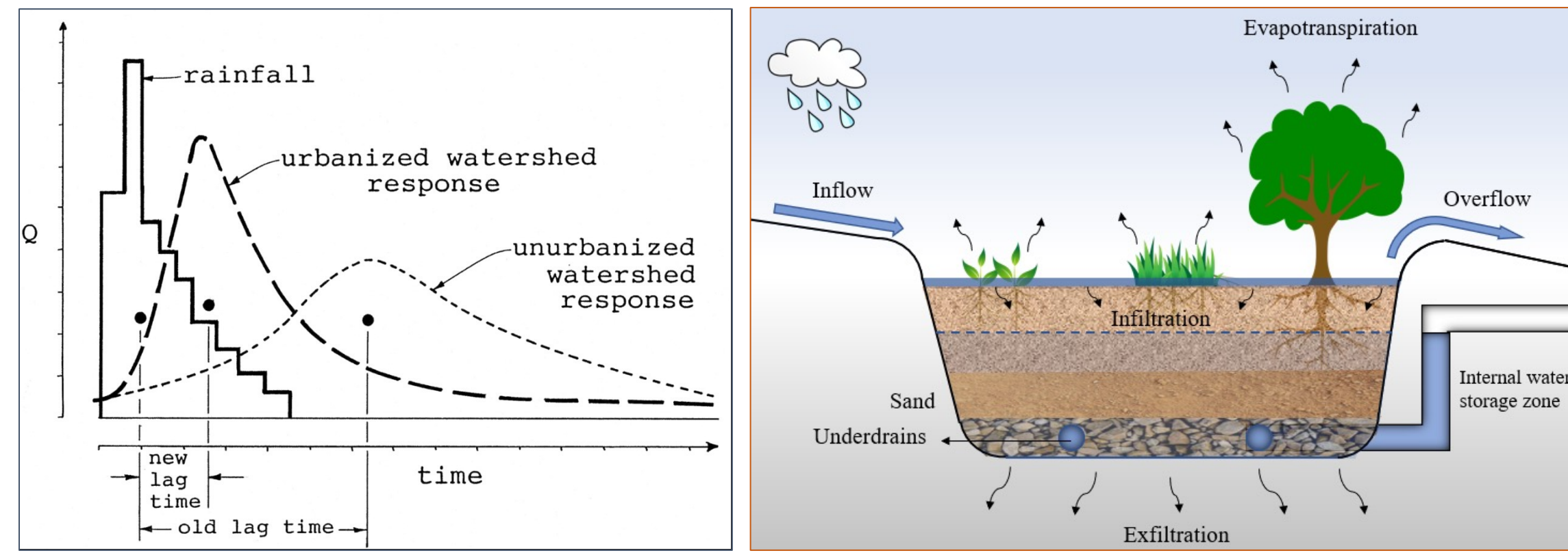# Enhancing Site Scale Bioretention Modeling to Investigate Watershed Scale Restoration

Ghada Diab[1], Jon Hathaway[1], Whitney Lisenbee[2], Robert Brown[3] and William Hunt[4]

[1]University of Tennessee, [2]Pennsylvania State University, [3]Goodwyn Mills Cawood, LLC, [4] North Carolina State University
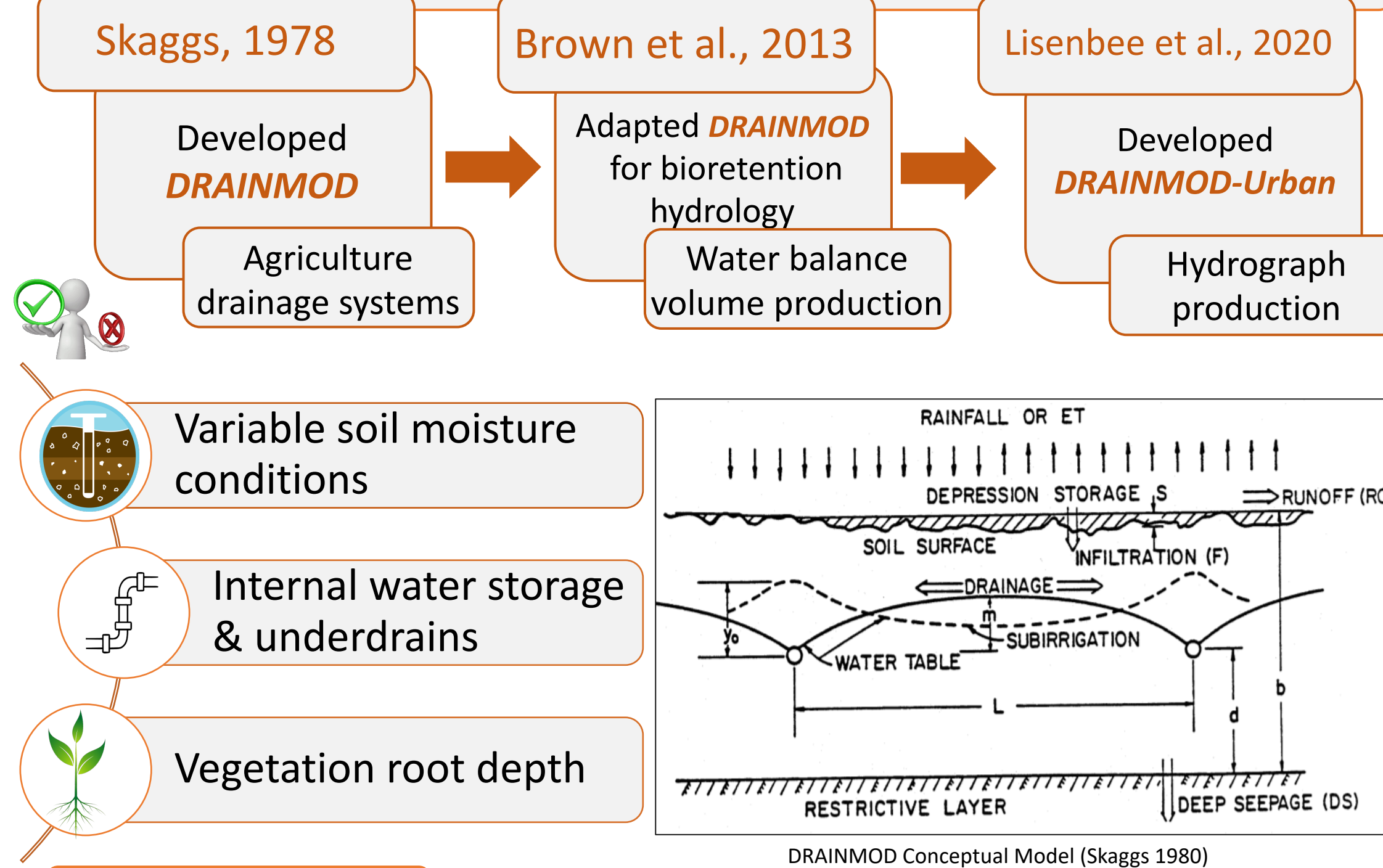
Introduction

- Bioretention is a widely used green Infrastructure that replicates natural hydrology in urban environment.
- Bioretention promotes infiltration and reduces runoff volume and peak flow of stormwater.

DRAINMOD-Urban

Process-based, field scale and long-term model

Skaggs, 1978 → Brown et al., 2013 → Lisenbee et al., 2020

- Skaggs, 1978: Developed *DRAINMOD* — Agriculture drainage systems
- Brown et al., 2013: Adapted *DRAINMOD* for bioretention hydrology — Water balance volume production
- Lisenbee et al., 2020: Developed *DRAINMOD-Urban* — Hydrograph production

- Variable soil moisture conditions
- Internal water storage & underdrains
- Vegetation root depth


DRAINMOD Conceptual Model (Skaggs 1980)

Objectives

1) Assess the model ability to simulate bioretention drainage over a diversity of sites.
2) Verify overflow prediction using a large monitoring dataset with more overflow events.

Methods

Study Area

📍 Nashville, NC, USA

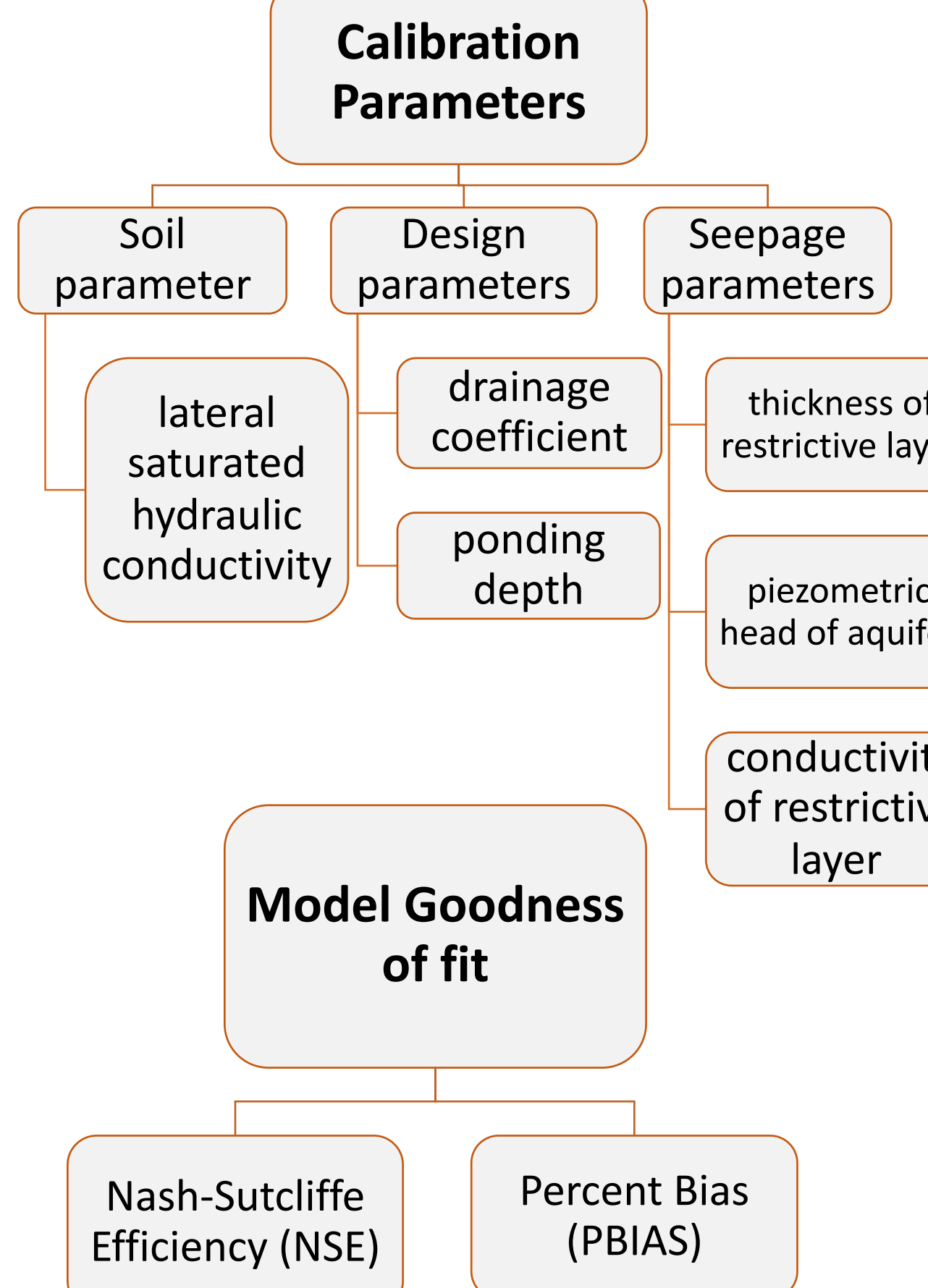| Site	0.6-m media depth		0.9-m media depth	
	Pre-repair	Post-repair	Pre-repair	Post-repair
Monitoring period	1 year	1 year	1 year	1 year
Catchment Imperviousness (%)	83	83	97	97
Catchment Area (ha)	0.68	0.68	0.43	0.43
Bioretention Area (m²)	290	322	206	226
Ponding depth (cm)	13	20	15	27
Fill media depth (m)	0.6	0.6	0.9	0.9
Design event (mm)	25	25	25	25
Fill media composition (%)	86-89% sand, 8-10% silt, 3-4% clay			
Site soil type	Sandy loam - loamy sand			
Drainage configuration	underdrain			

Brown and Hunt (2012)
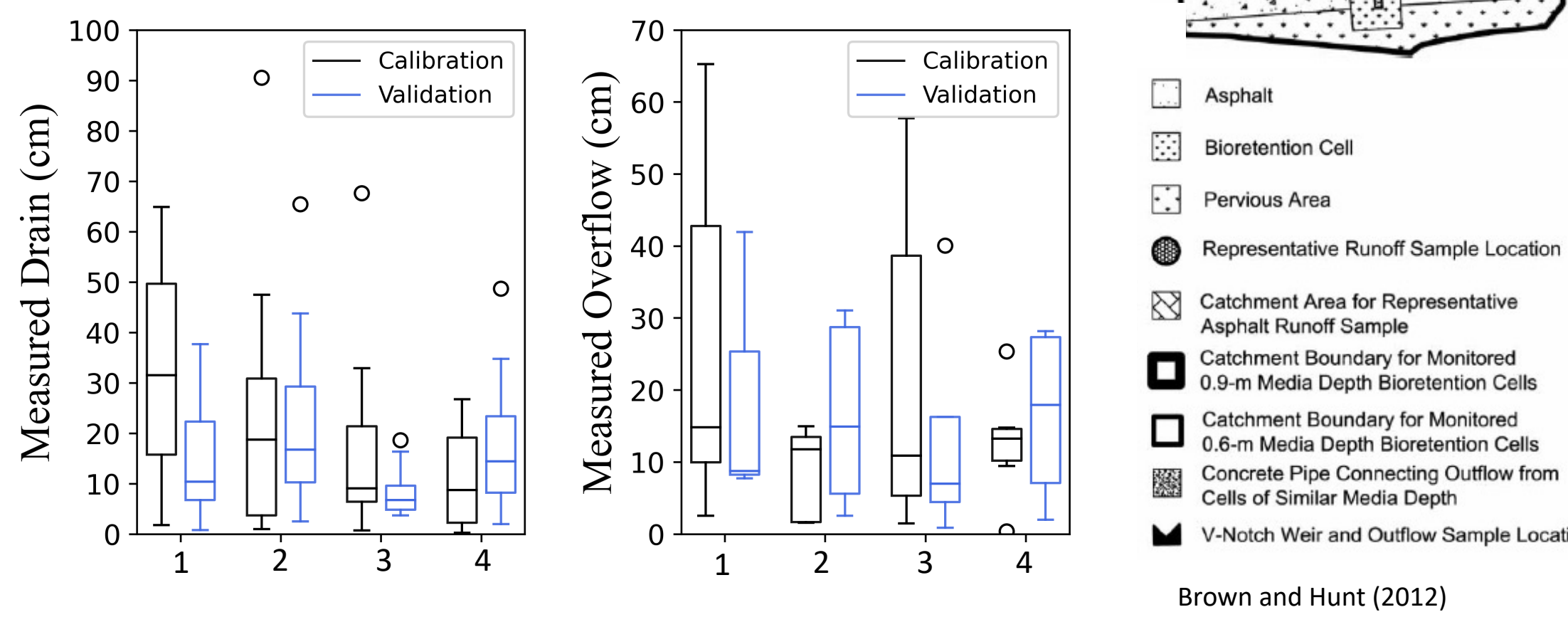
Prepare input files for DRAINMOD-Urban

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Split the data into calibration and validation period

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Calibrate the model using the most sensitive parameters

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Validate the model output using goodness of fit

Calibration Parameters

- Soil parameter
  - lateral saturated hydraulic conductivity
- Design parameters
  - drainage coefficient
  - ponding depth
- Seepage parameters
  - thickness of restrictive layer
  - piezometric head of aquifer
  - conductivity of restrictive layer

Model Goodness of fit

- Nash-Sutcliffe Efficiency (NSE)
- Percent Bias (PBIAS)

Results

Evaluation

NSE ≥ 0.40 → Acceptable
NSE ≥ 0.60 → Good
NSE ≥ 0.75 → Excellent
PBIAS ≤ 25% → Acceptable

Model Output		Hydrographs	
		NSE	PBIAS (%)
Drainage	Calibration	0.14~0.60	2.6~25.1
	Validation	0.19~0.60	5.5~25.4
Overflow	Calibration	0.49~0.89	6.0~38.8
	Validation	0.49~0.81	18.2~56.4

Hydrographs

Volumes

Peak Flow

- Calibration
- Validation
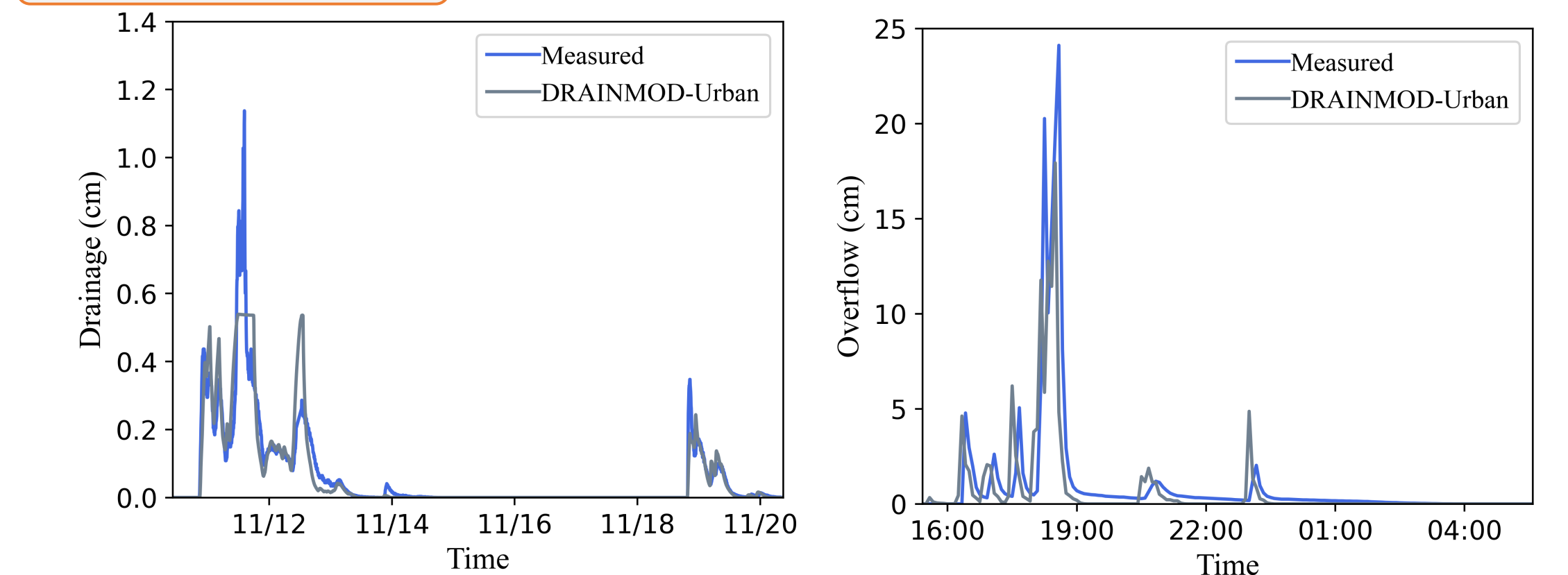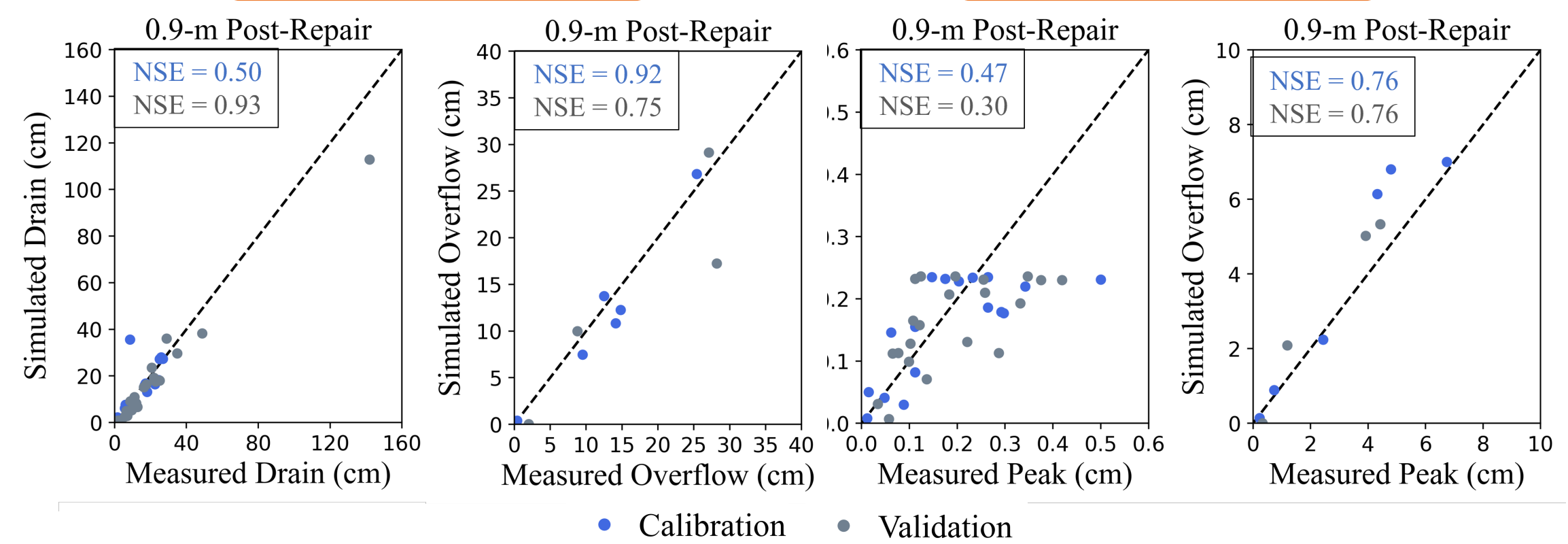
Conclusion

- DRAINMOD-Urban showed strong performance for modeling bioretention outflow hydrographs and volumes, accurately matching measured data.
- DRAINMOD-Urban is well-suited for bioretention application for different sites and varying conditions.

References

[1] Brown, R. A., Skaggs, R. W., & Hunt, W. F. (2013). Calibration and validation of DRAINMOD to model bioretention hydrology. Journal of Hydrology, 486, 430–442.
[2] Lisenbee, W., Hathaway, J., Negm, L., Youssef, M., & Winston, R. (2020). Enhanced bioretention cell modeling with DRAINMOD-Urban: Moving from water balances to hydrograph production. Journal of Hydrology, 582, 124491