SWMM Calibration and Sensitivity Analysis for Bioretention

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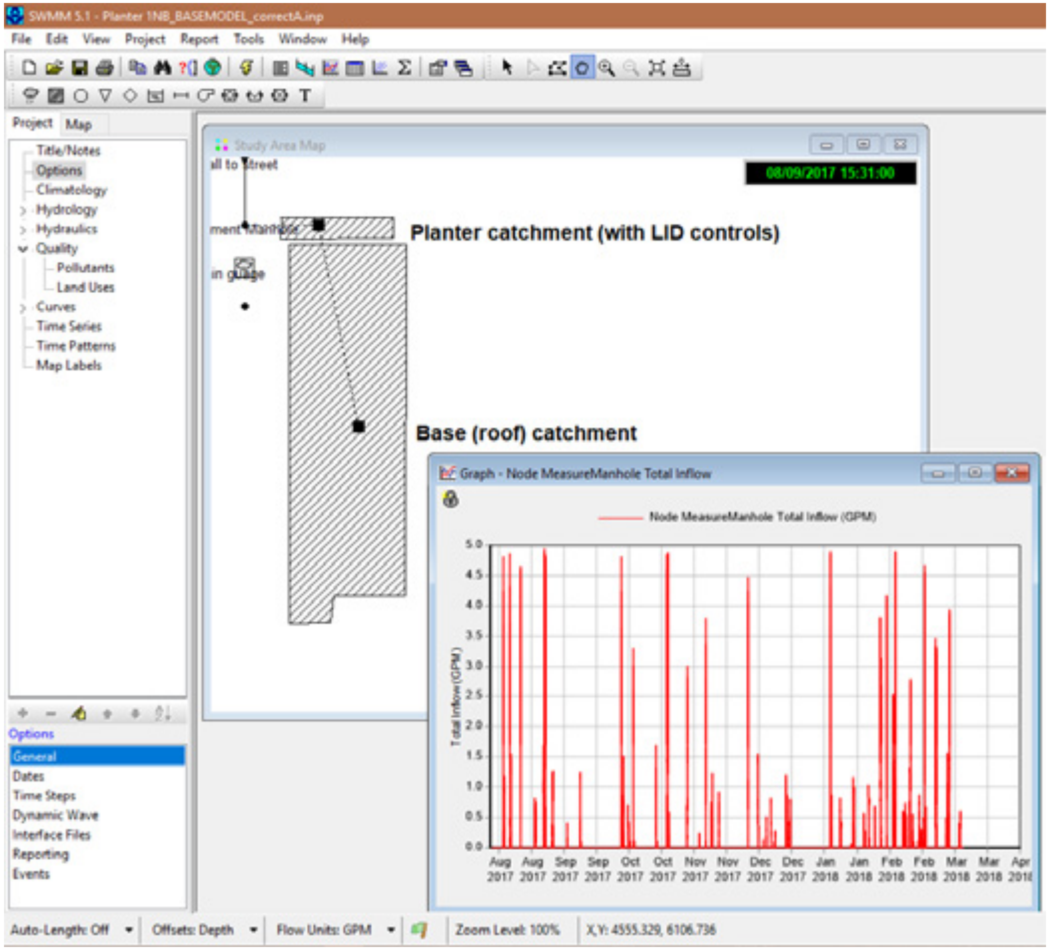
Storm Water Management Model (SWMM)



- Produced by the US Environmental Protection Agency
- Dynamic hydrology-hydraulic water quality simulation model
- Low Impact Development Controls were introduced as part of SWMM 5 in 2009

Objective

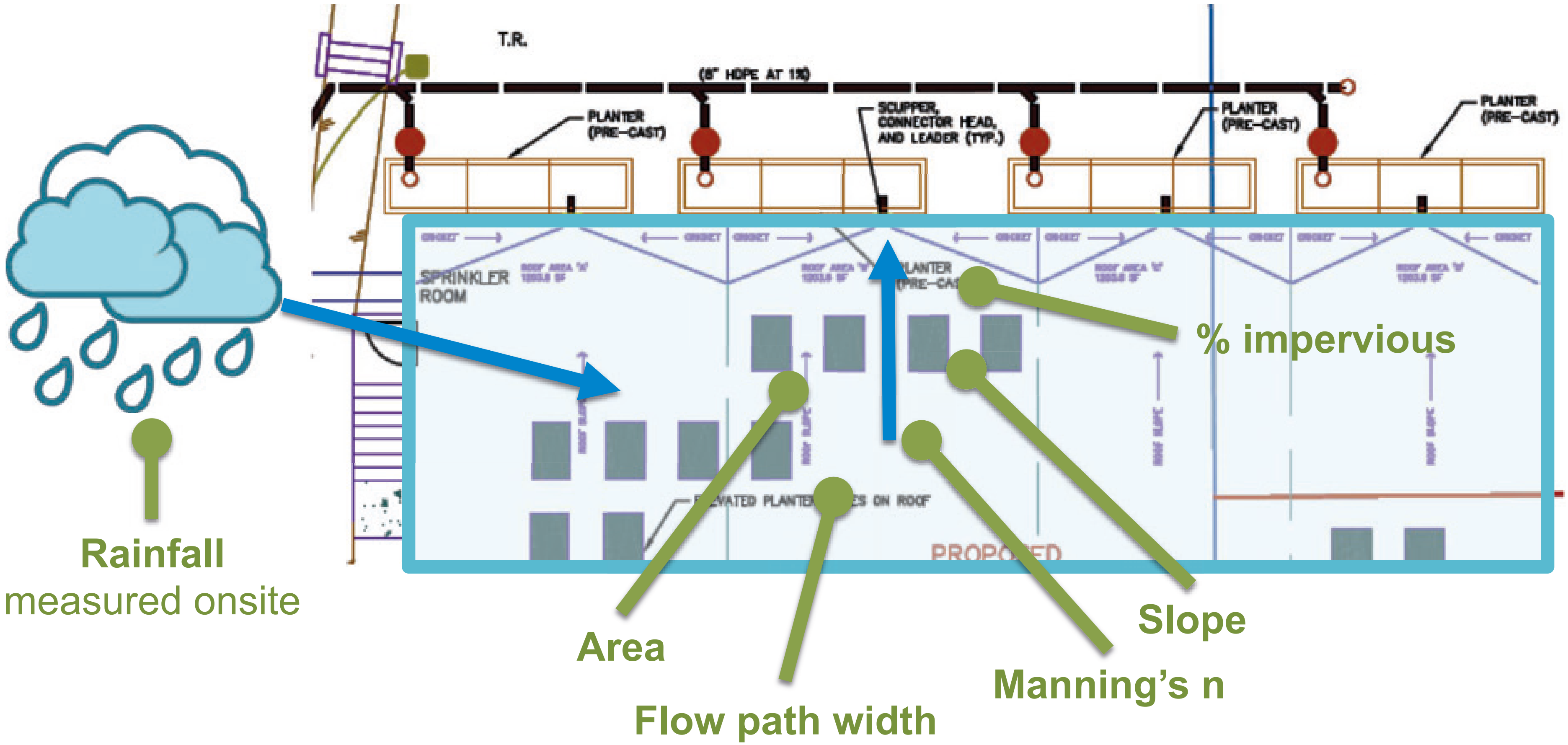
- Evaluate the accuracy of SWMM's LID controls using data collected from GI implementations at Stevens
  - Sensitivity analysis
  - Model calibration and validation
- Few published studies have evaluated the accuracy of SWMM with LID

- Accurate models critical to evaluating design alternatives, determining regulatory compliance, etc.

Site Characteristics

Planter acts as a **bioretention cell** to manage roof runoff

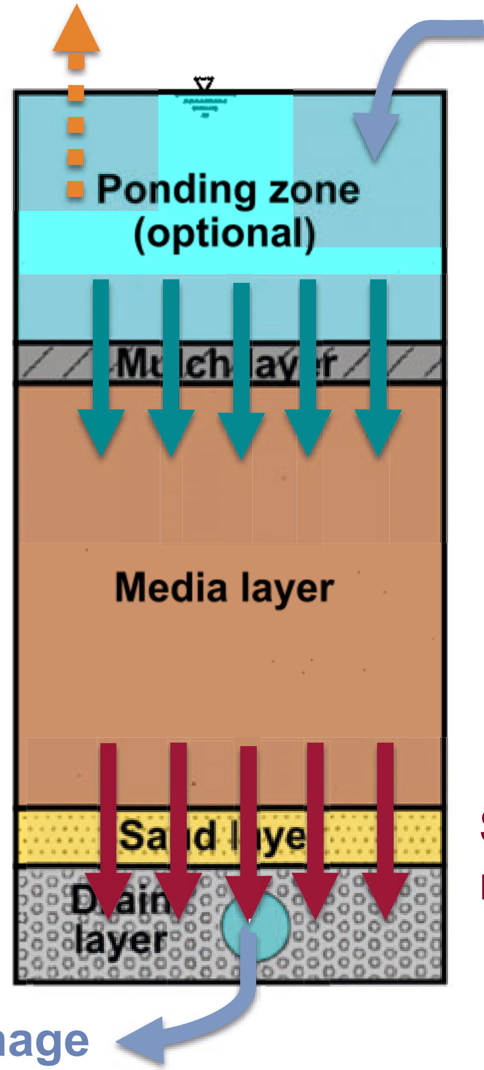
Planter Modeling



How SWMM Models LID Controls

Evapotranspiration
from field measured ET rates
or estimates from temperature

Inflow
SWMM runoff computations
for drainage area



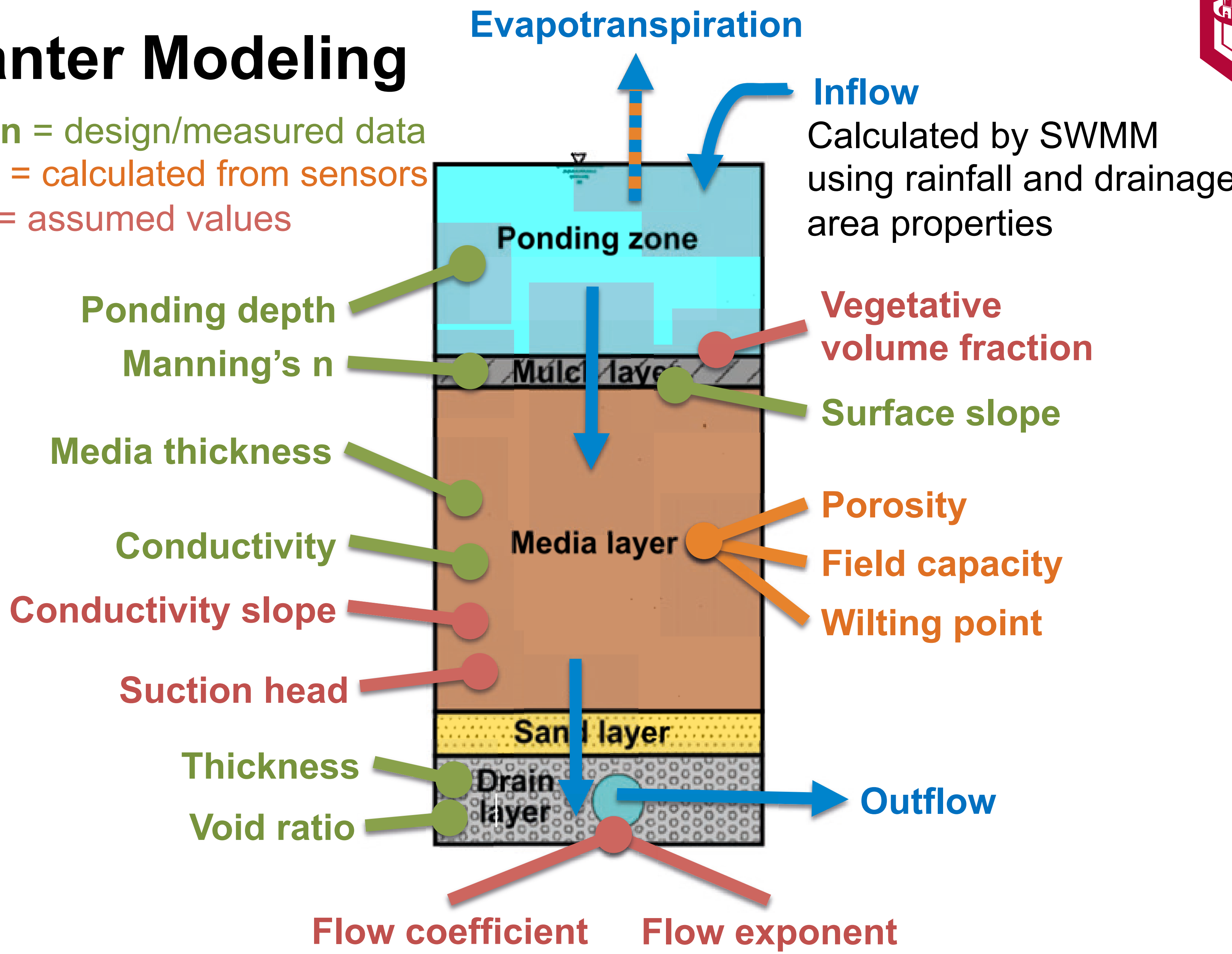
Infiltration from ponding zone to media layer
Green-Ampt infiltration model

Soil percolation
modeled using Darcy's law

Drainage
Empirical power law

Planter Modeling

Green = design/measured data
Gold = calculated from sensors
Red = assumed values

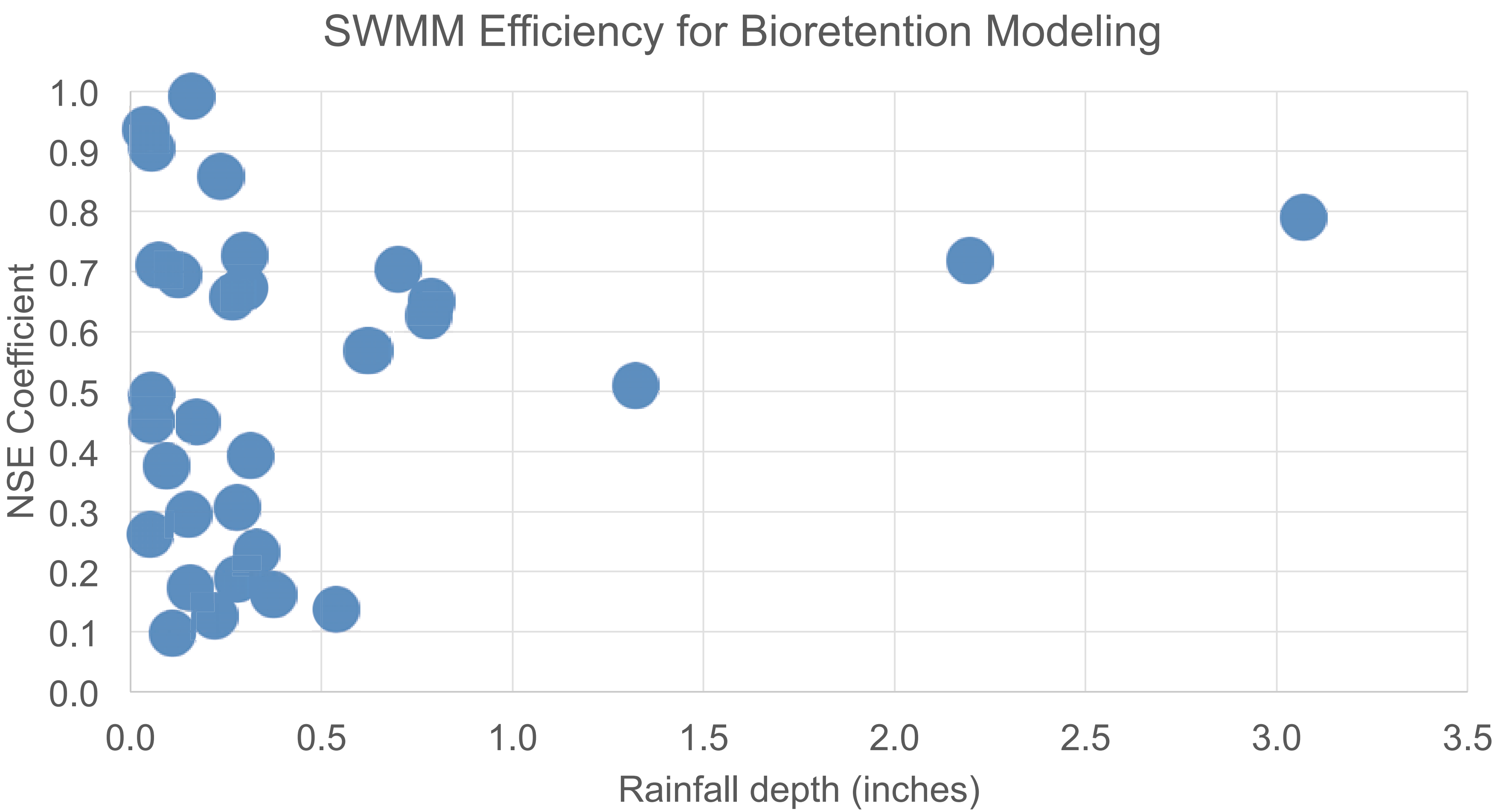


Uncalibrated Model Accuracy

- Continuous simulation
  - August 8, 2017 to March 14, 2018
  - 32 rain events (total P = 14.85 in)
- Model efficiency: Nash-Sutcliffe efficiency coefficient (NSE)
  - Ranges from $-\infty$ to 1
  - $\eta = 1$ → perfect match
- Continuous simulation NSE: **0.796**
- Individual storms NSE: **0.138** to **0.992**

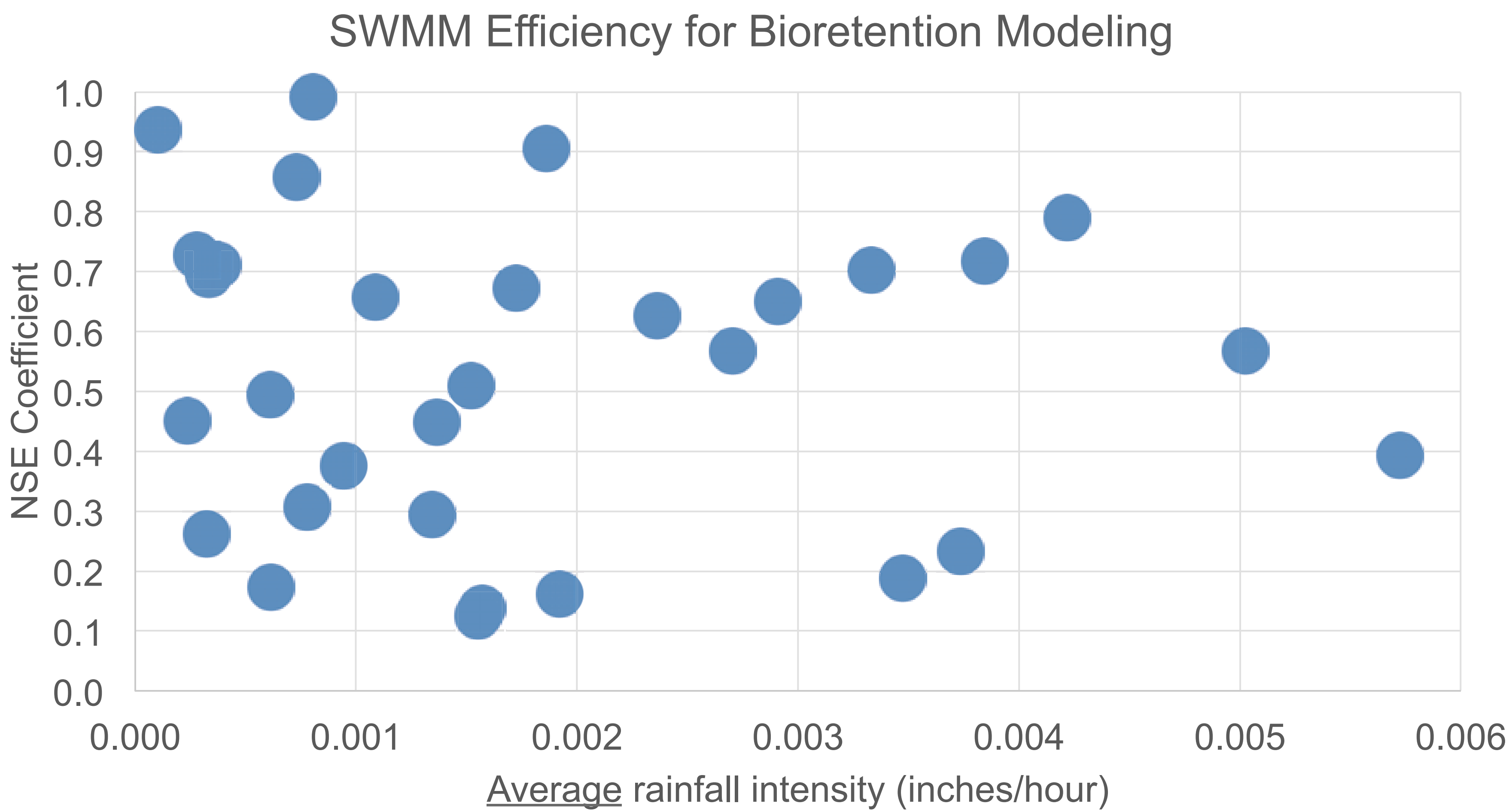
Uncalibrated Model Accuracy

Influence of rainfall depth



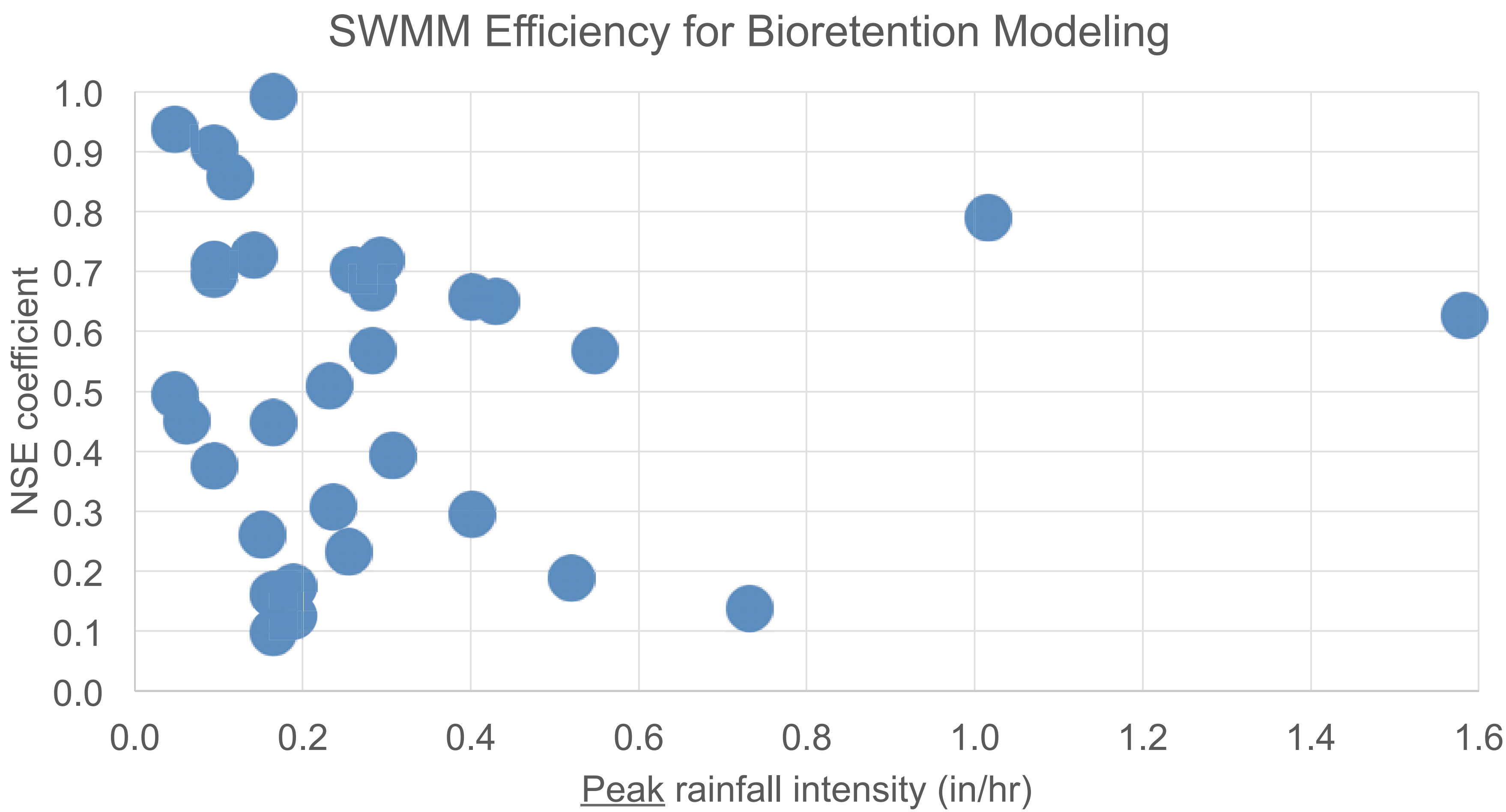
Uncalibrated Model Accuracy

Influence of average rainfall intensity

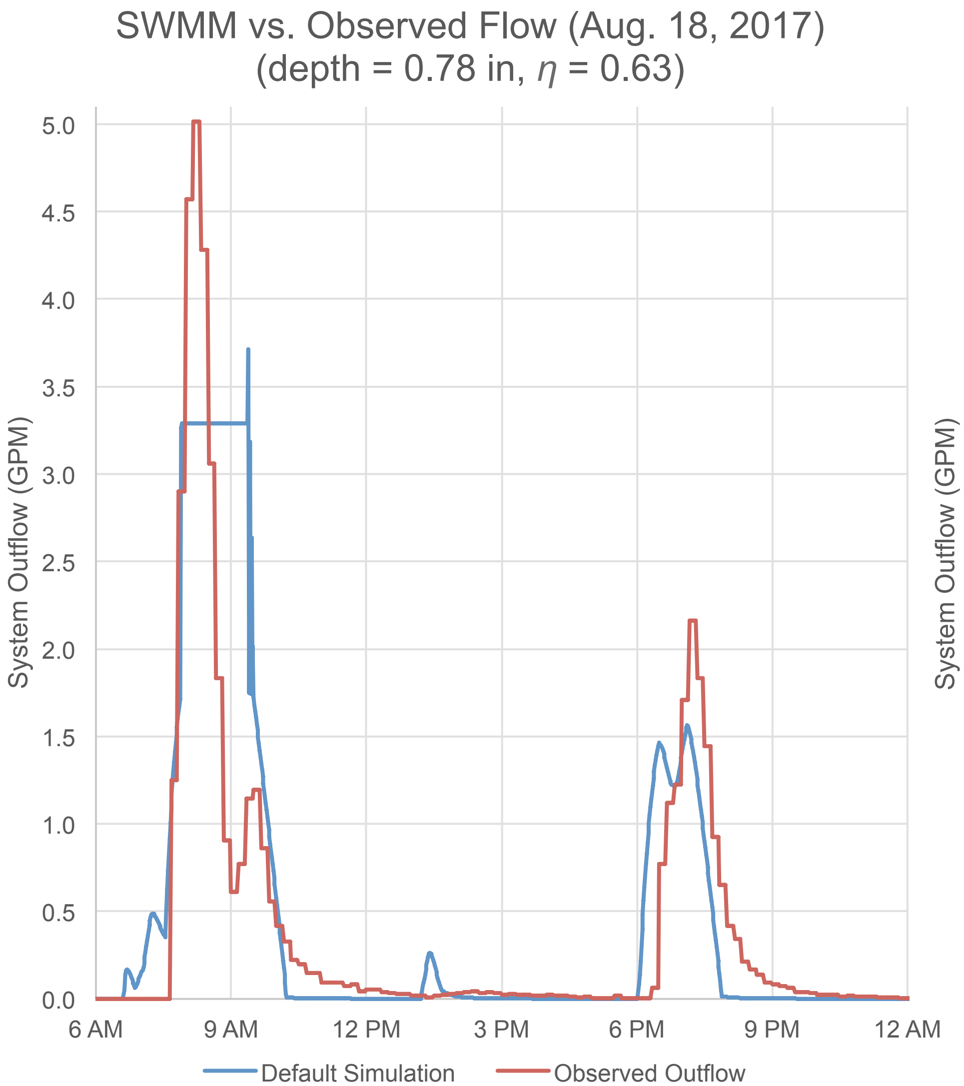


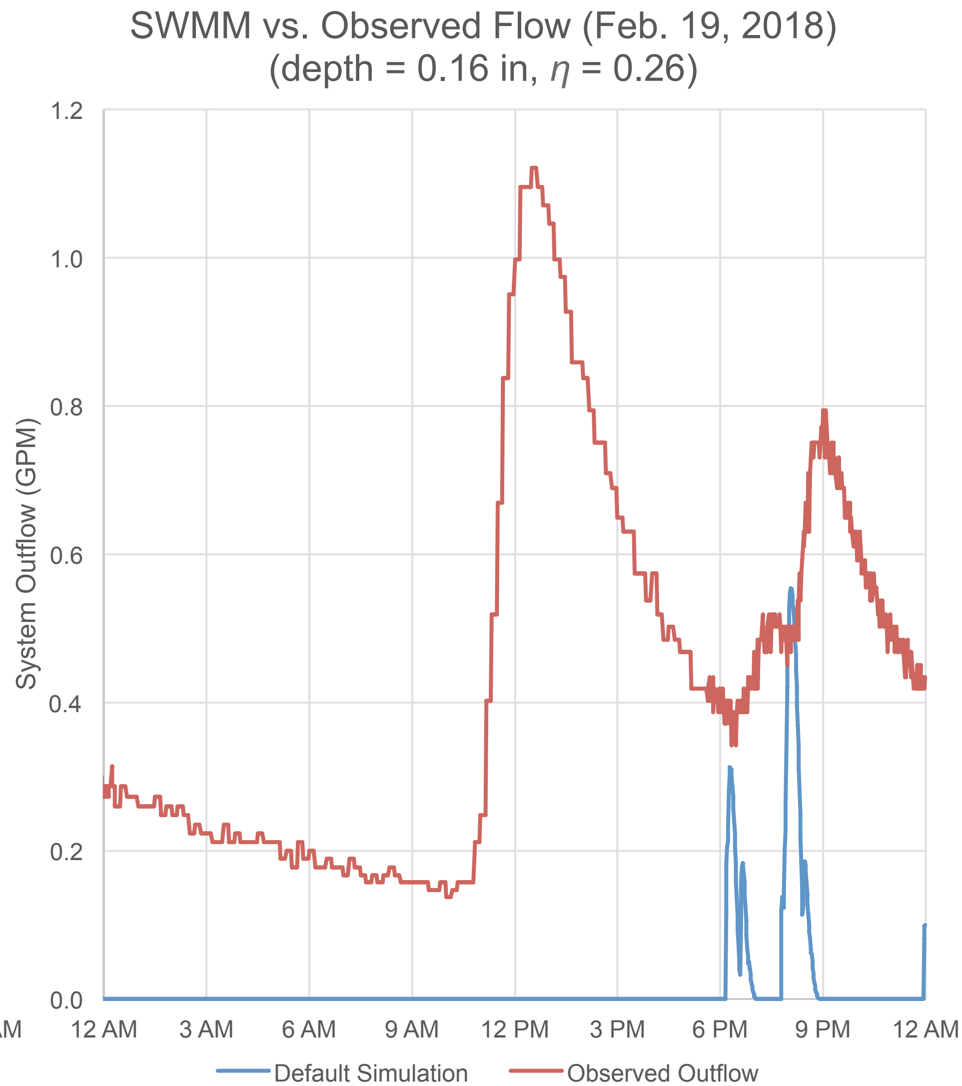
Uncalibrated Model Accuracy

Influence of <u>peak</u> rainfall intensity (5-minute peak)



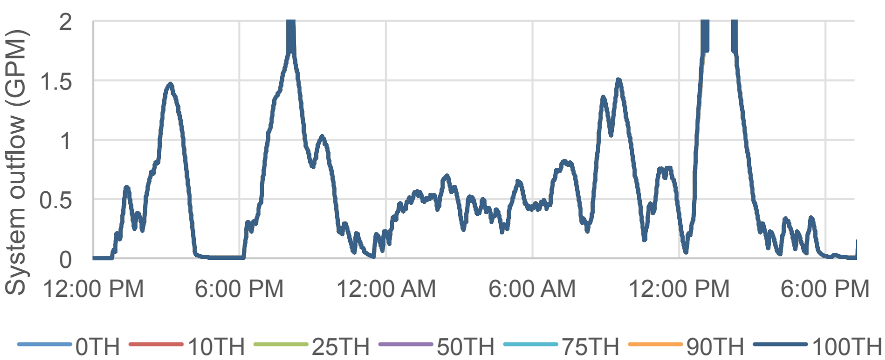
Uncalibrated Model Accuracy





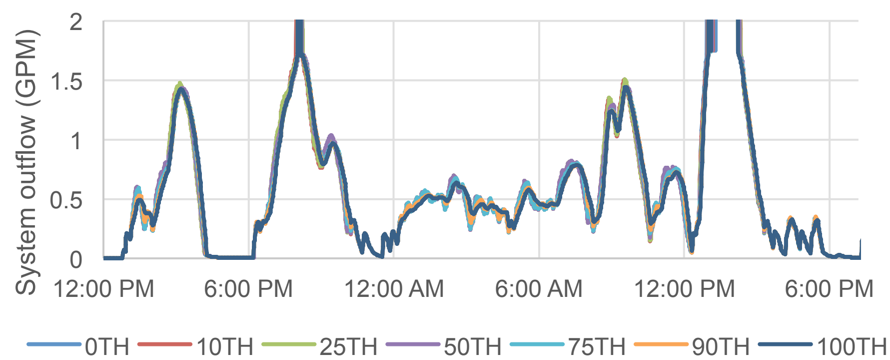
Sensitivity Analysis

Surface Roughness



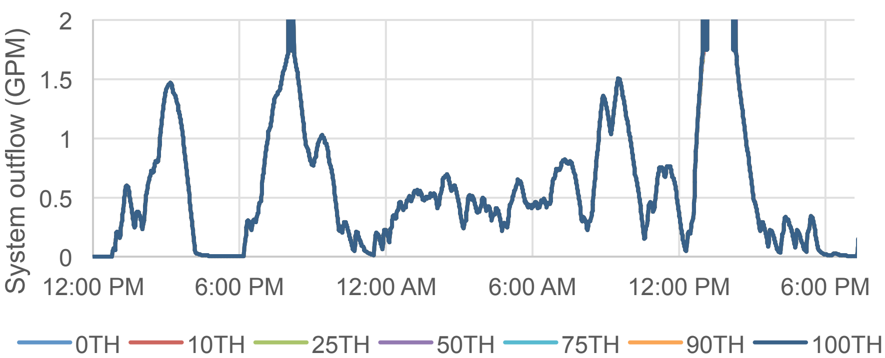
Surface Manning's n	Range	Std. Dv.	No sensitivity
	0.0018	0.0008	

Conductivity Slope



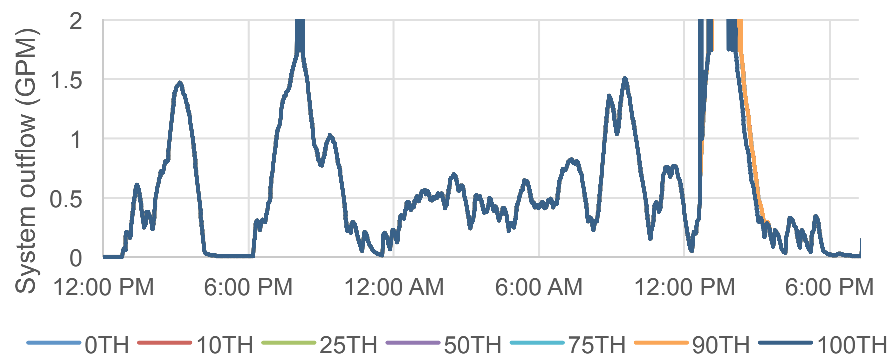
Media Cond'tvty Slope	Range	Std. Dv.	Minor sensitivity
	0.0085	0.0035	

Suction Head



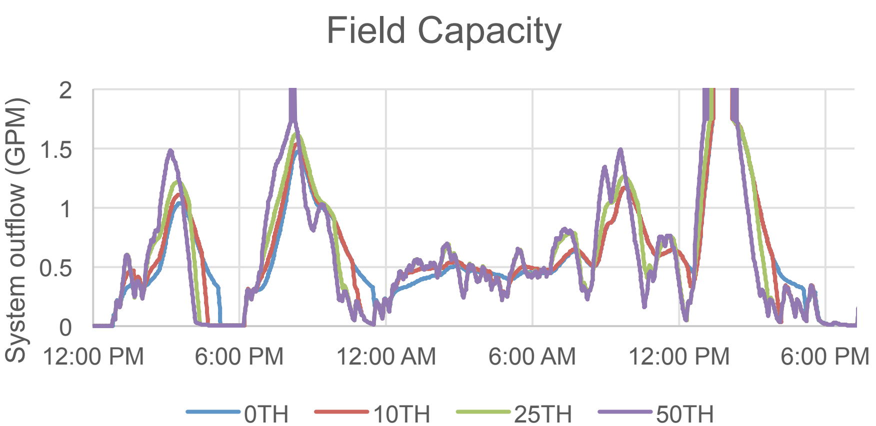
Media Suction Head	Range	Std. Dv.	No sensitivity
	0.0018	0.0008	

Vegetative Volume Fraction

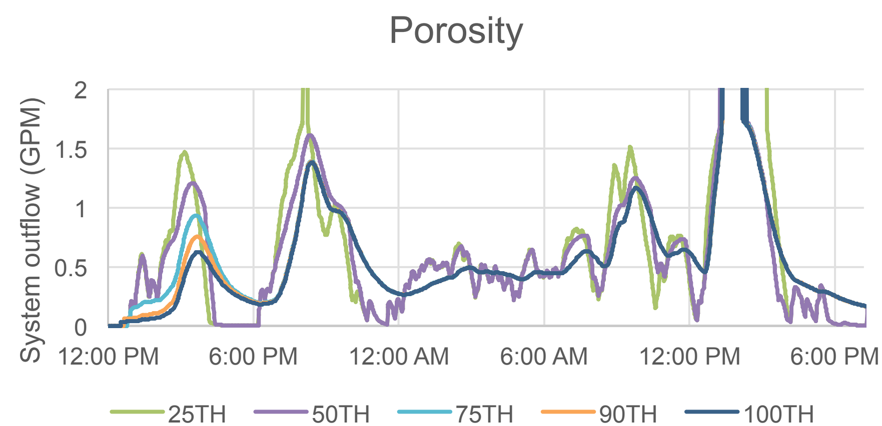


Vegetative Volume Fraction	Range	Std. Dv.	No sensitivity
	0.0078	0.0035	

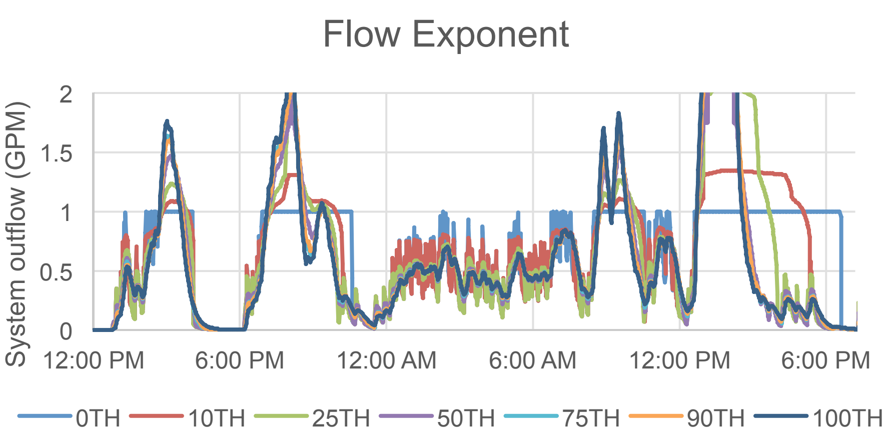
Sensitivity Analysis



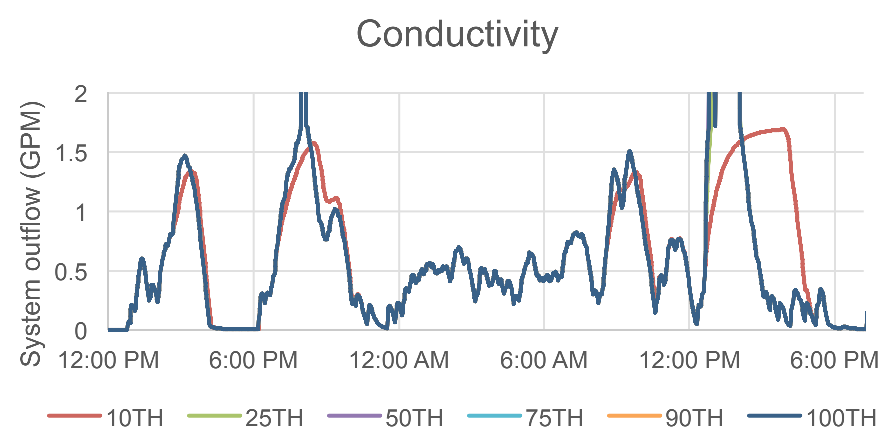
Media	Range	Std. Dv.	High
Field Capacity	0.0579	0.0279	sensitivity



Media	Range	Std. Dv.	High
Porosity	0.0686	0.0290	sensitivity



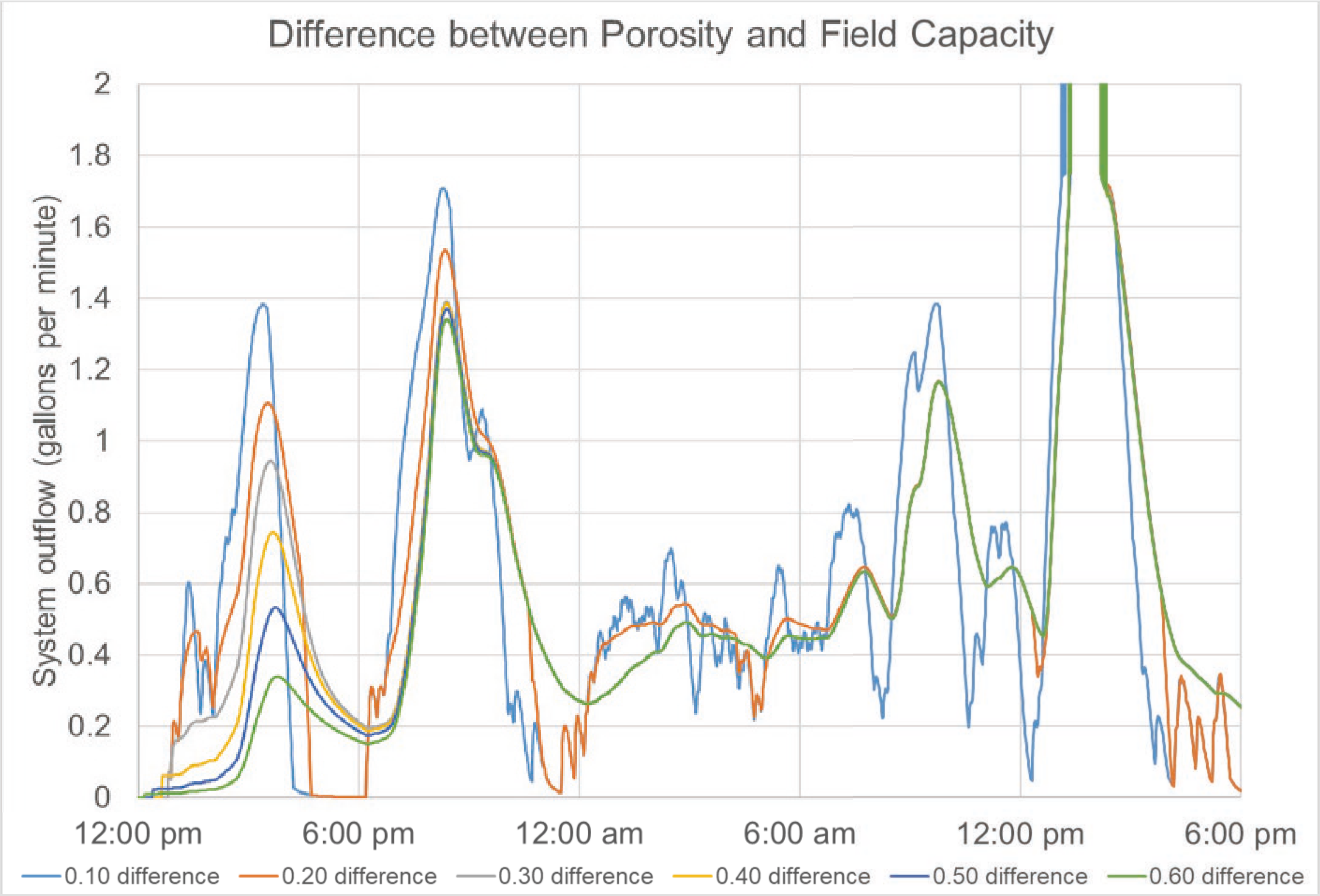
Drain	Range	Std. Dv.	High
Flow Exponent	0.0387	0.0153	sensitivity



Media	Range	Std. Dv.	Moderate
Conductivity	0.0526	0.0197	sensitivity

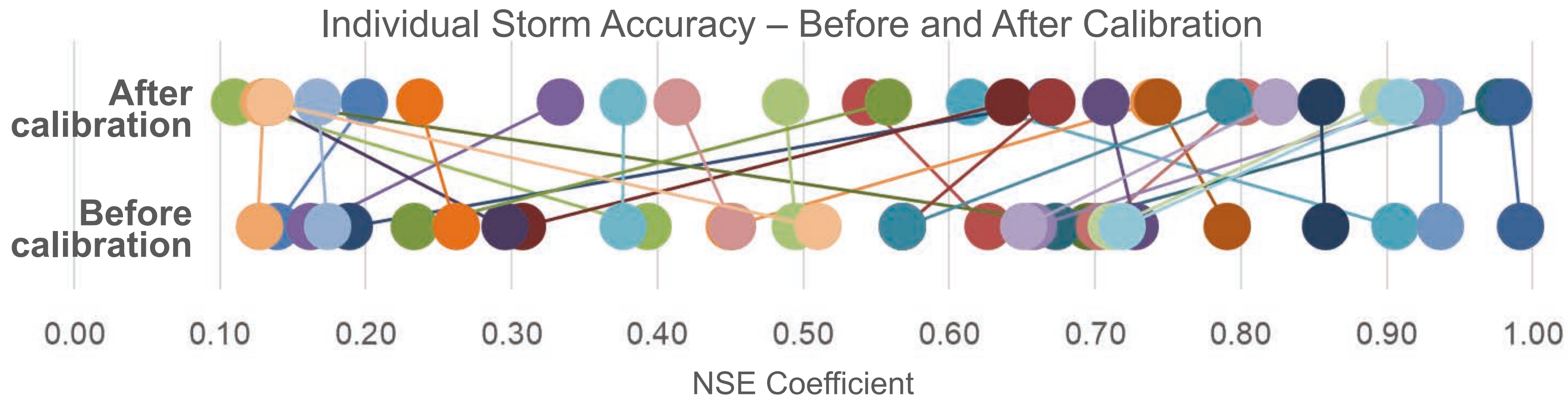
Sensitivity Analysis

Differences between parameter values also had an impact…



Model Calibration and Validation

- March 1, 2018 storm selected for calibration
  - NSE improved from **0.72** to **0.91** (27% improvement)
  - Peak flow error improved **12%**
- Overall continuous simulation improved by 5% to **0.84**.
  - Accuracy for individual storms generally improved, though some got worse



Model Calibration and Validation

- Calibration involved further lowering media porosity and field capacity

Parameter	Sensitivity Test Range	Measured Value	Calibrated Value	Change
Media porosity	0.34 to 0.70	0.290	**0.110**	↓ 0.180 (62%)
Media field capacity	0.10 to 0.40	0.244	**0.100**	↓ 0.144 (59%)
Conductivity (in/hr)	0.03 to 11.78	6.600	**8.000**	↑ 1.400 (21%)
Drain flow exponent	0.00 to 1.00	0.500	**0.660**	↑ 0.160 (32%)
Storage void ratio	0.25 to 1.00	0.750	**0.660**	↓ 0.090 (12%)
Wilting point	0.01 to 0.16	0.105	**0.001**	↓ 0.104 (99%)
Storage depth (in)	N/A	6.000	**5.000**	↓ 1.000 (17%)
Drain offset height (in)	N/A	3.000	**3.500**	↑ 0.500 (17%)

Conclusion

- SWMM is a useful tool for continuous simulations over an extended period of time and a range of conditions
- For individual storms, additional evaluation or calibration may be required for reliable results

- Accuracy of simulation highly dependent on measurements for porosity, field capacity, and other media properties

- Seasonal impacts of leaf clogging, snowfall, and snow melt not well accounted for in SWMM

Questions?