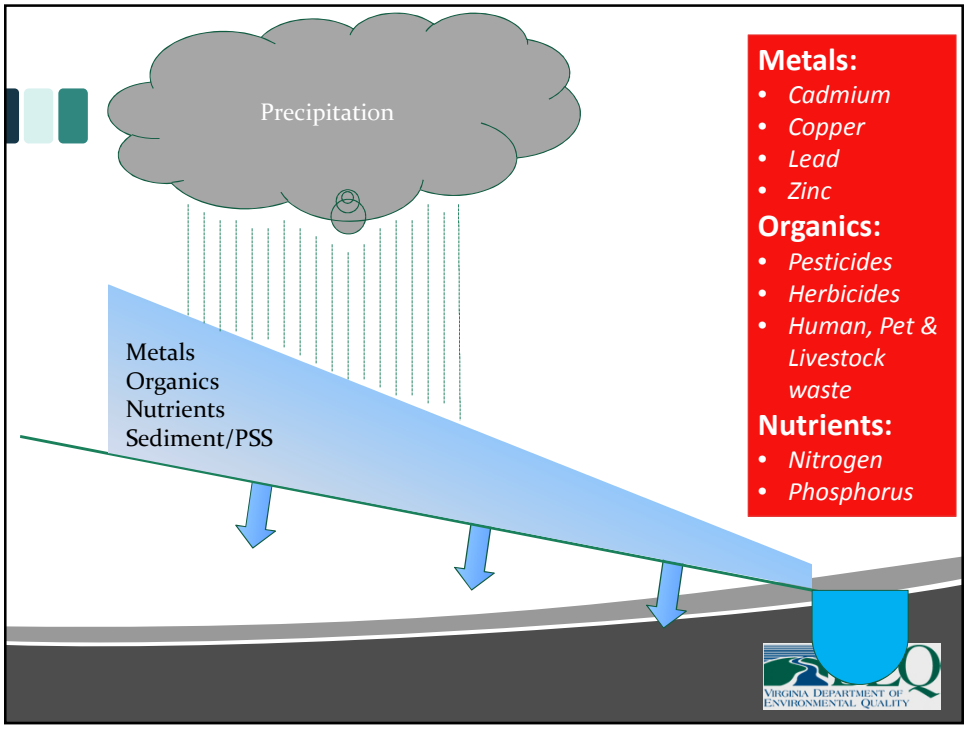
Module 3

Biorentention Stormwater BMPs

Module 3a

Stormwater Chemistry


Precipitation
Metals
Organics
Nutrients
Sediment/PSS
Metals:
Cadmium
Copper
Lead
Zinc
Organics:
Pesticides
Herbicides
Human, Pet & Livestock waste
Nutrients:
Nitrogen
Phosphorus
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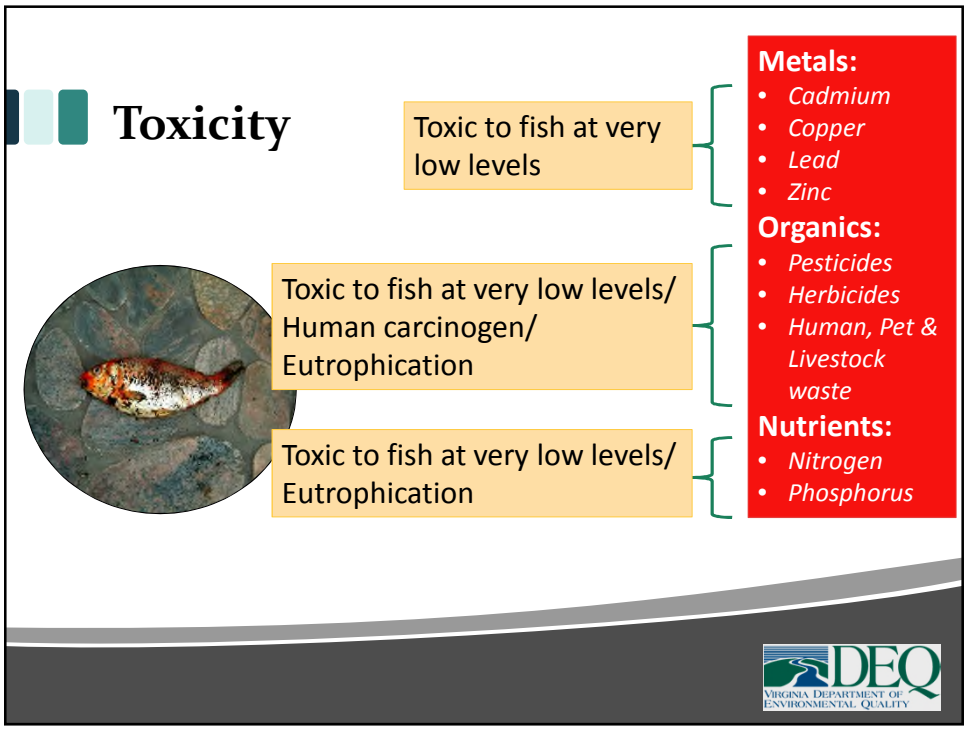
Toxicity
Toxic to fish at very low levels
Toxic to fish at very low levels/ Human carcinogen/ Eutrophication
Toxic to fish at very low levels/ Eutrophication
Metals:
Cadmium
Copper
Lead
Zinc
Organics:
Pesticides
Herbicides
Human, Pet & Livestock waste
Nutrients:
Nitrogen
Phosphorus
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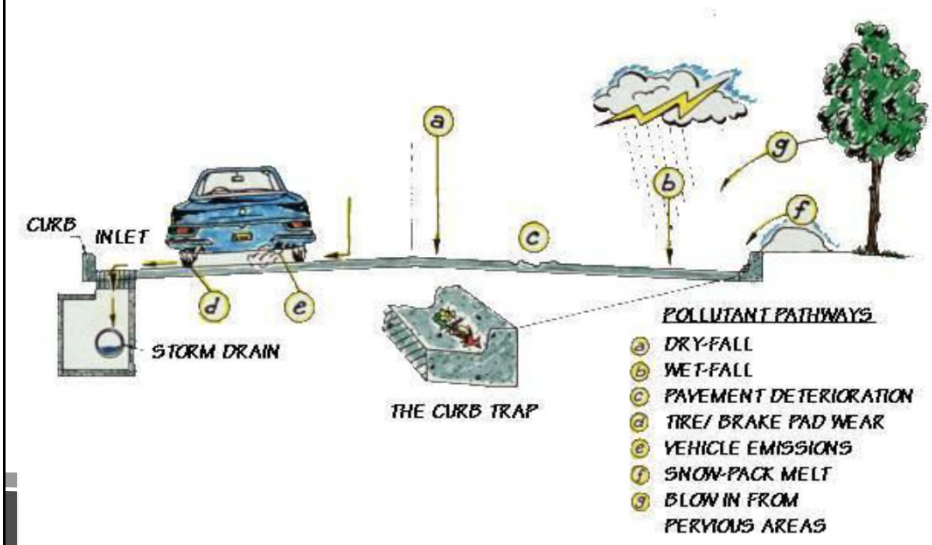
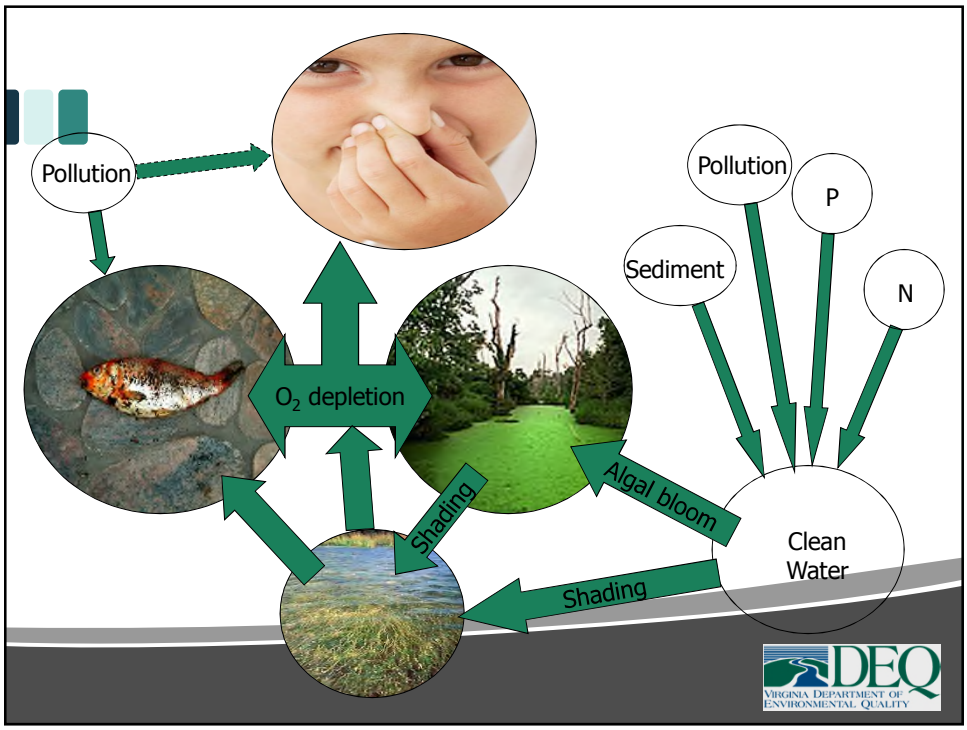
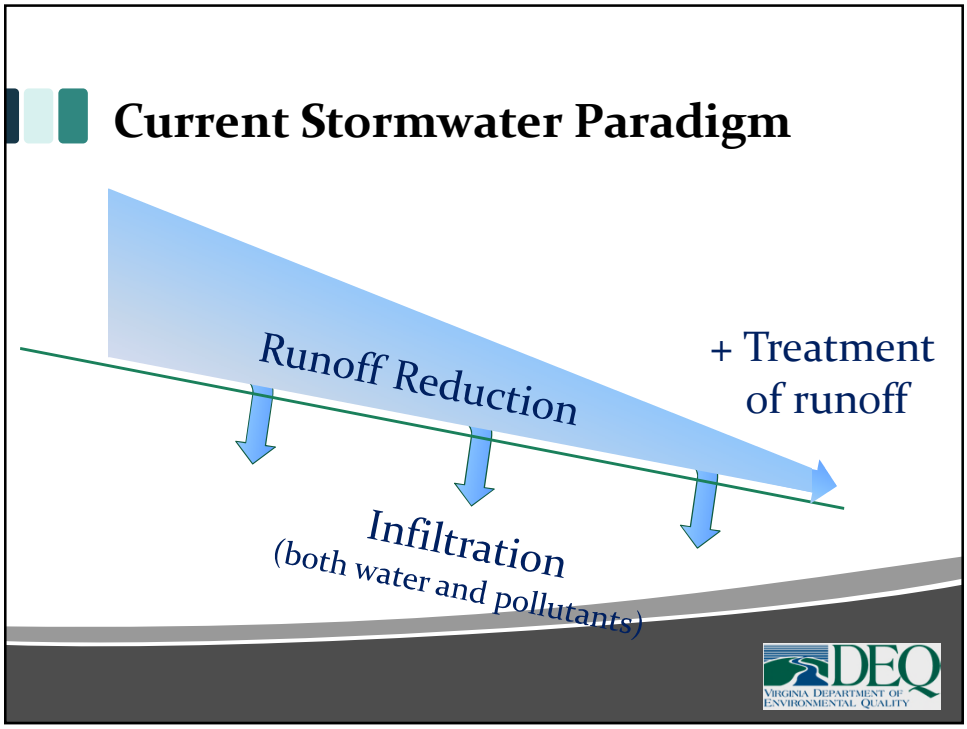
There are many sources of Pollutants (N and P) in the urban environment






Current Stormwater Paradigm
Runoff Reduction
+ Treatment of runoff
Infiltration
(both water and pollutants)
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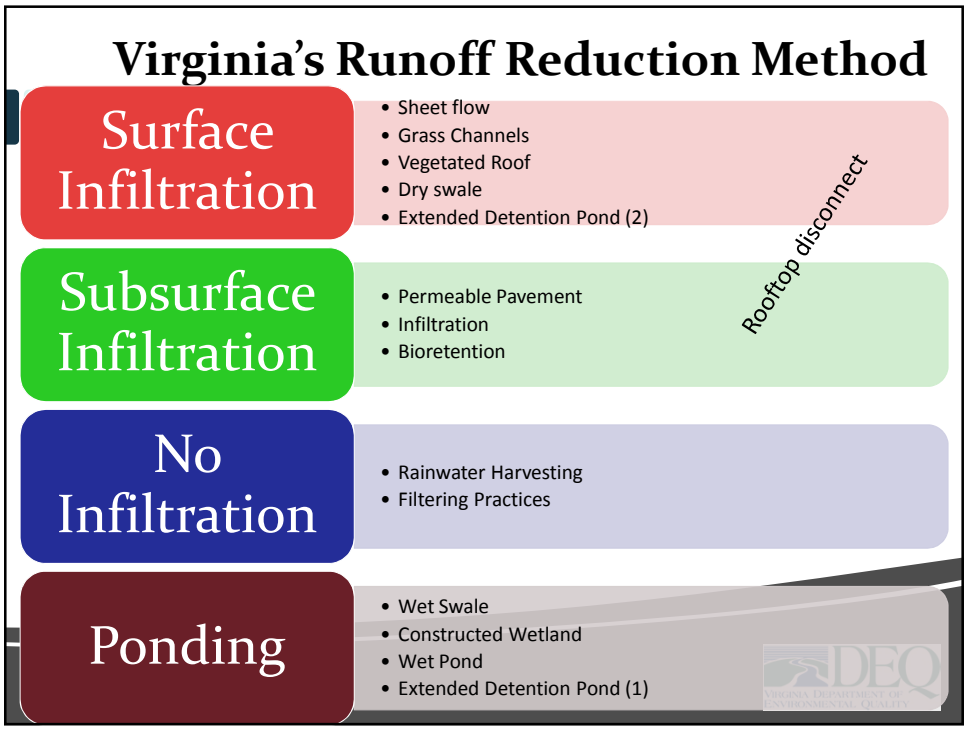
Virginia's Runoff Reduction Method
Surface Infiltration
• Sheet flow
• Grass Channels
• Vegetated Roof
• Dry swale
• Extended Detention Pond (2)
Subsurface Infiltration
• Permeable Pavement
• Infiltration
• Bioretention
Rooftop disconnect
No Infiltration
• Rainwater Harvesting
• Filtering Practices
Ponding
• Wet Swale
• Constructed Wetland
• Wet Pond
• Extended Detention Pond (1)
DEQ

Soil Amendments and the BMP Clearinghouse

BMP	Plants		Plants
1. Rooftop disconnection	No*	9. Bioretention	Yes [5]
2. Sheetflow	CA [1]	10. Dry swale	Yes [5]
3. Grass channels	CA [1]	11. Wet swale	No
4. Soil amendments	No	12. Filtering practices	No [6]
5. Vegetated roof	(Yes) [2]	13. Constructed wetland	No
6. Rainwater harvesting	No	14. Wet pond	No
7. Permeable pavement	No [3]	15. Extended detention	No
8. Infiltration	No [4]		

[1] on C and D soils; [2] depends on roof type; [3] reservoir stone depends on pavement type; [4] VDOT No. 1 Stone; [5] bioretention media; [6] sand

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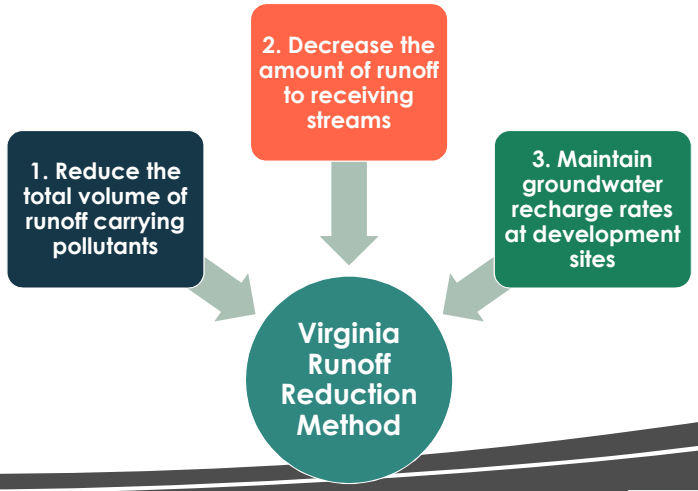
Runoff Reduction Method



BUT ALSO: Reduction of Pollutant load in remaining water!

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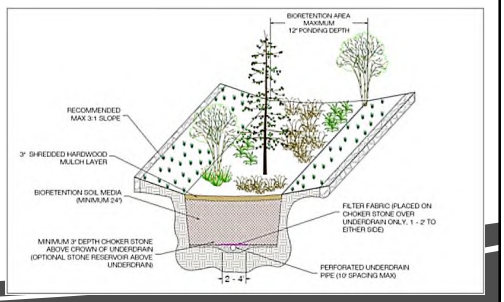
Principles behind pollutant reduction

VA Runoff Reduction has 2 distinct modes of action:

1. Filtering of runoff through vegetation (often combined with 2a)
2. Infiltration
   a) Surface infiltration
   b) Subsurface infiltration



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BMPs where the vegetation also filters the water

- Grass channels
- Bioretention
- Dry swale
- Wet swale
- Constructed wetland
- Wet pond
- Extended detention pond

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BMPs where the vegetation also filters the water

What does it filter?

- Nutrients (N and P)
- Sediment
- Organics
- Metals

How does it filter?

- Uptake
- Breakdown → Temperature/Radiation/ Micro-organisms

BMPs that rely on in infiltration or both

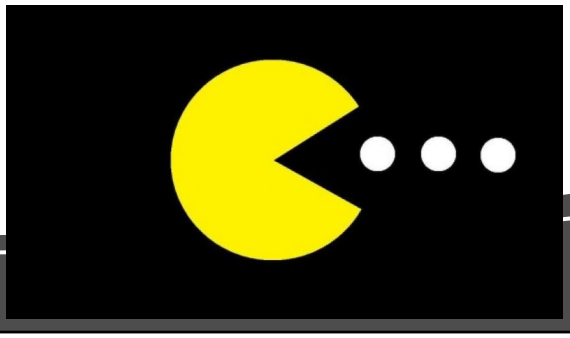
The rest?

Yes, except those that have a permanent pool of water:

- Wet swales
- (Filtering practices)
- Constructed wetlands
- Wet ponds
- Extended detention ponds (level 1)

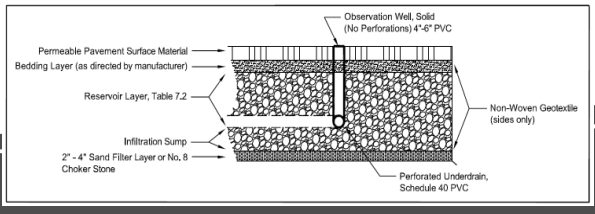
What happens when water (and pollutants) infiltrates?

- Chemical processes
- Physical processes
- Biological processes



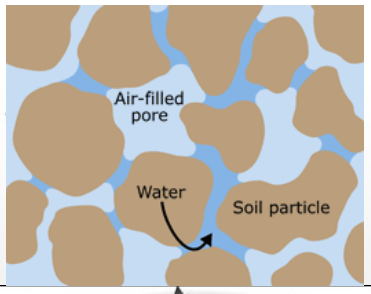
Chemical Processes in the Soil/Media

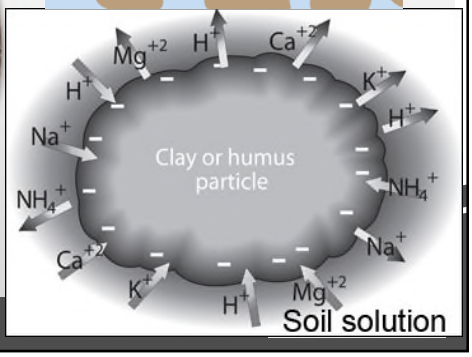
- Some organic compounds break down over time (a.k.a. half-life).
- Chemical processes.
- Under saturated conditions we may have denitrification where nitrate and ammonia is broken down into nitrogen gas and water.



Permeable pavement
Level 2
(81% N removal efficiency)

Physical Processes in the Soil/Media

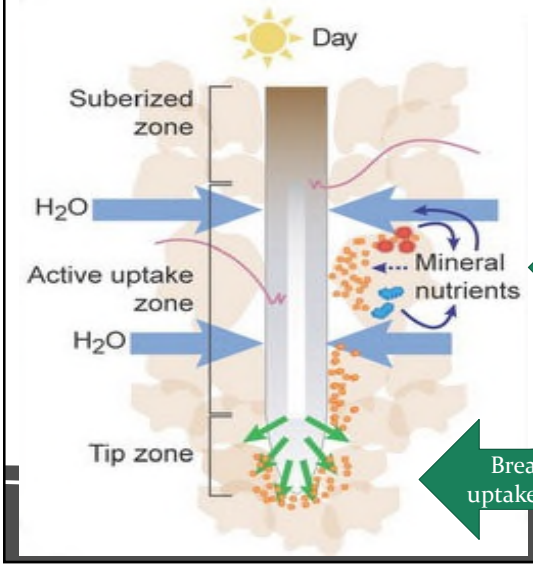




Biological Processes in the Soil/Media

Uptake

Biological Processes in the Soil/Media



Death of bacteria & uptake of nutrients by root

Break down & uptake by bacteria

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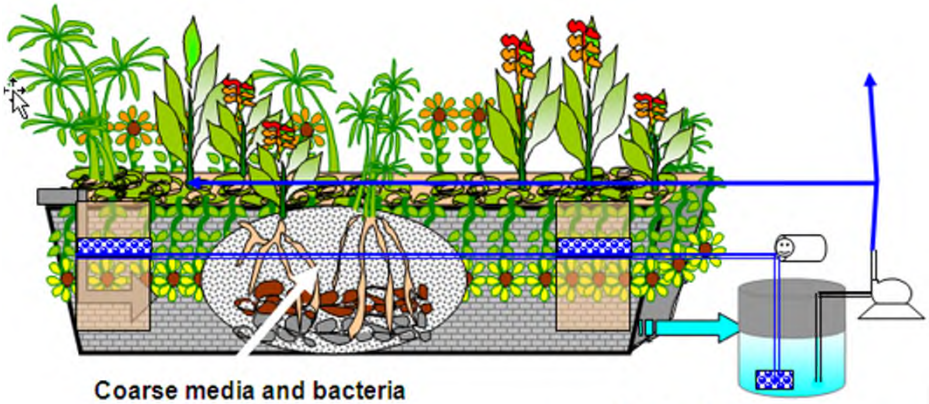
Biological Processes in the Soil/Media

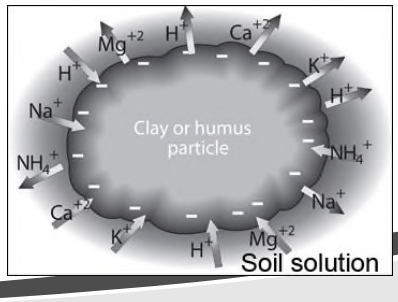


Coarse media and bacteria interacting with roots

Automated Pumps, micro-aerators and passive micron filters for effective treatment

Requirements of a BMP

- Needs plants → unless permeable pavement etc.
- Needs sufficient depth
- Good soil media
- Organic matter
- No restrictive layer



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Just like a tub, a BMP's gotta drain between baths!

Module 3b

Use of compost in runoff reduction BMPs

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Soil Amendments and the BMP Clearinghouse

BMP	Plants		Plants
1. Rooftop disconnection	No*	9. Bioretention	Yes [5]
2. Sheetflow	CA [1]	10. Dry swale	Yes [5]
3. Grass channels	CA [1]	11. Wet swale	No
4. Soil amendments	No	12. Filtering practices	No [6]
5. Vegetated roof	(Yes) [2]	13. Constructed wetland	No
6. Rainwater harvesting	No	14. Wet pond	No
7. Permeable pavement	No [3]	15. Extended detention	No
8. Infiltration	No [4]		

[1] on C and D soils; [2] depends on roof type; [3] reservoir stone depends on pavement type; [4] VDOT No. 1 Stone; [5] bioretention media; [6] sand

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Use of compost (Specification No. 4)

Stormwater Function	HSG Soils A and B		HSG Soils C and D	
	No CA [2]	With CA	No CA	With CA
Annual Runoff Volume Reduction (RR)				
Simple Rooftop Disconnection	50%	NA [3]	25%	50%
Filter Strip	50%	NA [3]	NA [4]	50%
Grass Channel	20%	NA [3]	10%	30%
Total Phosphorus (TP) EMC Reduction[4] by BMP Treatment Practice	0		0	
Total Phosphorus (TP) Mass Load Removal	Same as for RR (above)		Same as for RR (above)	
Total Nitrogen (TN) EMC Reduction by BMP Treatment Practice	0		0	
Total Nitrogen (TN) Mass Load Removal	Same as for RR (above)		Same as for RR (above)	
Channel Protection & Flood Mitigation	**Partial.** Designers can use the RRM spreadsheet to adjust the curve number for each design storm for the contributing drainage area, based on annual runoff volume reduction achieved.			

[1] CWP and CSN (2008), CWP (2007)
[2] CA = Compost Amended Soils,
[3] Compost amendments are generally not applicable for A and B soils, although it may be advisable to incorporate them on mass-graded B soils to maintain runoff reduction rates.
[4] Filter strips in HSG C and D should use composted amended soils to enhance runoff reduction capabilities. See Stormwater Design Specification No. 2: Sheetflow to Vegetated Filter Strip or Conserved Open Space.

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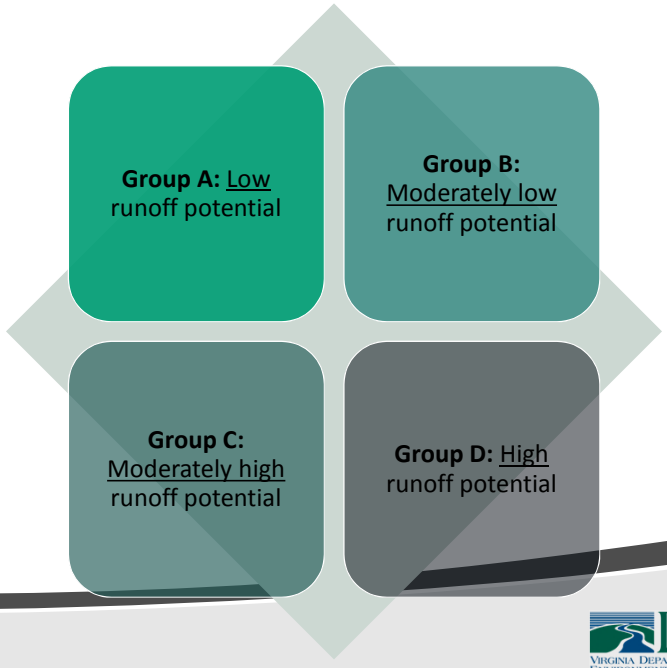

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Use of compost (Specification No. 4)

	Contributing Impervious Cover to Soil Amendment Area Ratio [1]			
	IC/SA = 0 [2]	IC/SA = 0.5	IC/SA = 0.75	**IC/SA = 1.0 [3]**
Compost (in) [4]	2 to 4 [5]	3 to 6 [5]	4 to 8 [5]	**6 to 10 [5]**
Incorporation Depth (in)	6 to 10 [5]	8 to 12 [5]	15 to 18 [5]	**18 to 24 [5]**
Incorporation Method	Rototiller	Tiller	Subsoiler	**Subsoiler**

Notes:
[1] IC = contrib. impervious cover (sq. ft.) and SA = surface area of compost amendment (sq. ft.)
[2] For amendment of compacted lawns that do not receive off-site runoff
[3] In general, IC/SA ratios greater than 1 should be avoided, unless applied to a simple rooftop disconnection
[4] Average depth of compost added
[5] Lower end for B soils, higher end for C/D soils

$$C = A * D * 0.0031$$

Where: C = compost needed (cu. yds.)
A = area of soil amended (sq. ft.)
D = depth of compost added (in.)

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Module 3c

Bioretention Media

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6.6. Filter Media and Surface Cover

General attributes:

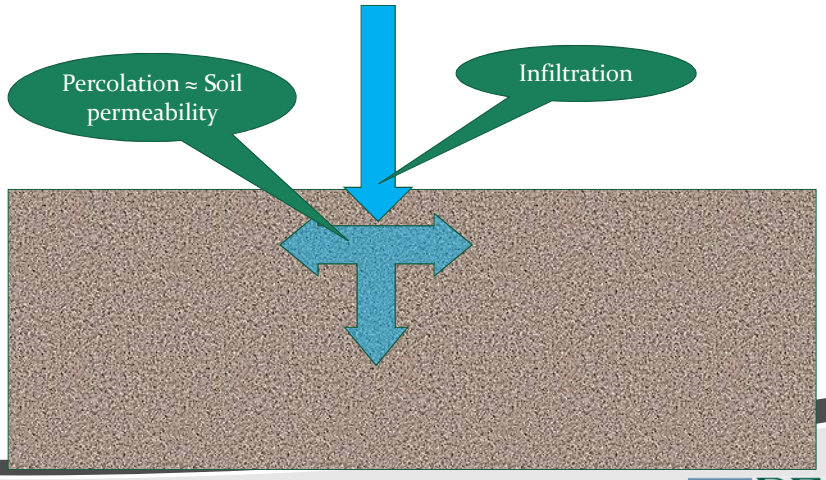
- Infiltration
- Percolation & Permeability
- Porosity
- Physical or Particle Size Composition
- Cation Exchange Capacity (CEC)
- Organic Matter

6.6. Filter Media and Surface Cover

Specialized needs:

- Depth
- Specific requirements for tree planting area
- Mulch
- Turf cover

Infiltration & Permeability



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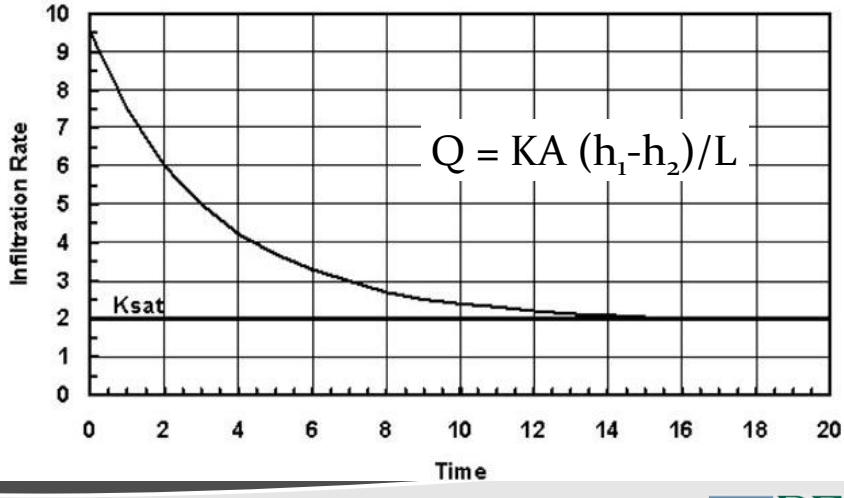
Saturated Hydraulic Conductivity



$Q = KA\ (h_1\text{-}h_2)/L$

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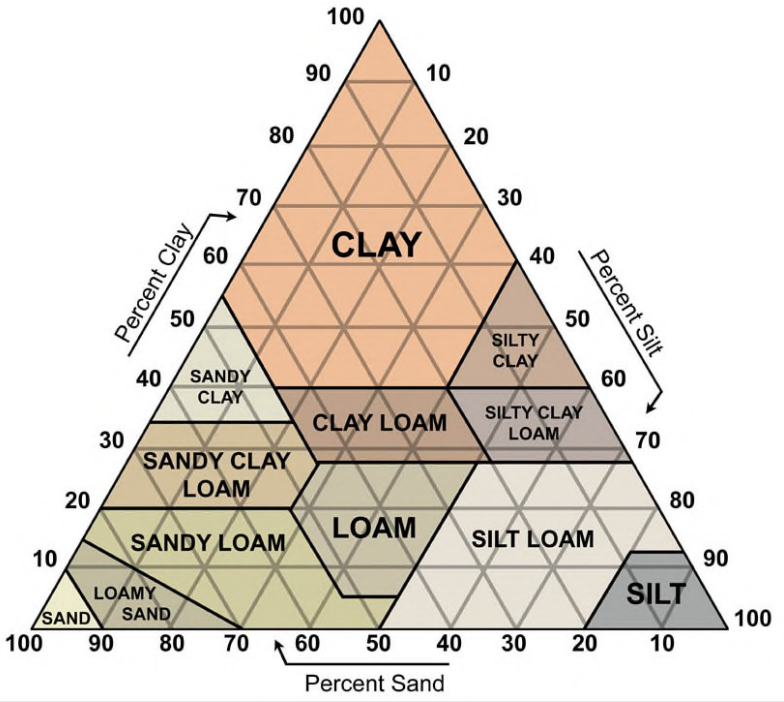
Biorention Mix

Needs to maintain the porosity (Ksat) over the life of the project!

How do we do that?

Develop a mix with a good particle size distribution!



Biorention Mix

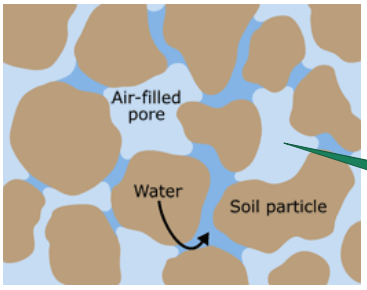
Needs to maintain the porosity (Ksat) over the life of the project!

How do we do that?

Develop a mix with a good particle size distribution!

Optimize void space and keep smaller particles to a minimum.

Biorention Mix



Optimize void space and keep smaller particles to a minimum

Void Space

Smaller particles = clays (>2 microns or 0.002 mm)
silt (between 2 and 50 microns)

Biorention Mix

CLAYS AND SILT ARE THE ENEMIES OF A BIORETENTION MIX/ AREA

Smaller particles = clays (>2 microns or 0.002 mm)
silt (between 2 and 50 microns)

They plug up the void space!

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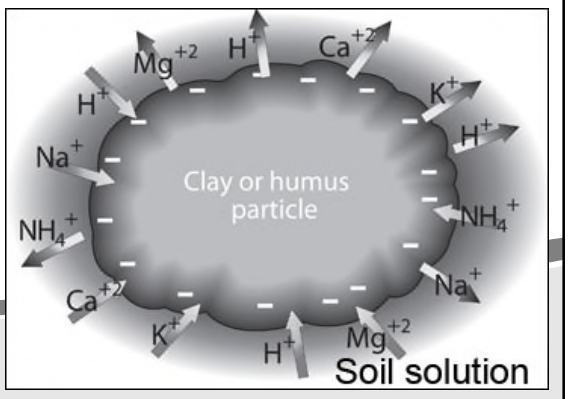
Biorention Mix

But

- Clays and humus are needed for CEC



Biorention Mix requirements

- ***General Filter Media Physical Composition.*** The mineral soil texture of the bioretention soil mix should be loamy coarse sand with no more than 10% clay, no more than 20% silt + clay and at least 75% of the sand fraction should be coarse or very coarse sand.
- To allow for appropriate Cation Exchange Capacity (CEC) and nutrient removal, ***the mix should contain at least 10% soil fines (silt + clay)*** while meeting the overall texture specification above. …..
- The Filter Media should contain ***3% to 5% organic matter*** ……

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Biorention Mix requirements

- Ksat = 1 to 2 inches per hour or 30 to 60 cm per day
- Specific requirements on sand, topsoil and organic matter
- Phosphorus content of the mix (5 to 15 mg/kg Mehlich I or 18 to 40 mg/kg Mehlich III … note ppm=mg/kg)
- 24 (level 1) to 36 (level 2) inches deep, 48 inches deep with trees

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Biorention Mix requirements

- Increase organic matter in tree holes
- 2 to 3 inch layer of mulch at planting
- Alternative mulch cover allowed, i.e., pea gravel
- Some additional compost in the top layer to get grass established is ok.

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LUCK ECOSYSTEMS

Greene Ecosystems
221 Luck Stone Road Ruckersville VA
(844) 228-5534
(844) 228-5534

Customer:

Date/Time: 03/03/2016 11:46 Ref #: 74393 / 248850 Ticket#: 115594
Cust Acct #: 612 Order: ABC MIDDLE SCHOOL P.O. #: ABC MIDDLE SCHOOL
Quotation:
Product: AC0200 : LF Biofilter Media

Job Site Contacts: Joe Smith (222) 555 - 8888
Lot Sample:

Instructions:
ABC MIDDLE SCHOOL--
MATERIAL ONSITE BETWEEN 7AM-4PM** **CALL JOE 30-45 MINS UPON ARRIVAL**

Max Gross:	Gross Scale Wt:	Tare Wt:	Net Wt:	Net Tons:	Material Rate:
84000 lbs	83640 lbs	32200 lbs	51440 lbs	25.72 Shrt	T
				23.33 Mtr	
Truck#:		Hauler::		Haul Rate:	
XYZ TRUCKING		000136	XYZ TRUCKING INC -HAULER	T	

Material
Haul
FSC $0.00

Total Qty Ordered: 5 L
Delivered Today: 129.64 Short tons 117.61 Metric tons 5 Load(s)

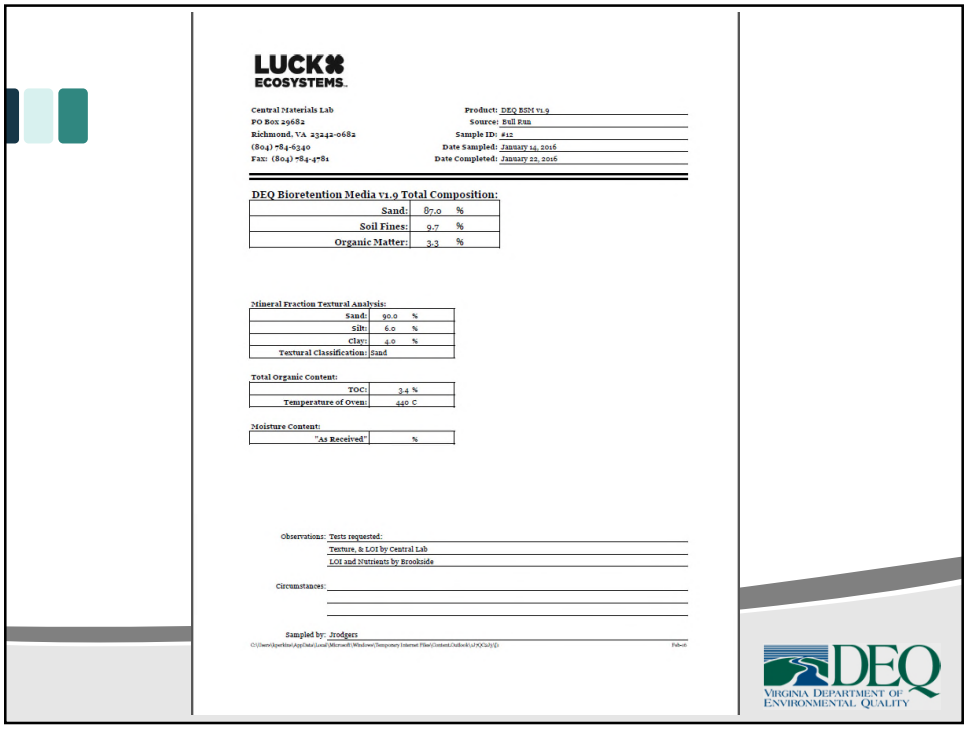
Total Charges:
Sales Tax:
Total:

Delivery is quoted to the curb line. Customer assumes responsibility for any damages beyond that point. All sales and deliveries made subject to seller's general terms & conditions

Weigh Master: jbrakowiecki
Received By: X

SEE PRODUCT WARNING ON REVERSE

Customer 115594



LUCK ECOSYSTEMS

Central Materials Lab
PO Box 29682
Richmond, VA 23242-0682
(804) 784-6340
Fax: (804) 784-4784

Product: DEQ BSM V1.9
Source: Soil Run
Sample ID: #12
Date Sampled: January 14, 2016
Date Completed: January 22, 2016

DEQ Bioretention Media V1.9 Total Composition:

Sand:	87.0	%
Soil Fines:	9.7	%
Organic Matter:	3.3	%

Mineral Fraction Textural Analysis:

Sand:	90.0	%
Silt:	6.0	%
Clay:	4.0	%
Textural Classification:	Sand	

Total Organic Content:

TOC:	3.4	%
Temperature of Oven:	440	C

Moisture Content:

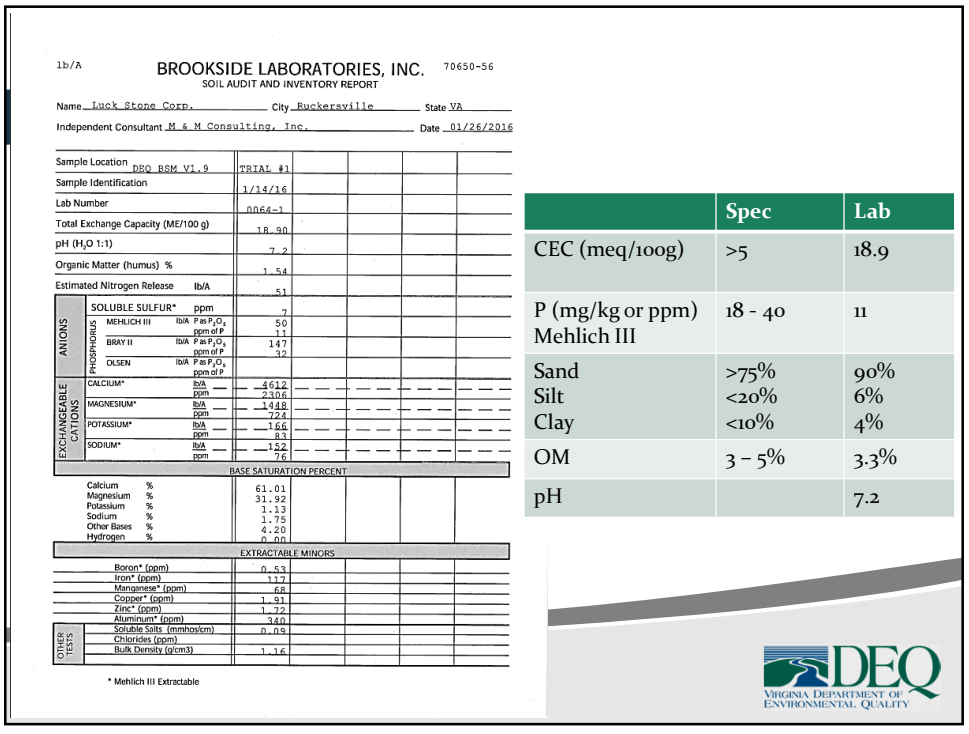
"As Received"	%

Observations: Tests requested:
Texture, & LOI by Central Lab
LOI and Nutrients by Brookside

Circumstances:

Sampled by: JRodgers

DEQ VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY



lb/A

BROOKSIDE LABORATORIES, INC. 70650-56
SOIL AUDIT AND INVENTORY REPORT

Name Luck Stone Corp. City Ruckersville State VA
Independent Consultant M & M Consulting, Inc. Date 01/26/2016

Sample Location		DEQ BSM V1.9	TRIAL #1
Sample Identification			1/14/16
Lab Number			0064-1
Total Exchange Capacity (ME/100 g)			18.90
pH (H_2O 1:1)			7.2
Organic Matter (humus) %			1.54
Estimated Nitrogen Release		lb/A	51
ANIONS	SOLUBLE SULFUR*	ppm	7
PHOSPHORUS	MEHLICH III	lb/A P as P_2O_5	50
		ppm of P	11
	BRAY II	lb/A P as P_2O_5	147
		ppm of P	32
	OLSEN	lb/A P as P_2O_5	
		ppm of P	
EXCHANGEABLE CATIONS	CALCIUM*	lb/A	4612
		ppm	2306
	MAGNESIUM*	lb/A	1448
		ppm	724
	POTASSIUM*	lb/A	166
		ppm	83
	SODIUM*	lb/A	152
		ppm	76
BASE SATURATION PERCENT			
	Calcium	%	61.01
	Magnesium	%	31.92
	Potassium	%	1.13
	Sodium	%	1.75
	Other Bases	%	4.20
	Hydrogen	%	0.00
EXTRACTABLE MINORS			
	Boron* (ppm)		0.53
	Iron* (ppm)		117
	Manganese* (ppm)		68
	Copper* (ppm)		1.91
	Zinc* (ppm)		1.72
	Aluminum* (ppm)		140
OTHER TESTS	Soluble Salts (mmhos/cm)		0.09
	Chlorides (ppm)		
	Bulk Density (g/cm3)		1.16

* Mehlich III Extractable

	Spec	Lab
CEC (meq/100g)	>5	18.9
P (mg/kg or ppm) Mehlich III	18 - 40	11
Sand Silt Clay	>75% <20% <10%	90% 6% 4%
OM	3 – 5%	3.3%
pH		7.2

DEQ VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

2nd Sample

a&lgreatlakes LABORATORIES
Scientists who don't mind getting dirty.™

3505 Conestoga Dr.
Fort Wayne, IN 46808
260.483.4759
algreatlakes.com

To: ROYAL OAK FARM, LLC
1223 ROYAL OAK FARM DR
EVINGTON, VA 24550-4356

For: ROF DCR-9 1-19-16

Report Number: F16033-0013
Account Number: 77522

Attn: KENNETH NEWMAN

SOIL TEST REPORT

Date Received: 2/2/2016
Date Reported: 2/4/2016
Page: 1 of 1

Sample ID	Lab Number	Organic Matter %	Phosphorus Bray-1 Equiv ppm-P	Phosphorus Bray P2 ppm-P	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	Soil pH	Buffer pH	CEC meq/100g	Percent Cation Saturation % K	% Mg	% Ca	% H	% Na
DCR-9	21807	5.4	21 M		381 H	415 L	12250 VH	167 VL	8.5		66.4	1.5	5.2	92.2		1.1

VL = Very Low L = Low M = Medium H = High VH = Very High

Sample ID	Sulfur S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Soluble Salts mmhos/cm	Nitrate NO_3-N ppm	Ammonium NH_4-N ppm	Bicarb-P P ppm				Comments
DCR-9							0.3 VL							

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3505 Conestoga Dr.
Fort Wayne, IN 46808
260.483.4759
algreatlakes.com

To: ROYAL OAK FARM, LLC
1223 ROYAL OAK FARM DR
EVINGTON, VA 24550-4356

For: ROF DCR-9 1-19-16
4 GAR 2016

Report Number: F16033-0013
Account Number: 77522

Attn: KENNETH NEWMAN

REPORT OF ANALYSIS

Date Received: 02/02/2016
Date Reported: 02/04/2016
Page: 1 of 1

Lab Number	Sample ID	Analysis	Result	Unit	Method
21807	DCR-9	Bulk Density	1.10	g/cm3	MSA Part 1 (1983) pp. 374-379
		Sand	82	%	Bouyoucos 1962
		Silt	11	%	Bouyoucos 1962
		Clay	7	%	Bouyoucos 1962
		Soil Textural Classification	Loamy Sand		USDA-NRCS

	Spec	Lab
CEC (meq/100g)	>5	66.4
P (mg/kg or ppm) Mehlich III	18 - 40	21 (15)
Sand Silt Clay	>75% <20% <10%	82% 11% 7%
OM	3 – 5%	5.4%
pH		8.5

Bray 1 = 21 ppm/1.4 =15 ppm (Mehlich III)

pH=8.5 → Low Mn, Fe, Zn, B, P
High Ca, Mo, Na availability

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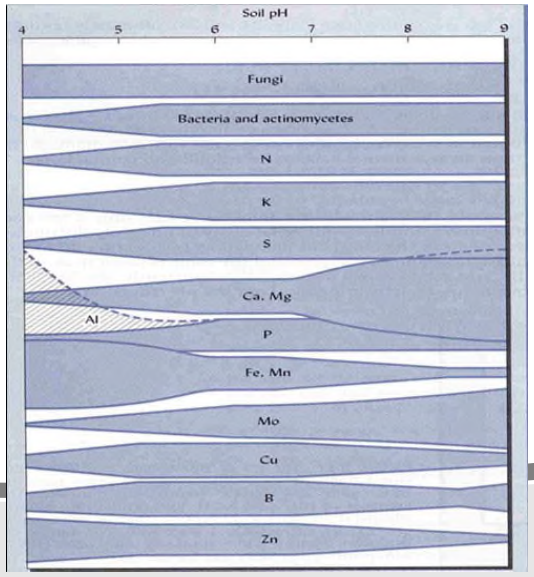
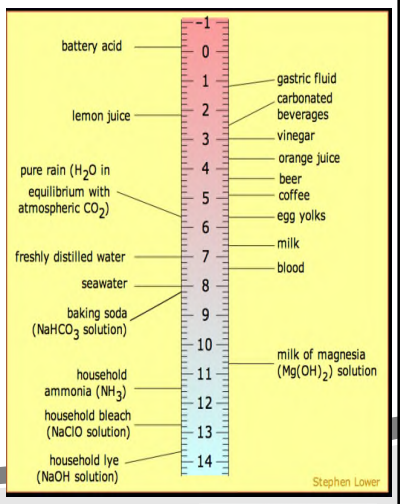
pH





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A quick Google search on bioretention media

- Luckstone (Central VA)
- Yardworks (Central/Tidewater VA)
- Rockydale Quarries (Roanoke)
- Permatill.com (distributors throughout VA)

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Module 3d

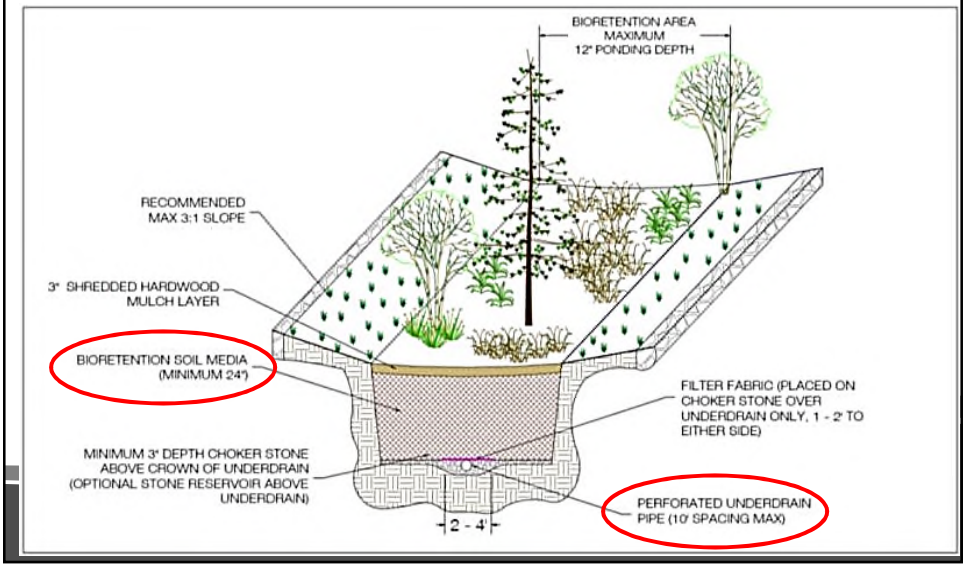
BMPs using Biorention Media

Soil Amendments and the BMP Clearinghouse

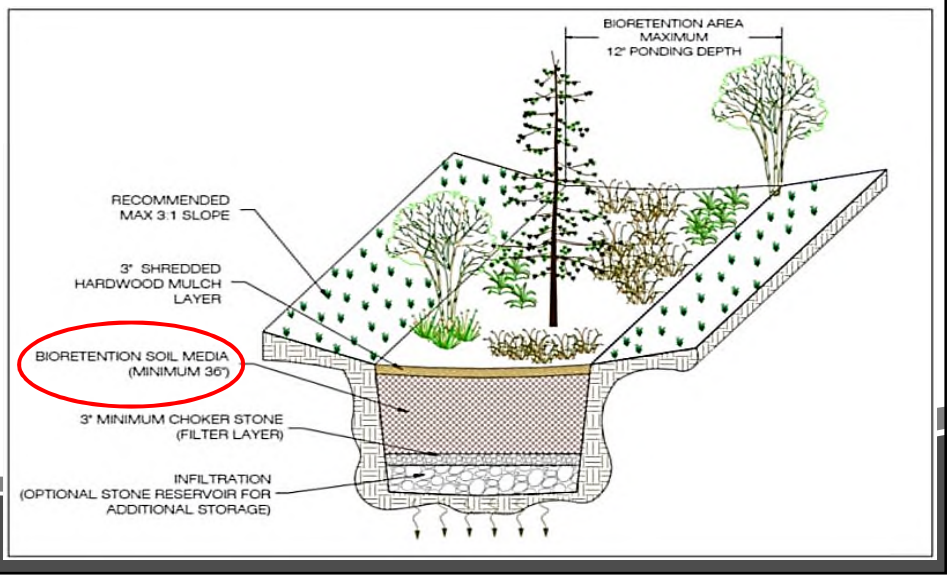
BMP	Plants		Plants
1. Rooftop disconnection	No*	9. Bioretention	Yes [5]
2. Sheetflow	CA [1]	10. Dry swale	Yes [5]
3. Grass channels	CA [1]	11. Wet swale	No
4. Soil amendments	No	12. Filtering practices	No [6]
5. Vegetated roof	(Yes) [2]	13. Constructed wetland	No
6. Rainwater harvesting	No	14. Wet pond	No
7. Permeable pavement	No [3]	15. Extended detention	No
8. Infiltration	No [4]		

[1] on C and D soils; [2] depends on roof type; [3] reservoir stone depends on pavement type; [4] VDOT No. 1 Stone; [5] bioretention media; [6] sand

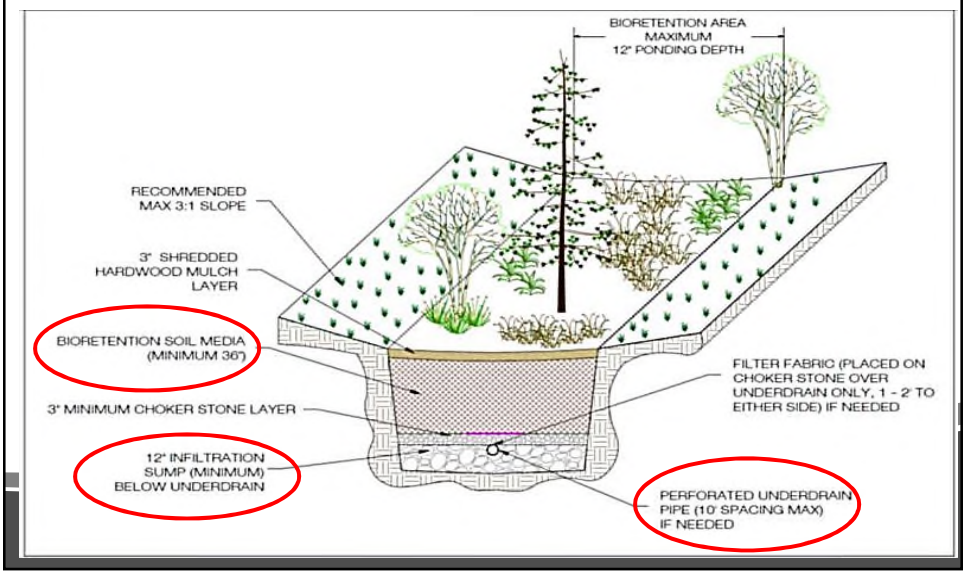
Bioretention (Level 1)



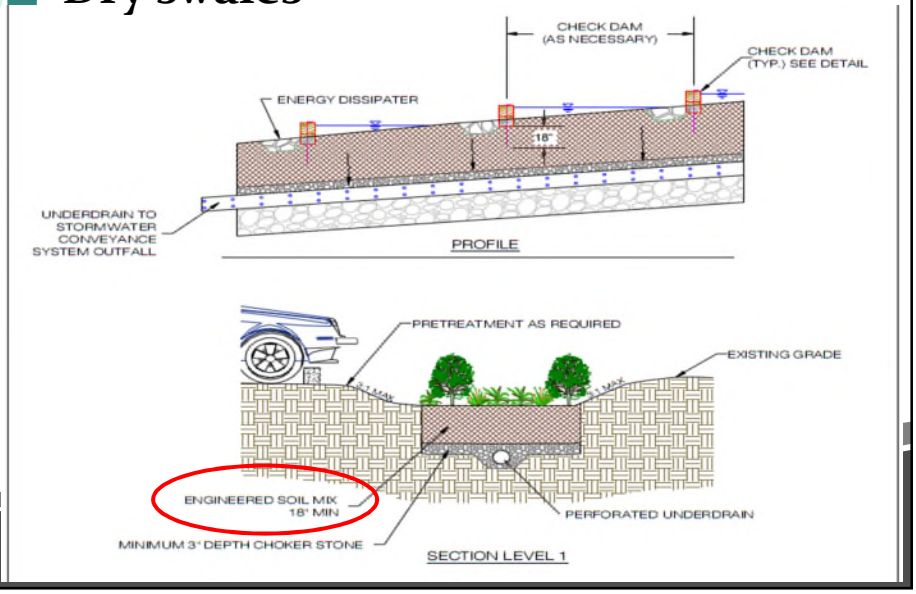
Bioretention (Level 2)



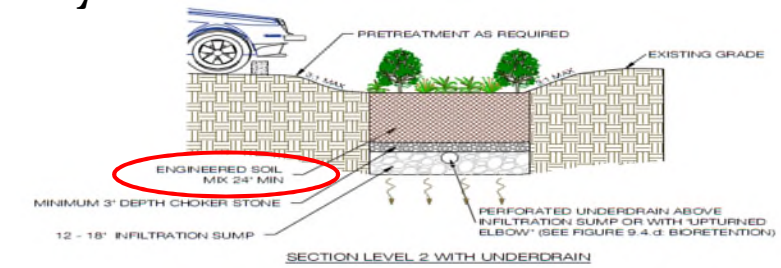
Bioretention (Level 2)



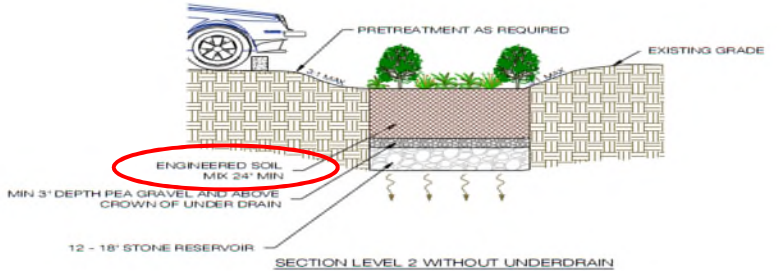
Dry swales



Dry swales



SECTION LEVEL 2 WITH UNDERDRAIN



SECTION LEVEL 2 WITHOUT UNDERDRAIN

ADDITIONAL DESIGN SPECIFICATION

No. 9 Bioretention &

No. 10 Dry Swale

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Applications/Types

Bioretention (Spec 9)

Micro Scale Applications

- Drainage Area = 250 to 2,500 square feet (Mostly impervious)

Typical Scale Applications

Basin Scale: Bioretention Basins

- Impervious Area Treated = Up to 5 acres & 2.5 acres of impervious

Linear Applications: Dry Swale

The BIG 5 Construction Issues

1. Stabilize drainage area
2. Check for Filter Fabric or Choker Stone
3. Verify Soil Media and Depth
4. Make Sure Water Gets to the Inlets
5. Check for Level Filter Bed or Correct Slope for Dry Swales

1. Make Sure Drainage Area is Stabilized. Block Inlets and/or Divert Water if Necessary

2. Check for Choker Stone Layer Between Underdrain & Soil; Filter Fabric on Sides Only (optional)

3. Verify Appropriate Soil Media and Depth

4. Make Sure Water Gets in Inlets!

5. Check for Level Filter Bed

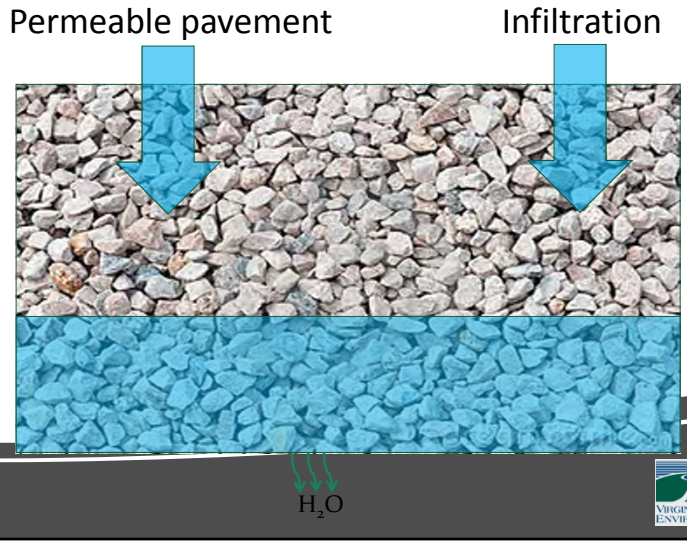
Unlevel filter bed concentrates water in only one area ; uneven filtering

Level filter bed -just like a bathtub - even distribution of flow across surface

Longitudinal Slope for Dry Swales: Possible Use of Check dams

Examples of longitudinal slope with or without check dams

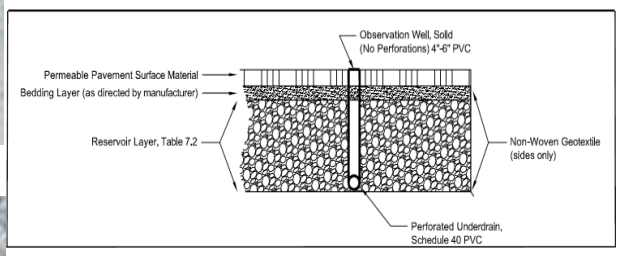
But … Don't forget



Permeable Pavement

Bedding layer: No. 57 stone

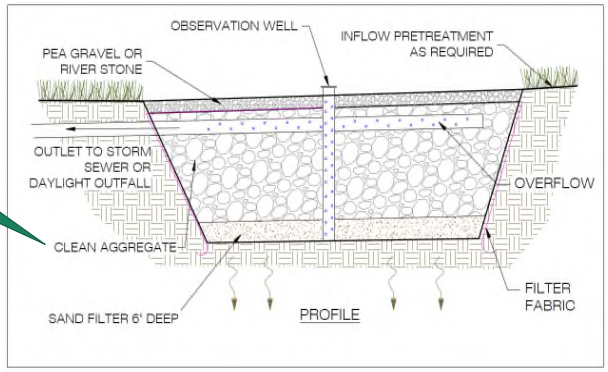
Reservoir layer: No. 2 stone



Level 1 Permeable Pavement

Infiltration Practices

Aggregate layer:
No. 1 stone



Infiltration trench

Module 3e

Inspection Items

The Good

The Good

The Good

The Good

Problems

- Standing water (algae) on surface

Problems

- Erosion in grass filter strip

Problems

Problems

Site visit March 3, 2016
Precipitation in the area since March 1 = 0.9 inches
Time for a bioretention are to drain = 2 days

Problems

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Problems

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Problems

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Problem 2

Problem 2

Problem 2

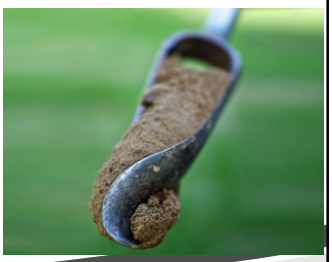
Problems

The issue:

- Plan review might not pick things up ➔ **Inspect after a few storms, but how do you enforce after bond release?**
- Conversion to early in the process ➔ **Construction sequence!**
- Fines filled the pore space ➔ **ESC & Final stabilization!**
- Too much drainage area ➔ **Grading plan!**
- After the fact stabilization did not work ➔ **Who is going to certify this? Start over?**

Some additional reasons Why BMPs fail

- Wrong bioretention mix?
  - Water logged?
  - Restrictions?
- Biorentention mix installed incorrectly?
- Filter cloth in the bottom of the practice?
- Toxicity?
- Underdrain plugged?



How do we test this?

- If not present ask contractor to take photographs of installation
- Soil samples

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Some reasons Why BMPs fail

But the most important questions of all:

1. What is the hydrology of the design and is the site actually draining to the BMP?
2. Does the BMP actually receive the runoff that it was promised?

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After Completion and for Maintenance

- BMPs require a maintenance agreement
- Need a regular maintenance and inspection cycle.

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