NC STATE UNIVERSITY

Ocean Protect Seminar – April 28, 2022

Designing Bioretention: Mid-Atlantic USA Style

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NC State University

https://stormwater.bae.ncsu.edu/

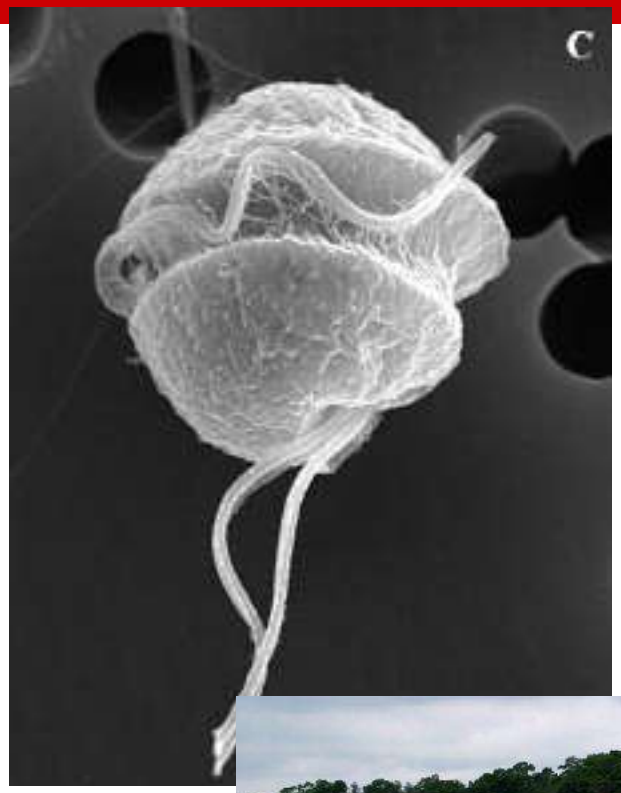
Bio&Ag ENGINEERING

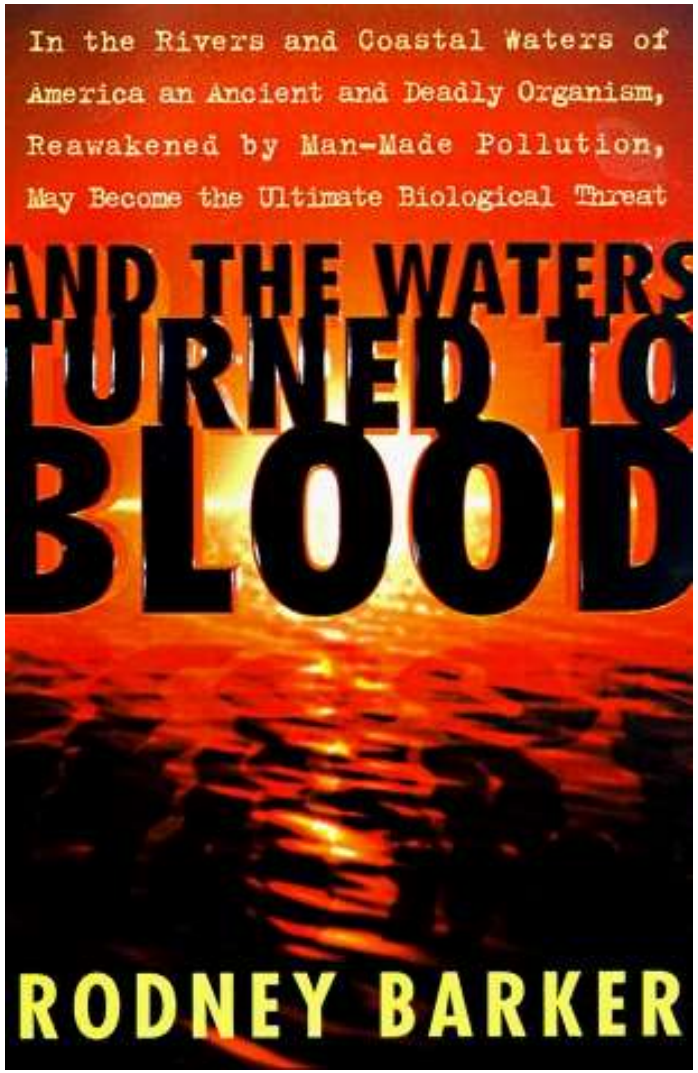
Nice to be “back” in Oz!

NC: Neuse Estuary, 1990's

https://stormwater.bae.ncsu.edu/

Major Public Outcry





Neuse (NC) Stormwater Rules

- Buffer rule enacted July 1997
- Stormwater rules enacted August 1999
  - New development – N loading @ 3.6 lbs N/acre, no peak flow increase from 1 yr storm
  - Illegal discharge i.d. and removal
  - Retrofit i.d.
  - Public education
  - Reporting requirements
  - Trading (offset payments) allowed

This is a short(?), audience participatory presentation

Project Needs/ Goals

Design Elements

Bill's Guesses: Goals

- Qp mitigation
- LID Hydrology/ Runoff Vol reduction
- TSS removal
- TN removal
- TP removal
- Thermal control
- Pathogen sequestration
- Price Tag
- Be Pretty
- Comply with Landscape Ordinances
- Carbon sequestration
- Trap Metals
- Function in Perpetuity
  - (Maintenance)
- Be loved & accepted by all/ World Peace

Further Hunt Guesses: Design Elements

- Surface Area
- Bowl Storage
- Outlet Structure
- Vegetation Type & Coverage
- Media Depth
- Media Type
- Underdrainage need & configuration
- Pre-treatment
- Underlying soil & SHWT

Now, Let's tackle these.

Brett Davis-USA TODAY Sports

https://stormwater.bae.ncsu.edu/

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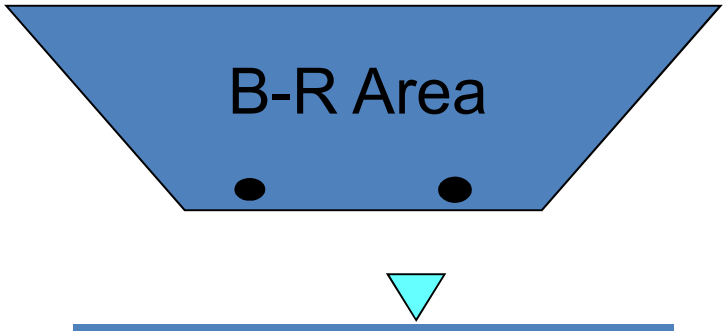
Minimum Design Criteria for Bioretention

(1) SEPARATION FROM THE SHWT

- The bottom of bioretention cells – Min. of 0.6m above the SHWT.
- However, the separation can be relaxed to 0.3m when the applicant can prove that the water table will subside to its pre-storm elevation in five days or less.



How Important Is This for Pollutant Reduction? Case Study

https://stormwater.bae.ncsu.edu/

Sign of the “BRC Apocalypse”

BRC Intersected the Water Table

Percent Removal" Provided by SCM Treatment Train of Stormwater Pollutants

	TN	TP	TSS
Storm Events Only	49%	51%	89%
Base Flow Included	**-64%**	30%	87%

https://stormwater.bae.ncsu.edu/

Brown et al. JEE. 2012. June issue.

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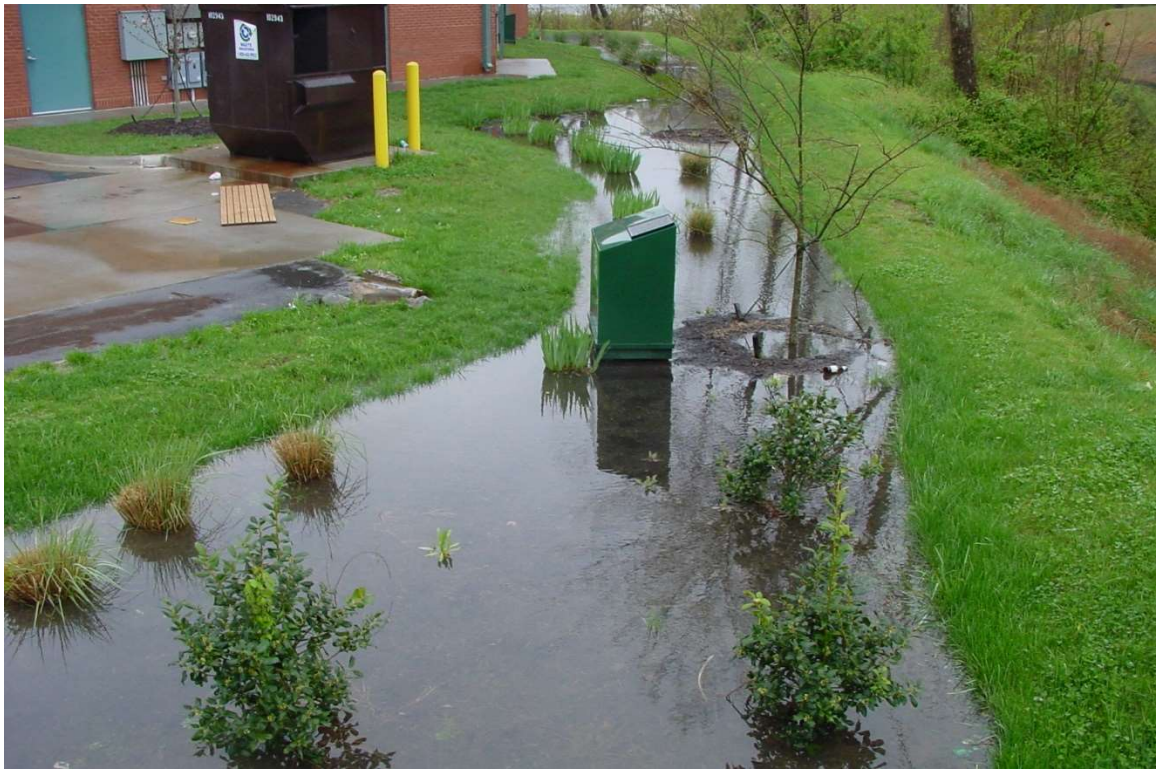
(2) MAXIMUM PONDING DEPTH FOR DESIGN VOLUME

- The maximum ponding depth for the design volume shall be 0.3m above the planting surface.
- But…

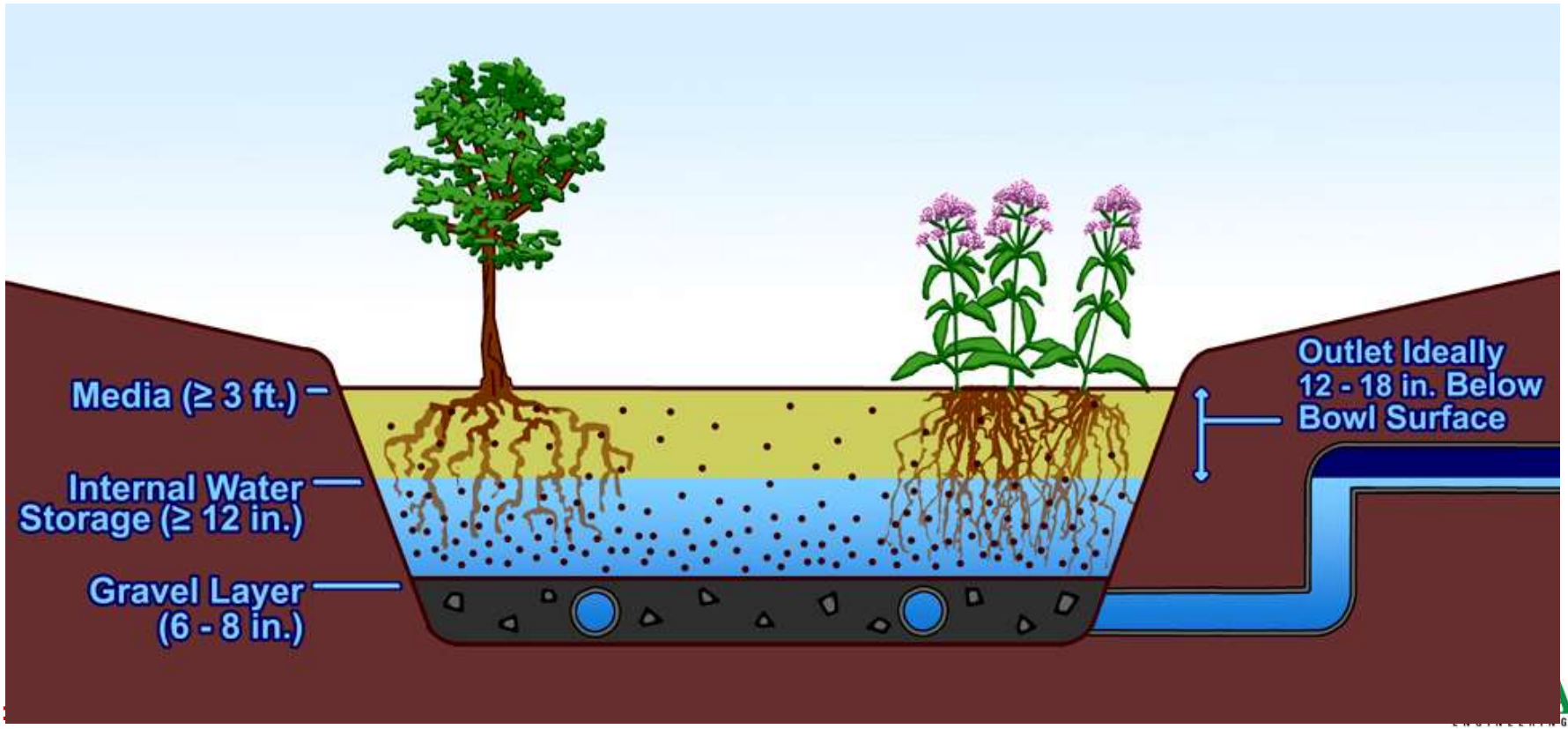


(3) PEAK ATTENUATION DEPTH

- Peak attenuation volume stored - up to 0.6m above the planting surface.
- The peak attenuation outlet shall be a maximum of 0.45m above the planting surface.

(10) UNDERDRAIN

- **Internal water storage underdrain required**
  - Unless Underlying Soil has >50 mm/hr infiltration rate
  - The internal water storage zone shall extend to a minimum of 0.45m below the planting surface.



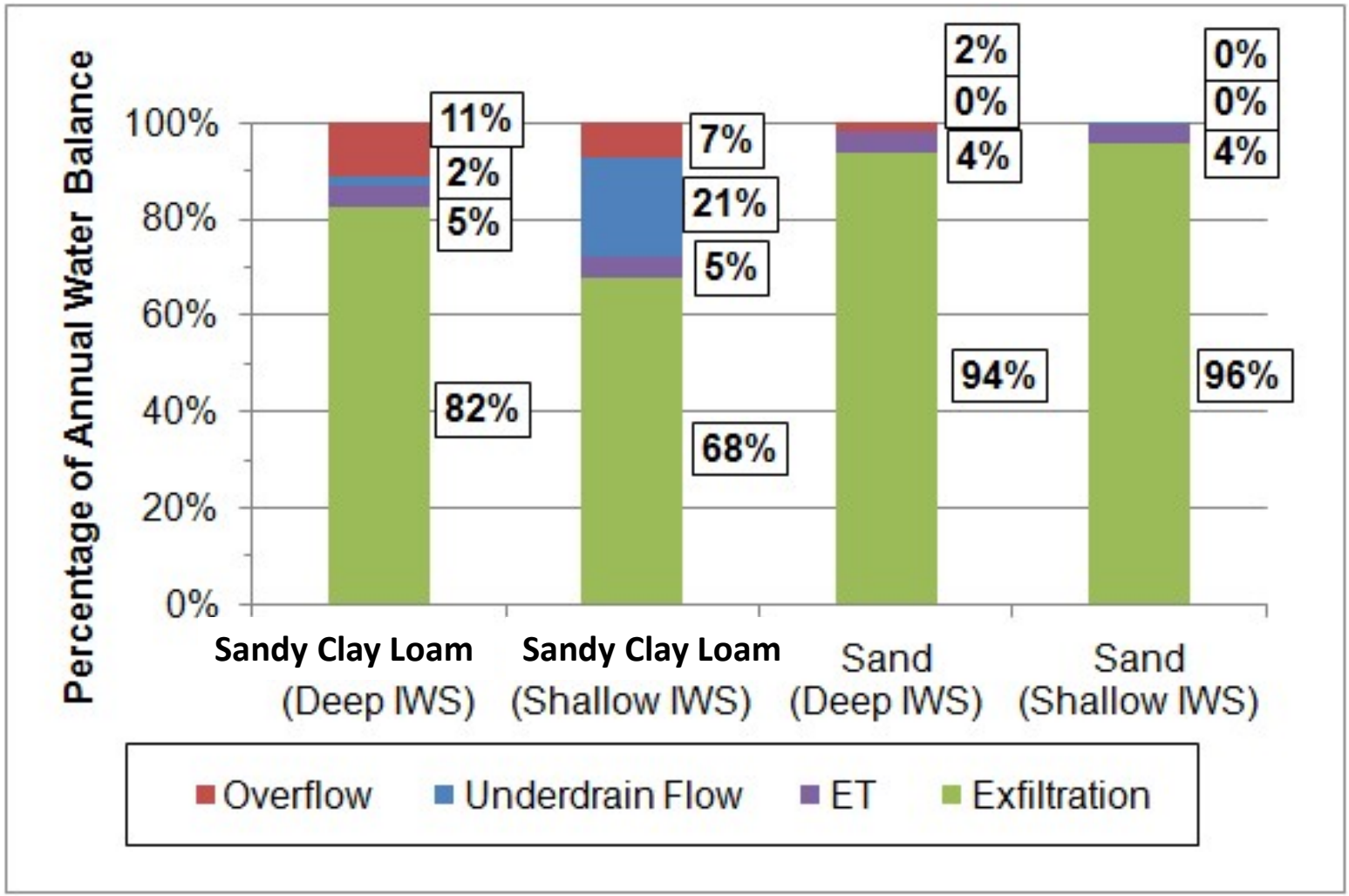
Looking down into the Catch Basin (upturned elbow)

Internal Water Storage (embedded in media)

Employing an IWS in Oz. Called: "Saturated Zone"

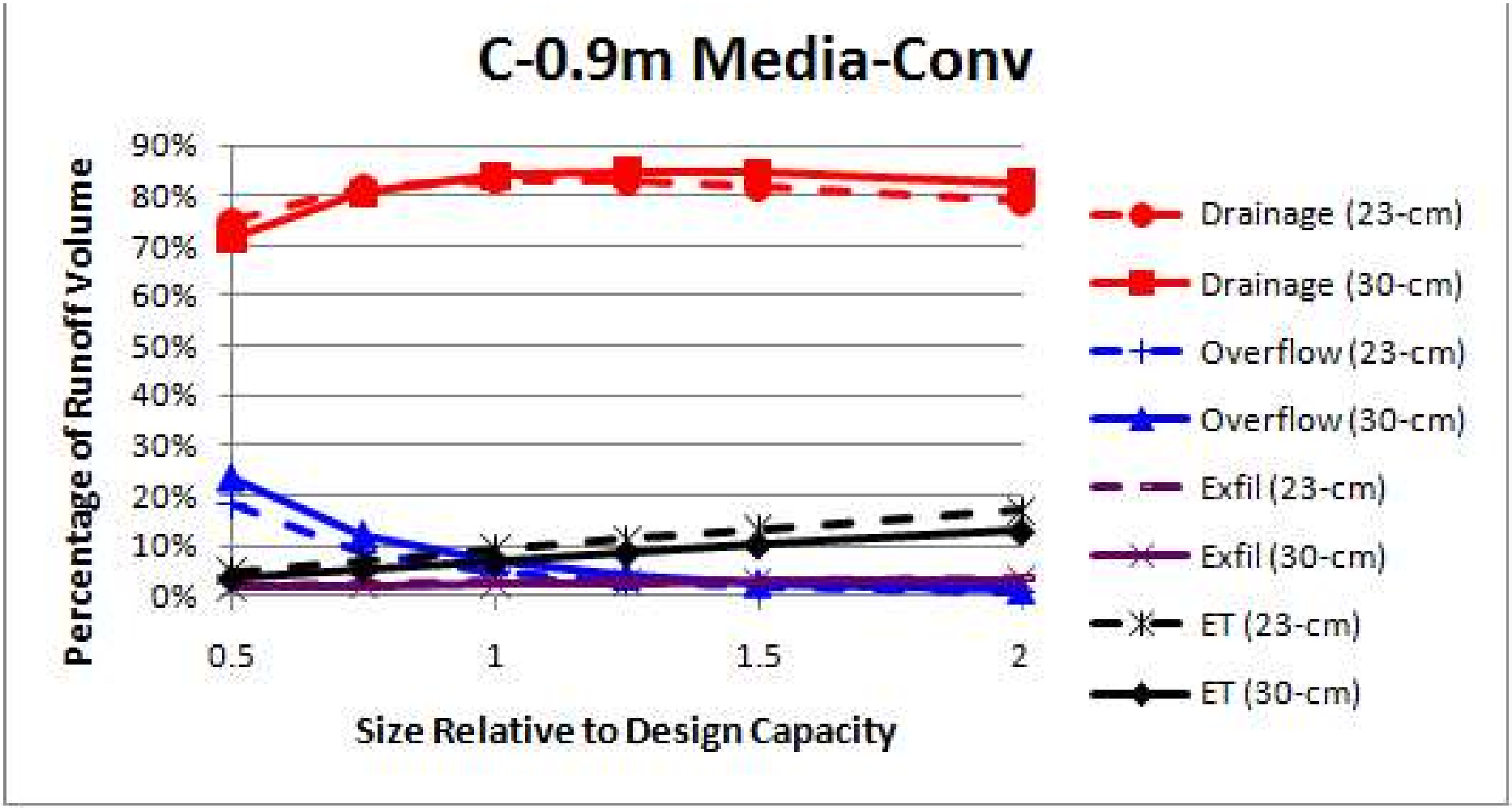
For Example…

Water Balance



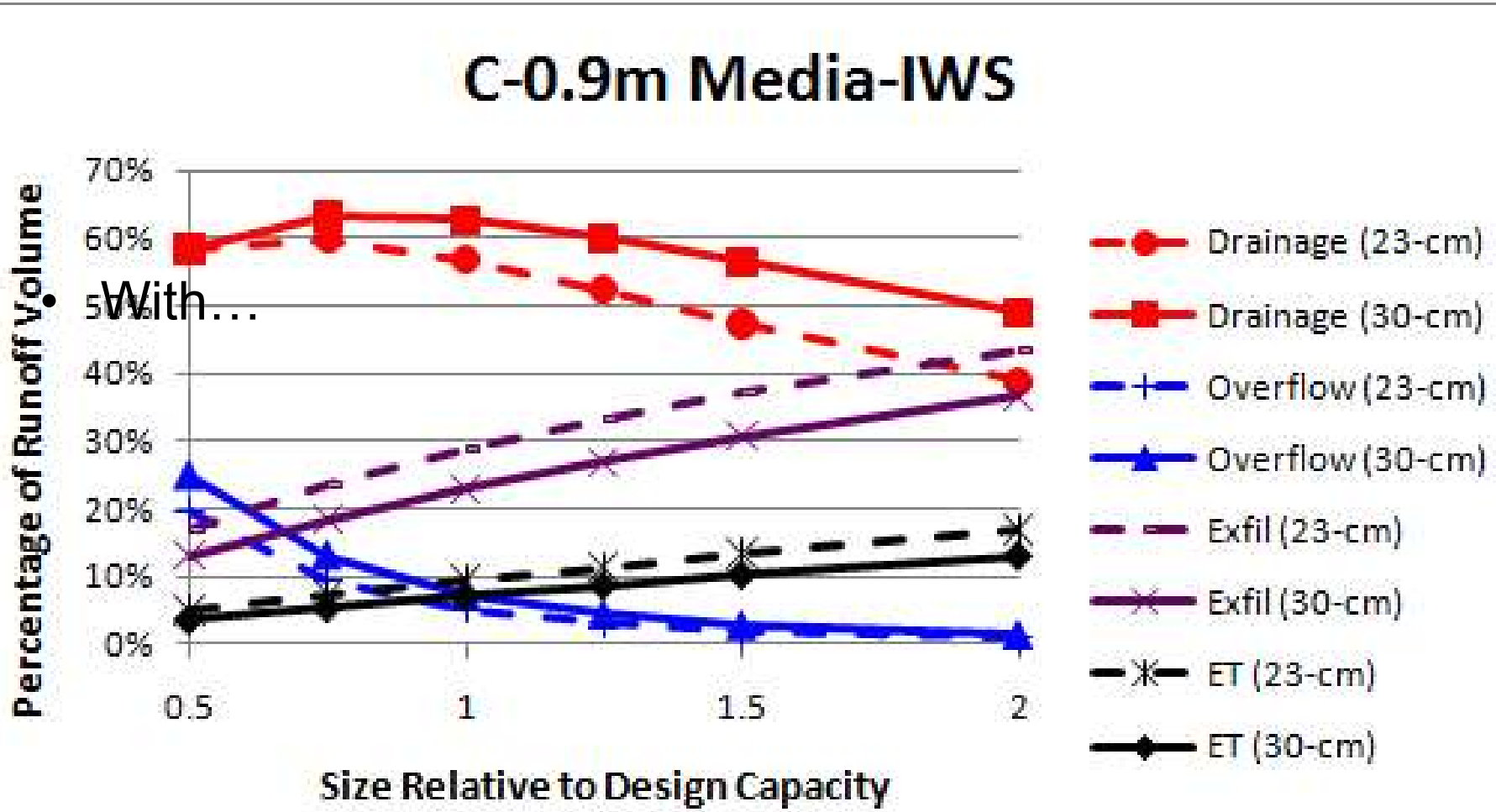
Modelling Impact of IWS

- …Without

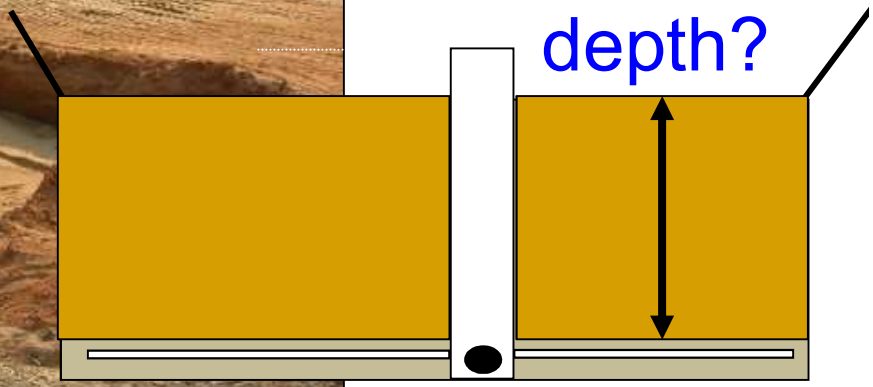


Modelling Impact of IWS (With)

- With…



(4) Media Depth



What is this depth?

(4) MEDIA DEPTH

- All grassed cells with no internal water storage: **24 inches (0.6m)**

(4) Media Depth

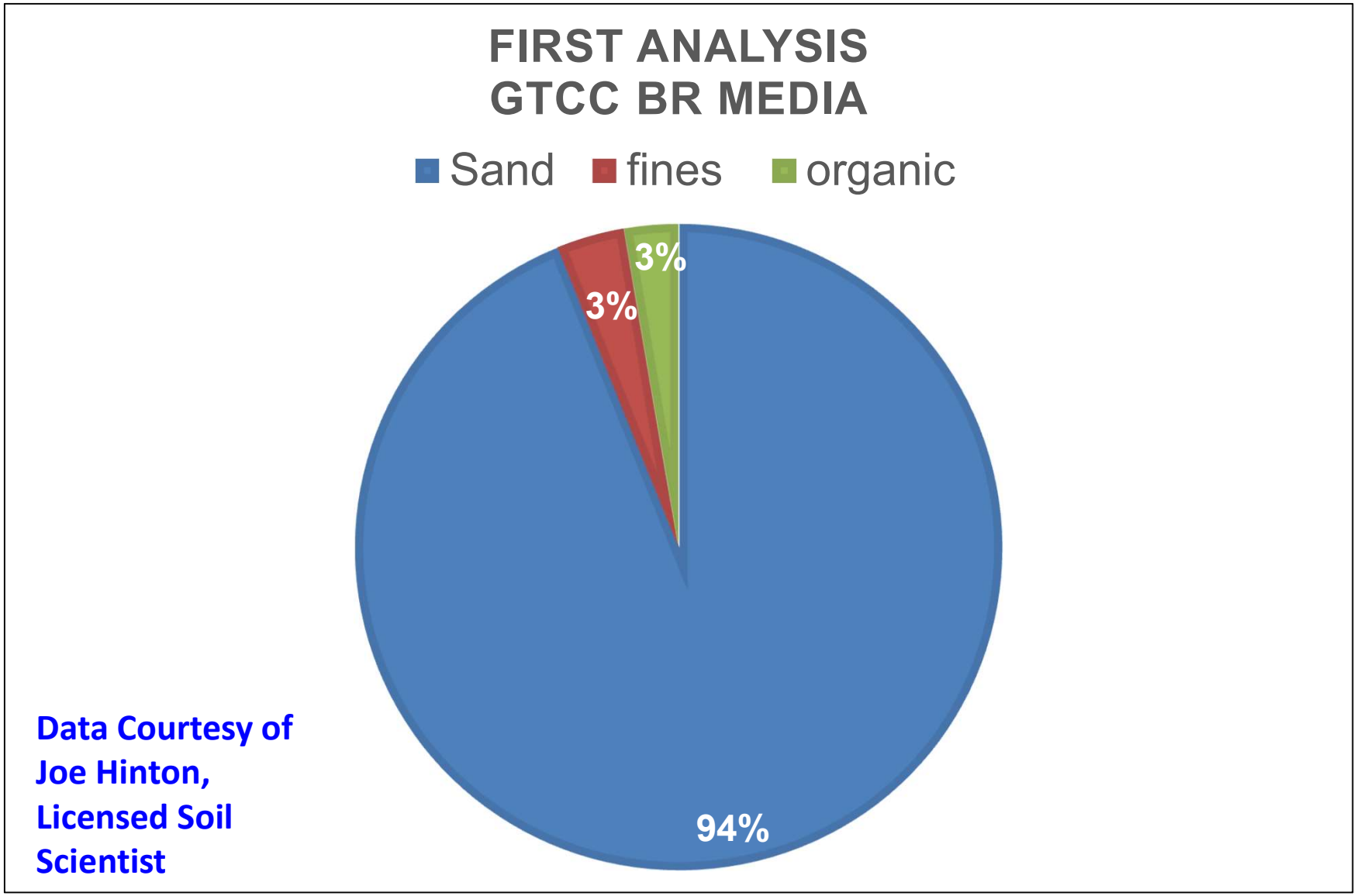
- Grass Cells WITH Internal Water Storage
  - Accounts for most of them
- **0.75m**

(4) MEDIA DEPTH

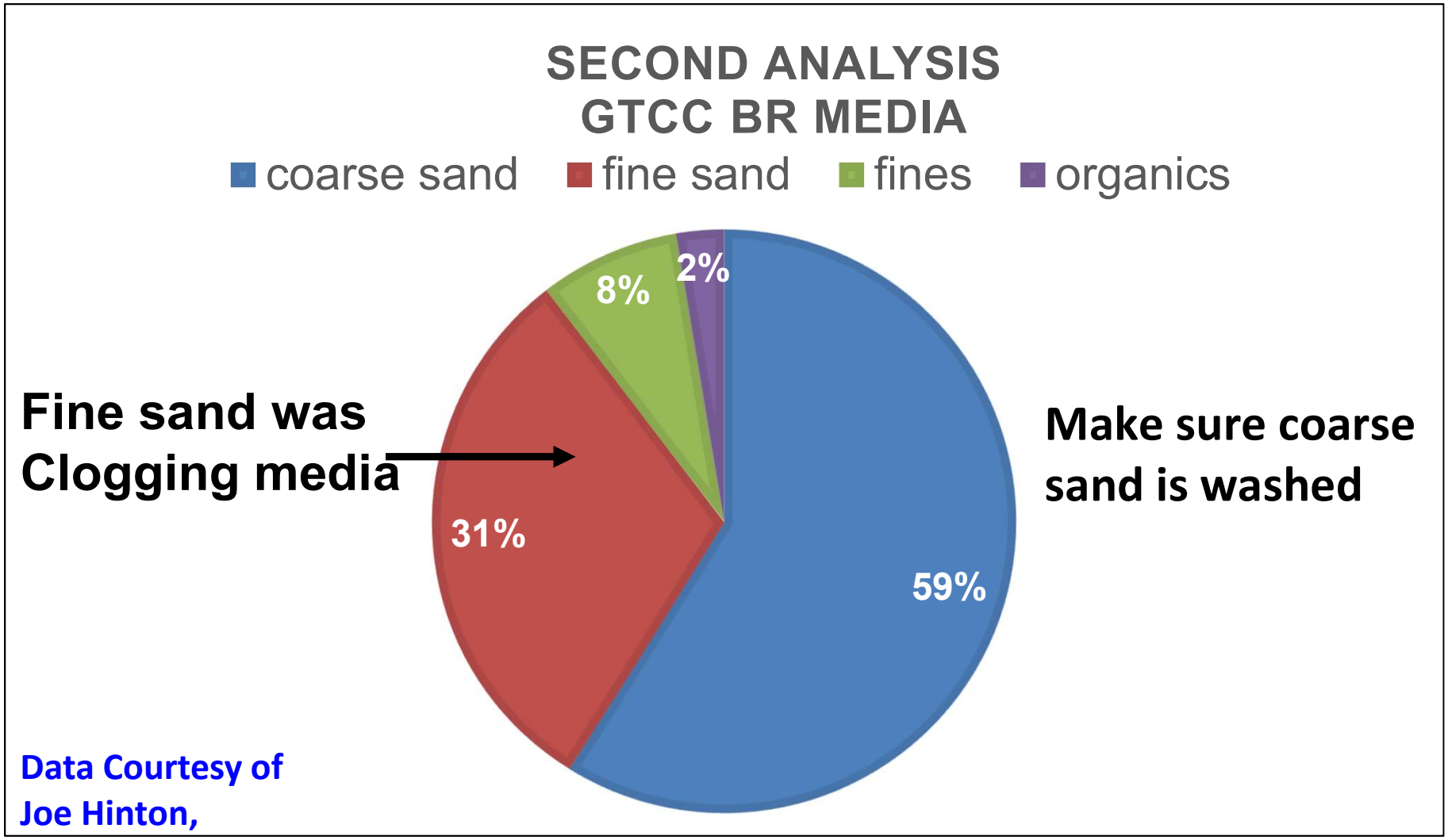
- All tree/shrub cells: **0.9m**. (IWS or otherwise)

(5) MEDIA MIX

- Homogeneous soil mix
- Approximate volumes of:
  - 75 to 85 percent **medium** to **coarse washed sand** (ASTM C33)
  - 8 to 12 percent fines (silt and clay)
  - 5 to 15 percent organic matter (such as pine bark fines).



Data Courtesy of Joe Hinton, Licensed Soil Scientist



Data Courtesy of Joe Hinton, Licensed Soil Scientist

(5) MEDIA MIX

- Homogeneous soil mix
- Approximate volumes of:
  - 75 to 85 percent medium to coarse washed sand (ASTM C33)
  - 8 to 12 percent fines (silt and clay)
  - 5 to 15 percent organic matter (such as pine bark fines).
- **If total nitrogen is the target pollutant, it is recommended to use 10 to 15 percent fines in the media mix.**

(6) MEDIA P-INDEX

- The phosphorus index (P-index) for the media shall not exceed 30 in NSW waters and shall not exceed 50 elsewhere.

Greensboro Battleground Ave

Chapel Hill Univ. Mall

Initial NCSU Research

- Relationship between P-Index (Soil Test P) and TP outflow load.

	Greensboro	Chapel Hill
TP	+240%	- 65%
P-Index	85-100	4-12

(Hunt 2003)

P-Index 50-100: High P-Index

0-25: Low

What was the Problem?

NCDA&CS Agronomic Division Phone: (919)733-2655 Web site: www.ncagr.gov/agronomi/ Report No: 06381

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-Al(1)	Mn-Al(2)	Zn-I	Zn-Al	Cu-I	S-I	SS-I	NO3-N	NH4-N	Na
		1.08	10.3	90.0	1.0	6.5	40	176	69.0	12.0	309	195	195	56	56	32					0.1

Field Information		Applied Lime			Recommendations												
Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year	Lime	N	P2O5	K2O	Mg	S	Cu	Zn	B	Mn	See Note
					1st Crop: Fes/OG/Tim,M		120-200	10-30	40-60	0	0	0	0	.0	0	12
					2nd Crop: Fes/OG/Tim,M		120-200	10-30	40-60	0	0	0	0	.0	0	12

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-Al(1)	Mn-Al(2)	Zn-I	Zn-Al	Cu-I	S-I	SS-I	NO3-N	NH4-N	Na
		1.04	11.3								85	68	68	65	65	35					0.1

Field Information		Applie															
Sample No.	Last Crop	Mo					N	P2O5	K2O	Mg	S	Cu	Zn	B	Mn	See Note	
							20-200	0	0	0	0	0	0	.0	0	12	
							20-200	0	0	0	0	0	0	.0	0	12	

Test Results

Soil Class	HM%	W/V	CEC																		
		0.92	8.8								n-I	Mn-Al(1)	Mn-Al(2)	Zn-I	Zn-Al	Cu-I	S-I	SS-I	NO3-N	NH4-N	Na
											91	192	192	321	321	40					0.1

Field Information		Applie															
Sample No.	Last Crop	Mo					N	P2O5	K2O	Mg	S	Cu	Zn	B	Mn	See Note	
							20-200	20-40	0	0	0	$	0	.0	0	12	
							20-200	20-40	0	0	0	$	0	.0	0	12	

Test Results

Soil Class	HM%	W/V	CEC																		
		0.94	8.7								n-I	Mn-Al(1)	Mn-Al(2)	Zn-I	Zn-Al	Cu-I	S-I	SS-I	NO3-N	NH4-N	Na
											81	66	66	91	91	25					0.1

Field Information		Applied Lime			Recommendations												
Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year	Lime	N	P2O5	K2O	Mg	S	Cu	Zn	B	Mn	See Note	
					1st Crop: Fes/OG/Tim,M		120-200	10-30	10-30	0	0	0	0	.0	0	12	
					2nd Crop: Fes/OG/Tim,M		120-200	10-30	10-30	0	0	0	0	.0	0	12	

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-Al(1)	Mn-Al(2)	Zn-I	Zn-Al	Cu-I	S-I	SS-I	NO3-N	NH4-N	Na
		1.09	7.2	65.0	2.5	5.1	54	62	49.0	13.0	355	230	230	320	320	28					0.1

Fes/OG/Tim,M

pH	P-I	K-I
5.1	132	107

mendations

Year

https://stormwater.bae.ncsu.edu/

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Aside: Can Compost Be Used in SCMs?

- Yes, but…
- Remember, SCMs are water quality and quantity treatment devices, NOT landscape features
- Compost can have very high nutrient levels
- Use compost to remediate poor soils, do not use inside SCMs

(7) NO MECHANICAL COMPACTION

- The media shall not be mechanically compacted.
- It is recommended to either water it or walk on it as it is placed.

(8) MAINTENANCE OF MEDIA

- A drawdown of at least 25mm/h at the planting surface must be maintained.

24 h post-Rain Event…. Uh oh!!!

Slide 43

B1 Bill, 11/10/2015

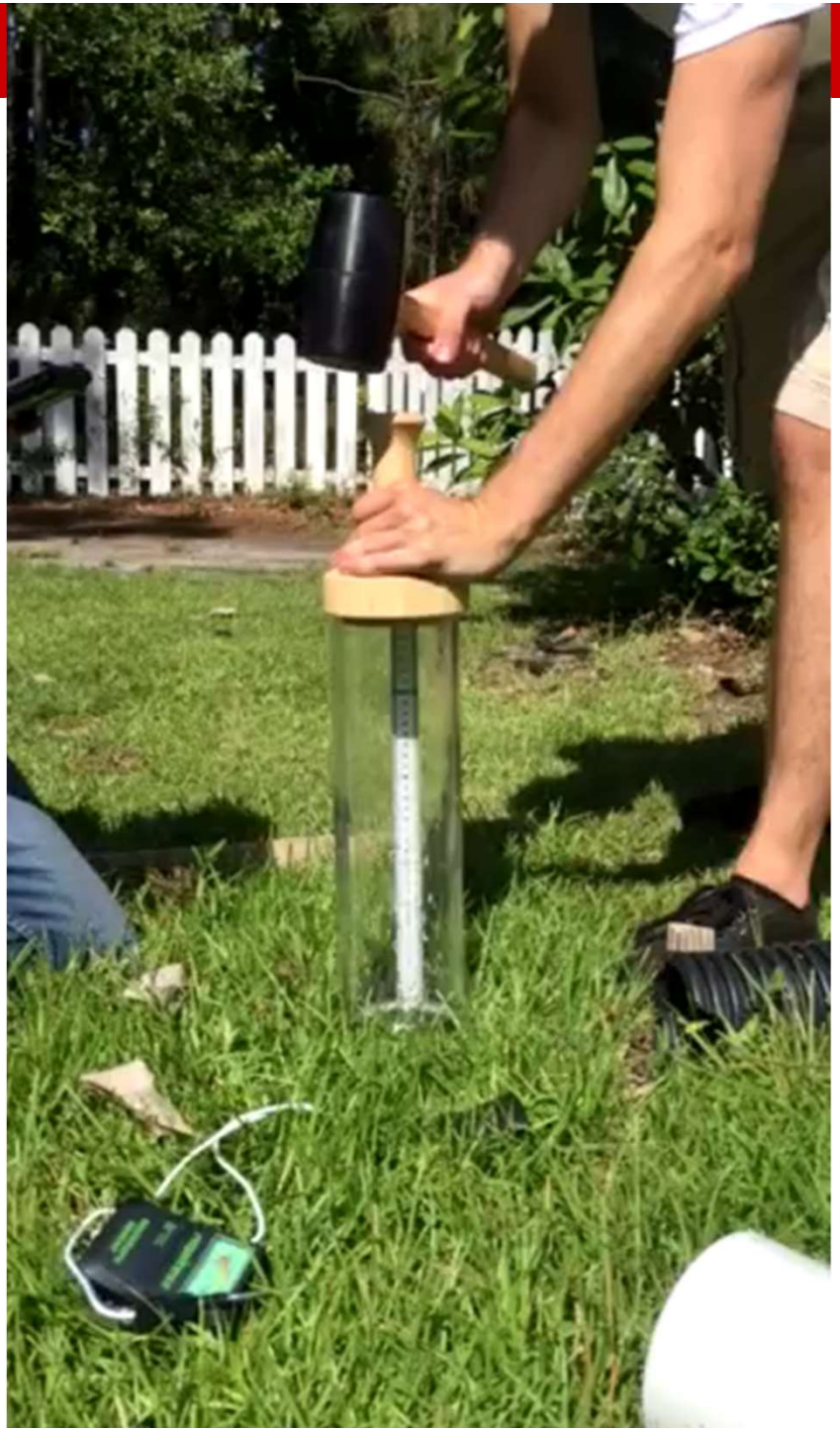
Keep Off! – Post Construction Compaction

The roller provided far too much compaction.

Double Ring Infiltrometer

Modified Philip-Dunne Infiltrometer

Test in Action



The REAL Key Point

- Over compaction will require removal and reinstallation of the media material.

(9) PLANTING PLAN

- Achieve 50% coverage with either:
- Canopy, ground cover, or a combination of canopy and ground cover
- At five years after planting.

Plant Density

Keep it open!

(9) PLANTING PLAN

- If sod is used, then it shall be a non-clumping, deep-rooted species.

Do They Need to Look Good?

Landscape Ecol (2007) 22:959–972
DOI 10.1007/s10980-007-9110-x

PERSPECTIVE

The shared landscape: what does aesthetics have to do with ecology?

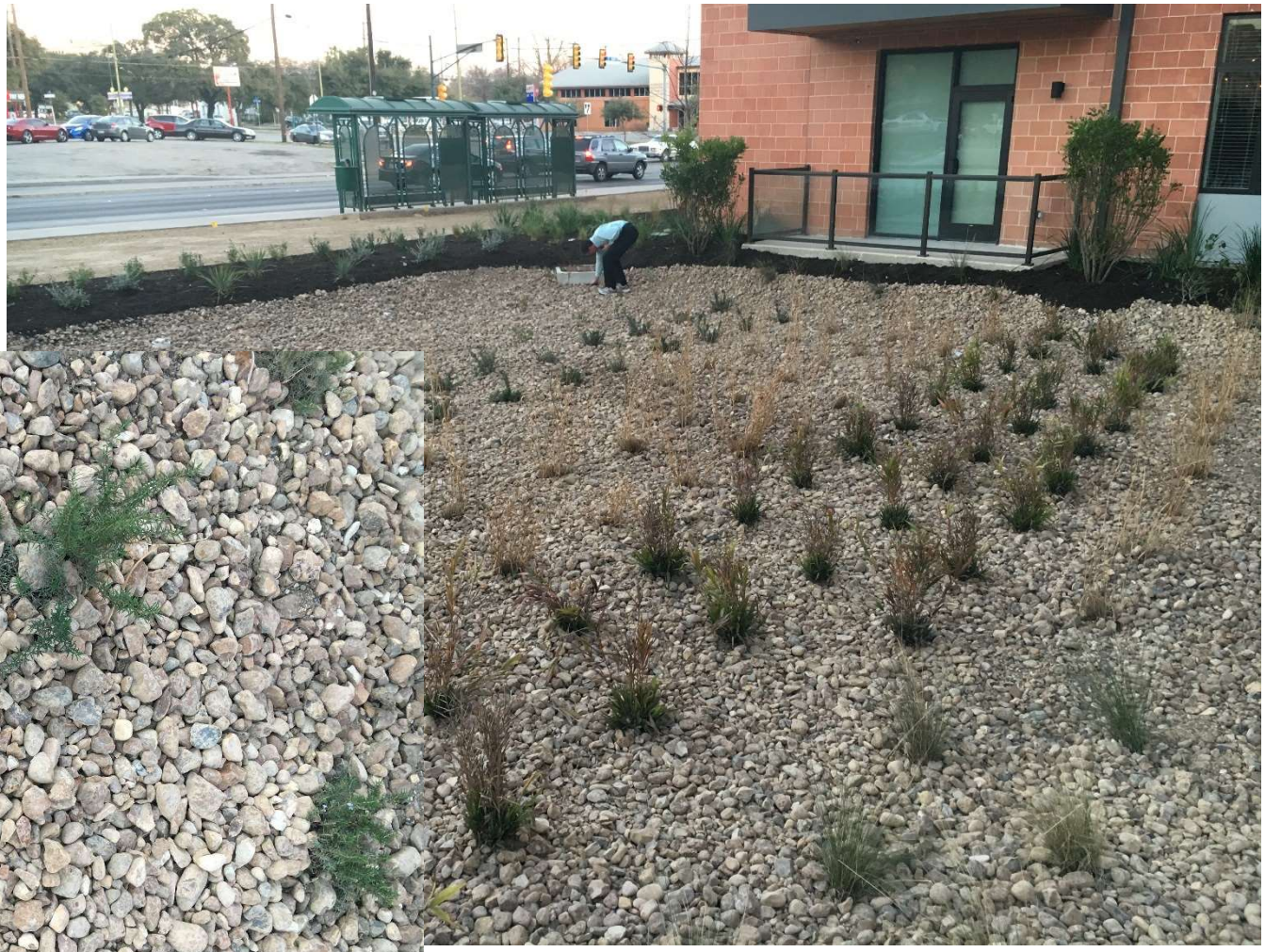
Paul H. Gobster · Joan I. Nassauer · Terry C. Daniel · Gary Fry

- If a BMP or landscape looks good, people are more inclined to respect them and take care of them

(11) MULCH

- For tree/shrub bioretention cells only
- Double or triple shredded hardwood mulch (portion of the cell that will be inundated)
- Uniformly placed two to four inches deep.

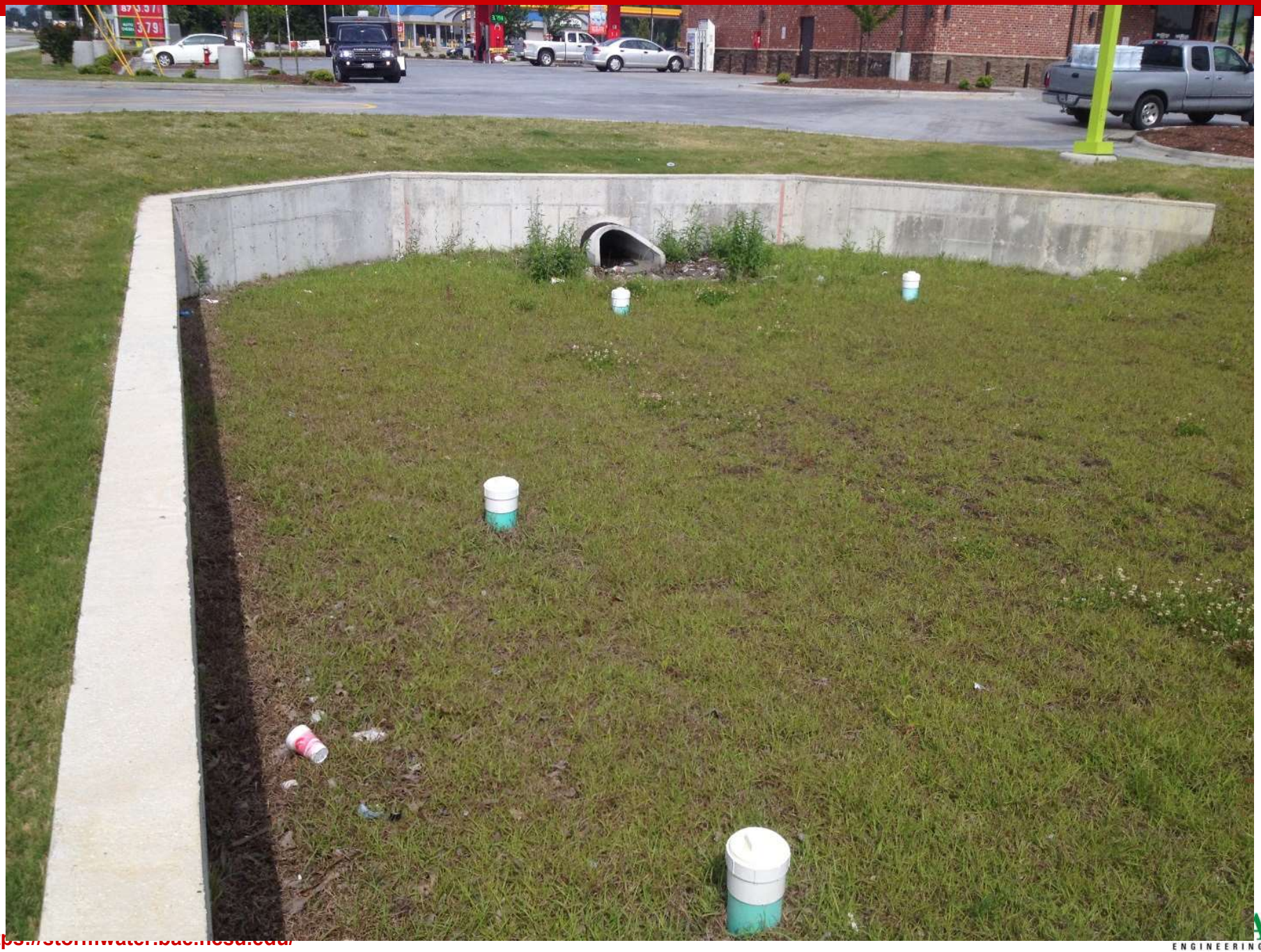
Might Gravel be OK?



https://stormwater.bae.ncsu.edu/

(12) CLEAN-OUT PIPES

- At least one clean-out pipe shall be provided on each underdrain line
- Clean out pipes shall be capped.



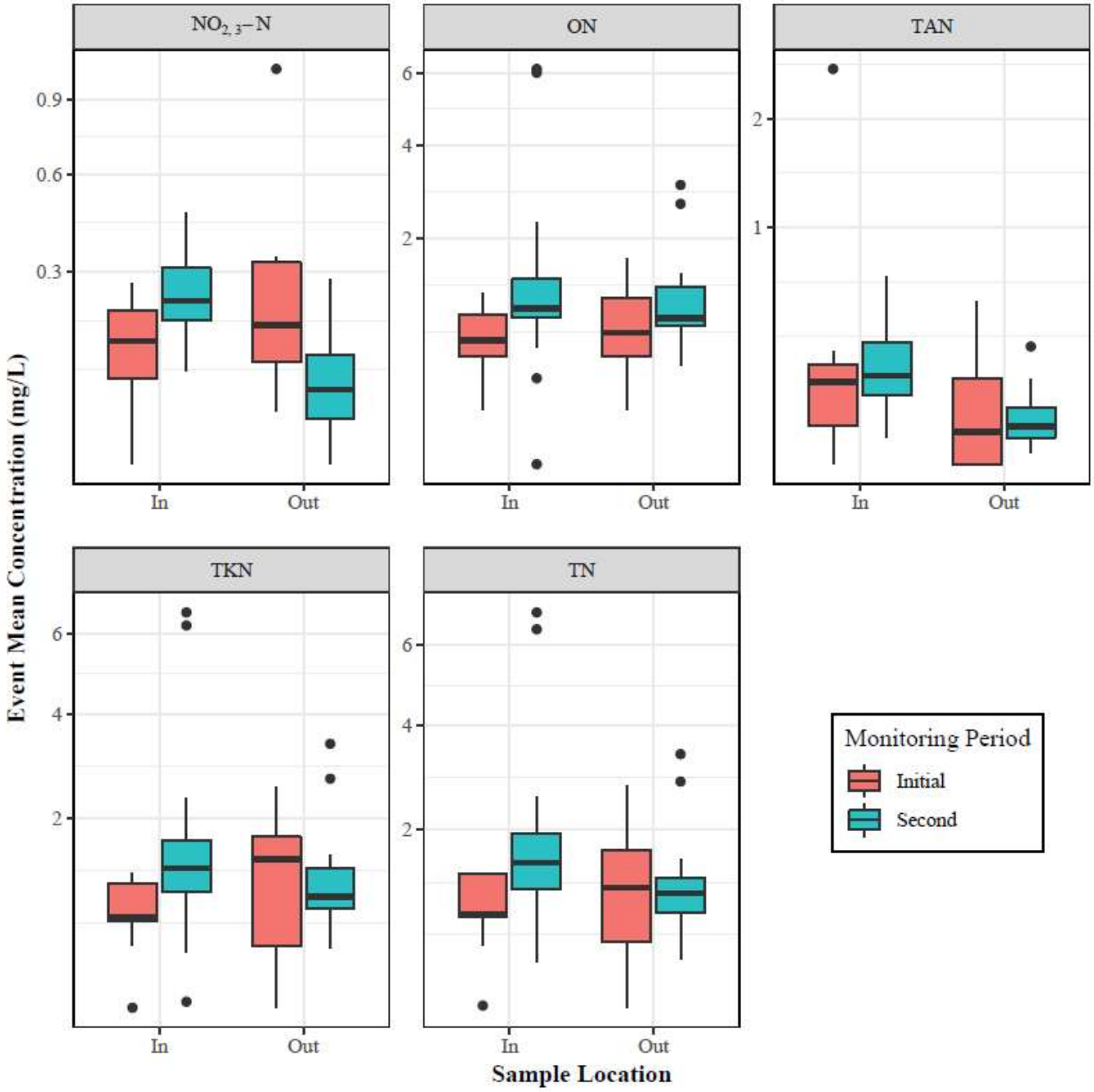
Maybe Use Concrete Donuts?

Quick Aside: How do BRC Performance Mature in the Long Term?

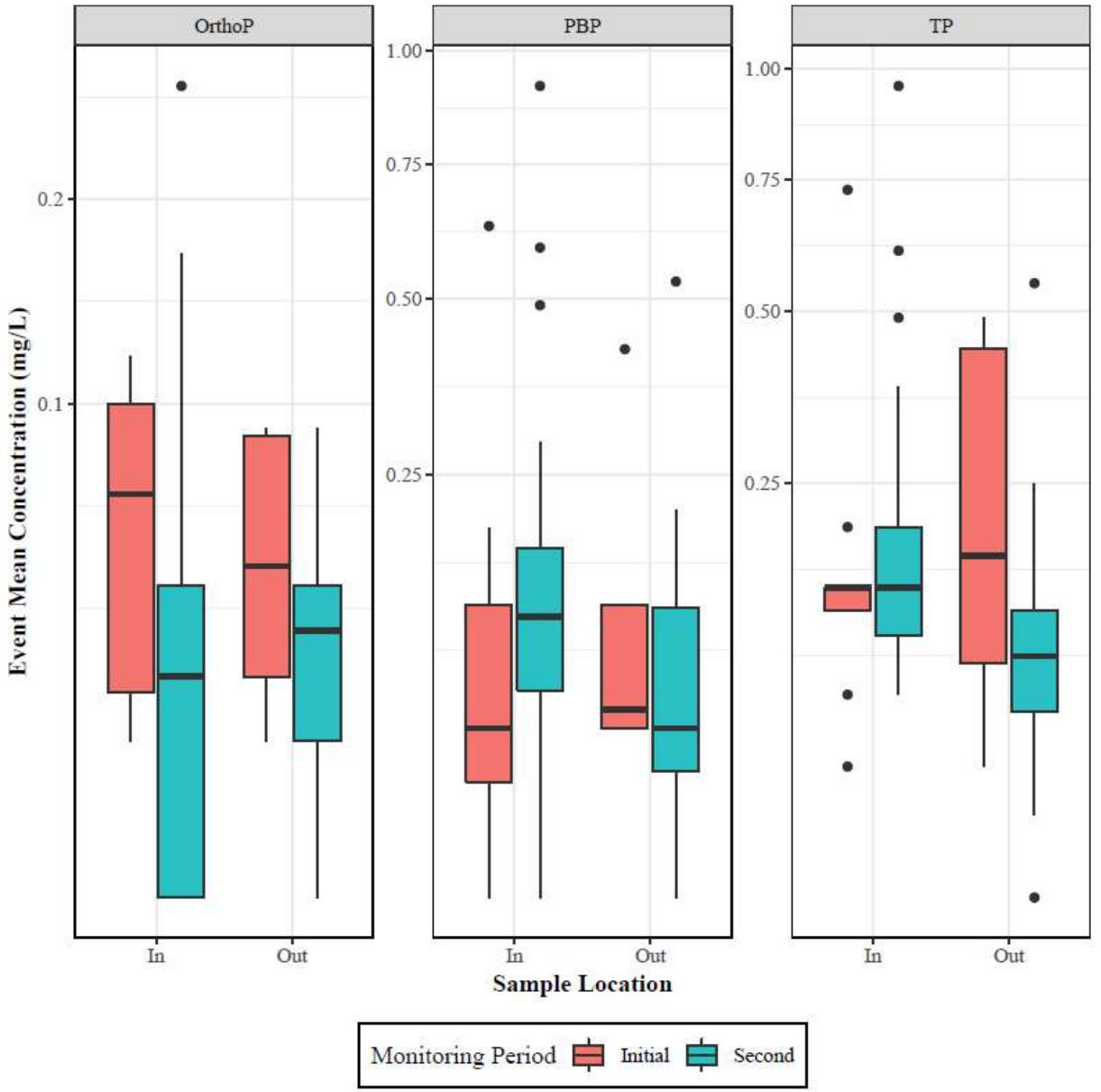
2001 – my Ph.D. research

16 Years Later: Studying the Cell Again

Results – Nitrogen



Results – Phosphorus



What's Different?

Vegetation is our long-term friend

NC DEQ Credit Comparisons

- TN and TP are now below assigned values for nutrient reduction calculations from NC DEQ

Period	TN (mg/L)	TP (mg/L)
NC DEQ Credit	1.20	0.12
2002 – 2003	1.23	0.17
2017 – 2018	1.12	0.09

- Not only does bioretention work, it can get even better with time and may even be ***undervalued***

Main Take Home Points

- Keep Sediment Out of Cell During Construction!!!
- Do not need to fertilize
  - May Need to Mow or Prune
- Broken Bioretention Can be Restored
- Well Maintained BRC's are like a fine wine
  - Get better with age

Questions?