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Water Balance of a Rain Garden

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Outcomes

DESCRIBE WHAT A RAIN IS AND DOES

DESCRIBE WATER BUDGET OF RAIN GARDEN ON VILLANOVA'S CAMPUS

Outline

- What is a rain garden?
- Research Question
- Site Background
- Method
- Results
- Design Application

Paradigm shift occurring

Larger storms
Gray infrastructure
Get rid of water
Centralized

Smaller storms
Green infrastructure
Hold onto water
Decentralized

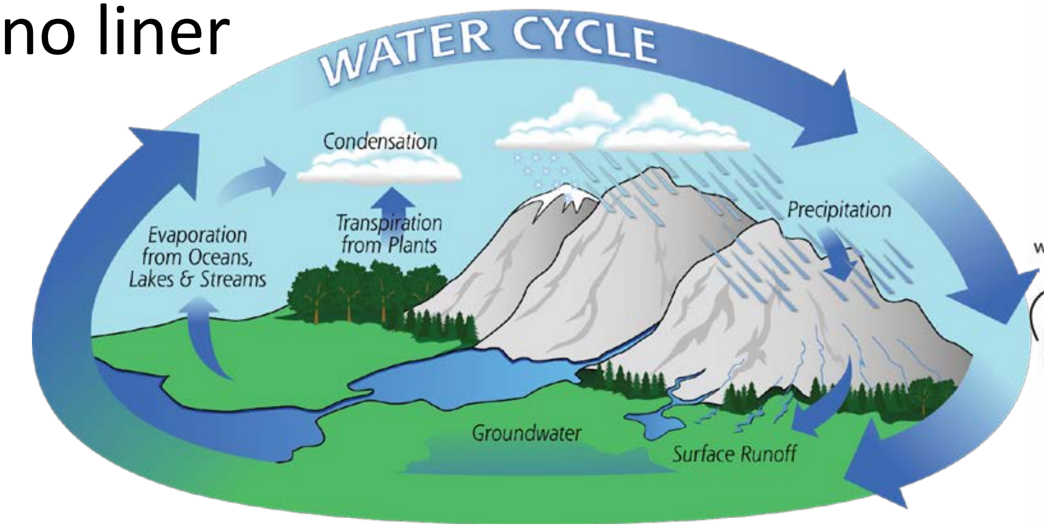
Many names for these…

Low Impact Development (LID)
Best Management Practices (BMP)
Green Stormwater Infrastructure (GSI)
Stormwater Control Measures (SCM)
Stormwater Management Practices (SMP)
Sustainable Urban Drainage Systems (SUDS)

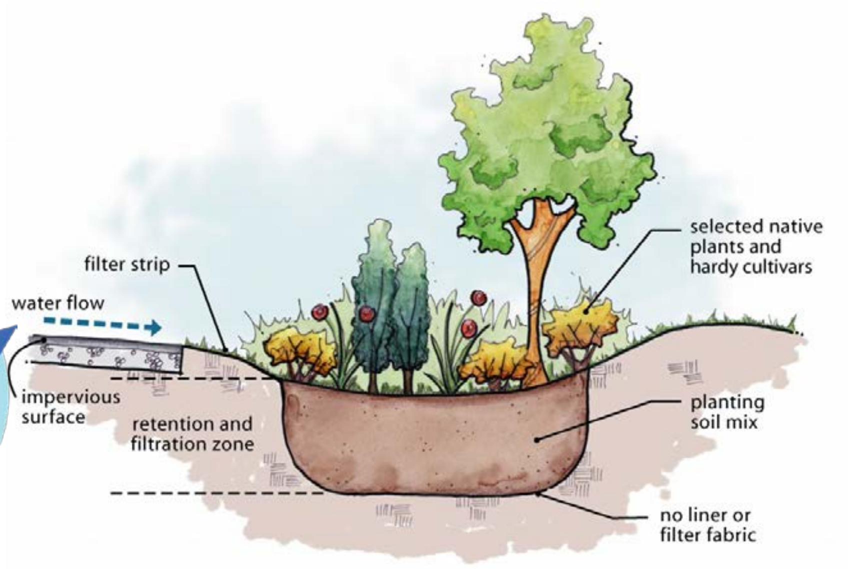
Sustainable Drainage Systems (SuDS)

Research Question: Can we determine water balance within a rain garden?

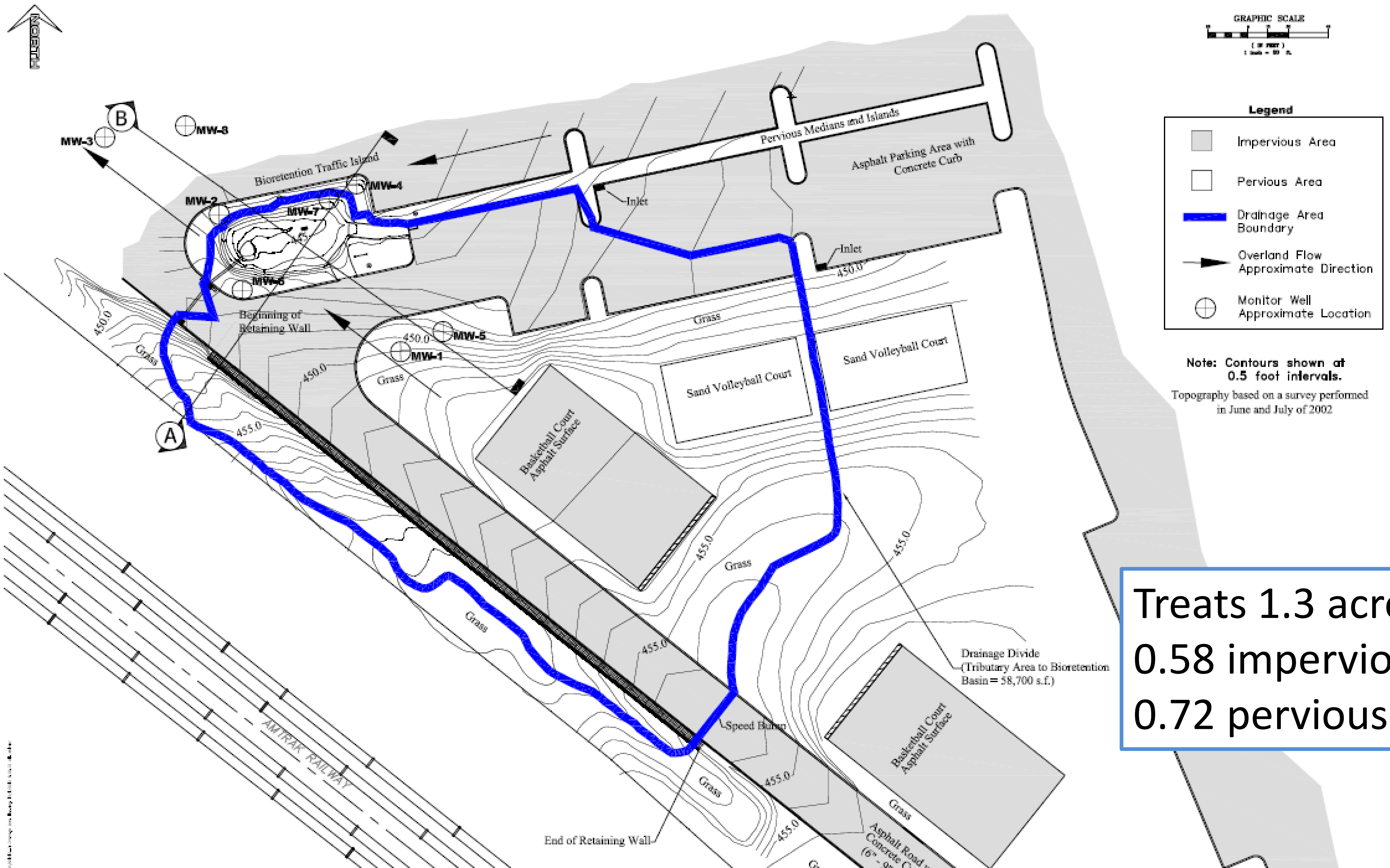
- Perform a mass balance to determine evapotranspiration (ET)
- Case Study: Inflow – Recharge – ET = Overflow
  - no underdrain
  - no liner



https://pmm.nasa.gov/education/water-cycle



http://www.betterground.org/rain-gardens/



Treats 1.3 acres

0.58 impervious acres

0.72 pervious acres

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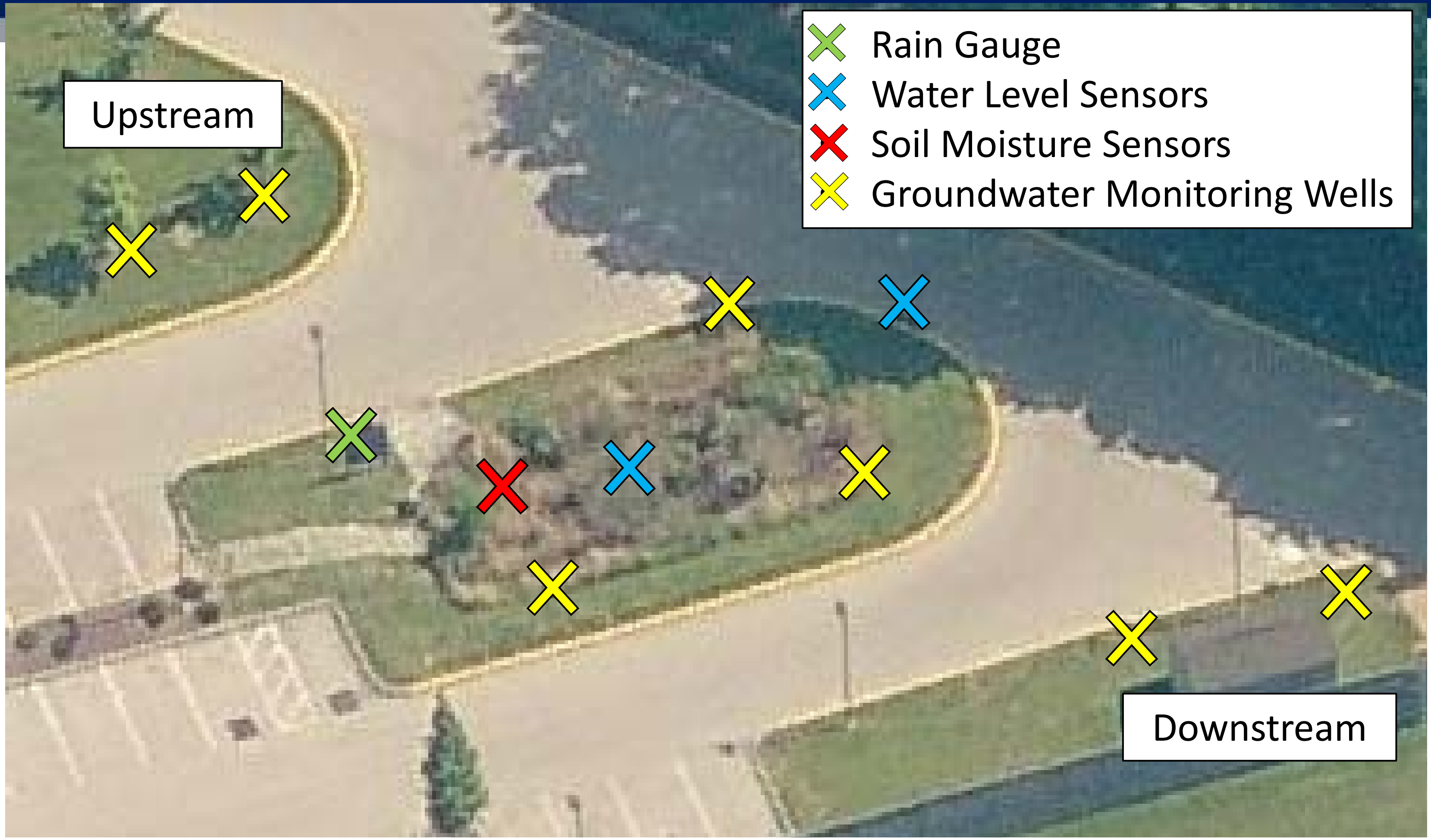
Site Background: Design

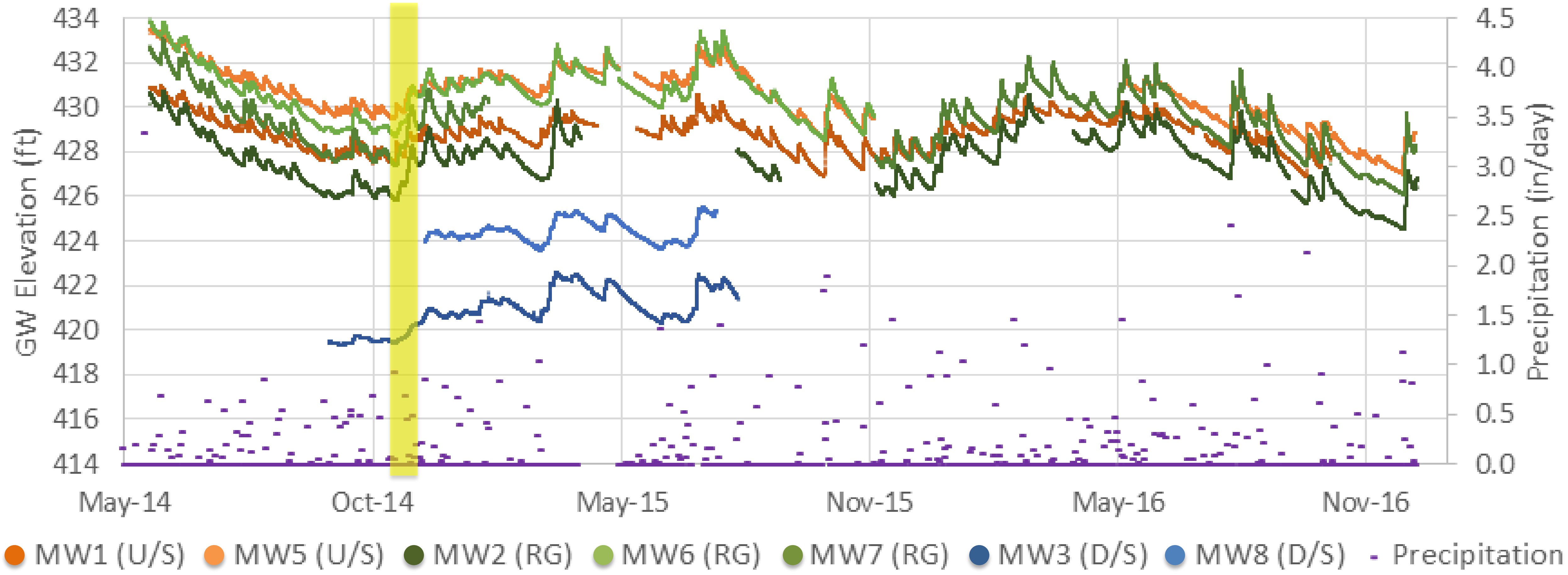
- Constructed and instrumented from 2001-2002
- Bowl 1.5 ft deep : Captures 1 in of rainfall
- Media 4 ft deep : Soil media 1:1 native soil to sand
- Drainage Area to Rain Garden ratio 10:1 (PADEP 5:1)

Site Background: Instrumentation/Models

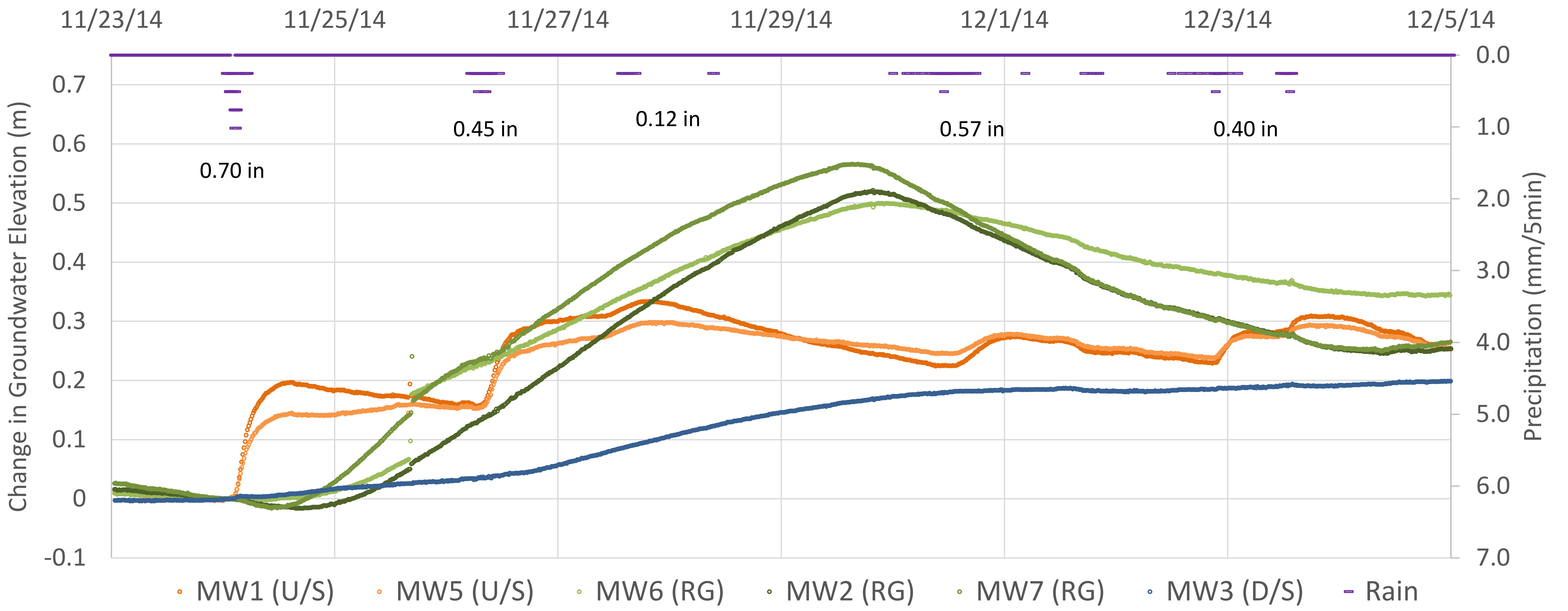
- Instrumentation:
  - Rainfall
  - Pond Level
  - Groundwater Level
  - Soil Moisture
- Verified Models:
  - Inflow
  - Overflow



Groundwater Elevation Fluctuations at BTI



Mounding Event Example (P = 2.24in)

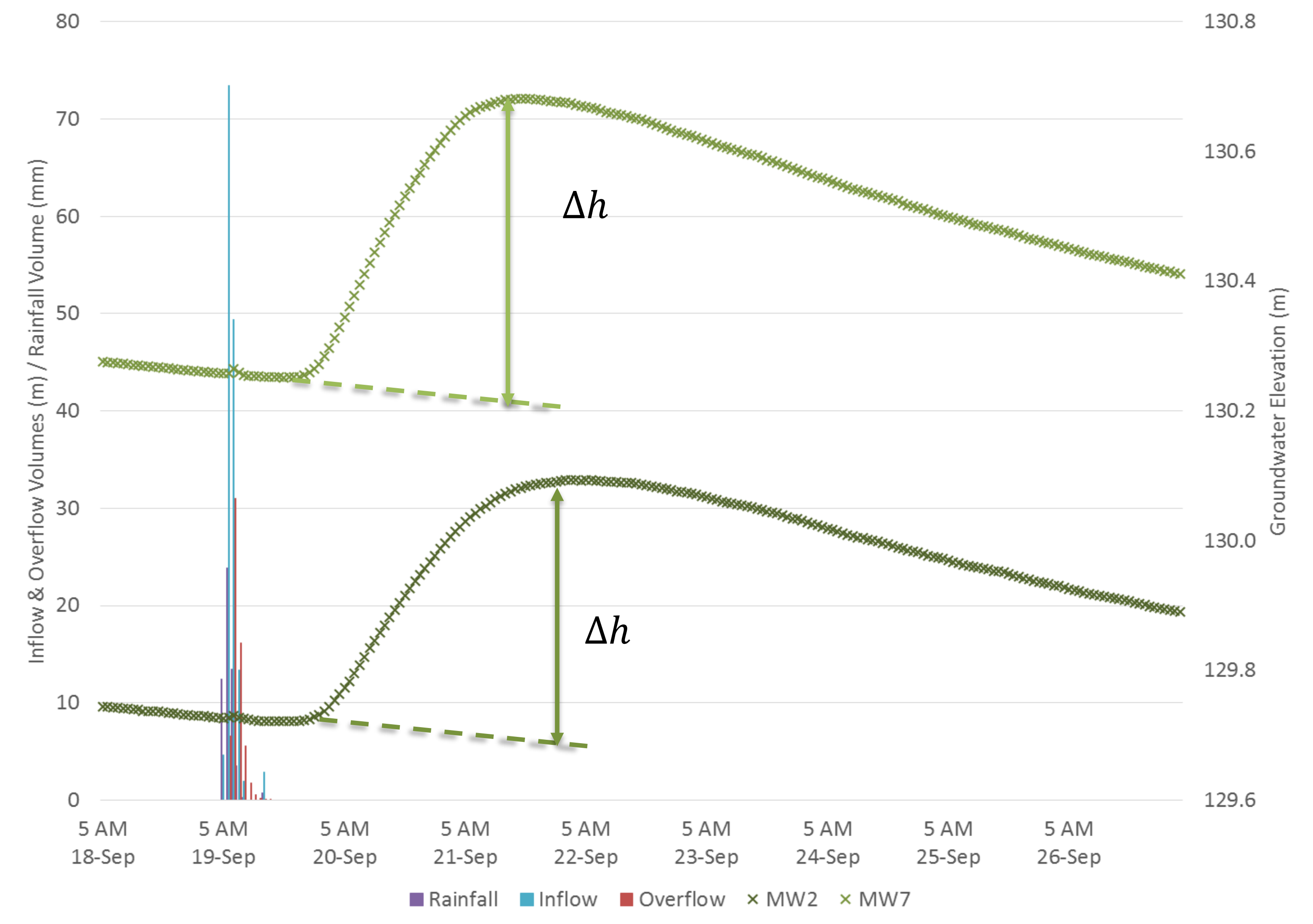


Water Table Fluctuation Method

- $R = \frac{S_y * \Delta h}{\Delta t}$

- *R* = recharge rate (L/T)
- S_y = specific yield of the soil in the aquifer
- *Δh* = water level rise due to recharge (L)
- *Δt* = time period that the recharge is calculated over (T)

Recharge Volume



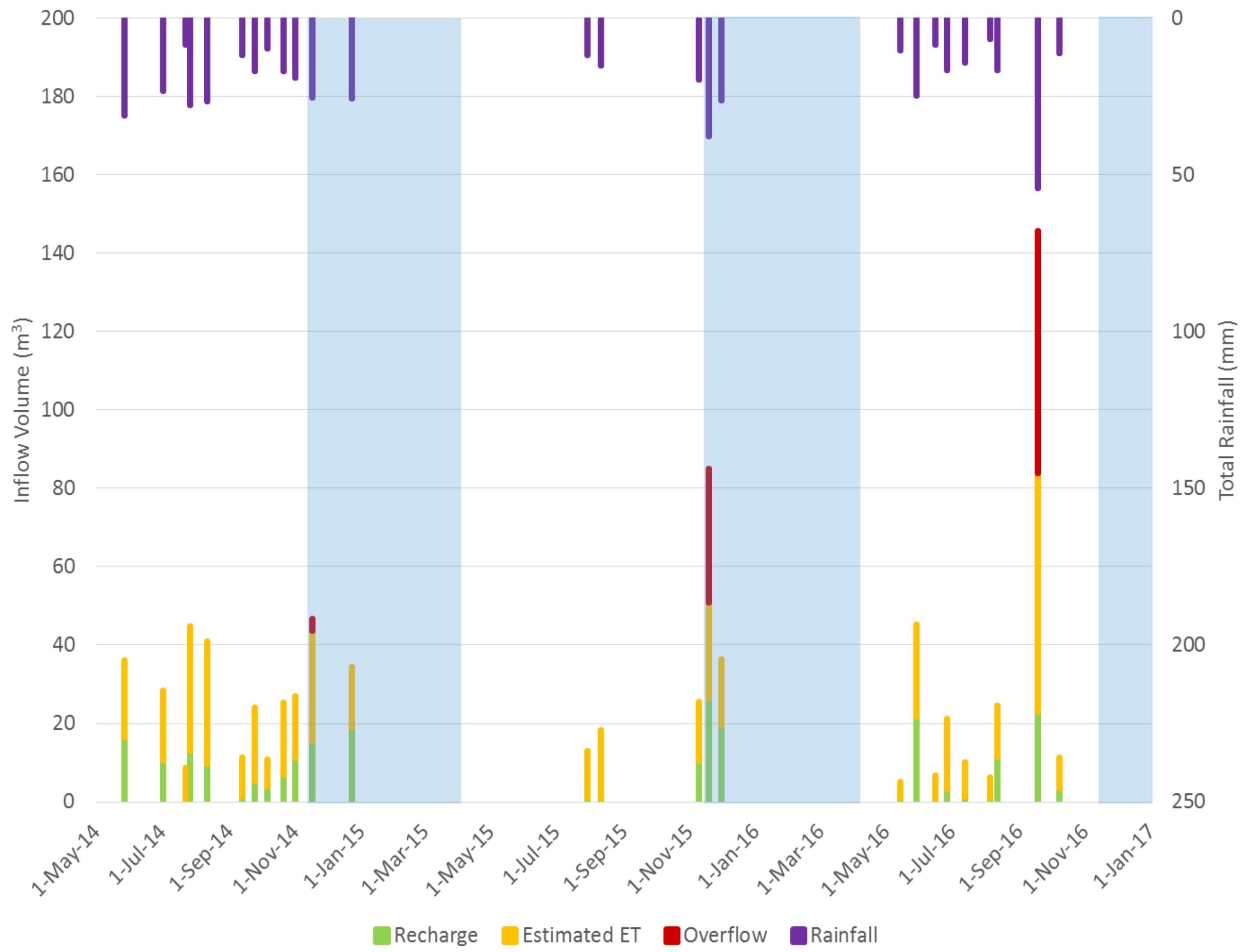
$R_{vol} = R * \text{Surface Area}$

$R_{vol} = \Delta h_{avg} * S_y * SA$

$S_y = 0.25$

$SA = 1130\ ft^2$

Estimated Evapotranspiration



$$\frac{\textit{Inflow} - \textit{Recharge} - \textit{Overflow}}{\textit{Evapotranspiration}}$$

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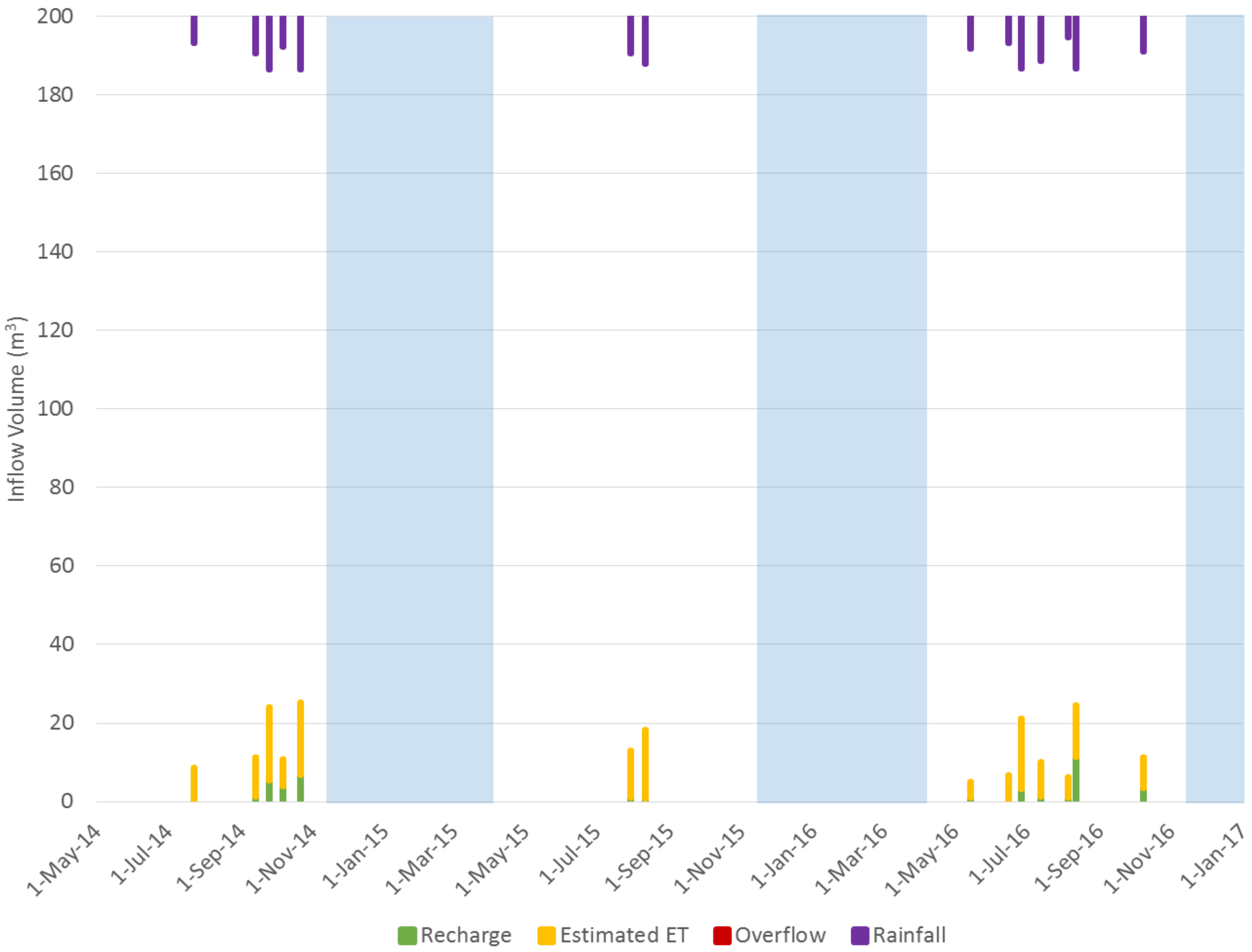
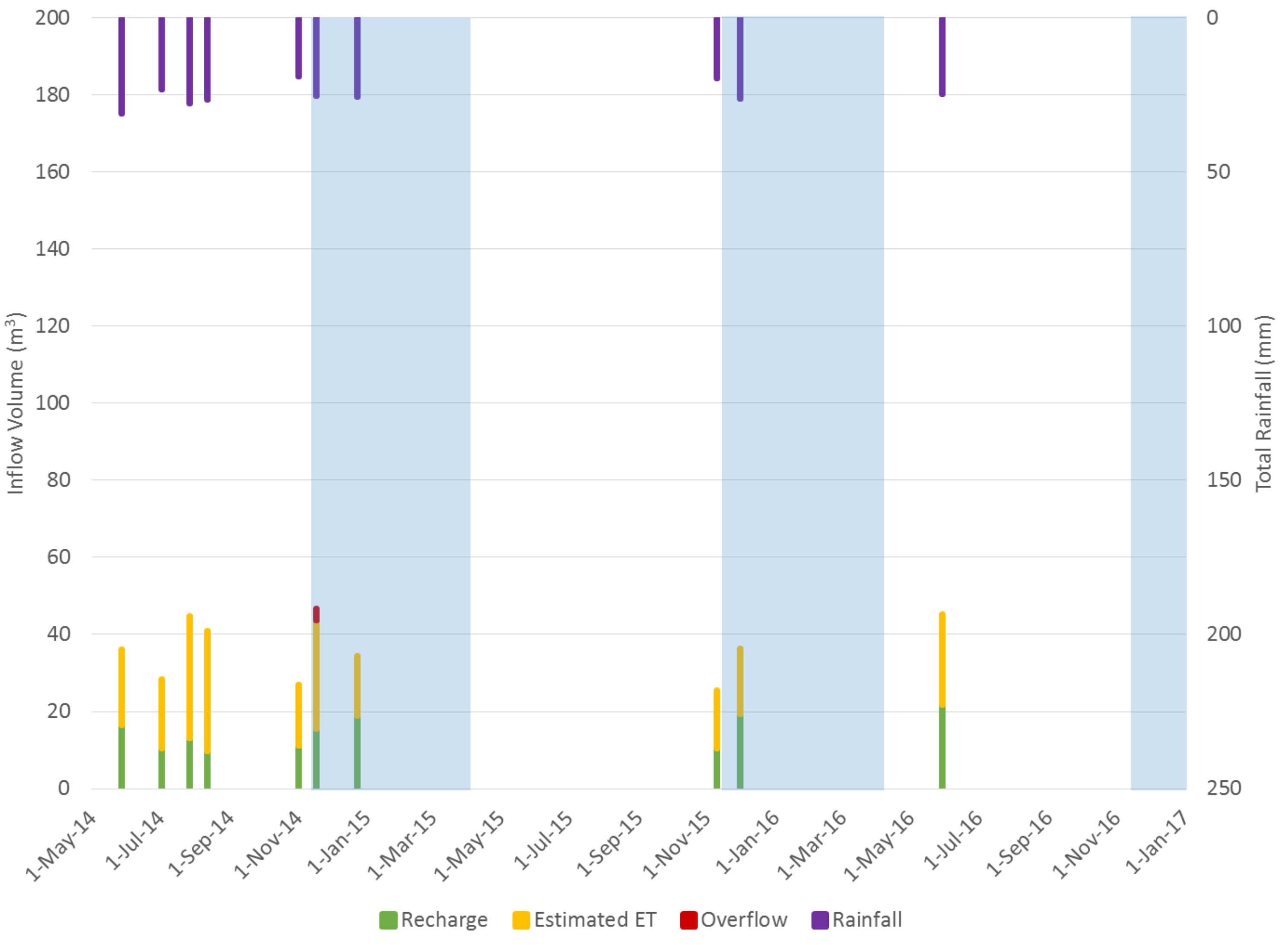
Small Events



- Storm less than 0.71 in
- No overflow
- Limited recharge

Sample Size		14	
	Volume		ET Fraction	
	m^3	cm	% Inflow	% Rain
Minimum	4.0	0.08	54%	7%
Maximum	18.7	0.35	100%	22%
Average	11.3	0.21	83%	16%
	Volume		Recharge Fraction	
	m^3	cm	% Inflow	% Rain
Minimum	0.0	0.00	0%	0%
Maximum	11.3	0.21	46%	13%
Average	2.8	0.05	17%	4%

Medium Events

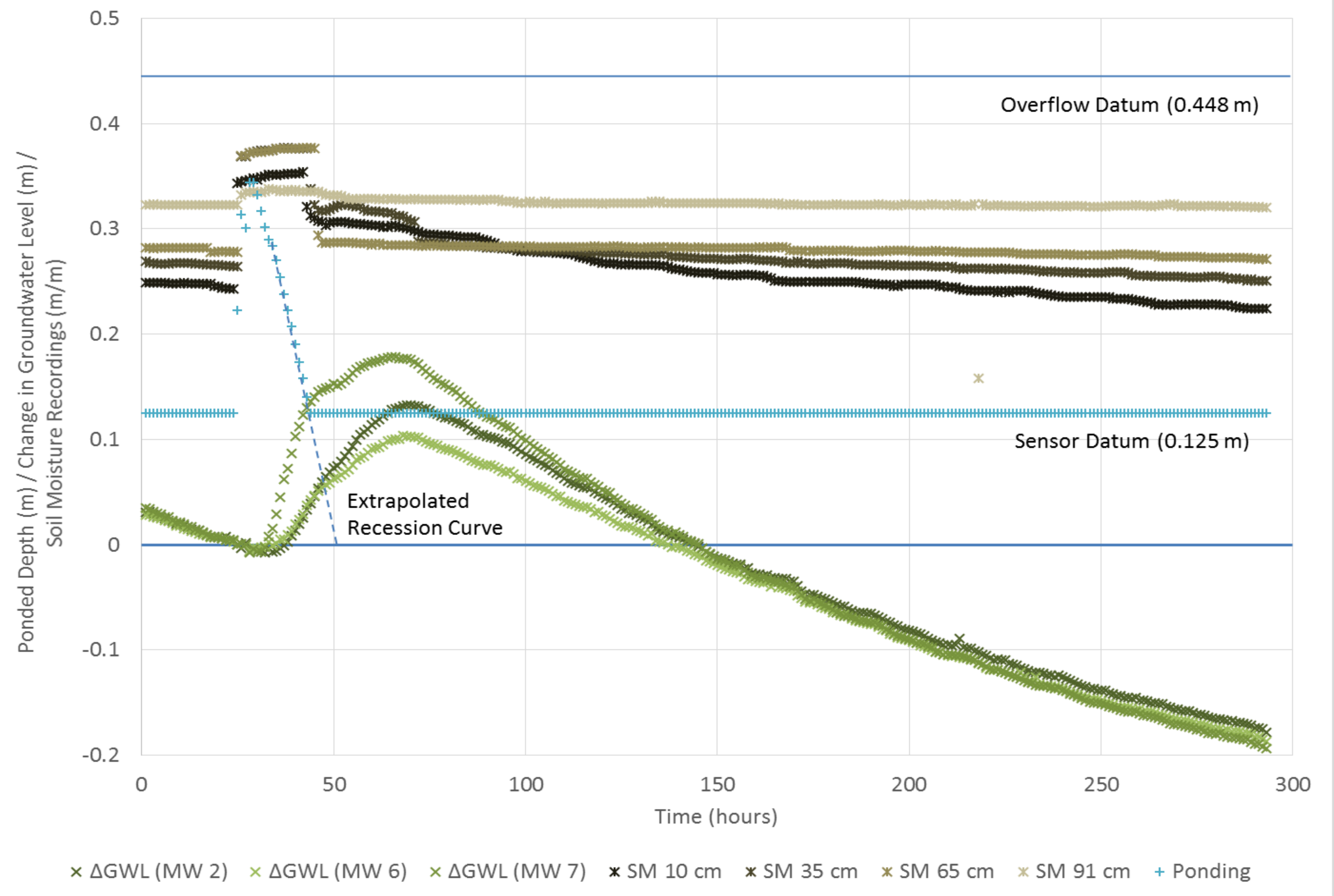


- Storm larger than 0.71 in
- No overflow
- Recharge

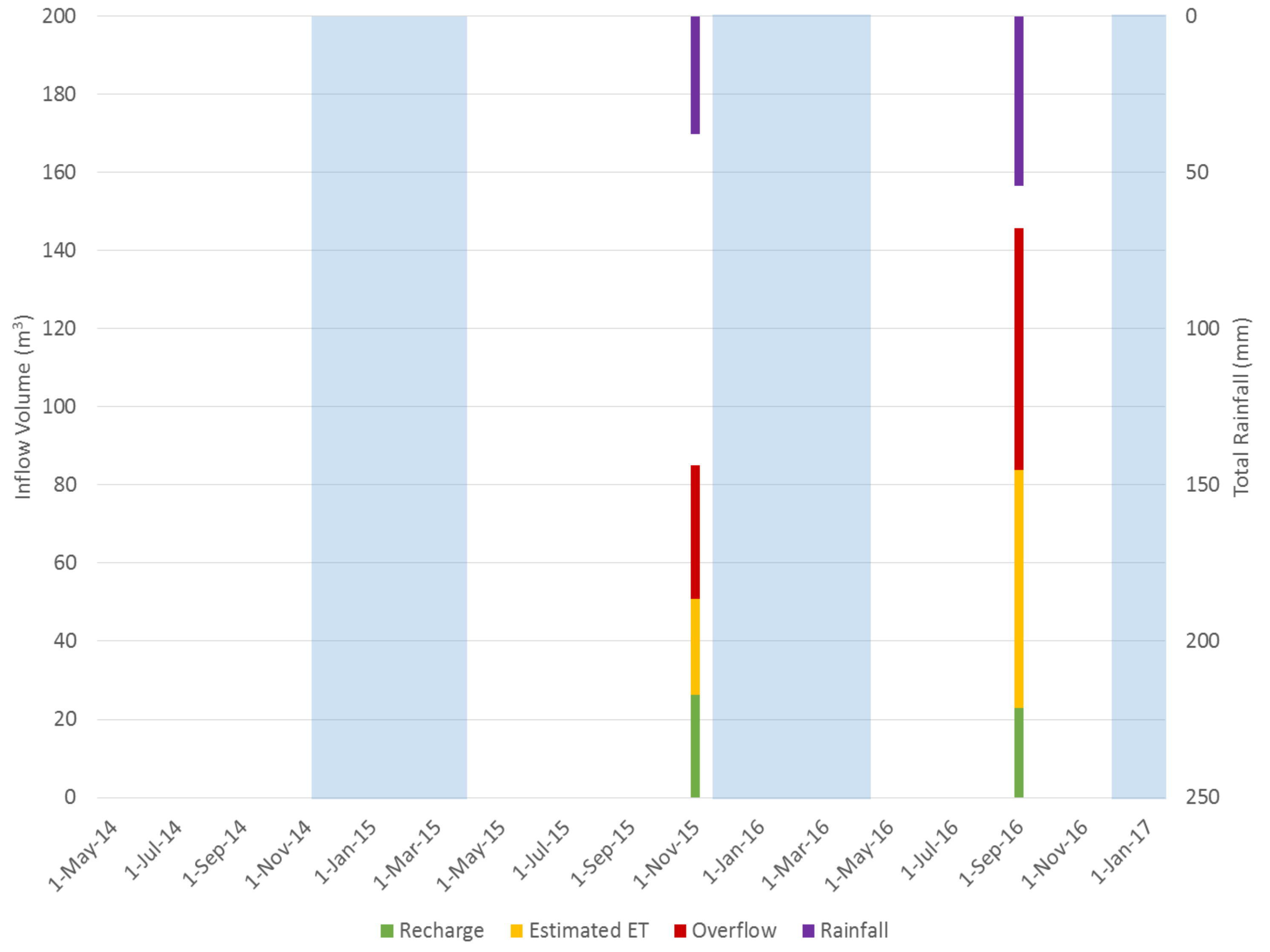
Sample Size			7	
	Volume		ET Fraction	
	m^3	cm	% Inflow	% Rain
Minimum	15.2	0.29	52%	12%
Maximum	31.7	0.60	77%	22%
Average	22.2	0.42	62%	17%
	Volume		Recharge Fraction	
	m^3	cm	% Inflow	% Rain
Minimum	9.6	0.18	23%	7%
Maximum	21.6	0.41	48%	16%
Average	13.2	0.25	38%	10%

Medium Storm Event

Rainfall	= 0.92 in
Inflow	= 999 ft^3
Recharge	= 371 ft^3
Estimated ET	= 628 ft^3



Large Events



- Storm larger than 0.71 in
- Overflow
- Recharge

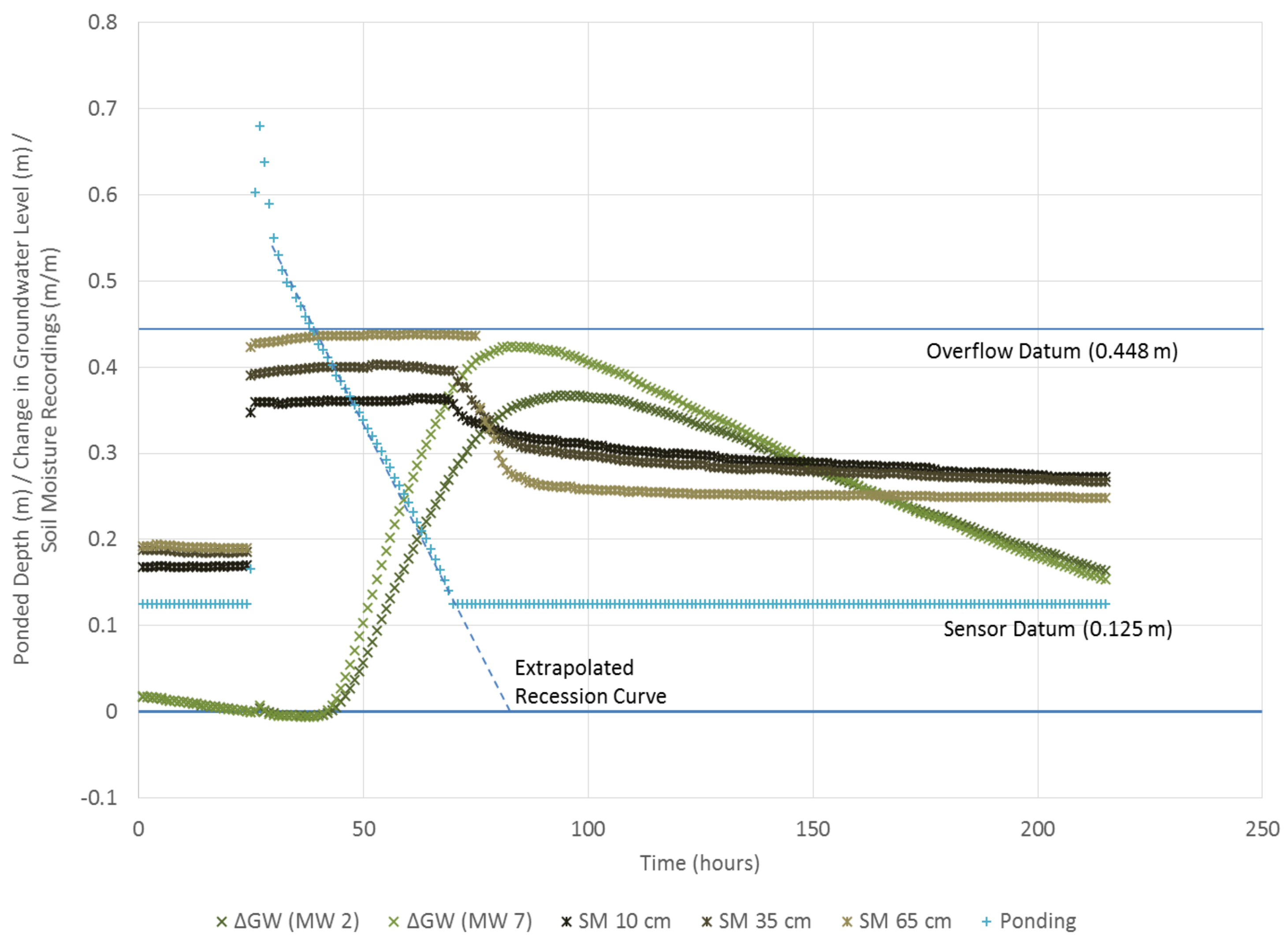
Sample Size				1	
	Volume		ET Fraction		
	m^3	cm	% Inflow	% Inflow Retained	% Rain
19-Sep-16	60.9	1.16	42%	73%	21%
	Volume		Recharge Fraction		
	m^3	cm	% Inflow	% Inflow Retained	% Rain
19-Sep-16	22.9	0.43	16%	27%	8%

Large Storm Event

Rainfall = 2.14 in

Inflow = 5145 ft^3
Overflow = 2186 ft^3

Retained Inflow = 2959 ft^3
Recharge = 809 ft^3
Estimated ET = 2150 ft^3

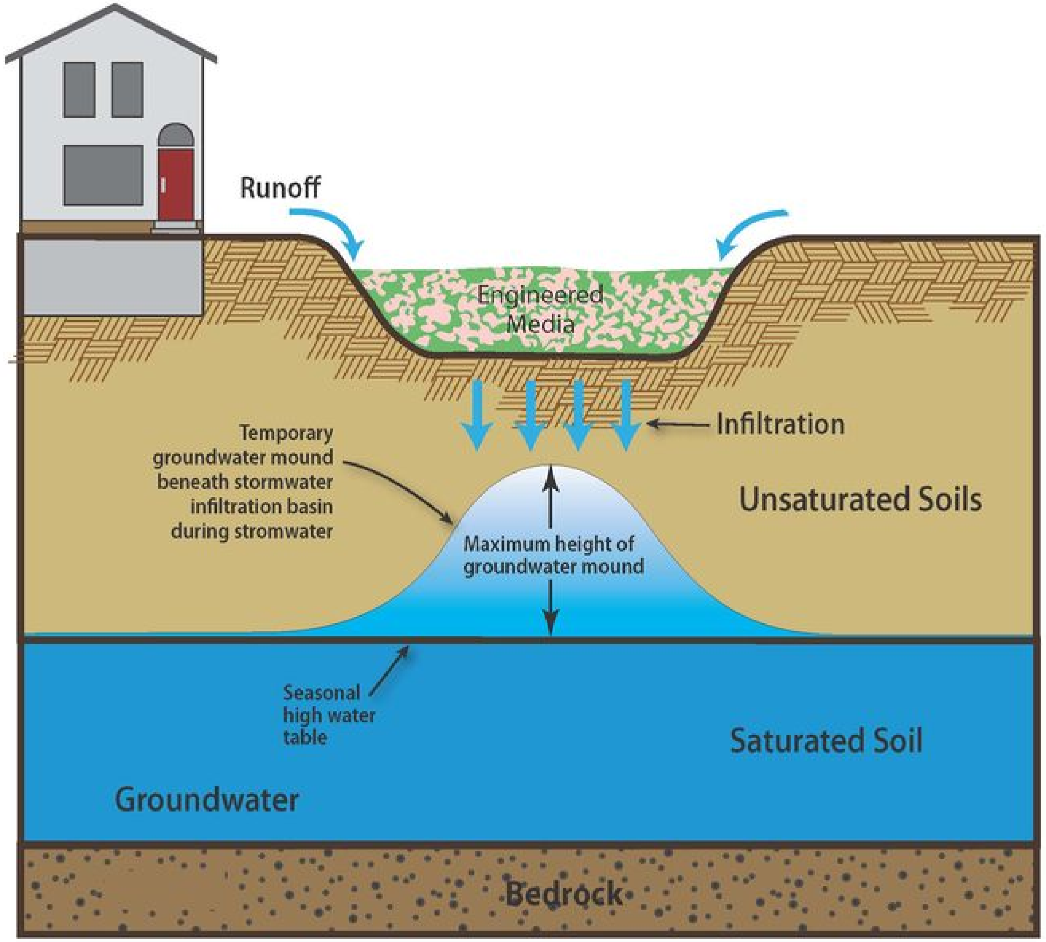


Estimated Hydrologic Budget

Rainfall Range		Avg. Inflow	Avg. Recharge	Avg. ET Estimate
mm	*in*	m^3	m^3	m^3
6.4 - 12.7	*0.25 - 0.50*	9.2	2.0	7.2
12.7 - 19.1	*0.50 - 0.75*	19.9	5.6	14.3
19.1 - 25.4	*0.75 - 1.00*	30.6	9.3	21.3
25.4 - 38.1	*1.00 - 1.50*	46.7	14.8	31.9
38.1 - 50.8	*1.50 - 2.00*	68.1	22.1	46.0
50.8 - 63.5	*2.00 - 2.50*	89.6	29.4	60.2

Design Applications

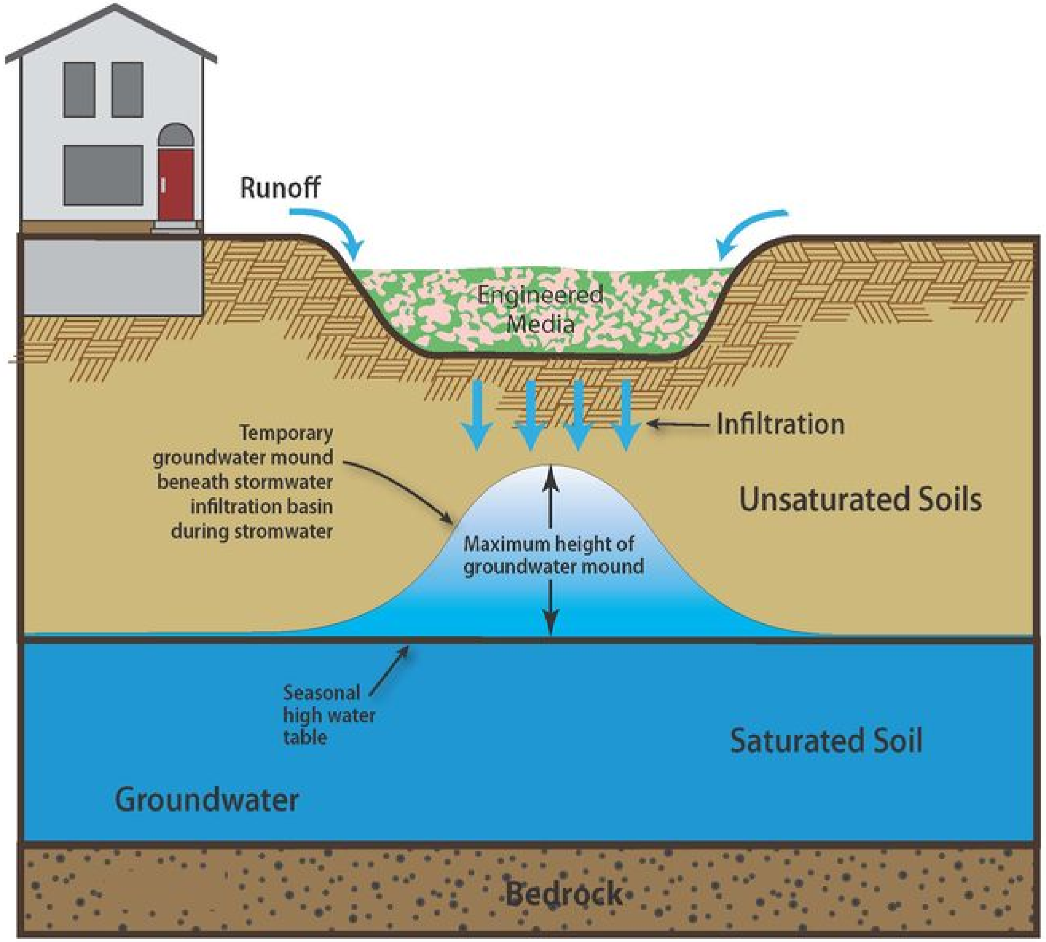
- Promote Evapotranspiration
  - Use liner
  - Reduce head
  - Soil with high void space
- Benefits
  - Avoid contaminating high water table
  - Prevent damage to structures



https://stormwater.pca.state.mn.us/index.php?title=Stormwater_infiltration_and_groundwater_mounding

Design Applications

- Promote Recharge
  - Avoid compacting native soil
  - Increase ponding time
- Benefits
  - Promote base flow in streams
  - Aid in reversing drought conditions



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Acknowledgements

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These are my views and not the views of the organizations listed