TECHNICAL MEMORANDUM

Evaluation of Wyckoff Groundwater Level Data October 1 through December 31, 2018

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This memorandum summarizes the Wyckoff groundwater level results for the October 1 through December 31, 2018, (Quarter 4) monitoring period and evaluates the data to support the determination on whether upper aquifer hydraulic containment was achieved for the quarterly monitoring period.

Summary/Recommendations

- The upper aquifer recovery wells and groundwater treatment system operated 24 hours per day, 7 days per week, except for temporary shutdowns due to low water levels, power outages, weather conditions, or maintenance.
- Hydraulic containment was maintained at all 10 well pairs over the 92-day monitoring period, with the lower aquifer to upper aquifer groundwater elevation ratios ranging from 1.32 to 3.93 for Quarter 4. A ratio greater than 1.0 indicates hydraulic containment was maintained.
- The groundwater elevation data from the transducers in the 10 well pairs will be downloaded again on March 31, 2019, to maintain a quarterly data evaluation schedule consistent with that used in the definition of hydraulic containment.
- All in-use transducers at the site were last calibrated on March 1, 2018. Calibration events are conducted annually to confirm accurate water level measurements.

Water Level Data Collection

The October 1 through December 31, 2018 period represents the next consecutive 92-day quarterly monitoring interval following the Quarter 3 (July 1 through September 30, 2018) period presented in *Evaluation of Wyckoff Groundwater Level Data July 1, 2018 through September 30, 2018* (CH2M, 2018).[1] The locations of the monitoring wells are shown on Figure 1 and the wells with transducers are listed in Table 1. Model 705 KPSI Level and Pressure Transducers are installed in 22 upper aquifer wells and 18 lower aquifer wells and were last calibrated in March 2018. All recorded water level data are available in e-format upon request.

[1] CH2M HILL, Inc. (CH2M). 2018. *Evaluation of Wyckoff Groundwater Level Data July 1, 2018 through September 30, 2018.* Technical Memorandum. November 21.

Table 1. Wells with Transducers and Upper Aquifer/Lower Aquifer Well Pairings, October 1 through December 31, 2018

Well Pairs for Vertical Gradient Evaluation			Other Wells with Transducers	
Upper Aquifer		Lower Aquifer		
Well ID	Compartment	Well ID	Upper Aquifer Extraction Wells[a]	Lower Aquifer Monitoring Wells
MW14	1	CW05	E-02b	CW09
MW18	1	02CDMW01	E-04b	P-1L
PO03	1	99CDMW02A	E-06b	P-2L
CW03	2/3	CW02	E-07b	P-3L
VG-2U	2/3	VG-2L	MW-21	P-5L
VG-3U	2/3	VG-3L	RPW-1	P-6L
VG-5U	1	VG-5L	RPW-2	PZ03
PO13	1	VG-1L	RPW-4	SE02
CW13	1	VG-4L	RPW-5	
CW08	1	P-4L	RPW-6	
			PW-8	
			PW-9	

[a] All upper aquifer recovery wells are screened across Compartments 1/2/3, except MW-21, which is screened in Compartment 1.

[b] The E-0x series of wells are located within the Pilot Test sheet pile wall.

Groundwater Treatment Plant Operations

The groundwater treatment plant and all nine upper aquifer extraction wells operated 24 hours per day, 7 days per week during Quarter 4, as conditions permitted. Several extraction well shutdowns occurred during the monitoring period because of low water levels, power outages, weather conditions, or maintenance. The dates during which the extraction wells were shut down for periods greater than 24 hours are listed in Table 2. These periods are graphically overlain with the rainfall records and are shown on Figure 3. For the Quarter 4 monitoring period (October 1 through December 31, 2018), 14.32 inches of rainfall were recorded.

The total volume of water extracted from the upper aquifer was 5,462,017 gallons during the 92-day monitoring period, equating to an average pumping rate of approximately 41 gallons per minute for the 92 days where all or portions of the wellfield were in operation. When fully operating, and upper aquifer water levels allow, the system can pump about 72 gallons per minute.

Hydraulic Containment Evaluation

Upper aquifer hydraulic containment at the Wyckoff site is evaluated using water level data from 10 upper and lower aquifer well pairs as shown in Table 1 (Figure 1 depicts the well locations). Hydrographs for each of the 10 well pairs have been prepared and are presented on Figures 2a through 2j. Seven of the upper aquifer wells are screened in Compartment 1 while three upper aquifer wells are screened in Compartment 2/3.

Table 2. Former Process Area Extraction Well Pump Shutdown Periods Greater than 1 Day

Offline Dates	Wells	Reason
May 14, 2018 – October 31, 2018	PW-6, PW-9	Low water level and maintenance
October 1 – October 8, 2018	EW-6	EW-2 & EW-6 pumps cycling on/off due to low water levels
October 8 – October 15, 2018	EW-2	EW-2 & EW-6 pumps cycling on/off due to low water levels
October 15 – October 22, 2018	EW-6	EW-2 & EW-6 pumps cycling on/off due to low water levels
October 22 – October 31, 2018	EW-2	EW-2 & EW-6 pumps cycling on/off due to low water levels
October 24 – October 31, 2018	PW-1, PW-2, PW-4, PW-5, PW-8, EW-6	Pumps off for maintenance
November 1 – November 29, 2018	PW-9	Low water level
November 30 – December 13, 2018	PW-9	Low water level

Hydraulic containment at each well pair is evaluated by first calculating the average groundwater elevations in the upper and lower aquifers using the water elevation data recorded every 15 minutes during the monitoring period. Then the average upper and lower aquifer groundwater elevations at each well pair are compared relative to each other. If the average lower aquifer groundwater elevation is greater than the average upper aquifer groundwater elevation at the well pair, an upward (positive) vertical gradient is indicated. Additionally, if an upward vertical gradient is present, the ratio of the average lower aquifer water elevation to the average upper aquifer water elevation for that well pair is greater than 1.0 for the duration of the monitoring period, and a hydraulic-containment-maintained determination is made.

Additional evaluations are conducted through examination of short-term periods when downward hydraulic gradients occur. Groundwater elevations for each well pair are compared at each 15-minute recording, and the summary statistics: average, maximum, and minimum difference in groundwater elevation for each well pair are calculated, along with a duration analysis for negative (downward) gradients. The duration analysis includes the number of downward gradient events observed during the monitoring period, their average duration (hours), and the cumulative duration (days and percent) for the monitoring period. A downward vertical gradient is indicated when the difference between the lower and upper aquifer groundwater elevations at each 15-minute recording have a negative value (e.g. average upper aquifer groundwater elevation greater than the average lower aquifer groundwater elevation). The summary statistics and hydraulic containment evaluation data for the well pairs are summarized in Table 3 and are based on the 92-day monitoring period (Quarter 4) from October 1 through December 31, 2018, which corresponds to the quarterly period used for assessing hydraulic containment.

Based on the information presented in Table 3, the following determinations were made:

- The average lower aquifer to upper aquifer groundwater elevation ratios were greater than 1.0 at all 10 well pairs for the 92-day monitoring period, indicating hydraulic containment was maintained at each location.

- Negative vertical gradients were observed at 6 of the 10 monitoring well pairs. Downward (negative) vertical gradient events typically occur during the lowest semidiurnal tide period when the lower aquifer groundwater elevation declines below the upper aquifer groundwater elevation (Figures 2a through 2j). Groundwater elevations in the upper aquifer Compartment 2/3 and all lower aquifer wells are strongly influenced by daily tidal fluctuations while water levels in the upper aquifer Compartment 1 wells show much less tidal influence. At all locations except well pair CW03/CW02 (Compartment 2/3), where negative gradients were observed (PO03/99CDMW02A, VG-5U/VG-5L, PO13/VG-1L, CW13/VG-4L, and CW08/P-4L), the upper aquifer well is screened in Compartment 1.
- At four of the six well pairs (PO03/99CDMW02A, CW03/CW02, PO13/VG-1L, and CW08/P-4L), the average duration of the downward gradient periods was between 2 and 4 hours. The total negative gradient duration for the 92-day period was between 0.9 percent and 3.5 percent (0.8 to 3.2 days) for these four well pairs.
- Well pair CW13/VG-4L had both the highest negative gradient duration (10.5 percent; 9.6 days) and the highest number of negative gradient events (30) for the 92-day monitoring period. This well pair is located on the far west side of the Former Process Area adjacent to extraction well PW-9, which was shut down for a 74 of the 92 days during Quarter 4 due to low water levels. The second highest negative gradient duration occurred at well pair VG-5U/VG-5L at 5 percent, approximately 4.6 days, of the 92-day monitoring period. This well pair is located in the southwest corner of the Former Process Area about 175 feet southwest of extraction well RPW1.
- Well pair CW08/P-4L had the second highest number of negative gradient events for the 92-day monitoring period at 25 events. While this well pair did not have the highest total negative gradient duration for the Quarter 4 monitoring period, this well pair does often have the highest total negative gradient duration, with the highest having occurred during 2017 Quarters 2 and 3, and 2018 Quarter 1 monitoring periods. The frequency of downward gradients at well pair CW08/P-4L is unusual in that this well pair is located a similar distance (190 feet) from production well RPW2 as is VG-3U/VG-3L, which had no negative gradient events. Monitoring well CW08 is screened in Compartment 1 while VG-3U is screened in Compartment 2/3.
- Maximum downward vertical gradients occurred on December 25 and December 26, 2018, at five of the six well pairs with downward gradients. The maximum downward vertical gradient at CW13/VG4L occurred on December 23, 2018. All the extraction wells were in operation during these dates. Minus tides of -3.26 feet mean lower low water (MLLW) on December 23, 2018, -3.06 feet MLLW on December 25, 2018, and -2.40 feet MLLW on December 26, 2018, occurred within an hour of the maximum downward gradients at the 6 well pairs.

Summary

During the Quarter 4 monitoring period, hydraulic containment was maintained at all 10 well pairs. Negative hydraulic gradient events occurred at 6 of the 10 well pairs. The maximum observed negative gradients, for the six well pairs during the Quarter 4 period, occurred during maximum low tides from December 23 through 26, 2018, when all the extraction wells were in operation (Figure 3), and following a cumulative precipitation amount of 2.66 inches from December 17 through 21, 2018. The greatest minus tide, during the observed maximum negative gradients was -3.26 feet MLLW, on December 23, 2018.

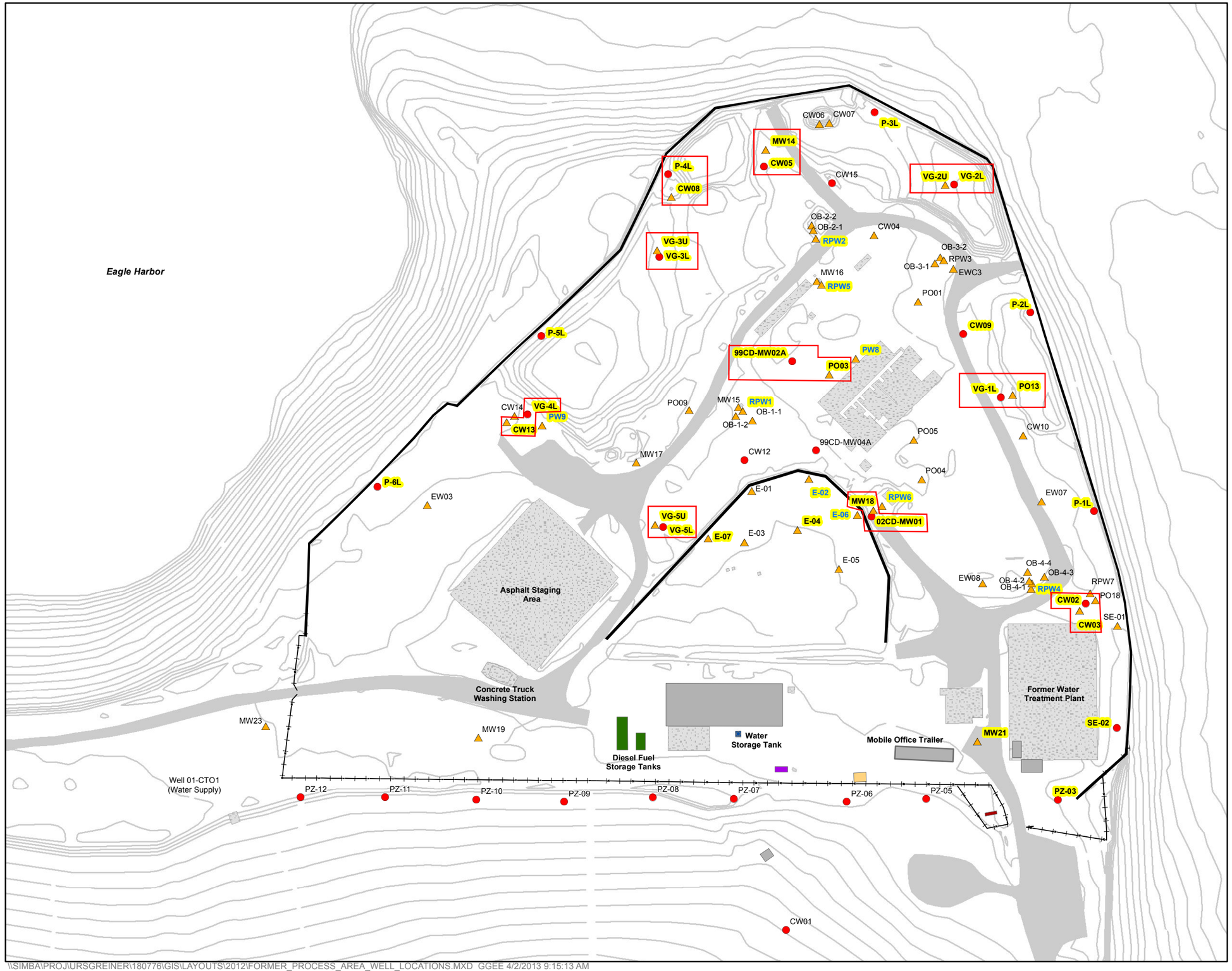
Table 3. Summary of Groundwater Elevation Data by Well Pair October 1 through December 31, 2018

Well Pair	Figure	Upper Aquifer Average Groundwater Elevation (feet MLLW)	Lower Aquifer Average Groundwater Elevation (feet MLLW)	Ratio (Average Lower Aquifer Water Level/ Average Upper Aquifer Water Level)[a]	Summary Statistics Short Term Comparison - Water Level Difference between the Upper and Lower Aquifer Wells (feet)			Duration Analysis – Downward (Negative) Gradient			
					Average	Max	Min	Number of Negative Gradient Events	Average Duration of Negative Gradient (hours)	Total Duration of Negative Gradient (days)	Percent Duration of 92-day Monitoring Period[b]
MW14/CW05	2a	4.59	9.34	2.03	4.74	7.74	0.10	none			
MW18/02CDMW01	2b	2.42	9.50	3.93	7.08	11.03	1.99	none			
PO03/99CDMW02A	2c	4.51	9.33	2.07	4.82	8.58	-0.78	7	3	0.9	1
CW03/CW02	2d	5.47	8.70	1.59	3.23	5.96	-0.47	8	2	0.8	0.9
VG-2U/VG-2L	2e	6.69	8.85	1.32	2.16	2.74	1.27	none			
VG-3U/VG-3L	2f	5.01	9.74	1.95	4.74	6.86	2.03	none			
VG-5U/VG-5L	2g	7.32	10.85	1.48	3.53	6.53	-2.42	17	7	4.6	5.
PO13/VG-1L	2h	5.12	8.97	1.75	10.85	7.34	-1.61	13	4	2.0	2.2%
CW13/VG-4L	2i	8.31	11.14	1.34	2.83	6.45	-4.57	30	8	9.6	10.5
CW08/P-4L	2j	5.49	8.78	1.60	3.30	7.04	-2.09	25	3	3.2	3.5

[a] Ratio > 1 = hydraulic containment was achieved

[b] Percent Duration of Monitoring Period = total duration of negative gradient in days divided by the number of calendar days in the monitoring period

Figures



LEGEND

- Lower Aquifer Well
- Upper Aquifer Well
- Fence
- Wall
- Roads
- Buildings
- Concrete Slab

Well labels:

highlighted - well is monitored with transducer
blue text - production well
red boxed wells - well pair monitored for hydraulic containment

N

0 50 100 Feet

FIGURE 1

Former Process Area Well Locations

WYCKOFF/EAGLE HARBOR SUPERFUND SITE

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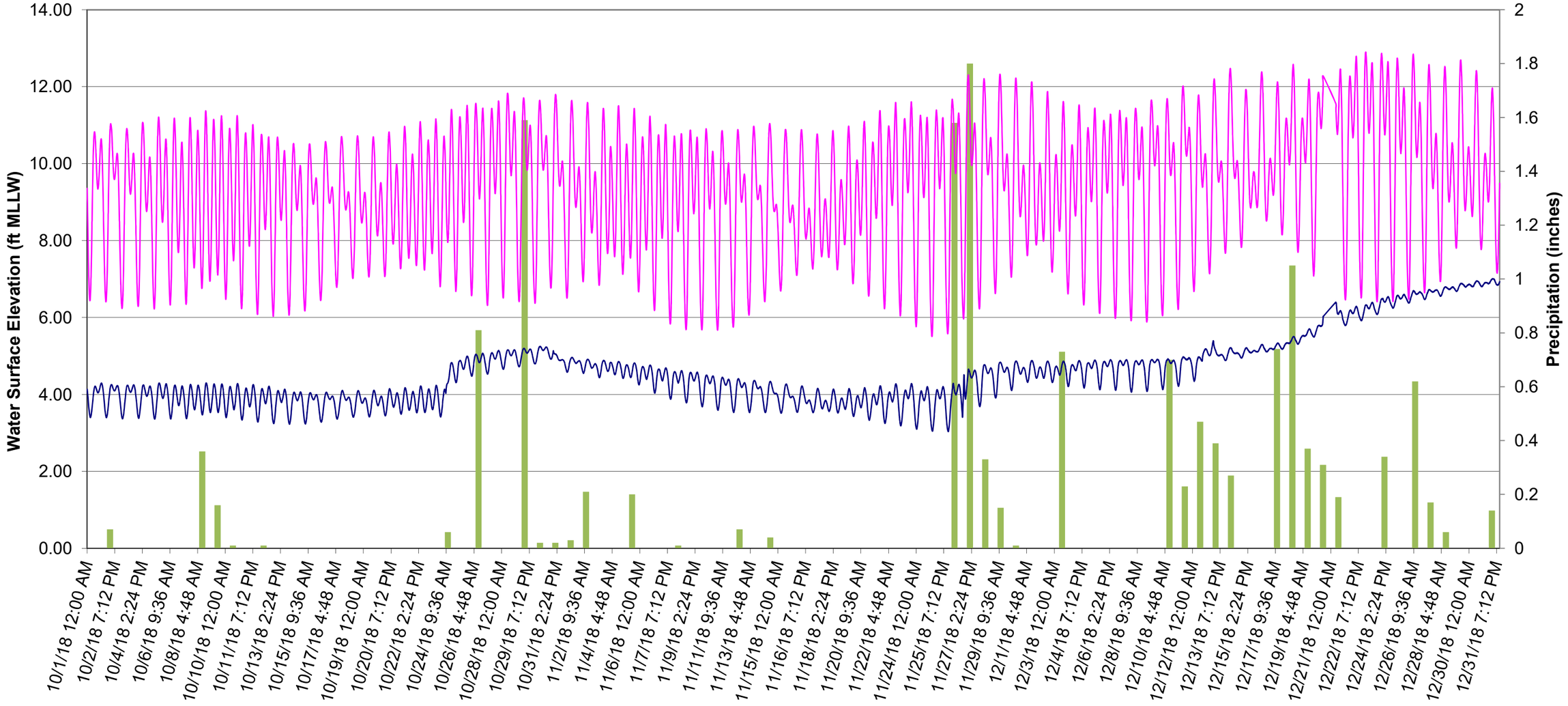

Figure 2a Well Pair Hydrographs
Upper Aquifer Well MW14 (Compartment 1) & Lower Aquifer Well CW05
October 1 through December 31, 2018

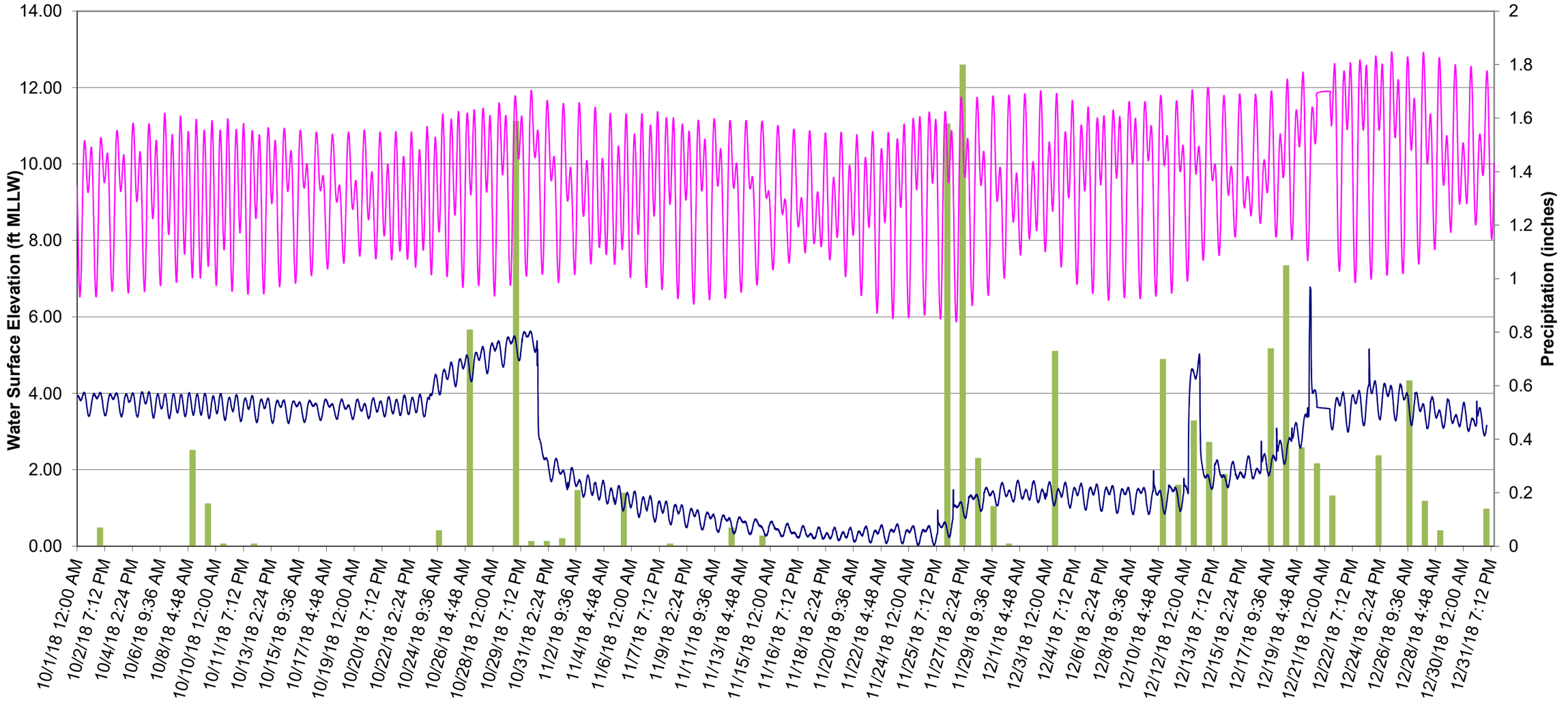

Figure 2b Well Pair Hydrographs
Upper Aquifer Well MW18 (Compartment 1) & Lower Aquifer Well 02CDMW01
October 1 through December 31, 2018

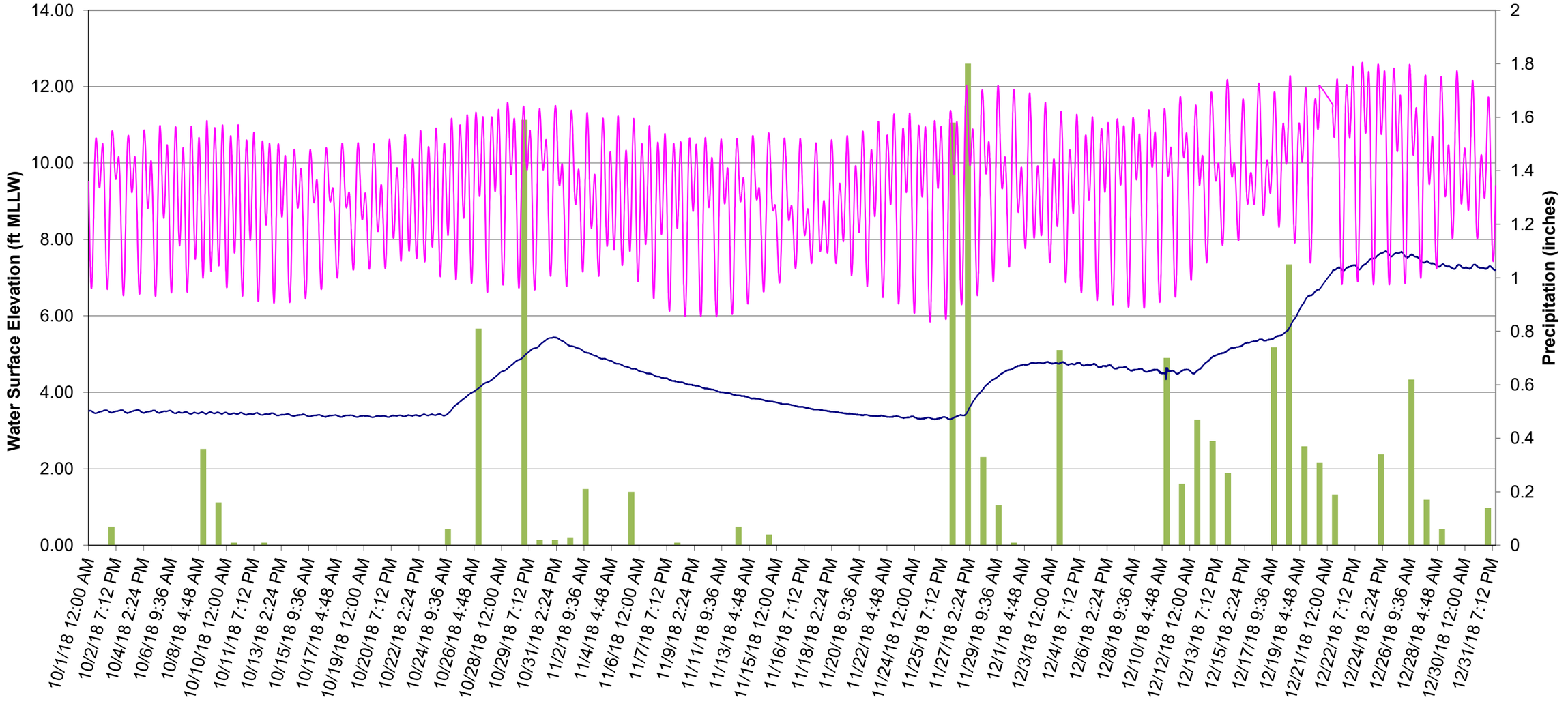

Figure 2c Well Pair Hydrographs
Upper Aquifer Well PO03 (Compartment 1) & Lower Aquifer Well 99CDMW02A
October 1 through December 31, 2018

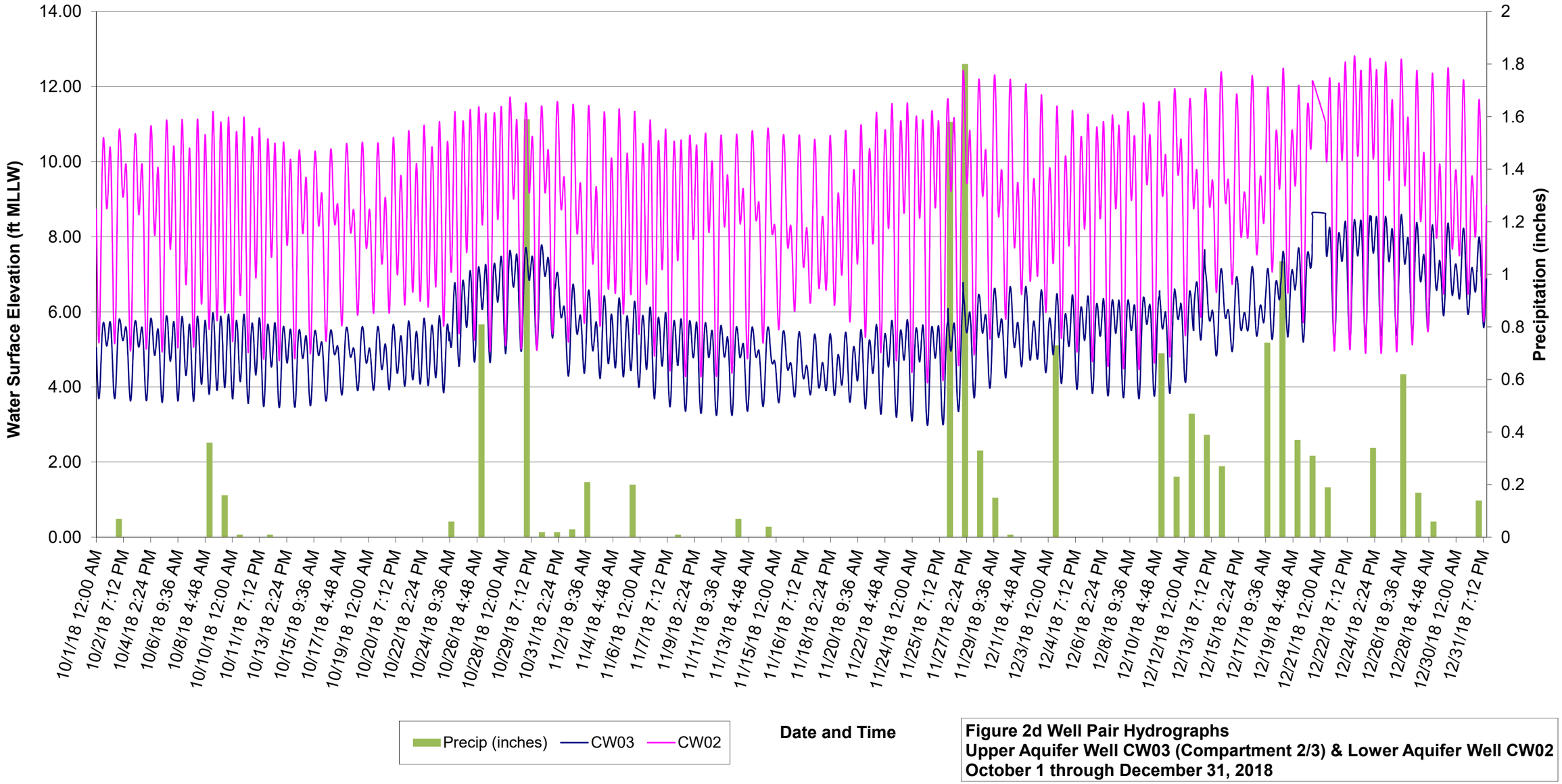

Figure 2d Well Pair Hydrographs
Upper Aquifer Well CW03 (Compartment 2/3) & Lower Aquifer Well CW02
October 1 through December 31, 2018

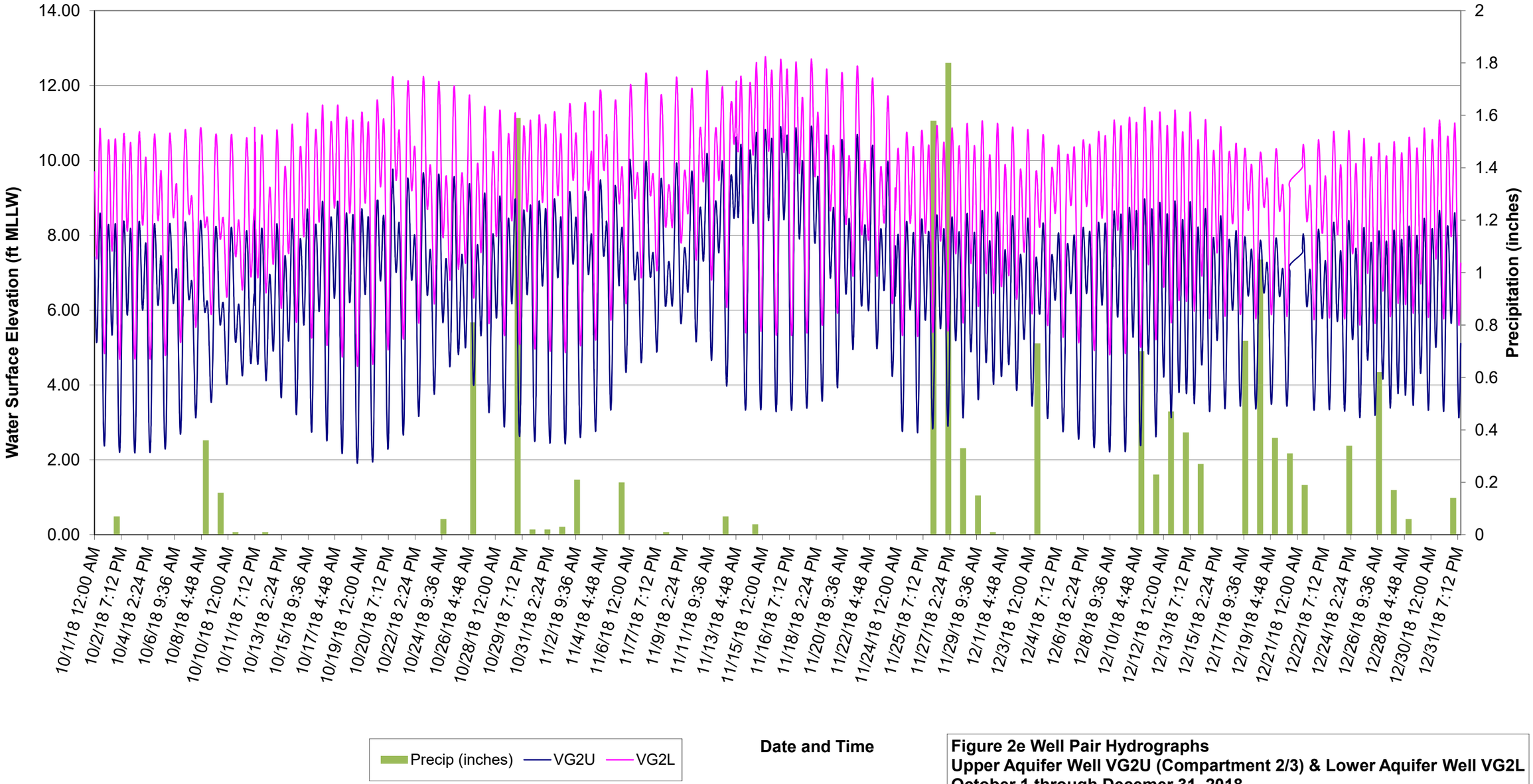

Figure 2e Well Pair Hydrographs
Upper Aquifer Well VG2U (Compartment 2/3) & Lower Aquifer Well VG2L
October 1 through Decemer 31, 2018

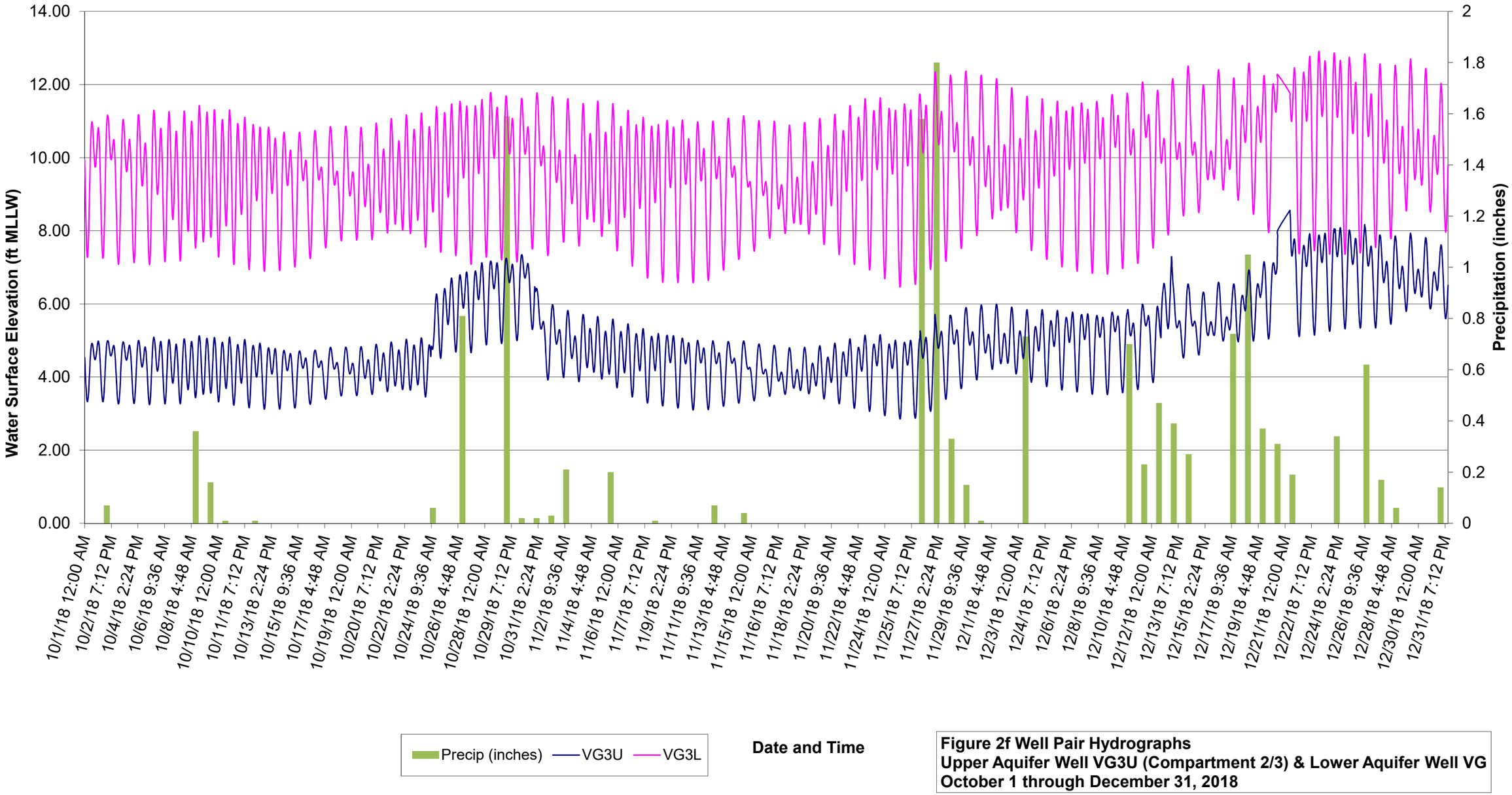

Figure 2f Well Pair Hydrographs
Upper Aquifer Well VG3U (Compartment 2/3) & Lower Aquifer Well VG
October 1 through December 31, 2018

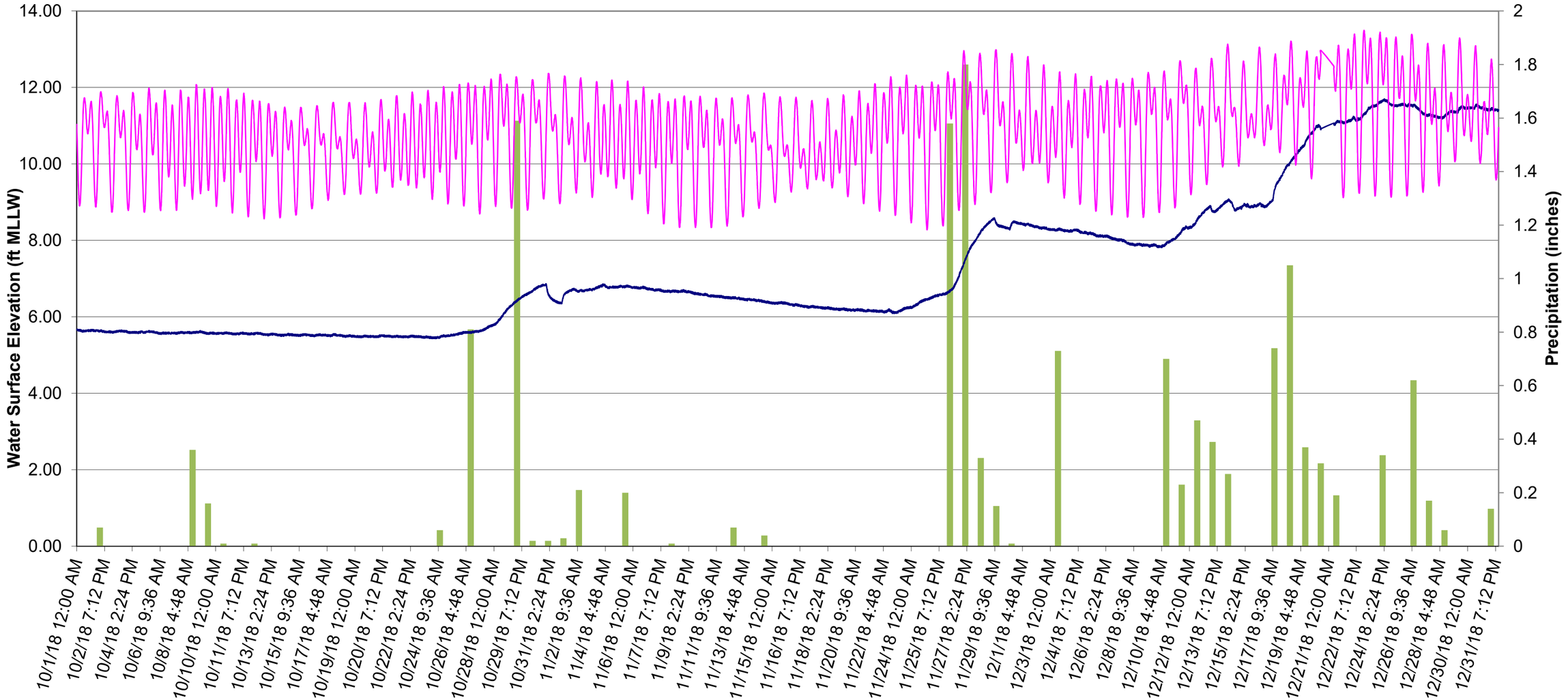

Figure 2g Well Pair Hydrographs
Upper Aquifer Well VG5U (Compartment 1) & Lower Aquifer Well VG5L
October 1 through December 31, 2018

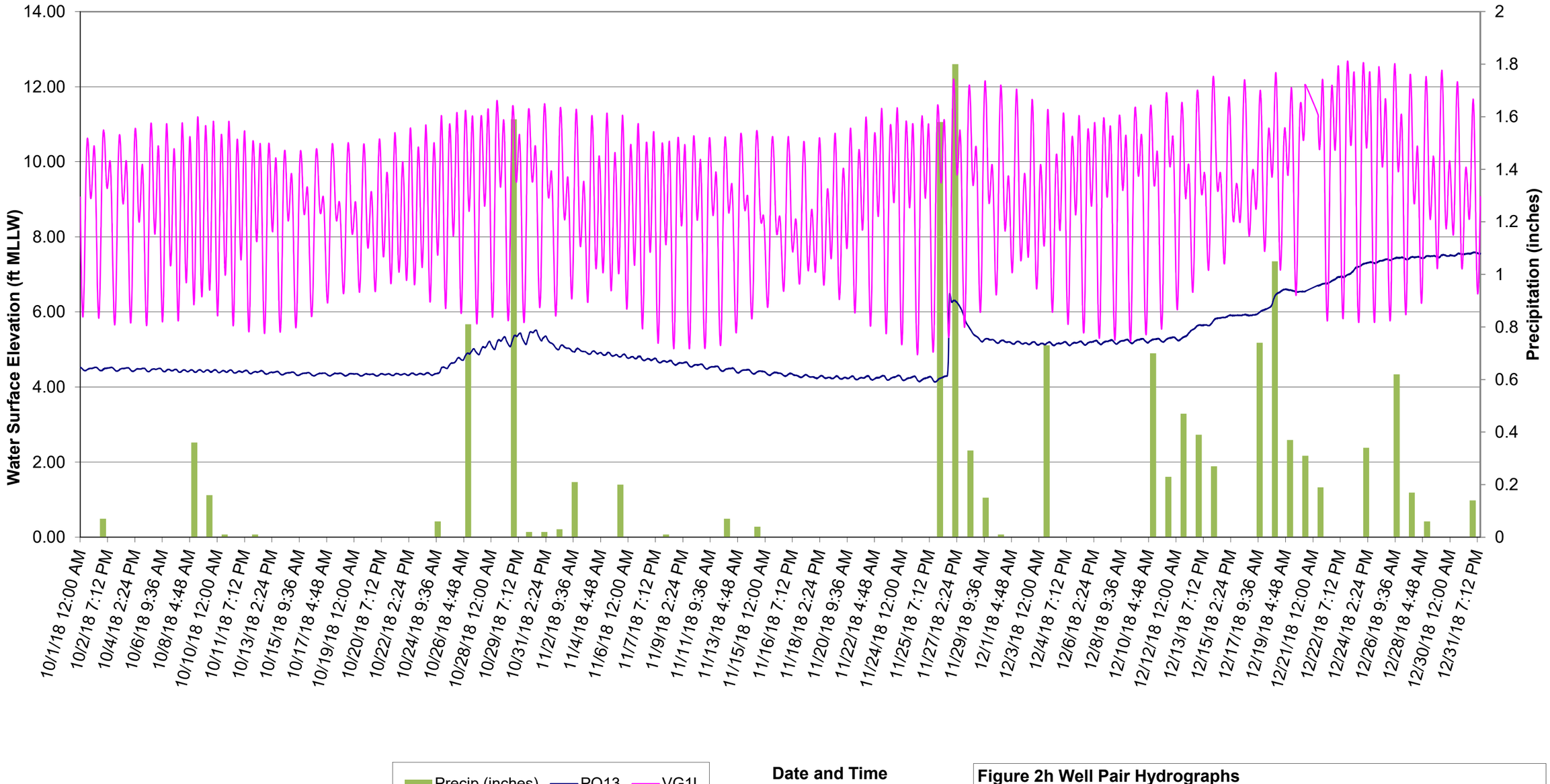

Figure 2h Well Pair Hydrographs
Upper Aquifer Well PO13 (Compartment 1) & Lower Aquifer Well VG1L
October 1 through December 31, 2018

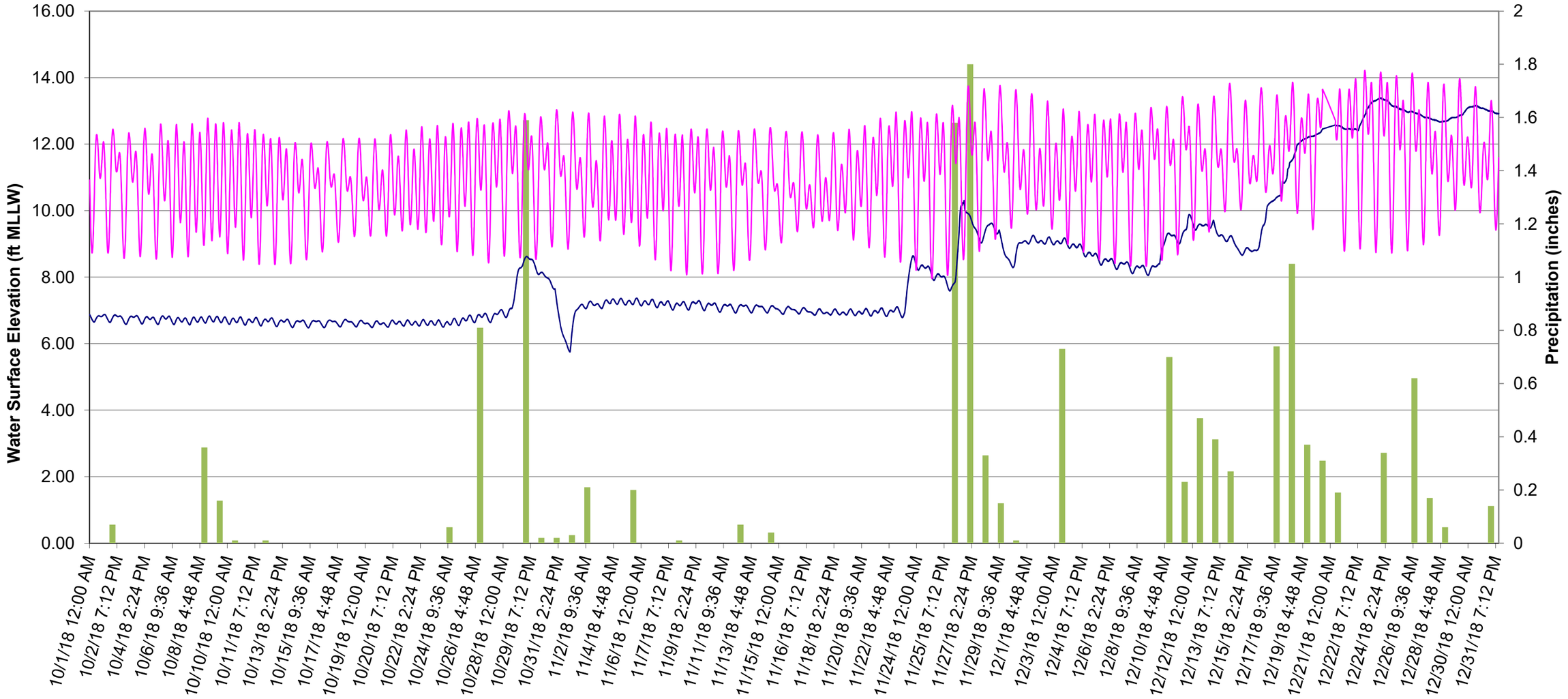

Figure 2i Well Pair Hydrographs
Upper Aquifer Well CW13 (Compartment 1) & Lower Aquifer Well VG4L
October 1 through December 31, 2018

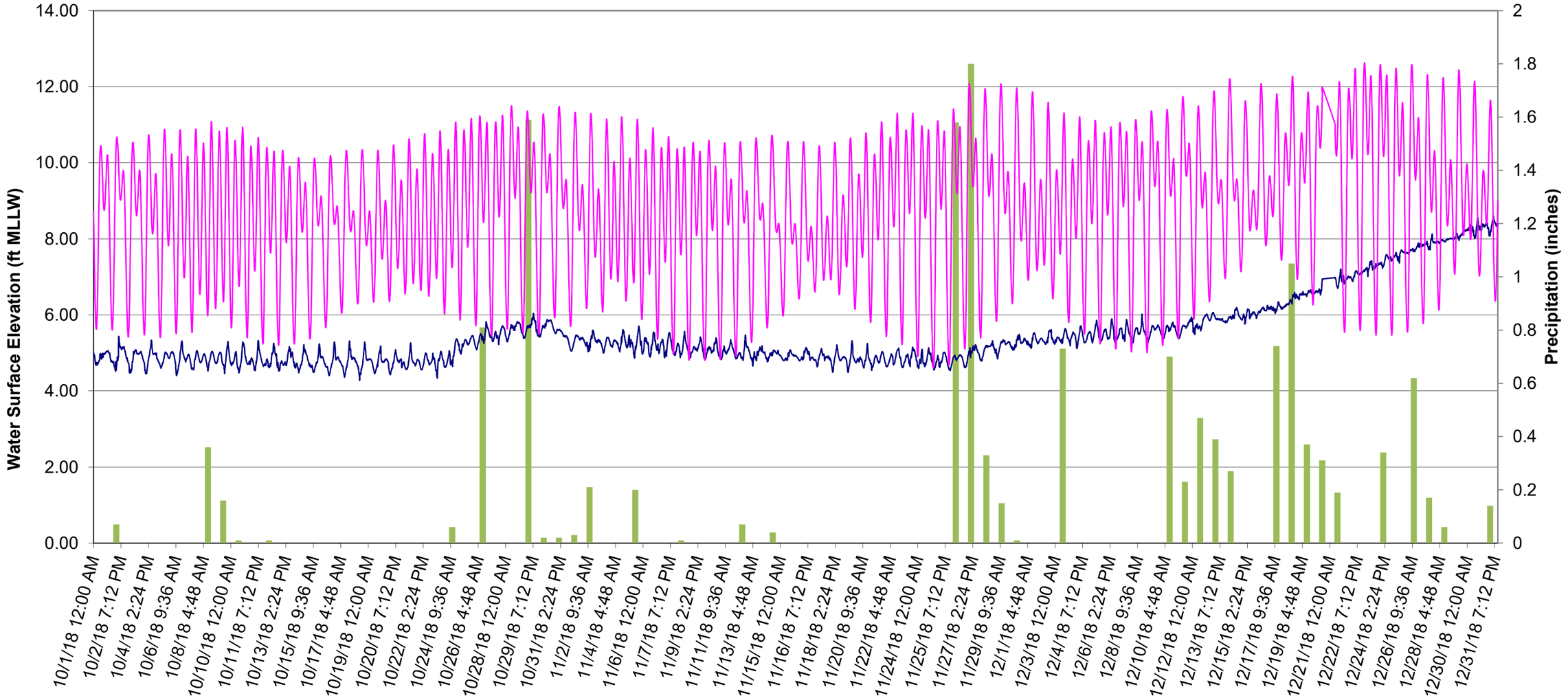

Figure 2j Well Pair Hydrographs
Upper Aquifer Well CW08 (Compartment 1) & Lower Aquifer Well P4L
October 1 through December 31, 2018

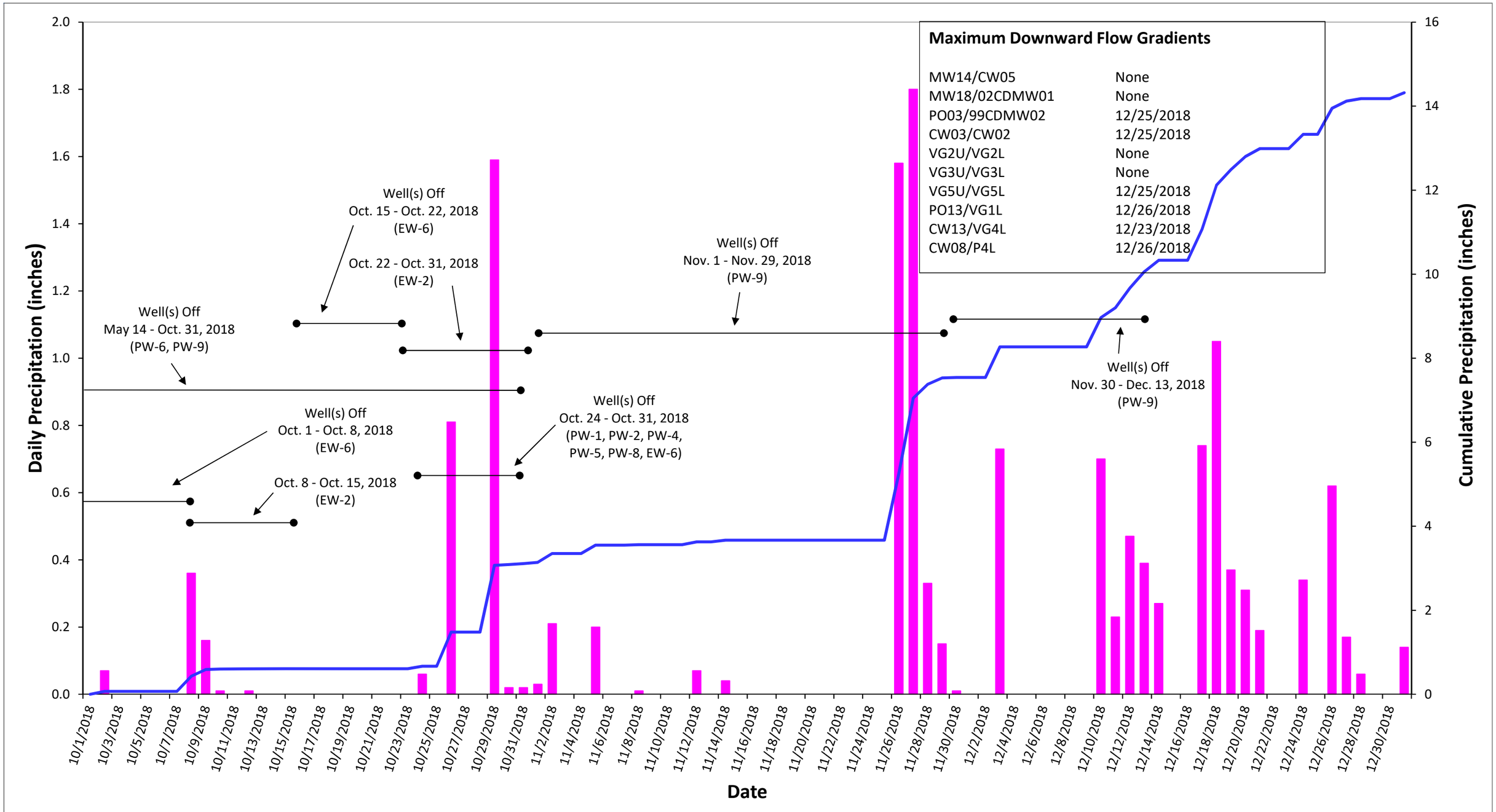

Figure 3 Wyckoff Site Precipitation, Well Field Shutdown, and Max Downward Flow Potential Summary October 1 through December 31, 2018