SELECTION, DESIGN, & MAINTENANCE OF STORMWATER FILTRATION SYSTEMS

Craig Fairbaugh - Contech Engineered Solutions

CONTECH® ENGINEERED SOLUTIONS
A QUIKRETE® COMPANY

Your Speaker

- B.S. , M.S. Environmental Engineering
- ASCE/EWRI: Urban Water Resources Research Council – Core Group Member
  - Chair – EWRI Stormwater Media Filtration Committee
- ASTM Committee E64 on SCMs
  - Chair of Subcommittee 03 – Components (media)
- Contech – Regional Regulatory Manager

ASTM INTERNATIONAL

EWRI ASCE

CONTECH® ENGINEERED SOLUTIONS

ASCE/EWRI SW Filtration Media Committee Technical Report:

"Stormwater Filtration Media for the Urban Environment"

7 yrs and 400+ pages later…

Peer review complete, publication by Q4 2026

SW experts from across the country

- Curtis Hinman – Vice Chair
- Amanda Hess – Secretary
- Academia, regulators, consultants, manufacturers
- Thanks Dr. Barrett! (peer review)

ASCE/EWRI SW Filtration Media Committee Technical Report:

"Stormwater Filtration Media for the Urban Environment"

- Ch. 2 – Pollutants
- Ch. 3 – Properties of Media
- Ch. 4 – Types of Media
- Ch. 5 – Sizing and Design
- Ch. 6 – Guidance for SW Treatment and Infiltration Applications
- Ch. 7 - Maintenance

What are Filter Media systems?

Vegetated:

1. Bioretention
2. Amended Bioretention (NEW)
3. High Rate Biofiltration

Non vegetated:

4. Media filters (sand filters)
5. Amended media filters (NEW)
6. High-Rate Media Filtration

https://www.semswa.org/types-of-water-quality-bmps

What are Filter Media systems?

Expanded BMP database categories:

- Bioretention
  - Sand, compost, topsoil
- Amended Bioretention (NEW)
  - Biochar, iron, alumina, fly ash, water treatment residuals, etc
- High Rate Biofiltration
  - WA State TAPE verified systems

https://www.epa.gov/green-infrastructure/types-green-infrastructure

What are Filter Media systems?

Expanded BMP database categories:

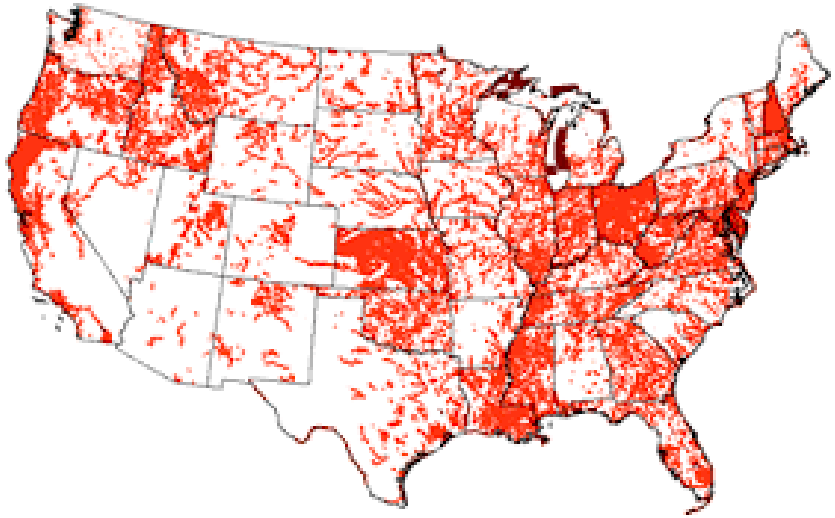
- Media filters
  - sand filters
- Amended media filters (NEW)
  - WTRs, biochar, iron, alumina, fly ash, etc
- High-Rate Media Filtration
  - WA TAPE verified systems

Why does this matter?

2025 ASCE infrastructure report card = D

Length of impaired waters increased

- 2010 = 424,000 miles
- 2022 = 704,000 miles
- more pollution or more assessment?
- more work to be done



https://www.epa.gov/sites/default/files/2015-09/documents/2010_1_28_tmdl_results_303d_impaired_waters_gis.pdf

https://infrastructurereportcard.org/cat-item/stormwater-infrastructure/

"Stormwater Filtration Media for the Urban Environment"

1. Stormwater Infiltration Feasibility Tool (SIFT)
   - Is infiltration feasible or is media treatment required?
   - If infiltration is feasible, is media treatment needed for pretreatment?

2. Media Selection Guide (MSG)
   - Which media will meet water quality, cost, and maintenance goals?

3. QAQC guidance
   - What level of QAQC is needed to meet media specification and performance goals?

Stormwater Infiltration Feasibility Tool (SIFT)

Pollutant Loading

- "low-medium-high"
- Average Daily Traffic
- Development density

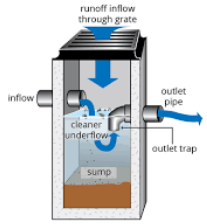
VS.

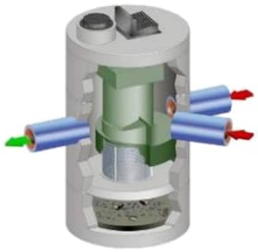
Vadose Zone (native soils)

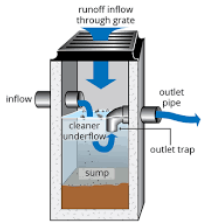
depth, Ksat, particle size distribution, soil classification, CEC, etc.

DRAFT: Stormwater Infiltration Feasibility Tool (SIFT)

Pollutant loading (see section XX)	Insignificant (see pg xx)	Low pollutant loading (see pg xx)		Moderate pollutant loading[1] (see pg xx)		High pollutant loading[1] (see pg xx)
Vadose zone (Determined in preliminary and detailed site assessment, see pg xx)	Low to high vadose zone treatment capacity (see pg xx)	Low vadose zone treatment capacity (see pg xx)	Moderate to high vadose zone treatment capacity (see pg xx)	Low to moderate vadose zone treatment capacity (see pg xx)	High vadose zone treatment capacity (see pg xx)	Low to high vadose zone treatment capacity (see pg xx)
Treatment	Basic pretreatment (sedimentation), dispersion (see pg XX)	Enhanced pretreatment (sedimentation), see pg xx	Basic pretreatment (sedimentation), dispersion (see pg XX)	Proceed to Treatment Selection Matrix. Consider Amended medias or TAPE GULD medias (see pg xx)	Proceed to Treatment Selection Matrix. (see pg xx)	Proceed to Treatment Selection Matrix. Consider OWS + Amended medias or TAPE GULD medias, with enhanced maintenance (see pg xx)

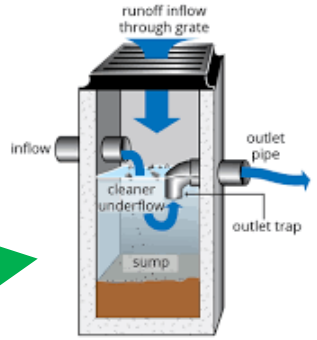


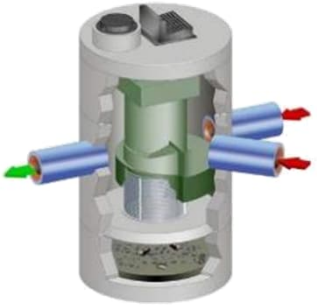




Stormwater Infiltration Feasibility Tool (SIFT)

- General recommendations
  - Low pollutant loading – good vadose zone soils
    - simple gravity device (sumped CBs, forebays)
  - low pollutant loading – decent vadose zone soils
    - Higher performing gravity device (HDS)
  - Med to high pollutant loading
    - Good vadose zone – standard filtration
    - Poor vadose zone – amended filtration





"Stormwater Filtration Media for the Urban Environment"

1. Stormwater Infiltration Feasibility Tool (SIFT)
   - Is infiltration feasible or is media treatment required?
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3. QAQC guidance
   - What level of QAQC is needed to meet media specification and performance goals?

Media Selection Guide (MSG)

BMP database style statistical analysis of field WQ results (“Media Database”)

- BMP database data + additional qualified data

Applying TAPE/ASTM protocols to data analysis

- TAPE influent ranges
- Minimum 15 storms
  - ≥15 storms for ≤~20% uncertainty
  - Fassman-Beck et al. 2022
- Choose your own data adventure

Media Selection Guide (MSG)

Statistical Analysis:

- 3 tests
  - 95% confidence interval overlap
  - Mann Whitney
  - Wilcoxon Rank Sum
- ▼ = significant removal 😍
- ◇ = no significant difference 😐
- △ = significant export 😫
- (# of studies, # of storms)
  - paired event mean concentrations

SCM type	Media Type	TSS	Total P	Total N
Bioretention	sand, compost, topsoil	▼▼▼ (27, 336)	△ △ △ (23, 330)	◇ △ △ (23, 237)
	amended	▼▼▼ (15, 205)	▼▼▼ (13, 209)	◇◇◇ (10, 111)

Media Selection Guide (MSG) – All Data

		Water Quality Performance: Influent vs. Effluent[1] (Study and Paired Sample Count)							Design Recommendations			Cost[7]		
SCM type	Media Type	TSS	Total P	Total N	Total Zn	Diss Zn	Total Cu	Diss Cu	Infiltration	Underdrain	Hydraulic Loading Rate[6] (in/hr) or Sizing Ratio (%)	Media Materials	QAQC[8]	O & M
Bioretention	sand, compost, topsoil	▼▼▼ (27,336)	Δ Δ Δ (23,330)	◇ Δ Δ (23,237)	▼▼▼ (15,263)	▼▼▼ (9,187)	◇ ▼▼ (15,257)	Δ Δ Δ (9,185)	Yes[2]	No[3]	1-12"/hr, 1.5-7%	$	$$	$$
	amended	▼▼▼ (15,205)	▼▼▼ (13,209)	◇◇◇ (10,111)	▼▼▼ (9,126)	N/A▼▼ (4,65)	◇◇◇ (5,75)	◇◇ Δ (5,70)	Yes	Yes[4]	2-6%	$$	$$$	$$
High Rate Biofiltration	TAPE GULD media	▼▼▼ (13,267)	▼▼▼ (12,219)	▼▼▼ (6,90)	◇▼▼ (8,121)	▼▼▼ (10,154)	▼▼▼ (8,114)	▼▼▼ (10,160)	Yes	Yes	100 - 324"/hr	$$$	n/a	$
Media Filter	sand	▼▼▼ (15,224)	▼▼▼ (13,218)	◇◇▼ (9,143)	▼▼▼ (14,215)	▼▼▼ (11,170)	▼▼▼ (14,216)	◇◇▼ (11,173)	Yes	Yes	0.5-7.5%	$	$$	$$
	amended	▼▼▼ (5,65)	▼▼▼ (20,214)	n/a	▼▼▼ (4,49)	n/a	▼▼▼ (4,53)	n/a	Yes	Yes[4]	88-115"/hr	$$	$$$	$$
High Rate Media Filter	TAPE GULD media	▼▼▼ (20,437)	▼▼▼ (22,445)	▼▼▼ (8,156)	▼▼▼ (18,346)	◇◇◇ (17,295)	▼▼▼ (17,311)	◇◇▼ (16,285)	Yes	Yes[5]	20-160"/hr	$$$	n/a	$$$

Media Selection Guide (MSG) – "TAPE & 15 Storms Data"

		Water Quality Performance: Influent vs. Effluent[1] (Study and Paired Sample Count)							Design Recommendations			Cost[7]		
SCM type	Media Type	TSS	Total P	Total N	Total Zn	Diss Zn	Total Cu	Diss Cu	Infiltration	Underdrain	Hydraulic Loading Rate[6] (in/hr) or Sizing Ratio (%)	Media Materials	QAQC[8]	O & M
Bioretention	sand, compost, topsoil	▼▼▼ (3,102)	▵ ▵ ▵ (5,149)	▵ ◇ ▵ (5,103)	▼▼▼ (6,175)	▼▼▼ (4,57)	◇ ▼▼ (6,176)	N/A	Yes[2]	No[3]	1-12"/hr, 1.5-7%	$	$$	$$
	amended	▼▼▼ (3,56)	◇ ▼▼ (6,86)	◇ ◇ ◇ (4,73)	▼▼▼ (5,90)	N/A	◇ ◇ ◇ (3,55)	N/A	Yes	Yes[4]	2-6%	$$	$$$	$$
High Rate Biofiltration	TAPE GULD media	▼▼▼ (6,129)	▼▼▼ (6,97)	▼▼▼ (3,82)	▼▼▼ (4,85)	▼▼▼ (5,106)	▼▼▼ (4,86)	▼▼▼ (4,86)	Yes	Yes	100 - 324"/hr	$$$	n/a	$
Media Filter	sand	▼▼▼ (5,87)	▼▼▼ (4,65)	◇ ◇ ▼ (4,88)	▼▼▼ (7,149)	N/A	▼▼▼ (7,150)	n/a	Yes	Yes	0.5-7.5%	$	$$	$$
	amended	n/a	▼▼▼ (5,85)	n/a	n/a	n/a	n/a	n/a	Yes	Yes[4]	88-115"/hr	$$	$$$	$$
High Rate Media Filter	TAPE GULD media	▼▼▼ (14,310)	◇ ◇ ▼ (7,158)	▼▼▼ (4,116)	▼▼▼ (12,285)	◇ ▼▼ (4,69)	▼▼▼ (11,250)	◇ ◇ ◇ (3,55)	Yes	Yes[5]	20-160"/hr	$$$	n/a	$$$

Takeaways:

- TSS is our easy surrogate…but nutrients and metals can be tough

▼ = 😍

◇ = 😐

△ = 😫

		Water Quality Performance: Influent vs. Effluent[1] (Study and Paired Sample Count)						
SCM type	Media Type	TSS	Total P	Total N	Total Zn	Diss Zn	Total Cu	Diss Cu
Bioretention	sand, compost, topsoil	▼▼▼ (27, 336)	△ △ △ (23, 330)	◇ △ △ (23, 237)	▼▼▼ (15, 263)	▼▼▼ (9, 187)	◇▼▼ (15, 257)	△ △ △ (9, 185)
	amended	▼▼▼ (15, 205)	▼▼▼ (13, 209)	◇◇◇ (10, 111)	▼▼▼ (9, 126)	N/A▼▼ (4, 65)	◇◇◇ (5, 75)	◇◇△ (5, 70)
High Rate Biofiltration	TAPE GULD media	▼▼▼ (13, 267)	▼▼▼ (12, 219)	▼▼▼ (6, 90)	◇▼▼ (8, 121)	▼▼▼ (10, 154)	▼▼▼ (8, 114)	▼▼▼ (10, 160)
Media Filter	sand	▼▼▼ (15, 224)	▼▼▼ (13, 218)	◇◇▼ (9, 143)	▼▼▼ (14, 215)	▼▼▼ (11, 170)	▼▼▼ (14, 216)	◇◇▼ (11, 173)
	amended	▼▼▼ (5, 65)	▼▼▼ (20, 214)	n/a	▼▼▼ (4, 49)	n/a	▼▼▼ (4, 53)	n/a
High Rate Media Filter	TAPE GULD media	▼▼▼ (20, 437)	▼▼▼ (22, 445)	▼▼▼ (8, 156)	▼▼▼ (18, 346)	◇◇◇ (17, 295)	▼▼▼ (17, 311)	◇◇▼ (16, 285)

Takeaways:

- Don't use compost in bioretention if discharging through an underdrain (biofiltration)

▼ = 😍

◇ = 😐

△ = 😣

		Water Quality Performance: Influent vs. Effluent[1] (Study and Paired Sample Count)						
SCM type	Media Type	TSS	Total P	Total N	Total Zn	Diss Zn	Total Cu	Diss Cu
Bioretention	sand, compost, topsoil	▼▼▼ (27, 336)	△△△ (23, 330)	◇△△ (23, 237)	▼▼▼ (15, 263)	▼▼▼ (9, 187)	◇▼▼ (15, 257)	△△△ (9, 185)
	amended	▼▼▼ (15, 205)	▼▼▼ (13, 209)	◇◇◇ (10, 111)	▼▼▼ (9, 126)	N/A▼▼ (4, 65)	◇◇◇ (5, 75)	◇◇△ (5, 70)
High Rate Biofiltration	TAPE GULD media	▼▼▼ (13, 267)	▼▼▼ (12, 219)	▼▼▼ (6, 90)	◇▼▼ (8, 121)	▼▼▼ (10, 154)	▼▼▼ (8, 114)	▼▼▼ (10, 160)
Media Filter	sand	▼▼▼ (15, 224)	▼▼▼ (13, 218)	◇◇▼ (9, 143)	▼▼▼ (14, 215)	▼▼▼ (11, 170)	▼▼▼ (14, 216)	◇◇▼ (11, 173)
	amended	▼▼▼ (5, 65)	▼▼▼ (20, 214)	n/a	▼▼▼ (4, 49)	n/a	▼▼▼ (4, 53)	n/a
High Rate Media Filter	TAPE GULD media	▼▼▼ (20, 437)	▼▼▼ (22, 445)	▼▼▼ (8, 156)	▼▼▼ (18, 346)	◇◇◇ (17, 295)	▼▼▼ (17, 311)	◇◇▼ (16, 285)

Takeaways:

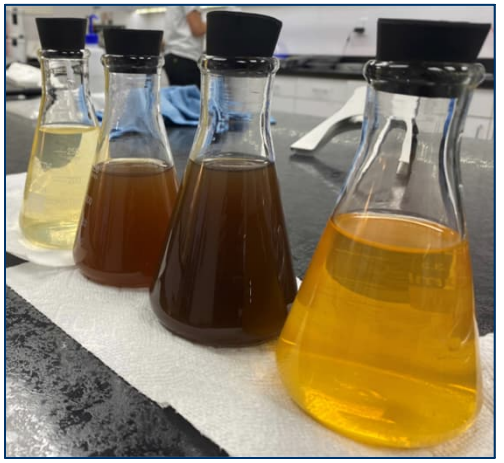
- Don’t use compost in bioretention if discharging through an underdrain
- Not just our finding:
  - Herrera 2014
  - Herrera 2015
  - Mullan et al. 2015
  - Chahal 2016
  - Herrera 2020
  - Fairbaugh 2022
  - Erickson et. al. 2023
  - Owen et al. 2023
  - National Academies 2023
- Compost leaches solids
- Compost can also leach bacteria

Takeaways:

- Doesn't compost leaching get better over time?
  - Herrera studies have shown no endpoint and leaching still in Year 5
  - Initial export is typically 2 orders of magnitude above EPA in-stream criteria…nearly impossible to ever catch up to a net positive removal, no a mass basis
- Consider how another industry would react…
  - Don't worry, it will work in a few years (maybe)

Takeaways:

- Compost is likely fine for infiltration
  - No nutrient sensitive waterbodies receiving interflow/GW connection
- Recommend different media specs for infiltration and treatment
  - Canadian Standards Association (CSA)



CANADIAN STANDARDS ASSOCIATION

Takeaways:

- Use amendments in bioretention if discharging through an underdrain

▼ = 😍

◇ = 😐

△ = 😣

		Water Quality Performance: Influent vs. Effluent[1] (Study and Paired Sample Count)						
SCM type	**Media Type**	**TSS**	**Total P**	**Total N**	**Total Zn**	**Diss Zn**	**Total Cu**	**Diss Cu**
Bioretention	sand, compost, topsoil	▼▼▼ (27, 336)	△△△ (23, 330)	◇△△ (23, 237)	▼▼▼ (15, 263)	▼▼▼ (9, 187)	◇▼▼ (15, 257)	△△△ (9, 185)
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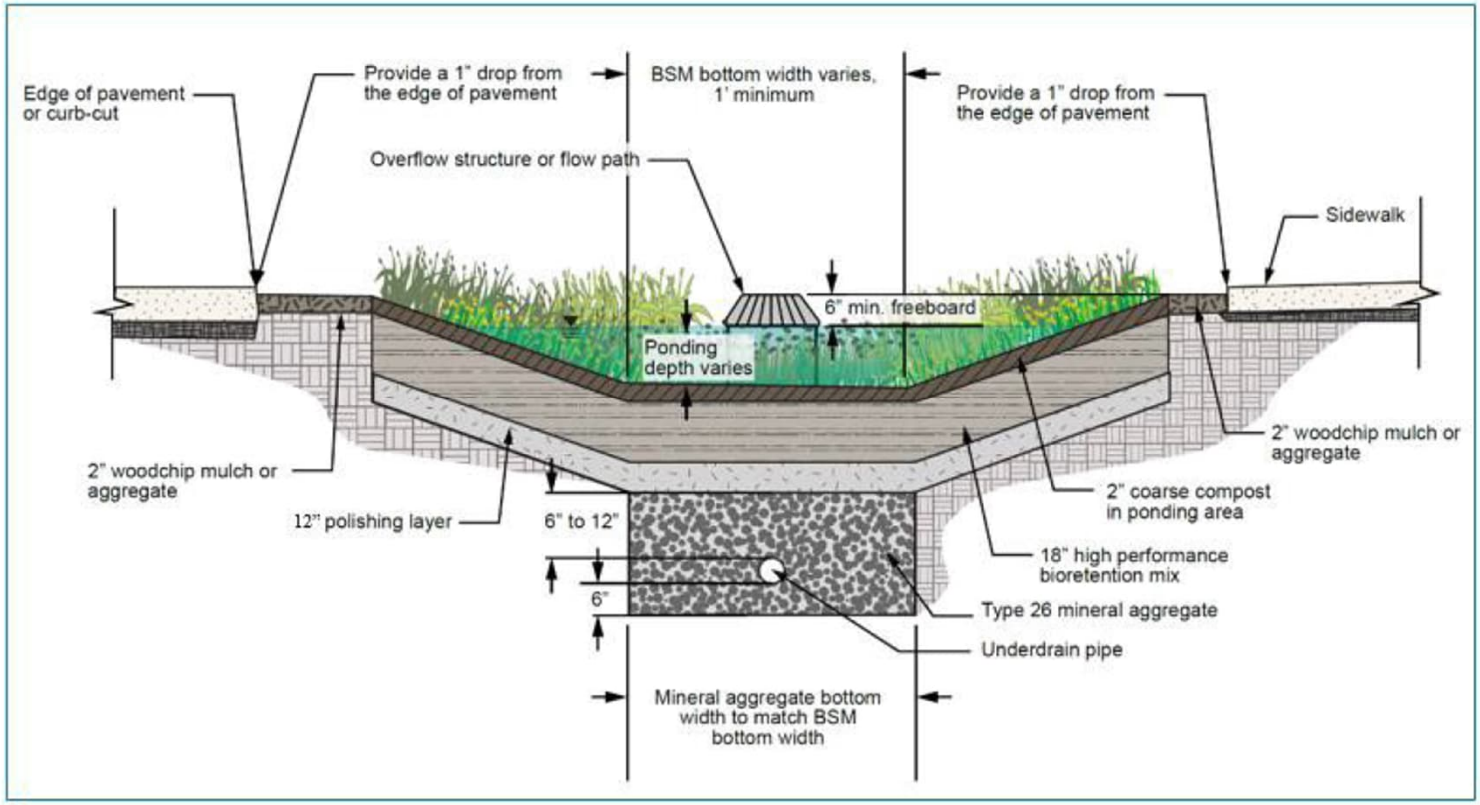
	amended	▼▼▼ (5, 65)	▼▼▼ (20, 214)	n/a	▼▼▼ (4, 49)	n/a	▼▼▼ (4, 53)	n/a
High Rate Media Filter	TAPE GULD media	▼▼▼ (20, 437)	▼▼▼ (22, 445)	▼▼▼ (8, 156)	▼▼▼ (18, 346)	◇◇◇ (17, 295)	▼▼▼ (17, 311)	◇◇▼ (16, 285)

Takeaways:

- WA State **High Performance Bioretention Soil Mix (HPBSM)**
- primary layer: sand, coir, biochar
- Secondary layer: sand, iron, alumina
- Optional compost layer on top for plant growth



https://apps.ecology.wa.gov/publications/documents/2110023.pdf

Takeaways:

- High Rate Biofilters typically use amendments

▼ = 😍

◇ = 😐

△ = 😣

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	amended	▼▼▼ (15, 205)	▼▼▼ (13, 209)	◇◇◇ (10, 111)	▼▼▼ (9, 126)	N/A▼▼ (4, 65)	◇◇◇ (5, 75)	◇◇△ (5, 70)
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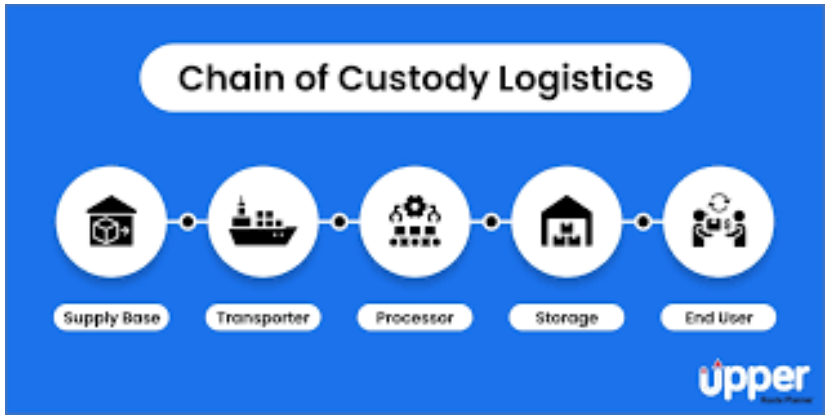
Takeaways:

- High Rate Biofilters typically use amendments

Takeaways:

- Media QAQC are critical
- Ensure media delivered to site meets design specs
- Blending, Delivery, Protection & Installation Plan (BDPIP)
- Manufactured systems can eliminate this risk

https://www.handymanvancouver.ca/ikea-furniture-assembly/



https://www.upperinc.com/blog/chain-of-custody-logistics/

Takeaways:

- Need more data…and better data
  - TAPE protocols -> ASTM
  - Pre-2010 data representative?
- Conventional Systems (bioretention and sand filters)
  - Need water quality + maintenance data
- Manufactured Systems
  - Need maintenance data (in progress)
- STEPP – Stormwater Testing & Evaluation of Products and Practices
  - National performance verification program – in progress

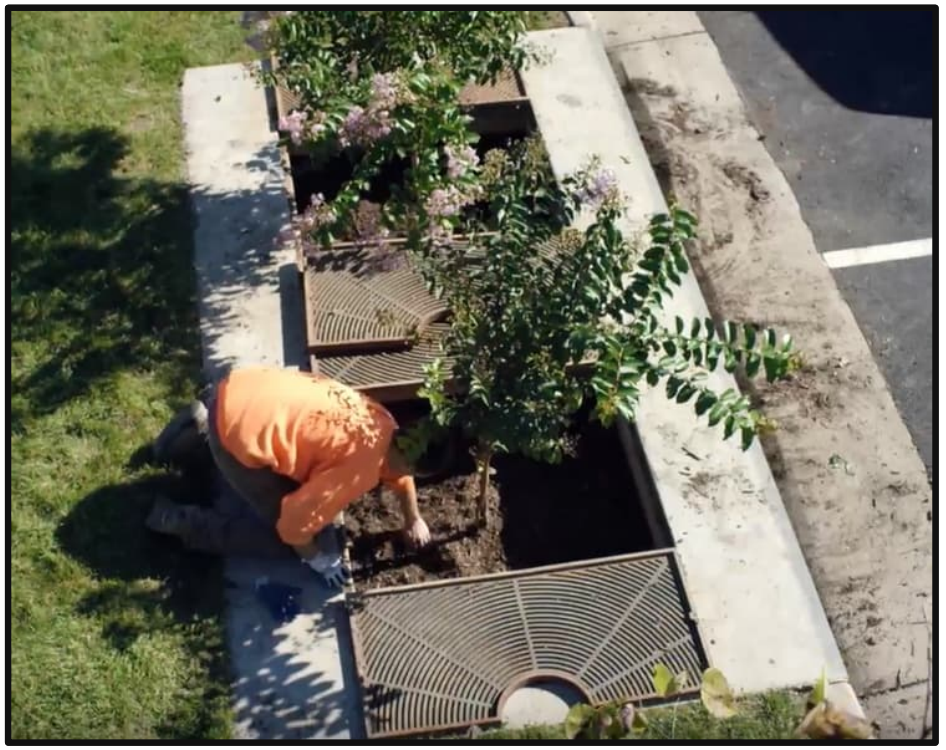
State of Washington TAPE GULD Basic Enhanced/Metals Phosphorus Oil

ASTM INTERNATIONAL

STEPP Stormwater Testing and Evaluation for Products and Practices

Maintenance

- Survey of U.S. manuals+permits
- Lack of maintenance guidance in regulations
  - Just “do it”?
- Beneficial legal provisions
  - Maintenance contracts for private facilities
  - Ordinances for non-compliance



Maintenance

- Standards and procedures
- Vegetated vs non-vegetated
- Timing and frequency
- Action needed

Table XX: Maintenance Standards and Procedures for Filter Media Facilities with and without Vegetation

	Inspection Timing and Frequency	Facility component	Vegetated	Non-vegetated	Routine	Non-Routine	Rehab	Condition when Maintenance is Needed (Standards)	Action Needed (Procedures)
Fall (annual inspections preferred during fall)	Annually (preferred during fall) and after major storm events (all seasons)	Splash block inlet	✓	✓		✓		Water is not being directed properly into the facility and away from the inlet structure	Reconfigure/ repair blocks to direct water into facility
		Erosion control at inlet	✓	✓	✓			Concentrated flows are causing erosion	Maintain and/or expand cover of rock or cobbles or other erosion protection measure (e.g., matting) to protect the ground where concentrated water enters the facility (e.g., a pipe, curb cut or swale)
	Weekly during fall leaf drop	Pipe inlet/outlet	✓	✓	✓			Accumulated leaves at inlets/outlets	Clear leaves (particularly important for key inlets and low points along long, linear facilities)
	At least one visit after leaf drop		✓	✓	✓			Pipe is clogged	Remove debris or roots
	Annually (preferred during fall) and after major storm events (all seasons)		✓	✓		✓		Pipe is damaged	Repair or replace
			✓	✓	✓			Sediment, debris, trash, or mulch reducing capacity of inlet/outlet	Clear the blockage. Identify the source of the blockage and take actions to prevent future blockages.
	Annually (preferred during fall)		✓	✓	✓			Maintain access for inspections	• Clear vegetation (transplant vegetation when possible) within 1 foot of inlets and outlets, maintain access pathways • Consultation with a landscape architect is recommended for removal, transplant, or substitution of plants
	Annually (preferred during fall) and after major storm events (all seasons)	Trash rack	✓	✓	✓			Trash or other debris present on trash rack	Remove and dispose
			✓	✓		✓		Bar screen damaged or missing	Repair or replace
		Overflow	✓	✓	✓			Capacity reduced by sediment or debris	Remove sediment or debris and dispose
	Annually (preferred during fall)	Check dams and weirs	✓	✓		✓		Erosion and/or undercutting present	Repair and take preventative measures (e.g. place or increase rock rip-rap over erosion pathway) to prevent future erosion and/or undercutting
			✓	✓		✓		Grade board or top of weir damaged or not level	Restore to level position
			✓	✓	✓			Sediment, vegetation, or debris accumulated or blocking check dam, flow control weir or orifice	Clear blockage
	Weekly during fall leaf drop; monthly during wet season and before severe storm is forecasted	Curb cut inlet/outlet	✓	✓	✓			Accumulated leaves at curb cuts	Clear leaves (particularly important for key inlets and low points along long, linear facilities)
	Annually (preferred during fall)		✓			✓	✓	Excessive vegetation growing at and blocking inlet or outlet	• Remove or transplant vegetation at least 24 inches back from inlet or outlet • Place permanent erosion control and sediment collection area where plants have been removed • Typical erosion control: cobble or concrete pad. For effective sediment collection, cobble or concrete pad should be at least 6 inches lower than inlet
	Annually (preferred during fall)	Trees and shrubs adjacent to vehicle travel areas (or areas where visibility needs to be maintained)	✓		✓	✓		Vegetation causes visibility (line of sight) or driver safety issues	• Maintain appropriate height for sight clearance • When continued, regular pruning (more than one time/growing season) is required to maintain visual sight lines for safety or clearance along a walk or drive, consider removing or relocating the plant to a more appropriate location • Consultation with a landscape architect is recommended for removal, transplant, or substitution of plants

Maintenance

- Levels of service

What to Inspect: Building Blocks	Service Level A (Excellent Effort)	Service Level B (Good Effort)	Service Level C (Moderate Effort)	Service Level D (Low Effort)	Service Level F (Poor Effort)	Re Ma
VEGETATION	▪ vegetation is healthy, dense, and attractive ▪ sun loving plants are not shaded ▪ no weeds are present ▪ mulch is evenly distributed ▪ no bare spots ▪ no evidence of erosion ▪ at least 80% survival of establishing plants, 0-3 years old	▪ vegetation is predominantly healthy, dense and attractive ▪ minimal weeds are present ▪ mulch is adequate ▪ minimal bare spots ▪ no evidence of erosion ▪ at least 80% survival of establishing plants, 0-3 years old	▪ vegetation is mostly healthy with a generally good appearance ▪ small quantities of weeds are present ▪ some mulch is present ▪ occasional bare spots ▪ erosion anticipated unless maintained	▪ considerable unhealthy vegetation, generally not with a good appearance ▪ weeds are beginning to dominate ▪ mulch is minimal ▪ bare spots are notable ▪ erosion occurring	▪ poor vegetation health and appearance ▪ weeds abound ▪ mulch is absent ▪ bare spots are frequent ▪ substantial eroded areas	VI
□ Appearance of vegetation –TYPE 1 (aesthetics) □ Trees and shrubs-appearance and health	lush vegetation; excellent appearance	vegetation appearance is very good	moderate appearance	messy appearance	poorly maintained appearance	
□ Appearance of vegetation –TYPE 2 (function and aesthetics)	healthy, well-maintained vegetation; excellent appearance	vegetation during storm event; good appearance and function	vegetation during storm; some bare areas; moderate function	vegetation sparse; reduced function and appearance	vegetation is very sparse; poor function and appearance	
□ Presence of weeds	no weedy species present	weedy species rare	occasional weedy species	some weeds and invasive species	weedy species predominant	

Conclusion: How can we use this info?

Regulators and stormwater managers (programmatic level)

- Use SIFT and MSG to identify filter types which may meet water quality goals
- Inform SW manuals: design, construction, maintenance guidance
- Incorporate QAQC and BDPIP guidance to improve filter media success

Consultants and designers (project level)

- Identify filter media which can achieve WQ goals

Academia and research

- Identify knowledge gaps and data needs

Thanks!

Questions?

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