Gravel Wetlands

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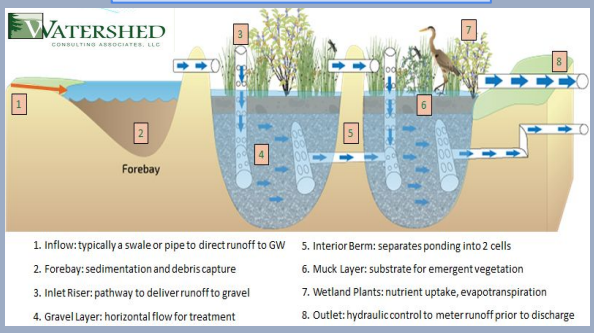
What is a Gravel Wetland?



1. Inflow: typically a swale or pipe to direct runoff to GW
2. Forebay: sedimentation and debris capture
3. Inlet Riser: pathway to deliver runoff to gravel
4. Gravel Layer: horizontal flow for treatment
5. Interior Berm: separates ponding into 2 cells
6. Muck Layer: substrate for emergent vegetation
7. Wetland Plants: nutrient uptake, evapotranspiration
8. Outlet: hydraulic control to meter runoff prior to discharge

Research Questions

Field:

1. Do gravel wetlands currently permitted under the Vermont Stormwater Management Manual (VSMM) perform as expected for flow attenuation & phosphorus capture?
2. How is chloride moving through (& being stored) within gravel wetlands"?

Lab:

1. How do design variables influence gravel wetland flow attenuation & phosphorus capture performance? Design characteristics considered include: impermeable wetland "muck" material sourcing & feedstock.

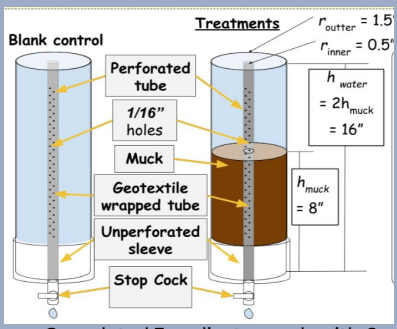
Muck Characteristics

Muck	Image	Texture*	Context	Initial P (%) dry basis
FNA		Clay loam (Peru fine sandy loam, Munson & Raynham silt loam, silty clay terraced enscarpments)	Fairview composite of native soil	0.08
KIS		Sandy loam (Livingston silty clay)	Kennedy *in situ* with M1 soil after one year in the field	0.14
M1		Sandy loam	GROW compost	0.16
KNA		Silty clay loam	Composite native soil	0.03

*According to Texture *by feel* test

Column Tests

Goal: to isolate the performance of wetland "muck" materials from gravels by simulating flooding & infiltration for muck materials



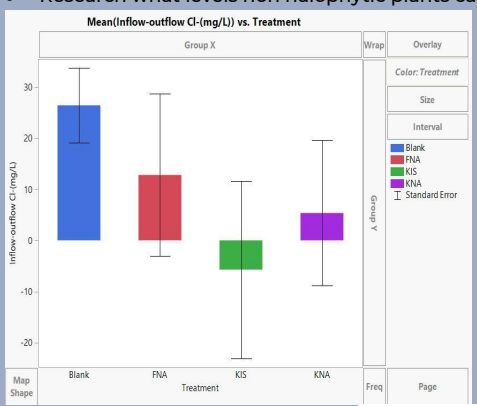
Completed 3 replicates each with 6 storm events (aka: days).

Tests:

- Influent vs. effluent for temperature, pH, Cl
- Effluent collected for soluble reactive phosphorus (SRP), total phosphorus (TP), total suspended solids (TSS)
- Complete Moisture Content (MC) & (WEP) Water Extractable Phosphorus

Chloride

- Not statistically significant
- Currently no specs., so research other states & add to manual
- Research what levels non halophytic plants can endure



Fairview Wetland

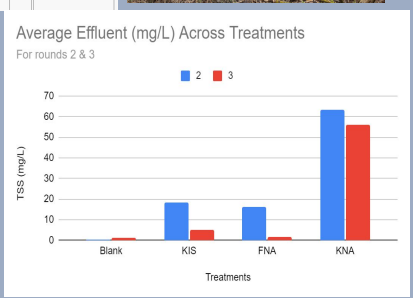
Hydraulic Conductivity

"Wetland Muck" Saturated Hydraulic Conductivity (K_{sat})		
Mucks Obtained	Average K_{sat} (ft/day)	Std Dev
M1	0.49	± 0.29
M2	65.12	± 26.19
M3	6.75	± 5.78
FNA	2.49	± 2.58
KIS	0.56	± 0.32
KNA	5.59	± 4.95
n = 3 per muck; 1:100 soil: solution ratio; target range 0.01 to 0.10 ft/day		

* None of the mucks met the K_{sat} standard

Total Suspended Solids (TSS)

- Indicates if fine solids washed into gravel layer
- Native soil FNA & KIS released least amount
- Continue to monitor annually



Soluble Reactive Phosphorus (SRP)

"Wetland Muck" Effluent Soluble Reactive Phosphorus (SRP)

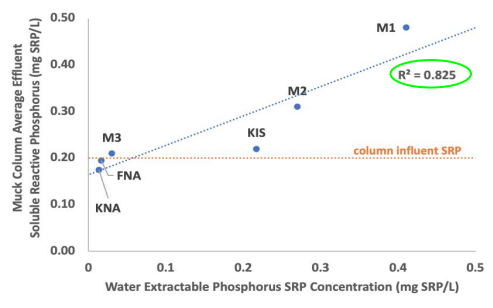
Mucks Obtained	Avg SRP, round 2 (mg/L)	Avg SRP, round 3 (mg/L)	Overall Avg SRP (mg/L)
Blank	0.19	0.21	0.20
FNA	0.20	0.19	0.195
KIS	0.21	0.23	0.22
KNA	0.18	0.17	0.175

n = 6 per muck; values > 0.2 mg P/L indicate leaching risk

* Highlighted values met the desired standard

WEP vs. SRP Comparison

An aim of this study was to see if the WEP results match the column tests, so that in the future, one only has to complete the WEP test.



Water Extractable Phosphorus (WEP)

"Wetland Muck" Water Extractable Phosphorus (WEP)

Mucks Obtained	Average WEP (mg P/kg dry muck)	Std Dev
M1	41	±3
M2	27	±5
M3	3	±2
FNA	1.6	±0.01
KIS	21.7	±0.19
KNA	1.3	±0.52

n = 3 per muck, 1:100 soil:solution ratio

Modified Morgan

"Wetland Muck" Phosphorus Saturation Ratio (PSR) of Modified Morgan Extraction

Mucks Obtained	Phosphorus, P (mg/kg)	PSR (%)
M1	307	2931.36
M2	572	3951.03
M3	30	52.89
FNA	3.3	4.05
KIS	192	1382.92
KNA	1.7	0.57

n = 1 per muck; upper target limit of 4 ppm

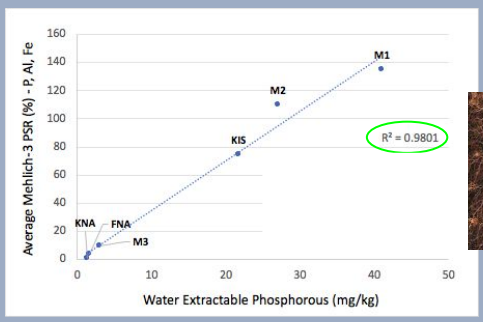
Mehlich-3

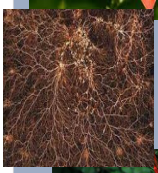
"Wetland Muck" Phosphorus Saturation Ratio (PSR) of Mehlich-3 Extraction

Mucks Obtained	Phosphorus, P (mg/kg)	PSR (%)
M1	339	134.46
M2	679	100.20
M3	161	9.82
FNA	56	3.93
KIS	316	74.50
KNA	10	0.62

n = 1 per muck;
values < 25% minimize phosphorus leaching

WEP vs. PSR Comparison





Recommendations

Chloride

- Investigate halophytic plants native to VT in column studies

Phosphorus

- Investigate hyper accumulating, halophytic plants in bench trials
  - Harvest plants in early autumn, dry, analyze & compare P concentrations

Mycorrhizae

- Investigate mycorrhizal facilitation of plant P uptake in hydric soils

Hydraulic Conductivity

- Lowest Ksat: KIS at .56 ft/day
  - Consider expanding 0.01-0.1 ft/day range in native soils
- Investigate other mediums which decrease Ksat
  - Liner - clay, sand, geotextile

M1 and KIS

- Experiment with Drinking Water Treatment Residuals (DWTR) to increase P sorption
  - Perform bench trials to assess plant viability

How did the Mucks Perform?

Muck	Analysis of Study: (Green Performed Well)					
	K_{sat} (0.01-0.1 ft/d)	SRP (<0.2 mgP/L)	MM-P (< 4 mgP/kg)	M3-P (PSR < 25%)	TSS ** (< 0 mg TSS/L SSW)	Cl *** (out-in < 0)
FNA	2.49	0.195	3.3	3.93	8.87	7.62
KIS	0.56	0.22	192	74.50	11.84	-21.67
KNA	5.59	0.175	1.7	0.62	59.76	-7.39

* There were no standards for WEP to compare to;
** TSS should not be released in the effluent so any detection is not wanted
*** Cl is aimed to be reduced from influent to effluent

References

NRCS, UVM Extension, Sea Grant, 2007. Vermont Rain Garden Manual; Gardening to Absorb the Storm.

VT Agency of Natural Resources, V.A. of T., Stone Environmental Inc. Horsley Witten Group, Adamant Accord, Otter Creek Engineering, 2017. Vermont Stormwater Management Manual.