On-Farm Flood Capture and Recharge (OFFCR) at an Organic Almond Orchard in the Central Valley (CV):

Recharge Rates, and Soil Water and Salt Profiles.

Chowchilla, California

2017 Groundwater Resources Association Annual Meeting

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Outline

1. Background
    1. Regional Groundwater Overdraft
    2. On-Farm Flood Capture and Recharge (OFFCR)
2. Investigation
    1. Design
    2. Pore Water Hydrologic Response
    3. Pore Water Chemistry Response
    4. Recharge Volumes
3. Related Investigations
    1. Effects on Groundwater
4. Conclusion

California Water Plan 2013
Tulare Lake Hydrologic Region,
DWR

Year	Regional Water Use	Consumptive Use (Ag, M&I, Wetlands)	GW Overdraft (MAF)	
	MAF	MAF	MAF	% CU
2001	19.5	8.0	4.1	52%
2002	18.3	8.1	3.9	48%
2003	20.1	7.7	3.0	39%
2004	21.0	8.2	4.0	49%
2005	22.3	7.0	0.1	2%
2006	23.4	7.4	0.2	2%
2007	16.0	8.2	4.1	50%
2008	18.8	8.6	5.3	61%
2009	18.0	8.7	5.5	63%
2010	22.7	7.7	2.3	31%
Mean	**20.0**	**7.9**	**3.2**	**40%**
Median	**19.8**	**8.1**	**4.0**	**49%**
Min	**16.0**	**7.0**	**0.1**	**2%**
Max	**23.4**	**8.7**	**5.5**	**63%**

Table TL-23 Tulare Lake Hydrologic Region Water Balance for 2001-2010 (in taf)

Tulare Lake (taf)	Water Year (Percent of Normal Precipitation)									
	2001 (87%)	2002 (71%)	2003 (86%)	2004 (85%)	2005 (120%)	2006 (123%)	2007 (50%)	2008 (77%)	2009 (71%)	2010 (116%)
WATER ENTERING THE REGION										
Precipitation	11,564	10,021	12,137	11,964	16,939	17,135	7,031	10,724	9,945	16,185
Inflow from Oregon/Mexico	0	0	0	0	0	0	0	0	0	0
Inflow from Colorado River	0	0	0	0	0	0	0	0	0	0
Imports from Other Regions	3,696	4,239	5,174	4,816	5,909	5,944	4,434	2,797	2,704	4,456
Total	**15,260**	**14,260**	**17,311**	**16,780**	**22,848**	**23,079**	**11,465**	**13,521**	**12,649**	**20,641**
WATER LEAVING THE REGION										
Consumptive use of applied water[a] (Ag, M&I, Wetlands)	7,986	8,124	7,667	8,221	6,953	7,376	8,214	8,592	8,684	7,668
Outflow to Oregon/Nevada/Mexico	0	0	0	0	0	0	0	0	0	0
Exports to other regions	1,093	1,643	1,898	1,961	1,724	2,269	2,053	1,215	1,204	1,502
Statutory required outflow to salt sink	0	0	0	0	0	0	0	0	0	0
Additional outflow to salt sink	458	305	458	457	300	468	456	514	456	456
Evaporation, evapotranspiration of native vegetation, groundwater subsurface outflows, natural and incidental runoff, ag effective precipitation & other outflows	9,979	8,276	10,090	10,342	13,297	13,241	5,303	8,528	7,667	13,095
Total	**19,516**	**18,348**	**20,113**	**20,981**	**22,274**	**23,350**	**16,026**	**18,849**	**18,011**	**22,721**
CHANGE IN SUPPLY										
[+] Water added to storage [-] Water removed from storage										
Surface reservoirs	-141	-161	173	-199	680	-108	-473	-59	101	259
Groundwater[b]	-4,115	-3,927	-2,975	-4,002	-106	-163	-4088	-5269	-5463	-2339
Total	**-4,256**	**-4,088**	**-2,802**	**-4,201**	**574**	**-271**	**-4561**	**-5328**	**-5362**	**-2080**
Applied water[a] (ag, urban, wetlands) (compare with consumptive use)	11,320	11,722	11,343	11,977	10,731	11,347	12,036	12,310	12,470	11,408

Notes:

taf = thousand acre-feet, M&I = municipal and industrial

[a] Definition: Consumptive use is the amount of applied water used and no longer available as a source of supply. Applied water is greater than consumptive use because it includes consumptive use, reuse, and outflows.

[b] Definition: Change in Supply: Groundwater – The difference between water extracted from and water recharged into groundwater basins in a region. All regions and years were calculated using the following equation: change in supply: groundwater = intentional recharge + deep percolation of applied water + conveyance deep percolation and seepage - withdrawals.

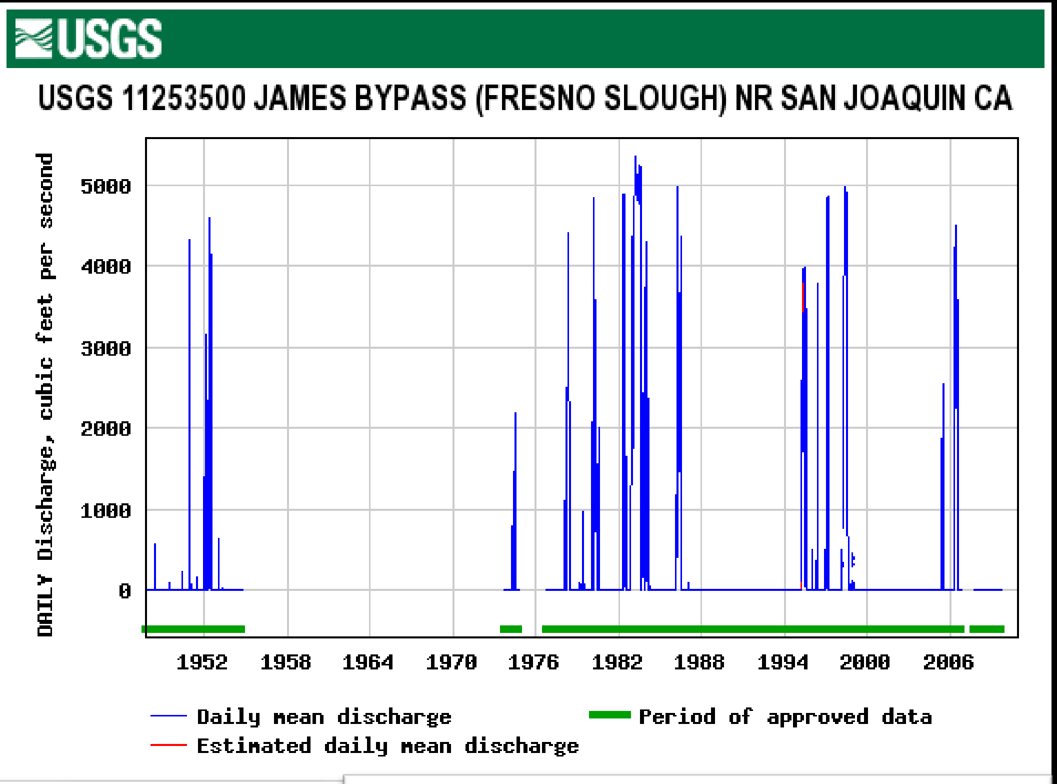
This equation does not include unknown factors such as natural recharge and subsurface inflow and outflow. For further details, refer to Volume 4, *Reference Guide*, the article "California's Groundwater Update 2013" and Volume 5, *Technical Guide*.

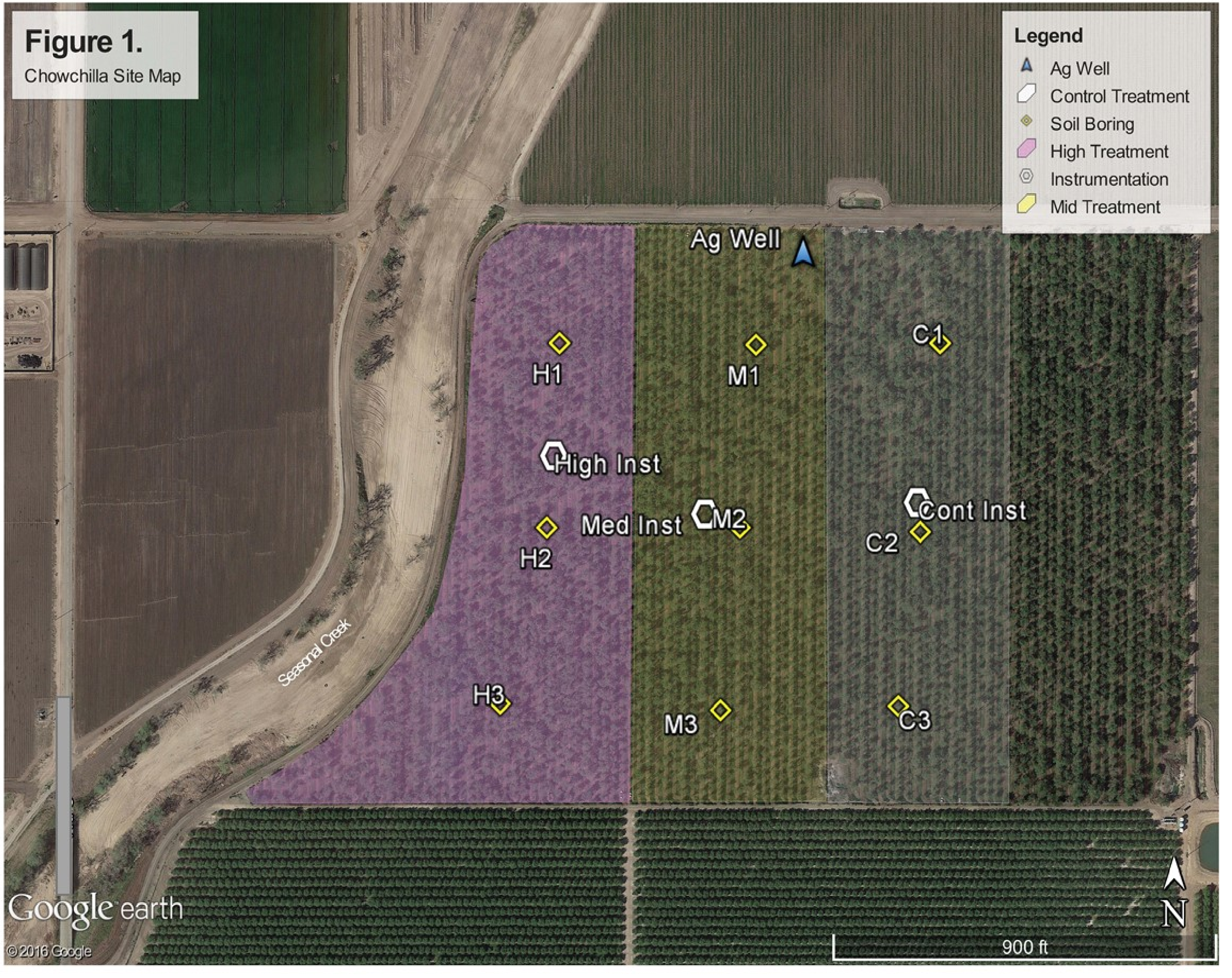
On-Farm Flood Capture and Recharge (OFFCR)

Capturing *Available* Flood Flows onto Farm Lands for Groundwater Recharge and to Mitigate Downstream Flood Risks

- *Available = Physical, Legal*
- Leveraging Private Lands
- Dual Use - Flood Management and Crop Irrigation
- Design into Farm Management
- Leveraging Community Resources

Typically <u>10 Acres</u> needed to capture and recharge <u>1 CFS</u> *(Bachand et al, 2014)*

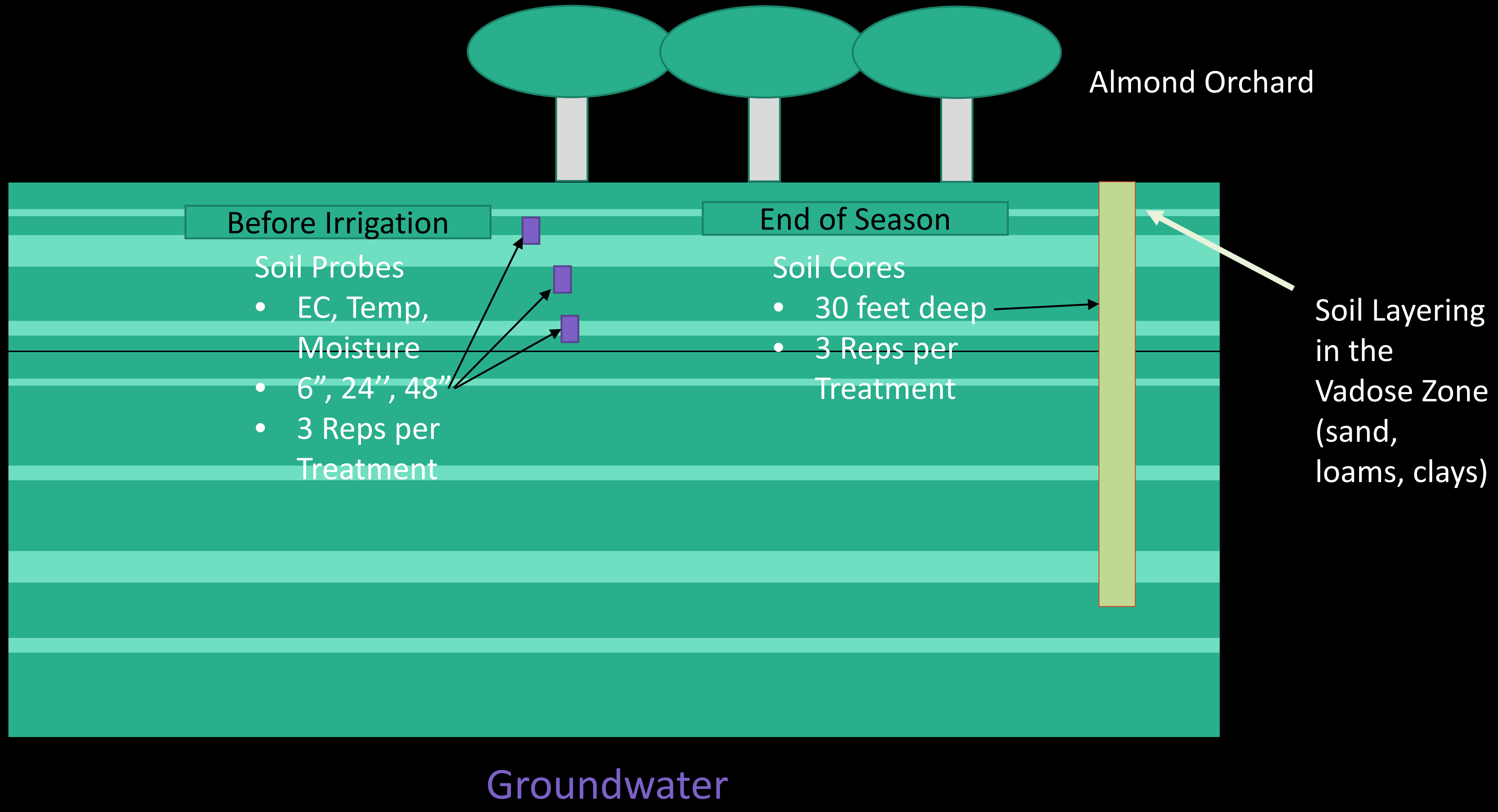




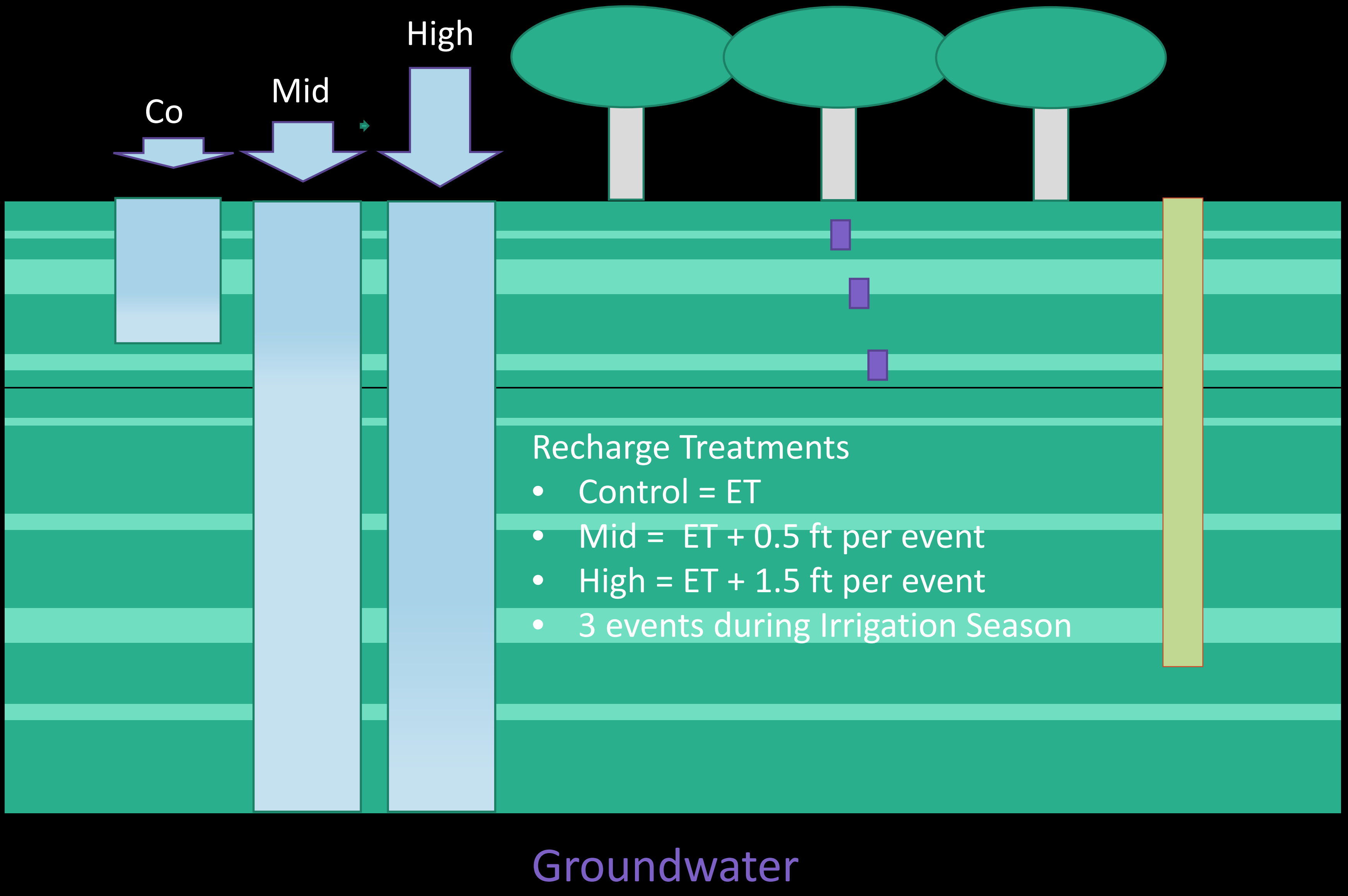
Test Site Map

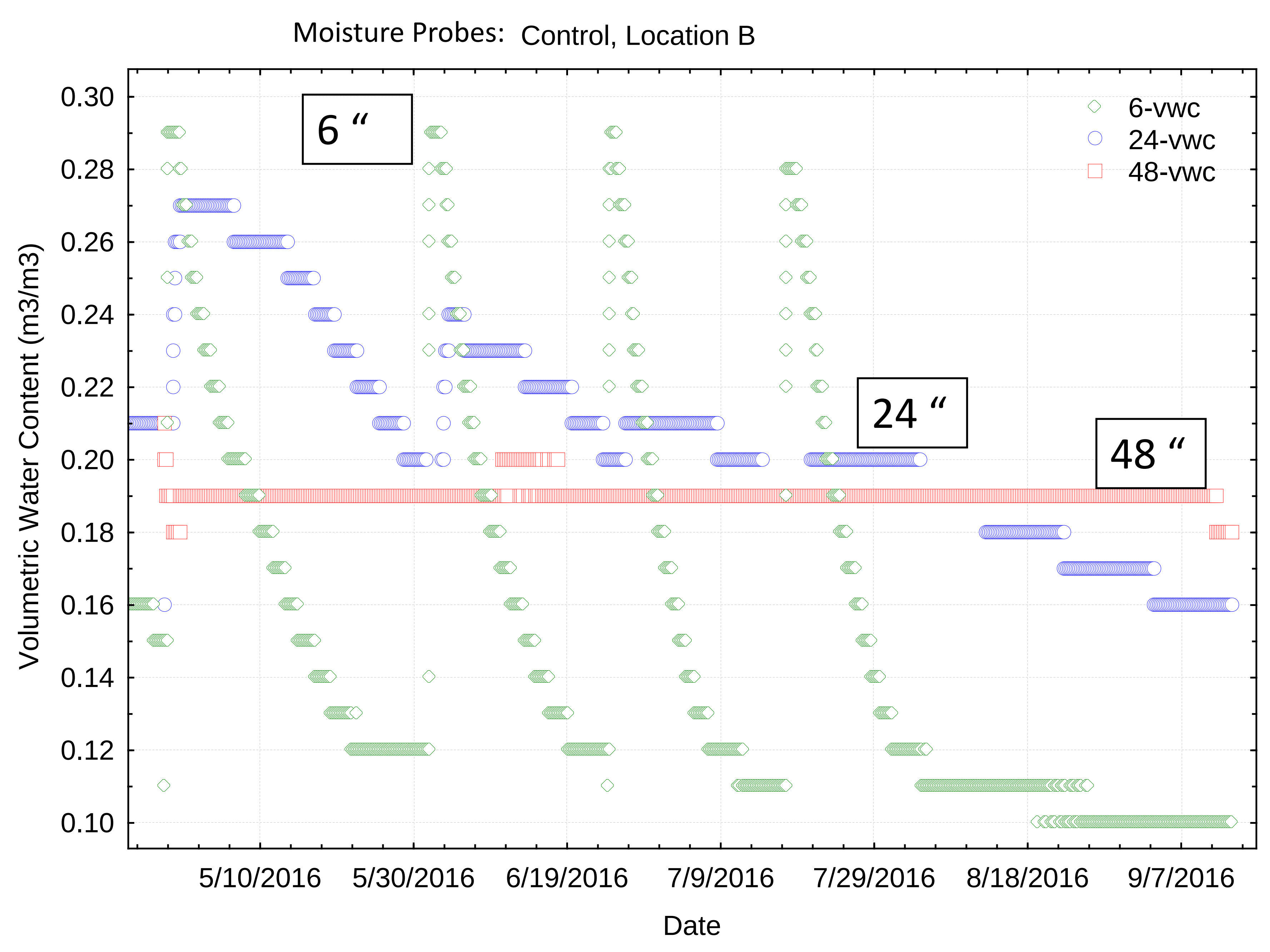
- Treatments:
  - Control –
    - No Recharge
    - 3 events
  - Mid –
    - Target 0.5 ft/event
    - 3 events
  - High –
    - Target 1.5 ft/event
    - 3 events
- Instrumentation
  - Soil Probes
- Post-Irrigation soil boring locations

Experimental Design - Instrumentation



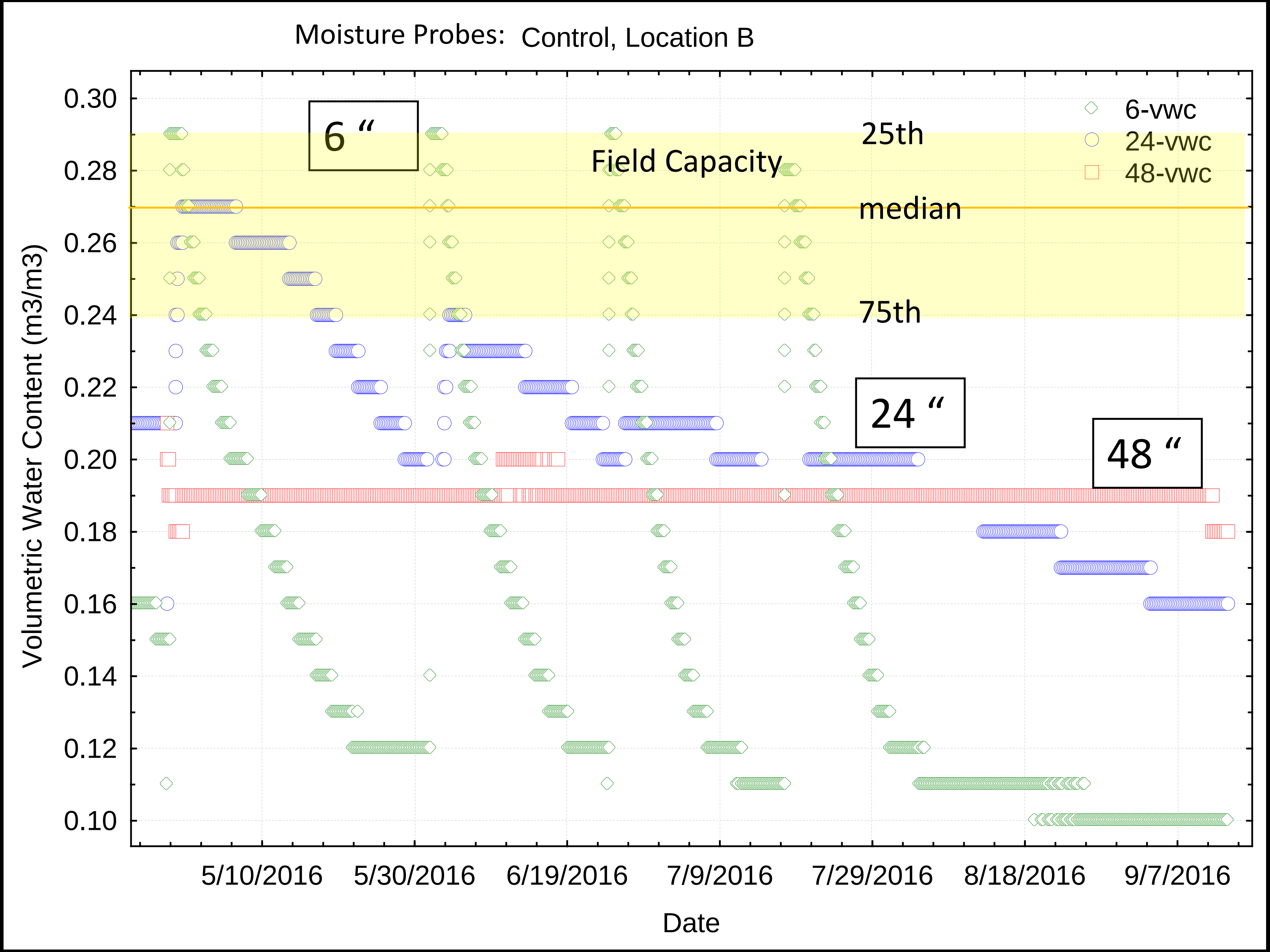
Experimental Design – Recharge Treatments





Control Results:

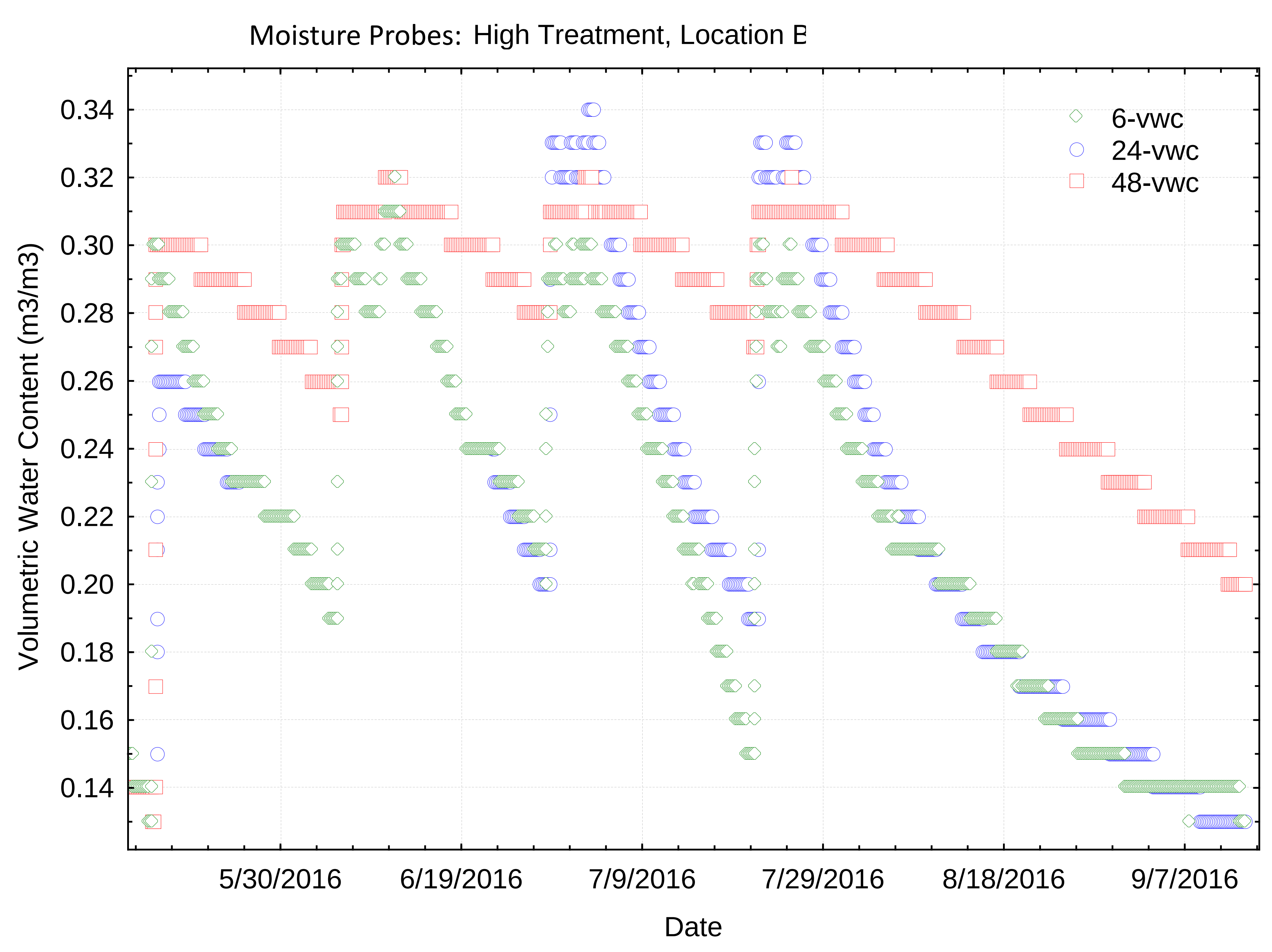
Changes in Volumetric Water Content Under Recharge



Control Results:

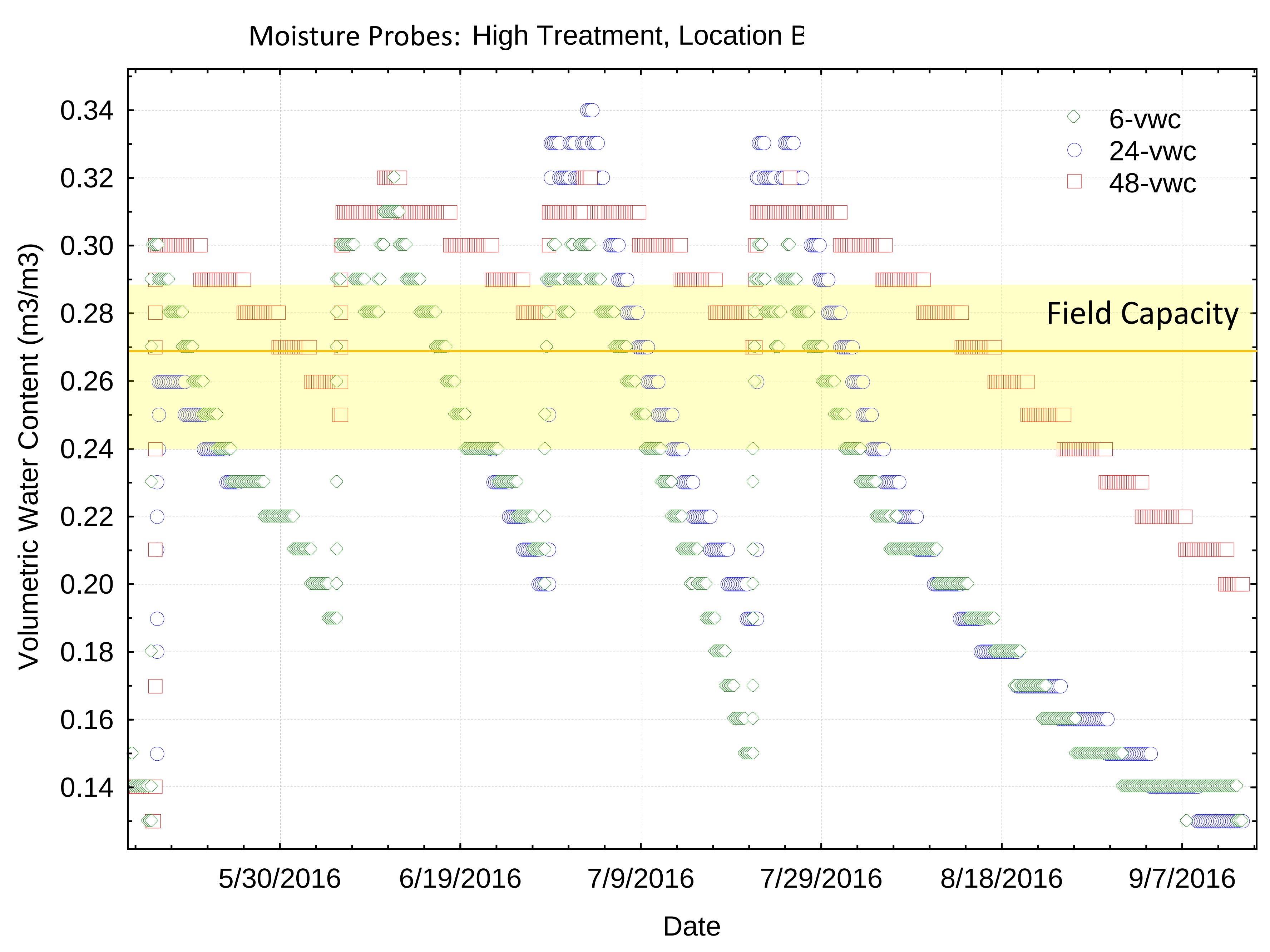
Changes in Volumetric Water Content Under Recharge

Irrigation water did not move past root zone



High Results:

Changes in Volumetric Water Content Under Recharge

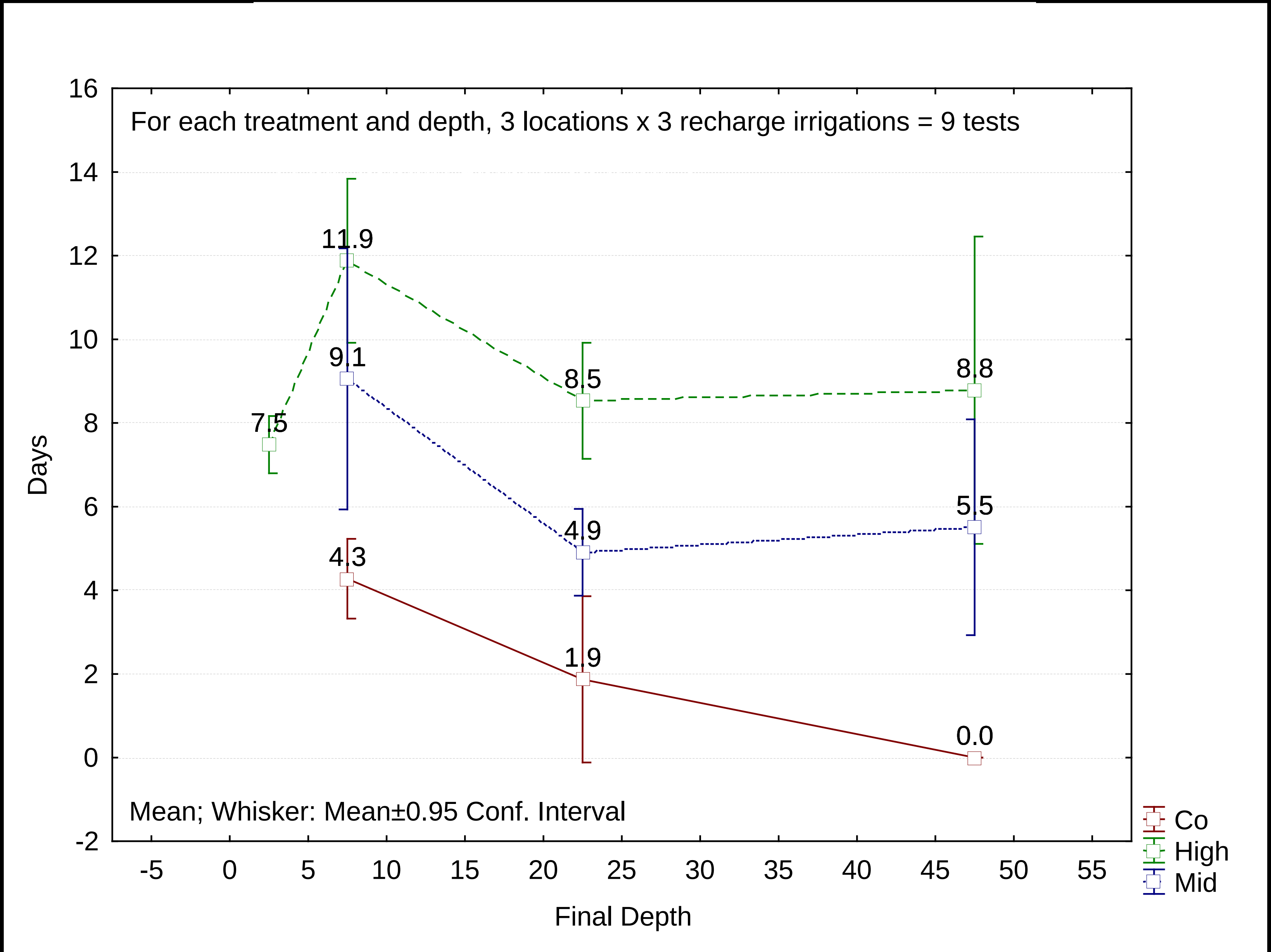


High Results:

Changes in Volumetric Water Content Under Recharge

- Irrigation water moved past root zone
- Soils were not saturated
  - Presumably no O2 deficit

Moisture Probes: Days Above Field Capacity by Depth and by Treatment



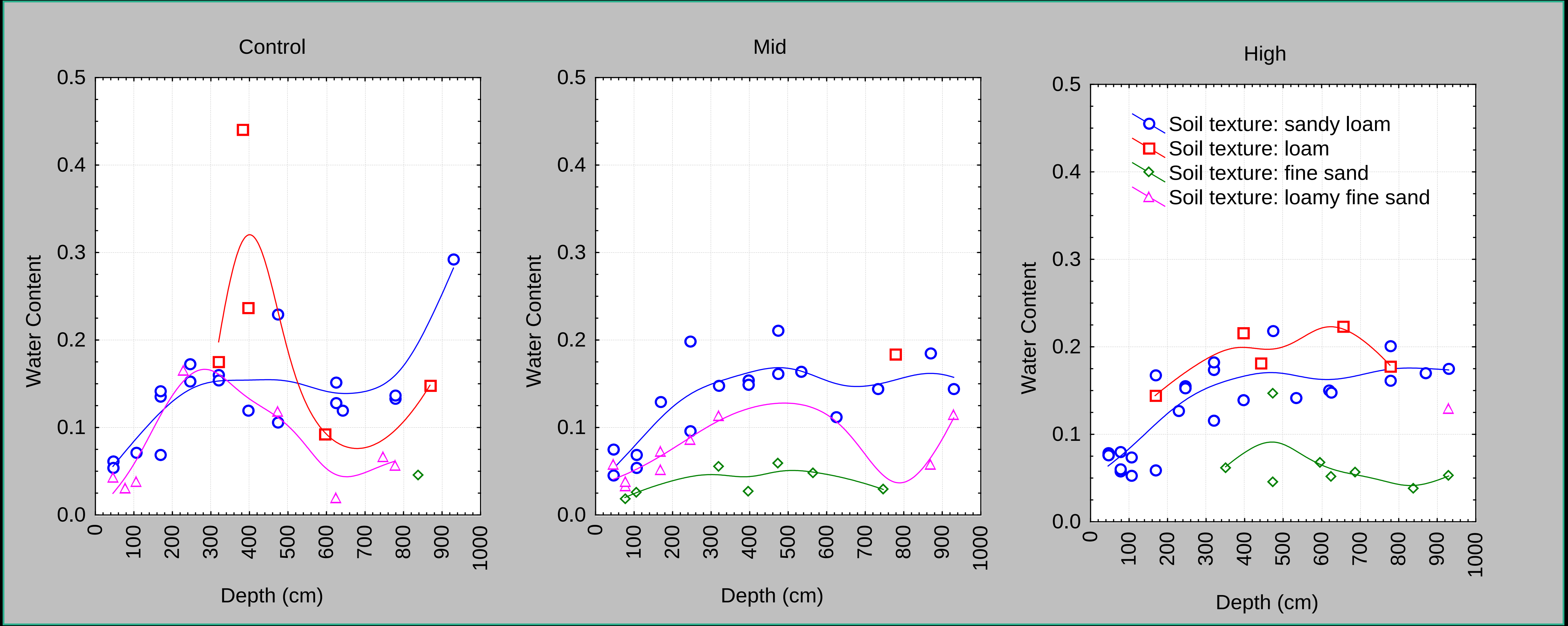
Recharge Rates Increase Periods of Flow Past the Root Zone

Control – No flow past root zone (48" depth)

High Treatment – Typically nearly 9 days of flow past root zone during a recharge event

Coring Results, Fall 2016 (3.5 months after last Recharge Event)

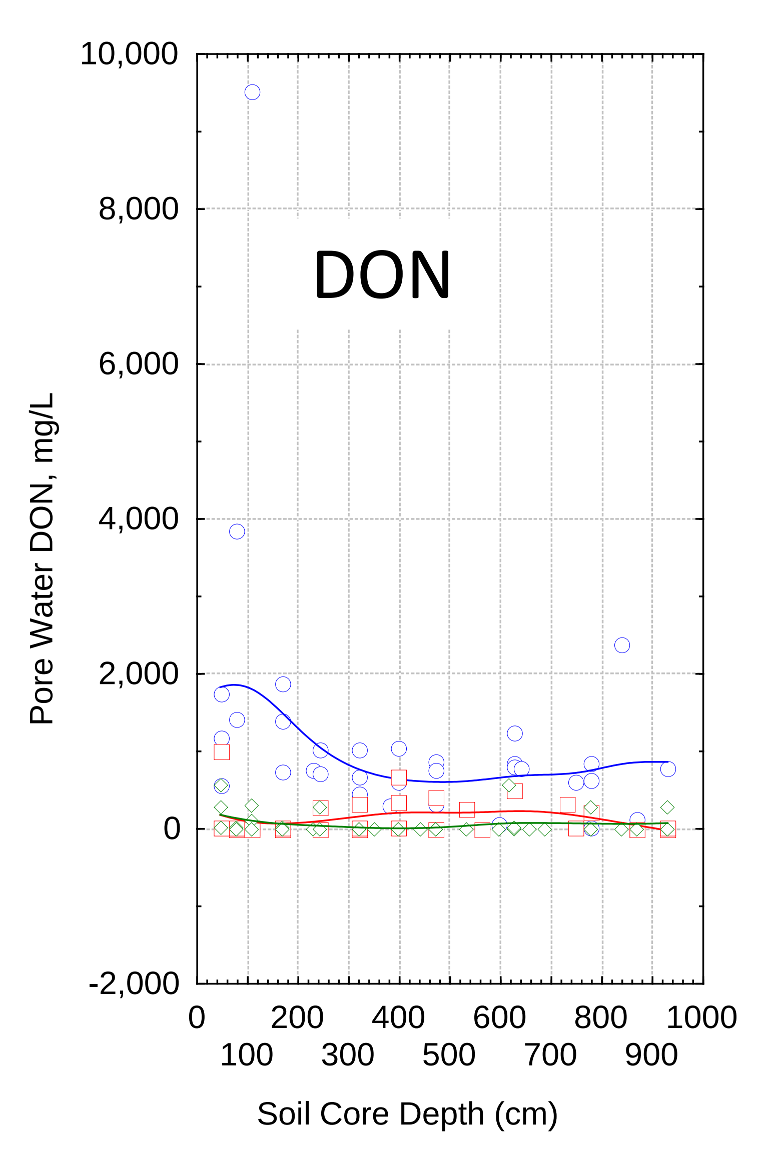
- Loams having a higher water content than sands.
- Water content lower in the shallow zone (< 150 cm) and higher and uniform with depth for all treatments consistent with trees uptake
- **No significant different in water content with depth indicating recharge water passed deeper than 30 -foot deep soil core.**

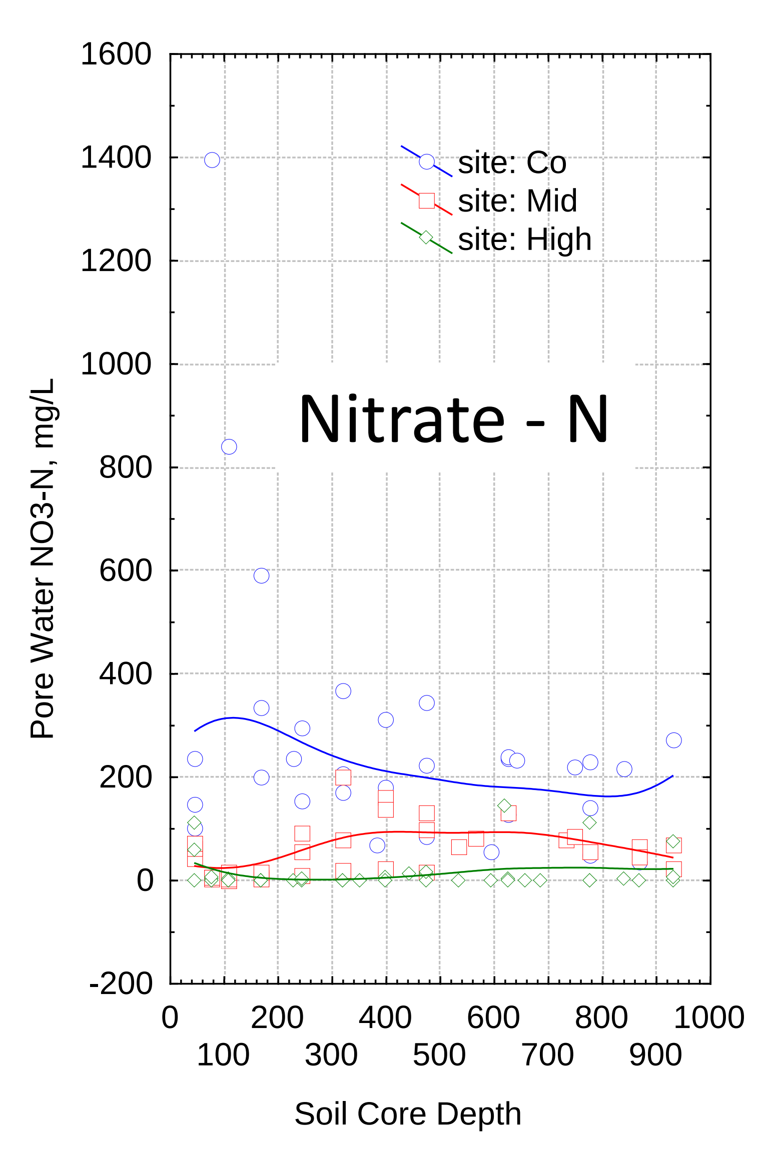


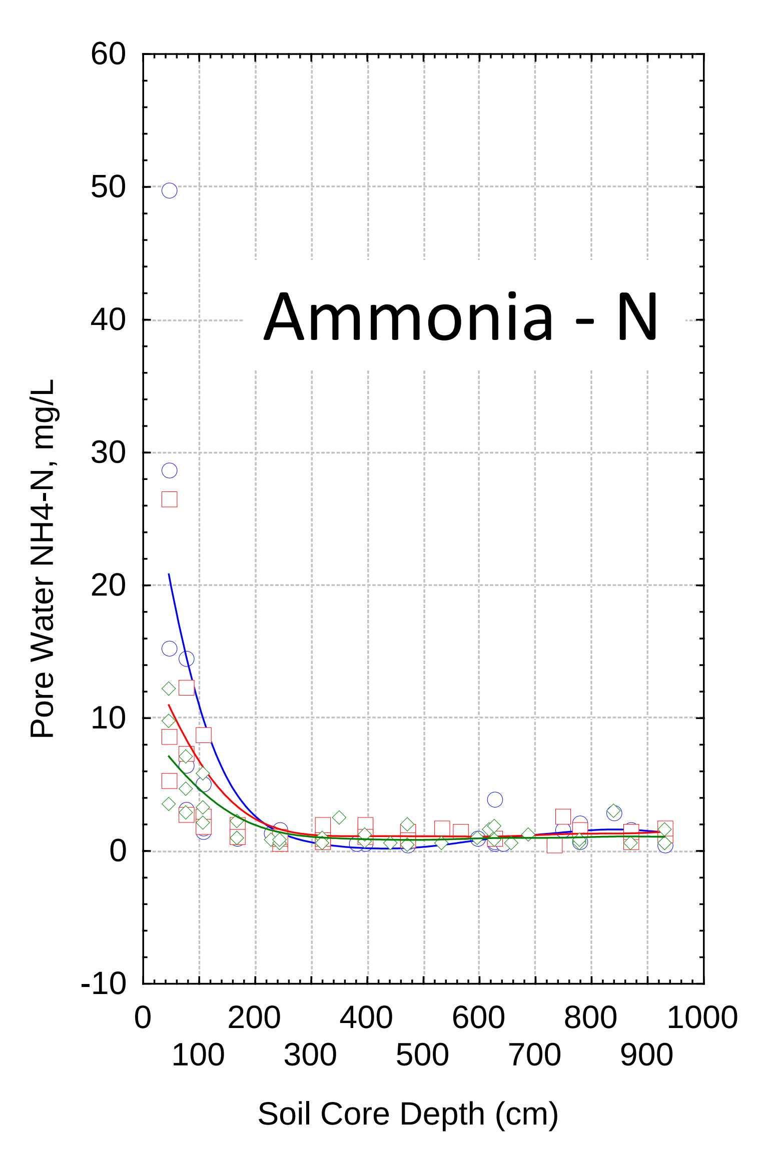
2016 Recharge at Chowchilla Almond Orchard

Recharge Event	Acres	Timing	Target Recharge (Ft)	Measured Recharge (Ft)
Control				
1	26.3	Early June	0.00	-0.07
2	26.3	Late June	0.00	-0.03
3	26.3	Mid July	0.00	-0.07
Total			***0.00***	***-0.18***
Middle				
1	13.8	Early June	0.50	0.90
2	13.8	Late June	0.50	0.38
3	13.8	Mid July	0.50	0.36
Total			***1.50***	***1.63***
High				
1	13.5	Early June	1.50	2.29
2	13.5	Late June	1.50	1.64
3	13.5	Mid July	1.50	1.38
Total			***4.50***	***5.31***

Nitrogen Concentrations with Depth (1000 cm = 10 m = 30 ft)







Flushing of Nitrogen and Salt Species During Recharge

Treatment[1]	NO3 - N	NH4 - N	TDN - N	DON - N	TDS
	Average Mass within Core to 945 cm (31'), g/m2				
Control	405	3.2	1792	1389	4071
Mid	107	2.5	375	268	2531
High	45	2.3	208	163	1561
	Change in Mass due to Recharge, g/m2				
Mid	297	0.7	1417	1121	1541
High	360	0.9	1584	1225	2511
	% Mass Removed due to Recharge				
Mid	73.5%	23.1%	79.1%	80.7%	37.8%
High	88.9%	27.2%	88.4%	88.2%	61.7%

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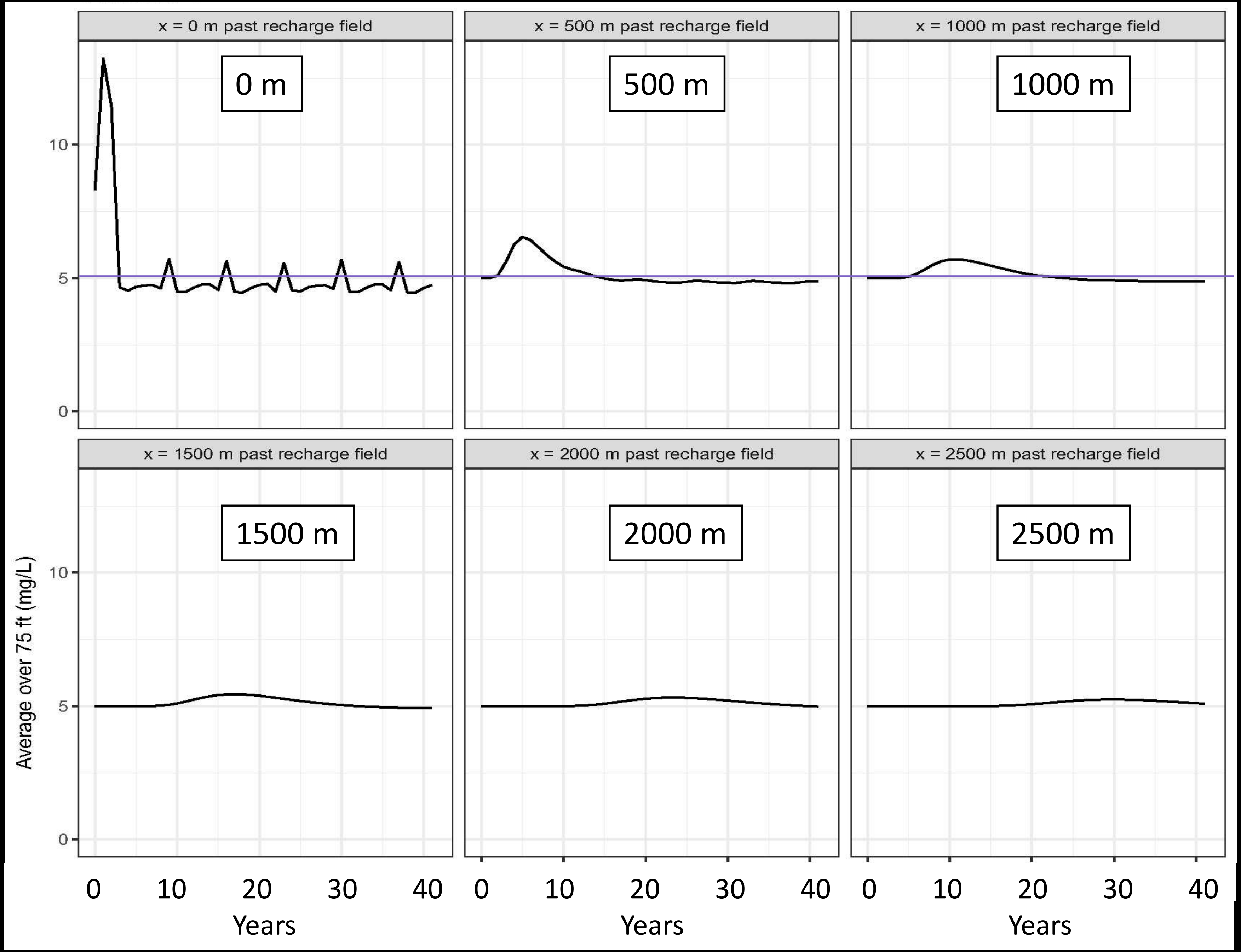
Mid	297	0.7	1417	1121	1541
High	360	0.9	1584	1225	2511
	% Mass Removed due to Recharge				
Mid	73.5%	23.1%	79.1%	80.7%	37.8%
High	88.9%	27.2%	88.4%	88.2%	61.7%

Tomatoes:

Modeling Groundwater Response in Domestic Well Zone

(Bachand, Roy, et al 2017)

- Represent an upper bookend recharge site
- Model
  - based upon historic Kings Basin Hydrology
    - 3 recharge years
    - followed by 4 dry years)
  - Background groundwater nitrate levels = 5 mg-N/L

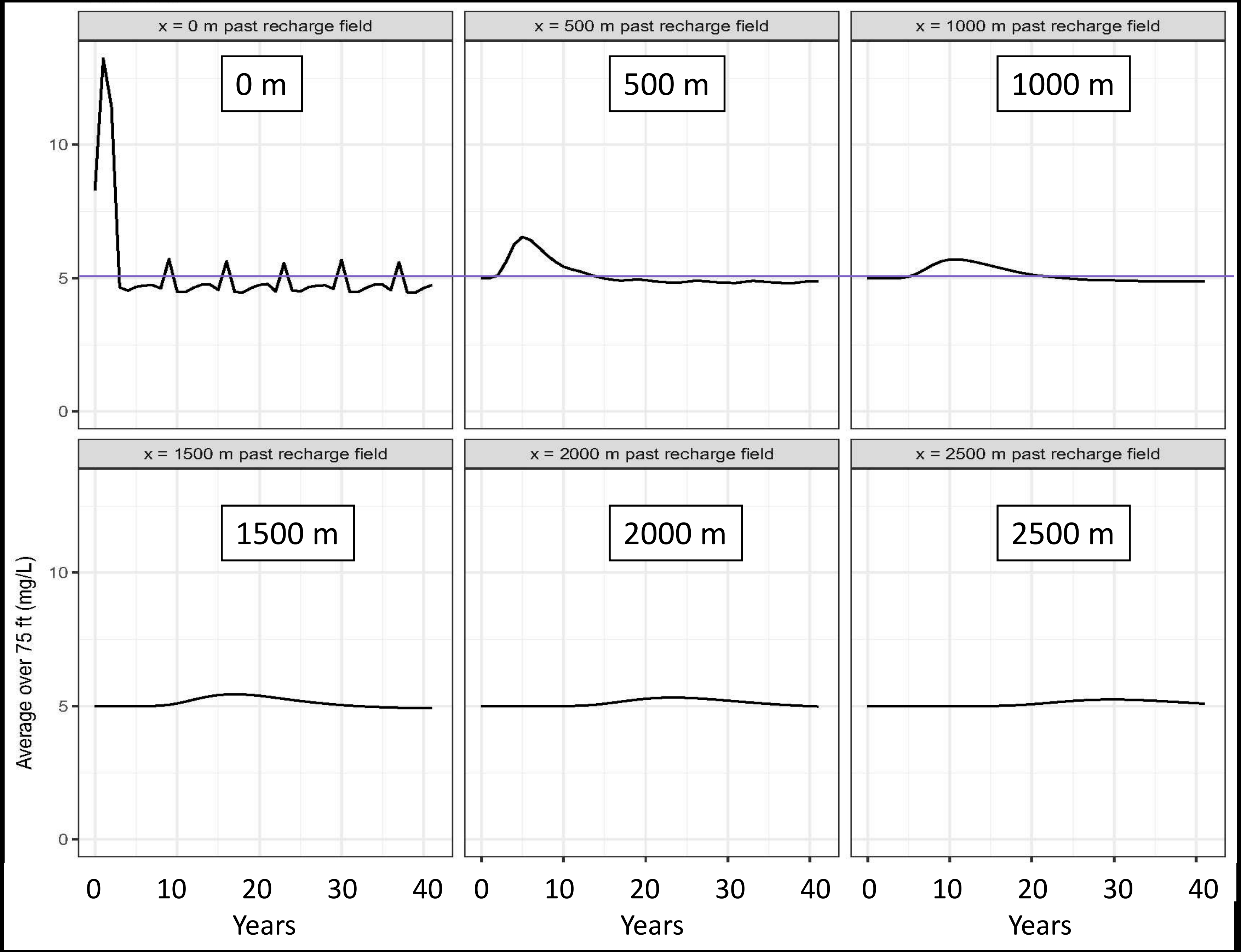


Tomatoes:

Modeling Groundwater Response in Domestic Well Zone

(Bachand, Roy, et al 2017)

- Initial legacy loading degrades water quality
- Returns to baseline by 10 years
- Effects decreases with distance and depth
- Lower bookend recharge opportunity improved groundwater quality



Summary

- GW shortfalls and water level declines are a serious problem in CA
  - OFFCR seeks to provide a flexible and cost effective opportunity to increase water supplies
- Recharge water under both Mid and High Treatments moved past the root zone but did not saturate soils
  - Longer duration under the High Treatment
- Cores suggests recharge water moved past the 30-foot deep core depth under Mid and High treatments.
- Under the High Treatment over 5 feet of recharge occurred and under the Mid Treatment about 1.6 feet occurred

Summary (cont.)

- Nitrate, DON and salts were <u>flushed</u> by recharge
  - Most N-species flushing (in the 30-foot deep cores) occurred under the <u>Mid Treatment</u> recharge level
    - Under High Treatment, most constituents already flushed
  - Represents <u>legacy load</u> in soils
- GW model suggests effects on groundwater quality are relatively <u>short-lived</u> (about a decade) and <u>decrease with both distance from the site and depth of groundwater</u>.
  - <u>High loading</u> crops can <u>decrease GW quality</u>, primarily from legacy loads
  - <u>Low loading</u> crops can <u>improve GW quality</u>.