Goliad County Recharge Evaluation

Summary of Field Data Collection for September 2021

Submitted by

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Submitted to

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118 S. Market Street

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September 2021

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Monitoring Sites

Rainwater and Coldren (2018a,b, 2019, 2020a, b) previously reported the details of the instrumentation choices and site positions at the Landgrebe, Dohmann, and Fuller locations in Goliad County. Table 1 summarizes the details about the depths of the soil moisture sensor probes (P1-P5) at each of the datalogger sites (L1-L3, D1-D3, and F1-F3), as well as the coordinates of the datalogger sites and weather stations (WS). Aerial images (Google Earth) of the locations are shown in Figures 1, 2, and 3, respectively. Local soil conditions were presented in the previous reports.

Table 1. Installation Details

Land Use, Location	Site	Latitude (DD)	Longitude (DD)	Sensor Depths (ft)				
				P1	P2	P3	P4	P5
Cultivated, Landgrebe	L1	28.88164	-97.39657	1.0	3.3	4.9	4.9	5.9
	L2	28.88614	-97.39632	1.0	3.3	lost	4.9	5.9
	L3	28.88155	-97.39714	1.0	3.3	4.9	4.9	9.5
	WS	28.88164	-97.39657					
Ranch, Dohmann	D1	28.79439	-97.42340	1.0	3.3	4.9	4.9	8.2
	D2	28.79519	-97.42325	1.0	3.3	4.9	4.9	8.2
	D3	28.79480	-97.42204	1.0	3.3	4.9	4.9	8.2
	WS	28.79410	-97.42496					
Ranch, Fuller	F1	28.6536039	-97.6195353	1.0	3.3	4.9	4.9	9.0
	F2	28.6537386	-97.6194403	1.0	lost	4.9	4.9	9.0
	F3	28.653917	-97.6194149	1.0	3.3	4.9	4.9	9.0
	WS	28.654	-97.619					

Data Collection

As reported by Rainwater and Coldren (2018b, 2019, 2020b, 2021), data collection began in late June 2018 at the Landgrebe and Dohmann locations, and later at the Fuller location in January 2020. Table 2 provides the timing of the seven data collection visits since the previous annual data summary. The TTU team is grateful for the data downloads and maintenance performed by the District staff who provided the datafiles as email attachments or as datafile transfers. Unfortunately, the downloaded soil moisture sensor files from all three locations from the 11/20/2020 downloads were somehow misplaced by the GCGCD staff before transfer to the TTU team. All the other data files were converted to Excel spreadsheets for analyses and plotting. All Excel files are available upon request, as the tables are too large for inclusion in this report. The data presented in this report were collected from 6/28/20 to 8/30/2021. It should be noted that the soil moisture sensors provide data on 30- or 60-min intervals, while the WSs report to their dataloggers on 30-min intervals.

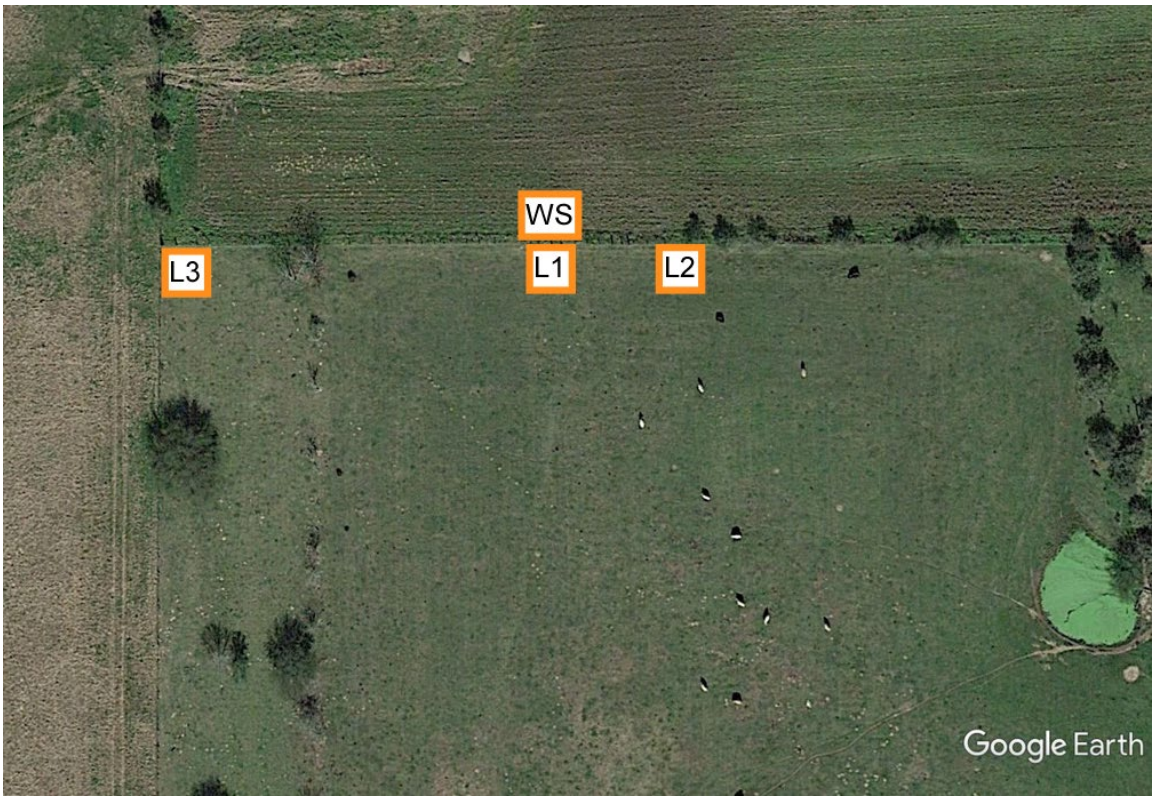

Figure 1. Approximate instrumentation sites at the Landgrebe cultivated location

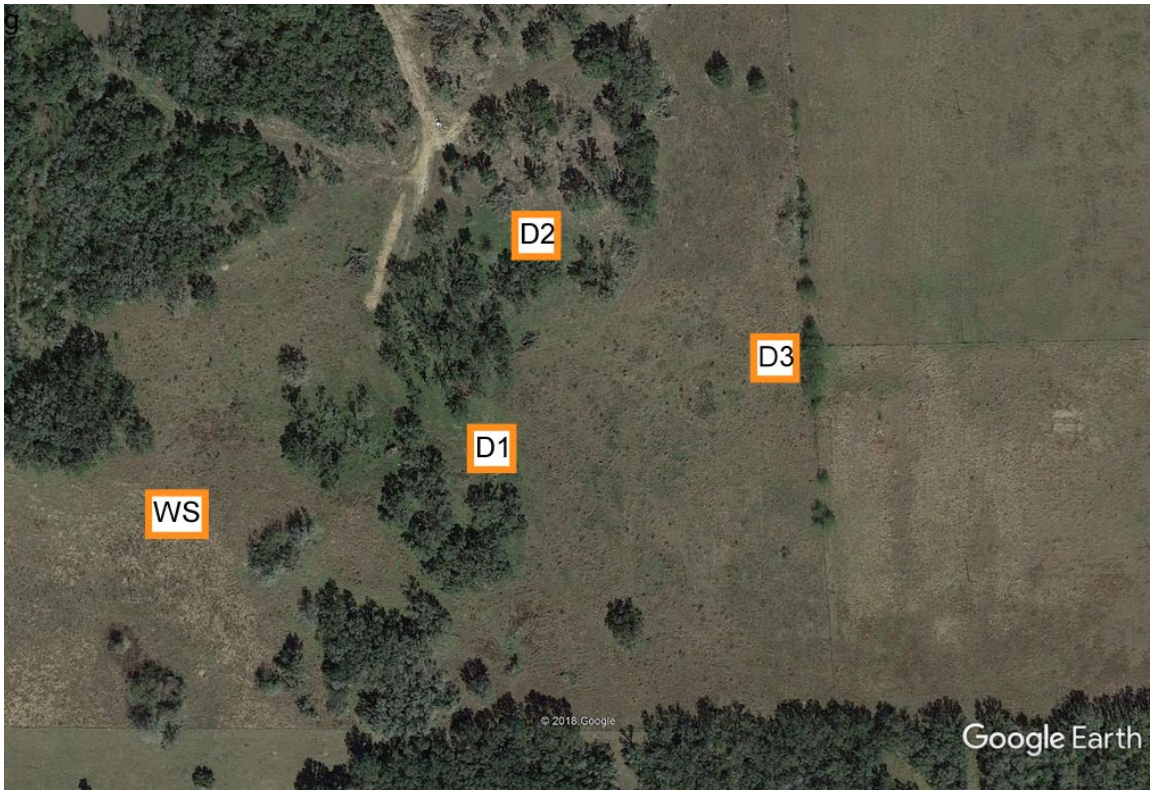

Figure 2. Approximate instrumentation sites at the Dohmann wooded location

Figure 3. Approximate instrumentation sites at the Fuller location

Table 2. Site Visit Dates Since August 2020

Date	Data Collectors
11/20/2020	GCGCD
2/3/2021	GCGCD
3/4/2021	GCGCD
4/6/2021	GCGCD
5/25/2021	GCGCD/TTU
6/24/2021	GCGCD
8/30/2021	GCGCD

Most of the soil moisture sensors have performed well continuously, but there have been some instrument problems. P3 at site L1 does not provide readings due to cable damage by livestock and a subsequent failed repair attempt. P1 at L1 provided no readings during February and early March 2021 as the probe was not completely plugged in to the datalogger, but the soil moisture probably didn't change during that time period. P2 at L2 failed in January 2020, but P3 is at the same depth and continues to work. P5 at L2 failed in August 2020. At Dohmann site D2, P5 provided reasonable readings until 10/2/2019 and then shut down. P2 at D2 failed on 2/4/2020, and P4 at D2 failed on 6/12/2020. These failures leave only P1 and P3 recording at D2. P2 at Fuller site F2 failed soon after installation, but the other Fuller sensors are still recording. As of the date of this report, 38 of the 45 installed soil moisture sensors were still working.

As noted in the previous reports, the WS at each location has instruments for rainfall (RF), wind speed, temperature, humidity, and solar radiation. The last four observations allow calculation of evapotranspiration for a reference grass (ET ref). The SpecWare Pro software presents the daily RF and ET ref values. As noted previously, we had problems with the anemometers at both the Landgrebe and Dohmann locations. The anemometers were not rotating freely due to increased resistance on their shafts. The Landgrebe problem was noted first, so the TTU team replaced the Landgrebe anemometer on 5/19/20, but the Dohmann WS problem was first noted on that same date. The GCGCD staff attempted to repair the Dohmann anemometer by carefully cleaning the shaft, but the repair did not last long, so that anemometer was replaced by the GCGCD staff. The TTU team reviewed the wind speed data from all three WSs [1] to identify when the wind speeds diminished incorrectly and [2] to select replacement wind speed and ET ref data from one of the other locations. The Landgrebe data were replaced by the Dohmann location data from 12/1/2019 to 3/31/2020 and by the Fuller location data from 4/1/2020 to 5/19/2020. The Dohmann data were replaced by the Fuller location data from 4/14/2020 to 9/30/2020, as the Dohmann anemometer was replaced in September 2020. This replacement of missing data was the best we could do, but it should be noted that the ET ref values will likely be more similar, but not identical, from location to location, while the RF values will likely be more variable. During the current year, the tipping bucket rain gauge at the Dohmann WS was found to be clogged and full of water during the site visit on 5/25/2021. This visit followed multiple significant rain events, so it is unknown how much rainfall data was missing. The GCGCD staff and TTU team cleared the clog and replaced the rain gauge with successful readings collected after the field site visit. The data from the August 2021 download showed unreasonable ET ref values from the Dohmann WS from July forward. The solution to that issue will be addressed this fall.

Results and Observations

With the start of data collection at the first two locations on 6/28/18, it was reasonable to see Year 1 of the dataset stretching from that date to 6/27/2019, Year 2 from 6/28/2019 to 6/27/2020, and Year 3 from 6/28/2020 to 6/27/2021. Year 4 began on 6/28/2021. Data collection at the Fuller location began on 1/10/2020, starting almost six months into Year 2 and continuing into the following years. Table 3 summarizes the RF and ET ref values for the three locations and the four years. It is notable that the Year 1 RF totals of 48.92 in and 41.39 in at the Dohmann and Landgrebe locations, respectively, were well above the average annual RF of 36 to 37 in for Goliad. The Year 2 RF totals of 23.52 in and 27.77 in at the Dohmann and Landgrebe locations, respectively, were well below the Goliad annual average, as were the Year 3 values of 28.85 and 23.64 in, respectively, at the Landgrebe and Fuller sites.

Table 3. Yearly Rainfall and ET ref

	6/28/18-6/27/19		6/28/19-6/27/20		6/28/20-6/27/21		6/28/21-8/30/21	
Location	RF (in)	ET ref (in)	RF (in)	ET ref (in)	RF (in)	ET ref (in)	RF (in)	ET ref (in)
Dohmann	48.92	43.41	23.52	50.45	9.34[1]	42.54	15.08	na
Landgrebe	41.39	45.52	27.77	49.13	28.86	46.42	12.00	10.71
Fuller	na	na	17.70	38.00	23.64	54.24	12.16	13.07

Note 1. Clogged rain gauge in May 2021 missed some significant storms

The ET ref values for these two locations are a little higher for Year 2 than Year 1. The Fuller location RF and ET ref values in Year 2 were much smaller than the other two locations because of the shorter observation time that began in January 2020. Table 4 demonstrates the difference in larger rainfall events across the three properties, showing the dates and rainfall depths for daily events greater than or equal to 1.0 in. The clogged rain gauge at the Dohmann site was filled to the brim on 5/25/2021, holding about 4 in of water, besides whatever amount spilled over the brim during the storms.

Table 4. Rainfall Events in Year 3 of 1 in/d or More

	Rainfall (in)		
Date	Dohmann WS	Landgrebe WS	Fuller WS
7/17/2020		1.42	
11/28/2020		1.75	1.79
12/1/2020	1.38		
1/10/2021		1.03	
5/1/2021	clog?	1.75	1.86
5/16/2021	clog?	1.09	1.38
5/18/2021	clog?		1.64
5/19/2021	clog?	1.47	2.35
5/25/2021	1.15		
6/3/2021	1.23	1.39	
6/5/2021		1.06	
6/15/2021		1.77	

Figures 4 to 13 display the Year 3 and early Year 4 observations for the Landgrebe locations, aligned vertically on tabloid-sized pages to allow visual comparison of the graphs while keeping the horizontal time axes aligned. Figure 4 is a bar chart that shows the daily values of RF and ET ref in in/d provided by the Landgrebe WS data. ET ref is calculated for a hypothetical reference grass as used in the Penman-Monteith approach, based on one of the most popular evapotranspiration formulas (Shuttleworth 1993). Figures 5 to 7 provide the variations in moisture content for the sensor probes at sites L1, L2, and L3, respectively, during Year 3. While the soil moisture data show decreased values in the summer months, responses to the winter and spring rainfall events were noted in the upper sensors. The three lower sensors at all three sites changed little over most of the year, then the P3 and P4 probes showed some response to the May and June rainfall events. Small increases in moisture content at the P5 probes were noted by the end of June. Figure 8 shows the cumulative depths of rainfall and ET ref for Year 4. Coupled with the large deficit between ET ref and RF, this dataset indicates that both evaporation from the soil and transpiration through the plants were drying the upper soils and limited downward migration of water. Figures 9 to 13 display the data from the first two months of Year 4. The upper three probes responded to the July rainfall events, then the moisture contents began declining. Unfortunately, only L1 still had the lowest P5 operating, and its moisture content was stable, indicating little arrival of water from above.

Figures 14 to 23 summarize the Year 3 and early Year 4 data for the Dohmann locations. Responses to rainfall events were similar to those at the Landgrebe locations. The moisture contents at P5 remained stable for both D1 and D3 in Year 3, but there was some increase in moisture content at P5 in July of Year 4. As noted, the missing rainfall data lowered the annual total for Year 3, and the early Year 4 ET ref values were not available from the Dohmann WS.

Figures 24 to 33 display the Year 3 and early Year 4 data for the Fuller locations. No significant changes in soil moisture were seen at these sites. The upper three probes responded to the rainfall events in both years, but the lowest P5 remained stable across both years. The spike in moisture content at P4 in May at F1 is unexpected, but the values did decrease soon afterward.

Next Steps

The TTU team will continue this monitoring and reporting work with the GCGCD staff with occasional field visits by the TTU for maintenance of the instrumentation. We understand the GCGCD may be interested in an additional field installation, so that issue can be addressed in the next proposal. Dr. Terry McLendon (2020) has provided a report that characterized the vegetation types at all three sites for assignment of appropriate ET crop coefficients to refine the estimates of soil water lost to ET at the sites. His complex analysis used ecohydrological and literature information about the water requirements of the vegetation, species-specific water-use efficiencies, root architecture, vegetation canopy, and surface runoff. After the TTU team reviewed his report, additional explanation of his findings was included to clarify the differences in water use by immature and mature huisache and mesquite stands over time. His complete report is provided as a separate submittal with this document.

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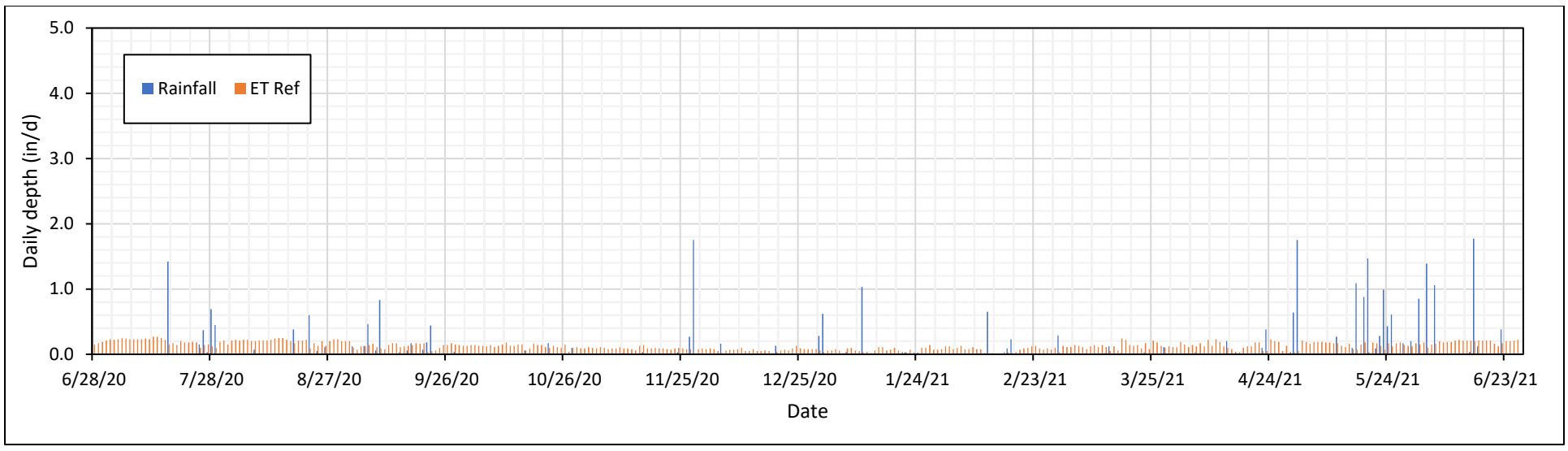


Figure 4. Landgrebe daily rainfall and ET ref June 28, 2020 to June 27, 2021

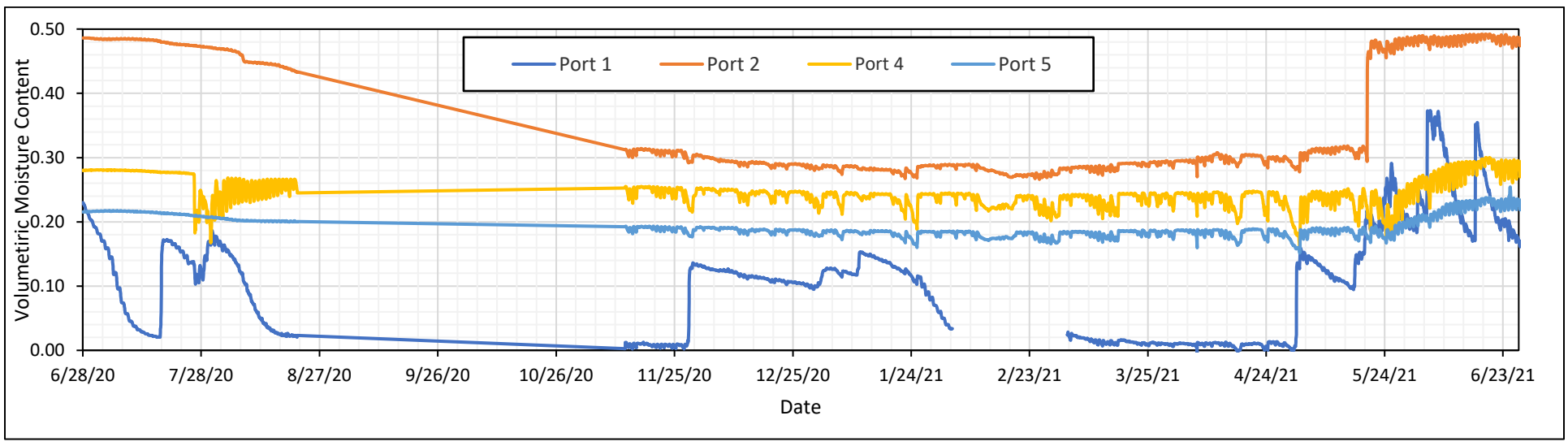


Figure 5. Landgrebe L1 soil moisture probes June 28, 2020 to June 27, 2021

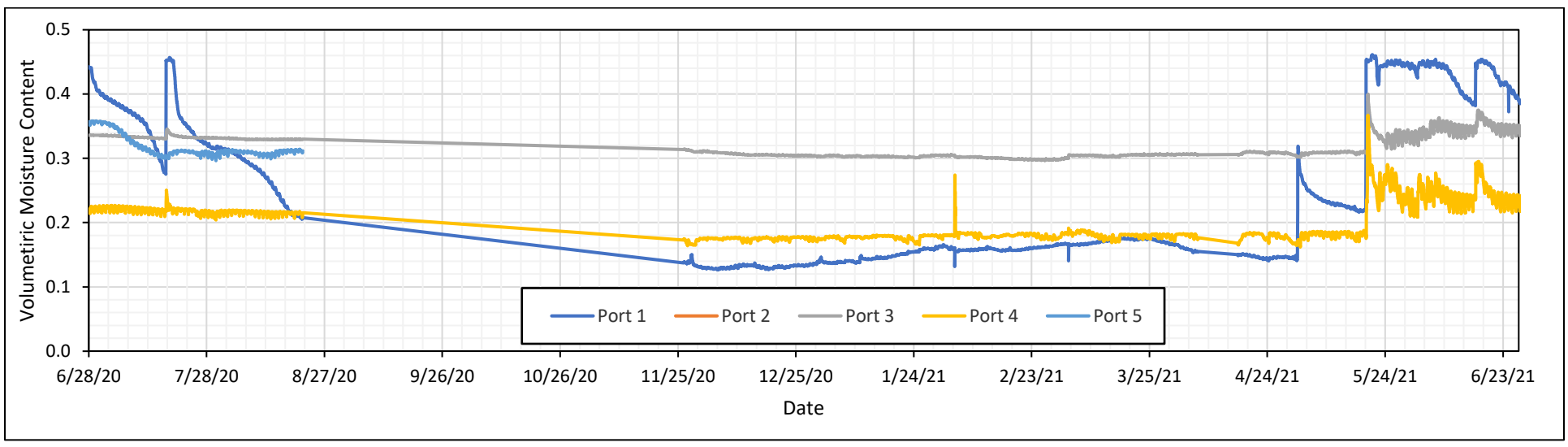


Figure 6. Landgrebe L2 soil moisture probes June 28, 2020 to June 27, 2021

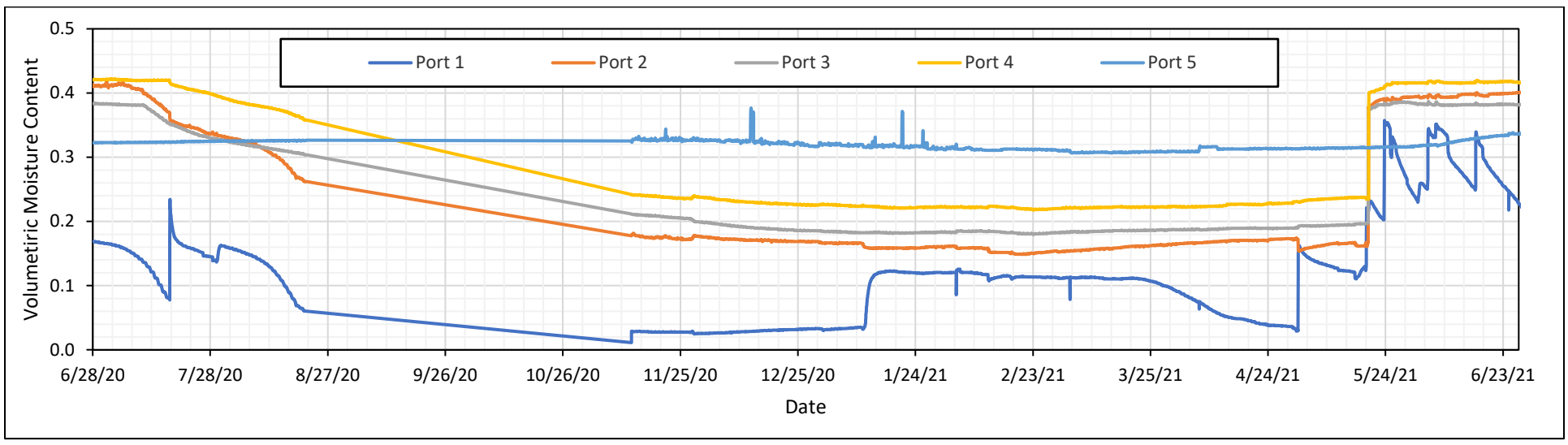


Figure 7. Landgrebe L3 soil moisture probes June 28, 2020 to June 27, 2021

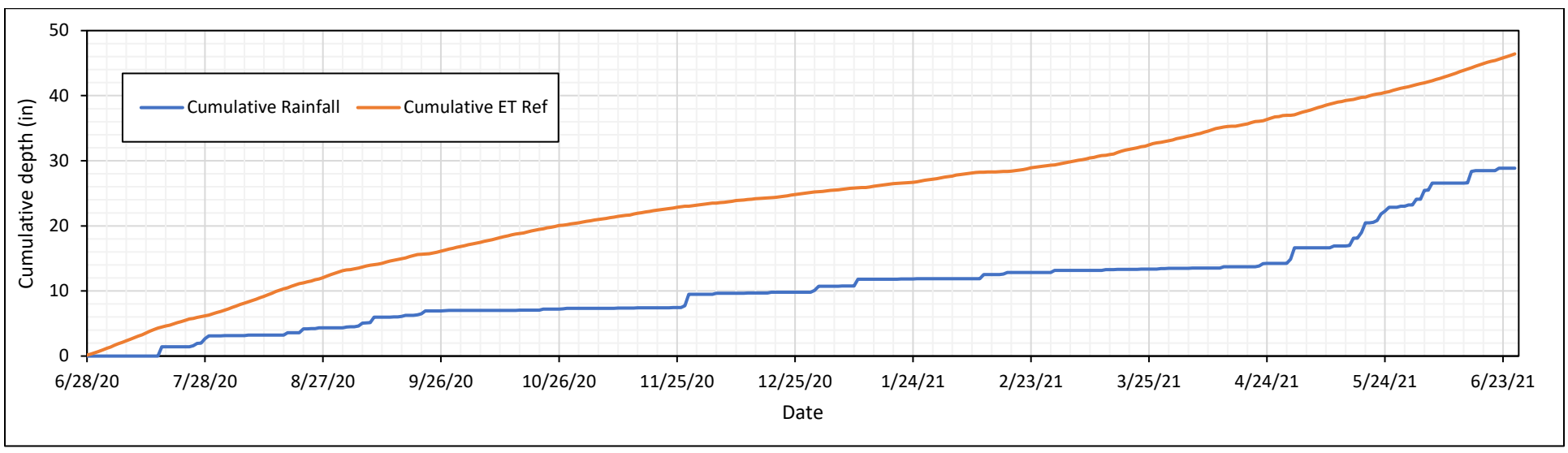


Figure 8. Landgrebe cumulative rainfall and ET ref June 28, 2020 to June 27, 2021

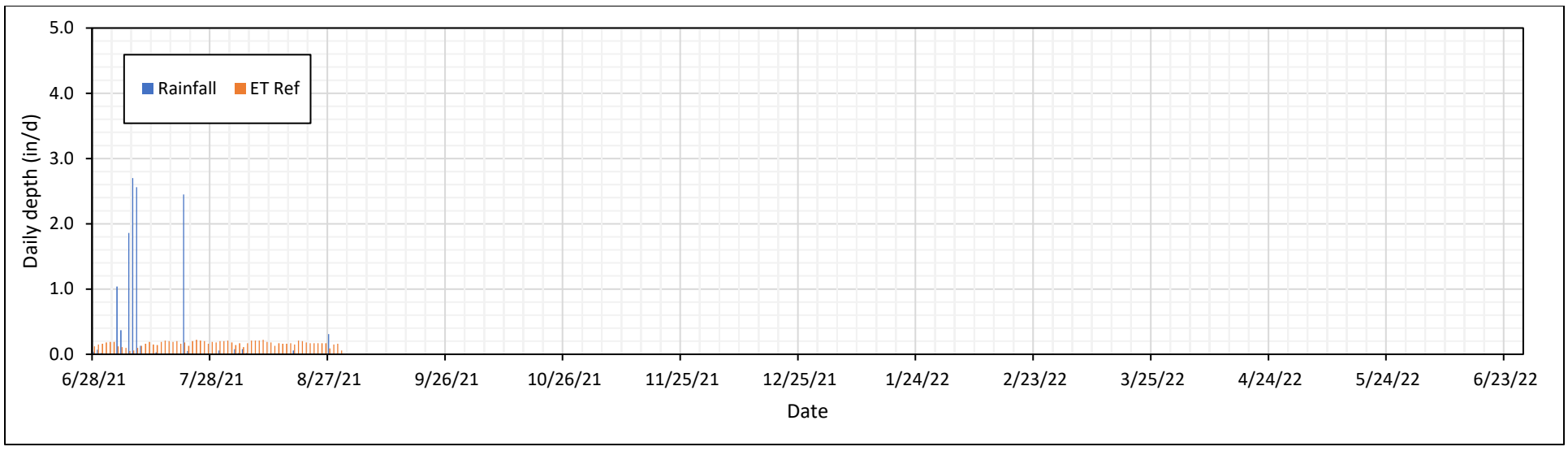


Figure 9. Landgrebe daily rainfall and ET ref June 28, 2021 to August 30, 2021

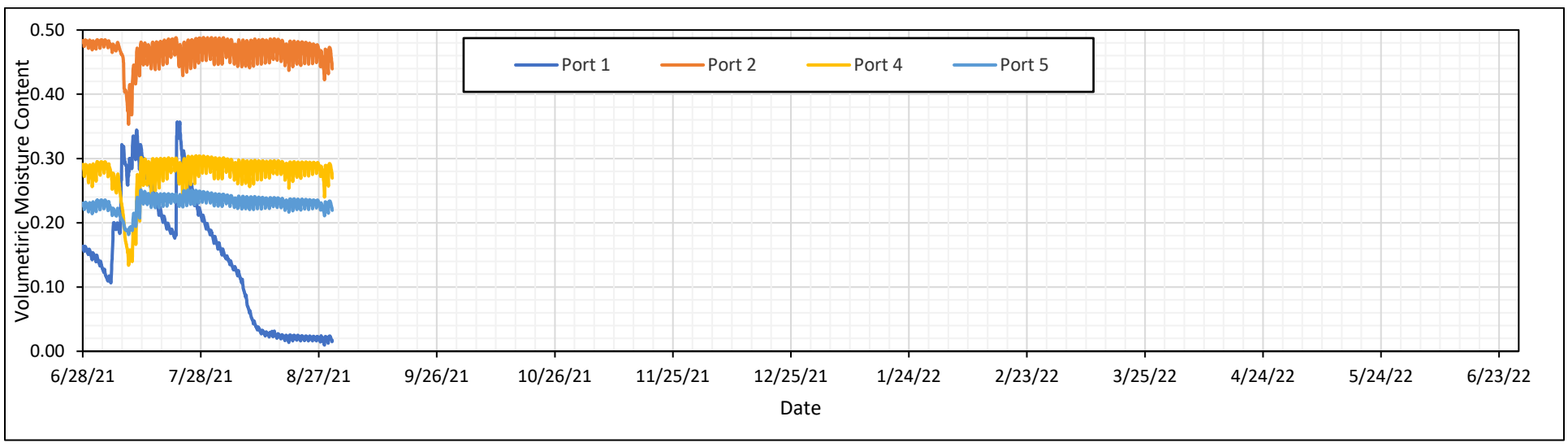


Figure 10. Landgrebe L1 soil moisture probes June 28, 2021 to August 30, 2021

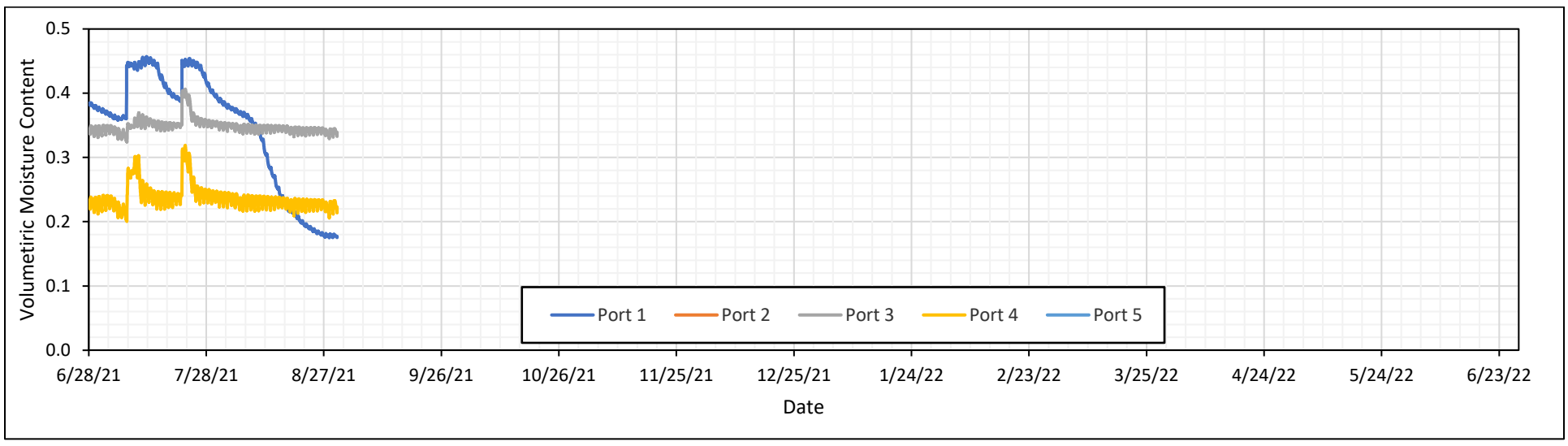


Figure 11. Landgrebe L2 soil moisture probes June 28, 2021 to August 30, 2021

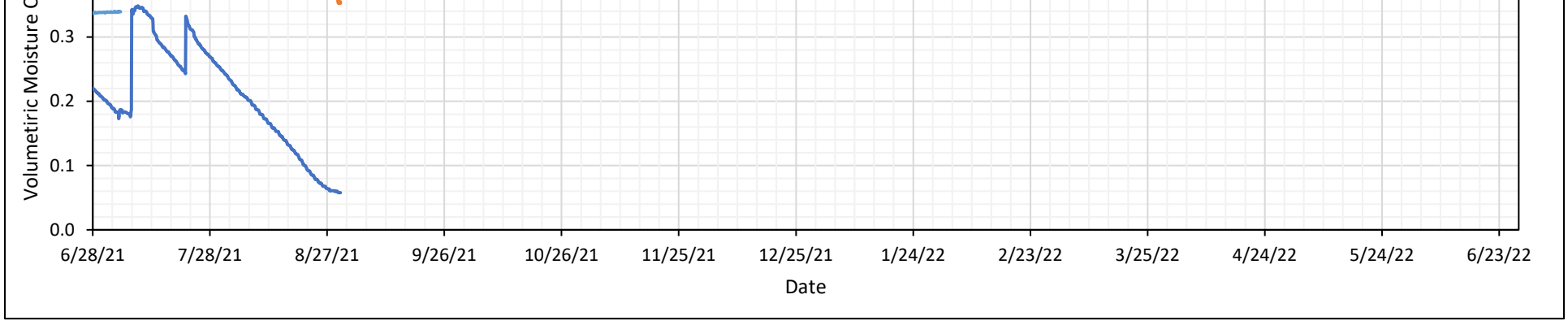


Figure 12. Landgrebe L3 soil moisture probes June 28, 2021 to August 30, 2021

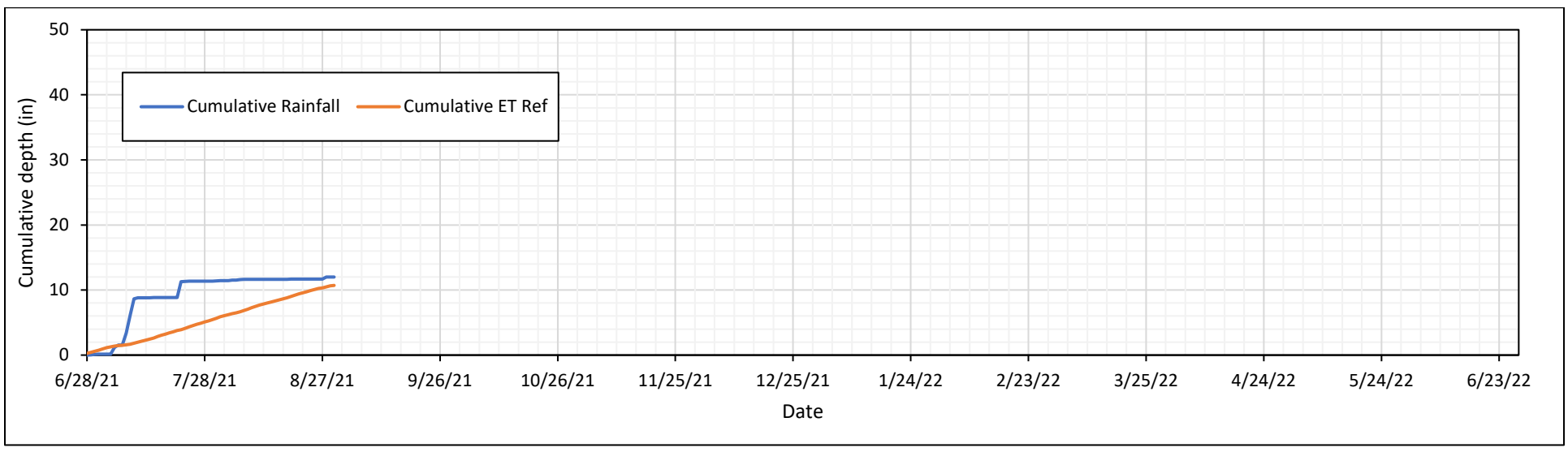


Figure 13. Landgrebe cumulative rainfall and ET ref June 28, 2021 to August 30, 2021

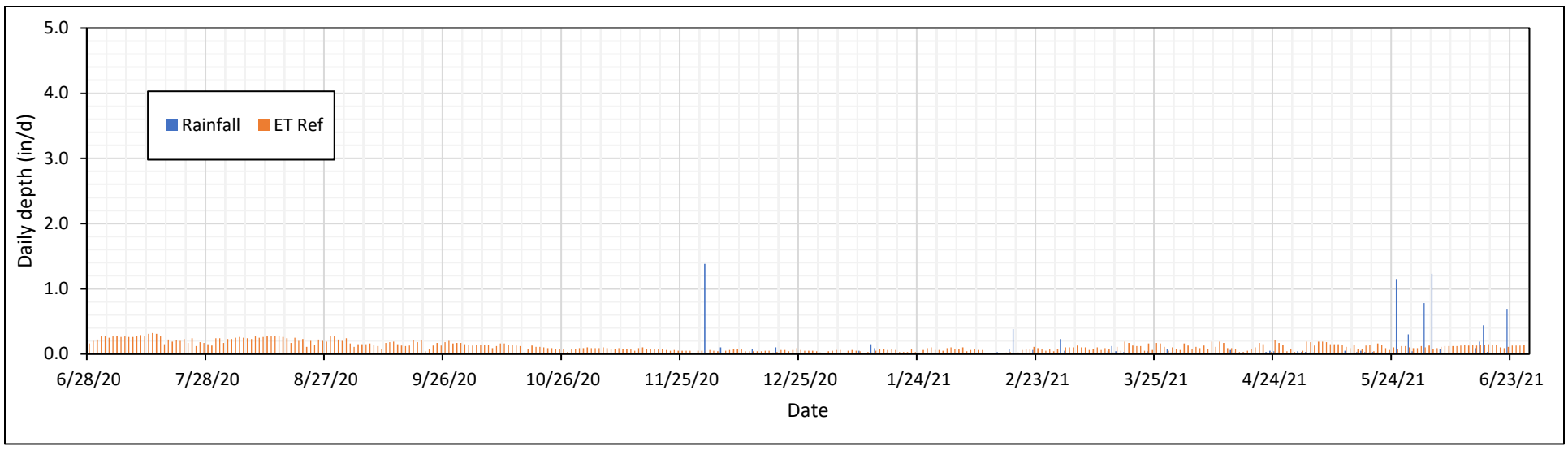
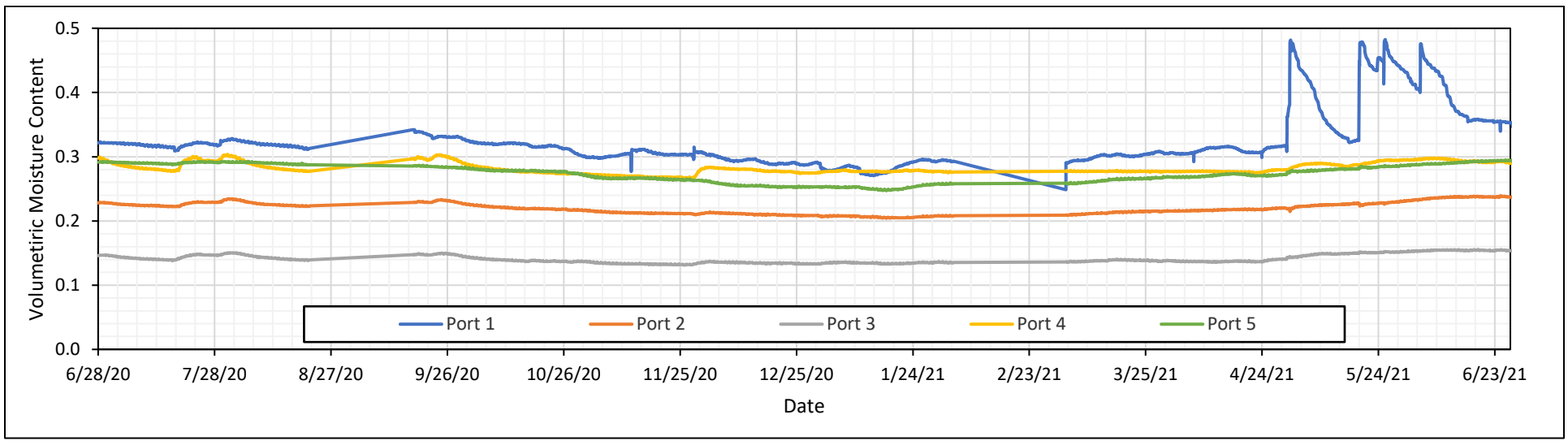


Figure 14. Dohmann daily rainfall and ET ref June 28, 2020 to June 27, 2021 (rain gauge clogged/cleared in late May 2021)



15. Dohmann D1 soil moisture probes June 28, 2020 to June 27, 2021

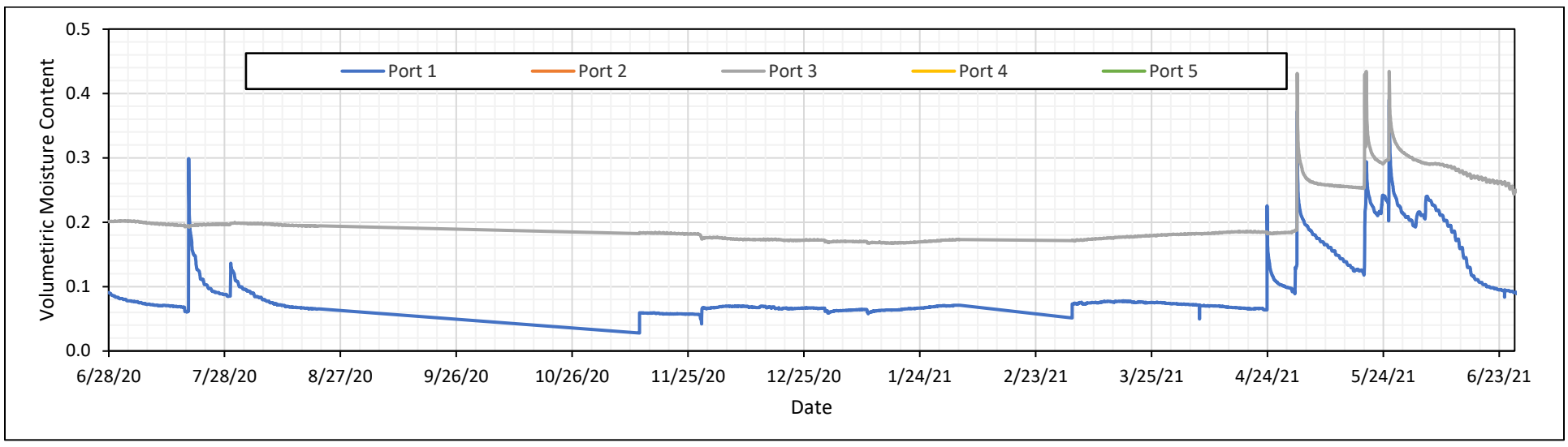


Figure 16. Dohmann D2 soil moisture probes June 28, 2020 to June 27, 2021

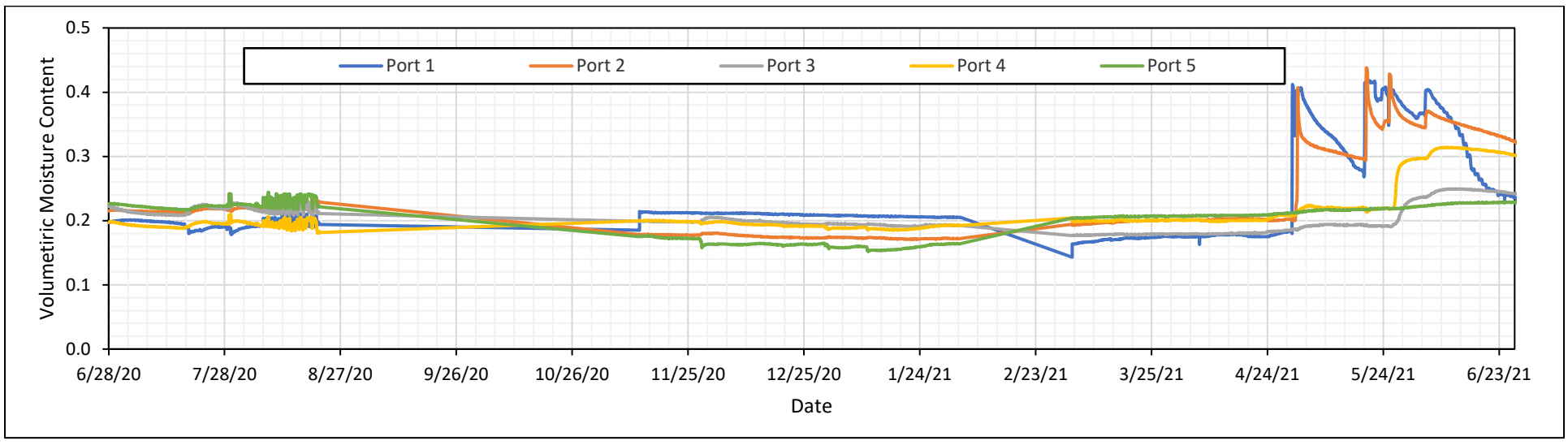


Figure 17. Dohmann D3 soil moisture probes June 28, 2020 to June 27, 2021

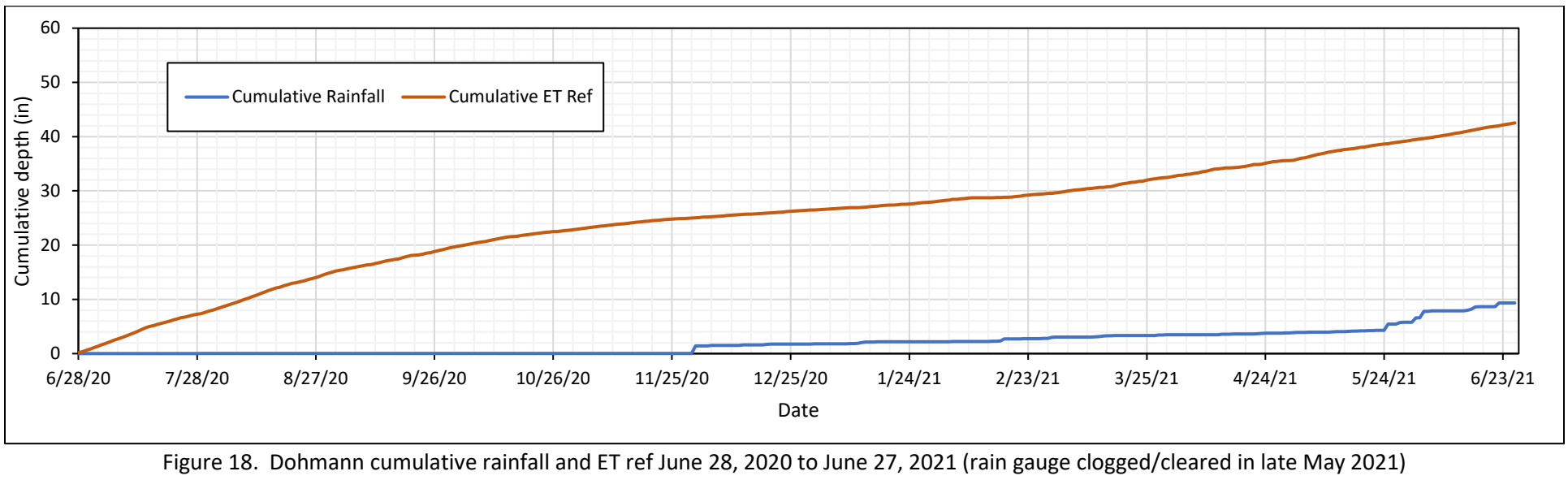


Figure 18. Dohmann cumulative rainfall and ET ref June 28, 2020 to June 27, 2021 (rain gauge clogged/cleared in late May 2021)

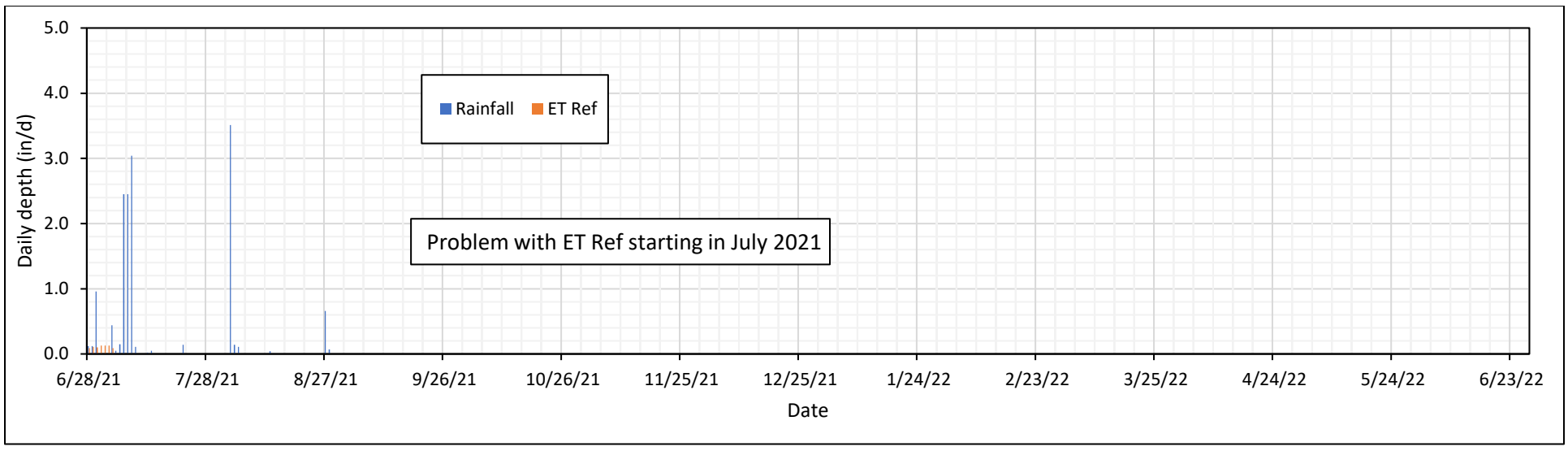
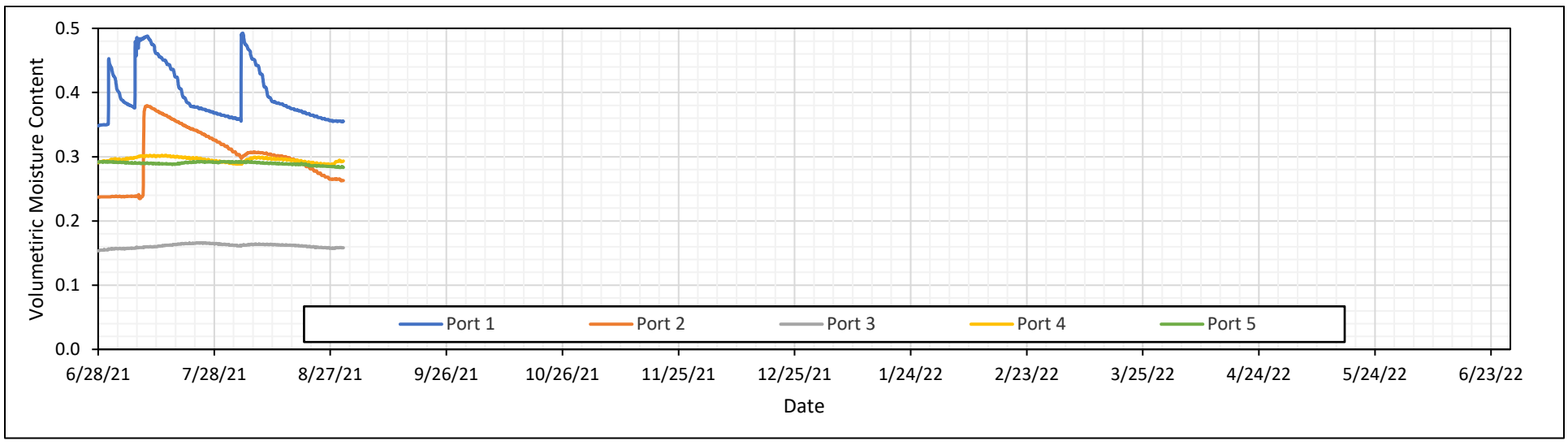


Figure 19. Dohmann daily rainfall and ET ref June 28, 2021 to August 30, 2021



20. Dohmann D1 soil moisture probes June 28, 2021 to August 30, 2021

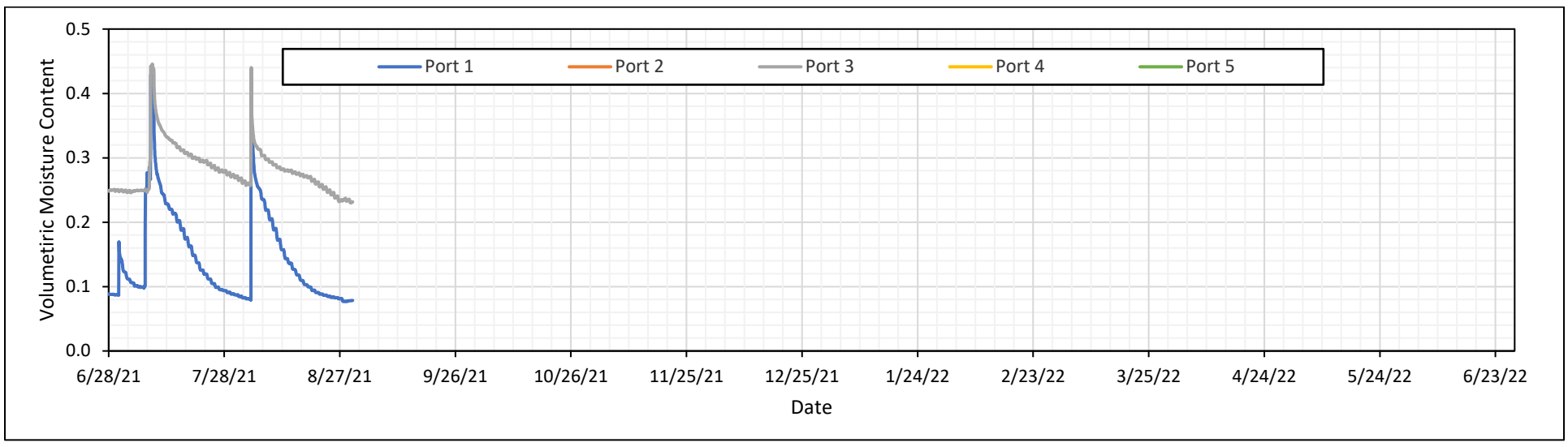


Figure 21. Dohmann D2 soil moisture probes June 28, 2021 to August 30, 2021

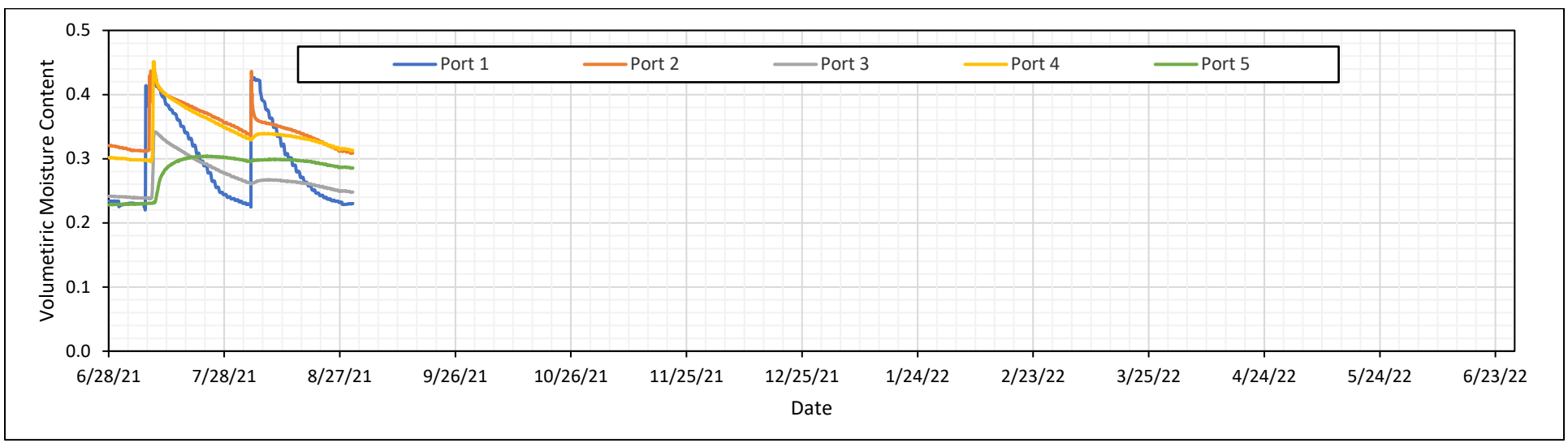


Figure 22. Dohmann D3 soil moisture probes June 28, 2021 to August 30, 2021

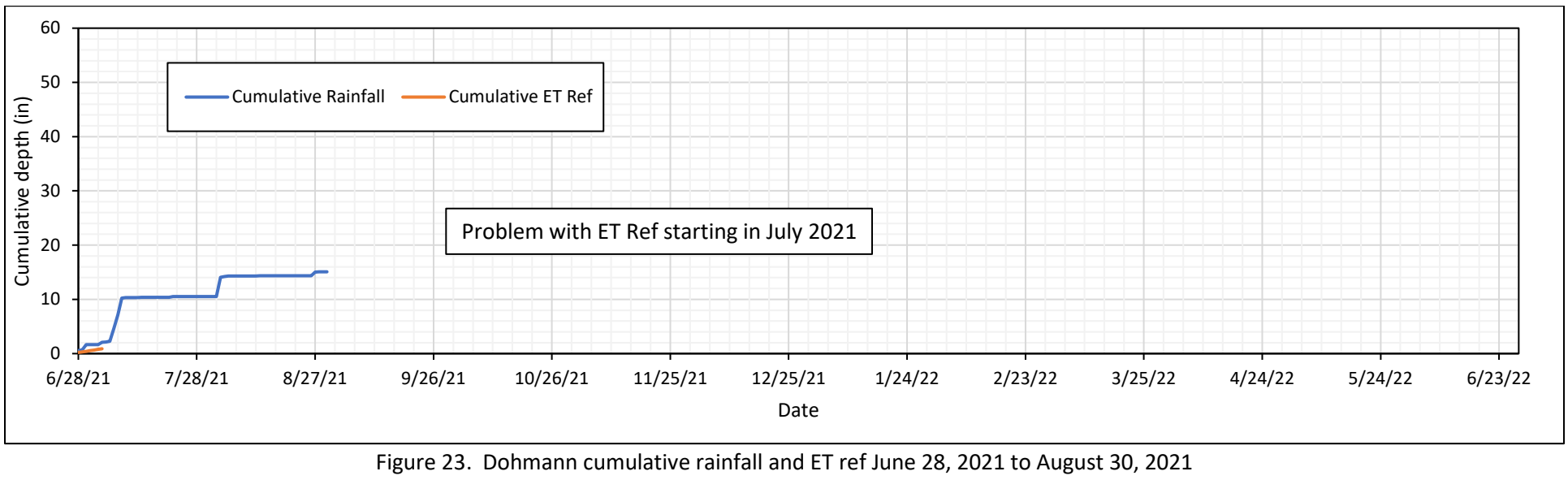


Figure 23. Dohmann cumulative rainfall and ET ref June 28, 2021 to August 30, 2021

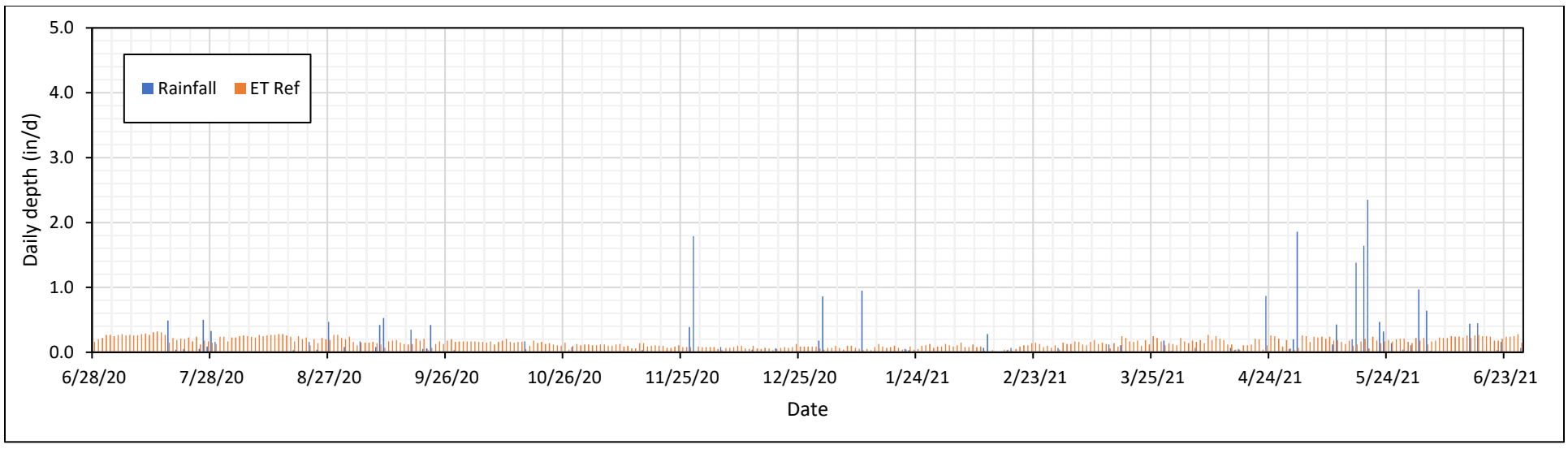


Figure 24. Fuller daily rainfall and ET ref June 28, 2020 to June 27, 2021

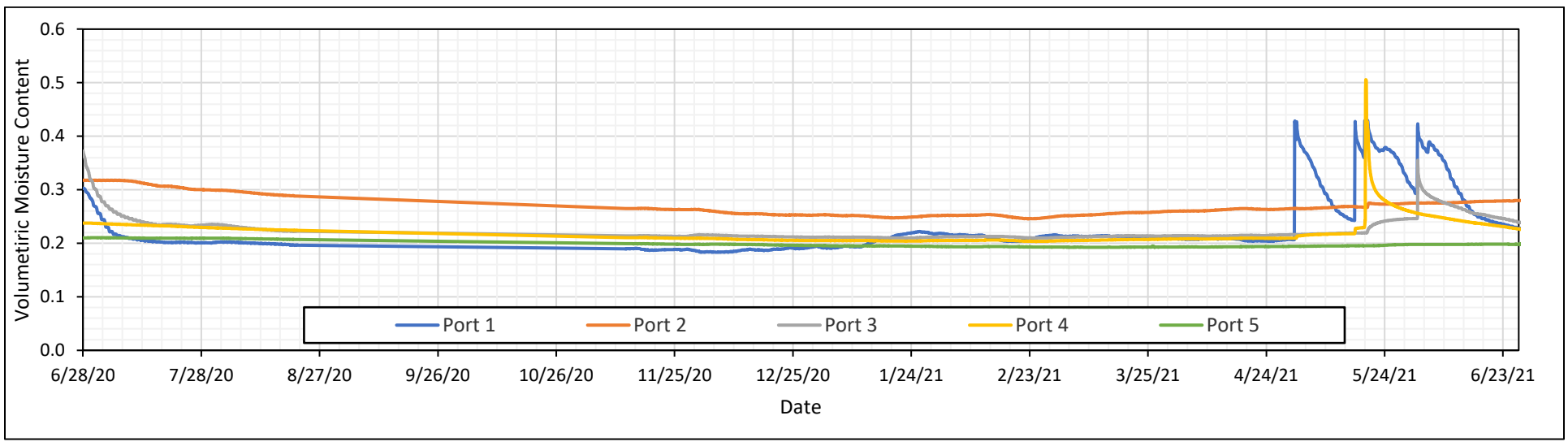


Figure 25. Fuller F1 soil moisture probes June 28, 2020 to June 27, 2021

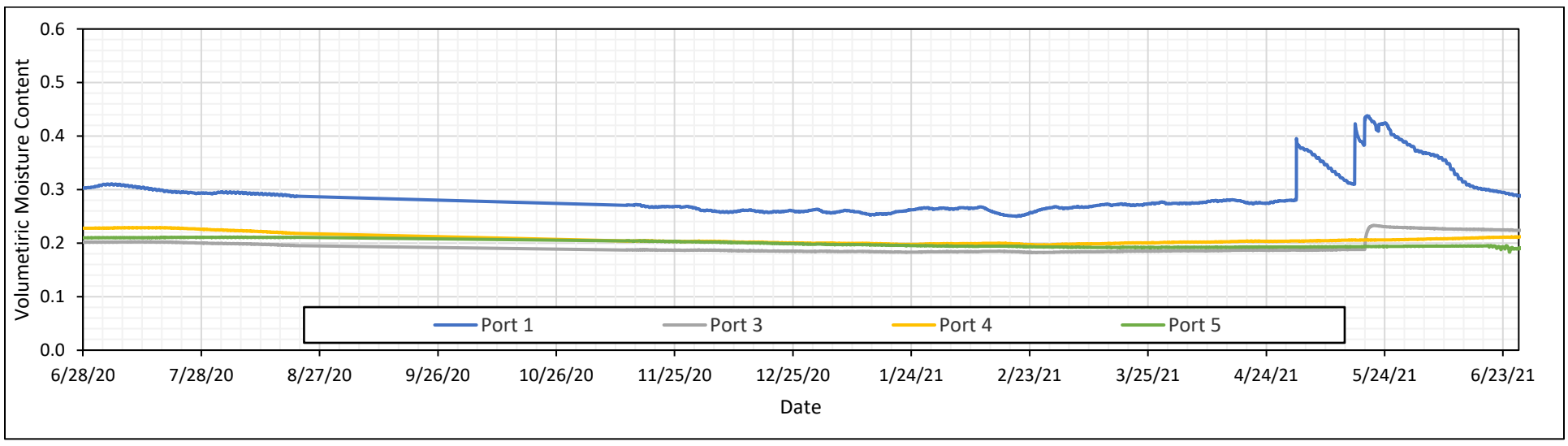


Figure 26. Fuller F2 soil moisture probes June 28, 2020 to June 27, 2021

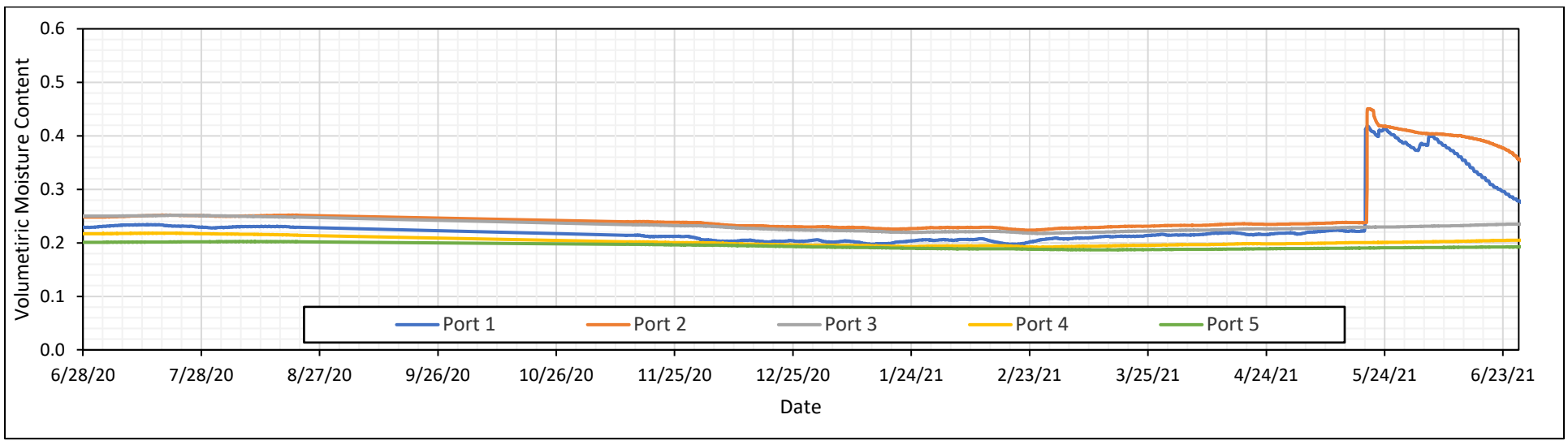


Figure 27. Fuller F3 soil moisture probes June 28, 2020 to June 27, 2021

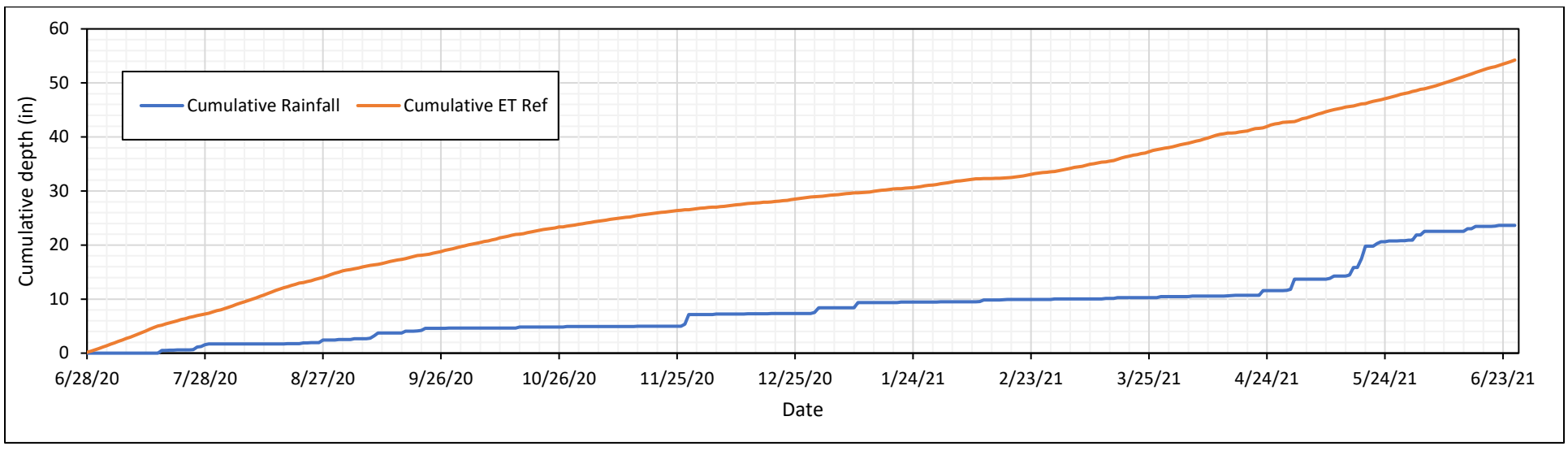


Figure 28. Fuller cumulative rainfall and ET ref June 28, 2020 to June 27, 2021

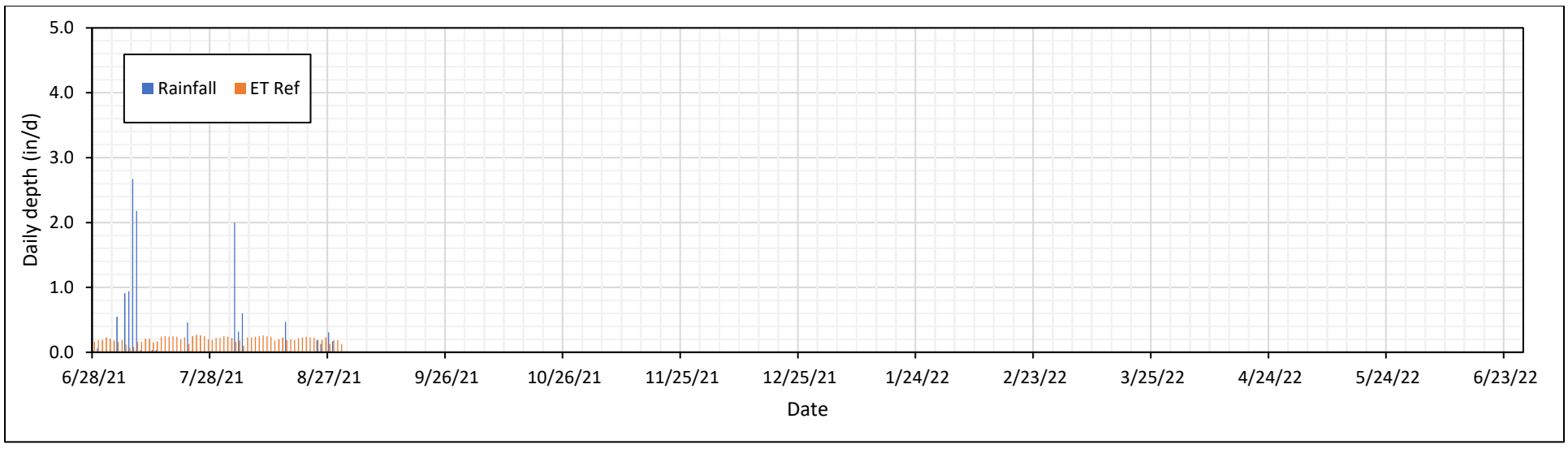


Figure 29. Fuller daily rainfall and ET ref June 28, 2021 to August 30, 2021

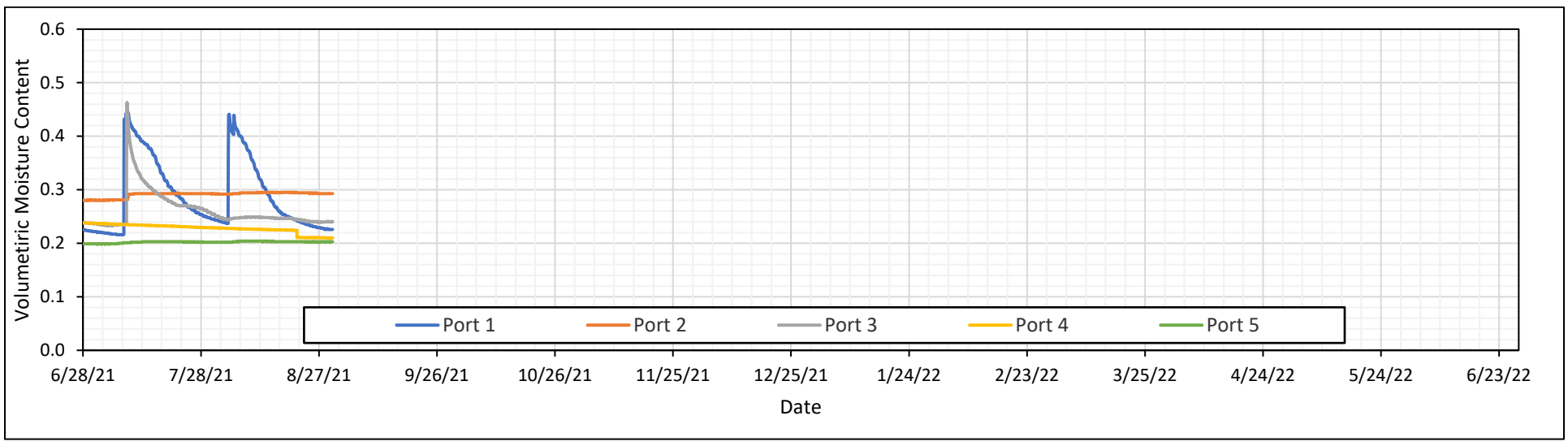


Figure 30. Fuller F1 soil moisture probes June 28, 2021 to August 30, 2021

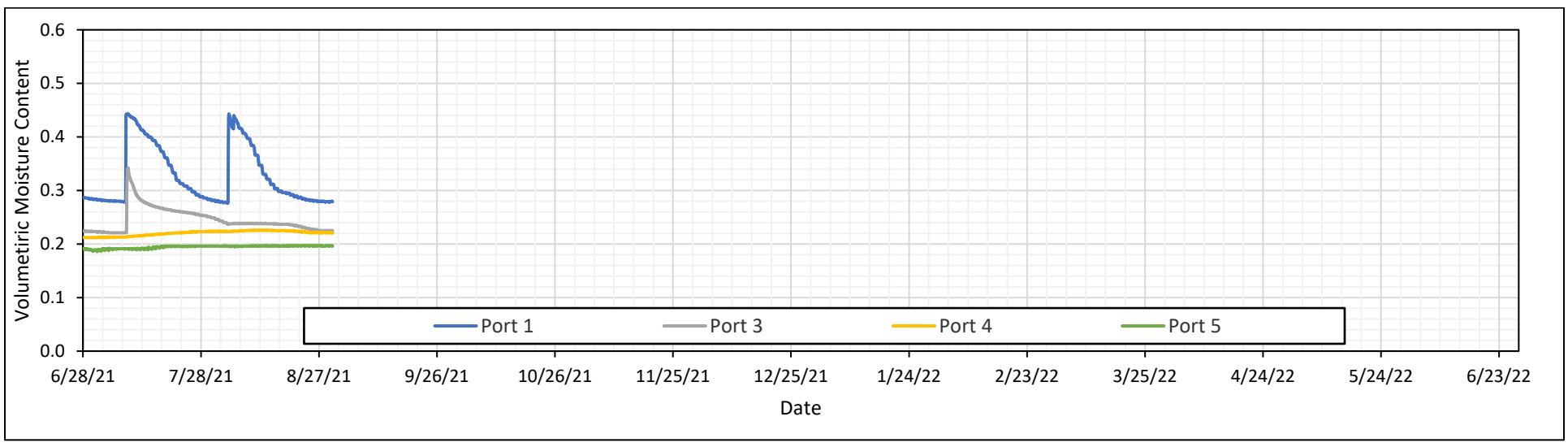


Figure 31. Fuller F2 soil moisture probes June 28, 2021 to August 30, 2021

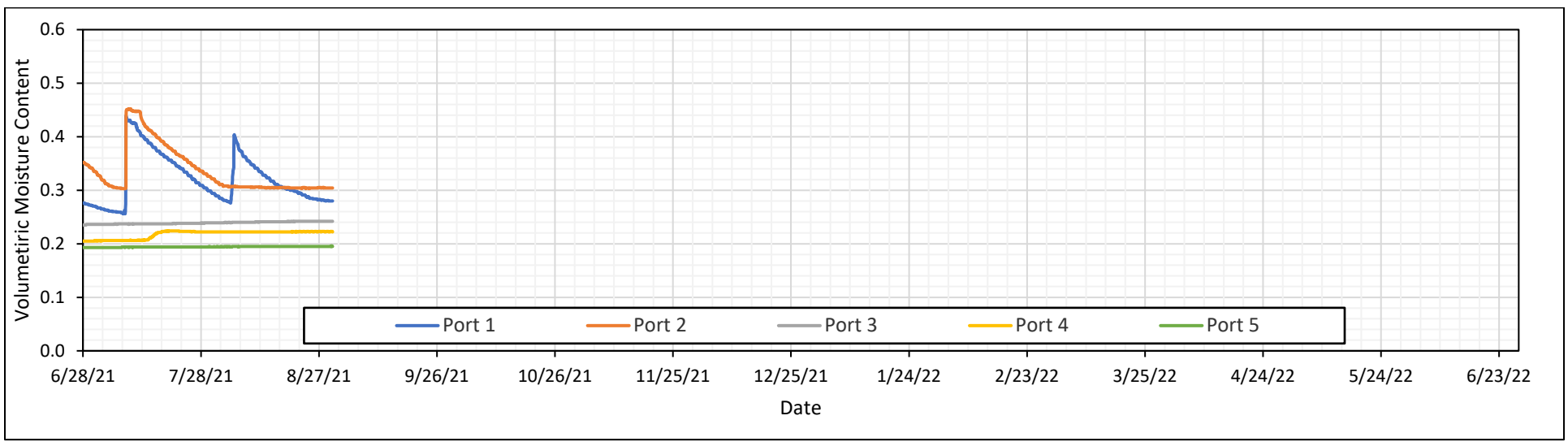


Figure 32. Fuller F3 soil moisture probes June 28, 2021 to August 30, 2021

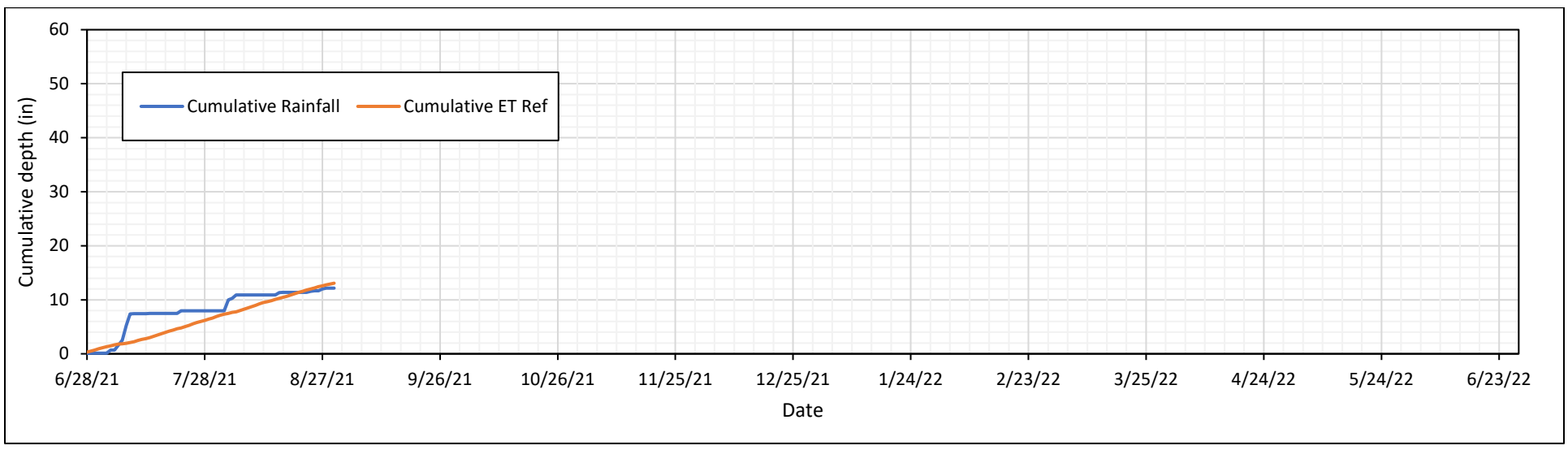


Figure 33. Fuller cumulative rainfall and ET ref June 2021 to August 30, 2021