Media Selection

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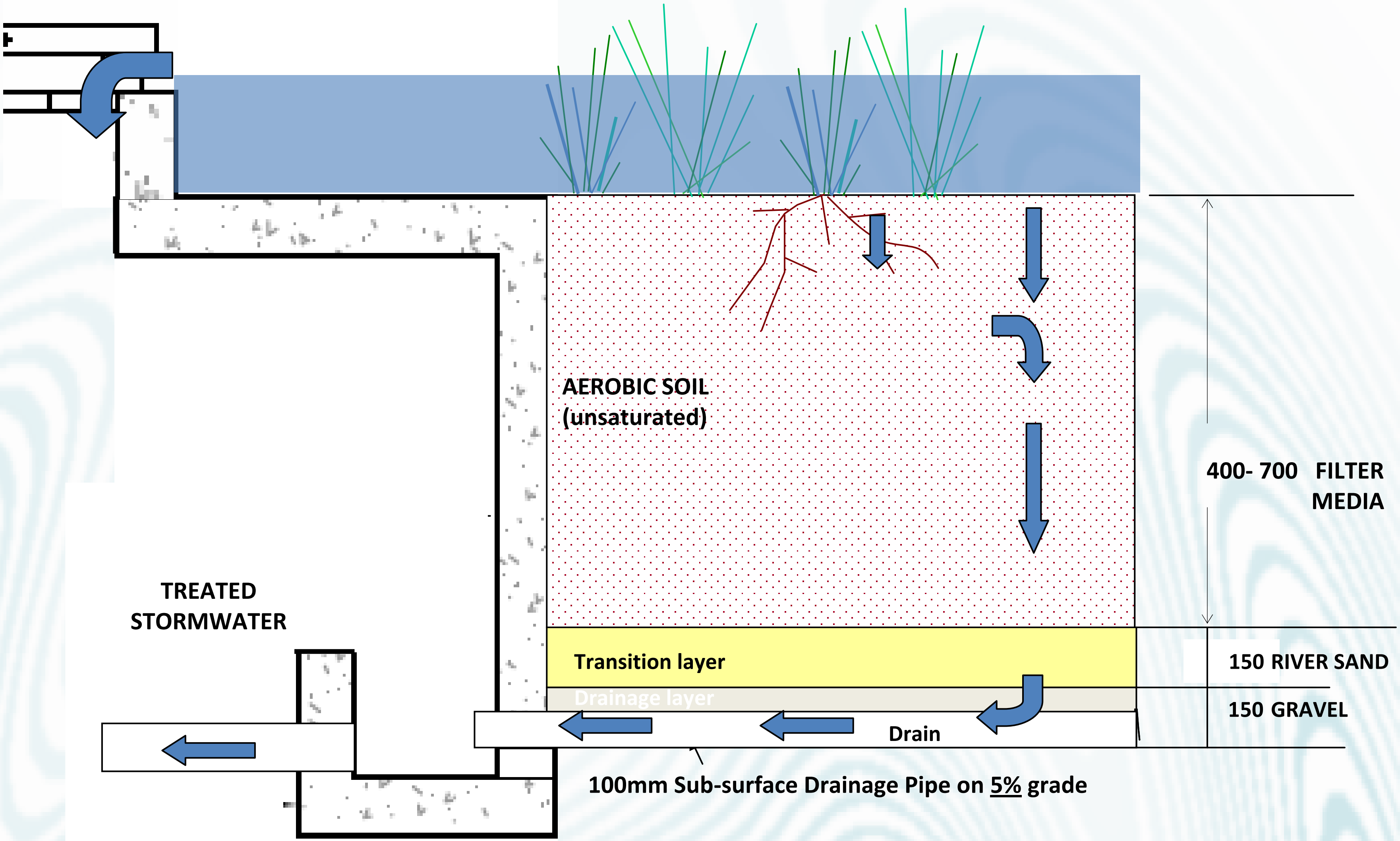

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Role of Filter Media

- Have adequate capacity to infiltrate incoming stormwater
- Provide physico-chemical filtration of stormwater pollutants
- Support biological community for enhanced treatment and aesthetic benefits

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Key Findings

- Loamy sand
- Hydraulic conductivity:
  - 100 – 300 mm/hr in temperate climates
  - 100 – 600 mm/hr in tropical climates
  - An exact hydraulic conductivity is less important than selecting something in the appropriate range
  - Initial laboratory assessment is ***essential*** – use ASTM F1815-06 (USGA) test method
  - Field testing should also be performed intermittently throughout the life of the system
- To ensure structural stability:
  - Material should be well-graded and contain no gaps in the particle size range
  - Total silt and clay content should be less than 3% w/w
- To avoid leaching of nutrients:
  - Organic matter content should be less than 5% w/w
  - Phosphorus content should be less than 100 mg/kg

Media Type

- Activity 1.02 (a) Non-vegetated filters
  - How does filter media perform for removal of (i) nutrients and (ii) heavy metals?
  - What is the optimal filter media for (i) pollutant removal and (ii) clogging prevention?
  - Filter columns dosed with stormwater for 42 weeks
    - Equivalent to 15 months in “real life”

Non-vegetated filters: results

TABLE 2. Pollutant Removal Summary for Six Filter Media Types

	TSS	TP	TN	TOC	Cu	Mn	Pb	Zn
	Event mean hydraulic loading (g/m^2)							
	29	0.08	0.45	1	0.06	0.01	0.15	0.22
	Load Reduction (%)							
S	99 ± 1	97 ± 1	38 ± 1	59 ± 8	97 ± 1	94 ± 1	99 ± 1	99 ± 1
SL	93 ± 4	−65 ± 16	−18 ± 15	−103 ± 17	97 ± 1	−32 ± 54	99 ± 1	99 ± 1
SLH	92 ± 3	−143 ± 17	−37 ± 4	−146 ± 19	96 ± 1	−71 ± 19	99 ± 1	98 ± 1
SLVP	90 ± 3	−73 ± 15	−23 ± 12	−129 ± 22	94 ± 2	−26 ± 52	95 ± 2	96 ± 4
SLCM	92 ± 4	−409 ± 40	−111 ± 41	−178 ± 13	94 ± 1	−152 ± 100	97 ± 1	96 ± 1
SLCMCH	96 ± 1	−437 ± 50	−164 ± 14	−165 ± 5	93 ± 1	−178 ± 189	97 ± 1	96 ± 1

Load reductions are reported as the mean of three replicates ± standard deviation. Note: a negative load reduction indicates leaching of previously retained pollutants and/or native material.

Hatt, B. E., T. D. Fletcher and A. Deletic (2008). Hydraulic and pollutant removal performance of fine media stormwater filtration systems. *Environmental Science & Technology* ***42(7): 2535-2541.***

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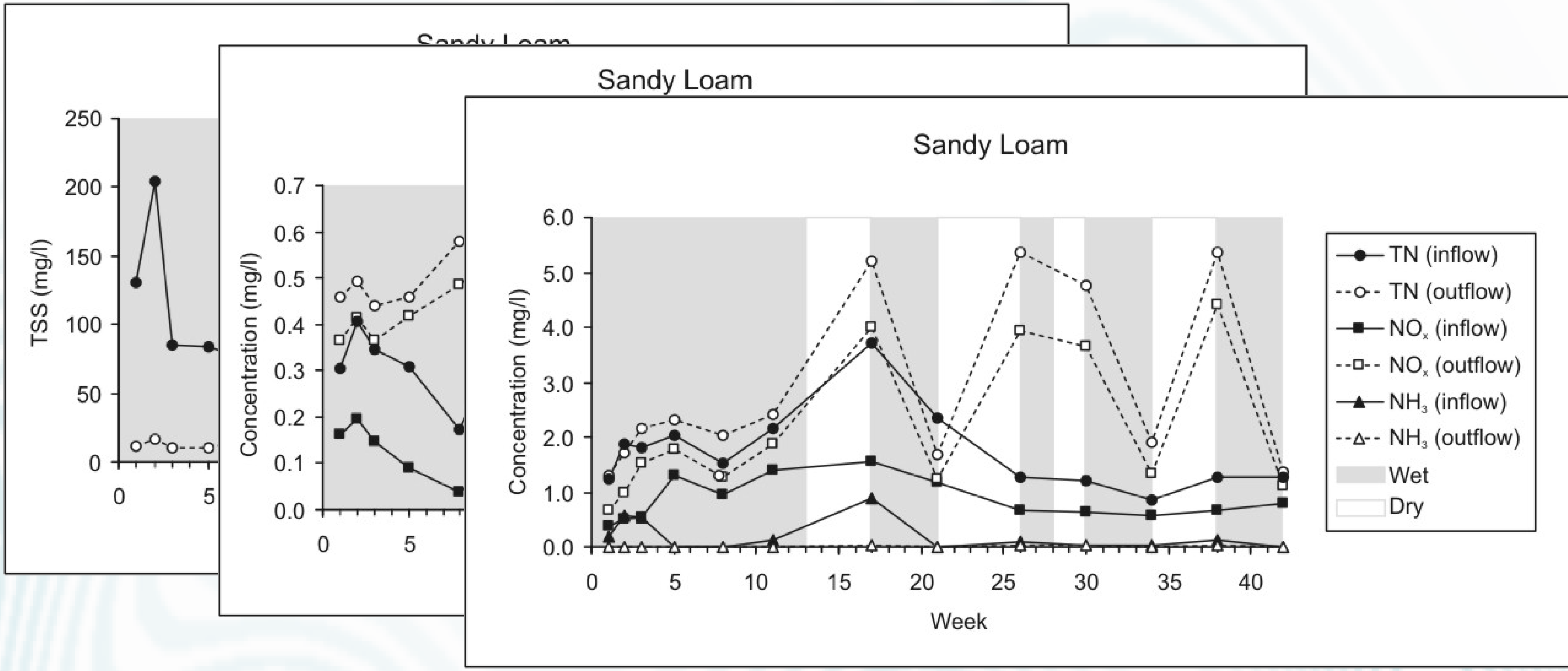
Non-vegetated filters: results



Hatt, B. E., T. D. Fletcher and A. Deletic (2007). Hydraulic and pollutant removal performance of stormwater filters under variable wetting and drying regimes. *Water Science & Technology* ***56(12): 11-19.***

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Non-vegetated filters: conclusions

- Soil and sand-based filters provide:
  - Excellent TSS removal
  - Excellent metals removal

BUT

  - They will not reliably remove nutrients on their own
- Wetting and drying has a significant influence on treatment

Media Type

- Activity 1.02 (a) Non-vegetated filters
- Activity 1.02 (b) Optimisation of standard biofilter design
  – Optimising biofilter design for (i) pollutant removal and (ii) hydraulic conductivity

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Vegetated filters: results

Factors tested	Vegetation	Inflow volume	Filter media depth	Filter media type	Inflow conc.	TP		PO_4^{3-}	
						Concentration (mg/L)	Removal (%)	Concentration (mg/L)	Removal (%)
Vegetation	None	Std.	700	SL	Std.	0.083 (15)	81 (4)	0.064 (15)	50 (15)
	Carex	Std.	700	SL	Std.	0.023 (22)	95 (1)	0.013 (21)	90 (2)
	Dianella	Std.	700	SL	Std.	0.092 (19)	78 (5)	0.072 (16)	44 (20)
	Microleana	Std.	700	SL	Std.	0.074 (12)	83 (3)	0.050 (22)	61 (14)
	Leucophyta	Std.	700	SL	Std.	0.098 (9)	77 (3)	0.076 (13)	40 (19)
	Melaleuca	Std.	700	SL	Std.	0.070 (17)	84 (3)	0.034 (35)	74 (13)
Volume	Carex	Low	700	SL	Std.	0.024 (48)	94 (3)	0.013 (45)	90 (5)
	Carex	High	700	SL	Std.	0.046 (12)	89 (1)	0.027 (28)	79 (8)
	Microleana	High	700	SL	Std.	0.104 (9)	76 (3)	0.087 (8)	32 (17)
	Melaleuca	High	700	SL	Std.	0.078 (29)	82 (7)	0.045 (39)	64 (22)
Filter media depth	Carex	Std.	500	SL	Std.	0.032 (26)	93 (2)	0.016 (24)	87 (4)
	Carex	Std.	300	SL	Std.	0.038 (22)	91 (2)	0.022 (18)	83 (4)
	Microleana	Std.	500	SL	Std.	0.078 (14)	82 (3)	0.062 (17)	52 (16)
	Microleana	Std.	300	SL	Std.	0.078 (6)	82 (1)	0.053 (6)	58 (4)
	Melaleuca	Std.	500	SL	Std.	0.060 (39)	86 (6)	0.033 (60)	74 (21)
	Melaleuca	Std.	300	SL	Std.	0.050 (40)	88 (5)	0.024 (79)	81 (18)
Filter media type	Carex	Std.	700	SLVP	Std.	0.040 (31)	91 (3)	0.021 (35)	83 (7)
	Carex	Std.	700	SLCM	Std.	0.264 (48)	38 (78)	0.226 (49)	-78 (>100)
Inflow Conc.	Melaleuca	Std.	700	SL	High	0.068 (24)	91 (2)	0.030 (34)	96 (1)
	Microleana	Std.	700	SL	High	0.064 (14)	91 (1)	0.049 (17)	93 (1)
	Carex	Std.	700	SL	High	0.028 (30)	96 (1)	0.015 (35)	98 (1)
	None	Std.	700	SL	High	0.086 (6)	88 (1)	0.065 (6)	91 (1)

Bratieres, K., T. D. Fletcher, A. Deletic and Y. Zinger (in press). Optimisation of the treatment efficiency of biofilters; results of a large-scale laboratory study. *Water Research.*

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Vegetated filters: results

- Use of an appropriate soil type provides:
  - Excellent TSS removal
  - Excellent metals removal
  - Excellent P removal (total *and* dissolved)

- Removal of N is more complicated and is not governed by media type alone
  - More to come on this during the day

Media Type

- Activity 1.02 (a) Non-vegetated filters
- Activity 1.02 (b) Optimisation of standard biofilter design
- Loamy sand
  - Why not sand?
    - Clogging risk
    - Low sorption capacity
    - Ability to support healthy plant community?

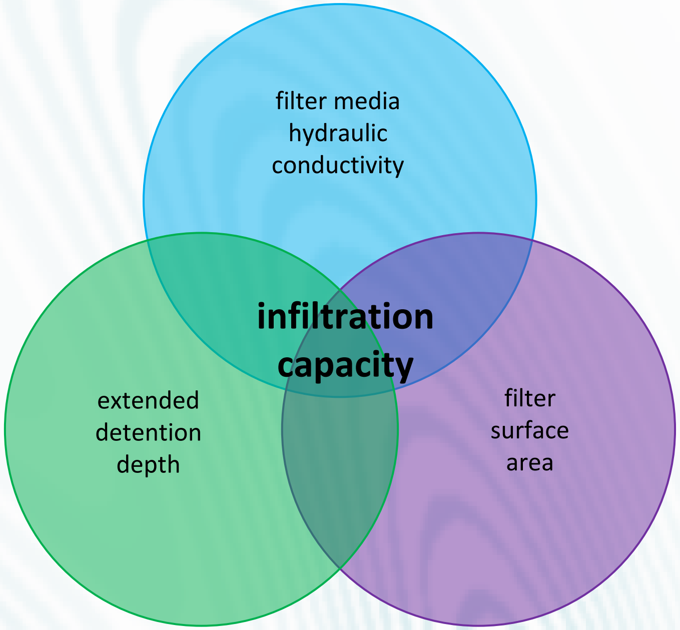
Hydraulic Conductivity

- Infiltration capacity not determined by hydraulic conductivity (K_s) alone

↑ K_s to be able to treat more water

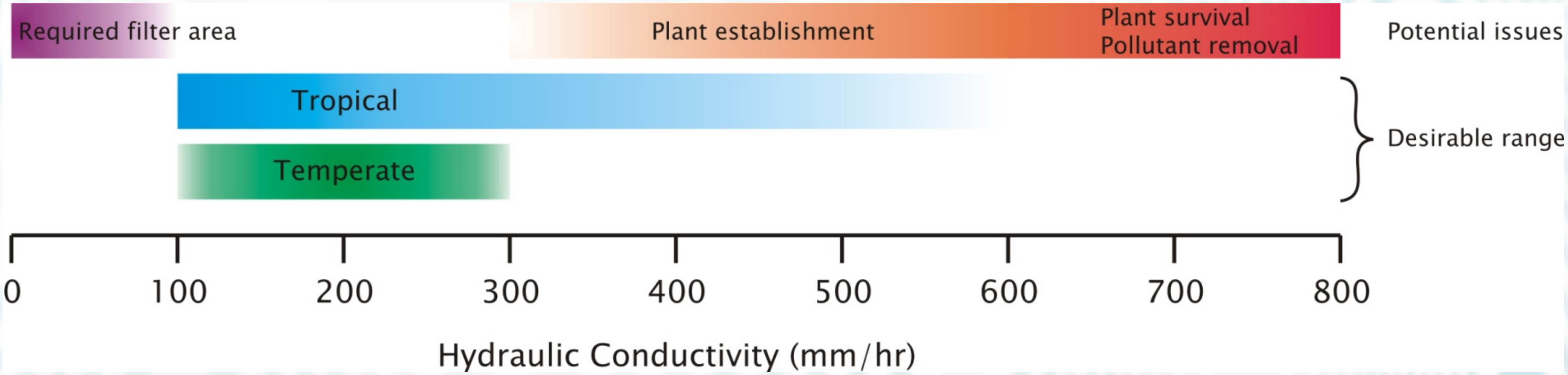
BUT

↓K_s for better pollutant removal and plant growth



Hydraulic Conductivity

- For a biofilter that is 2% of the contributing catchment, use a K_s of:
  - 100 – 300 mm/hr (for temperate climates)
  - 100 – 600 mm/hr (for tropical climates)



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Hydraulic Conductivity

- How to measure?
- Three potential methods tested
  - AS 4419-2003
  - ASTM F1815-06
  - McIntyre & Jackobsen

- Most representative compaction method
- Most consistent results
- Simple apparatus

Particle Size Distribution

	Composition (% w/w)
Clay & Silt	<3
Very Fine Sand	5 – 30
Fine Sand	10 – 30
Medium – Coarse Sand	40 – 60
Coarse Sand	7 – 10
Fine Gravel	<3

A general guide only!

Particle Size Distribution

- Impact of silt and clay
  - Important for water retention and sorption of dissolved pollutants

    BUT

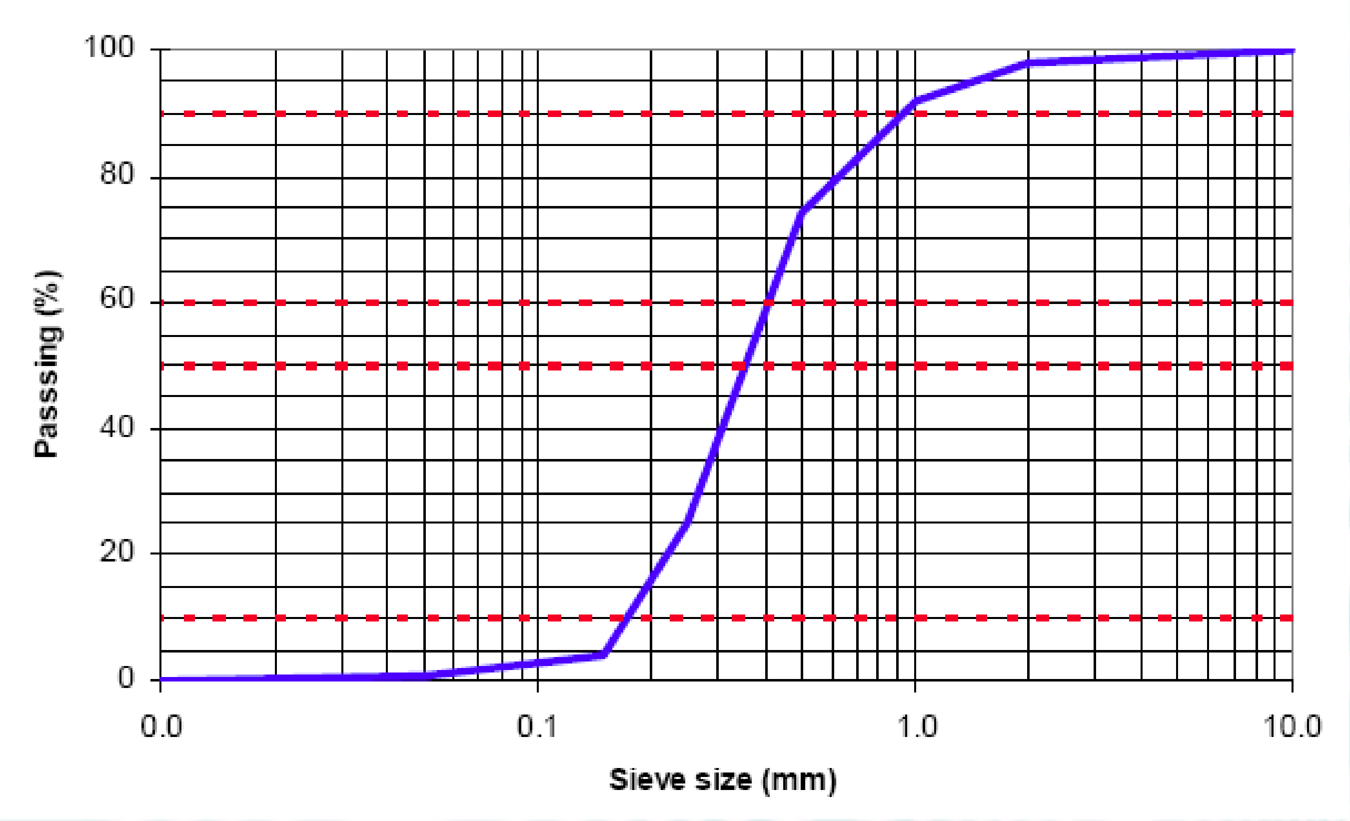
  - Reduces hydraulic conductivity if present in anything more than very small quantities
    - Based on a laboratory trial where silt & clay were added to the a loamy sand in different proportions (0 – 15%)

Particle Size Distribution

To ensure structural stability, the filter media should:

- Have all particle size ranges present from the 0.075 mm to the 4.75 mm sieve (AS1289.3.6.1 – 1995)
- Have no gap gradings
- Not be dominated by a small particle size range

Particle Size Distribution



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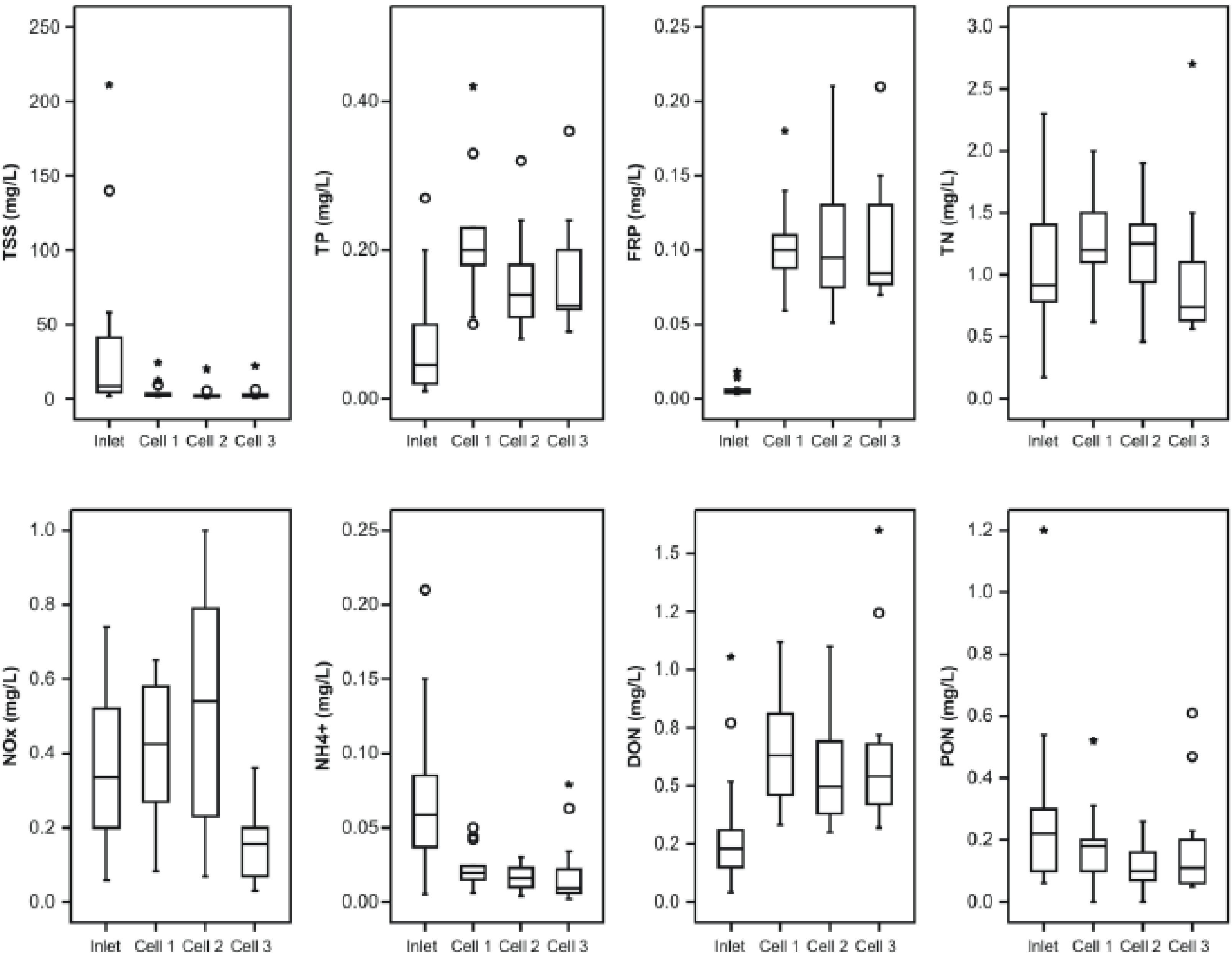
Soil Properties

- pH: 5.5 – 7.5
- EC: < 1.2 dS/m
- Organic matter: <5% (w/w)
- Phosphorus: 100 mg/kg
- Soil Nutrition

AS 4419-2003: Soils for Landscaping and Garden Use

Based on results of non-vegetated filters, large vegetated filter column study, and field studies

Field Studies



Hatt, B. E., T. D. Fletcher and A. Deletic (in press). Hydrologic and pollutant removal performance of stormwater biofiltration systems at the field scale. *Journal of Hydrology.*

Field Studies

	Load Reduction (%)	
	Monash University	McDowall
TSS	76 ± 25	93 ± 4
TP	-398 ± 559	86 ± 3
FRP	-1271 ± 1067	81 ± 15
TN	-7 ± 72	37 ± 21
NO_x	-13 ± 93	-17 ± 35
NH_4^+	64 ± 42	96 ± 7
DON	-129 ± 232	58 ± 11
PON	38 ± 55	79 ± 12
Cd	-	91 ± 2
Cu	67 ± 23	98 ± 1
Mn	38 ± 53	-
Pb	80 ± 15	98 ± 0.5
Zn	84 ± 26	99 ± 0.1

Hatt, B. E., T. D. Fletcher and A. Deletic (in press). Hydrologic and pollutant removal performance of stormwater biofiltration systems at the field scale. *Journal of Hydrology.*

Soil Properties

- pH: 5.5 – 7.5
- EC: < 1.2 dS/m
- Organic matter: <5% (w/w)
- Phosphorus: 100 mg/kg
- Soil Nutrition

Other Considerations

- Filter media should:
  - Be free of rubbish, toxicants, declared plants and local weeds
  - Not be hydrophobic
- Avoid dispersive clays

Other Considerations

- Drainage Layer
  - Efficiently conveys treated water to collection pipes
  - Clean, fine gravel e.g. 2 – 5 mm washed screenings
- Transition Layer
  - Prevents filter media from washing into drainage layer
  - Clean, well-graded sand/coarse sand containing little

DON'T use geotextile fabrics to separate layers.

Use open-weave shade cloth **ONLY** where there is insufficient depth for a transition layer

Recap…

- Loamy sand
- Hydraulic conductivity
  - 100 – 300 mm/hr in temperate climates
  - 100 – 600 mm/hr in tropical climates
  - An exact hydraulic conductivity is less important than selecting something in the appropriate range
  - Initial laboratory assessment is ***essential*** – use ASTM F1815-06 (USGA) test method
  - Field testing should also be performed intermittently throughout the life of the system
- To ensure structural stability:
  - Material should be well-graded and contain no gaps in the particle size range
  - Total silt and clay content should be less than 3% w/w
- To avoid leaching of nutrients:
  - Organic matter content should be less than 5% w/w
  - Phosphorus content should be less than 100 mg/kg

Now that we've got a suitable filter media...

- Installation
  - Compact lightly to prevent migration of fine particles
- Field testing of hydraulic conductivity
  1. One month into operation
  2. In the second year of operation

Useful Tools

http://www.monash.edu.au/fawb/products/index.html

FAWB Facility for Advancing Water Biofiltration

GUIDELINES FOR SOIL FILTER MEDIA IN BIORETENTION SYSTEMS (Version 2.01)
March 2008

The following guidelines for soil filter media in bioretention systems have been prepared on behalf of the Facility for Advancing Water Biofiltration (FAWB) to assist in the development of bioretention systems, including the planning, design, construction and operation of those systems.

NOTE: This is a revision of the previous FAWB guideline specifications (published in 2006). It attempts to provide a simpler and more robust guideline. FAWB acknowledges the contribution of EDAW Inc., Melbourne Water Corporation, Dr Nicholas Somes (Ecodynamics), Alan Hoban (SEQ Healthy Waterways Partnership), and STORM Consulting to the preparation of the revised guidelines.

Disclaimer

The Guidelines for Soil Filter Media in Bioretention Systems are made available and distributed solely

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1 GENERAL DESCRIPTION

The bioretention filter media guidelines require three layers of media: the filter media itself (400-600 mm deep or as specified in the engineering design), a transition layer (100 mm deep), and a drainage layer (50 mm minimum underdrainage pipe cover). The bioretention system will operate so that water will infiltrate into the filter media and move vertically down through the profile.

The filter media is required to support a range of vegetation types (from groundcovers to trees) that are adapted to freely draining soils with occasional flooding. The material should be based on natural soils or amended natural soils and can be of siliceous or calcareous origin. In general, the media should be a loamy sand with an appropriately high permeability under compaction and should be free of rubbish, deleterious material, toxicants, declared plants and local weeds (as listed in local guidelines/Acts), and should not be hydrophobic. The filter media should contain some organic matter for increased water holding capacity but be low in nutrient content.

Bioretention Filter Media Guidelines (Version 2.01). Prepared by the Facility for Advancing Water Biofiltration (FAWB), March 2008.

FAWB Facility for Advancing Water Biofiltration

CONDITION ASSESSMENT AND PERFORMANCE EVALUATION OF BIORETENTION SYSTEMS

PRACTICE NOTE 1: *In Situ* Measurement of Hydraulic Conductivity

Belinda Hatt, Sebastien Le Coustumer
April 2008

The Facility for Advancing Water Biofiltration (FAWB) aims to deliver its research findings in a variety of forms in order to facilitate widespread and successful implementation of biofiltration technologies. This Practice Note for *In Situ* Measurement of Hydraulic Conductivity is the first in a series of Practice Notes being developed to assist practitioners with the assessment of construction and operation of biofiltration systems.

Disclaimer: Information contained in this Practice Note is believed to be correct at the time of

FAWB's Guidelines for Soil Filter Media in Bioretention Systems, Version 2.01 (visit http://www.monash.edu.au/fawb/publications/index.html for a copy of these guidelines). However, the recommendations contained within this document are more widely applicable to assessing the hydraulic conductivity of filter media in existing biofiltration systems.

For new systems, this Practice Note *does not* remove the need to conduct laboratory testing of filter media prior to installation.

2. DETERMINATION OF HYDRAULIC CONDUCTIVITY

The recommended method for determining *in situ* hydraulic conductivity uses a single ring infiltrometer under constant head. The single ring infiltrometer consists of a small plastic or metal ring that is driven 50 mm into the soil filter media. It is a constant head test that is conducted for two different pressure heads (50 mm and 150 mm). The head is kept constant during all the experiments by pouring water into the ring. The frequency of readings of the volume poured depends on the filter media, but typically varies from 30 seconds to 5 minutes. The experiment is stopped when the infiltration rate is considered steady (i.e., when the volume poured per time interval remains constant for at least 30 minutes). This method has been used extensively (e.g. Reynolds and Elrick, 1990; Youngs *et al.*, 1993).

Note: This method measures the hydraulic conductivity at the surface of the soil filter media. In most cases, it is this top layer which controls the hydraulic conductivity of the system as a whole (i.e., the underlying drainage layer has a flow capacity several orders of magnitude higher than the filter media), as it is this layer where fine sediment will generally be deposited to form a "clogging layer". However this shallow test would not be appropriate for systems where the controlling layer

1