Introduction to NC Long-Term Bioretention HYdrologic PERformance (HyPer) Tool

In Collaboration with Robert A. Brown, Ph.D.
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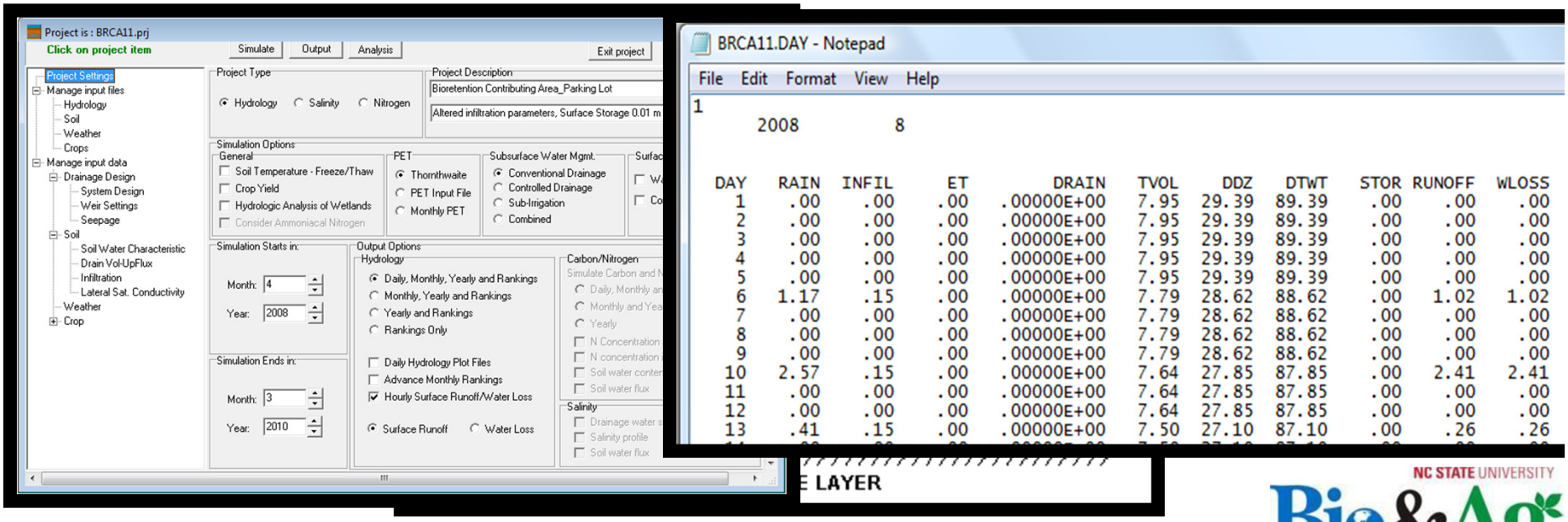
The Need for a Model

- Data are available to improve analysis/design
  - Extensive field data
  - Calibrated DRAINMOD simulations
- One size does NOT fit all
  - Intra-event infiltration
  - Antecedent conditions
  - ET
  - Soil water properties, etc…

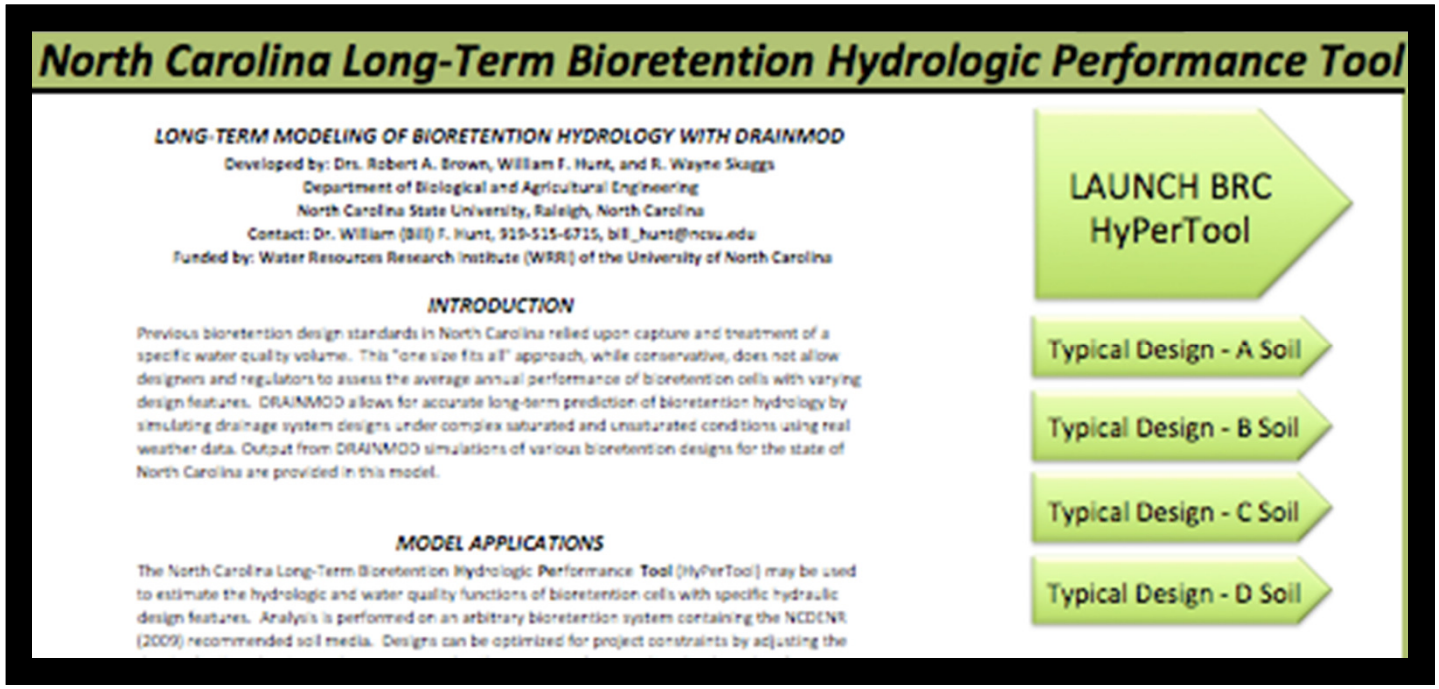
Why not use DRAINMOD?

- DRAINMOD requires intensive training
  - Commands expert knowledge
  - Parameter sensitivity varies
- Need a user- and regulator-friendly model



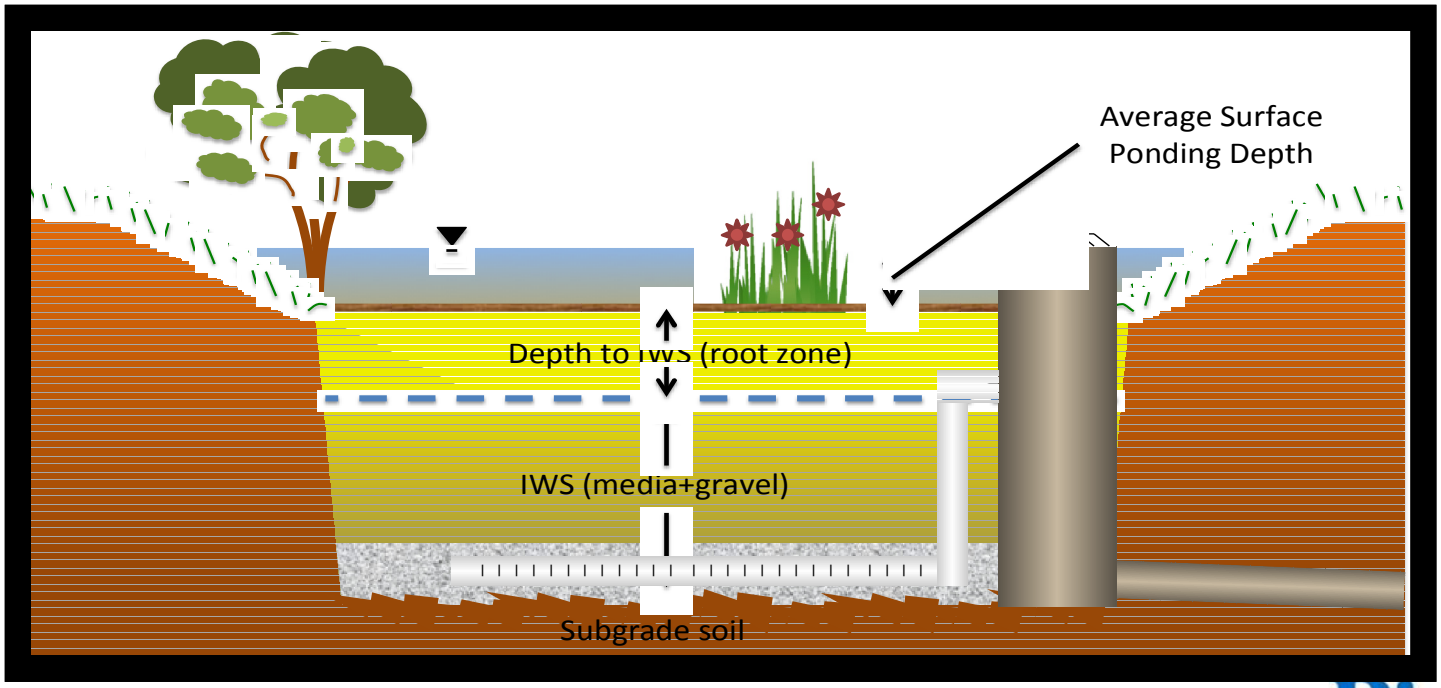
Bioretention HyPer Tool

- Macro-Embedded Excel Spreadsheet Model
  - Developed by NC State Stormwater Engineering Group



Bioretention HyPer Tool

- Data developed from 432 DRAINMOD simulations as defined in Final Report to WRRI of the Univ. of NC "Long-term Modeling of Bioretention Hydrology with DRAINMOD"



HyPer Tool Features

1. Quantify hydrologic performance
   - Different underlying soil types
   - Various design specifications
     - Drainage configuration (IWS vs. Conv.)
     - Media Depth
   - Undersized / oversized systems
2. Determines if design treats 90% of runoff
   - ***Water quality volume***
3. Computes total volume reduction to stormwater network

HyPer Tool Features

4. Water balance used to estimate influent and effluent TN & TP loads
   - ET → **Load eliminated**
   - Exfiltration → **Load eliminated**
   - Drainage → **Treated**

   Drainage conc. = typical BRC effluent conc.

   - Overflow → **Untreated**

   Overflow conc. = typical parking lot runoff conc.

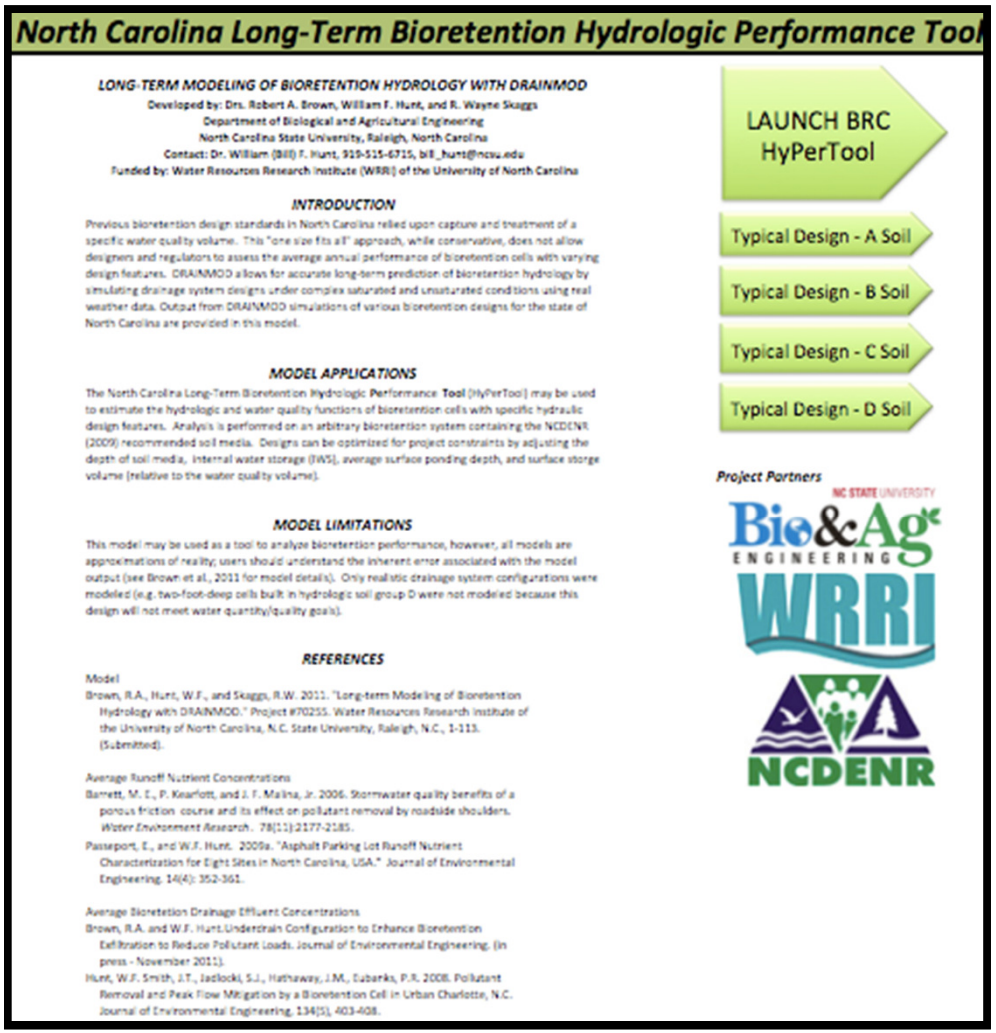
HyPer Tool Weather Data

- Long-term Weather Station
  - Raleigh-Durham International Airport (Piedmont)
    - Currently the only option with the full spectrum of simulations.
    - 60-yr data is available for Wilmington (Coastal Plain)
- Long-term data range: 1950-2009 (60 yrs)
  - Daily Max. & Min. Temperature
    - Source: State Climate Office of NC
  - Hourly Rainfall
    - Source: NOAA - National Climatic Data Center

HyPer Tool Soil Data Inputs

- Soil Water Char. Curve
  - Media (standard NC spec.)
  - Sand
  - Gravel
- K_{sat} = 2.5 cm/hr (1 in/hr per standard NC spec.)

HyPer Tool Interface



North Carolina Long-Term Bioretention Hydrologic Performance Tool

LONG-TERM MODELING OF BIORETENTION HYDROLOGY WITH DRAINMOD

Developed by: Drs. Robert A. Brown, William F. Hunt, and R. Wayne Skaggs
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Funded by: Water Resources Research Institute (WRRI) of the University of North Carolina

INTRODUCTION

Previous bioretention design standards in North Carolina relied upon capture and treatment of a specific water quality volume. This "one size fits all" approach, while conservative, does not allow designers and regulators to assess the average annual performance of bioretention cells with varying design features. DRAINMOD allows for accurate long-term prediction of bioretention hydrology by simulating drainage system designs under complex saturated and unsaturated conditions using real weather data. Output from DRAINMOD simulations of various bioretention designs for the state of North Carolina are provided in this model.

MODEL APPLICATIONS

The North Carolina Long-Term Bioretention Hydrologic Performance Tool (HyPerTool) may be used to estimate the hydrologic and water quality functions of bioretention cells with specific hydraulic design features. Analysis is performed on an arbitrary bioretention system containing the NCDENR (2009) recommended soil media. Designs can be optimized for project constraints by adjusting the depth of soil media, internal water storage (IWS), average surface ponding depth, and surface storge volume (relative to the water quality volume).

MODEL LIMITATIONS

This model may be used as a tool to analyze bioretention performance, however, all models are approximations of reality; users should understand the inherent error associated with the model output (see Brown et al., 2011 for model details). Only realistic drainage system configurations were modeled (e.g. two-foot-deep cells built in hydrologic soil group D were not modeled because this design will not meet water quantity/quality goals).

REFERENCES

Model

Brown, R.A., Hunt, W.F., and Skaggs, R.W. 2011. "Long-term Modeling of Bioretention Hydrology with DRAINMOD." Project #70255. Water Resources Research Institute of the University of North Carolina, N.C. State University, Raleigh, N.C., 1-113. (Submitted).

Average Runoff Nutrient Concentrations

Barrett, M. E., P. Kearfott, and J. F. Malina, Jr. 2006. Stormwater quality benefits of a porous friction course and its effect on pollutant removal by roadside shoulders. *Water Environment Research*. 78(11):2177-2185.

Passeport, E., and W.F. Hunt. 2009a. "Asphalt Parking Lot Runoff Nutrient Characterization for Eight Sites in North Carolina, USA." Journal of Environmental Engineering. 14(4): 352-361.

Average Bioretetion Drainage Effluent Concentrations

Brown, R.A. and W.F. Hunt.Underdrain Configuration to Enhance Bioretention Exfiltration to Reduce Pollutant Loads. Journal of Environmental Engineering. (in press - November 2011).

Hunt, W.F. Smith, J.T., Jadlocki, S.J., Hathaway, J.M., Eubanks, P.R. 2008. Pollutant Removal and Peak Flow Mitigation by a Bioretention Cell in Urban Charlotte, N.C. Journal of Environmental Engineering. 134(5). 403-408.

LAUNCH BRC HyPerTool

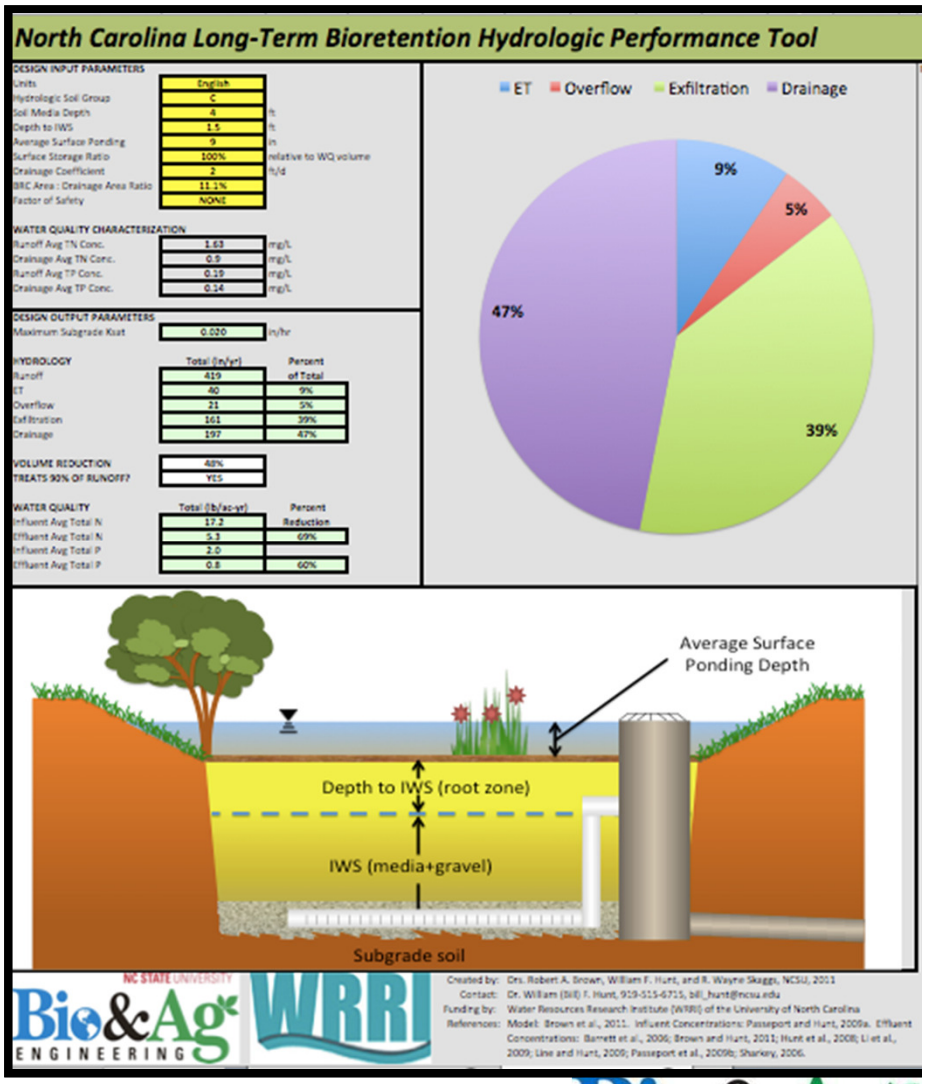
Typical Design - A Soil

Typical Design - B Soil

Typical Design - C Soil

Typical Design - D Soil

Project Partners



North Carolina Long-Term Bioretention Hydrologic Performance Tool

DESIGN INPUT PARAMETERS		
Units	English	
Hydrologic Soil Group	C	
Soil Media Depth	4	ft
Depth to IWS	1.5	ft
Average Surface Ponding	9	in
Surface Storage Ratio	100%	relative to WQ volume
Drainage Coefficient	2	ft/d
BRC Area : Drainage Area Ratio	11.1%	
Factor of Safety	NONE	

WATER QUALITY CHARACTERIZATION		
Runoff Avg TN Conc.	1.63	mg/L
Drainage Avg TN Conc.	0.9	mg/L
Runoff Avg TP Conc.	0.19	mg/L
Drainage Avg TP Conc.	0.14	mg/L

DESIGN OUTPUT PARAMETERS		
Maximum Subgrade Ksat	0.020	in/hr

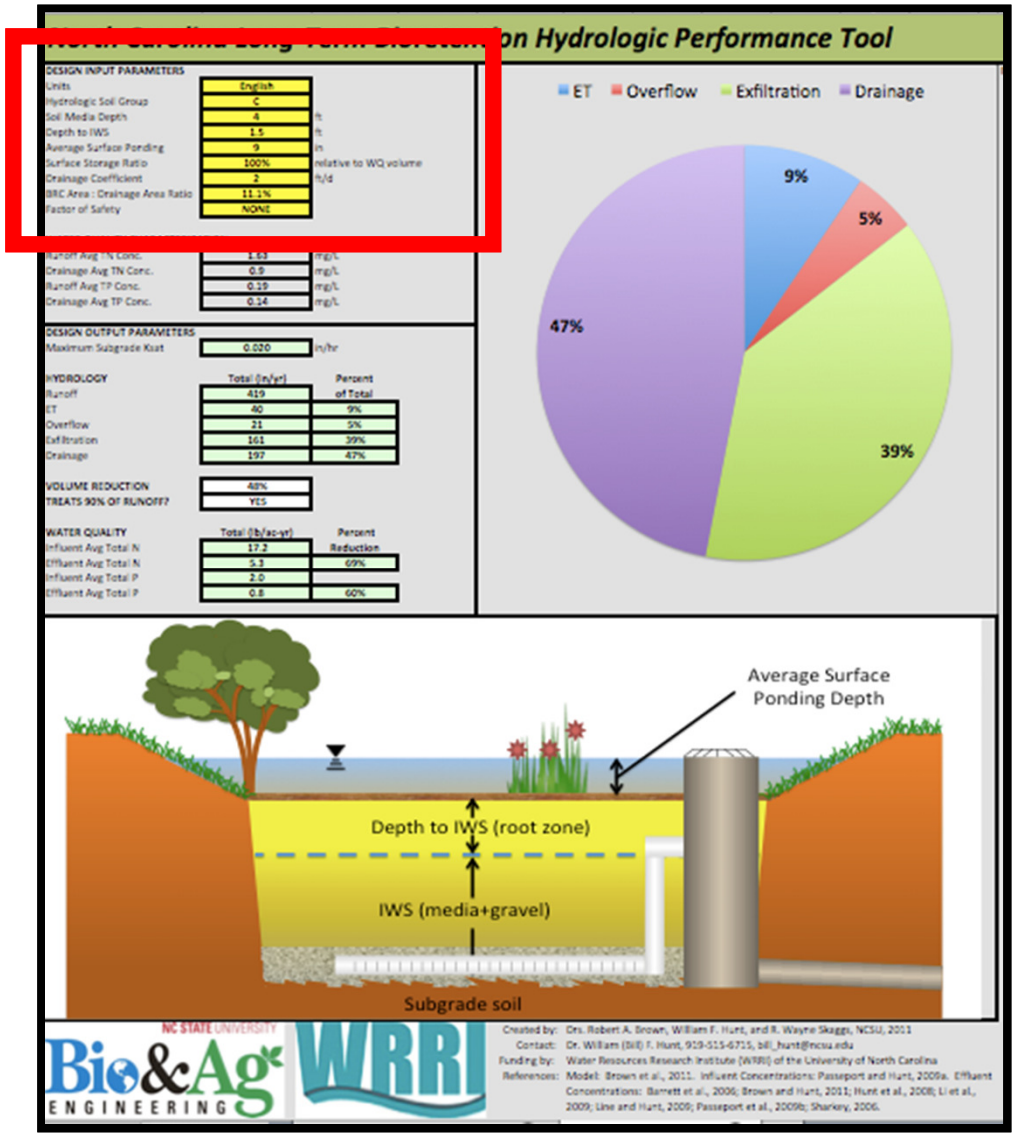
HYDROLOGY	Total (in/yr)	Percent of Total
Runoff	419	
ET	40	9%
Overflow	21	5%
Exfiltration	161	39%
Drainage	197	47%

VOLUME REDUCTION	
	48%
TREATS 90% OF RUNOFF?	YES

WATER QUALITY	Total (lb/ac-yr)	Percent Reduction
Influent Avg Total N	17.2	
Effluent Avg Total N	5.3	69%
Influent Avg Total P	2.0	
Effluent Avg Total P	0.8	60%

Created by: Drs. Robert A. Brown, William F. Hunt, and R. Wayne Skaggs, NCSU, 2011
Contact: Dr. William (Bill) F. Hunt, 919-515-6715, bill_hunt@ncsu.edu
Funding by: Water Resources Research Institute (WRRI) of the University of North Carolina
References: Model: Brown et al., 2011. Influent Concentrations: Passeport and Hunt, 2009a. Effluent Concentrations: Barrett et al., 2006; Brown and Hunt, 2011; Hunt et al., 2008; Li et al., 2009; Line and Hunt, 2009; Passeport et al., 2009b; Sharkey, 2006.

HyPer Tool Interface



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Vertical Conductivity of Restricting Layer

- Divided based on Hydrologic Soil Group
  - A, B, C, & D
- Numbers selected from:
  - Measured exfiltration rates
    - Rocky Mount (A & B), Graham (B & C), Knightdale (C), Greensboro (C)
  - Sat. Hydraulic Conductivity – Rawls et al. (1998)
    - Defined by soil textural class & 75th percentile under high bulk density → compacted from construction

Rawls et al. (1998). *Transactions of the ASAE*. "Use of soil texture, bulk density, and slope of water retention curve to predict saturated hydraulic conductivity"

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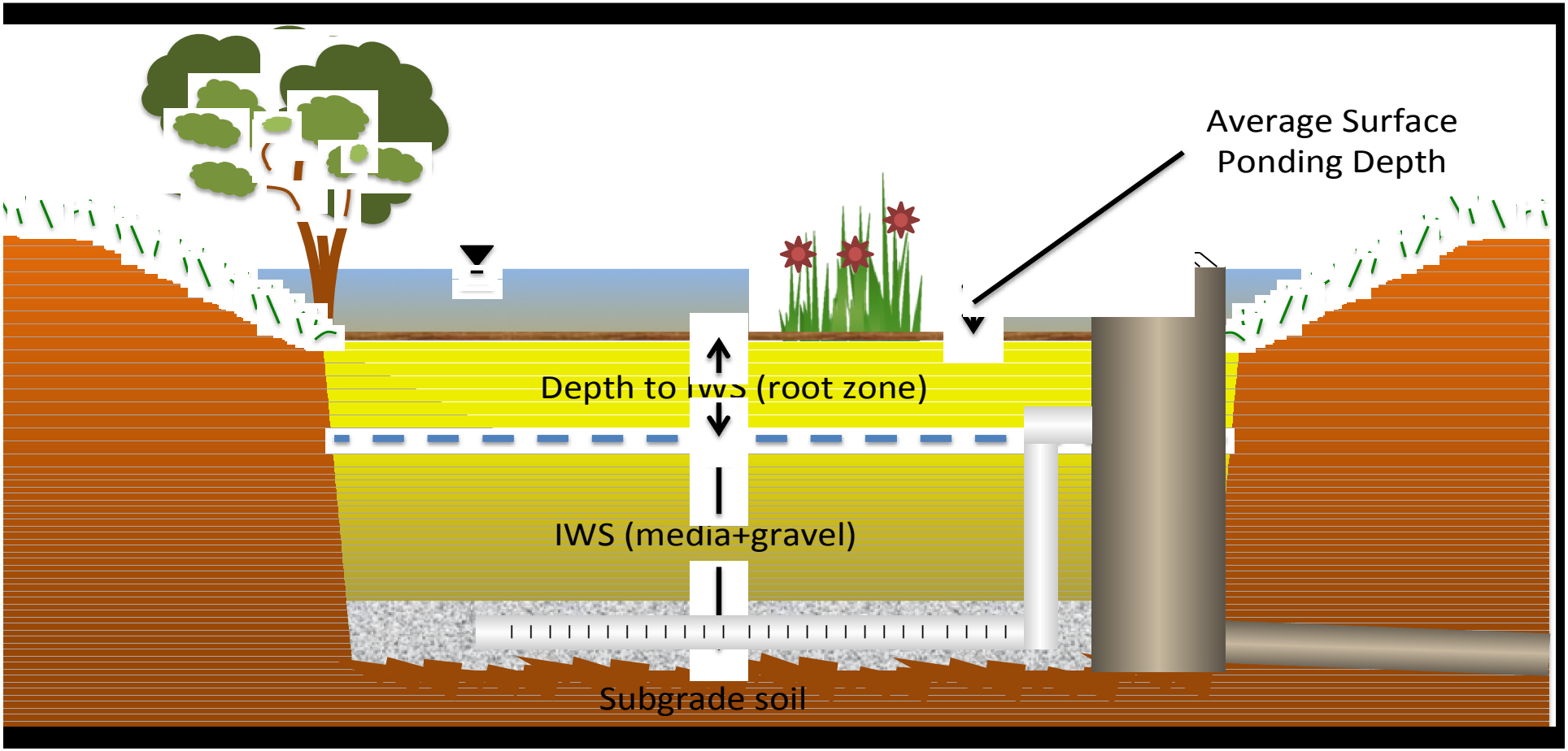

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Surface Storage Volume

- 0.4 ha (1 ac) 100% imp. drainage area
- Surface storage depth = 23 cm (9 in)
  - Drainage Area : Bioretention Area
    - **10.2 : 1**
- Surface storage depth = 30 cm (12 in)
  - Drainage Area : Bioretention Area
    - **14.0 : 1**
- Variations of surface storage volume
  - 50%, 75%, 100%, 125%, 150%, & 200% of design capacity

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