Evaluation of methods of measuring flowrates for bioretention planters

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Disclaimer

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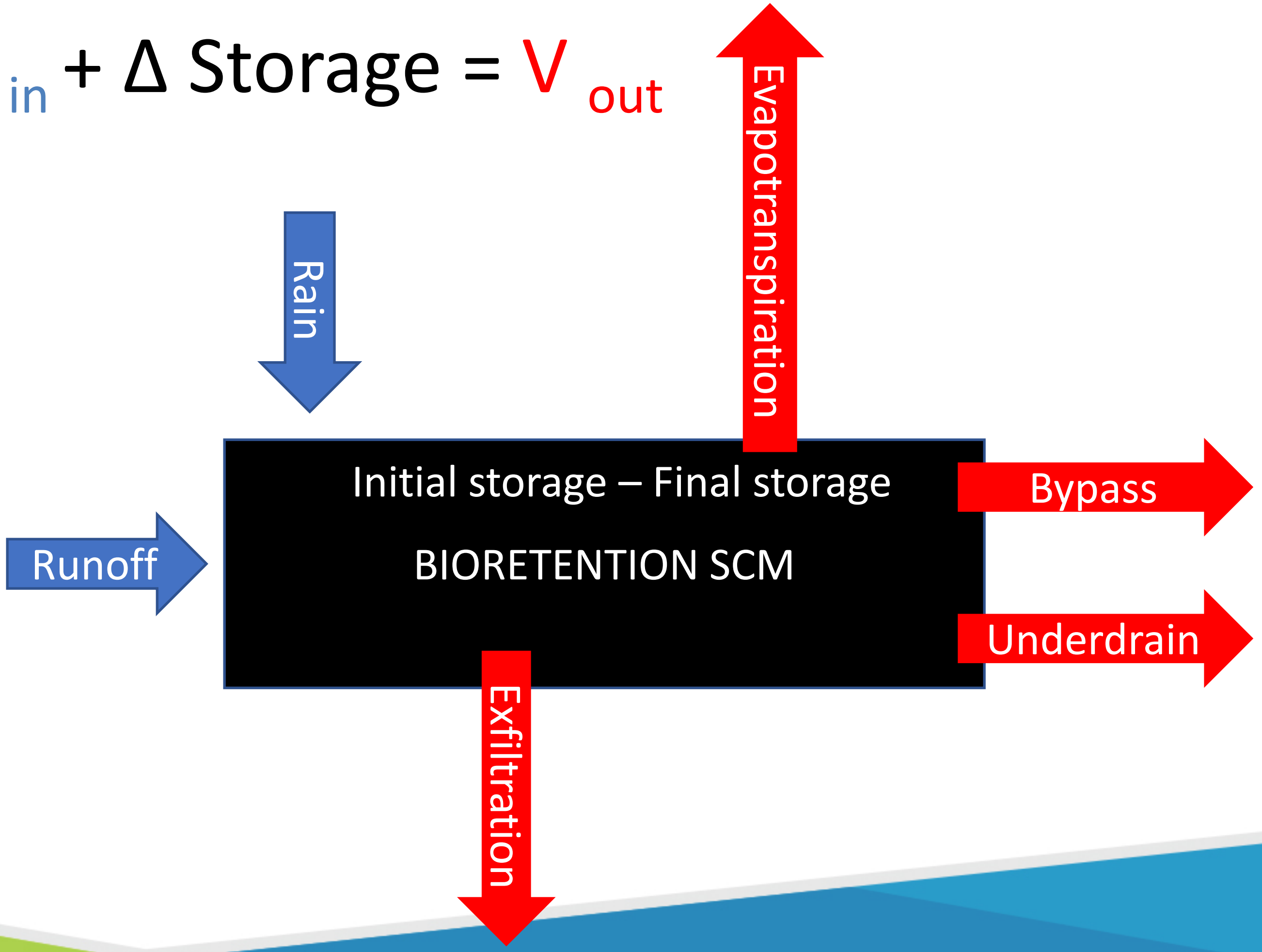
SCM performance is often based on a mass balance

$V_{in} + \Delta\ \text{Storage} = V_{out}$

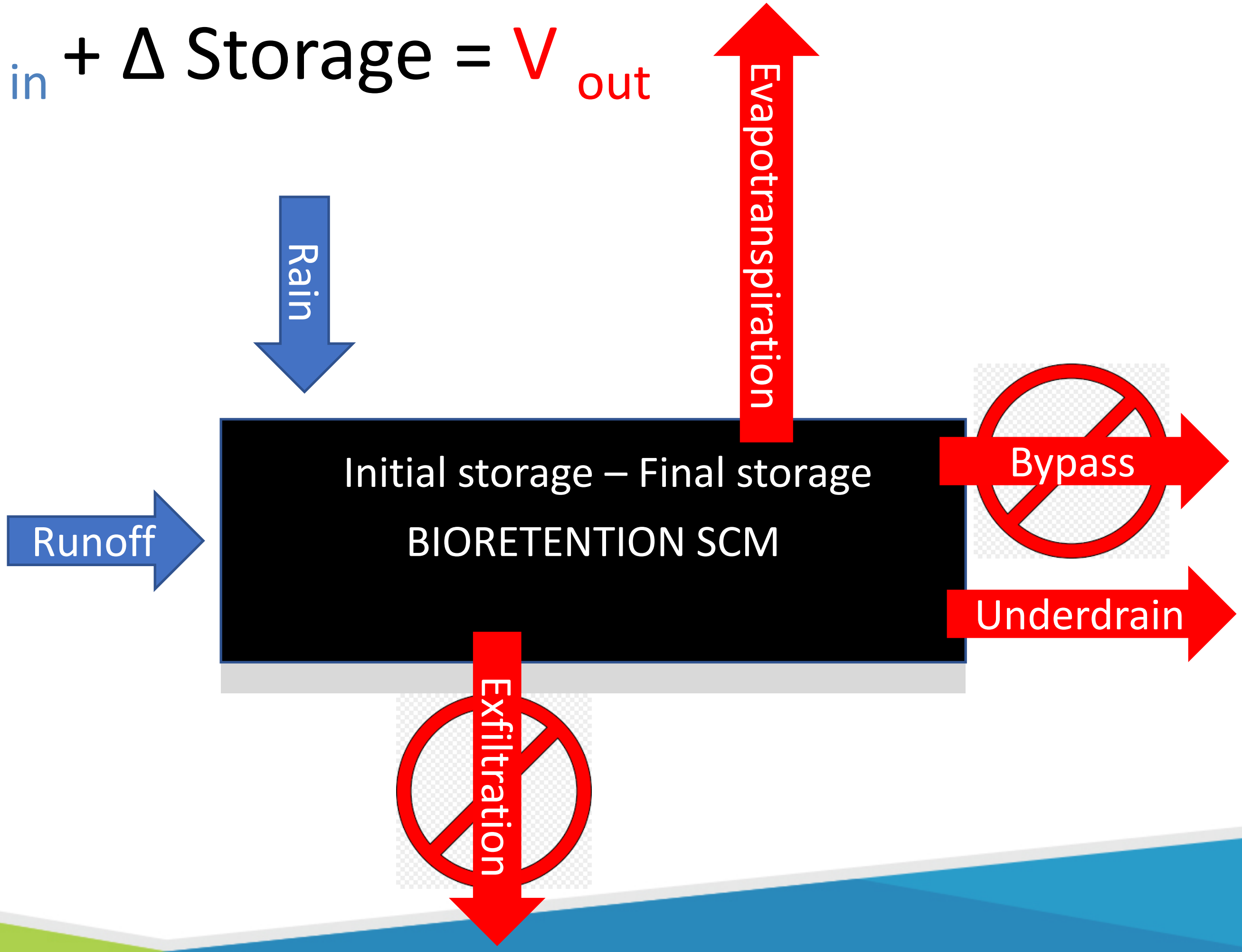


Experimental Set Up

- 4 Bioretention flow through planters with concrete bottom and sides
- Sensors monitoring inflow, outflow, and the volumetric water content (VWC) of the media

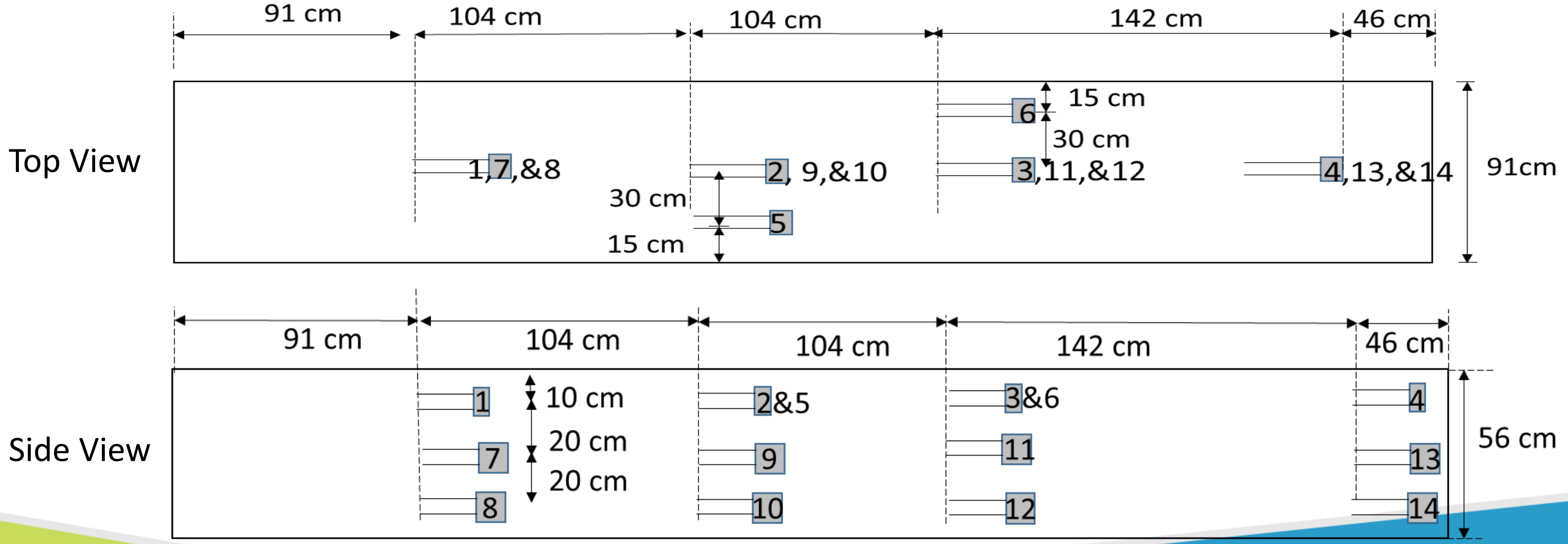
Mass balance for flow through planters

$$V_{in} + \Delta\ \text{Storage} = V_{out}$$

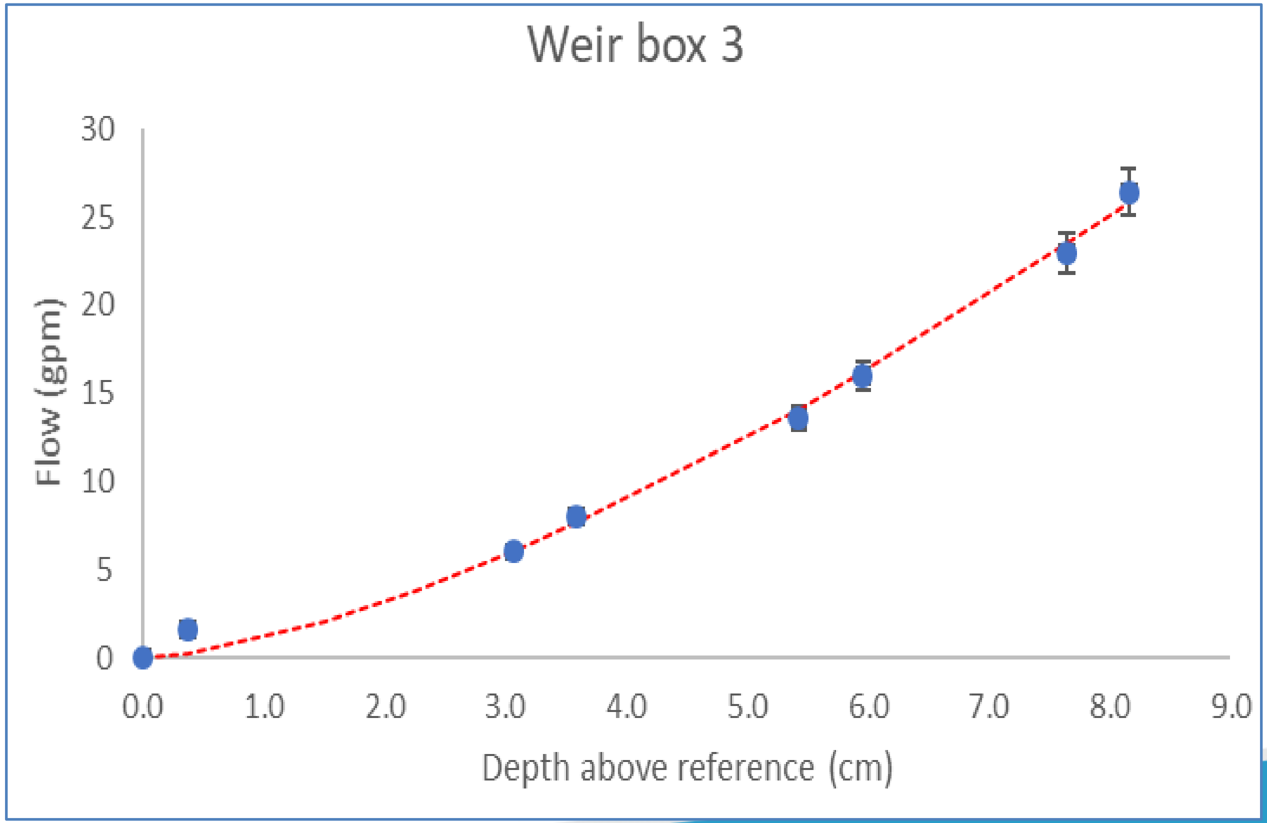


Media Storage Monitoring

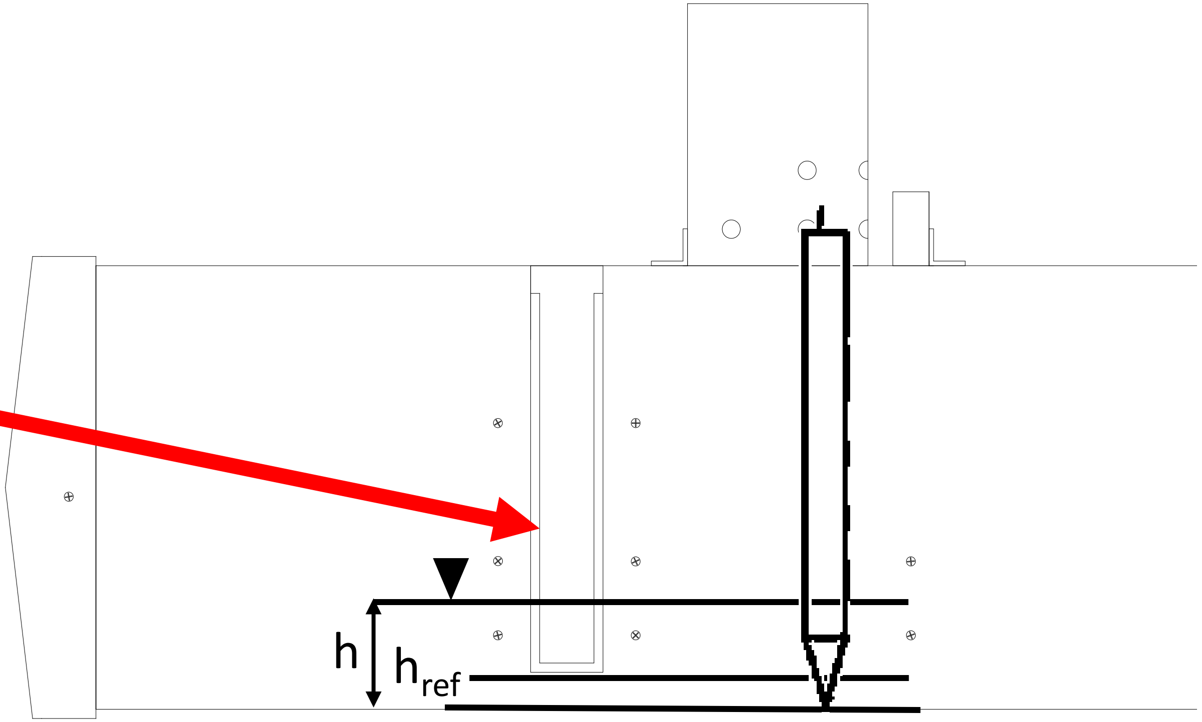
$$\Delta \text{ Storage} = \text{Media Volume x (Weighted VWC}_0 - \text{Weighted VWC}_f)$$



Inlet Monitoring

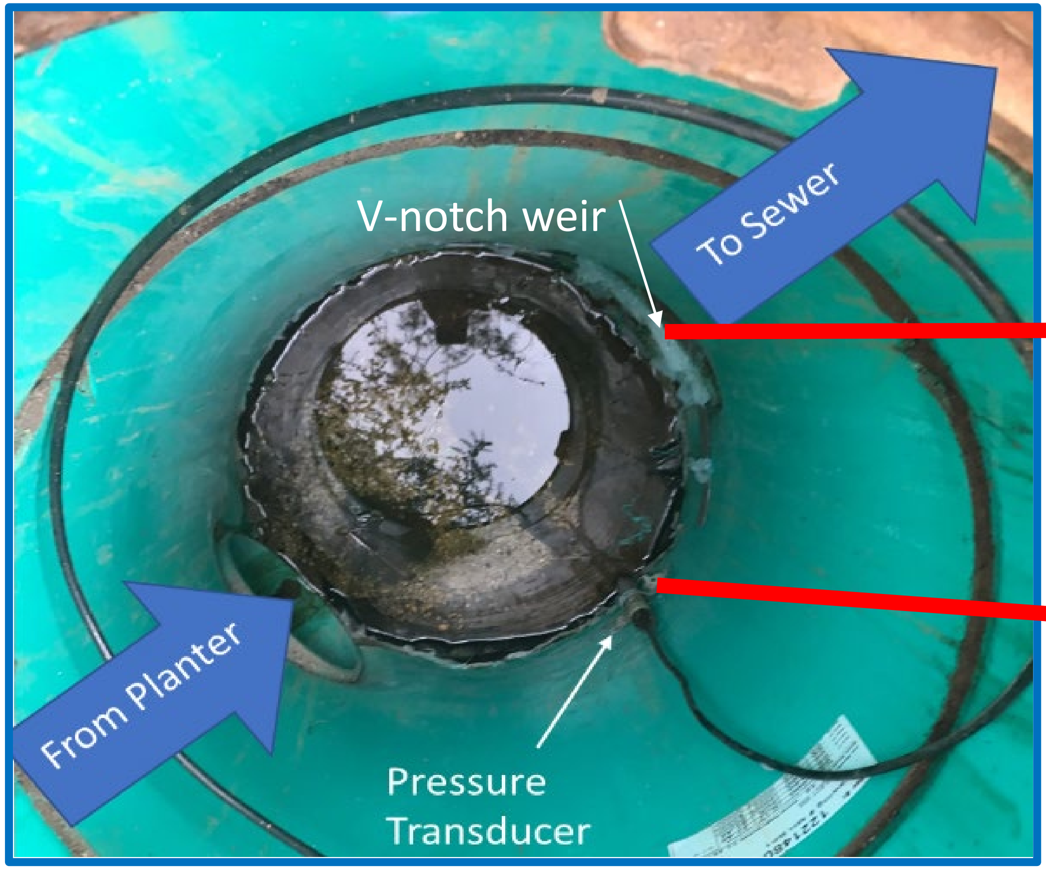


Inlet Monitoring

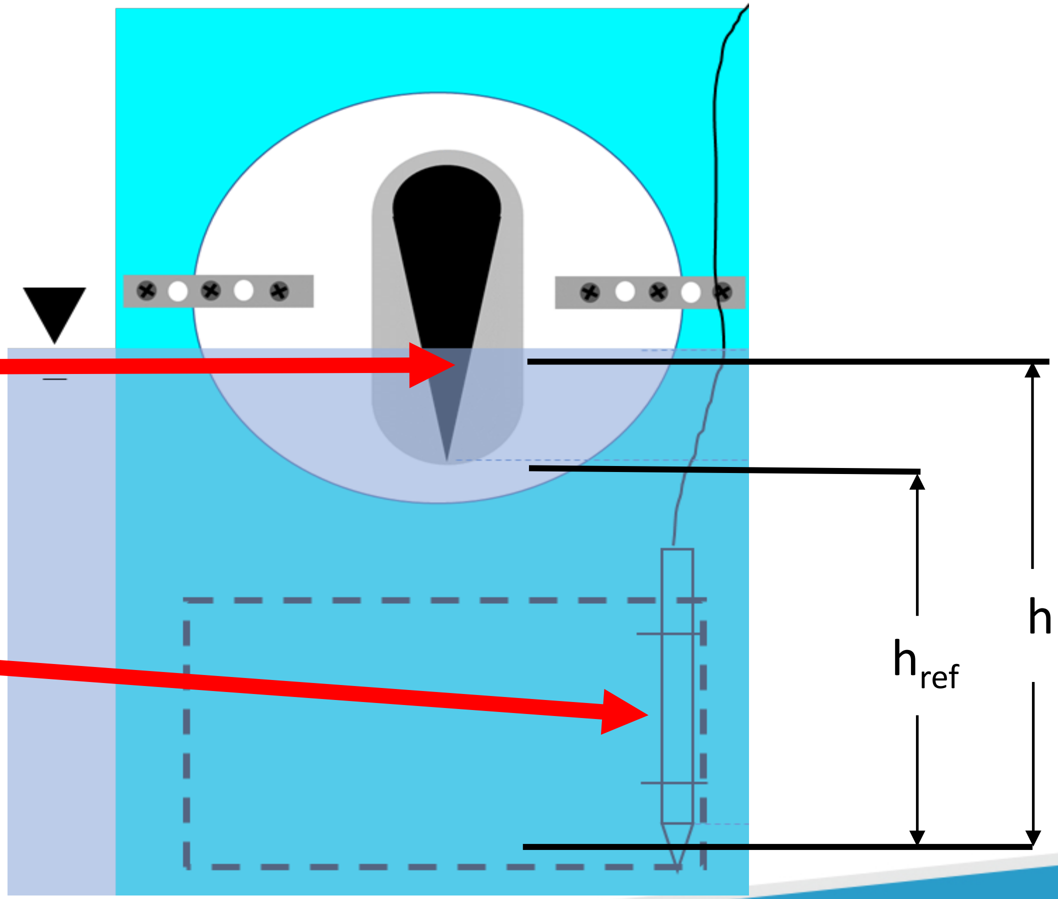


Outlet Monitoring

Overhead View



Side View



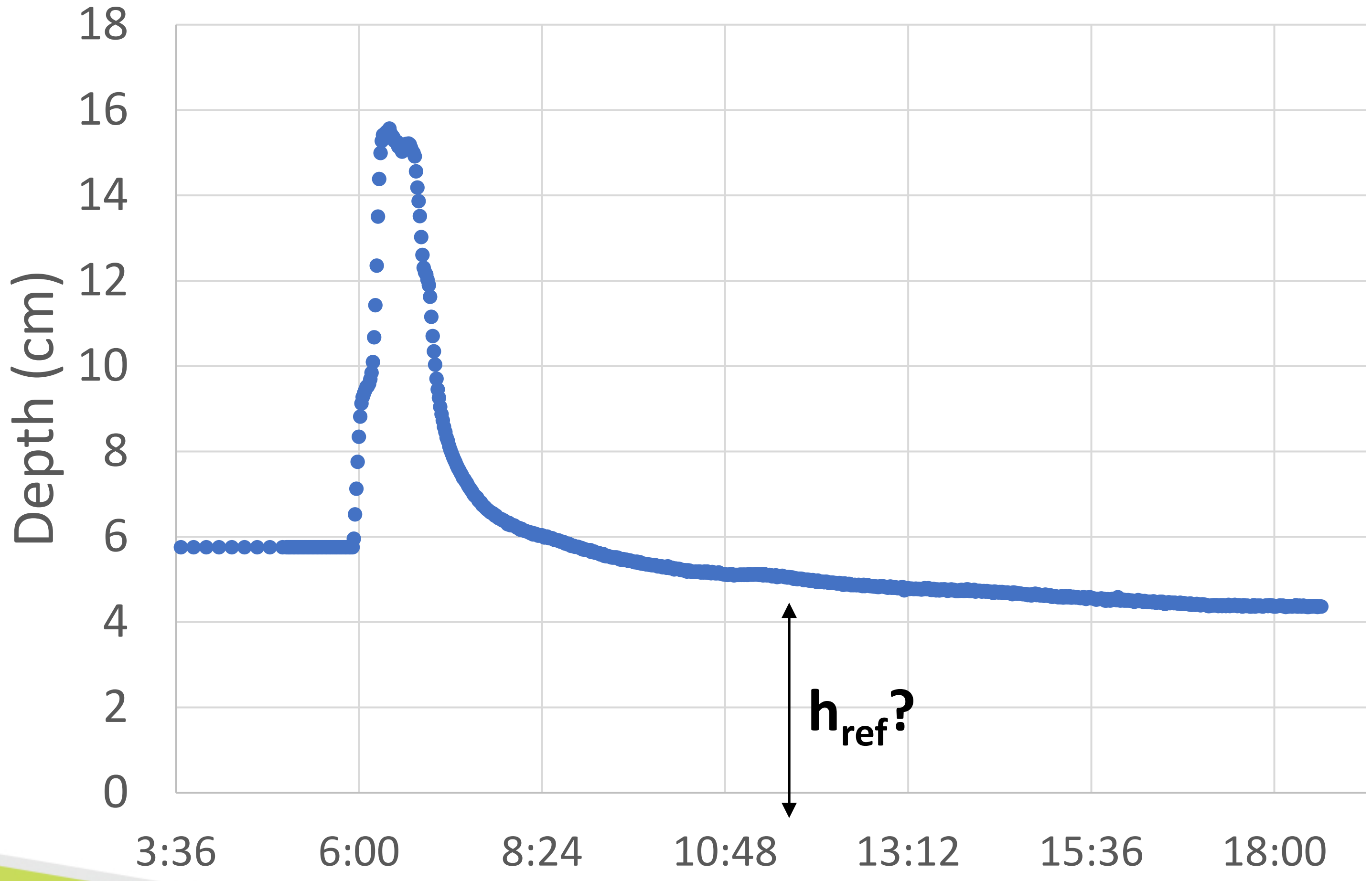
Flow Rates and Volume Calculations

- $Q = a \times (h - h_{ref})^n$
  - *a and n are weir specific constants*

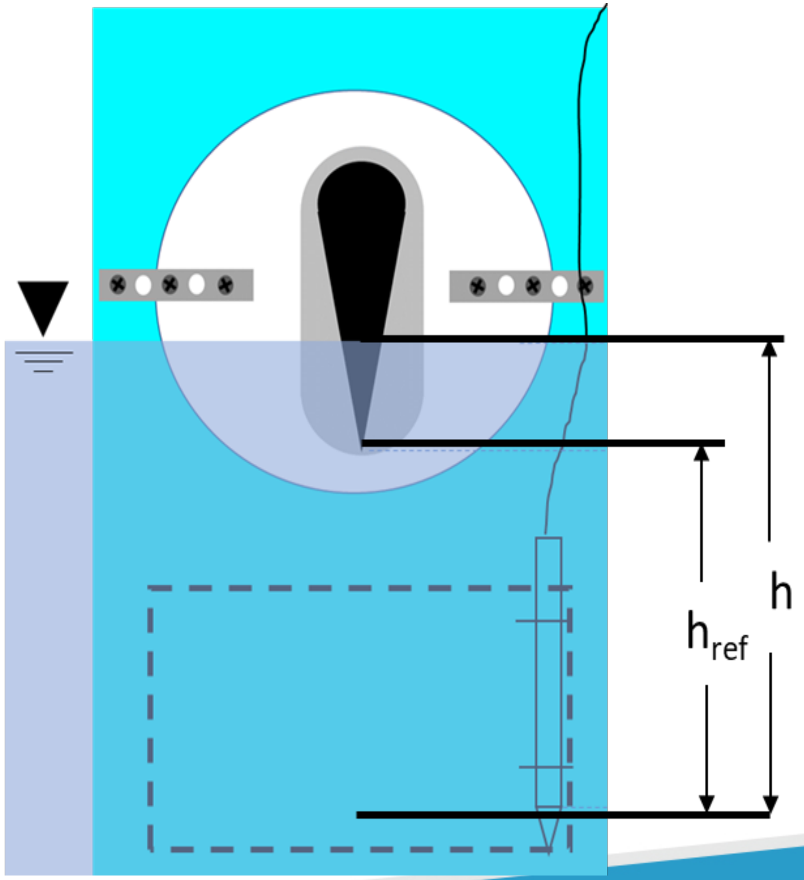
- $V = \sum_{i=1}^{N} Q_i \, \Delta t$

- h_{ref} is weir specific and important in calculating Q and V

h_{ref} ?



Depth (cm)
18
16
14
12
10
8
6
4
2
0
3:36
6:00
8:24
10:48
13:12
15:36
18:00
h_{ref}?



h
h_{ref}

Different methods of estimating h_{ref}

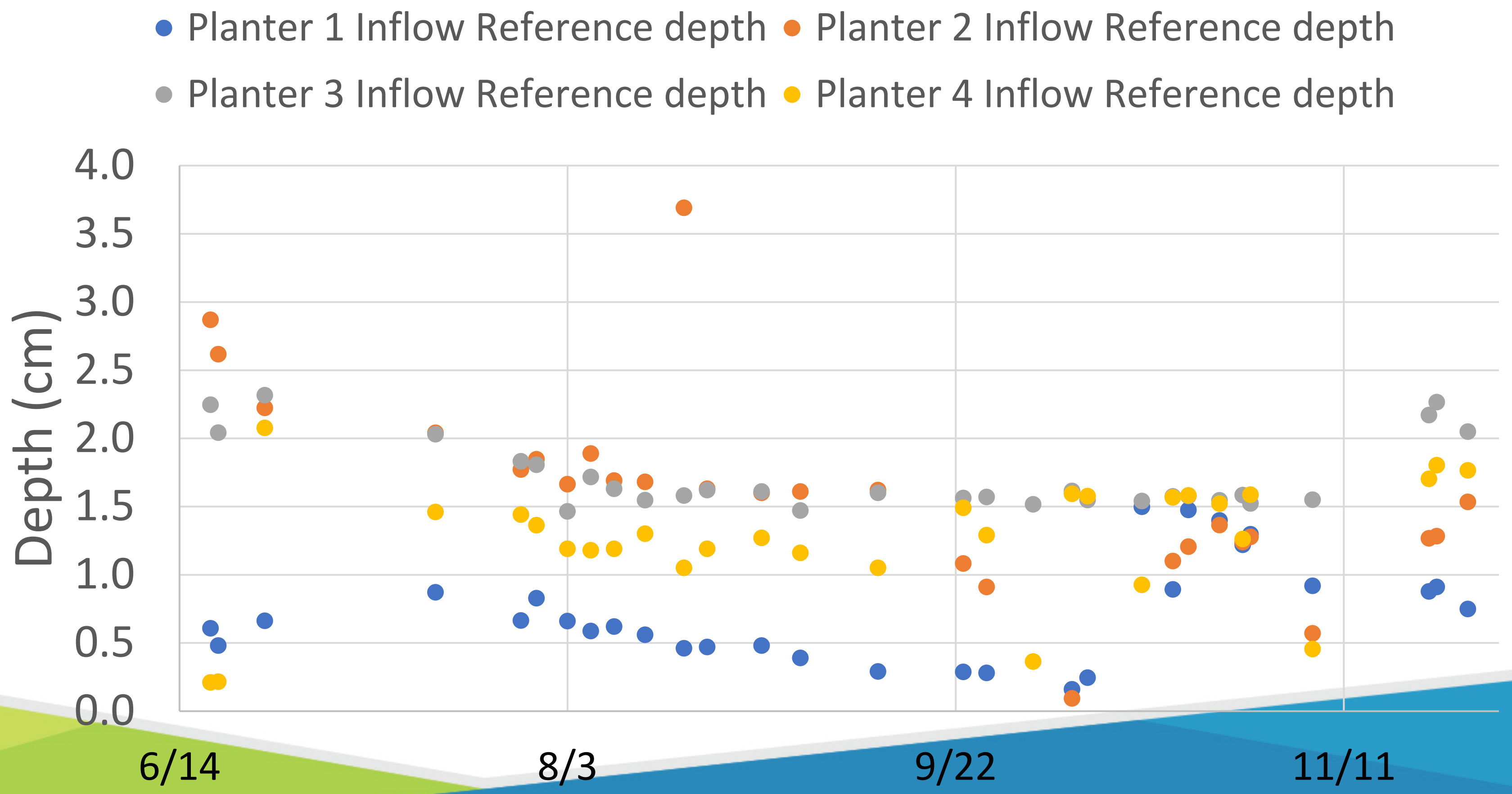
We tried

- Level at the start of the rainfall
- Level when 30-min slope $\frac{\Delta h}{\Delta t} < 0.01$ cm/min
- Level when 30-min slope $\frac{\Delta h}{\Delta t} < 0.001$ cm/min
- Level when changing depth is within ±0.2 cm per hour (published total error band of sensor)
- Level 1 hr, 3hr, 6 hr, and 12 hr after rainfall ends

- Literature
  - Eyeball from graph
  - Use the pre-event for first half and post-event for second half
  - Back calculate to match expected runoff volume
  - Unreported

Calculating h_{ref} for inlet

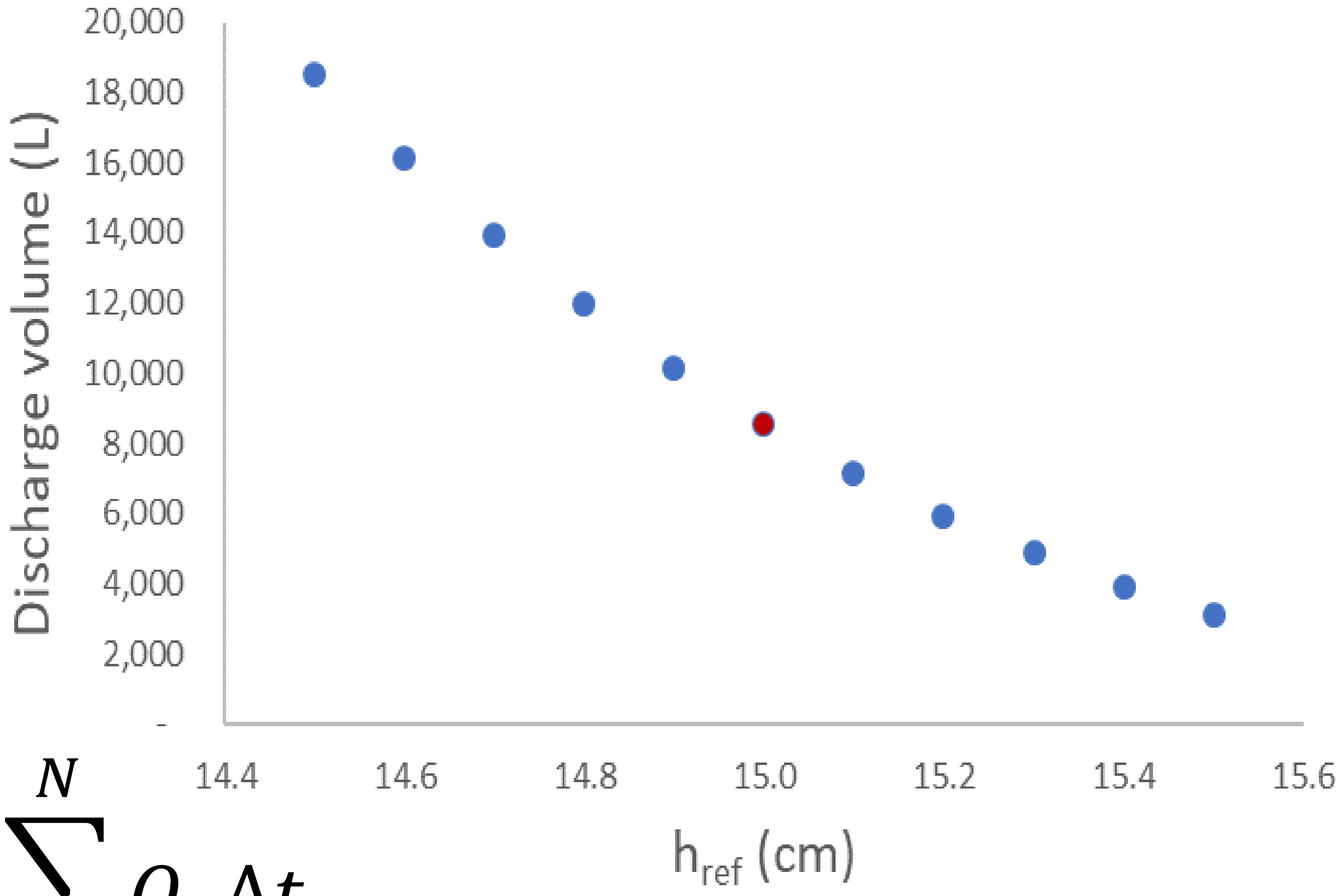
- h_{ref} should be relatively consistent storm to storm
- Changing h_{ref} thought to be partially due to measuring at the end of operating range



h_{ref} presented here found using slope < 0.001 cm/min rule

How important is h ?

H_{ref} (cm)	Volume (L)
14.5	18,484
14.6	16,106
14.7	13,927
14.8	11,944
14.9	10,157
15.0	8,561
15.1	7,153
15.2	5,925
15.3	4,858
15.4	3,924
15.5	3,105



$$Q = a \times (h - h_{ref})^n$$

$$V = \sum_{i=1}^{N} Q_i \, \Delta t$$

Mass Balance for Planters

$$V_{in}\,(L) = V_{out}(L) + \Delta\,\text{Storage}\,(L) + \text{Missing Water}\,(L)$$

$$1715 = 1573 + 120 + \text{Missing Water}$$

Missing Water = 22 Liters

Uncertainty = 444 Liters**

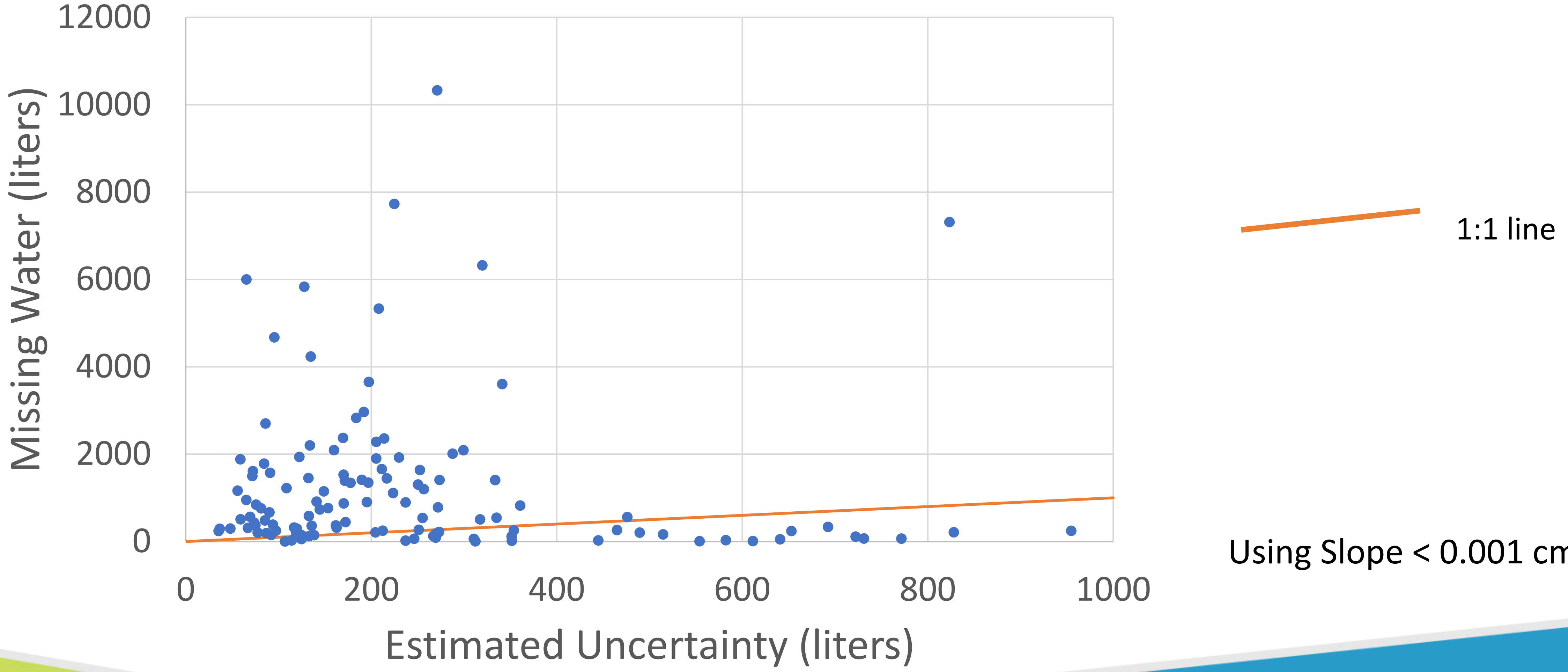
Closure if |Missing Water| < Uncertainty

* Example data from 10/20/2019 Planter 1

** Uncertainty calculated using Taylor Series Method including uncertainty from rating curves and instruments

EPA

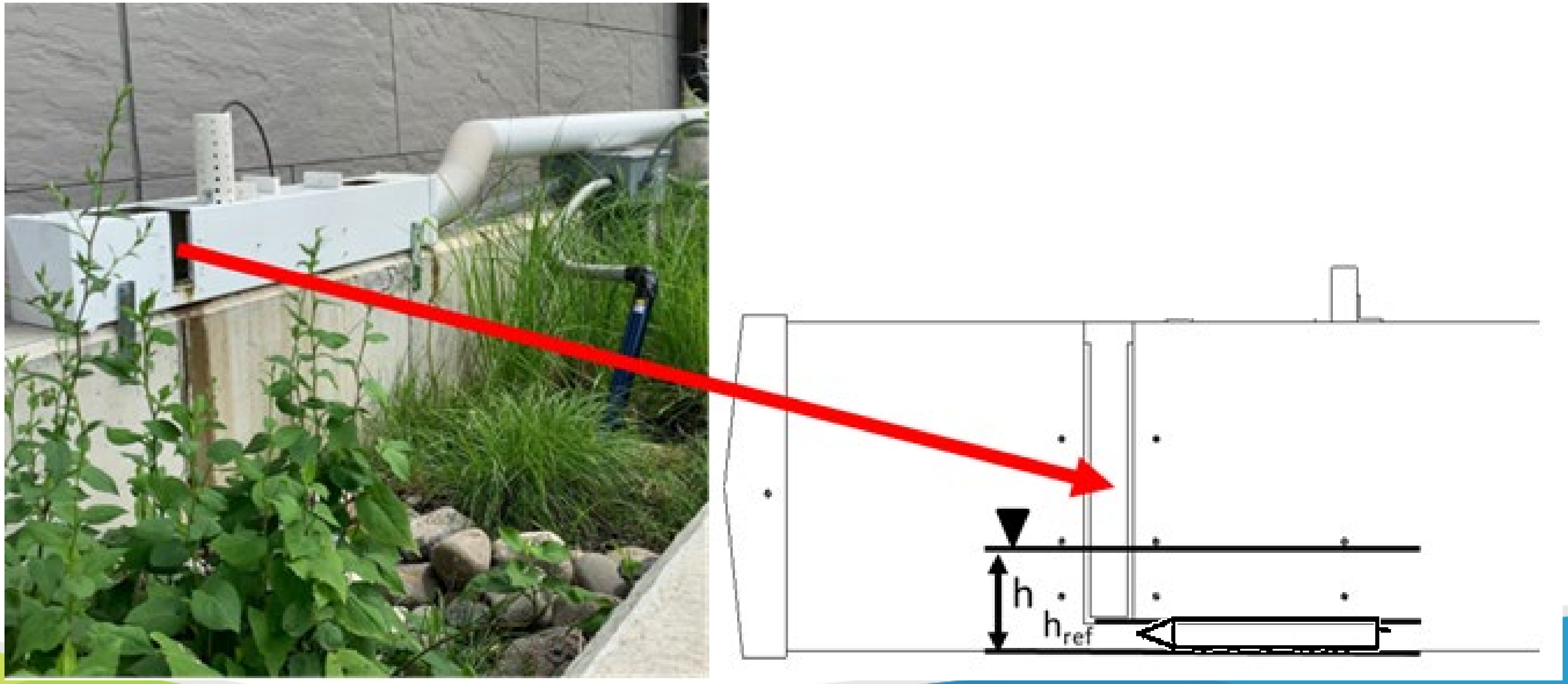
2019 Monitoring



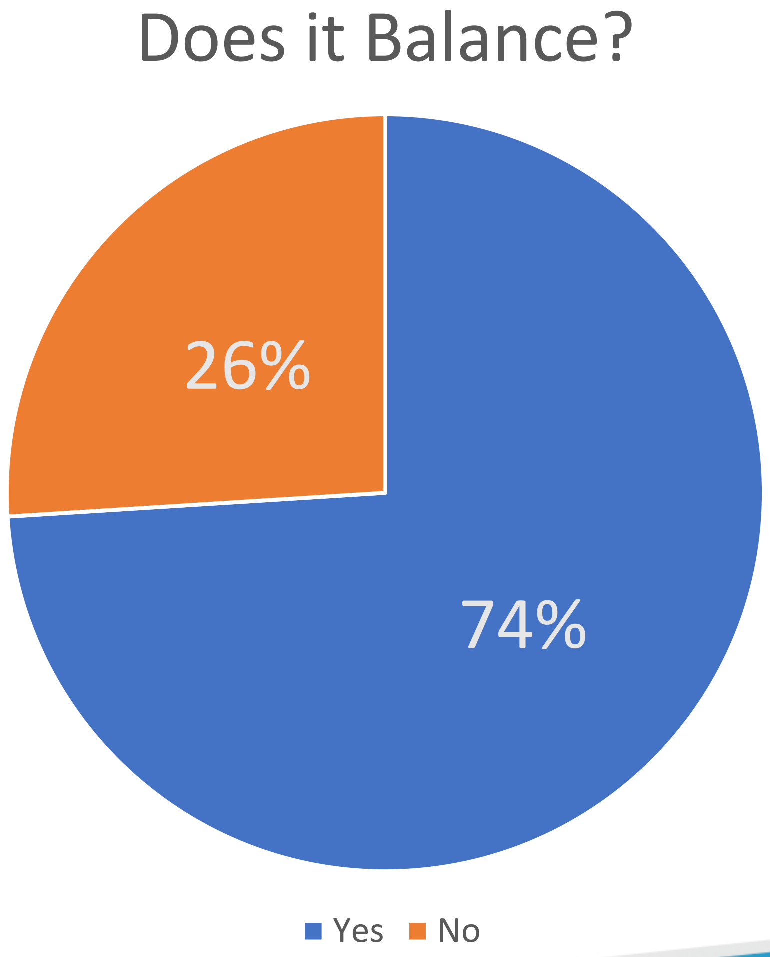
Using Slope < 0.001 cm/min

Changes for 2021 Monitoring Season

- Before each storm, weirs filled to the base of the weir to establish h_{ref} before the storm
- Pressure transducers installed horizontally to account for temperature sensor correction



2021 Monitoring Season



Conclusions

- Topping off the water level in a weir box or sump to the level of the weir crest or V-notch before the storm improved the mass balance.
- Filling the weir boxes and sumps is labor intensive and may not always be practical.
- Further research is needed to determine what other changes could be made to close the remaining 26%

Questions?

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