Second Report on the Five-Year Review of Water Availability in the Western Spink-Hitchcock Management Unit of the Tulare Aquifer

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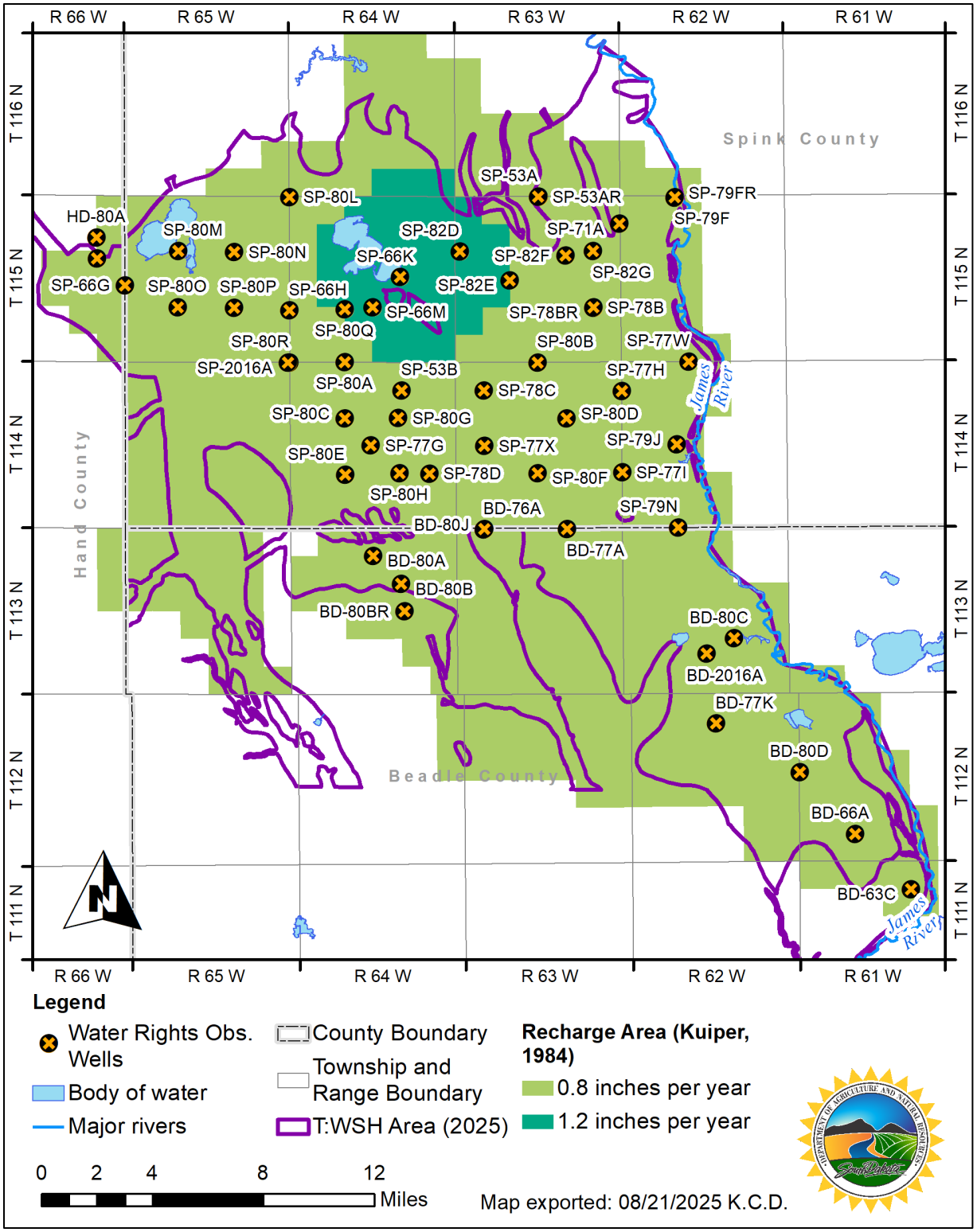

Figure 1: Map of Tulare: Western Spink-Hitchcock aquifer (modified from First Five-Year Review) [1] [2], Water Rights Program observation wells [3], and model area from the 1984 Kuiper [4] model.

Introduction

In 2013, the South Dakota Water Management Board determined that the Western Spink-Hitchcock management unit of the Tulare aquifer was fully appropriated. Subsequently, the South Dakota Legislature provided a process for management of fully appropriated aquifers by enacting South Dakota Codified Law (SDCL) 46-2A-7 through 46-2A-7.7. The Water Management Board met in 2015 to satisfy the requirements provided by that legislation, using technical analysis by Ken Buhler [5]. In 2020, the first five-year, as required by legislation, review was presented to the Water Management Board, using technical analysis by John Farmer [1]. The Board concluded that based on the information available, there was not unappropriated water available for any of the 28 water right permit applications on hold at that time. This report serves as the technical review of the groundwater source, all permits appropriating water from that source, and all held applications for that source, as required pursuant to SDCL 46-2A-7.5. For the second 5-year review. There are 27 remaining water right/permit applications on hold requesting to divert water from the Western Spink-Hitchcock management unit of the Tulare aquifer as of July 2025.

Tulare: Western Spink-Hitchcock Aquifer (T:WSH) Hydrogeologic Characteristics

The Tulare aquifer is a Quaternary-aged system of sand and gravel layers that were deposited as outwash by meltwater from receding glaciers. The Western Spink Hitchcock management unit of the Tulare aquifer (Figure 1) is a buried aquifer generally lying immediately above the bedrock (a.k.a. basal) [6] [7]. The bedrock is composed of an erosional surface of exposed Cretaceous-aged Pierre Shale and Niobrara Formation, with the lowest erosional surface possibly incising into the Carlisle Shale, which contains the Codell Sandstone member [8]. The Niobrara Formation and Codell Sandstone can also be aquifers in portions of South Dakota [3] [9]. The Tulare: Western Spink-Hitchcock aquifer underlies approximately 260,000 acres of Hand, Spink, and Beadle Counties [1] [2]. The Tulare aquifer has an average thickness of 37 feet [10]. Assuming a porosity of 0.15 [11], the estimated recoverable water in storage in the Tulare: Western Spink-Hitchcock aquifer is approximately 1.4 million acre-feet. The Tulare: Western Spink-Hitchcock aquifer is hydrologically connected to the Tulare: East James aquifer to the east, the Floyd: East James aquifer to the southeast, and the Warren: West James aquifer to the southwest. There may also be a hydrologic connection between the Tulare: Western Spink-Hitchcock aquifer and the Cretaceous-aged aquifers where the formations are in contact with one another. Buhler [5] estimated that approximately 77,000 acres of the Tulare: Western Spink-Hitchcock aquifer were under unconfined conditions in October 2012, and showed that at the time, a majority of the aquifer was under confined conditions. The area of the aquifer under confined conditions fluctuates with the amount of water in the aquifer. Since water is essentially incompressible, when the aquifer has more water in storage, more area is confined and vice-versa for when there is less water in the aquifer.

Applicable SDCL for Five-Year Reviews of Fully Appropriated Aquifers

Pursuant to SDCL 46-2A-7.5, the Board shall hold a public hearing to review the groundwater source, all permits appropriating water from that source, and all held applications once every five years to determine the availability of unappropriated water. The first five-year review was conducted in 2020, so it is required for the second five-year review to be conducted in 2025.

Pursuant to SDCL 46-2A-7.6, if the Board determines that unappropriated water has become available from a fully appropriated aquifer during the five-year review, the Board shall make the unappropriated water available to the applications being held by the Chief Engineer based on priority established in SDCL 46-2A-7.2 and 46-2A-7.4. The Chief Engineer shall process held applications pursuant to SDCL 46-2A until such time as the Board determines the groundwater source to again, be fully appropriated. Any remaining applications shall continue to be held by the Chief Engineer for future five-year reviews by the board.

Pursuant to SDCL 46-6-3.1, 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 the water to the groundwater source. An exception allows water distribution systems to withdraw from groundwater sources older or stratigraphically lower than the Greenhorn Formation regardless of the results of a hydrologic budget. None of the held applications are a water distribution system as defined in SDCL 46-1-6(17) and the Tulare: Western Spink-Hitchcock aquifer is younger and stratigraphically higher than the Greenhorn Formation. Therefore, the Water Management Board must find that recharge to the aquifer exceeds withdrawals to approve any new applications or applications on hold.

Hydrologic Budget

Recharge

Recharge to the Tulare: Western Spink-Hitchcock aquifer occurs primarily through infiltration of precipitation where the aquifer is at or near land surface. Some recharge may occur from bedrock aquifers that are in contact with the Tulare: Western Spink-Hitchcock aquifer [12]. Some recharge could occur from infiltration of surface water if the stage of the surface water is higher than the water table of the aquifer. The amount of recharge to the aquifer is somewhat governed by withdrawals from the aquifer. When there are few withdrawals and storage in the aquifer is full, excess precipitation which could provide recharge bypasses the aquifer. Only when storage in the aquifer is less than full can recharge to the aquifer be measured directly (e.g. observation well analysis). Indirect methods of measuring recharge to the aquifer can include flow-net analysis and numerical modeling. The accuracy of these methods of analysis is dependent on the amount and quality of data available regarding information on precipitation, aquifer properties, withdrawals, evapotranspiration, and potentiometric surface.

Recharge to the Tulare aquifer management units in Beadle, Hand, and Spink Counties was published by Kuiper in 1984 [4] with a numerical groundwater flow model. The Tulare: Western Spink-Hitchcock aquifer most closely corresponds with Model Area A in the Kuiper [4] model (Figure 1). Kuiper used one-mile-square cells in a single layer to compare 1968 to 1978 observation well data to 1978 irrigation data. The Kuiper model produced an estimated average annual recharge of 0.83 inches per acre in area A, which meant the average annual recharge to the Tulare: Western Spink-Hitchcock aquifer was estimated to be 23,000 ac-ft/yr.

Hedges, Allen, and Holly [13] performed a flow-net analysis of the Tulare aquifer management units in 1985 and found an estimated recharge rate to the aquifer to be 0.24 inches per year. Based on observation well analysis, Hedges, Allen, and Holly [13] estimated the average annual

recharge to the aquifer was 2.0 inches per year in unconfined portions of the aquifer, but they did not provide a delineation of the unconfined area of the aquifer. For both the Hedges, Allen, and Holly [13] flow-net analysis and the Kuiper [4] numerical model, recharge estimates could be lower than the amount estimated if the aquifer was not under heavy utilization.

Buhler [14] used data from the Kuiper [4] model and subsequent mapping of first occurrence of aquifer materials in Spink, Beadle, and Hand Counties to provide a new delineation of the Tulare: Western Spink-Hitchcock aquifer to estimate the average annual recharge to the aquifer was 0.83 inches per year, for a total estimated recharge of 18,192 ac-ft/yr [1]. Farmer [1] found in the first five-year review of the Tulare: Western Spink-Hitchcock aquifer that the Buhler [5] estimate was the best information available to the Water Rights Program at the time. No further formal studies have occurred since the 2020 review. However, new water well completion reports and lithologic information indicate approximately 3,000 acres that Buhler estimated was part of the aquifer is not hydrologically connected to the Tulare: Western Spink-Hitchcock aquifer and is instead most likely Quaternary Alluvium [6] [7]. Therefore, by applying 0.83 inches per acre across the 260,539 acres in the current delineation of the aquifer, the estimated average annual recharge to the Tulare: Western Spink-Hitchcock aquifer is approximately 18,000 ac-ft/yr.

Discharge

Discharge from the Tulare: Western Spink-Hitchcock aquifer occurs through well withdrawals, evapotranspiration from areas where the aquifer is near land surface, outflow to surface water features when the stage of the surface water is below the water table of the aquifer, and possibly by outflow to other hydrologically connected aquifers [4].

Domestic self-supply

There are 270 wells on file with the Water Rights Program [7] that are likely to be completed into the Tulare: Western Spink-Hitchcock aquifer. Following the methodology of the Buhler [5] and Farmer reviews [1], domestic use is estimated at 7,000 gallons per well per month, which equates to an estimated average annual use from domestic self-supply of 70 ac-ft.

Appropriative water use

As of March 17, 2025, there are 153 water rights appropriating water from the Tulare: Western Spink-Hitchcock aquifer [9]. Two of those water rights are for commercial use but are no longer using their permits and may be subject to cancellation [9]. The 151 other water rights in the aquifer are for irrigation [9].

Farmer [1] estimated average annual withdrawal by irrigation, by finding the average reported irrigation per reported acre and multiplying that value across all permitted acres. Farmer [1] found the average reported irrigation per reported acre from 1979-2019 was 9.06 inches per year. The average reported irrigation per reported acre for the period of record of 1979-2024, inclusive, (excluding 1980-1982 due to lack of data) is 8.89 inches per year, which is 1.9% less than the average found by Farmer [1]. The total irrigation area licensed in the aquifer is 25,541.9 acres. Therefore, following Farmer's [1] method of estimation, which was previously accepted by the Board, the estimated average annual irrigation withdrawal from the Tulare: Western

Spink-Hitchcock aquifer is approximately 18,900 ac-ft/yr. Figure 2 shows the total irrigation reported in the Tulare: Western Spink-Hitchcock aquifer from 1979-2024, the period of record. Farmer [1, pp. 24-25] noted in the first review that using the entire period of record to average the withdrawals from the aquifer biases the average in favor of historical use when there were fewer appropriations. Farmer [1] provided estimated withdrawal rates using multiple time periods and utilization rates, with withdrawal estimates ranging from 11,845 to 19,709 ac-ft/yr. At the time, not all water permits had been developed and Farmer [1] indicated that more years of irrigation reporting with the existing permits and permits under development were required to gain confidence in the estimated average annual withdrawals.

Figure 3 shows a graph of the trends in irrigation practices over the period of record. In general, as time goes on, irrigators in the aquifer tend to irrigate a higher percentage of their permitted land in any given year but tend to use fewer inches of water per acre. This is likely due to increased efficiency in irrigation technology. Therefore, the average annual use by an individual irrigator or irrigation system may change over time even when there are no changes in permitted acres or diversion rate authority.

Since 2014, no new water permits have been issued which would increase appropriations from the Tulare: Western Spink-Hitchcock aquifer and by the summer of 2024, all permits in the aquifer had been inspected and licensed. Therefore, the average annual withdrawal by irrigation can be estimated by taking the average of reported irrigation, without assuming how much water an undeveloped permit might withdraw. To estimate the withdrawals by irrigation, the average reported withdrawal of each irrigation permit for the period of record of 1979 through 2024 was summed as shown in Table 3 (p. 17). Included is an analysis of annual withdrawals depending on whether each permit tended to increase, decrease, or stay the same over the period of record. By taking the average reported withdrawal over the period of record on a per-permit basis, the total estimated average annual withdrawal does not favor the record of irrigation reporting when there were fewer permits reporting in the aquifer. However, within a water right permit, irrigation practices may change due to circumstances such as new irrigation technology, financial incentives to grow different crops or grow them differently, etc. Therefore, the same calculations were performed for only the last ten years of record (2015-2024) shown in Table 4 (p. 21). Most irrigation permits tended to have a relatively stable use trend over both the 1979 – 2024 and 2015 – 2024 periods of record, as shown in Table 5 (p. 24). The sum of the average annual reported irrigation water use for the period of record of 1979 through 2024 is 13,212 ac-ft/yr. The sum of the average annual reported irrigation water use from 2015 through 2024 is 12,083 ac-ft/yr. The average from 2015 through 2024 is the value most likely to represent average annual irrigation withdrawals currently from the aquifer.

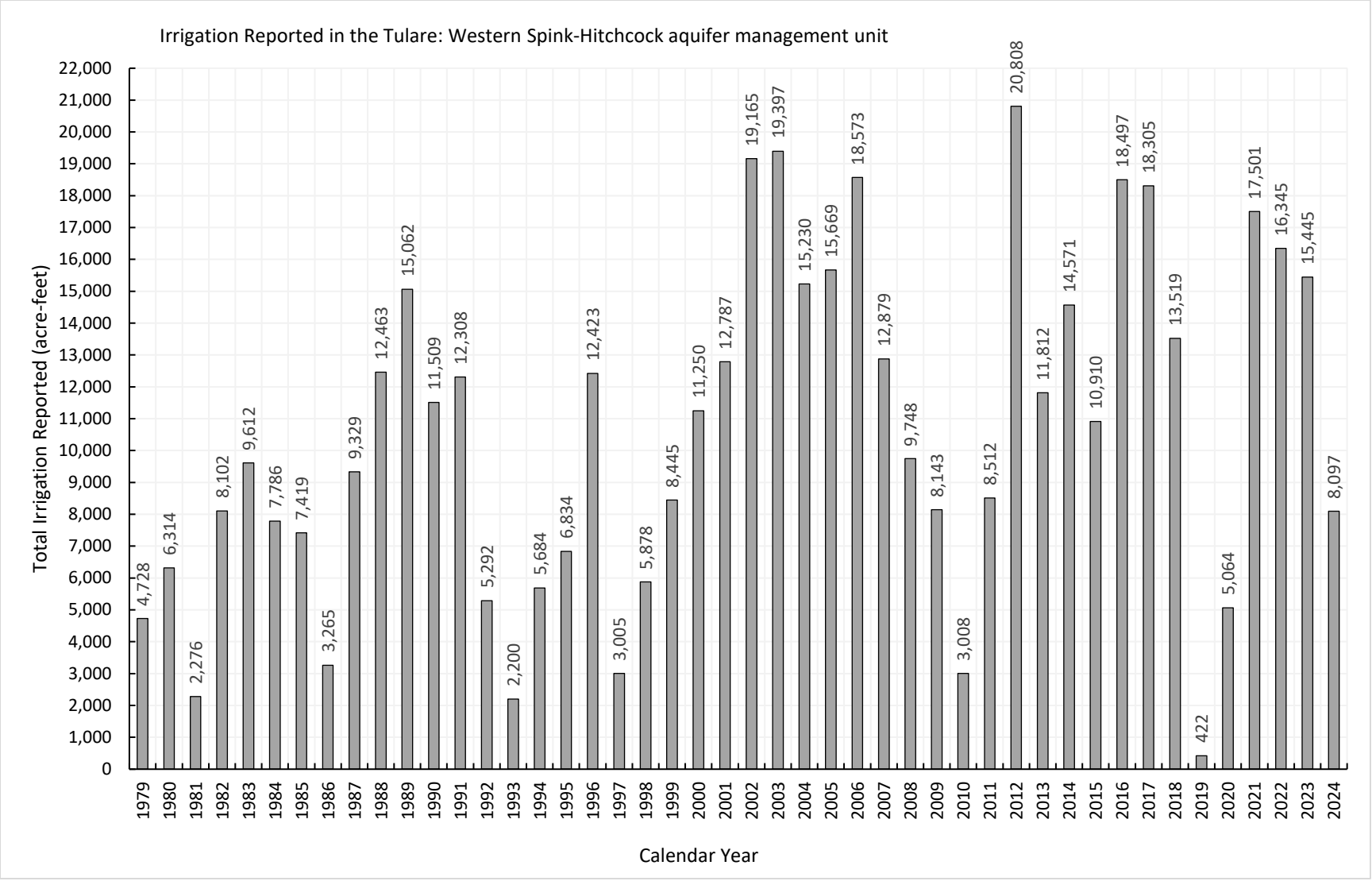

Figure 2: Irrigation reported in the Tulare: Western Spink-Hitchcock aquifer over the period of record of 1979-2024 [15] [16]

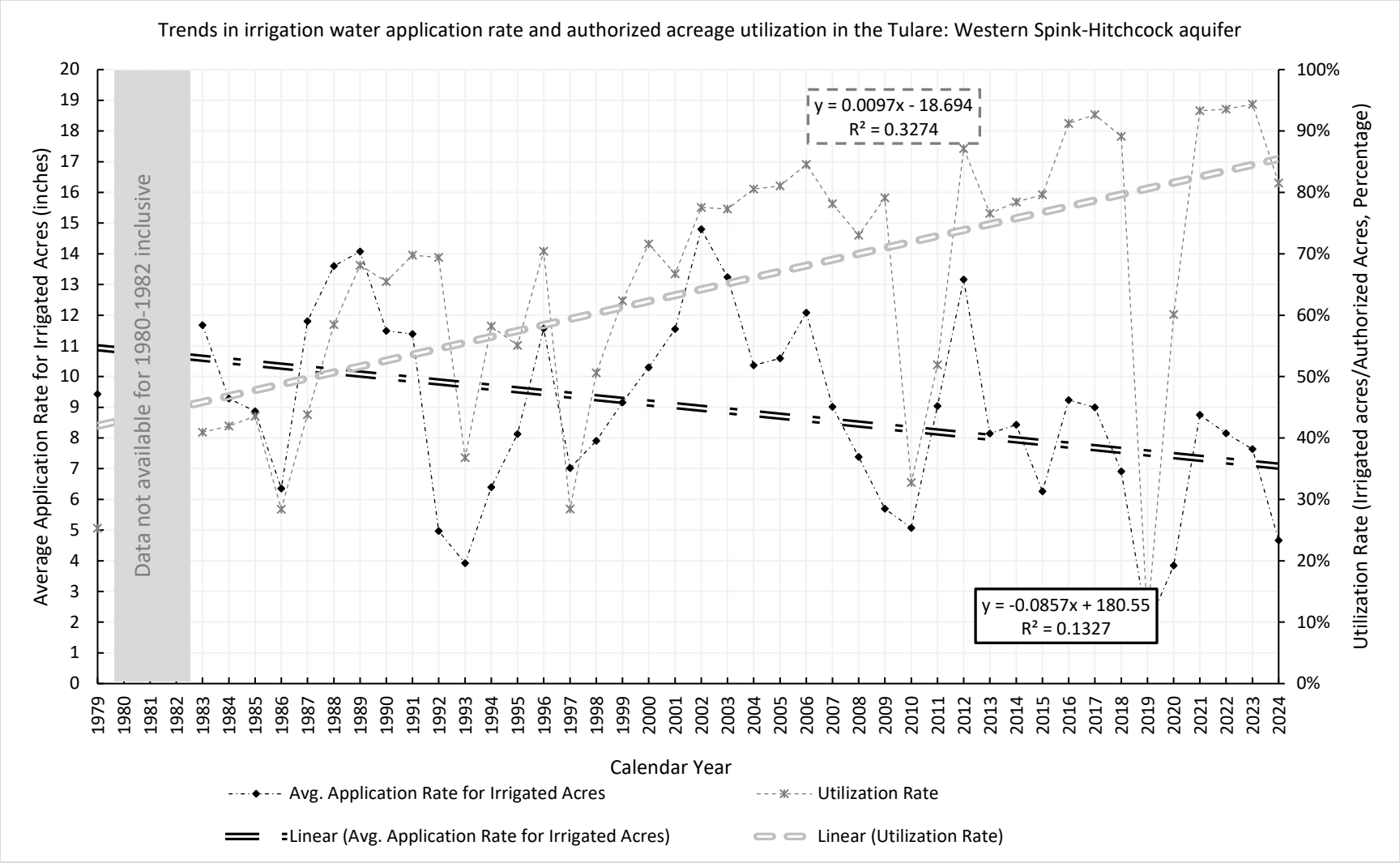

Figure 3: Trends in irrigation water application rate and authorized acreage utilization rate in the Tulare: Western Spink-Hitchcock aquifer [15]

Summary of Hydrologic Budget

The estimated recharge to the Tulare: Western Spink-Hitchcock aquifer, based on the currently delineated area and the 0.83 in/yr recharge rate from the 1984 Kuiper model, is 18,000 ac-ft/yr. However, this amount is uncertain due to changes in precipitation patterns, aquifer delineation, land use, and uncertainty of the original model given the amount of time and water use development since that model was created. The estimated average annual withdrawal due to irrigation is approximately 12,083 ac-ft/yr (Table 1). The estimated withdrawal for the two commercial use permits is zero ac-ft/yr. The estimated withdrawal for domestic self-supply is 70 ac-ft/yr. Therefore, the total estimated withdrawal from the Tulare: Western Spink-Hitchcock aquifer is 12,153 ac-ft/yr.

Table 1: Summary of various methods of estimating irrigation withdrawals [16] [15]

Irrigation withdrawal estimate method	Interval	Average (ac-ft/yr)
Irrigation Questionnaire Summaries	1979 - 2024	10,568
	2015 - 2024	12,411
Average by Permit	1979 - 2024	13,212
	2015 - 2024	12,083

There are 27 water permit applications on hold for the Tulare: Western Spink-Hitchcock aquifer, all for irrigation, which cumulatively propose to irrigate 5,214 acres [9]. Assuming the Kuiper [4] report per-acre recharge estimate is correct and the average annual recharge to the aquifer is 18,000 ac-ft/yr, the remaining recharge available for appropriation is 5,847 ac-ft/yr. Water Rights Staff use various values to estimate the amount an irrigation permit is likely to withdraw on average, ranging from 10 inches to two feet per year. Based on previous experience, Staff Engineer Drennon (the author) finds that 10 inches per year is a safe over-estimate for permit applications proposing to irrigate row crops east of the Missouri River. Using that value, the estimated average annual withdrawal from the 27 applications on hold would be 4,345 ac-ft/yr. Using the average reported irrigation rate from 2015-2024 of 6.631 inches per year and an average utilization rate of 79% of permitted acreage, the estimated average annual withdrawal from the held permits would be 2,276 ac-ft/yr [15]. Using the maximum reported irrigation rate from 2015-2024 of 9.237 inches per year and the maximum utilization rate of 94% of permitted acreage, the estimated average annual withdrawal from the held applications would be 3,773 ac-ft/yr [15]. Finally, over the period of record of 1979 and 1983 through 2024, using the maximum reported irrigation rate of 14.803 inches per year applied over the maximum utilization rate of 94%, the estimated average annual withdrawal from the 27 held permits would be 6,046 ac-ft/yr [15]. Given the trends and factors described above, the estimate using the maximum rate and utilization for the entire period of record is unlikely to be reflective of average annual withdrawals. Therefore, based on the hydrologic budget, there is reasonable probability unappropriated water is available for the 27 held permits, but the aquifer should once again be considered fully appropriated and new permit applications should be held pursuant to the applicable statute for fully appropriated aquifers. Out of an abundance of caution, if they are approved, qualifications should be placed on the 27 held permits providing a term limit and

terms by which curtailment may be enacted if it is found that average annual withdrawals exceed average annual recharge.

Observation Wells

Administrative Rule of South Dakota (ARSD) 74:02:05:07 requires that the Water Management Board rely upon the record of observation wells in addition to other data to determine the availability of unappropriated water. The Water Rights Program maintains 55 observation wells completed into the Tulare: Western Spink-Hitchcock aquifer. Four of these observation wells (SP-79FR, BD-80BR, SP-53AR, and SP-78BR) are intended to be replacement wells for the wells that have the same name as them minus the final *R*. These wells are pending review and analysis of the readings until finding they sufficiently match their predecessors, so there are effectively 51 unique observation wells completed into the Western Spink-Hitchcock management unit of the Tulare aquifer. For analysis of the observation wells in the aquifer, the wells were divided into 11 groups based on location in the aquifer. Figure 5 (p. 25) shows a map of the 11 groups. Figure 6 through Figure 16 (pp. 26-36) show the hydrographs of the observation wells in each group and elevations of the tops of the aquifer formation.

In his report on the first five-year review of the Tulare: Western Spink-Hitchcock aquifer, Farmer noted that the water levels in the aquifer had a tendency to decline over the period of 2013 through 2018. In his analysis, he treated the water level increase from 2019 as possibly anomalous and did not apply them to his conclusions. However, five additional years of irrigation reports, observation well, and climactic data are available. Indeed, 2019 was the wettest year on record for the region, but precipitation in the region has also been increasing with time and the precipitation from 2019 is not anomalous enough to ignore. Despite a period of near-continuous unusual dryness or drought in the area since the first five-year review (Figure 20) [17], water levels in the aquifer have remained relatively steady [3], and water elevations in areas far from the James River are higher than water elevations in areas near the James River, indicating the aquifer is discharging naturally.

In general, water levels in the aquifer rise during periods of higher-than-average precipitation and decline during periods of lower-than-average precipitation [18]. On average, precipitation in S.D. Climate Division 7 (Figure 17, p. 37) has been increasing over time. In a study done by Hullinger [19], flows in the James River have been increasing over the period of record available back to 1946. If use in the aquifer remains the same over time and precipitation and stream flow are increasing, then the water in storage in the aquifer should also be increasing provided the aquifer is not already at capacity. Indeed, as the period of record for observation wells in the Tulare: Western Spink-Hitchcock aquifer continues, a larger percentage of the observation well water levels are likely to be above the top of the aquifer. However, the amount of recharge cannot be directly measured from observation well water-level increases in observation wells under confined conditions. Water level fluctuations above the top of aquifer (confined aquifer areas) indicate a change in water pressure in the confined area of the aquifer, not a significant change in storage. Higher water pressure in the aquifer will cause the water stored in the aquifer to naturally discharge to other aquifers or surface water features which are in contact with the aquifer. Therefore, recharge to the aquifer is more than withdrawals, and based on observation

well analysis, there is unappropriated water available, but the exact amount cannot be known without comprehensive modeling of flows into and out of the aquifer.

Conclusions

1. The estimated average annual recharge to the Tulare: Western Spink-Hitchcock aquifer is 0.83 inches per year, based on a model run in 1984.
2. The estimated aerial extent of the Tulare: Western Spink-Hitchcock aquifer is approximately 260,000 acres.
3. Assuming the 0.83 inches per year recharge applies to the entire area of the aquifer, recharge to the Tulare: Western Spink-Hitchcock aquifer is approximately 18,000 ac-ft/yr.
4. The estimated average annual withdrawal from the Tulare: Western Spink-Hitchcock aquifer is 12,153 ac-ft/yr.
5. There are 27 water permit applications on hold in the Tulare: Western Spink-Hitchcock aquifer proposing to irrigate a combined total of 5,214 acres.
6. Assuming they irrigate at the average rate other irrigators in the aquifer have reported over the period of record of 2015 through 2024, the 27 held permits would withdraw an estimated average of 2,276 ac-ft/yr. Assuming they irrigate at the maximum rate reported over the period of record of 2015 through 2024, the 27 held permits would withdraw an estimated 3,773 ac-ft/yr.
7. Based on the hydrologic budget and observation well analysis, there is reasonable probability unappropriated water is available in this aquifer for the 27 held applications.
8. The Tulare: Western Spink-Hitchcock aquifer has areas which fluctuate between confined and unconfined depending on water use and climactic conditions.
9. Water level fluctuations above the top of the formation (changes in artesian head pressure for confined areas) do not represent changes in storage in that part of the aquifer, so changes in storage in the aquifer cannot be directly calculated from those values.
10. A heavily-used aquifer may induce more recharge than a little-used aquifer.
11. The only available model estimate of recharge was done during a period of time when the aquifer was less used than it is now.
12. Therefore, it is not possible to know the amount of water recharge to the aquifer based on direct observation well measurements, and a model of the aquifer is the only way to know how much water is recharging to the aquifer.
13. The creation and maintenance of a new model of the Tulare: Western Spink-Hitchcock aquifer to estimate the amount of unappropriated water available is highly recommended.
14. If the 27 held permits are approved, the aquifer should once again be considered fully appropriated until better information is available, including the observation well network response to further development.

Kimberly C. Drennon, E.I.
Natural Resources Engineer III – DANR Water Rights Program

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Glossary

Average (Avg.): a measure of central tendency. In this report, the average is the sum of all values in a set divided by the number of values in that set. Also known as arithmetic average or mean.

Coefficient of Determination (R^2). A measure by which one can assess if a trend line correlates well to the data. As the coefficient of determination approaches 100%, the trend line predicts 100% of the variance in the data set. If the coefficient of determination is 0%, the trend line shows no correlation to variance in data. It is the square of the Pearson correlation coefficient.

Confined. A state of an aquifer or part of an aquifer were water levels in observation wells rise above the top of the aquifer formation. Also known as "artesian" in South Dakota water law.

Minimum (Min.): The smallest value in a set of data.

Maximum (Max.): The largest value in a set of data.

Median: When a set of data is sorted from smallest to largest, the median is the value which falls in the middle.

Standard deviation (St. Dev.): A measure of how much values in a set vary from average. One standard deviation is the amount where, if added or subtracted from the average, approximately 68.2% of the data would fall within that range (Figure 4).

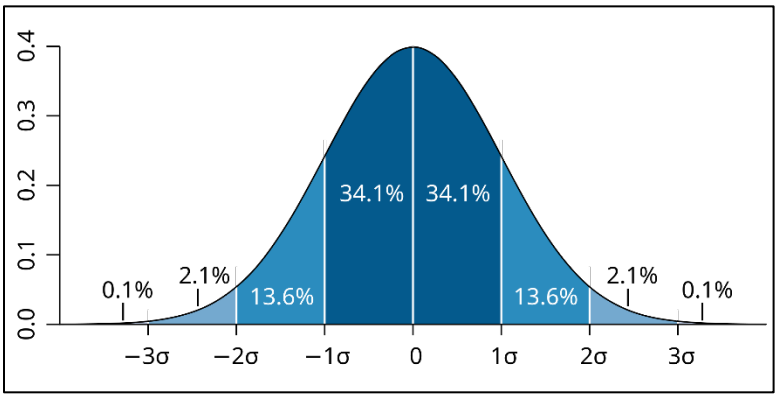

Figure 4: A diagram of a normal distribution and the standard deviations (σ) within it [20].

Unconfined. A state of an aquifer or part of an aquifer where water levels in observation wells are below the top of the aquifer formation. Also known as "water table" in South Dakota water law.

Year: Calendar Year: January 1 through December 31.

- **Water Year**: October 1 through September 30. The number of a water year corresponds to the larger proportion of the Calendar Year in which the Water Year falls. For example, Water Year 2025 is October 1, 2024 through September 30, 2025. The designation of water year versus calendar year is an attempt to keep climactically related phenomena within the same year designation.

Appendix A: Supplementary Tables

Table 2: Irrigation Reported from 1979 through 2024 [15] [16]

Year	No. Licenses	No. Permits	All License/ Permits	Authorized Acres	Acres Irrigated	Reported Irrigation (ac-ft/yr)	Avg. App. Rate for Irr. Acres (in/yr)	Utilization Rate (Irr. Acres/ Auth. Acres)
1979	49	83	132	23,781	6,018	4,728	9.429	25%
1980	60	71	131	23,103	N/A	6,314	N/A	N/A
1981	61	77	138	23,955	N/A	2,276	N/A	N/A
1982	61	88	149	25,513	N/A	8,102	N/A	N/A
1983	75	69	144	24,154	9,883	9,612	11.671	41%
1984	82	62	144	24,006	10,068	7,786	9.280	42%
1985	83	55	138	23,047	10,034	7,419	8.873	44%
1986	86	49	135	21,716	6,164	3,265	6.356	28%
1987	87	47	134	21,660	9,487	9,329	11.800	44%
1988	92	29	121	18,818	10,997	12,463	13.600	58%
1989	96	23	119	18,852	12,842	15,062	14.074	68%
1990	96	19	115	18,368	12,024	11,509	11.486	65%
1991	95	20	115	18,590	12,973	12,308	11.385	70%
1992	96	19	115	18,429	12,792	5,292	4.964	69%
1993	96	20	116	18,280	6,728	2,200	3.924	37%
1994	96	19	115	18,330	10,671	5,684	6.392	58%
1995	97	15	112	18,304	10,085	6,834	8.131	55%
1996	97	16	113	18,304	12,891	12,423	11.564	70%
1997	105	5	110	18,077	5,136	3,005	7.021	28%
1998	106	3	109	17,620	8,916	5,878	7.912	51%
1999	106	4	110	17,756	11,069	8,445	9.155	62%
2000	106	8	114	18,308	13,107	11,250	10.300	72%
2001	105	19	124	19,906	13,287	12,787	11.548	67%
2002	107	17	124	20,038	15,536	19,165	14.803	78%
2003	108	28	136	22,745	17,582	19,397	13.239	77%
2004	102	27	129	21,886	17,630	15,230	10.366	81%
2005	102	28	130	21,886	17,744	15,669	10.597	81%
2006	105	25	130	21,821	18,456	18,573	12.076	85%
2007	103	28	131	21,943	17,146	12,879	9.014	78%
2008	119	14	133	21,709	15,850	9,748	7.380	73%
2009	126	4	130	21,698	17,170	8,143	5.692	79%
2010	126	5	131	21,743	7,118	3,008	5.071	33%
2011	125	6	131	21,772	11,301	8,512	9.039	52%
2012	125	6	131	21,772	19,101	21,095	13.253	88%
2013	123	14	137	22,718	17,399	11,812	8.147	77%
2014	121	38	159	26,430	21,131	14,804	8.407	80%
2015	119	42	161	26,278	20,918	10,910	6.259	80%
2016	118	44	162	26,337	24,029	18,497	9.237	91%
2017	124	39	163	26,336	24,404	18,305	9.001	93%
2018	124	39	163	26,336	23,468	13,519	6.913	89%
2019	126	36	162	26,235	2,732	422	1.851	10%
2020	147	11	158	26,308	15,817	5,064	3.842	60%
2021	147	8	155	25,721	24,000	17,501	8.751	93%

Appendix A: Table 2 (cont.)

Year	No. Licenses	No. Permits	All License/ Permits	Authorized Acres	Acres Irrigated	Reported Irrigation (ac-ft/yr)	Avg. App. Rate for Irr. Acres (in/yr)	Utilization Rate (Irr. Acres/ Auth. Acres)
2022	147	8	155	25,721	24,066	16,345	8.150	94%
2023	147	8	155	25,721	24,272	15,445	7.636	94%
2024	151	0	151	25,542	20,825	8,097	4.666	82%
From 1979 through 2024								
Min.	49	0	109	17,620	2,732	422	1.851	10%
Max.	151	88	163	26,430	24,404	21,095	14.803	94%
Avg.	106	28	134	22,121	14,485	10,568	8.890	65%
From 2015 through 2024								
Min.	118	0	151	25,542	2,732	422	1.851	10%
Max.	151	44	163	26,337	24,404	18,497	9.237	94%
Avg.	135	24	159	26,053	20,453	12,411	6.631	79%

Calculation methods for Table 3 and Table 4. Calculations done using Microsoft Excel for Microsoft Office 365 (Version 2408 Build 16.0.17928.20572) 64-bit.

1. Average: sum of all reports divided by number of reports.
2. Standard Deviation: STDEV.P([REPORTS]) or STDEV.S([REPORTS]) depending on context.
3. Coefficient of Determination: PEARSON([REPORTS], [RANGE OF YEARS])^2
4. Trend (ac-ft/yr): FORECAST.LINEAR(2025, [REPORTS], [RANGE OF YEARS])-FORECAST.LINEAR(2024, [REPORTS], [RANGE OF YEARS])
5. Trend (% Avg.): Trend (ac-ft/yr) divided by Average.
6. Trend (in/yr): Trend (ac-ft/yr) divided by Licensed Acres.
7. Trend Assessment:

   Significant – Trend (in/yr) minus Average of Trends (in/yr) exceeds two standard deviations.

   Moderate – Trend (in/yr) minus Average of Trends (in/yr) is between one and two standard deviations.

   No significant trend – Trend (in/yr) minus Average of Trends (in/yr) is less than one standard deviation.

   Increase – Values tend to rise from year to year.

   Decrease – Values tend to decline from year to year.
8. Rows starting with **Total** and below are calculated based on the above column, except ***Total Trend (in/yr)***, which is calculated using the same method as the rows for that column using the Total of Trend (ac-ft/yr) and Total Licensed Acres.

Table 3: Irrigation reported statistics per permit (1979-2024) [15] [16]

Permit No.	Lic. Acres	No. Reports	Average (ac-ft/yr)	St. Dev. (ac-ft/yr)	R^2	Trend (ac-ft/yr)	Trend (% Avg.)	Trend (in/yr)	Trend Assessment
130A-3	75	35	63.61	63.88	29.54%	-3.44	-5.4%	-0.55	≈
149-3	320	46	90.75	74.21	1.15%	0.60	0.7%	0.02	≈
246-3	160	46	65.35	43.48	13.80%	1.22	1.9%	0.09	≈
398-3	140	46	80.20	103.48	4.95%	-1.73	-2.2%	-0.15	≈
471-3	160	46	120.91	85.54	0.10%	0.21	0.2%	0.02	≈
472A-3	140	18	54.00	55.12	1.96%	1.49	2.8%	0.13	≈
498-3	320	46	113.32	122.87	0.03%	-0.15	-0.1%	-0.01	≈
563-3	296	46	125.25	115.24	1.91%	-1.20	-1.0%	-0.05	≈
782A-3	136	10	122.28	91.87	2.35%	-4.91	-4.0%	-0.43	≈
839-3	160	46	125.12	95.63	0.05%	0.16	0.1%	0.01	≈
960-3	624	46	108.25	111.02	1.49%	-1.02	-0.9%	-0.02	≈
962-3	160	46	55.23	62.88	0.78%	0.42	0.8%	0.03	≈
971-3	156	46	154.12	87.45	0.07%	-0.18	-0.1%	-0.01	≈
1040-3	160	46	81.82	86.68	0.66%	-0.53	-0.6%	-0.04	≈
1203-3	181	46	80.99	76.32	0.33%	-0.33	-0.4%	-0.02	≈
1423-3	132	46	68.67	55.93	6.64%	1.09	1.6%	0.10	≈
1424-3	254	46	25.70	41.86	6.56%	0.81	3.1%	0.04	≈
1509-3	135	46	87.46	52.53	3.50%	0.74	0.8%	0.07	≈
1512-3	135	46	85.40	60.03	1.54%	0.56	0.7%	0.05	≈
1523-3	131	46	57.84	59.05	4.48%	0.94	1.6%	0.09	≈
1571-3	160	46	79.10	63.03	6.29%	1.19	1.5%	0.09	≈
1600-3	132	46	76.35	62.23	4.59%	1.00	1.3%	0.09	≈
1708-3	160	46	66.97	59.17	0.02%	-0.06	-0.1%	0.00	≈
1725-3	149	46	143.48	77.20	2.33%	0.89	0.6%	0.07	≈
1923-3	136	46	71.99	71.86	0.09%	-0.16	-0.2%	-0.01	≈
2078A-3	132	9	50.11	33.99	2.80%	2.20	4.4%	0.20	≈
2078-3	792	46	401.34	450.51	0.03%	-0.55	-0.1%	-0.01	≈
2278-3	136	46	115.01	48.25	17.03%	-1.50	-1.3%	-0.13	≈
2422-3	135	46	122.68	55.62	6.72%	-1.09	-0.9%	-0.10	≈
2428A-3	136	24	140.08	75.10	14.14%	-4.08	-2.9%	-0.36	≈
2440-3	132	46	50.23	52.25	16.72%	1.61	3.2%	0.15	≈
2471B-3	202	32	79.33	67.95	2.72%	-1.21	-1.5%	-0.07	≈
2476-3	96	46	66.87	59.64	0.04%	-0.09	-0.1%	-0.01	≈
2486-3	125	46	63.19	55.78	25.84%	-2.14	-3.4%	-0.21	≈
2487-3	136	46	104.14	93.38	0.15%	-0.27	-0.3%	-0.02	≈
2592A-3	131	39	92.19	69.20	1.46%	0.74	0.8%	0.07	≈
2659-3	132	46	55.29	58.10	1.74%	-0.58	-1.0%	-0.05	≈
2853-3	132	46	60.62	87.12	1.01%	0.66	1.1%	0.06	≈
2976A-3	126	30	93.59	47.95	14.96%	-2.14	-2.3%	-0.20	≈
3045-3	120	39	40.28	42.15	2.30%	-0.57	-1.4%	-0.06	≈
3046-3	130	46	35.60	57.21	0.09%	-0.13	-0.4%	-0.01	≈
3052-3	180	46	109.30	59.86	4.21%	-0.93	-0.8%	-0.06	≈
3053A-3	130	10	84.98	45.86	20.27%	7.19	8.5%	0.66	↑
3065B-3	130	17	82.99	59.37	8.61%	-3.56	-4.3%	-0.33	≈
3126-3	136	46	58.68	62.01	0.41%	-0.30	-0.5%	-0.03	≈
3162A-3	267	39	201.64	142.57	2.06%	1.82	0.9%	0.08	≈

Permit No.	Lic. Acres	No. Reports	Average (ac-ft/yr)	St. Dev. (ac-ft/yr)	R^2	Trend (ac-ft/yr)	Trend (% Avg.)	Trend (in/yr)	Trend Assessment
3164-3	136	46	71.97	73.66	10.61%	-1.81	-2.5%	-0.16	≈
3172-3	136	46	63.45	47.83	7.26%	0.97	1.5%	0.09	≈
3174A-3	138	39	105.31	58.43	3.05%	0.91	0.9%	0.08	≈
3191-3	118	46	59.27	48.58	0.61%	0.29	0.5%	0.03	≈
3192-3	132	46	79.06	64.19	0.03%	0.08	0.1%	0.01	≈
3261-3A	130	44	107.75	45.24	4.84%	-0.78	-0.7%	-0.07	≈
3321A-3	120	10	19.52	17.19	4.07%	-1.21	-6.2%	-0.12	≈
3603-3	132	46	76.31	62.43	2.58%	0.75	1.0%	0.07	≈
3860-3	136	46	116.43	77.46	0.28%	-0.31	-0.3%	-0.03	≈
3861-3	109	46	42.78	27.56	1.23%	-0.23	-0.5%	-0.03	≈
4134A-3	128	10	90.11	96.47	13.23%	12.22	13.6%	1.15	↑↑
4167-3	132	46	69.39	57.55	3.10%	0.76	1.1%	0.07	≈
4194-3	90	46	26.20	22.17	0.16%	-0.07	-0.3%	-0.01	≈
4308-3	184	46	86.71	57.80	11.29%	1.46	1.7%	0.10	≈
4350-3	132	46	106.00	90.53	2.09%	0.99	0.9%	0.09	≈
4400A-3	102	38	61.20	52.79	1.96%	-0.67	-1.1%	-0.08	≈
4482-3	132	44	65.37	44.39	7.65%	-0.97	-1.5%	-0.09	≈
4550-3	264	44	120.57	140.13	0.29%	-0.59	-0.5%	-0.03	≈
4591-3	132	44	114.31	78.49	13.36%	-2.26	-2.0%	-0.21	≈
4622A-3	130	14	61.03	42.11	0.17%	0.43	0.7%	0.04	≈
4703-3	130	43	92.07	54.09	18.49%	-1.87	-2.0%	-0.17	≈
4794B-3	278	9	135.46	76.46	5.27%	6.80	5.0%	0.29	≈
4794C-3	124	9	71.38	28.11	3.66%	-2.08	-2.9%	-0.20	≈
4819-3	121	43	134.15	50.57	17.08%	-1.68	-1.3%	-0.17	≈
4912A-3*	165	18	26.35	44.16	18.53%	-1.90	-7.2%	-0.14	≈
4912B-3	136	24	50.25	39.60	6.58%	1.47	2.9%	0.13	≈
4935-3	184	42	56.26	69.90	2.11%	0.84	1.5%	0.05	≈
5035-3	135	40	107.35	54.87	0.23%	0.23	0.2%	0.02	≈
5123-3	136	37	85.16	52.68	0.33%	-0.28	-0.3%	-0.02	≈
5149-3	132	37	92.91	59.36	0.47%	-0.38	-0.4%	-0.03	≈
5162-3	132	37	83.53	54.96	3.29%	0.93	1.1%	0.08	≈
5163-3	132	37	92.96	57.03	0.24%	0.26	0.3%	0.02	≈
5182-3	279	36	138.52	100.42	0.14%	0.36	0.3%	0.02	≈
5231-3	162	35	39.68	45.85	0.69%	0.37	0.9%	0.03	≈
5234-3	128	36	45.52	52.70	0.10%	-0.16	-0.3%	-0.01	≈
5266-3	129	36	109.90	50.81	2.19%	0.72	0.7%	0.07	≈
5301-3	132	35	79.35	59.80	8.85%	1.76	2.2%	0.16	≈
5390-3	272	34	140.85	84.08	14.23%	-3.23	-2.3%	-0.14	≈
5568-3	122	33	170.54	75.42	0.06%	-0.20	-0.1%	-0.02	≈
5601-3	5	33	18.61	38.45	29.62%	-2.20	-11.8%	-5.27	↓↓
5634-3	266	32	184.20	112.14	0.12%	0.43	0.2%	0.02	≈
5671-3	263	32	195.17	112.50	2.36%	-1.87	-1.0%	-0.09	≈
5798-3	132	30	48.05	45.28	14.03%	-1.96	-4.1%	-0.18	≈
5897-3	268	29	165.04	108.56	1.47%	-1.58	-1.0%	-0.07	≈
6108-3	304	26	101.57	60.32	11.07%	2.68	2.6%	0.11	≈
6142-3	240	25	203.32	62.66	0.59%	0.67	0.3%	0.03	≈
6159-3	128	25	74.25	38.45	2.17%	-0.79	-1.1%	-0.07	≈
6160-3	136	25	56.92	48.42	0.49%	-0.47	-0.8%	-0.04	≈

Permit No.	Lic. Acres	No. Reports	Average (ac-ft/yr)	St. Dev. (ac-ft/yr)	R^2	Trend (ac-ft/yr)	Trend (% Avg.)	Trend (in/yr)	Trend Assessment
6175-3	136	25	88.94	66.65	0.00%	-0.04	0.0%	0.00	≈
6184-3	270	24	136.68	94.31	39.87%	-8.60	-6.3%	-0.38	≈
6196-3	136	24	79.29	39.48	0.85%	-0.53	-0.7%	-0.05	≈
6200-3	136	24	73.26	56.29	4.45%	-1.72	-2.3%	-0.15	≈
6201B-3	132	12	95.92	48.78	4.76%	-3.08	-3.2%	-0.28	≈
6201C-3	264	11	125.19	78.64	2.38%	-3.84	-3.1%	-0.17	≈
6201D-3	132	11	48.82	38.63	29.78%	-6.67	-13.7%	-0.61	↓
6234-3	134	24	112.62	48.66	0.21%	0.32	0.3%	0.03	≈
6238-3	130	24	90.31	52.19	0.89%	-0.71	-0.8%	-0.07	≈
6239-3	260	24	131.31	85.16	2.56%	1.97	1.5%	0.09	≈
6240-3	132	24	73.17	38.68	2.16%	0.82	1.1%	0.07	≈
6288-3	136	23	44.31	32.43	10.64%	-1.59	-3.6%	-0.14	≈
6312A-3	264	17	49.29	52.23	60.49%	-8.29	-16.8%	-0.38	≈
6312-3	132	21	92.16	66.59	17.72%	-4.42	-4.8%	-0.40	≈
6331A-3	132	17	90.61	48.01	2.28%	1.48	1.6%	0.13	≈
6332-3	136	22	67.00	47.07	5.13%	-1.68	-2.5%	-0.15	≈
6333A-3	215	17	73.13	65.36	1.56%	-1.67	-2.3%	-0.09	≈
6333B-3	134	17	83.22	66.40	0.30%	0.74	0.9%	0.07	≈
6334A-3	132	22	98.24	67.25	13.44%	-3.89	-4.0%	-0.35	≈
6334B-3	132	22	42.80	65.63	8.76%	3.06	7.2%	0.28	≈
6336-3	136	22	117.19	73.09	3.61%	-2.19	-1.9%	-0.19	≈
6337-3	272	22	253.59	132.28	6.86%	-5.46	-2.2%	-0.24	≈
6338A-3	68	18	29.27	30.94	14.62%	-2.28	-7.8%	-0.40	≈
6338-3	264	22	136.20	112.29	8.09%	5.03	3.7%	0.23	≈
6339A-3	132	22	93.26	54.33	0.59%	-0.66	-0.7%	-0.06	≈
6340-3	132	22	77.16	63.38	2.91%	1.70	2.2%	0.15	≈
6343A-3	132	8	70.53	45.16	0.28%	-1.04	-1.5%	-0.09	≈
6343B-3	132	8	27.51	22.83	0.70%	0.83	3.0%	0.08	≈
6764-3	272	18	252.05	137.42	6.73%	-6.87	-2.7%	-0.30	≈
7289-3	270	12	128.36	84.29	5.32%	-5.63	-4.4%	-0.25	≈
7290-3	135	12	108.32	68.23	10.58%	6.43	5.9%	0.57	↑
7291-3	135	12	93.44	73.07	8.23%	6.07	6.5%	0.54	↑
7292A-3	133	8	76.20	60.21	1.46%	-3.17	-4.2%	-0.29	≈
7292B-3	133	8	76.44	60.28	1.30%	-3.00	-3.9%	-0.27	≈
7293-3	135	12	84.35	56.12	0.64%	-1.30	-1.5%	-0.12	≈
7373-3	152	12	89.07	31.56	16.11%	-3.67	-4.1%	-0.29	≈
7551-3	219	11	122.88	58.53	4.65%	-3.99	-3.2%	-0.22	≈
7570-3	259	11	64.01	48.56	5.47%	3.59	5.6%	0.17	≈
7571A-3	270	9	59.98	42.07	2.17%	2.40	4.0%	0.11	≈
7572B-3	135	9	81.73	36.93	9.65%	-4.44	-5.4%	-0.39	≈
7573A-3	156	9	99.80	47.78	12.16%	-6.45	-6.5%	-0.50	≈
7573-3	134	11	34.67	32.29	1.75%	1.35	3.9%	0.12	≈
7574-3	268	11	50.20	49.19	11.22%	5.21	10.4%	0.23	≈
7575B-3	134	11	12.47	18.12	1.15%	0.62	4.9%	0.06	≈
7620A-3	72	9	33.88	30.40	4.79%	-2.58	-7.6%	-0.43	≈
7620B-3	64	9	28.02	17.79	15.98%	-2.75	-9.8%	-0.52	≈
7637-3	135	11	40.68	30.93	12.55%	-3.47	-8.5%	-0.31	≈
7639-3	135	11	61.84	37.04	6.29%	2.94	4.8%	0.26	≈

Permit No.	Lic. Acres	No. Reports	Average (ac-ft/yr)	St. Dev. (ac-ft/yr)	R^2	Trend (ac-ft/yr)	Trend (% Avg.)	Trend (in/yr)	Trend Assessment
7640-3	156	11	99.49	43.95	2.90%	-2.37	-2.4%	-0.18	≈
7685-3	75	11	59.22	31.14	15.60%	-3.89	-6.6%	-0.62	↓
7716-3	135	11	5.56	6.32	48.56%	1.39	25.1%	0.12	≈
7718A-3	135	10	77.31	31.50	9.08%	-3.30	-4.3%	-0.29	≈
7720-3	135	11	39.67	30.78	8.32%	-2.81	-7.1%	-0.25	≈
7721-3	344	11	31.68	30.72	54.20%	7.15	22.6%	0.25	≈
7723-3	405	11	79.60	76.48	35.58%	14.43	18.1%	0.43	↑
7724-3	300	11	38.60	38.69	9.76%	3.82	9.9%	0.15	≈
7725C-3	135	10	27.48	31.18	1.02%	1.10	4.0%	0.10	≈
Total	**25,542**	**4,399**	**13,212.35**	**9,579.35**	--	**-46.08**	--	***-0.02***	**≈**
Average	169	29	87.50	63.44	7.02%	-0.31	-0.2%	-0.07	--
St.Dev	90	15	49.62	40.61	10.06%	3.08	5.1%	**0.48**	--
Min	5	8	5.56	6.32	0.00%	-8.60	-16.8%	-5.27	--
Max	792	46	401.34	450.51	60.49%	14.43	25.1%	1.15	--
Median	135	30	79.60	57.55	2.91%	-0.23	-0.3%	-0.02	--

* Water Right No. 4912A-3 has not reported irrigation since 2002, as ownership of the water right was unclear. This water right may be subject to cancellation due to abandonment or forfeiture [21].

Table 4: Irrigation reported statistics per permit (2015-2024) [15]

Permit No.	Lic. Acres	No. Reports	Average (ac-ft/yr)	St. Dev. (ac-ft/yr)	R^2	Trend (ac-ft/yr)	Trend (% Avg.)	Trend (in/yr)	Trend Assessment
130A-3	75	10	31.13	19.11	0.0%	-0.11	-0.35%	-0.02	≈
149-3	320	10	85.94	74.97	7.0%	6.54	7.61%	0.25	≈
246-3	160	10	89.14	40.11	0.9%	-1.28	-1.43%	-0.10	≈
398-3	140	10	37.11	30.03	11.8%	-3.40	-9.17%	-0.29	≈
471-3	160	10	136.67	101.79	24.5%	-16.62	-12.16%	-1.25	↓↓
472A-3	140	10	58.28	49.80	0.2%	-0.74	-1.27%	-0.06	≈
498-3	320	10	124.10	90.62	23.3%	-14.46	-11.65%	-0.54	≈
563-3	296	10	98.08	55.74	4.5%	3.89	3.97%	0.16	≈
782A-3	136	10	122.28	96.84	2.4%	-4.91	-4.01%	-0.43	≈
839-3	160	10	122.86	50.11	0.2%	0.78	0.64%	0.06	≈
960-3	624	10	93.08	93.26	0.0%	0.14	0.15%	0.00	≈
962-3	160	10	68.40	59.63	39.1%	-12.32	-18.01%	-0.92	↓
971-3	156	10	142.87	93.11	0.5%	2.21	1.54%	0.17	≈
1040-3	160	10	58.97	46.11	0.0%	0.26	0.44%	0.02	≈
1203-3	181	10	55.33	34.48	0.1%	-0.26	-0.48%	-0.02	≈
1423-3	132	10	70.98	32.70	8.5%	-3.15	-4.44%	-0.29	≈
1424-3	254	10	63.25	40.33	1.3%	1.49	2.36%	0.07	≈
1509-3	135	10	78.08	40.80	14.5%	5.13	6.57%	0.46	↑
1512-3	135	10	55.90	43.37	7.8%	-3.99	-7.14%	-0.35	≈
1523-3	131	10	58.75	34.22	1.9%	1.55	2.64%	0.14	≈
1571-3	160	10	87.59	61.25	14.0%	-7.57	-8.65%	-0.57	≈
1600-3	132	10	82.31	59.81	18.3%	-8.45	-10.27%	-0.77	↓
1708-3	160	10	70.88	62.93	0.1%	-0.74	-1.04%	-0.06	≈
1725-3	149	10	133.86	62.17	0.1%	0.70	0.52%	0.06	≈
1923-3	136	10	60.25	31.71	1.2%	-1.17	-1.94%	-0.10	≈
2078A-3	132	9	50.11	36.05	2.8%	2.20	4.40%	0.20	≈
2078-3	792	10	220.44	192.31	57.0%	-47.96	-21.76%	-0.73	↓
2278-3	136	10	97.62	41.21	0.0%	-0.12	-0.12%	-0.01	≈
2422-3	135	10	116.90	72.99	3.3%	4.39	3.75%	0.39	≈
2428A-3	136	10	109.29	66.60	0.3%	1.25	1.14%	0.11	≈
2440-3	132	10	69.76	48.46	1.4%	-1.90	-2.72%	-0.17	≈
2471B-3	202	10	61.17	37.62	18.2%	-5.30	-8.66%	-0.31	≈
2476-3	96	10	61.90	45.66	33.3%	-8.70	-14.06%	-1.09	↓
2486-3	125	10	29.49	19.80	1.6%	-0.83	-2.81%	-0.08	≈
2487-3	136	10	85.67	75.88	3.4%	4.63	5.41%	0.41	≈
2592A-3	131	10	74.32	43.66	11.7%	-4.94	-6.64%	-0.45	≈
2659-3	132	10	55.98	60.24	0.0%	0.16	0.29%	0.01	≈
2853-3	132	10	118.13	114.67	31.4%	21.22	17.97%	1.93	↑↑
2976A-3	126	10	72.69	62.55	14.0%	-7.73	-10.63%	-0.74	↓
3045-3	120	10	25.59	47.88	14.2%	-5.97	-23.32%	-0.60	≈
3046-3	130	10	37.71	44.97	19.1%	6.49	17.20%	0.60	↑
3052-3	180	10	85.64	41.98	11.8%	4.76	5.56%	0.32	≈
3053A-3	130	10	84.98	48.35	20.3%	7.19	8.46%	0.66	↑
3065B-3	130	10	64.21	34.55	0.6%	-0.87	-1.36%	-0.08	≈
3126-3	136	10	36.25	37.07	14.4%	-4.64	-12.81%	-0.41	≈
3162A-3	267	10	183.56	114.63	14.1%	-14.23	-7.75%	-0.64	↓
3164-3	136	10	50.86	33.33	9.4%	3.37	6.63%	0.30	≈

Permit No.	Lic. Acres	No. Reports	Average (ac-ft/yr)	St. Dev. (ac-ft/yr)	R^2	Trend (ac-ft/yr)	Trend (% Avg.)	Trend (in/yr)	Trend Assessment
3172-3	136	10	60.01	36.47	4.3%	2.48	4.14%	0.22	≈
3174A-3	138	10	109.84	45.46	0.8%	-1.38	-1.25%	-0.12	≈
3191-3	118	10	60.15	59.96	17.0%	-8.16	-13.56%	-0.83	↓
3192-3	132	10	75.30	44.81	12.6%	-5.25	-6.97%	-0.48	≈
3261-3A	130	10	97.21	40.34	5.7%	3.18	3.27%	0.29	≈
3321A-3	120	10	19.52	18.12	4.1%	-1.21	-6.19%	-0.12	≈
3603-3	132	10	81.81	71.37	3.7%	-4.51	-5.51%	-0.41	≈
3860-3	136	10	78.96	61.67	4.3%	-4.24	-5.37%	-0.37	≈
3861-3	109	10	22.46	11.06	0.1%	-0.09	-0.40%	-0.01	≈
4134A-3	128	10	90.11	101.69	13.2%	12.22	13.56%	1.15	↑↑
4167-3	132	10	84.70	58.62	1.9%	2.67	3.15%	0.24	≈
4194-3	90	10	29.42	17.47	0.6%	0.46	1.57%	0.06	≈
4308-3	184	10	109.32	46.46	1.7%	-2.02	-1.85%	-0.13	≈
4350-3	132	10	109.55	76.73	41.9%	-16.40	-14.97%	-1.49	↓↓
4400A-3	102	10	36.09	20.50	5.3%	-1.57	-4.34%	-0.18	≈
4482-3	132	10	56.04	28.26	1.1%	0.98	1.76%	0.09	≈
4550-3	264	10	109.42	73.09	2.9%	-4.14	-3.78%	-0.19	≈
4591-3	132	10	78.86	54.40	3.1%	3.14	3.98%	0.29	≈
4622A-3	130	10	64.23	34.52	2.9%	-1.95	-3.04%	-0.18	≈
4703-3	130	10	56.02	43.70	10.4%	4.66	8.32%	0.43	≈
4794B-3	278	9	135.46	81.10	5.3%	6.80	5.02%	0.29	≈
4794C-3	124	9	71.38	29.81	3.7%	-2.08	-2.92%	-0.20	≈
4819-3	121	10	99.34	48.30	0.5%	-1.10	-1.11%	-0.11	≈
4912A-3*	165	0	0.00	0.00	N/A	0.00	N/A	0.00	≈
4912B-3	136	10	67.58	34.46	2.1%	1.66	2.45%	0.15	≈
4935-3	184	10	65.27	72.67	4.2%	4.90	7.51%	0.32	≈
5035-3	135	10	102.12	45.93	8.0%	-4.29	-4.20%	-0.38	≈
5123-3	136	10	78.76	59.29	12.7%	-6.98	-8.86%	-0.62	≈
5149-3	132	10	83.67	63.64	6.4%	-5.30	-6.33%	-0.48	≈
5162-3	132	10	79.28	43.02	1.2%	-1.57	-1.99%	-0.14	≈
5163-3	132	10	89.77	57.04	6.9%	-4.94	-5.50%	-0.45	≈
5182-3	279	10	127.22	80.89	0.4%	1.68	1.32%	0.07	≈
5231-3	162	9	56.30	46.74	1.0%	1.43	2.54%	0.11	≈
5234-3	128	10	52.91	59.17	0.0%	-0.02	-0.04%	0.00	≈
5266-3	129	10	108.42	40.04	20.9%	-6.05	-5.58%	-0.56	≈
5301-3	132	10	93.53	62.28	4.4%	4.33	4.63%	0.39	≈
5390-3	272	10	72.24	43.05	0.6%	-1.13	-1.56%	-0.05	≈
5568-3	122	10	166.74	73.57	1.1%	2.59	1.55%	0.26	≈
5601-3	5	10	4.49	7.86	35.7%	1.55	34.58%	3.72	↑↑
5634-3	266	10	183.04	130.62	2.2%	-6.41	-3.50%	-0.29	≈
5671-3	263	10	128.20	107.79	10.8%	-11.71	-9.13%	-0.53	≈
5798-3	132	10	21.79	23.02	8.3%	-2.19	-10.04%	-0.20	≈
5897-3	268	10	149.96	115.74	4.4%	-8.01	-5.34%	-0.36	≈
6108-3	304	10	116.37	73.15	0.0%	0.02	0.02%	0.00	≈
6142-3	240	10	211.46	75.53	0.0%	0.09	0.04%	0.00	≈
6159-3	128	10	70.78	32.69	0.0%	0.10	0.14%	0.01	≈
6160-3	136	10	64.52	52.70	3.2%	-3.10	-4.80%	-0.27	≈
6175-3	136	10	78.16	45.96	19.6%	-6.73	-8.61%	-0.59	≈

Permit No.	Lic. Acres	No. Reports	Average (ac-ft/yr)	St. Dev. (ac-ft/yr)	R^2	Trend (ac-ft/yr)	Trend (% Avg.)	Trend (in/yr)	Trend Assessment
6184-3	270	10	75.81	50.01	2.3%	-2.49	-3.28%	-0.11	≈
6196-3	136	10	68.40	32.46	0.2%	0.51	0.75%	0.05	≈
6200-3	136	10	45.02	39.32	49.1%	-9.10	-20.22%	-0.80	↓
6201B-3	132	10	86.12	45.42	2.4%	2.35	2.72%	0.21	≈
6201C-3	264	10	118.63	83.87	0.1%	-0.74	-0.63%	-0.03	≈
6201D-3	132	10	49.46	42.65	43.7%	-9.31	-18.83%	-0.85	↓
6234-3	134	10	117.76	54.22	5.0%	4.00	3.40%	0.36	≈
6238-3	130	10	81.17	54.09	5.4%	4.16	5.13%	0.38	≈
6239-3	260	10	146.69	96.03	0.1%	0.71	0.49%	0.03	≈
6240-3	132	10	78.15	35.88	1.9%	-1.63	-2.09%	-0.15	≈
6288-3	136	10	32.71	21.02	20.1%	-3.11	-9.50%	-0.27	≈
6312A-3	264	10	13.08	29.63	16.1%	-3.92	-29.97%	-0.18	≈
6312-3	132	10	59.53	39.47	9.9%	-4.10	-6.88%	-0.37	≈
6331A-3	132	10	88.99	53.44	9.4%	5.42	6.10%	0.49	↑
6332-3	136	10	58.80	43.57	11.7%	-4.93	-8.38%	-0.43	≈
6333A-3	215	10	58.84	40.32	23.9%	6.51	11.06%	0.36	≈
6333B-3	134	10	84.17	45.51	5.0%	3.35	3.98%	0.30	≈
6334A-3	132	10	66.22	63.74	13.0%	-7.59	-11.46%	-0.69	↓
6334B-3	132	10	56.33	62.96	1.2%	-2.25	-4.00%	-0.20	≈
6336-3	136	10	106.83	83.00	0.1%	0.73	0.68%	0.06	≈
6337-3	272	10	212.24	143.80	1.1%	4.92	2.32%	0.22	≈
6338A-3	68	10	19.10	15.45	17.8%	-2.15	-11.25%	-0.38	≈
6338-3	264	10	172.02	108.34	11.9%	-12.37	-7.19%	-0.56	≈
6339A-3	132	10	93.45	70.67	5.9%	-5.69	-6.09%	-0.52	≈
6340-3	132	10	84.56	63.31	7.1%	-5.55	-6.57%	-0.50	≈
6343A-3	132	8	70.53	48.28	0.3%	-1.04	-1.48%	-0.09	≈
6343B-3	132	8	27.51	24.41	0.7%	0.83	3.02%	0.08	≈
6764-3	272	10	211.52	142.87	16.9%	19.40	9.17%	0.86	↑
7289-3	270	10	122.92	96.07	3.5%	-5.98	-4.86%	-0.27	≈
7290-3	135	10	109.83	75.40	14.4%	9.46	8.61%	0.84	↑
7291-3	135	10	93.30	83.65	14.0%	10.34	11.09%	0.92	↑
7292A-3	133	8	76.20	64.37	1.5%	-3.17	-4.16%	-0.29	≈
7292B-3	133	8	76.44	64.45	1.3%	-3.00	-3.93%	-0.27	≈
7293-3	135	10	84.13	62.98	1.4%	-2.49	-2.96%	-0.22	≈
7373-3	152	10	84.46	34.44	7.0%	-3.00	-3.55%	-0.24	≈
7551-3	219	10	118.93	63.21	1.7%	-2.68	-2.26%	-0.15	≈
7570-3	259	10	70.41	48.80	0.1%	0.52	0.74%	0.02	≈
7571A-3	270	9	59.98	44.62	2.2%	2.40	4.00%	0.11	≈
7572B-3	135	9	81.73	39.17	9.6%	-4.44	-5.44%	-0.39	≈
7573A-3	156	9	99.80	50.68	12.2%	-6.45	-6.47%	-0.50	≈
7573-3	134	10	38.14	33.57	0.2%	-0.51	-1.33%	-0.05	≈
7574-3	268	10	51.77	54.10	10.9%	5.90	11.40%	0.26	≈
7575B-3	134	10	13.72	19.55	0.0%	-0.01	-0.08%	0.00	≈
7620A-3	72	9	33.88	32.25	4.8%	-2.58	-7.61%	-0.43	≈
7620B-3	64	9	28.02	18.87	16.0%	-2.75	-9.83%	-0.52	≈
7637-3	135	10	38.74	33.52	9.0%	-3.33	-8.59%	-0.30	≈
7639-3	135	10	63.07	40.72	5.3%	3.09	4.91%	0.28	≈
7640-3	156	10	99.85	48.57	4.5%	-3.39	-3.40%	-0.26	≈

Permit No.	Lic. Acres	No. Reports	Average (ac-ft/yr)	St. Dev. (ac-ft/yr)	R^2	Trend (ac-ft/yr)	Trend (% Avg.)	Trend (in/yr)	Trend Assessment
7685-3	75	10	55.55	31.94	6.7%	-2.73	-4.92%	-0.44	≈
7716-3	135	10	6.12	6.71	45.0%	1.49	24.30%	0.13	≈
7718A-3	135	10	77.31	33.20	9.1%	-3.30	-4.27%	-0.29	≈
7720-3	135	10	39.58	34.03	10.8%	-3.69	-9.31%	-0.33	≈
7721-3	344	10	34.84	32.11	49.0%	7.42	21.31%	0.26	≈
7723-3	405	10	84.46	82.82	34.2%	15.99	18.93%	0.47	↑
7724-3	300	10	42.46	40.59	3.5%	2.52	5.94%	0.10	≈
7725C-3	135	10	27.48	32.86	1.0%	1.10	4.00%	0.10	≈
Total	**25,542**	**1,483**	**12,082.83**	**8,213.24**	**--**	**-187.91**	**--**	***-0.09***	**≈**
Average	169	10	80.02	54.39	8.8%	-1.24	-1.48%	-0.07	--
St.Dev.	90	1	41.67	28.52	11.3%	6.89	8.60%	**0.54**	--
Min.	5	0	0.00	0.00	0.00%	-47.96	-30.0%	-1.49	--
Max.	792	10	220.44	192.31	57.01%	21.22	34.6%	3.72	--
Median	135	10	76.20	47.88	4.44%	-1.04	-1.4%	-0.08	--

* Water Right No. 4912A-3 has not reported irrigation since 2002, as ownership of the water right was unclear. This water right may be subject to cancellation due to abandonment or forfeiture [21].

Table 5: Summary of Irrigation reported statistics per permit

1979-2024 (Table 3)		2015-2024 (Table 4)	
Trend Assessment	Number of Permits	Trend Assessment	Number of Permits
↑↑	1	↑↑	3
↑	4	↑	7
≈	143	≈	128
↓	2	↓	11
↓↓	1	↓↓	2
↑↑ - significant increase; ↑ - moderate increase; ≈ - no significant trend; ↓ - moderate decrease; ↓↓ - significant decrease			

Appendix B: Observation Well Hydrographs

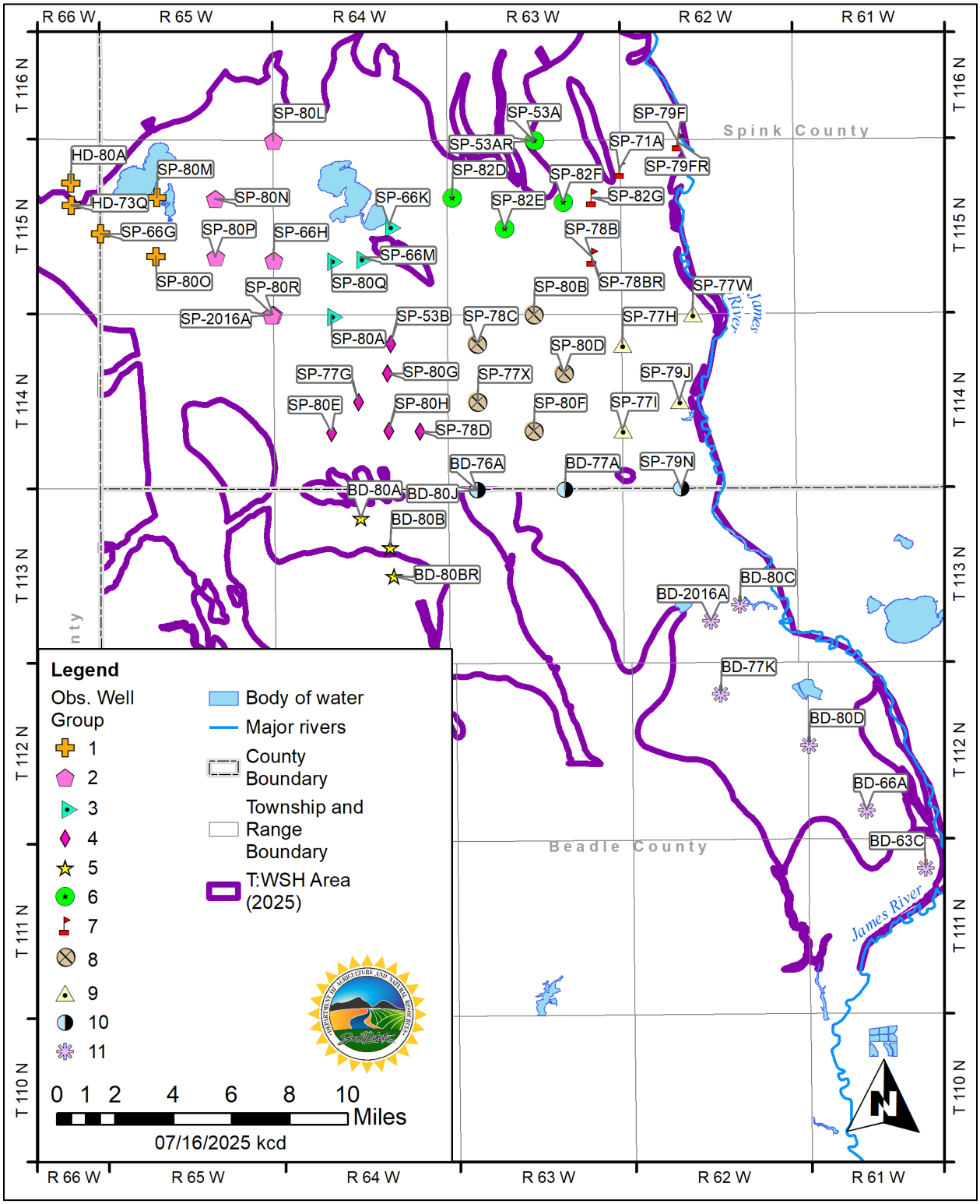

Figure 5: Map of groups of observation wells in T:WSH [3]

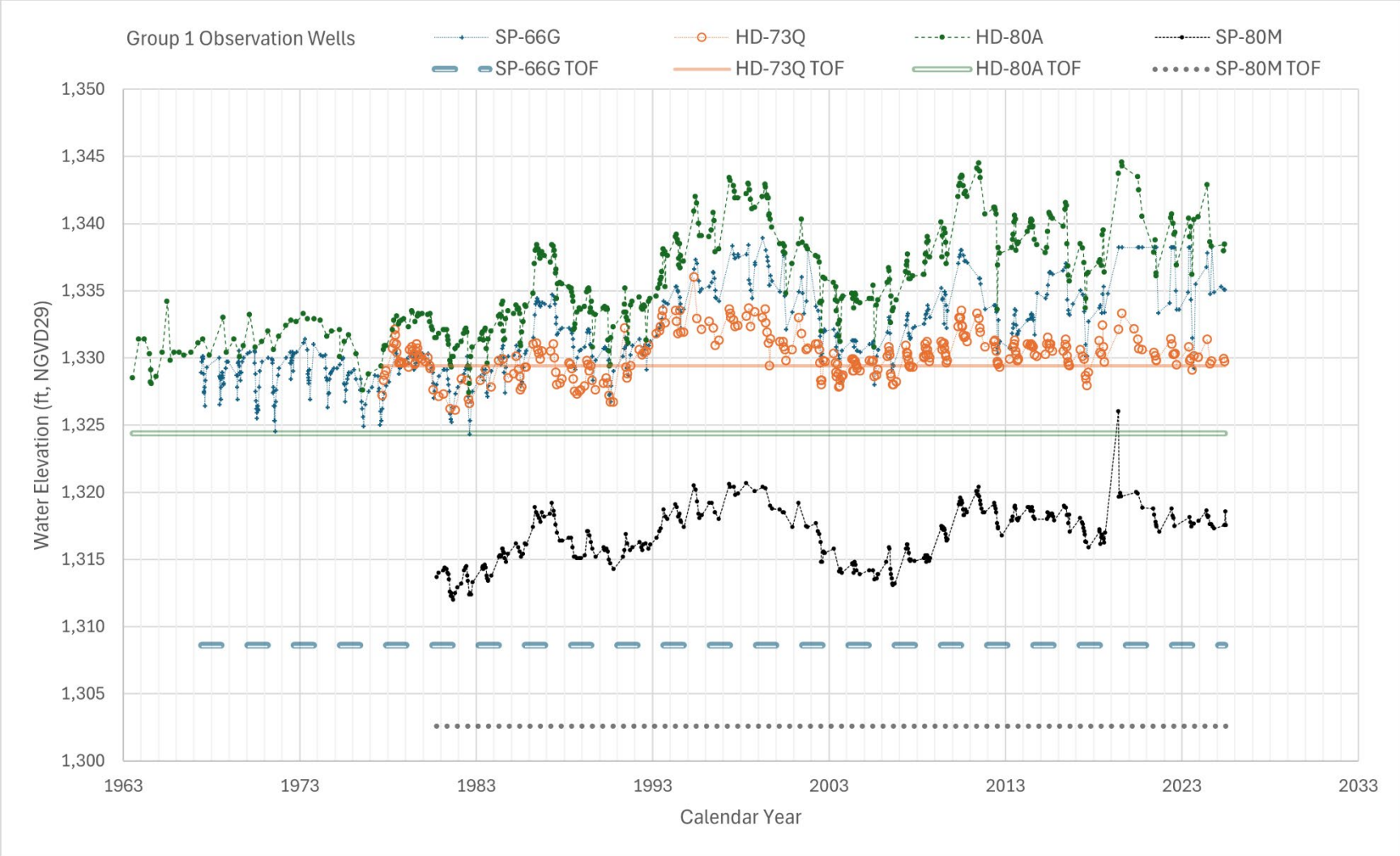

Figure 6: Observation well water level elevations and formation top (TOF) elevations for Group 1 [3]

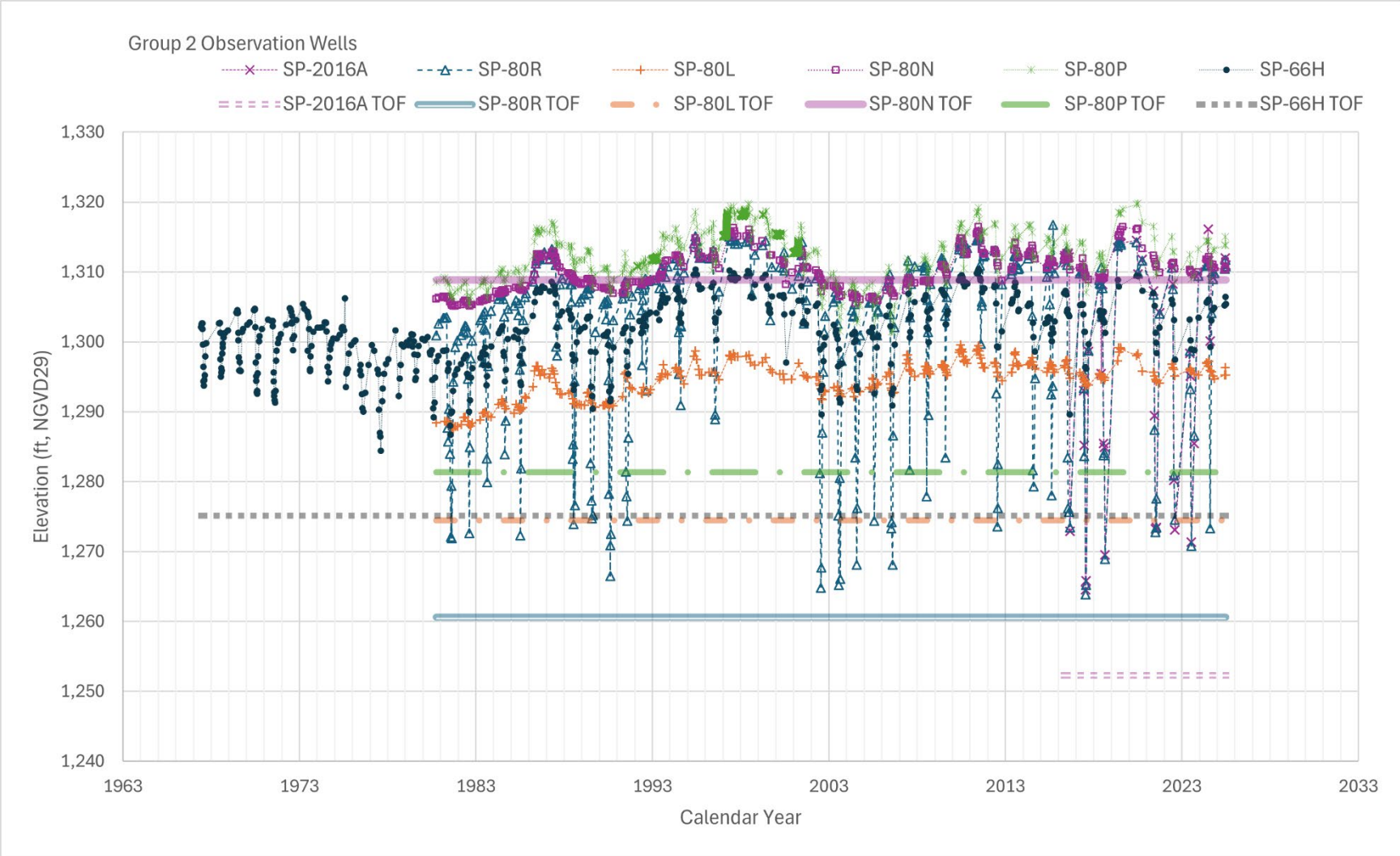

Figure 7: Observation well water level elevations and TOF elevations for Group 2 [3]

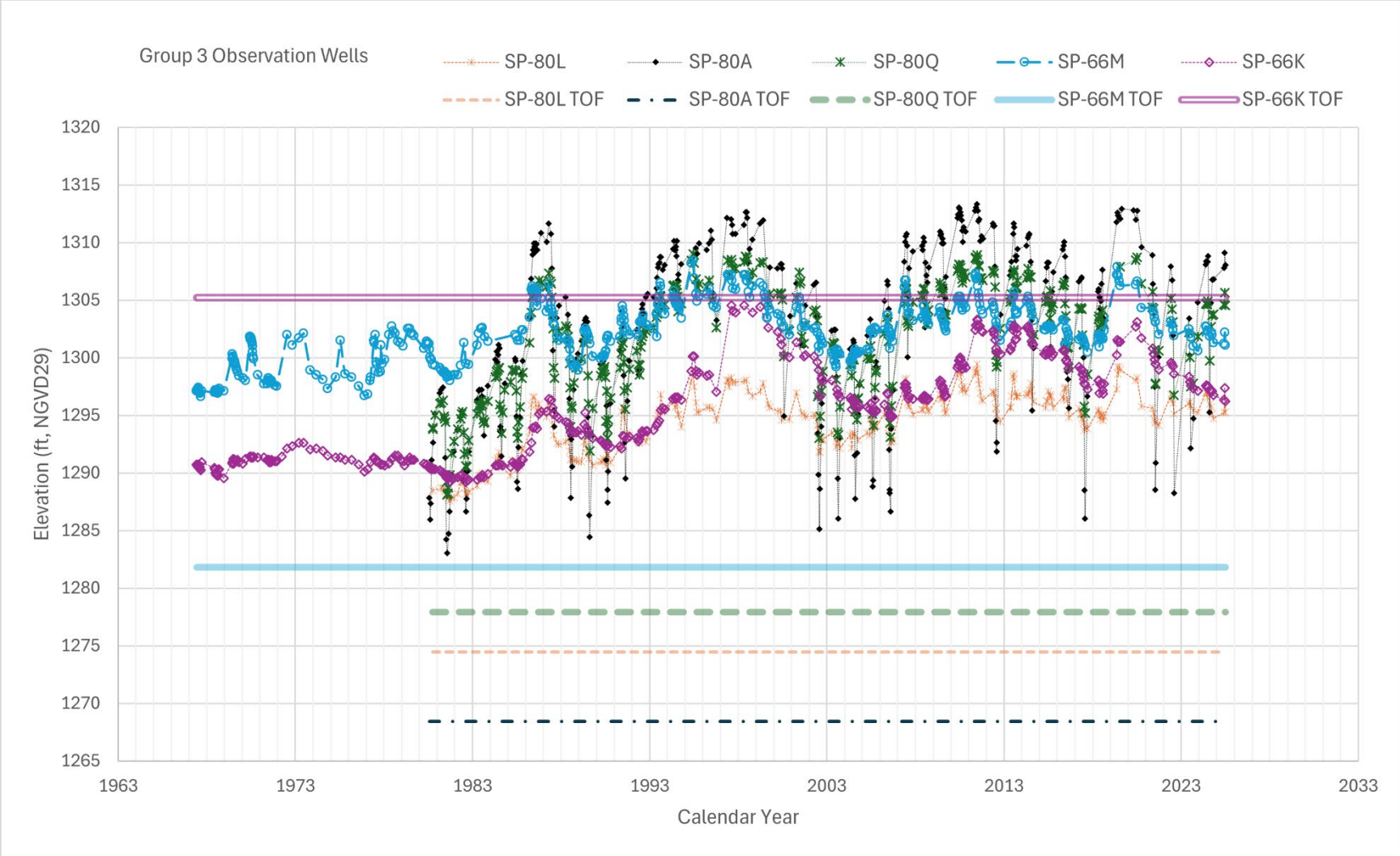

Figure 8: Observation well water level elevations and TOF elevations for Group 3 [3]

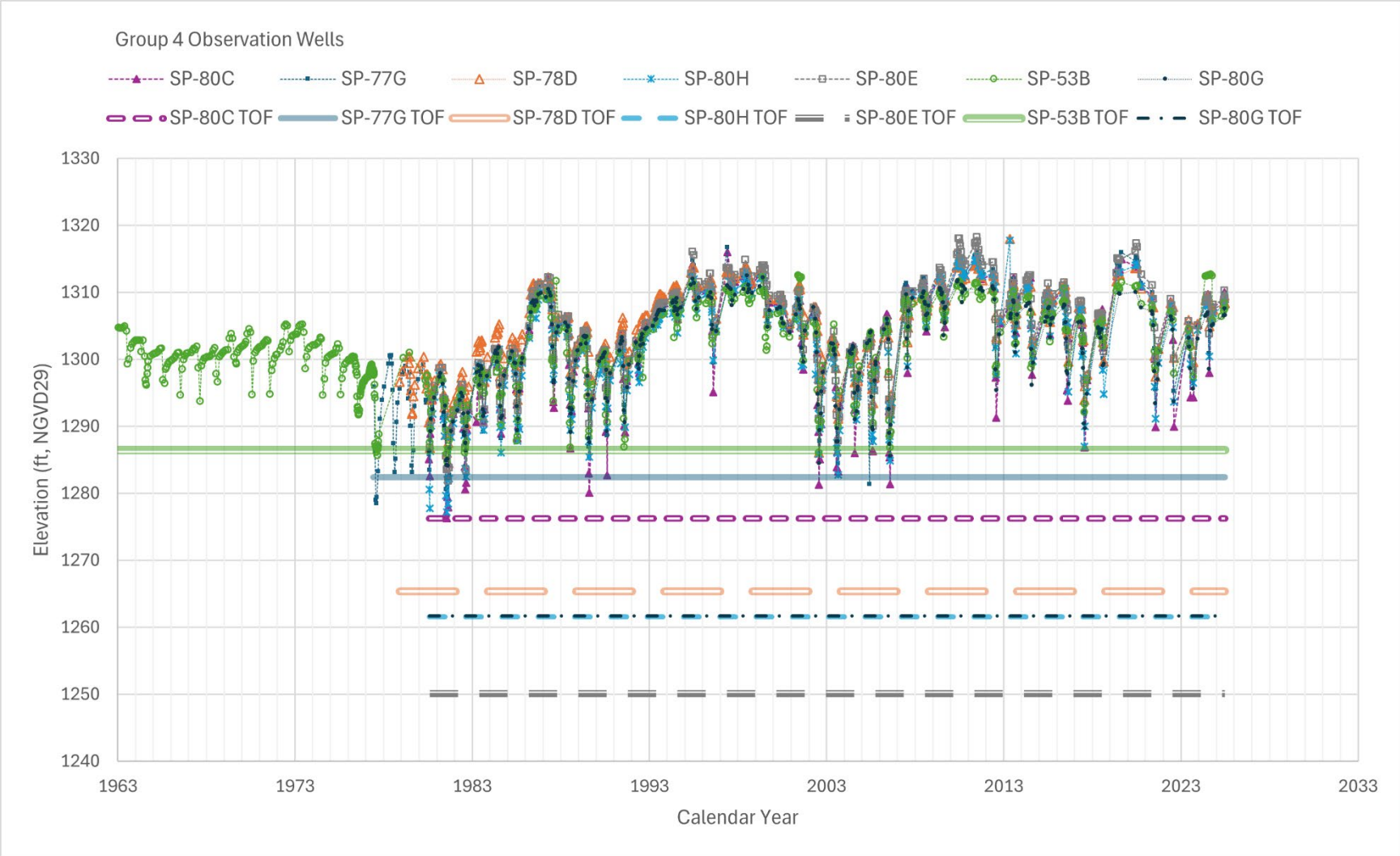

Figure 9: Observation well water level elevations and TOF elevations for Group 4 [2]

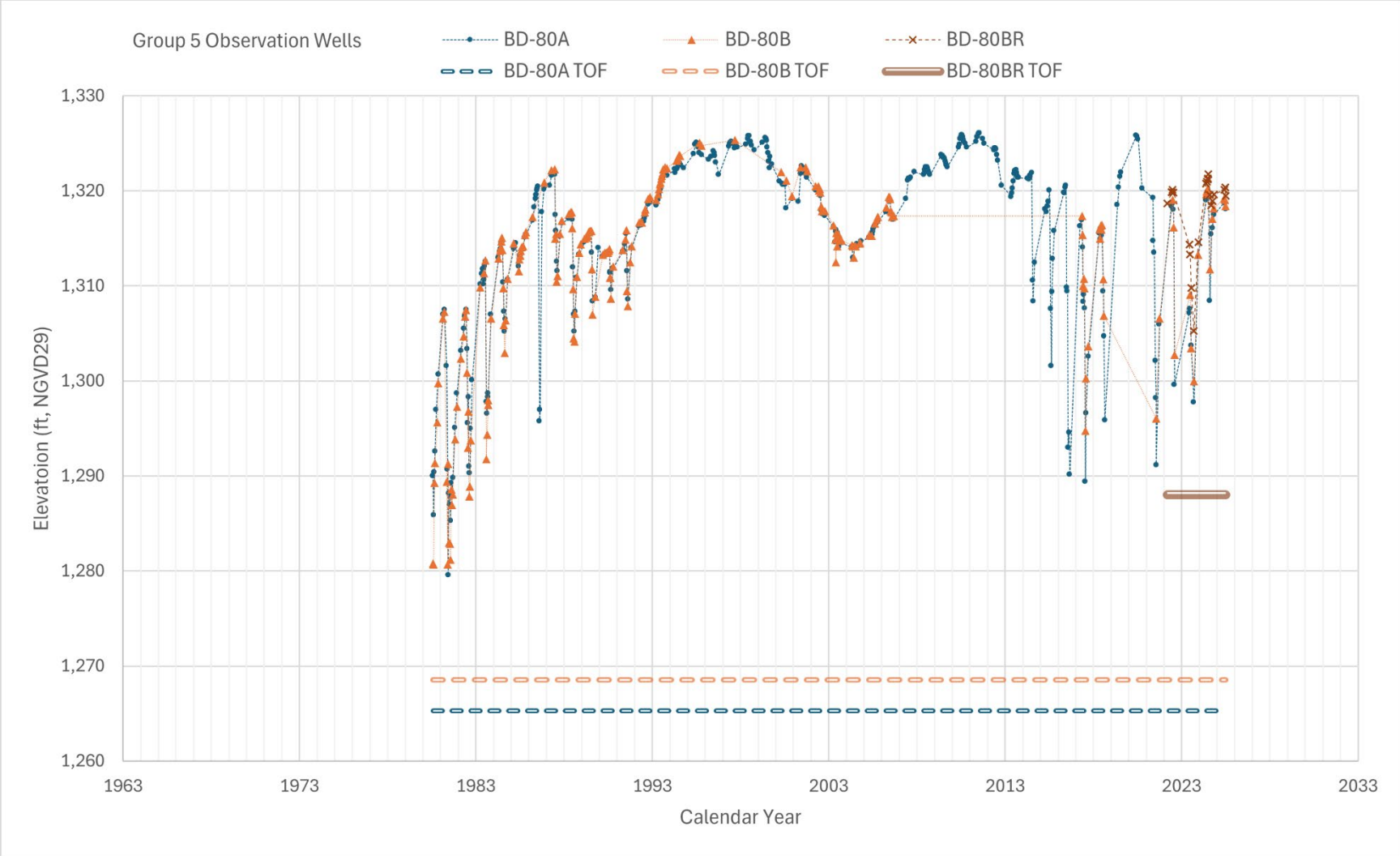

Figure 10: Observation well water level elevations and TOF elevations for Group 5 [2]

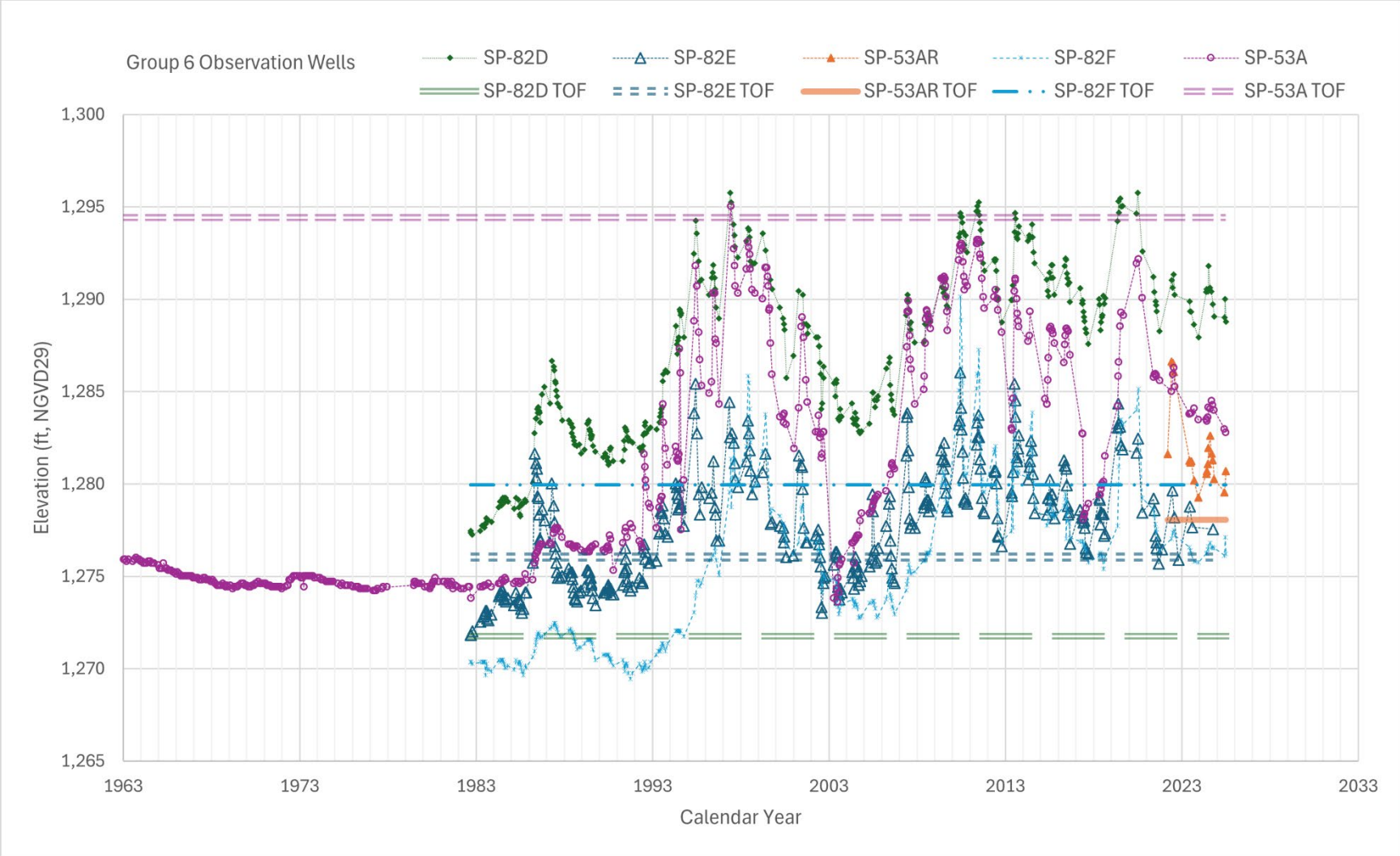

Figure 11: Observation well water level elevations and TOF elevations for Group 6 [2]

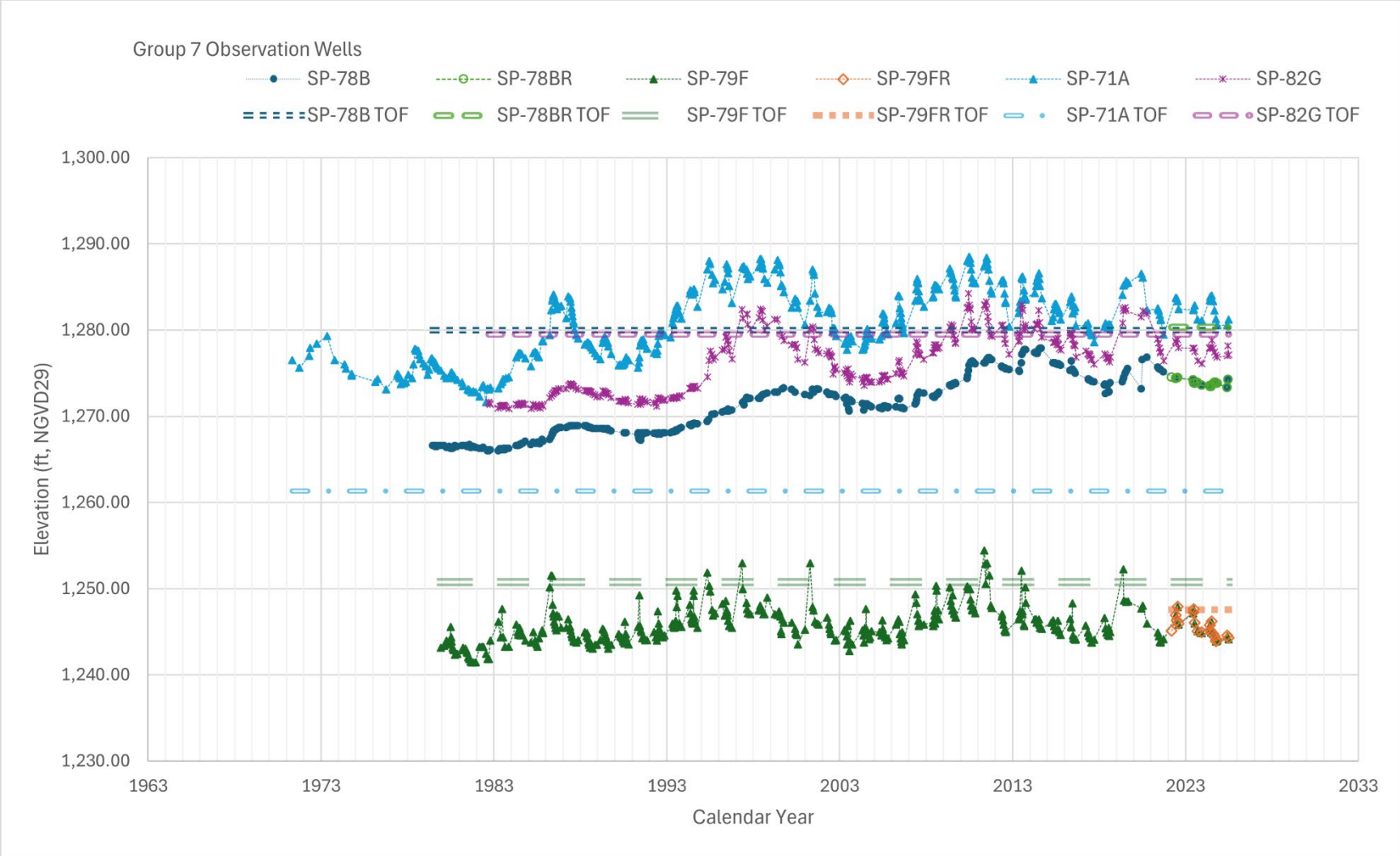

Figure 12: Observation well water level elevations and TOF elevations for Group 7 [2]

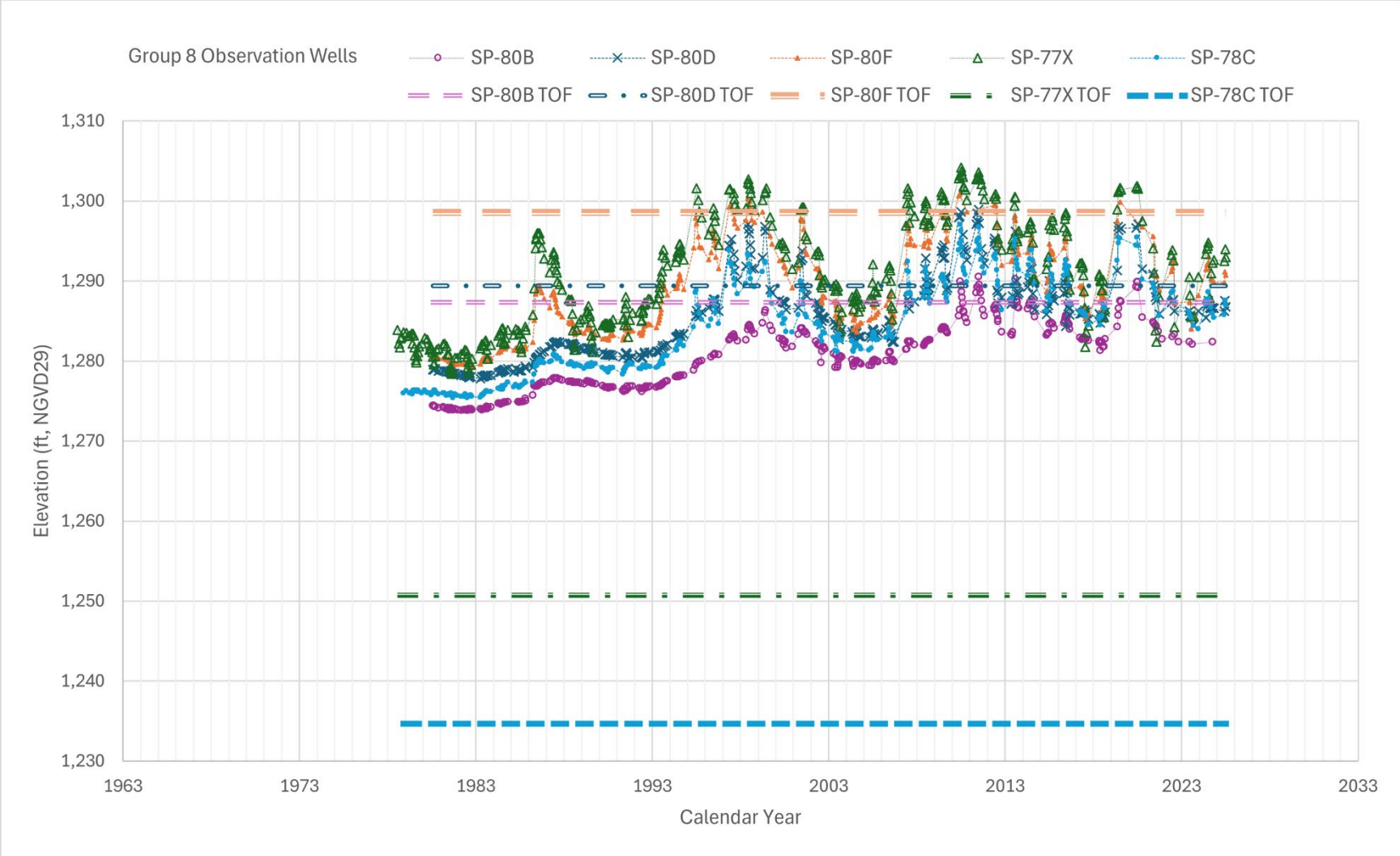

Figure 13: Observation well water level elevations and TOF elevations for Group 8 [2]

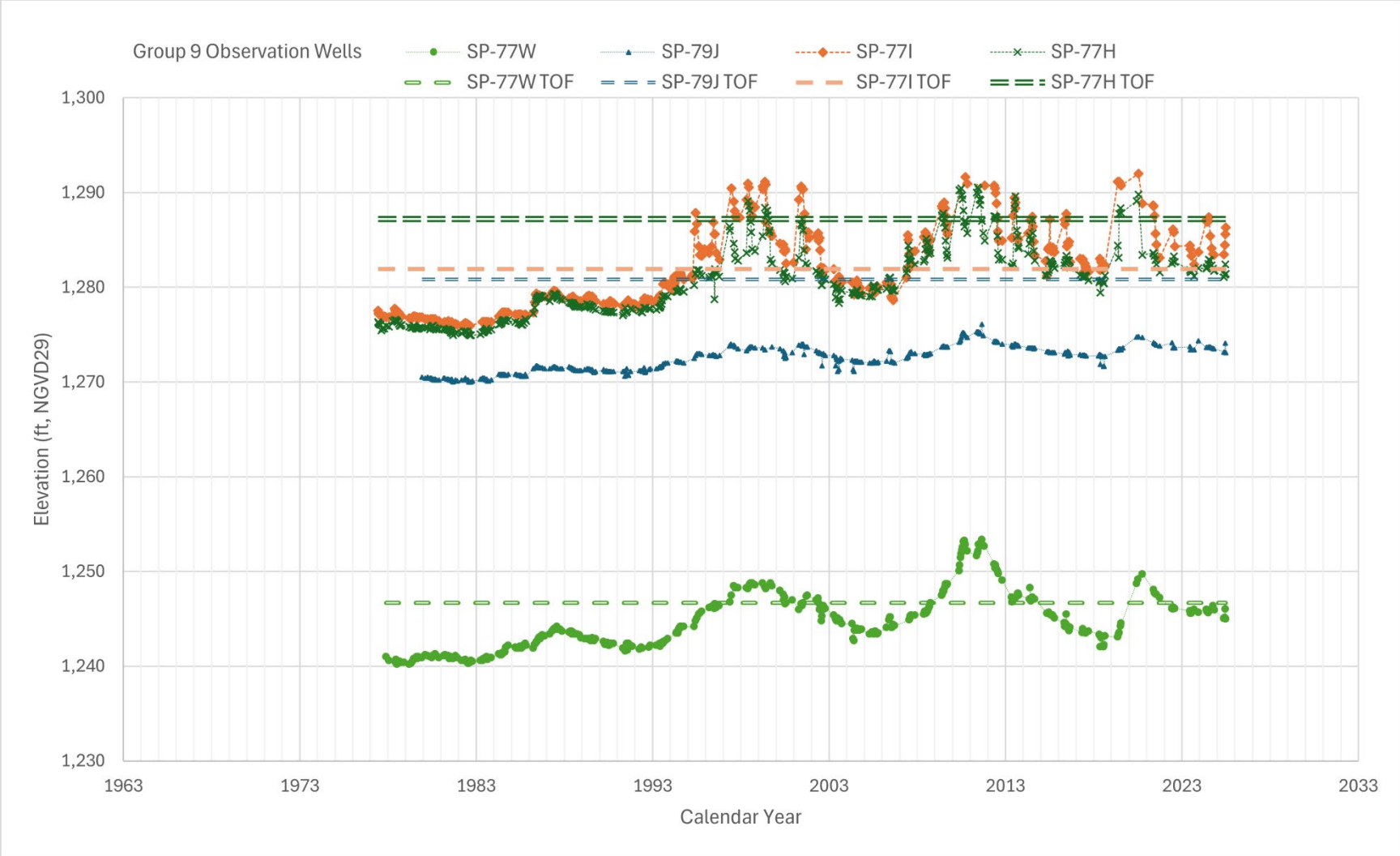

Figure 14: Observation well water level elevations and TOF elevations for Group 9 [2]

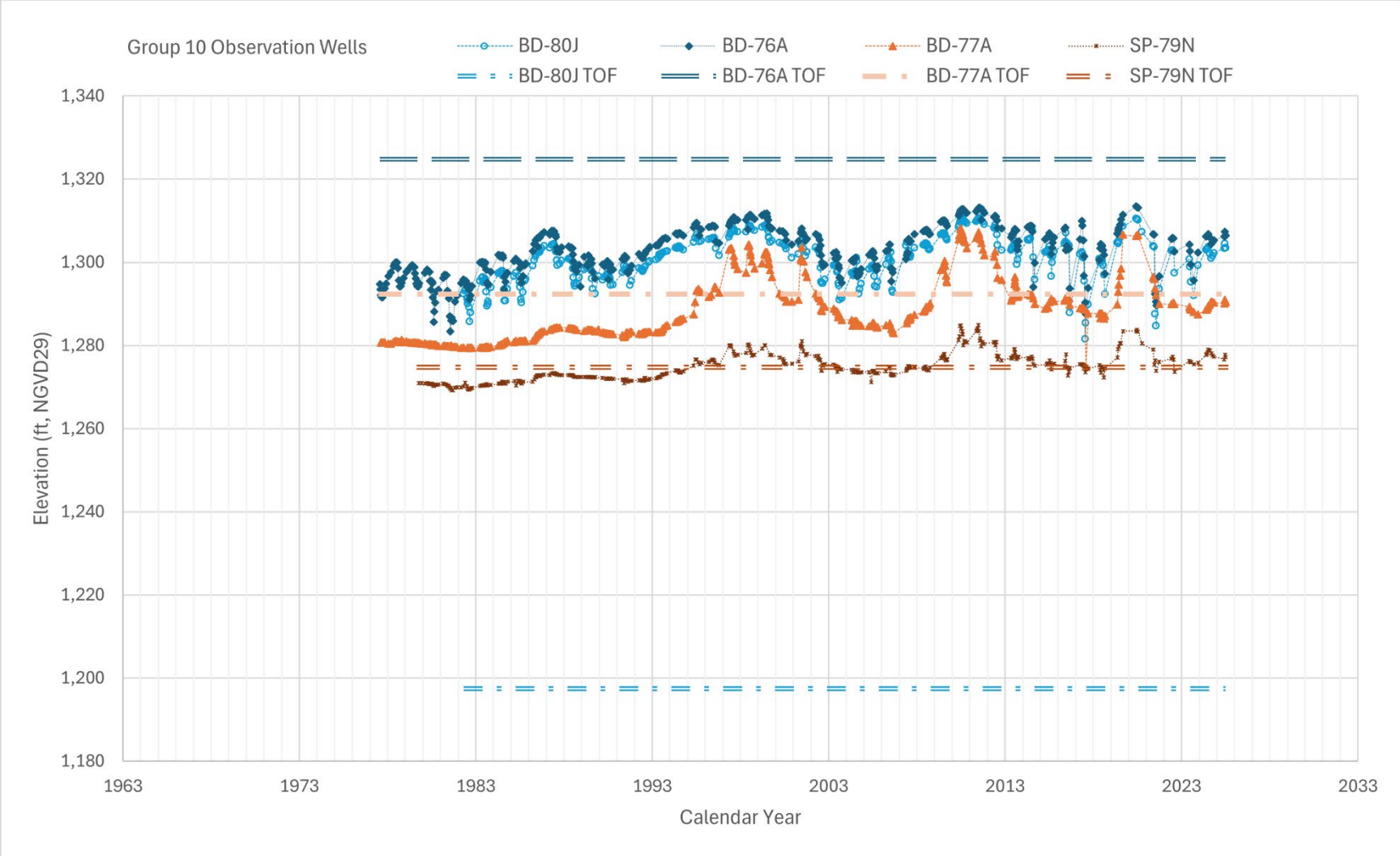

Figure 15: Observation well water level elevations and TOF elevations for Group 10 [2]

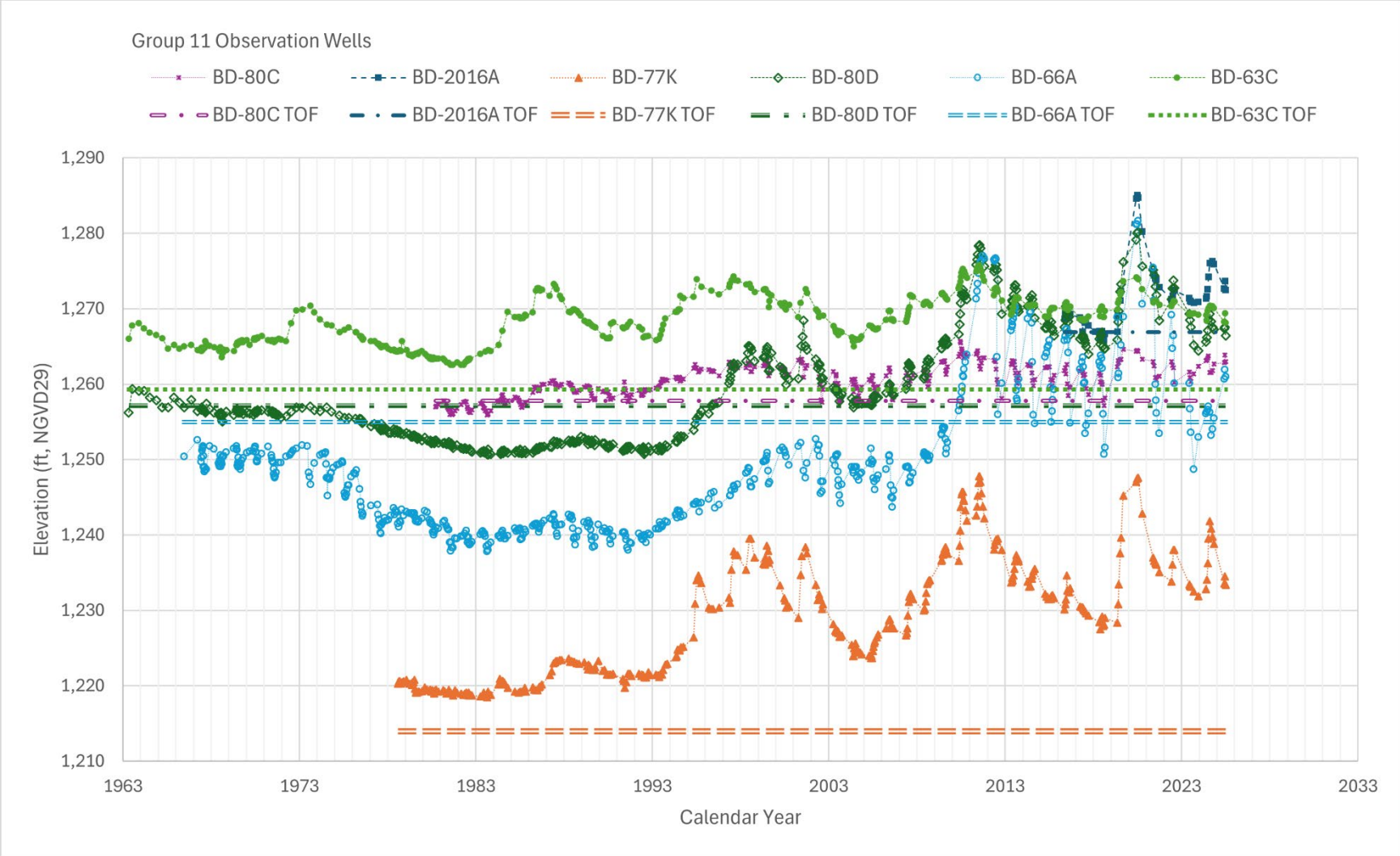

Figure 16: Observation well water level elevations and TOF elevations for Group 11 [2]

Appendix C: Climactic Data

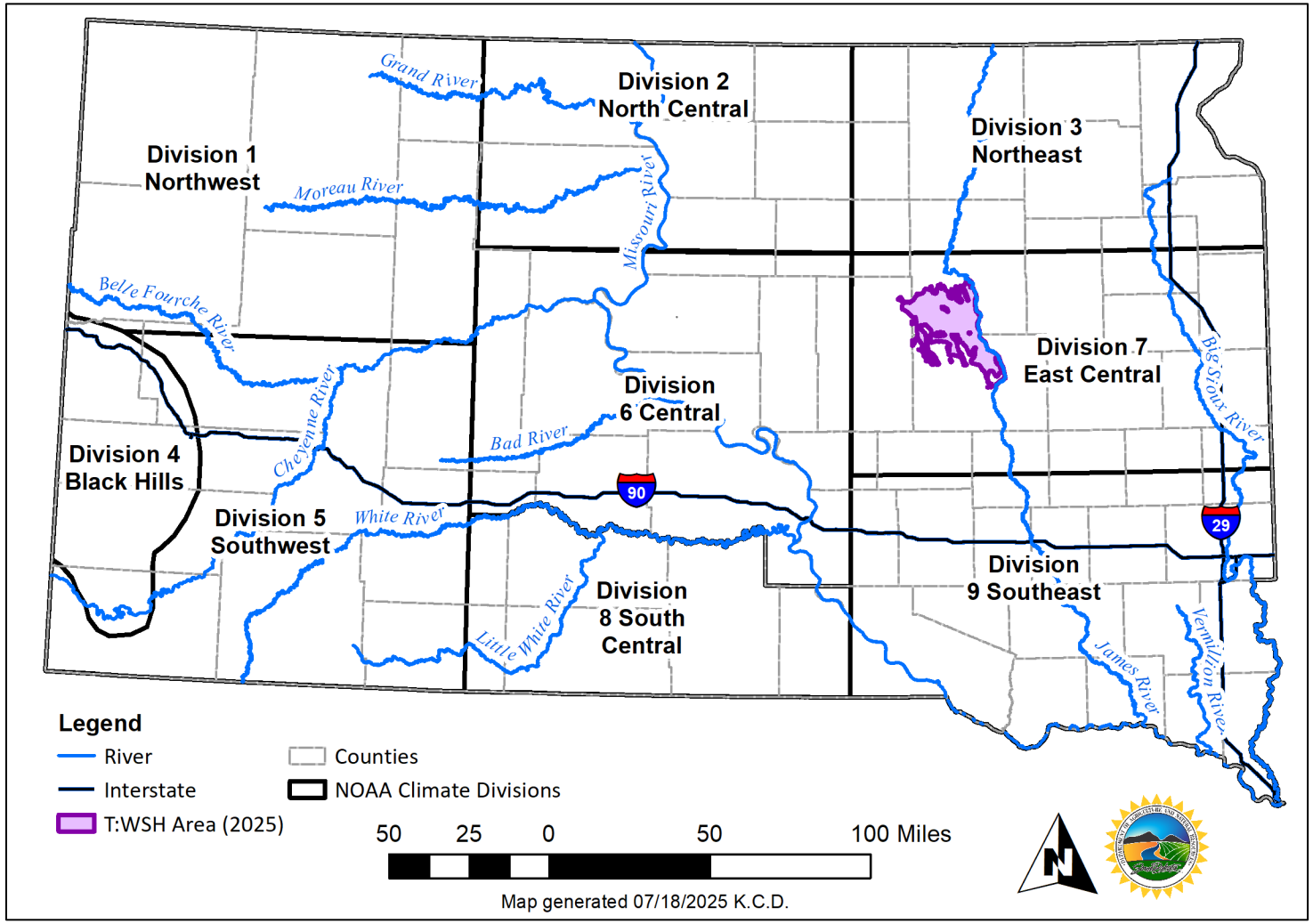

Figure 17: Map of NOAA Climate Divisions in South Dakota [18]

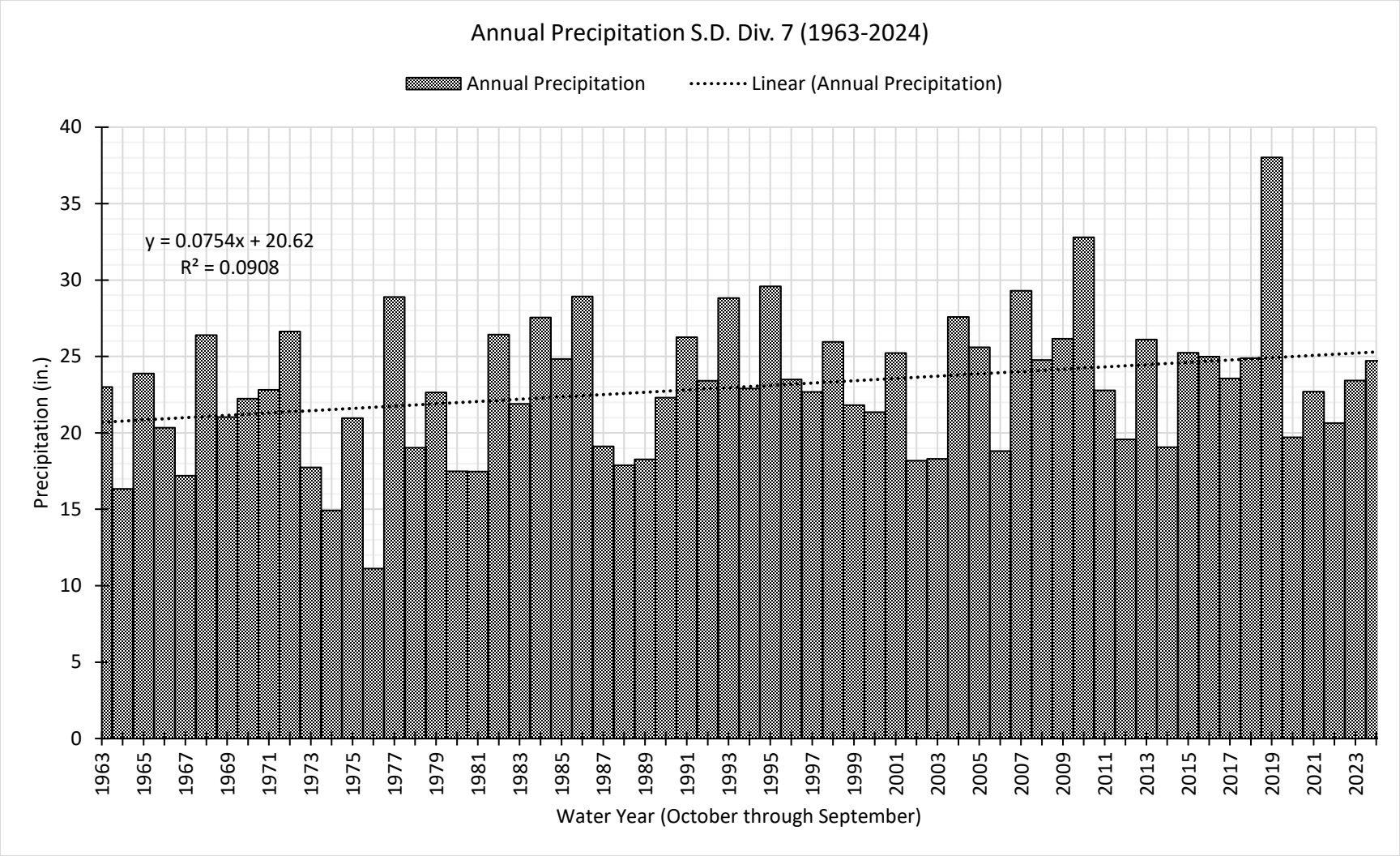

Figure 18: Annual precipitation for South Dakota Climate Division 7 from 1963 through 2024. The average from the 1900-2000 period of record was 21.6 inches [18].

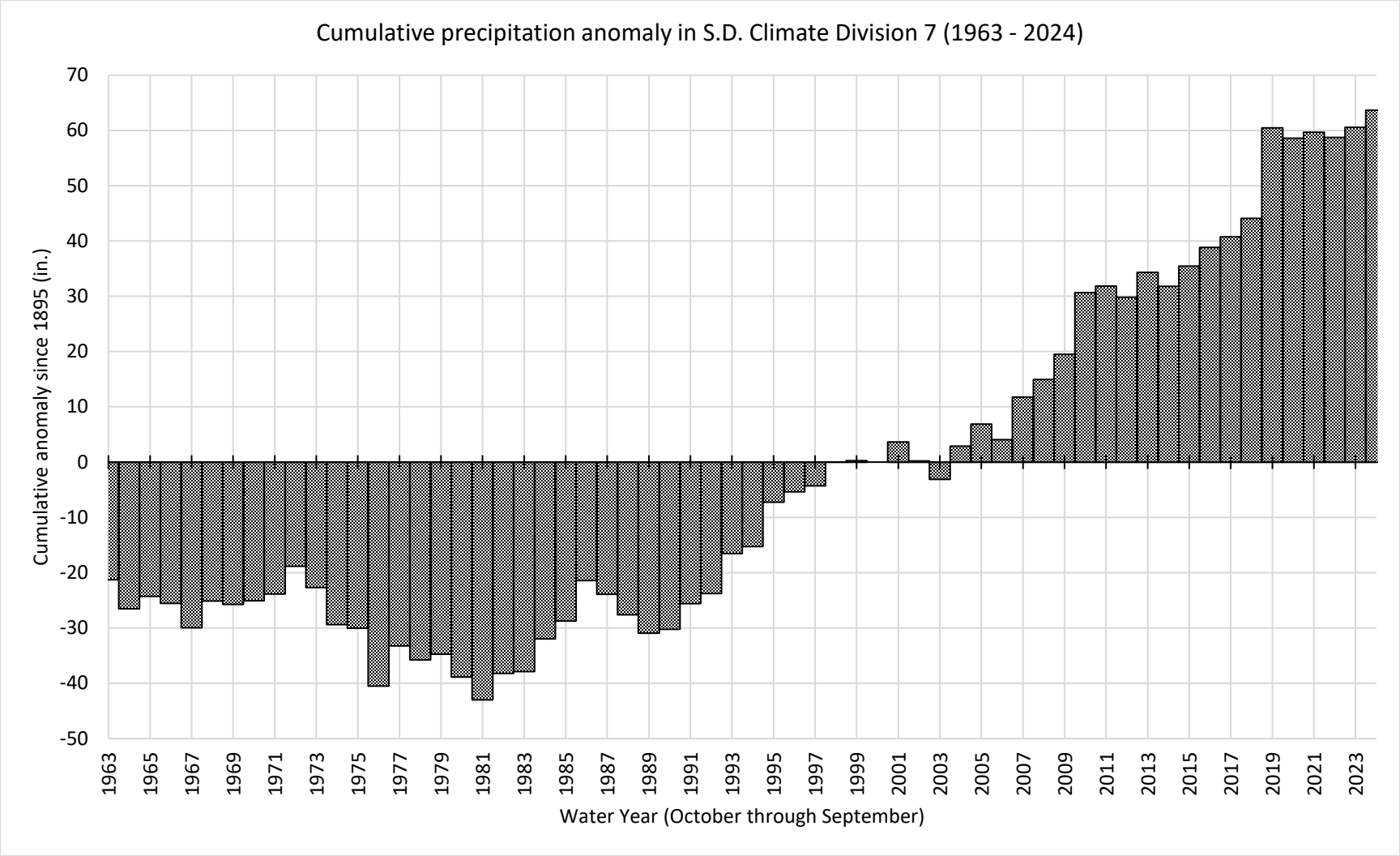

Figure 19: Cumulative Precipitation Anomaly from 1963 through 2024 [18]

Table 6: Annual Precipitation data for South Dakota Climate Division 7 (East Central) [18]

Water Year	Precip. (in)	Anomaly (in)	Cumulative Anom. (in)	Water Year	Precip. (in)	Anomaly (in)	Cumulative Anom. (in)	Water Year	Precip. (in)	Anomaly (in)	Cumulative Anom. (in)	Water Year	Precip. (in)	Anomaly (in)	Cumulative Anom. (in)
1895	17.98	-3.62	-3.62	1928	18.48	-3.12	18.71	1961	20.15	-1.45	-28.79	1994	22.9	1.30	-15.26
1896	26.44	4.84	1.22	1929	20.88	-0.72	17.98	1962	27.72	6.12	-22.67	1995	29.59	7.99	-7.27
1897	25.23	3.63	4.84	1930	19.5	-2.10	15.88	1963	23	1.40	-21.27	1996	23.49	1.89	-5.38
1898	16.83	-4.77	0.07	1931	15.72	-5.88	10.00	1964	16.33	-5.27	-26.54	1997	22.67	1.07	-4.31
1899	19.55	-2.05	-1.98	1932	18.57	-3.03	6.97	1965	23.88	2.28	-24.26	1998	25.96	4.36	0.04
1900	26.93	5.33	3.35	1933	13.92	-7.68	-0.71	1966	20.34	-1.26	-25.53	1999	21.81	0.21	0.25
1901	23.83	2.23	5.57	1934	14.9	-6.70	-7.42	1967	17.19	-4.41	-29.94	2000	21.35	-0.25	0.00
1902	21.09	-0.51	5.06	1935	19.92	-1.68	-9.10	1968	26.4	4.80	-25.14	2001	25.23	3.63	3.63
1903	23.13	1.53	6.59	1936	14.45	-7.15	-16.25	1969	21.03	-0.57	-25.71	2002	18.18	-3.42	0.21
1904	18.19	-3.41	3.18	1937	18.49	-3.11	-19.36	1970	22.24	0.64	-25.07	2003	18.3	-3.30	-3.10
1905	28.95	7.35	10.53	1938	20.22	-1.38	-20.75	1971	22.81	1.21	-23.87	2004	27.59	5.99	2.89
1906	27.66	6.06	16.58	1939	17.96	-3.64	-24.39	1972	26.63	5.03	-18.84	2005	25.59	3.99	6.88
1907	18.43	-3.17	13.41	1940	18.55	-3.05	-27.44	1973	17.74	-3.86	-22.70	2006	18.8	-2.80	4.08
1908	27.38	5.78	19.19	1941	21.28	-0.32	-27.76	1974	14.92	-6.68	-29.38	2007	29.29	7.69	11.76
1909	23.21	1.61	20.80	1942	26.74	5.14	-22.62	1975	20.96	-0.64	-30.03	2008	24.77	3.17	14.93
1910	14.57	-7.03	13.77	1943	21.76	0.16	-22.47	1976	11.12	-10.48	-40.51	2009	26.15	4.55	19.48
1911	20.63	-0.97	12.79	1944	26.35	4.75	-17.72	1977	28.89	7.29	-33.22	2010	32.79	11.19	30.67
1912	19.61	-1.99	10.80	1945	21.37	-0.23	-17.95	1978	19.03	-2.57	-35.79	2011	22.78	1.18	31.85
1913	19.16	-2.44	8.36	1946	26.59	4.99	-12.96	1979	22.65	1.05	-34.74	2012	19.57	-2.03	29.81
1914	28.51	6.91	15.27	1947	21.48	-0.12	-13.09	1980	17.48	-4.12	-38.87	2013	26.11	4.51	34.32
1915	24.45	2.85	18.11	1948	22.89	1.29	-11.80	1981	17.46	-4.14	-43.01	2014	19.07	-2.53	31.79
1916	23.6	2.00	20.11	1949	18.4	-3.20	-15.00	1982	26.42	4.82	-38.19	2015	25.24	3.64	35.43
1917	19.26	-2.34	17.77	1950	19.38	-2.22	-17.22	1983	21.89	0.29	-37.90	2016	24.99	3.39	38.82
1918	23.98	2.38	20.15	1951	24.79	3.19	-14.03	1984	27.55	5.95	-31.96	2017	23.56	1.96	40.77
1919	24.97	3.37	23.52	1952	14.79	-6.81	-20.85	1985	24.84	3.24	-28.72	2018	24.89	3.29	44.06
1920	27.81	6.21	29.72	1953	25.21	3.61	-17.24	1986	28.92	7.32	-21.40	2019	38.02	16.42	60.48
1921	22.85	1.25	30.97	1954	18.57	-3.03	-20.27	1987	19.12	-2.48	-23.88	2020	19.71	-1.89	58.59
1922	19.76	-1.84	29.13	1955	17.49	-4.11	-24.38	1988	17.88	-3.72	-27.60	2021	22.69	1.09	59.67
1923	19.98	-1.62	27.51	1956	22.86	1.26	-23.12	1989	18.26	-3.34	-30.95	2022	20.64	-0.96	58.71
1924	22.74	1.14	28.64	1957	24.58	2.98	-20.15	1990	22.31	0.71	-30.24	2023	23.42	1.82	60.53
1925	15.46	-6.14	22.50	1958	15.27	-6.33	-26.48	1991	26.26	4.66	-25.58	2024	24.72	3.12	63.65
1926	19.16	-2.44	20.06	1959	19.36	-2.24	-28.72	1992	23.41	1.81	-23.77	2025	12.34	-9.26	54.39
1927	23.37	1.77	21.83	1960	22.99	1.39	-27.33	1993	28.82	7.22	-16.55	Water Year 2025 ends September 30			

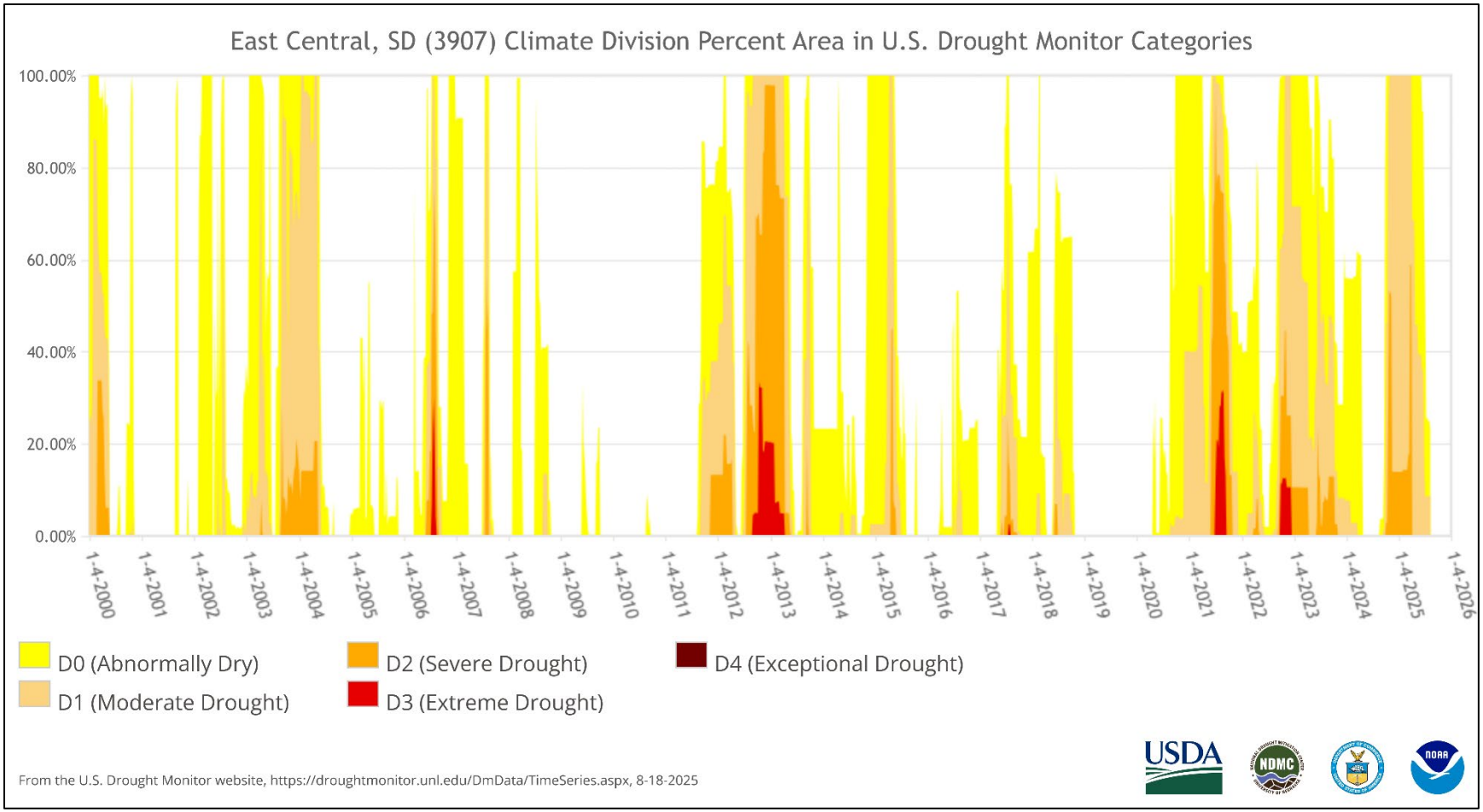

Figure 20: US Drought Monitor for S.D. Division 7 over the period of record (2000 through July, 2025) [17]