

# UNH Stormwater Center BMP Treatment Performance



14 October 2010  
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Lake George, NY

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# Stormwater BMP Treatment Mechanisms

- Just as in the wastewater and drinking water field, stormwater BMPs employ unit operations and unit processes (UOP) for treatment
- UOPs for removal of pollutants from waste streams are the building blocks of environmental engineering

# Unit Operations and Unit Processes (UOP's)

Flow and Volume Controls

Sediment and Sediment Associated  
Contaminants

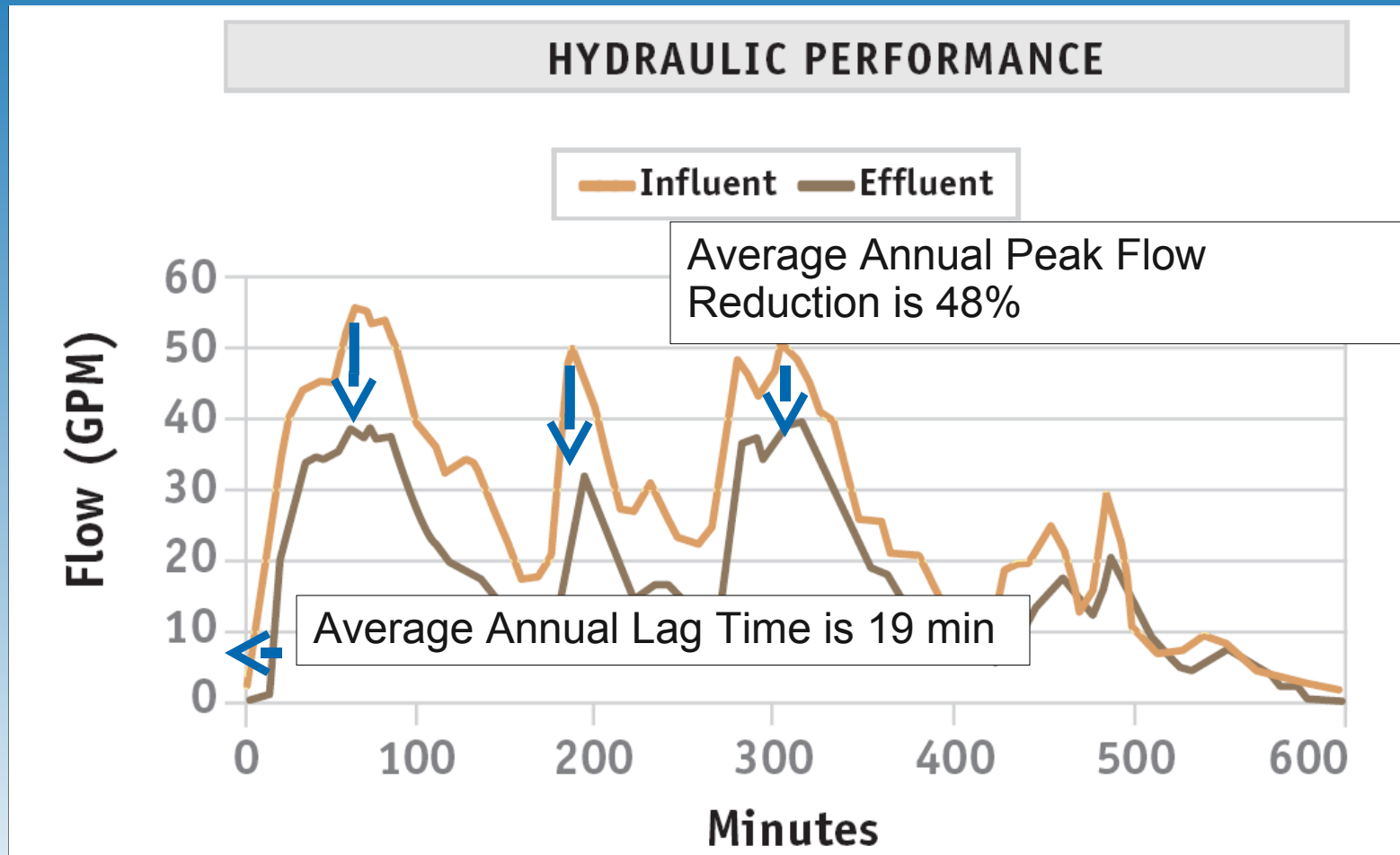
Biological Processes, microbes  
Nutrients (DIN)

Dissolved Contaminants,  
Phosphorus

A photograph of a stormwater pond. The pond is filled with greyish water and has several black pipes protruding from the grassy banks. The surrounding area is a mix of green grass and brown, dry-looking vegetation. In the background, there are trees and a pile of gravel or sand. The text "Hydrologic Performance Results" is overlaid in the center of the image in a large, bold, blue font.

# Hydrologic Performance Results

# Swale Flow and Volume Attenuation



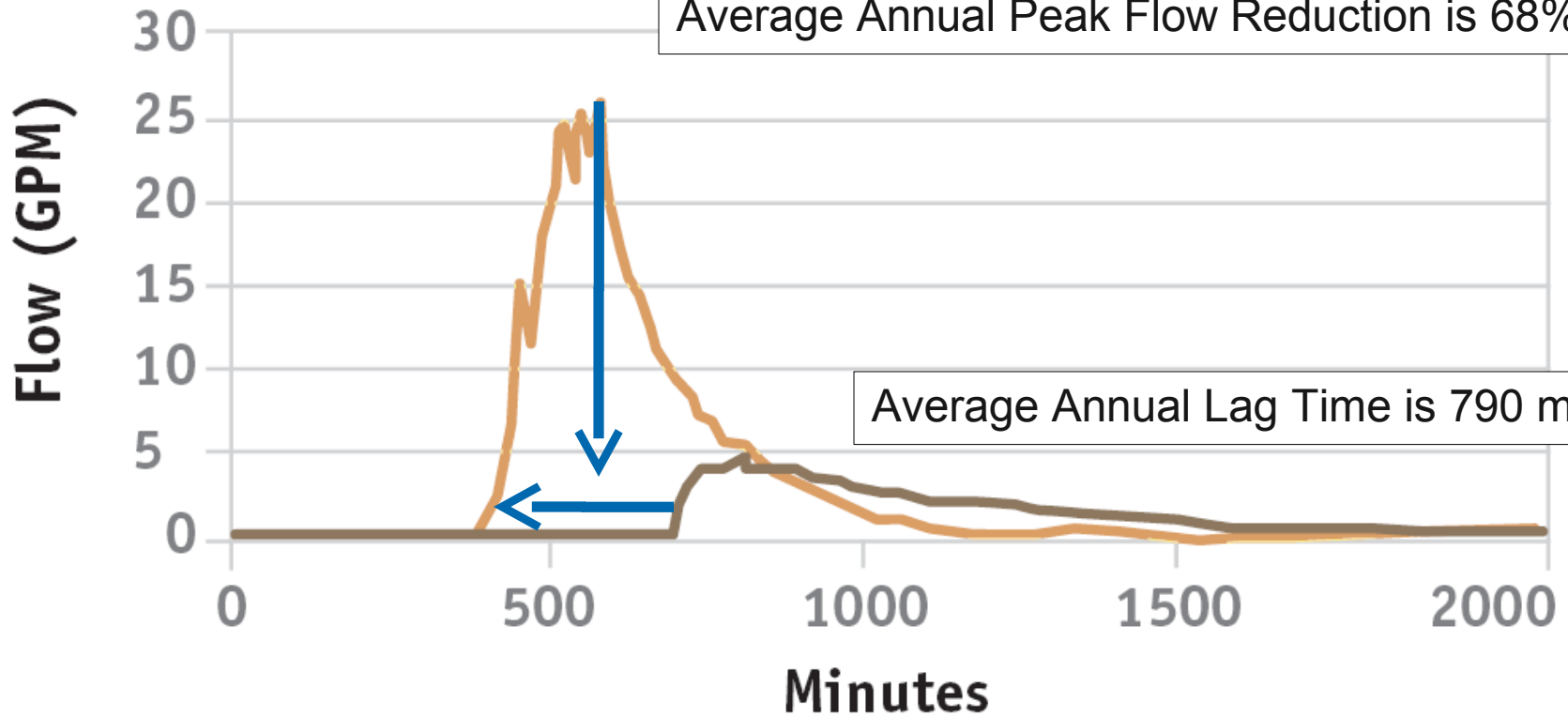
# Porous Asphalt Flow and Volume Attenuation

## HYDRAULIC PERFORMANCE

— Influent — Effluent

Average Annual Peak Flow Reduction is 68%

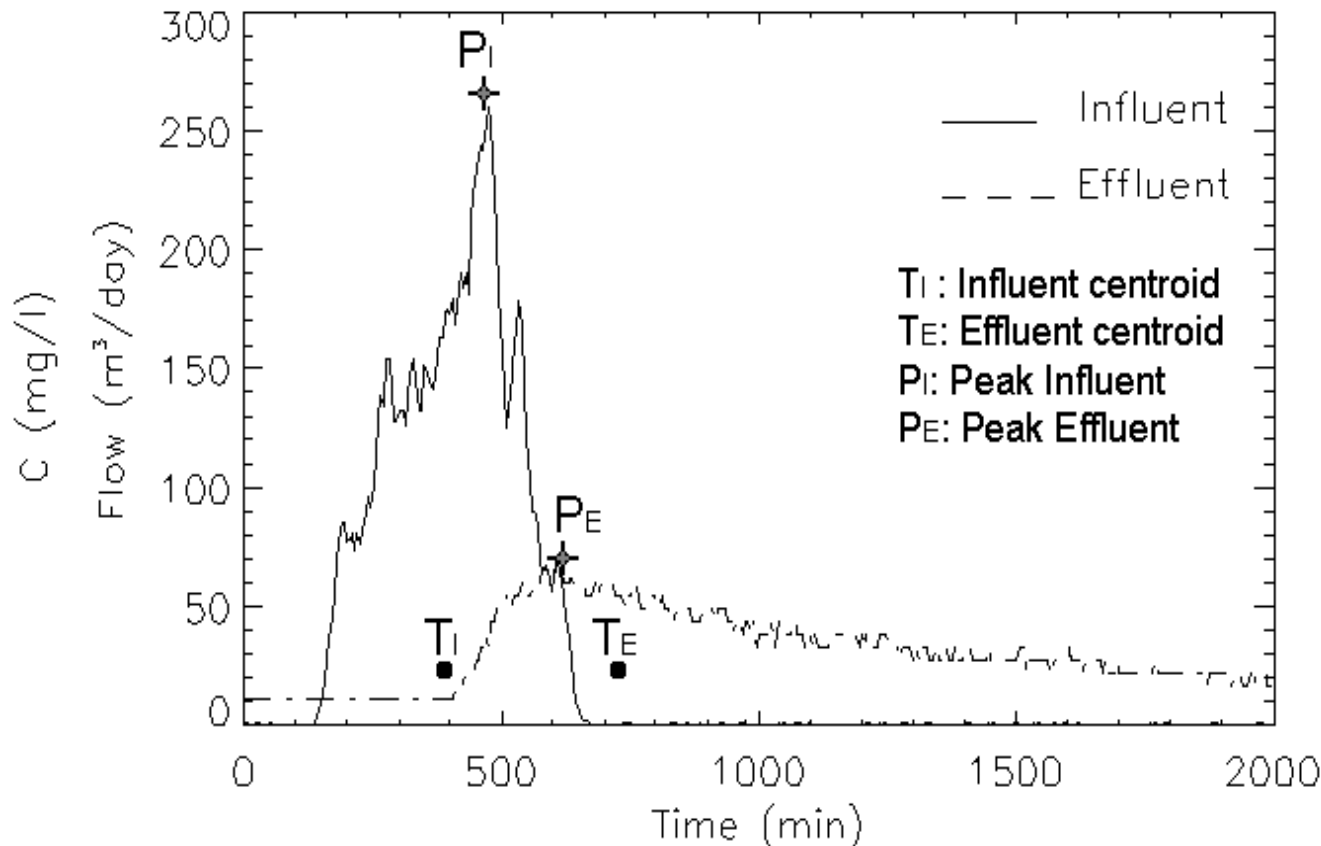
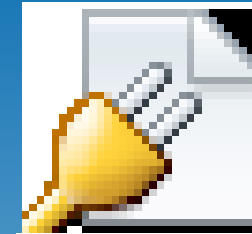
Average Annual Lag Time is 790 min



# Seasonal Hydraulic Efficiency

**Equation 1: Peak reduction coefficient**

**Equation 2: Lag coefficient**



# Hydraulic Performance

Lag Time (kL)

Peak Reduction (kP)

5

2

1

0.5

0.1



# Performance Results



# Event Mean Concentration

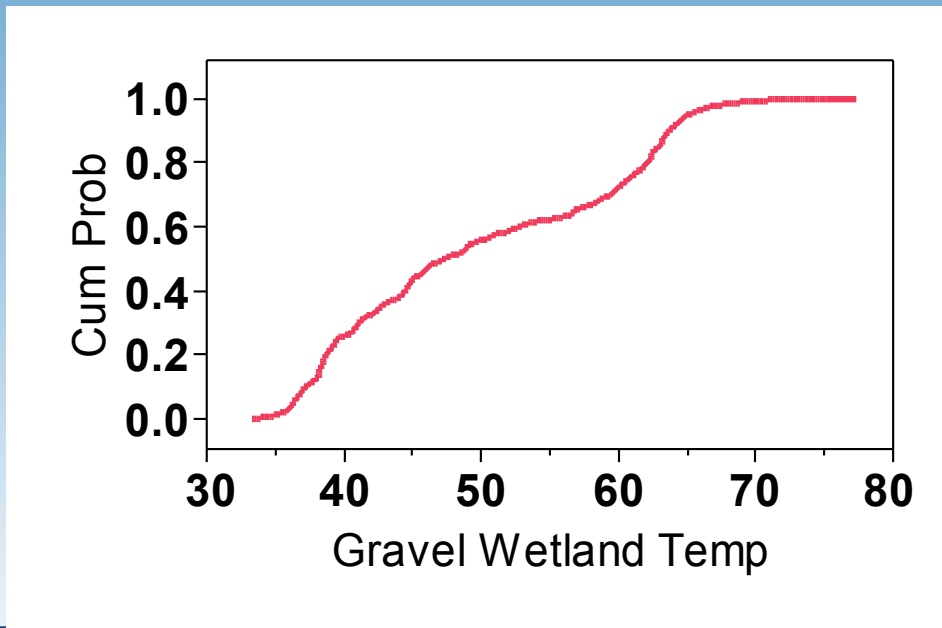
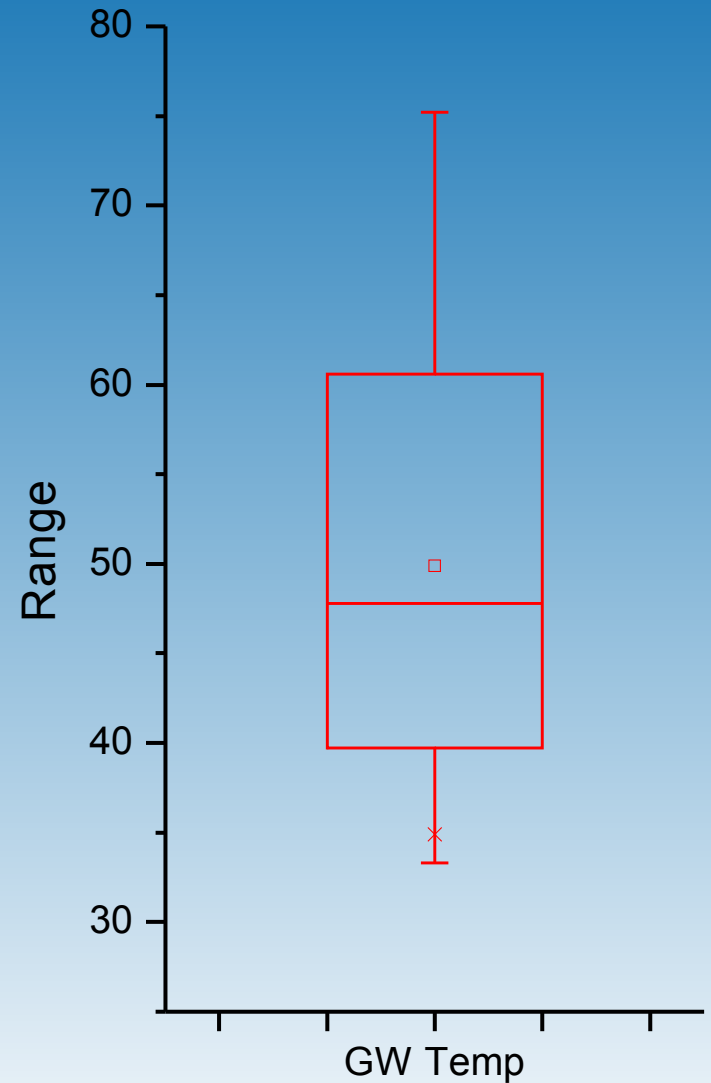
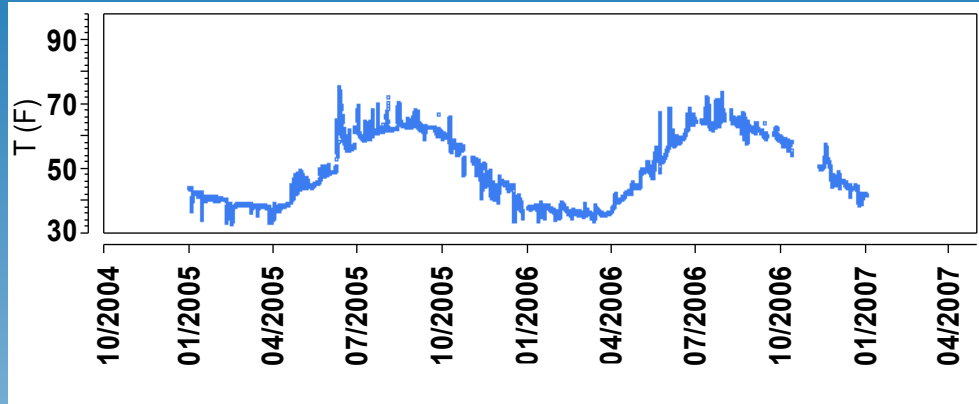
Discharge-weighted average concentration

$$EMC = \frac{\int Q(t)C(t)}{\int Q(t)}$$

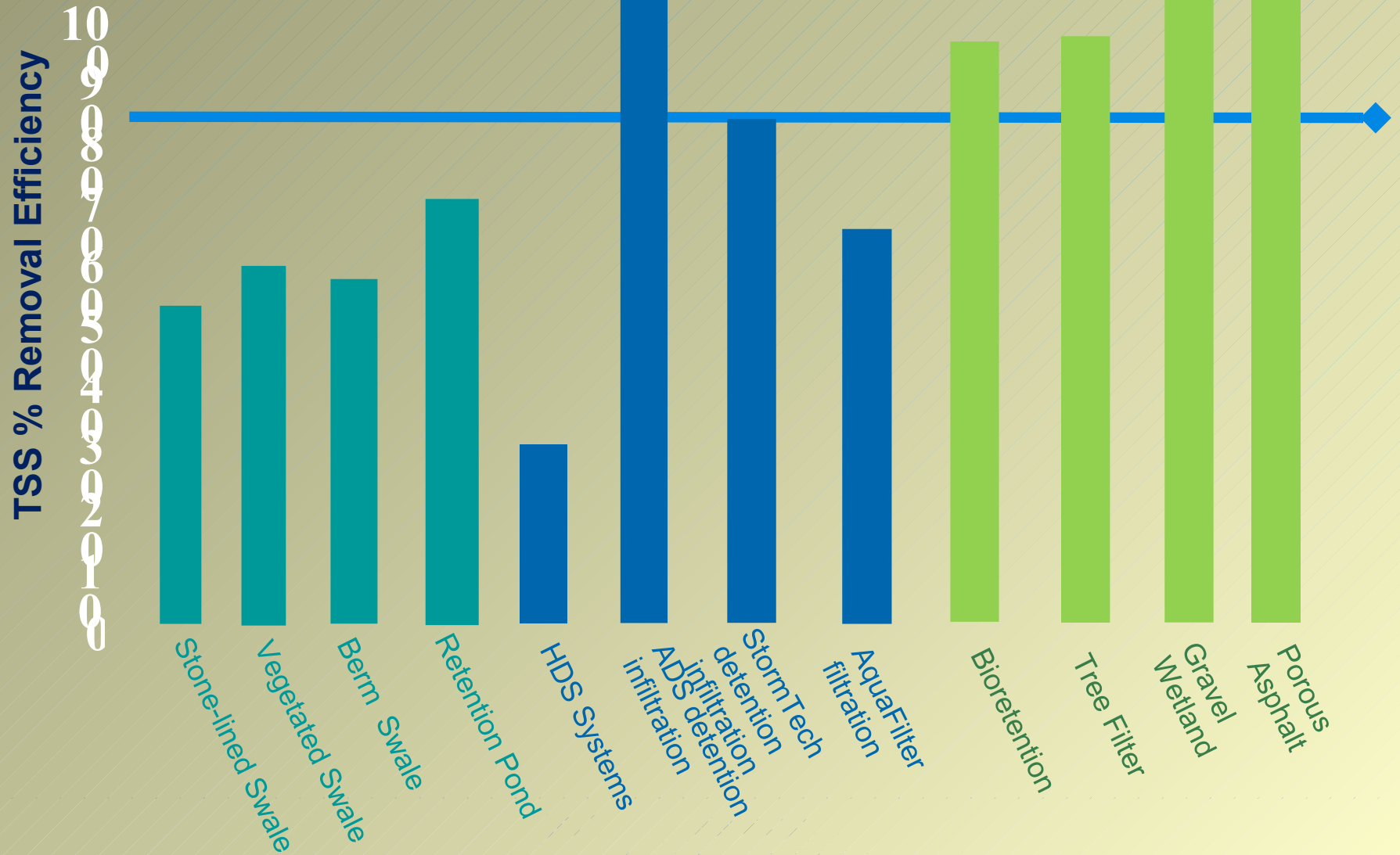
$$\approx \frac{\sum Q_i C_i}{\sum Q_i}$$

# Data Data Data

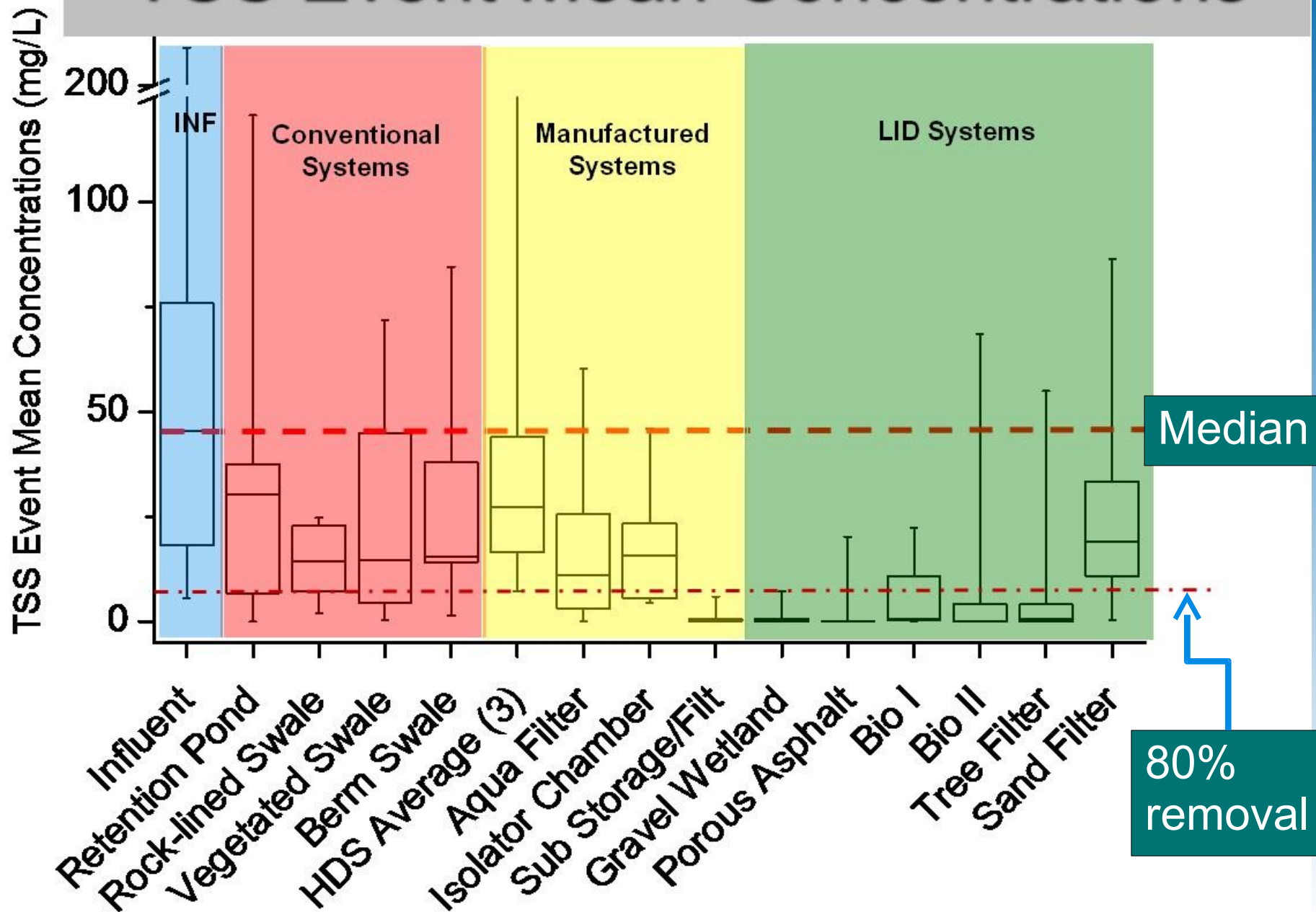
## Inflow Temperature



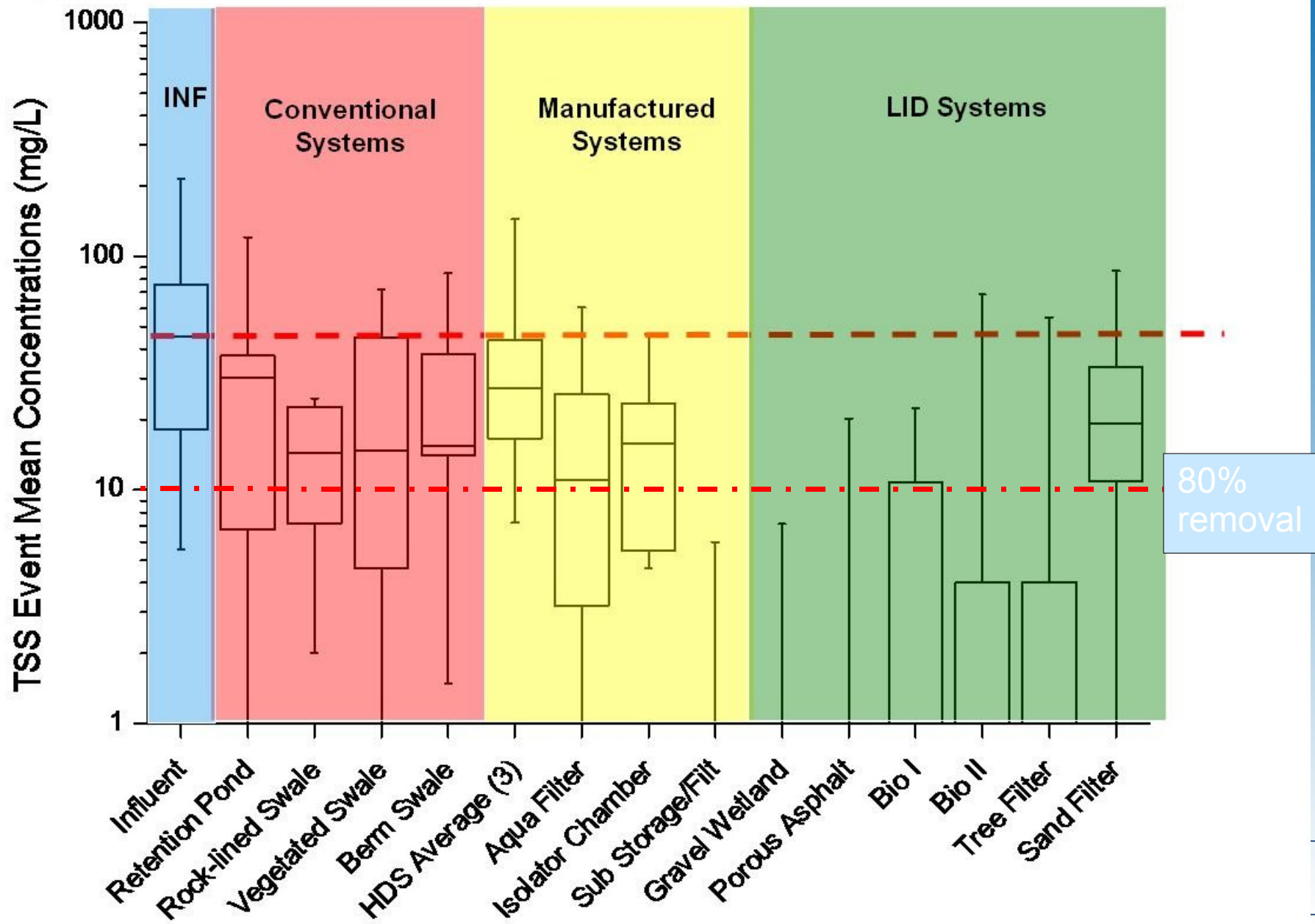
# TSS Removal Efficiencies



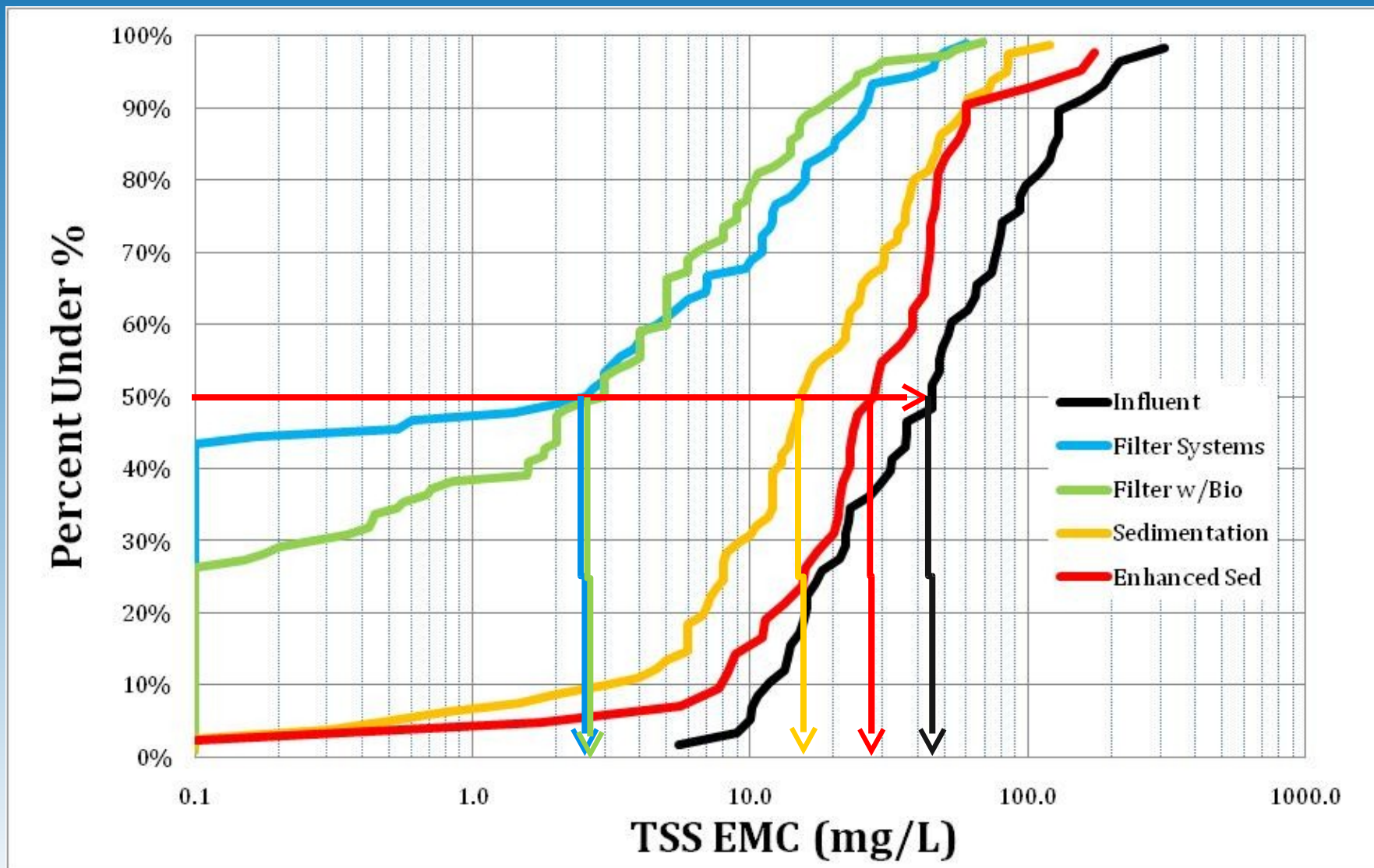
# TSS Event Mean Concentrations



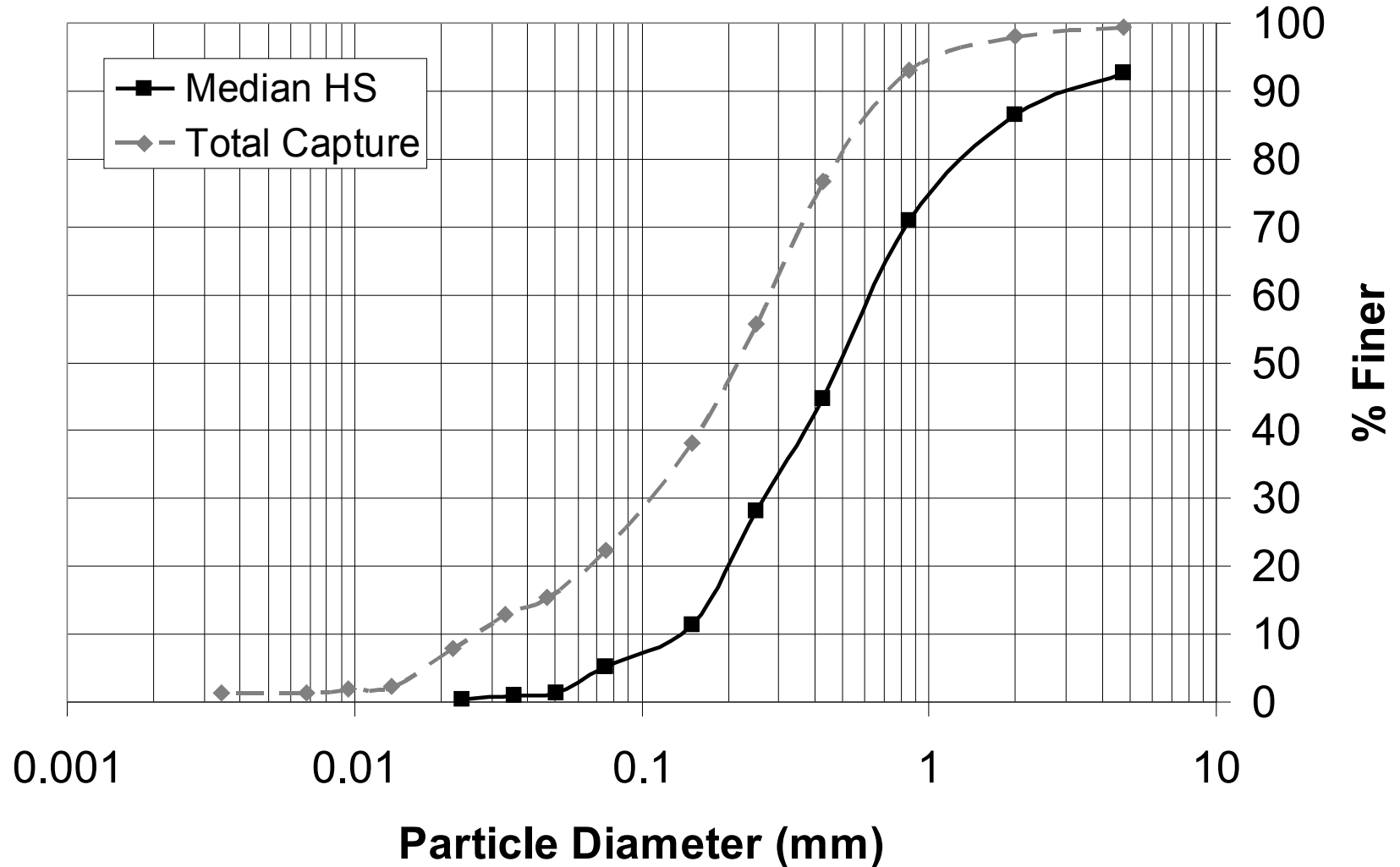
# TSS Event Mean Concentrations



# TSS Removal Performance

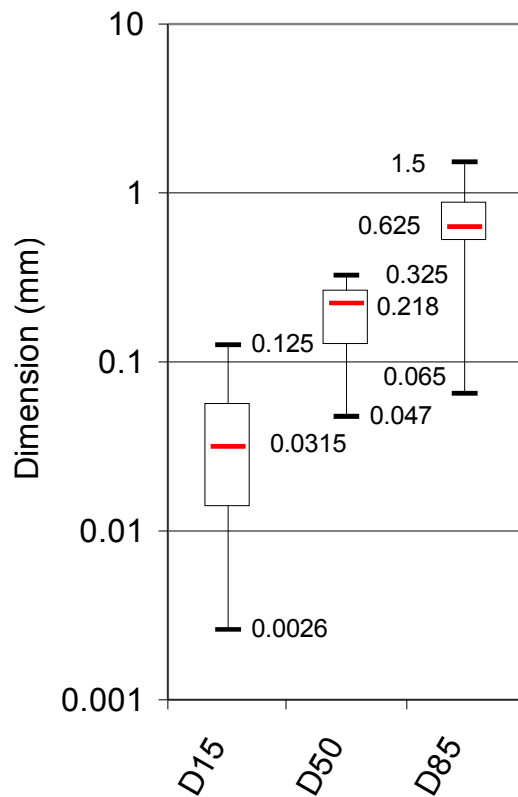


# Particle size distribution for influent vs. sediments captured within hydrodynamic separators

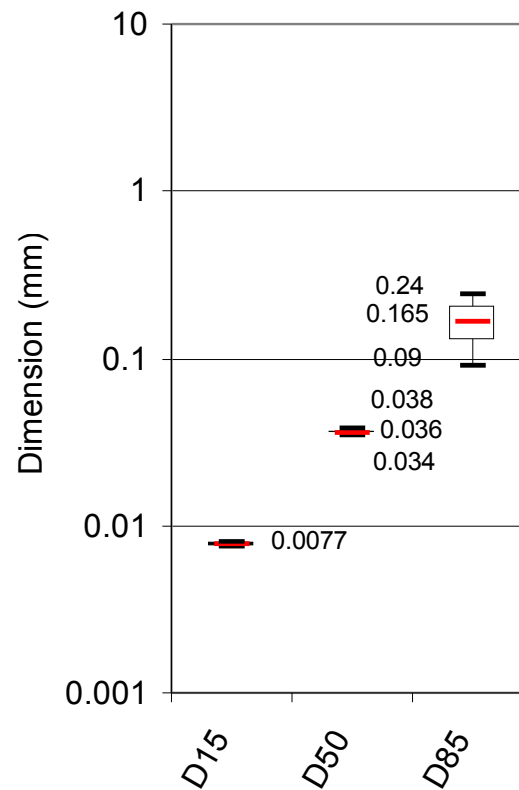


# Sediment Size Removal

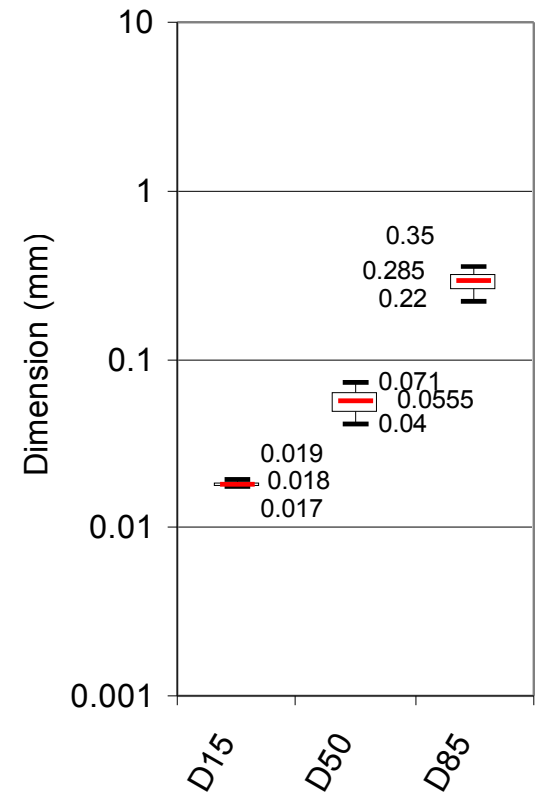
**Influent PSD Range D15-50-85 for N=8 Storms by Total Capture**



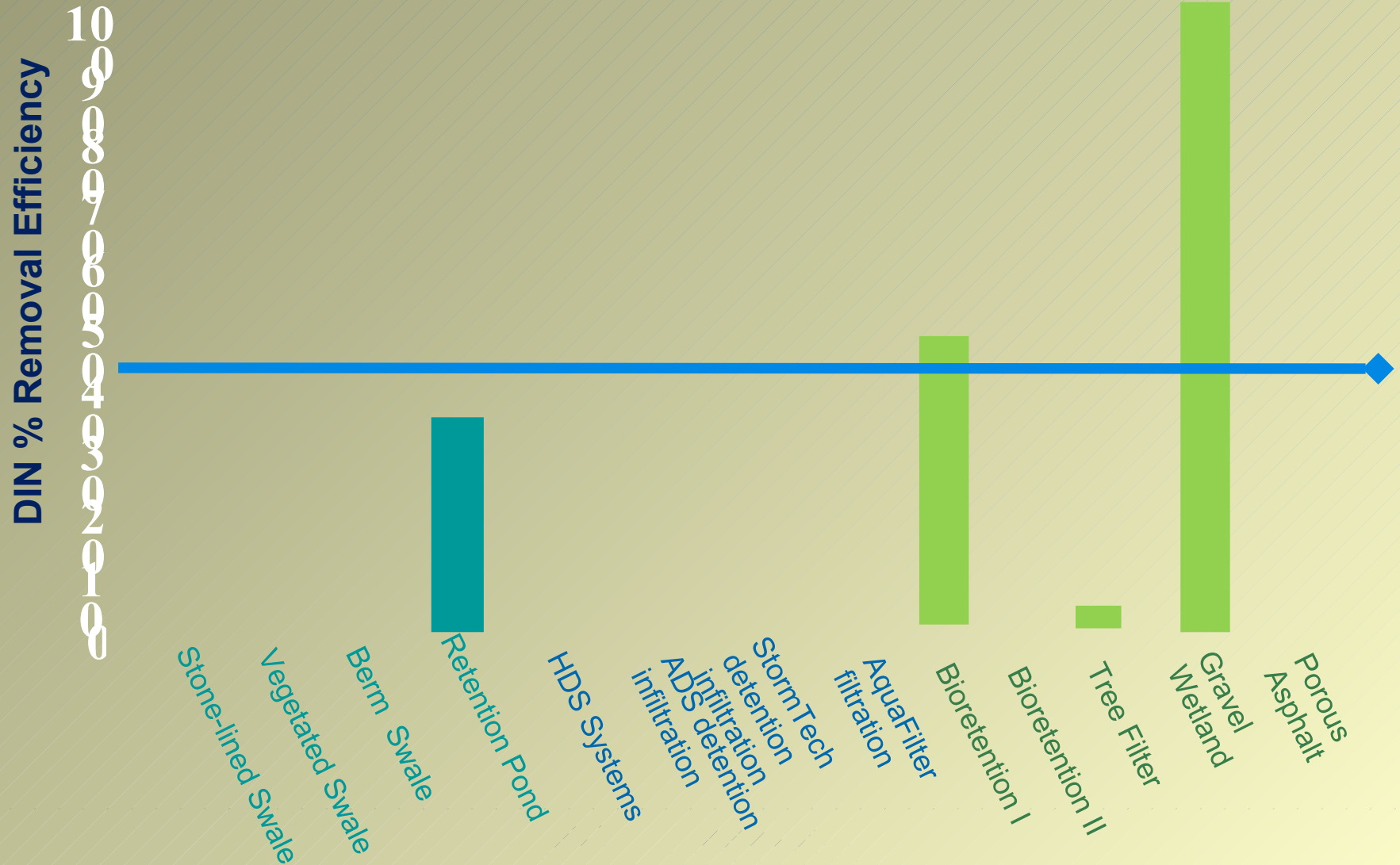
**Gravel Wetland Effluent PSD Range D15-50-85 for N=2 Storms by Total Capture**



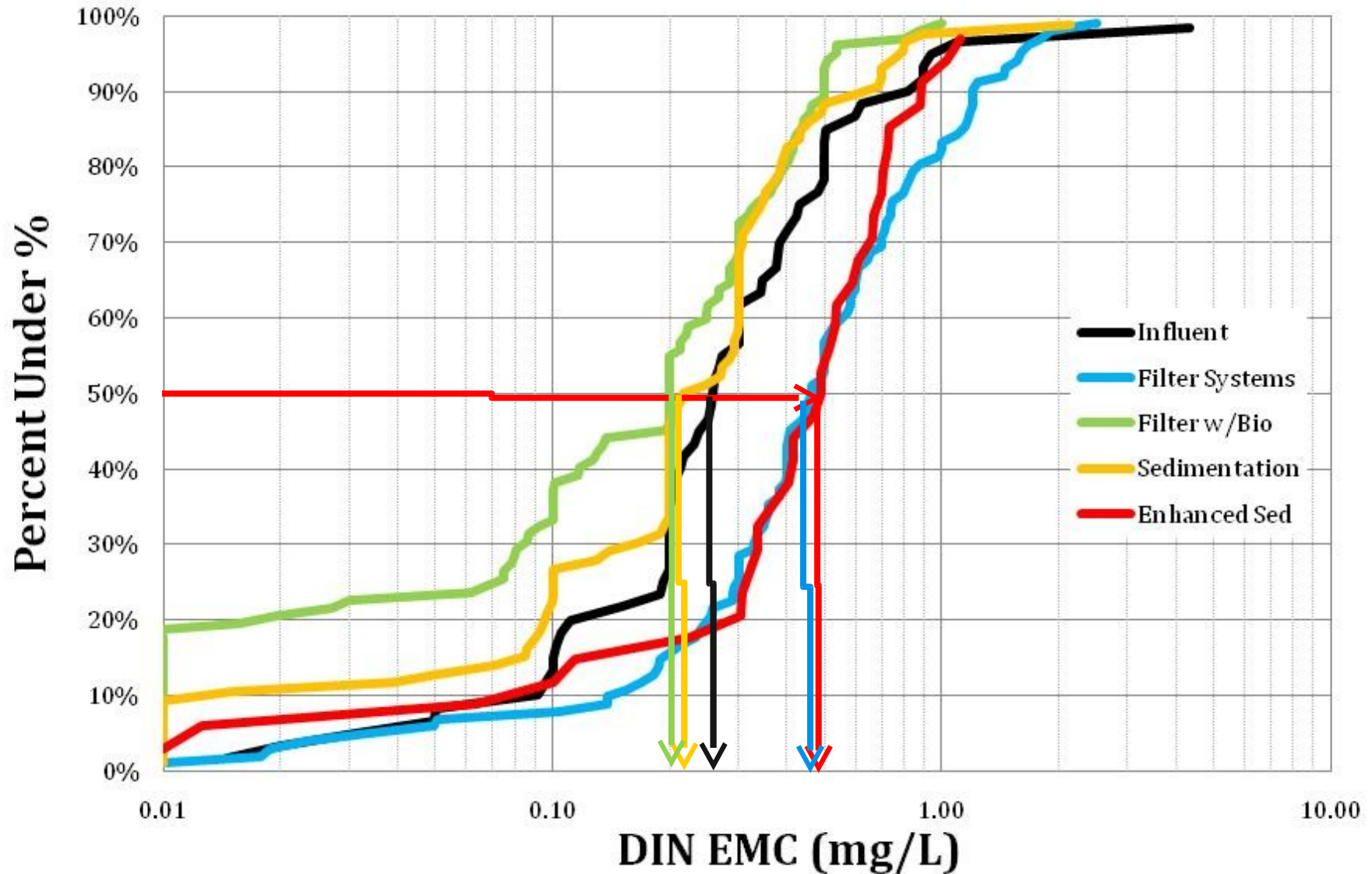
**Bioretention Effluent PSD Range D15-50-85 for N=2 Storms by Total Capture**



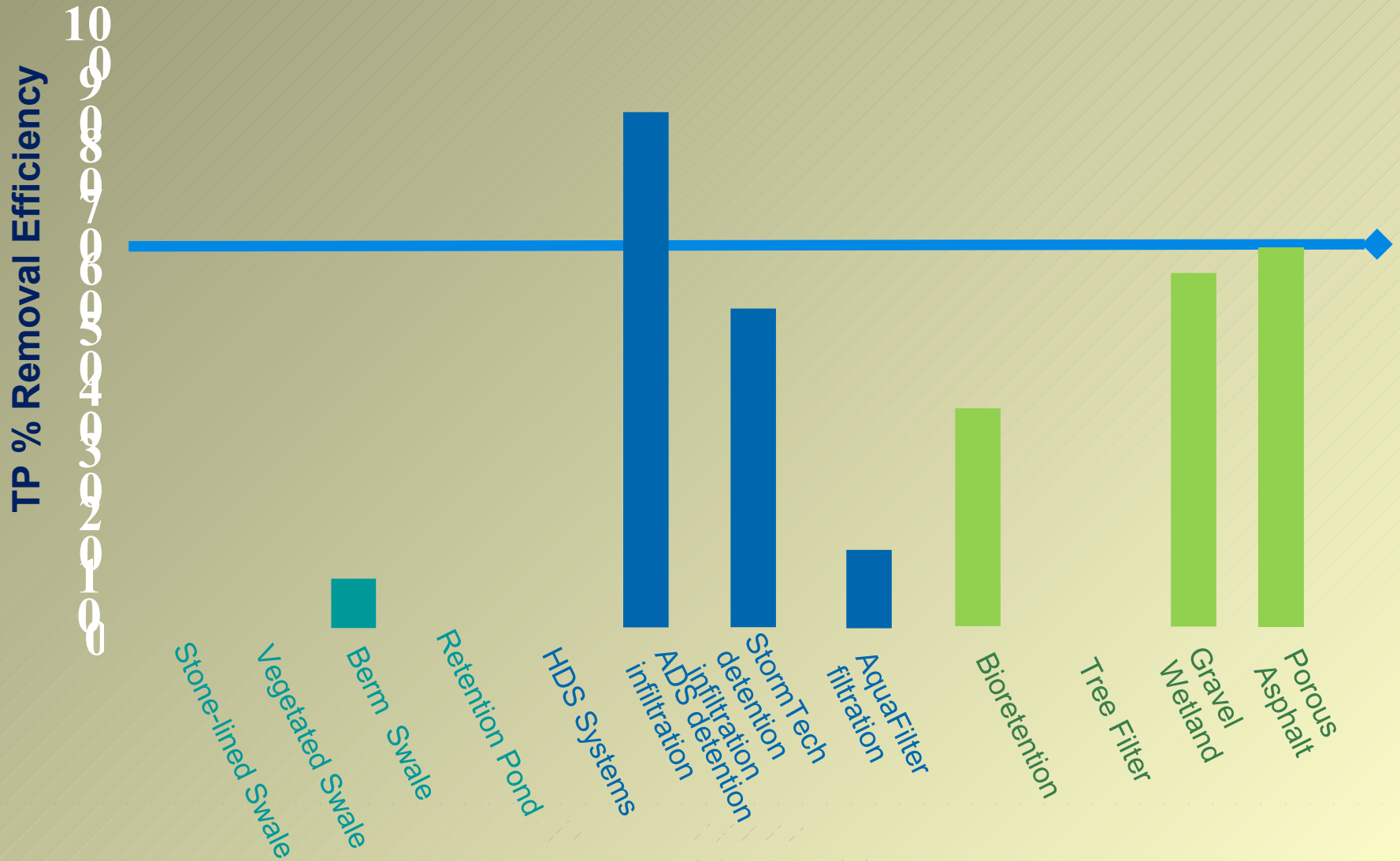
# DIN Removal Efficiencies



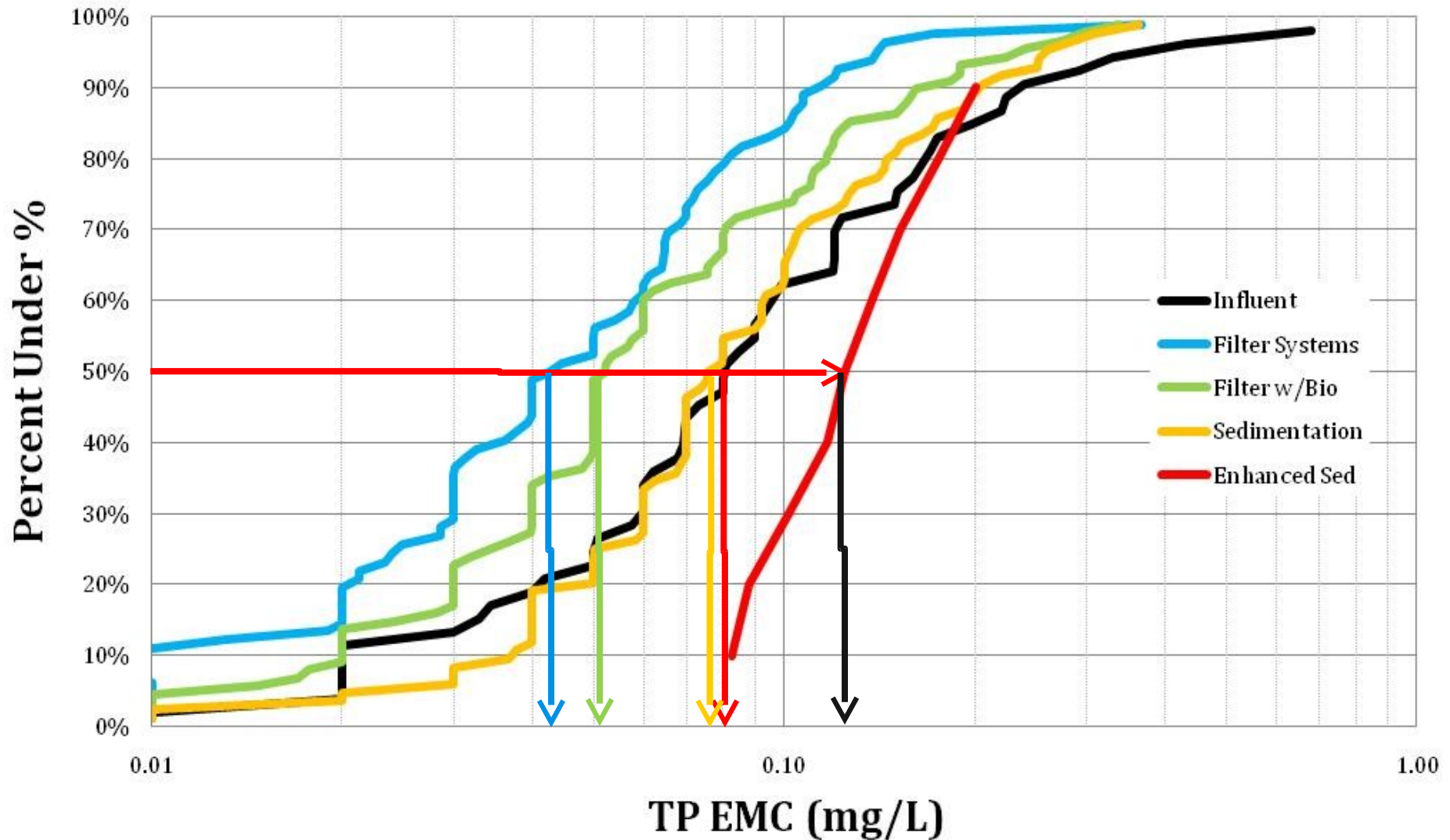
# Nitrogen Removal Performance



# TP Removal Efficiencies

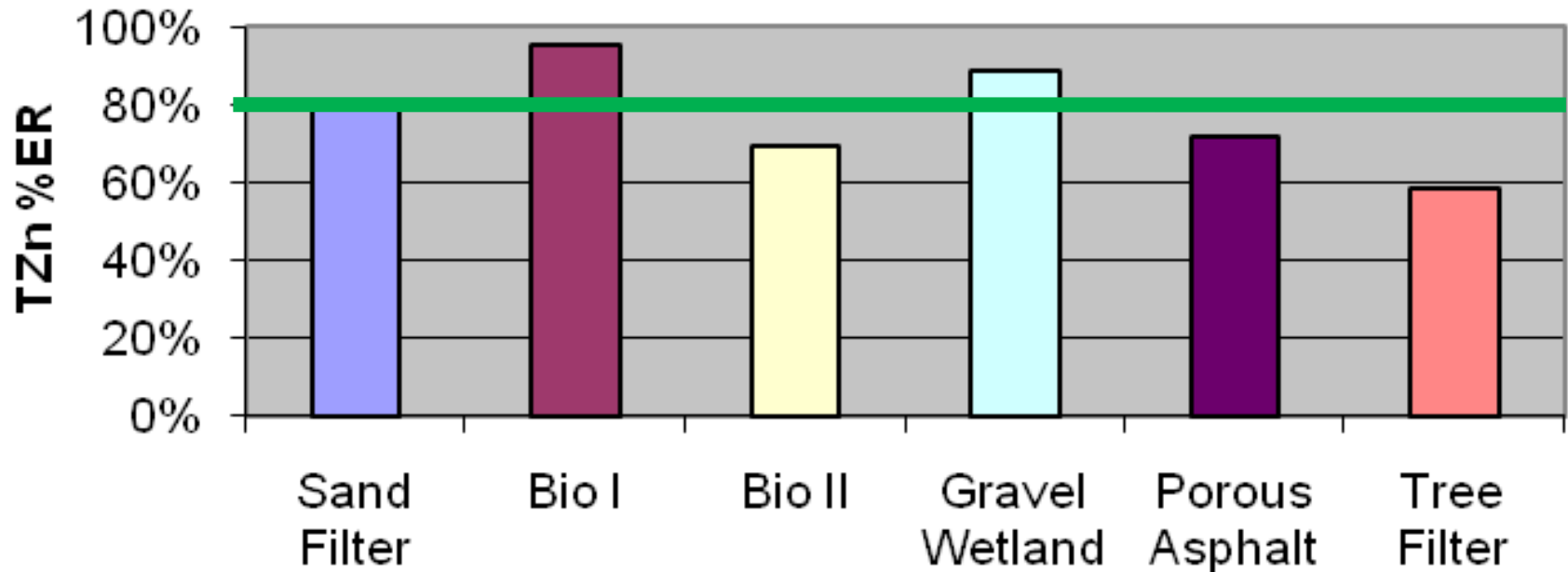


# Phosphorous Removal Performance

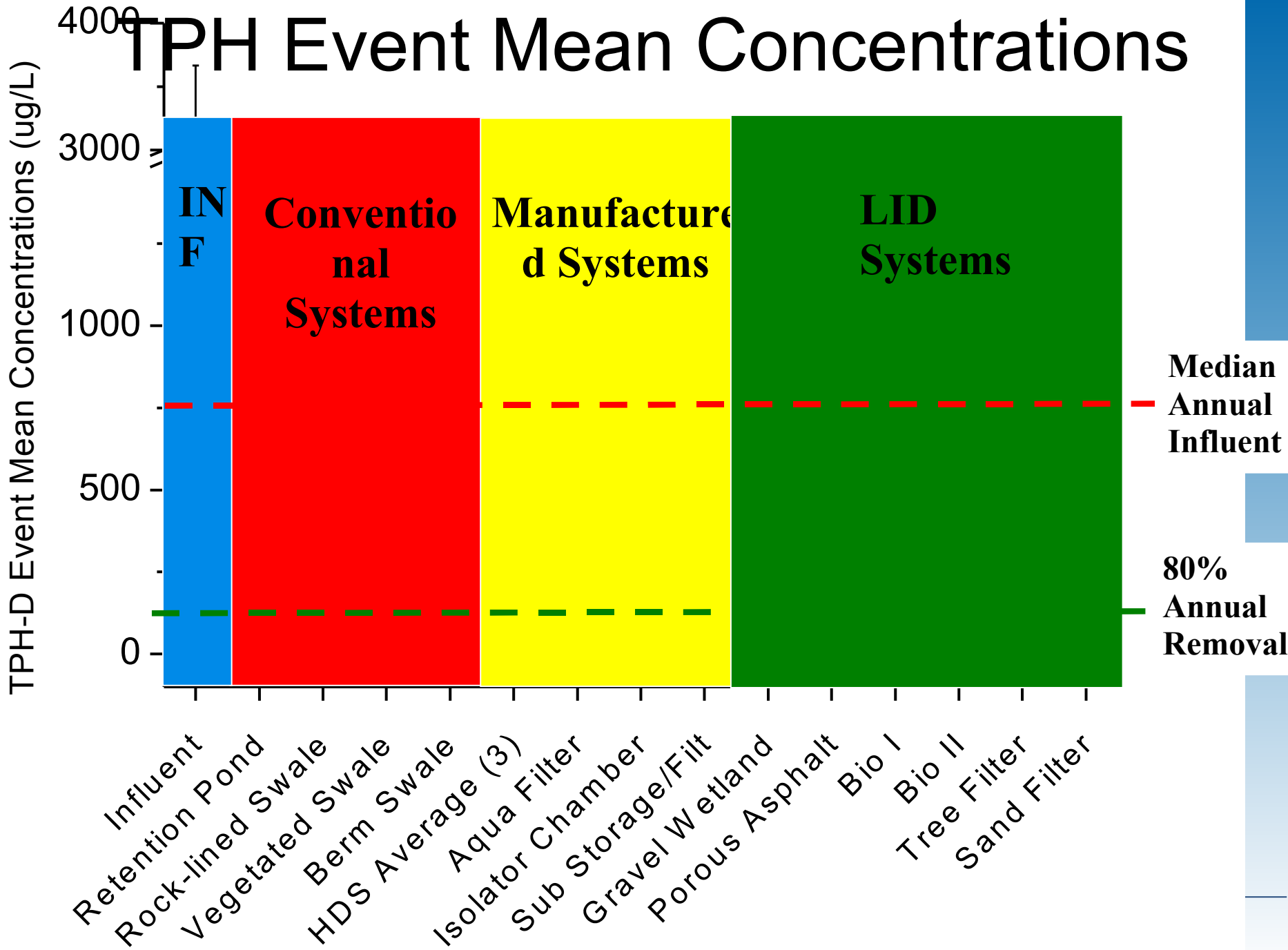


# TZn Removal

## LID Efficiency Ratio

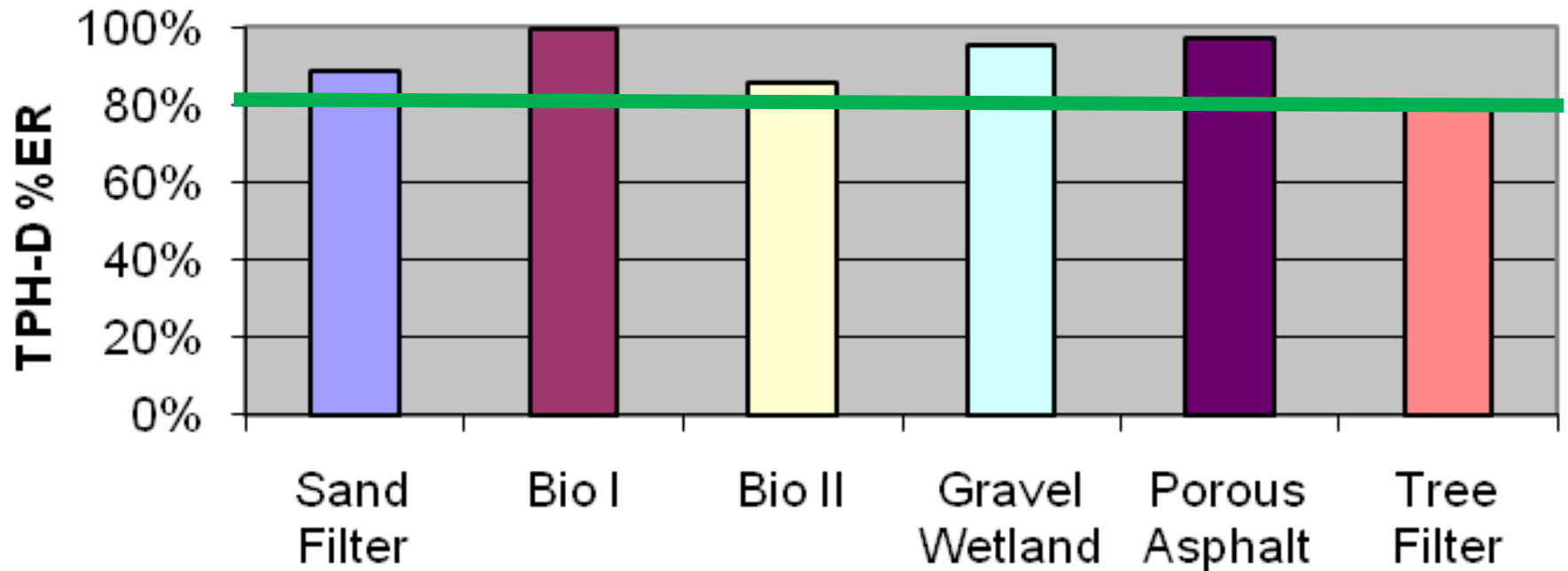


# TPH Event Mean Concentrations

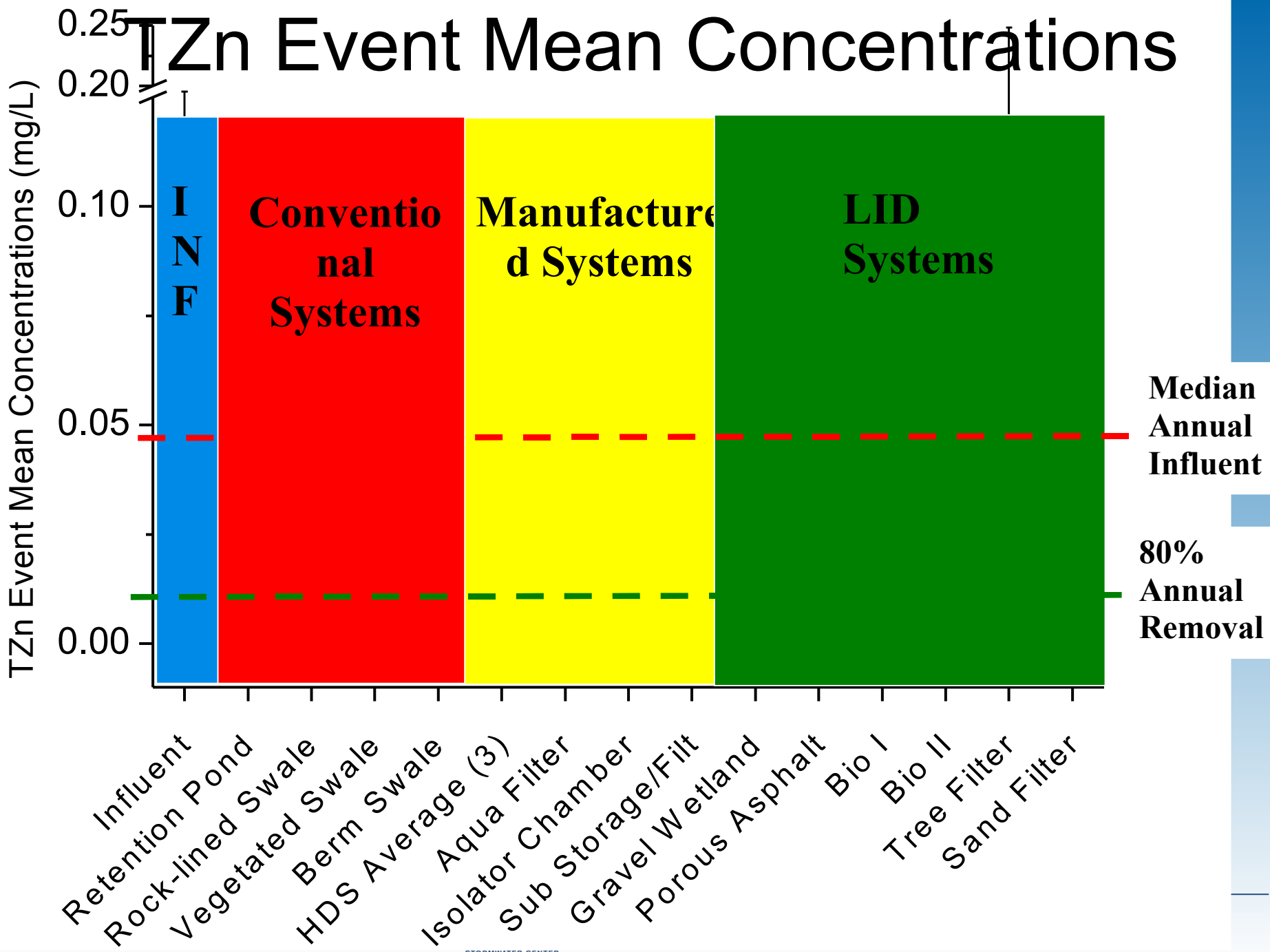


# TPH-D Removal

## LID Efficiency Ratio



# TZn Event Mean Concentrations



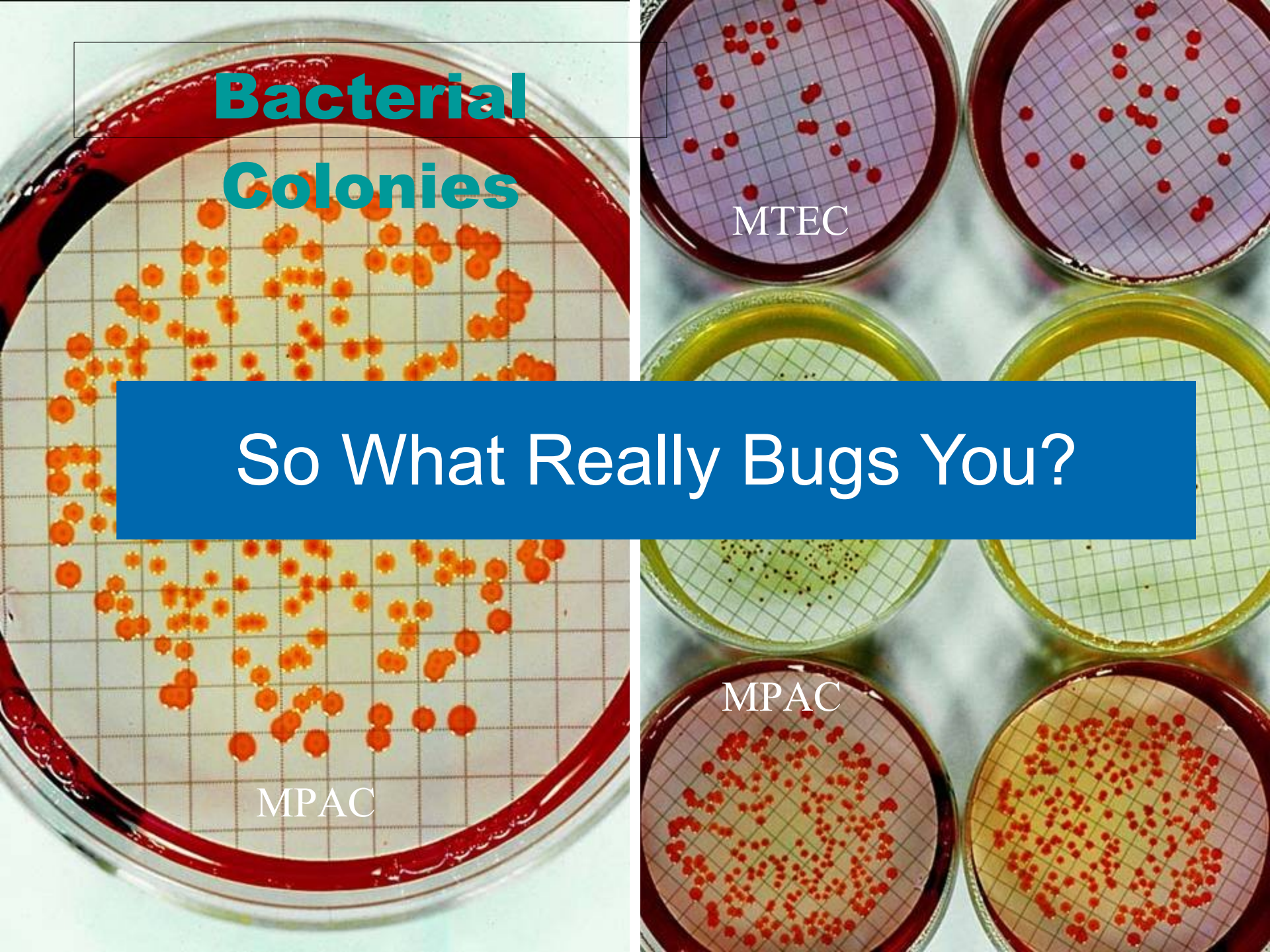
# Bacterial Colonies

So What Really Bugs You?

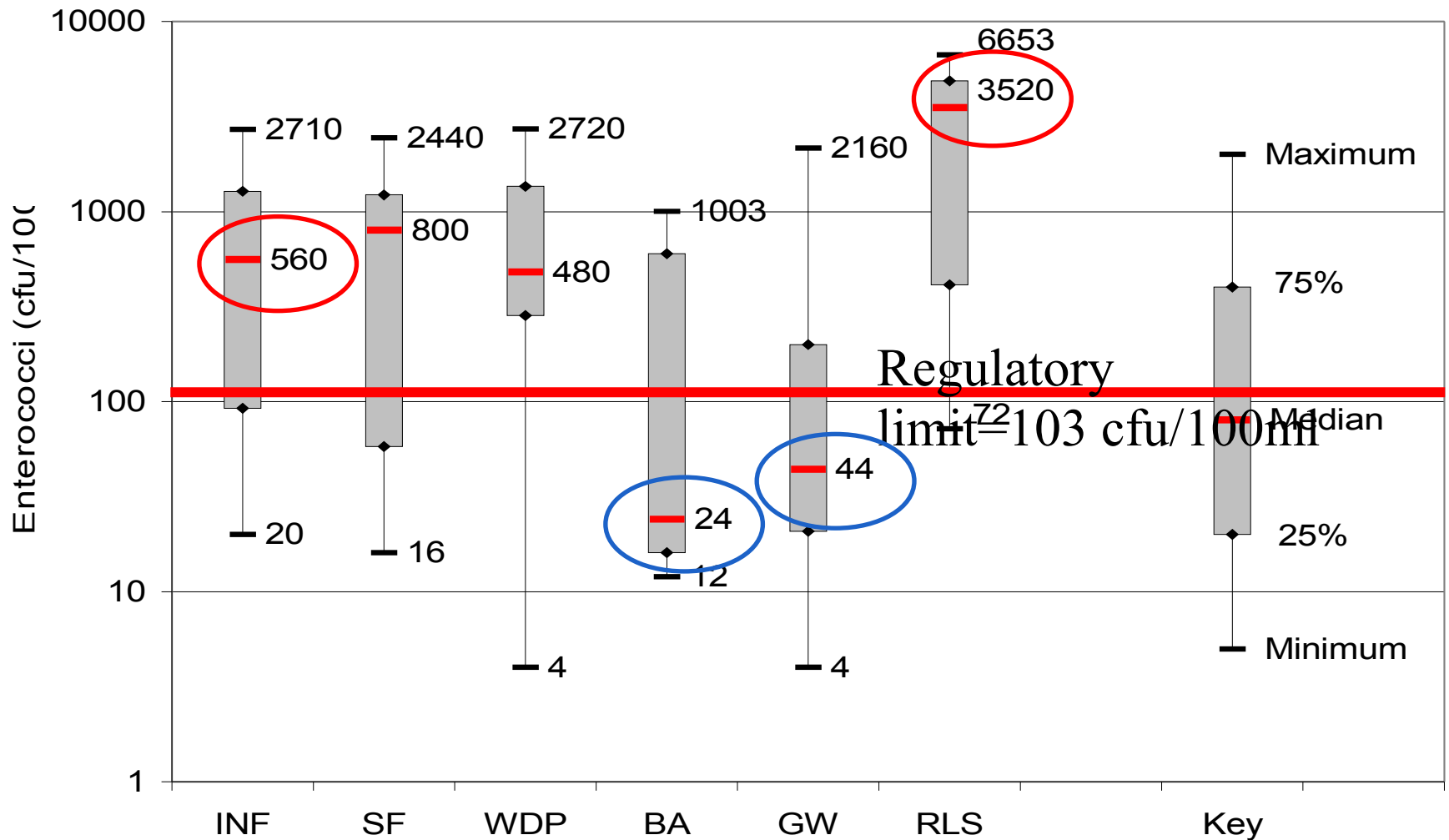
MTEC

MPAC

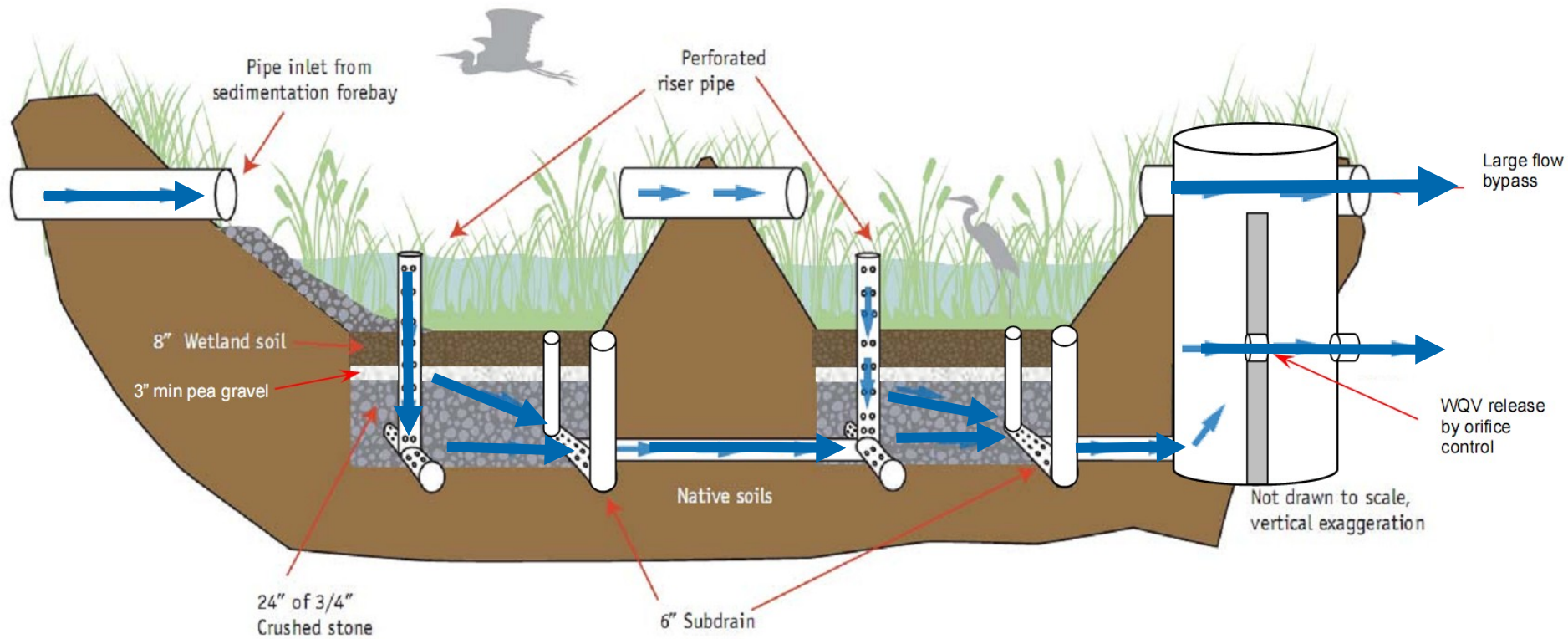
MPAC



# Bacterial Concentrations



# Subsurface Gravel Wetland



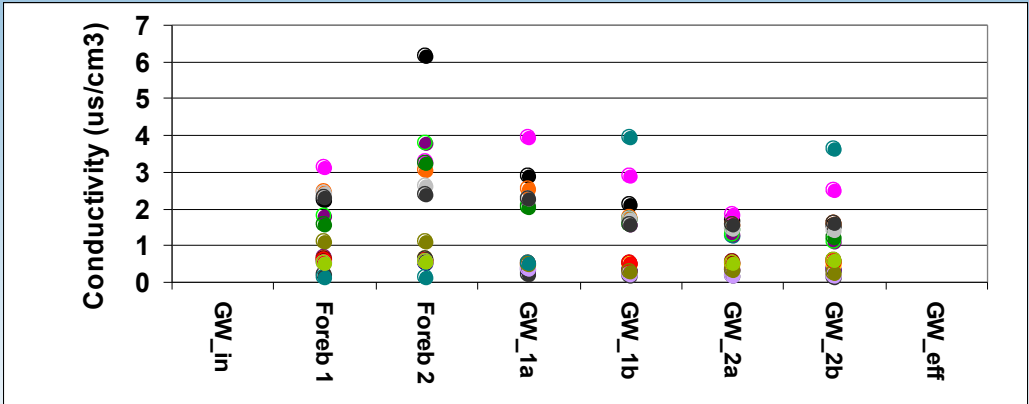
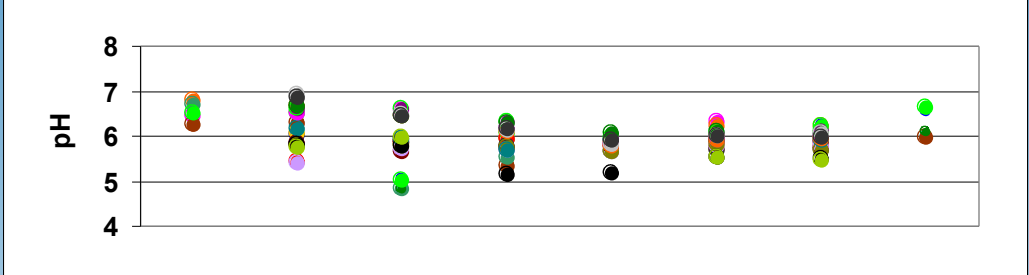
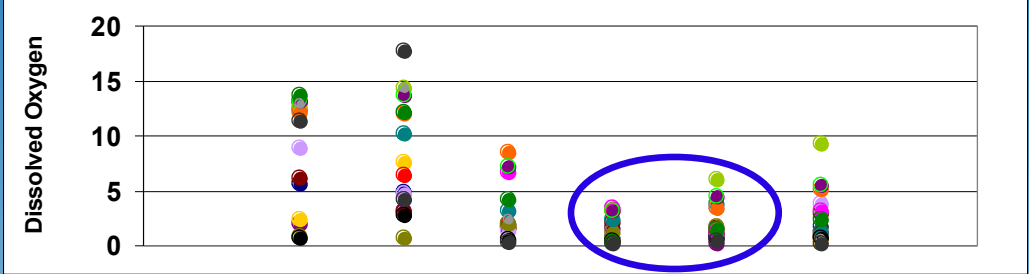
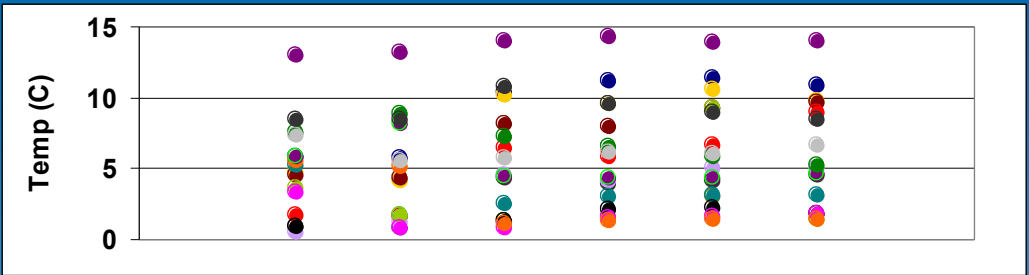
## Design Sources:

Claytor, R. A., and Schueler, T. R. (1996). Design of Stormwater Filtering Systems, Center for Watershed Protection, Silver Spring, MD.

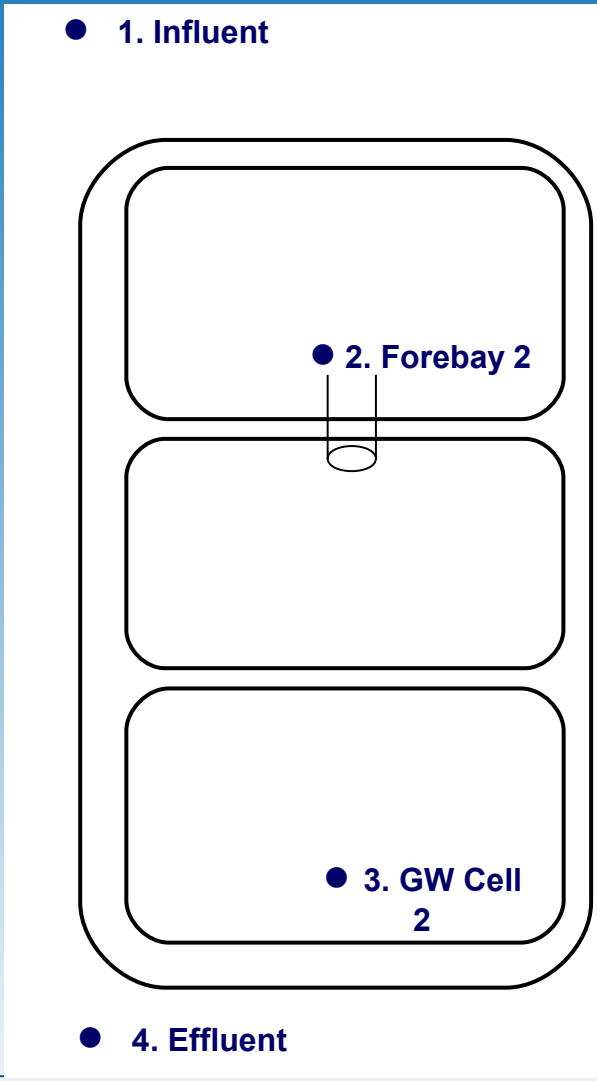
Georgia Stormwater Management Manual, Volume 2: Technical Handbook, August 2001, prepared by AMEC Earth and Environmental, Center for Watershed Protection, Debo and Associates, Jordan Jones and Goulding, Atlanta Regional Commission.

# Nutrient Cycling in the Gravel Wetland: Maintenance is Important

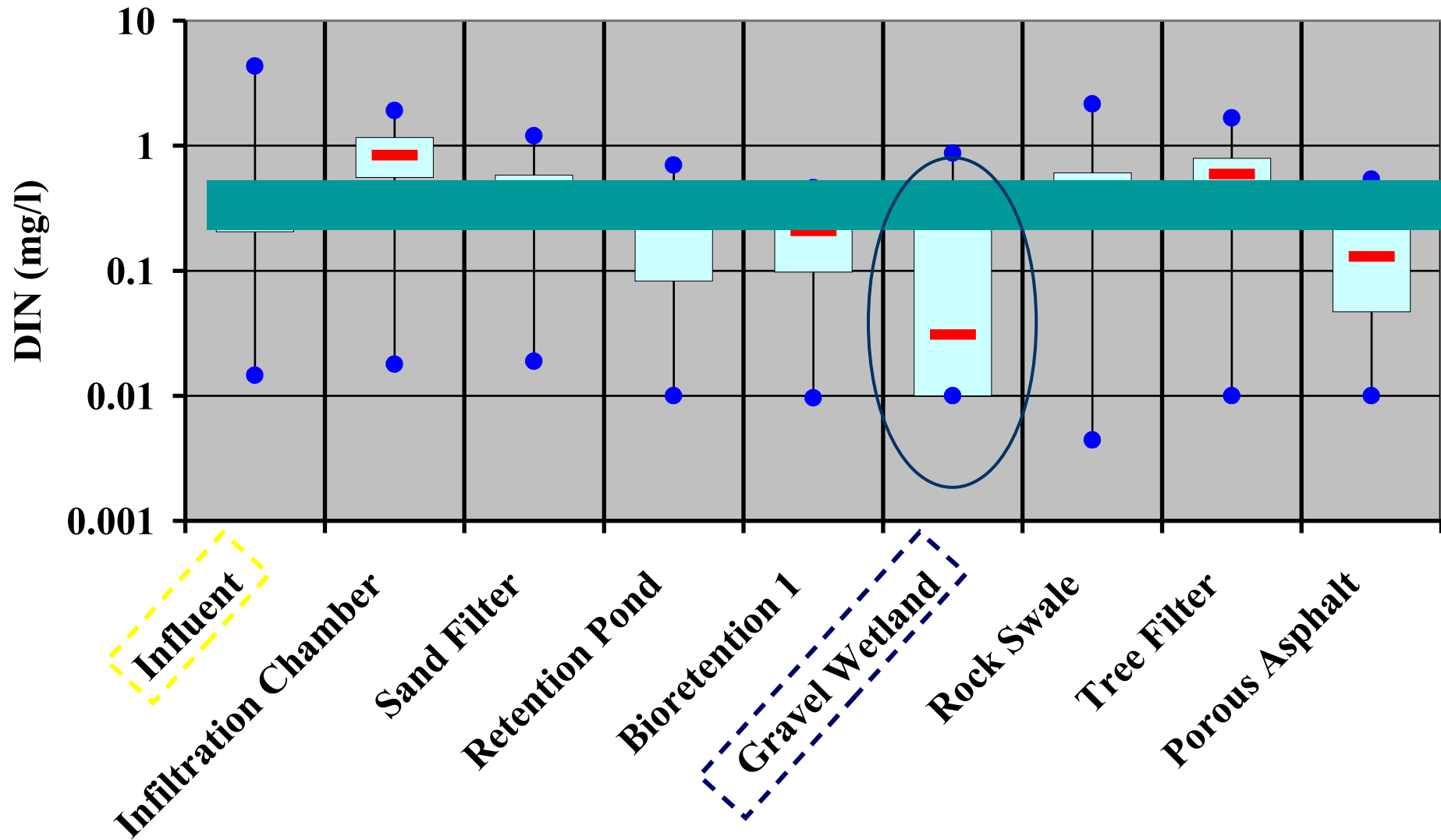
Click to edit Master subtitle style



- 10/17/2007   ● 10/24/2007   ● 10/31/2007   ● 11/7/2007   ● 11/14/2007   ● 11/20/2007   ● 11/28/2007
- 12/4/2007   ● 12/12/2007   ● 12/18/2007   ● 2/15/2008   ● 2/25/2008   ● 3/24/2008   ● 4/4/2008
- 4/10/2008   ● 4/16/2008   ● 4/23/2008



# Dissolved Inorganic Nitrogen



# Denitrification

NH<sub>4</sub>

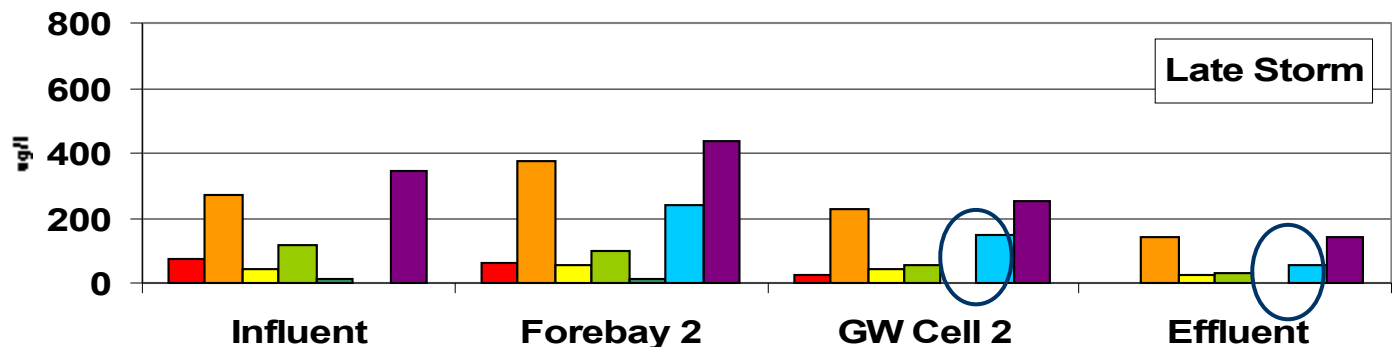
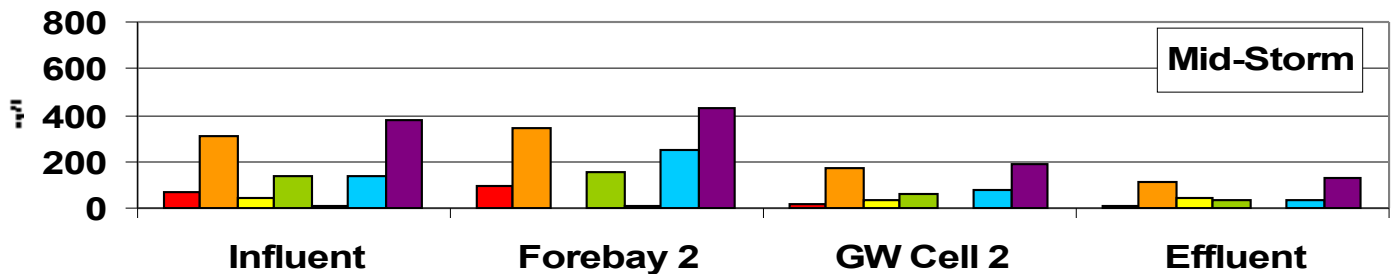
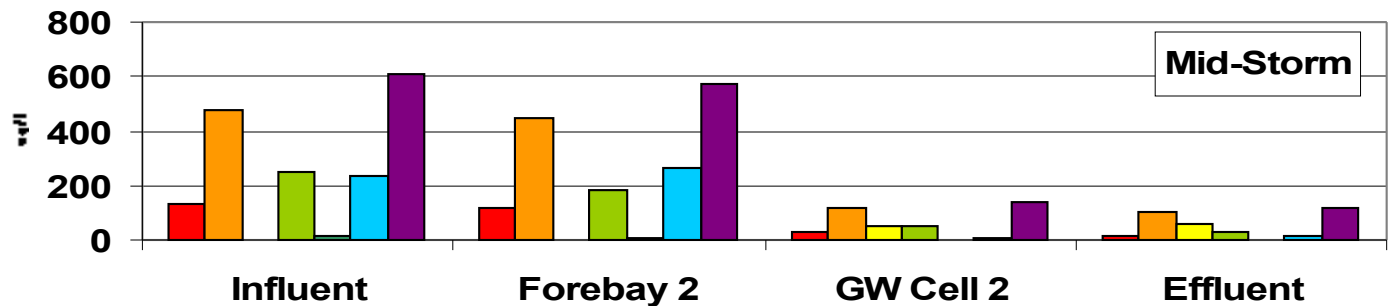
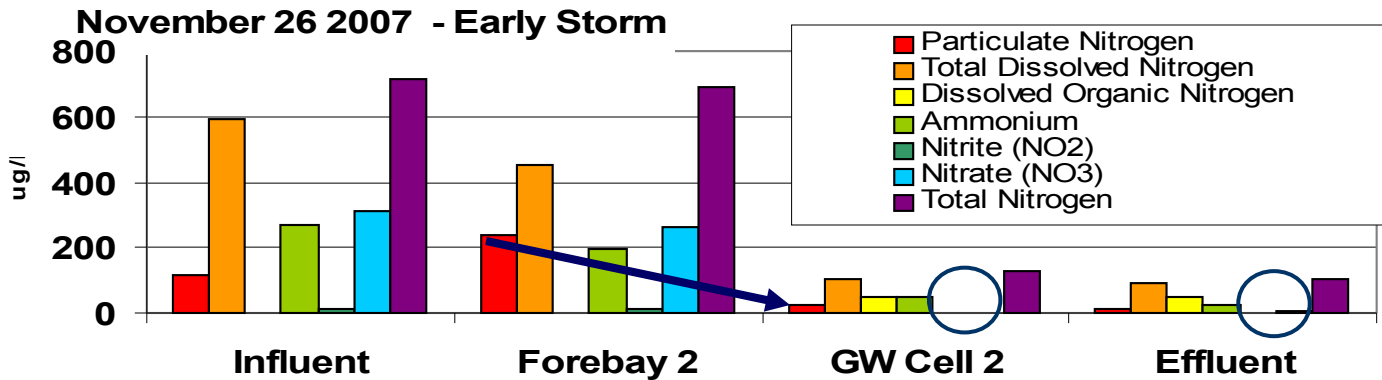
NO<sub>2</sub>

NO<sub>3</sub>

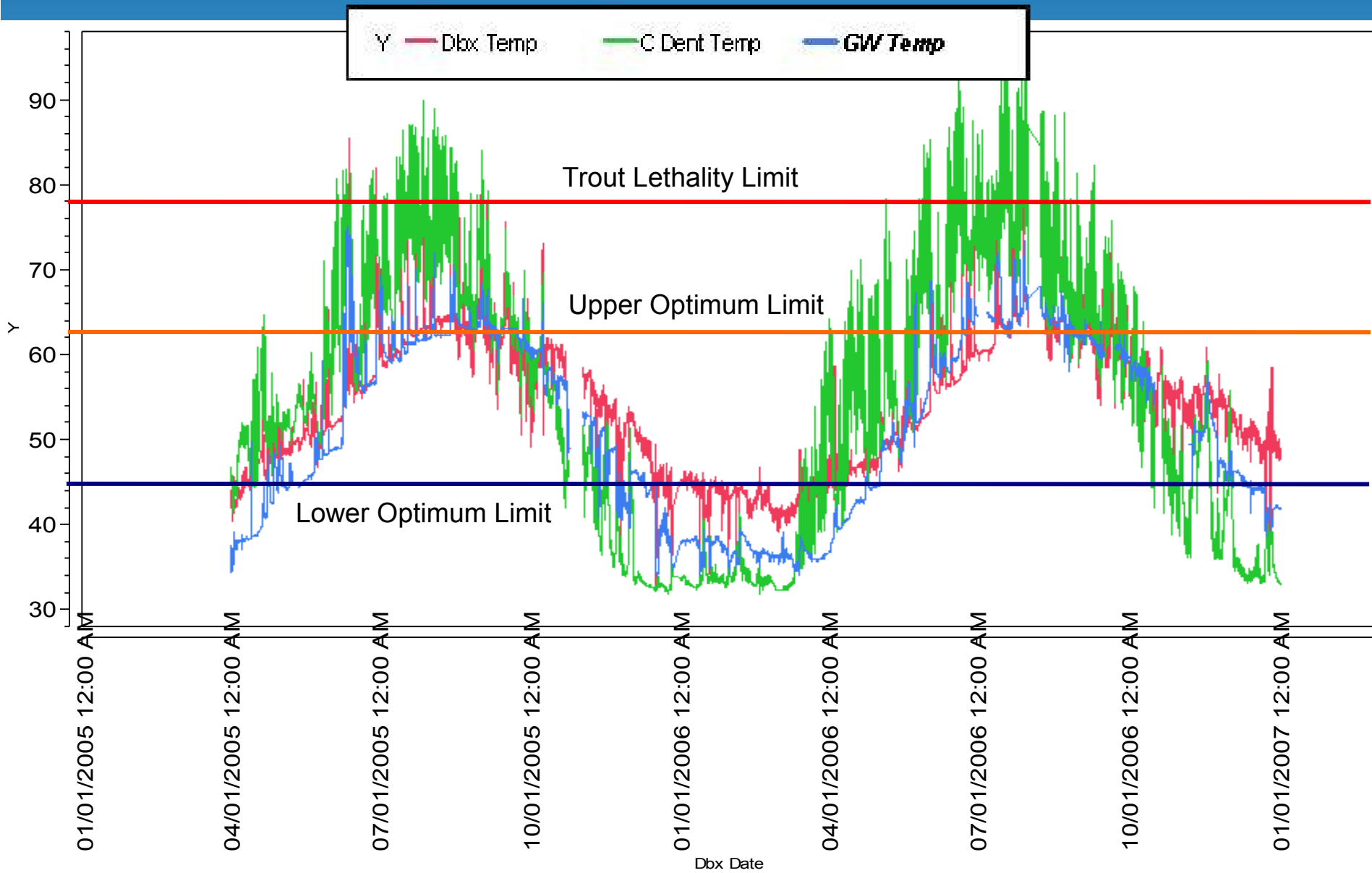
N<sub>2</sub> (gas)

Aerobic Zone  
Forebay and surface of  
gravel wetland

Anaerobic Zone  
Subsurface  
gravel wetland



# Thermal Impacts



# Porous Pavements

## Porous Pavements

- Aggregate gradation: No fines added to mix
- Air voids: 18-20%
- Cold climate and WQ functionality dependent on sub base design
- Long-term function dependent on production, not maintenance

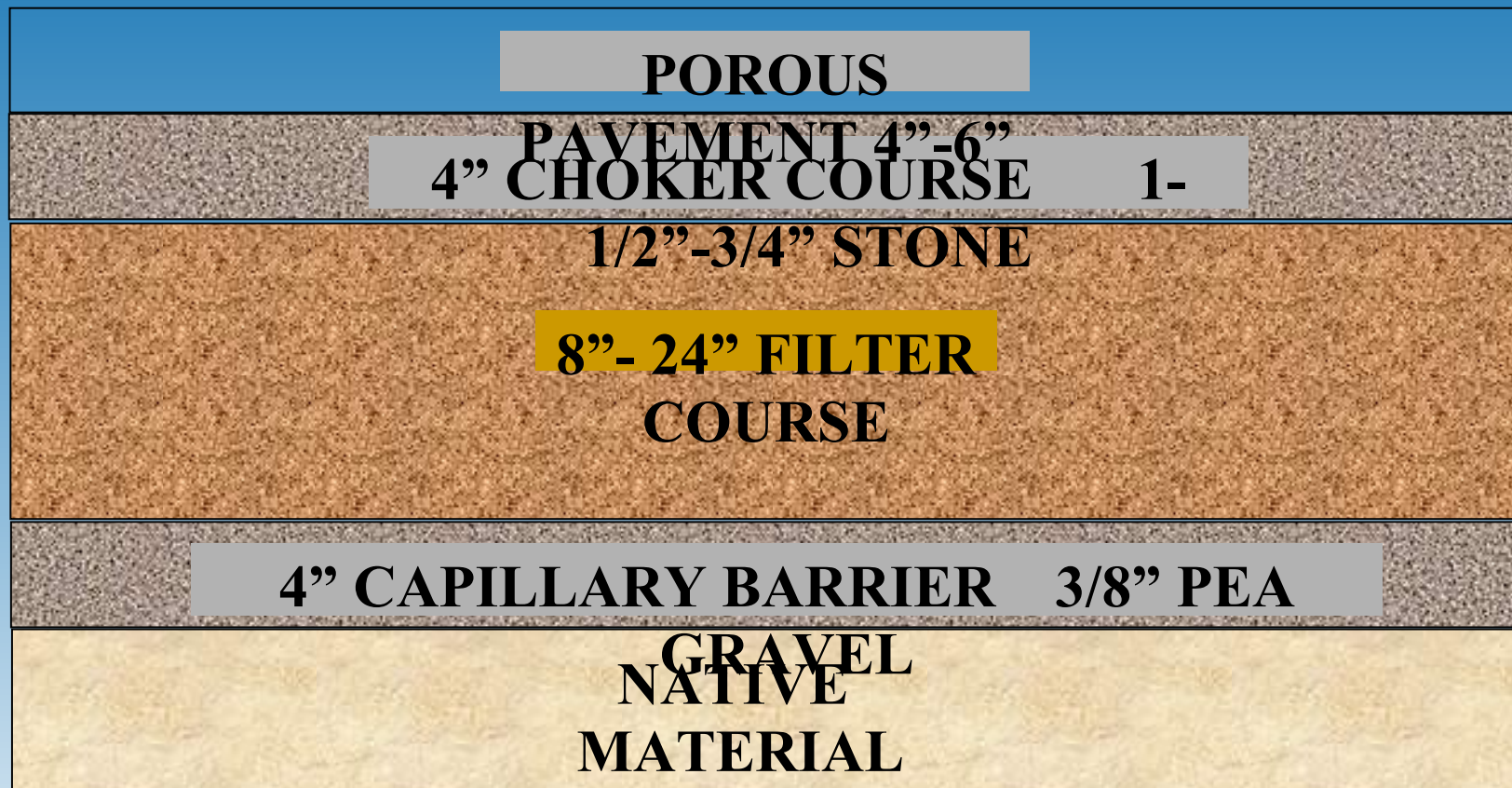


## Pervious Concrete - PC

- Placement is challenging and requires certified installers
- Compressive strength: 3000 psi at 7 days



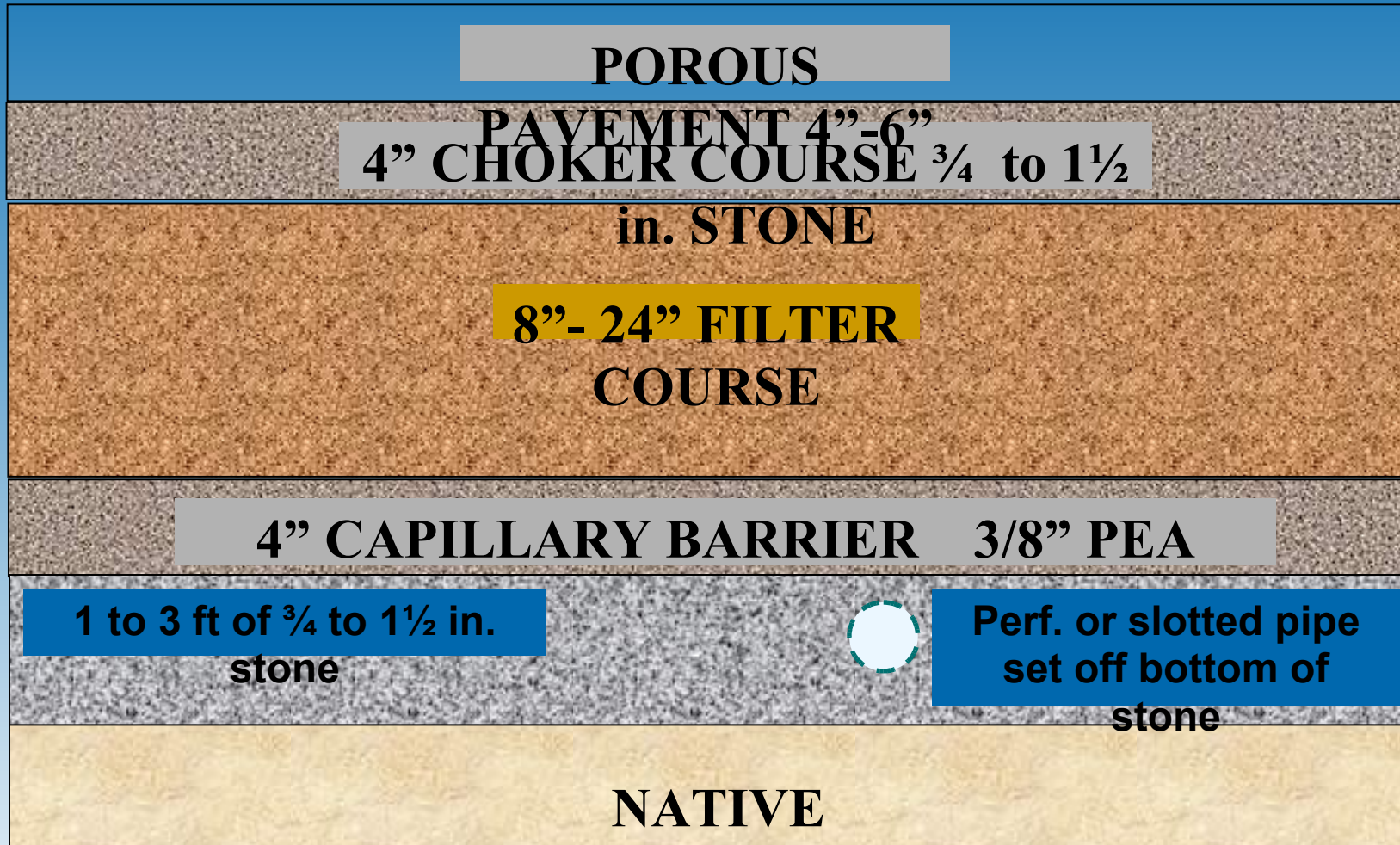
# Typical Porous Pavement Parking Lot System Cross-Section – *well draining*



S

- Diverged from design guidance for use of filter coarse for improved water quality function
- Common reservoir base is 1-3" minus bank run sand and gravel

# Typical Porous Pavement Parking Lot System Cross-Section – *poor draining*



- Use stone at base to store water and infiltrate between storms, drain pipe to remove excess treated water.

# Porous Asphalt (PA) Basics

## Original uses of PA was Open Graded Friction Course (OGFC)

- OGFC = permeable mix of stone, binder & modifiers over impermeable base
- OGFC used on highways for improved visibility, reduced tire noise, reduced hydroplaning, enhanced friction

## PA = OGFC over permeable base

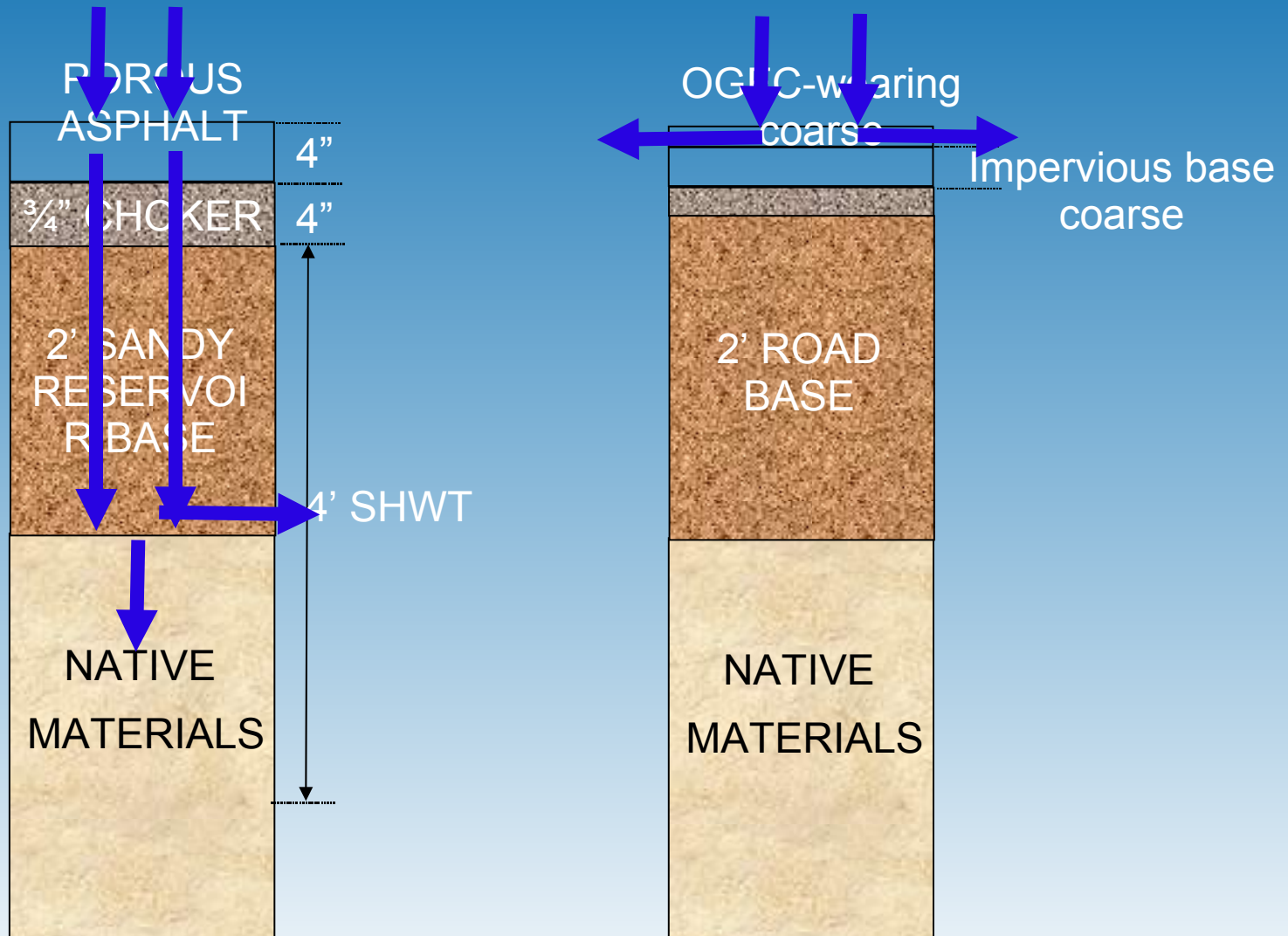
- PA used in parking lots for SWM objectives (water quality treatment and hydraulic dampening) **one component of a system**

## OGFC & PA

- Similar mixes
- Different objectives & applications
- Similar challenges (draindown, ravelling, clogging)



# PA vs OGFC



# Introducing the New & Improved UNH Porous Asphalt Spec!!!



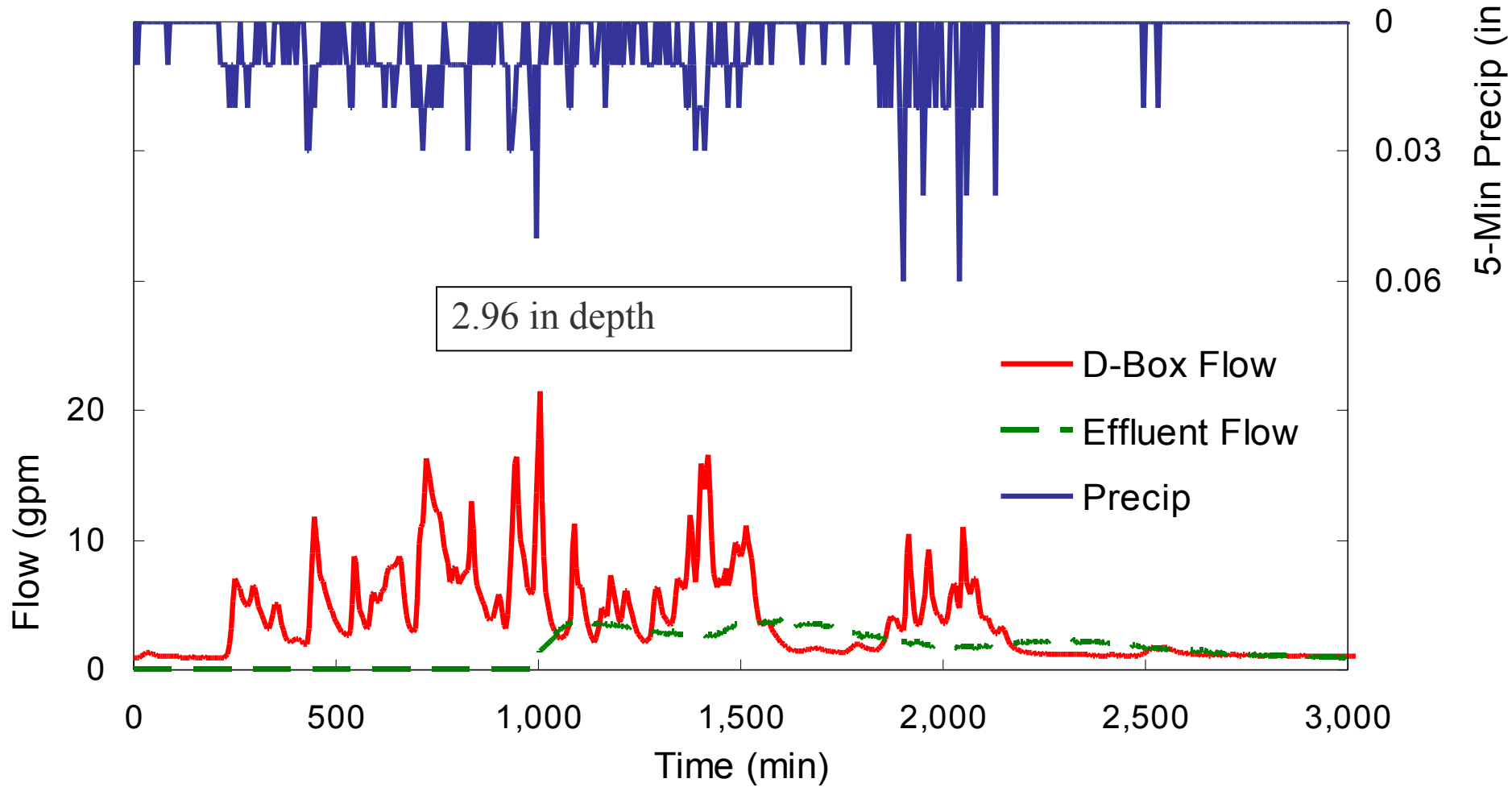
## UNHSC Design Specifications for Porous Asphalt Pavement and Infiltration Beds



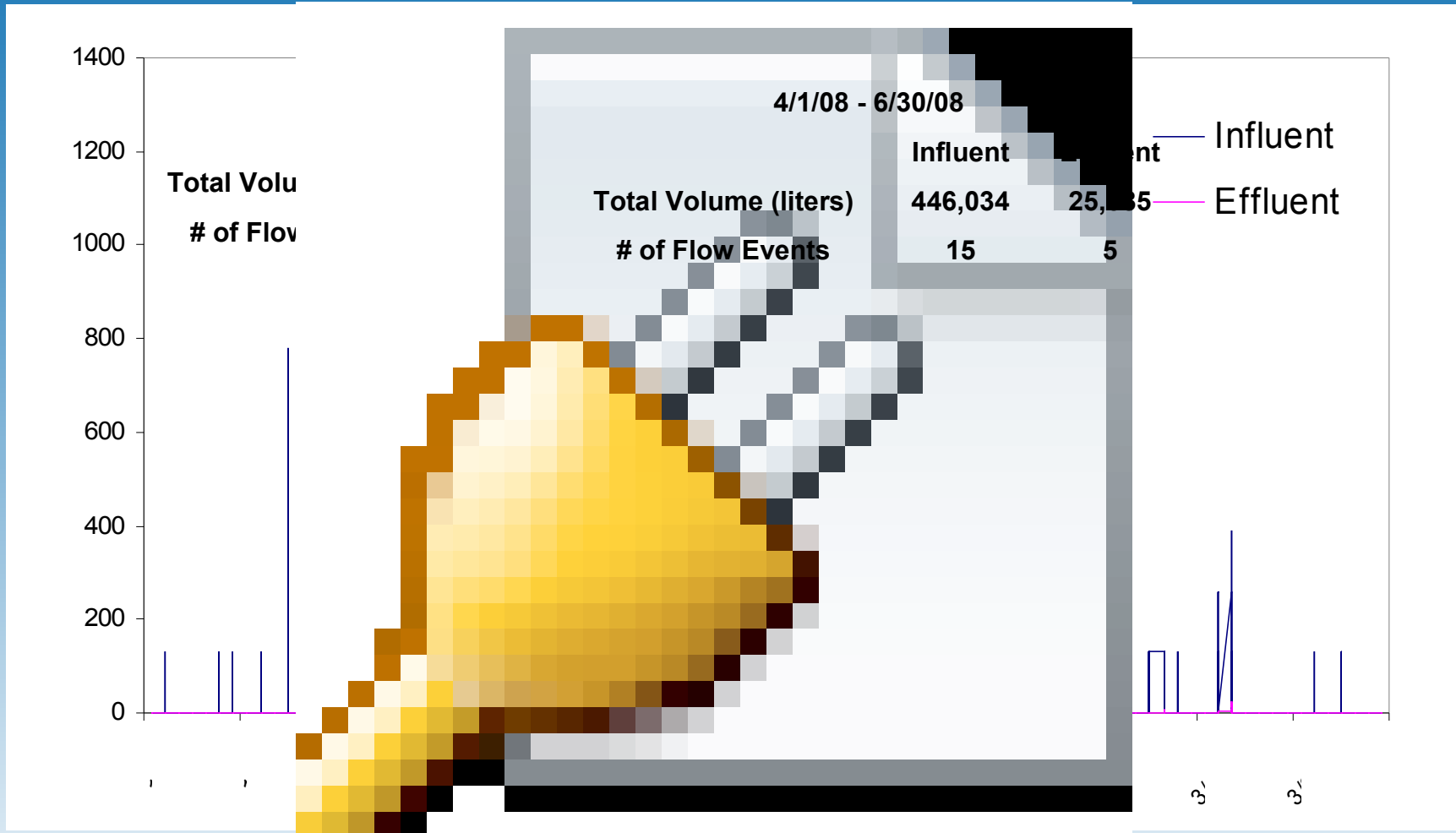
July 2007

University of New Hampshire Stormwater Center (UNHSC)  
Gregg Hall • 35 Colovos Road • Durham, New Hampshire 03824-3534 • <http://www.unh.edu/eng/ostev>

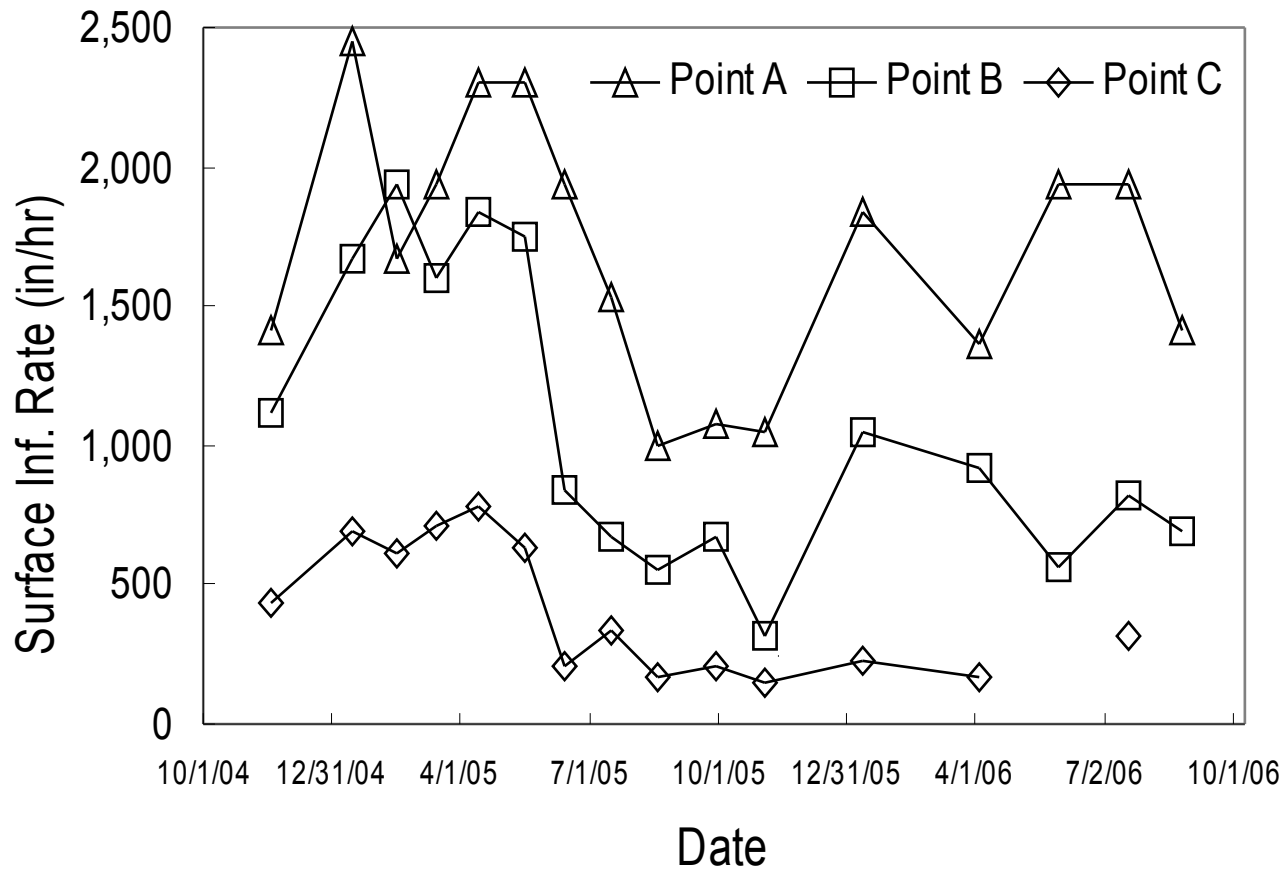
# Flow Attenuation



# PC Flow Attenuation



# Surface infiltration rates for the porous asphalt 11/04-10/06



2,500

Even with 99% clogging the IR=10 in/hr > most sands & soils

0

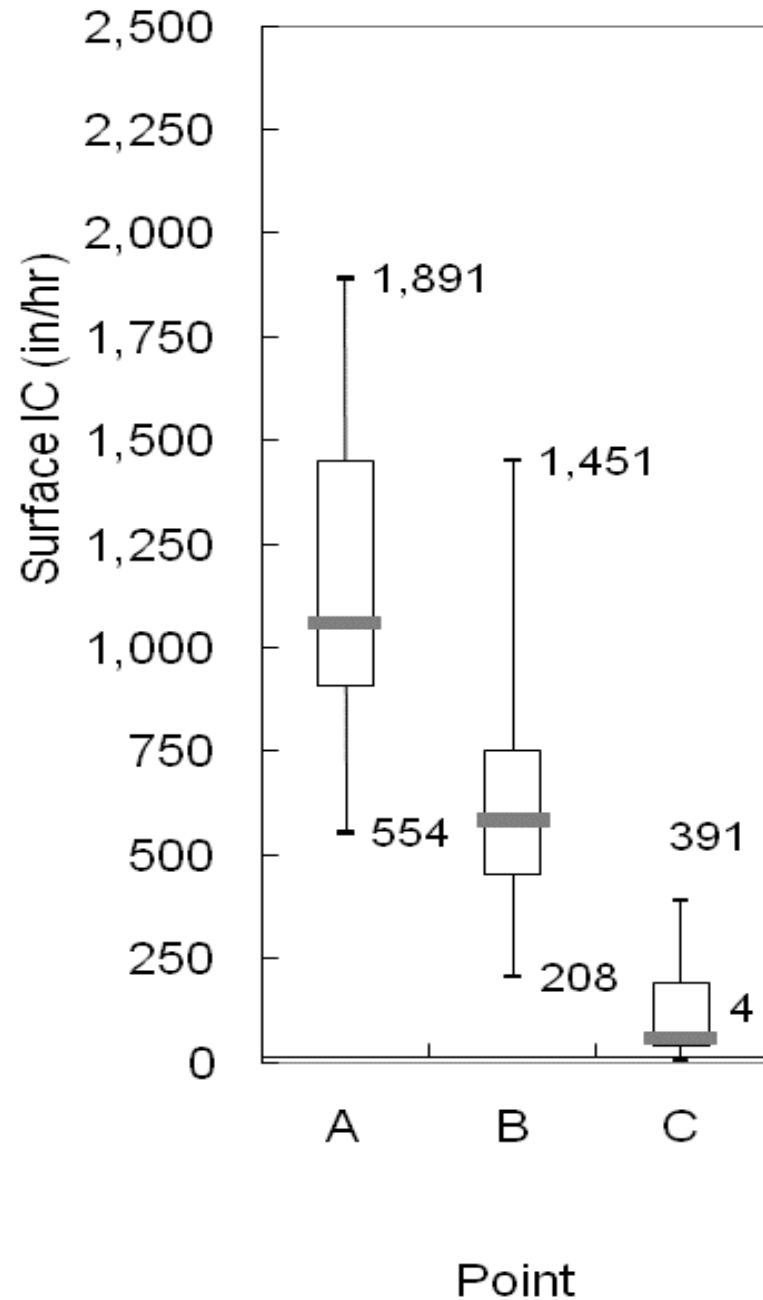
A B C

Point

# Is Infiltration Capacity Reducing?

Variable	IC A (in/hr)	IC B (in/hr)	IC C (in/hr)
Slope	-0.403	-0.681	-0.373
IC Loss/year	147	248	136
Average IC	1,260	680	151
r <sup>2</sup>	0.11	0.36	0.72

# Great Variability to Infiltration Capacity



# Maintenance

# Repairs and Replacement

- Damage can occur to PA from non-design loads
- Repairs may be needed from cuts for utilities
- Repairs can be made with standard HMA for most damages up to 15% of surface area
- PA can be repaired by heating and rerolling at \$2000/day at approximately 500' of trench
- When pavement reaches end of life, it is replaced by milling to choker coarse.

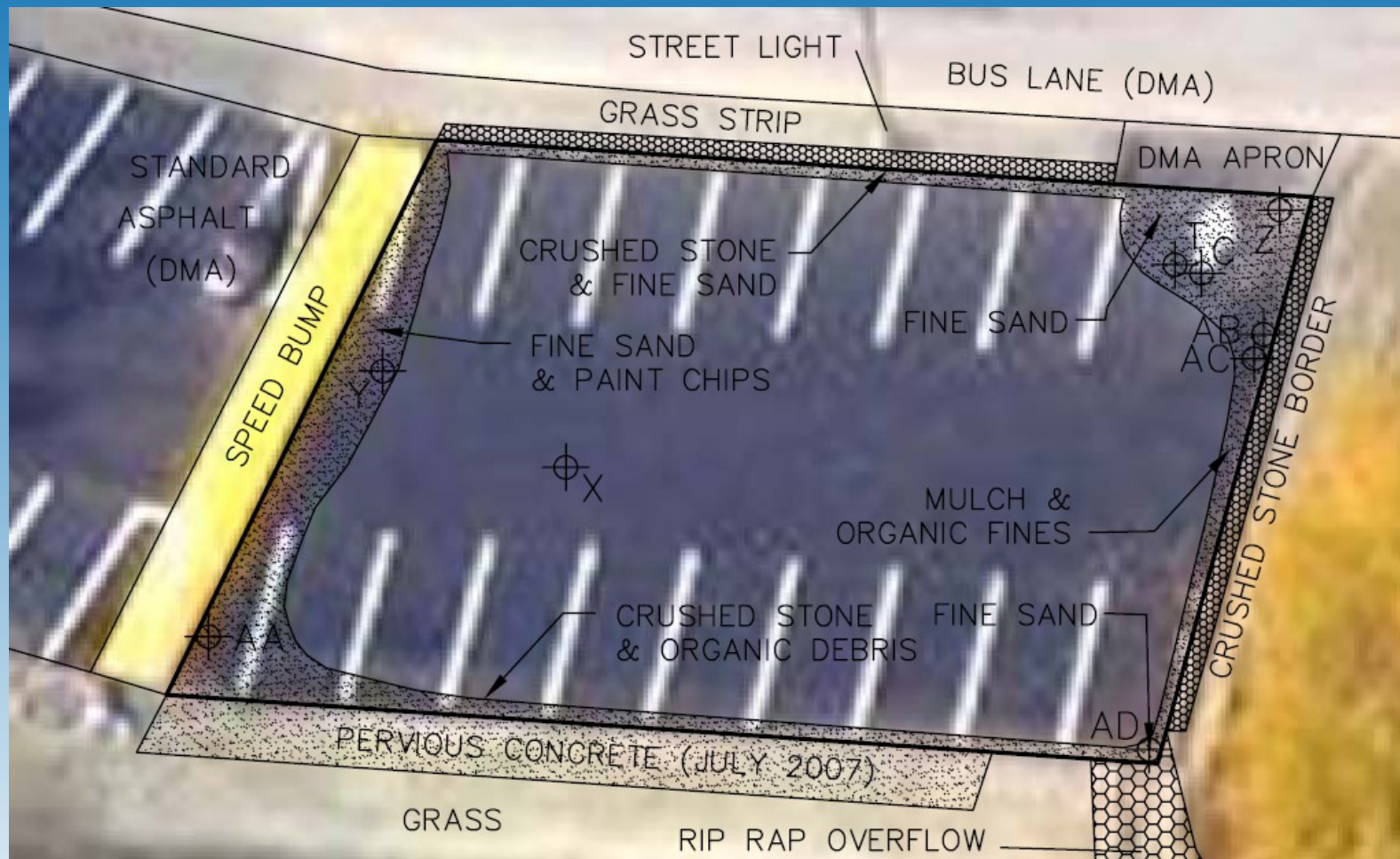


# Research Questions

- How do we define “clogged”?
- To what extent is a site clogged?
- How is infiltration capacity measured?
- Can we develop better infiltration tests?
- What cleaning methods are used?
- What cleaning methods are effective?
- Are cleaning methods cost effective and scalable?
- What are general guidelines for cleaning?

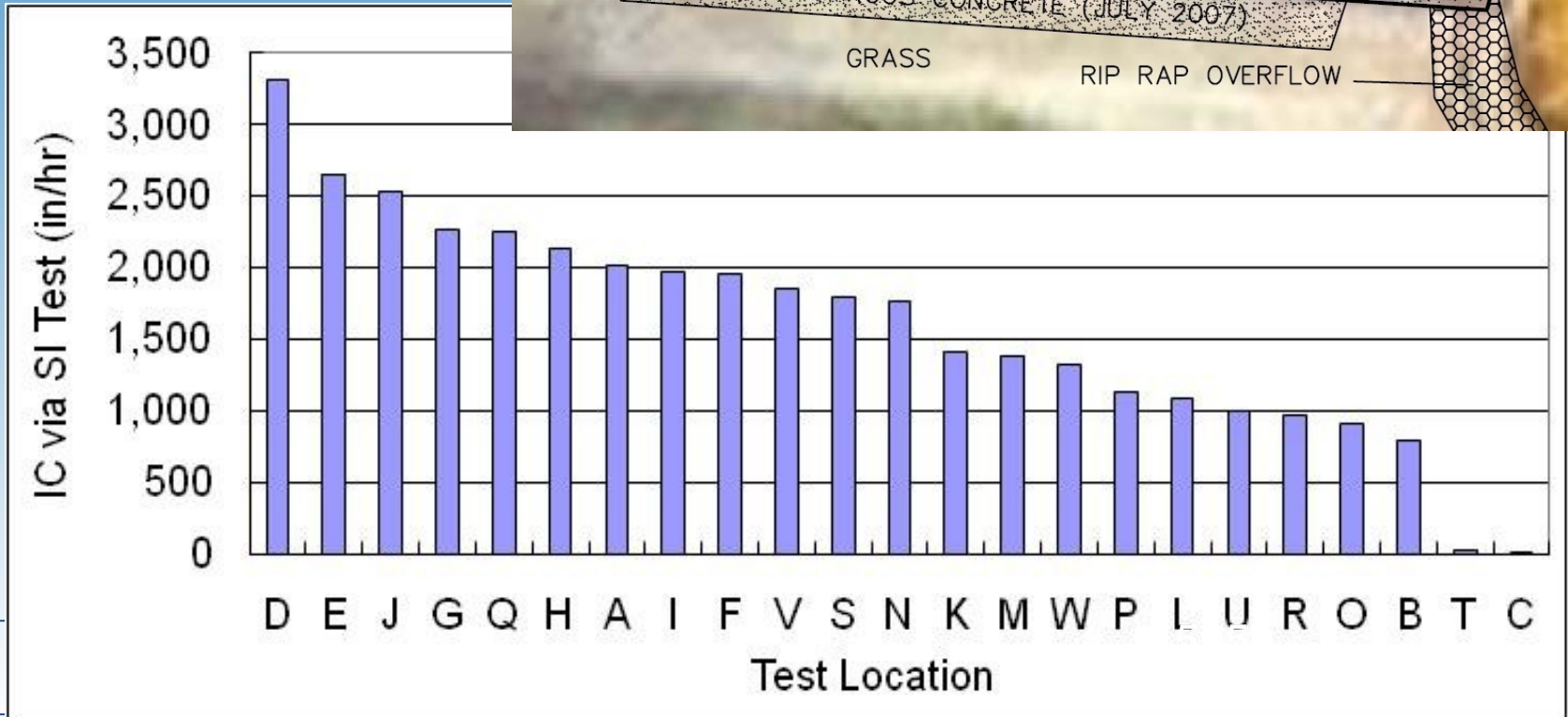
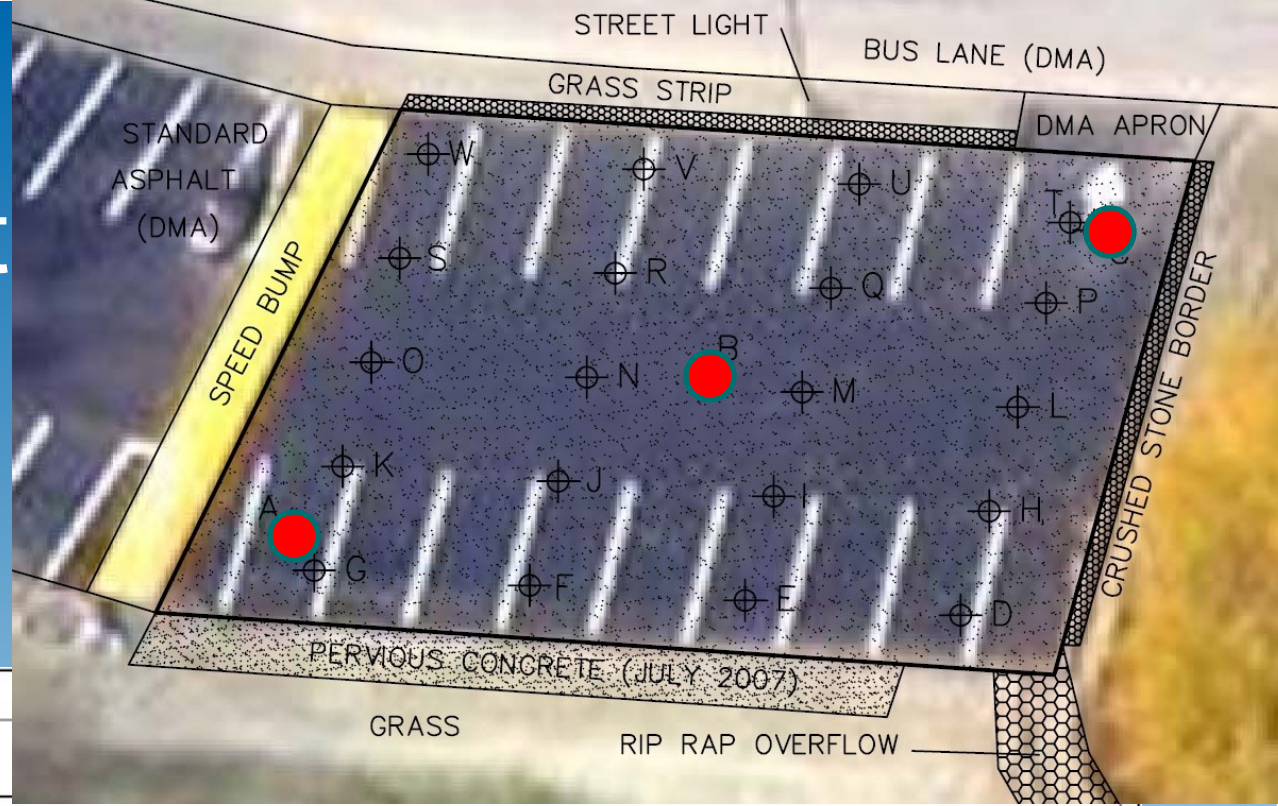


# Pre-Tx Extent of Debris/Clogging

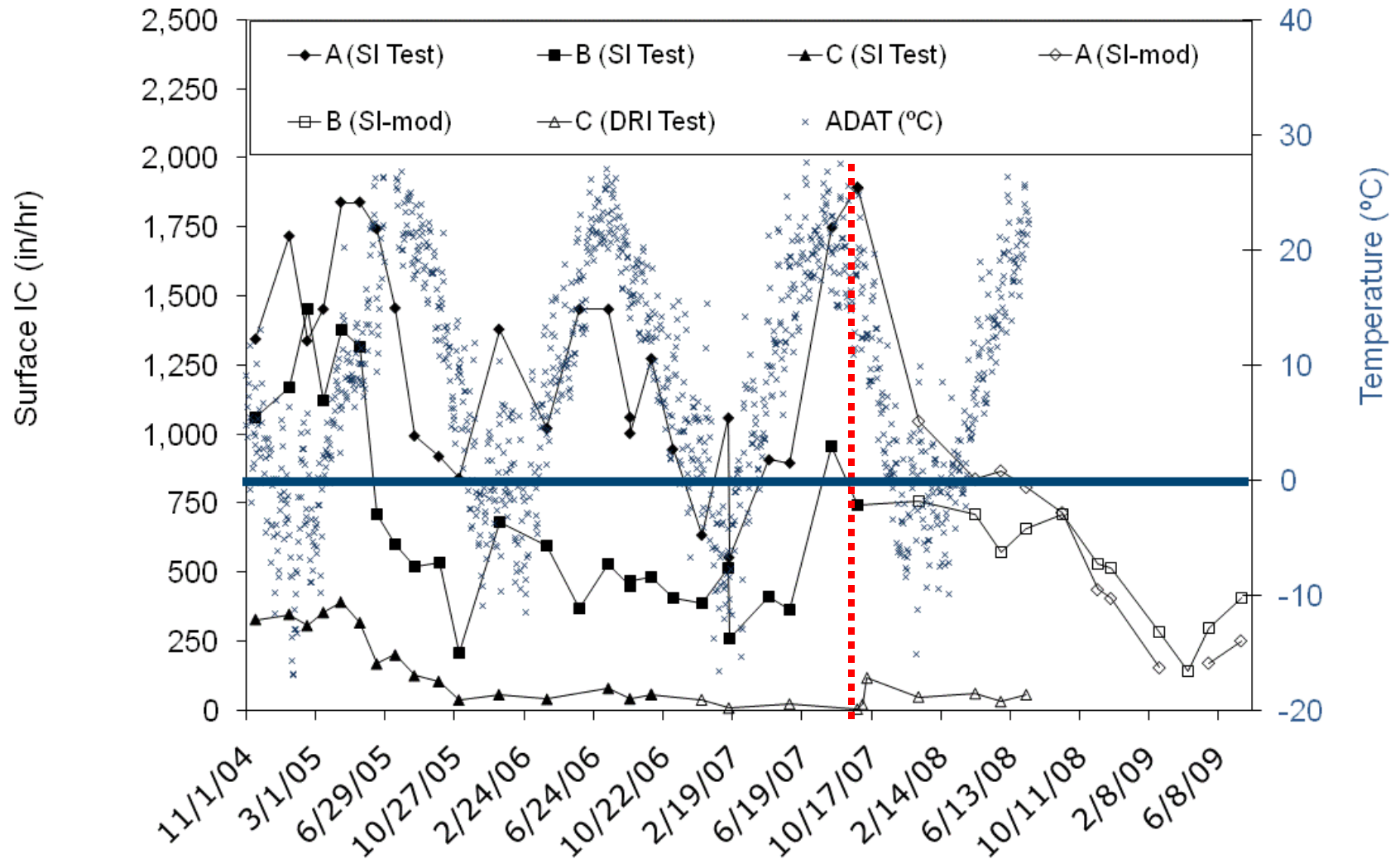


Infiltration capacity via the Pre-Treatment DRI test varied from 0 to 8 in/hr, all effectively clogged when slope is considered.

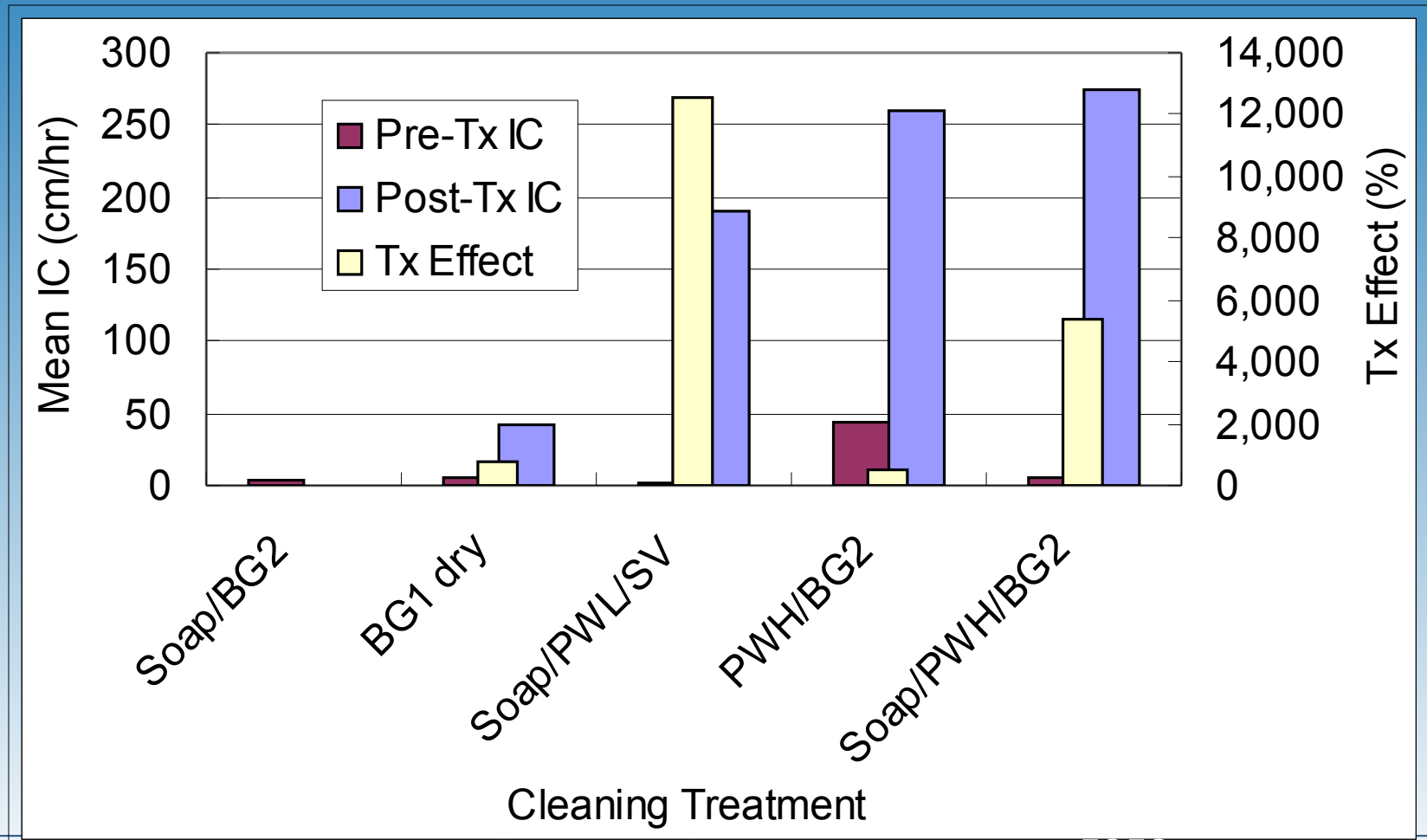
# Pre-Tx Infiltration at Grid



# Long Term Observations of Infiltration Capacity



# Treatment Effectiveness for Clogged Locations



# PAHs and Sealcoat

New study is looking at parking lot sealant contaminants



# Samples from 1st storm after sealcoat was applied.

EPA Surface Water Quality Criteria for total PAHs = 300ug/l

COAL TAR

5,890  $\mu\text{g}/\text{L}$

ASPHALT

642  $\mu\text{g}/\text{L}$

CONTROL

4.39  $\mu\text{g}/\text{L}$

L

L

L

# Sediment Samples



**Unsealed control  
9 acres**

**Coal tar sealant  
0.3 acres**

Sample locations, concentrations in mg/kg  
Pre sealant - Oct 2007

9 months after sealant June 2008

12 months after sealant Oct 2008

30 months after sealant April 2010

1.58  
95.7  
89.6  
9.96

3.08  
51.2  
58.3  
27.8

1.3  
10.9  
4.62  
3.6

0.4  
27.1  
4.18

0.69  
1.61  
4.32

4% of watershed sealcoated  
NOAA Effects Range Median = 44.7 mg/kg

**4% of surface sealed  
109-162 mg/kg  
(Gravel Wetland, Bioretention, Detention Pond)**

**Unsealed  
1.6 mg/kg  
(Bioretention)**

**100% of surface sealed  
390 – 1,700 mg/kg  
(Tree Filter)**

<http://www.unh.edu/erg/cstev>

