



## **PRAIRIE RESEARCH INSTITUTE**

Illinois State Water Survey  
2204 Griffith Drive  
Champaign, IL 61820

June 2, 2020

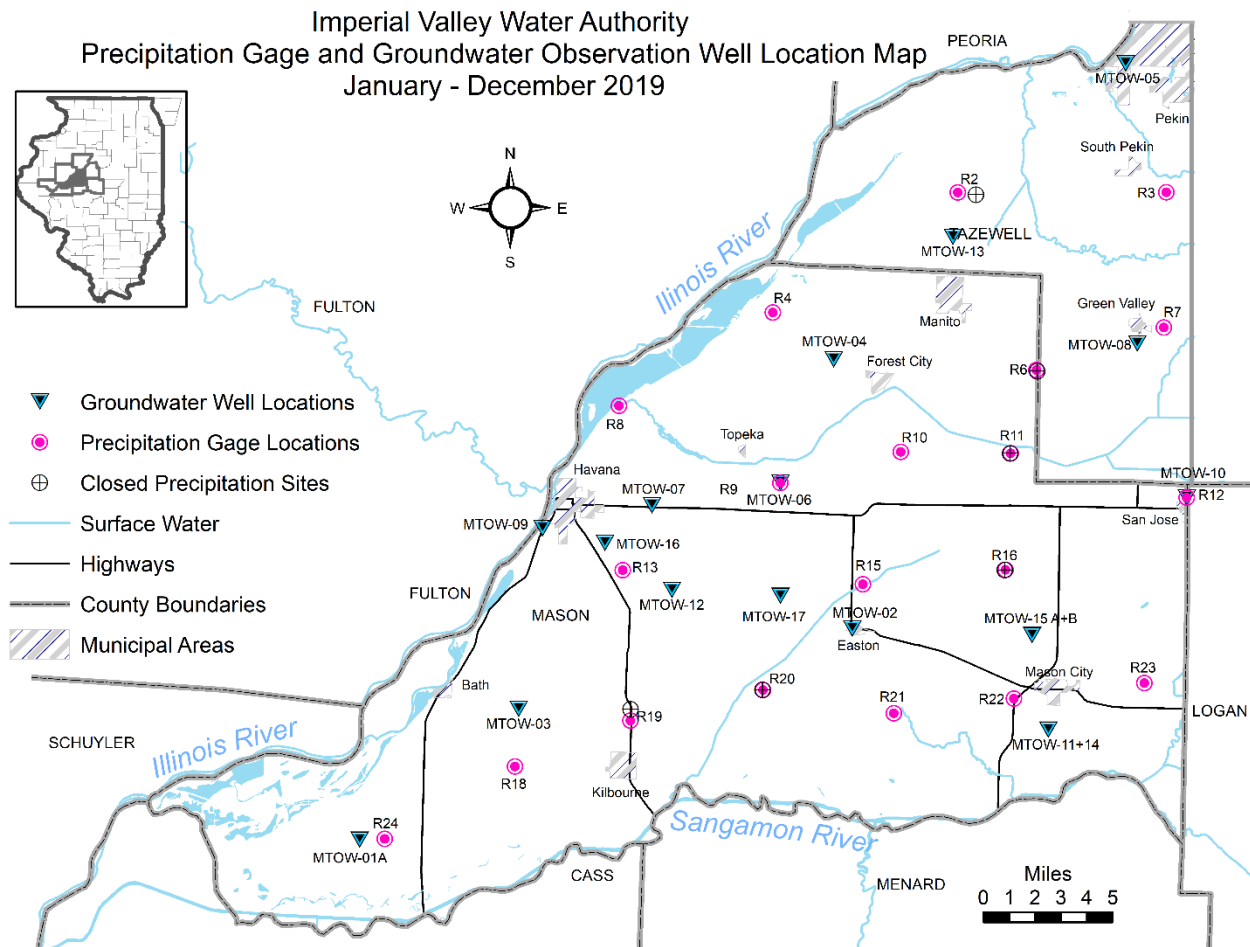
Mr. Jeff Smith, Chairman  
Imperial Valley Water Authority  
25865 E. County Road 1000 N  
Easton, IL 62633

Dear Chairman Smith:

The Illinois State Water Survey (ISWS), under contract to the Imperial Valley Water Authority (IVWA), has operated a network of rain gages in Mason and Tazewell Counties since August 1992 and a network of groundwater observation wells since 1994. The purpose of the rain gage and groundwater observation well networks is to collect long-term data to determine the impact of groundwater withdrawals during dry periods and the growing season, and the rate at which the aquifer recharges. This letter serves as the years end report for Year 27, project/calendar year 2019 (CY2019), which covers the time period from January 1, 2019 through December 31, 2019.

The groundwater observation well network was established in 1995-96 and consists of eighteen wells, MTOW-01 through MTOW-17. MTOW-15 A & B, located northwest of Mason City near Ellsberry Lake, are nested. MTOW-17 is a former 24-inch irrigation well located north of Biggs, Illinois. All the other observation wells within the network are drilled wells between 2 and 6 inches in diameter. In accordance with our agreement, each well, except for MTOW-05 and MTOW-09, is visited by ISWS personnel during the first few days of the month during irrigation season and approximately bi-monthly during the non-irrigated portion of the year. In addition, all wells except for MTOW-05 and MTOW-09 are equipped with data loggers that electronically log the groundwater level data. Figure 1 shows the location of each well.

A 25-site rain gage network (Figure 1) was established in late August 1992 with approximately 5 miles between gages. The network was reduced to 20 sites in September 1996 and during 2019 was maintained by ISWS field technicians Dana Grabowski, Hayden Wennerdahl and Erin Bauer. During these visits, data are downloaded, other routine services are performed, and major maintenance and repairs are completed as needed.



**Figure 1. Configuration of the 16-Site Observation Well and 25-Site Rain Gage Networks.**

Precipitation data collection and reduction activities are similar to those of the previous 26 years. Six gages were moved away from possible obstructions. On August 21, 2019, four gages were moved. The gage at site #2 was moved about 0.66 miles west. At site #6, the gage was moved about 200 feet at a heading of 35 degrees west. The gage at site #11 was moved about 145 ft east. At site #16, the gage was moved about 195 feet east. Two gages were moved on September 3, 2019. The gage at site #19 was moved about 0.44 miles south and at site #20, the gage was moved east 173 feet.

Groundwater levels for each well for the period of record (January 1, 2019 - December 31, 2019) are presented in Appendix A. For MTOW-05, and -09, these wells do not have digital recorders and have only been measured periodically since 2005. These two wells have been shown to mimic the stage in the Illinois River. Stage data from the Illinois River can be used, if necessary to recreate groundwater levels in those regions of the study area. Each hydrograph also contains the daily precipitation for the nearest rain gage, or average of several nearby gages.

Since 1995, the IVWA has estimated irrigation pumpage from wells in the Imperial Valley based on electric power consumption. Menard Electric Cooperative provides the IVWA with electric power consumption data for the irrigation services they provide during the growing

season (June-September). The pumpage estimate assumed that application rates for the irrigation wells with electric pumps in Menard Electric Cooperative also are representative of other utilities and other energy sources. Past estimates assumed that 33 percent of the irrigation wells were in Menard Electric Cooperative in 1995-1997, 40 percent in 1998-2001.

In 2002, the U.S. Geological Survey (USGS) updated the formula used to calculate pumpage by closely measuring the pumping rate at 77 irrigation systems serviced by Menard Electric. The updated formula provides estimates that are appreciably lower than the previous formula, by approximately 20 percent. Therefore, irrigation withdrawals for the years 1997 to the present were recalculated using the new formula, replacing earlier published estimates (reports through Year 12 use the original formula).

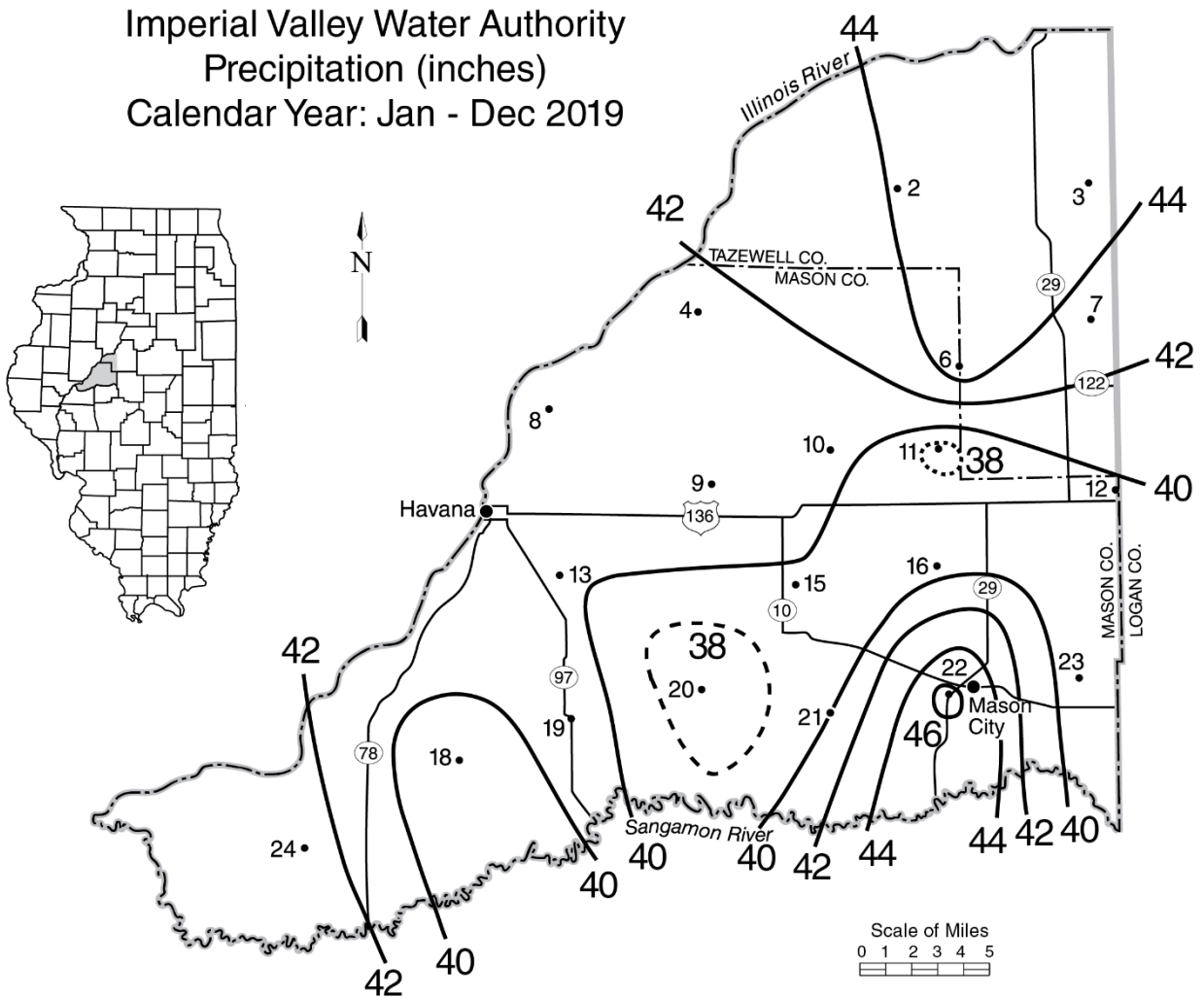
The CY2019 rain gage dataset was used to produce gage and network-wide summaries of total and average precipitation at various time scales including individual storm events, monthly, seasonal, and annual time periods. Monthly and annual time scale summaries are compared with the previous 26-year (1993-2018) network average precipitation record, unless explicitly noted to clearly compare the CY2019 record with a long-term average.

In accordance with our agreement, the ISWS also maintains the Imperial Valley Water Authority website (<http://imperialvalleywaterauthority.org/>). The most frequently updated portion of this site is the data collection tab, which includes annual updates of estimated irrigation, links to real-time groundwater levels, monthly precipitation reports, and archived version of this letter report dating back to 2004. The site is also used to update important items, such as details of proposed ordinances.

## **Precipitation Analysis**

The Imperial Valley network precipitation was 41.09 inches in CY2019, January – December 2019, which was much more than the previous 26-year annual (Jan – Dec., 1993-2018) average of 34.91 inches. Figure 2 shows the distribution of total annual precipitation in CY2019. Table 1 provides the monthly and annual total precipitation for each rain gage and the network monthly and annual average precipitation for January - December 2019.

The lowest annual precipitation occurred in the central region of the network, centered on gages #20 and #11. Gages #22 and #3 collected the most precipitation in CY2019, 46.82 and 45.60 inches, respectively. During CY2019, annual gage totals ranged 10.68 inches, from 36.14 inches at site #20 to 46.82 inches at site #22. Ten-inch differences between gages in annual precipitation amounts are not unusual during any given year, representing natural variability. If large differences between individual gages are repeated year after year, this would suggest possible differences caused by differences in gage exposure to the wind or by measurement errors. Gages that are overly sheltered or with little or no shelter from the wind (most of the gage sites) can underestimate precipitation under strong wind conditions.

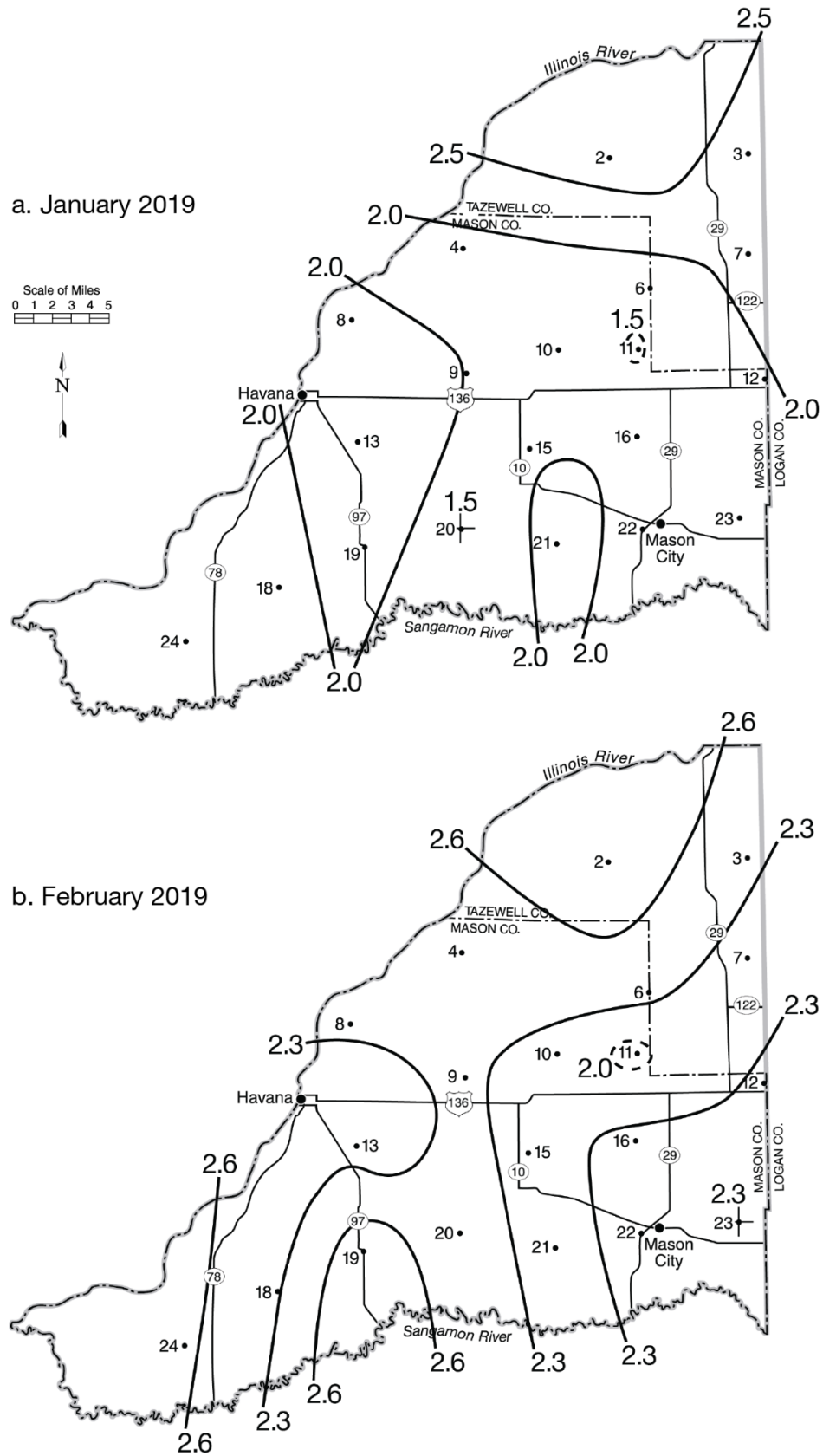


**Figure 2. Total Precipitation (inches) for January - December 2019 (CY2019).**

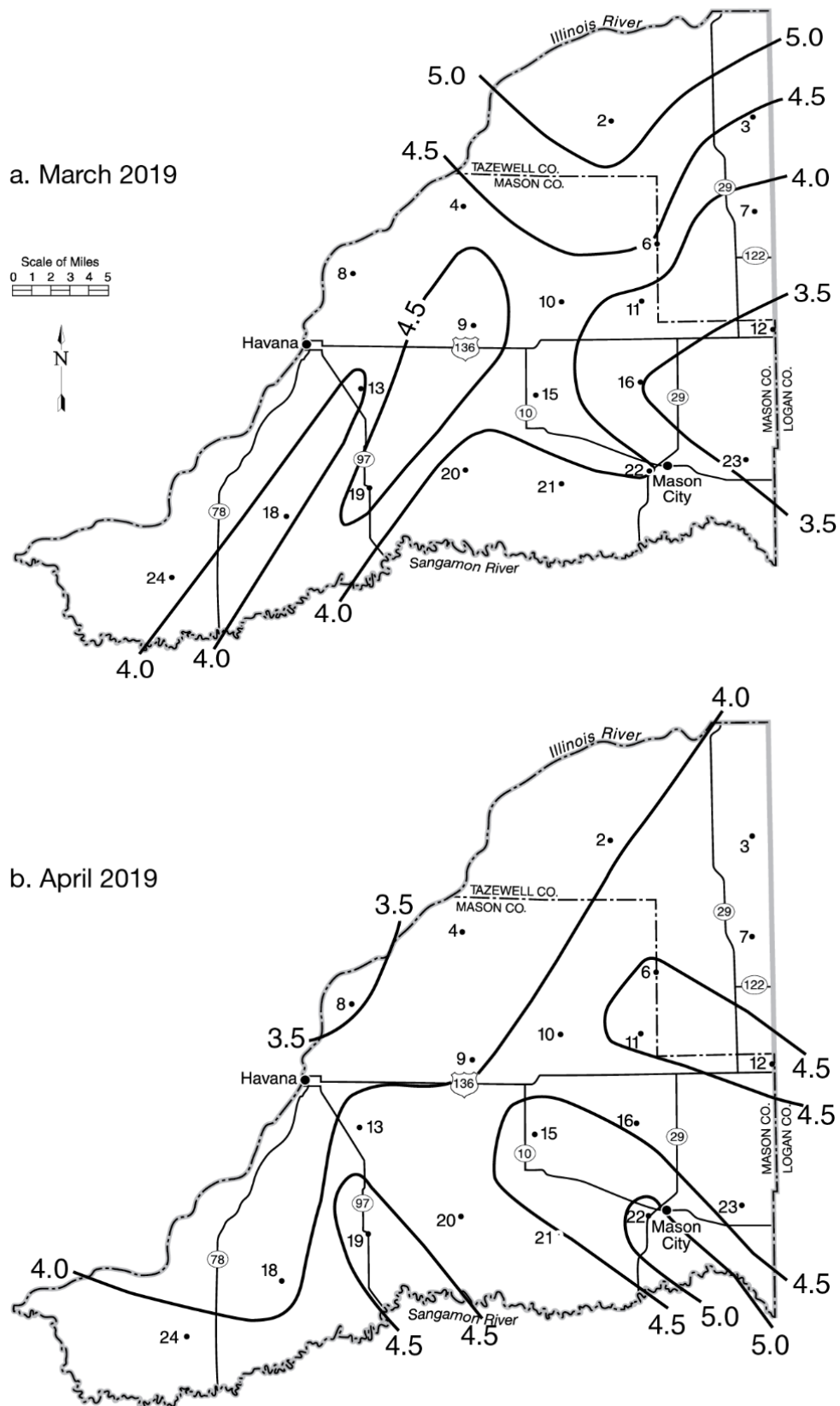
**Table 1. Monthly Precipitation Amounts (inches), January-December 2019**  
**Calendar Year Annual Totals**

<i>Station</i>	<i>Month</i>												<i>CY</i>
	<i>2019</i>												<i>2019</i>
	<i>Jan</i>	<i>Feb</i>	<i>Mar</i>	<i>Apr</i>	<i>May</i>	<i>Jun</i>	<i>Jul</i>	<i>Aug</i>	<i>Sep</i>	<i>Oct</i>	<i>Nov</i>	<i>Dec</i>	<i>Total</i>
2	2.73	2.83	5.28	3.92	7.45	4.10	1.04	1.82	6.27	4.68	1.76	2.13	44.01
3	2.41	2.41	4.48	4.41	8.11	4.75	2.88	2.48	6.38	3.97	1.76	1.56	45.60
4	1.86	2.35	4.38	3.95	9.49	3.96	0.65	1.00	6.00	4.33	1.68	1.63	41.28
6	1.74	2.39	4.48	4.53	7.37	5.71	1.22	1.52	7.18	4.70	2.12	2.12	45.08
7	2.15	2.12	3.79	4.28	7.28	4.88	3.11	1.61	6.37	4.04	1.69	1.56	42.88
8	2.05	2.32	4.15	3.37	7.40	4.93	1.09	2.48	6.07	3.73	1.50	1.04	40.49
9	2.00	2.34	4.71	3.83	7.91	5.17	0.55	1.25	4.90	4.31	2.13	1.67	40.77
10	1.65	2.18	4.19	4.02	7.25	5.79	1.08	1.01	6.51	3.77	1.83	1.68	40.96
11	1.49	1.94	3.86	4.81	4.29	5.77	0.85	1.31	5.97	3.92	1.93	1.59	37.73
12	1.97	2.36	3.42	4.58	6.22	6.36	0.76	2.15	4.99	3.71	1.70	1.36	39.58
13	2.25	2.19	3.97	4.29	7.02	5.34	1.47	1.64	5.02	4.05	2.03	1.48	40.75
15	1.67	2.23	4.33	4.84	6.72	4.23	1.91	1.69	4.72	3.94	1.88	1.58	39.74
16	1.87	2.34	3.51	4.41	5.60	6.93	0.94	1.82	4.78	4.13	1.68	1.38	39.39
18	1.74	2.28	3.74	3.67	5.70	3.69	3.86	2.01	4.07	3.93	1.78	1.47	37.94
19	2.42	2.75	4.80	4.79	7.18	4.77	1.79	1.86	3.89	4.24	1.79	1.52	41.80
20	1.50	2.43	3.67	4.16	6.58	4.23	0.99	1.80	3.77	3.74	1.75	1.52	36.14
21	2.13	2.20	3.87	4.49	6.70	4.77	2.66	2.59	3.79	3.82	1.53	1.30	39.85
22	1.86	2.39	4.06	5.18	7.78	7.14	3.90	2.69	4.62	4.12	1.59	1.49	46.82
23	1.80	2.30	3.32	4.23	6.52	4.86	2.14	2.06	4.18	3.92	1.64	1.20	38.17
24	1.99	2.75	4.26	4.41	7.04	4.01	3.55	4.01	3.62	4.06	1.71	1.40	42.81
Avg	1.96	2.36	4.11	4.31	6.98	5.07	1.82	1.94	5.15	4.06	1.77	1.55	41.09

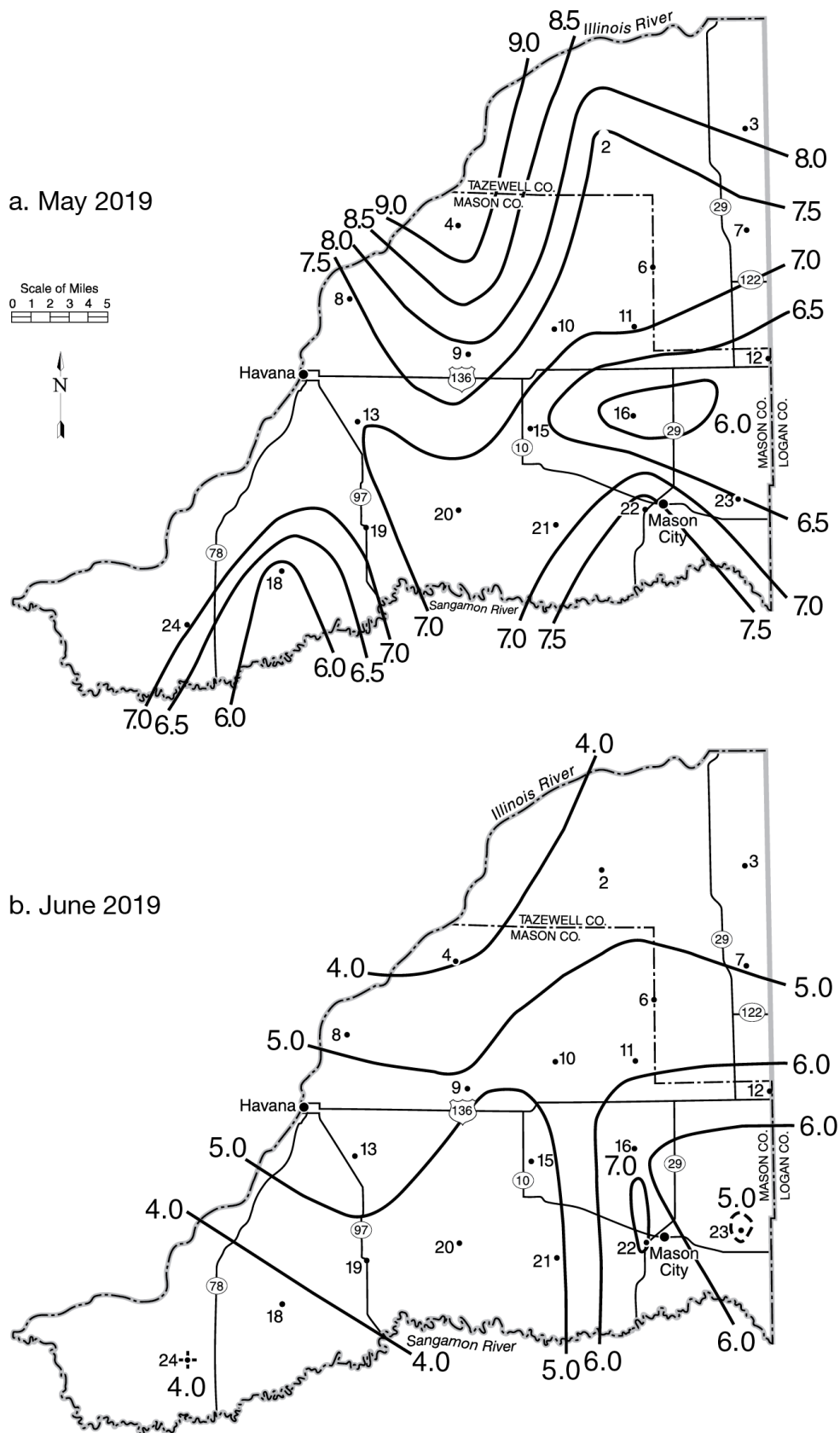
The monthly network precipitation maps for CY2019 are shown in Figures 3 - 8.



**Figure 3. Precipitation (inches) for January 2019 and February 2019**

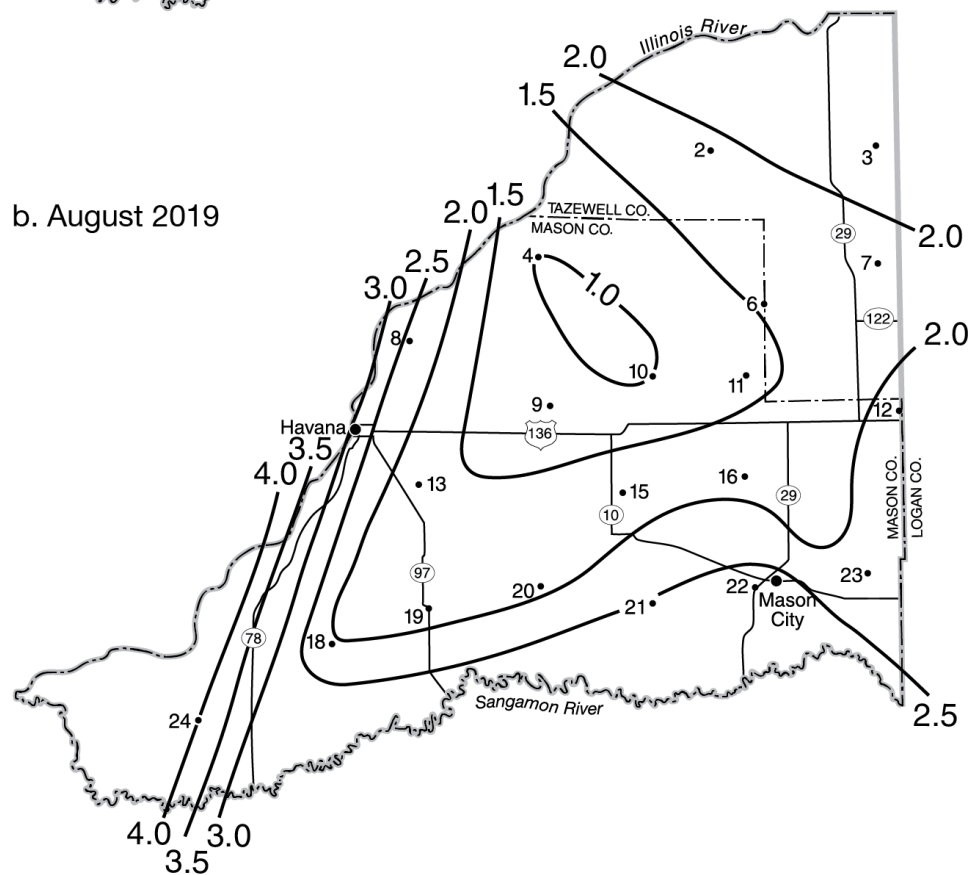
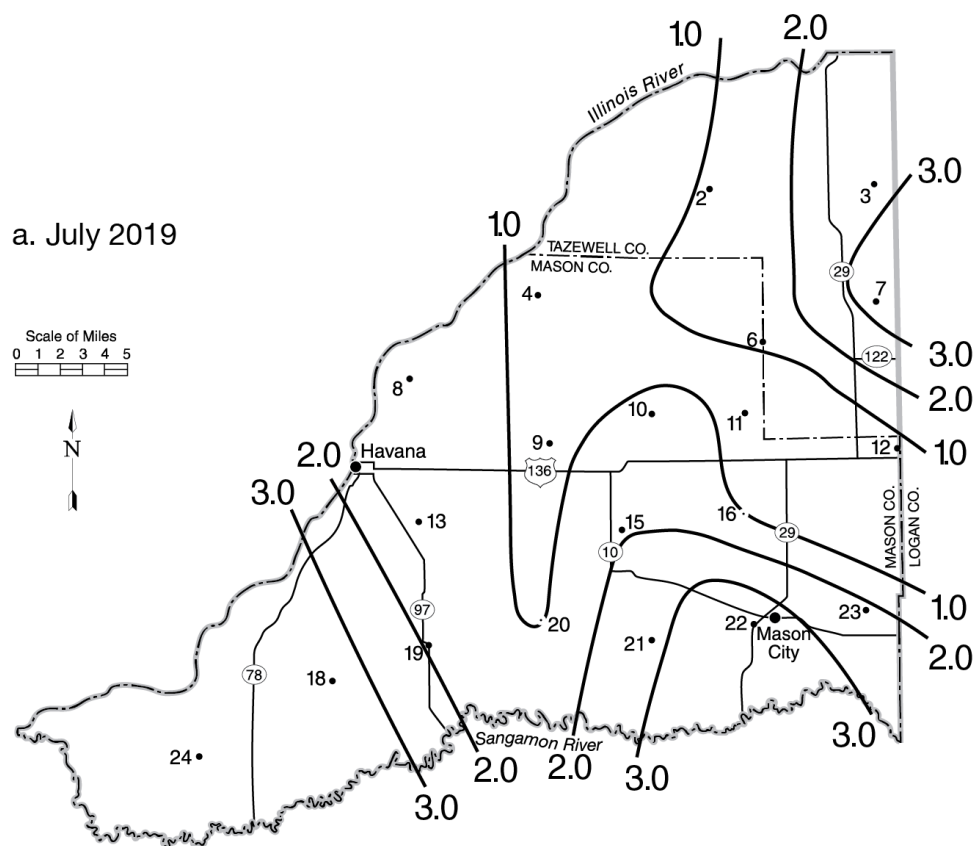


**Figure 4. Precipitation (inches) for March 2019 and April 2019**

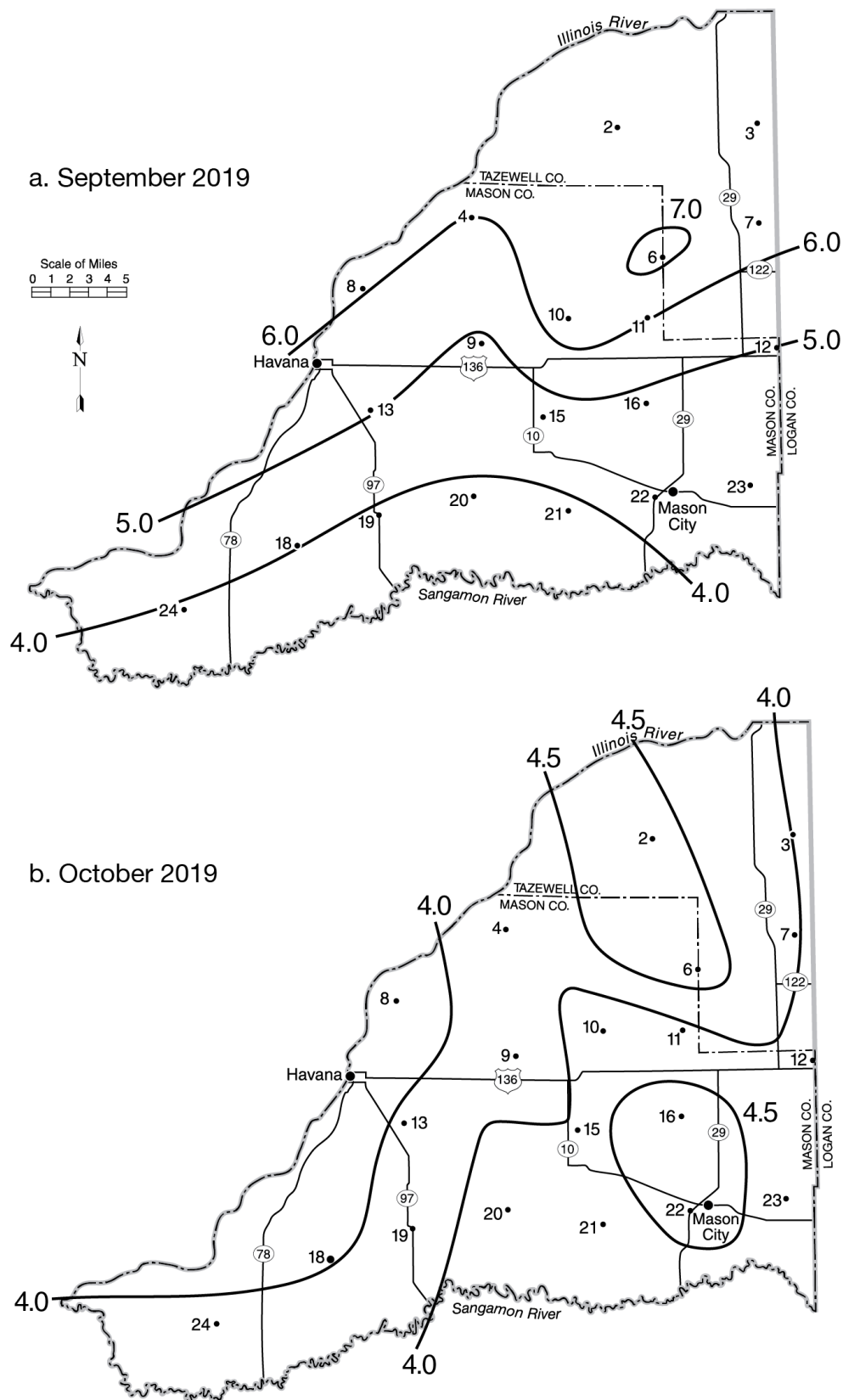


**Figure 5. Precipitation (inches) for May 2019 and June 2019**

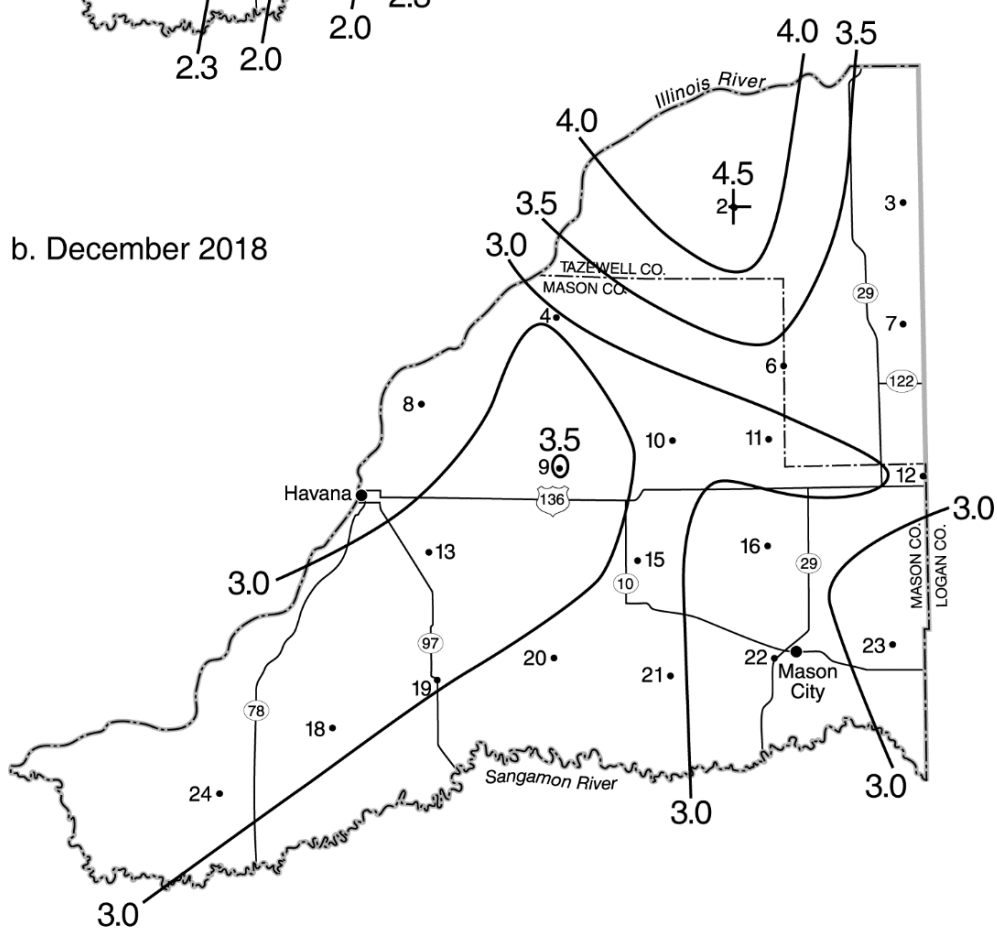
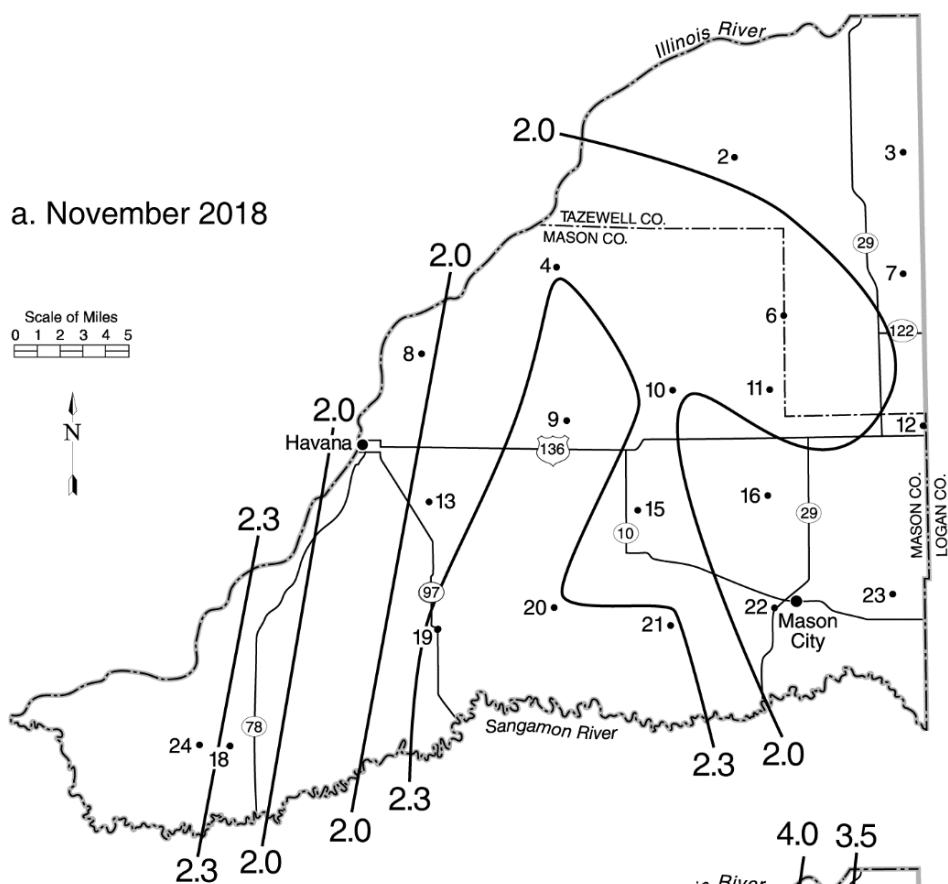




**Figure 6. Precipitation (inches) for July 2019 and August 2019**



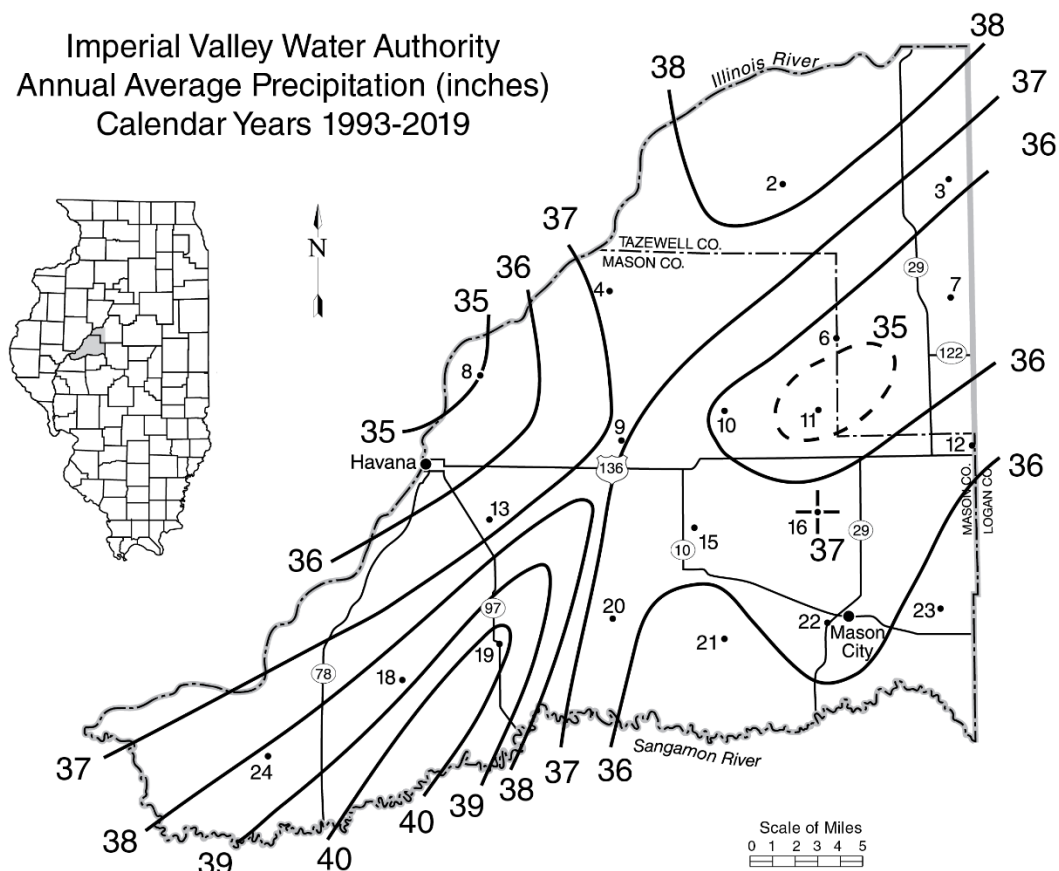
**Figure 7. Precipitation (inches) for September 2019 and October 2019**



**Figure 8. Precipitation (inches) for November 2019 and December 2019**

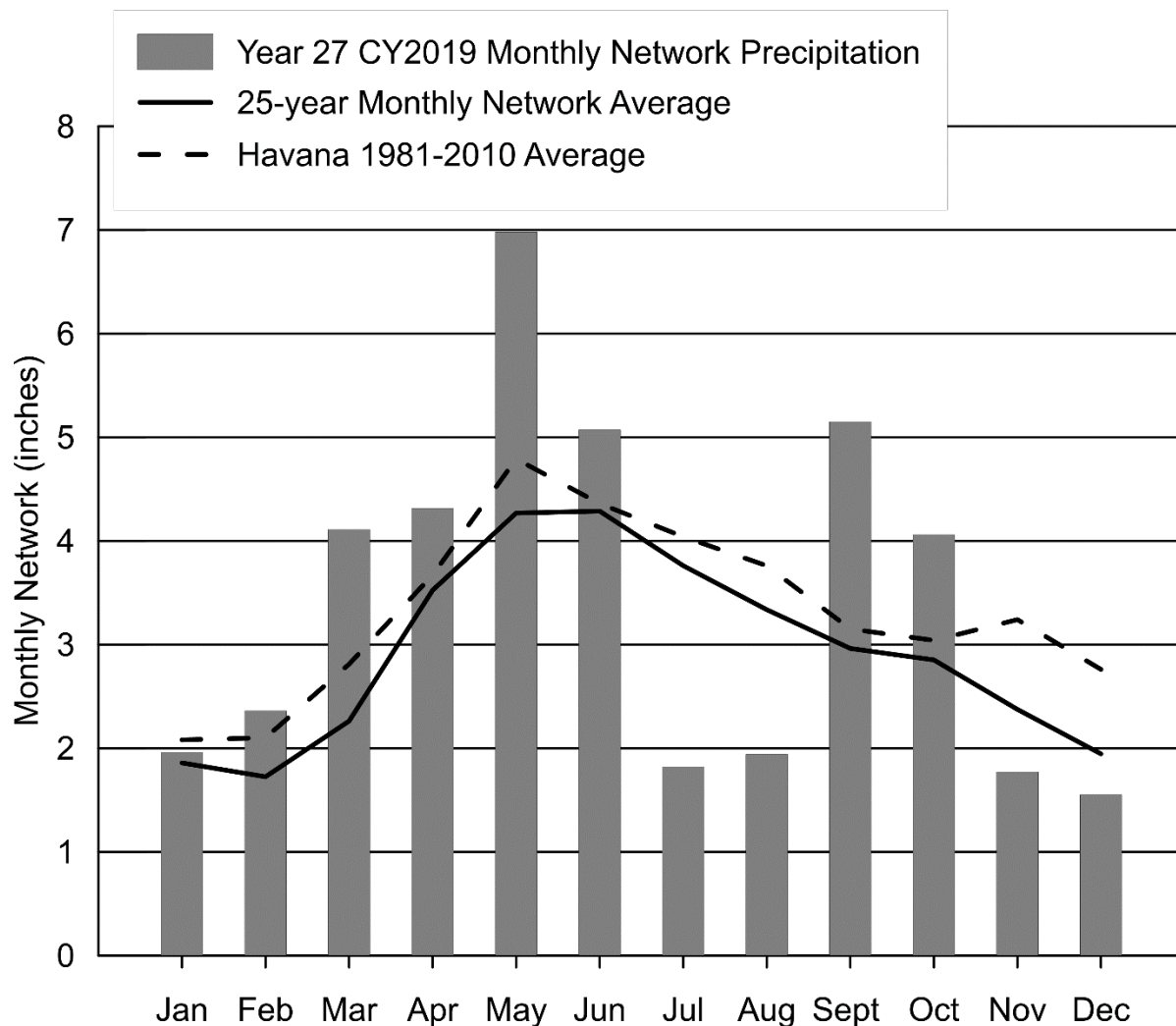
## Network Long-term Average Precipitation

Network annual average precipitation is the average of calendar years 1993 - 2019 annual precipitation. Figure 9 provides the contours for the 27-year annual average precipitation, January 1993 through 2019. Precipitation contours create a pattern of parallel trending contours to the Illinois River along the southwestern half of Mason County. The 27-year average annual precipitation was highest along a line from Gage #24 to #18 to #16, roughly parallel to the Illinois River.



**Figure 9. Average Annual Precipitation (inches, calendar year) for January 1993 – December 2019, 27 years.**

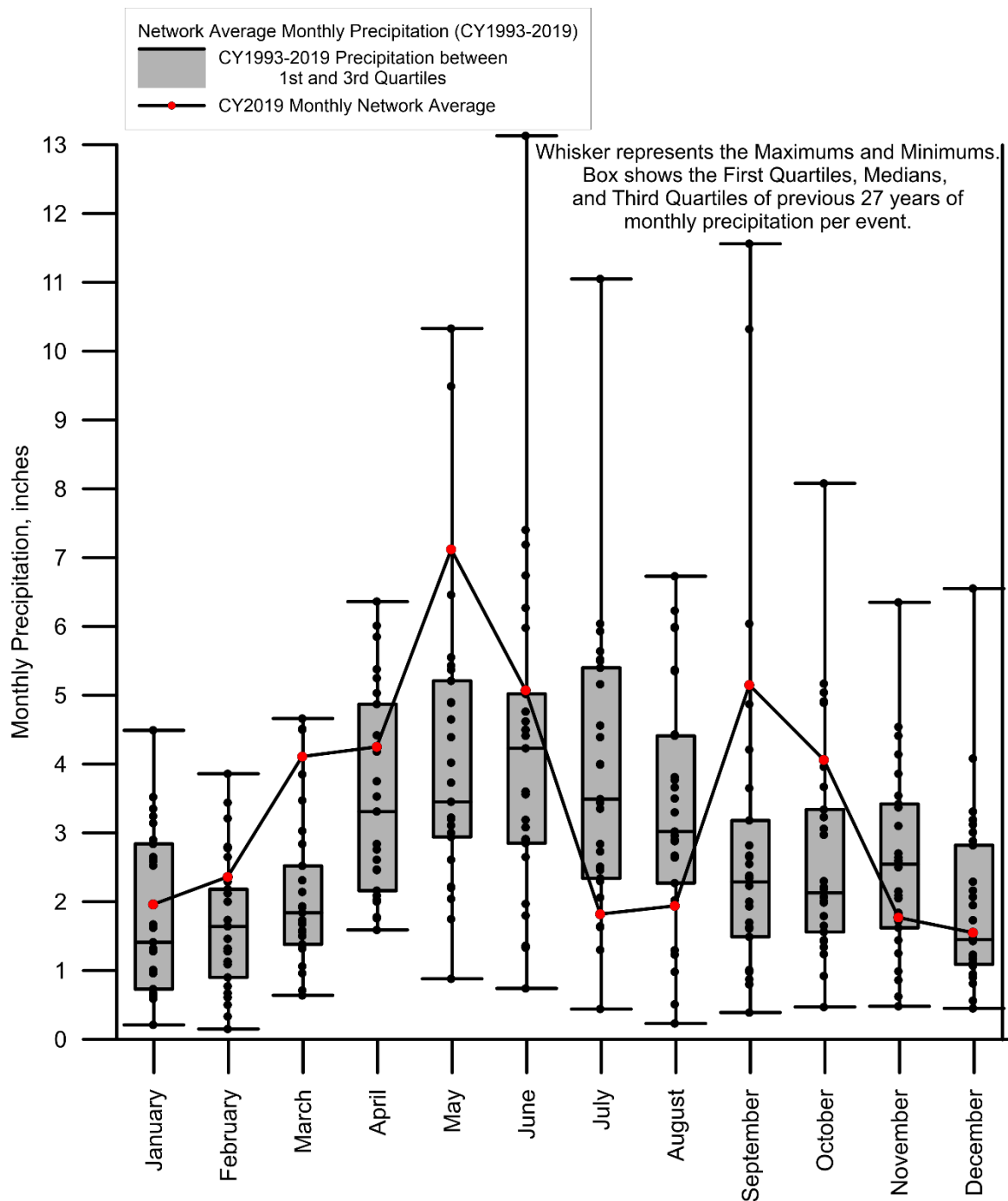
The following bar graph, Figure 10, compares the network monthly averages for CY2019 with the previous 26-yr historical monthly network averages (1993-2018 not including 2019) and the 1981-2010 (30 yrs.) Havana, IL monthly averages. During CY2019, the heaviest precipitation occurred during May and September which were 168% and 179% of the previous 26-yr network monthly average. May received 2.82 inches and September 2.27 inches more than average. March precipitation was also much higher than the previous long-term average, at 188% or 1.92 inches greater than the previous 26-yr average. Four months of 2019 had below average precipitation. The IV network received 1.82 inches in July (2.02 inches deficit) and 1.94 inches in August 2019 (1.45 inches deficit), this is 47% and 57% the previous 26-year average for those months. November and December 2019 also reported lower than average precipitation. November received 1.77 inches or 74% and December received 1.55 inches or 79% of the previous 26-year average. January 2019 was the only month with monthly network precipitation near the long-term average (within 6%). Seven months had well above and four months had well below the previous 26-year monthly averages.



**Figure 10. Monthly Comparison with 27-Year IVWA Network Average and 1981-2010 (30 Year Average) at Havana, IL Gage.**

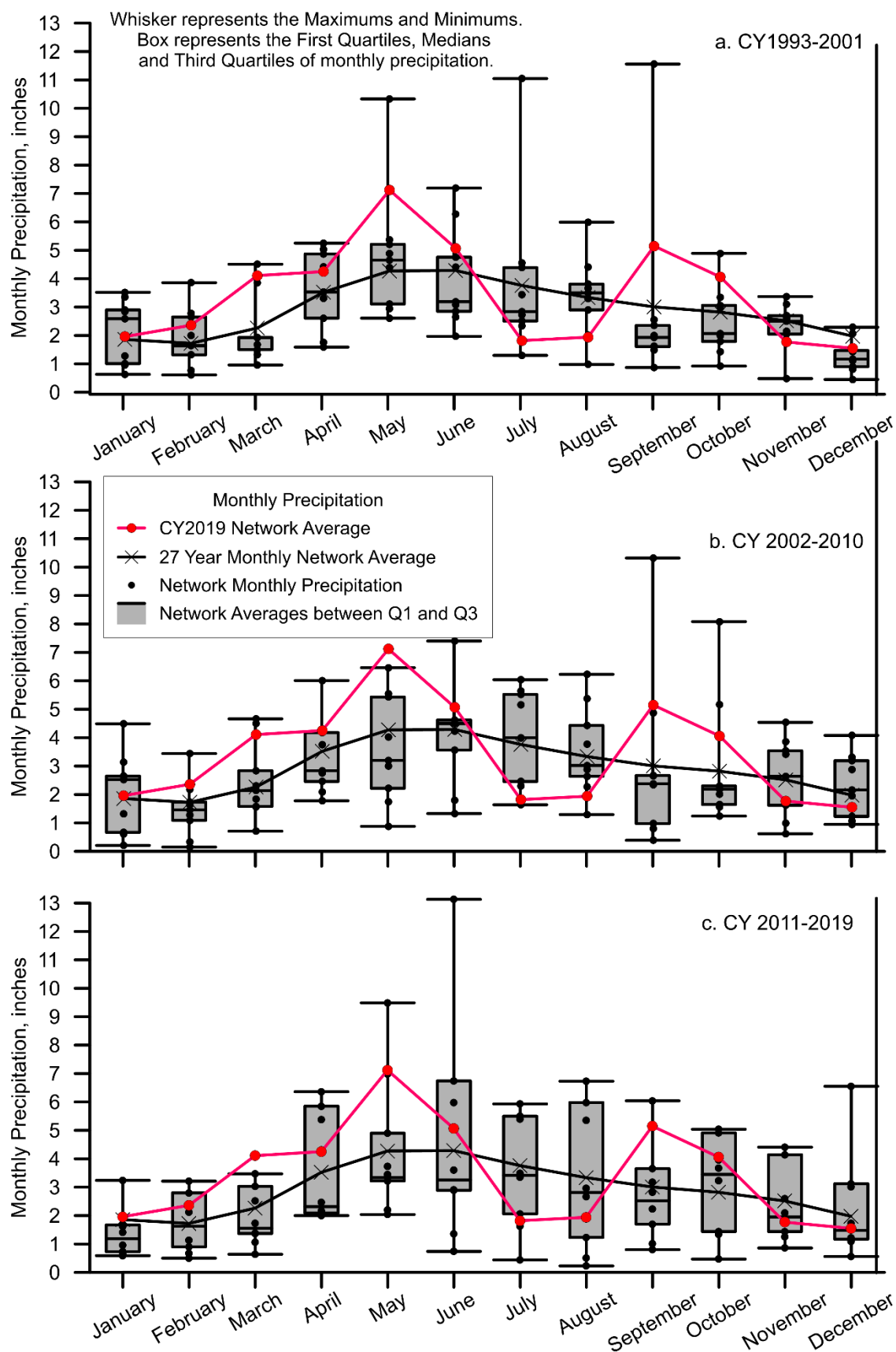
Monthly network variability including minimum, maximum, medians, and quartiles of the 27-yr monthly precipitation data are shown in Figure 11. See Appendix B: Explanation of Box-Whisker Plots for an explanation of how to interpret box-whisker plots.

Monthly precipitation during the spring of 2019 was well above and in summer well below the previous 26-yr average. Monthly precipitation was above the 3<sup>rd</sup> quartile (> 75% of occurrences) for six months (February, March, May, June, September, and October), and below the 1<sup>st</sup> quartile (< 25% of occurrences) in July and August. Months with the larger interquartile range (longest box) indicate greater variability of precipitation during that month. This variability can change over time.



**Figure 11. 27-year Monthly Average Precipitation Distribution with CY2019 Monthly Network Averages**

In the following analysis, the 27-year period of record is divided into 3 periods, 1993-2001, 2002-2010, and 2011-2019. Figure 12 presents the monthly precipitation variability during these periods in comparison to the current year's average monthly precipitation. In comparing the length of the boxes (variability in total monthly precipitation), the earliest period had the least amount of variability and the last period has had the greatest overall variability. Monthly precipitation variability has increased for all months except for January and May. Monthly variability for August increased the most compared to other months from the first to the third period.



**Figure 12. Monthly Box-Whisker Plots of ~9 Year Time Spans. a. CY 1993-2002, b. CY 2003-2010 and c. CY 2011-2019**

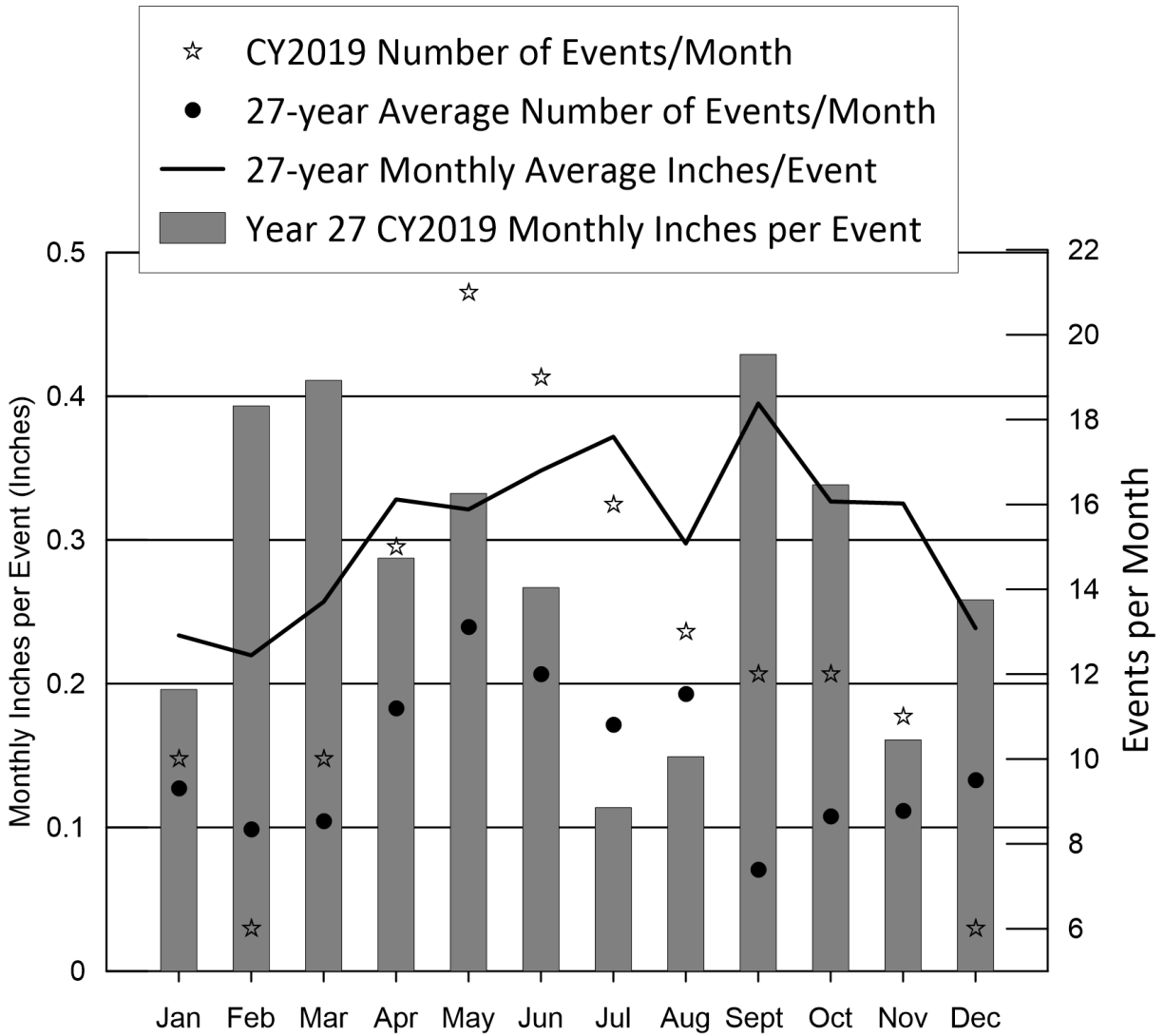
Mean monthly, seasonal, and annual number of network storms (precipitation events) were determined for January through December 2019 and presented in Table 2. A network storm period is defined as a precipitation event separated from proceeding and succeeding events at all network stations by at least three hours. The historic average for inches per event over the previous 26 years (1993-2018) is 0.30 inches per event. Calendar year 2019 received an average of 0.27 inches per event.

**Table 2. Comparison of Total Precipitation (inches), Number of Precipitation Events, and Average Precipitation per Event for Each Month and Season, 1993-2018 and CY 2019**

<i>Period</i>	<i>1993-2018 26-yr average</i>			<i>January -December 2019</i>		
	<i>Precipitation</i>	<i>Events</i>	<i>Inches/event</i>	<i>Precipitation</i>	<i>Events</i>	<i>Inches/event</i>
<b>January</b>	1.85	9.3	0.23	1.96	10	0.20
<b>February</b>	1.70	8.3	0.22	2.36	6	0.39
<b>March</b>	2.19	8.5	0.26	4.11	10	0.41
<b>April</b>	3.49	11.2	0.33	4.31	15	0.29
<b>May</b>	4.16	13.1	0.32	6.98	21	0.33
<b>June</b>	4.26	12.0	0.35	5.07	19	0.27
<b>July</b>	3.84	10.8	0.37	1.82	16	0.11
<b>August</b>	3.39	11.5	0.30	1.94	13	0.15
<b>September</b>	2.88	7.4	0.39	5.15	12	0.43
<b>October</b>	2.80	8.7	0.33	4.06	12	0.34
<b>November</b>	2.40	8.8	0.33	1.77	11	0.16
<b>December</b>	1.96	9.5	0.24	1.55	6	0.26
<b>Winter 2018</b>	5.74	26.2	0.23	8.43	26	0.32
<b>Spring 2018</b>	11.91	36.3	0.33	16.36	55	0.30
<b>Summer 2018</b>	10.10	29.7	0.34	8.91	41	0.22
<b>Fall 2018</b>	7.16	26.9	0.27	7.38	29	0.25
<b>Calendar Annual</b>	34.92	119.5	0.30	41.08	151	0.27

The Imperial Valley Water Authority precipitation network has an average of 119.5 storm events per year during the previous 26-years. During CY2019, there were 151 precipitation events, 32 events more than the previous 26-year average, 26 percent above the average. Seasonally, spring of 2019 had 18.5 more events than the average of the previous 26 years. As also shown in Figure 13, summer 2019 had 11 events more than average and fall had 2 events more than average. May and June had over 7 and 8 more events than the 26-year average. September and July had around 5 more events than the 26-year average. February and December 2019 were the only months with less than the 26-year average of precipitation events.

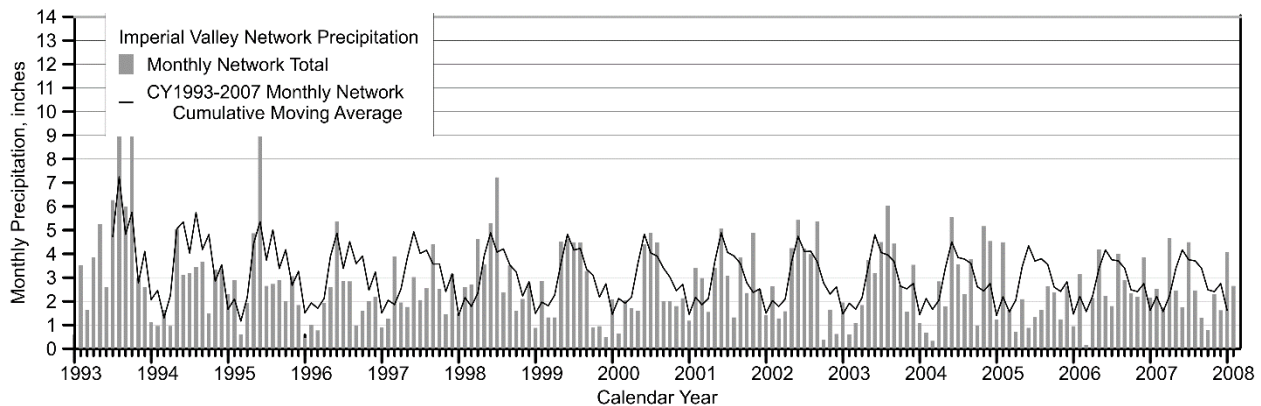




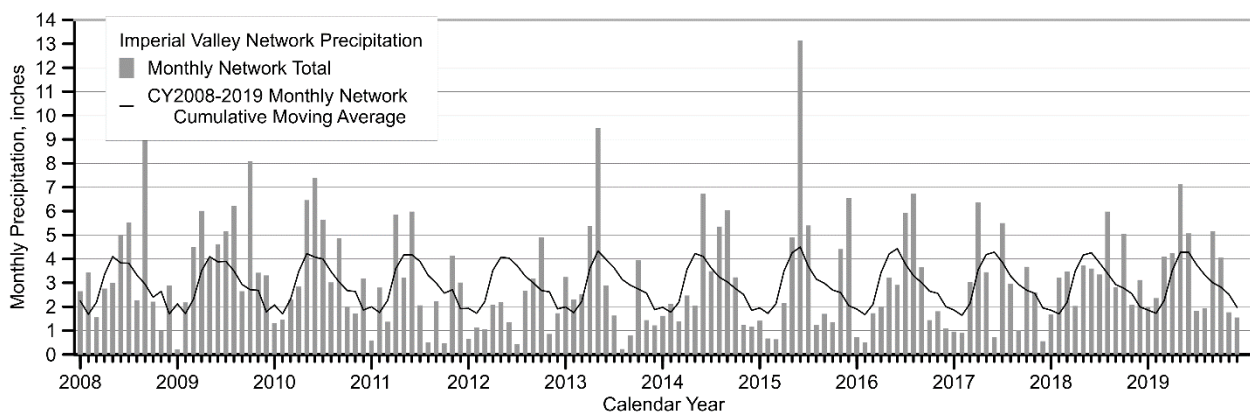
**Figure 13. CY 2019 Events per Month and Inches per Month compared to 27-year Averages**

The following 2 plots in Figure 14 compare the network average monthly precipitation for January 1993 through December 2019 and the cumulative moving average of the monthly precipitation. The cumulative moving average is the average of the preceding years. For example, the cumulative moving average compared with January 2019 is the average precipitation of Januarys 1992-2019. The change in the shape of the cumulative moving average shows how each month's precipitation affects the monthly precipitation average over time.

#### a. 1993 – 2007



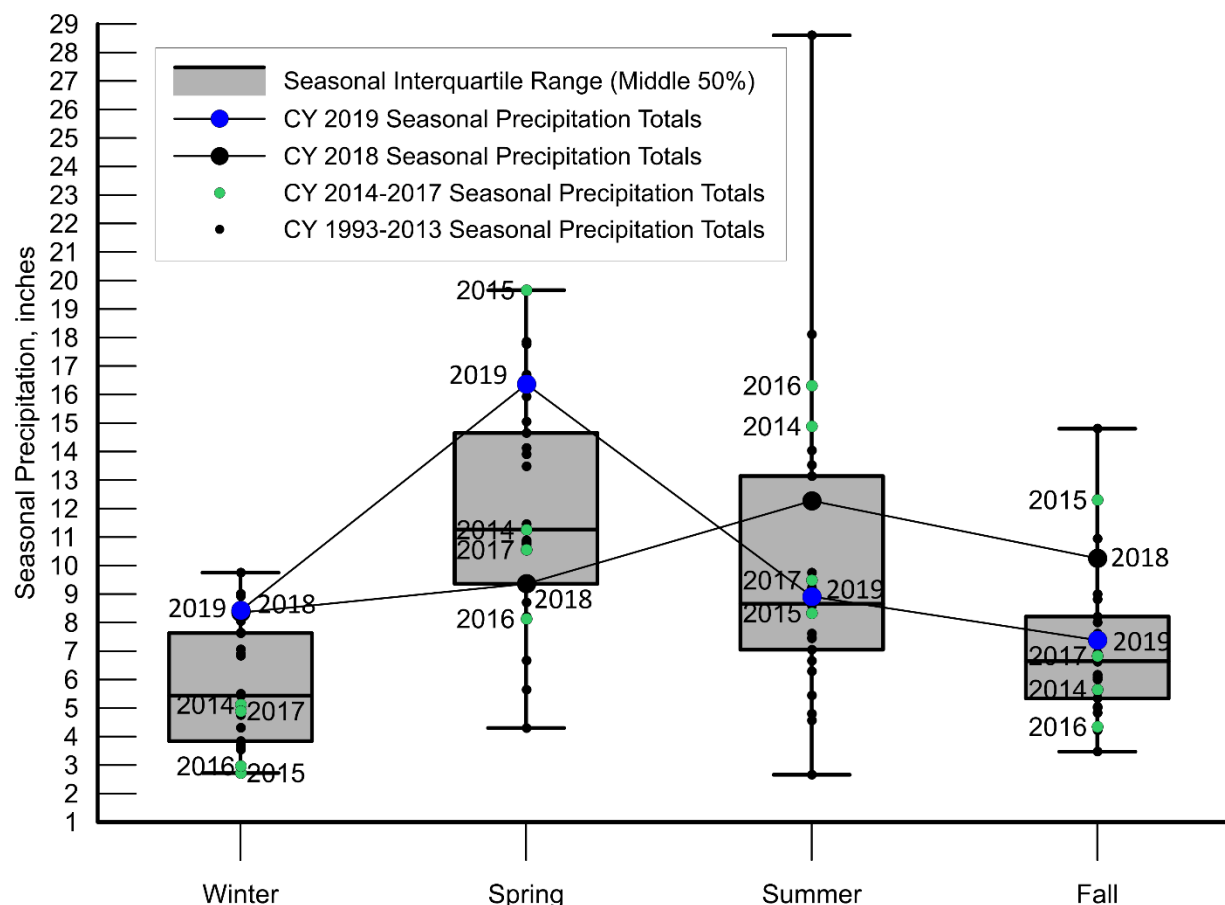
#### b. 2008 - 2019



**Figure 14. Network Average Monthly Precipitation (inches)**  
**a. January 1993 - December 2007, b. January 2008 - December 2019**

CY2019 network average of 41.08 was 5.19 inches wetter than the previous 26-year (1993-2018) network average of 34.92 inches. Precipitation was much greater than average (> 125%) during 5 months of the year and less than 90 percent of average during another 4 months. July 2019 received only 47 percent of the July 26-yr average.

Figure 15 compares the 26-year seasonal medians and variations with the CY2019 seasonal totals. Winter 2018 (January – March) received much more rain than the previous 26-yr seasonal median and was the fourth wettest winter (just above CY2018) since this precipitation collection began in fall of 1992. Spring also ranked as the fourth wettest in 27 years, well-above the 3rd quartile (> 75% frequency). The summer (July, August, and Sept) precipitation total was near the 26-year median due to unusually large precipitation during September, which was more than July and August precipitation combined. Fall 2019 was also within the 50% frequency due to October precipitation, more precipitation occurred in October than in November and December combined.

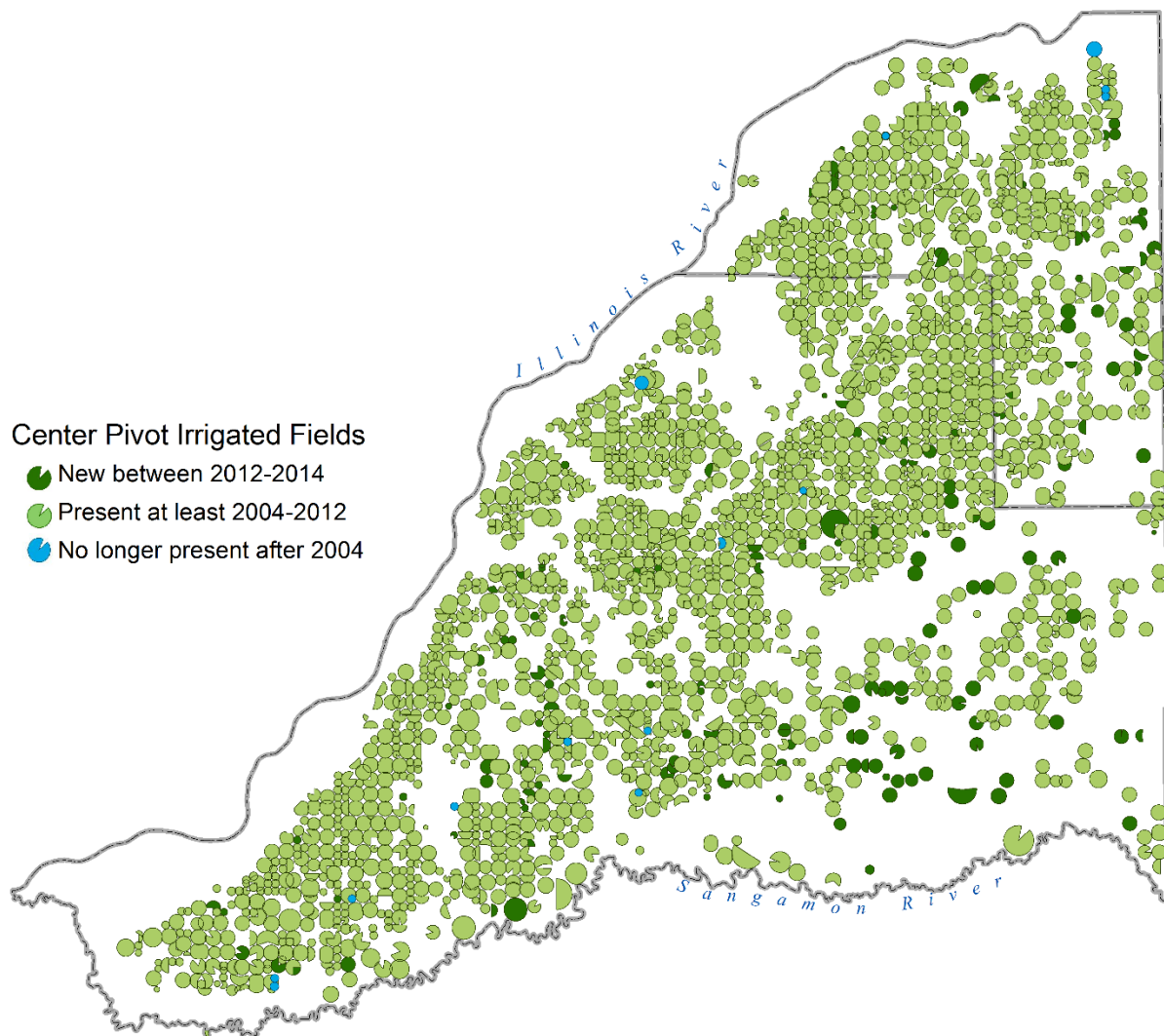


**Figure 15. Seasonal Network Average Precipitation with Seasonal Totals for Each Calendar Year. Box Plots Show the Interquartile Range (Middle 50% of Values, Median (horizontal line within the box), Minimum, and Maximum Values at whisker ends.**

## Irrigation Water Use

The IVWA has provided the ISWS a monthly estimated total pumpage of irrigation since 1997. These data are calculated by the Imperial Valley by evaluating power consumption at nearly 1100 irrigations systems in the area supplied by the Menard Electric Cooperative. The pumpage is a monthly aggregate of all irrigation which occurs over the water authority area. The water authority area includes Mason County and parts of six townships in Tazewell County as shown in Figure 1.

The total irrigation pumpage in 2019 was approximately 52.9 billion gallons (bg), which is the sixth highest irrigation amount for the observation period. The number of irrigation systems is now at 2252. During 2014, the ISWS developed a statewide map of irrigation based on USDA aerial photography. Based on those data, it was determined the number of irrigation systems in the IVWA was lower than the IVWA was estimating. The IVWA uses new well construction reports to determine the number of irrigation systems each year, which does not necessarily account for wells installed to replace existing wells. This likely led to the over-counting of irrigation systems by the IVWA. Figure 16 shows the location of irrigation systems in the IVWA area in 2014.



**Figure 16. Location of Irrigation Systems within the IVWA (2014).**

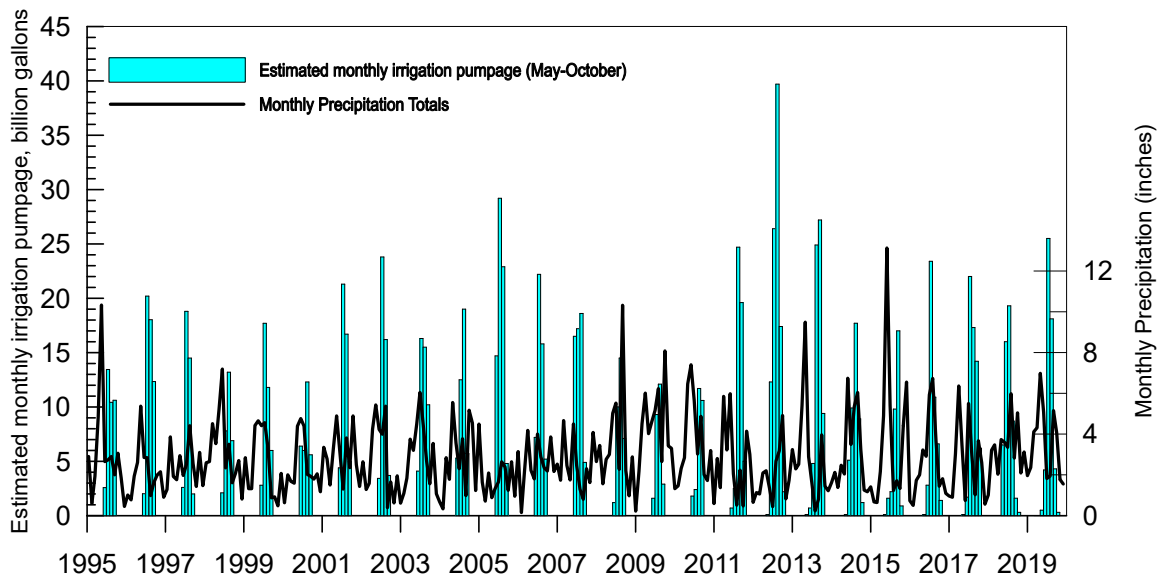
The monthly and seasonal estimates of irrigation withdrawals are shown in Table 3, with the right-hand column ranking from irrigation amounts from highest to lowest. Year 27 was near the top, ranking sixth overall with 52.9 bg pumped for the year. The higher than normal precipitation during the spring and lower than normal precipitation amounts during summer affected irrigation practices. Irrigation for May and June were less than their respective averages at 0.5 bg and 4.2 bg. July had the third highest irrigation total for the period of record, at 25.5 billion gallons (bg), 10.2 bg more than the long-term average. August was at 18.1 bg, slightly (1.5 bg) above the long-term average. September and October were below average.

**Table 3. Estimated Monthly Irrigation Withdrawals (billion gallons), Number of Irrigation Systems, Withdrawal per System and Withdrawal Rank**

<i>Year</i>	<i>May</i>	<i>June</i>	<i>July</i>	<i>August</i>	<i>September</i>	<i>October</i>	<i>Total#</i>	<i>Systems</i>	<i>BG/system</i>	<i>Rank</i>
1995		2.6	14	10	11		38			18
1996		2.0	20	18	12		52			8
1997		2.6	19	14	2.0		38			18
1998		2.1	7.8	13	6.9		30	1622	.018	22
1999		2.8	18	12	6.0		39	1771	.022	17
2000		6.4	6.0	12	5.6		30	1799	.017	22
2001		4.4	21	17	5.0		47	1818	.026	11
2002		3.4	24	16	3.7		47	1839	.026	11
2003		4.1	16	15	10		46	1867	.025	13
2004		5.3	12	19	5.7		42	1889	.022	15
2005		15	29	23	4.8		72	1909	.038	2
2006		7.2	22	16	5.2		50	1940	.026	10
2007		16	17	19	4.9		57	1971	.029	5
2008		1.2	10	14.5	7.1		33	2014	.016	20
2009		1.6	9.3	12.1	2.9		26	2054	.013	25
2010		1.8	2.4	11.7	10.6		27	2077	.013	24
2011		0.7	2.5	24.7	19.6	5.0	52	2100	.025	8
2012	0.1	12.3	26.4	39.7	17.4	2.2	98	2160	.045	1
2013	0.1	0.7	4.8	25.0	27.2	9.4	67	2293	.029	3
2014	0.1	4.7	9.2	16.3	8.2	1.1	40	2169*	.018	16
2015	0.1	1.6	2.2	9.8	17.0	0.9	31	2197	.014	21
2016	0.1	2.8	23.4	10.9	6.6	1.4	45	2223	.020	14
2017	0.1	1.7	22.0	17.3	14.2	6.2	61.5	2237	.027	4
2018	6.5	16.0	19.3	8.7	1.6	0.3	52.4	2252	.023	7
2019	0.5	4.2	25.5	18.1	4.3	0.3	52.9	2262	.023	6
Average	1.0	4.9	15.3	16.5	8.9	3.0	49.6		.023	

**Note:** Total annual withdrawal may differ from sum of monthly withdrawals due to rounding error.

\*Total number of systems was updated during June 2014 by ISWS using aerial photography.



**Figure 17. Estimated Irrigation Pumpage and Average Monthly Precipitation, IVWA.**

The estimated monthly irrigation pumpage is displayed graphically in Figure 17 along with average monthly network precipitation. These pumpage values show a tendency for lower irrigation amounts during times of increasing precipitation and vice versa, but also show that irrigation is dependent on the timing of precipitation. Table 4 provides a comparison of rainfall and irrigation parameters showing their overall relationship. The irrigation rank is from least pumpage to most so that ranks between precipitation and pumpage are comparable.

In many years, the total precipitation is not a good indicator for how much irrigation was necessary. 2019 is a great example of this. Although 2019 was the fifth wettest year since this study began, it also required the sixth most irrigation. Why is this? Even though the spring was incredibly wet, July and August were much drier than average (Figure 10). A similar observation can be made in 2018, which had the seventh most precipitation and seventh most irrigation.

**Table 4. Average Annual Precipitation, Annual Precipitation Surplus, and Ranked Annual Precipitation and Irrigation, Imperial Valley Network**

<i>Project Year*</i>	<i>Network average precipitation (in.)</i>	<i>Annual surplus (in.)</i>	<i>Rank Precip.</i>	<i>Irrigation**</i>
1992 - 1993	55.55	+17.17	1	-
1993 - 1994	40.21	+1.83	6	-
1994 - 1995	39.42	+1.04	10	18
1995 - 1996	25.70	-12.68	26	8
1996 - 1997	27.31	-11.07	24	18
1997 - 1998	40.06	+1.68	8	22
1998 - 1999	34.02	-4.36	15	17
1999 - 2000	25.81	-12.57	25	22
2000 - 2001	30.97	-7.41	19	11
2001 - 2002	39.91	+1.53	9	11
2002 - 2003	30.06	-8.32	20	13
2003 - 2004	29.64	-8.74	21	15
2004 - 2005	27.34	-11.04	23	2
2005 - 2006	27.74	-10.64	22	10
2006 - 2007	31.94	-6.44	17	5
2007 - 2008	35.02	-3.36	13	20
2008 - 2009	49.34	+10.96	2	25
2009 - 2010	47.91	+9.53	3	24
2010 - 2011	34.17	-4.21	14	8
2011 - 2012	21.44	-16.94	27	1
2012 - 2013	38.35	-0.03	11	3
2013 - 2014	32.63	-5.75	16	16
2014 - 2015	41.23	2.85	4	21
2015 - 2016	37.75	-0.63	12	14
2016 - 2017	31.88	-6.50	18	4
CY2018	40.11	1.73	7	7
CY2019	41.09	2.71	5	6

\*Starting in 2018, the Project Year ran from Jan-Dec, prior it ran from Sept-Aug

\*\*Irrigation ranks are from lowest total pumpage to highest for comparison with precipitation.

1981 - 2010 30-yr average	39.80 (Havana)
1981 - 2010 30-yr average	36.98 (Mason City)
1981 - 2010 30-yr average	38.38 (average of Mason City and Havana used to determine surplus)
1993 - 2017 26-yr average	35.21 (26-year IVWA network average)

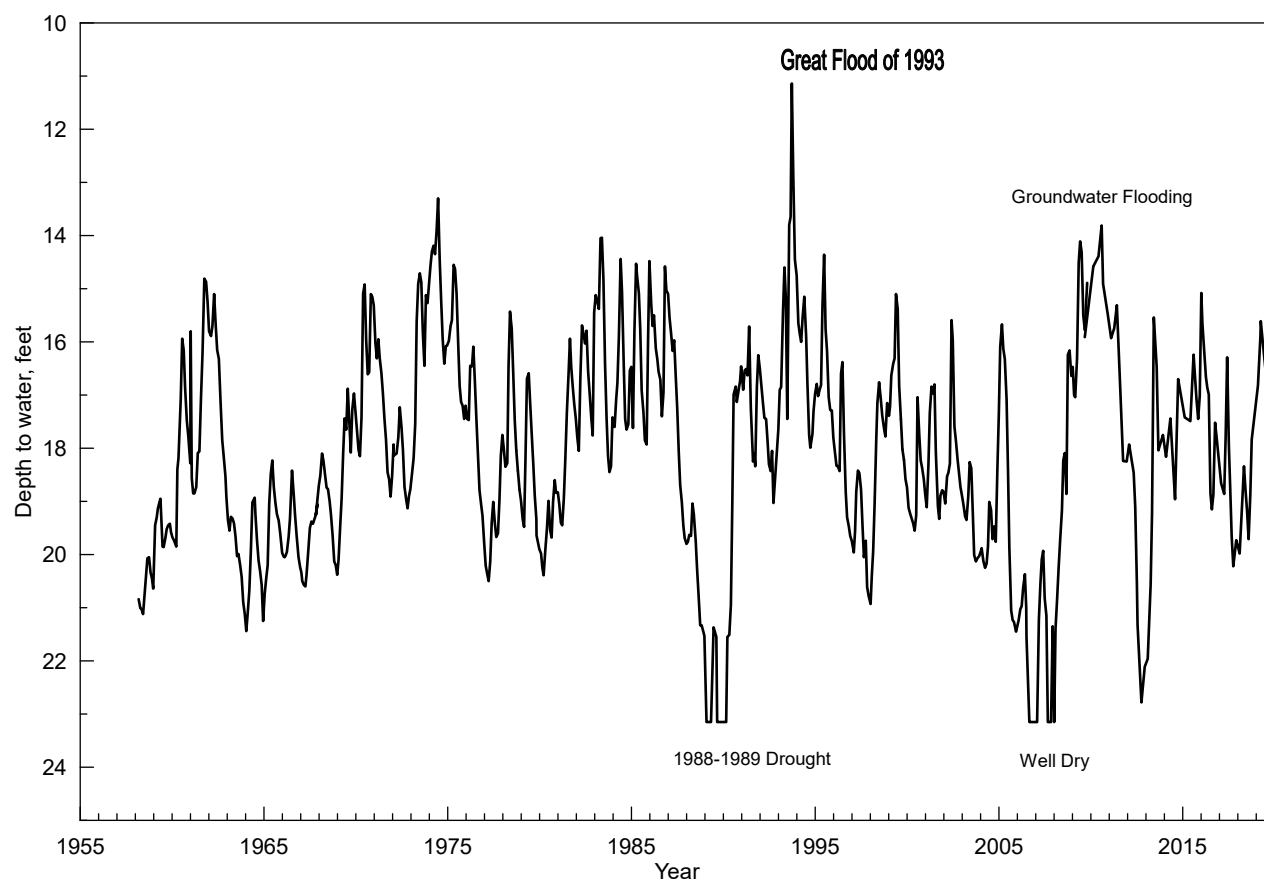
## Groundwater Levels

In an unconfined system, like the aquifer in the Havana lowlands, water levels typically vary by season. The highest water levels in the aquifer generally occurs during the spring and lowest during early fall. Hydrographs for each well show that water levels in the study area generally fall in late spring through the summer when discharge and withdrawals from the aquifer due to evapotranspiration and irrigation pumpage are at their greatest. Precipitation is not high enough during this time to raise water levels in the aquifer. Most rainfall goes to replenish soil moisture, and make up for irrigation withdrawals. Significant recharge to the aquifer most often occurs during winter and early spring when there is little pumpage, evapotranspiration is low, and soil moisture is more likely high.

### Observations from hourly hydrographs

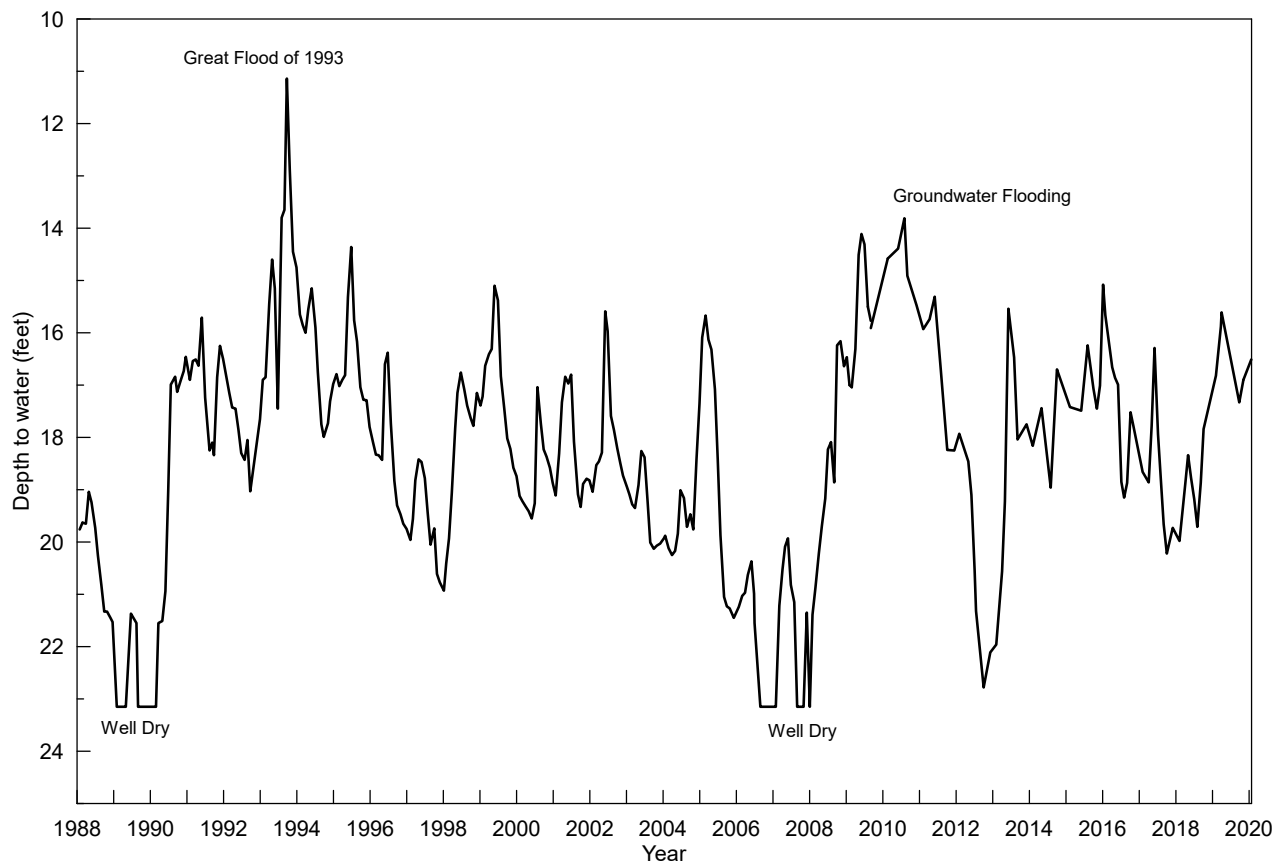
Appendix A shows the hydrographs for the 18 long-term wells within the observation well network. The hydrographs in Appendix A show water levels in each well for CY2019, from January 1, 2019 to December 31, 2019, and contain all groundwater elevation or depth to water from land surface data and daily precipitation totals for nearby rain gages. The hydrographs created from hourly water level measurements have led to an increased understanding of the relationship between rainfall, irrigation, water levels, and recharge. They have also raised more questions which modelers are attempting to understand better.

**MTOW-01A.** The long-term hydrograph at MTOW-01A (Snicarte, 1958 to present) in Figure 18 provides a historical reference for comparison with the shorter records of the other network wells. The ISWS has a record of water levels at this site since 1958. Annual fluctuations from less than a foot to more than 8 feet have been observed. A detailed look at water levels at the Snicarte site since 1990 is shown in Figure 19. During the 1988-1989 drought, the water level fell to 40.5 feet below land surface in the Snicarte well. At the time, it was the only time in its 45-year history that the well had went dry, until it did so again in 2006 and 2007. During the 1993 flood, groundwater levels rose and peaked at approximately 11 feet below land surface in September 1993. The September 1993 water level of 11.14 feet below land surface is the highest water level to date for the Snicarte well.



**Figure 18. Groundwater Levels at the Snicarte Well, 1958-2019.**

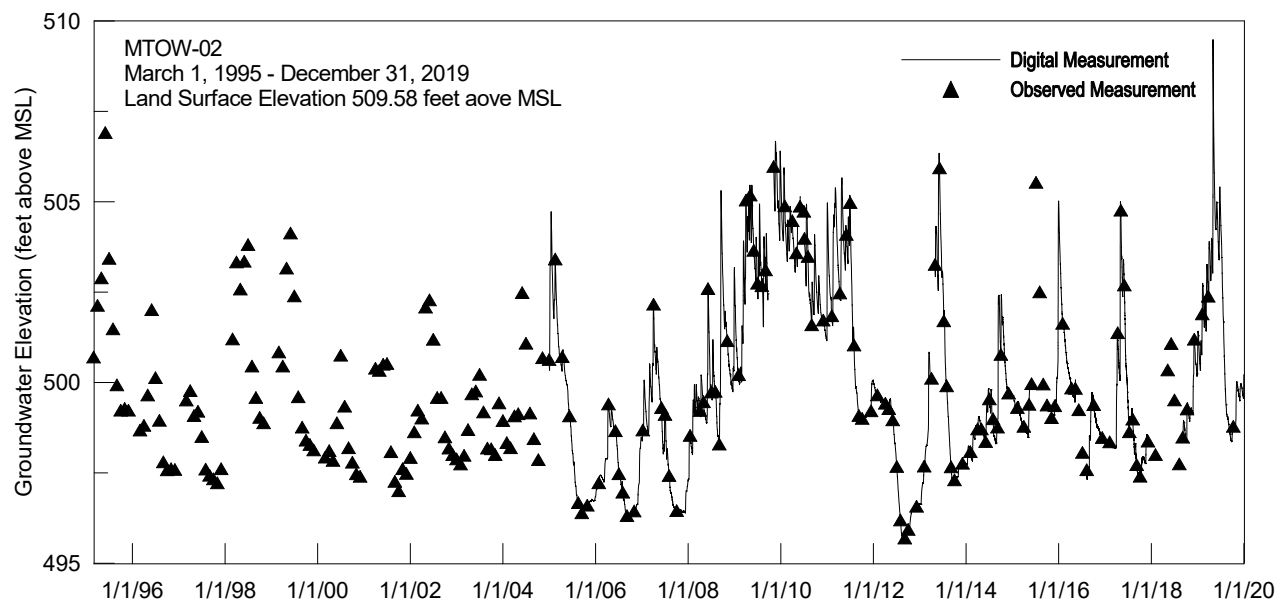




**Figure 19. Groundwater Levels at the Snicarte Well, 1988-2019.**

Even though estimated irrigation withdrawals were the sixth highest on record for the region in 2019, observed drawdown at this well was among the smallest observed over the period of record (Figure 19). May precipitation at the closest rain gage to the Snicarte well, 24, was 7.04 inches, very similar to the regional average (6.98 inches). However, June precipitation for this gage, 4.01 inches, was 1.06 inches less than average. This trend did not continue. The rain gage measured 3.55 and 4.01 inches in July and August, as opposed to the average precipitation of 1.82 and 1.94 inches for the rest of the region. This indicates that a regional assessment of precipitation and irrigation cannot provide a complete story for every well in the monitoring network- local variability can have a major impact on the degree of change in water levels. This is also a strong indicator for the importance of continuing to pair as many rain gages as possible with respective wells.

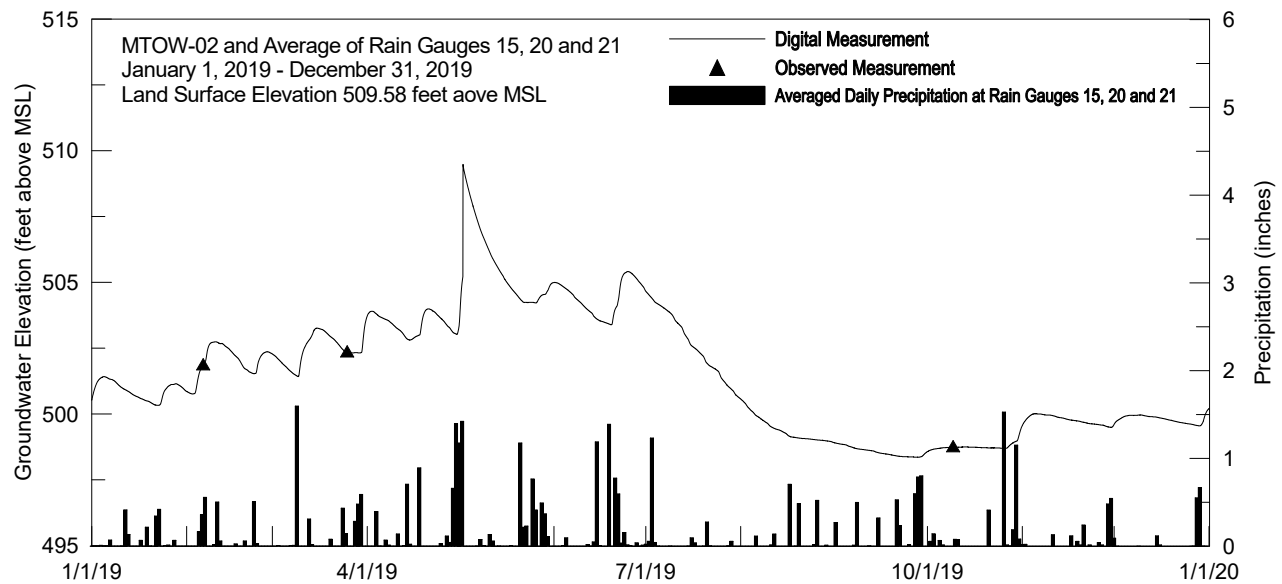
## **MTOW-02:**



**Figure 20. Groundwater Elevations at the Easton Well, MTOW-02, September 1, 1995-December 31, 2019.**

Figure 20 shows the entire period of record for MTOW-02, located within the village limits of Easton, IL. The highest observed head at this well occurred on May 2, 2019, with an elevation of 509.34 ft, only 0.24 ft from land surface. While rare, water levels this high are not unprecedented, with a similar event occurring in June 1995. In contrast, water levels on September 27, 2019 reached a low of 498.36 ft, similar to the other end of irrigation season water levels observed since the 2012 drought. The difference in the maximum and minimum water level in 2019 was 10.98 ft. For comparison, the difference between the lowest water level during the 2012 drought and the highest coming out of the drought was 9.79 ft. Having such high and low water levels in such a short time period reflects the recharge capabilities of the aquifer, particularly in the Easton region. It also highlights the influence rainfall has on the aquifer when the water table is so shallow and the aquifer is unconfined.

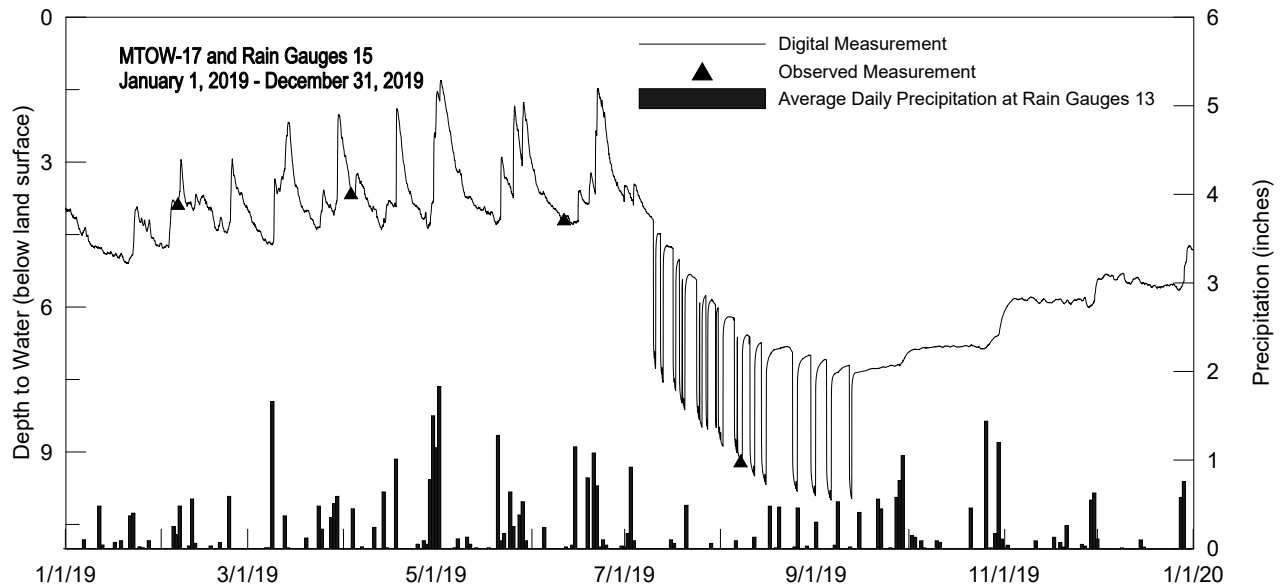
In Figure 21, which shows the response in water levels due to precipitation events in 2019, the relationship between rainfall and recharge is more easily observed as groundwater levels rise during periods of heavy precipitation. Most of the events are subdued, for example, water levels rose from 502.33 ft on March 27 to 503.90 ft on April 2, a rise of 1.57 ft. However, the response to precipitation on April 30 was much greater, with water levels rising from 503.06 ft to 509.3 ft, a rise of 6.24 ft. Also notable about this event is that it comes to a discrete point and is followed by a recession curve, as opposed to the smoother, more gradually changing water level fluctuations that preceded and followed this event. The ISWS is currently working to model this event to try to better understand drivers of recharge in the IVWA. The leading hypothesis is that the combination of magnitude (~1.5 inches) and duration of the rain event (4-5 days) in late April/early May led to the spikier response.



**Figure 21. Groundwater Elevations at the Easton Well, MTOW-02, January 1, 2019 - December 31, 2019**

**MTOW-17.** MTOW-17 is a unique well in that it is within a few feet of an active irrigation well, allowing for a crisper understanding of the local impacts of irrigation. As seen in Figure 22, the impact of pumping on aquifer water levels is evident. Each “downward spike” on the hydrograph is a pumping event from the nearby irrigation pivot. Even still, each pumping event only causes a short-term drawdown of about 3 feet, superimposed on an additional months long three feet decline that is indicative of a combination of local and regional withdrawals.

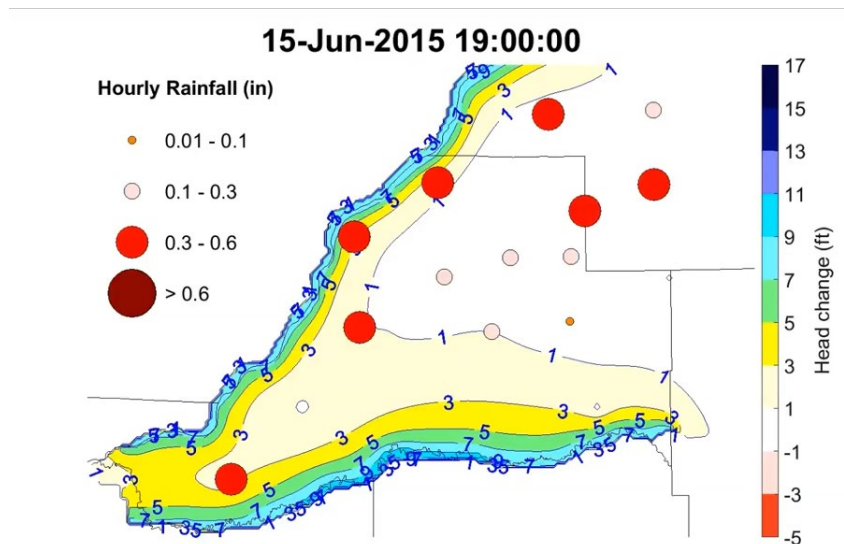
Interestingly, during precipitation events, water levels behave more similarly to the spiky response at Easton during late April-early May 2019. This is likely due to the shallow depth to water at MTOW-17 during the spring, which results in recharge events happening much more rapidly than they would if water levels were deeper. Contrast with MTOW-02 (Easton), where springtime water levels start deeper and took consecutive days of persistent rain to exhibit this spiky response. This impact of deeper water levels is evident at MTOW-17 during the precipitation events immediately following the irrigation season in 2019. In September and onward, the rise in water levels is much more gradual and not punctuated by “sharp upward spikes”.



**Figure 22. Groundwater Elevations and Precipitation at the Biggs Well, MTOW-17, January 1, 2019-December 31, 2019**

### Groundwater Flow Modeling Update

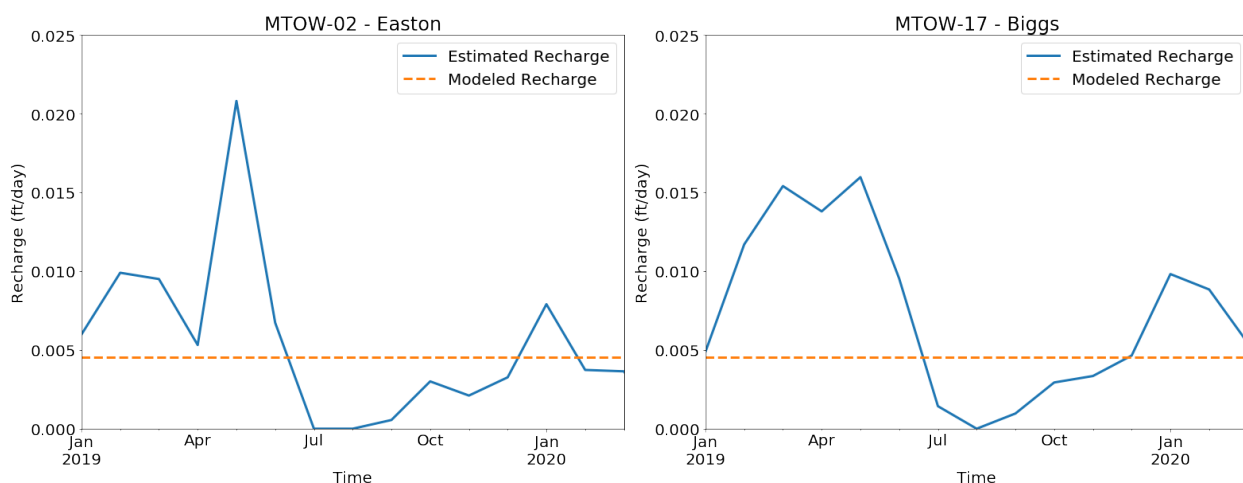
The ISWS continues to work to improve existing models of the region with the data collected in this study. This includes the development of head change maps, such as the one linked to in this video showing hourly changes in response to storm events from 2015. Figure 23 shows a screen capture from this video- with contour lines showing head increases since the start of the modeled storm event and circles showing rainfall for that hour. Please note that current efforts are underway to create real-time potentiometric surfaces of the data. More detail on the progress on this work will be updated at 2020 meetings of the IVWA.



**Figure 23. Water level (head) change from May 1, 2015, with measured hourly rainfall.**

In addition to potentiometric surfaces, the ISWS is also investigating methodologies to estimate recharge using different modeling approaches. The simplest of these uses the “Water Table Fluctuation Method” defined by the United States Geological Survey (<https://water.usgs.gov/ogw/gwrp/methods/wtf/>). Simply explained, the method estimates recharge by multiplying the change in head between measurements by the specified yield of the aquifer and dividing by the time between measurements. Specific yield is the property that determines how quickly water is added or removed from the pore spaces of an aquifer. This method only approximates recharge when heads are increasing- when heads are decreasing, the simplifying assumption of no recharge is applied. During periods of heavy pumpage, recharge is also assumed to be zero.

Provisional results of this method were evaluated at MTOW-02 and MTOW-17, see Figure 24. Note that the curves are smoothed to eliminate noise by calculating the monthly average of the recharge rate. Both oscillate throughout the year around the modeled recharge value of 20 inches/yr, estimated in the most recent Mahomet Aquifer modeling report (<https://www.ideals.illinois.edu/handle/2142/39869>). At MTOW-02, the average 2019 recharge is 22.5% higher than the modeled value. At MTOW-17, the average 2019 recharge rate is 54% higher than modeled. It should be noted that the Mahomet Aquifer model was calibrated to data from 2005, the fifth driest year of this study. In contrast, 2019 was the fifth wettest year. This is one likely reason that recharge estimates are considerably higher in 2019, although it is possible that the simpler methodology used for 2019 also overestimates recharge. The next step of this analysis will be to attempt to establish a relationship between depth to water and the amount of rainfall to better understand the drivers of recharge. In addition, we will attempt to replicate these recharge rates/water levels in a recalibrated groundwater flow model.



**Figure 24. Estimated recharge using the Water Table Fluctuation Method compared to annually averaged recharge from Roadcap et al. 2011.**

As new modeling approaches are developed/refined, the accuracy of these recharge plots will be improved. A major shortcoming of the current approach is that the assumption of no recharge when heads are falling or wells are pumping is not accurate. Combining the theory of this approach with the aforementioned method of creating potentiometric surfaces will help to inform some additional complexities (particularly water levels that are heavily influenced by surface water features). As these approaches are refined, the ISWS continue to include updates analyses on recharge in this report. Also, we will provide periodic updates at IVWA meetings.

### Notes on other hydrographs

Groundwater levels in the Pekin (MTOW-05) and Havana-IDOT (MTOW-09) wells have been found to fluctuate largely in response to river stage because of their proximity to the Illinois River. Since these two monitoring wells are so strongly influenced by the Illinois River, the wells are not outfitted with pressure transducers and are measured three to four times a year. The hydrographs for these two wells (MTOW-05 and MTOW-09) are located in Appendix A.

### **Summary**

During CY2019 of the rain gage network operation (January 2019-December 2019), the network received an average of 41.09 inches of precipitation, 5.88 inches above the previous 26-year network average precipitation of 35.21 inches, and 2.71 inches above the 30-year average for the study area, 38.38 inches. CY2019 was the 5<sup>th</sup> wettest year since the deployment of the precipitation network. Before 2018, years with more precipitation generally resulted in less irrigation. However, in the last two years precipitation and irrigation amounts were in the top seven observed/ estimated. In CY2018, this was due to April precipitation being ~1.5 inches below average, with May-July being <1 inch below average. In 2019, this was because July and August precipitation were >1.5 inches below average, even though May and June were above. The timing of precipitation events bears closer investigation in the coming years.

The data collected over the last 27 years as part of this project have been invaluable to the ISWS in developing a better understanding of the groundwater system in the Havana Lowlands, as well as the Mahomet Aquifer as a whole. What amazes many people who have looked at the data for the Havana Lowlands Region is the fact that water levels are basically unchanged from the 1960's even though there are now over 2000 irrigation systems in the region and in the early 1960's, there were less than 100. What is particularly remarkable is that the difference in water levels from the very wet May 2019 to very dry July/August 2019 is only observed at a maximum of 10 ft at MTOW-17, which is adjacent to an active center pivot. This despite an average water usage in the IVWA of 0.82 Bgd, which approaches what the city of Chicago uses on average.

ISWS scientists are using these data in new ways. Recently developed methods for evaluating water level information using MODFLOW are leading to a better approach to understanding how irrigation, rainfall, river stage, and groundwater levels all affect each other. We will continue to provide some of these results to the IVWA in the coming years as we continue to develop our understanding the groundwater resources of the area. Furthermore, all water levels are now posted as interactive, provisional hydrographs on the Imperial Valley Water Authority's webpage, as well as at: <https://www.isws.illinois.edu/groundwater-science/groundwater-monitoring-well-networks/imperial-valley>.

The ISWS is grateful to the IVWA for their continued support of the rain gage and observation well networks. Please contact Kevin Rennels, Erin Bauer, Daniel Abrams, or Steve Wilson if you have any questions or comments.


Sincerely,



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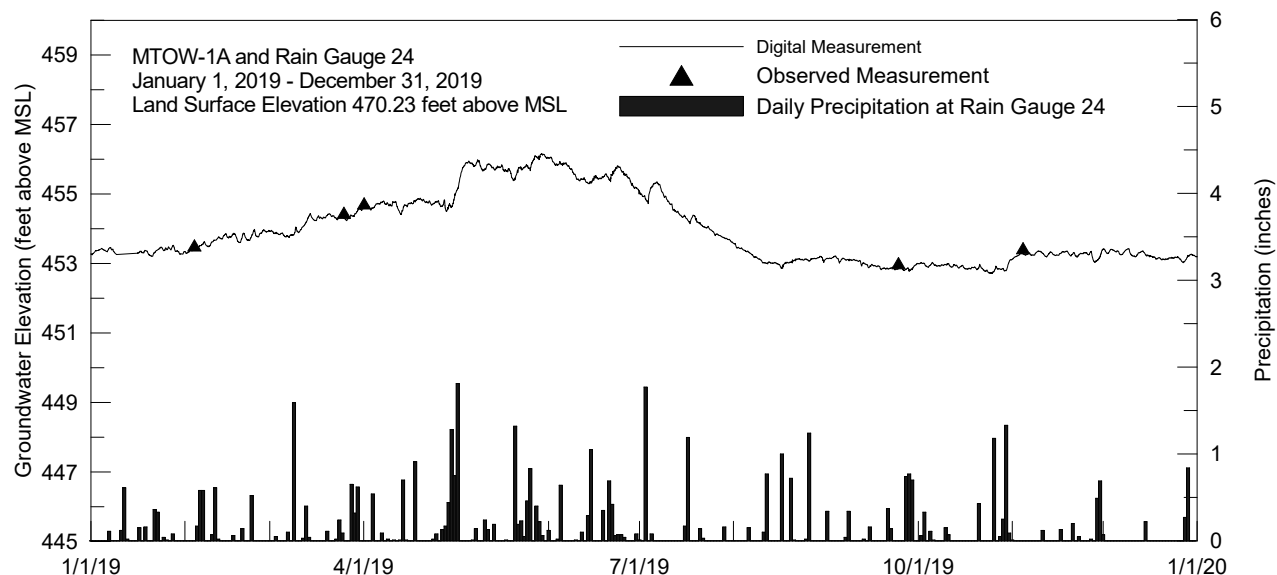
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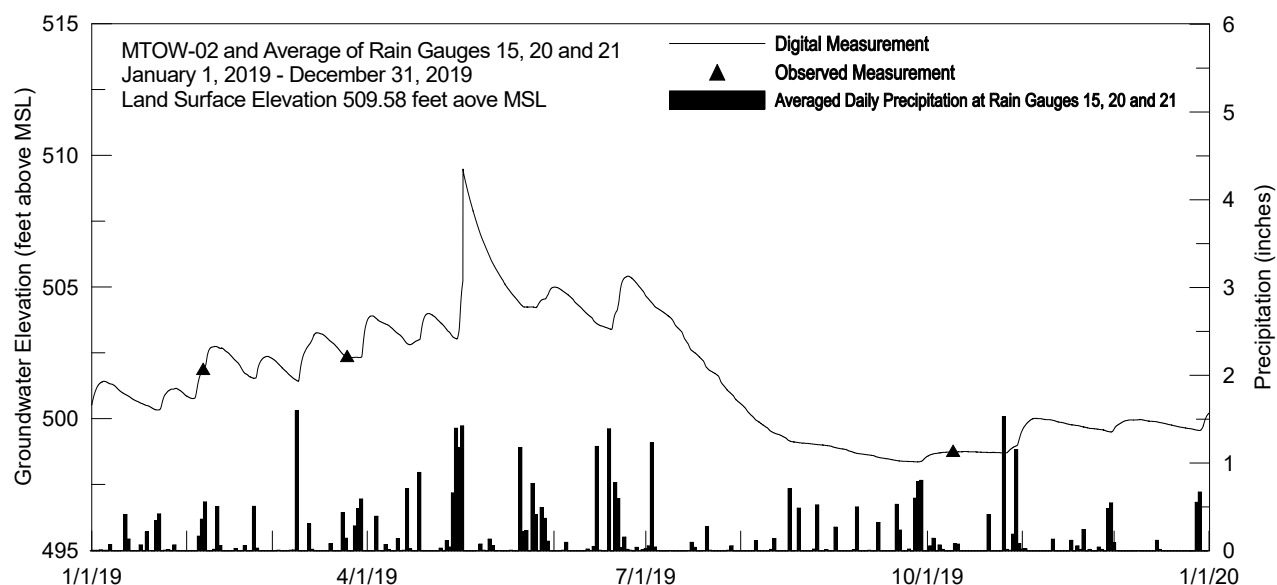
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Dorland Smith  
Wayne Deppert  
Don Osborn, Jr.  
Mark McGrath  
Lisa Young

## Appendix A. Hydrographs, Imperial Valley Observation Well Network

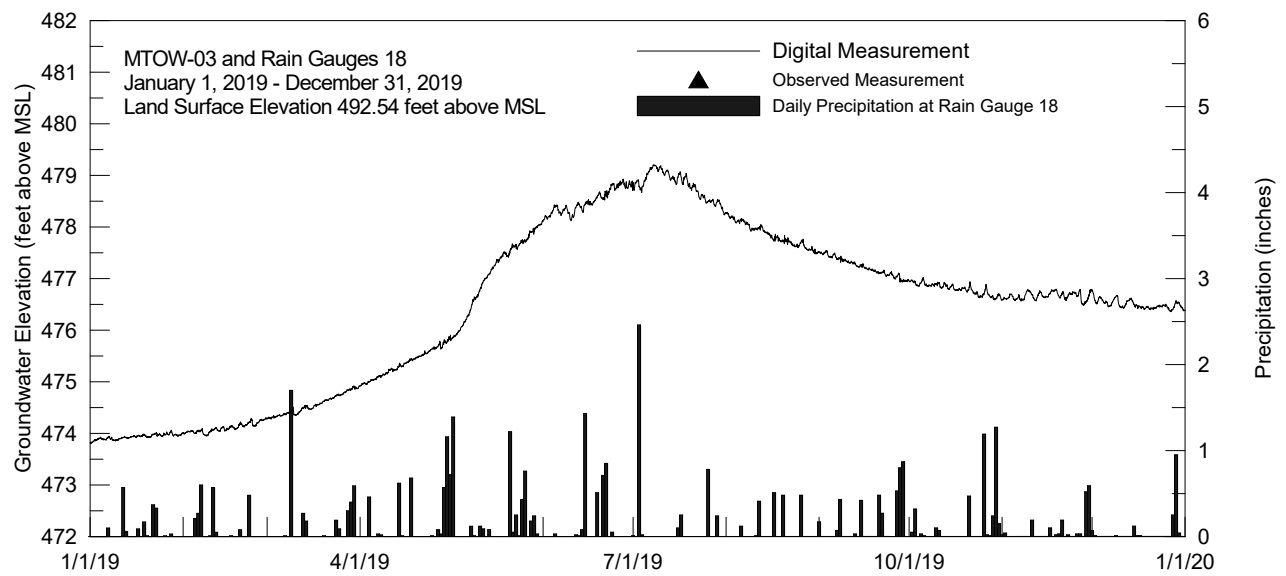


**Figure A-1. Year 27 Groundwater Elevation and Precipitation for MTOW-01A**

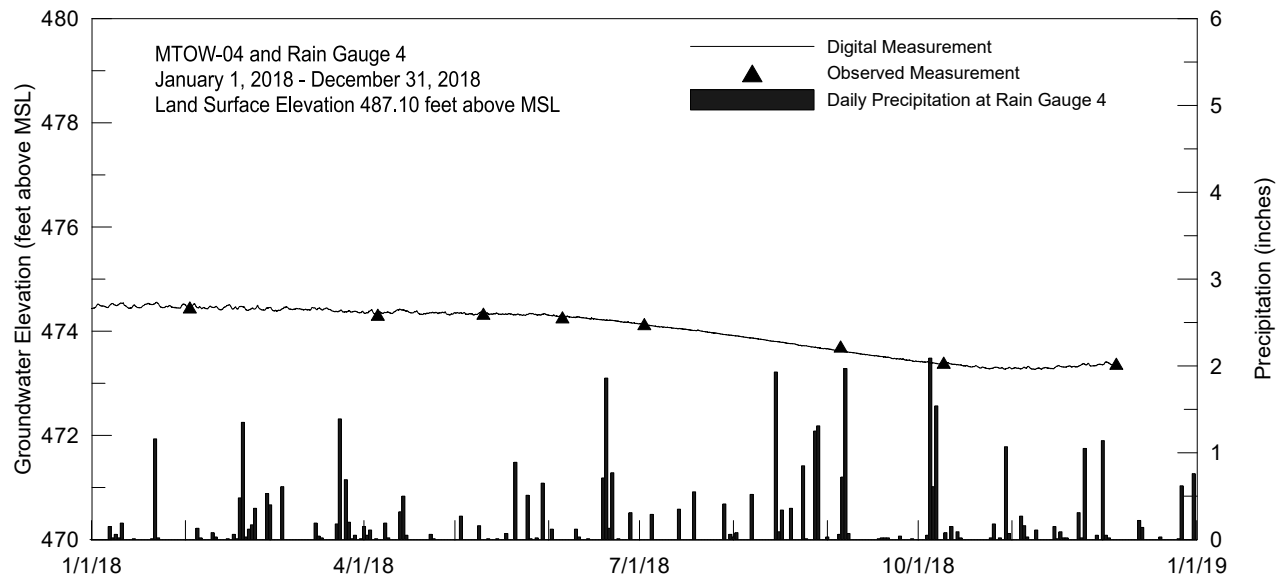


**Figure A-2. Year 27 Groundwater Elevation and Precipitation for MTOW-02**

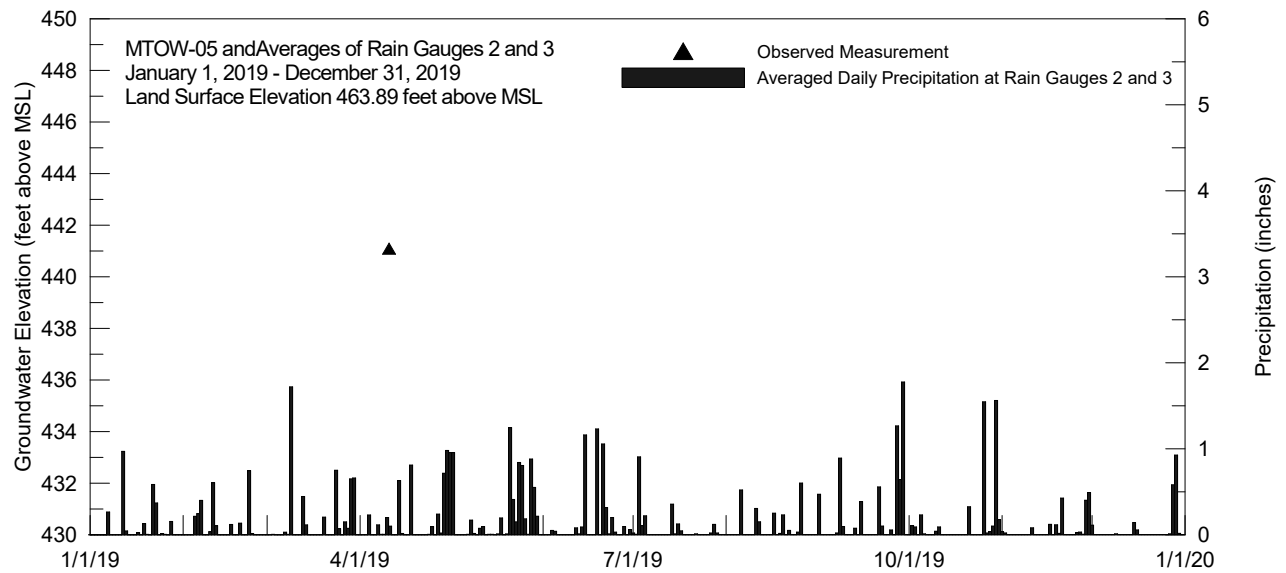




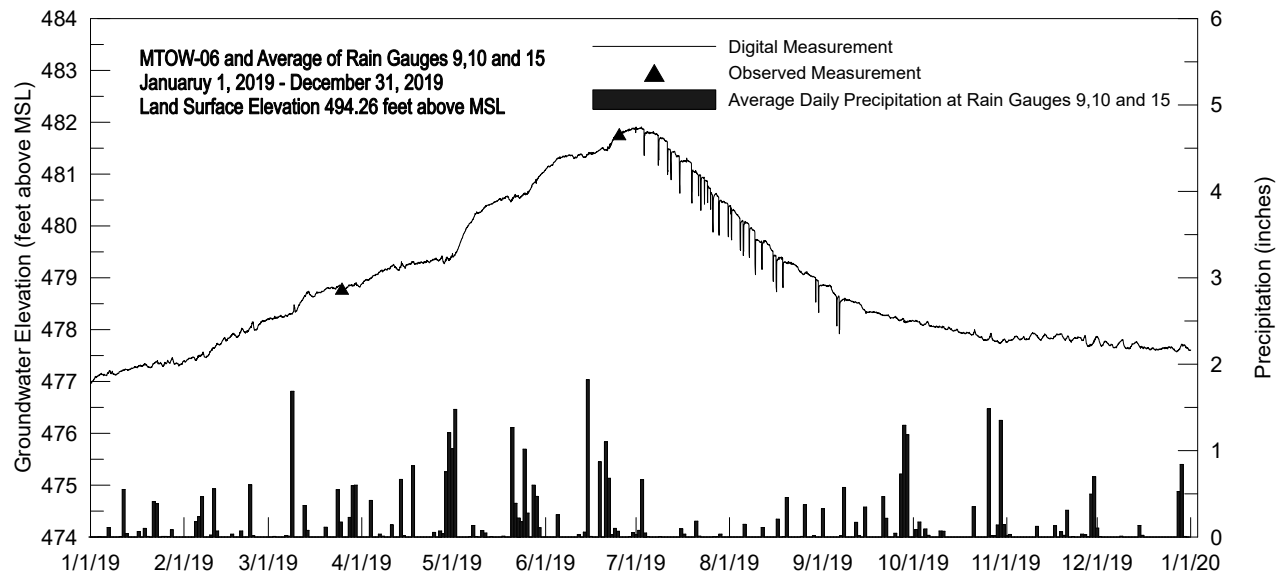
**Figure A-3. Year 27 Groundwater Elevation and Precipitation for MTOW-03**



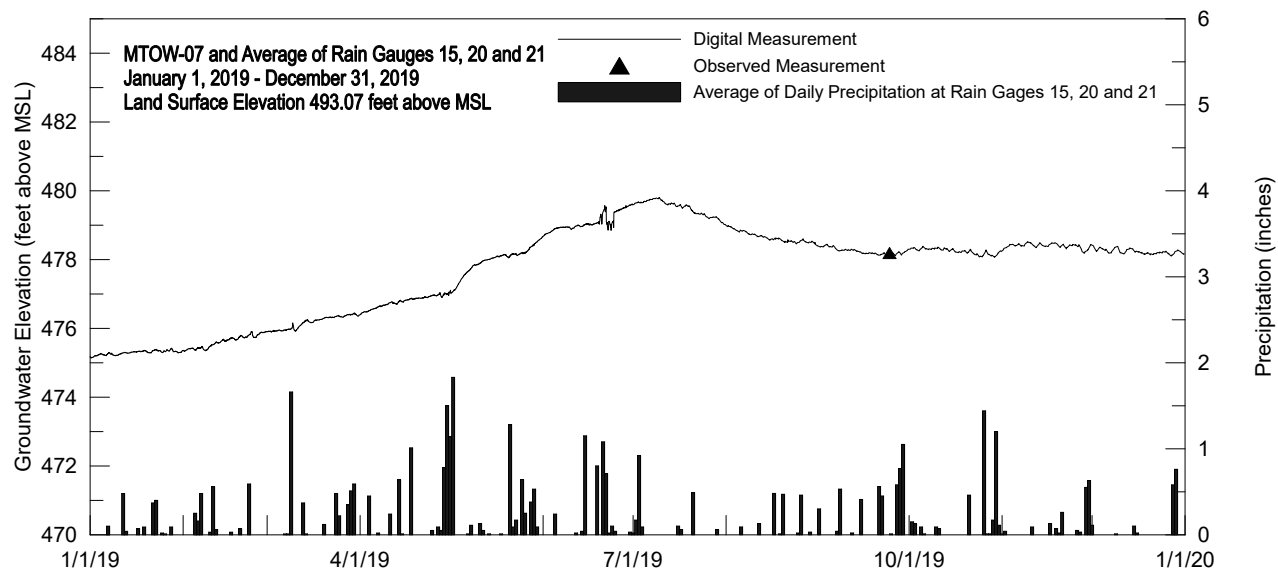
**Figure A-4. Year 27 Groundwater Elevation and Precipitation for MTOW-04**



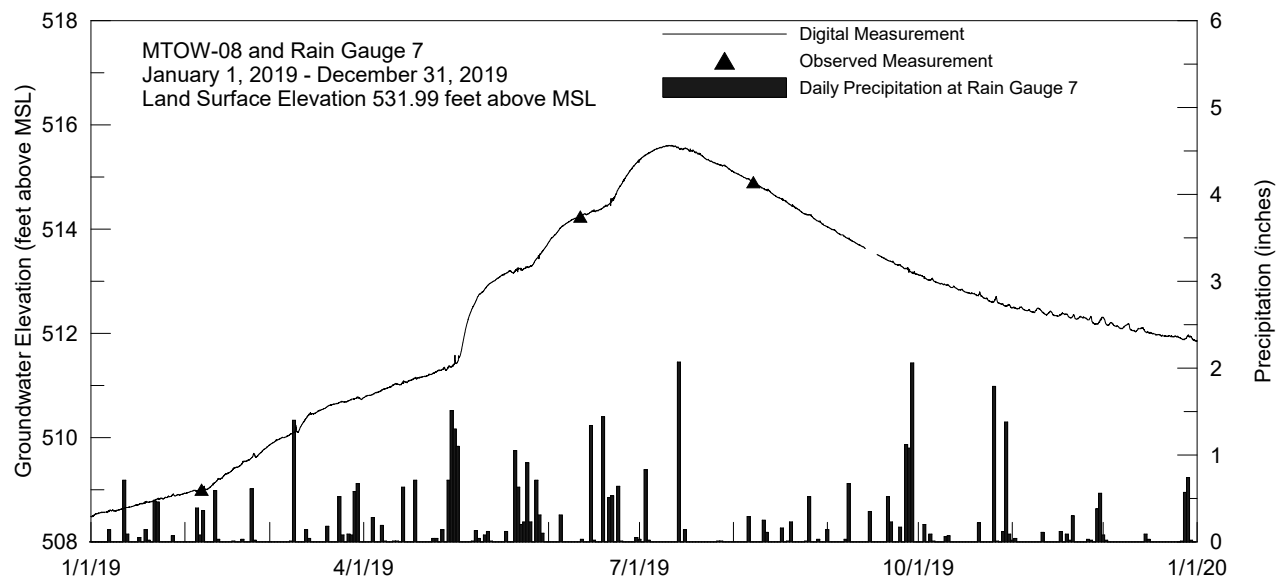
**Figure A-5. Year 27 Groundwater Elevation and Precipitation for MTOW-05 (not continuous recorder)**



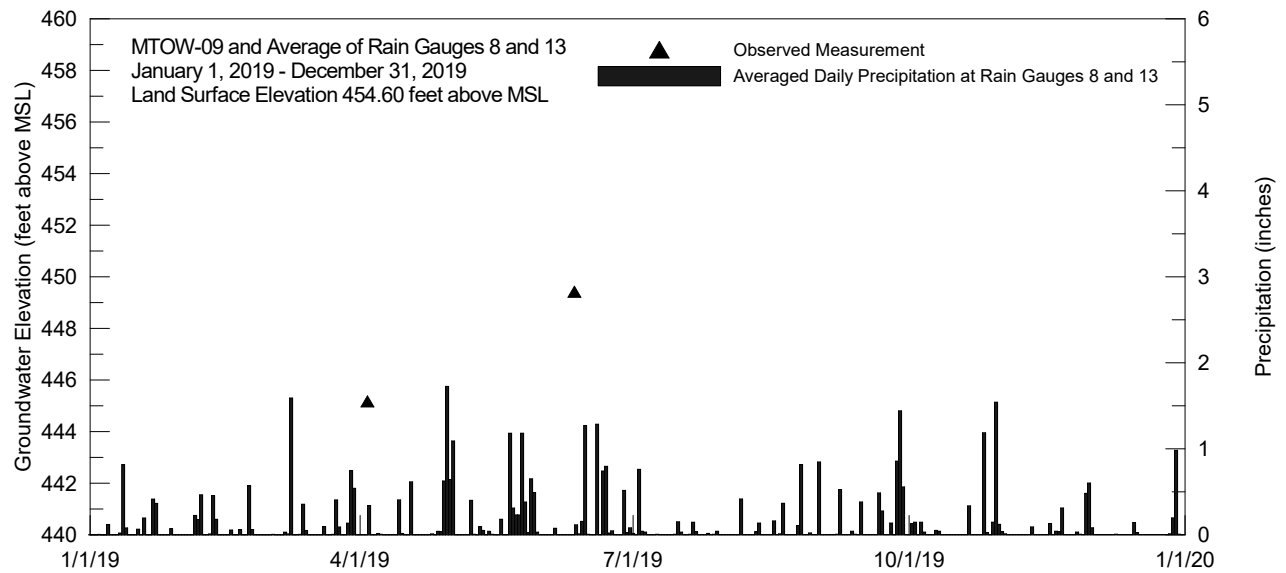
**Figure A-6. Year 27 Groundwater Elevation and Precipitation for MTOW-06**



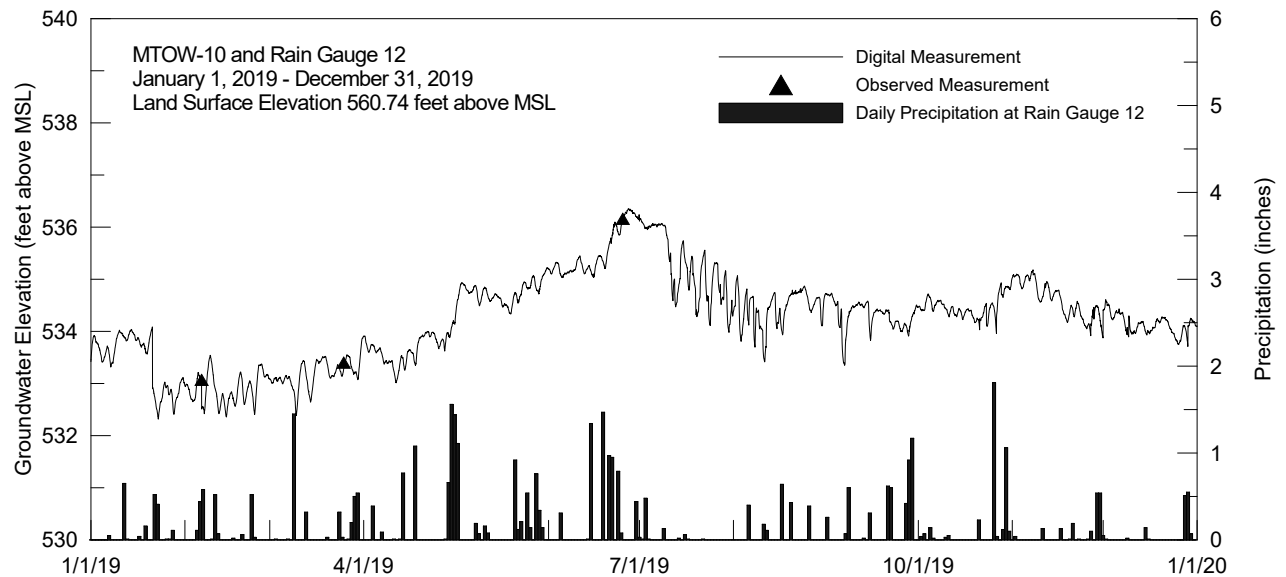
**Figure A-7. Year 27 Groundwater Elevation and Precipitation for MTOW-07**



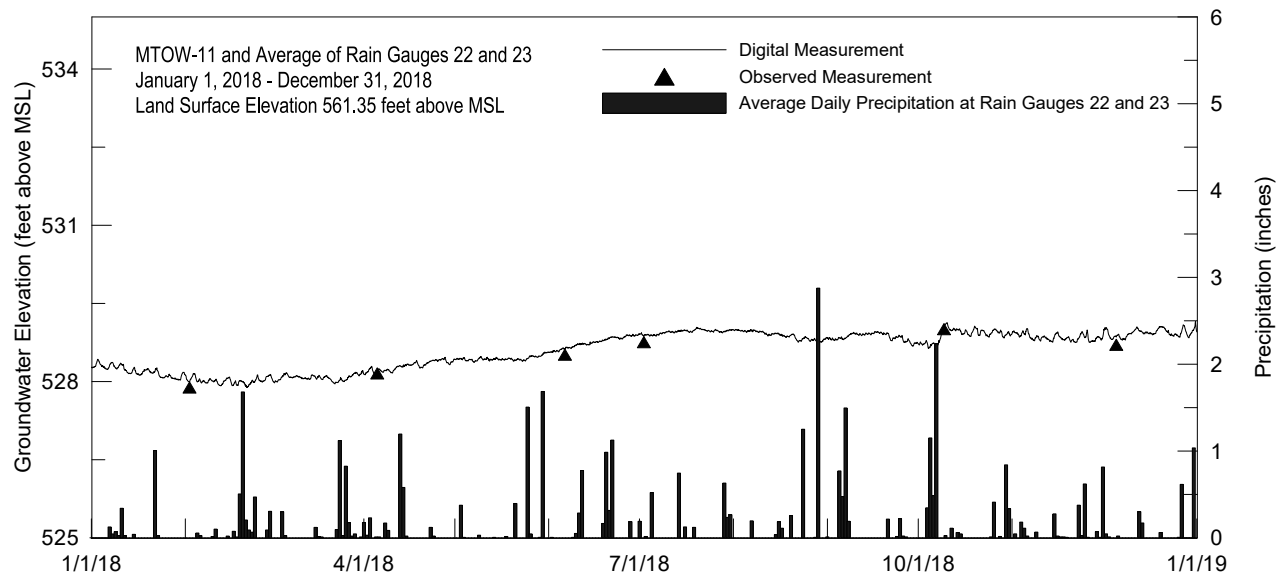
**Figure A-8. Year 27 Groundwater Elevation and Precipitation for MTOW-08**



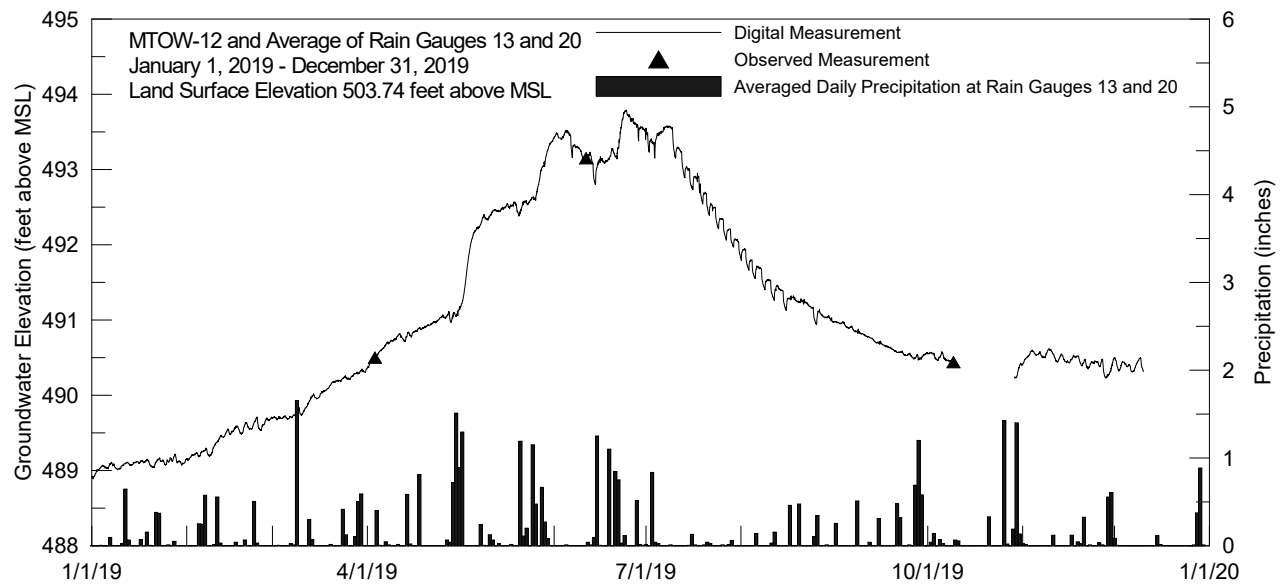
**Figure A-9. Year 27 Groundwater Elevation and Precipitation for MTOW-09 (not continuous recorder)**



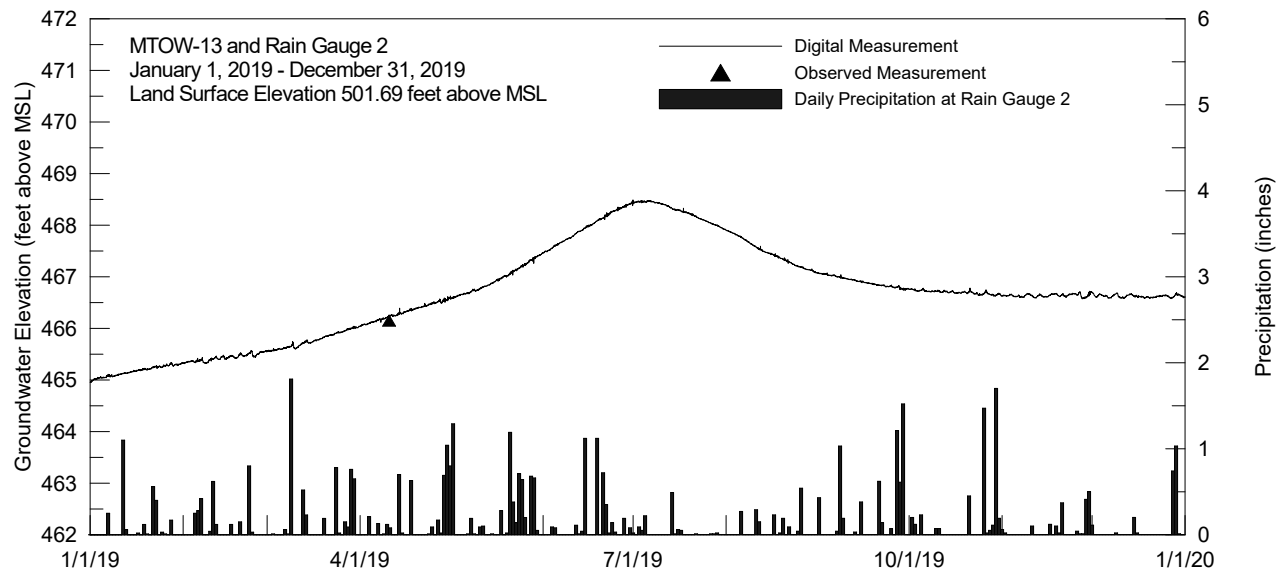
**Figure A-10. Year 27 Groundwater Elevation and Precipitation for MTOW-10**



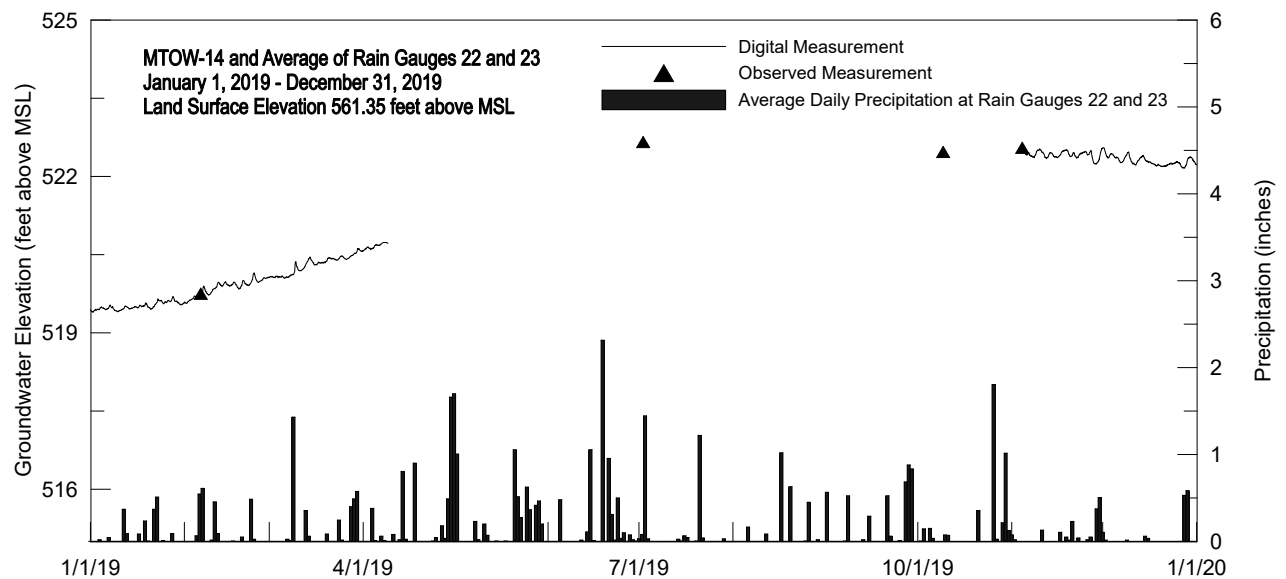
**Figure A-11. Year 27 Groundwater Elevation and Precipitation for MTOW-11**



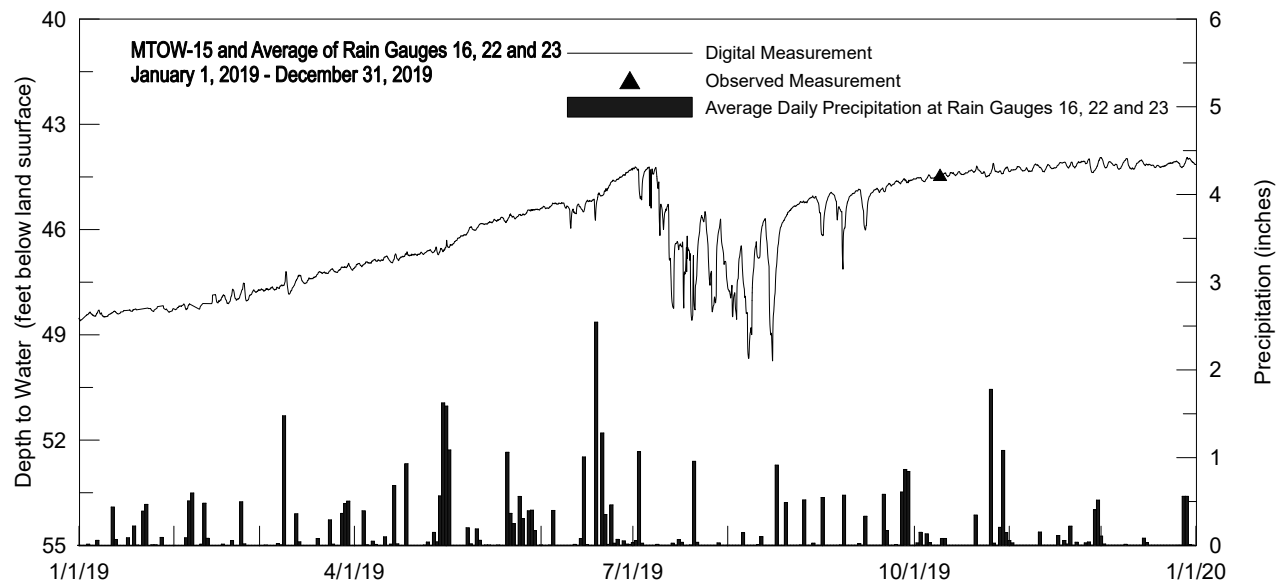
**Figure A-12. Year 27 Groundwater Elevation and Precipitation for MTOW-12**



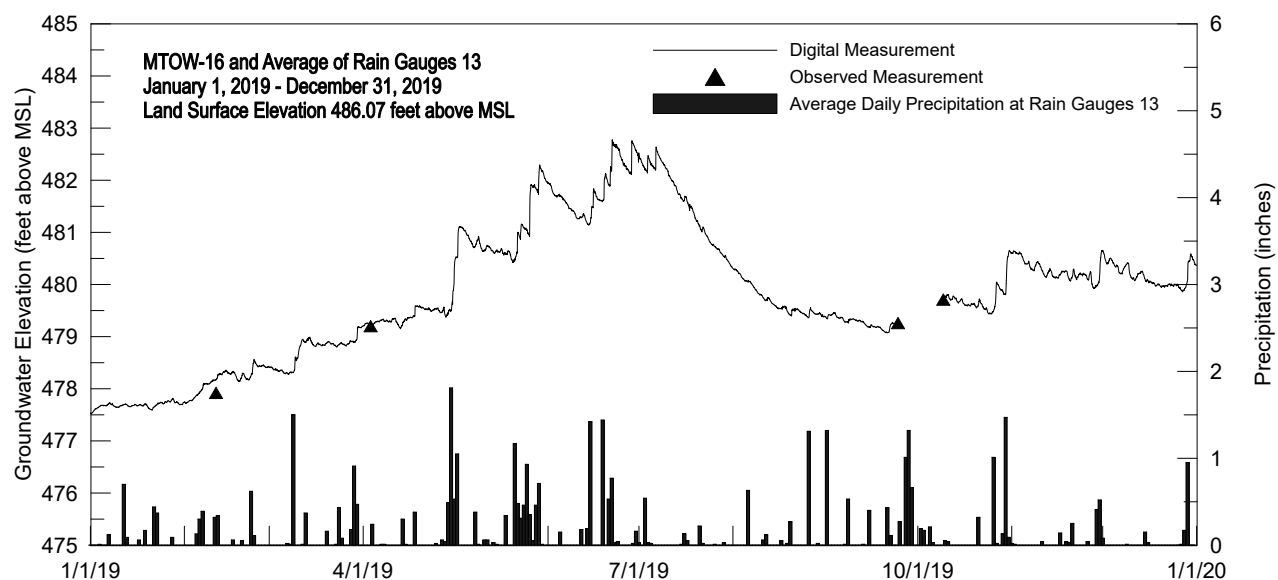
**Figure A-13. Year 27 Groundwater Elevation and Precipitation for MTOW-13**



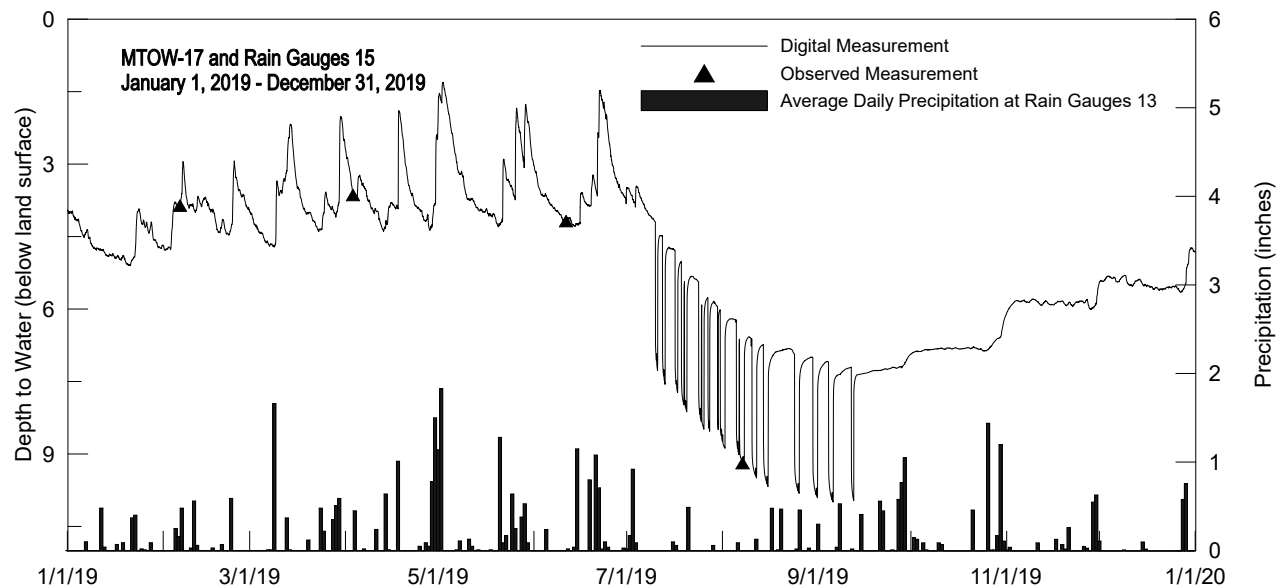
**Figure A-14. Year 27 Groundwater Elevation and Precipitation for MTOW-14**



**Figure A-15. Year 27 Groundwater Elevation and Precipitation for MTOW-15**



**Figure A-16. Year 27 Groundwater Elevation and Precipitation for MTOW-16**



**Figure A-17. Year 27 Groundwater Elevation and Precipitation for MTOW-17**



## Appendix B. Explanation of Box-Whisker Plots

Box-whisker plots are a visual display of the quartiles and upper and lower extremes of the data, in this case, monthly precipitation. Using the monthly precipitation totals for 26 Januarys from 1993-2018 for the Imperial Valley, the box-whisker plot in Figure B1 shows the maximum, median, minimum, and 1<sup>st</sup> and 3<sup>rd</sup> quartiles of each month. The May data are sorted from large to small to clearly display the median, 1<sup>st</sup> and 3<sup>rd</sup> quartiles in a list view. This presentation divides the data into quarters, not by value but by place order of the sorted set.

The **median** divides the set in half. It is the value where half the set values are above and half the numbers are below. (24 divided by 2 = 12). This is also called the **2<sup>nd</sup> quartile**.

- **1<sup>st</sup> quartile (Q1)** is the value where  $\frac{1}{4}$  of the numbers are below. ( $24 \times \frac{1}{4} = 6$  are below)
- **3<sup>rd</sup> quartile (Q3)** is the value where  $\frac{3}{4}$  of the numbers are below. ( $24 \times \frac{3}{4} = 18$  are below)
- In this report, the upper and lower caps present the minimum and maximum values.

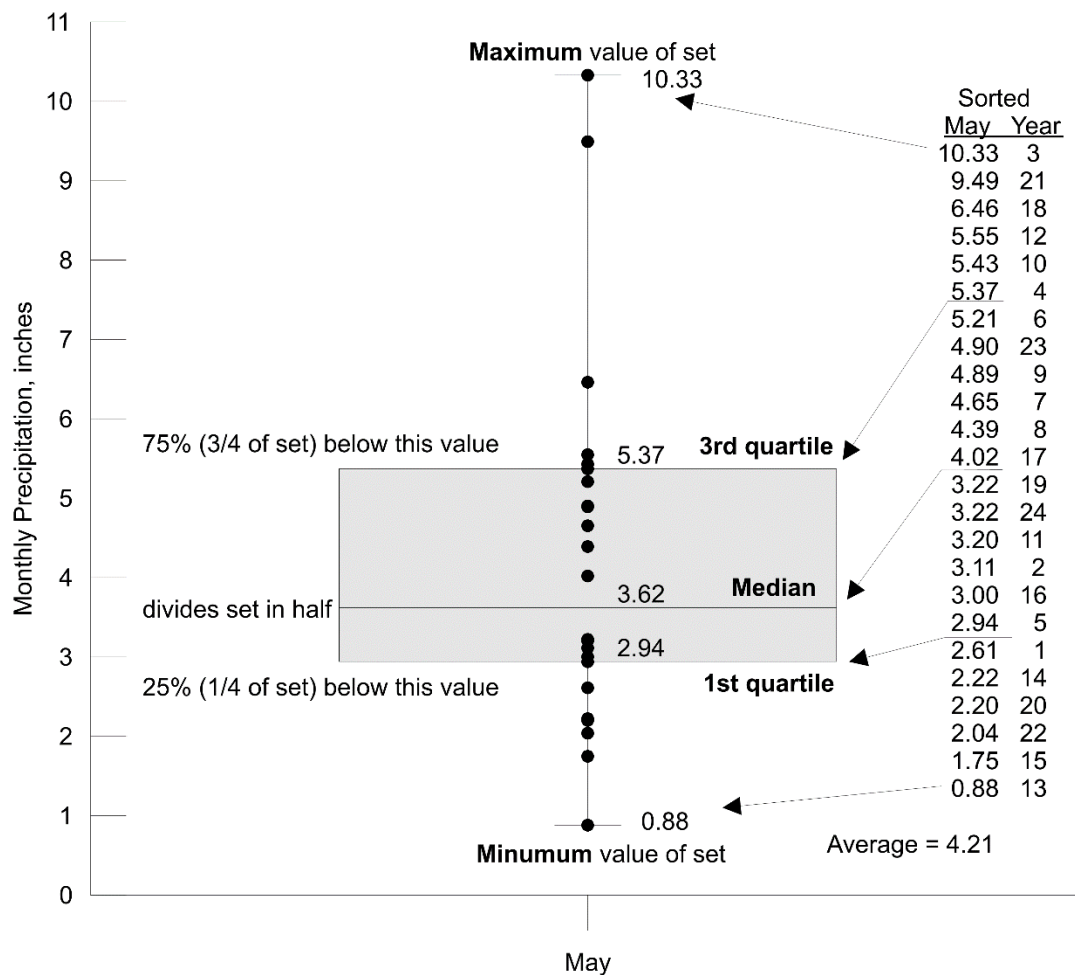


Figure B1. Features of an Example Box-Whisker Plot and Quartiles Using May Data for the Imperial Valley