VUSP
VILLANOVA URBAN STORMWATER PARTNERSHIP

VILLANOVA UNIVERSITY
VCASE

Soil-The Critical Element in Stormwater Design

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Villanova University

Agenda

Sustainable Stormwater

Roles of Soils

Stormwater Research

Mission Statement

*The mission of the Villanova Urban Stormwater Partnership is to advance **sustainable** stormwater management practices and to foster the development of public and private Partnerships through research on innovative stormwater best management practices, directed studies, technology transfer, and education.*

- *Research and directed studies emphasize sustainable stormwater management planning, implementation, and evaluation*
- *Technology transfer provides tools, guidance, and education for the professional*
- *The goal of the partnership is to promote cooperation amongst the private, public and academic sectors*

Corporate Partners

Down To Earth Design

Baker

Philadelphia PWD Water Department

amec

MOMENEE AND ASSOCIATES, INC.
Bryn Mawr Office: 924 County Line Road, Bryn Mawr, PA 19010
Exton Office: 420 Exton Square Parkway, Exton, PA 19341

CH2MHILL

ADVANCED GeoServices
Engineering for the Environment. Planning for People.

Princeton Hydro pH

Newell Tereska & MacKay ENGINEERING

Borton Lawson ENGINEERING ARCHITECTURE

vnh van note - harvey

FXB F. X. Browne, Inc.

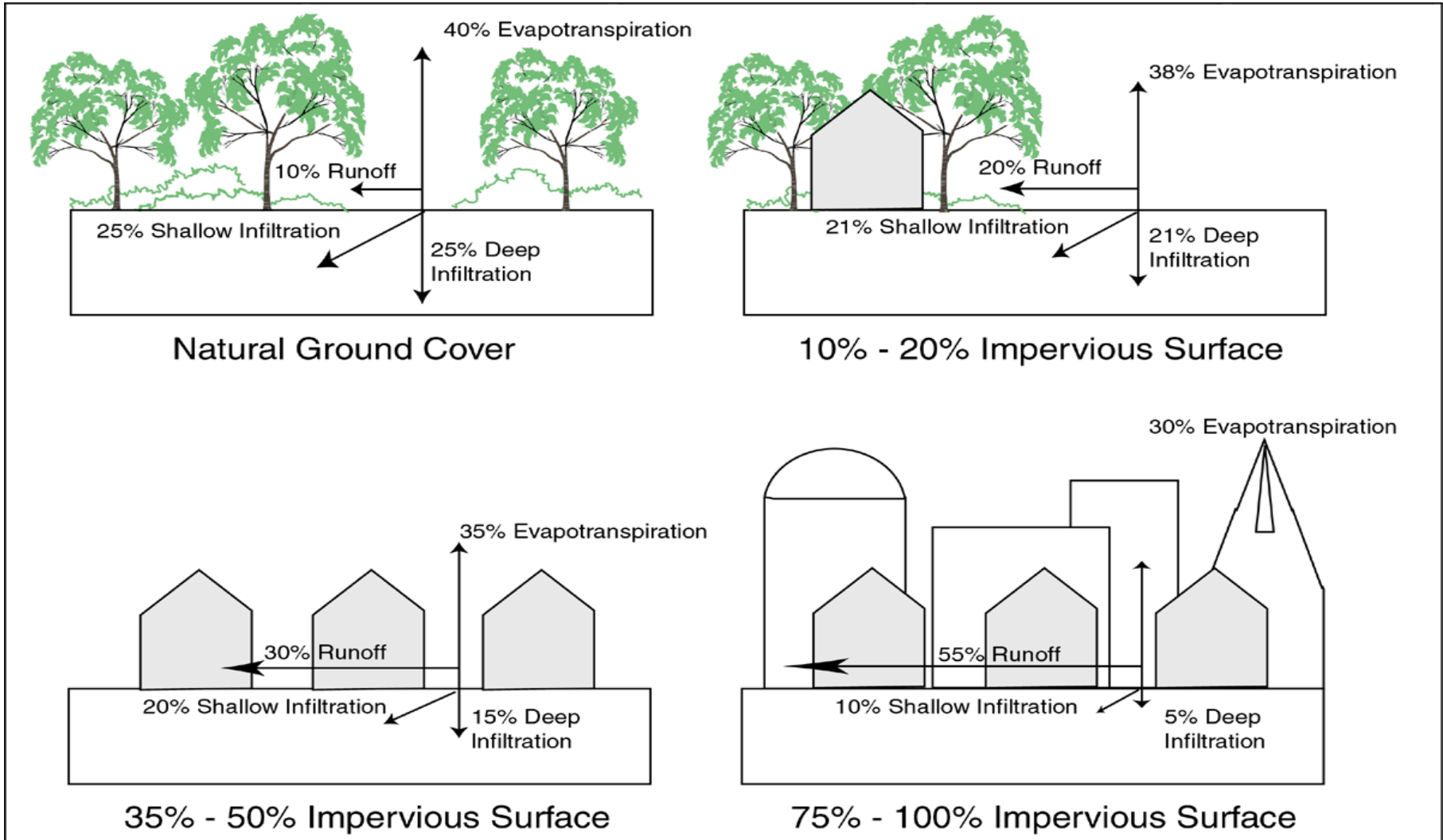
Meliora Environmental Design, LLC

LANGAN ENGINEERING & ENVIRONMENTAL SERVICES

HRG Herbert, Rowland & Grubic, Inc. Engineering & Related Services

O'BRIEN & GERE www.obg.com

Imperviousness vs. Runoff



Changes in runoff flow resulting from increased impervious area (NC Dept. of Nat. Res. and Community Dev., in Livingston and McCarron, 1992.)

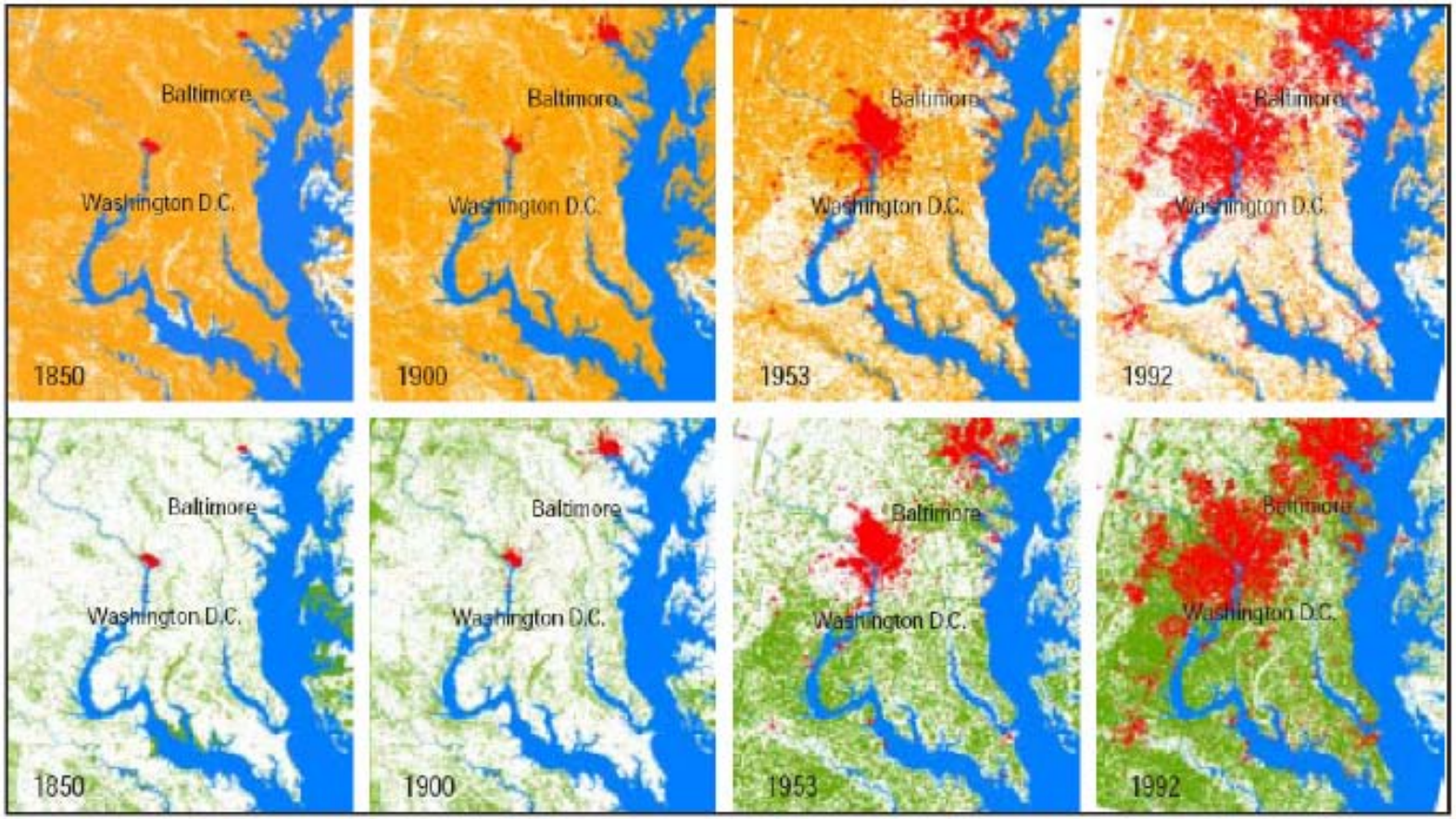


FIGURE 3-3 This series of maps compares changes in urban, agricultural, and forested lands in the Patuxent River watershed over the past 140 years. The top series shows the extent of urban areas (red) along with agriculture (gold), which was at its peak in the mid- to late 1800s. Since 1900, the amount of agricultural land has declined as urban and forested land (green) has increased. SOURCE: USGS (1999).

National Academies 2008

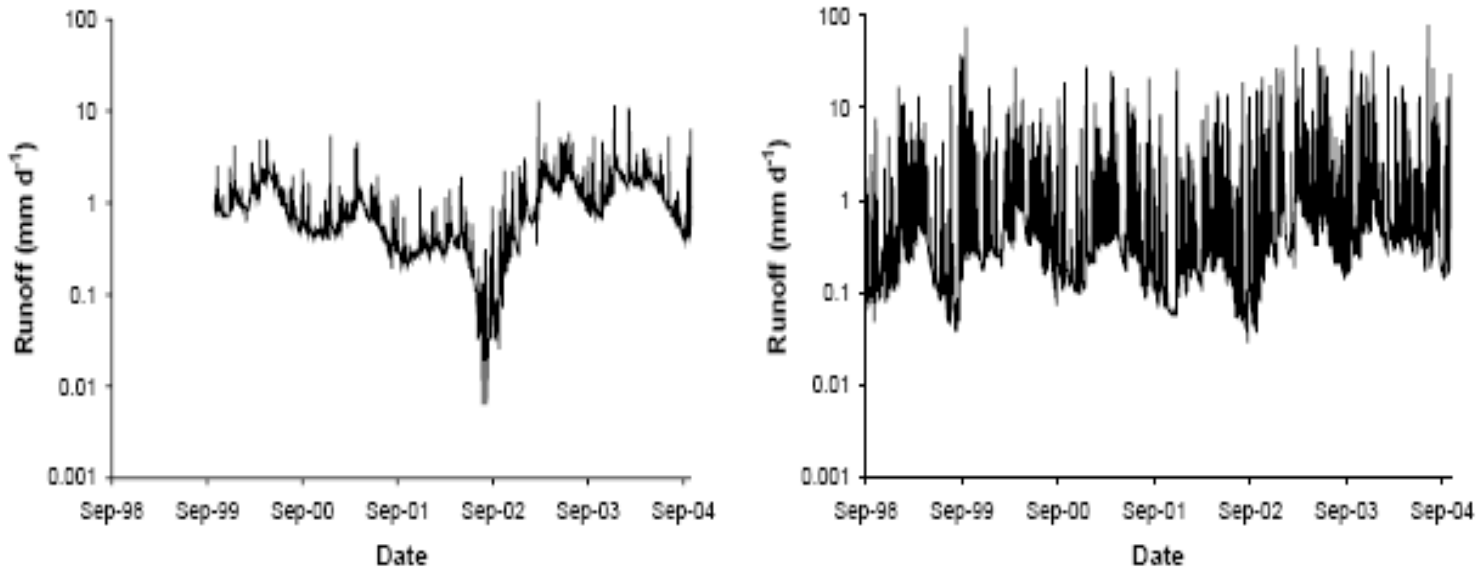
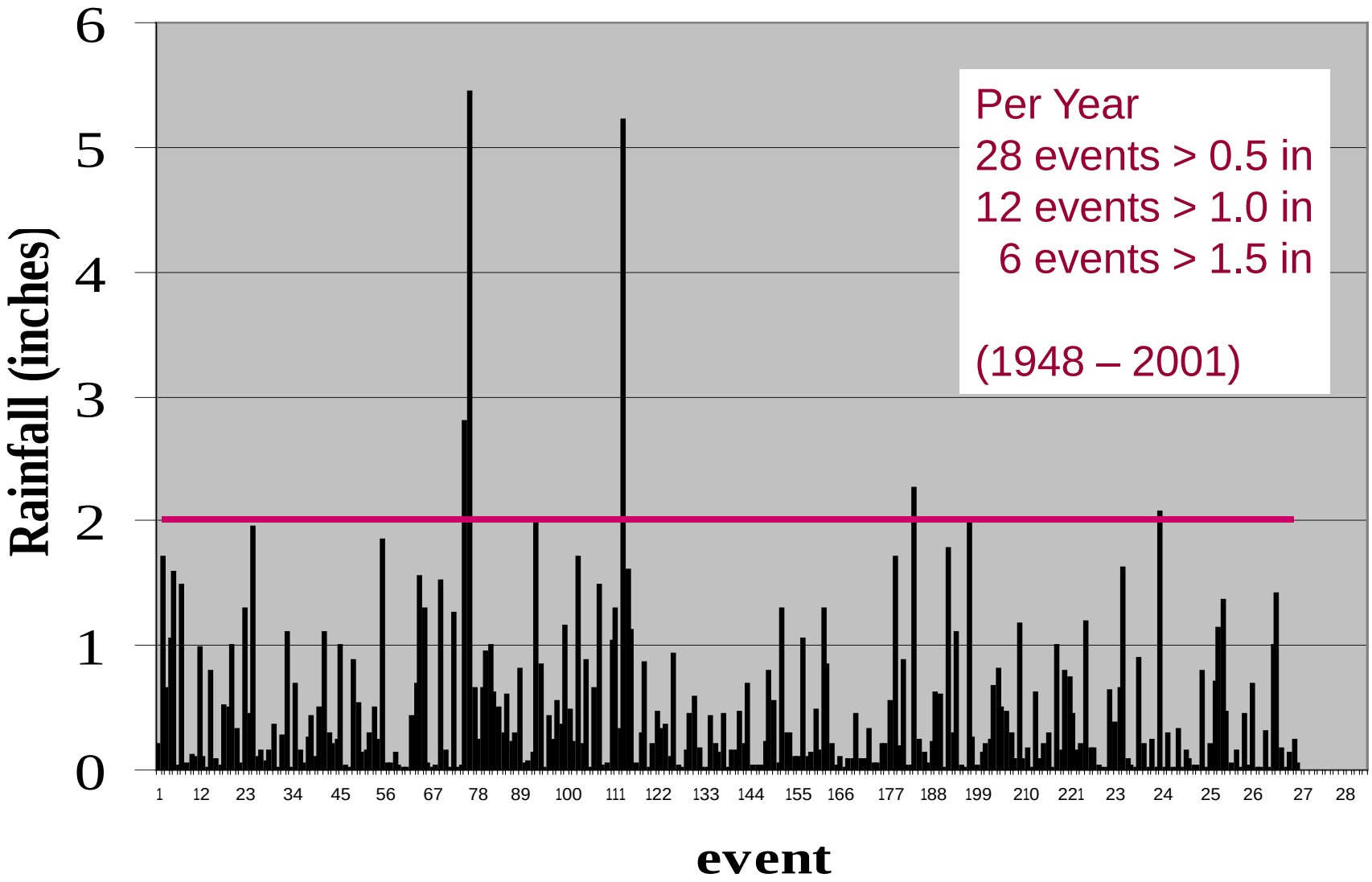


FIGURE 3-12 Daily time series of flows in (A) a low-density suburban and forested catchment (Baisman Run, http://waterdata.usgs.gov/md/nwis/uv/?site_no=01583580) and (B) a catchment dominated by medium- to high-density residential and commercial land uses (Dead Run, http://waterdata.usgs.gov/md/nwis/uv/?site_no=01589330). Both lie within the Piedmont physiographic province.

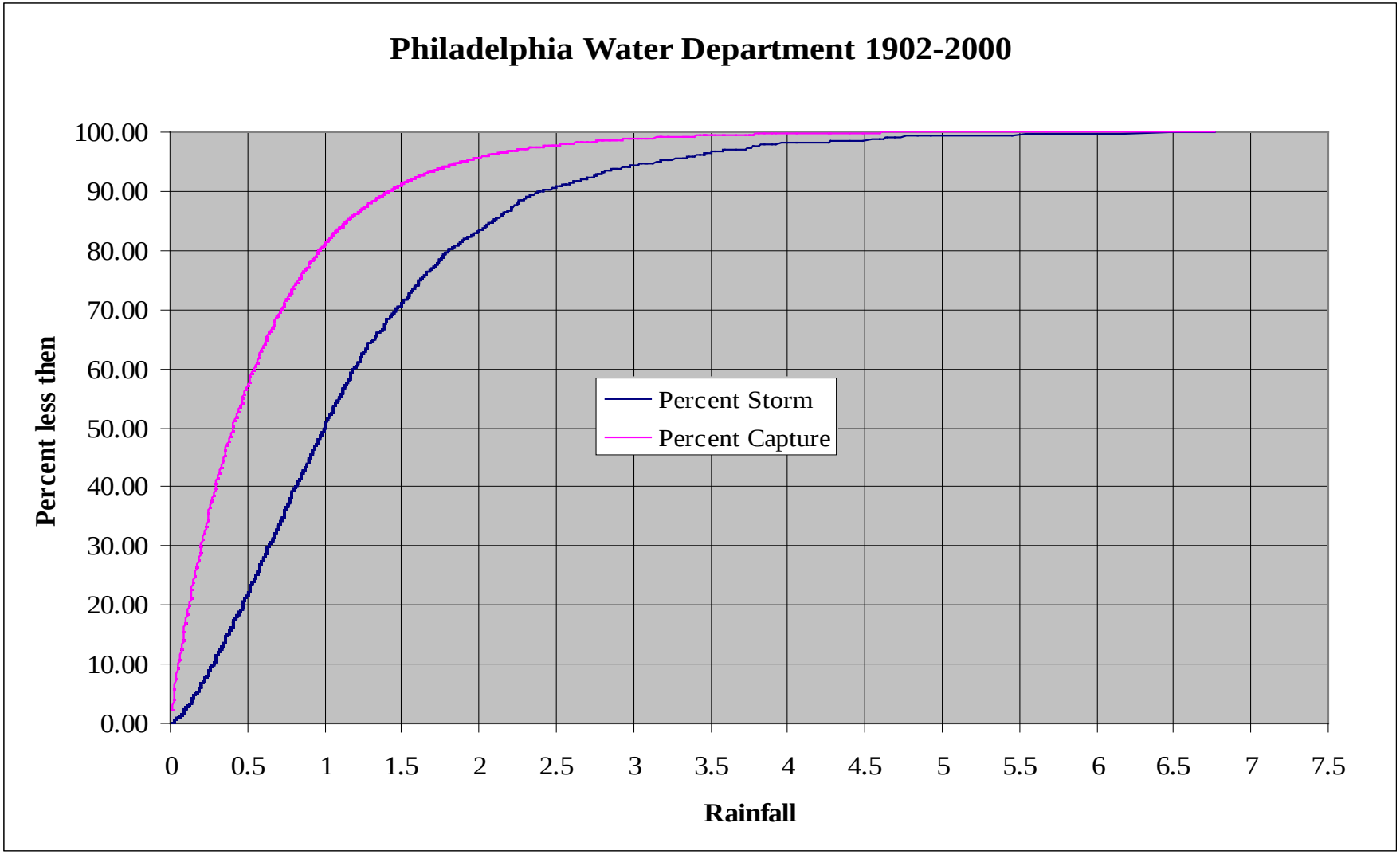
National Academies 2008

Chadds Ford 1999-2001 Depth (in.)



Design Criteria? – Impacts?

Brandywine River	Rainfall –	45”/yr
Base Flow	30% -	14.0”
Runoff	15% -	6.5”
ET- Deep GW	55% -	24.6”



- **Land Use / Product Substitution**
  - LID / Green Infrastructure

- **Volume Reduction**
  - Capture / Reuse
  - Green Infiltration
    - BioInfiltration, Swales, etc
  - Green Evapotranspiration
    - BioRetention
    - Green Roofs
  - Rock Bed Infiltration
    - Pervious pavements
    - Infiltration Trenches / Basins

- **Extended Detention**
  - Stormwater Wetlands
  - Dry / Wet Ponds

- **Management**
  - Inspection & Maintenance
  - Street Sweeping
  - Replacement

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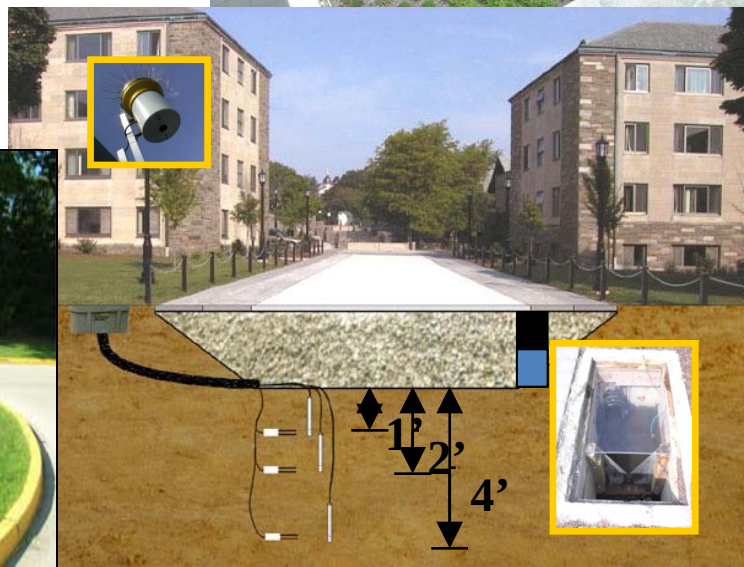
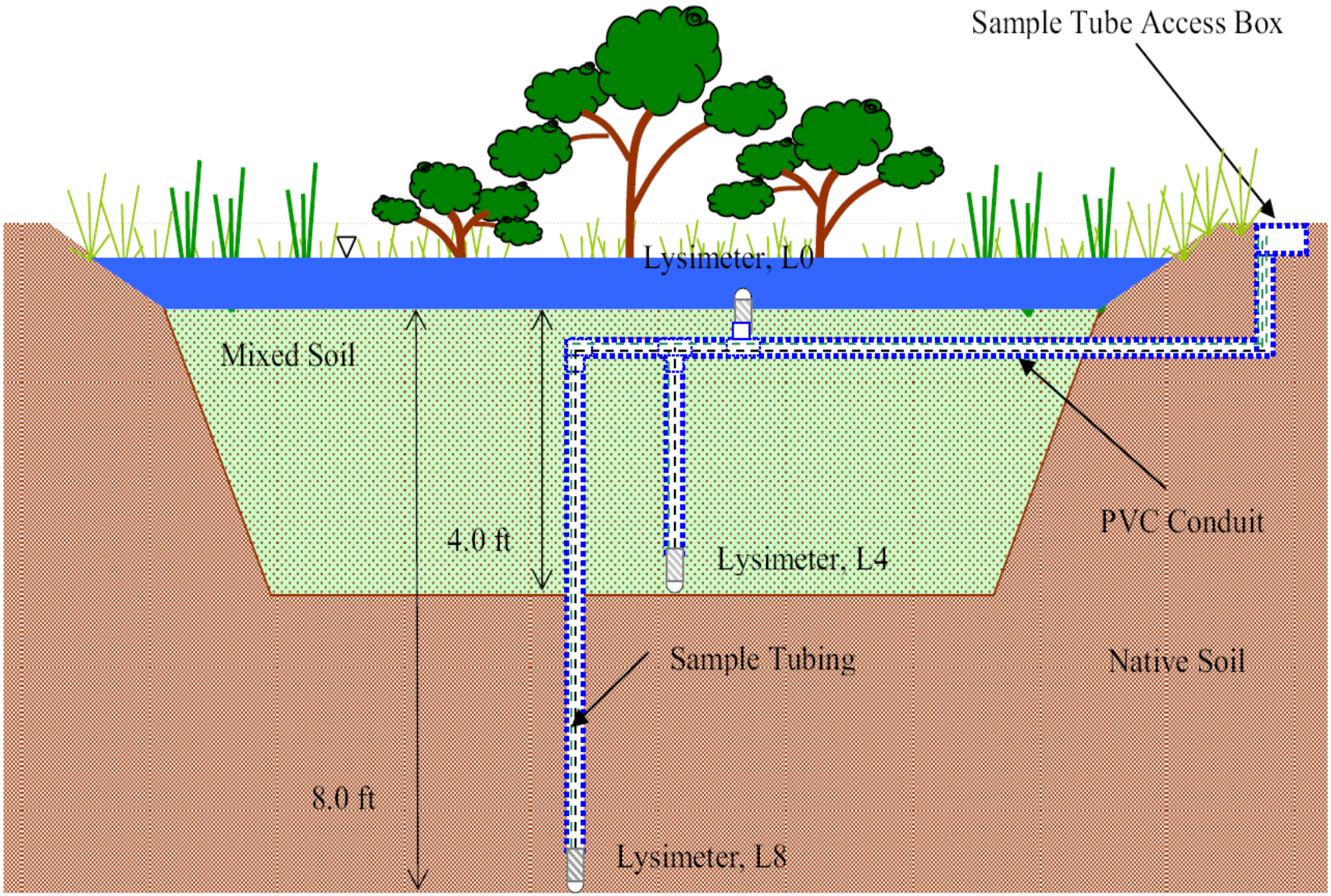
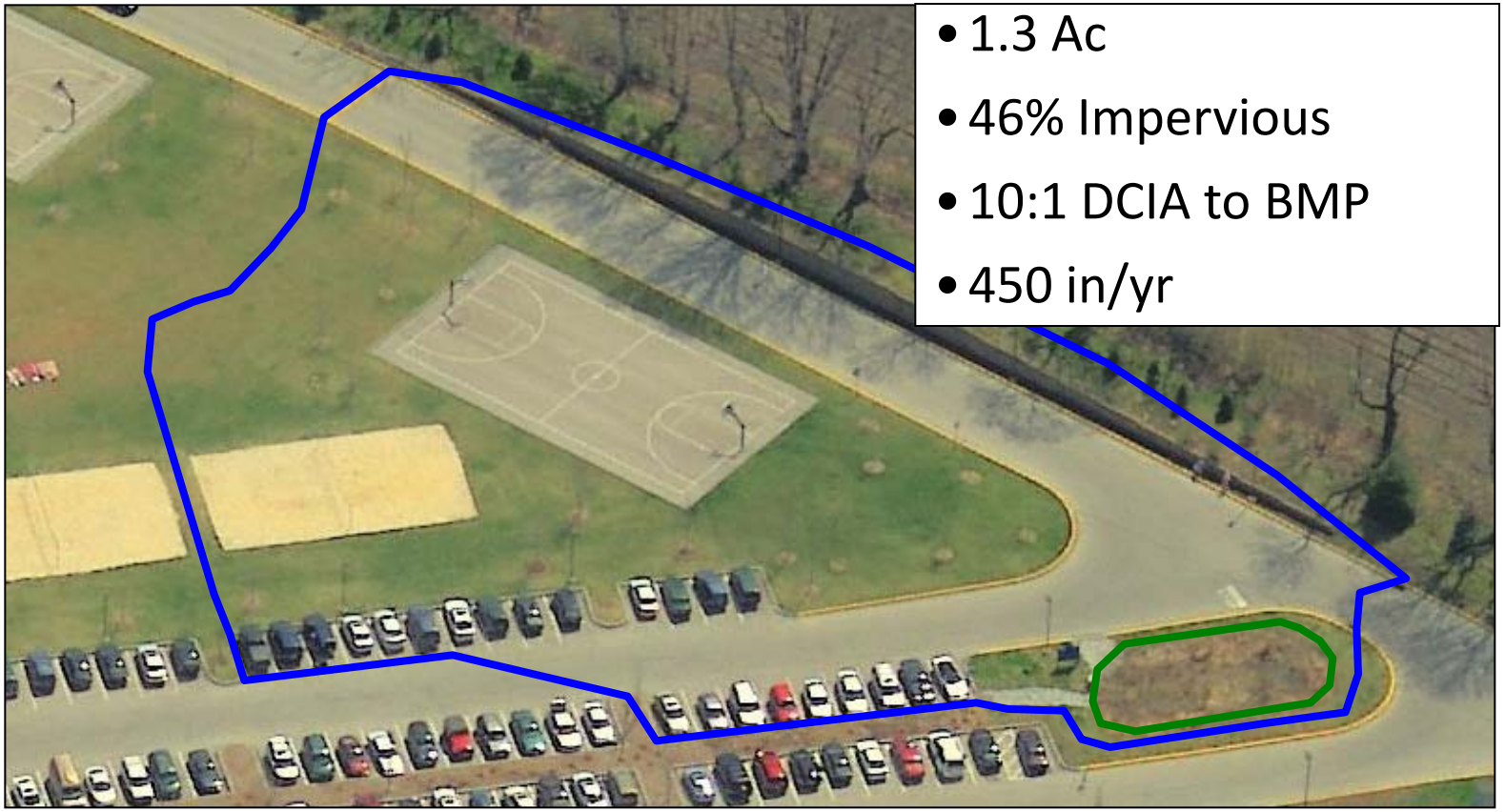


BioInfiltration Rain Garden

Profile


Sample Tube Access Box
Lysimeter, L0
Mixed Soil
4.0 ft
Lysimeter, L4
PVC Conduit
Sample Tubing
Native Soil
8.0 ft
Lysimeter, L8

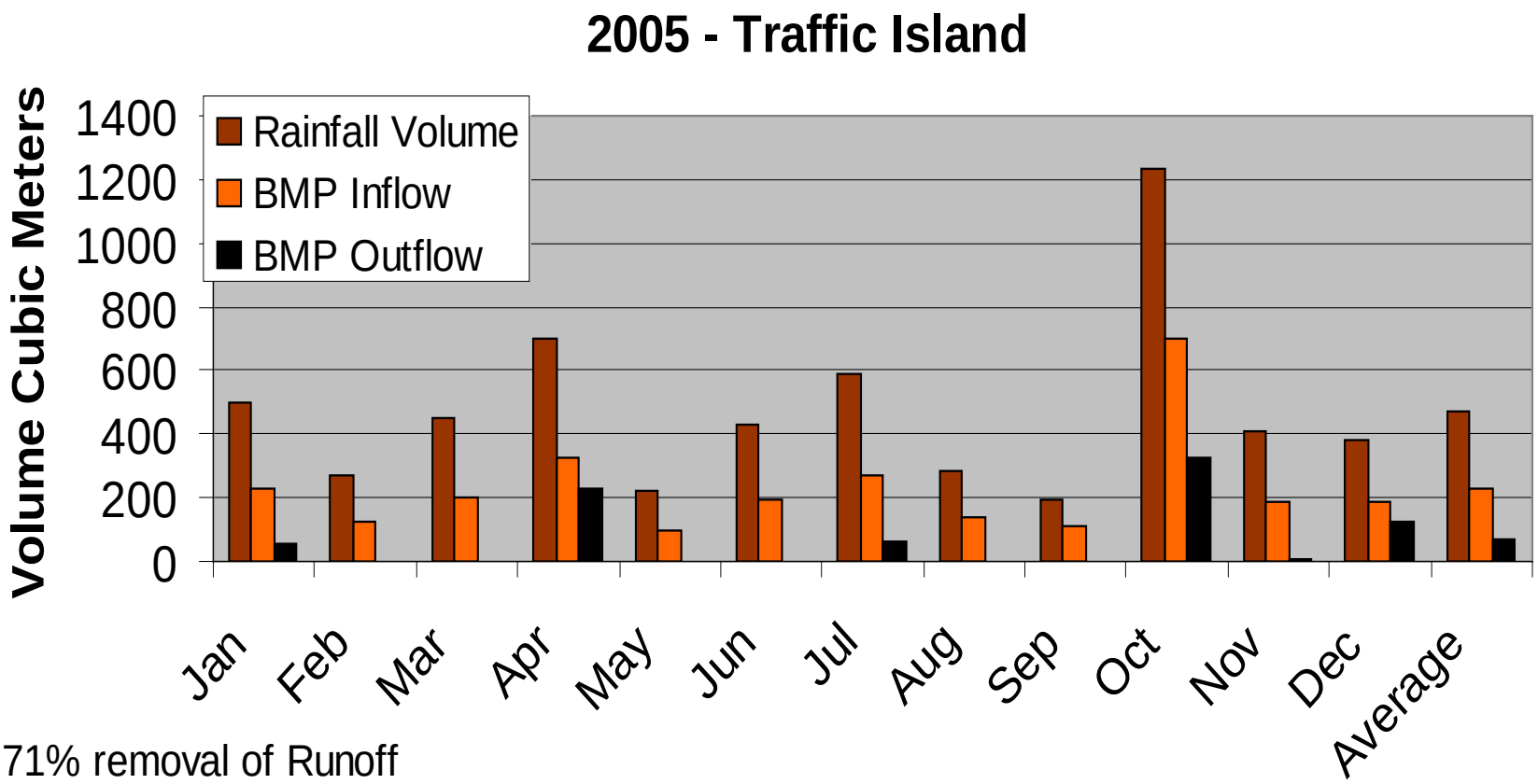
Rain garden



- 1.3 Ac
- 46% Impervious
- 10:1 DCIA to BMP
- 450 in/yr

- Constructed in 2001
- ~4 ft excavation, filled with a 1:1 sand/soil mixture
- Planted with vegetation typically found along the eastern seaboard

Hydrologic Performance



71% removal of Runoff
86% removal of Rainfall

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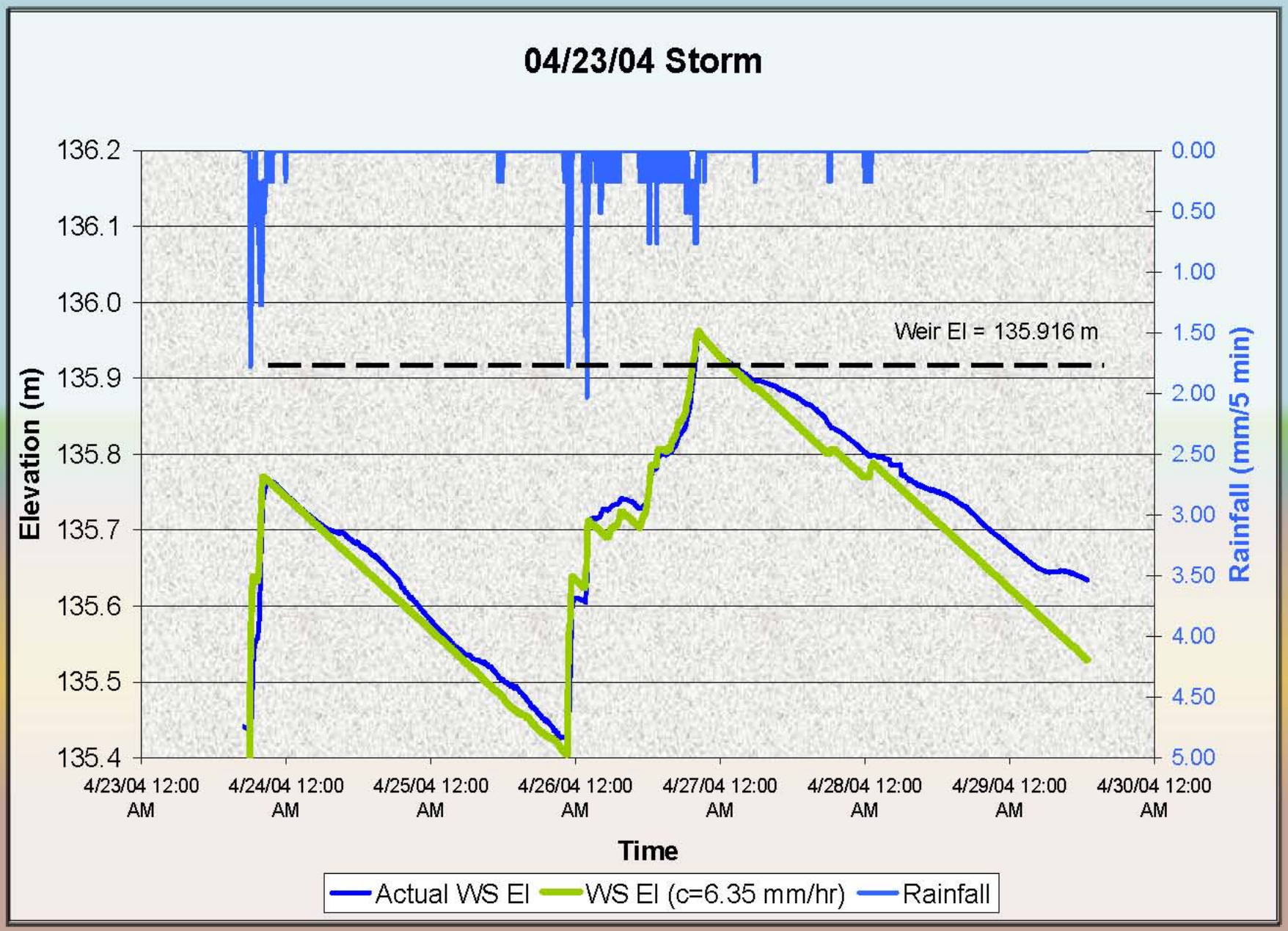
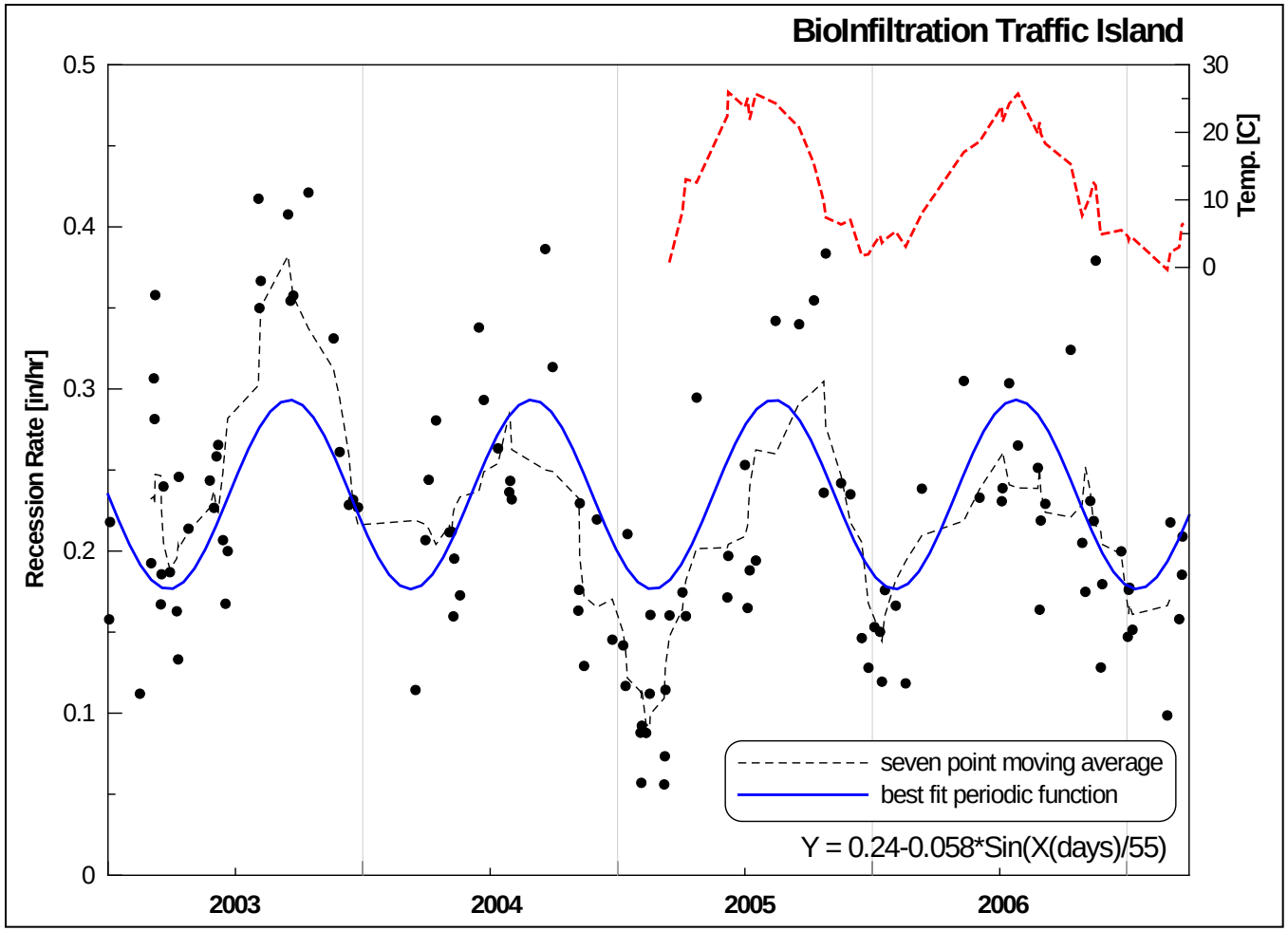
2007 Traffic Island Surface Water Analysis				
	# of Storms	Inflow	Outflow	Removal Efficiency
Water Quantity (1/2007 - 12/2007 Total)	19	983,843 L	185,117 L	81.2%
Water Quantity (1/2007 - 12/2007 Sampled)	17	943,874 L	185,117 L	80.4%
Total Phosphorus (TP) as P	17	614.4 g	142.4 g	76.8%
NO2 as N	16	55.0 g	13.6 g	75.2%
NO3 as N	16	505.3 g	46.7 g	90.8%
Phosphate (PO4) as P	16	131.0 g	30.7 g	76.6%
Chloride (CHL)	16	325.7 kg	0.3 kg	99.9%
Total Suspended Solids (TSS)	17	187.7 kg	1.4 kg	99.3%
Total Dissolved Solids (TDS)	17	156.2 kg	7.2 kg	95.4%
Total Copper	8	21.0 g	2.3 g	89.0%
Total Lead	10	13.5 g	0.7 g	94.7%
Total Cadmium	10	1.9 g	0.1 g	97.3%
Total Chromium	12	21.8 g	0.8 g	96.1%



William Heasom

Temperature Variation



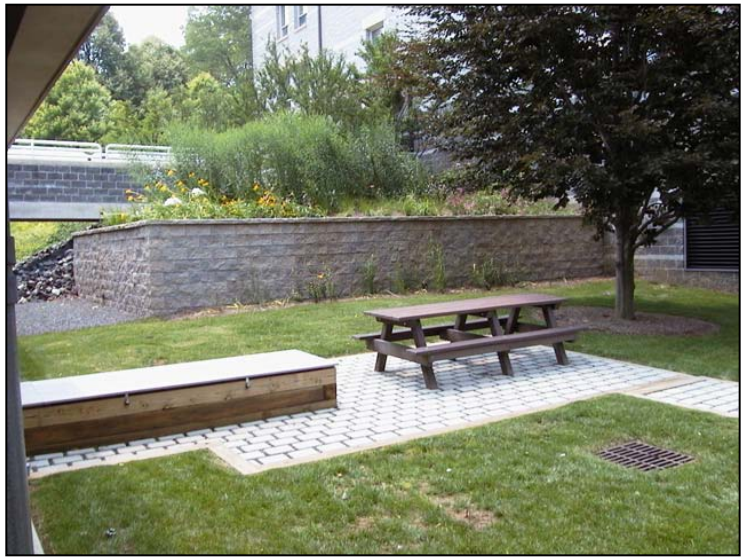
BTI (4.25 years of data)

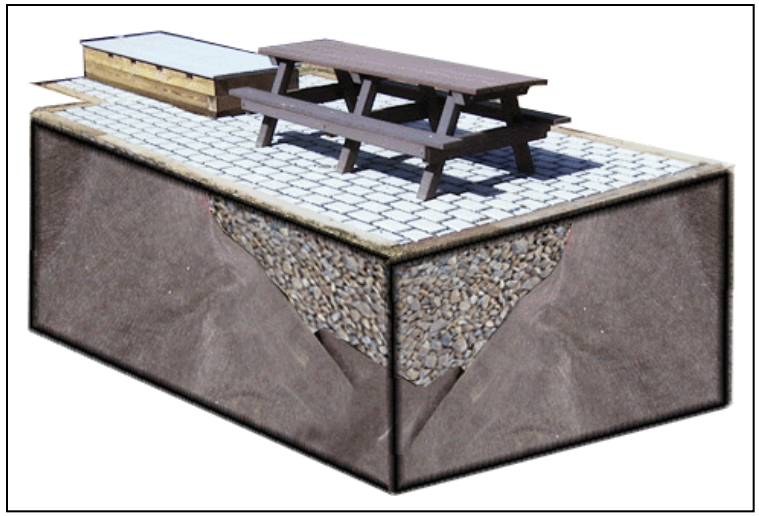
EMERSON

Infiltration Trench (IT)

- 0.47 Ac
- 100% Impervious
- 130:1 DCIA to BMP
- 5,900 in/yr

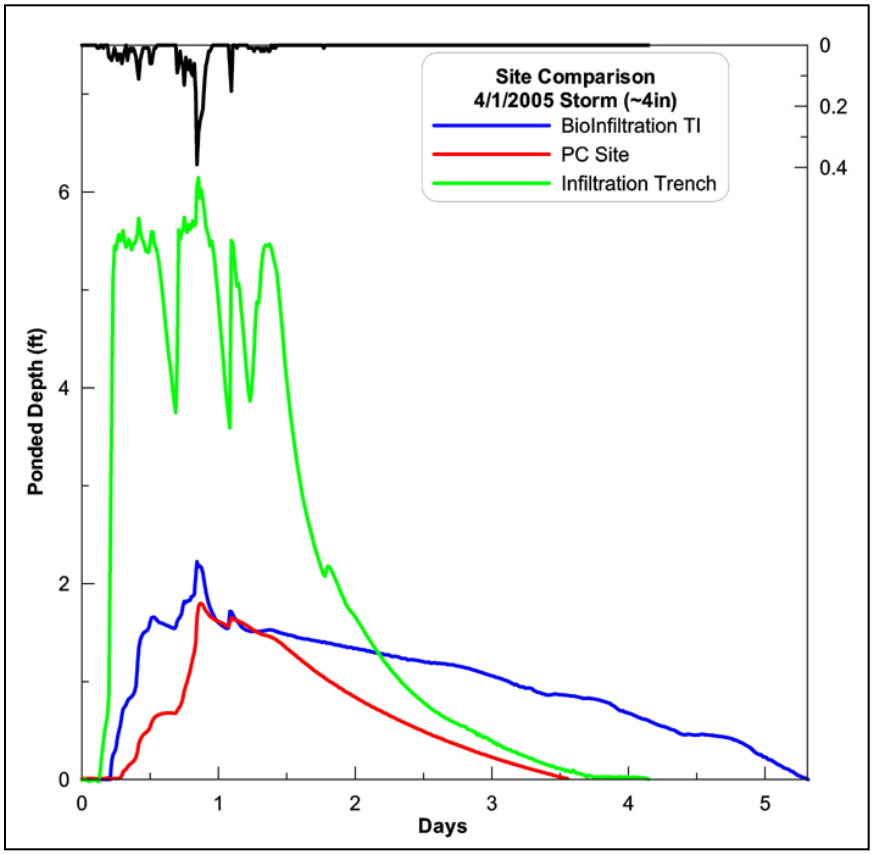
Infiltration Trench (IT)





- Depth measured using a pressure transducer
- Rainfall and temperature measurements
- Intentionally under (poorly) designed…

PERFORMANCE INDICATOR

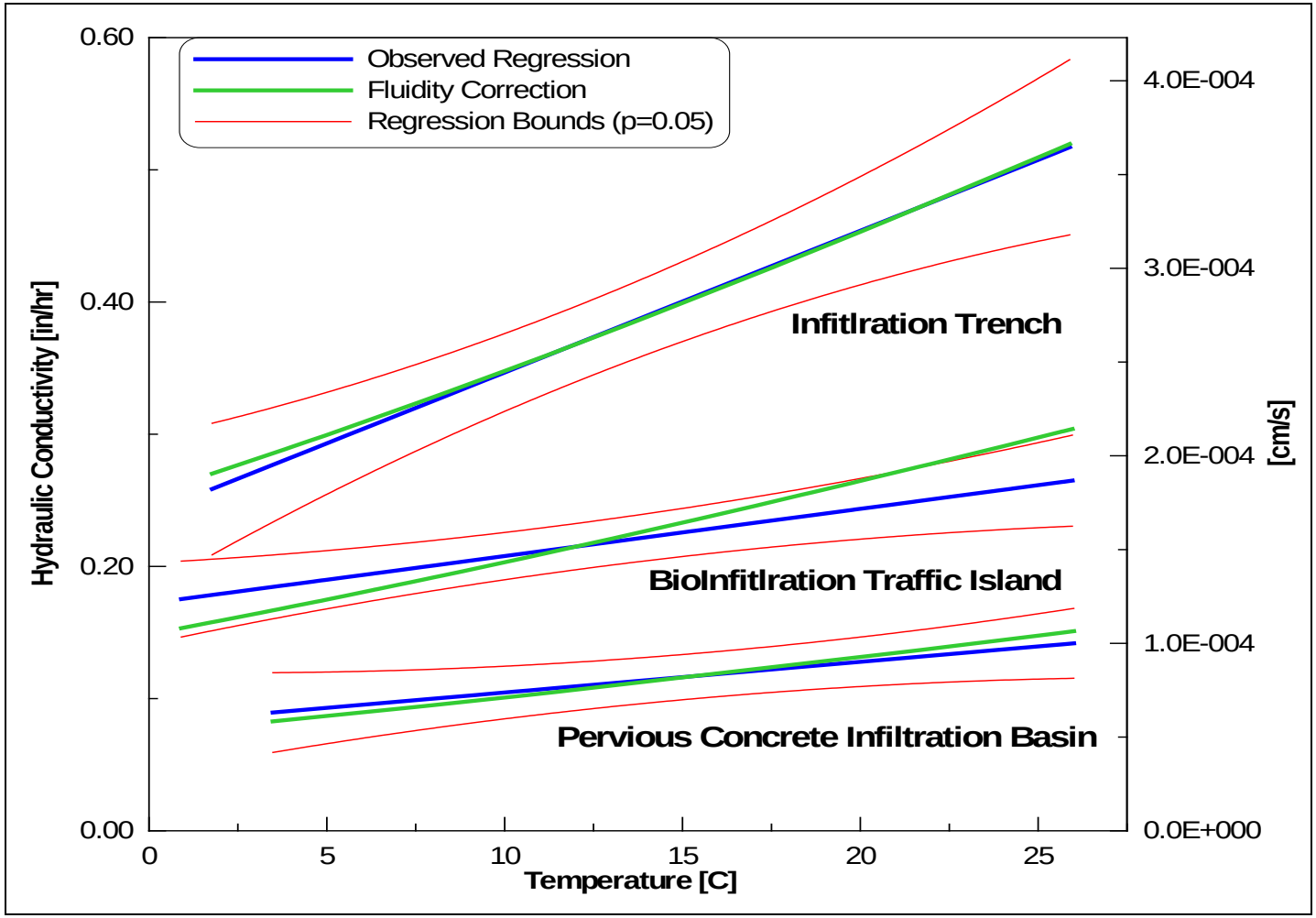


Ponded Recession Rate

- Not always constant with depth
- Each BMP has its own characteristic recession limb (shape) from storm to storm
- Can be compared over time (longevity)

Emerson

SEASONAL VARIATION

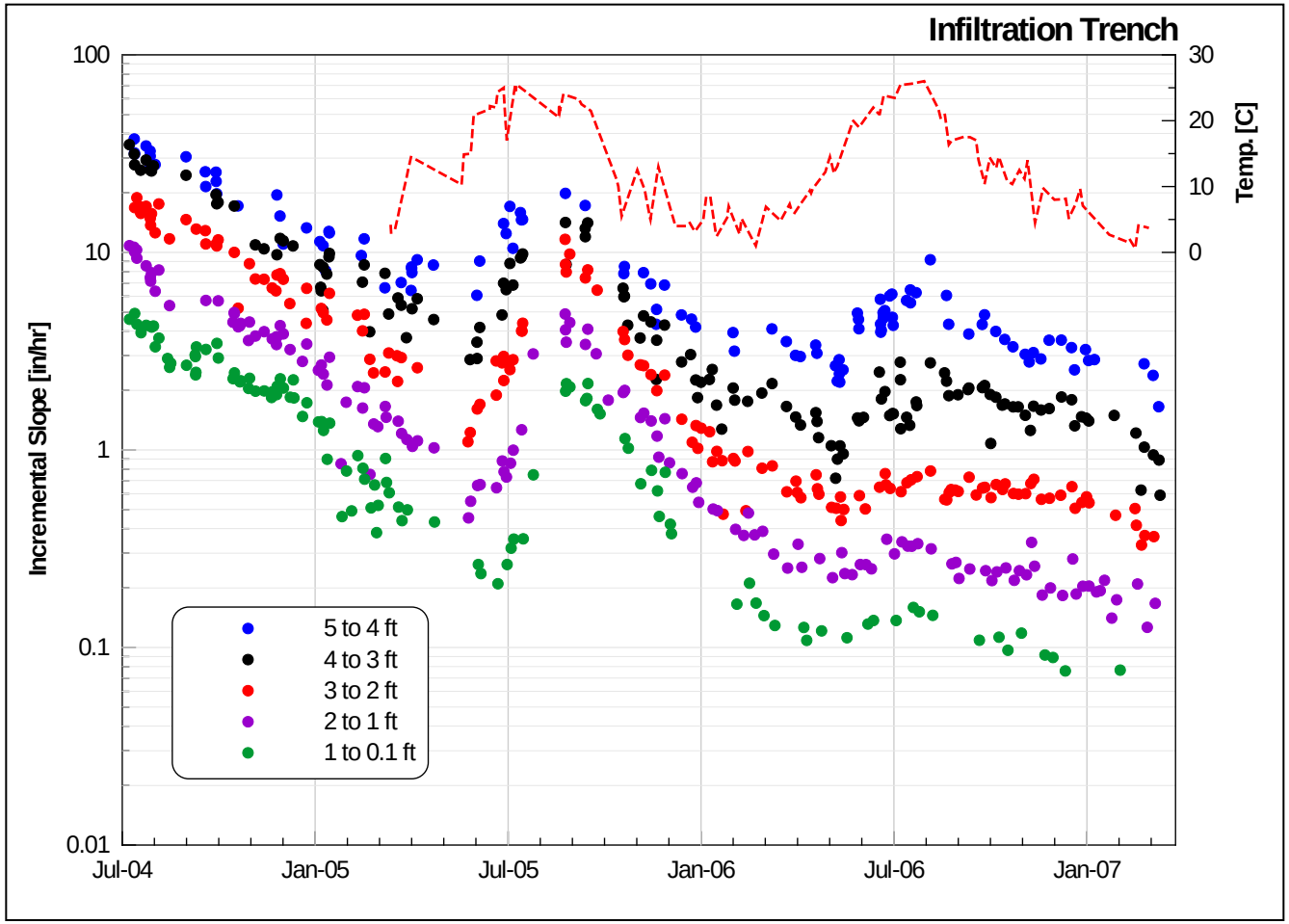


LONGEVITY

Infiltration Trench (IT)

Emerson

(log scale)



LONGEVITY

Extremely high (130:1) ratio of DCIA to BMP area

Inflow with characteristically high TSS concentrations

Closed bed, no vegetation, mulch, organic matter, or freeze-thaw

Deep and Sediments- Danger!

No Maintenance

Low (3-6:1) ratio of DCIA to BMP area

Inflow with characteristically low TSS concentrations

PC Filter

Shallow bed

Closed bed, no vegetation, mulch, organic matter, or freeze-thaw.

Heavily vegetated, Protective mulch layer, High organic matter content in surficial soil

Shallow bed

Freeze-thaw action

Can be maintained

Moderate (~10:1) DCIA to BMP ratio

Emerson

Performance Mis? Perceptions

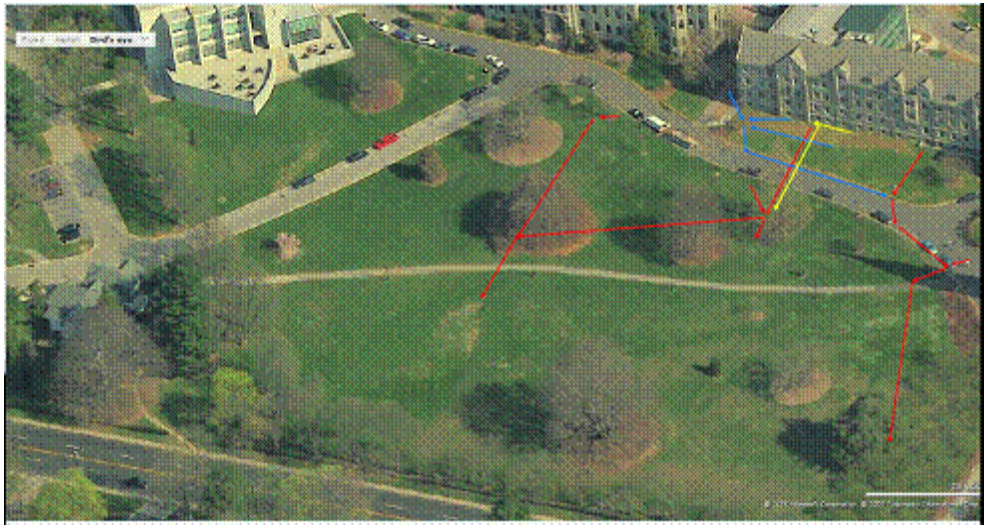
- PGC Md, Galli 1993
  - > 60 Infiltration (mostly trenches)
  - Most not working as designed
  - Listed sediment in pre treatment, location, construction and
  - (
- Subu
  1992
  - 1
- > ½ f

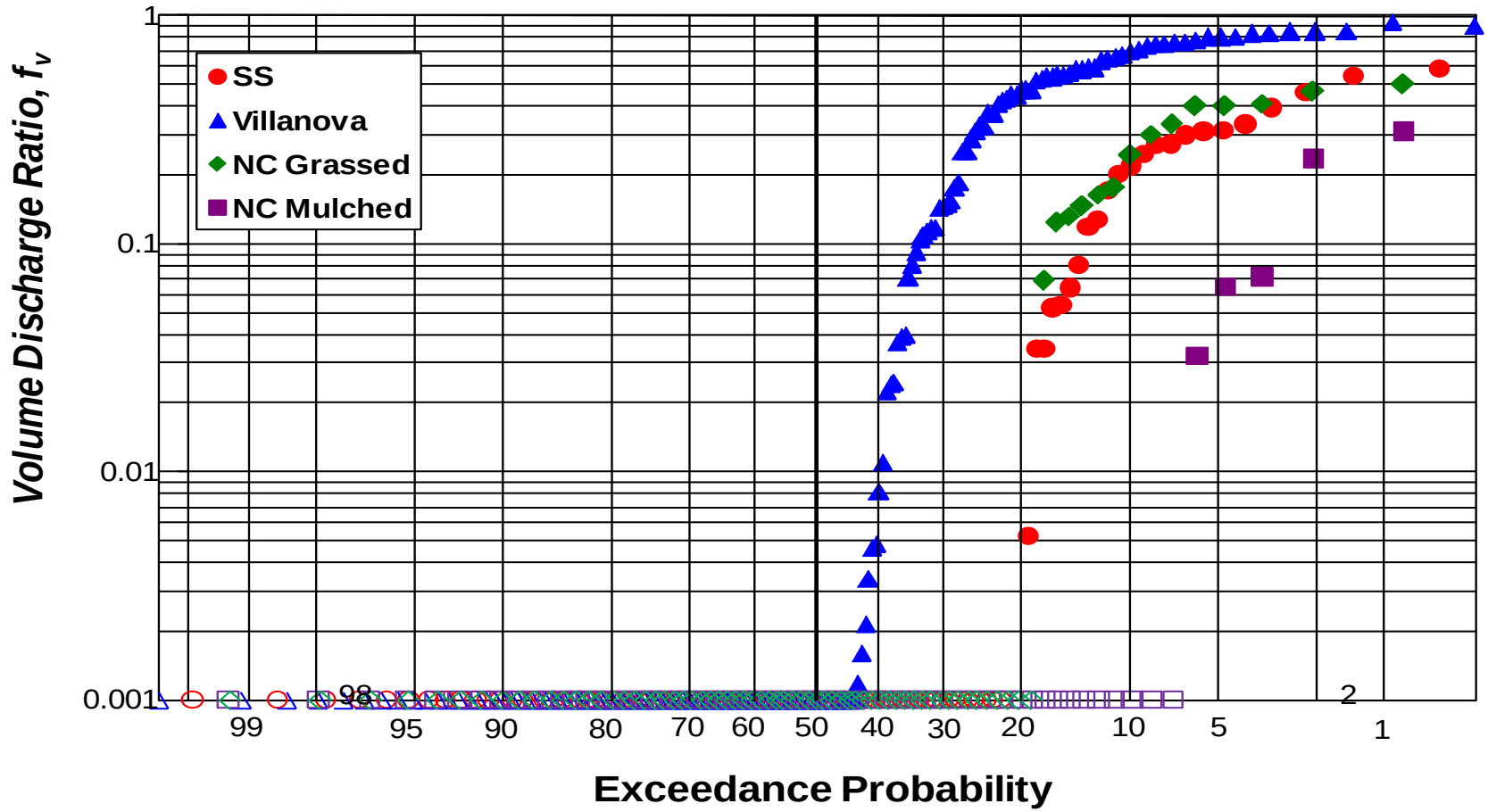
- Washington State Hilding 1996
  - Majority working
  - 1/3 had sediment buildup
- NJ Pine Barrens Princeton Hydro, LLC 2005

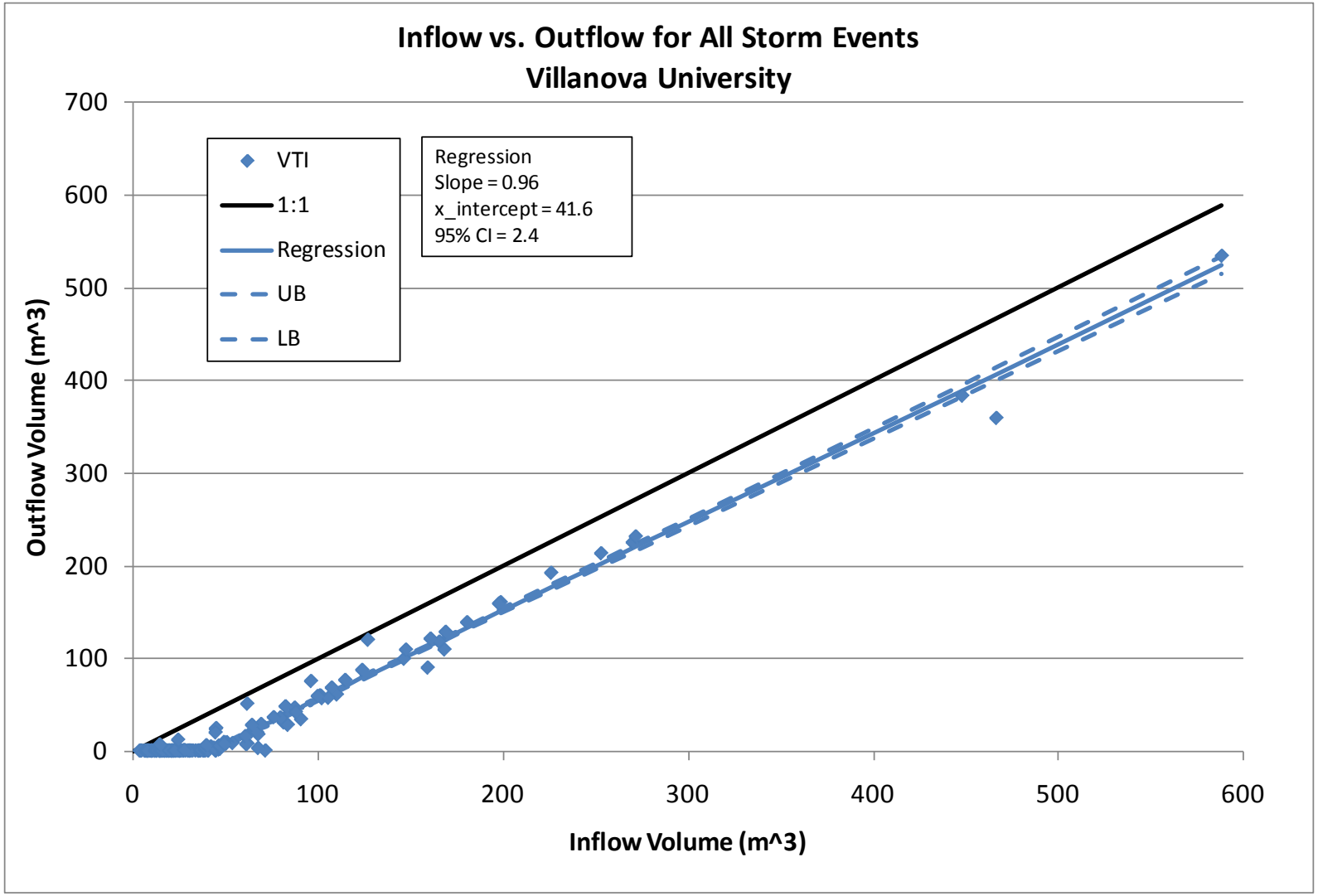
So, if you locate, design, construct, and maintain poorly.....

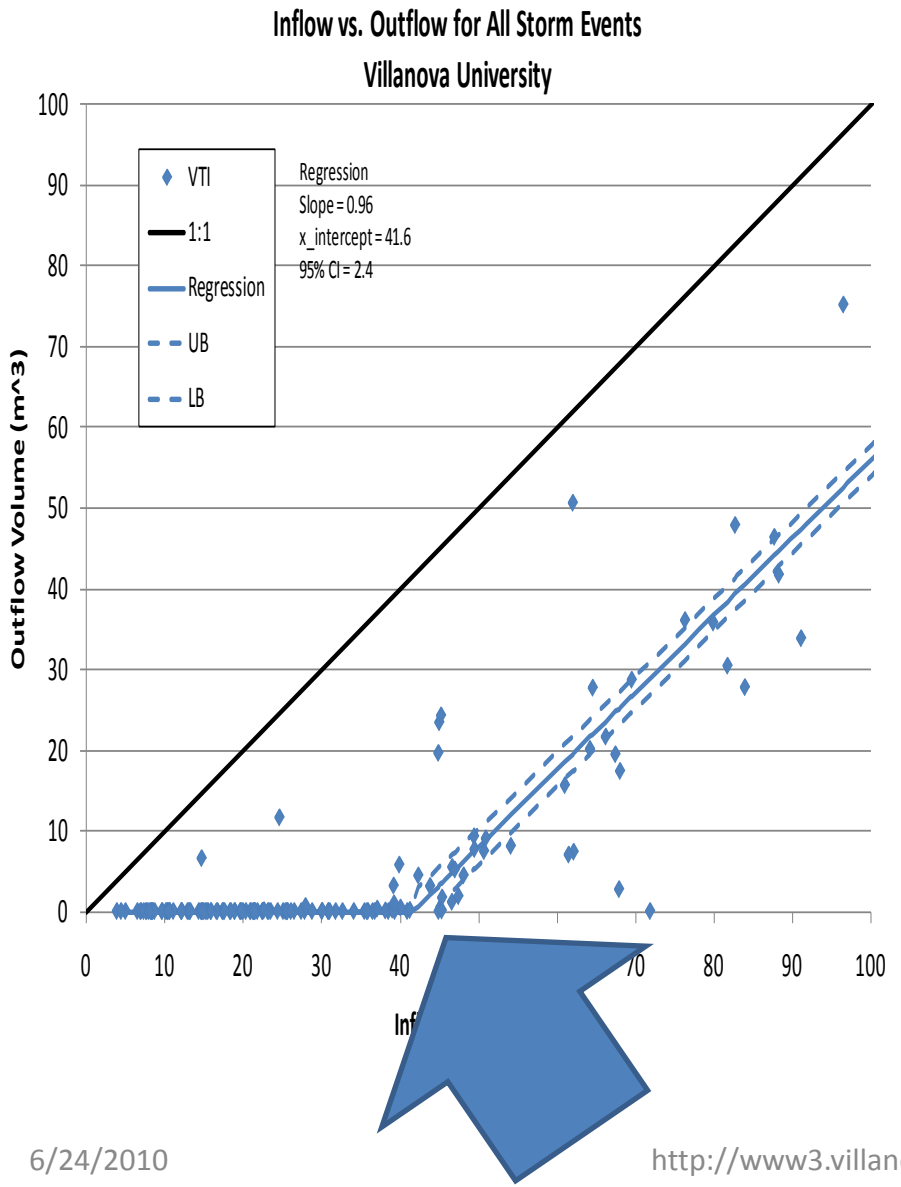
It will WORK 50% of the time.....

Villanova Seepage Pit




Volume Discharge Ratio, f_v
1
0.1
0.01
0.001
SS
Villanova
NC Grassed
NC Mulched
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
Exceedance Probability


Inflow vs. Outflow for All Storm Events
Villanova University
VTI
1:1
Regression
UB
LB
Regression
Slope = 0.96
x_intercept = 41.6
95% CI = 2.4
Outflow Volume (m^3)
Inflow Volume (m^3)
0
100
200
300
400
500
600
700



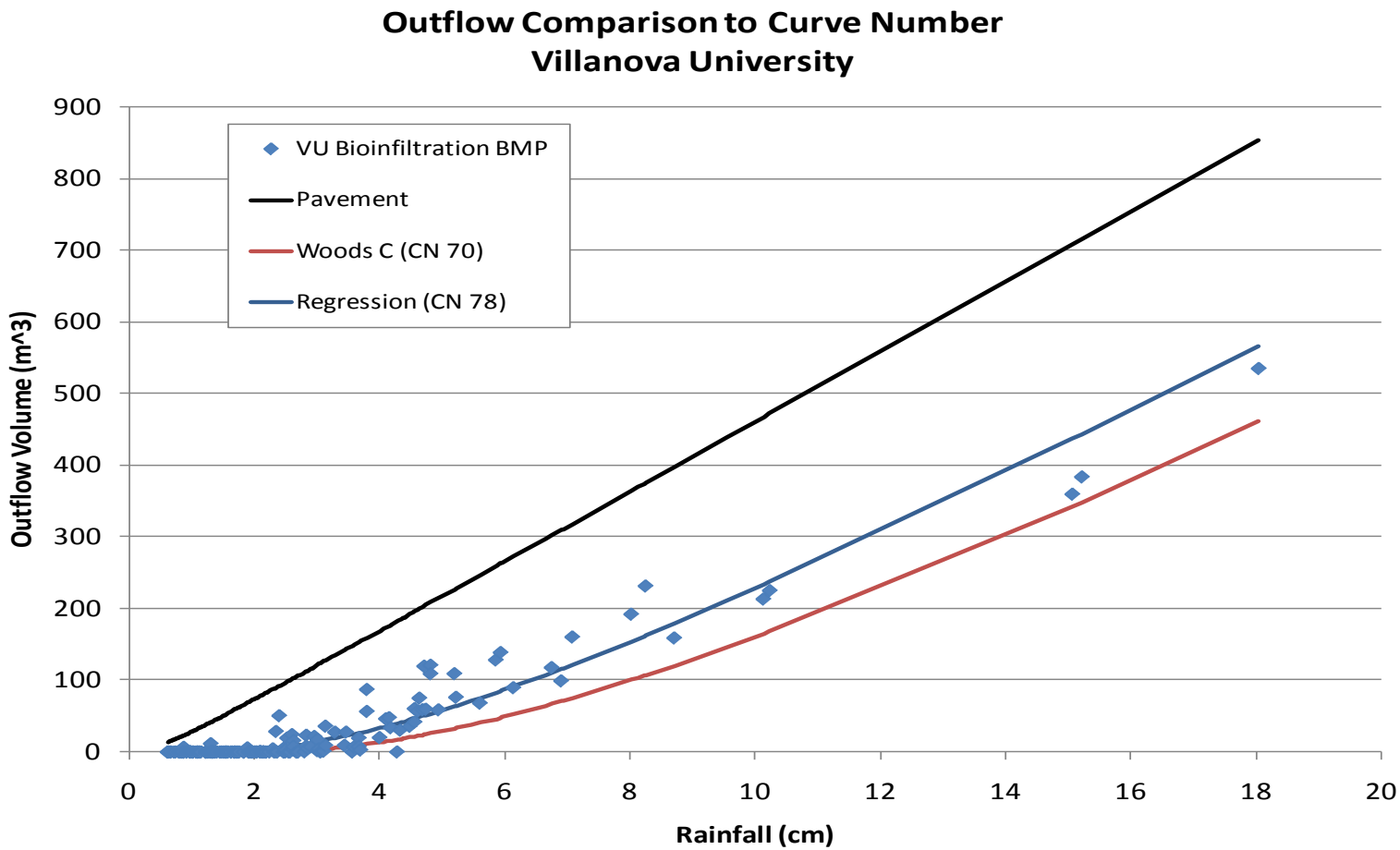
Break Point

Wilting Point?

Saturation?

Field Capacity?

6/24/2010
http://www3.villanova.edu/VUSP/
30


Outflow Comparison to Curve Number
Villanova University
VU Bioinfiltration BMP
Pavement
Woods C (CN 70)
Regression (CN 78)
Outflow Volume (m^3)
Rainfall (cm)
0
100
200
300
400
500
600
700
800
900
0
2
4
6
8
10
12
14
16
18
20

The Model Brocca CFM

- Brocca et al, 2008

$$e(t) = ET_P(t)\frac{W(t)}{W_{\max}}$$

$$ET_p(t) = a + b\left[\xi\left(0.018T_a(t) + 0.32\right)\right]$$

$$DP(t) = K_s\left[\frac{W(t)}{W_{\max}}\right]^{3+2/\lambda}$$

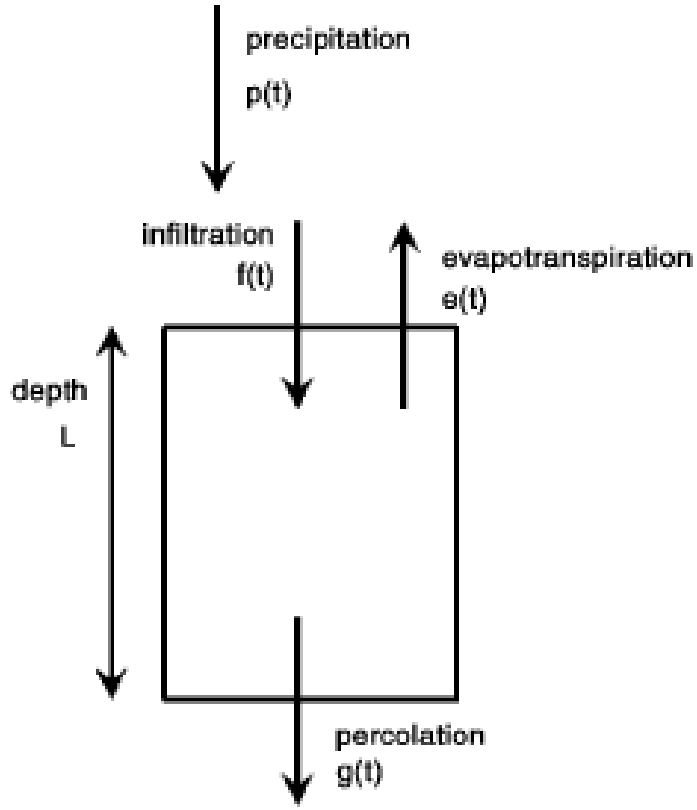
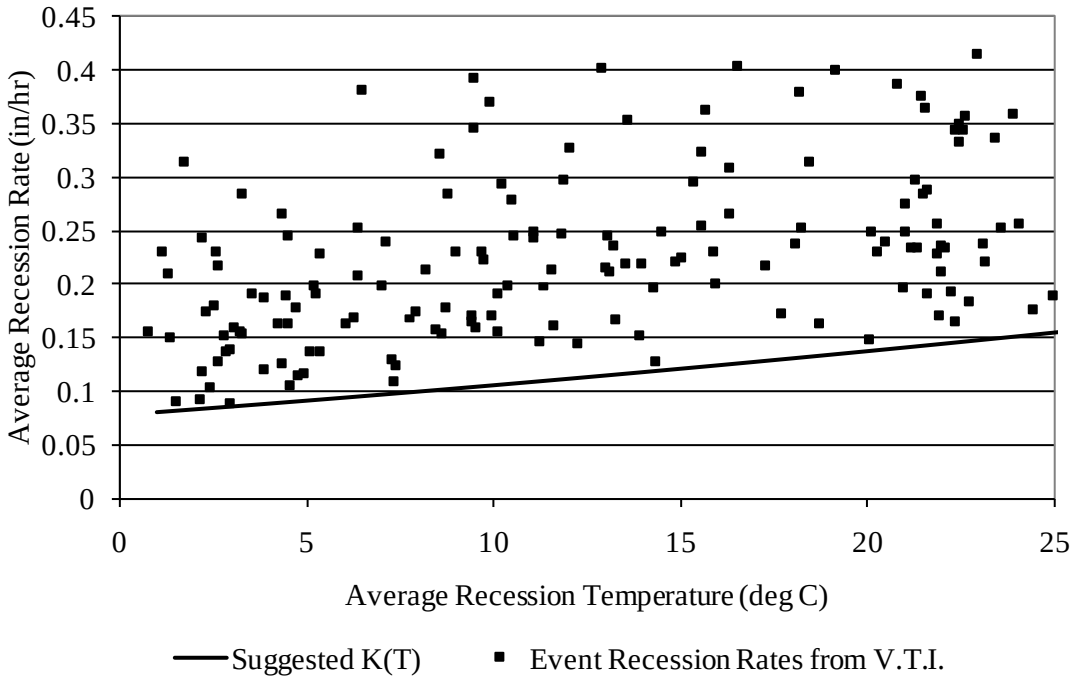


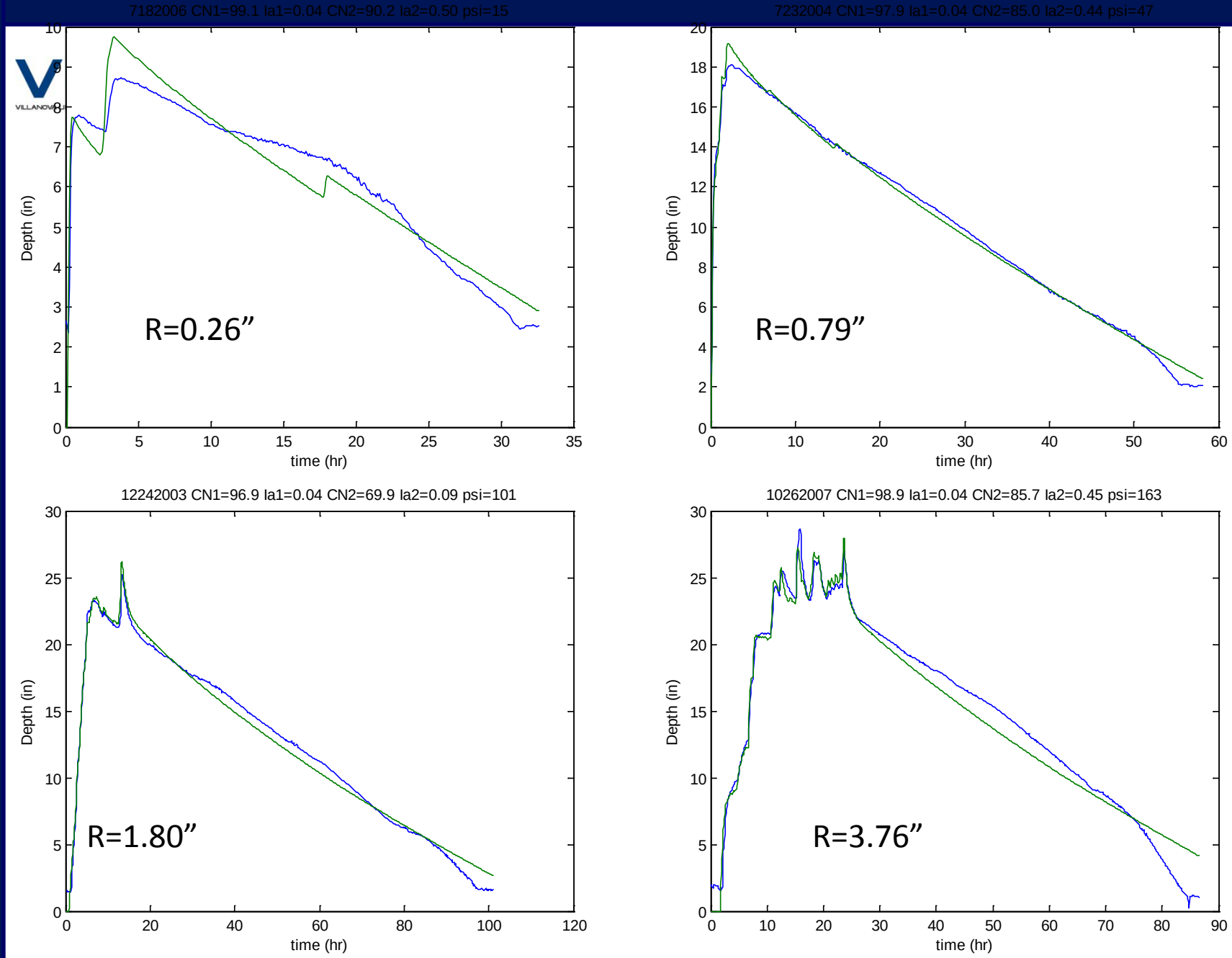
Figure 1. The root zone as a lumped hydrological system

Ryan Lee

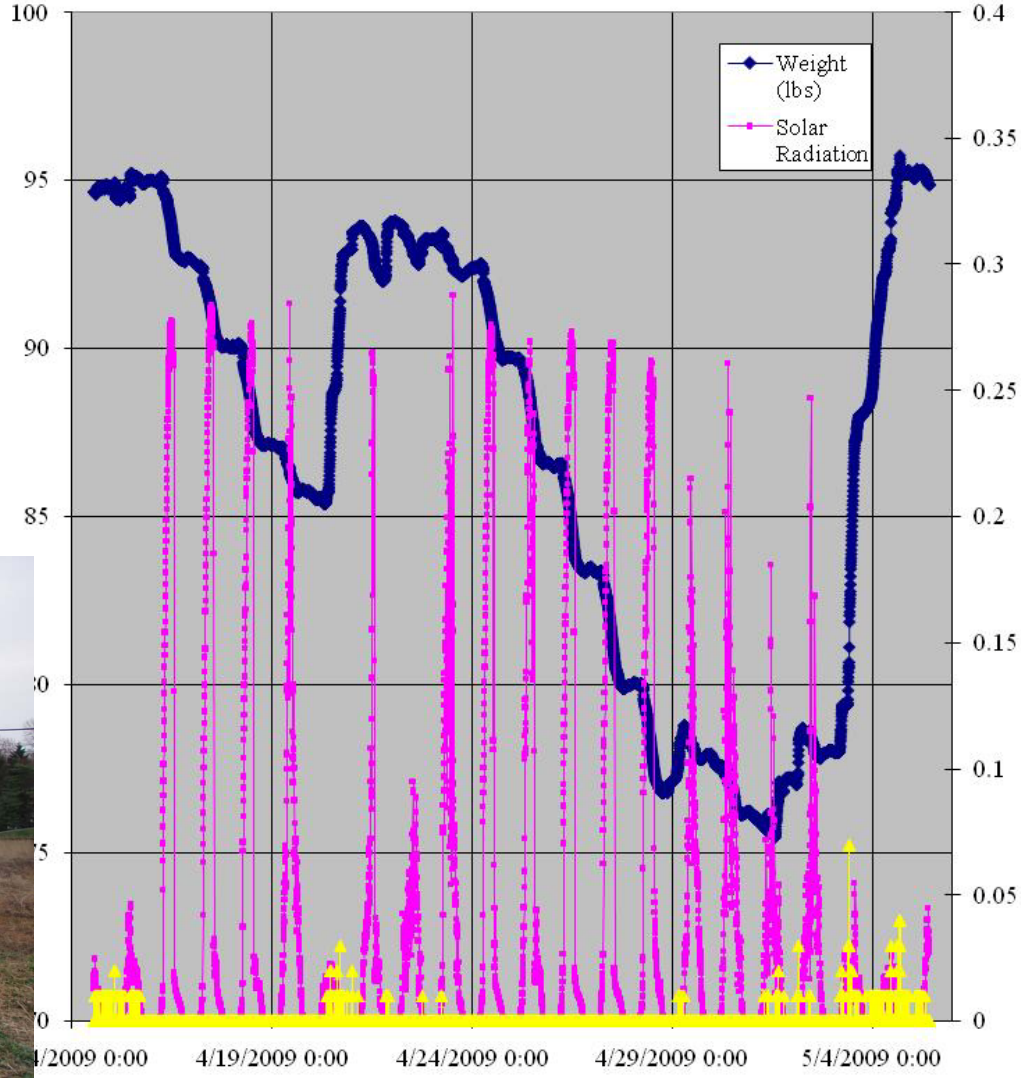
Determining K(T) from data

- Look at the infiltration eqn… dD/dt is <u>always</u> greater than K. This recession rate will approach K for low values of ψ (high moisture content).

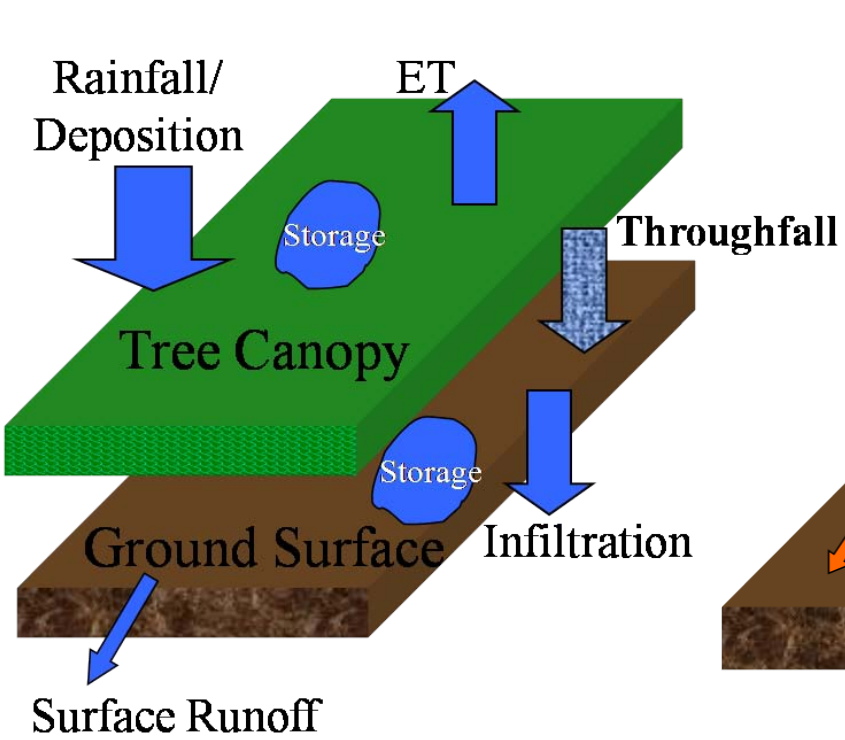


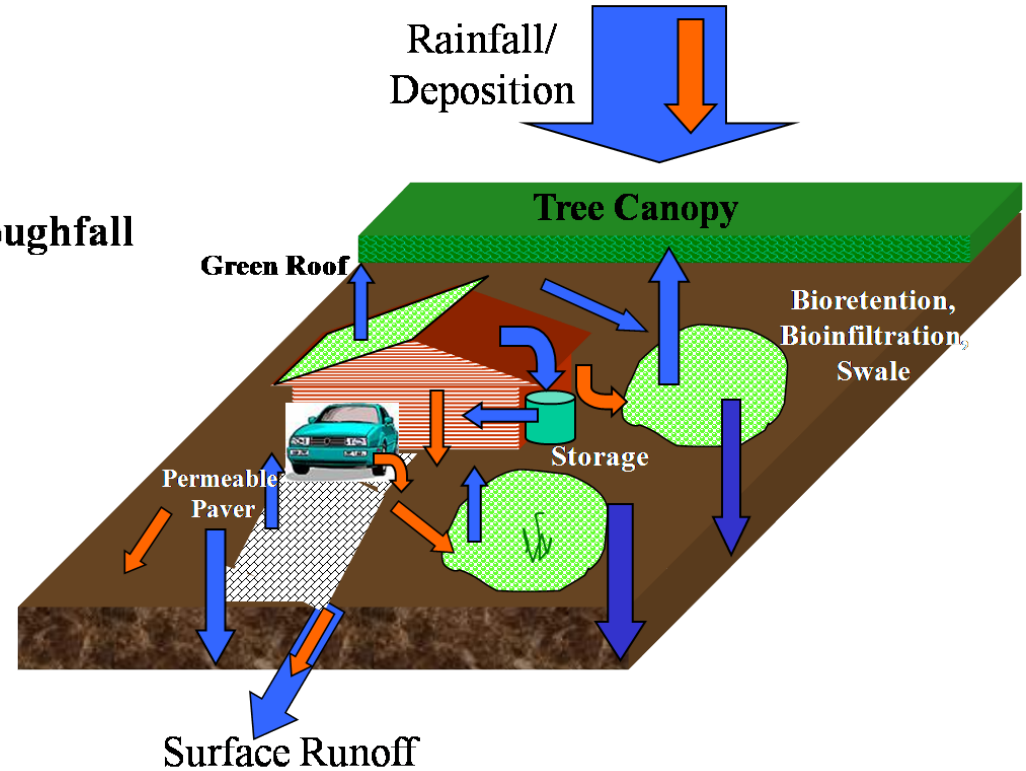

7182006 CN1=99.1 Ia1=0.04 CN2=90.2 Ia2=0.50 psi=15
Depth (in)
time (hr)
R=0.26”
7232004 CN1=97.9 Ia1=0.04 CN2=85.0 Ia2=0.44 psi=47
Depth (in)
time (hr)
R=0.79”
12242003 CN1=96.9 Ia1=0.04 CN2=69.9 Ia2=0.09 psi=101
Depth (in)
time (hr)
R=1.80”
10262007 CN1=98.9 Ia1=0.04 CN2=85.7 Ia2=0.45 psi=163
Depth (in)
time (hr)
R=3.76”

Other Studies - ET



Hydrology





Thanks to Allen Davis U Md.