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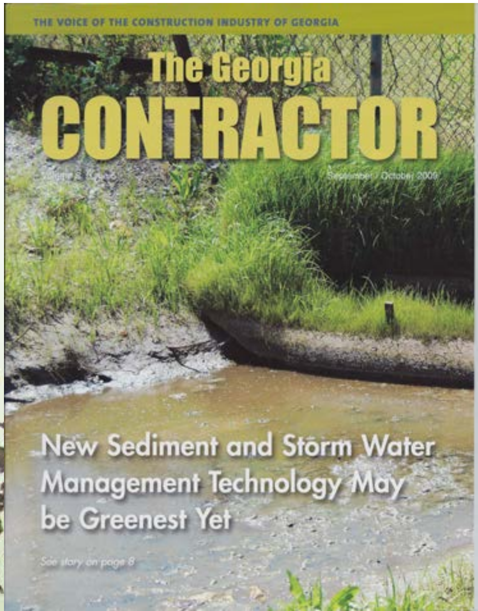
Designing with Nature:
LID & Stormwater Quality Treatment with Compost BMPs

Dr. Britt Faucette, PhD, CPESC, LEED AP
Director of Research/Technical Services,
Filtrexx International

August 7, 2014

Outline

- Stormwater: Gray to Green Infrastructure (LID)
- Compost & Stormwater Volume and Quality
- Compost Applications (BMPs)
- Research, Performance, & Design
- Case Study
- Q/A



Stormwater Impact

- 850 - US cities w/ outdated & under-designed SWM infrastructure
- 75% of Americans live near polluted waters
- 48,800 TMDL listed (impaired) water bodies
- $44,000,000,000 – annual total cost to society

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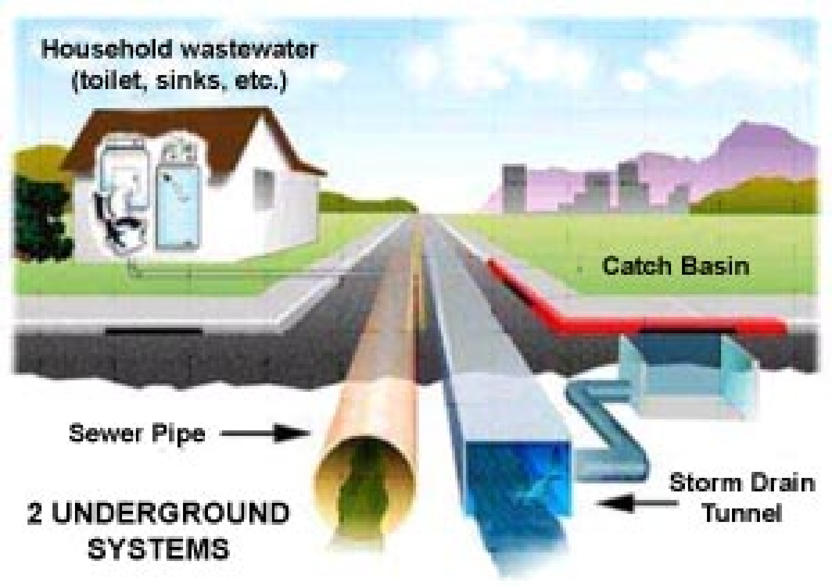
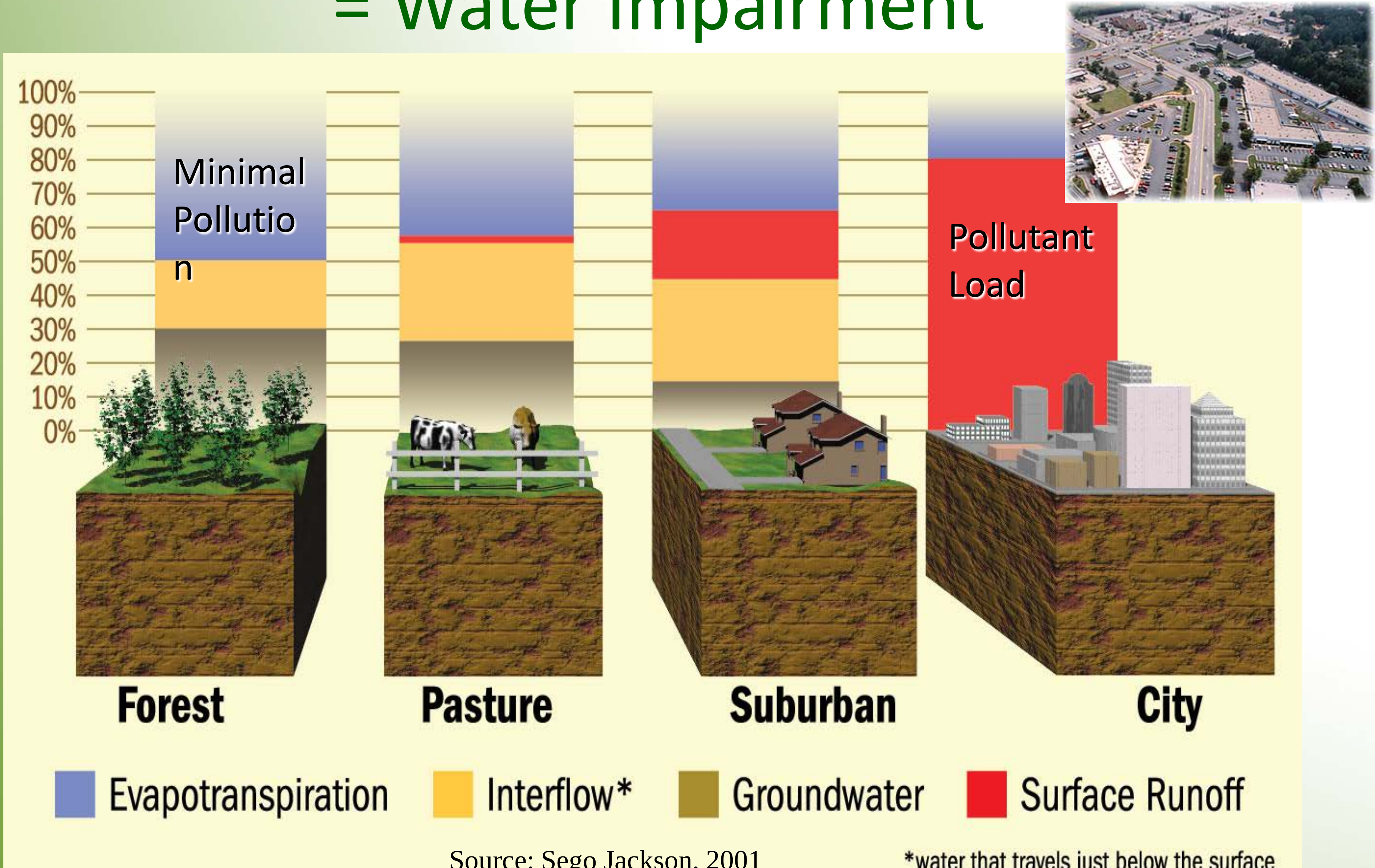
Grey Infrastructure is..$$$$$$



- ✓ Centralize Collection, Conveyance & Treatment
- ✓ Land Intensive
- ✓ Infrastructure Intensive
- ✓ Pollution Intensive
- ✓ Energy Intensive

Chesapeake Bay Foundation

Land Use = Hydrology = Pollutant Load = Water Impairment



Source: Sego Jackson, 2001

75% of Us Live Near a Polluted Water

- Coliform bacteria (10,900 streams)
- Metals – Cu, Cd, Cr, Ni, Pb, Zn (8600 streams)
- Nutrients – N & P (5300 streams)
- Turbidity/TSS - Clay & Fine Silt Sediment (5100 streams)
- Petroleum Hydrocarbons - Motor Oil, Diesel Fuel, Gasoline (polycyclic aromatic hydrocarbons)

Storm Water Pollution Areas

What

- Parking Lots, Highways/Streets, Rooftops
- Golf Courses, Lawns, Pet Parks

Who

- NPDES Stormwater Permits:
- MS4s, Industrial, Construction
- CAFOs, CSOs

Sources

✓Trout/Salmon bearing
✓Endangered species
✓Eutrophic water bodies
✓Beaches/Recreational
✓TMDL designated streams

Priority Areas

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Low Impact Development (LID) =

hydrology mimics natural site, distributed, decentralized

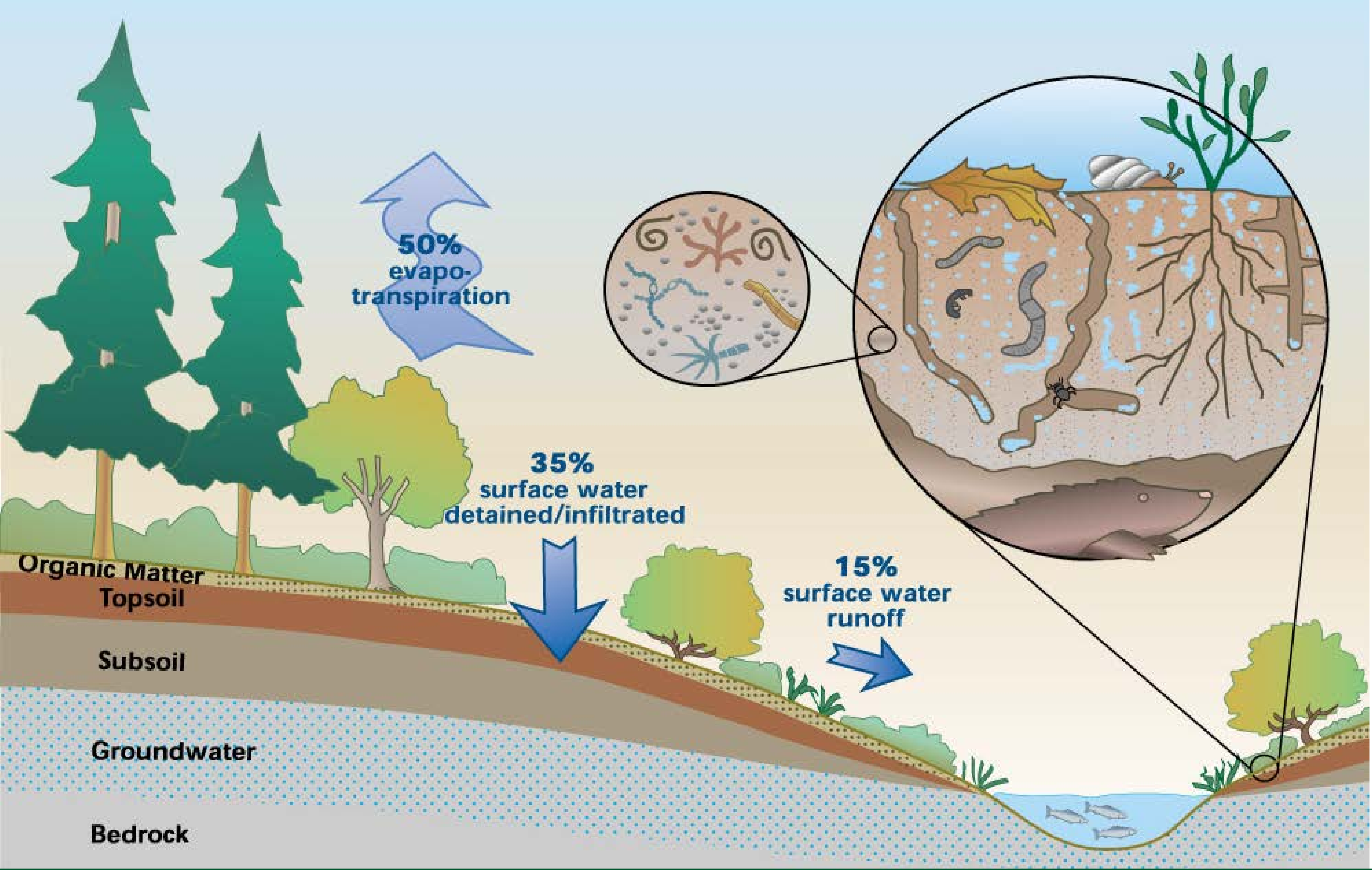
- Runoff Volume ⬇
- Runoff Rate ⬇
- Pollutant Loading ⬇
- Flooding ⬇
- CSOs ⬇

✓ *Water Quality* ⬆

✓ *Wildlife Habitat/Biodiversity* ⬆

✓ *Aesthetics/Land Value* ⬆

Green Infrastructure = green stormwater management; site preservation/restoration; integrated design & practices; reuse



Low Impact Development (LID) =
restore natural site hydrology; decentralize

Compost Tools

Filter Media

- Designed for Optimum Filtration & Hydraulic-flow

Growing Media

- Designed for Optimum Water Absorption & Plant Growth

Stormwater BMPs

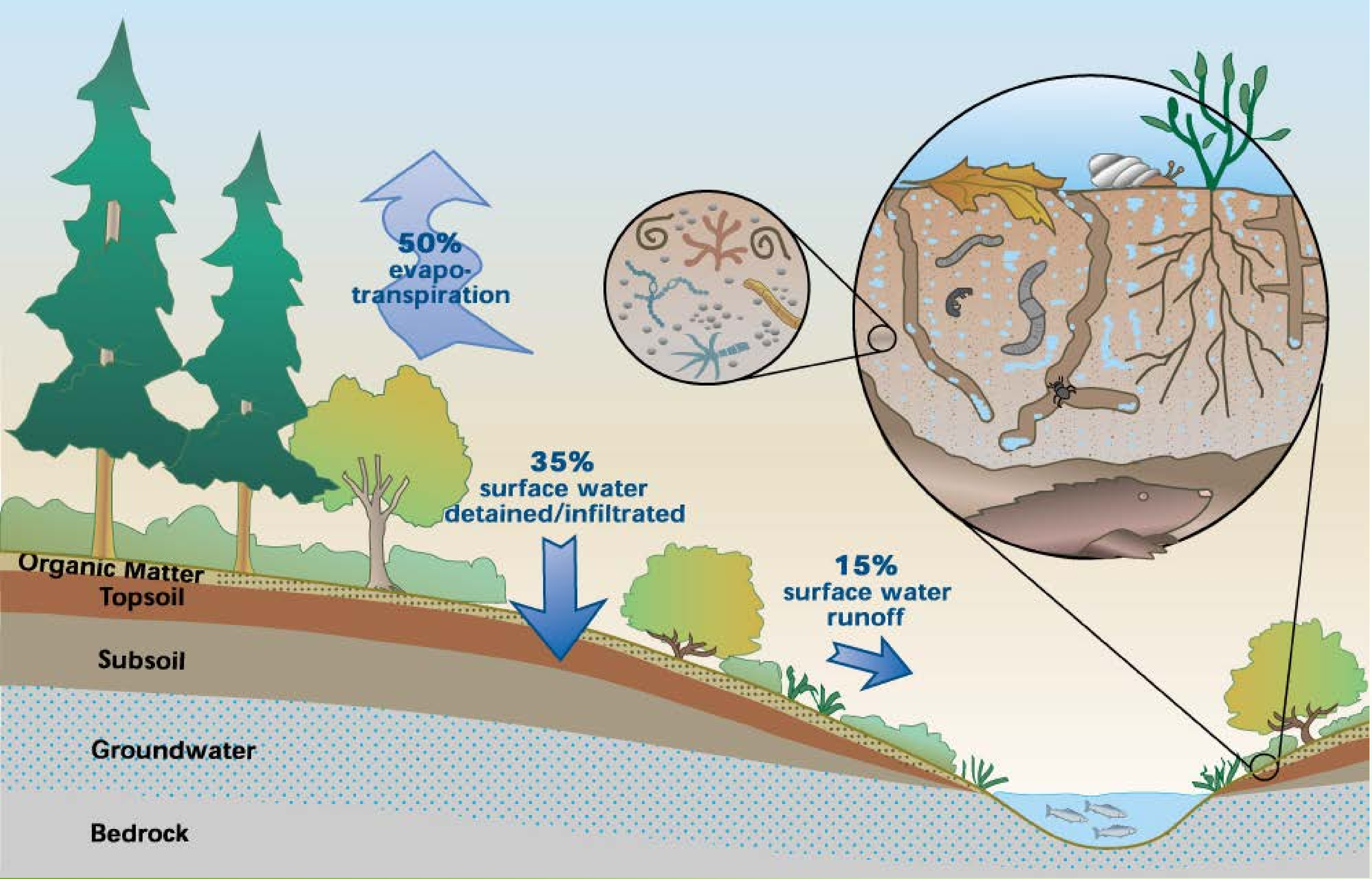
Erosion & Sediment Control

1. Perimeter Control
2. Inlet Protection
3. Ditch Check
4. Filter Ring/Concrete washout
5. Slope Interruption
6. Runoff Diversion
7. Vegetated Cover
8. Erosion Control Blanket
9. Vegetated Sediment Trap
10. Pond Riser Pipe Filter

Low Impact Development

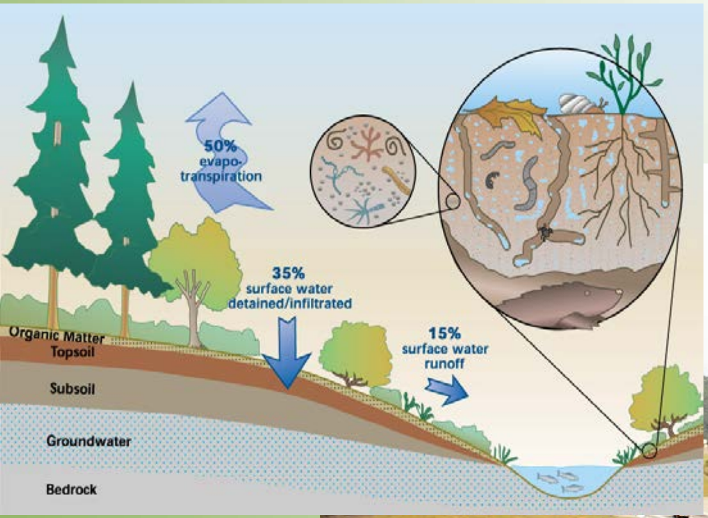
11. Runoff Control Blanket
12. Vegetated Filter Strip
13. Engineered Soil
14. Channel Liner
15. Streambank Stabilization
16. Biofiltration System
17. Bioretention System
18. Green Roof System
19. Living Wall
20. Green Retaining Wall
21. Vegetated Rip Rap
22. Level Spreader
23. Green Gabion
24. Bioswale

Natural Stormwater Management




10.30.2001

Runoff + Erosion Control



Designed to: 1) dissipate energy of rain impact; 2) hold, infiltrate & evaporate water; 3) slow down/disperse energy of sheet flow; 4) provide for optimum vegetation growth

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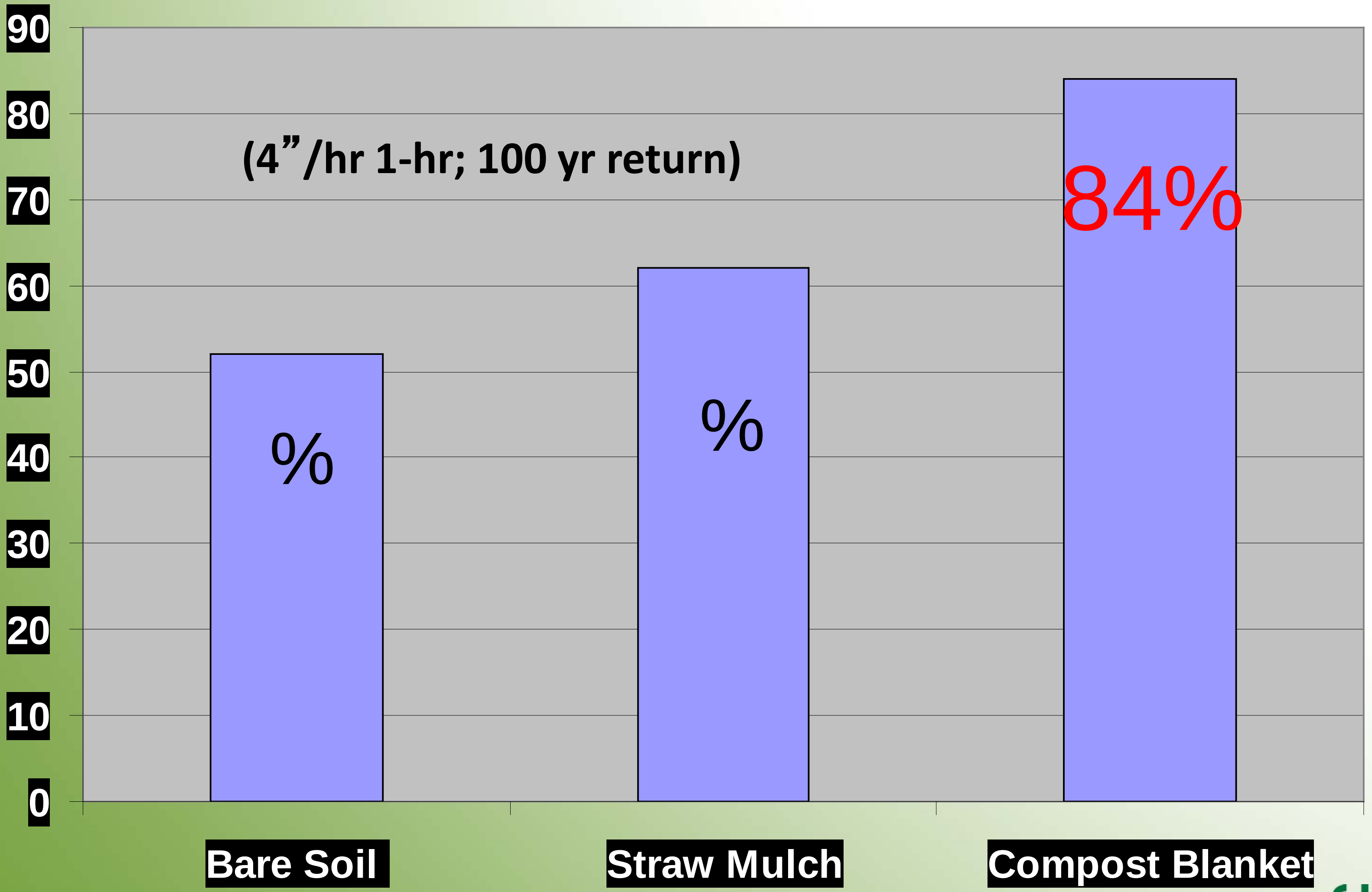
LID: Rainfall Absorption



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Runoff Volume Reduction

Reduction	Influencing Factors	Reference
49%	Sandy clay loam, 10% slope, 1.5” blanket, 3.2 in/hr – 1 hr rain	Faucette et al, 2005
60%	Sandy clay loam, 10% slope, 1.5” blanket, 4.0 in/hr – 1 hr rain	Faucette et al, 2007
76%	Silty sand, 2:1 slope, 3” blanket, 1.8 in/hr - 2.4 hr rain	Demars et al, 2000
90%	Loamy sand, 3:1 slope, 2” blanket, 4.0 in/hr – 2 hr rain	Persyn et al, 2004

Peak Flow Rate Reduction

Reduction	Influencing Factors	Reference
36%	Sandy clay loam, 10% slope, 1.5" blanket, 3.2 in/hr – 1 hr rain	Faucette et al, 2005
42% **(30% relative to straw)**	Sandy clay loam, 10% slope, 1.5" blanket, 4.0 in/hr – 1 hr rain	Faucette et al, 2007
79%	Loamy sand, 3:1 slope, 2" blanket, 4.0 in/hr – 2 hr rain	Persyn et al, 2004

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Pollutant Load Reduction:

Compost Blanket vs Conventional Seeding

	Total N	Nitrate N	Total P	Soluble P	Total Sediment
Mukhtar et al, 2004 (seed+fertilizer)	88%	45%	87%	87%	99%
Faucette et al, 2007 (seed+fertilizer)	92%	ND	ND	97%	94%
Faucette et al, 2005 (hydromulch)	58%	98%	83%	83%	80%
Persyn et al 2004 (seed+topsoil)	99%	ND	99%	99%	96%

Peak Flow Rate Reduction

Reduction	Influencing Factors	Reference
36%	Sandy clay loam, 10% slope, 1.5" blanket, 3.2 in/hr – 1 hr rain	Faucette et al, 2005
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Runoff Curve Numbers

Watershed Surface	Curve Number*
Parking lot, driveway, roof	98
Commercial district	92
Dirt road	82
Residential lot: ¼ ac, ½ ac, 1 ac	75, 70, 68
Cropland	71-81
Pasture	61-79
Public green space	61-69
Woodland and forests	55-66
Brush >75% cover	48
Vegetated Compost Blanket	55

*Based Hydrologic Soil Group B

Reference: USDA SCS, 1986

Ecosystem Services:
Economics of Grey vs Green SWM

- Compost Blanket vs Impervious Surface
- Area = 10 acres
- Design Storm = 3 in/24 hr

✓ Stormwater Volume = 54,300 vs 752,100 gallons (1400% increase!)

- **<u>Option 1: Containment/Pond:</u>**
- Real Estate Value = $50,000/acre
- SW Pond Design/Construction = $1/gal

✓ Stormwater Pond (4 ft deep) = 0.5 acre

- - $25,000 (lost usable real estate)

✓ Stormwater Pond Cost = $697,800 (design/construction)

- TOTAL = $722,800

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Ecosystem Services:

Economics of Grey vs Green SWM

- Compost Blanket vs Impervious Surface
- Area = 10 acres
- Design Storm = 3 in/24 hr

✓ Stormwater Volume = 54,300 vs 752,100 gallons (1400% increase!)

- **<u>Option 2: Off-Site Discharge (Grid):</u>**
- Water Conveyance Cost = $0.26/gal
- Water Treatment Energy Cost = 2 kWh/1000 gal
- Energy Cost = $0.13/kWh
- Carbon Emission = 2 lbs CO2/kWh

✓ Water Conveyance = $181,428/yr
✓ Energy Cost = $91/year
✓ Carbon Emission = 1,396 lbs/CO2/yr

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Stormwater BMPs

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Sediment Control/ Stormwater BMPs

- Silt Fence
- Straw Bale
- Mulch Berm
- Fiber Rolls
- Straw Wattles
- Filtration
- Chemical Treatment
- Stormwater Ponds

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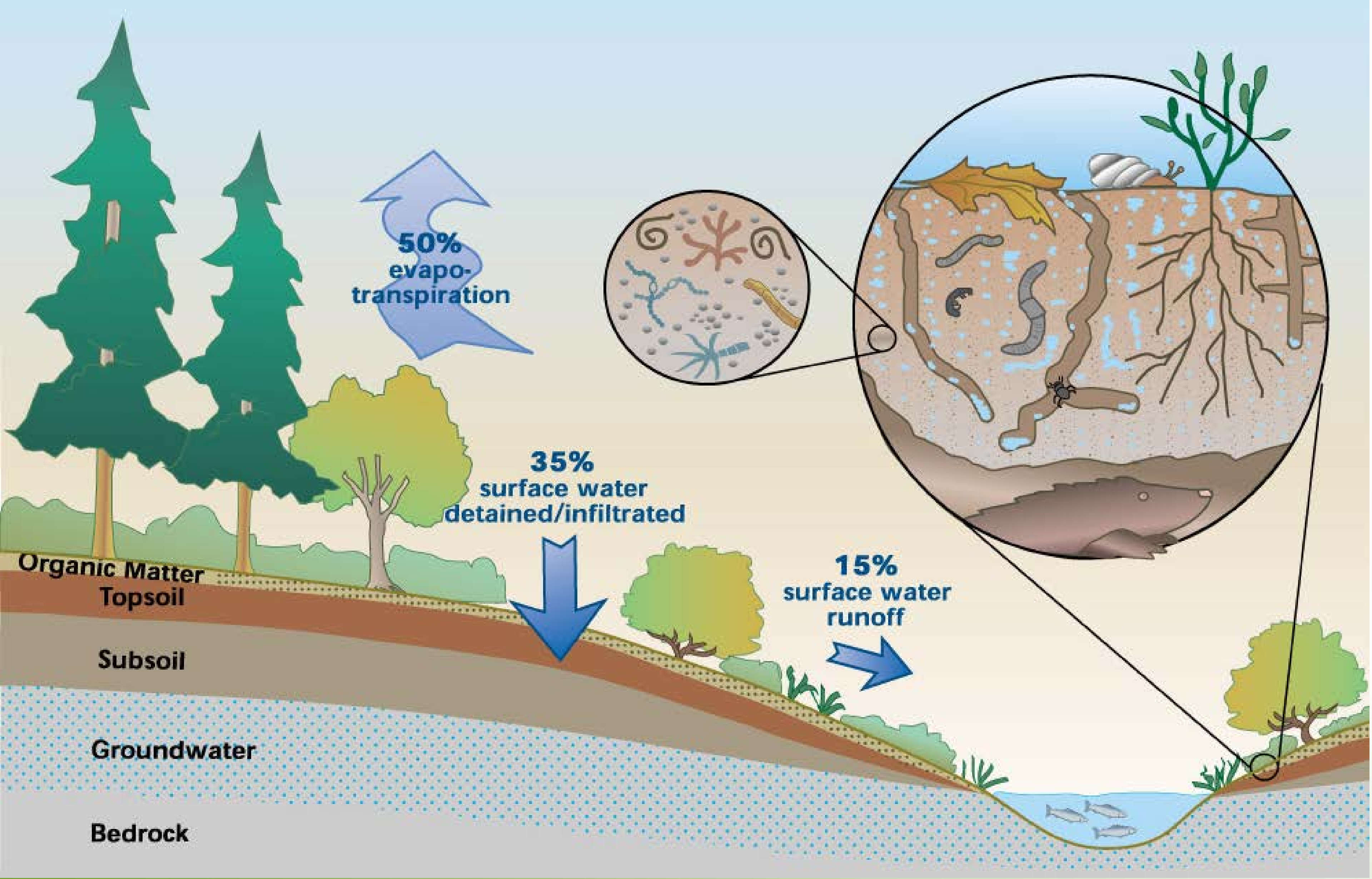
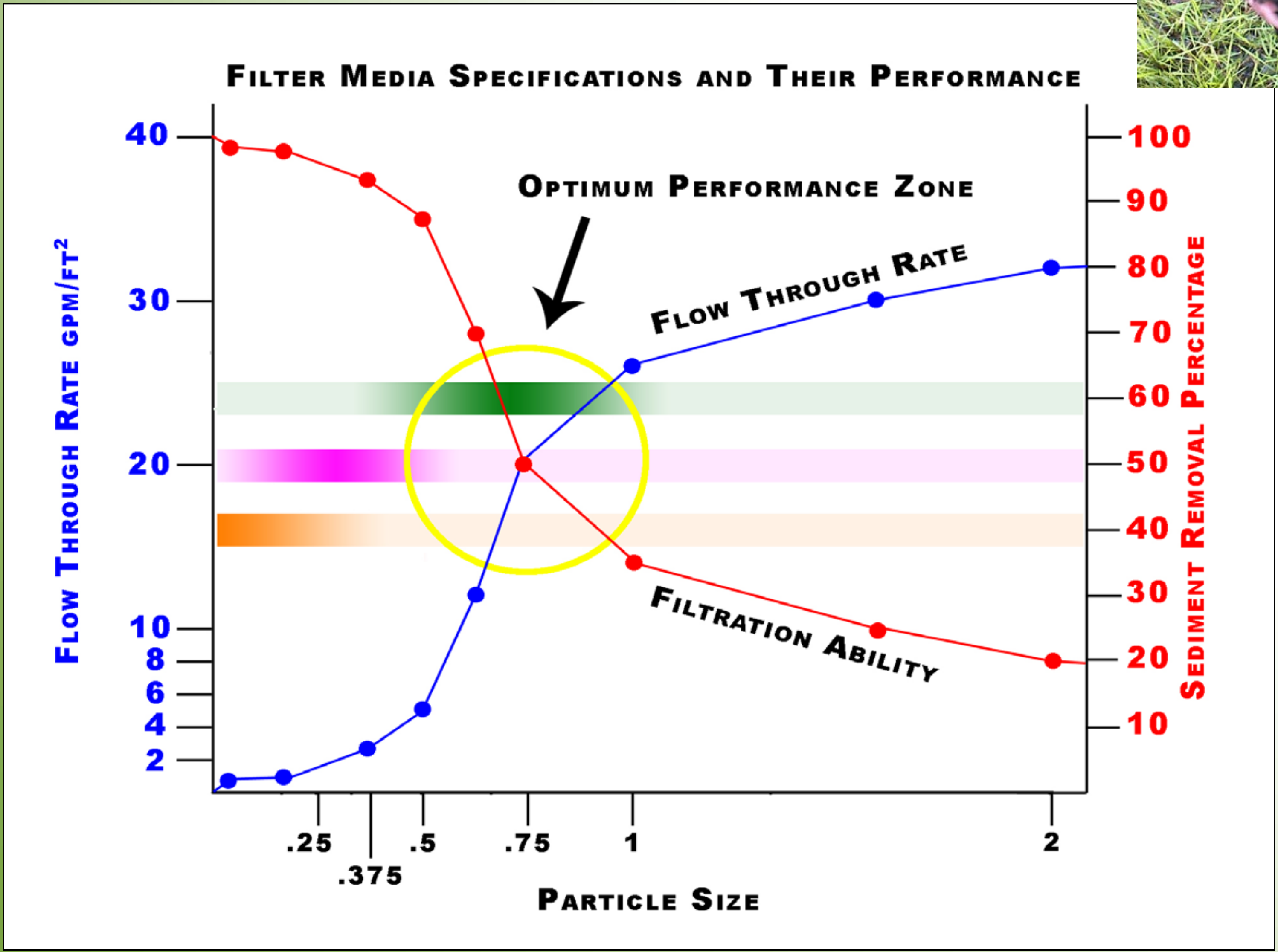
Natural Stormwater Management



Compost Sock
3-Way Biofiltration

- Physical
  - Traps sediment in matrix of varying pore spaces and sizes
- Chemical
  - Binds and adsorbs pollutants in storm runoff
- Biological
  - Degrades various compounds with bacteria and fungi

Particle Size Specifications



(Bio)Filtration Devices use Filter Media

TS Reduction of Sediment Barriers

San Diego State University	Runoff Exposure	Sediment Exposure	Removal
Filter Sock	•260 gal •1.7 g/ft^2 •2.75 ac-in	•850 lbs •150 lbs/ft^2 •125 t/a	77%
Silt Fence	•260 gal •1.7 g/ft^2 •2.75 ac-in	•850 lbs •150 lbs/ft^2 •125 t/a	72%
Straw Wattle	•260 gal •1.7 g/ft^2 •2.75 ac-in	•850 lbs •150 lbs/ft^2 •125 t/a	59%

ASTM 6459 for RECPs

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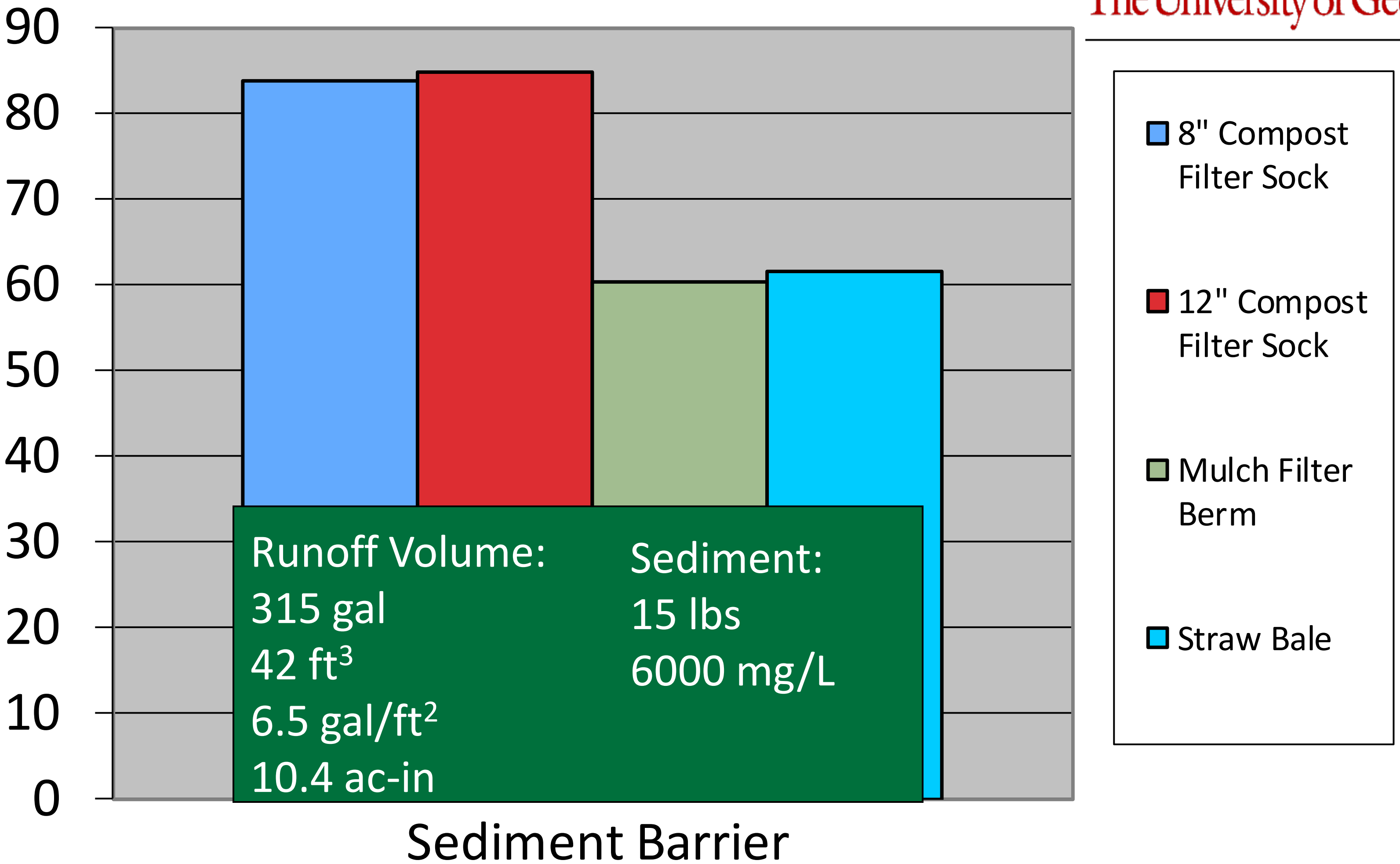
% TSS Reduction of Sediment Barrier

The University of Georgia



Sediment Summary

% Reduction of TSS & Turbidity

Treatment	TSS	Turbidity
Silt Fence	67	52
Filter Sock	78	63

* Based on rainfall of 3.0 in/hr for 30 min; runoff sediment concentration (sandy clay loam) of 70,000 mg/L.

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Stormwater Pollutant Removal

	TSS	Turbidity	Total N	NH_4-N	NO_3-N	Total P	Sol. P	Total coli.	E. coli.	Metals	Oil	Diesel
Filter Sock	80%	63%	35%	35%	25%	60%	92%	98%	98%	37-78%	99%	99%

Stormwater Pollutant Removal w/ Filter Socks

- Britt Faucette[1], Fatima Cardoso[1&2], Eton Codling[2], Carrie Green[2], Dan Shelton[2], Yakov Pachepsky[2], Gregory McCarty[2], Andrey Guber[2]
  1. Filtrexx International, Atlanta, GA;
  2. USDA-ARS, Beltsville, MD

Compost + Additives

- To target specific runoff pollutant
  - Fine Sediment
  - Nutrients (N & P)
  - Bacteria
  - Metals
  - Petroleum Hydrocarbons

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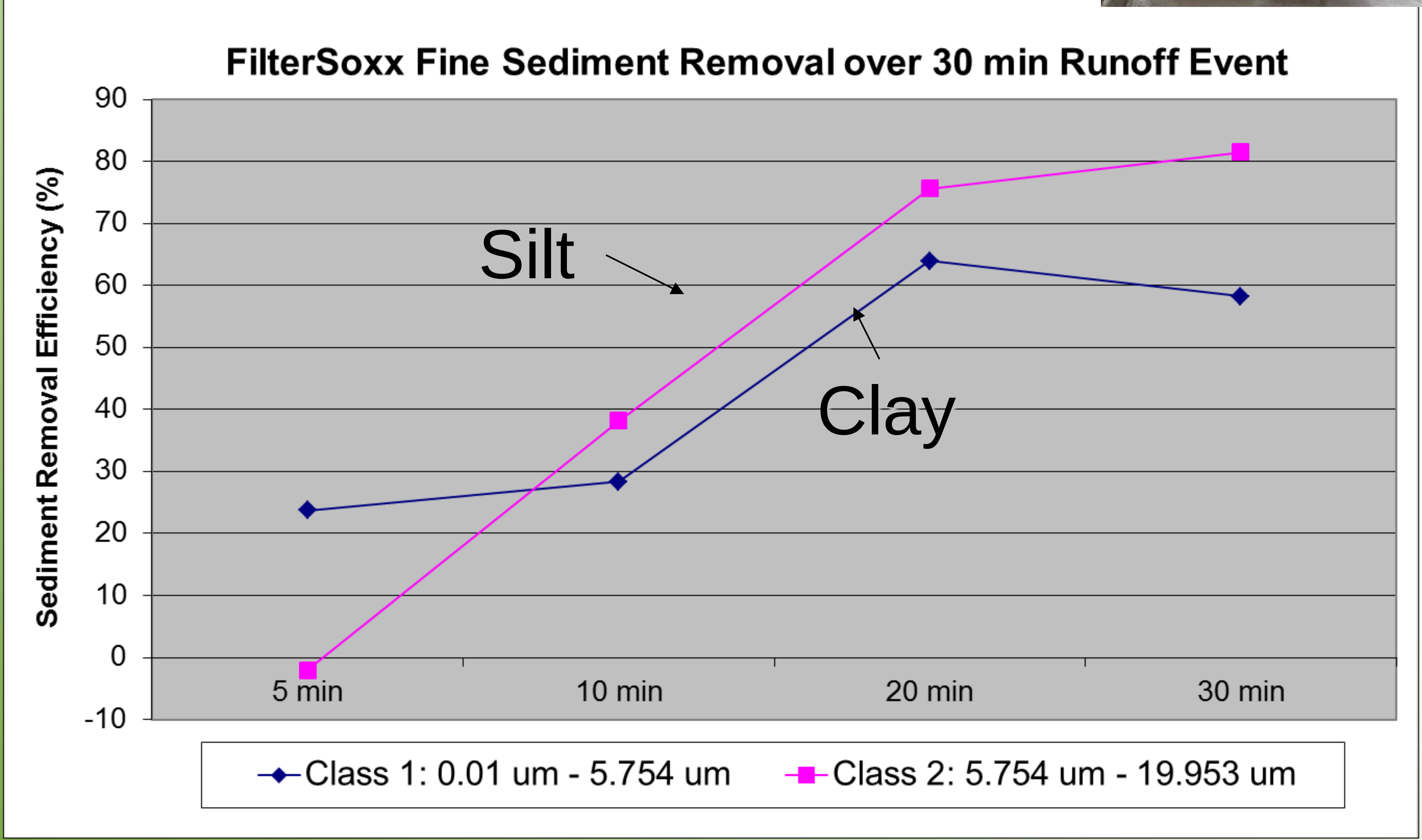
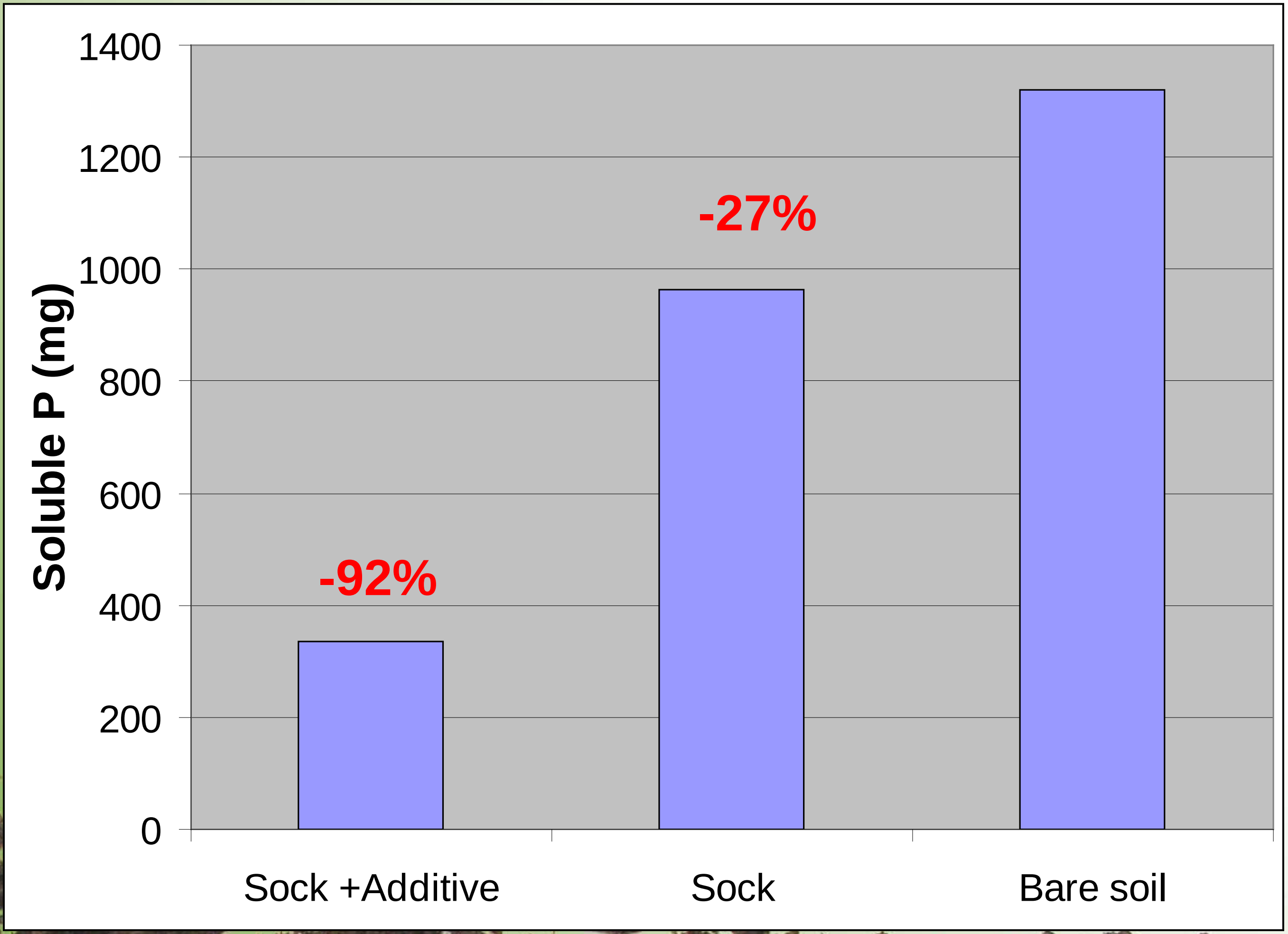
Fine Sediment Removal

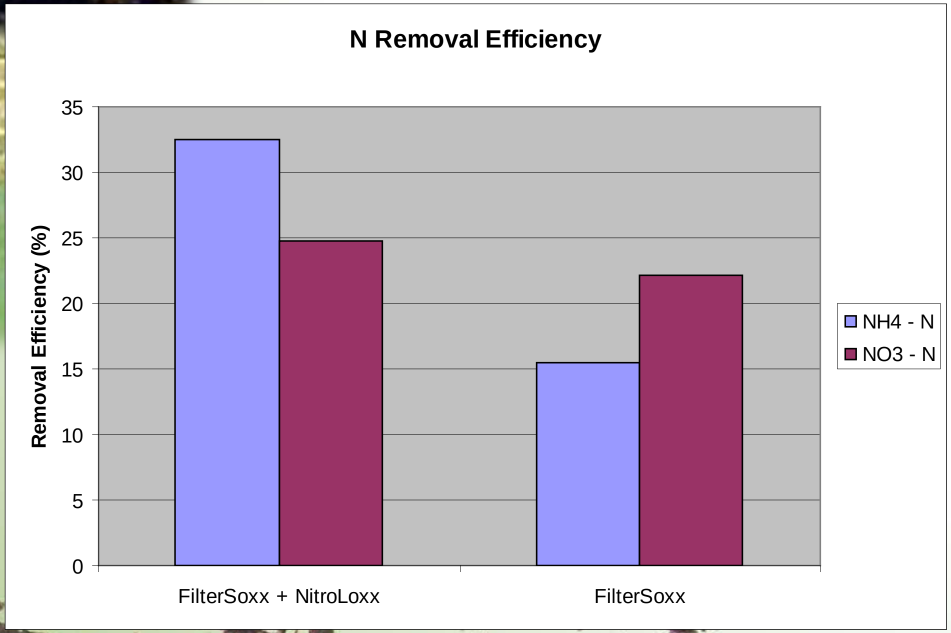


Soluble P



Soluble P (mg)
1400
1200
1000
800
600
400
200
0
-92%
-27%
Sock +Additive
Sock
Bare soil

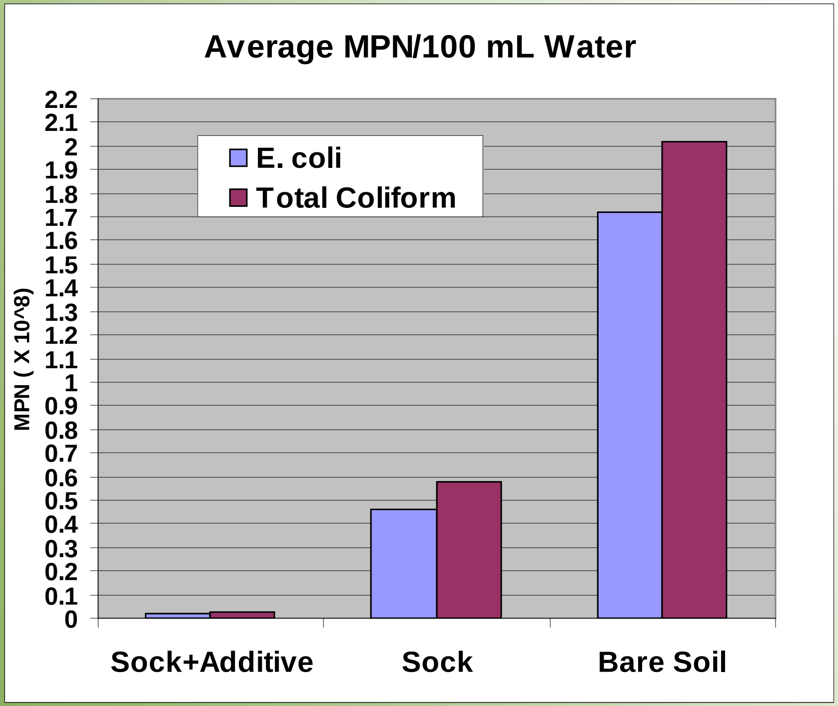
Nitrogen Removal

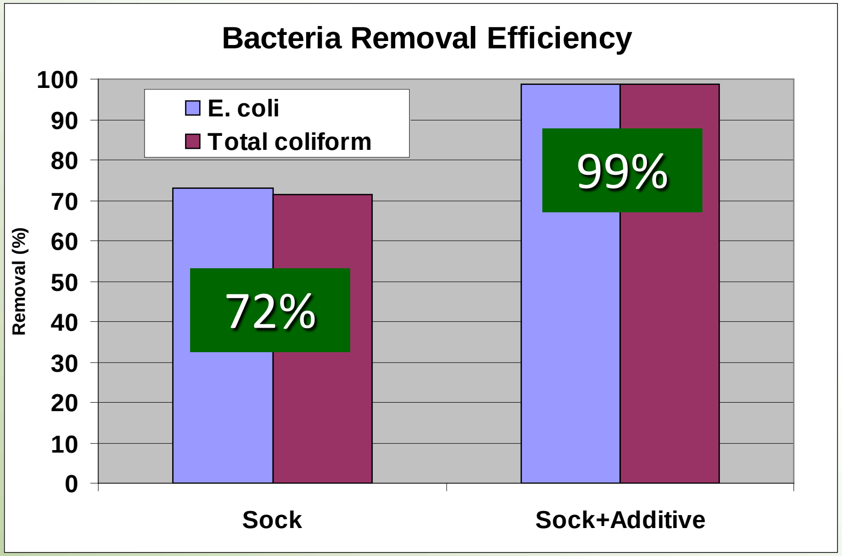


+ Additive

Filter Sock

Bacteria Removal





Bacteria (MPN) Exposure

- Total coliform – 200 million/100 mL
- E. coli – 170 million/100 mL
- *Typical* – 50,000/100 mL

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Metals Removal

		METALS (water extractable)					
Treatment	**Parameters (mg)**	**Cd**	**Cr**	**Cu**	**Ni**	**Pb**	**Zn**
FS + MetalLoxx	Applied	7.915	6.740	7.320	8.070	6.025	6.545
	Soil Surface	0.004	0.019	6.491	0.144	0.154	2.028
	Total	7.919	6.759	13.811	8.214	6.179	8.573
	Transported to Soxx	0.812	0.490	1.640	1.056	0.937	1.669
	Runoff Water	0.210	0.221	0.383	0.301	0.144	0.621
	Removal Efficiency*	**72**	**29**	**70**	**69**	**79**	**57**
	Runoff Sediment	0.014	0.039	0.122	0.029	0.105	0.161
	Removal Efficiency*	**77**	**78**	**45**	**63**	**61**	**47**
	Total Runoff	0.224	0.260	0.505	0.330	0.249	0.782
	Removal Efficiency (%)	**73**	**47**	**70**	**69**	**73**	**53**

*Relative to Bare Soil w/out Treatment

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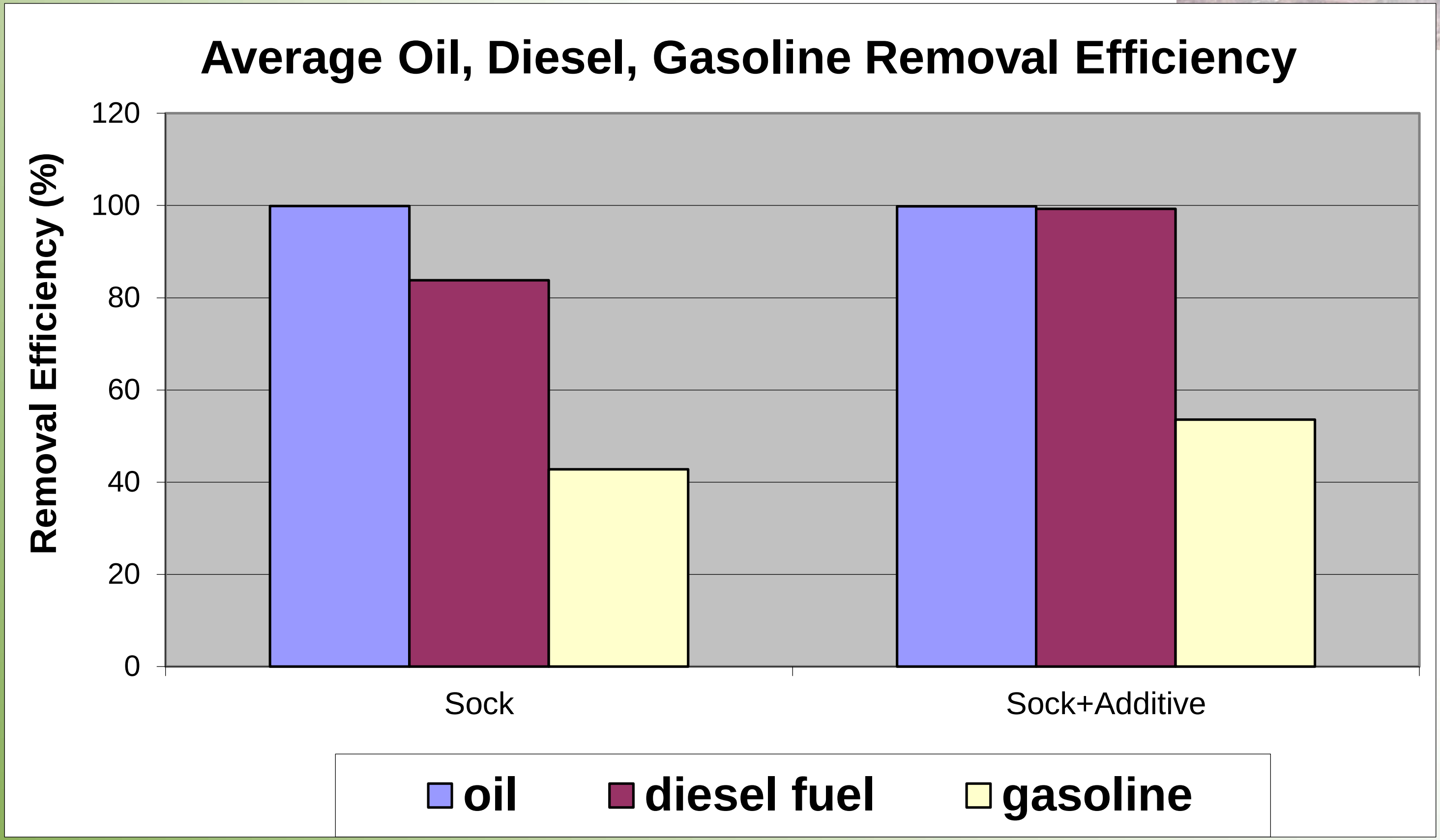
Petroleum Hydrocarbons



- Runoff Concentrations = 1,400 mg/L (motor oil), 5,400 mg/L (diesel), and 74 mg/L (gasoline)
- Runoff Loads = 20,820 mg (motor oil), 77,440 mg (diesel), and 1070 mg (gasoline)

City of Chattanooga

Analysis	2-1-2007 (Pre-retrofit)	6-8-2007	8-30-2007	12-13-2007	3-19-2008	1-28-2009	7-28-2009	% Reduction
COD	1600 mg/L	259 mg/L	255 mg/L	125 mg/L	125 mg/L	405 mg/L	214 mg/L	**75-93**
TSS	1370 mg/L	208 mg/L	38 mg/L	18 mg/L	24 mg/L	249 mg/L	177 mg/L	**82-99**
Oil/Grease	107 mg/L	27 mg/L	N/A	N/A	5 mg/L	18 mg/L	37 mg/L	**65-95**

Table of Contents

24 Compost-Based BMPs Inside

"…. an essential tool for engineers, designers, architects, regulators, planners, managers, contractors, consultants, policymakers, builders, and water resource managers." – *Forester Press*

Contact Me

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  Director of Research/Technical Services

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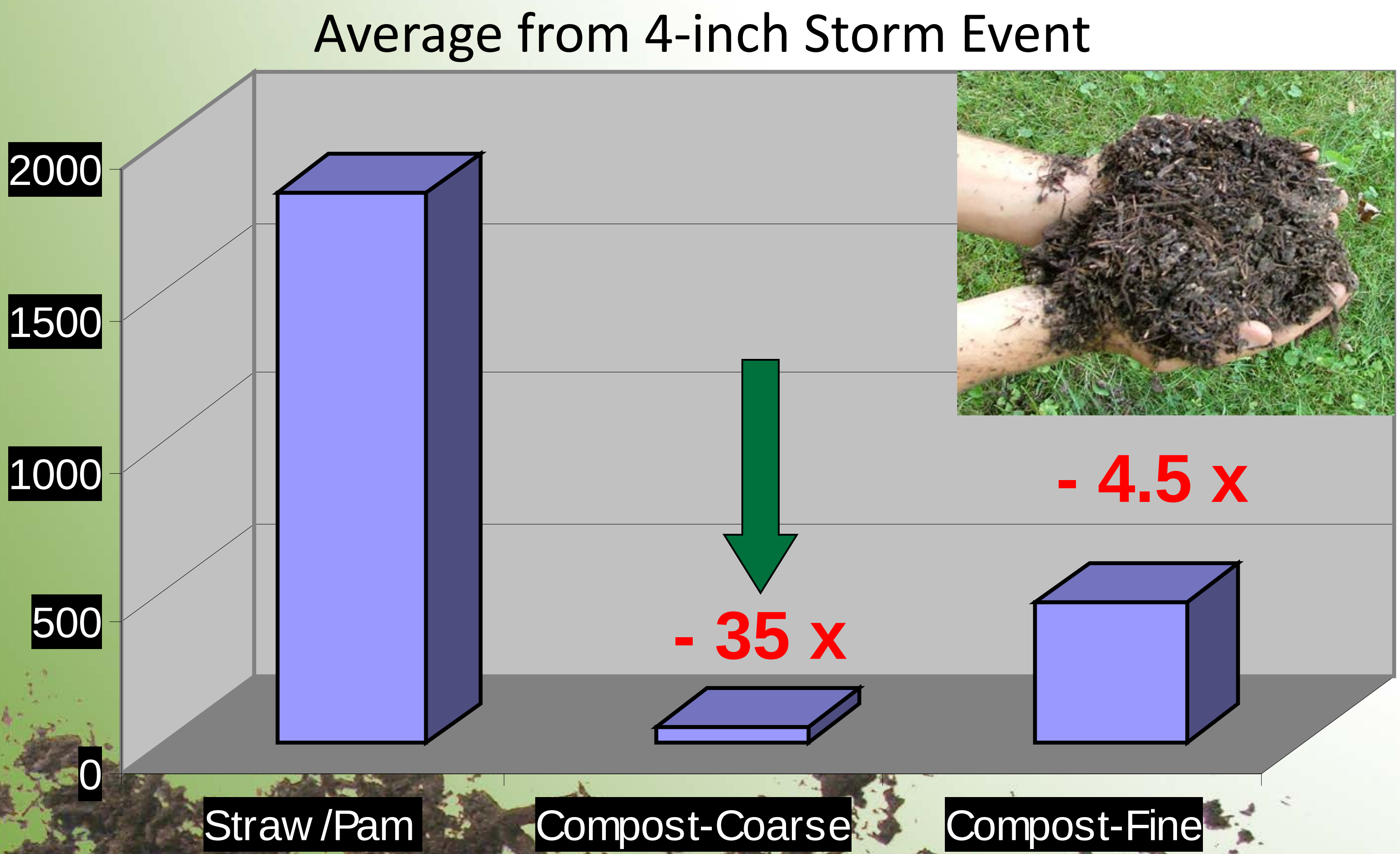
Turbidity (NTU)



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Soil Erosion at 2:1

Erosion Control Practice	Soil loss @ 2 in/hr 20 min (0.67 in)		Soil loss @ 4 in/hr 40 min (2.0 in)		Soil loss @ 6 in/hr 60 min (4.0 in)	
	t/ac	% reduction	t/ac	% reduction	t/ac	% reduction
Bare soil	61	NA	137	NA	171	NA
CECB 2.0 in	0.02	99.8	46	66.8	48	71.9
CECB 1.0 in	0.09	99.1	53	61.1	53	68.9
CECB 0.5 in	29	52.1	96	30.1	72	57.7
Single-net straw	31	48.8	84	38.3	101	40.8
Single-net excelsior fiber	18	70.2	55	60.1	66	61.1
Double-net straw	23	62.7	62	54.7	76	56.0
Double-net coconut fiber	0.05	99.5	36	73.5	71	58.8
Tackifier	12	79.9	60	56.2	101	41.2
PAM	43	29.9	146	-6.8	158	7.7

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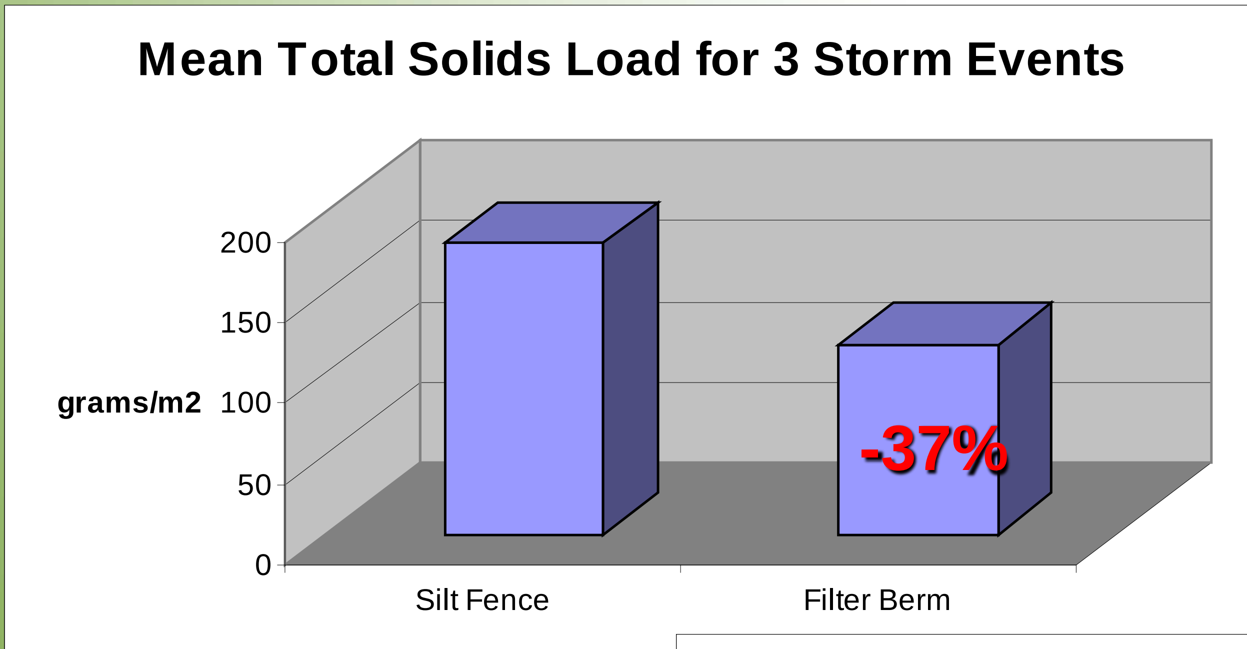
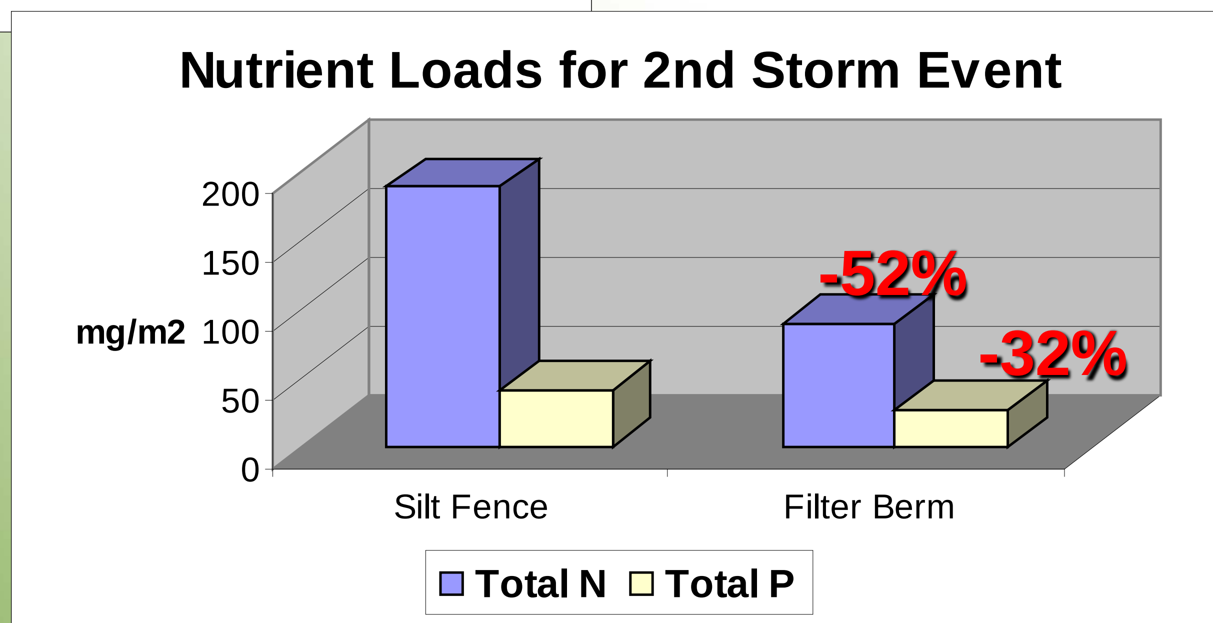
Silt Fence vs Compost Berm

The University of Georgia



✓All Plots used Hydromulching

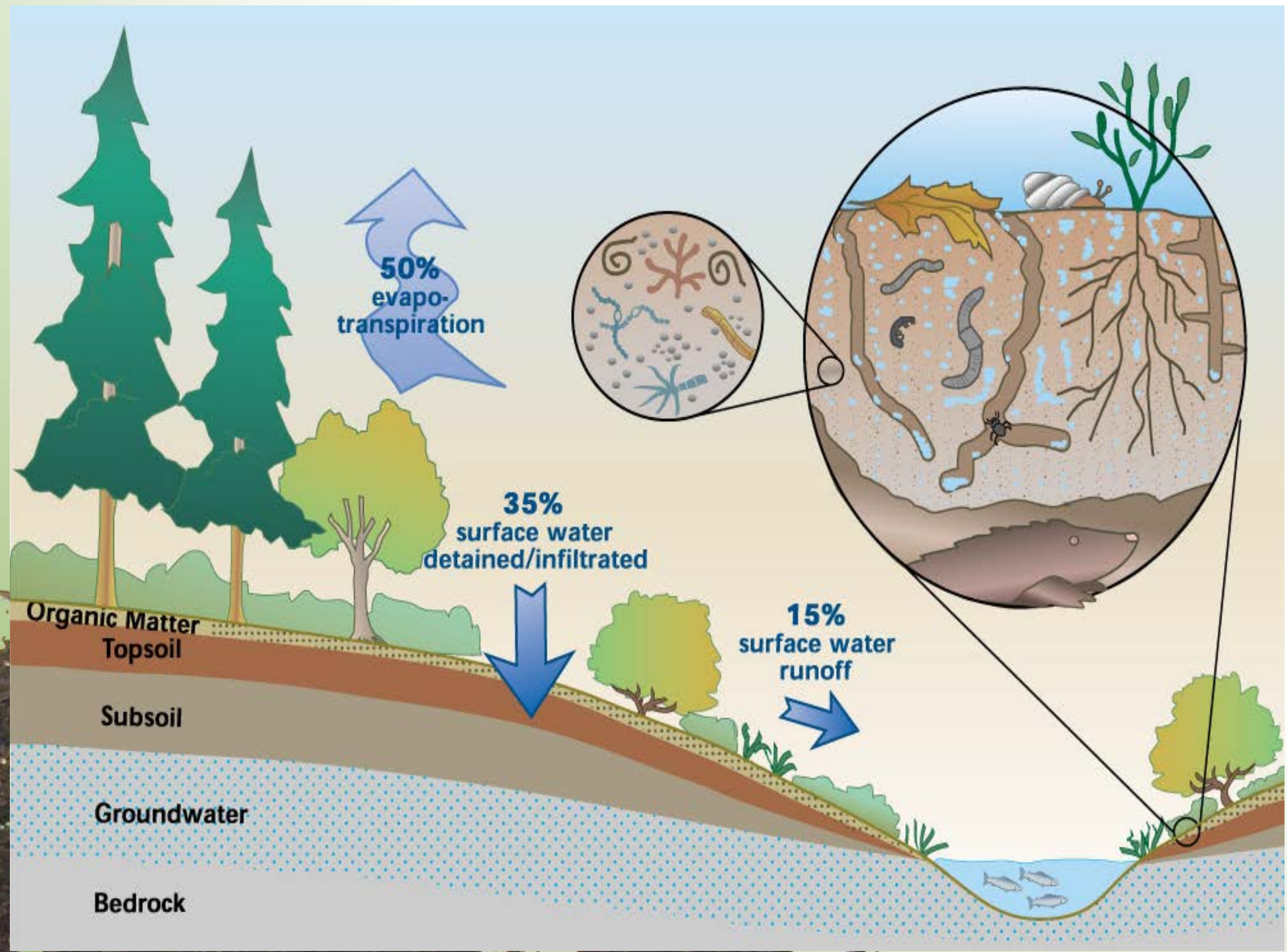



Compost Blanket
Hydroseeding
Demo project in Atlanta
after 3” Storm Event

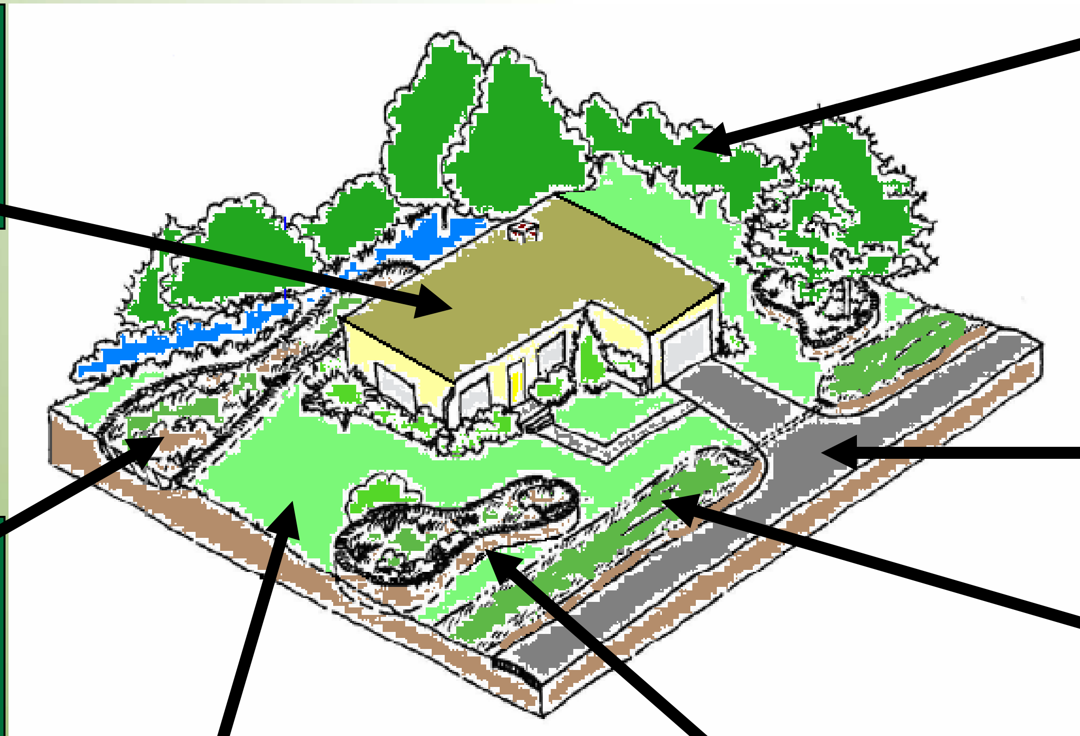
Green Infrastructure & Pollutant Reduction *Design*

How?

1. Interception
2. Transpiration
3. Infiltration
4. Evaporation
5. Surface Roughness
6. Flow Path Disruption
7. Biofiltration



Green Infrastructure Site = Max Pollutant Load Reduction



U.S. GREEN BUILDING COUNCIL LEED PLATINUM USGBC

Southface Responsible Solutions for Environmental Living

- ✓100% rain/stormwater capture
- ✓Zero discharge
- ✓84% Water Savings
- ✓130,000 gal/yr

U.S. GREEN BUILDING COUNCIL
LEED PLATINUM
USGBC

Southface

Responsible Solutions for Environmental Living

Real Value of Green Infrastructure

- National average real estate values down 25% from 2007 (-$82,000)
- Low Impact Development Sites:
  - $5000 more value/lot
  - $4000 less cost/lot
  - 6% - green infrastructure
  - 15% - water quality
  - 5% - reduce flooding in flood plain
  - 33-50% energy savings

(Source: NCSU)

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Runoff Coefficients

Watershed Surface	Coefficient
Asphalt, concrete, rooftop, downtown area	0.95
Neighborhood, apartment homes	0.7
Single family home site	0.5
Bare graded soil –clay, silt, sand	0.6, 0.5, 0.3
Lawn, pasture	0.1 – 0.35
Undisturbed forest	0.15
Compost blanket	0.1 – 0.32 (0.28)

Reference: GA Storm Water Management Manual, 2001

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Design: CECB Thickness based on Slope & 24 Rainfall Total

Slope Angle (≤)	Rainfall = 1.0 in	Rainfall = 2.0 in	Rainfall = 4.0 in
4:1	½ in	2 in	2 in
3:1	½ in	1 in	2 in
2:1	1 in	1 in	1 in

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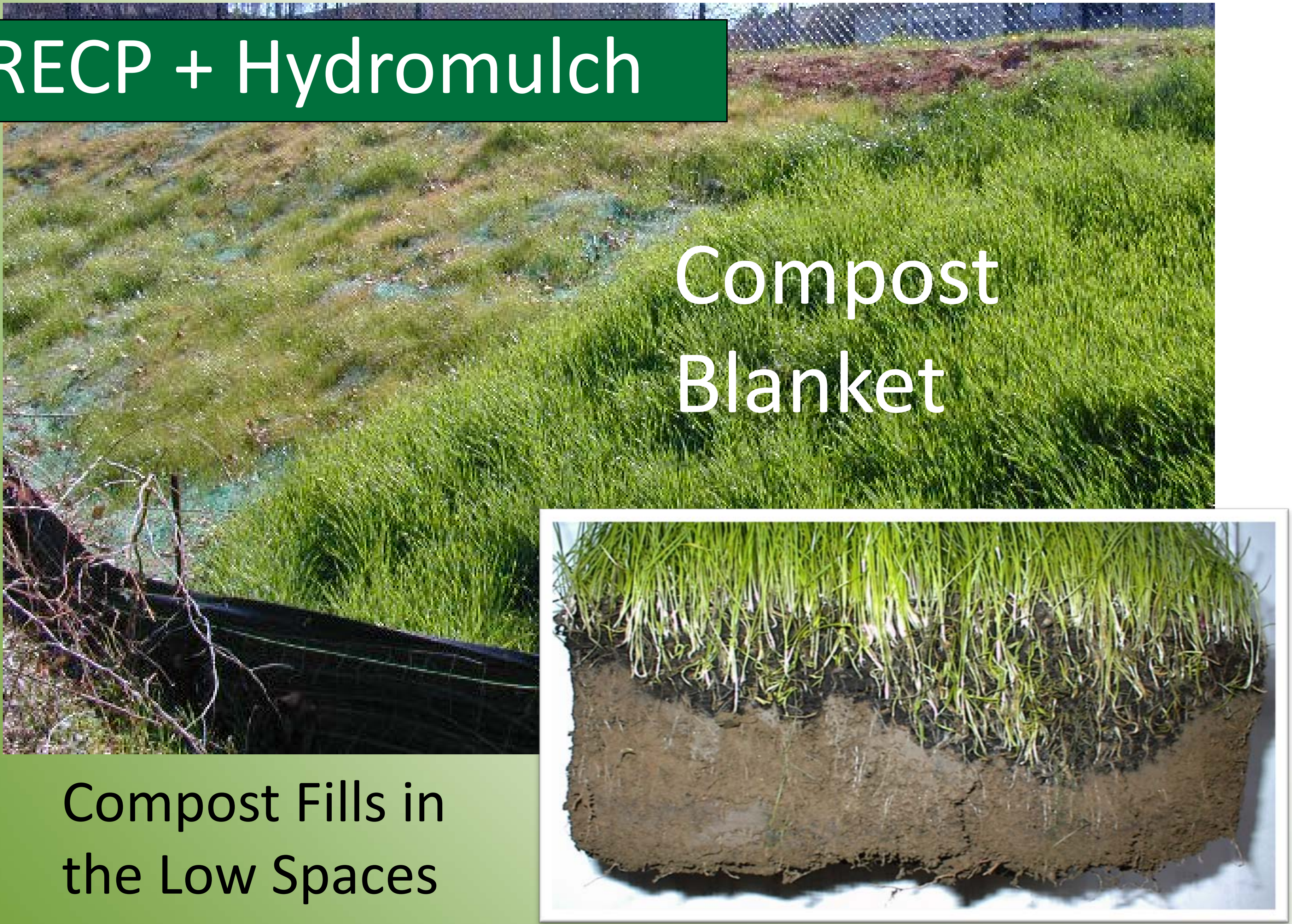
RECP + Hydromulch



Compost Fills in the Low Spaces

The *Sustainable* BMP

- 100% Recycled (compost)
- Bio-based, organic materials
- Locally manufactured
- Reduces Carbon Footprint
- Uses Natural Principles
- (Natural Capital & Ecosystem Services)
- High Performance

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Designing with Nature:
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Results: CECB Thickness & Slope Steepness

CECB Thickness (in)	Slope Angle (H:V)	Soil loss @ 2 in/hr 20 min (0.67 in)		Soil loss @ 4 in/hr 40 min (2.0 in)		Soil loss @ 6 in/hr 60 min (4.0 in)	
		t/ac	**% reduction**	t/ac	**% reduction**	t/ac	**% reduction**
Bare soil	**2:1**	61	**NA**	137	**NA**	171	**NA**
2.0	**2:1**	0.02	**99.8**	46	**66.8**	48	**71.9**
1.0	**2:1**	0.9	**99.1**	53	**61.1**	53	**68.9**
0.5	**2:1**	29	**52.1**	96	**30.1**	72	**57.7**
Bare soil	**3:1**	55	**NA**	132	**NA**	144	**NA**
2.0	**3:1**	0.09	**99.0**	26	**80.1**	35	**75.7**
1.0	**3:1**	0.25	**97.4**	18	**86.4**	72	**50.4**
0.5	**3:1**	0.9	**90.0**	94	**29.1**	100	**30.5**
Bare soil	**4:1**	72	**NA**	108	**NA**	110	**NA**
2.0	**4:1**	0.005	**100.0**	9	**91.4**	19	**82.6**
1.0	**4:1**	0.37	**96.8**	42	**61.4**	60	**45.9**
0.5	**4:1**	0.25	**98.2**	56	**48.4**	68	**38.0**

USLE C Factors

$$A = R \times K \times LS \times \underline{\mathbf{C}} \times P$$

Erosion Control	C Factor	Reference
Bare Soil	**1.0**	
Wood Mulch	**0.08-0.16**	Demars and Long, 1998; Faucette et al, 2004
Straw Mulch	**0.08-0.19**	Demars and Long, 1998; Faucette et al, 2006
Compost Blanket	**0.01-0.07**	Mukhtar et al, 2004; Demars and Long, 1998; Demars et al, 2000; Faucette et al 2005; Faucette et al, 2006
Forest floor	**0.001**	GA SWCC, 2000

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Hydraulic Design Capacity of Filter Socks & Silt Fence in Runoff Control Applications

H. Keener, B. Faucette, M. Klingman

Flow through rates were **<u>50%</u>** greater for filter socks

12” Compost sock = 24” silt fence
18” Compost sock = 36” silt fence

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Filter Sock Design Tool

Step 1: Choose units, **ft** or m		ft					
Step 2. Choose input: **Tr** or **I**		Tr					
total rainfall	**inches**	1.5		**storm duration**	**hours**	24	
Step 3. Choose input: **A** or **W**		W					
width of area	**ft**	400.00		**length of slope**	**ft**	250	43560
Step 4. Input slope	**%**	10					452.588
Step 5. Input reduction runoff percent	**%**	10					
		siltsoxx (8,12,18)	silt fence(24,30)				
Step 6. Input effective length of filter	**ft**	400	400				
Step 7. Input diameter/height of filter	**inches**	12	36				

Step 8. Find time to overflow filter and
total flow/ft the filter can handle

Step 9. On figure find for given flow
expected time to overflow filter.

Part A. Evaluation of q_i

I inches/hr	A acres	s percent	Q gpm	L_{ss} ft	q_i gpm/ft
0.063	2.2957	10	58.15	400	0.145

Part B. Predicted time and total flow to top filter.

	q_o gpm/ft	D inches	Effective D inches	time overflow hr	total flow gal/f	Filter Okay time > tr
SiltSoxx[TM] (Coarse Material)	0.145	12	9.6	99.1	865	OKAY
Silt Fence	0.145	36	30.6	97.5	851	OKAY

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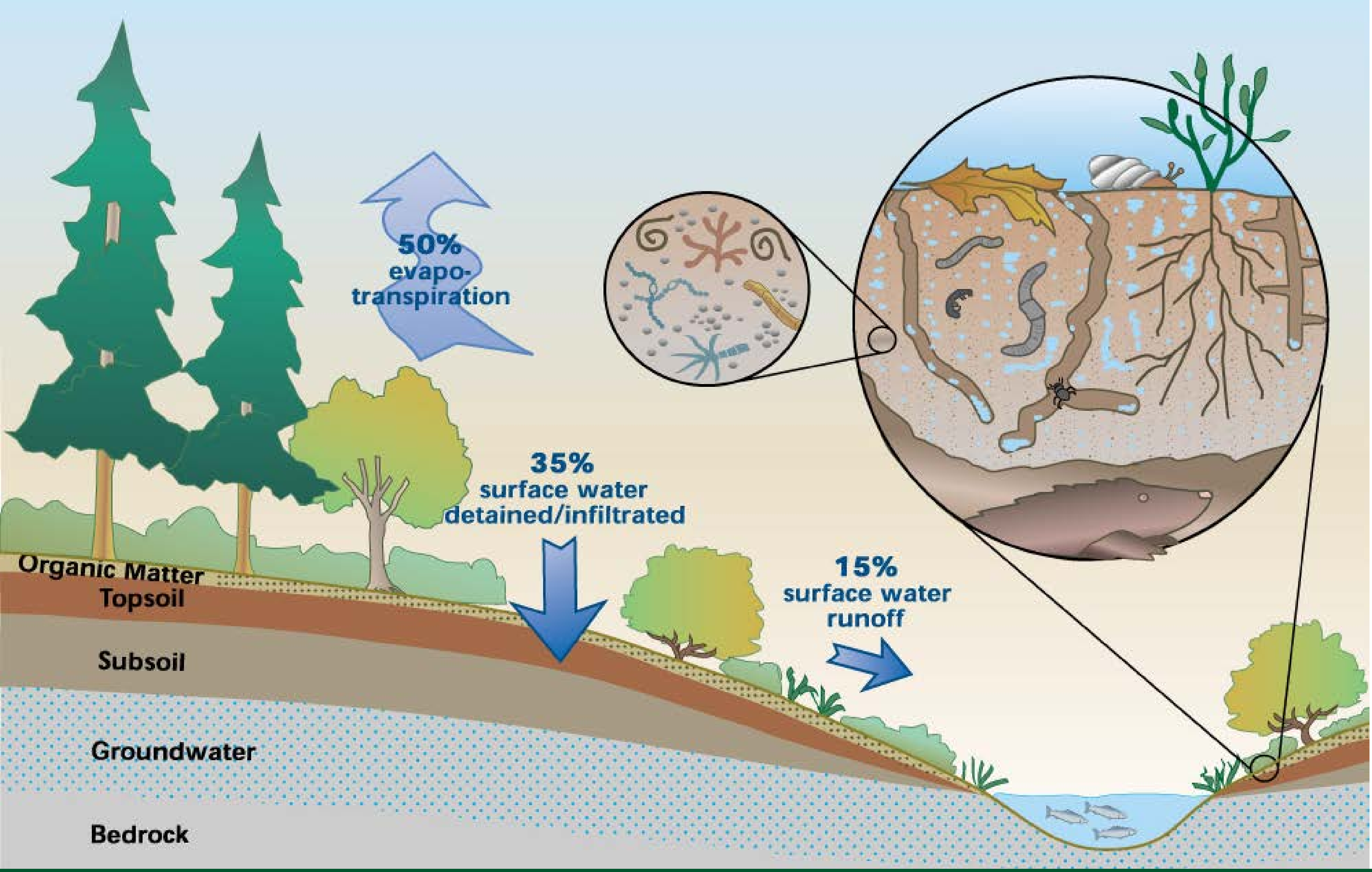

Low Impact Development (LID) =
restore natural site hydrology; decentralize

Total Soil Loss

The University of Georgia

Hydromulch vs Compost Blanket: Two 3”/hr storm events

- ✓Day 1 = **2,750 & 1,230 lb/ac**
- ✓3 mo = **1,960 & 115 lb/ac**

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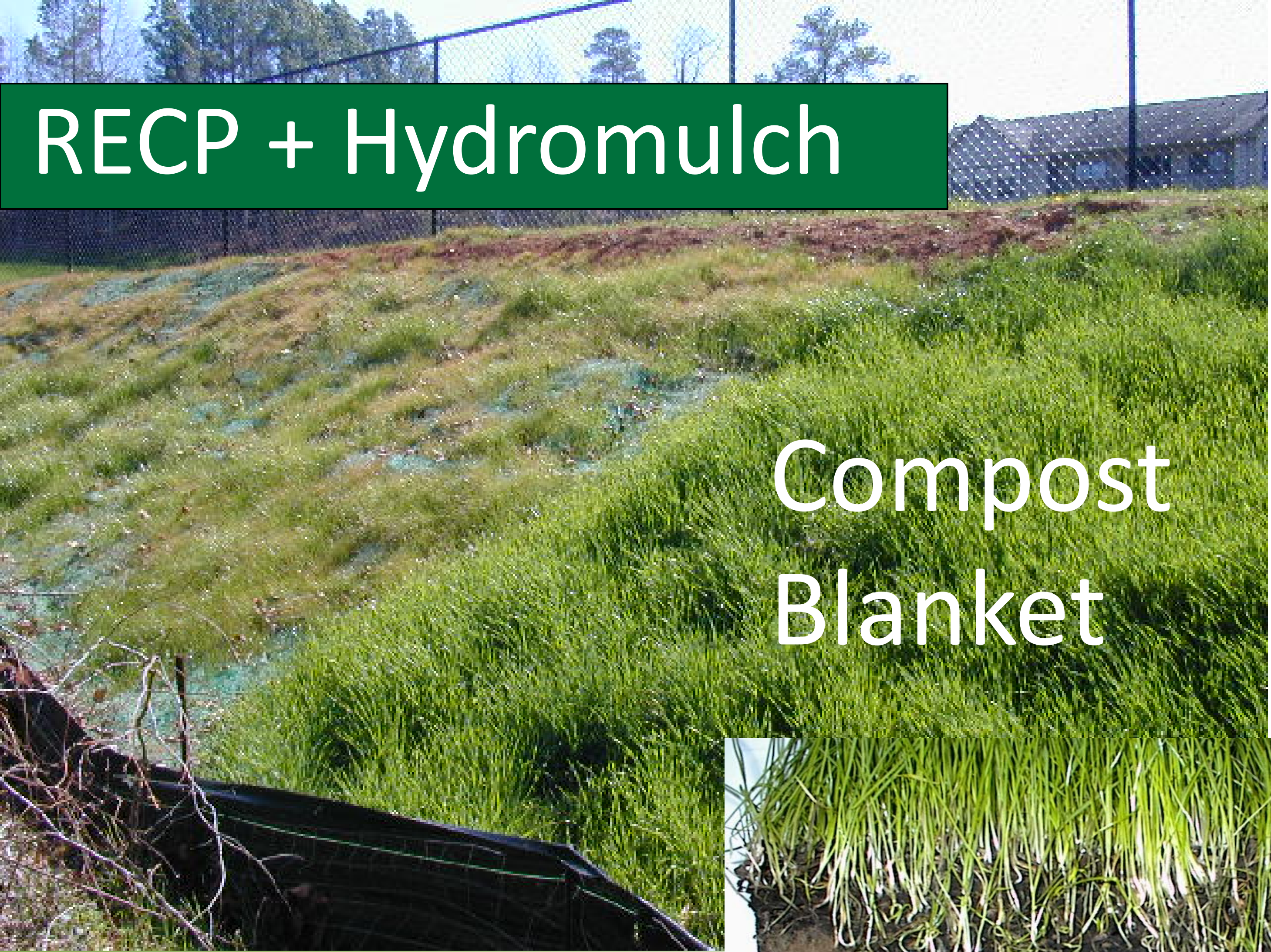

Compost Fills in the Low Spaces

Particle Size Matters

Treatment	Soil Loss (kg ha^{-1})	TSS (kg ha^{-1})	Turbidity (NTU)	Particle size % passing		
				1 in	1/2 in	1/4 in
Compost 1	95.8	52.1	36	99	64	30
Compost 2*	129.2	60.4	60	99	85	67
Compost 3*	208.3	64.6	87	99	89	76
Compost 4**	408.3	283.3	288	99	99	95

*Did not meet TX DOT specification for erosion control compost particle size distribution.

**Did not meet TX DOT, USEPA, IN DNR, or CONEG specification for erosion control blanket particle size distribution

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