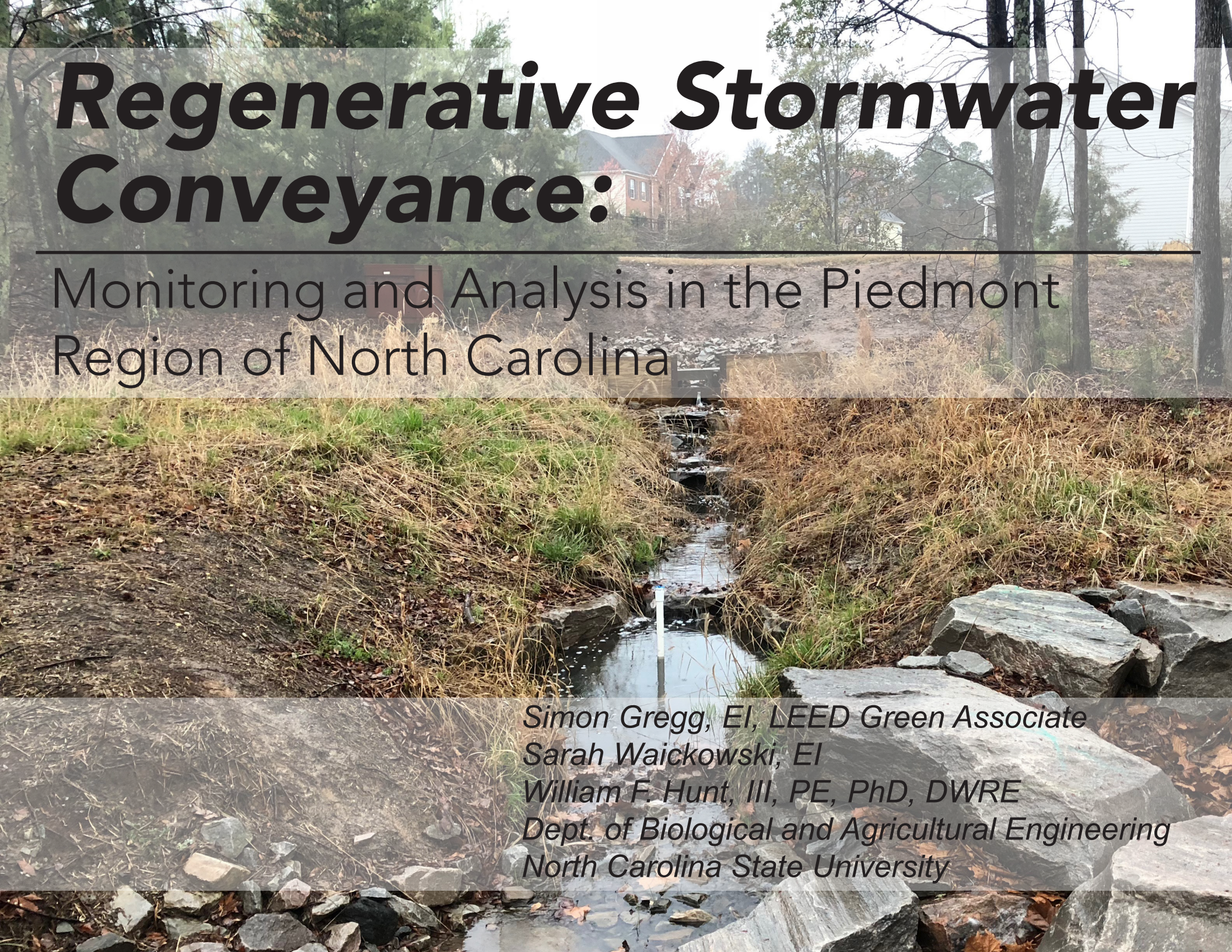
Regenerative Stormwater Conveyance:

Monitoring and Analysis in the Piedmont Region of North Carolina



Simon Gregg, EI, LEED Green Associate
Sarah Waickowski, EI
William F. Hunt, III, PE, PhD, DWRE
Dept. of Biological and Agricultural Engineering
North Carolina State University

Background

+ innovative technique to convey and treat stormwater
+ sequence of grade control structures and pools
    + riffles, boulder-weirs, cascade
+ 80% sand 20% wood chip media to raise the stream bed
+ used to stabilize eroded gullies
+ promote infiltration & improve hyporheic interactions
+ guidance from Anne Arundel County, MD

figure 1. Baltimore County, MD headcut
source: Gannett Fleming

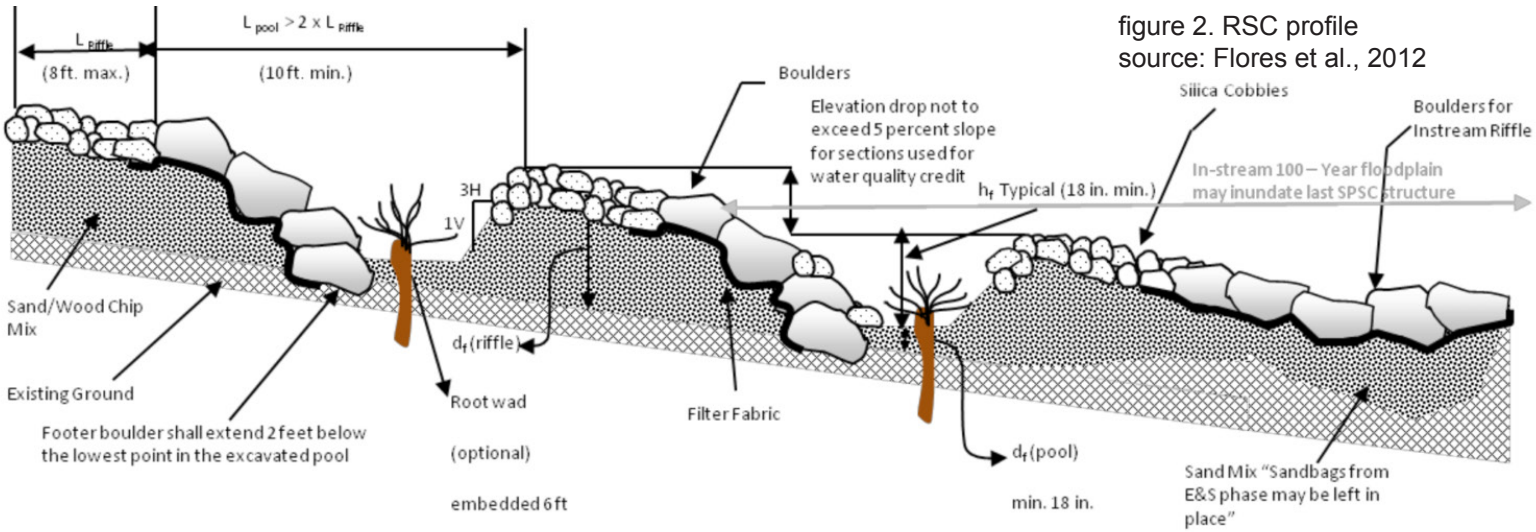


figure 2. RSC profile
source: Flores et al., 2012

Background

TREATMENT MECHANISMs

+ velocity reduction & settling
    + Stoke's Law
+ media filtration & adsorption to organic matter
    + Darcy's Law
    + Cation Exchange Capacity
+ denitrification
+ biological uptake

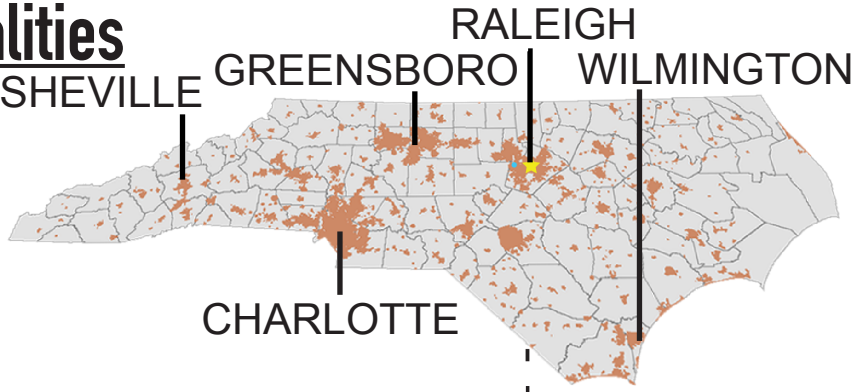
figure 3. sediment loads
source: greatecology.com

figure 4. Clements Creek, MD pre-construction
source: ecosystemrestoration.com

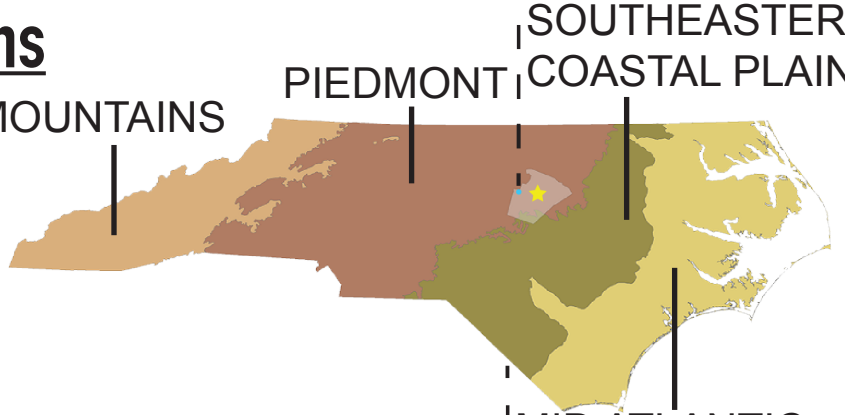
figure 5. Carriage Hills RSC Clements Creek, MD
source: ecosystemrestoration.com

Site Location

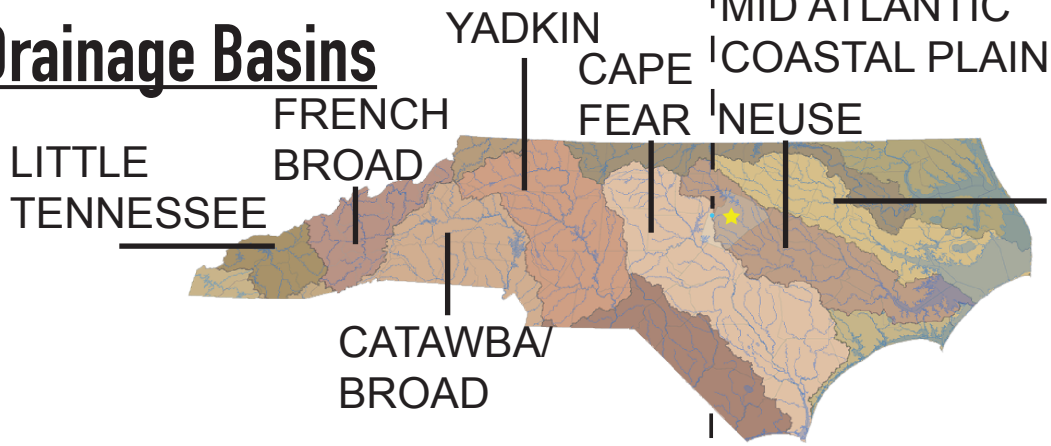
Municipalities



Ecoregions



Drainage Basins



Wake County

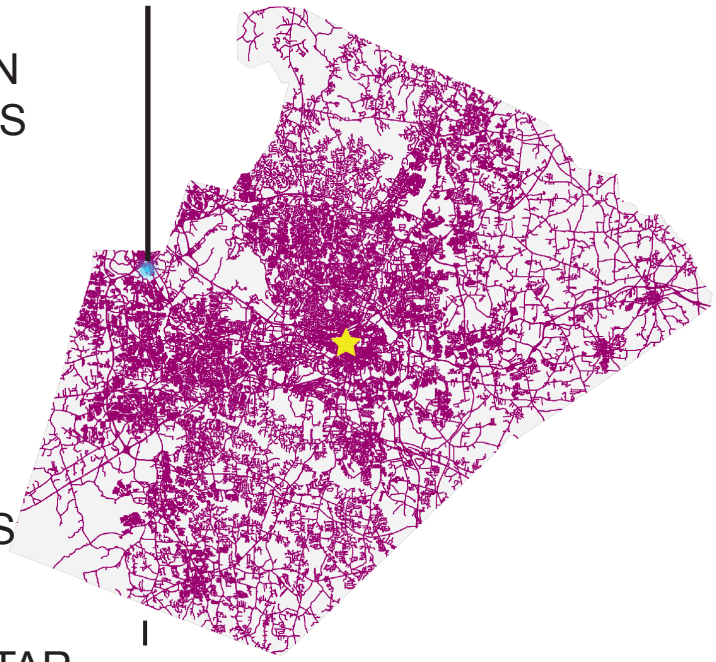


figure 6. Morrisville, NC RSC location

Site Description

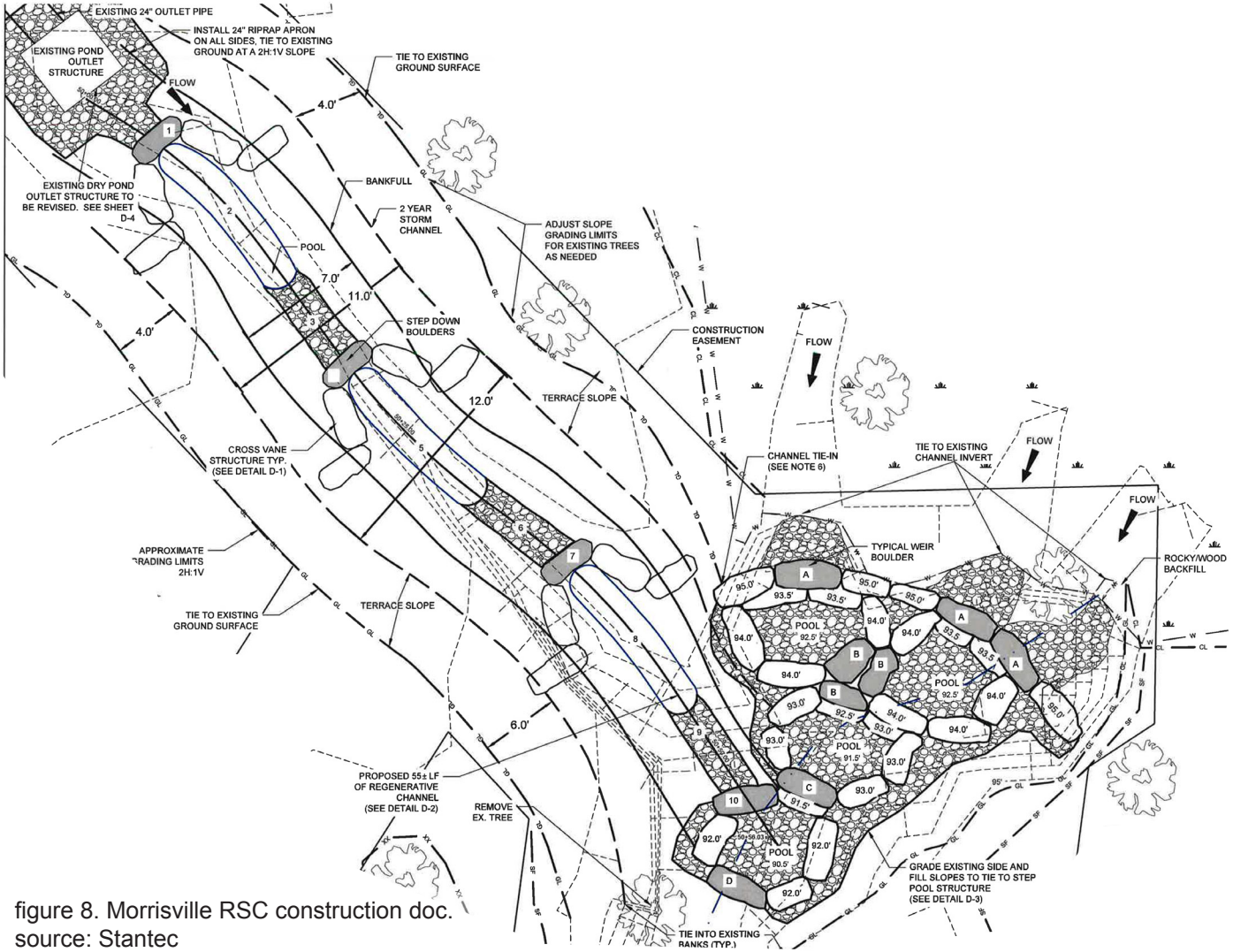
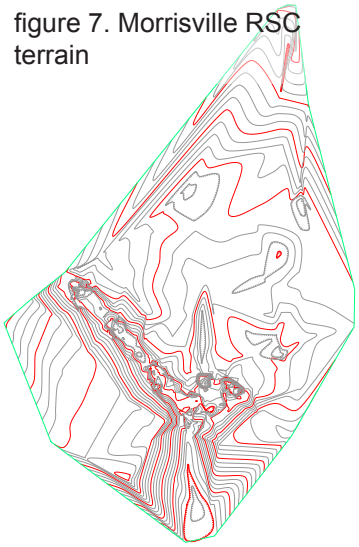
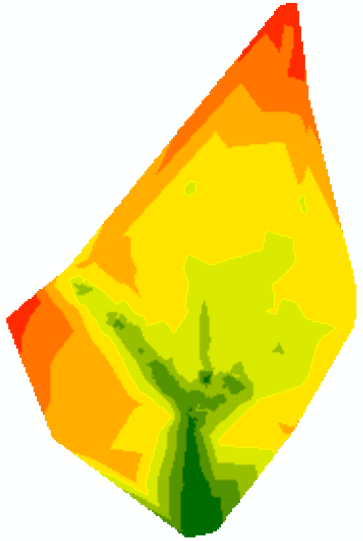


figure 8. Morrisville RSC construction doc.
source: Stantec

figure 7. Morrisville RSC terrain





Site Description

DRAINAGE AREAs

Dry Pond

7.2 ha

Secondary Inlet

12.4 ha

Run-On

0.7 ha

COMPOSITE CN

85

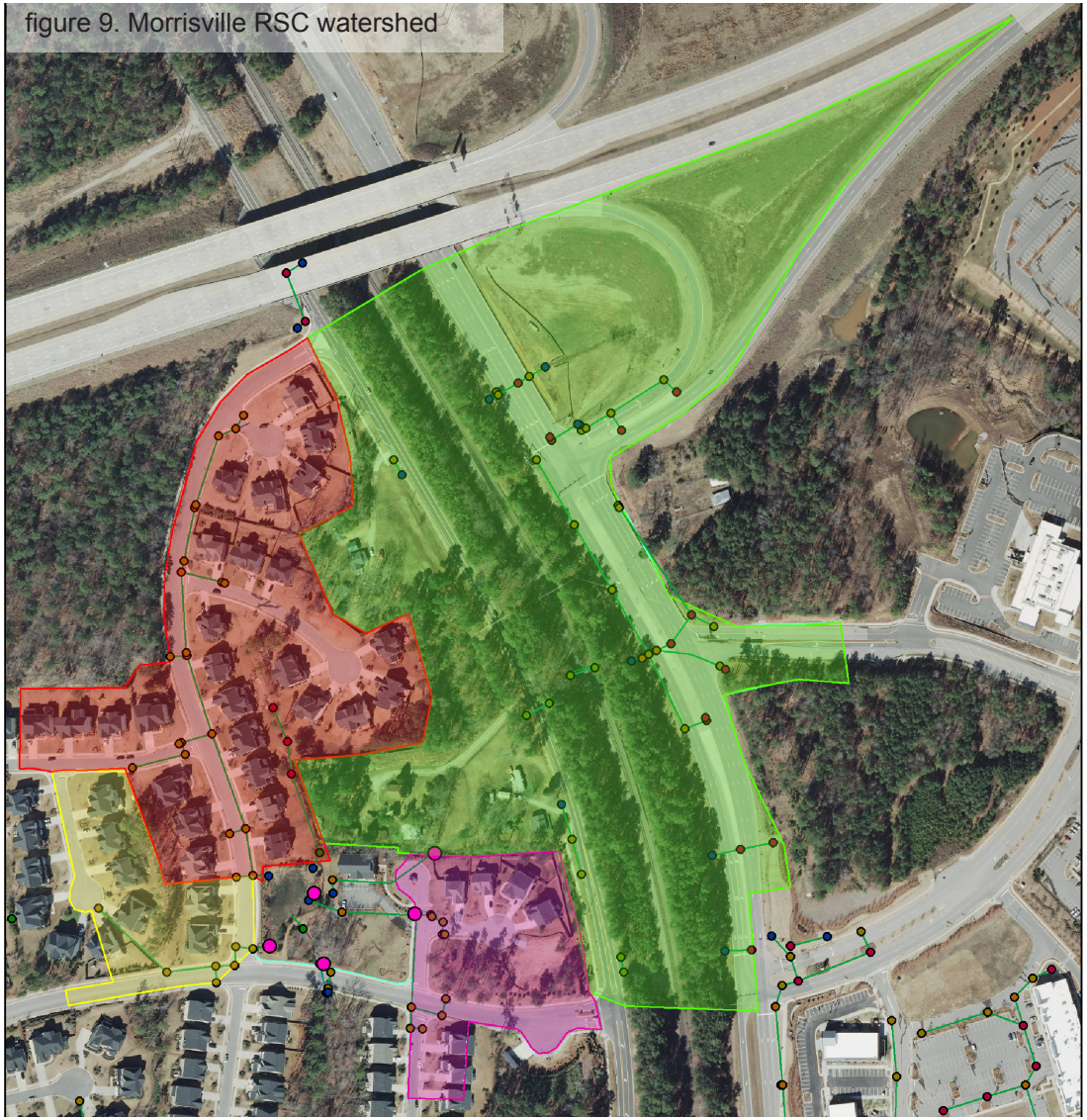


figure 9. Morrisville RSC watershed

Design Characteristics

+ total storage volume: 3.17-m^3
+ 25-mm runoff volume: 876.07-m^3
+ % sized 0.4%
+ Loading ratio: 25,000:1

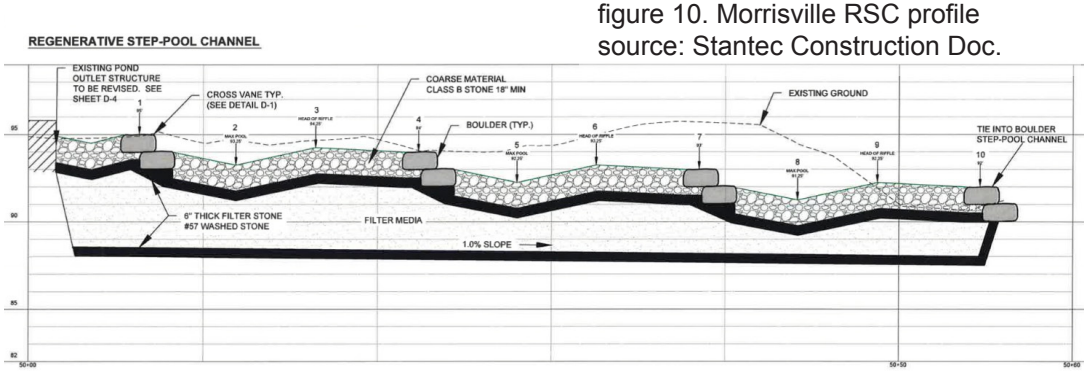


figure 10. Morrisville RSC profile
source: Stantec Construction Doc.

figure 11. Morrisville RSC

Monitoring Design

EQUIPMENT

+ ISCO 6712 automated samplers
+ HOBO U20 water level loggers
+ HOBO manual & tipping bucket rain gauge
+ compound weirs w/ end contractions
+ interevent baseflow grab samples

figure 12. monitoring methods

Preliminary Results

83%
VOLUME REDUCTION

192%
PEAK FLOW INCREASE

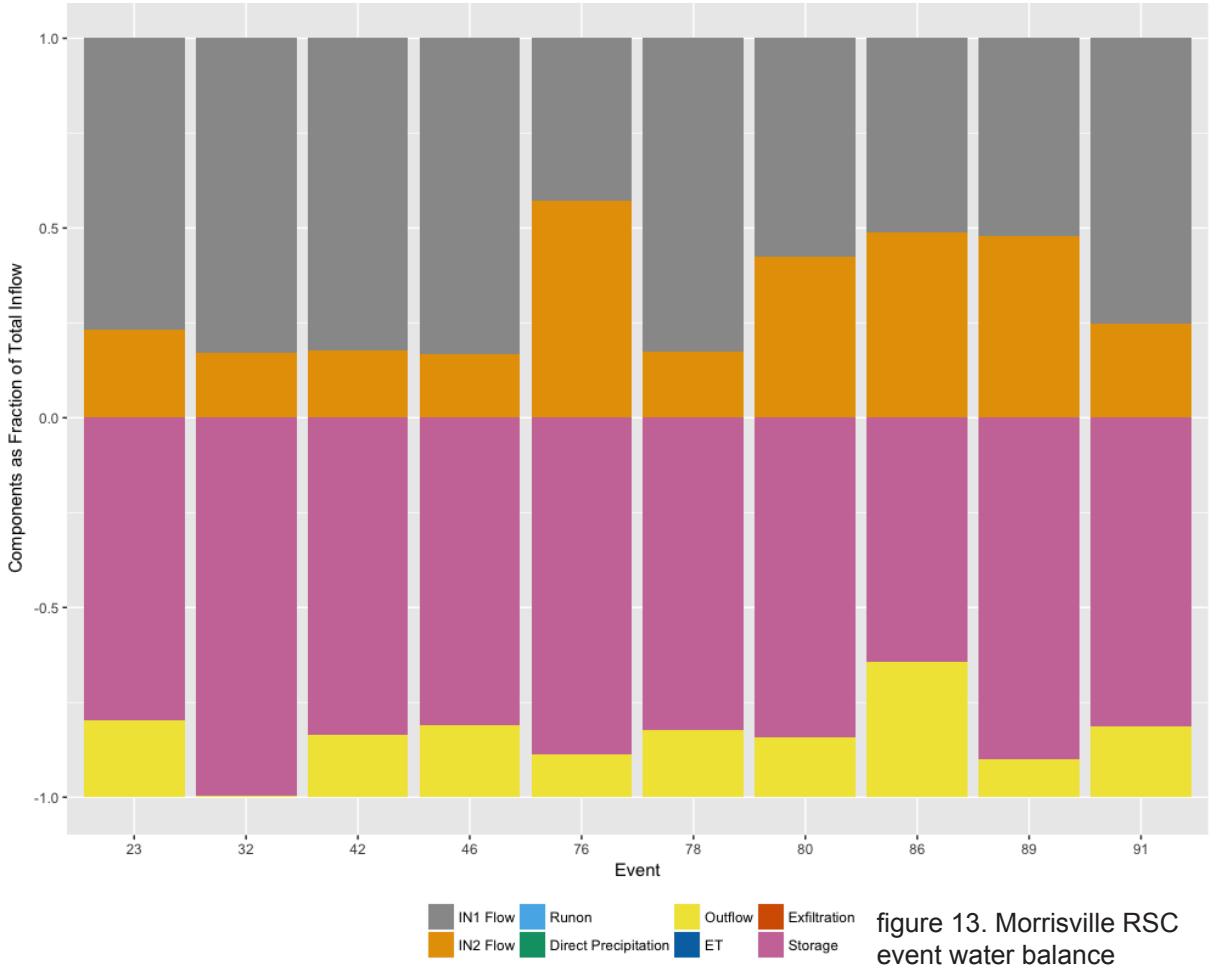


figure 13. Morrisville RSC event water balance

Previous Research

+ 4 peer-reviewed articles
    + 5 reports of RSC performance
+ piedmont & coastal plains
+ drainage areas: 0.3 - 94-ha
+ loading ratios: 24 - 310:1
+ slopes: 0.8 - 12.5%
+ storage ratio: 0.42 - 3.34:1
    + SR = $V_{surface}$ / V_{media}
+ inconsistency in methods, reporting, & analysis

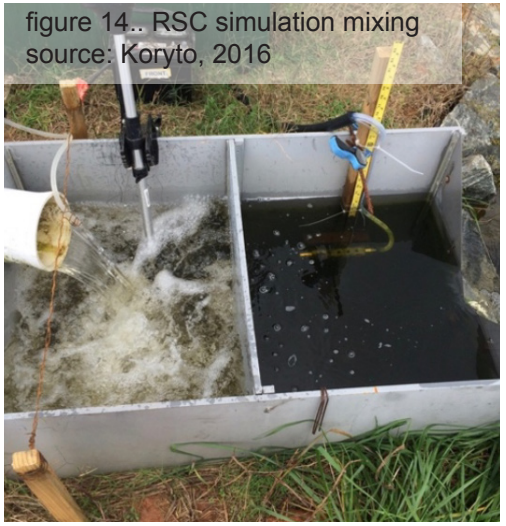


figure 14.. RSC simulation mixing
source: Koryto, 2016

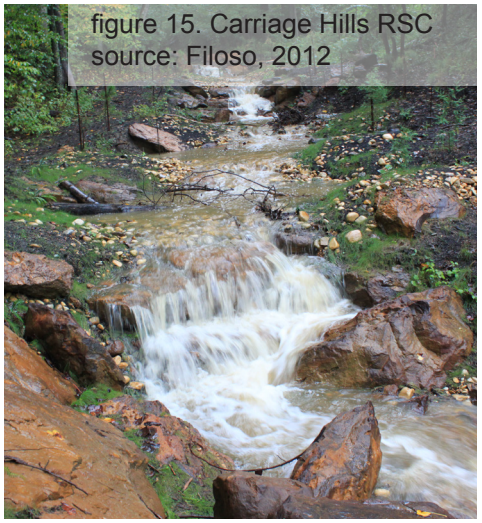


figure 15. Carriage Hills RSC
source: Filoso, 2012

figure 16. Alamance County, NC
source: Cizek, 2014

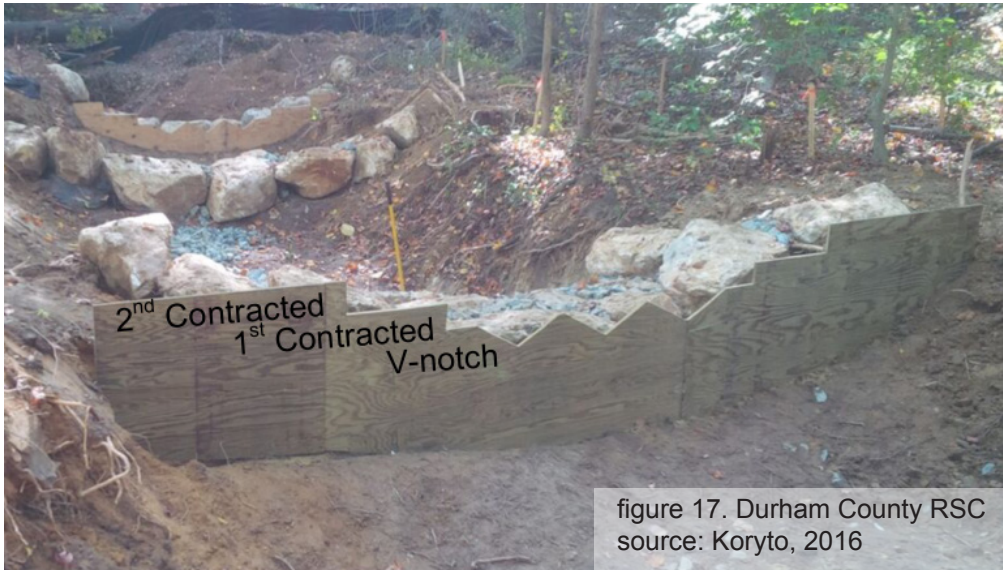


figure 17. Durham County RSC
source: Koryto, 2016

Previous Research

+ potential for media clogging
+ media saturation limits available storage
    + trend of under sizing

DURHAM RSC

+10%
VOLUME REDUCTION

21%
PEAK FLOW REDUCTION

DURHAM RSC

10%
TSS REDUCTION

4.4%
TN REDUCTION

6.8%
TP REDUCTION

Previous Research

+ high media OM can leach TAN & TKN in interevent periods
    + denitrification vs. DNRA
+ WQ performance scattered
    + TSS: 30-70% reduction
    + TN: 25-50% reduction
    + TP: 30-70% reduction

WELL DRAINED RSCs

>80% VOLUME REDUCTION

>75% PEAK FLOW REDUCTION

ALAMANCE RSC

94% TSS REDUCTION

81% TN REDUCTION

84% TP REDUCTION

Recommendations

DESIGN VOLUME	+ 38-mm Coastal Plains; + 25-mm elsewhere	Koryto et al. (2017); Cizek et al. (2016); Koryto et al. (2018)
LOADING RATIO	+ 80 - 120:1; depends on storage demand	Koryto et al. (2017); Cizek et al. (2016); Koryto et al. (2018)
STORAGE RATIO	+ 0.5 - 1.5:1; lower ratios improve surface-to-seepage	Koryto et al. (2017); Cizek et al. (2016); Koryto et al. (2018); Cizek et al. (2017)
SLOPE	+ depends on site; steeper slopes require larger structures	Flores et al. (2012); Koryto et al. (2017); Cizek et al. (2016)
IN-STREAM STRUCTURES	+ larger in-stream structures improve hyporheic exchange	Hester & Doyle (2008)
CONSTRUCTION TECHNIQUES	+ gulley or exfiltration trench; rake subsoils; pool 1 forebay; SHWT	Cizek et al. (2016); Koryto et al. (2017); Brown & Hunt (2009); Filoso (2012); Hsieh & Davis (2005a); Hunt et al. (2006)
VEGETATION	+ yes; zone planting	Li et al., (2009); Wardynski & Hunt, (2012)
MEDIA	+ 80-85% coarse sand, 10-15% OM, 0-5% fines; P-index ≤ 30 in NSW P-index ≤ 50 elsewhere	Hunt et al. (2006); Hsieh & Davis (2005a); Koryto et al. (2017); Cizek et al. (2016)

Questions?

References

+ Brown, R. A., & Hunt, W. F. (2009). Effects of Media Depth on Bioretention Performance in the Upper Coastal Plain of North Carolina and Bioretention Construction Impacts Study. World Enviromental and Water Resources Congress.
+ Cizek, A. R., Hunt, W. F., Winston, R. J., & Lauffer, M. S. (2017). Hydrologic Performance of Regenerative Stormwater Conveyance in the North Carolina Coastal Plain. Journal of Environmental Engineering, 143(9).
+ Cizek, A. R., Hunt, W. F., Winston, R. J., Waickowski, S., Narayanaswamy, K., & Lauffer, M. S. (2016). Water Quality and Hydrologic Performance of a Regenerative Stormwater Conveyance (RSC) in the Piedmont of North Carolina. Journal of Environmental Engineering.
+ Filoso, S. (2012). Assessing the Effectiveness of Regenerative Stormwater Conveyance in reducing Sediment and Nutrient Loads to Three Mid-River Creeks in the Severn River watershed, (410), 1–22.
+ Flores, H., Mcmonigle, D., & Underwood, K. (2012). Design Guidelines for Regenerative Step Pool Storm Conveyance.
+ Hester, E. T., & Doyle, M. W. (2008). In-stream geomorphic structures as drivers of hyporheic exchange. Water Resources Research, 44(3).
+ Hsieh, C., & Davis, A. P. (2005a). Evaluation and Optimization of Bioretention Media for Treatment of Urban Storm Water Runoff. Journal of Environmental Engineering, 131, 1521–1531.
+ Hunt, W. F., Jarrett, A. R. R., Smith, J. T., & Sharkey, L. J. (2006). Evaluating Bioretention Hydrology and Nutrient Removal at Three Field Sites in North Carolina. Journal of Irrigation and Drainage Engineering, 132(6).
+ Koryto, K. M., Asce, M., Hunt, W. F., Arellano, C., & Page, J. L. (2018). Performance of Regenerative Stormwater Conveyance on the Removal of Dissolved Pollutants: Field Scale Simulation Study, 144(6), 1–13.
+ Koryto, K. M., Hunt, W. F., & Page, J. L. (2017). Hydrologic and water quality performance of regenerative stormwater conveyance installed to stabilize an eroded outfall. Ecological Engineering, 108, 263–276.
+ Li, H., Sharkey, L. J., Asce, M., Hunt, W. F., Davis, A. P., & Asce, F. (n.d.). Mitigation of Impervious Surface Hydrology Using Bioretention in North Carolina and Maryland.
+ Wardynski, B. J., & Hunt, W. F. (2012). Are Bioretention Cells Being Installed Per Design Standards in North Carolina? A Field Study. Journal of Environmental Engineering, 138(12), 1210–1217.