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Optimization of Bioretention Soil Mix for Nutrient Removal

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LID Research and Innovation Symposium

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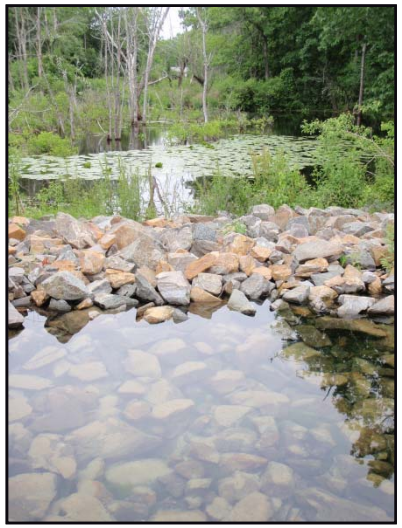
UNH Stormwater Center, Environmental Research Group,
Department of Civil Engineering
University of New Hampshire



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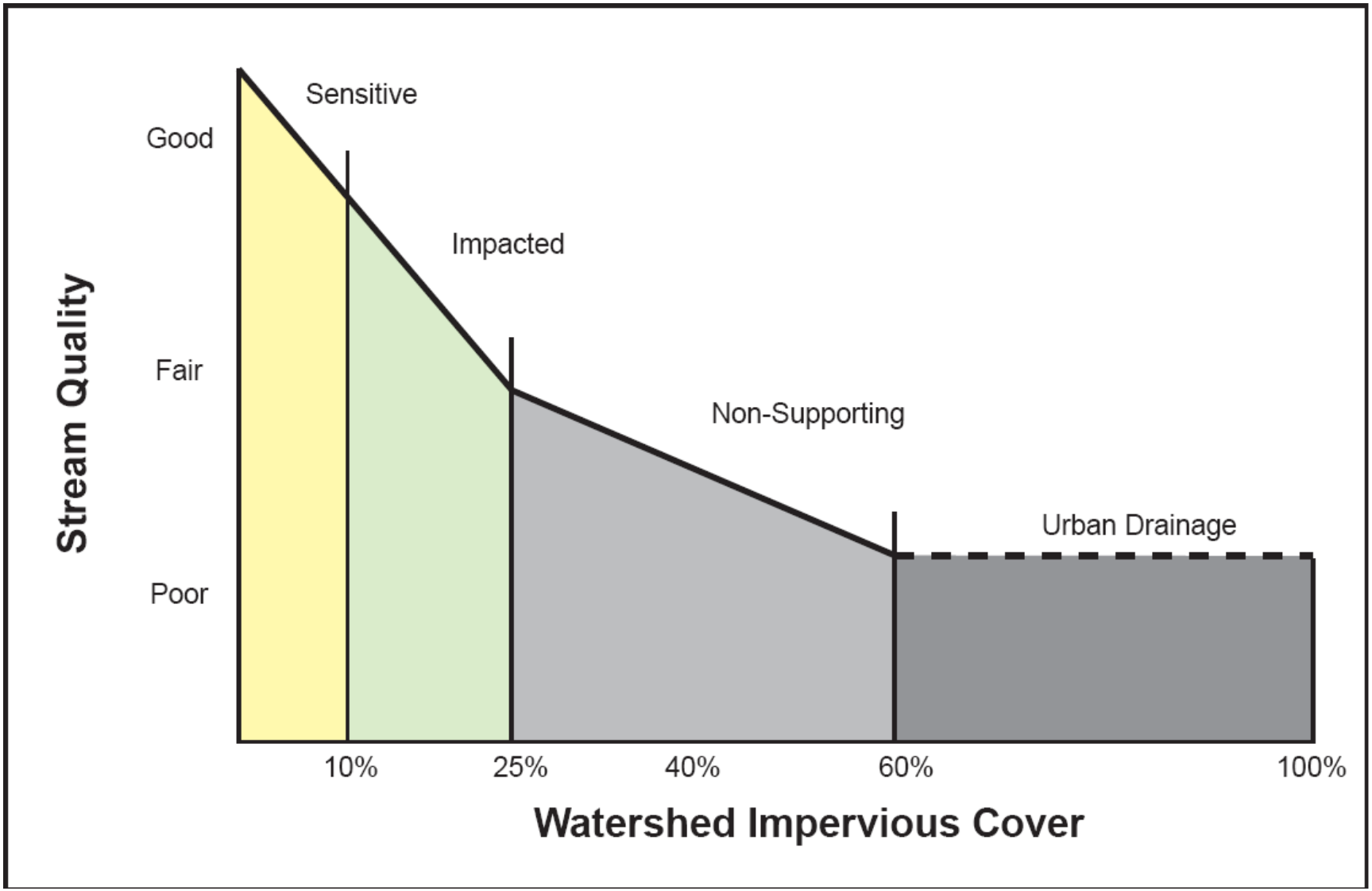
Funders:
Stantec
EPA Region 1

Part of the Problem – Point Source Pollution

SMP97-11/1-CLEVELAND,O.:Firemen stand on bridge over Cuyahoga River to play water on tug Arizona as fire,started in an oil slick on the river,swept docks at the Great Lakes Towing Co.,here today.The blaze destroyed three tugs,three building and the ship repair yards.Damage was not estimated. UNITED PRESS TELEPHOTO rw

Impact of Impervious Cover



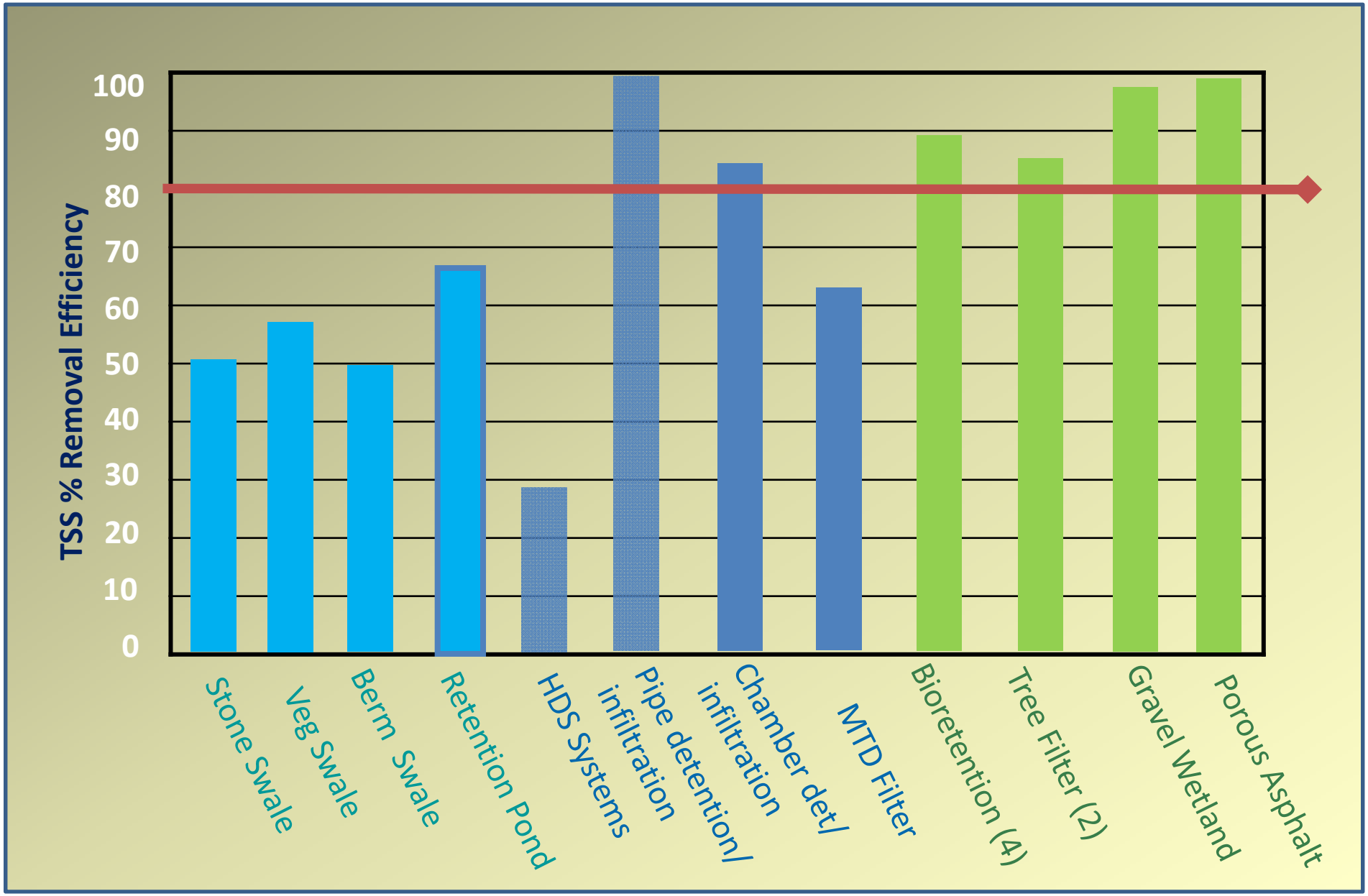
LID in 2006


Washington
Montana
North Dakota
Minnesota
Wisconsin
Michigan
New Brunswick
Nova Scotia
Oregon
Idaho
Wyoming
South Dakota
Nebraska
Iowa
Illinois
Ohio
Pennsylvania
New York
Vermont
New Hampshire
Massachusetts
Rhode Island
Connecticut
New Jersey
Delaware
Maryland
District of Columbia
Nevada
Utah
Colorado
United States
Kansas
Missouri
Indiana
West Virginia
California
Oklahoma
Arkansas
Tennessee
Mississippi
Alabama
Georgia
Louisiana
Texas
New Mexico
Arizona
Florida
Gulf of California
Gulf of Mexico
Map data ©2012 Google,

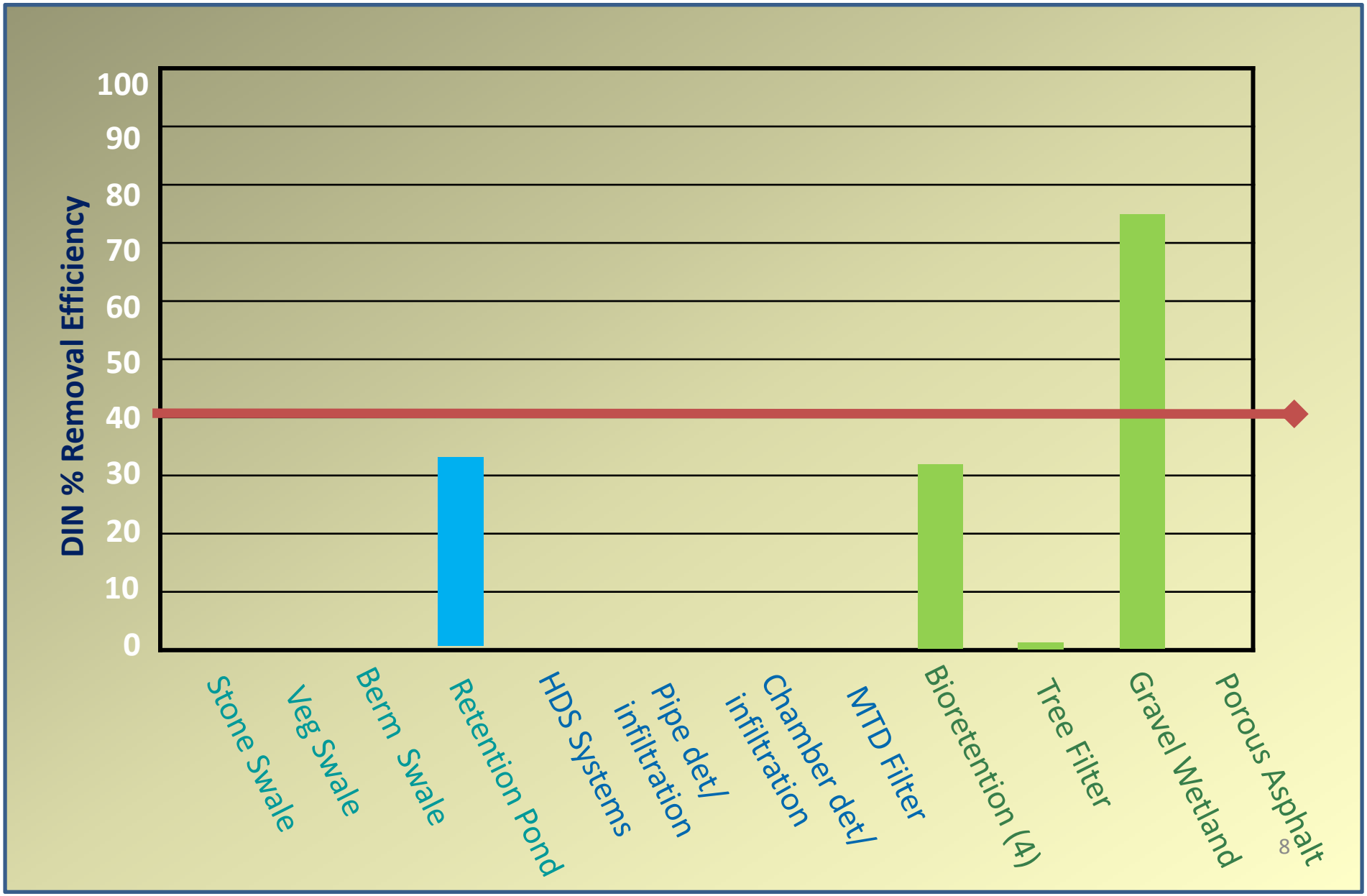
LID in 2013


Montana
North Dakota
Minn
Wisconsin
Michigan
South Dakota
Wyoming
Idaho
Oregon
Nebraska
Iowa
Ohio
Indiana
Pennsylv
New Y
Vermont
New Hampshire
Massachusetts
Rhode Island
Connecticut
New Jersey
Delaware
Maryland
District of Columbia
Nevada
Utah
Colorado
Kansas
West
California
Oklahoma
Arkansas
Mississippi
New Mexico
Texas
Georgia
Louisiana
Florida
Gulf of California
Gulf of Mexico
Map data ©2012 Goog

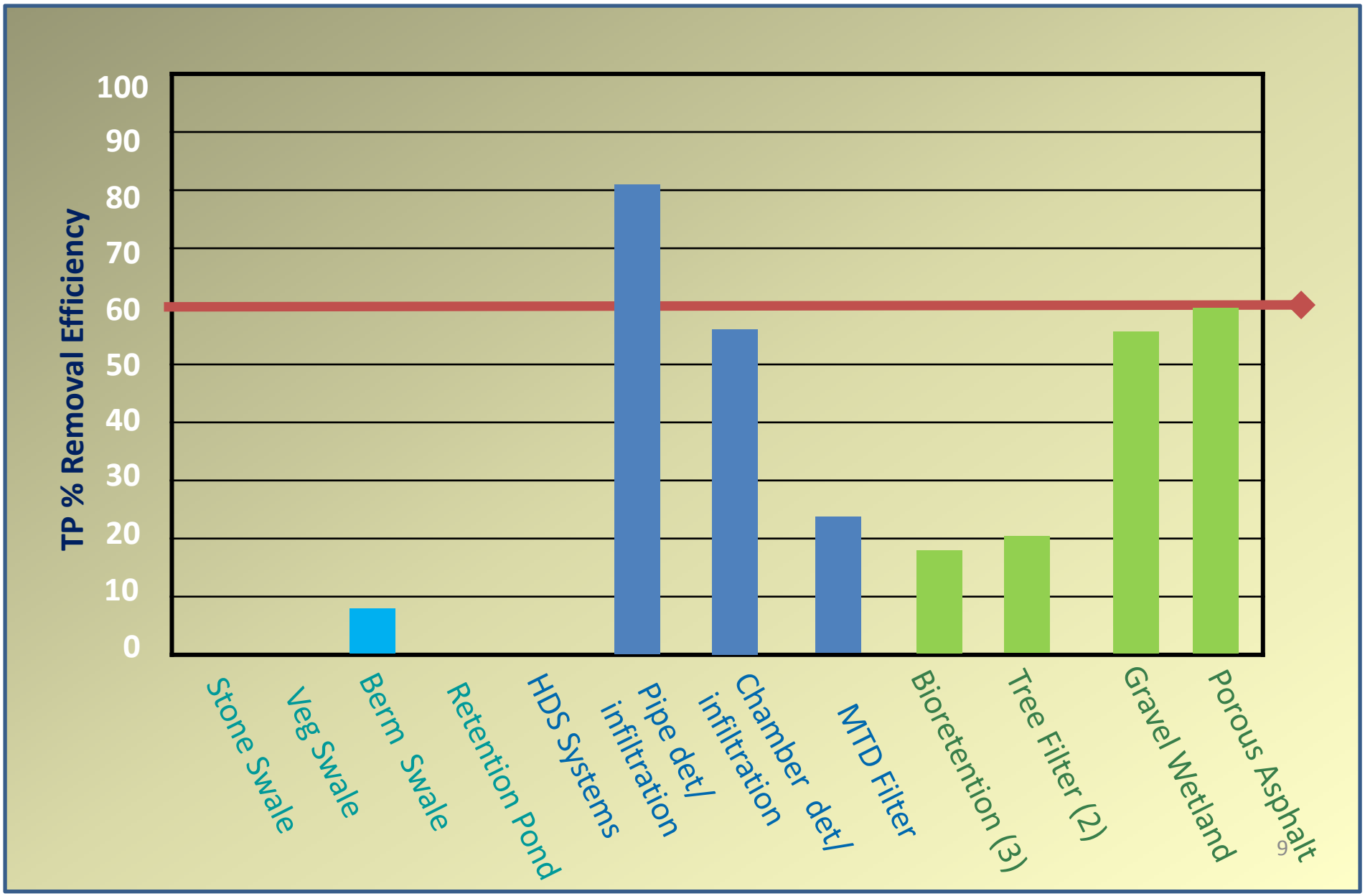
TSS Removal Efficiencies



DIN Removal Efficiencies



TP Removal Efficiencies

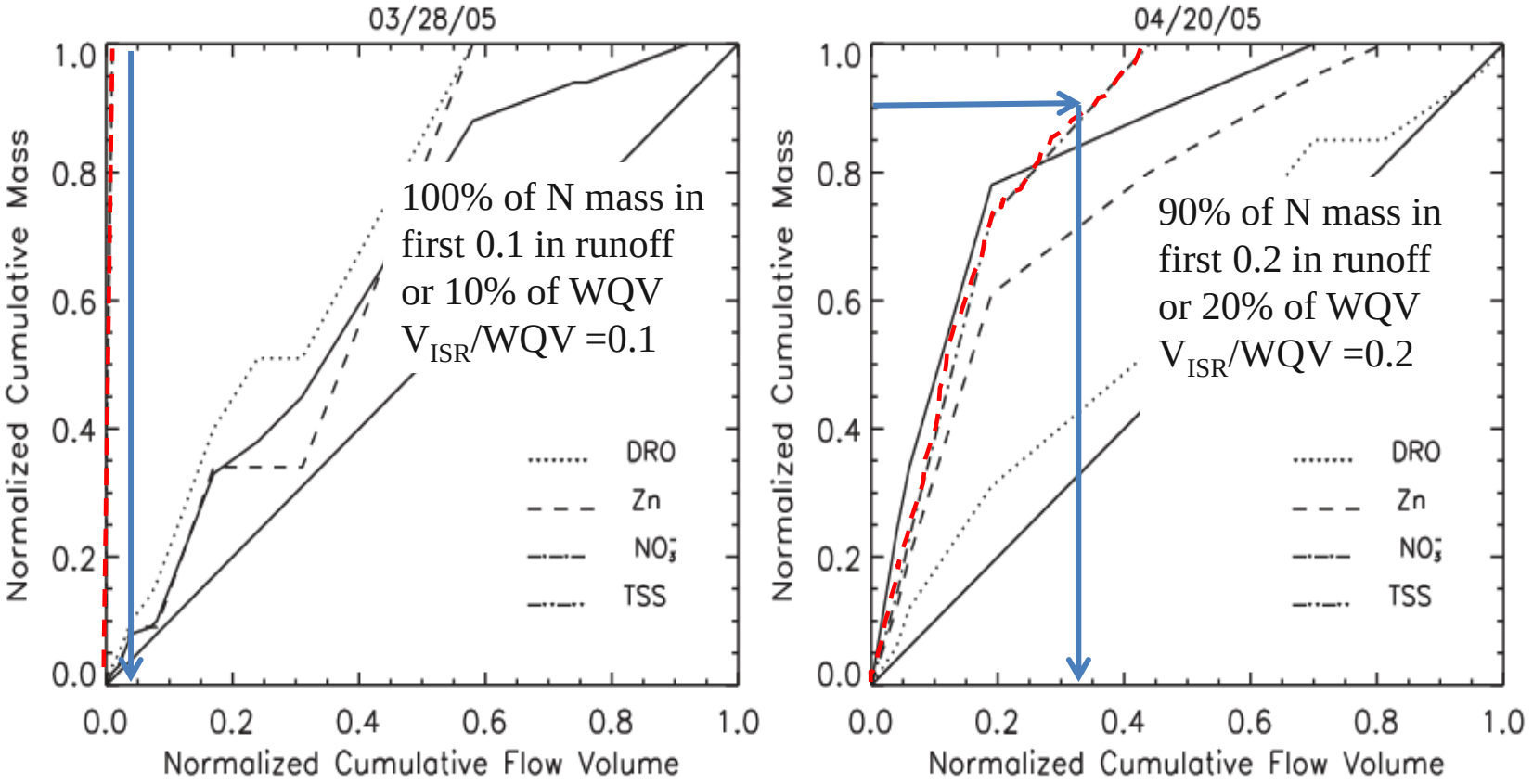


Unit Operations & Processes (UOPs) in the Gravel Wetland

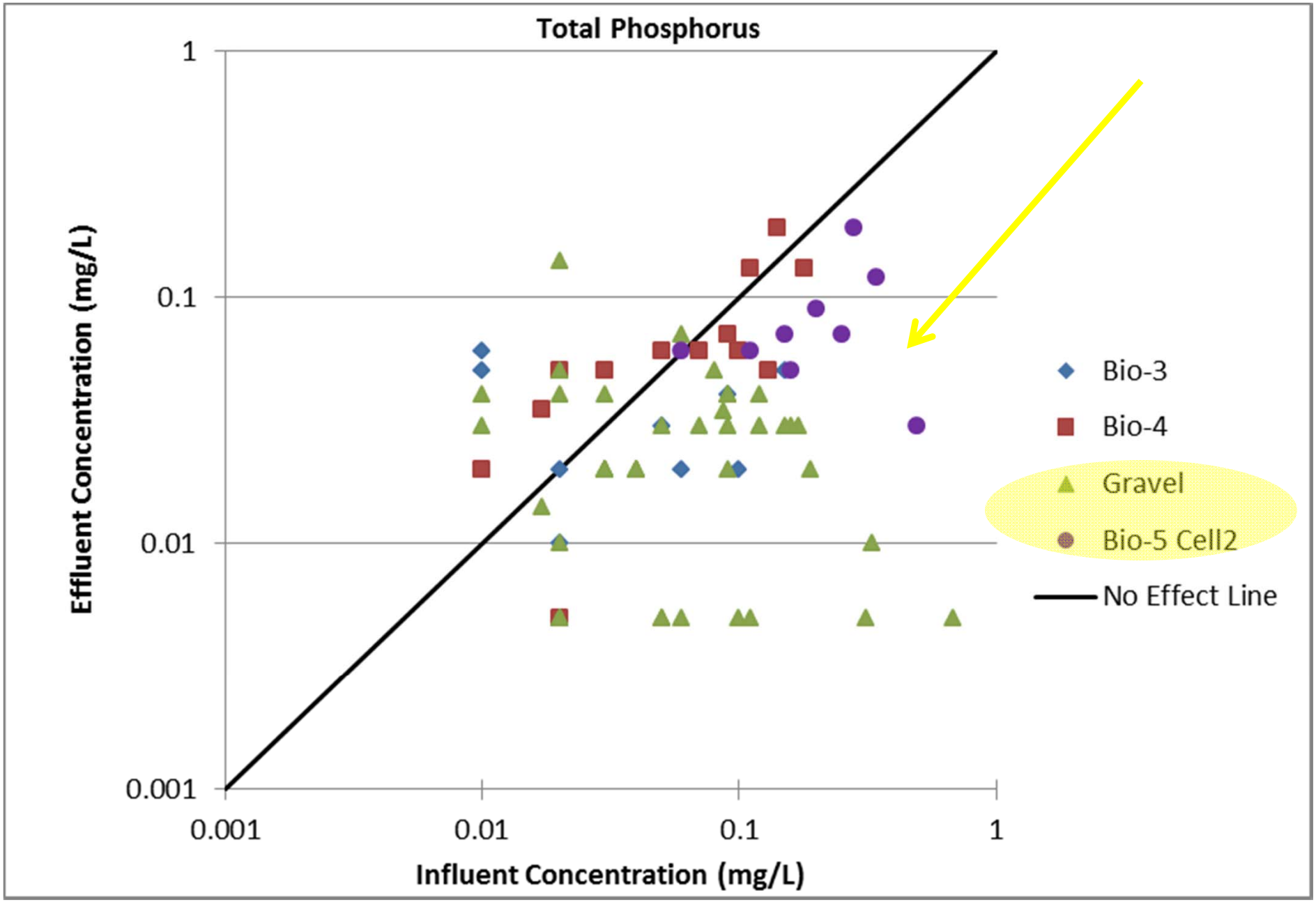
- Physical Operations
- Biological Processes
- Chemical Processes
- Hydrologic Operations

What we know

- Nitrogen is controlled through vegetative uptake and anaerobically through microbial denitrification
- Phosphorus is controlled through veg uptake and sorbed to electrostatically charged soil particles (clay/humus/orgnaic matter)



Mass loading for DRO, Zn, NO3, TSS as a function of normalized storm volume for two storms: (a) a large 2.3 in rainfall over 1685 minutes; (b) a smaller 0.6 in storm depth over 490 minute. DRO=diesel range organics, Zn= zinc, NO3= nitrate, TSS= total suspended solids


Total Phosphorus
1
0.1
0.01
0.001
Effluent Concentration (mg/L)
0.001
0.01
0.1
1
Influent Concentration (mg/L)
Bio-3
Bio-4
Gravel
Bio-5 Cell2
No Effect Line

Experimental Design

Phase 1: Test Drain time and ISR:WQV Ratio

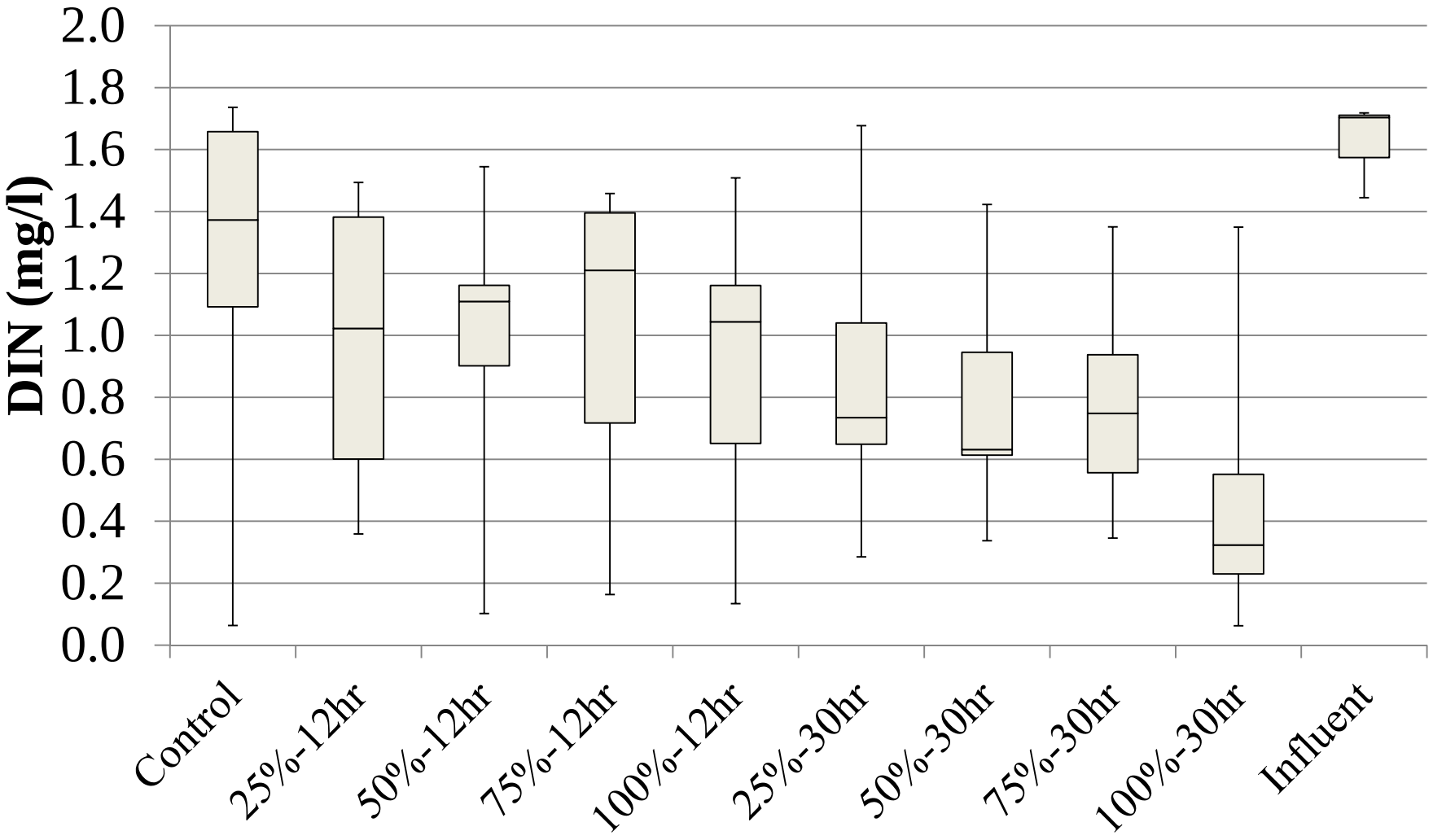
Phase 2: Test bioretention soil mix and four different soil amendments

Phase 3: optimize the ratio of loam to sand for P removal, as well as to further optimize the soil to soil amendment ratio for top mixes (Fe_2 and WTR)

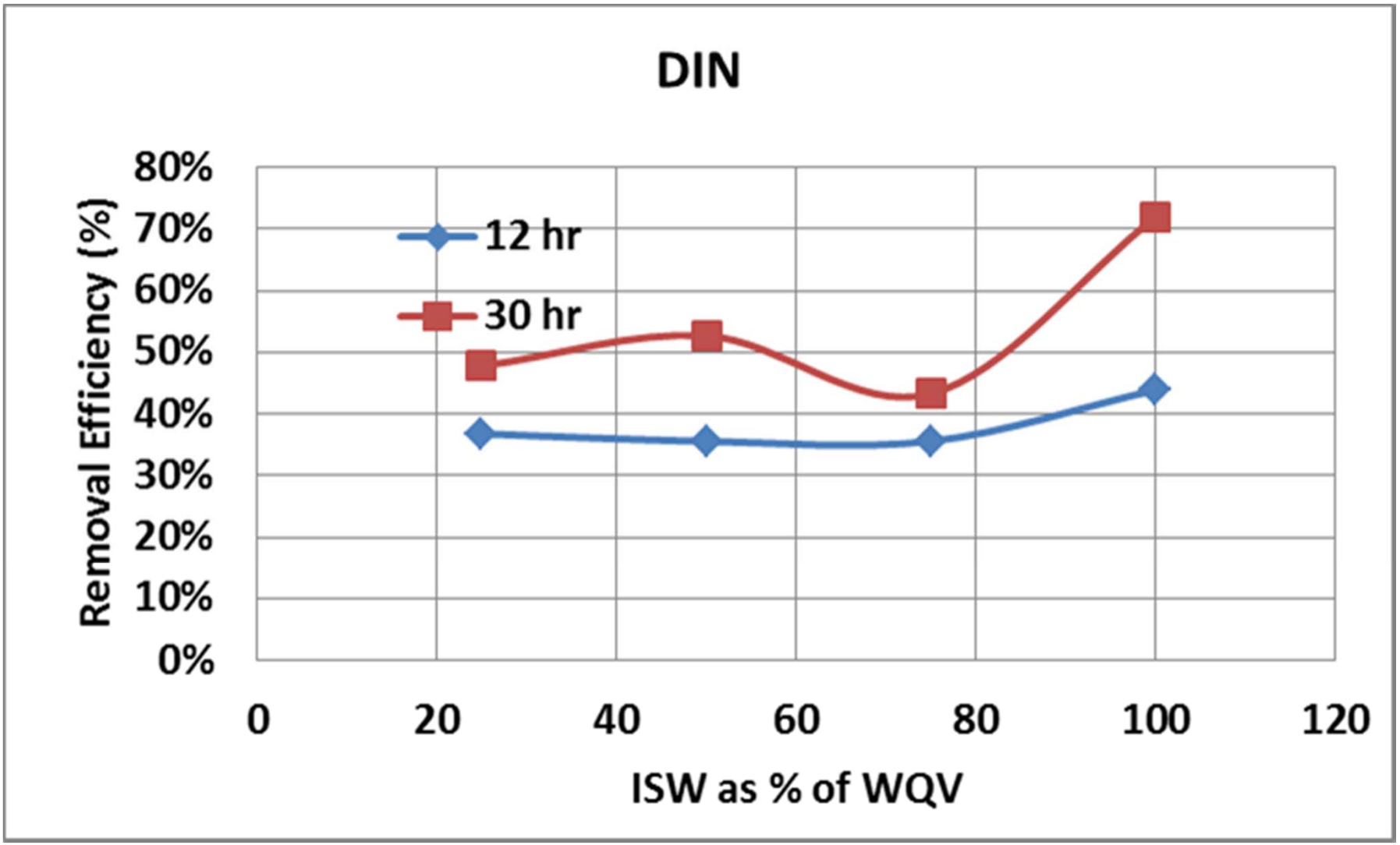
Phase 1

Column #	Soil Mix and saturation zone size	Notes
T1-N0	UNHSC BSM with no saturation zone (control)	• Drainage to filter ratio 80:1 • Soil depth in columns: 24” • 12 hour drain time • Soil tested: UNHSC mix
T1-N1	UNHSC BSM with 25% WQV	
T1-N2	UNHSC BSM with 50% WQV	
T1-N3	UNHSC BSM with 75% WQV	
T1-N4	UNHSC BSM with 100% WQV	
T1-N5	UNHSC BSM with 25% WQV	• Drainage to filter ratio 80:1 • Soil depth in columns: 24” • 30 hour drain time • Soil tested: UNHSC mix
T1-N6	UNHSC BSM with 50% WQV	
T1-N7	UNHSC BSM with 75% WQV	
T1-N8	UNHSC BSM with 100% WQV	

Nitrogen Results



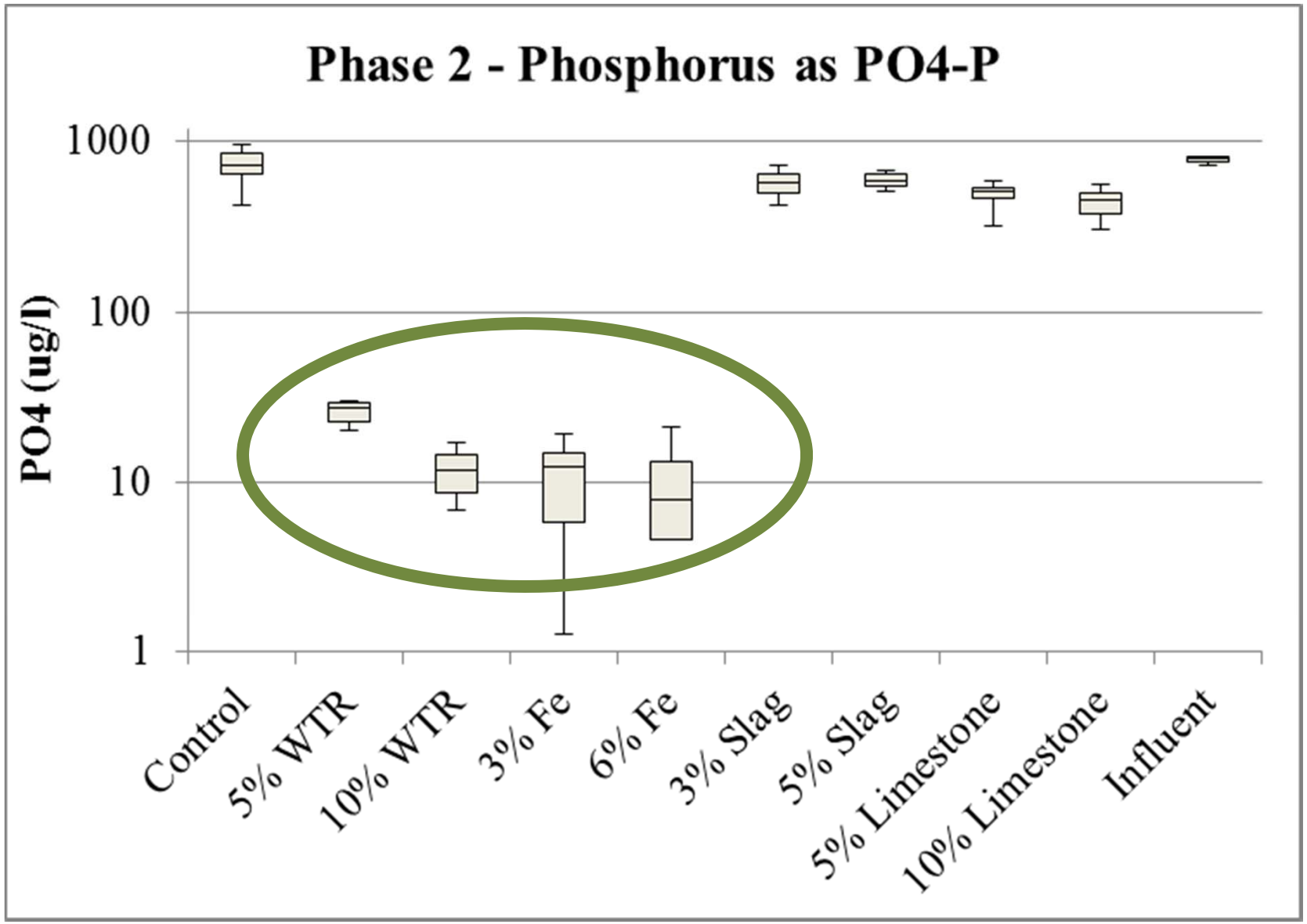
Nitrogen Results

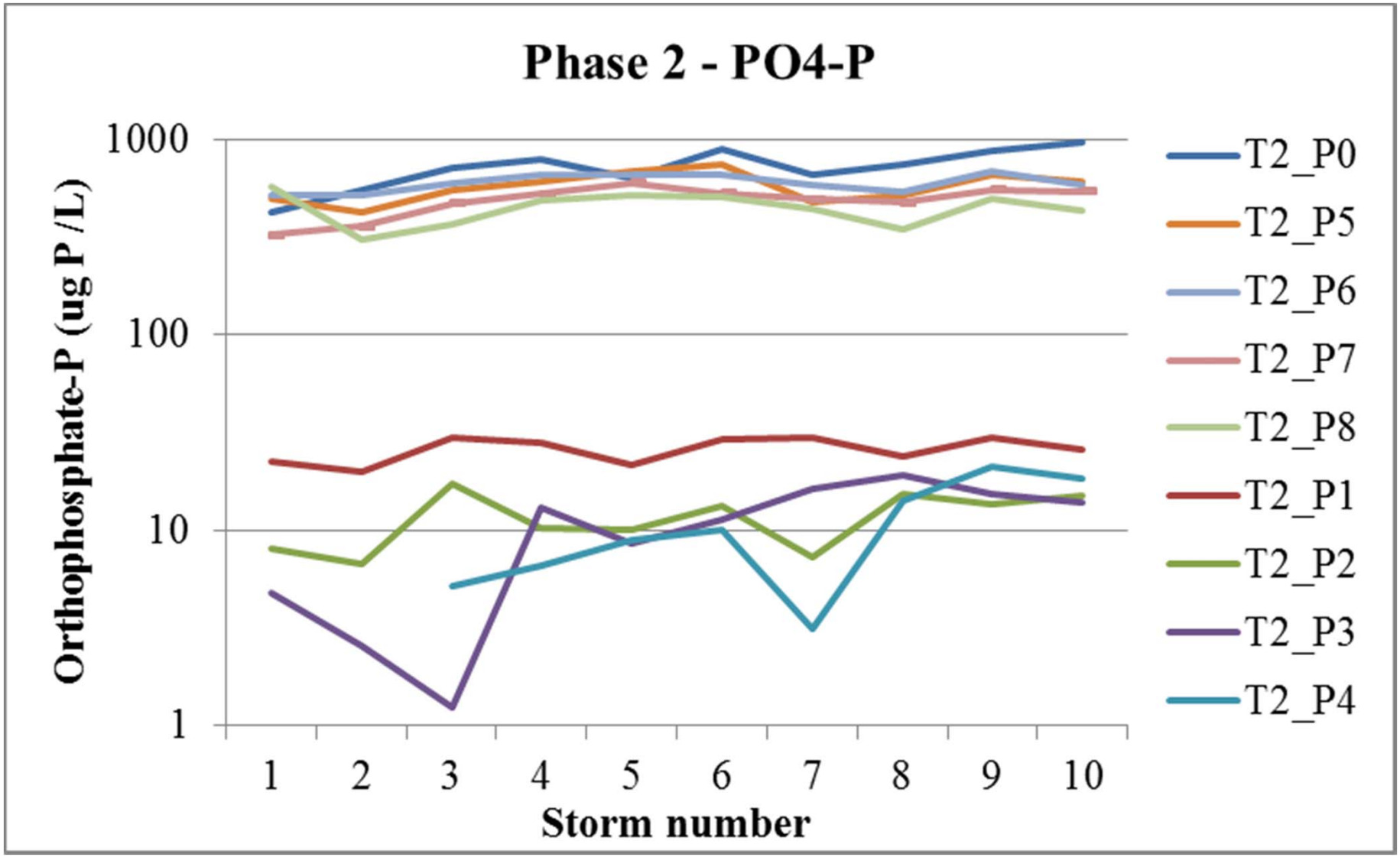


Phase 2: Phosphorus

Column #	Soil Mix	Notes
T2-P0	UNHSC BSM (control)	• Drainage to filter ratio 80:1 • Soil depth in columns: 24” • 24 hour drain time • Soil tested: UNHSC mix
T2-P1	UNHSC 95% BSM + 5% WTR	
T2-P2	UNHSC 90% BSM + 10% WTR	
T2-P3	UNHSC 97% BSM+3% Fe_2	
T2-P4	UNHSC 94% BSM+6% Fe_2	
T2-P5	UNHSC 97% BSM+3% Slag	
T2-P6	UNHSC 95% BSM+5% Slag	
T2-P7	UNHSC 95% BSM +5% Limestone	
T2-P8	UNHSC 90% BSM +10% Limestone	

Phosphorus Results

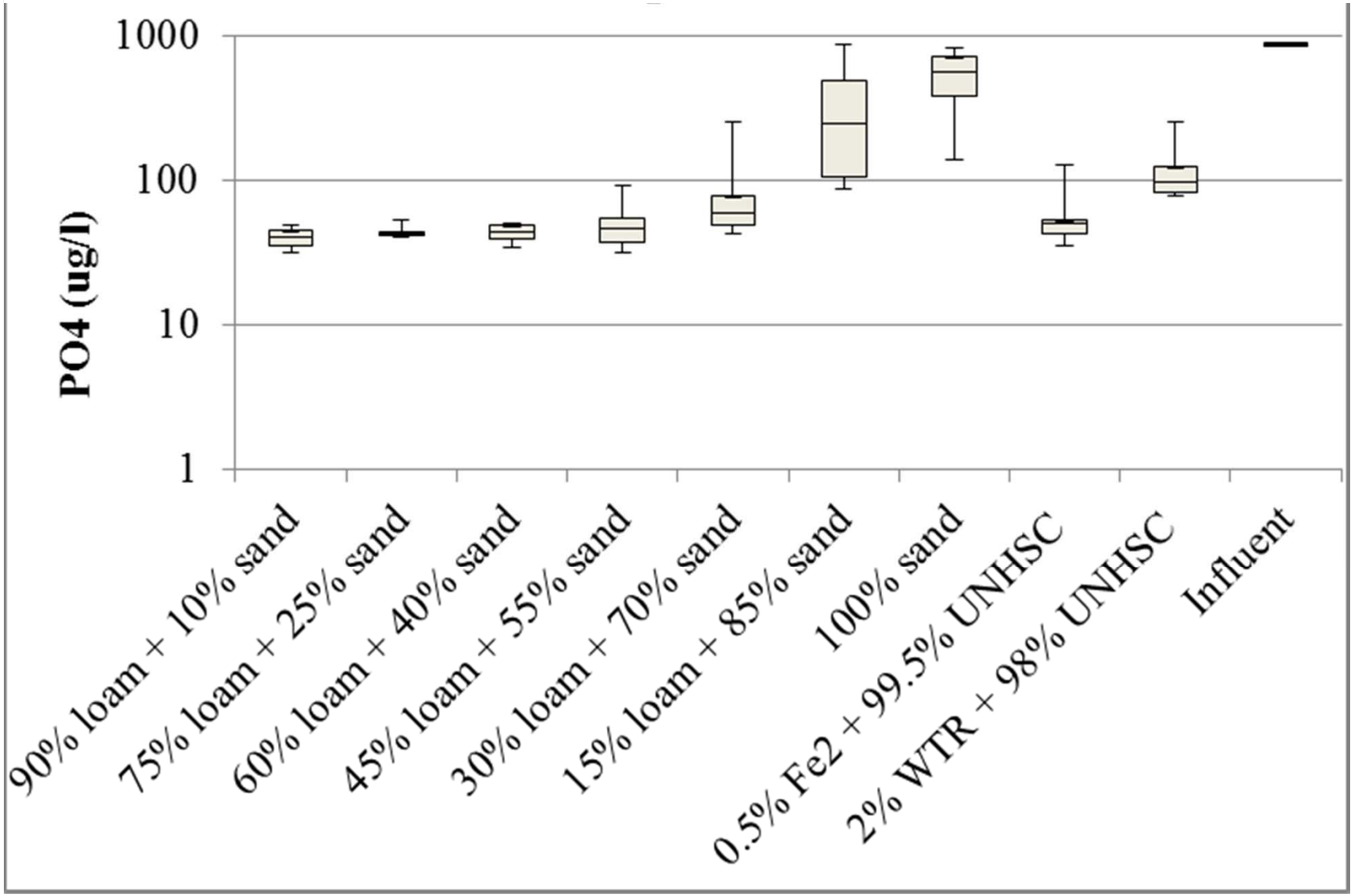


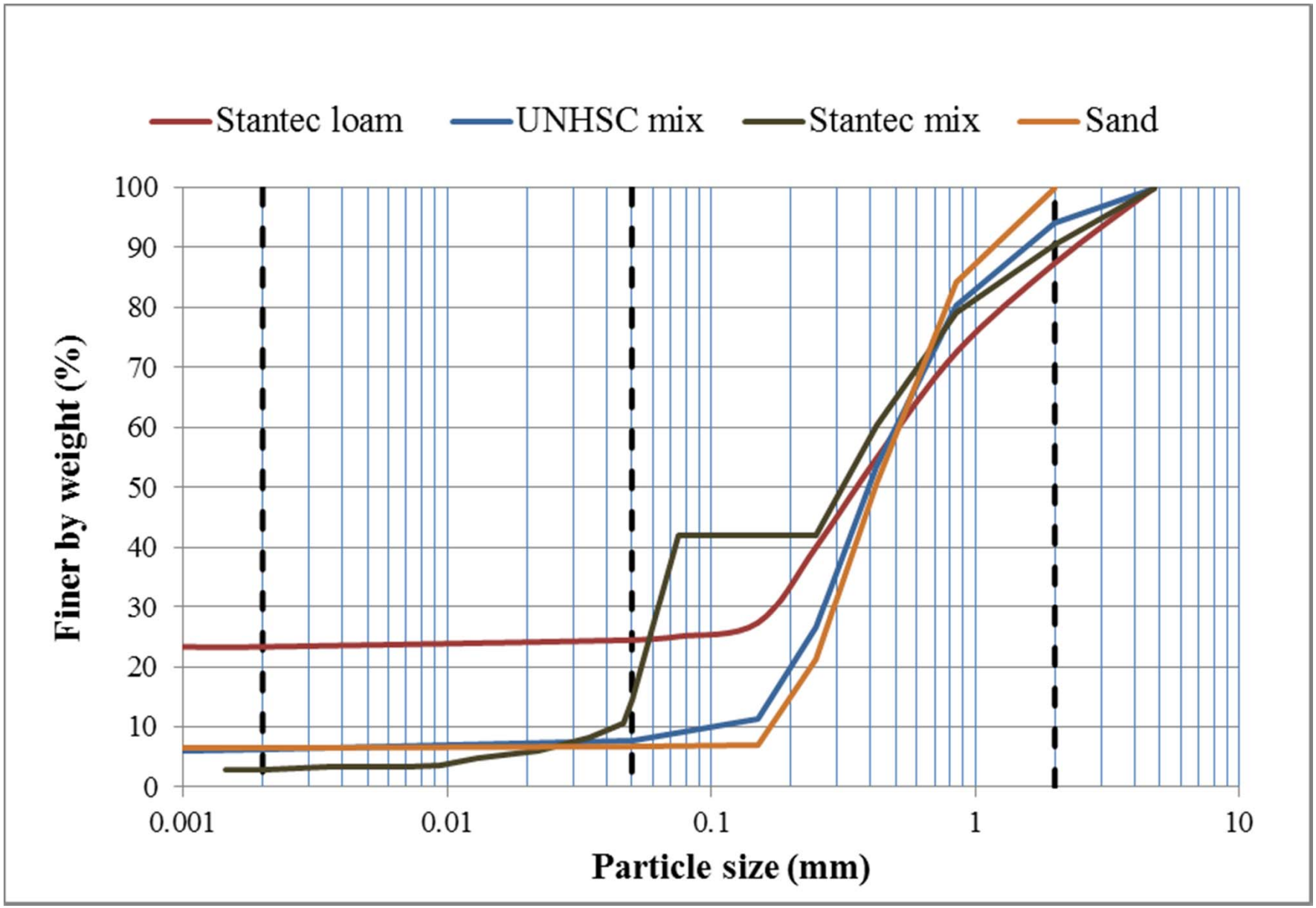

Phase 2 - PO4-P
Orthophosphate-P (ug P /L)
1000
100
10
1
1
2
3
4
5
6
7
8
9
10
Storm number
T2_P0
T2_P5
T2_P6
T2_P7
T2_P8
T2_P1
T2_P2
T2_P3
T2_P4

Phase 3: Phosphorus Optimization

Column #	Soil Mix	Notes
T4-P1	90% Stantec loam + 10% sand	• Drainage to filter ratio 25:1 • Soil depth: 12” • Percentage of amending materials was based on test results from Phases 2 and 3
T4-P2	75% Stantec loam + 25% sand	
T4-P3	60% Stantec loam + 40% sand	
T4-P4	45% Stantec loam + 55% sand	
T4-P5	30% Stantec loam + 70% sand	
T4-P6	15% Stantec loam + 85% sand	
T4-P7	100% sand	
T4-P8	0.5% Fe_2 + 99.5% UNHSC mix	
T4-P9	2% WTR + 98% UNHSC mix	

Optimization Results




Stantec loam
UNHSC mix
Stantec mix
Sand
Finer by weight (%)
100
90
80
70
60
50
40
30
20
10
0
0.001
0.01
0.1
1
10
Particle size (mm)

Conclusions - the obvious!

- Compost leaches nutrients
- Filters are superior at sediment removal
- Hydraulic loading ratio and retention time have a large influence on performance

Conclusions – the promising…

- Modified bio systems show remarkable improvements to DIN and Ortho-P removals in the lab and in the field: ~ 60 - >90%
- Nitrogen removal is less media dependent and improves with ISR and with longer retention
- Loam has an excellent P-sorp capacity and should be incorporated in higher proportions in BSM

Conclusions – the curious…

- Details regarding BSM components are vague at best
- If optimal RE are to be achieved designs should be fine tuned and systems maintained


Questions?