

low impact development technical workshop series

Water Quality Treatment in Bioretention

Topics

Mechanisms

Performance

Special considerations

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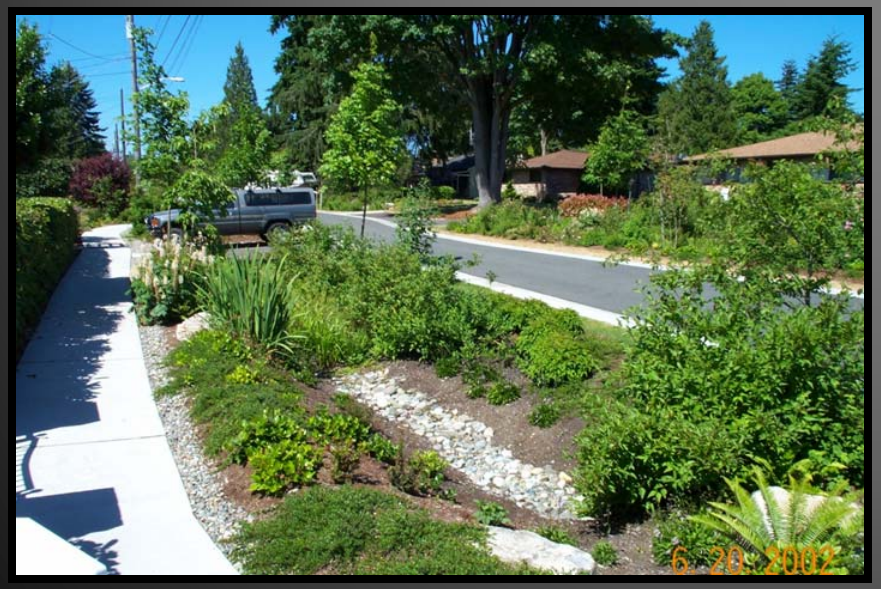
All primary pathways for removing pollutants from storm flows are active in bioretention



Stormwater volume reduction.

Sedimentation.

Filtration.

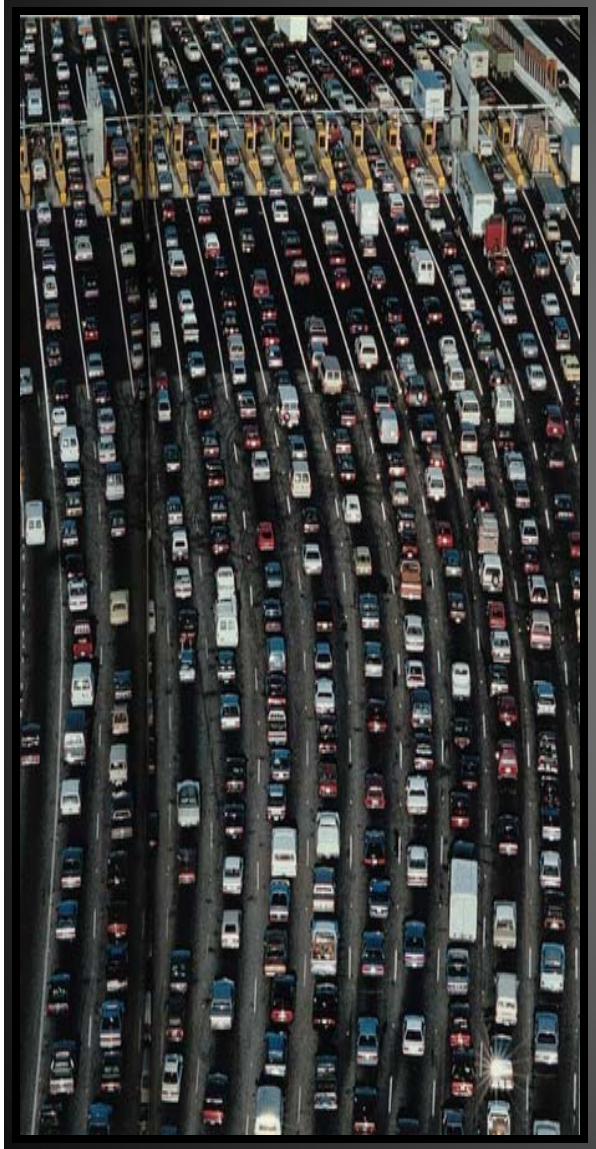
Phytoremediation.

Thermal attenuation.

Adsorption.

Volatilization.

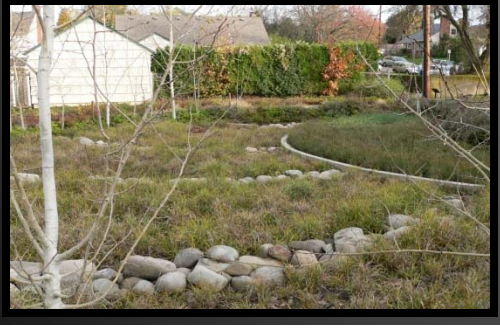
Some characteristics of our urban pollutants



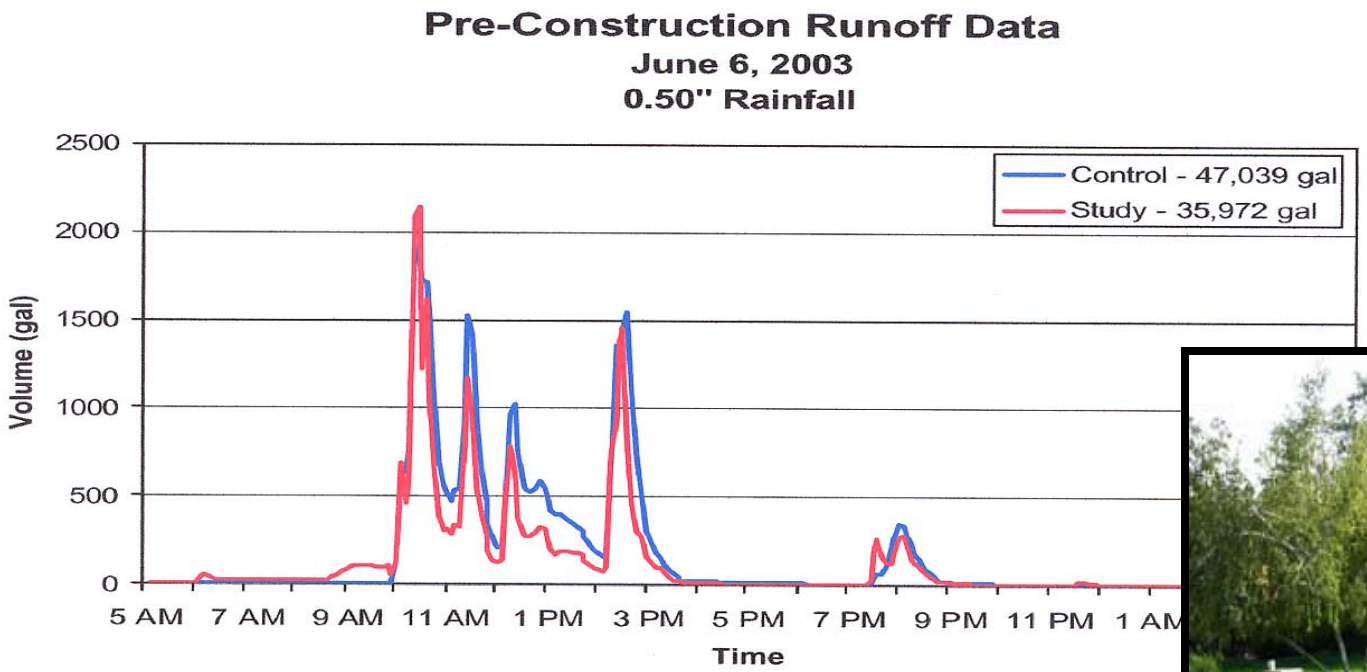
- Little known about mixtures of pollutants, but strong synergism indicated for some pollutants (e.g. pesticides).
- Many pollutants associated with fines (particularly metals), many <0.45 microns (dissolved).
- Structural stormwater controls alone limited for WQ protection.

Flow volume reductions in bioretention

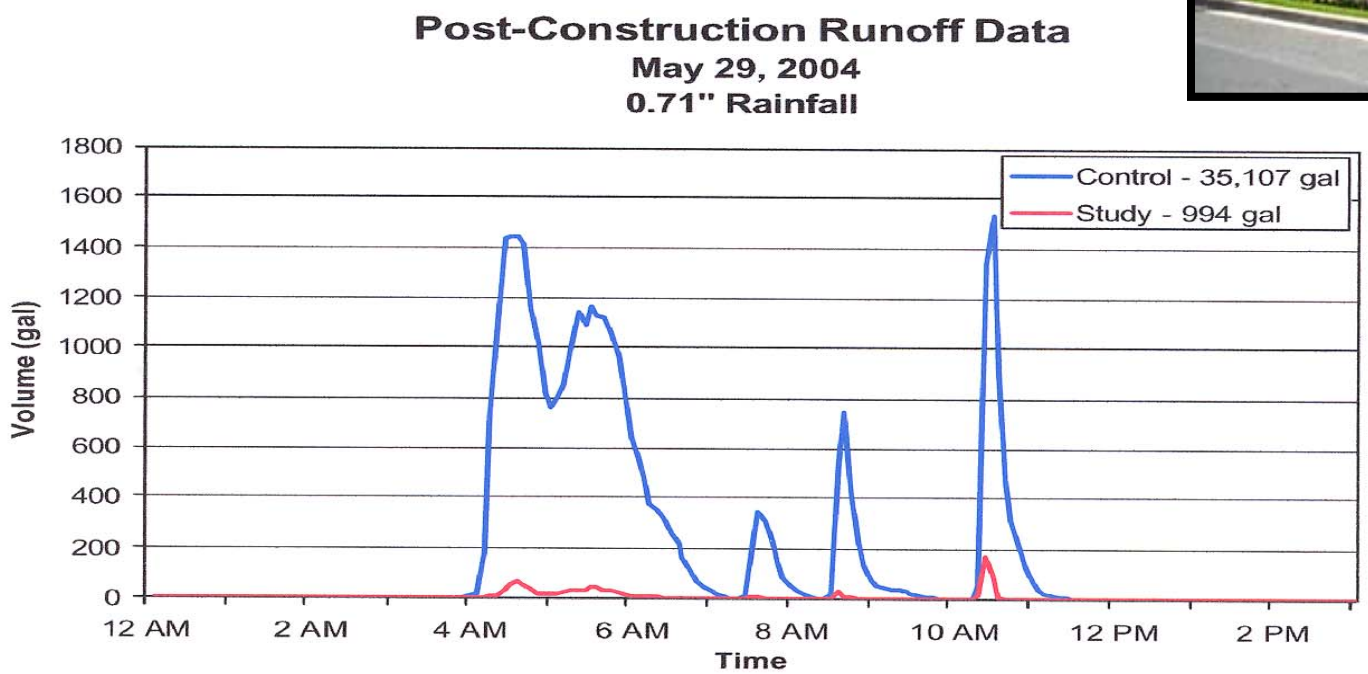
	Completed	Infiltration	Sizing	Volume Reduction (%)
Siskiyou Green Street	Oct 2003	1.5 -2.0 in/hr	6%	*(1/04 – 12/05) 83%
Glencoe Rain Garden	Oct 2003	1.8 - 3.0 in/hr	6%	(1/04 – 12/05) 94%
Greensboro NC	2001	0.2 – 0.6 in/hr	5%	(2002) 78%
Sea Street	2001	variable		(2001 – present) 98%
110th Cascade	2003			(10/04 – 06) 74%
Meadow on the Hylebos	2006	0.0 – 0.8 in/hr	15%	(10/07 – 5/08) 99.99%



water quality treatment



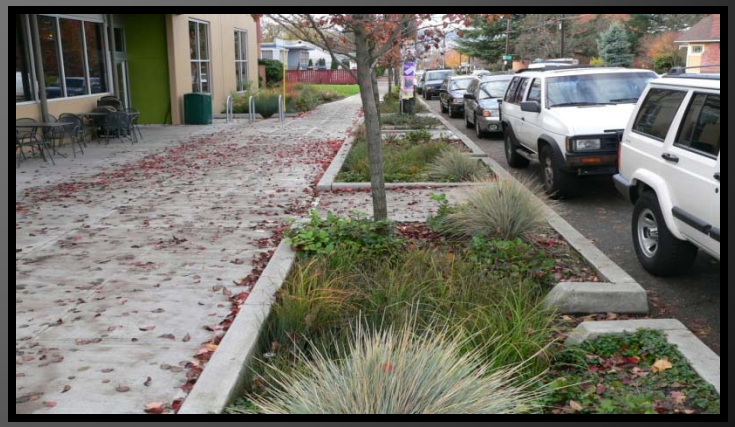
Burnsville, MN



Soil sampling in bioretention facilities

	e. Coli (mpn/g)	Cu (mg/kg)	Pb (mg/kg)	Hg (mg/kg)	Zn (mg/kg)
Siskiyou Green Street					
0-6”	280	34.4	56.8	0.103	170
6-12’	--	17.0	12.2	0.032	100
12-18”	--	17.6	10.9	0.054	96
SW 12th & Montgomery					
0-6”	7	30.1	29.9	0.043	120
12-18”	--	22.2	18.9	0.082	92

MTCA
Pb: 250 mg/kg
Hg: 2 mg/kg



Percent removal of metals and TSS in bioretention and grass bioswales

	TSS mgL-1	P/TP mgL-1	P/diss mgL-1	NO3+2-N mgL-1	NH4-N* mgL-1	TKN mgL-1	Total Cu ugL-1	Total Pb ugL-1	Total Zn ugL-1	FC
Grass Swales (dry)										
25th percentile										
In	8.00	0.06	0.03	0.11	--	0.31	5.02	1.65	19.1	1400
Out	5.12	0.12	0.05	0.13	--	0.29	3.57	1.08	15.5	1900
Median										
In	21.70	0.11	0.06	0.30	--	0.72	10.86	3.93	36.2	4720
Out	13.60	0.19	0.07	0.25	--	0.62	6.54	2.02	22.9	5000
75th percentile										
In	56.00	0.24	0.09	0.62	--	1.48	27.00	18.20	136.0	20300
Out	33.00	0.32	0.26	0.47	--	1.10	13.20	6.27	50.0	18500
Bioretention Facilities										
25th percentile										
In	18.30	0.06	--	0.16	--	0.54	8.35	2.06	46.3	--
Out	3.80	0.05	--	0.11	--	0.32	3.98	2.50	4.8	--
Median										
In	37.50	0.11	--	0.26	--	0.94	17.00	3.76	73.8	--
Out	8.30	0.09	--	0.22	--	0.60	7.67	2.53	18.3	--
75th percentile										
In	87.80	0.22	--	0.41	--	1.58	38.50	7.00	153.8	--
Out	16.00	0.20	--	0.39	--	1.25	12.00	5.00	36.0	--

Percent removal of metals and TSS in bioretention and grass bioswales

	TSS (mg/L)	Cu (µg/L)	Pb (µg/L)	Zn (µg/L)
Davis etal 2001*		89% (u) 92% (l)	>98% (u) >98 (l)	>98% (u) >98 (l)
Davis etal 2003**		>99%	>99%	>99%
Greenbelt		97%	>95%	>95%
Largo		43%	70%	64%
Hunt etal 2006				
Greensboro	-180%	99%	81%	98%
Chapel Hill	--	--	--	--
Hsieh, Davis 2005	91%			
Multhanna etal 2007		63%	93%	87%
PNW Bioswales (Herrera 2006)	64%			47%
National Bioswales (Herrera from Barrett)	43%			53%

Event mean concentrations

* Percent reduction at 18 cm (upper) and 61 cm (lower) depths (lab)

** Percent mass removal (lab)

Percent removal of nutrients in bioretention and grass bioswales

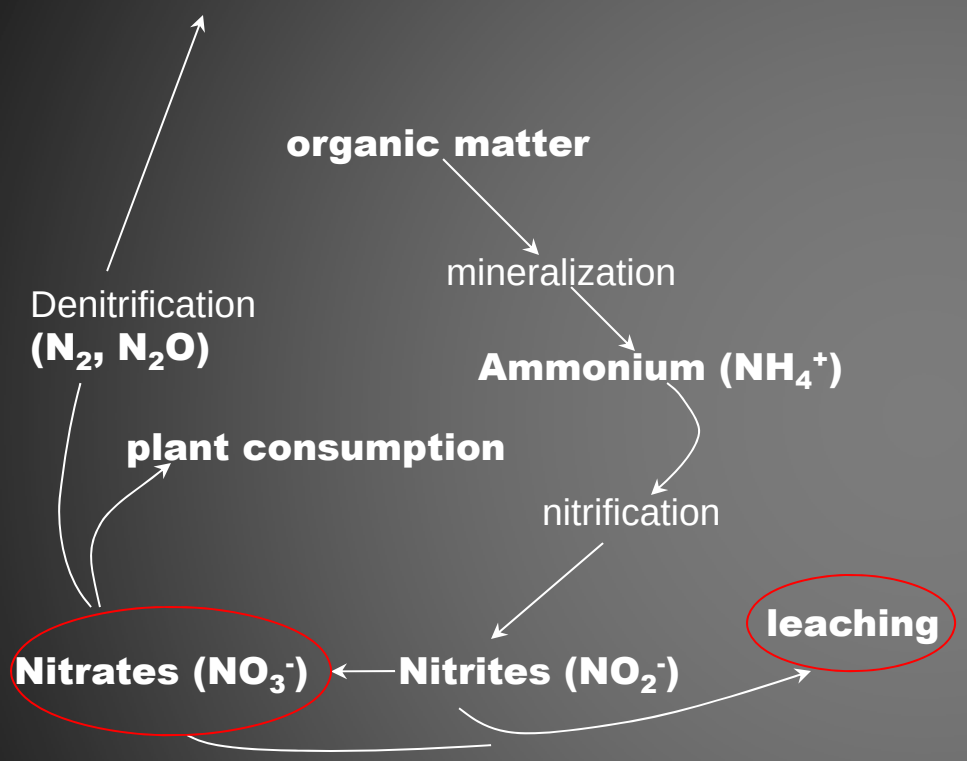
	TKN (mg/L)	NO_3 (mg/L)	TP (mg/L)	Hydrocarbons (µg/L)
Davis etal 2006*	38% (u) 68% (l)	-96% (u) 24% (l)	1% (u) 81% (l)	
Greenbelt	57%	16%	65%	
Largo	67%	15%	87%	
Mass removal	97%	97%	99%	
Hunt etal 2006				
Greensboro	-4.9%	75%	-240%	
Chapel Hill	45%	13%	65%	
Hsieh 2005				>97%
PNW Bioswales (Herrera 2006)			18%	-10%
Nat'l Bioswales**				-88%

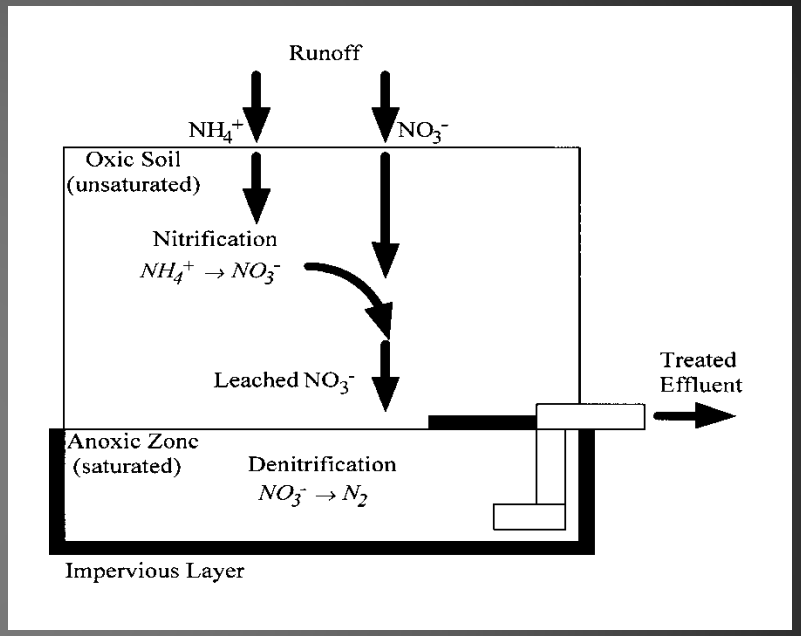
Event mean concentrations

* Percent reduction at 18 cm (upper) and 61 cm (lower) depths (lab)

**Herrera from Barrett

Methods for managing nitrate



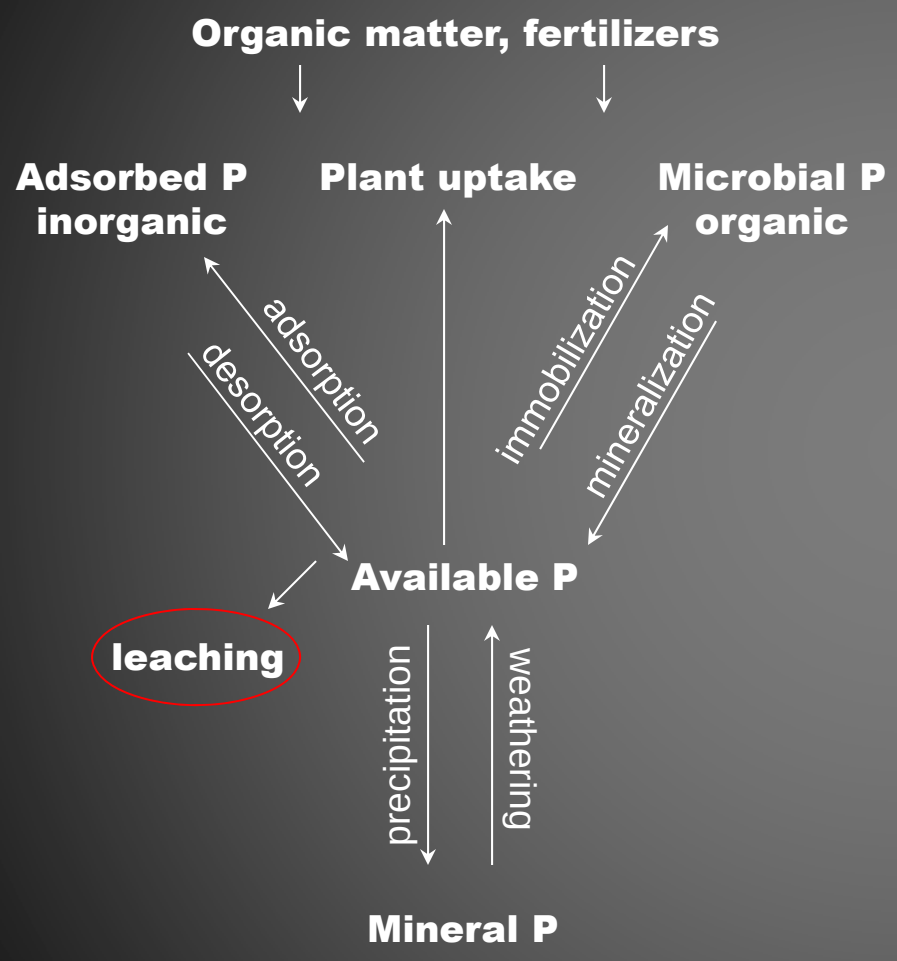


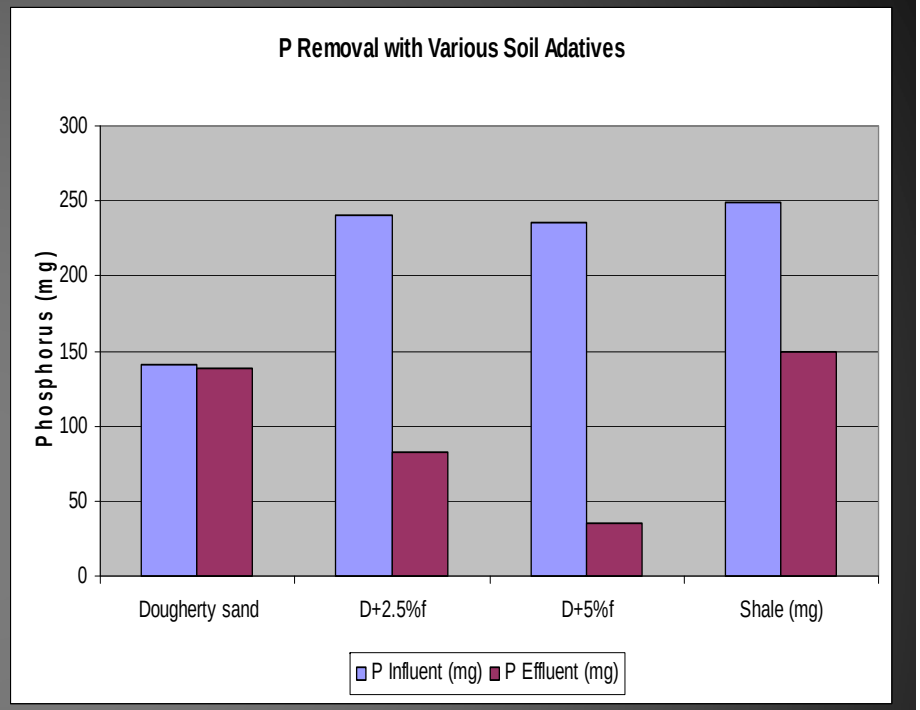
NO_3^- electron acceptor not O_2 in anaerobic conditions

$2NO_3^- + 10e^- + 12H^+ \rightarrow N_2 + 6H_2O$

Electron donor may be sugar, hydrocarbon (simple) or complex (mulch).

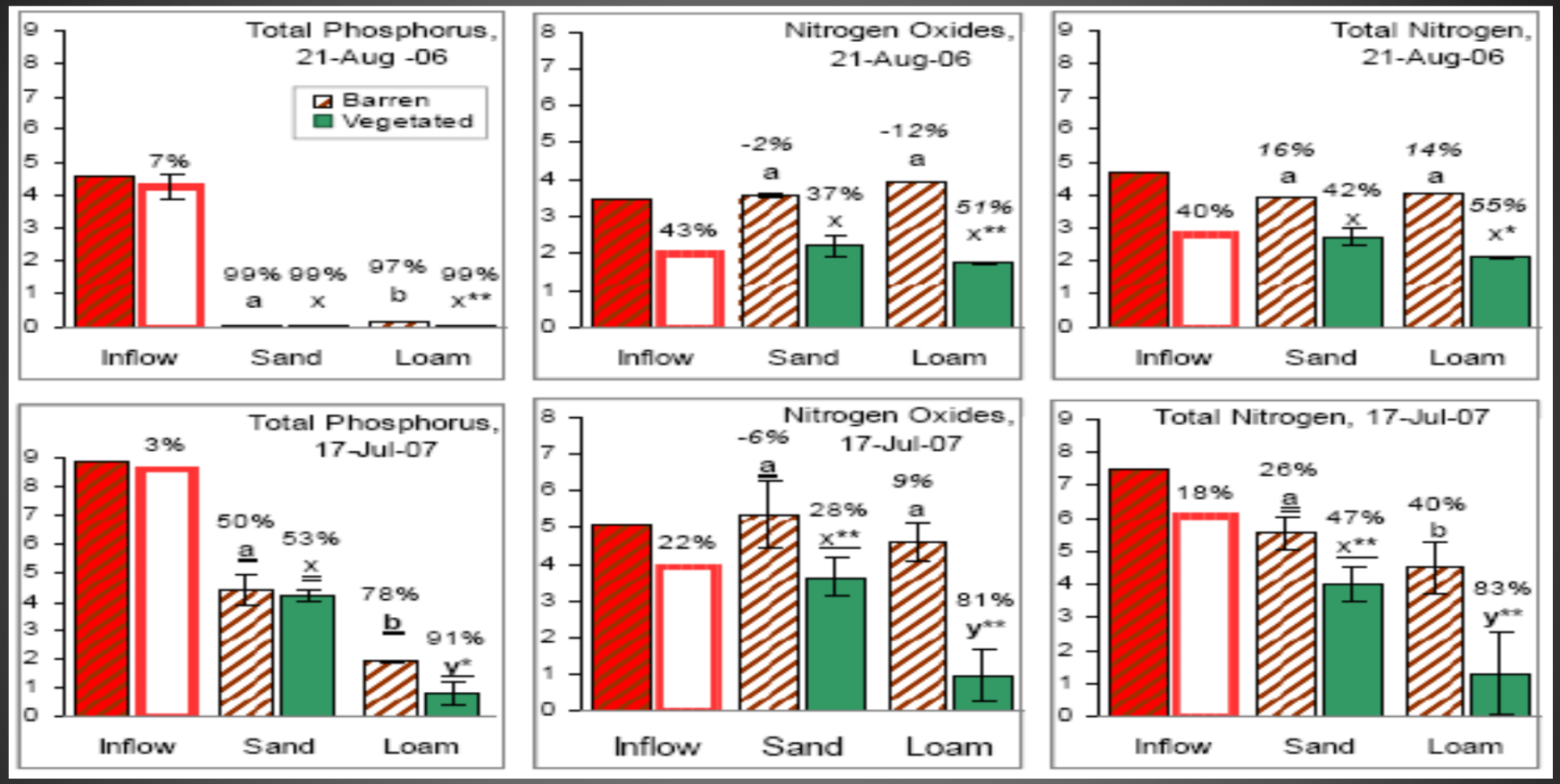
Methods for retaining phosphate





Fly ash significantly improves P retention, but significantly reduces K. (Zhang 2000)

Phosphate retention mechanisms



P-sorption increased significantly in vegetated vs non-vegetated plots. Increased O_2 from roots→oxidizes Fe (ferric form has high P sorption capacity) and arbuscular mycorrhizal fungi associated with roots (luxury uptake) possible mechanisms. (Lucas, Greenway 2007)

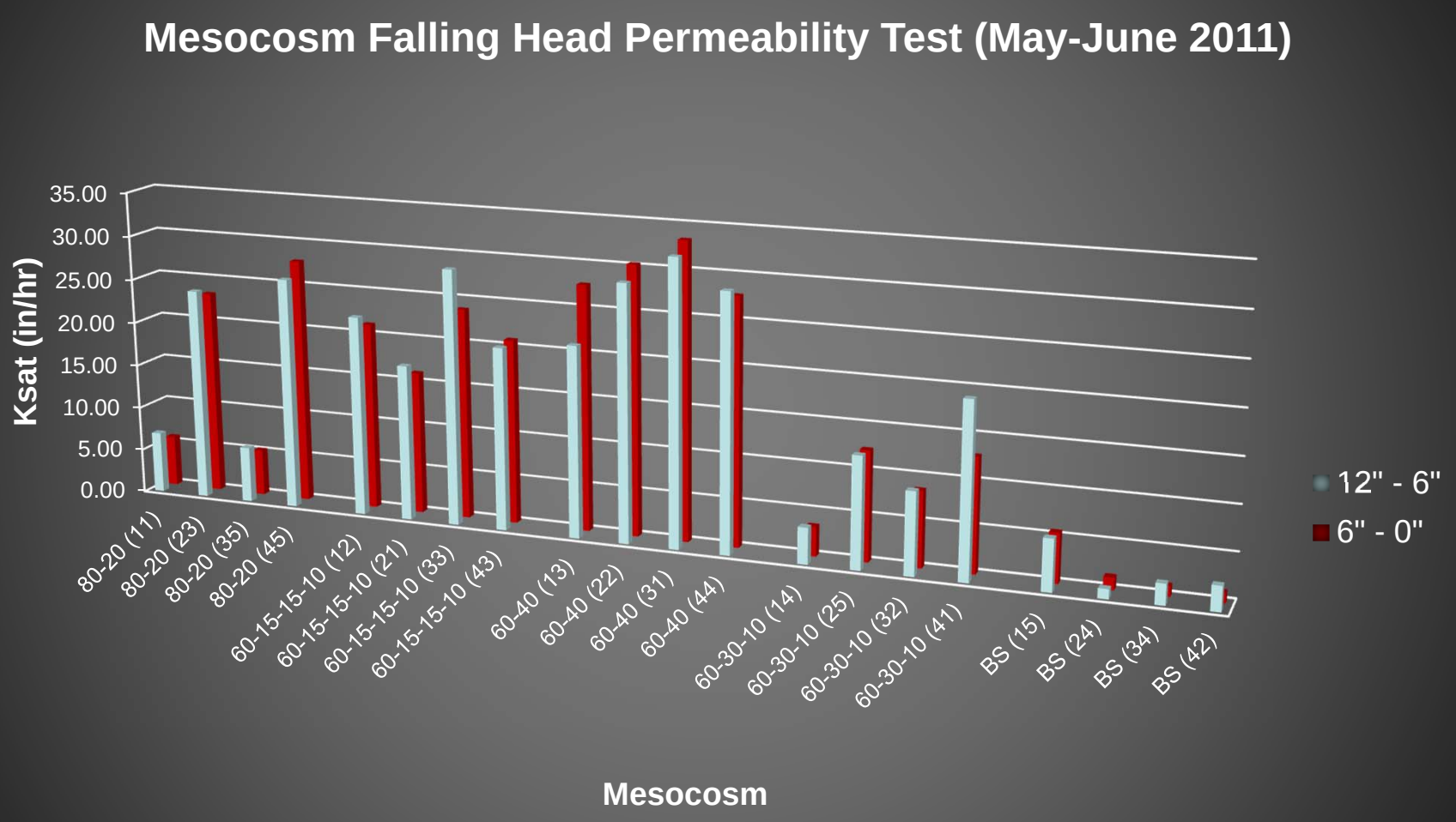
WSU LID Research Program: Bioretention Soils

bioretention: mesocosms

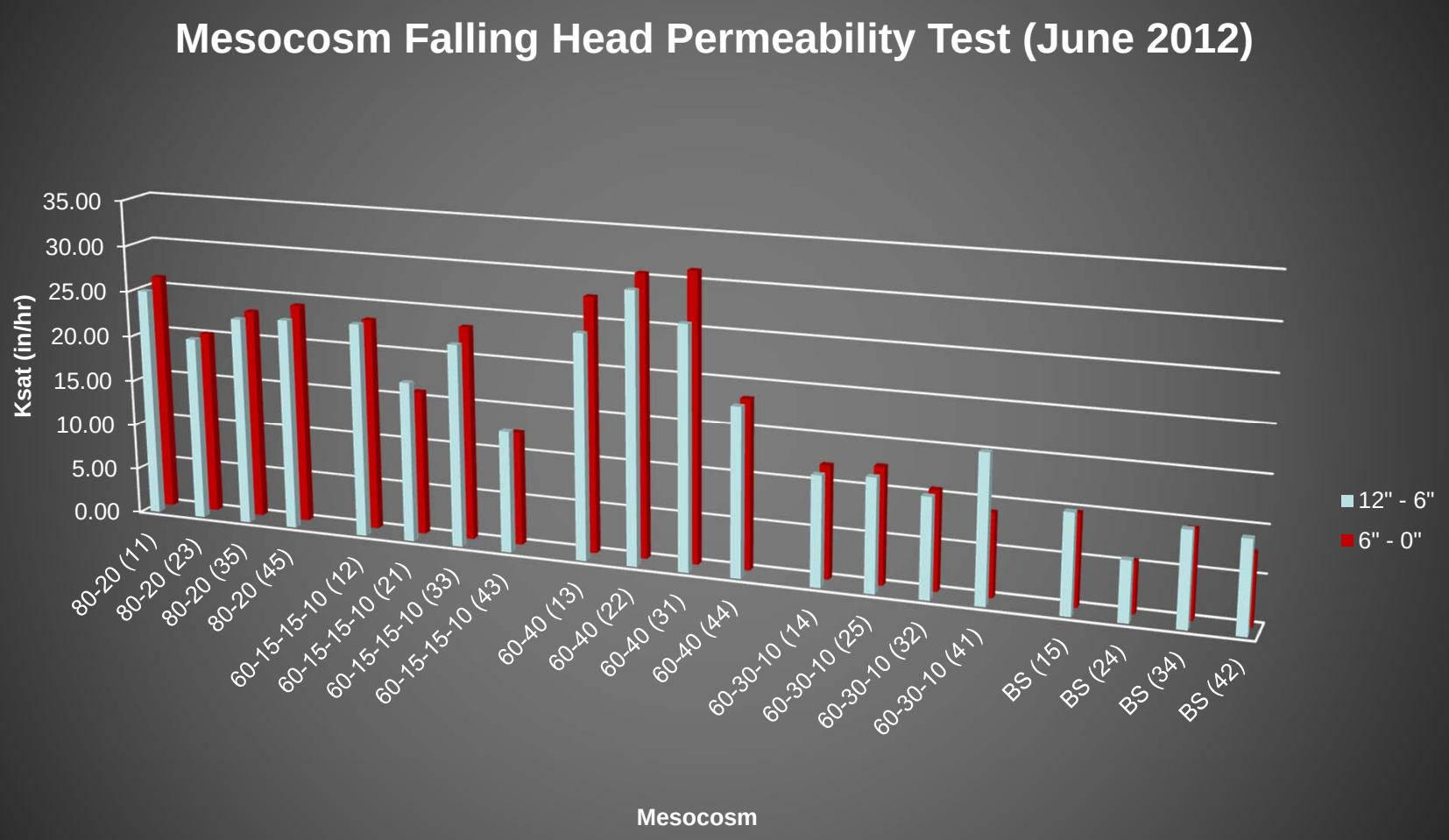
Soil treatments

- 60% sand--40% compost.
- 80% sand--20% compost.
- 60% sand--30% compost--10% WTRs.
- 60%sand--15% compost--15% shredded bark--10% WTRs.
- Compost and biochar media.

WSU LID Research Program: Bioretention Soils

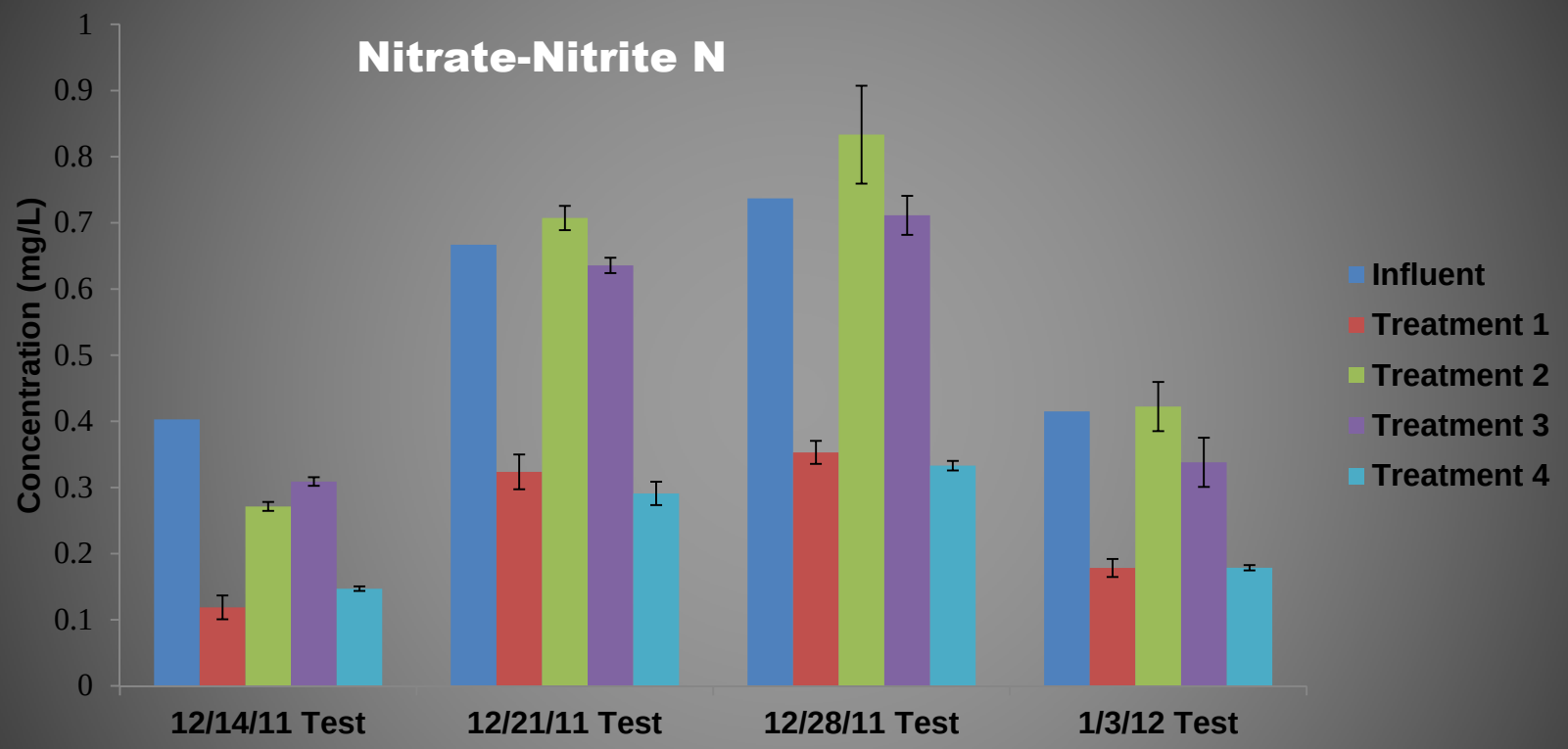


WSU LID Research Program: Bioretention Soils



Bioretention Water Quality Treatment

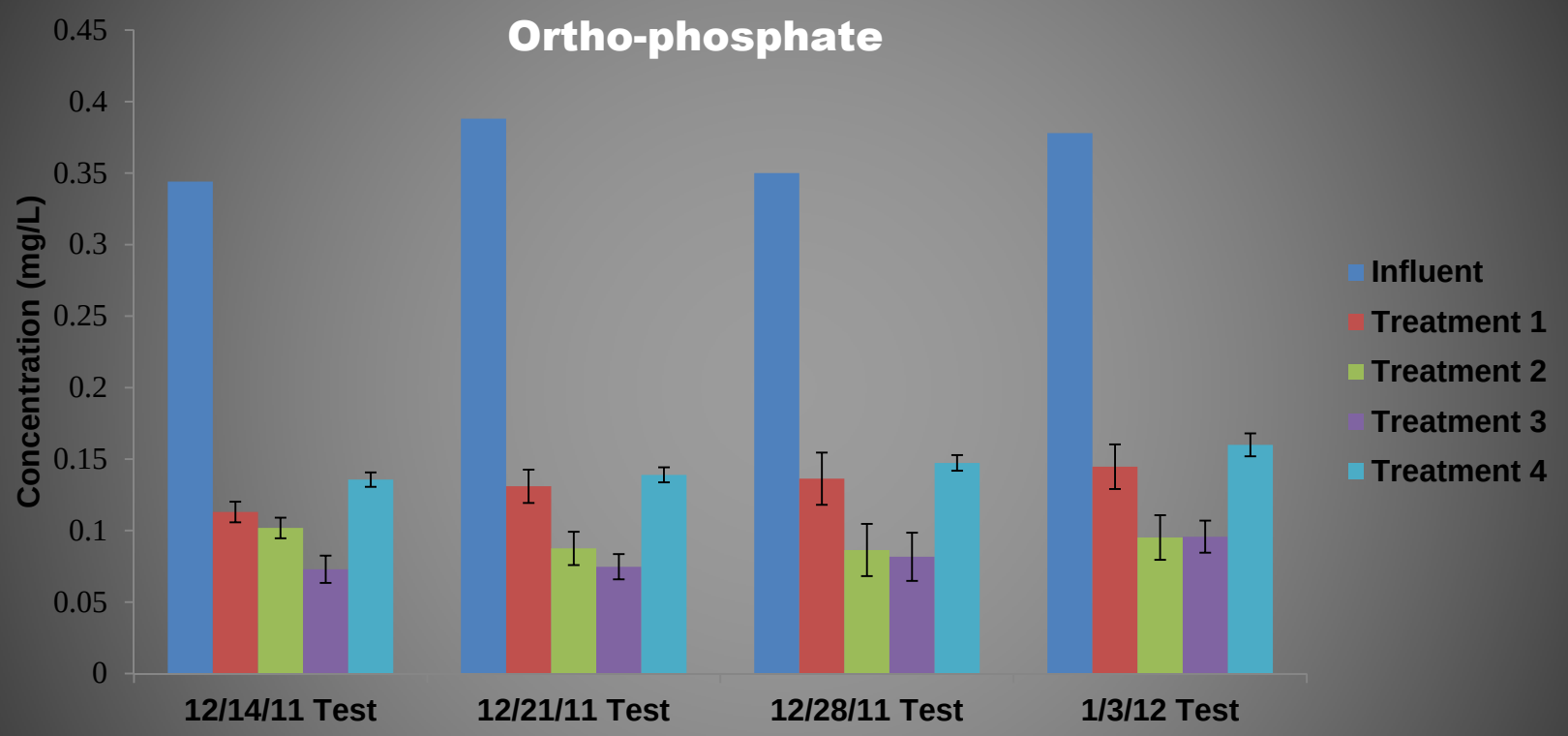
Balancing N removal and P capture (60-15-15-10 columns)



Date	Influent	Median Effluent	% Change	n
12/14/2011	0.403	0.209	48.14	12
12/21/2011	0.667	0.48	28.04	12
12/28/2011	0.737	0.532	27.82	12
1/3/2012	0.415	0.2585	37.71	12

Bioretention Water Quality Treatment

Balancing N removal and P capture (60-15-15-10 columns)



Date	Influent	Median Effluent	% Change	n
12/14/2011	0.344	0.1075	68.75	12
12/21/2011	0.388	0.1095	71.78	12
12/28/2011	0.35	0.111	68.29	12
1/3/2012	0.378	0.1205	68.12	12

Bioretention Water Quality Treatment

All mesocosms (Phase 1 leaching regime)

Analyte	Units	Median Influent	Min	Median Effluent	Max	n
TSS	mg/L	4.9	1	5.3	22.5	36
Diss Zn	µg/L	71	4	4	10	40
Diss Cu	µg/L	3	1.7	8.6	15.9	40
PO4	mg/L	0.016	0.086	0.236	0.461	40
NO3-NO2	mg/L	0.361	0.05	0.145	1.03	32
Fecal coliform	CFU/100mL	229	5	22.5	65	32

Bioretention Water Quality Treatment

Water quality treatment mechanisms

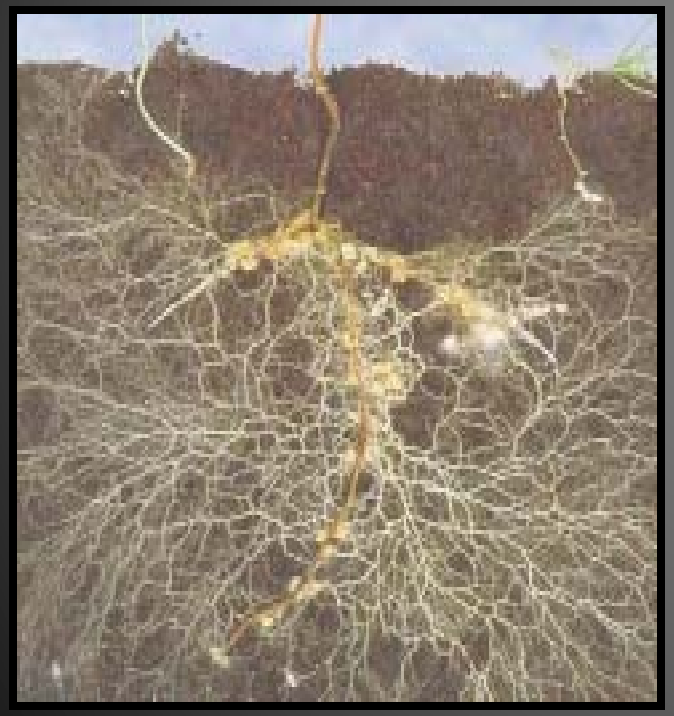
Is the following statement true:

If 0.5 µg/L influent concentration of dissolved Cu results in 2 µg/L effluent concentration, then

100 µg/L influent concentration dissolved Cu will result in 400 µg/L effluent concentration

Plants play a critical role in bioretention flow and water quality treatment performance

- Plant roots penetrate soil creating flow paths, exude saccharides and dead material that feed soil organisms and create soil aggregates.



- Treatment mechanisms:
  - Nutrient uptake.
  - Metal uptake.
  - Uptake, volatilization, transformation of organics.

- Plants influence water quality directly (e.g. uptake) and indirectly through physical an chemical changes to rhizosphere.

Summary and recommendations

- Bioretention areas provide excellent Zn, hydrocarbon, bacteria and TSS removal.
- Metal, hydrocarbon and TSS removal primarily in upper few centimeters. Hydrocarbons transformed within a few days. Mulch layer most important for metal and hydrocarbon removal.
- Phosphorus, nitrogen and Cu removal is variable. Nitrate, phosphate and Cu export is possible.
- Phosphate management: 1) sorption capacity (short and long term); 2) plants likely necessary for improved and adequate P management; 3) precipitation (longer-term and likely between events process; 4) HRT and BSM depth (likely due to increased contact time).

Summary and recommendations

- Nitrate removal dependent on O_2 levels. Use raised under-drain to create an anaerobic zone and improve NOx for effluent release to marine water.
- More research needed for optimizing for phosphate and Cu removal. Research in progress at WSU.
- Discussion focused on percent removal and concentrations. When considering volume reduction in rain gardens, loads dramatically reduced for all constituents.
- Need to be careful with selection of materials and suppliers (particularly with compost).