




Biohabitats
SOUTHEAST BIOREGION
Incorporated

NC STATE UNIVERSITY

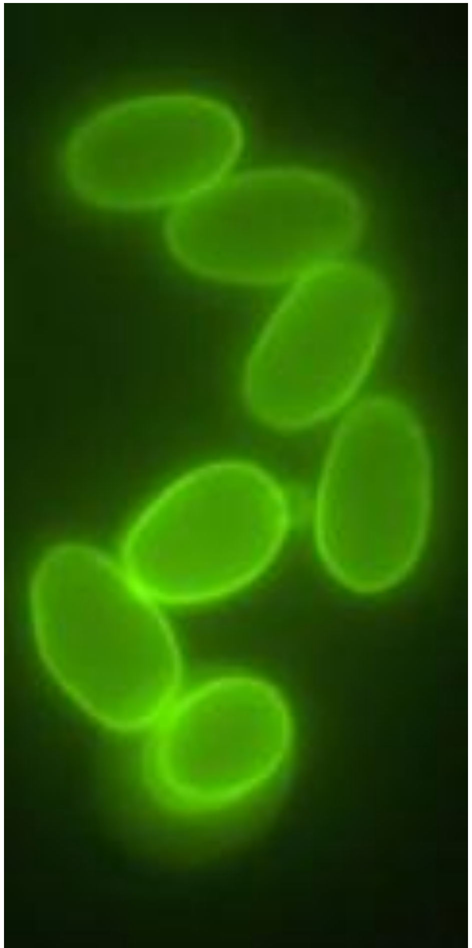
Indicator Bacteria Sequestration in Stormwater Wetlands

Jon Hathaway, PhD, PE

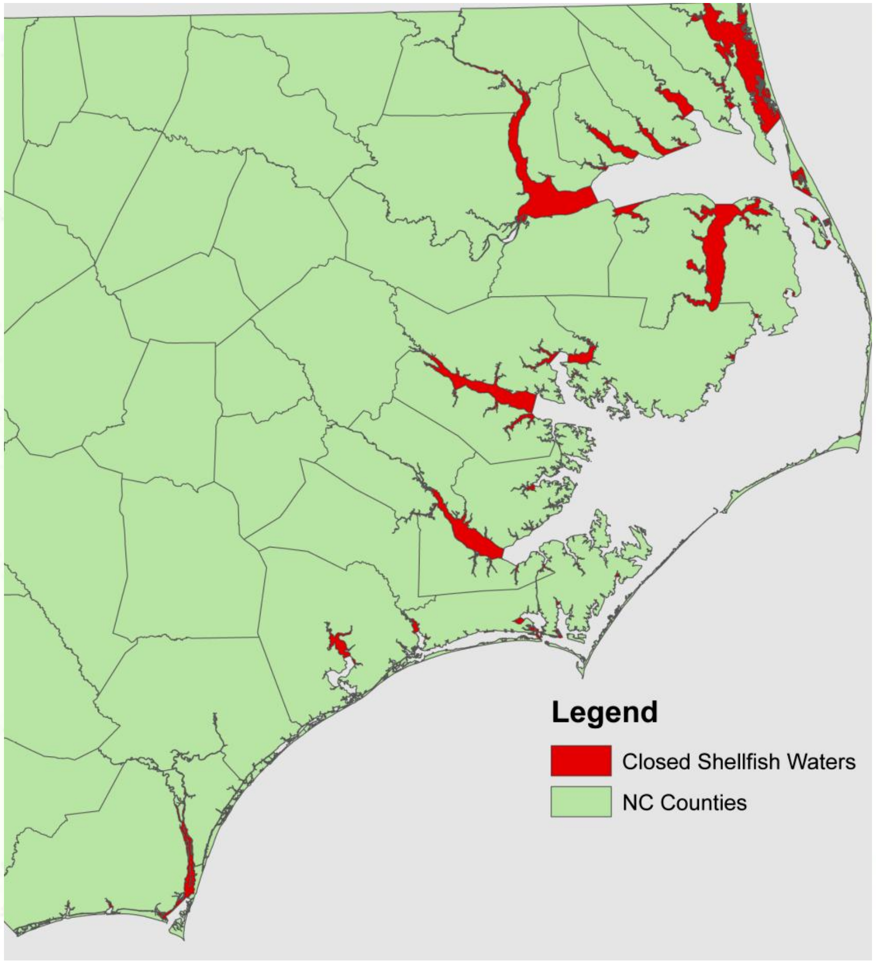
Bill Hunt, PhD, PE

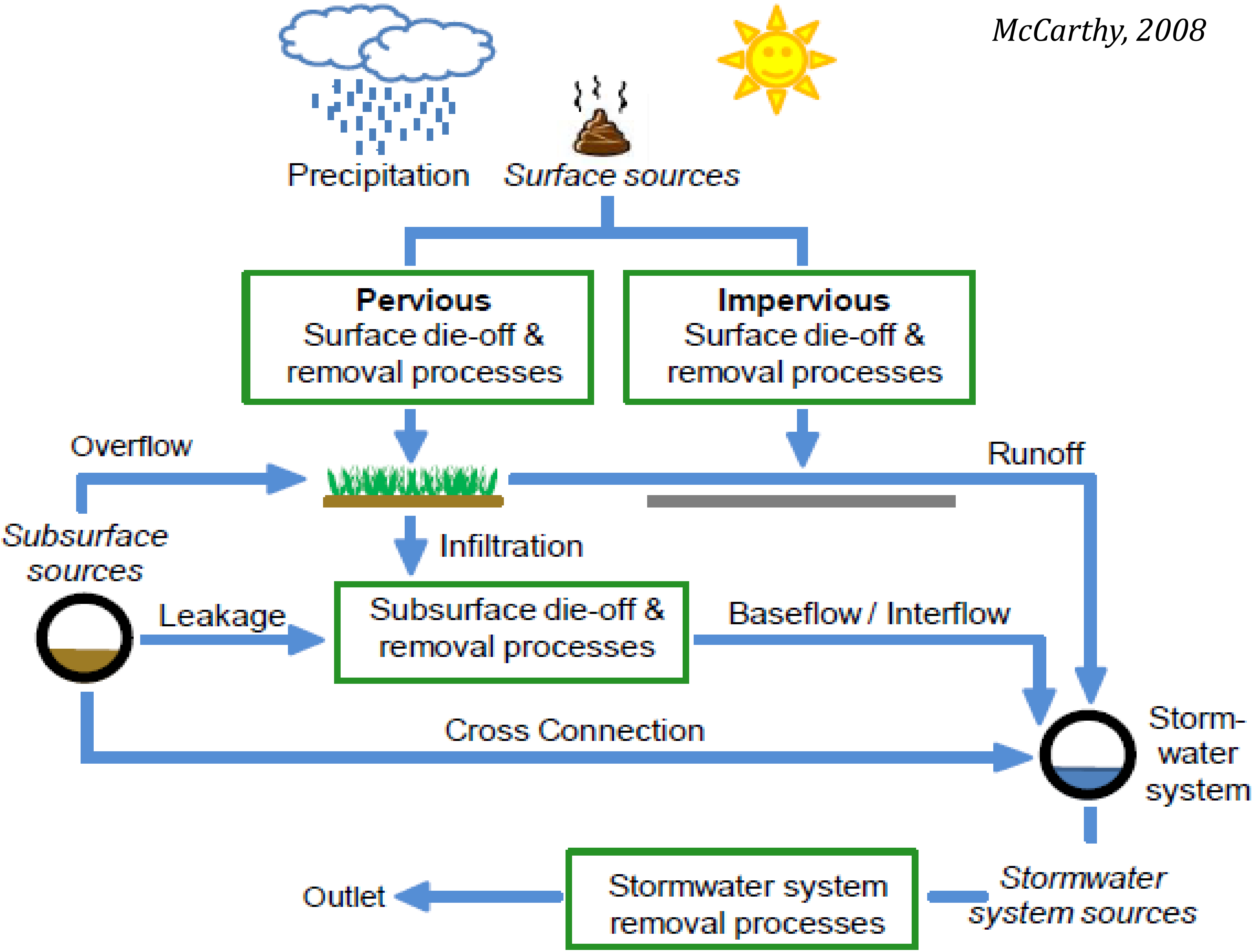
Bacteria Pollution

- USEPA – National Water Quality Inventory (2006)
  - 12% of surveyed streams and rivers were impacted by indicator bacteria
- Public health risk from pathogens
  - Recreation, Shellfish
  - Economic impact
- Indicator bacteria
  - Fecal coliform
  - *E. coli*
  - Enterococci


(H.D.A Lindquist, U.S. EPA)

Threat From Pathogens

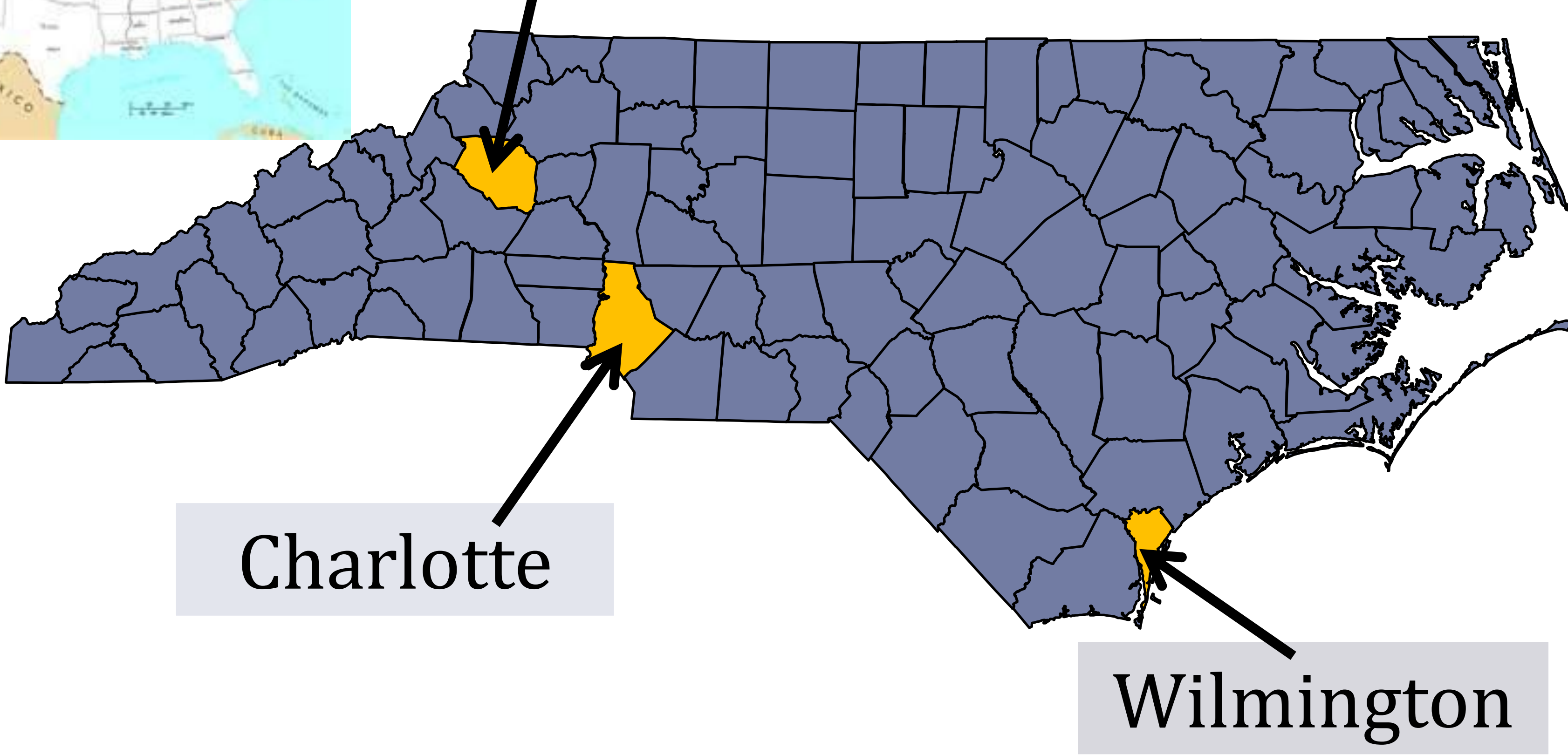



McCarthy, 2008
Precipitation
Surface sources
Pervious
Surface die-off &
removal processes
Impervious
Surface die-off &
removal processes
Overflow
Runoff
Subsurface
sources
Infiltration
Leakage
Subsurface die-off &
removal processes
Baseflow / Interflow
Cross Connection
Storm-
water
system
Stormwater
system sources
Outlet
Stormwater system
removal processes

Stormwater Wetlands

- Pros
  - UV Exposure?
  - Sedimentation
  - Predation
- Cons
  - Persistence in Soils?
  - Wildlife
  - Resuspension

Project Locations



Monitoring

- Scratching the surface
- Grab samples at inlet and outlet of each BMP
  - Charlotte: Fecal Coliform and *E. coli*
  - Wilmington: *E. coli* and enterococci
- Charlotte: 5 -19 samples
  - 9 BMPs monitored
- Wilmington: 15-20 samples
  - 6 BMPs monitored

Wetland 1 - Charlotte

Wetland 2 - Charlotte

Wetland 1 - Wilmington

Wetland 2 - Wilmington

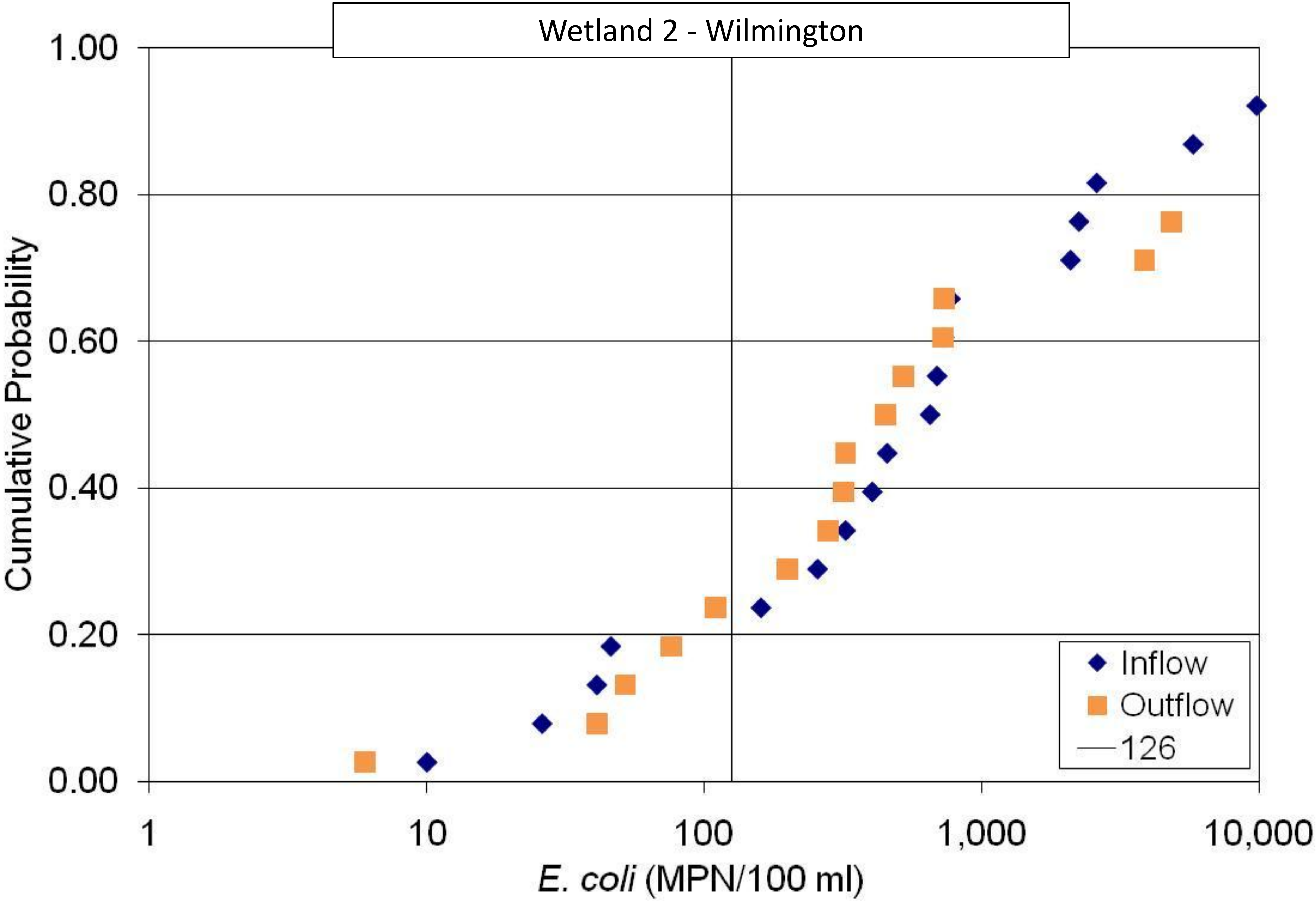
BMP Efficiency

BMP Type	Efficiency Fecal Coliform (%)	Efficiency E. coli (%)	Efficiency Enterococci (%)
Wetland 1 - Charlotte	98*	96*	-
Wetland 2 - Charlotte	56	33	-
Wetland 1 – Wilmington	-	1	69
Wetland 2 - Wilmington	-	-18	41

*** = statistically significant**

(Hathaway et al. (2009) Journal of Environmental Engineering)

(Hathaway and Hunt (2012) Journal of Irrigation and Drainage Engineering)


Wetland 2 - Wilmington
1.00
0.80
0.60
0.40
0.20
0.00
Cumulative Probability
1
10
100
1,000
10,000
E. coli (MPN/100 ml)
Inflow
Outflow
126

Effluent Concentrations

BMP Type	*E. coli* Concentrations		
	Geometric Mean Influent	Geometric Mean Effluent	% of samples under 126 counts/100 ml
Wetland 1 - Charlotte	2400	106	33
Wetland 2 - Charlotte	1295	864	10
Wetland 1 – Wilmington	834	826	28
Wetland 2 - Wilmington	425	503	28

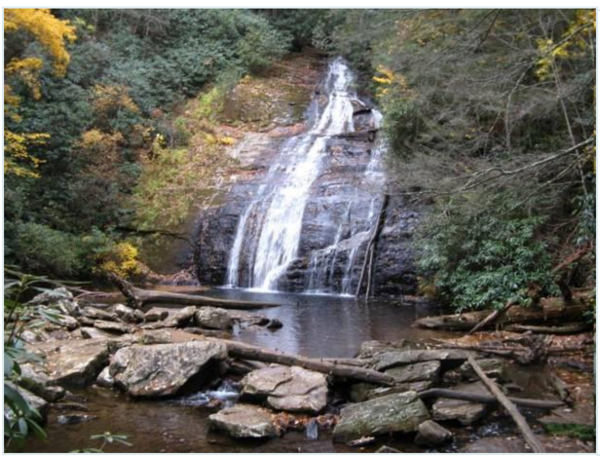
BMP Efficiency - Charlotte

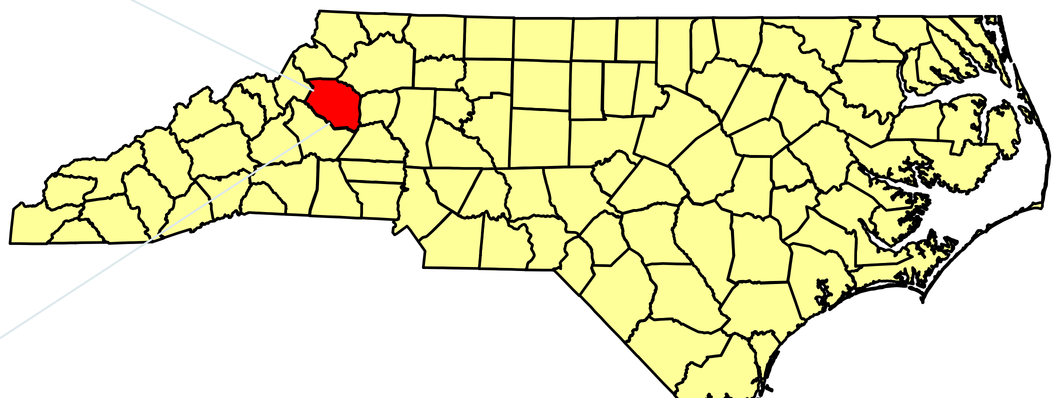
Take Home Points – Stormwater Controls

- Wetland performance
  - Poor sunlight exposure
  - Production within system
- Some stormwater controls may be sources of bacteria
  - Presence of animal activity
  - Wet, nutrient and organic rich environments
- Can data be extrapolated between regions?
  - Potential differences in particle-association
    - Sands vs. clays
    - Transport and/or resuspension
- Differences in performance for indicators?

City of Lenoir and Caldwell County

- Developing City and County
  - Phase II
- Demonstration Projects
- Google!





Lenoir Wetland

Design Summary

- Excavation Depth: 2.1 – 2.7 m
- Surface area: 2.1 acres
- Normal Pool Depth: 0-15 cm
- Storage depth: 30-38 cm
- Storage for > 90% of the 2.5cm storm
- Site will hold water - But topsoil is necessary to support plant growth

Winter Aerial

Restore the Earth and Inspire Ecological Stewardship

Biohabitats
SOUTHEAST BIOREGION
Incorporated

August 2009

Research

Lenoir Wetland Monitoring

- Grab samples
  - Base flow and during events
  - Multiple points
- Soil bacteria sampling
  - Multiple locations
  - Multiple “zones”

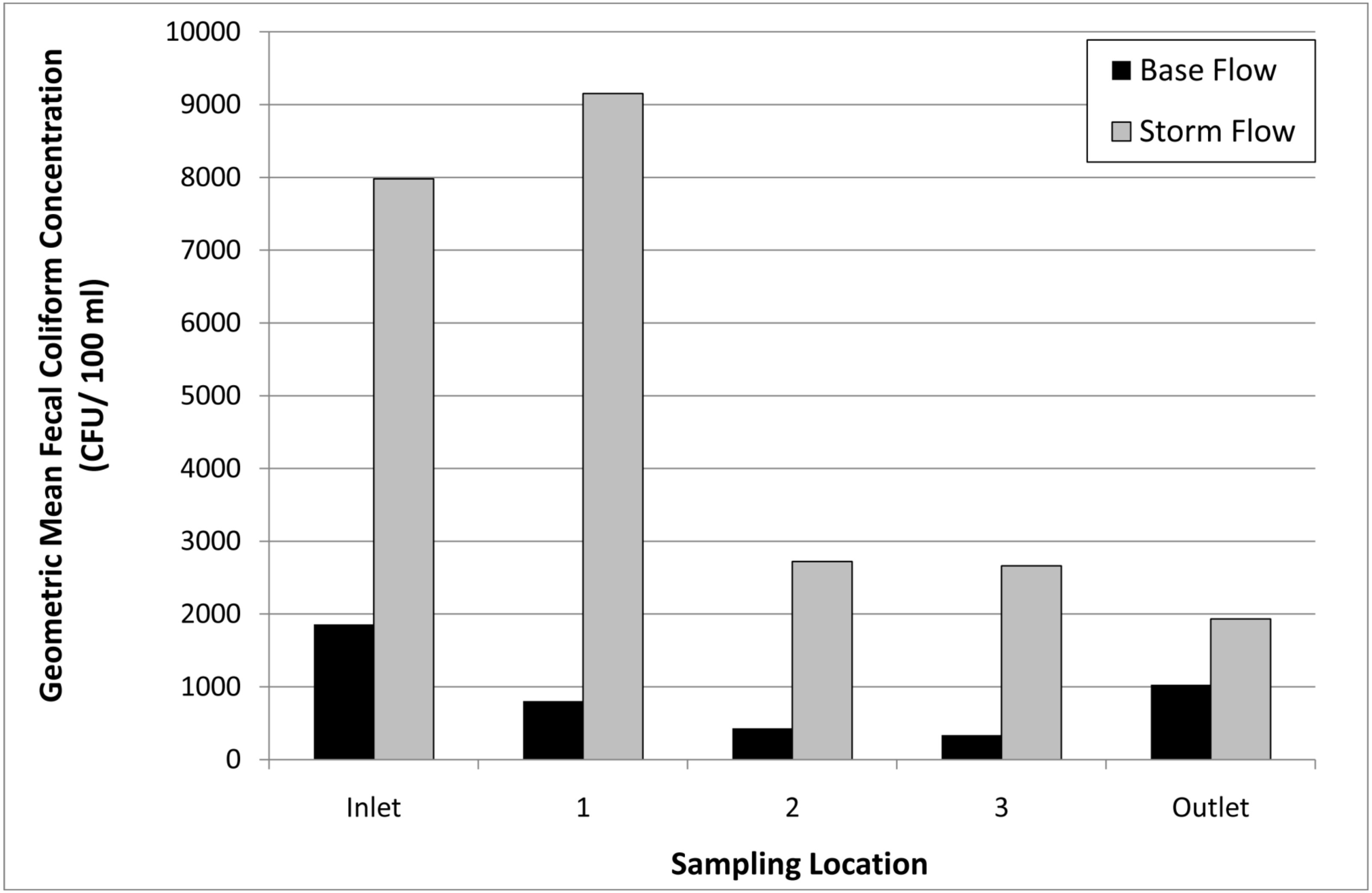
Lenoir Wetland

Restore the Earth and Inspire Ecological Stewardship

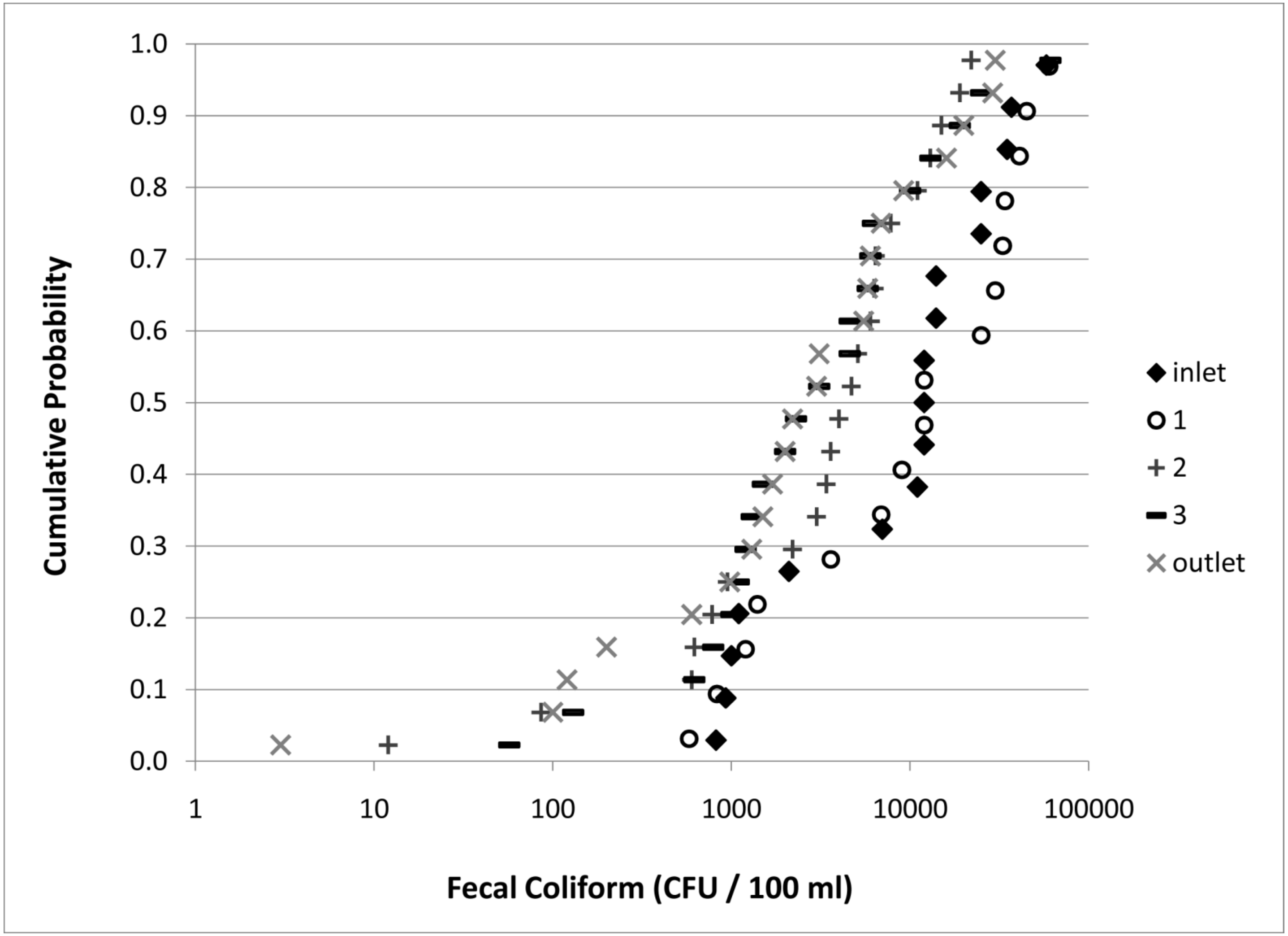
Biohabitats
SOUTHEAST BIOREGION
Incorporated

Lenoir Wetland

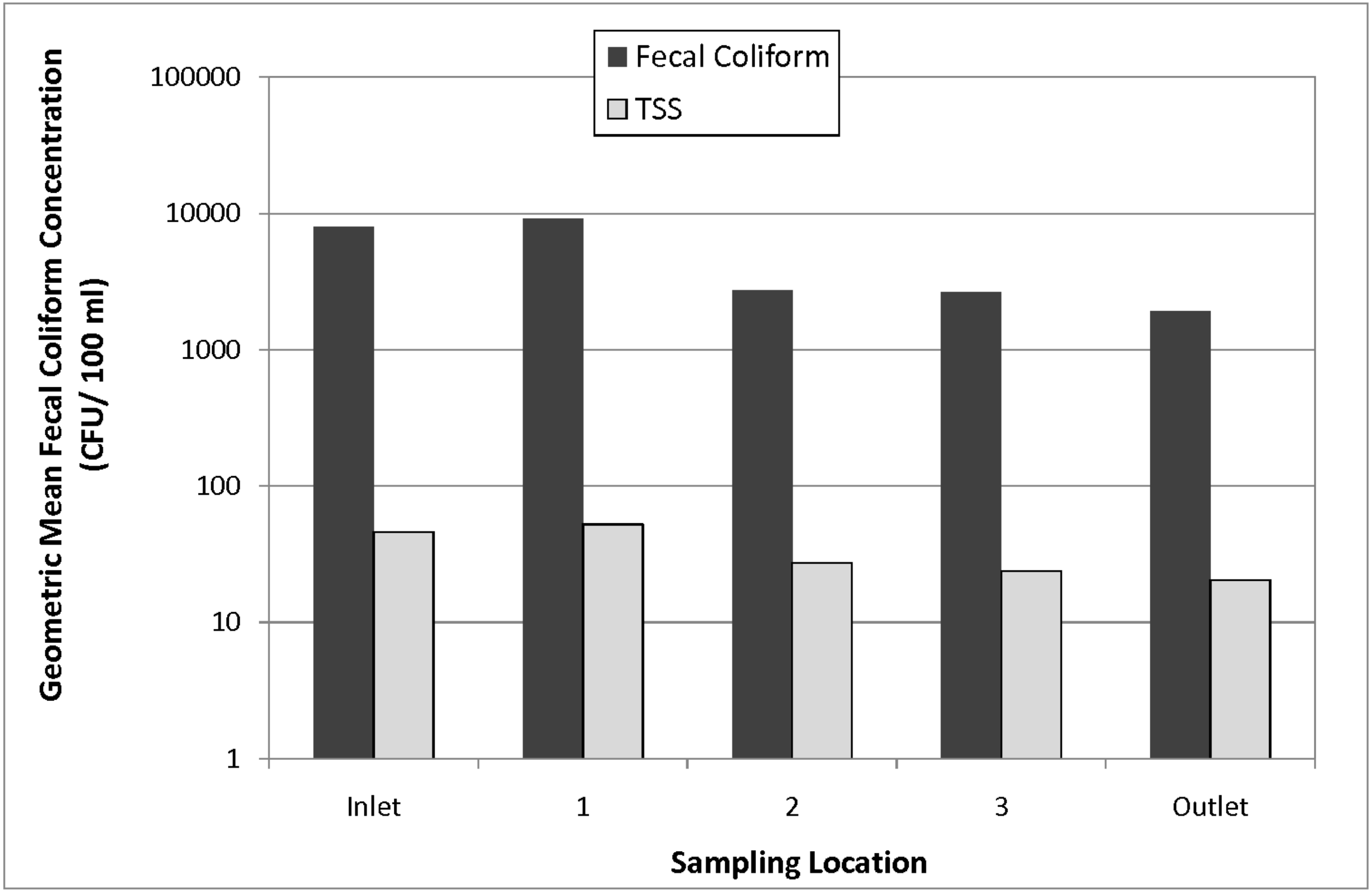
Lenoir Wetland



Lenoir Wetland



Lenoir Wetland



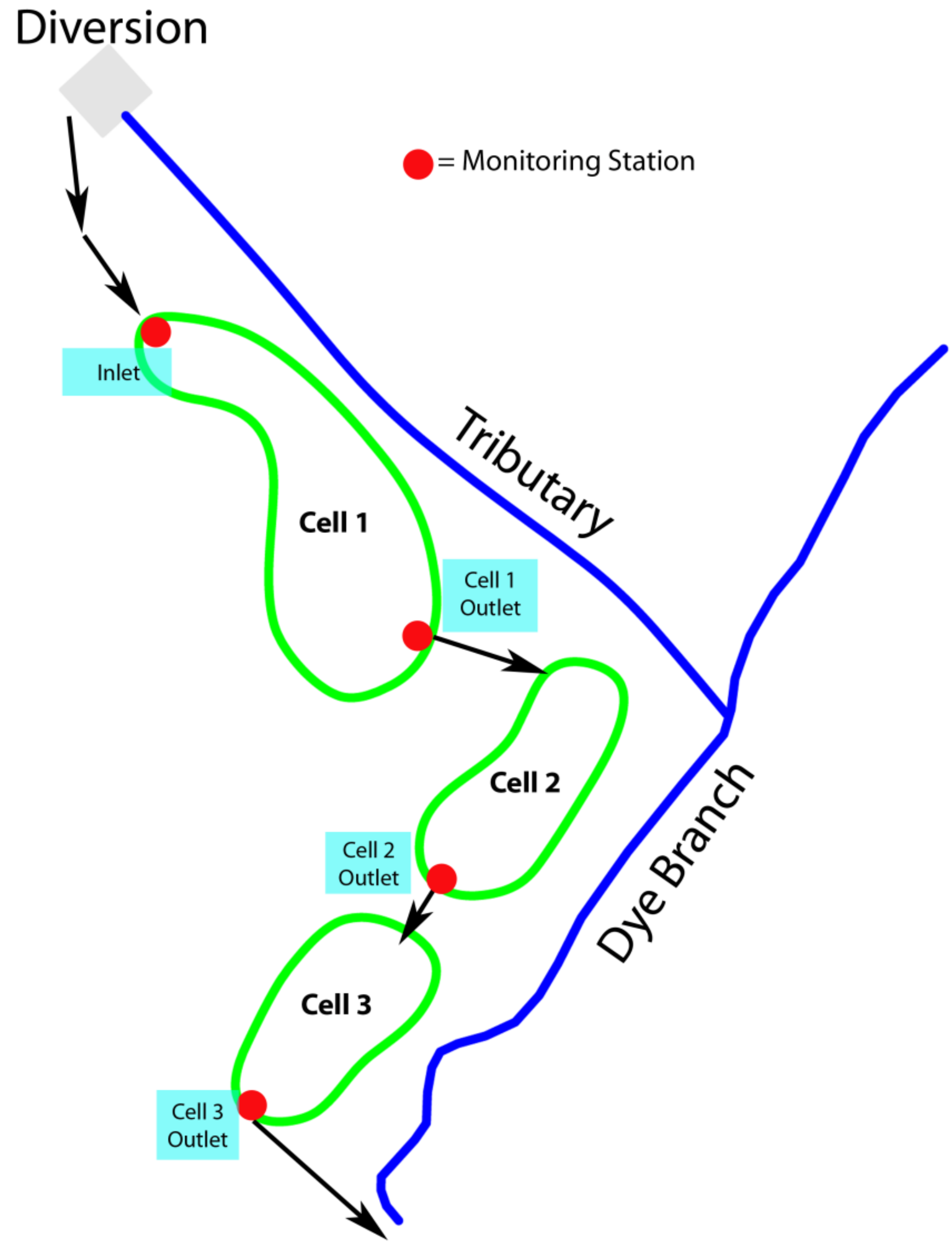
Take Home Points

- Storm flow clearly has higher concentrations
- Baseline microbe concentration appears to be reached
- No consistent correlations with TSS observed
- Relatively low soil-microbe concentrations
    - No difference noted among wetland regions

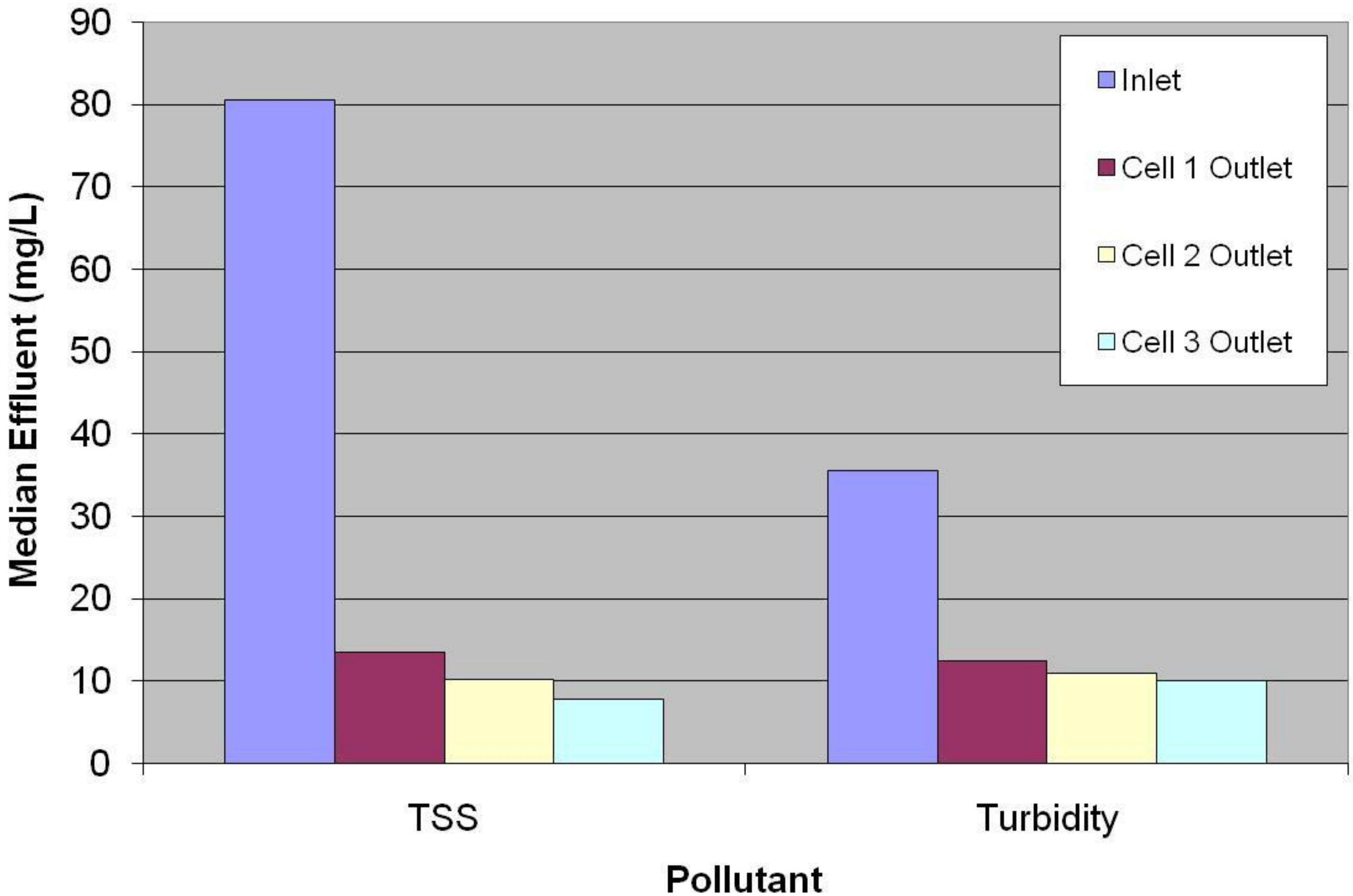
Dye Branch Wetlands

Restore the Earth and Inspire Ecological Stewardship

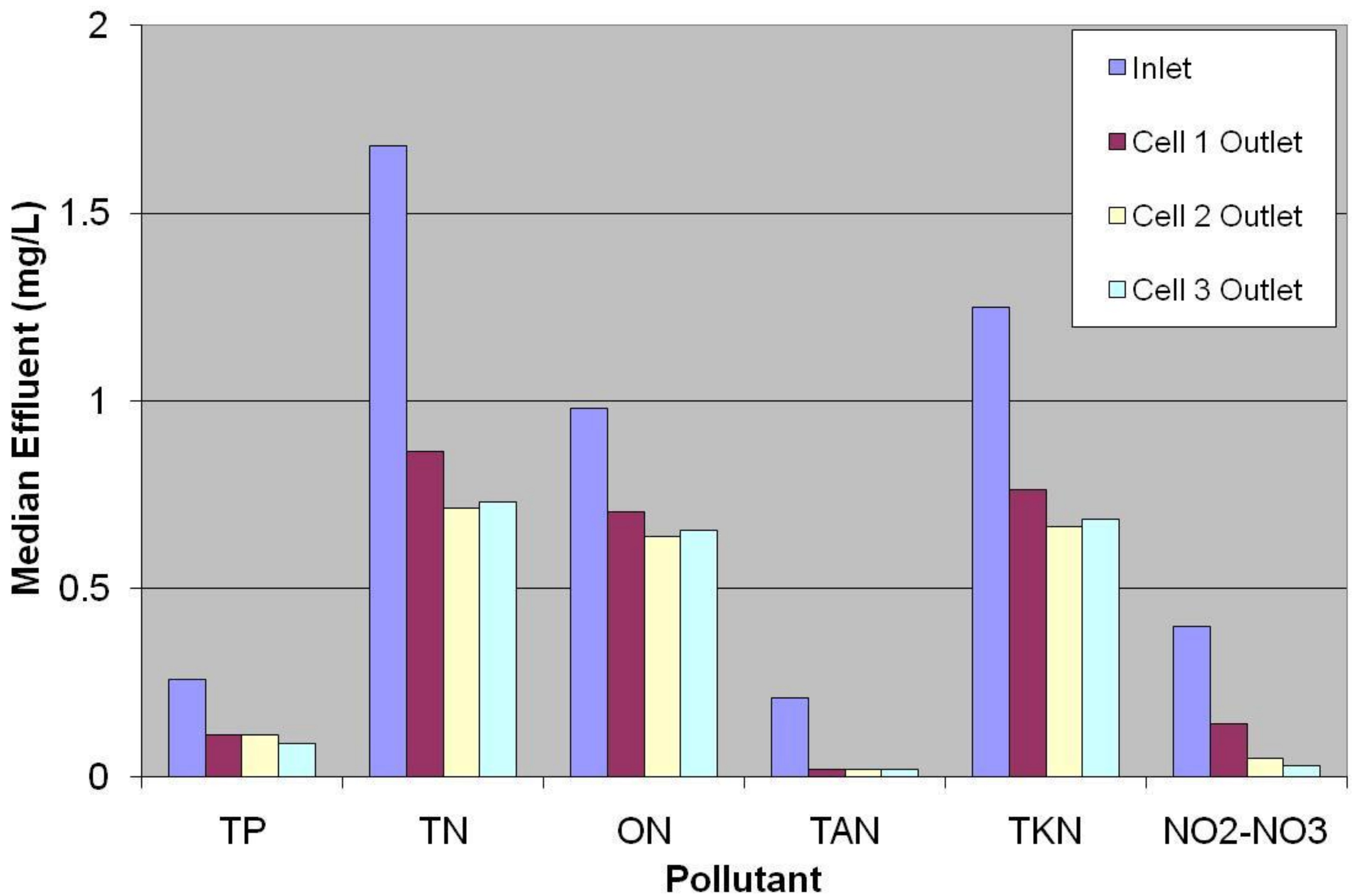
Biohabitats
SOUTHEAST BIOREGION
Incorporated


Diversion
= Monitoring Station
Inlet
Cell 1
Cell 1 Outlet
Tributary
Cell 2
Cell 2 Outlet
Cell 3
Cell 3 Outlet
Dye Branch

Results


90
80
70
60
50
40
30
20
10
0
Median Effluent (mg/L)
Inlet
Cell 1 Outlet
Cell 2 Outlet
Cell 3 Outlet
TSS
Turbidity
Pollutant

Results



2
1.5
1
0.5
0
Median Effluent (mg/L)
Inlet
Cell 1 Outlet
Cell 2 Outlet
Cell 3 Outlet
TP
TN
ON
TAN
TKN
NO2-NO3
Pollutant

Results – Efficiency Ratios

Pollutant	Inlet to Cell 1 Outlet	Cell 1 Outlet to Cell 2 Outlet	Cell 2 Outlet to Cell 3 Outlet
TSS	0.84[1]	0.11	0.18
TP	0.62	0.03	0.11
TN	0.52	0.12	0.03
ON	0.32	0.07	-0.02
TAN	0.85	0.26	0.13
TKN	0.44	0.09	-0.01
NO_2-NO_3	0.67	0.47	0.12
Turbidity	0.62	0.09	0.24

1: Significant differences are highlighted

Organic Nitrogen - EMC

Location	ON Concentration (mg/L)
Inlet	1.0
Outlet Cell 1	0.68
Outlet Cell 2	0.63
Outlet Cell 3	0.64

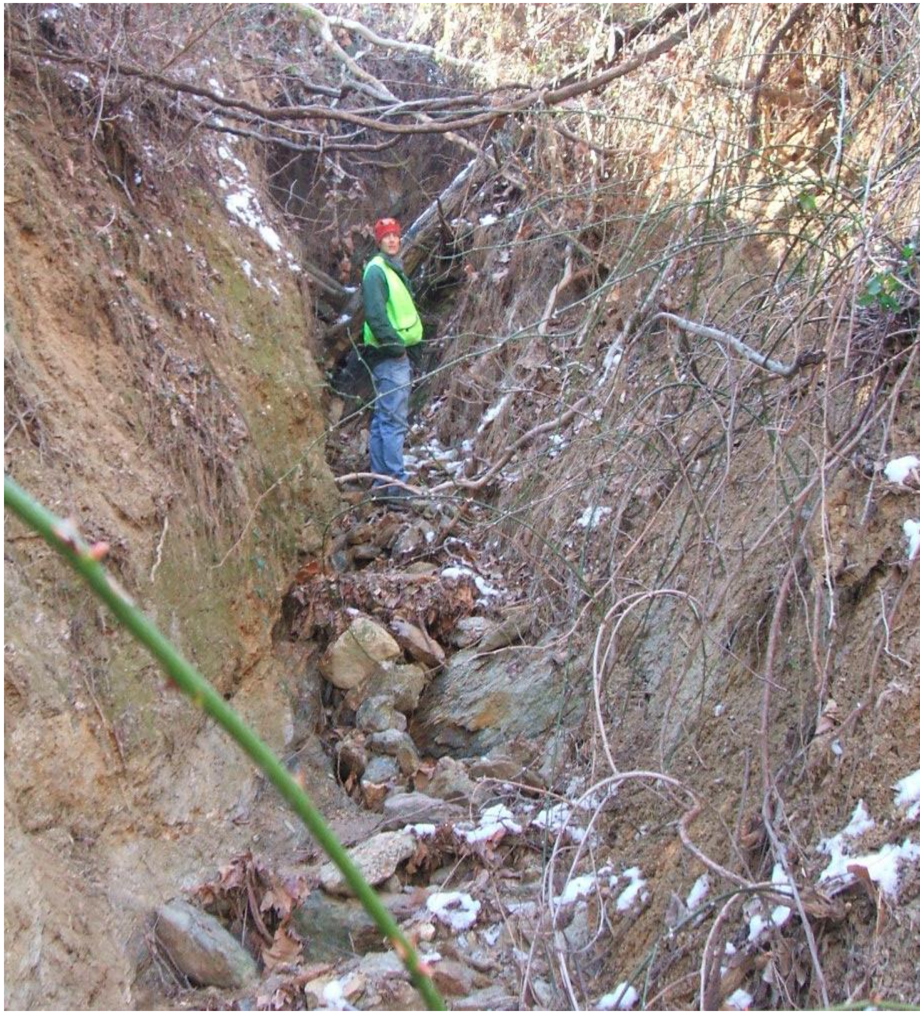
Looking Forward

- Revision of EPA standards for microbes
  - Not much detail here
- Narrow down on performance
  - What are reasonable expectations for BMPs?
- What factors explain variability in data?
- How can we link water quality requirements/BMP performance to public health?

Going Forward

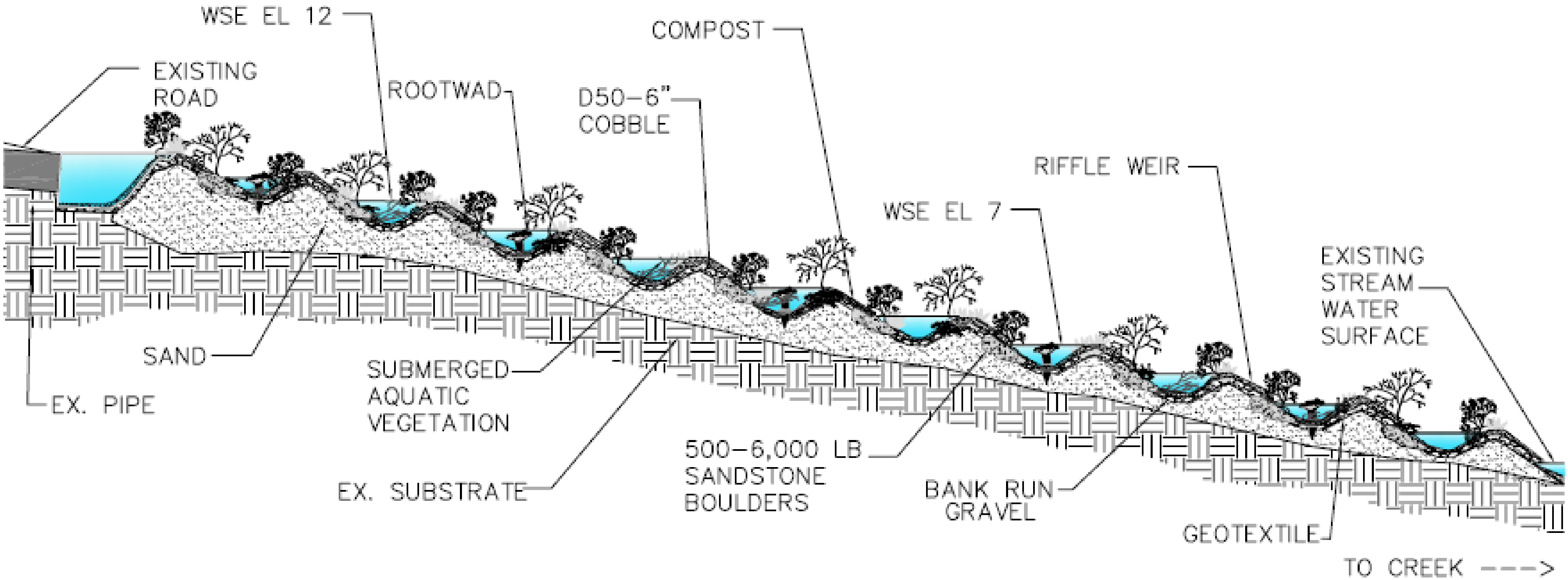
- Stacked Benefits
  - Water quality
  - Quantity control
  - Habitat
  - Aesthetics
  - Carbon sequestration
  - Ecosystem services
  - Urban heat island

End of Pipe Solutions?



Regenerative Stormwater Conveyance

Regenerative Stormwater Conveyance



Regenerative Stormwater Conveyance / Biofiltration Conveyance

- Retrofit "Batting Cleanup"
- Fixing maintenance issue
  - Integrate maintenance and WQ
- Ecological value
- Aesthetics
- Volume Reduction / Peak Flow Mitigation / WQ ?

References

- Hathaway, W.F. Hunt, S. Jadlocki. (**2009**). "Indicator bacteria removal in storm-water best management practices in Charlotte, North Carolina." *Journal of Environmental Engineering*, 135(12): 1275-1285.
- Hathaway, J.M., W.F. Hunt. (**2012**). "Indicator bacteria performance of stormwater control measures in Wilmington, NC." *Journal of Irrigation and Drainage Engineering*, 138(2): 185-197.
- Hathaway, J.M., W.F. Hunt, A.K. Graves, K.L. Bass, and A. Caldwell. (**2011**). "Exploring fecal indicator bacteria in a constructed stormwater wetland." *Water Science and Technology.* 63(11): 2707-2712.
- Hathaway, J.M., and W.F. Hunt. (**2010**). "An evaluation of wetlands in series in Piedmont, North Carolina." *Journal of Environmental Engineering*. 136(1): 140-146.

NCSU Resources

www.bae.ncsu.edu/stormwater

- Workshops
  - Design and maintenance
- Publications
  - Journal citations
  - Extension publications
- Additional websites
  - Specific to each research area

Questions?

- Jon Hathaway, PhD, PE
  - Water Resources Engineer, Biohabitats, Inc
  - jhathaway@biohabitats.com
  - (919) 518 - 0311