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LID Summit – Raleigh, NC – 27Mar14

Bioretention Overview & Common Design Elements

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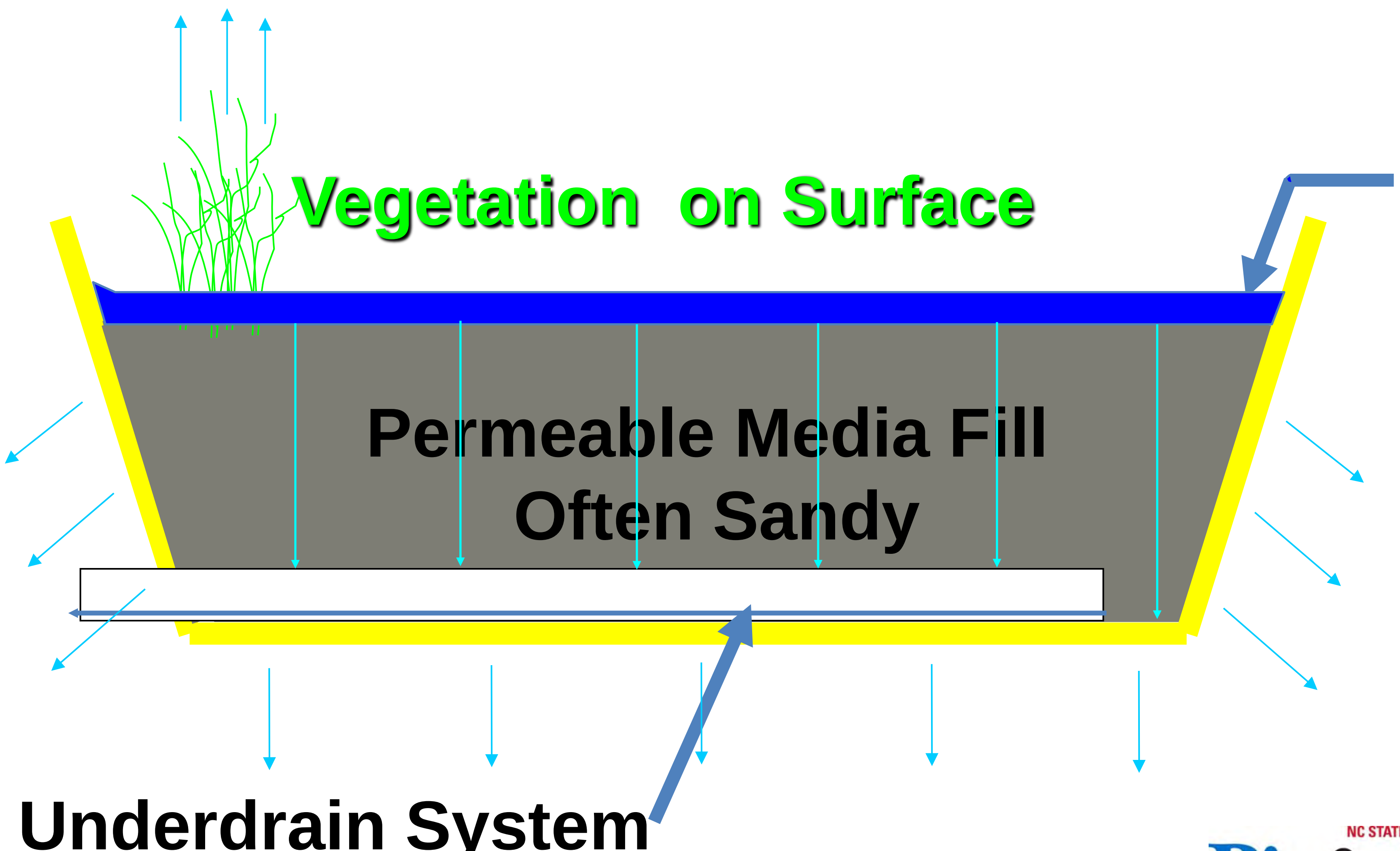
Question: How does Bioretention Work?

Bioretention Schematic



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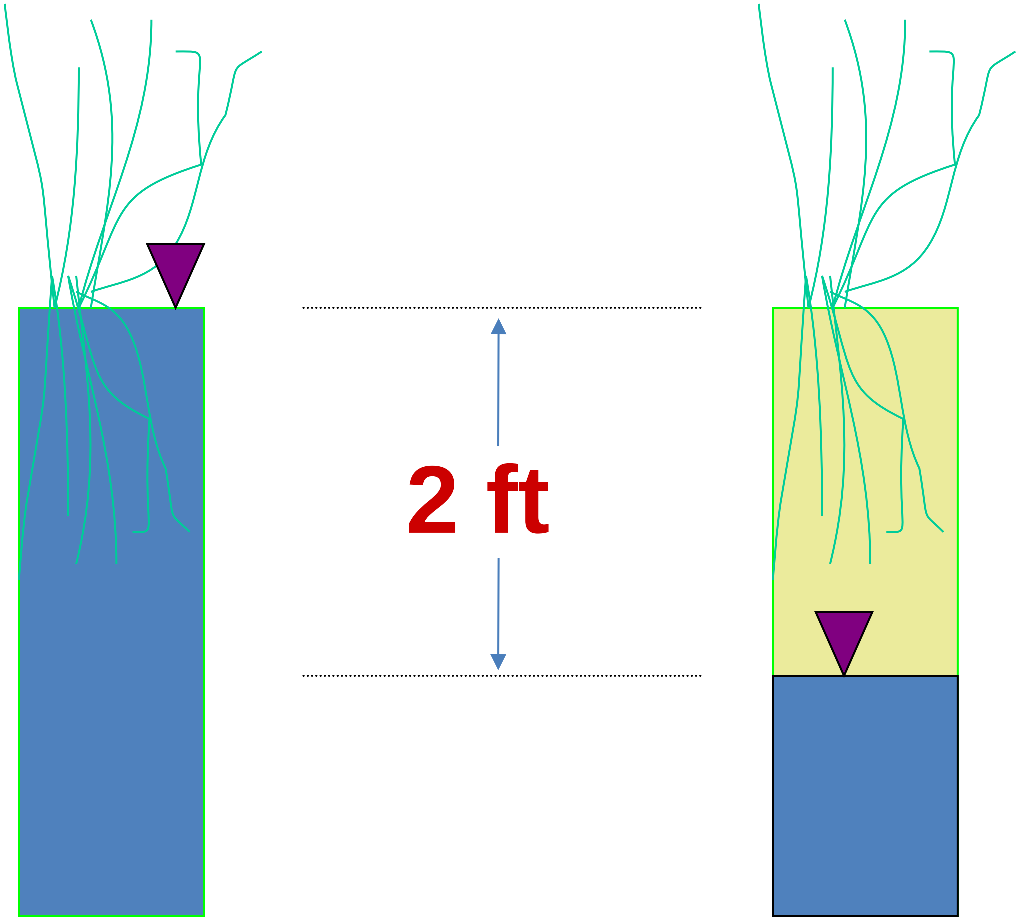
Bioretention Water Table



Draw Water Table Down 2 ft below surface in maximum of 2 days

+ 4 Hours

+14 Hours

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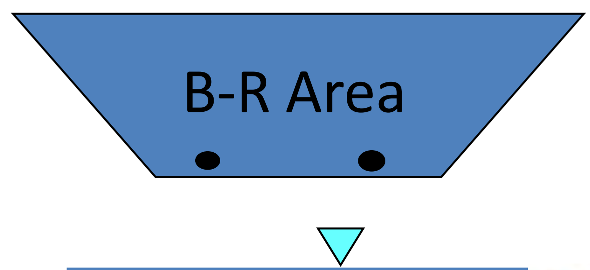
Seasonally High Water Table Depths & Bioretention

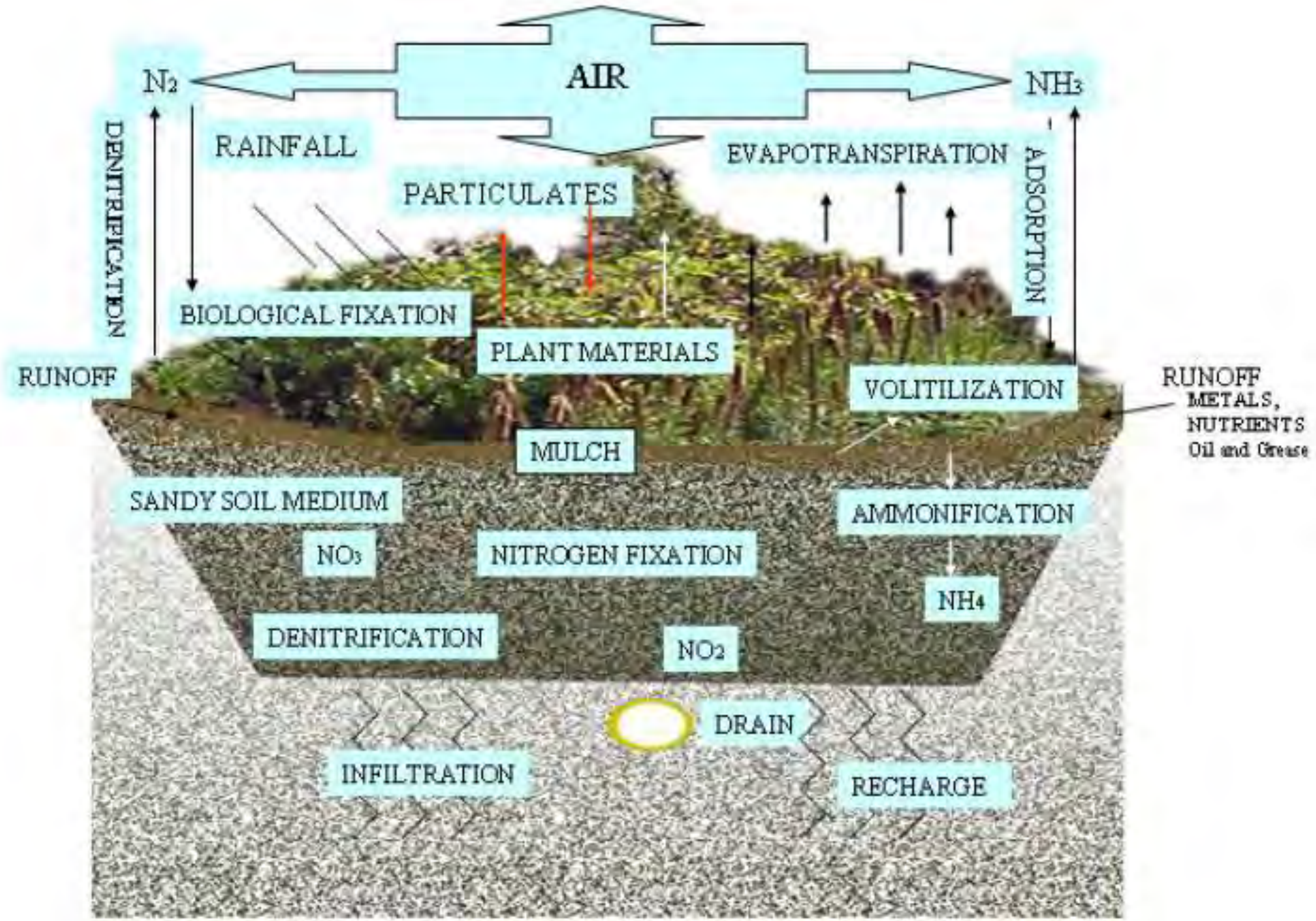
- Seasonally High Water Tables. A Problem? (Coastal Plain NC)
- Depends on Depth of Bioretention area
- Recommend: No W.T. within 1-2 ft of bottom



Q: How does Bioretention work: Pollutant Removal Mechanisms

- Sedimentation (temporary)
  - Trash, TSS, Phosphorus
- Microbial Processes
  - Nitrogen
- Chemical Processes & Media Filtration
  - Metals, Phosphorus
- Exposure to Sunlight & Dryness
  - Pathogens, Oil & Grease
- Infiltration

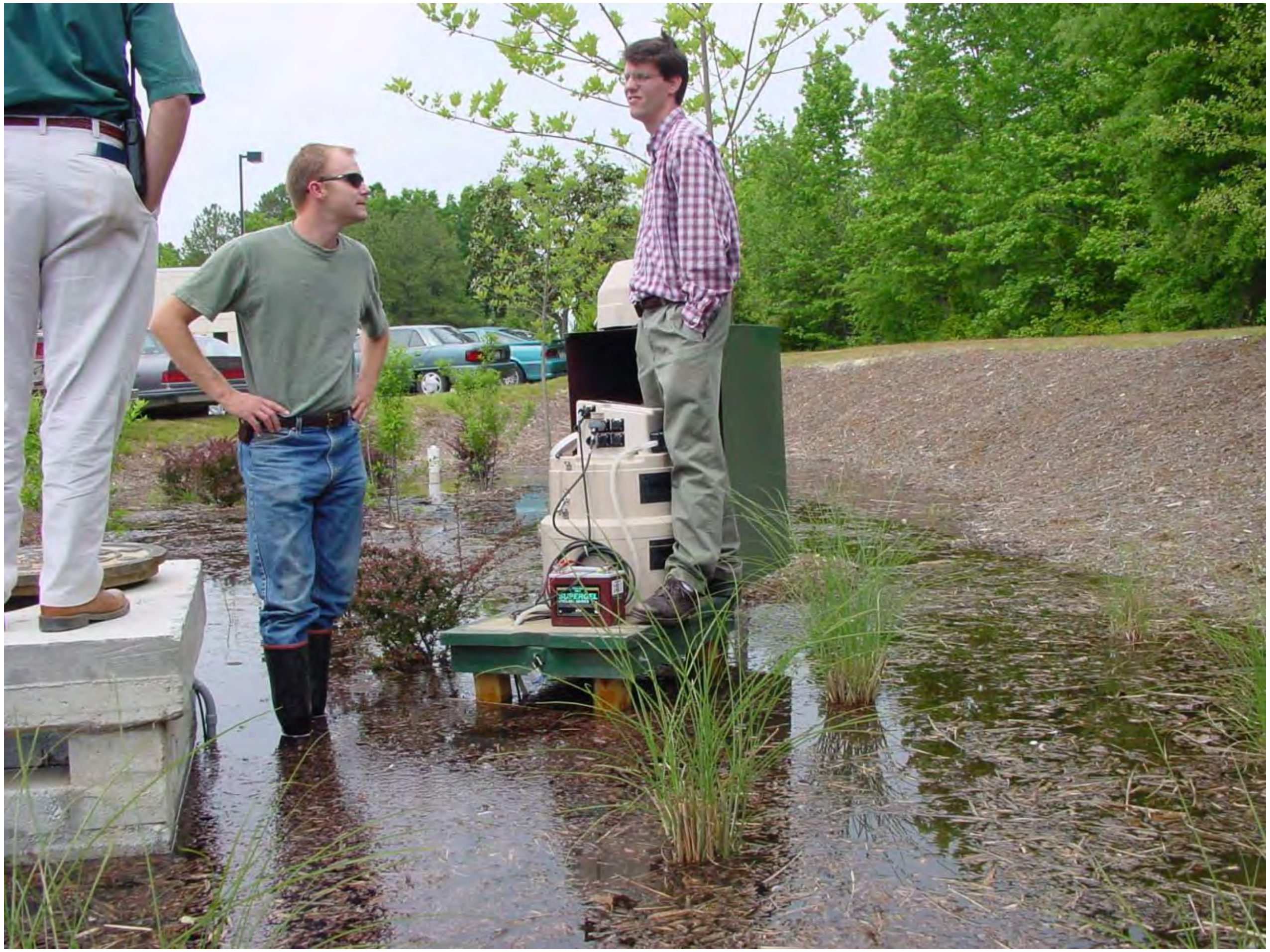
Biochemical Pollutant Removal Mechanisms in a Bioretention Cell



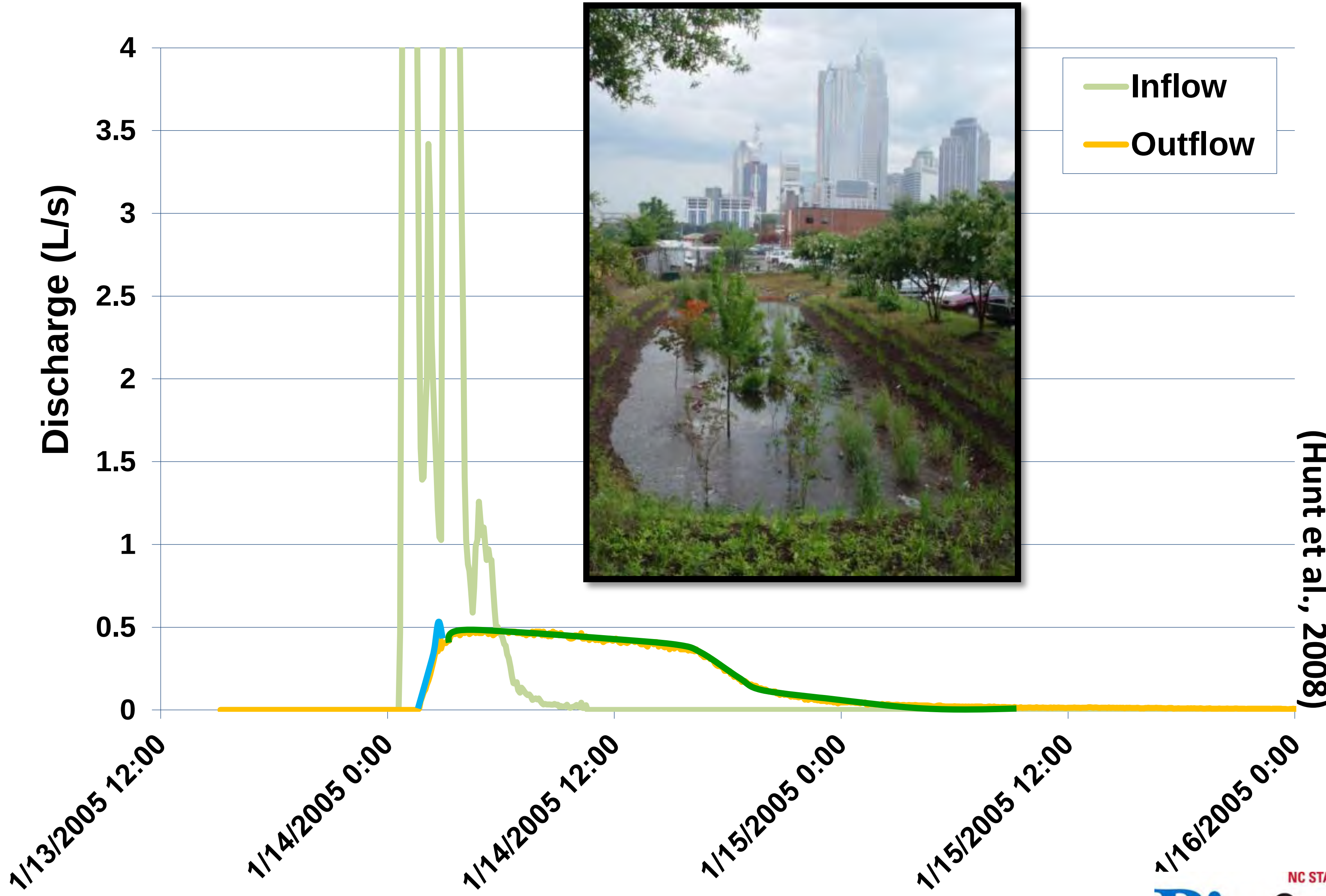
Q: How do Rain Gardens work: Hydrologic (Flow) Control

- Temporary surface storage
- Slow flow through porous media (peak flow control).
- Media with good field capacity means volume control, whether or not exfiltration is possible.
- Especially effective for small(ish), frequently occurring storm events → typically little to no system discharge!

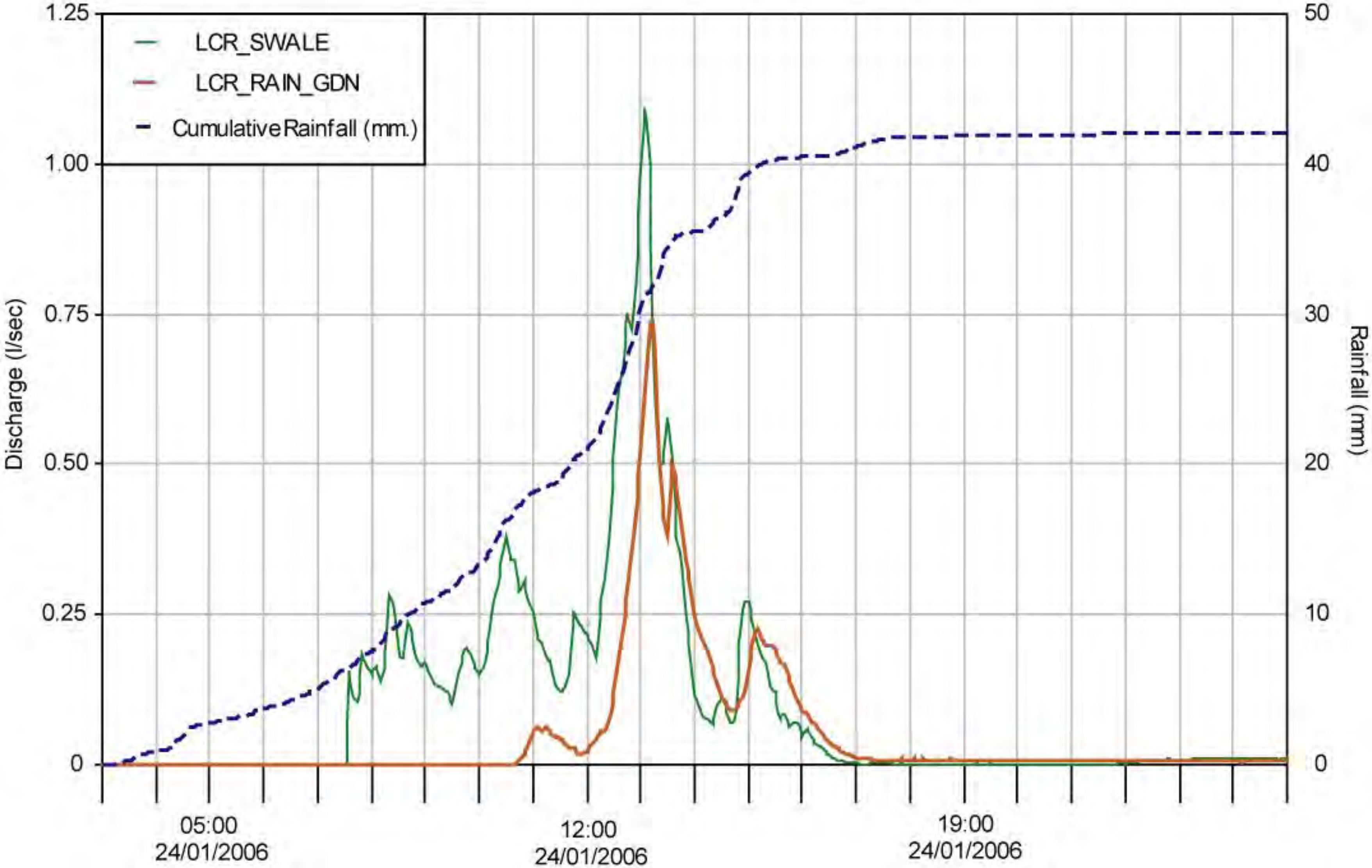
How well does Bioretention Work?



Bioretention Hydrology



Swale and Rain Garden Treatment Train at Landcare Research (NZ): Hydrologic Performance



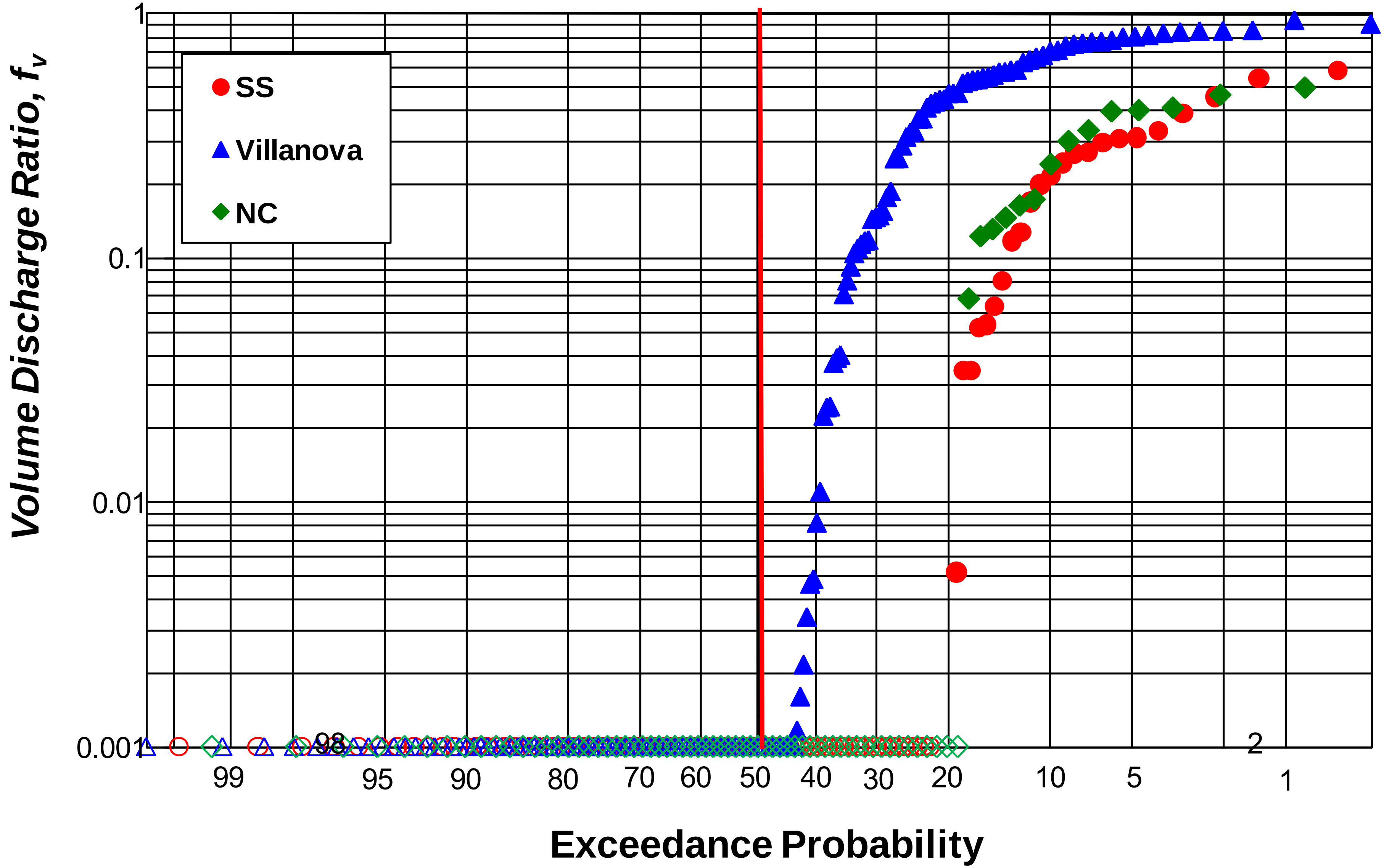
Courtesy of Dr Sam Trowsdale, Landcare Research, March 2008

From an Individual Event Perspective, we see…

- Peak Flow Mitigation (for events up to 30mm)
- Total Volume Reduction (for nearly all events)

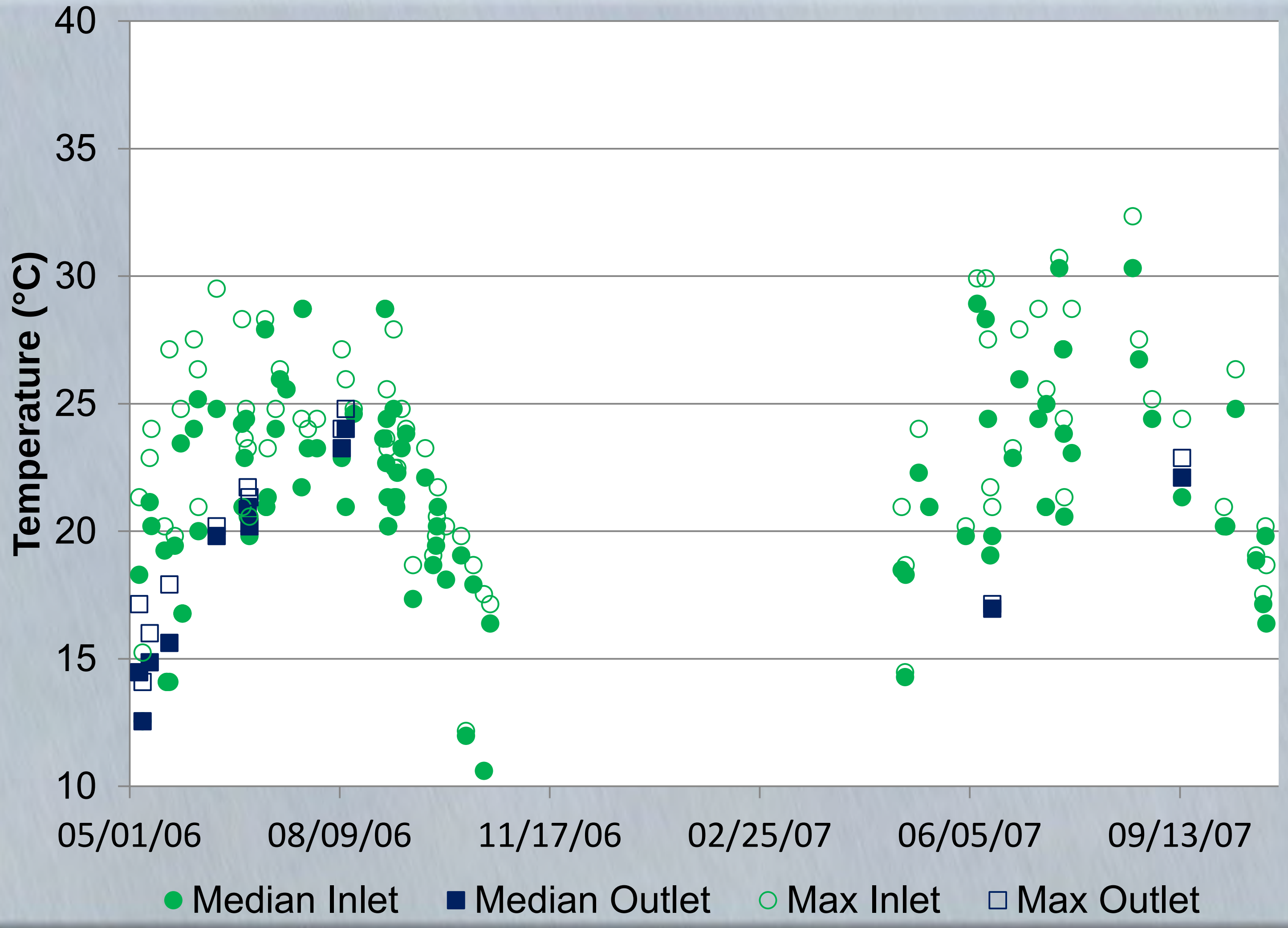
- This Translates to Significant Long Term Hydrologic Benefits

Three More Examples of Volume Abatement: MD, NC, PA



Bioretention Areas

Jones and Hunt, 2009



Bioretention Area

- Ability of bioretention to exfiltrate water leads to reductions in thermal load
- Effluent reductions were greatest for bioretention media volumes larger with respect to their watershed

	Percentage of Watershed Area	Events with Outflow
Asheville	16%	12%
Lenoir	4%	79%
Brevard East	7%	76%
Brevard West	11%	27%

Take Home Point

- From a Long Term Hydrology Perspective, Bioretention Cells "Convert" Lots of Runoff to Infiltration & Evapotranspiration
- Often more than 50%
- Depends on Several Factors
  - Underlying Soil
  - Media Volume & Type
  - Relative Surface Area

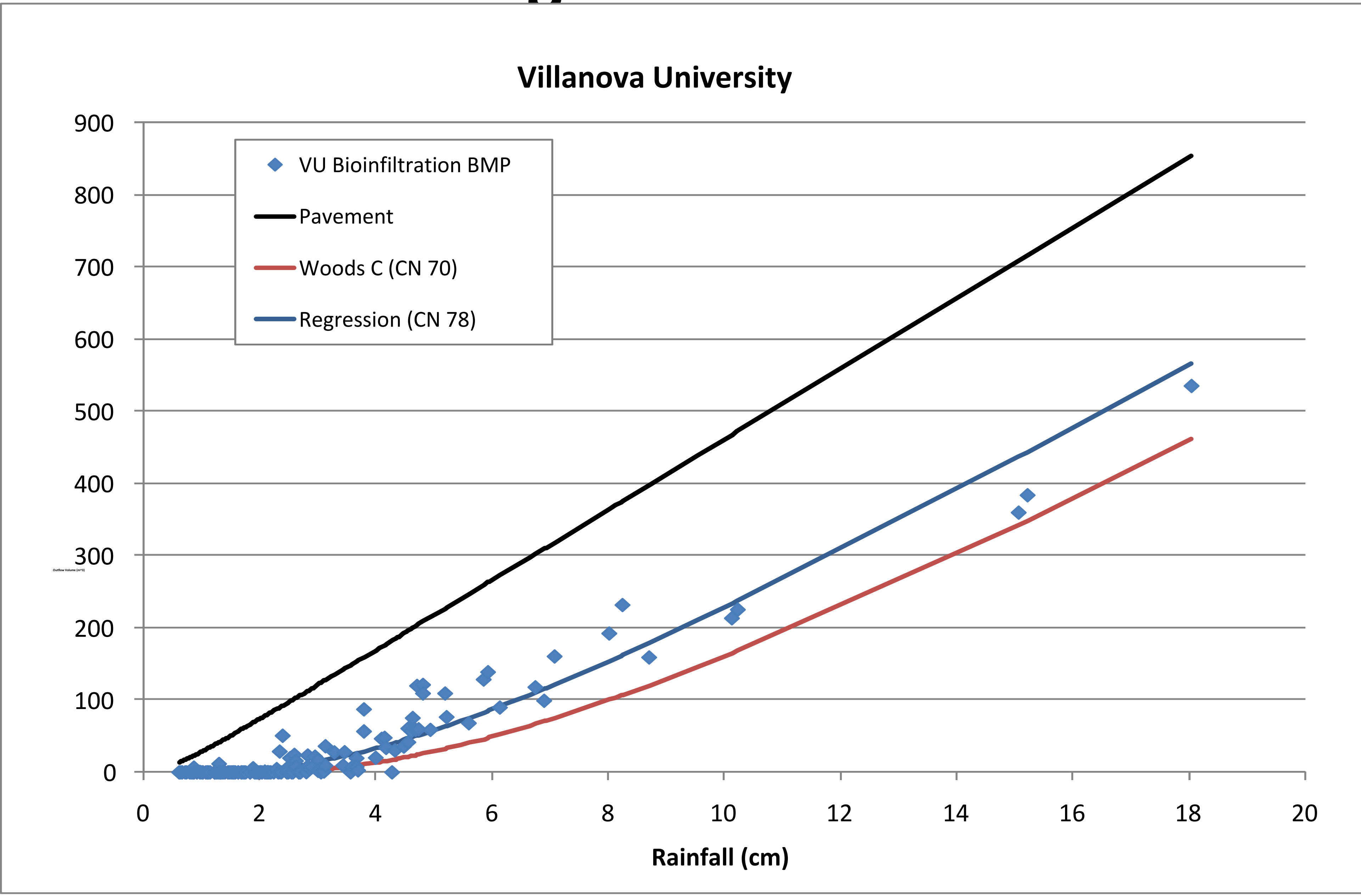
Another Way of Assessing Performance is Relating to Landscape Conditions

In other words… how much runoff does a given/target landscape produce?

Characterizing the Landsape: Curve Numbers (USDA-NRCS)

Land Use	Soil Group A	B	C	D
Paved Parking Lots; Roofs	98	98	98	98
Commercial & Bus. Distr.	89	92	94	95
Townhouses	77	85	90	92
Residential Lot (1/2 AC)	54	70	80	85
Residential Lot (1 AC)	51	68	79	84
Open Space: grass > 75%	39	61	74	80

Translating Rain Gardens Into



Studies on Water Quality

College Park (CP) Site

Watershed	**Anacostia**
Year Built	**2004**
Watershed Size	**0.26 ha**
Surface to Drainage Area Ratio	**6%**
General Shape	**Trapezoidal**
Ponding Depth	**15 cm**
Fill Media Depth	**0.5-0.8 m**
Soil Texture[b]	**Sandy loam**

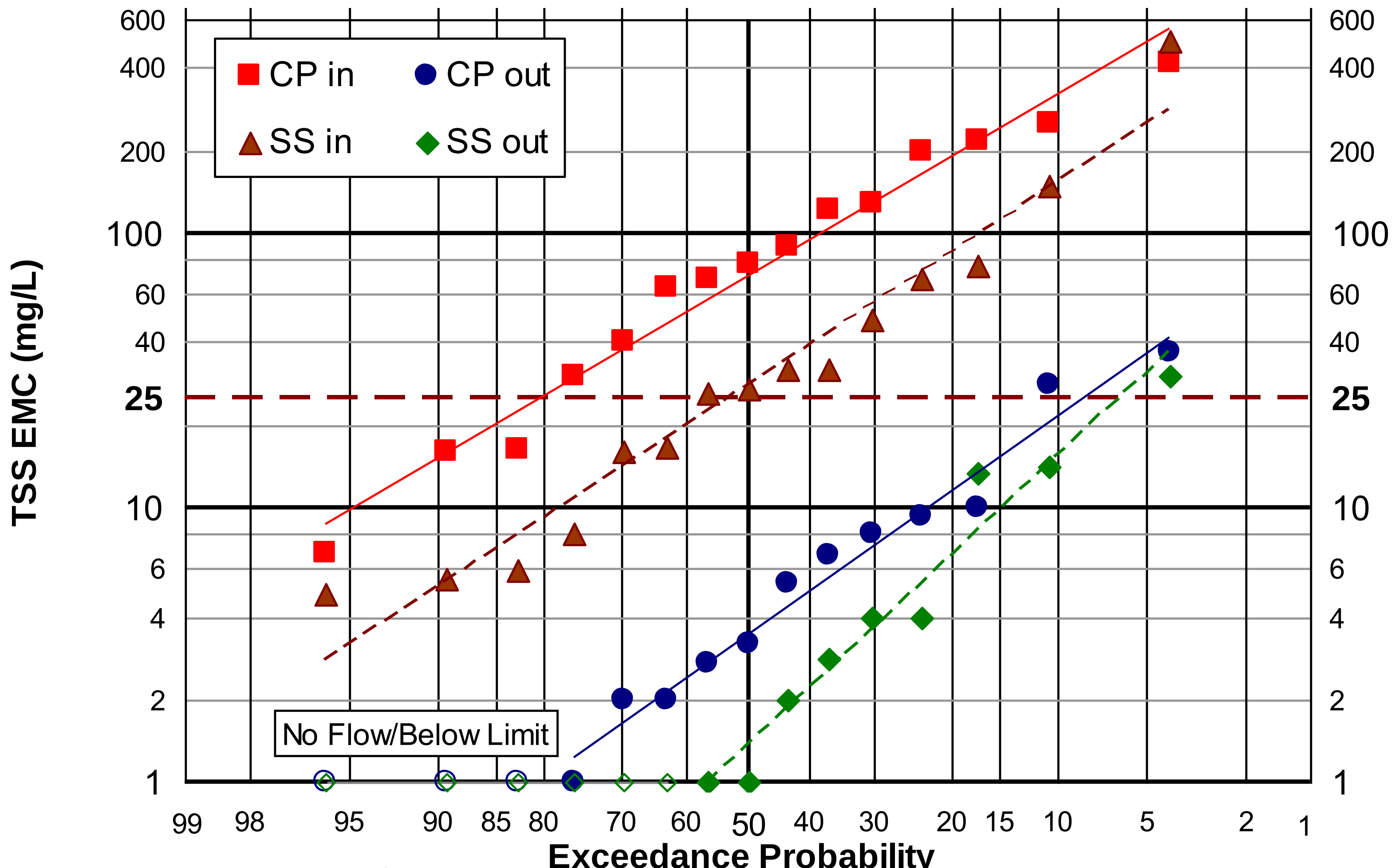
Underdrain discharge to Stream

Silver Spring (SS) Site

Watershed	Anacostia
Year Built	2006
Watershed Size	0.45 ha
Surface to Drainage Area Ratio	2%
General Shape	Triangle
Ponding Depth	30 cm
Fill Media Depth	0.9 m
Soil Texture	Sandy clay loam

Underdrain discharge to Storm Drain to Stream

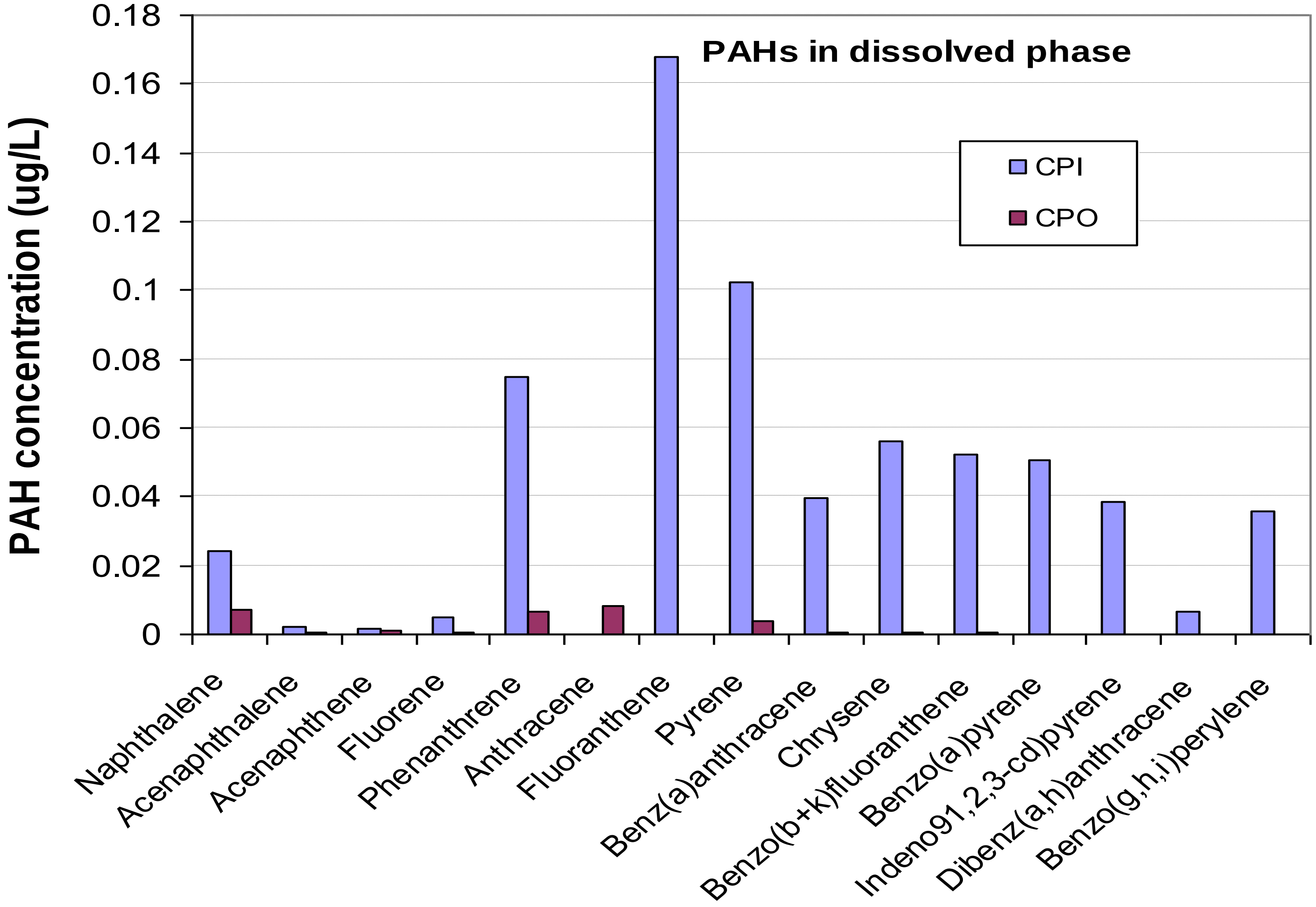
Bioretention TSS (CP & SS)



Excellent treatment of TSS

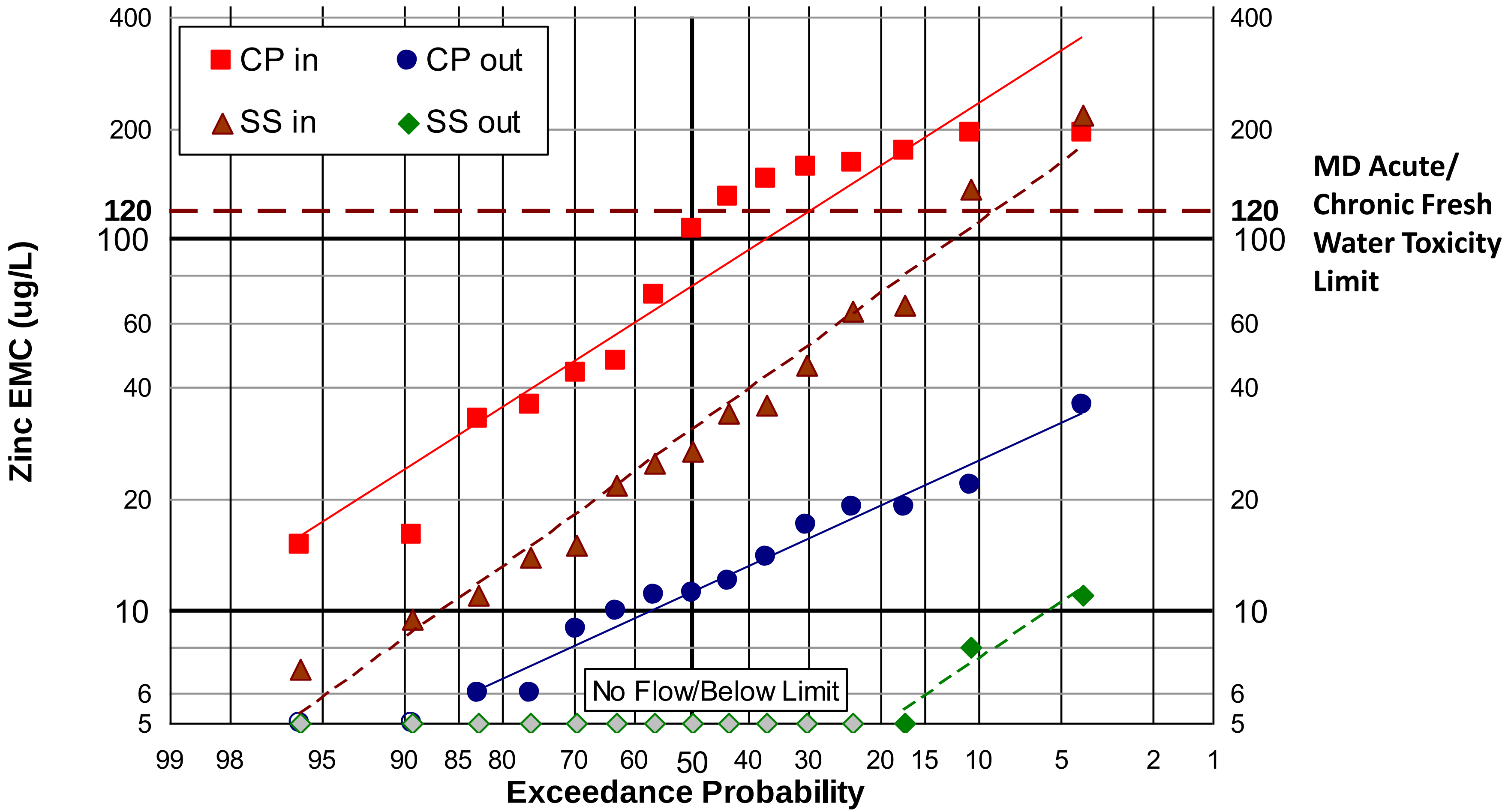
Li & Davis, J. Env. Eng. 2009

Bioretention PAH Field (CP)



Diblasi, Li, Davis & Ghosh, Environ. Sci Technol., 2009

Zinc (CP & SS)



Zinc is very well removed as evidenced by field bioretention data.

Li & Davis, J. Env. Eng. 2009

Take Home Point

- The Mulch and Upper Media Layers are critical for removal of…
  - Metals
  - Hydrocarbons
  - TSS
- Performance appears to be independent of type of media used

Greensboro Battleground Ave

Chapel Hill Univ. Mall

Initial NCSU Research

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

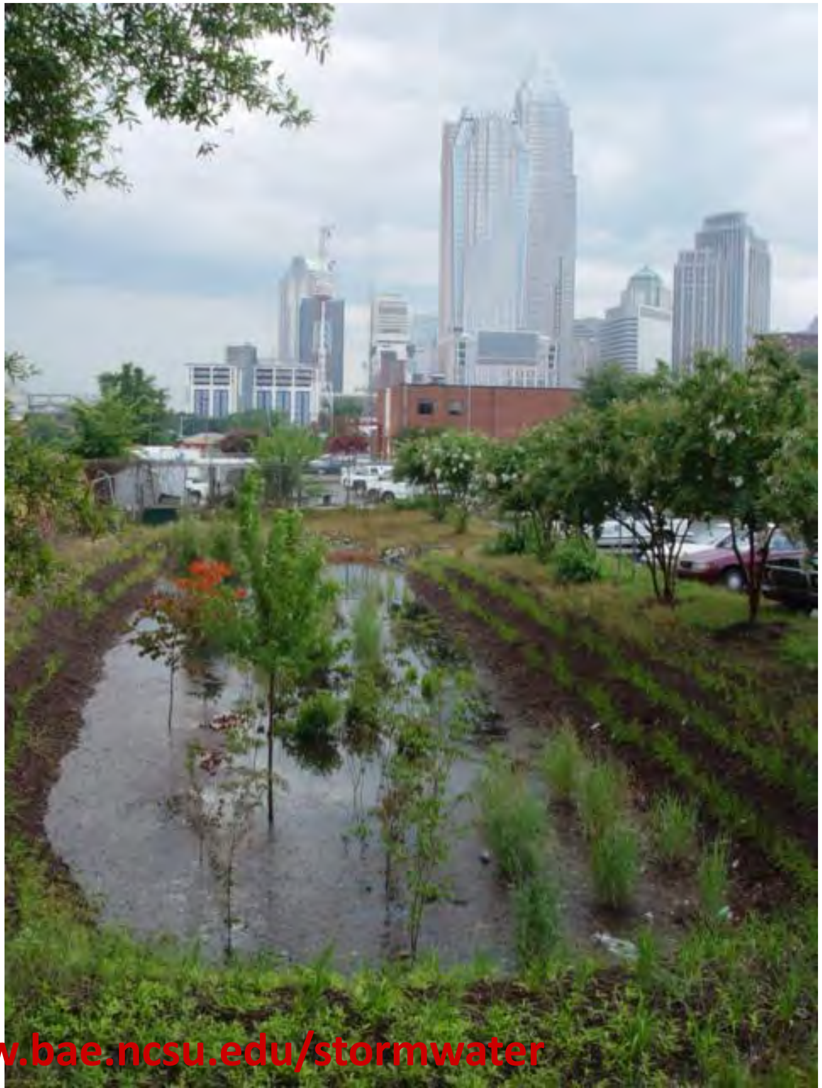
	Greensboro	Chapel Hill
TP	+240%	- 65%
P-Index	85-100	4-12

(Hunt 2003)

P-Index 50-100: High P-Index

0-25: Low

Mecklenburg Co. Hal Marshall Bioretention Cell (2004-2006)

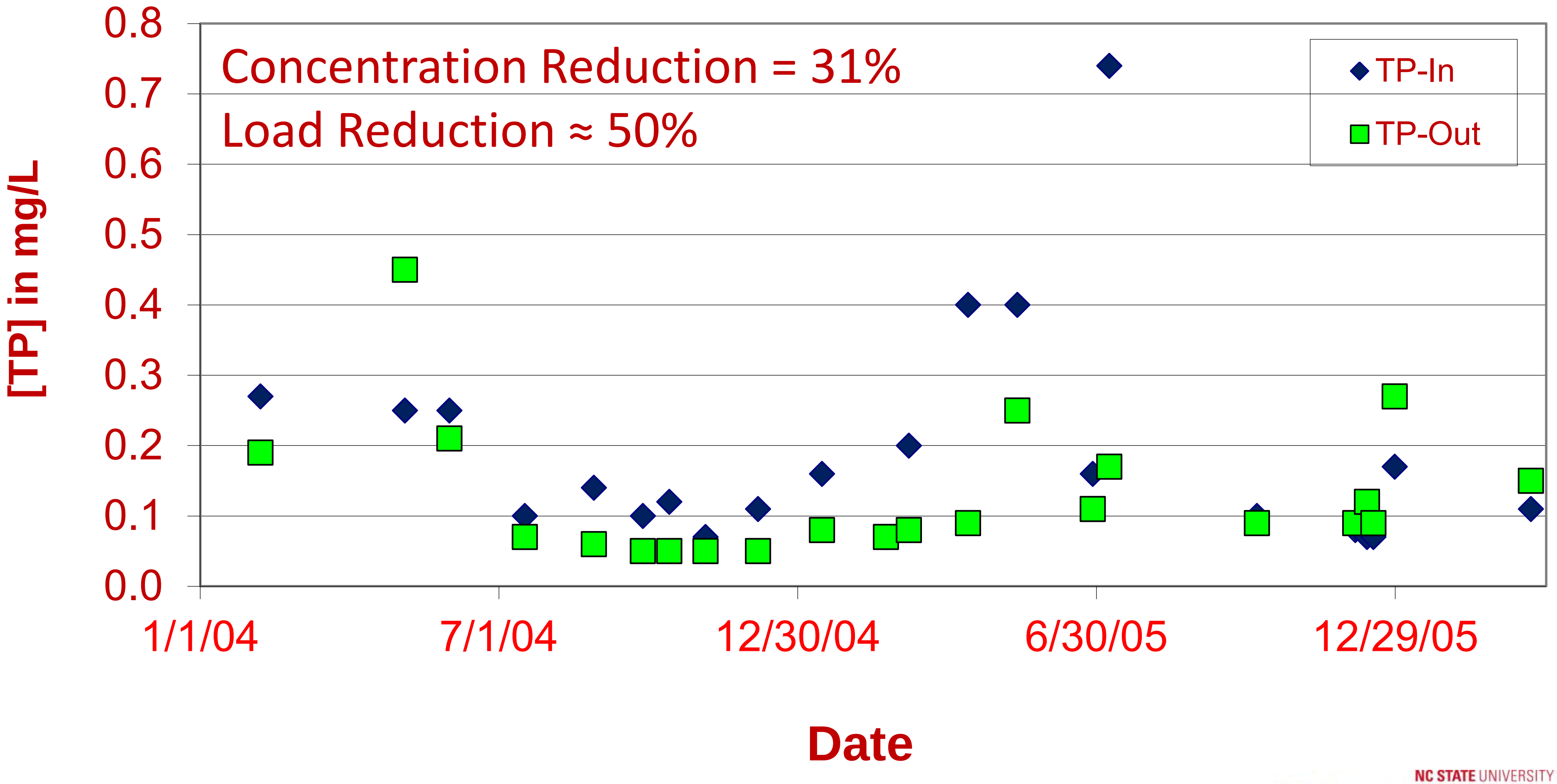


Soil

- 80% Mason Sand
- 20% Fines + Compost
- P-Index = 6
- 4 ft (1.2 m) Depth

TP Charlotte, NC (2004-2006)

Hunt et al., 2008



Concentration vs. P-Index

Site	P-Index	Depth (in)	Outflow (mg/L)
C-1	6	48	0.13
L-1	1-2	30	0.16
L-2	1-2	30	0.18
G-1	35-50	48	0.57
G-2	85-100	48	1.85

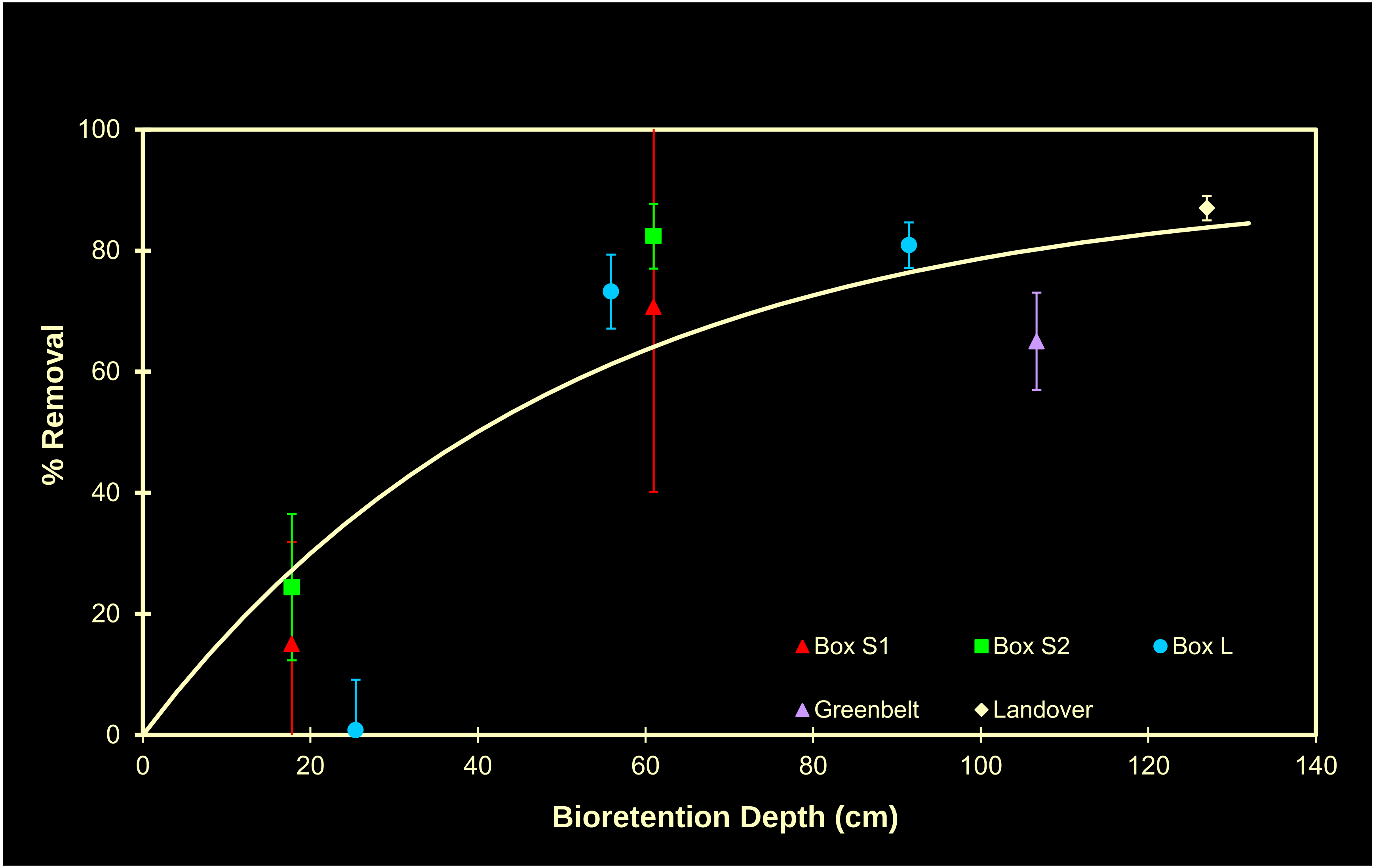
LOW

Mass Loads (kg/ha/yr)

	CP		SS	
	In	Out	In	Out
TSS	1190	37	570	38
Chromium	0.09	0.015	0.02	~0.007
Copper	0.26	0.073	0.12	0.045
Lead	0.09	0.013	0.03	~0.005
Zinc	1.0	0.063	0.36	0.017
Chloride	6800	458	320	25
TN	27	7.2	9.6	3.6
Nitrate	12	2.5	3.7	~0.19
TKN	15	4.1	6.0	3.6
TP	3.6	0.72	0.9	0.38
TOC	44	154	43	78

Li & Davis, J. Env. Eng. 2009

Overall Results: Phosphorus



Phosphorus removal increases gradually with bioretention depth.

Davis, Shokouhian, Sharma, Minami, Wat. Environ. Res. 2006

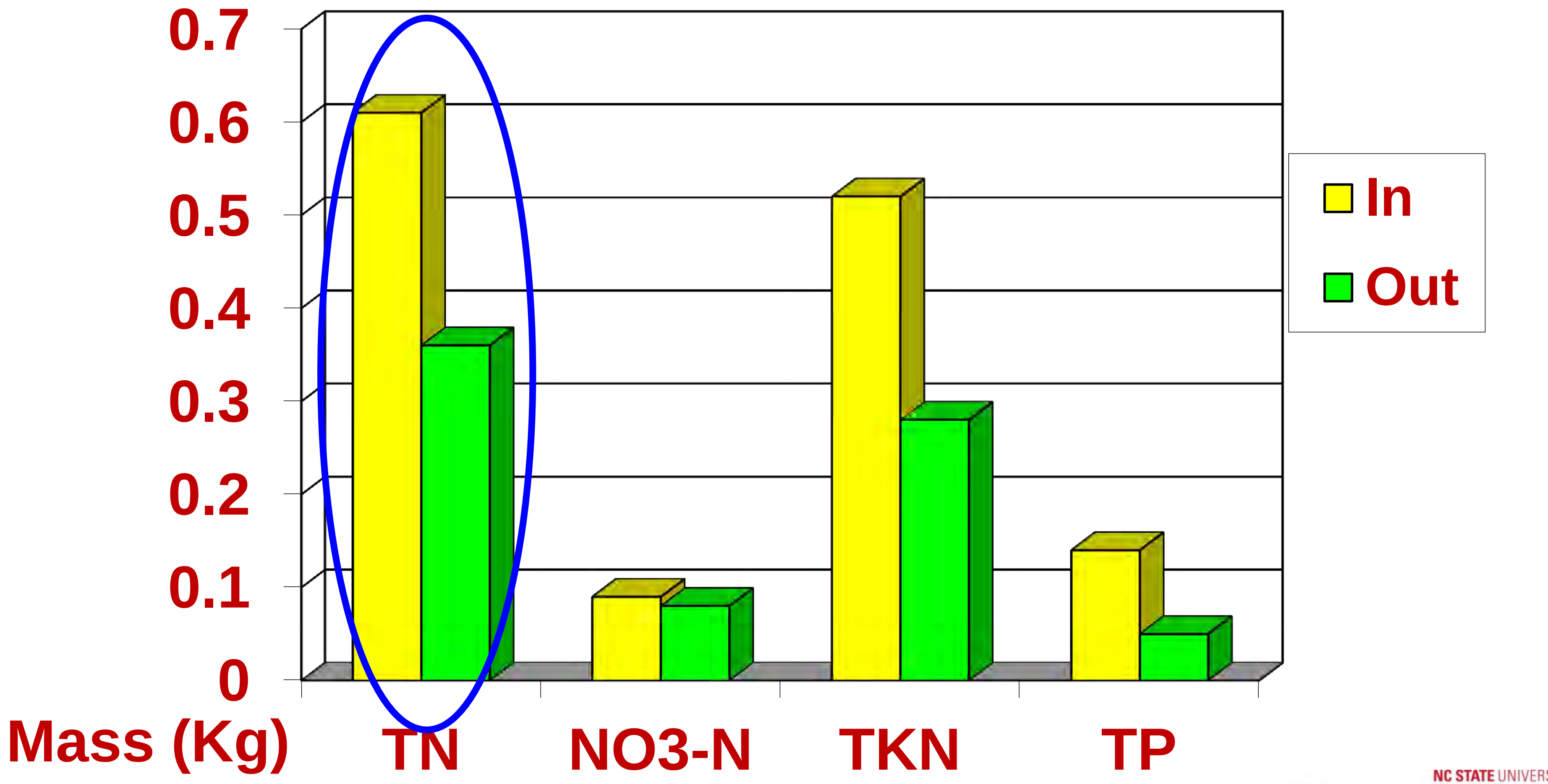
Take Home Point: Phosphorus

- Proper Media Selection is Critical
- With good media, TP sequestration is high.
- Most appears to occur in the upper layers of media
  - At least 2 ft of media might be best?


Chapel Hill Cell, C1
STP/WS = 0.14
Conventional Drainage

Annual Loadings (2002-03)

Chapel Hill Cell C1 - *Hunt et al., 2006*

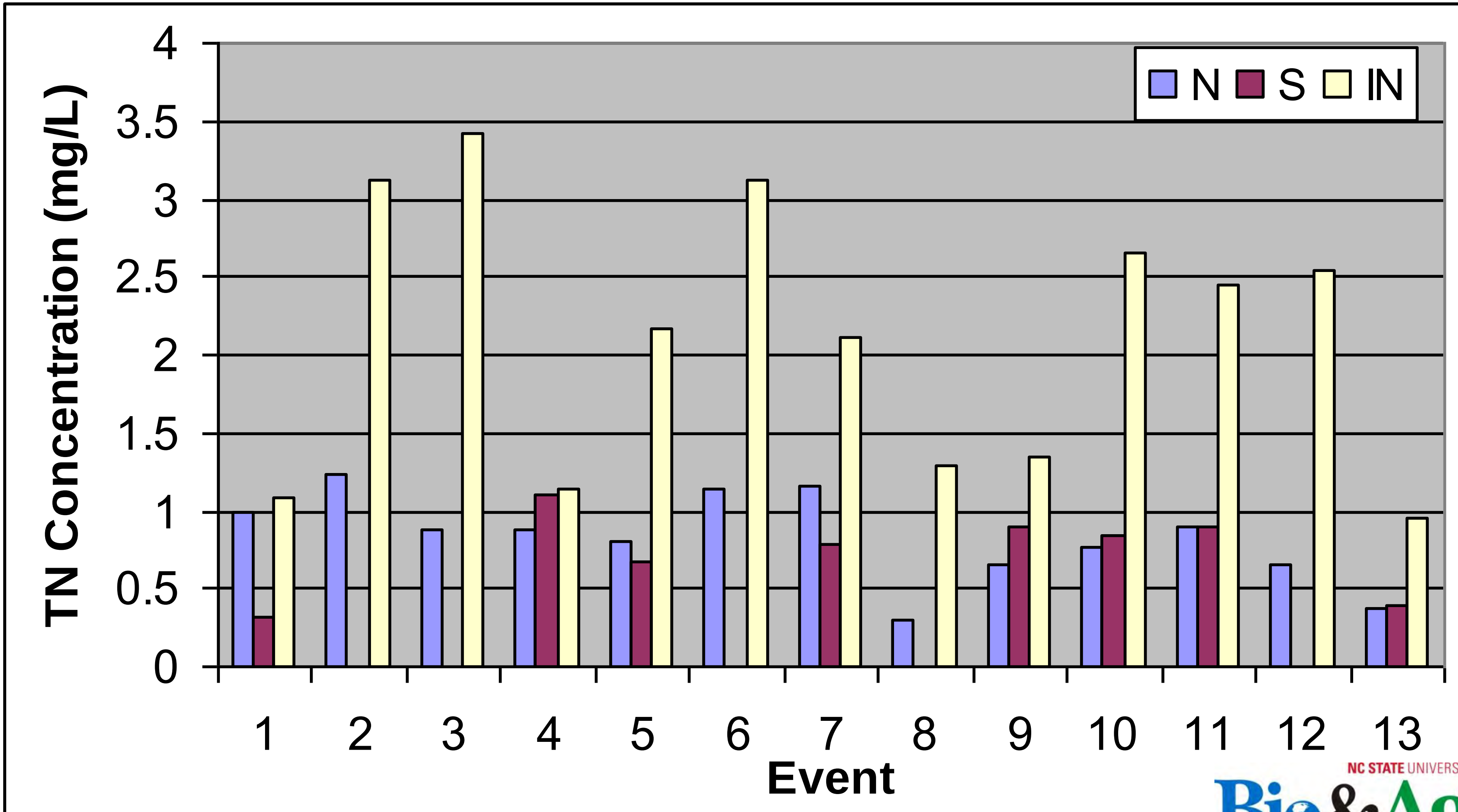


Graham High School (2006-2007)

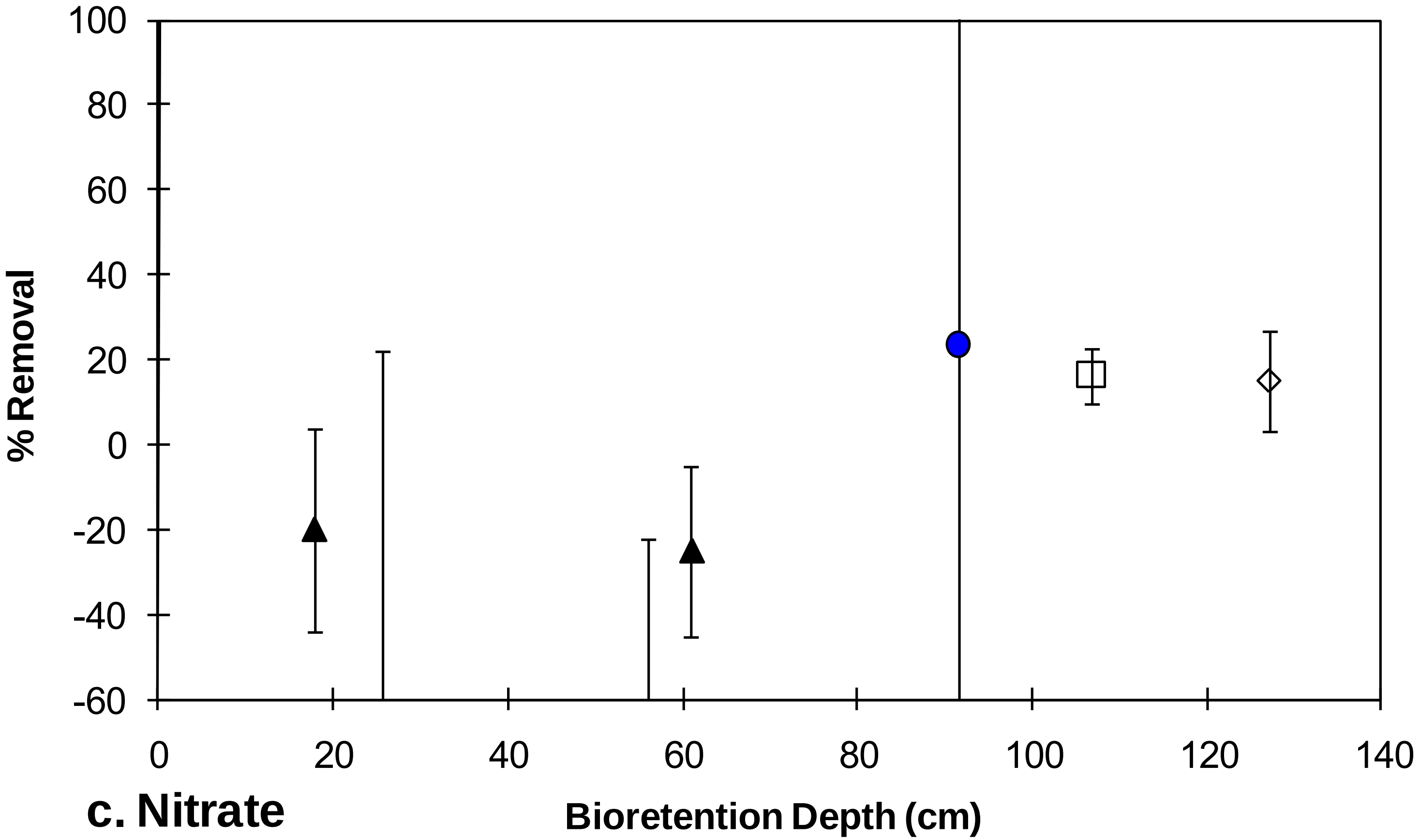
Passeport et al. 2009

- Watershed area = 0.69 ha
- Bioretention Cells Area = 204m^2
- Fill Media/ Soil
  - 90% Expanded Slate Byproduct
  - 10% Top Soil
  - P-Index: Low
  - 0.6 m & 0.9 m (2 & 3 feet) depth
- Both Cells Covered in Turf (Hybrid Bermuda)

TN concentrations: Grassed Graham HS Bioretention (2006)



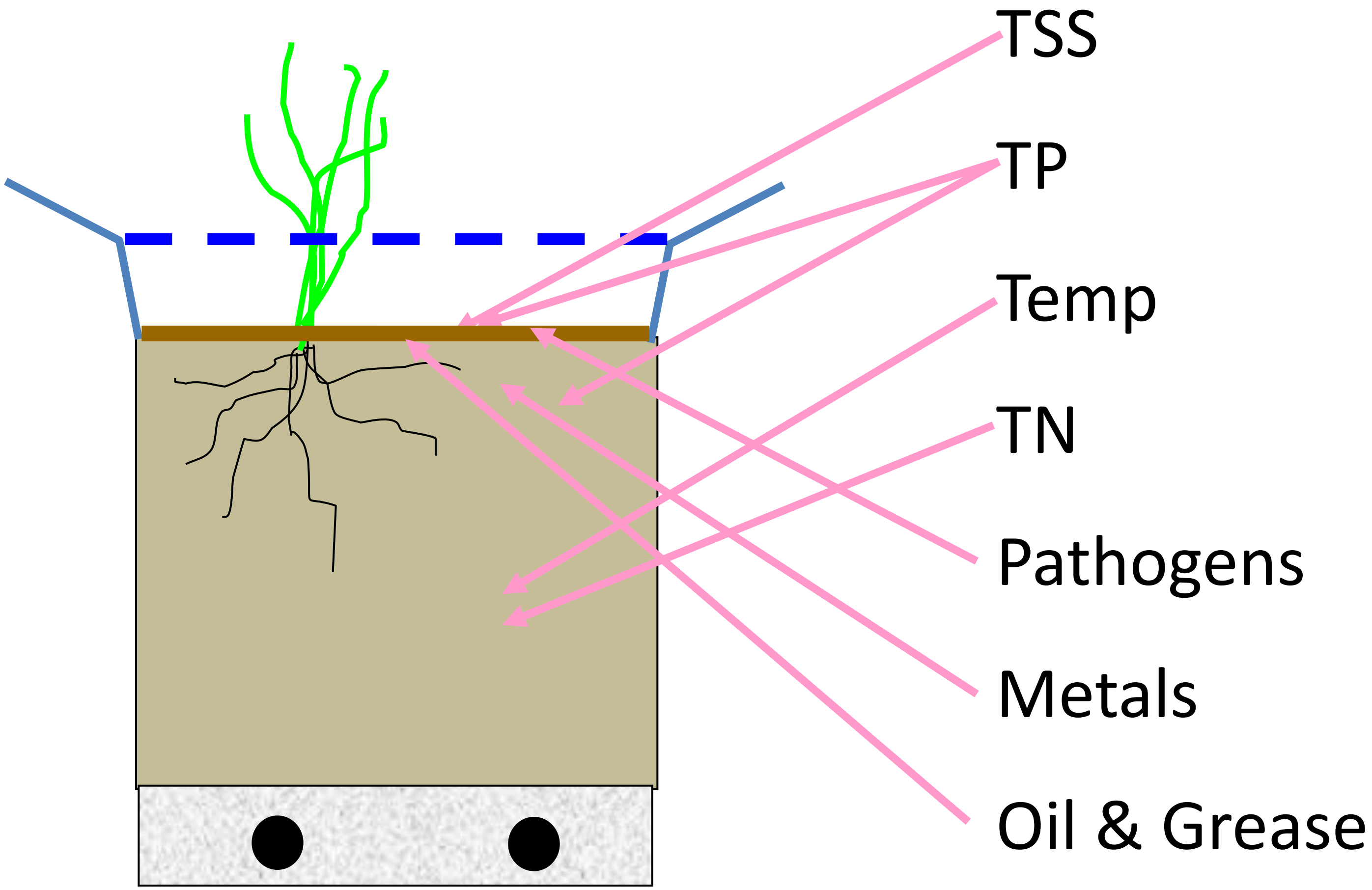
Nitrate with Depth



Take Home Points: Nitrogen

- Proper Amts of Organic Matter is Critical
- With good media, TN sequestration is high.
- Somewhat deeper media (≥ 3 ft) may be best (esp. for NO_{2-3}-N)

Where are pollutants removed?



Literature/Research Justification for Minimum Media Depths: WQ

Pollutant	Depth (ft)	Studies
TSS	1	Diblasi et al. 2009, Li et al. 2008
Metals	1	Li and Davis 2008, Hatt et al. 2009
O&G	1	Diblasi et al. 2009,
Phosphorus	2 (min); 3 (conservative)	Hatt et al. 2009, Hsieh and Davis 2007, Passeport et al. 2009
Nitrogen	3	Passeport et al. 2009
Temperature	3 (min); 4 (optim)	Jones and Hunt 2009

DON'T FORGET HYDROLOGY… deeper cells = greater potential for volume control

Hunt et al. 2012. JEE (June Issue)

Question: What's the Ideal Fill Media Composition?

Infiltration Rate:

- Varies: Contact Time
- Temperature reduction and N removal
  - More Contact Time
  - 1-2 in/hr
- TSS, High Sat K is OK
  - > 6 in/hr
- Heavy metals… jury is out

Final Take Home Points: from Bioretention Research…

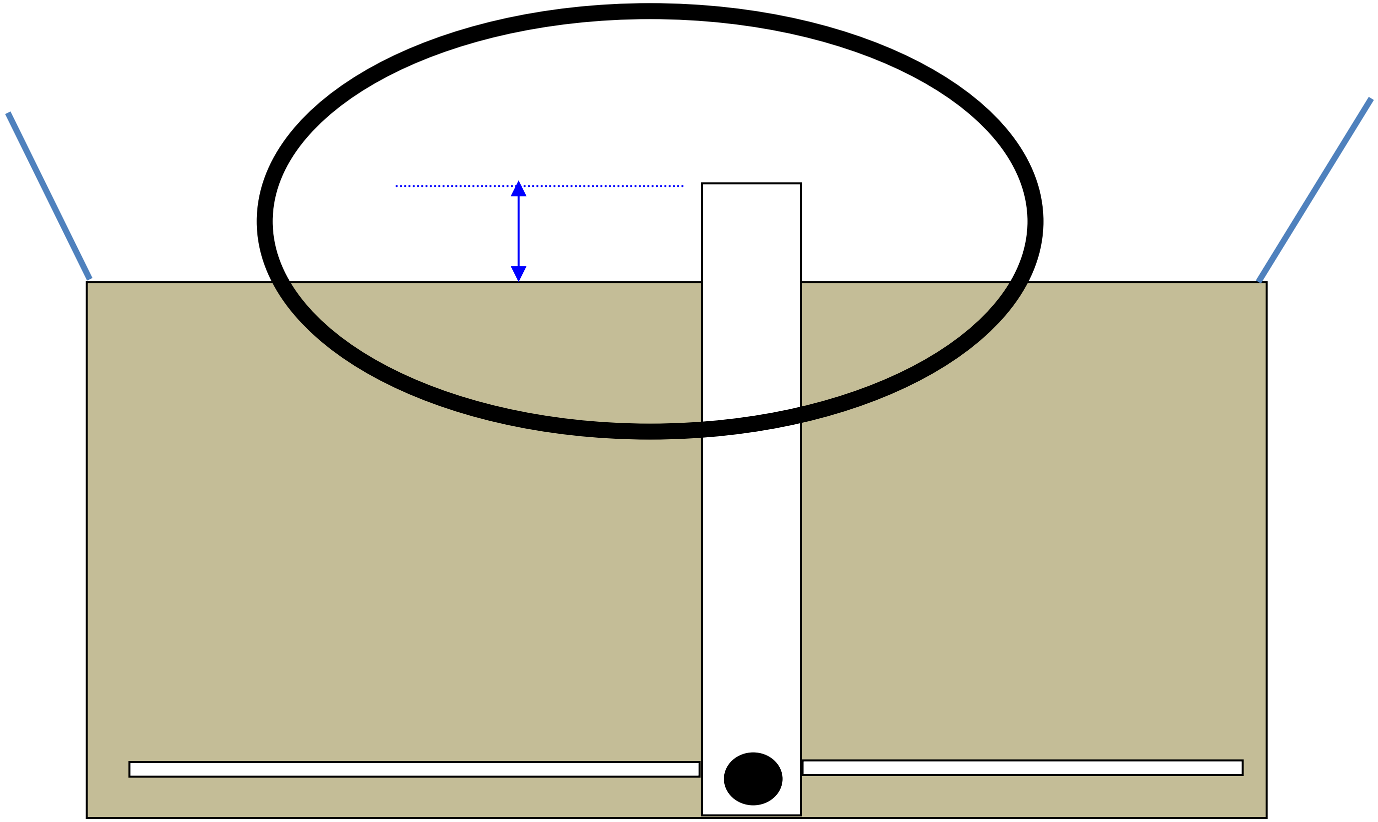
- Improve Hydrology
  - Modest Peak Flow Mitigation
  - Long-term Hydrology Balance
  - Leads to Pollutant Load Reduction
- Reduce Pollutant Concentrations / Release Low Pollutant Concentrations
  - TSS
  - Metals & Hydrocarbons
  - TP & TN
  - Bacteria

But, must be careful with Media Selection.

Common Design Questions

Question: Ponding Depths

What is this depth?



Pretty Nice Amount of Ponding

Bowl Depth Particularly Important. Determines S.A. of BRC

Ponding?

Recommended Ponding Depths

For Water Quality Volume Treatment

- PG Co, Maryland specifies 6 in
- Dr. Hunt (NCDENR) suggests 12 in reasonable for most applications WITH maintenance
- 18 in only if VERY SANDY application (e.g. on remnant dunes?)
- TP10 - NZ (2003): average 9 in
- Waitakere City LID CoP - NZ (2010): 12 in

Q:How much Fill Soil Media Needed?

“W

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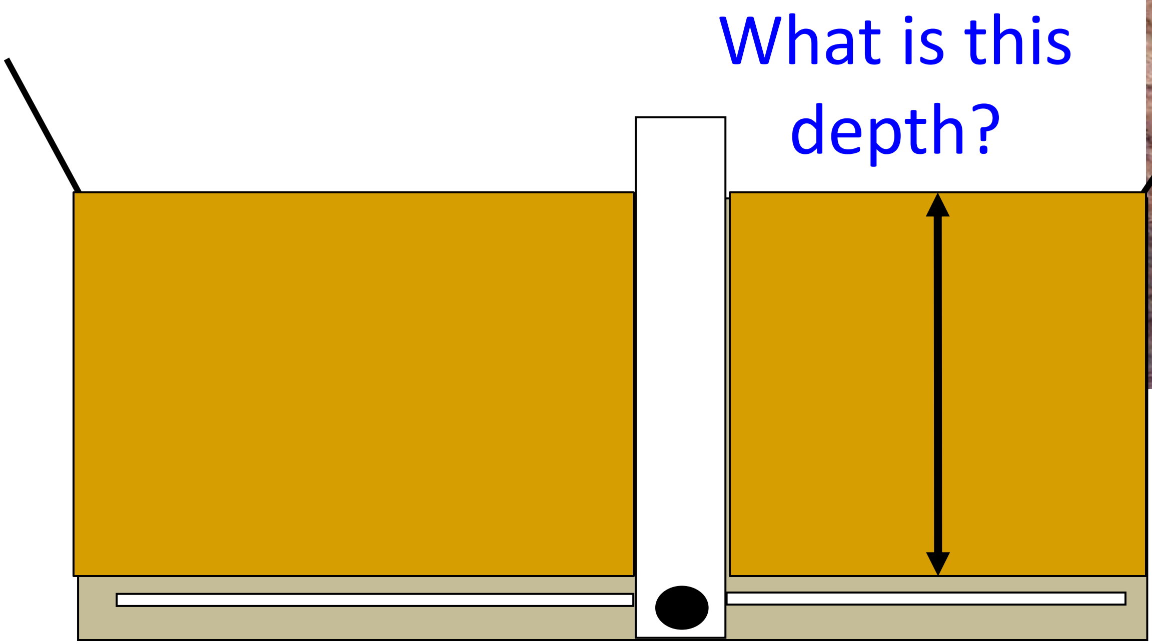
Media Depth

- Major Cost Consideration



Fill Media Depth predicated upon 3 factors

- Vegetation Health
- Hydrologic Goals
- Water quality needs
- Perhaps the most restrictive goal dictates design

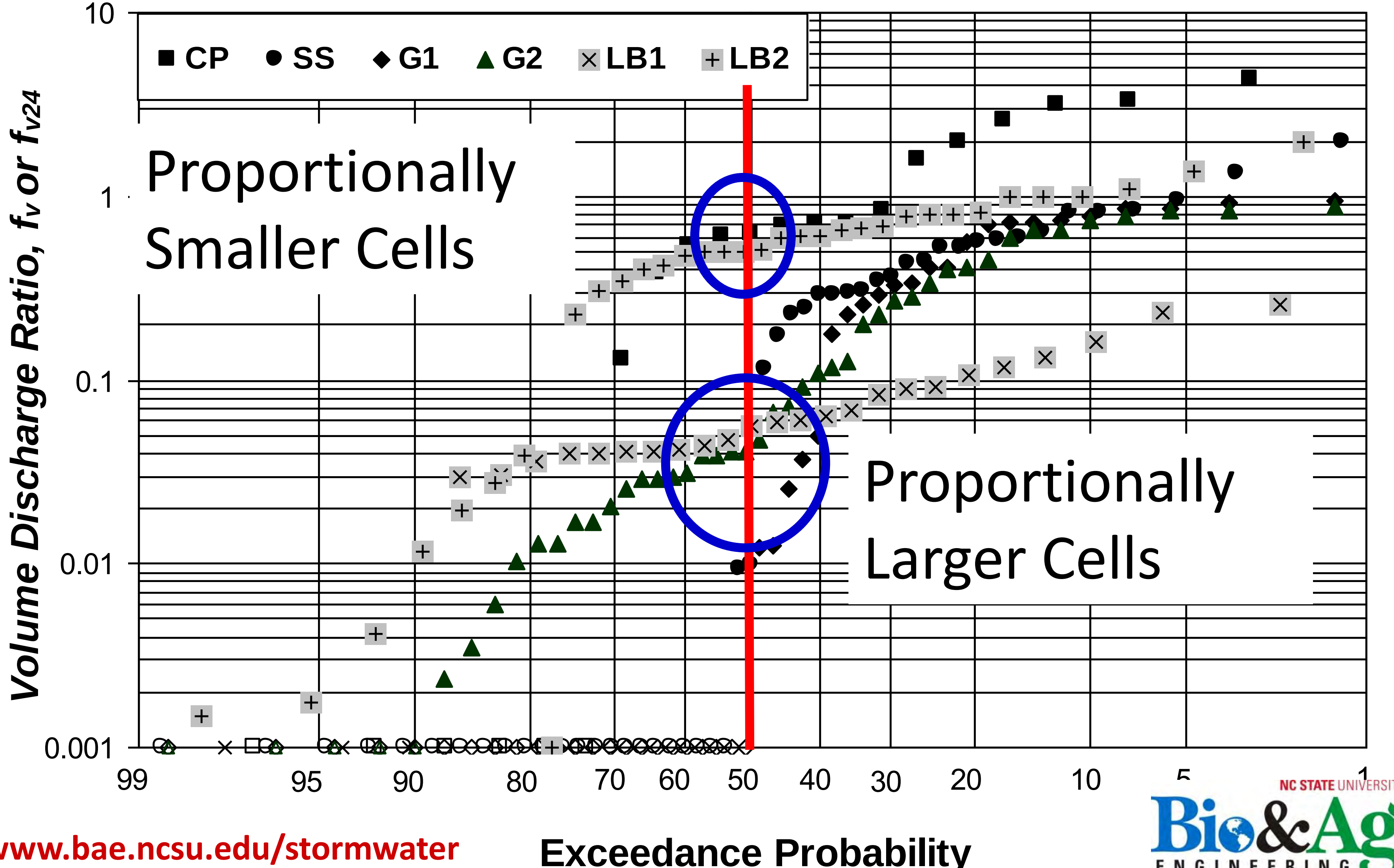
Bioretention Soil Depth: Vegetation Health

Vegetation	Depth (ft)
Grass	1.0-1.5
Shrubs	1.5-2.5
Shrubs/Trees	2.5-3.0

Some thoughts…

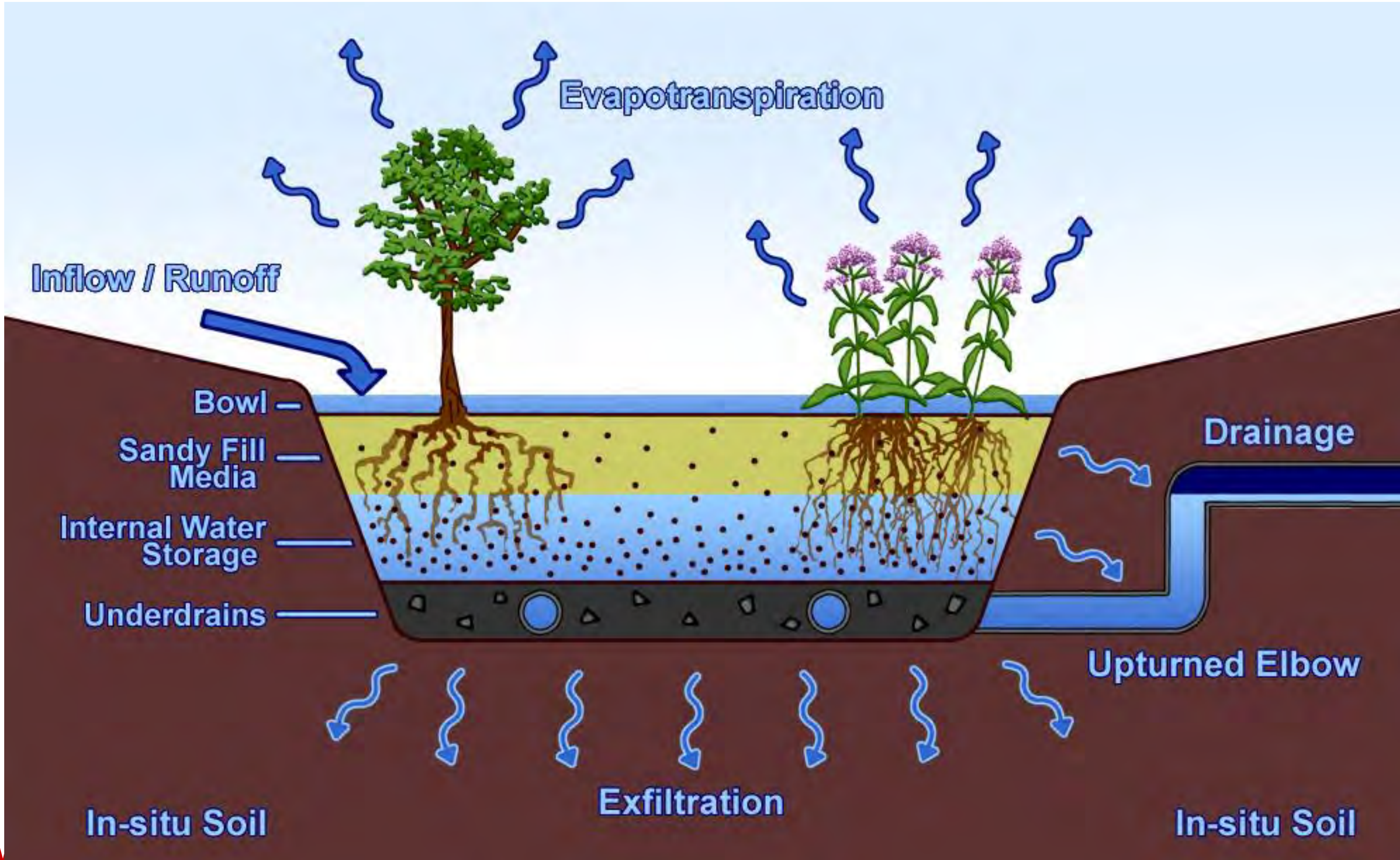
1. **Deeper cells may provide moisture reserves for extended dry periods.**
2. **Deeper cells provide runoff VOLUME reduction, regardless of in-situ soil condition or lining.**

Hydro & WQ Design Goals



Media Selection – Must have **LOW** P-Index must be low/low-mod. (10-30)

Internal Water Zone Bioretention Cell Schematic



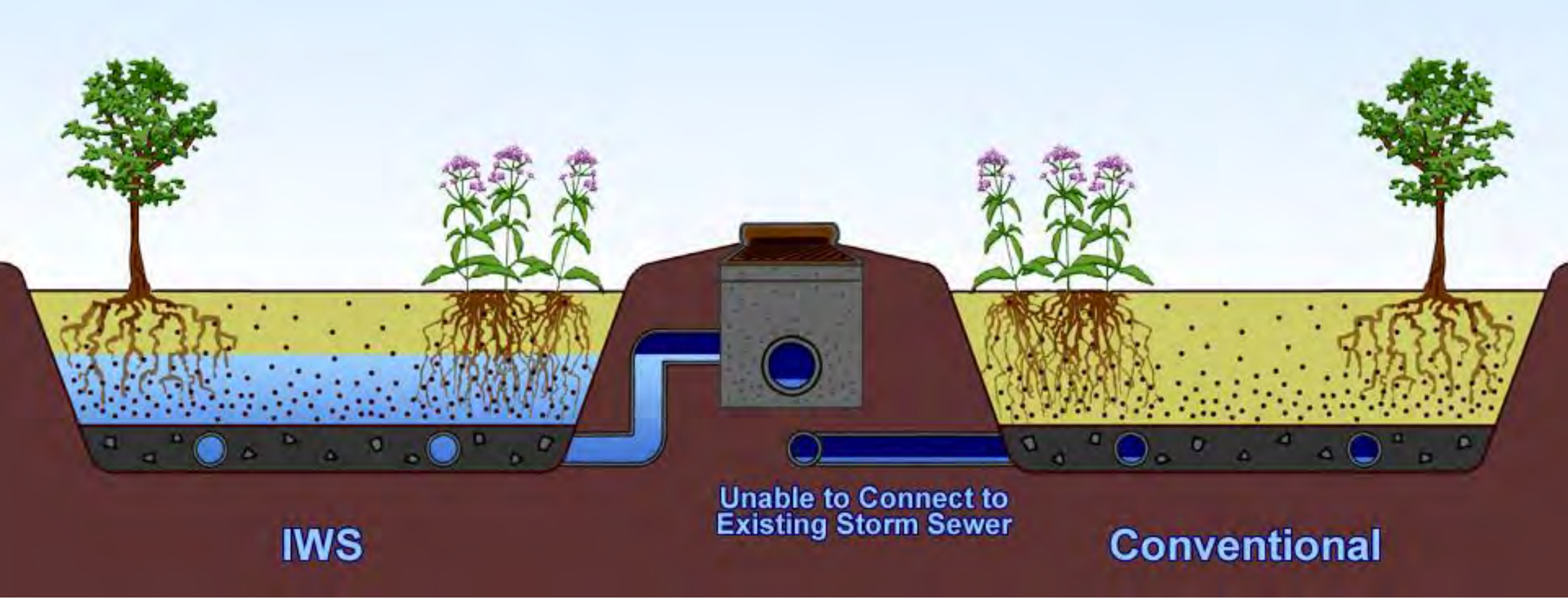
What is an Internal Water Storage Zone?

- Internal Water Storage = IWS
- Originally developed to improve nitrate reduction in N-sensitive watershed
  - Bottom of cell remains saturated → anaerobic conditions created to reduce nitrate TN
- Main benefit → "Infiltration Enhancer"
  - Biggest impact in sandy in-situ soils
    - Outflow → rare

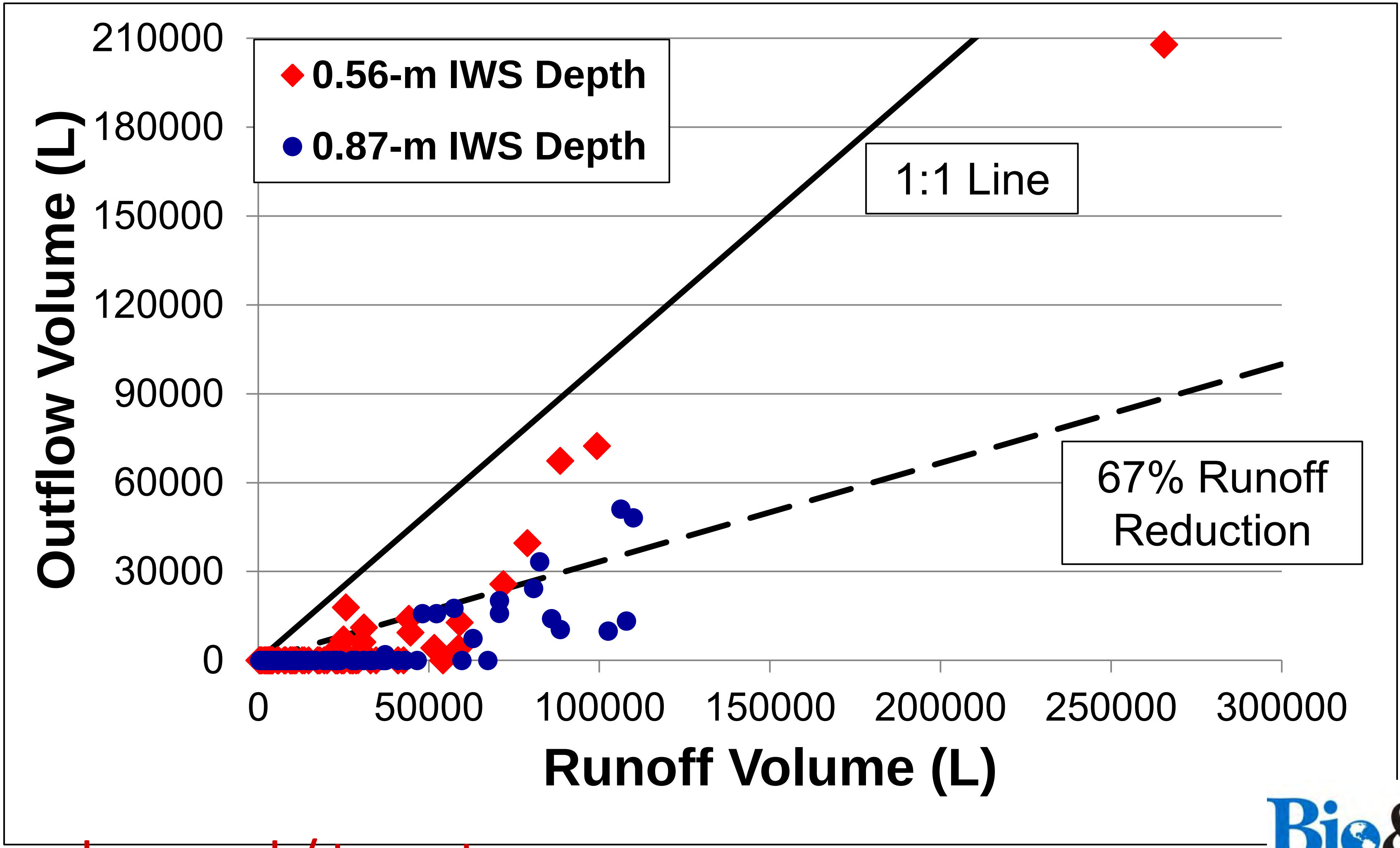
Most Common Install Method: Upturned Pipe in Outlet

Looking down into the Overflow Basin

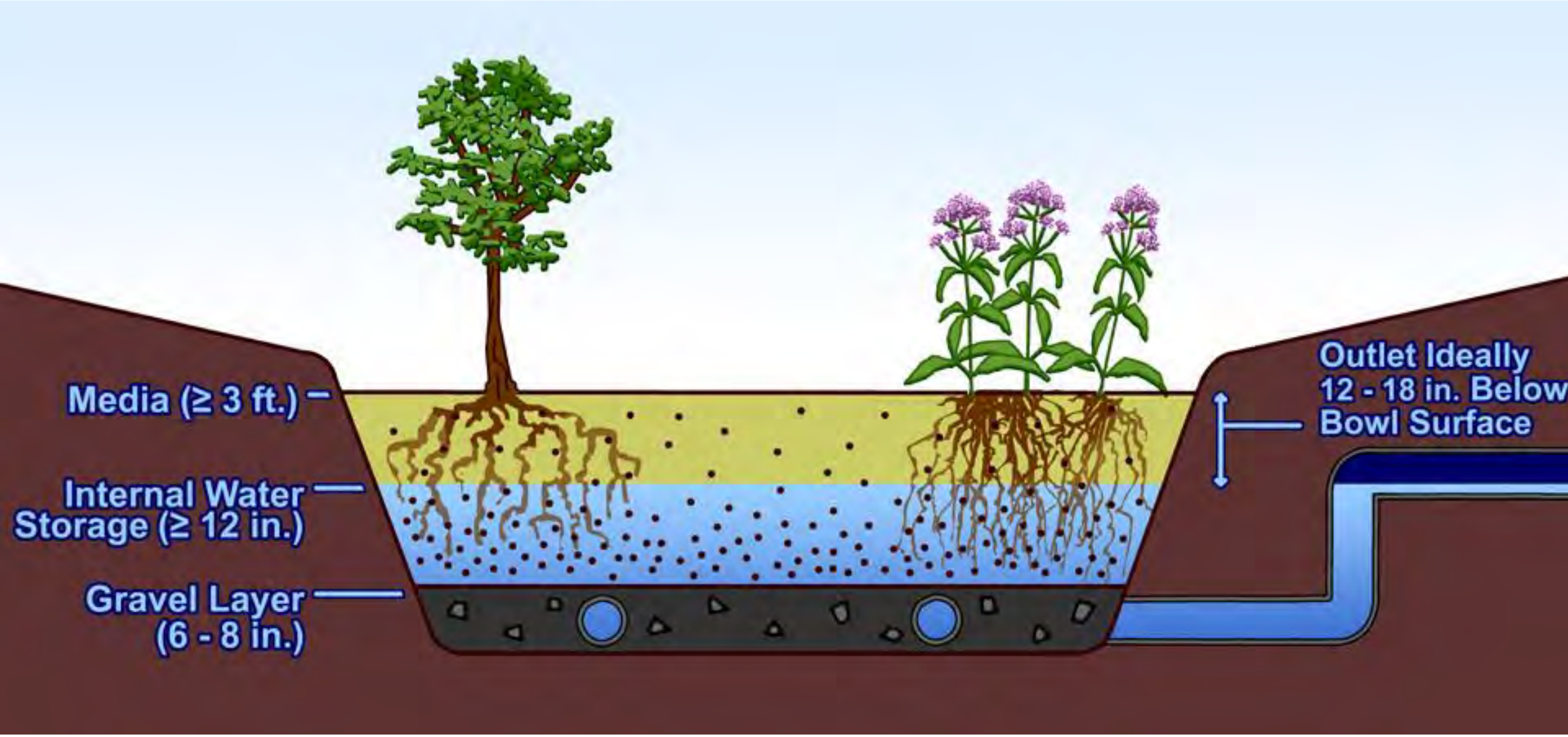
Retrofit Ease / Cost Savings



Outflow vs. Runoff
(Sandy clay loam underlying soil)



New NCDENR Design Guidance



Should the Sides & Bottom of Rain Gardens be Lined?

- Not usually, except…
- Brownfield Construction
- Foundation preservation
- Research
- Maybe, if SHWT a concern

Question: What Pretreatment is Needed?

- Rain Gardens NEED pre-treatment, but not necessarily forebays.

BRC Forebays

Pretreatment: Swales

Take Home Design Points: Pre-treatment

- Include pre-treatment (forebay, swale or filter strip) with Rain Garden
- Effectiveness is determined using Aberdeen Eqn or Stokes Law

Concerns With Bioretention

Despite popular myths... NOT a panacea

Bioretention Clogging & Plant Growth

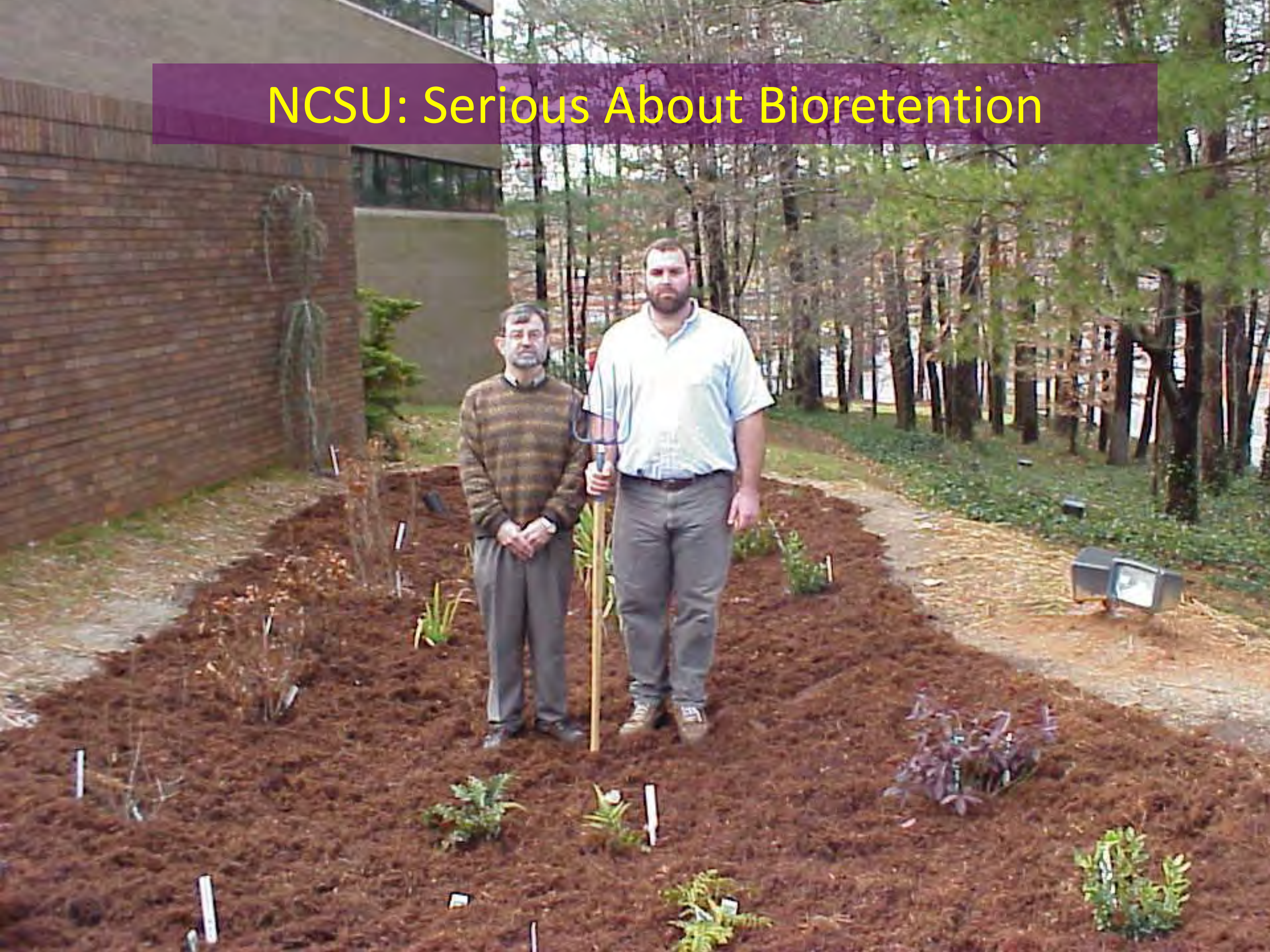
Take Home Construction Point:

- Sequencing is Essential
- B-R will CLOG
- Install as close to practical @ End of Project
- Stabilize Watershed

Excavation Technique to Enhance Infiltration – Read Bulletin

- Scoop vs. Rake
  - For final 0.25m of excavation, depth most affected by compaction

NCSU: Serious About Bioretention



Questions?

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