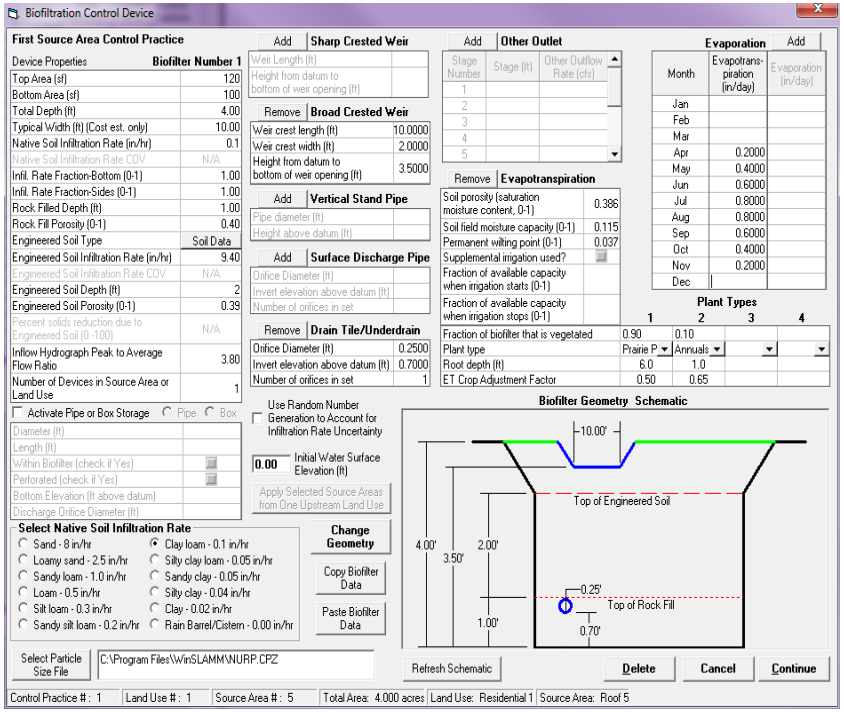
Designing with Our Bioretention Standard 1004 – Focus on the Engineered Soils

Roger Bannerman, WDNR/ USGS

What Are We Going To Talk About?

- What are the recent changes to 1004 and their justifications
  - pH of soil
  - Choice of mulch
  - Planting density
  - Depth of engineered soil
  - TSS reduction
- Brief overview of bioretention in WinSLAMM
- What are we learning about selecting an engineered soil to reduce phosphorus loads



Soil Mixing

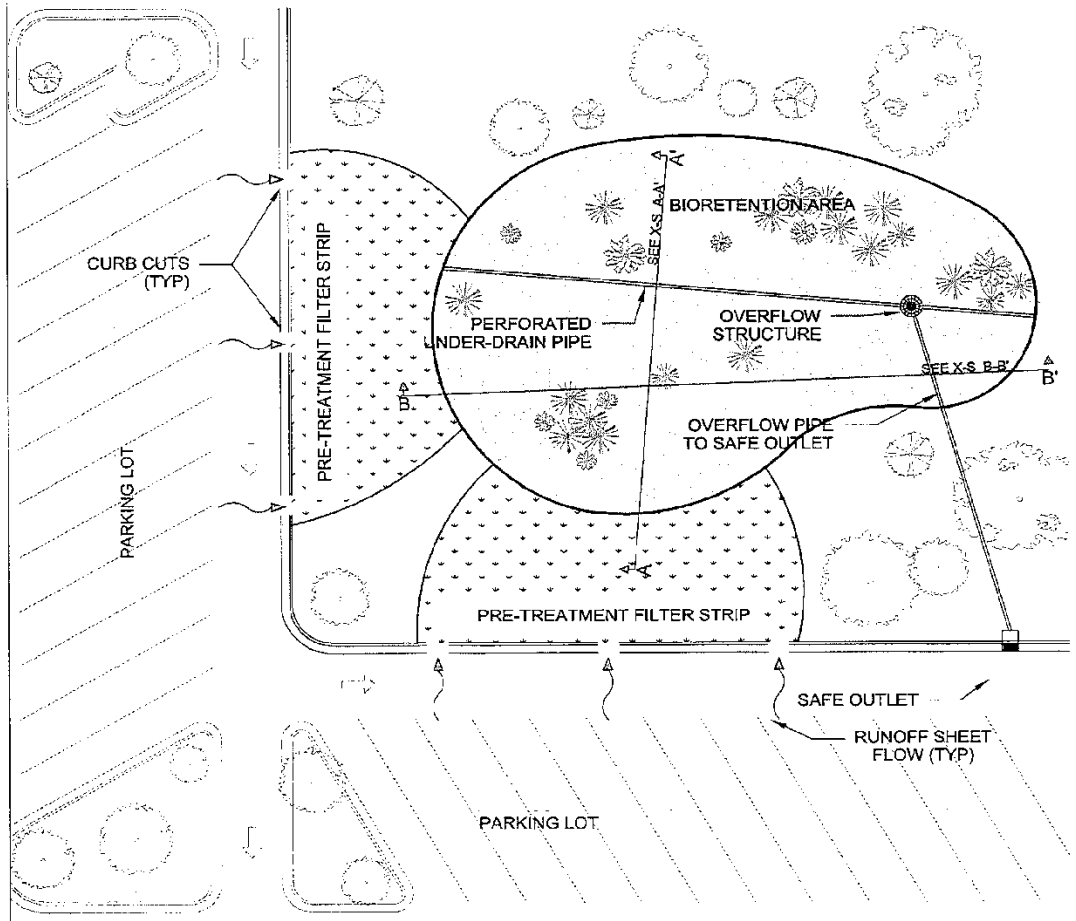
Wisconsin DNR Technical Standard 1004 trying to achieve a balance between:

1. **Adequate infiltration rate**
2. **Reducing pollutant concentration**
3. **Supporting plant growth**
4. **Sodium Adsorption Ratio (SAR)**
5. **Cost**
6. **Ease of Installation**

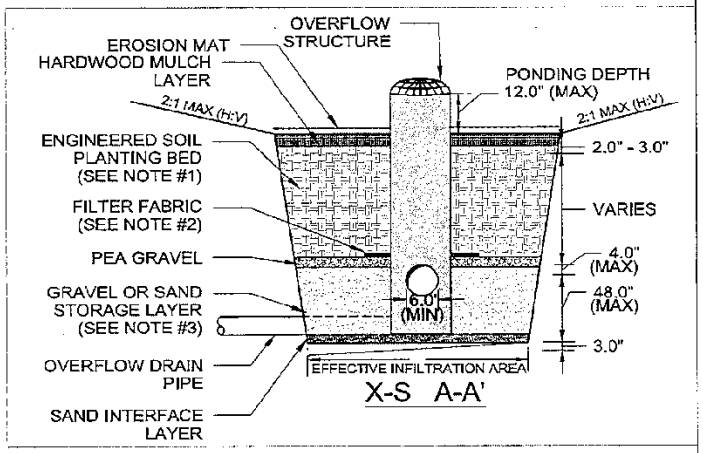
Bioretention Technical Standard - 1004

http://dnr.wi.gov/topic/stormwater/standards/postconst_standards.html

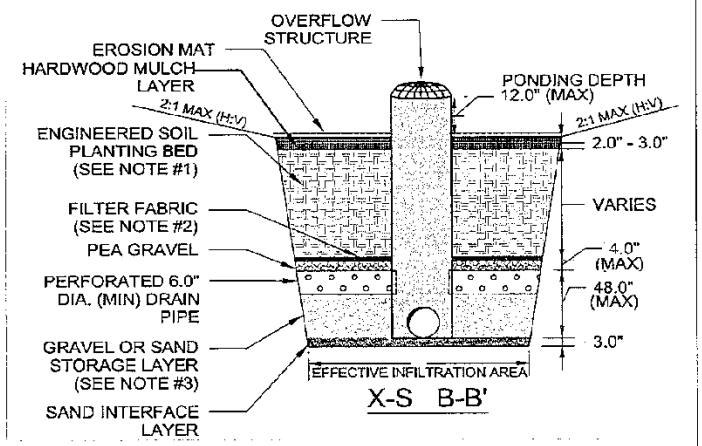
FIGURE 1. BIORETENTION DEVICE



PLAN VIEW



X-S A-A'



X-S B-B'

NOTES:

1. RECOMMENDED ENGINEERED SOIL PLANTING DEPTH IS 24.0". SHALLOWER PLANTING DEPTH IS ALLOWED WHEN SITE CONDITIONS ARE LIMITED. SOIL PLANTING DEPTH SHALL BE MINIMUM OF 18.0".
2. GEOTEXTILE FILTER FABRIC TO BE PLACED OVER PERFORATED UNDER-DRAIN.
3. GRAVEL / SAND STORAGE LAYER TO BE MAXIMUM OF 48.0" BELOW PERFORATED UNDER-DRAIN PIPE.

WISCONSIN DEPT. OF NATURAL RESOURCES

1062	TECHNICAL STANDARD No.
10/17/2014	REVISION DATE
NOT TO SCALE	

Site Evaluation Standard for Stormwater Infiltration -1002

http://dnr.wi.gov/topic/stormwater/documents/techstd1002.pdf

Rain Gardens – Create Depression and Install Some Plants

Rain Garden – Madison, WI

City of Madison Terrace Rain Gardens

Greg Fries, P.E.
City of Madison-Engineering
gfries@cityofmadison.com
(608) 267-1199

Examples of Replacing Topsoil with Engineered Soil

Burnsville, MN

Maplewood, Minnesota

Lathrup Village

Bioretention Cell (40:1)

Bioretention – Lodi, WI; WDOT (John Voorhees)

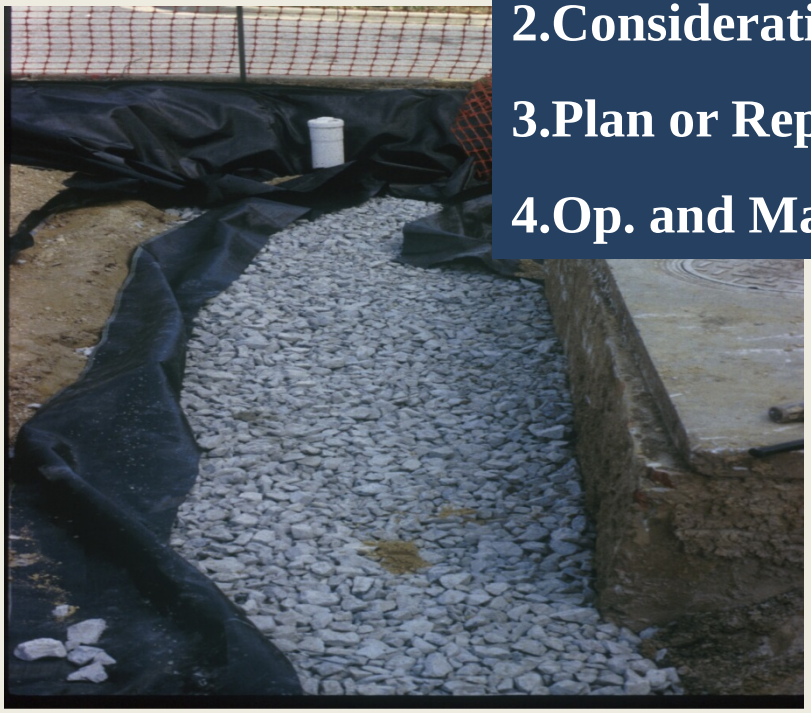
Bioretention Technical Standard - 1004

http://dnr.wi.gov/topic/stormwater/standards/postconst_standards.html

Construction of Biofiltration Facility with Amended Soils and Underdrain

Contents of Technical Std.:

1. Criteria
2. Considerations
3. Plan or Report
4. Op. and Maintenance



Larry Coffman, Prince George's County

Planting Density

"A planting density of one foot on center is required unless the type of plants selected would justify a larger space between the plants. As stated in Section R of the Considerations, shrubs and trees would be planted with more than one foot between them."

Dane County: Consultants designing bioretention systems have challenged this planting density by using a design with a decreased planting density.

Neil Diboll with Prairie Nursery in Westfield, WI and Eric Jacobson with Formecology in Evansville, WI have extensive experience working with our native plants. They both thought a planting density of one foot on center for the forbs and grasses is a good choice. In their experience this would promote a sustainable plant community in a reasonable amount of time.

Surface Mulch Layer – **Shredded hardwood mulch or chips, aged a minimum of 12 months or a Class II erosion control mat (blanket), shall be placed on the surface of the bioretention area. The shredded hardwood mulch or chips shall be 2 to 3 inches in depth and the mat shall be anchored, overlapped, staked and entrenched per the manufacturer's recommendations (WDNR, 2004).**

Given the problem of shredded hardwood mulch or chips floating away, it seems reasonable to give the choice of using an erosion control mat – especially for sites with more intensive runoff.

Soil pH

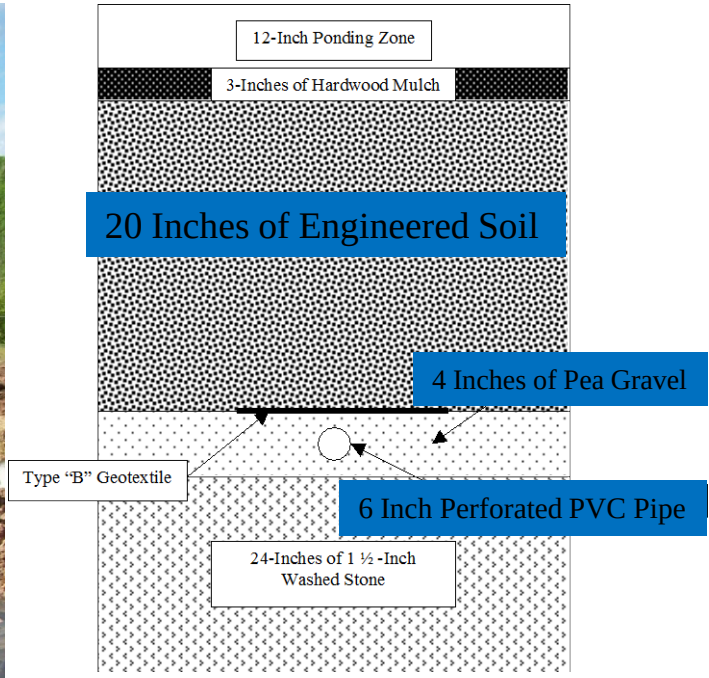
“The engineered soil mix shall have a pH between 5.5 and 8.0.”

Jame (Sandy) Syburg said Standard 1004 is too difficult to achieve by reasonable methods. The media they make usually has a pH between 7 and 8 and they would have to add sulfur to lower the pH.

Purple Cow Organics

"I would doubt that there would be many local plants that would fail on calcareous sand. Indeed, bringing the pH into range would require considerable effort and present a large cost w/o benefit. I would recommend a pH range between 5.5 and 8.0."

Depth of Engineered Soil



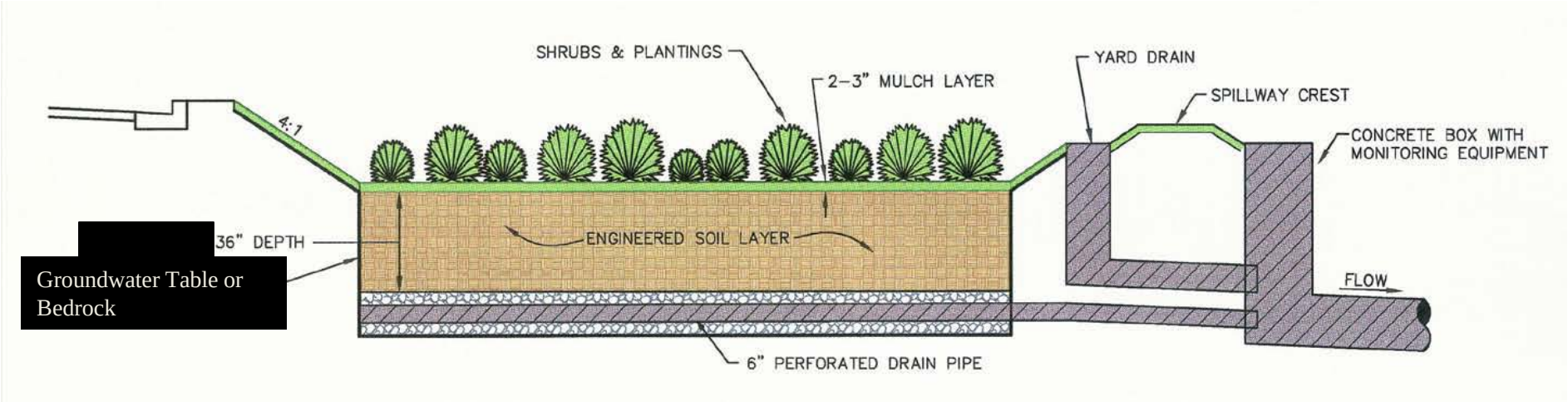
soil layer (including the pea gravel lens) shall be at least 2 feet deep. A depth of 18 inches will also be allowed for sites with more restrictive elevation requirements.

How Did Depth Requirement Become an Issue in Wisconsin?

Bioretention Technical Standard 1004 required 3 foot depth for an engineered soil – based on experiences from Maryland Standards

Obstacles to 3 Foot Depth

- **High Bedrock Limits Depth**
- **High Groundwater**
- **Insufficient elevation to daylight drain tile.**



Three Systems in Neenah – 1,2,&3 Foot – 50% Sand/50% Compost

ISCO Sampler & Control Panel

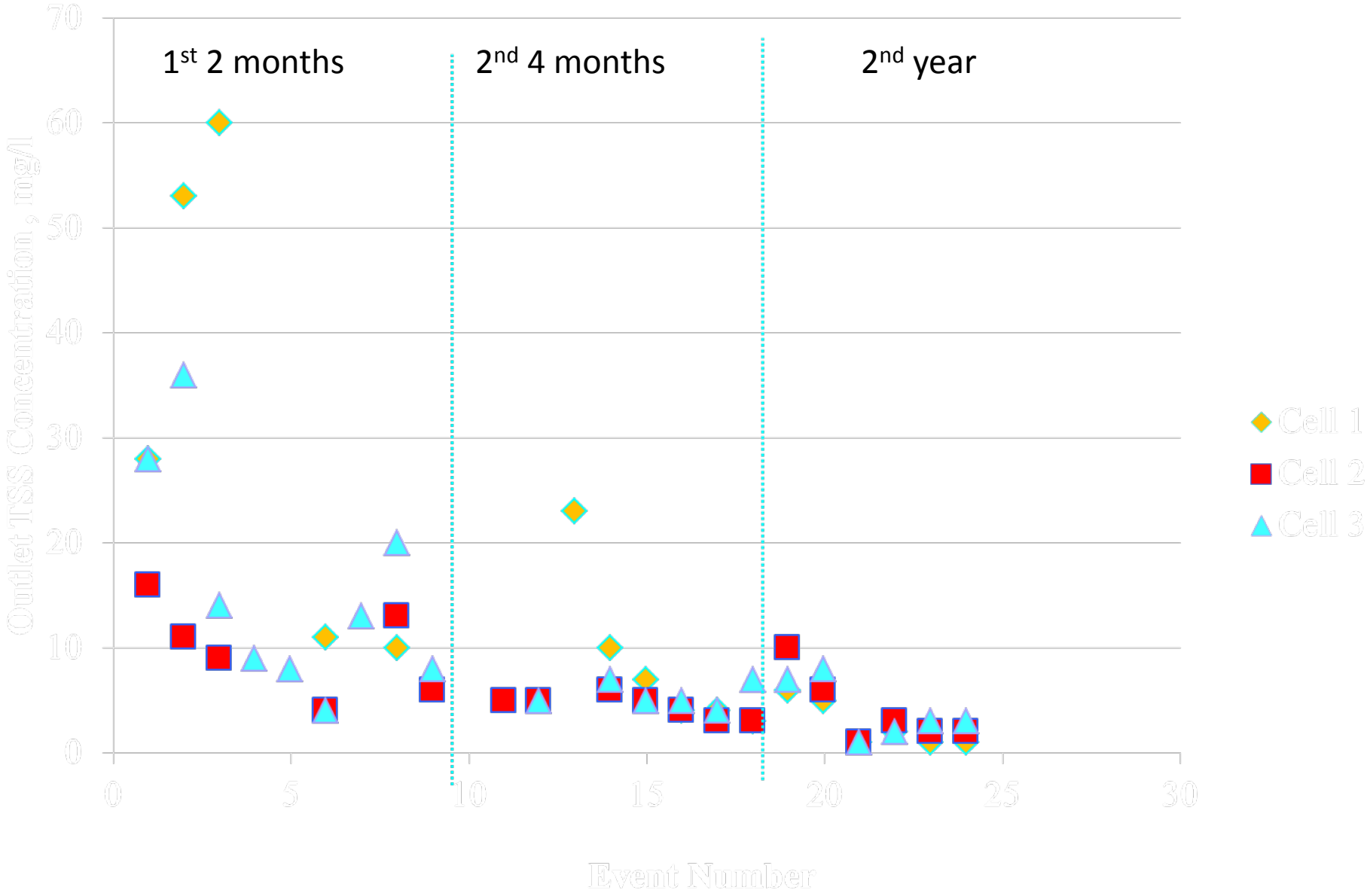
Monitoring Tasks:

1. **Flow and EMCs inlet**
2. **Flow and EMCs outlet**
3. **Bypass flow**
4. **Soil Moisture**
5. **Weather**
6. **Soil Chemistry**

Media-1 Efficiency Ratios for TSS:

Eff Ratio = 1- (avg. outlet conc./avg. inlet conc.)

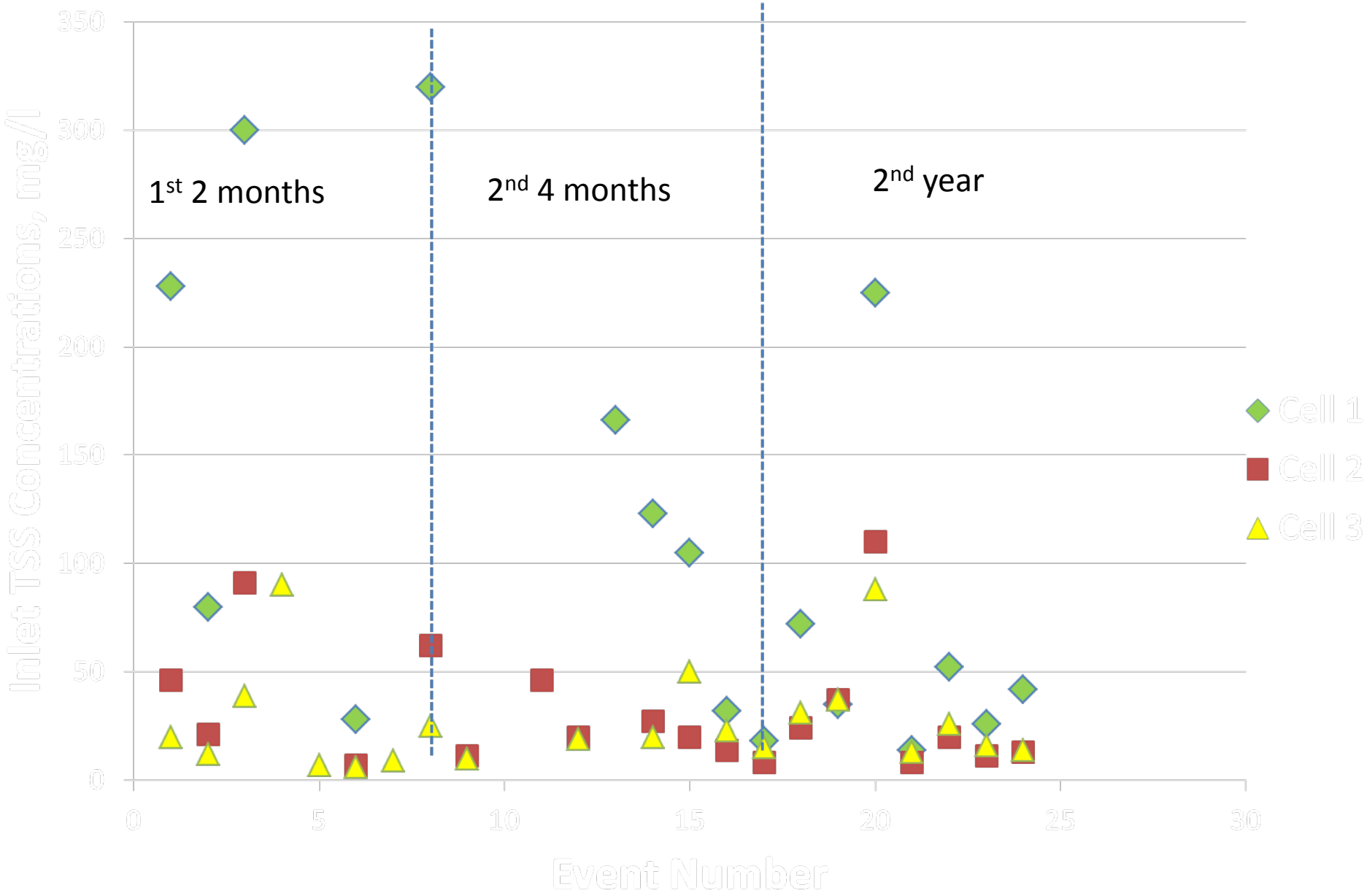
Site	Inlet TSS, mg/l	Outlet TSS, mg/l	Efficiency Ratio, %	Sum of Loads, %
1-Ft Cell (16)	113	10	91	88
2-Ft Cell (19)	31	6	81	80
3-Ft Cell (21)	27	9	65	60



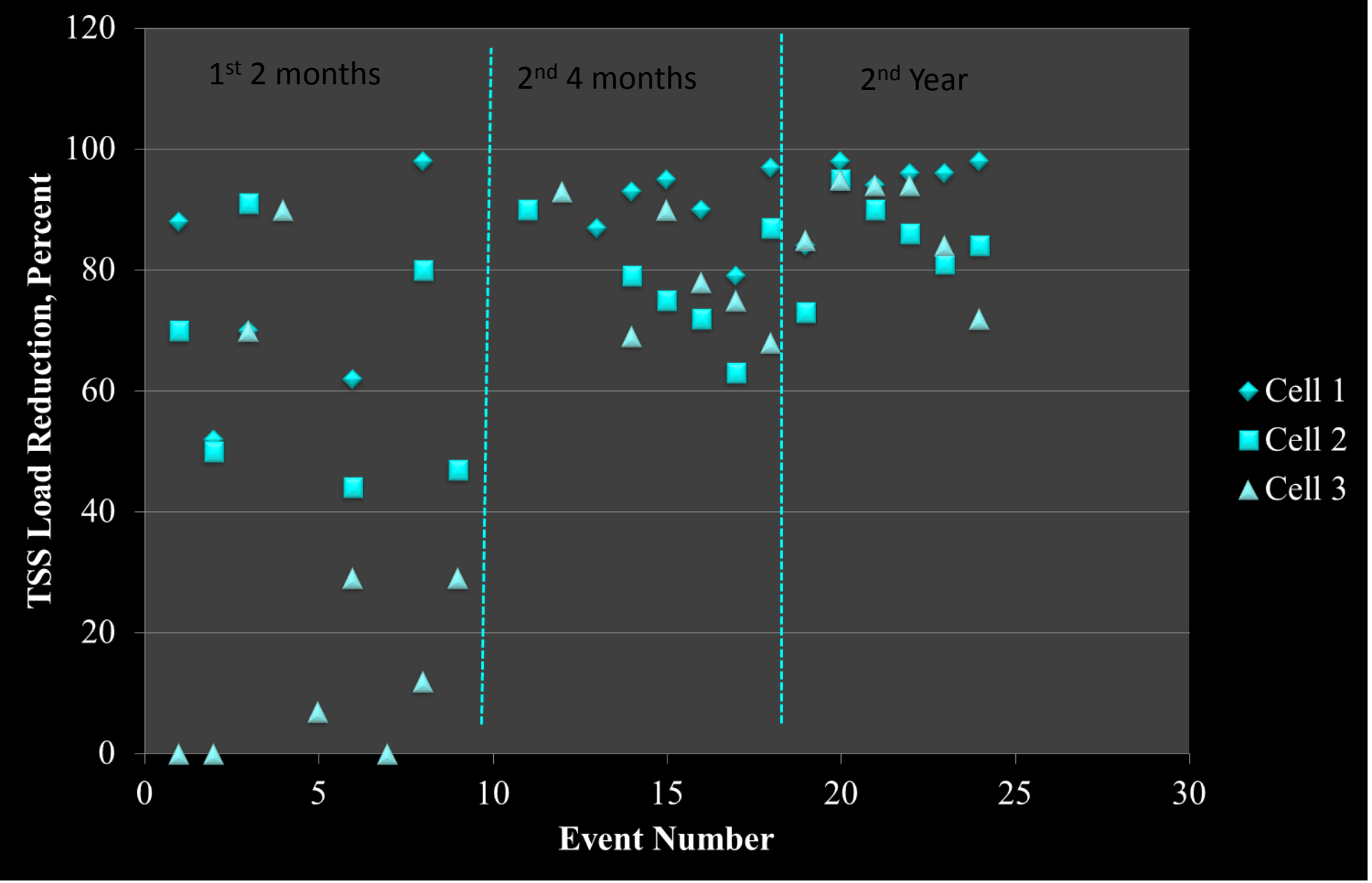
The TSS outlet concentrations as a function of time

Simulating Event with City Water to Determine Mobility of Media Particles May 2011

Type of Value	2 Foot Depth Media	3 Foot Depth Media
City Water - Inlet TSS	< 2 mg/l	< 2 mg/l
City Water - Outlet TSS	3	3
Event Outlet TSS	3	7



Inlet TSS concentrations of the three cells as a function of time



TSS Load Reductions for Each Cell as a Function of Time

Sum of the Loads Values for Selected Combinations of Monitoring Dates.

Selected Combinations of Monitoring Dates	TSS SOL Reductions, %		
	Cell 1	Cell 2	Cell 3
All Events	88	78	63
1st 2 months	85	74	31
2nd 4 months	91	82	82
2nd Year	96	87	90

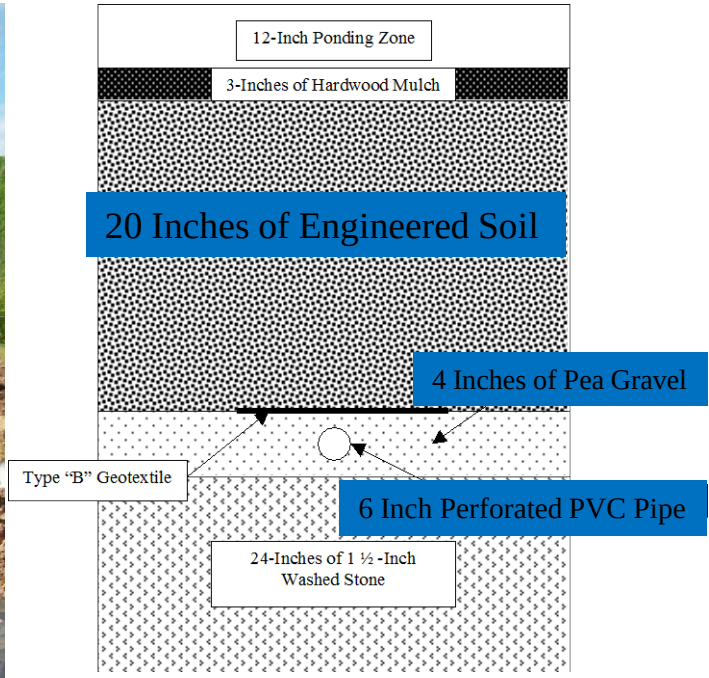
Site	Efficiency Ratio TSS, %
Cell 1 (16)	88
Cell 2 (16)	71
Cell 3 (14)	74

Media-2: 86% Concrete Sand, 11% Peat Moss, and 3% Sorbtive Media

Is the TSS Reduction Related to the Depth of the Media?

- Statistical Test Show Percent Reduction Not Different For Cell 2 and 3, but Cell 1 is Different from the Other Two – This test used all the numbers.
- With Time Outlet Numbers are Not Significantly Different – Any difference becomes more a function of inlet numbers.
- 80% TSS reduction is a reasonable default value.

Depth of Engineered Soil



soil layer (including the pea gravel lens) shall be at least 2 feet deep. A depth of 18 inches will also be allowed for sites with more restrictive elevation requirements.

Guidelines for Depth of Engineered Soil – William Hunt, 2006

Pollutant	Minimum Engineered Mix Depth
TSS	No Minimum
Metals	18 inches
TN	36 inches
TP	24 inches

William Hunt, 2006
Media Depth for Plants:
Trees – 3 feet
Shrubs – 2 feet
Grass – 18 inches

Bioretention Technical Standard - 1004

- What are the recent changes to 1004 and their justifications
  - **pH of soil**
  - **Choice of mulch**
  - **Planting density**
  - **Depth of engineered soil**
  - **TSS reduction**

Purpose of Source Load and Management Model (SLAMM)

Developed to assist cities in evaluating the benefits of alternative stormwater treatment practices for both runoff quality and quantity in existing and developing urban areas.

Authors: Robert Pitt and John Voorhees

www.winslamm.com

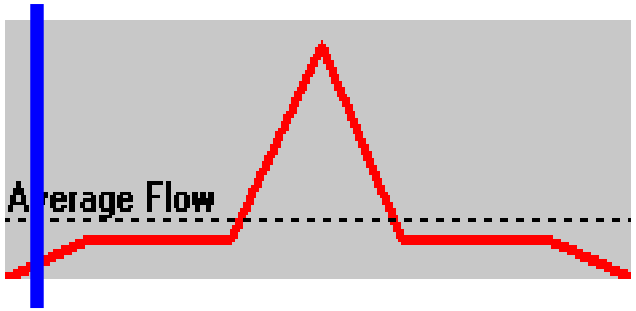
Modeling Notes

- **Control practice used to model:**
  - **Biofilters**
  - **Rain Gardens**
  - **Infiltration Fields**
  - **Infiltration Trenches**

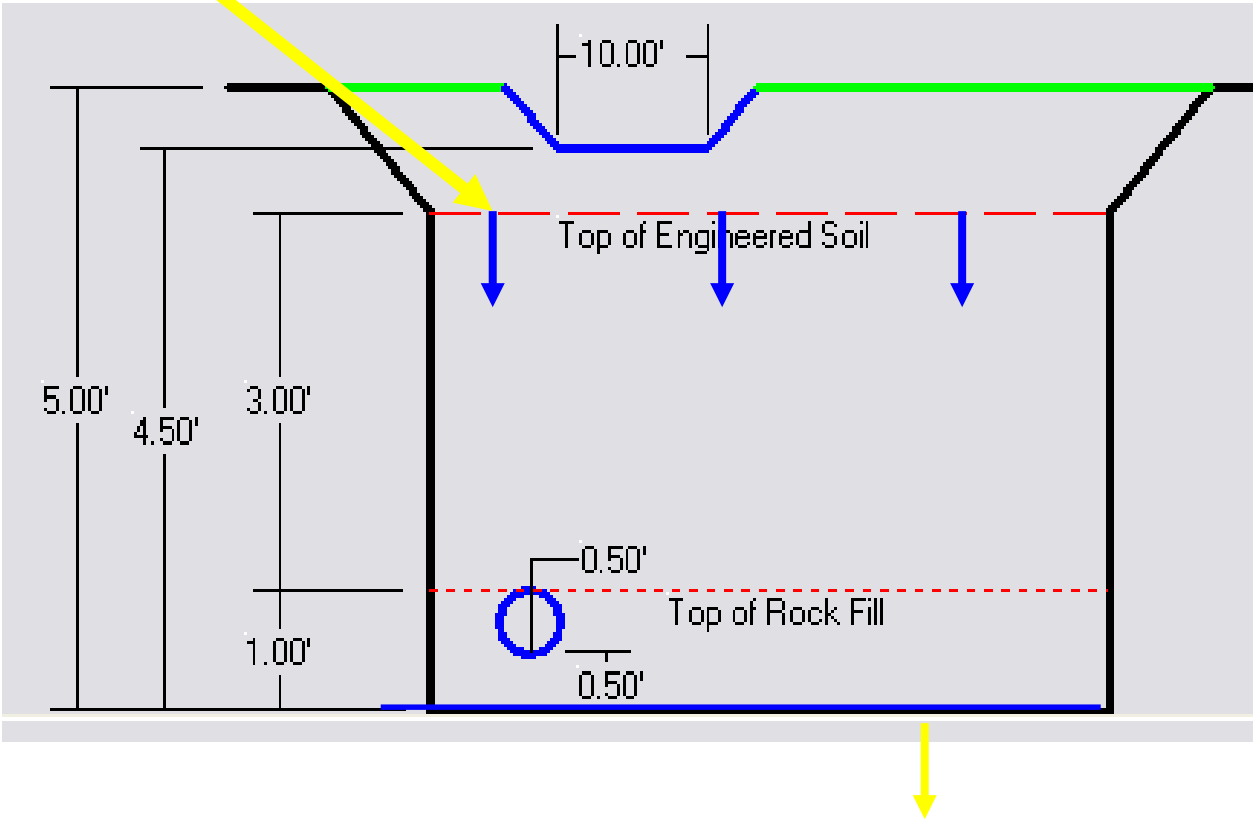
Modeling Notes

- **Biofilter routing is performed using the Modified Puls Storage – Indication Method.**
- **Time increments are established by the user – default = 6 minutes**
- **Yield reductions due to runoff volume reduction through infiltration and filtering through engineered soil**

Control Practice Overview



- **Inflow rate – Low**
- **All runoff flows through engineered soil**
- **Native soil restricts below ground discharge**
- **Water level below ground rises**



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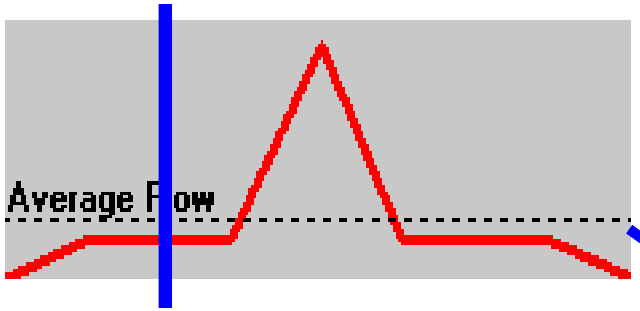
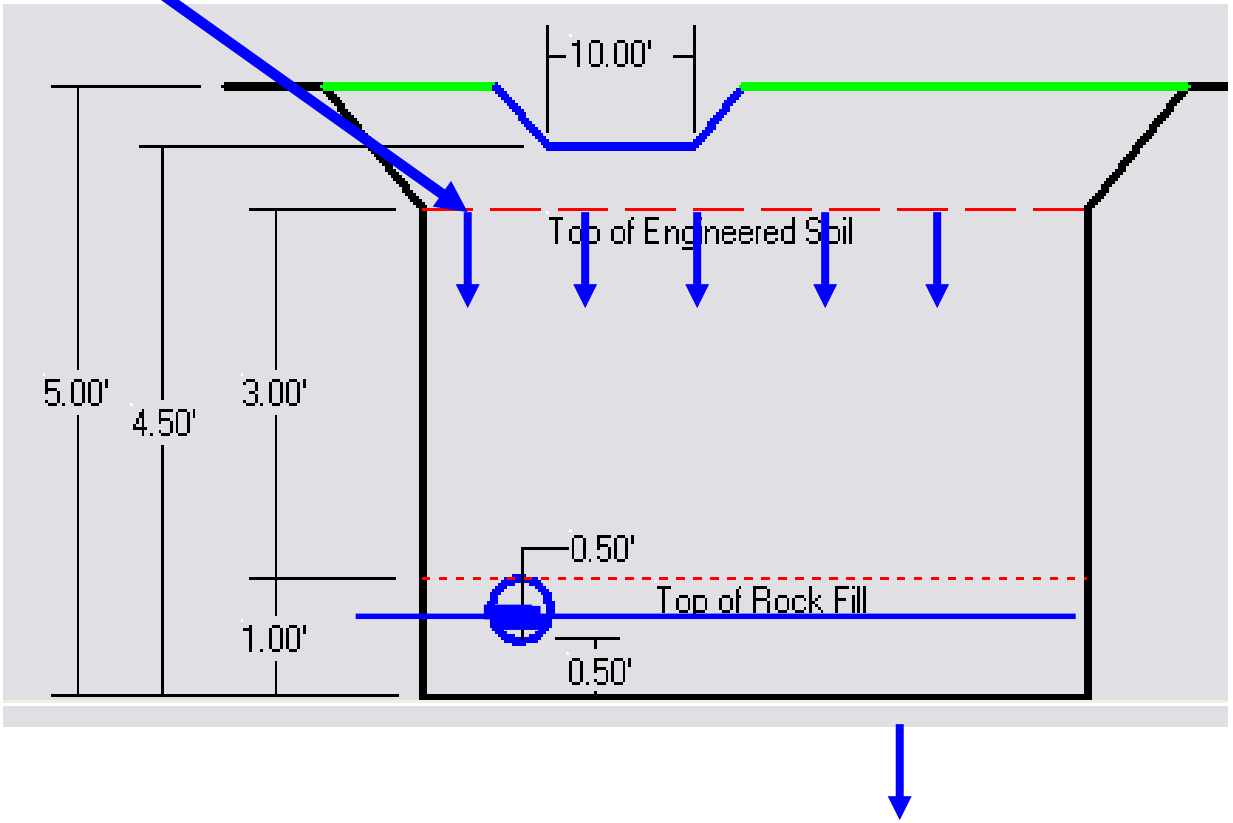


- Inflow rate – Moderate
- All runoff flows through engineered soil
- Native soil restricts below ground discharge
- Water level below ground rises
- Water discharges through underdrain



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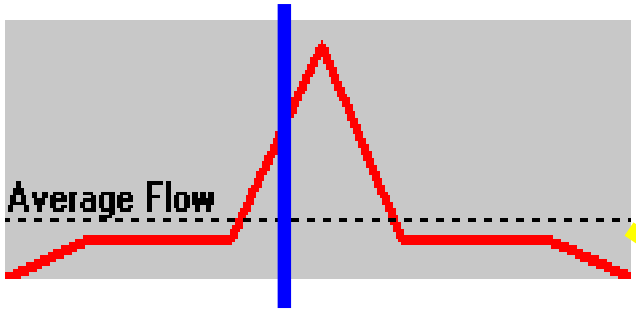
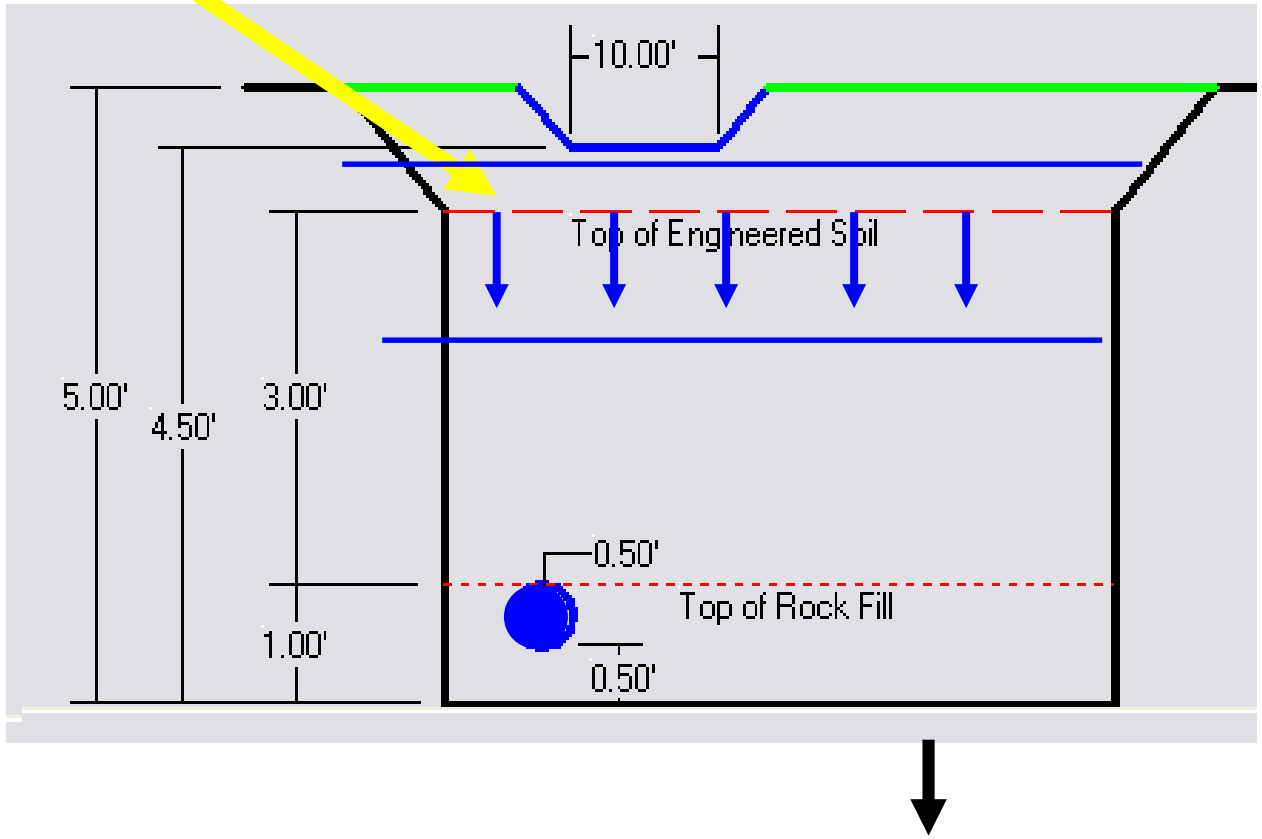


- Inflow rate – High
- Some runoff flows through engineered soil
- Native soil restricts below ground discharge
- Water level above ground rises
- Water level below ground rises
- Water discharges through underdrain



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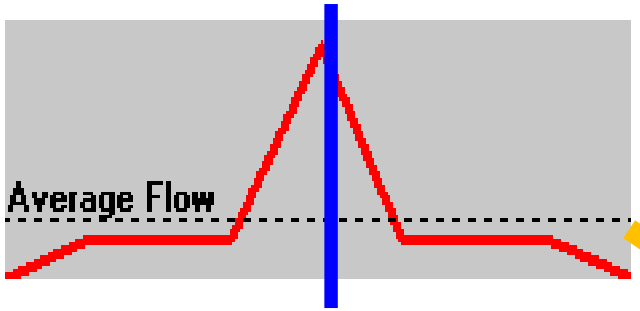
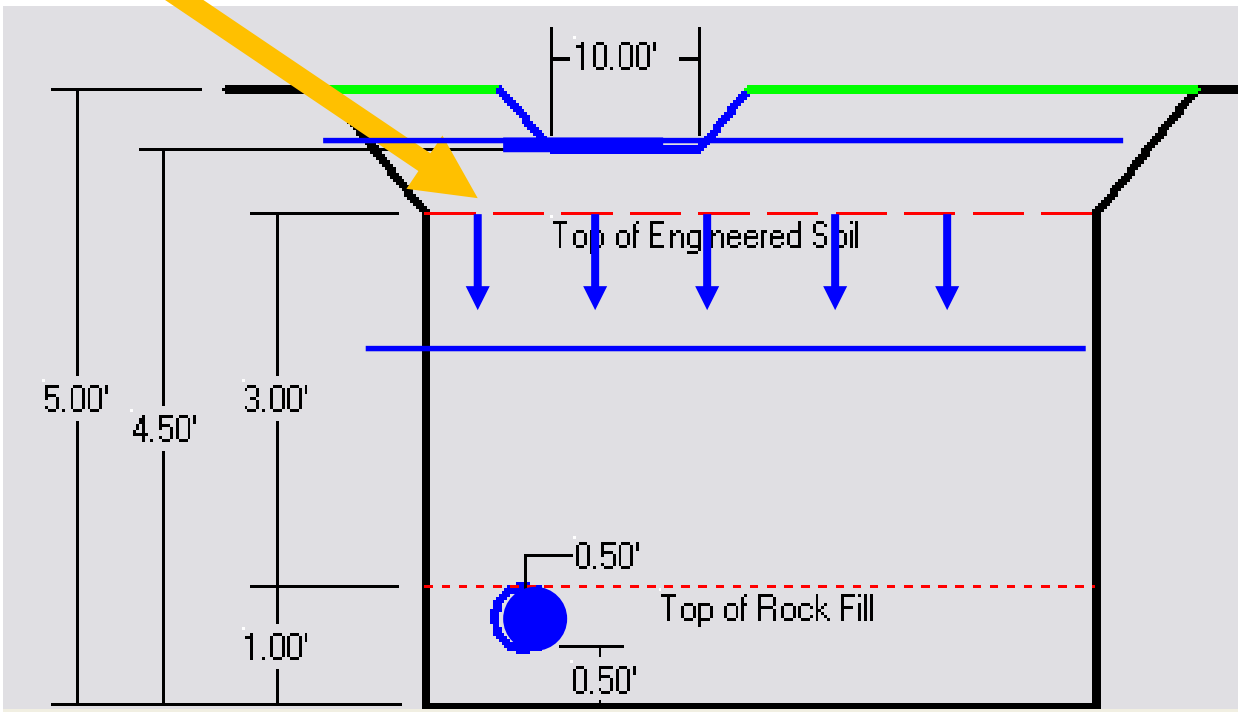
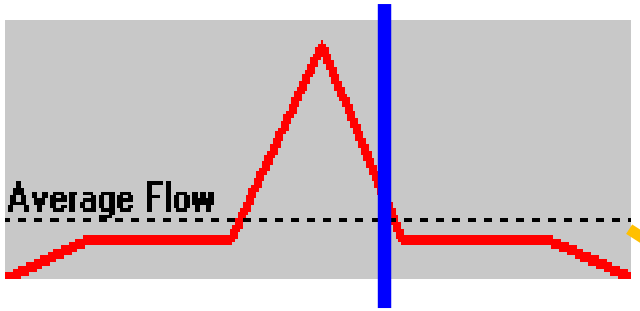


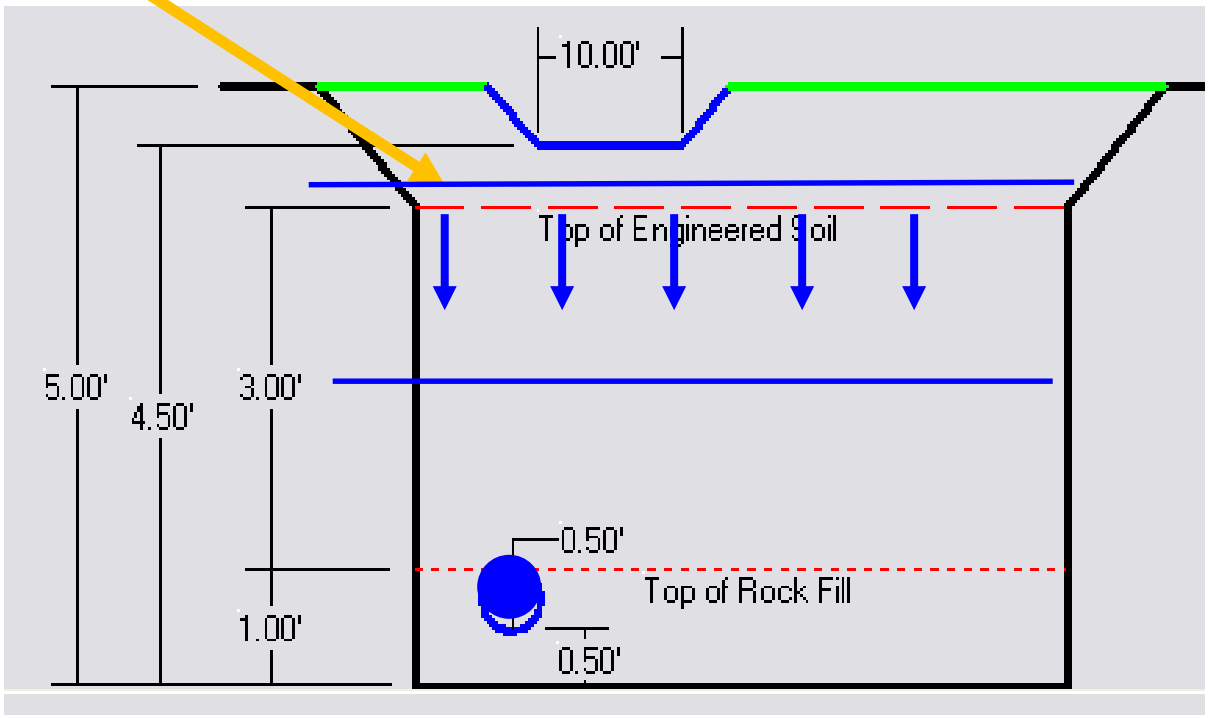


- **Inflow rate – High**
- **Some runoff flows through engineered soil**
- **Native soil restricts below ground discharge**
- **Water level above ground rises**
- **Water level below ground rises**
- **Water discharges through underdrain and above ground**

Control Practice Overview



- Inflow rate – Moderate
- Some runoff flows through engineered soil
- Native soil restricts below ground discharge
- Water level above ground falls
- Water level below ground falls
- Water discharges through underdrain



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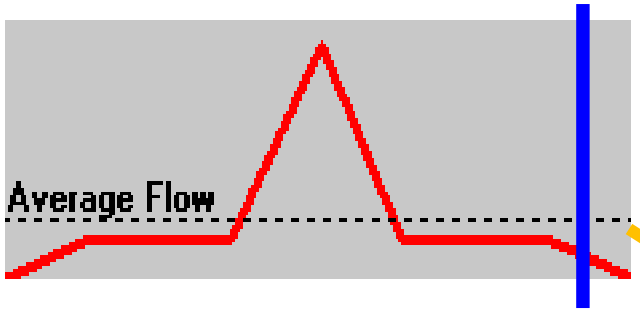
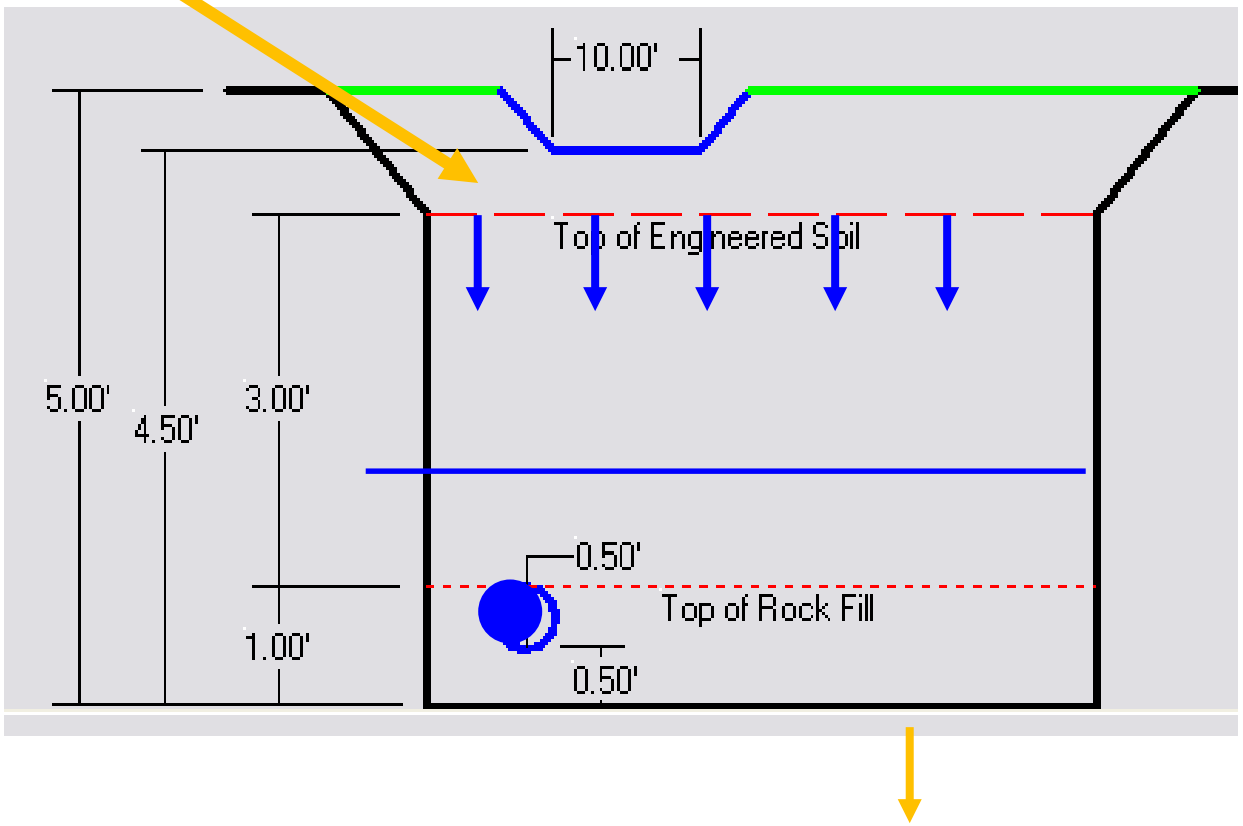


- Inflow rate – Moderate
- All runoff flows through engineered soil
- Native soil restricts below ground discharge
- Water level above ground zeros out
- Water level below ground falls
- Water discharges through underdrain



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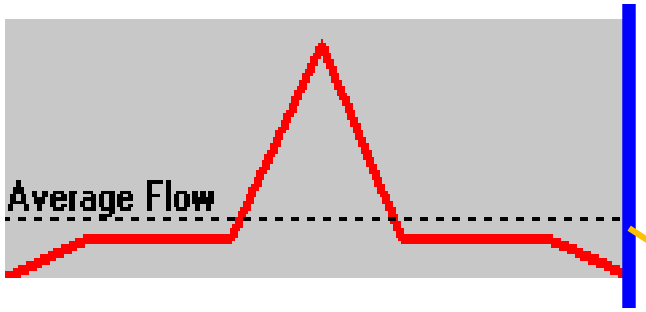
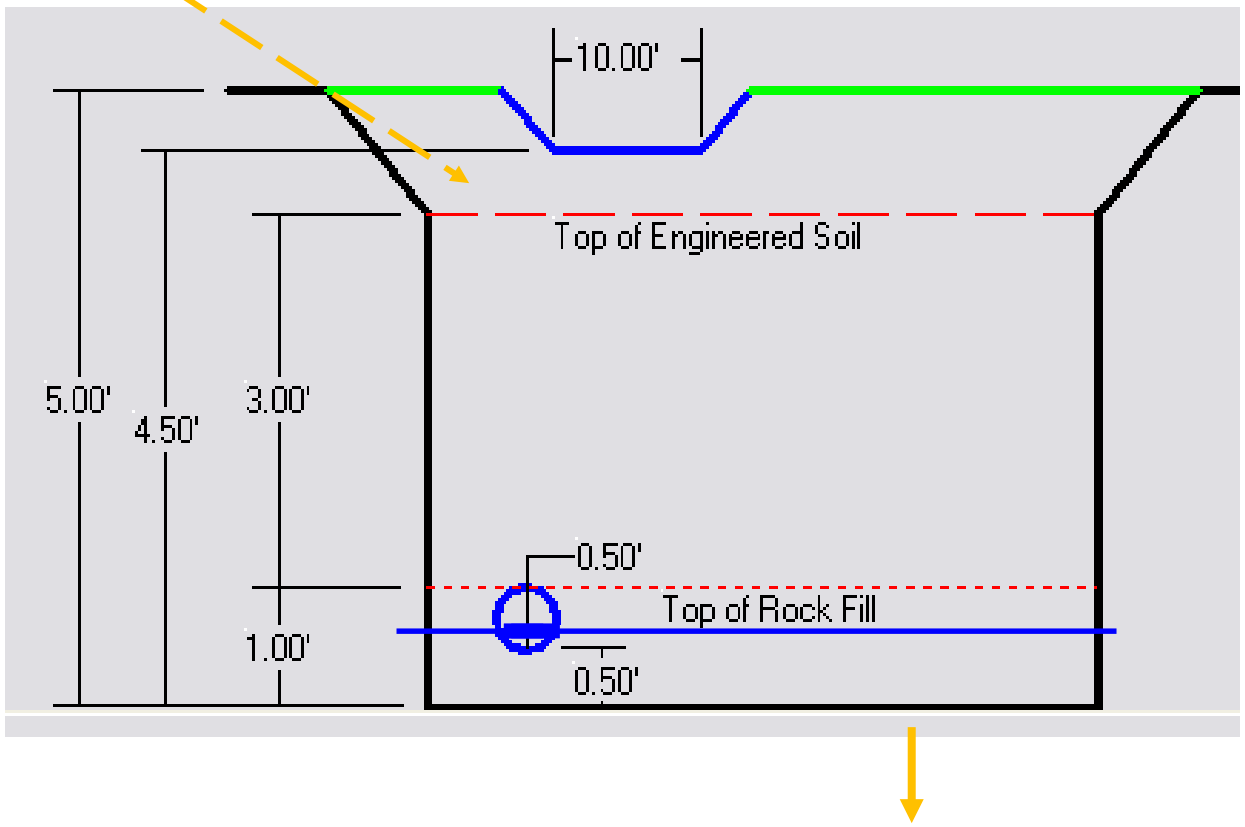
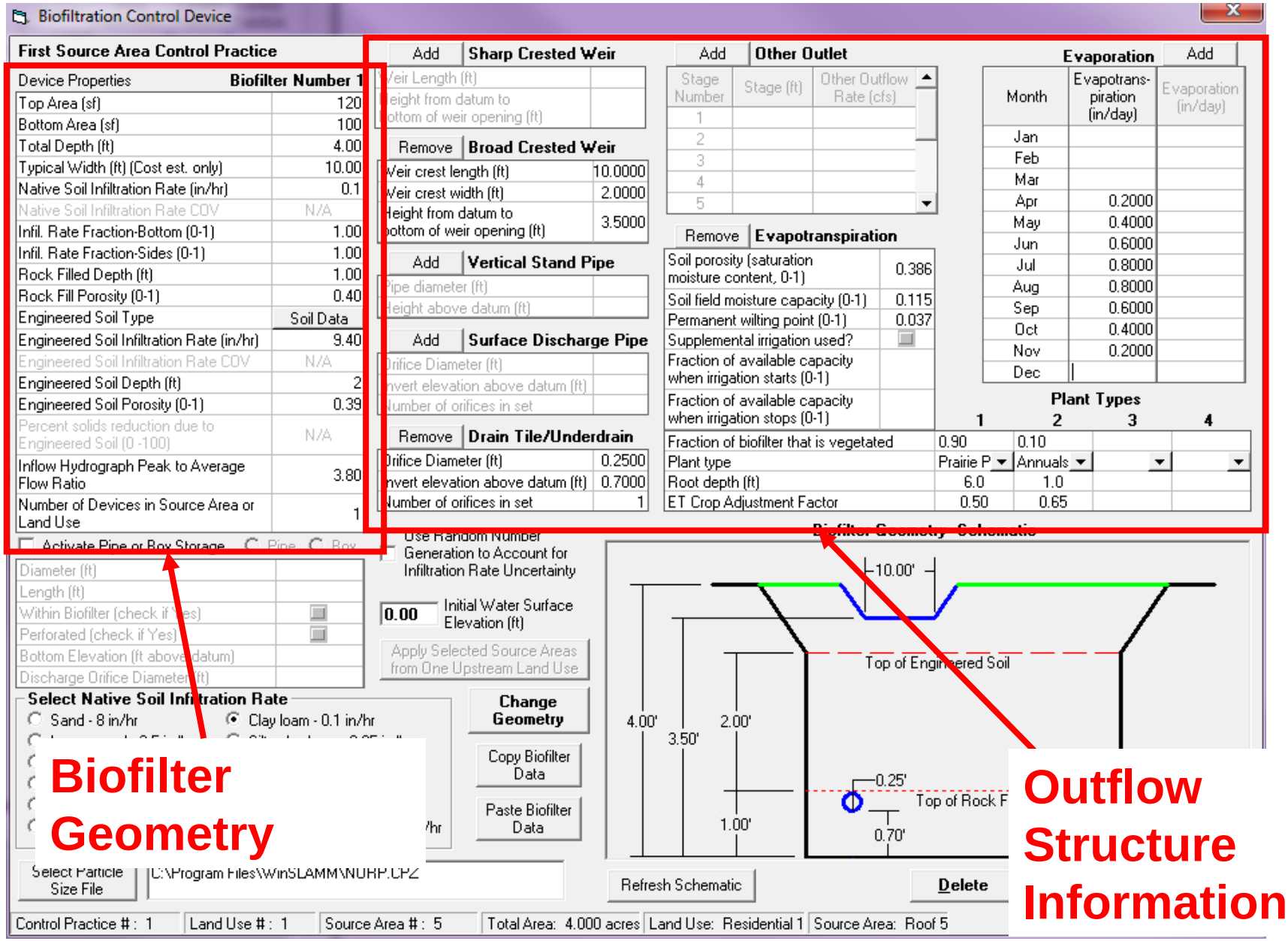


- Inflow rate – Zero
- No runoff
- Native soil restricts below ground discharge
- Water level below ground falls
- Water discharges through underdrain, eventually only through native soil



Biofilter Data Entry Form



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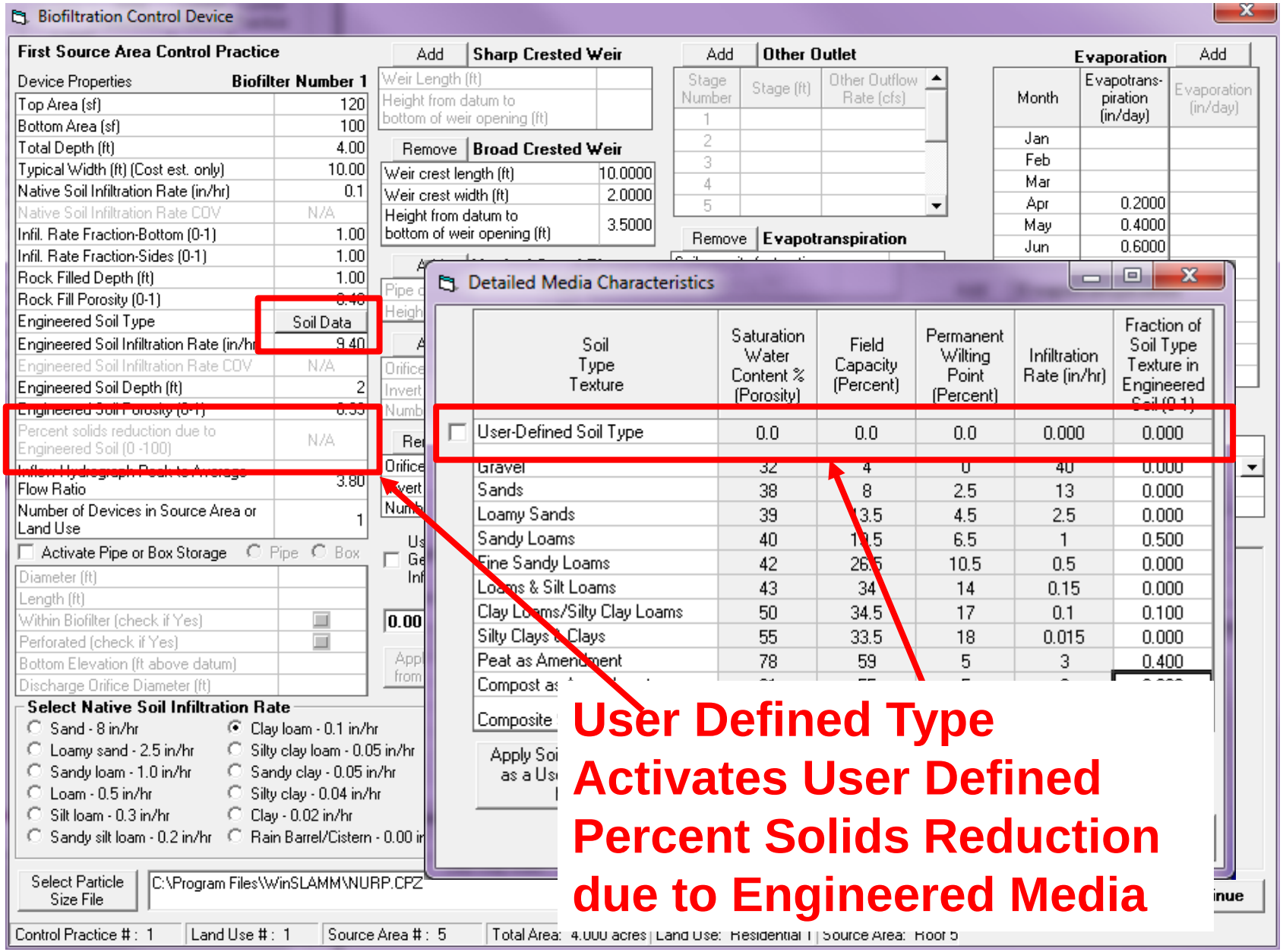

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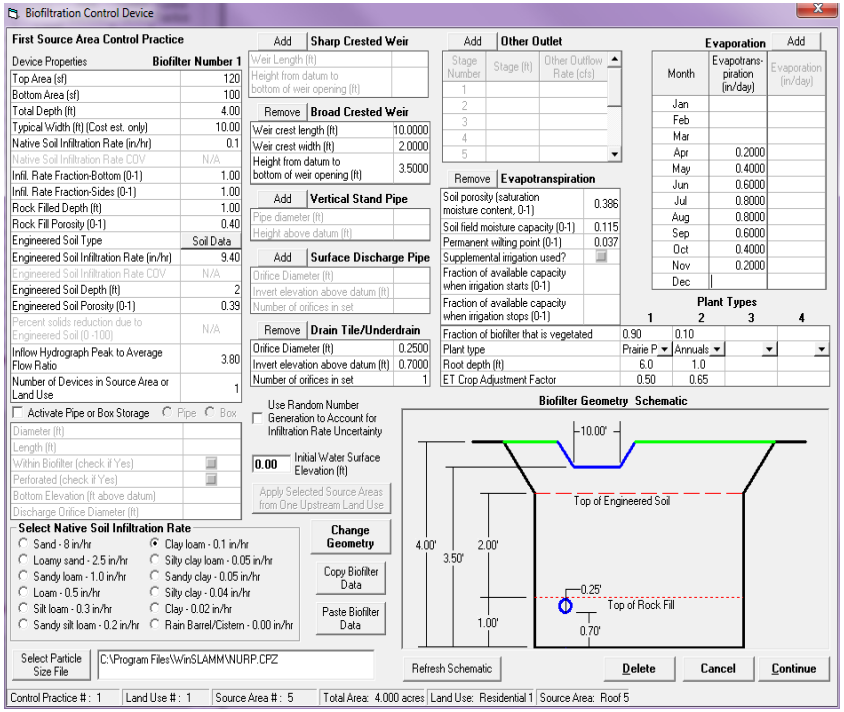
- Brief overview of bioretention in WinSLAMM
- **What are we learning about selecting an engineered soil to reduce phosphorus loads**



Efforts to Evaluate a Number of Engineered Soil Mixes for Wisconsin's Bioretention Technical Standard 1004 – Focus on Phosphorus Control

1. **40% Concrete Sand; 20 to 30%Topsoil; 30 to 40% Compost**
2. **50% sand/50% compost**
3. ***70 to 85% Sand/15 to 30% Compost***
4. **87% Sand, 8% fines, 5% Bark**
5. ***86% Sand; 11% Peat Moss; 3% SorbtiveMedia (Imbrium)***
6. **Six Inch *Growth layer on top of sand***
7. ***Sand***
8. **Growth layer on top of sand with iron filings**

Engineered Soil Mix 50% sand/ 50% compost – Technical Standard 1004

Total P = 600 mg/kg
% Org. Matter = 2.6%
P index = 118 ppm
% Fines = 10%
Cost = $36/yard

Observations for Reducing Export of Phosphorus from Bioretention Systems

- To go from exporting phosphorus to controlling phosphorus the engineered soil mix should have a low phosphorus content– less than 100 mg/Kg (FAWB, 2008)
- Low P index soils: between 10 and 30, but lower retards plant growth (Hunt, 2006).
- Postive correlation between organic matter content and P removal – 2% organic matter produced good P removal (Davis, 2005).

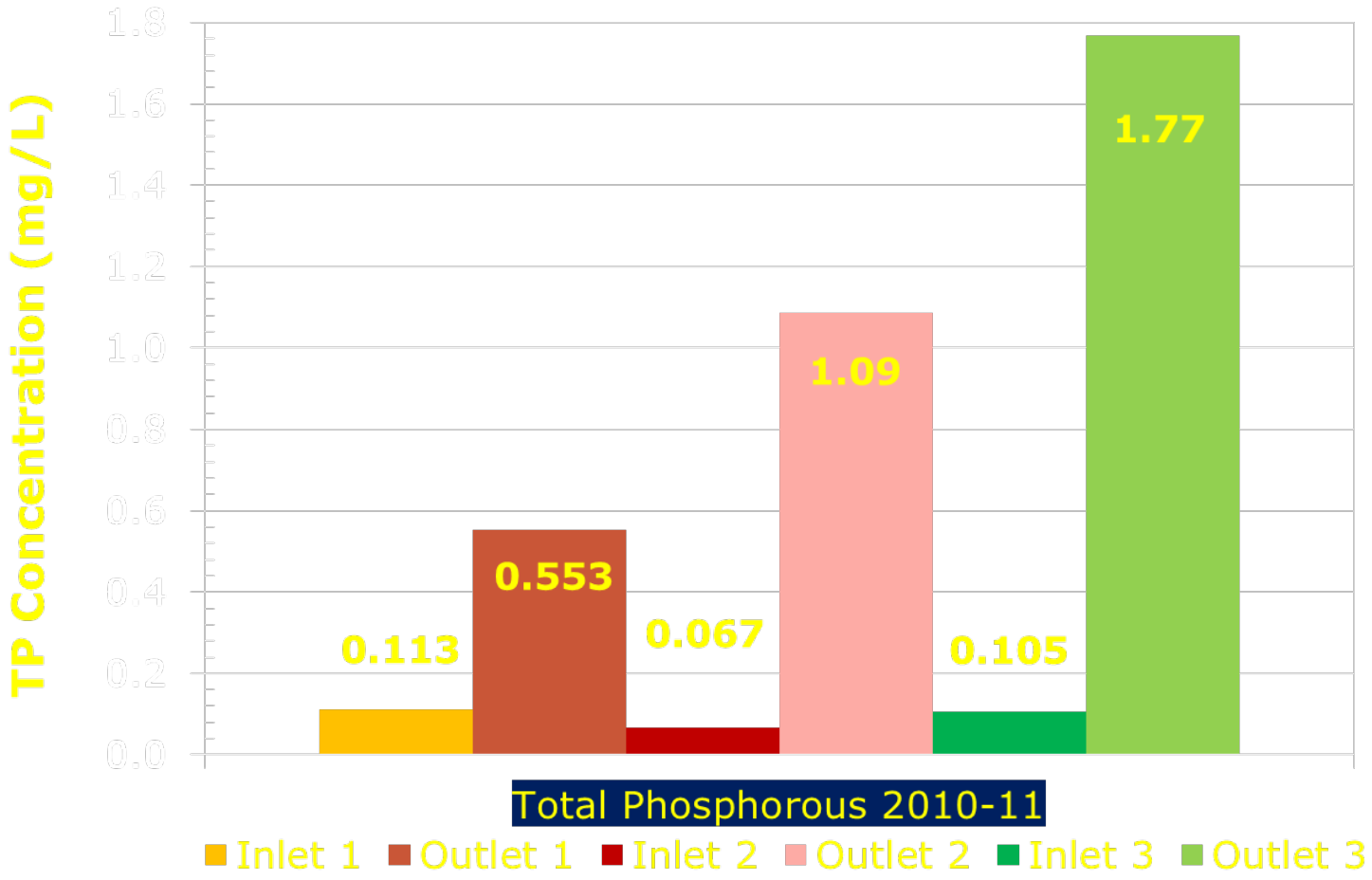
ISCO Sampler & Control Panel

Monitoring Tasks:

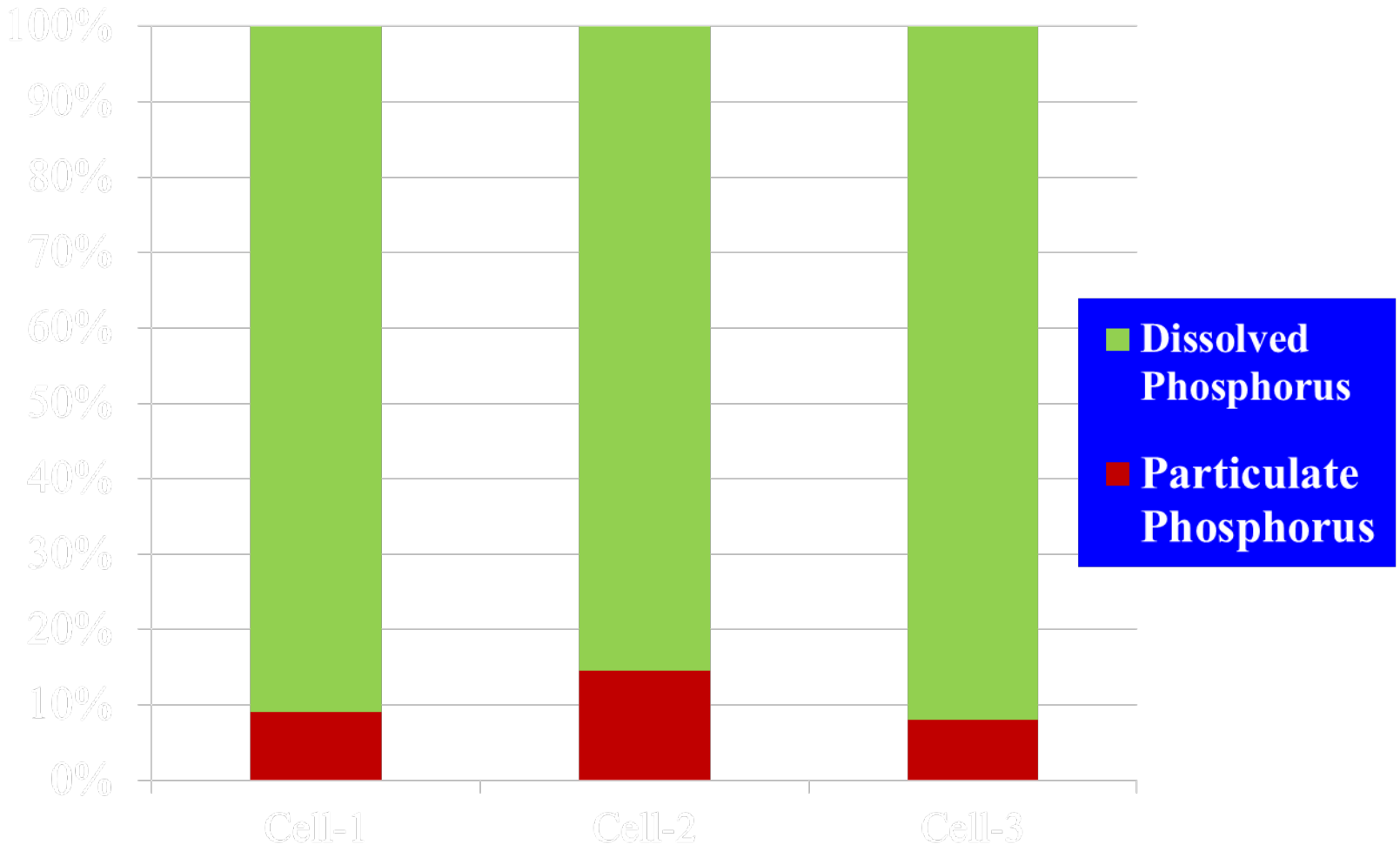
1. **Flow and EMCs inlet**
2. **Flow and EMCs outlet**
3. **Bypass flow**
4. **Soil Moisture**
5. **Weather**
6. **Soil Chemistry**

BIO 3I
30S
INLET
BIO3O
60S
OUTLET
MIRON
5/26/10

Engineered Soil Mix 50% sand/ 50% compost



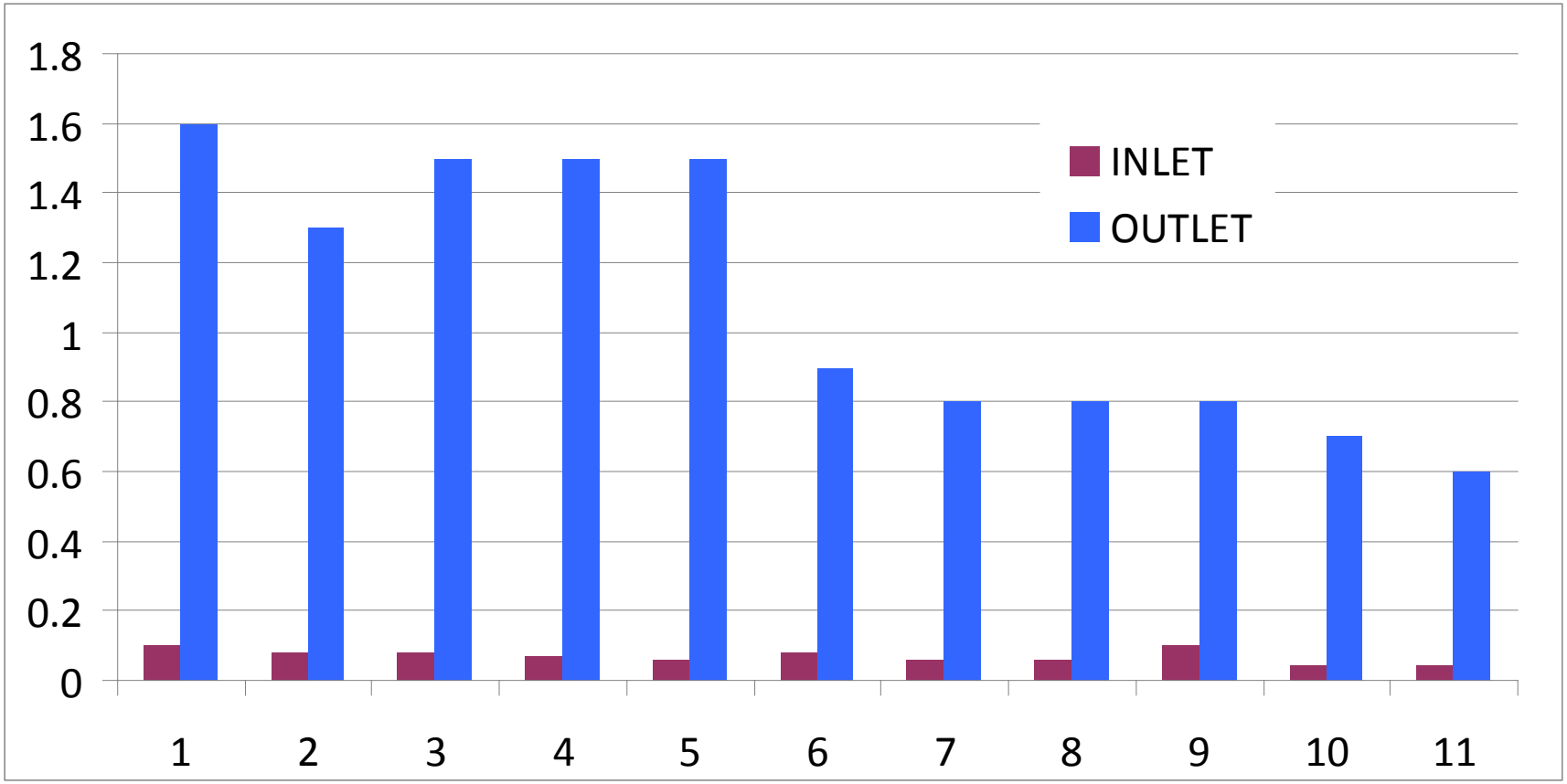
Media-1 Comparing Average Dissolved and Particulate Concentration



Simulating Event with City Water to Determine Mobility of Phosphorus May 2011

Type of Value	2 Foot Depth Media	3 Foot Depth Media
City Water – Outlet TP	0.93	0.98
Event Outlet TP	0.75	1.3

Total Phosphorus Concentrations, mg/l, at the Inlet and Outlet of 2 Foot Depth Media

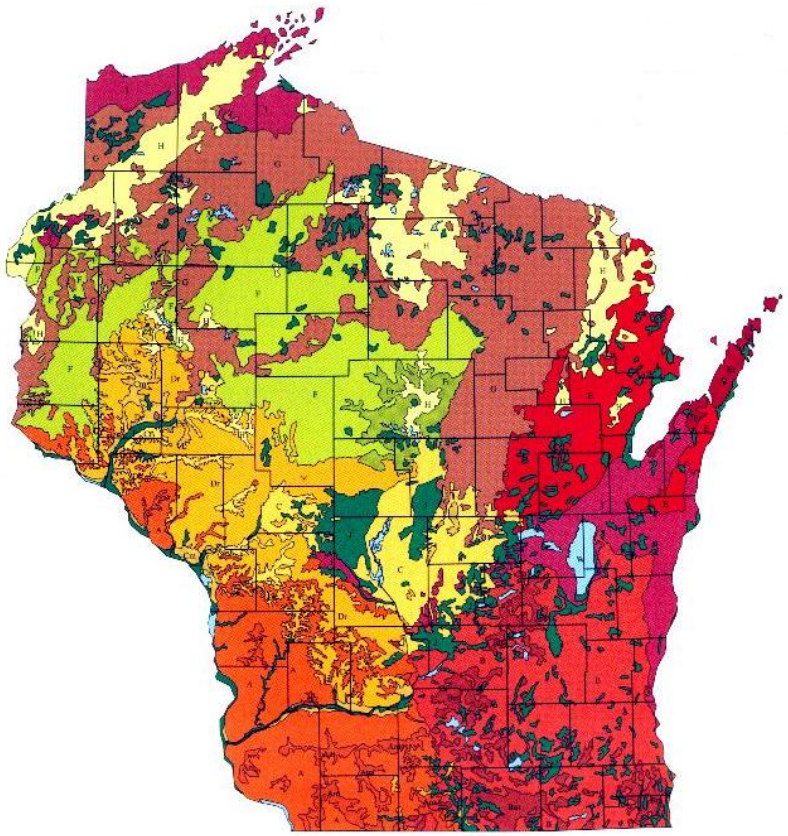


Total Phosphorus Concentration After 2 Years in Media-1 at Different Depths

Type of Sample	TP Concentration, mg/kg
Media-1 before installed	367
2 inches	223
4 to 6 inches	302
18 inches	304
24 inches	212

Media-1 During Installation

Why Are We Concerned About Phosphorus Discharge From Drain Tile?



1. Not much infiltration in parts of state with tight soils.
2. Lower Infiltration After Construction
3. Many places have high bedrock or groundwater table.
4. Installations near sensitive water ways.

Media in 1004:

70 to 85% Sand/15 to 30% Compost

Low Phosphorus Media Being Tested:

1.86% Sand; 11% Peat Moss; 3% SorbtiveMedia

2.87% Sand, 8% fines, 5% Bark

3.Sand (ASTM C33)

4.6” Growth layer with sand underneath

5.75% Sand and 25% Compost

6.Growth layer on top of sand with iron filings

Choices of Additives to Reduce Dissolved P

Spread Sheet to Calculate How Much SorbtiveMedia to Use

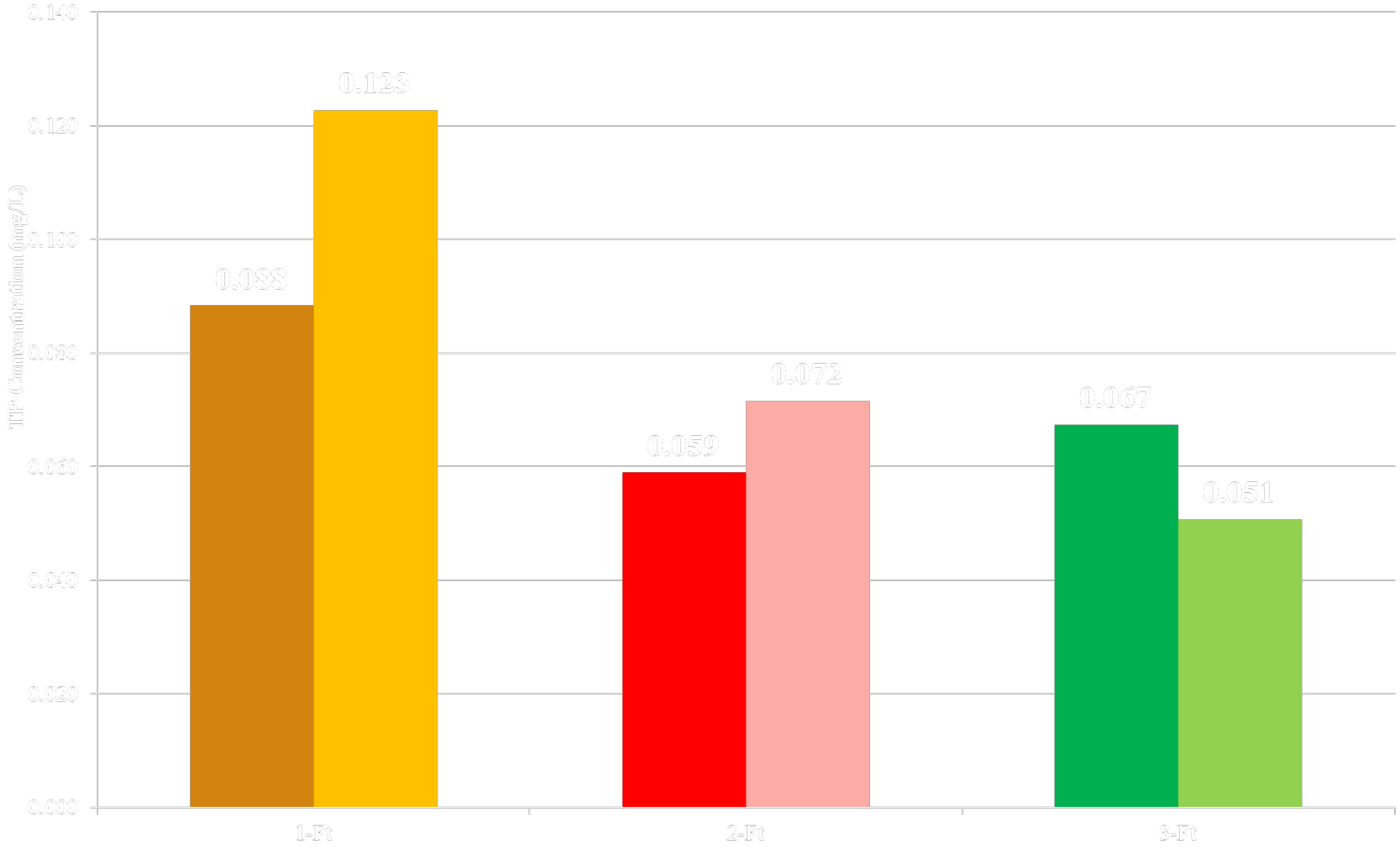
% sorptive media		5.00	%				
P sorption capacity		1.00	%				
P concentration in runoff		0.2	ppm				
basin depth		1.5	ft				
ratio drainage area/basin		20					
Basin area	sorbent	P sorption	area served	total drainage	P load per	Service life	
ft2	mass, lbs	capacity, lbs	acres	per year, gal	year, lbs	expected, yr	
100	131	1.31	0.05	49655	0.08		
200	261	2.61	0.09	99309	0.17		
400	523	5.23	0.18	198618	0.33		
800	1,045	10.45	0.37	397237	0.66		
1600	2,090	20.90	0.73	794473	1.32	15.8	
3200	4,180	41.80	1.47	1588947	2.65		
7200	9,405	94.05	3.31	3575130	5.95		
14800	19,333	193.33	6.80	7348879	12.24		
29600	38,665	386.65	13.59	14697758	24.48		

Replacing Media at Neenah Sites

86% Sand; 11% Peat Moss; 3% Sorbtive Media (Imbrium)

- **Total P =200 mg/kg**
- **P Index = 8.0 ppm**
- **% Org. = 2.5%**
- **% Fines = 7%**
- **Cost = $161/yd.**

Comparing Average Inlet and Outlet Total Phosphorus Concentrations for Sorbtivemedia

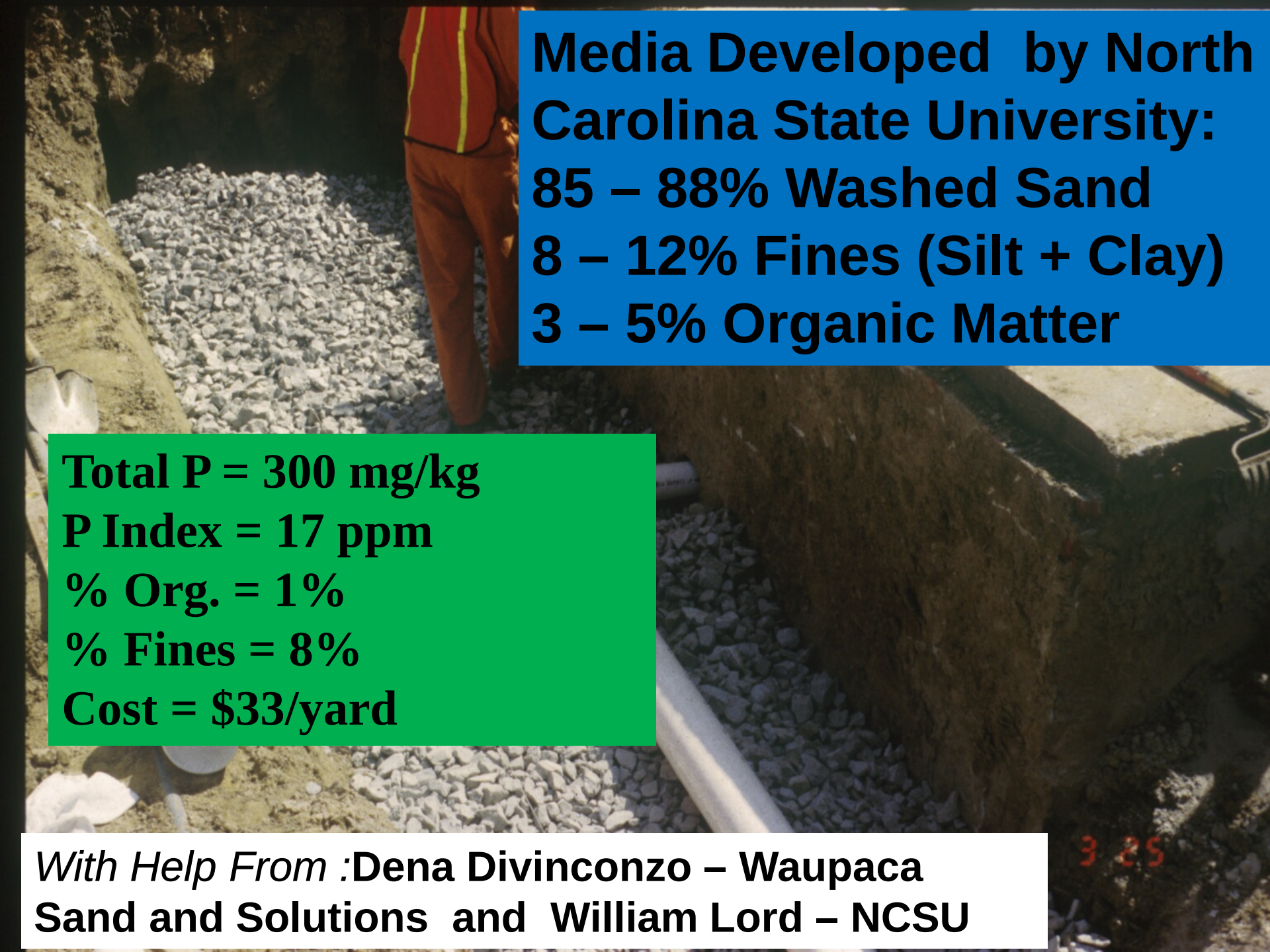


Wilcoxon Paired test sample from sample distribution

Diss. P is ~ 45% of TP

Average Total Phosphorus Concentrations for the Inlet and Outlet of Two Foot Media

	Inlet TP, mg/l	Outlet TP, mg/l
50/50	0.067	1.09
Sorbtivemedia	0.059	0.072



Media Developed by North Carolina State University:
85 – 88% Washed Sand
8 – 12% Fines (Silt + Clay)
3 – 5% Organic Matter

Total P = 300 mg/kg
P Index = 17 ppm
% Org. = 1%
% Fines = 8%
Cost = $33/yard

*With Help From :***Dena Divinconzo – Waupaca Sand and Solutions and William Lord – NCSU**

NCSU mix:
87% Sand; 8% Fines & 5% Pine Bark

Inlet USGS Bioretention – April, 2013

Outlet USGS Bioretention - April, 2013

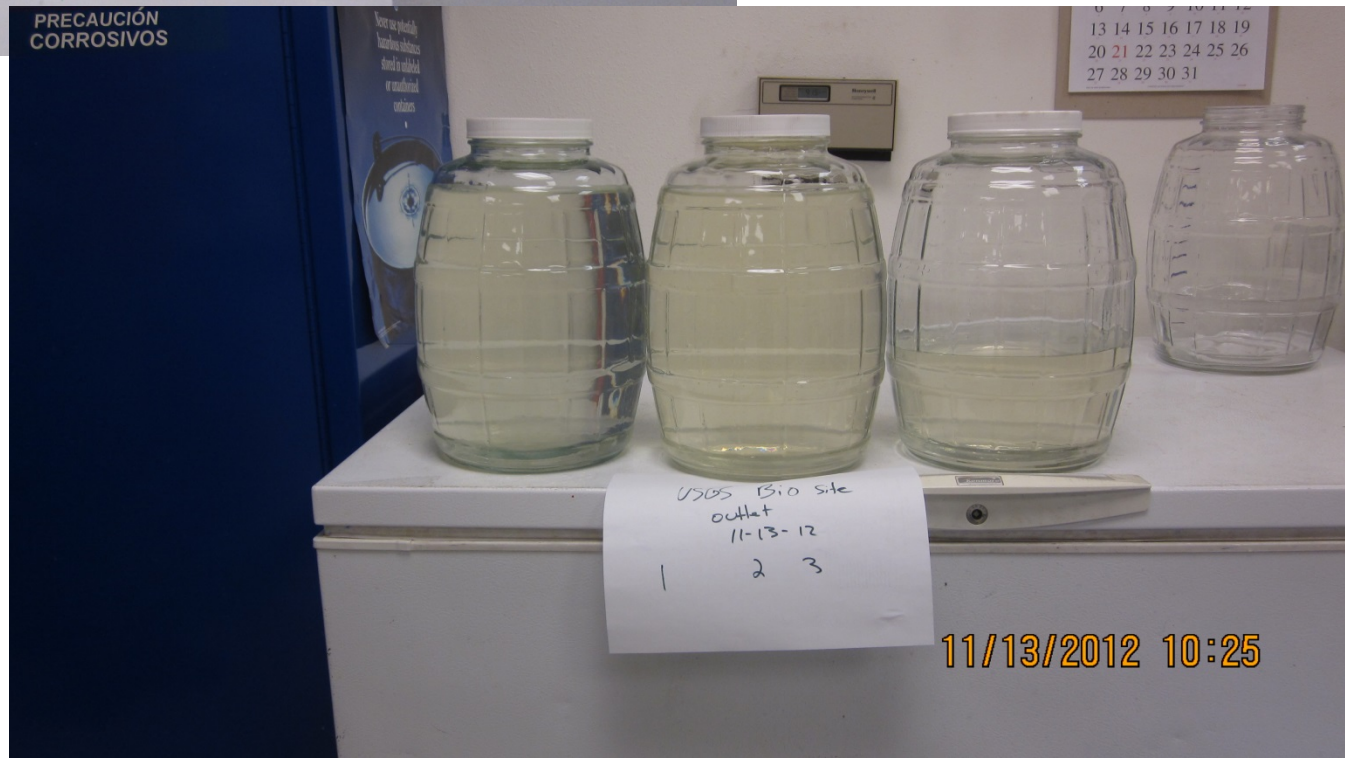
Inlet USGS Bioretention – April 12, 2014

Outlet USGS Bioretention – April 12, 2014

Inlet USGS Bioretention – May 6, 2013

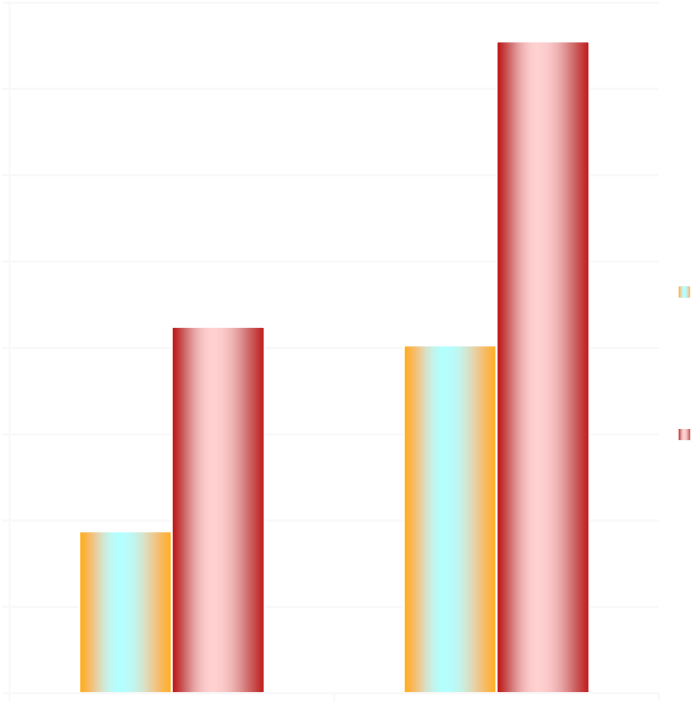
Outlet USGS Bioretention – May 6, 2013

Inlet USGS Bioretention – Nov 13, 2011



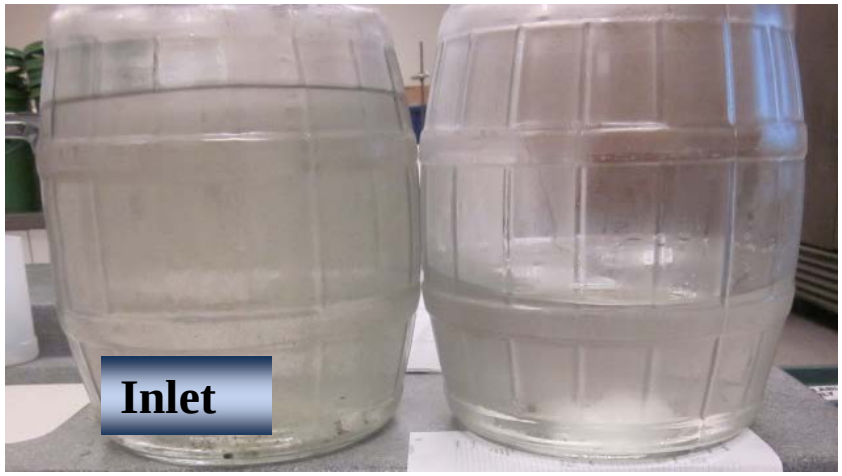
Outlet USGS Bioretention – Nov 13, 2011

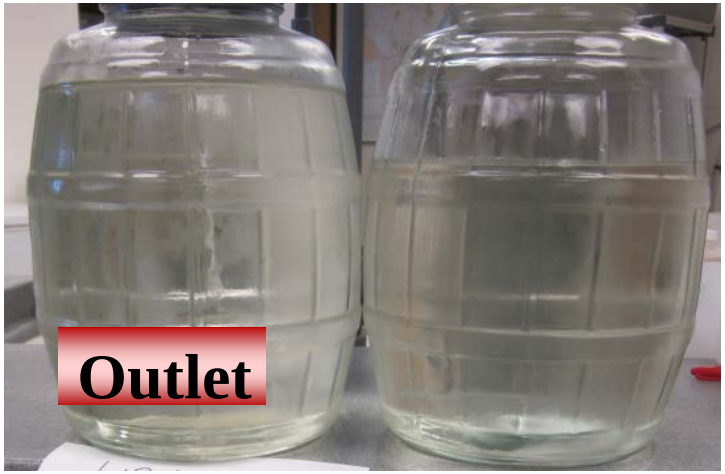
Runoff Event
May 9, 2013

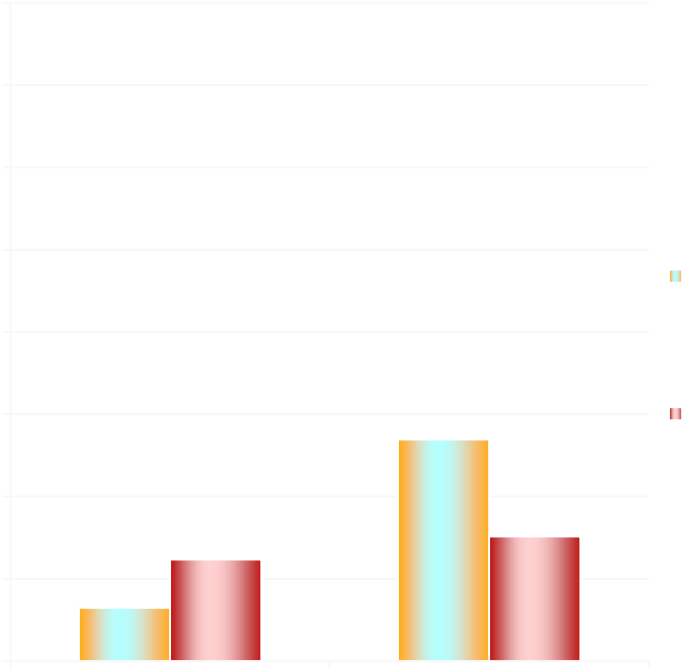


	Percent Dissolved
Inlet	47%
Outlet	56%

Runoff Event
May 28, 2013

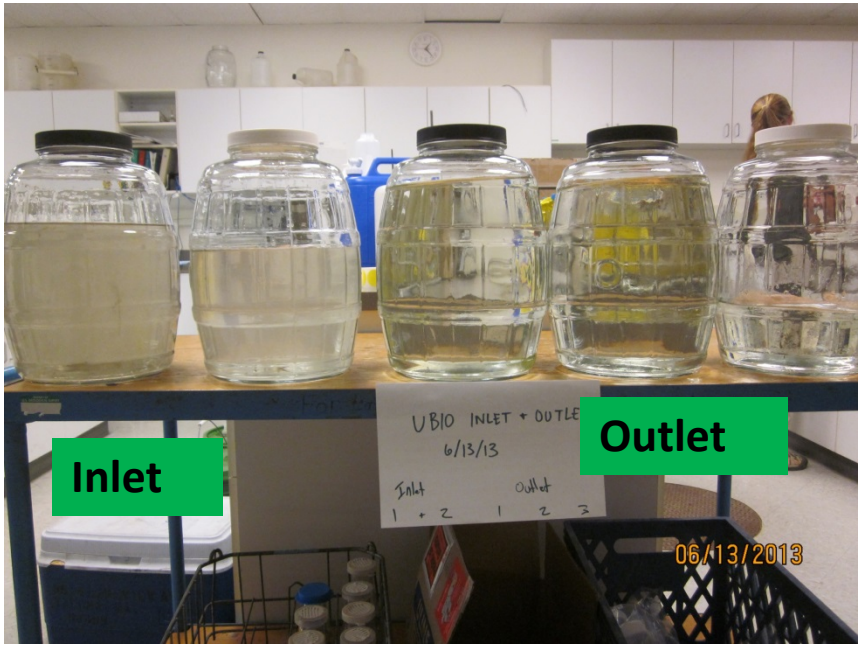


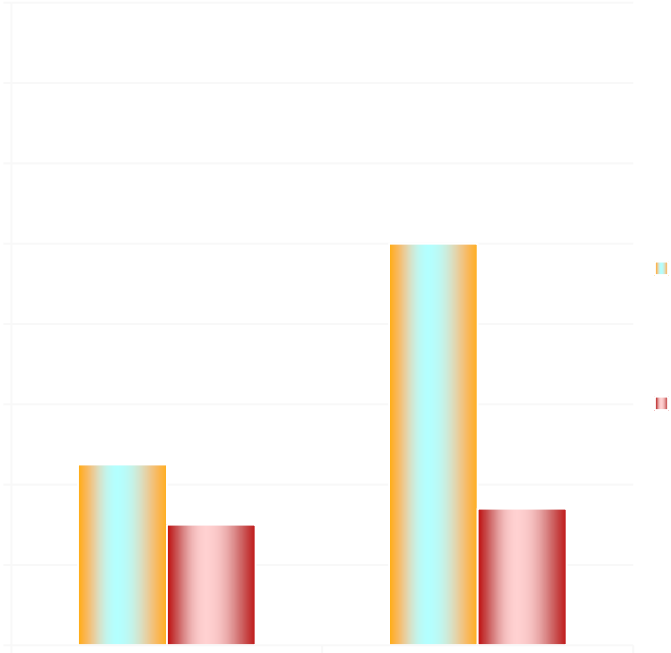




	Percent Dissolved
Inlet	24%
Outlet	82%

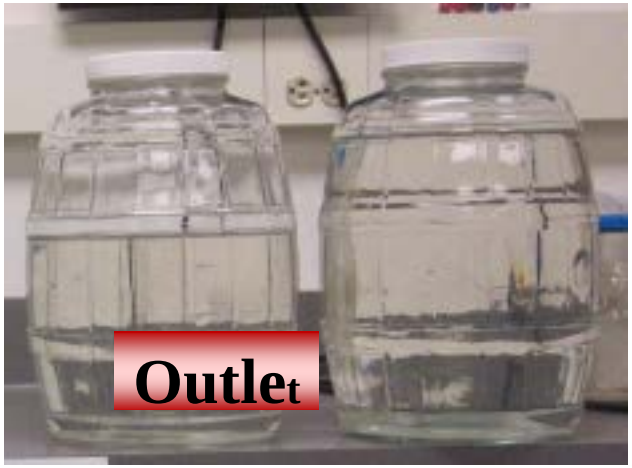
Runoff Event
June 25, 2012

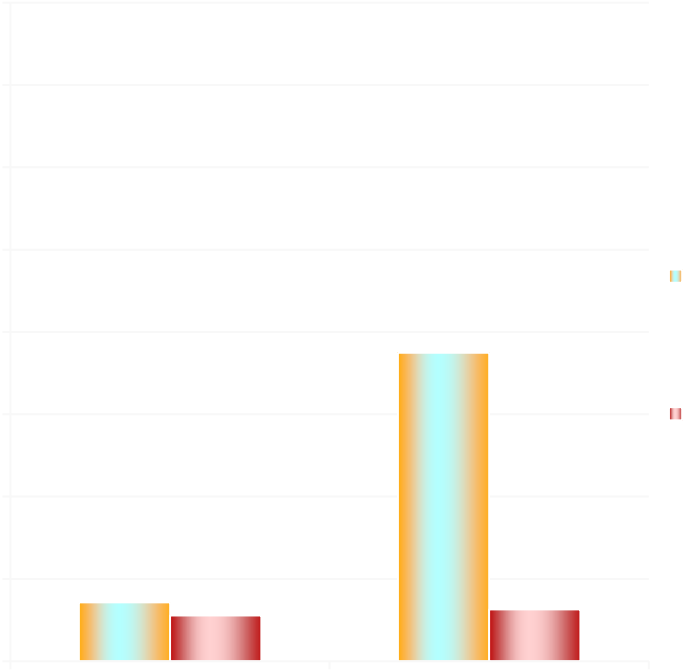




	Percent Dissolved
Inlet	45%
Outlet	88%

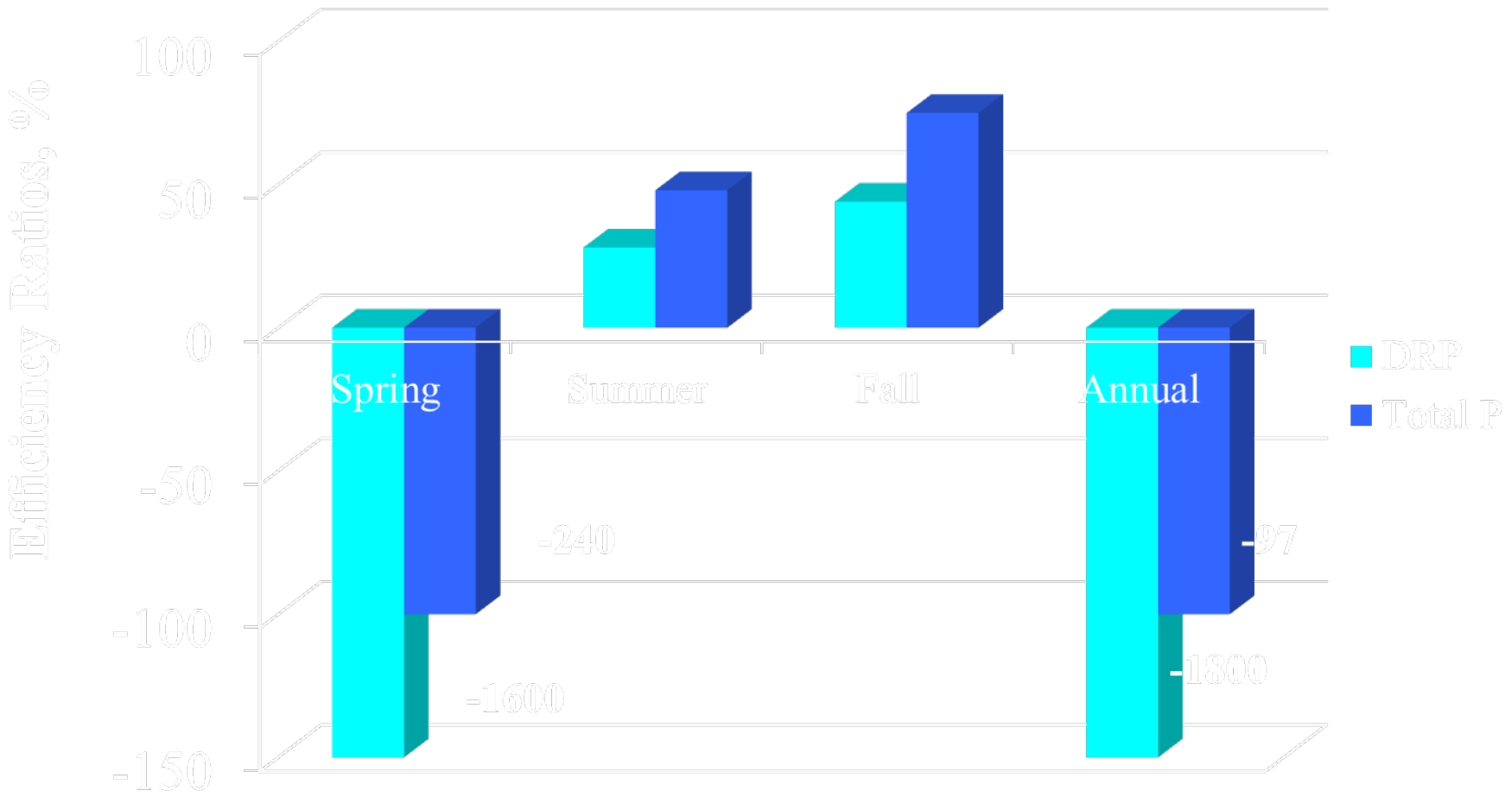
Runoff Event
Nov 16, 2013

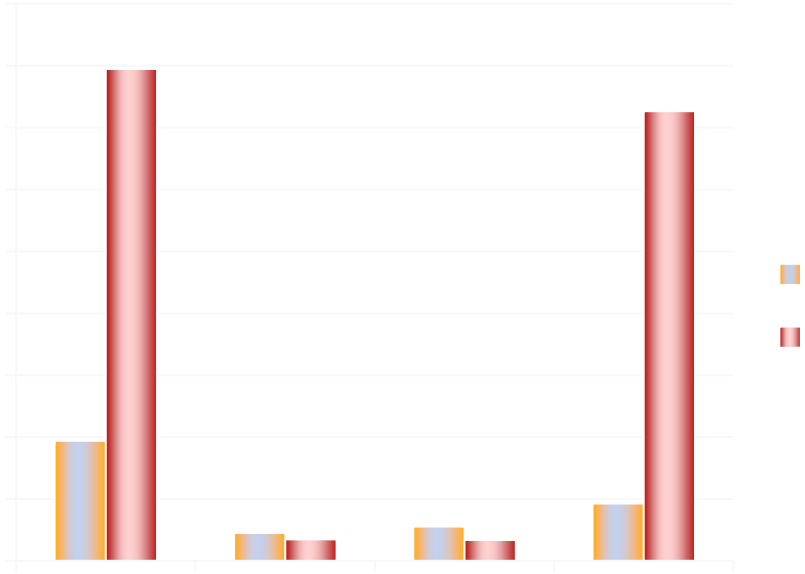




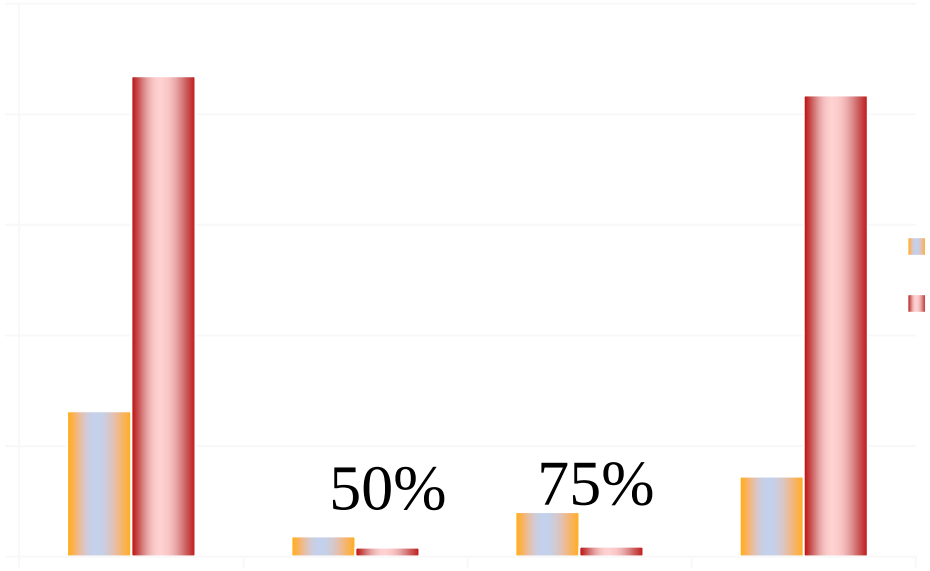
	Percent Dissolved
Inlet	19%
Outlet	88%

Dissolved P and Total P Reductions Expressed as Efficiency Ratios, %





Phosphorus Loads at USGS Bioretention - Sampled Events June 2012 - May 2013



Average Total Phosphorus Concentrations for the Inlet and Outlet of Three Medias

Media Type	**Three Foot Media**	
	Inlet TP, mg/l	Outlet TP, mg/l
50/50	0.105	1.77
Sorbtivemedia	0.067	0.051
NCSU	0.119	0.235

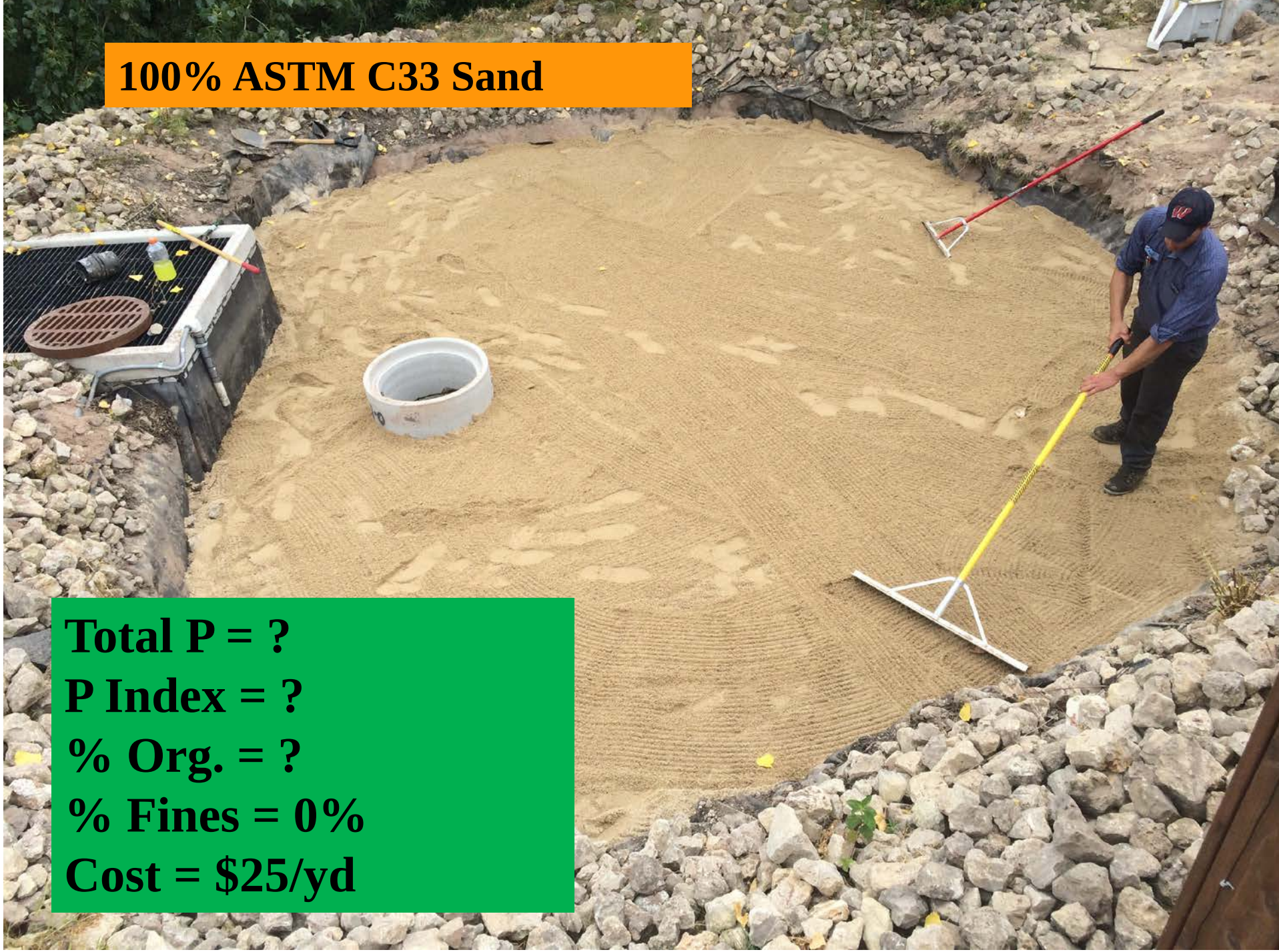
Presented Liaison Group, County, and City Choices For Next Media

1. **State Standard 1004 – 75% Sand and 25% Compost.**
2. **A 6 inch Growth Layer (75% Sand and 25% Compost) on Top of 18 inches of Sand**
3. **100% Sand**

TSS - 78 75 87 %

TP - 27 59 61 %

Austin Surface Sand Filter – 18 to 24 inches Thick


100% ASTM C33 Sand
Total P = ?
P Index = ?
% Org. = ?
% Fines = 0%
Cost = $25/yd

Waukesha County Hwy VV

Two Bioretention Cells:

1. State Standard -75% sand 25% compost
2. 6 " Growth Layer on top of 18" of Sand

Summary of Results for Testing Engineered Soil Mixes

Type of Media	P Index, ppm	Annual TP Load Increase	Support Plant Growth	Cost, $/yard	Concerns
Sand, Compost, and Soil	?	Yes	Yes	36	Clogs
50/50	118	Yes	Yes	36	P Source
NCSU	17	Yes	Yes	33	SAR
1004	?	Yes	Yes	36	P Source
Sorbtive Media	8	No	Yes	161	Cost
100% Sand	?	?	?	25	?
Growth Layer	?	?	?	30	?

Bioretention Engineered Soil Mix – Technical Standard 1004

Jeremy Balousek

What to do in the mean time

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Questions?