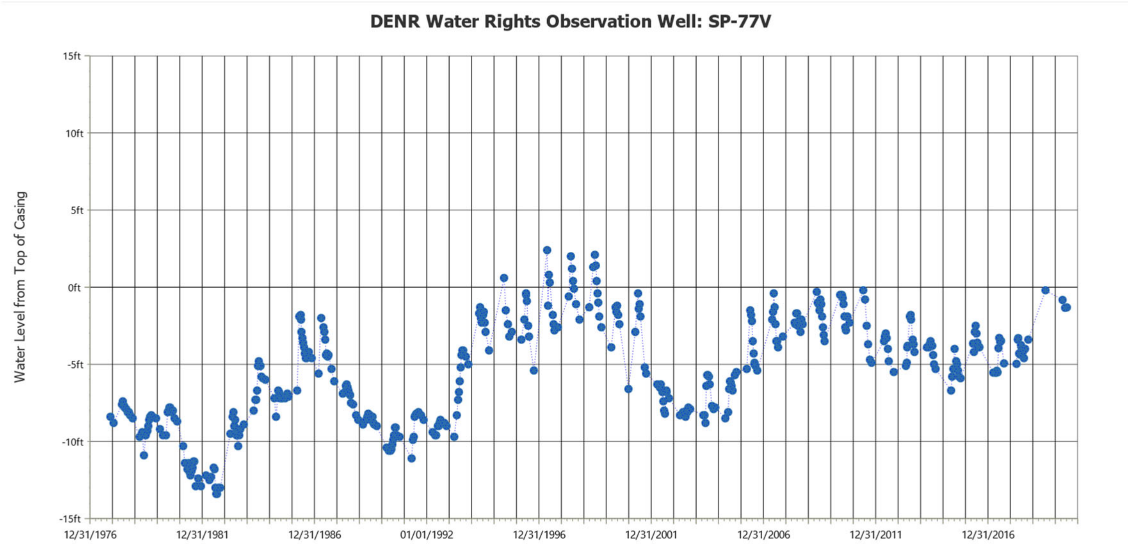

DENR Water Rights Observation Well: SP-77N
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
-35ft
-40ft
-45ft
12/31/1976
12/31/1981
12/31/1986
01/01/1992
12/31/1996
12/31/2001
12/31/2006
12/31/2011
12/31/2016

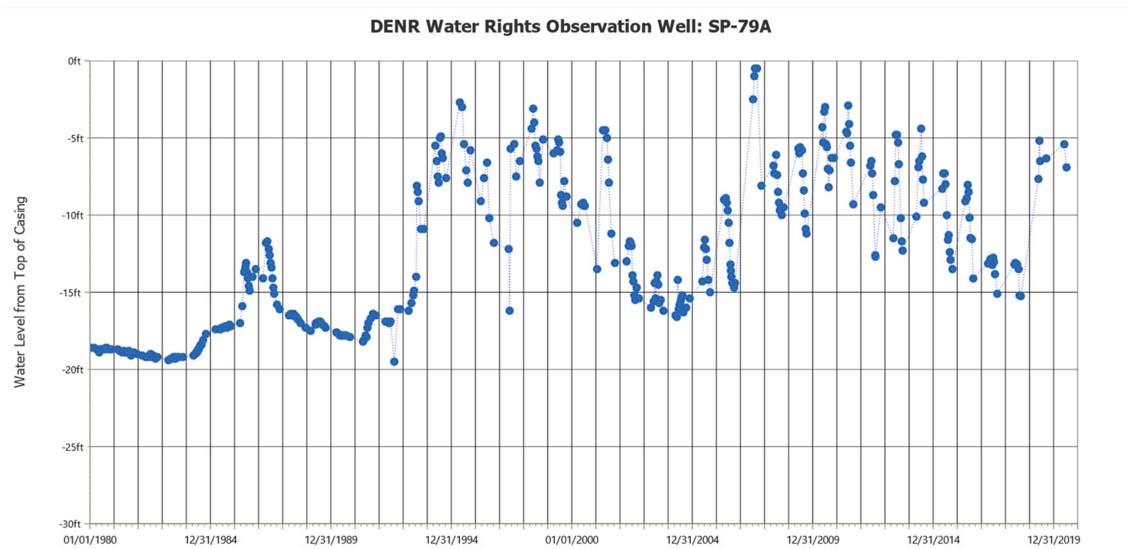

DENR Water Rights Observation Well: SP-77P
Water Level from Top of Casing
-15ft
-20ft
-25ft
-30ft
-35ft
-40ft
-45ft
12/31/1976
12/31/1981
12/31/1986
01/01/1992
12/31/1996
12/31/2001
12/31/2006
12/31/2011
12/31/2016

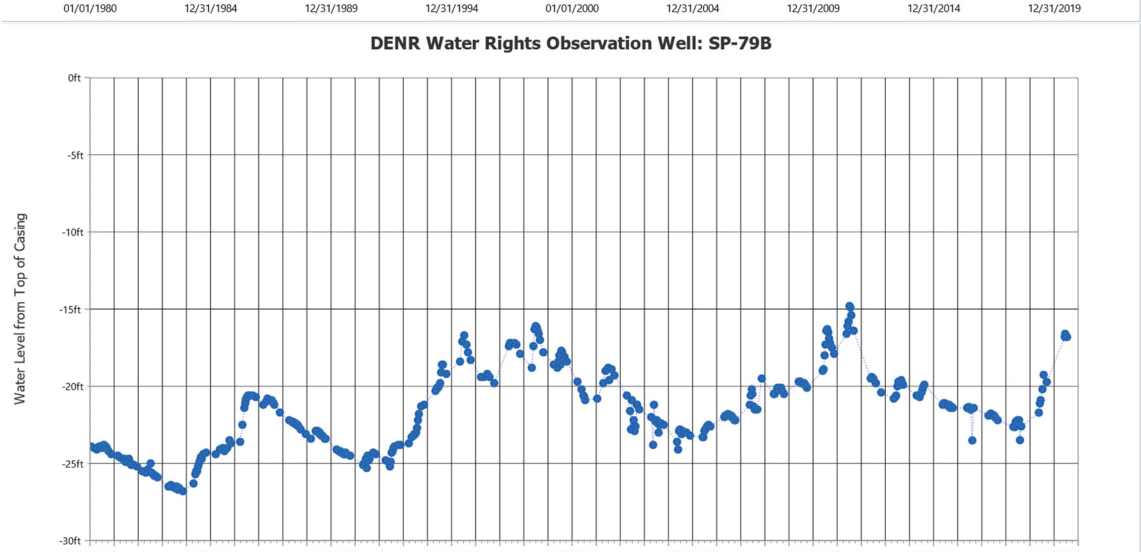

DENR Water Rights Observation Well: SP-77R
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
12/31/1977
12/31/1982
01/01/1988
12/31/1992
12/31/1997
12/31/2002
12/31/2007
12/31/2012
12/31/2017

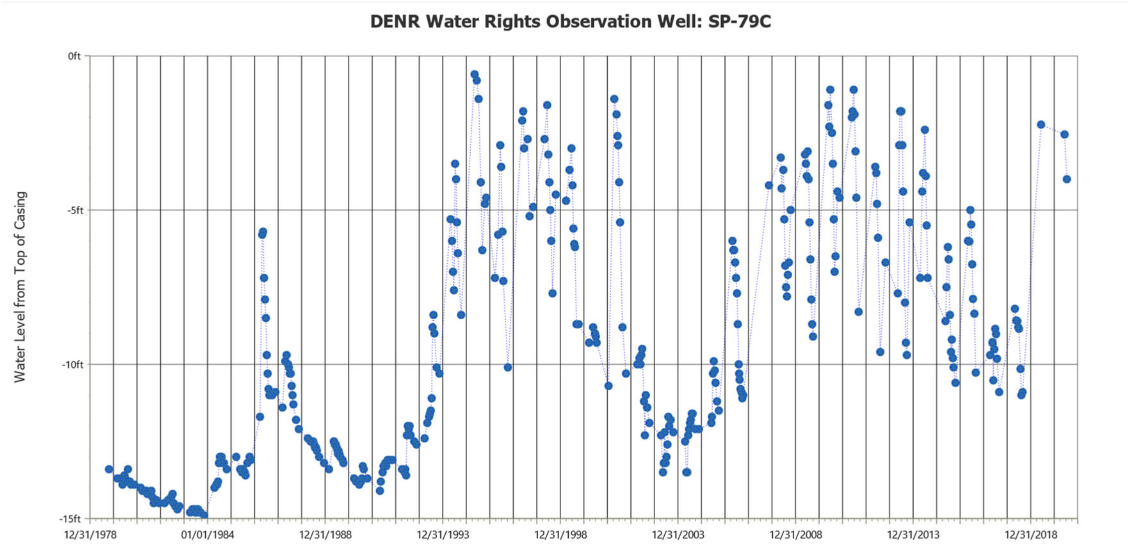

DENR Water Rights Observation Well: SP-77S
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
-35ft
-40ft
-45ft
12/31/1976
12/31/1981
12/31/1986
01/01/1992
12/31/1996
12/31/2001
12/31/2006
12/31/2011
12/31/2016

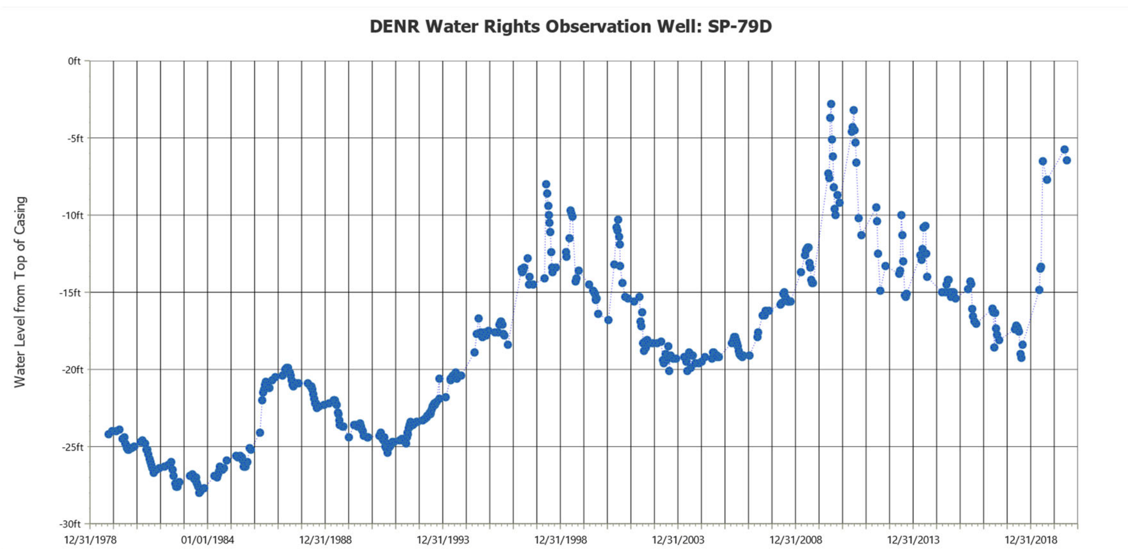

DENR Water Rights Observation Well: SP-77U
Water Level from Top of Casing
-15ft
-20ft
-25ft
-30ft
-35ft
-40ft
-45ft
12/31/1976
12/31/1981
12/31/1986
01/01/1992
12/31/1996
12/31/2001
12/31/2006
12/31/2011
12/31/2016

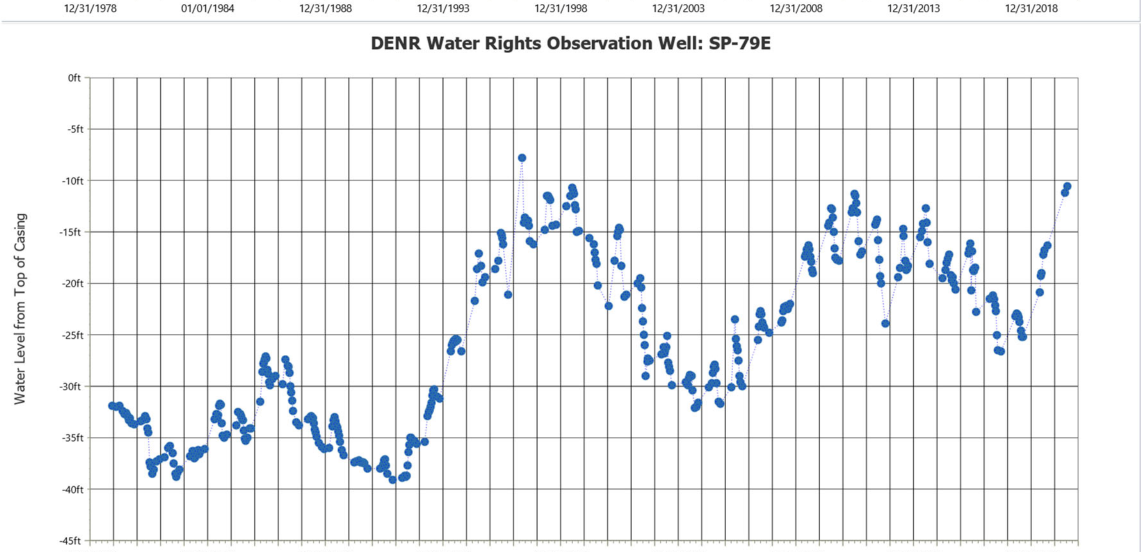

DENR Water Rights Observation Well: SP-77V
Water Level from Top of Casing
15ft
10ft
5ft
0ft
-5ft
-10ft
-15ft
12/31/1976
12/31/1981
12/31/1986
01/01/1992
12/31/1996
12/31/2001
12/31/2006
12/31/2011
12/31/2016

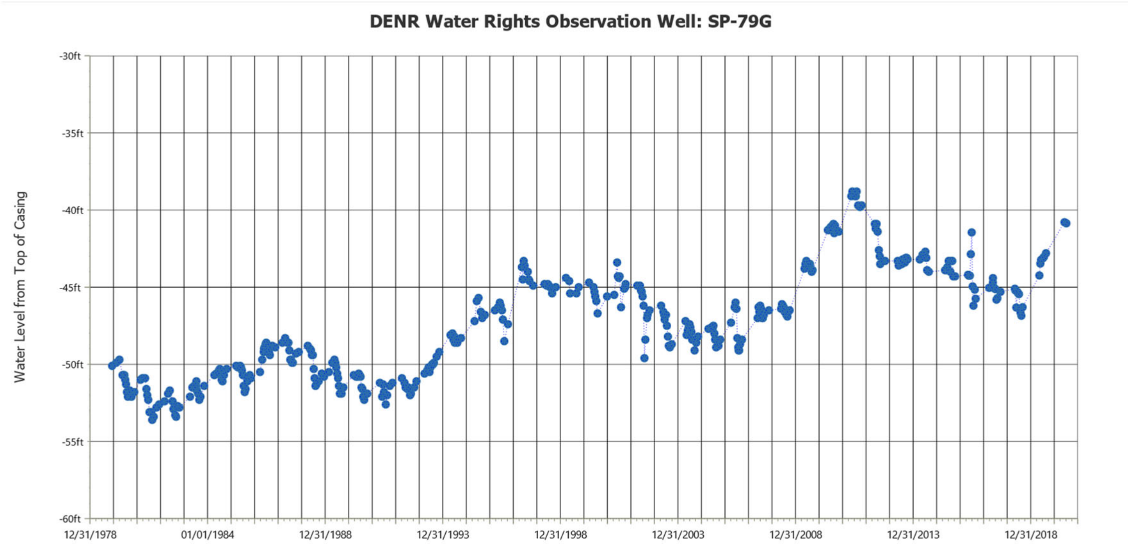

DENR Water Rights Observation Well: SP-79A
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
01/01/1980
12/31/1984
12/31/1989
12/31/1994
01/01/2000
12/31/2004
12/31/2009
12/31/2014
12/31/2019

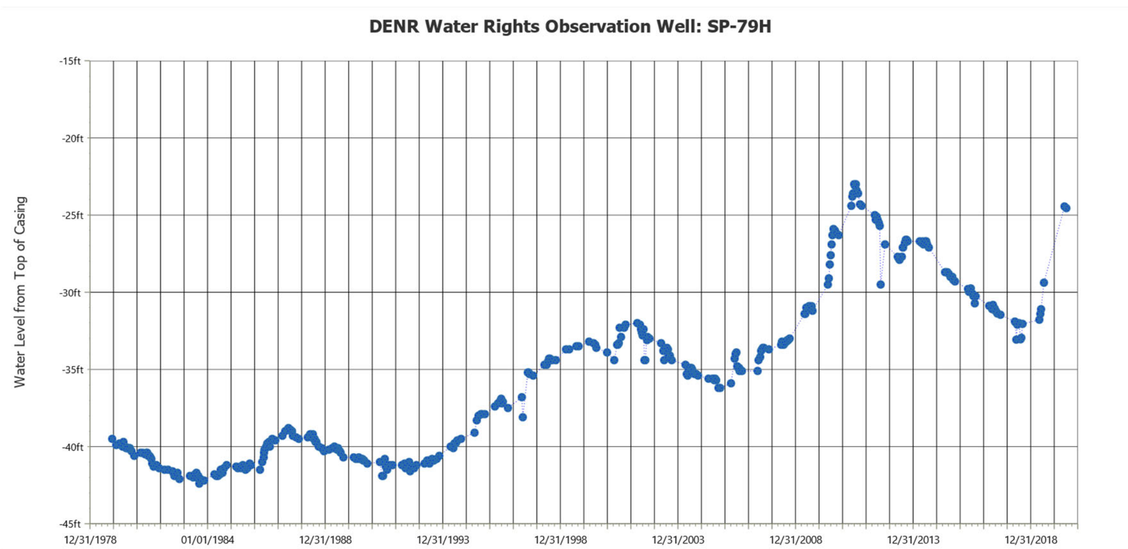

DENR Water Rights Observation Well: SP-79B
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
01/01/1980
12/31/1984
12/31/1989
12/31/1994
01/01/2000
12/31/2004
12/31/2009
12/31/2014
12/31/2019

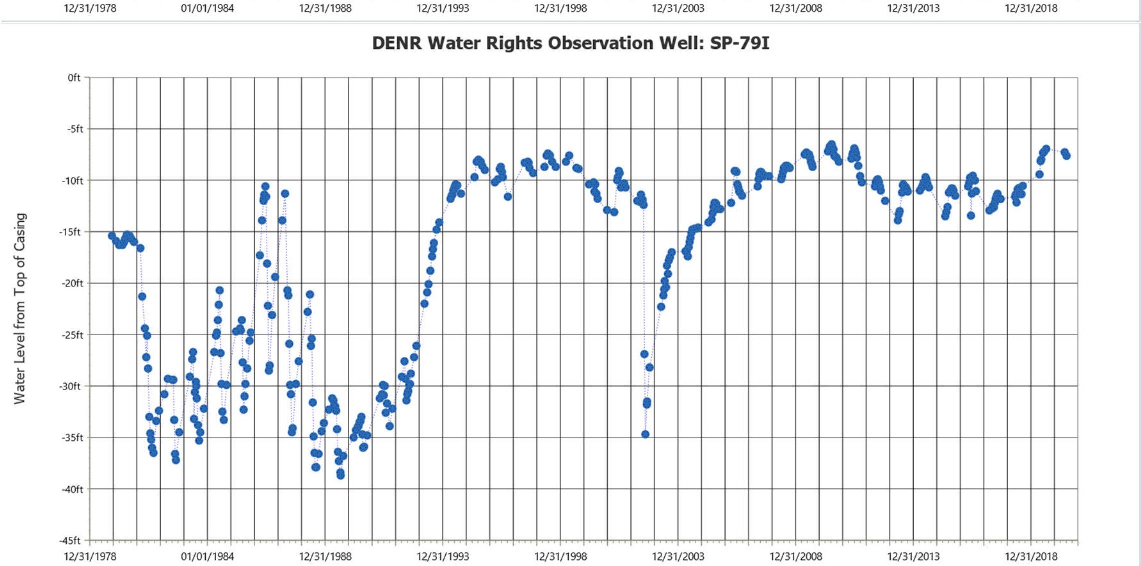

DENR Water Rights Observation Well: SP-79C
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
12/31/1978
01/01/1984
12/31/1988
12/31/1993
12/31/1998
12/31/2003
12/31/2008
12/31/2013
12/31/2018

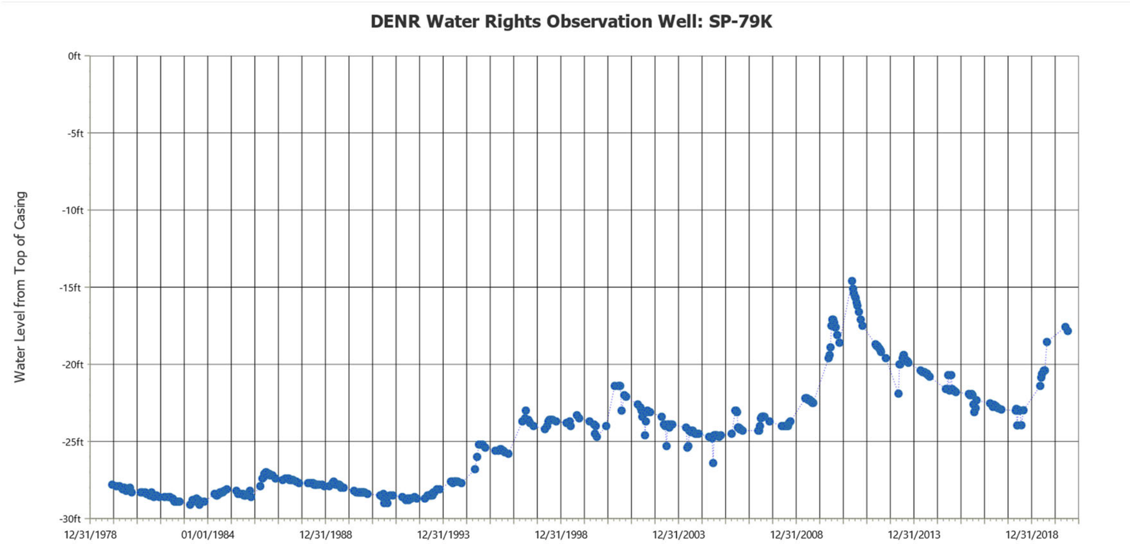

DENR Water Rights Observation Well: SP-79D
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
12/31/1978
01/01/1984
12/31/1988
12/31/1993
12/31/1998
12/31/2003
12/31/2008
12/31/2013
12/31/2018

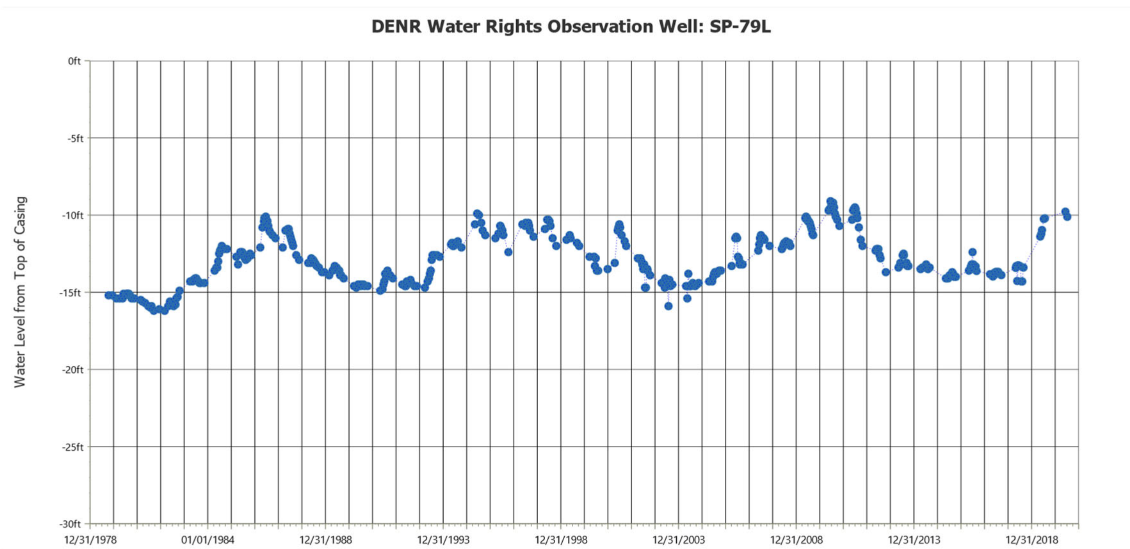

DENR Water Rights Observation Well: SP-79E
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
-35ft
-40ft
-45ft
12/31/1978
01/01/1984
12/31/1988
12/31/1993
12/31/1998
12/31/2003
12/31/2008
12/31/2013
12/31/2018

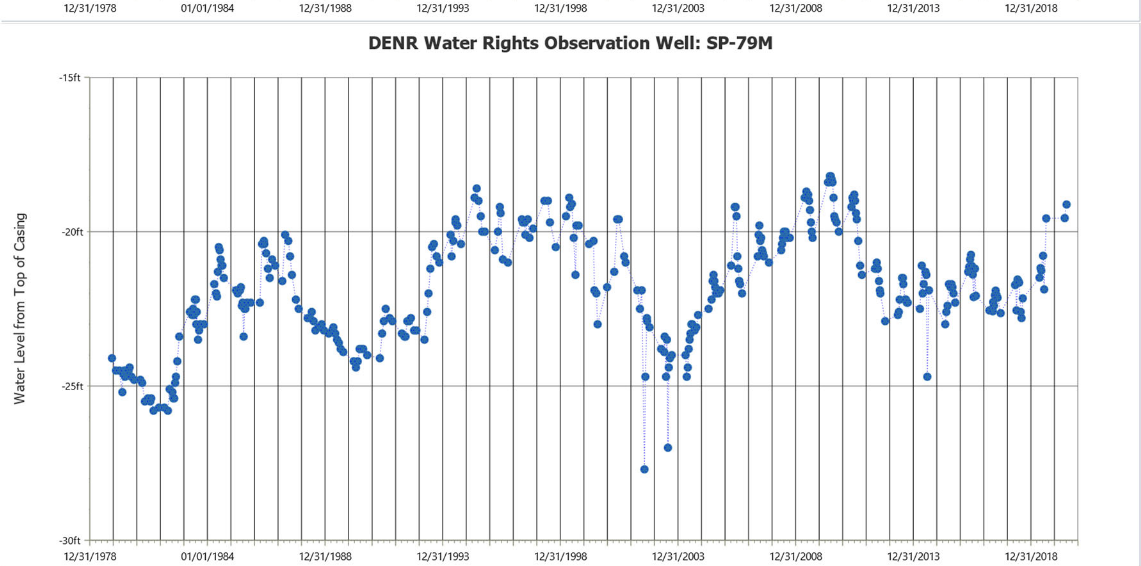

DENR Water Rights Observation Well: SP-79G
Water Level from Top of Casing
-30ft
-35ft
-40ft
-45ft
-50ft
-55ft
-60ft
12/31/1978
01/01/1984
12/31/1988
12/31/1993
12/31/1998
12/31/2003
12/31/2008
12/31/2013
12/31/2018

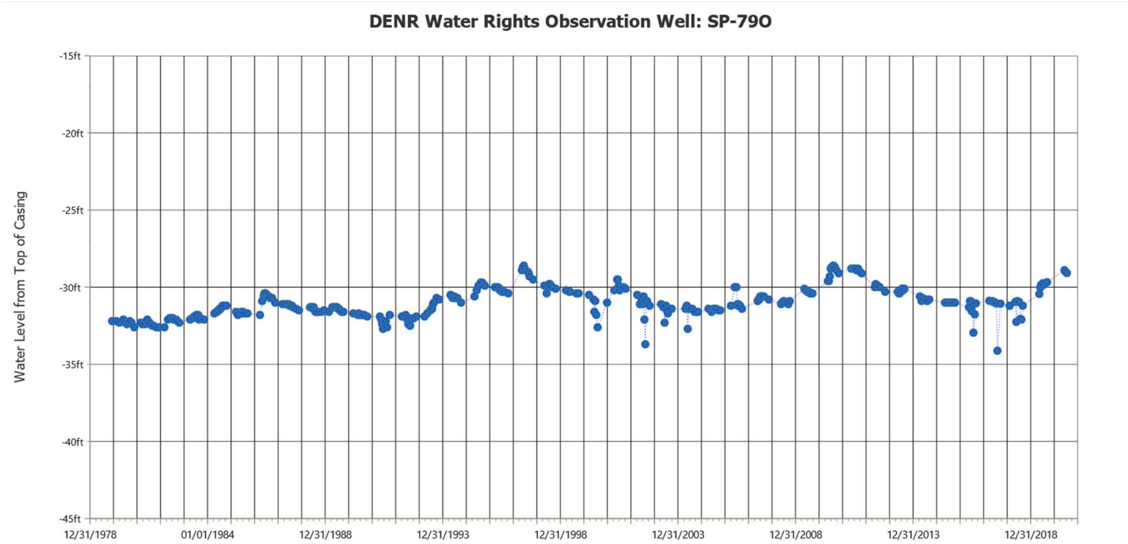

DENR Water Rights Observation Well: SP-79H
Water Level from Top of Casing
-15ft
-20ft
-25ft
-30ft
-35ft
-40ft
-45ft
12/31/1978
01/01/1984
12/31/1988
12/31/1993
12/31/1998
12/31/2003
12/31/2008
12/31/2013
12/31/2018

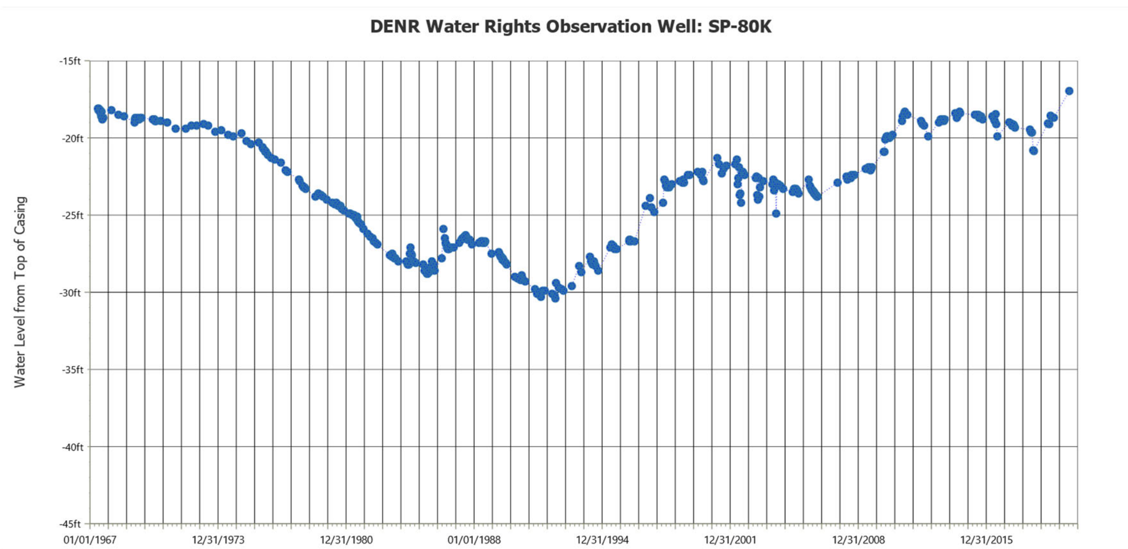

DENR Water Rights Observation Well: SP-79I
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
-35ft
-40ft
-45ft
12/31/1978
01/01/1984
12/31/1988
12/31/1993
12/31/1998
12/31/2003
12/31/2008
12/31/2013
12/31/2018

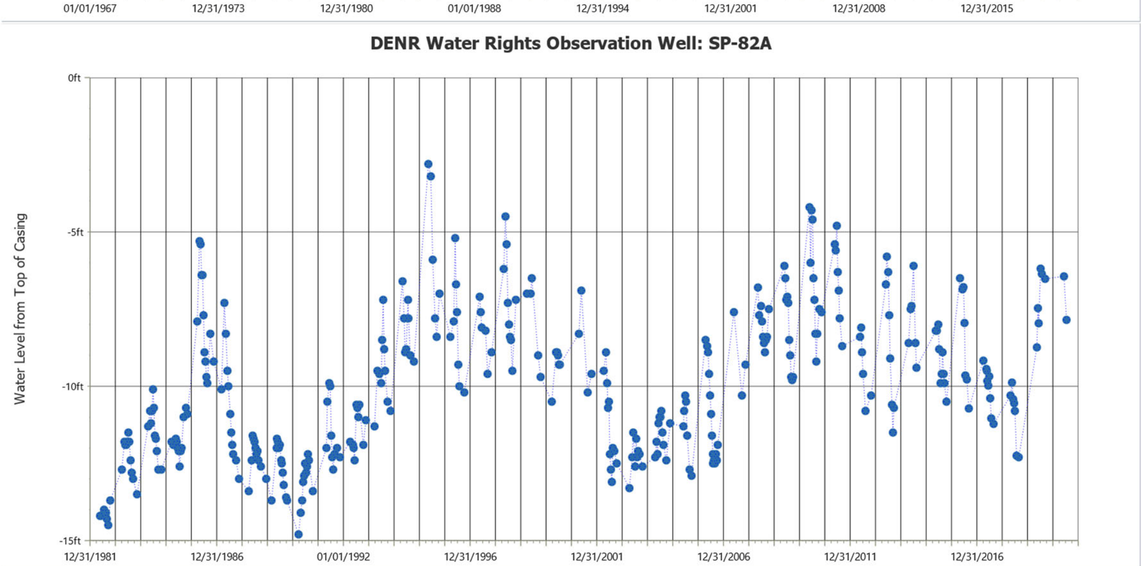

DENR Water Rights Observation Well: SP-79K
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
12/31/1978
01/01/1984
12/31/1988
12/31/1993
12/31/1998
12/31/2003
12/31/2008
12/31/2013
12/31/2018

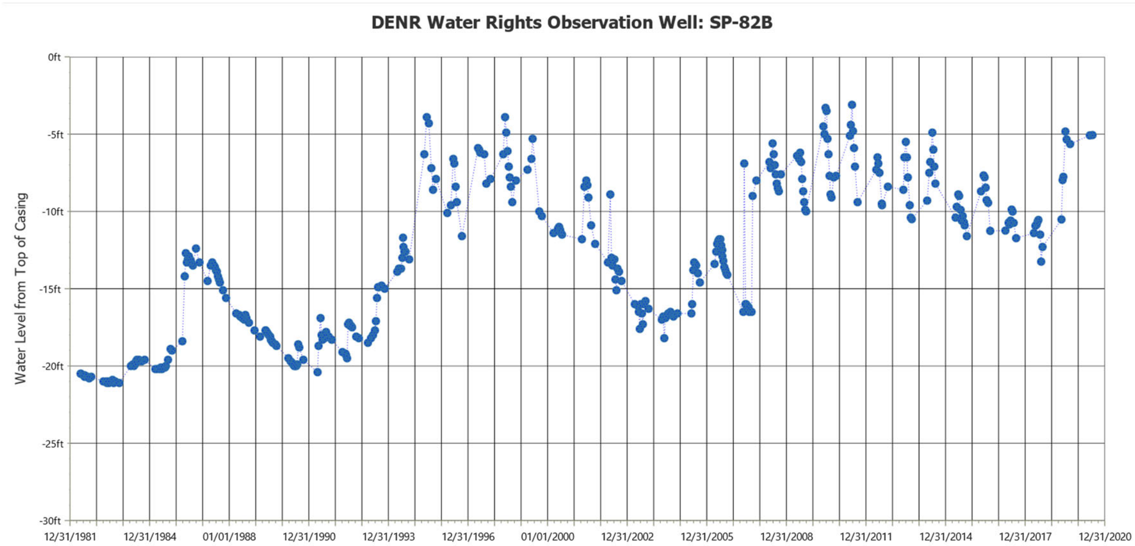

DENR Water Rights Observation Well: SP-79L
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
12/31/1978
01/01/1984
12/31/1988
12/31/1993
12/31/1998
12/31/2003
12/31/2008
12/31/2013
12/31/2018


DENR Water Rights Observation Well: SP-79M
Water Level from Top of Casing
-15ft
-20ft
-25ft
-30ft
12/31/1978
01/01/1984
12/31/1988
12/31/1993
12/31/1998
12/31/2003
12/31/2008
12/31/2013
12/31/2018


DENR Water Rights Observation Well: SP-79O
Water Level from Top of Casing
-15ft
-20ft
-25ft
-30ft
-35ft
-40ft
-45ft
12/31/1978
01/01/1984
12/31/1988
12/31/1993
12/31/1998
12/31/2003
12/31/2008
12/31/2013
12/31/2018


DENR Water Rights Observation Well: SP-80K
Water Level from Top of Casing
-15ft
-20ft
-25ft
-30ft
-35ft
-40ft
-45ft
01/01/1967
12/31/1973
12/31/1980
01/01/1988
12/31/1994
12/31/2001
12/31/2008
12/31/2015


DENR Water Rights Observation Well: SP-82A
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
12/31/1981
12/31/1986
01/01/1992
12/31/1996
12/31/2001
12/31/2006
12/31/2011
12/31/2016


DENR Water Rights Observation Well: SP-82B
Water Level from Top of Casing
0ft
-5ft
-10ft
-15ft
-20ft
-25ft
-30ft
12/31/1981
12/31/1984
01/01/1988
12/31/1990
12/31/1993
12/31/1996
01/01/2000
12/31/2002
12/31/2005
12/31/2008
12/31/2011
12/31/2014
12/31/2017
12/31/2020