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Water Sensitive Cities

Biofilter Adoption Guidelines v2

Australian Government
Department of Industry and Science

Business
Cooperative Research
Centres Programme

Revision of the biofilter guidelines

- Collaborative process
  - Led by an industry advisory panel
  - Nation-wide input
  - Consultation with other industry participants on specific issues

- Industry Advisory Panel members
  - Krish Seewraj and Antonietta Torre (Western Australian Department of Water)
  - Sam Phillips (Natural Resources Adelaide and Mt Lofty Ranges, South Australia Department of Environment, Water and Natural Resources)
  - David Beharrell (Hornsby Council)
  - David Carew and Justin Lewis (Melbourne Water)
  - Jay Jonasson (Ku-ring-gai Council)
  - Dale Browne (E2DesignLab)
  - Adrian Crocetti (Brisbane City Council)

Overview of revised biofilter guidelines

- Chapter 1: Introduction
- Chapter 2: The Business Case for Biofiltration
- Chapter 3: Technical Considerations
- Chapter 4: Practical Implementation
- Appendices e.g.
  - Filter media guidelines
  - Practice notes
  - Checklists
  - Fact sheets

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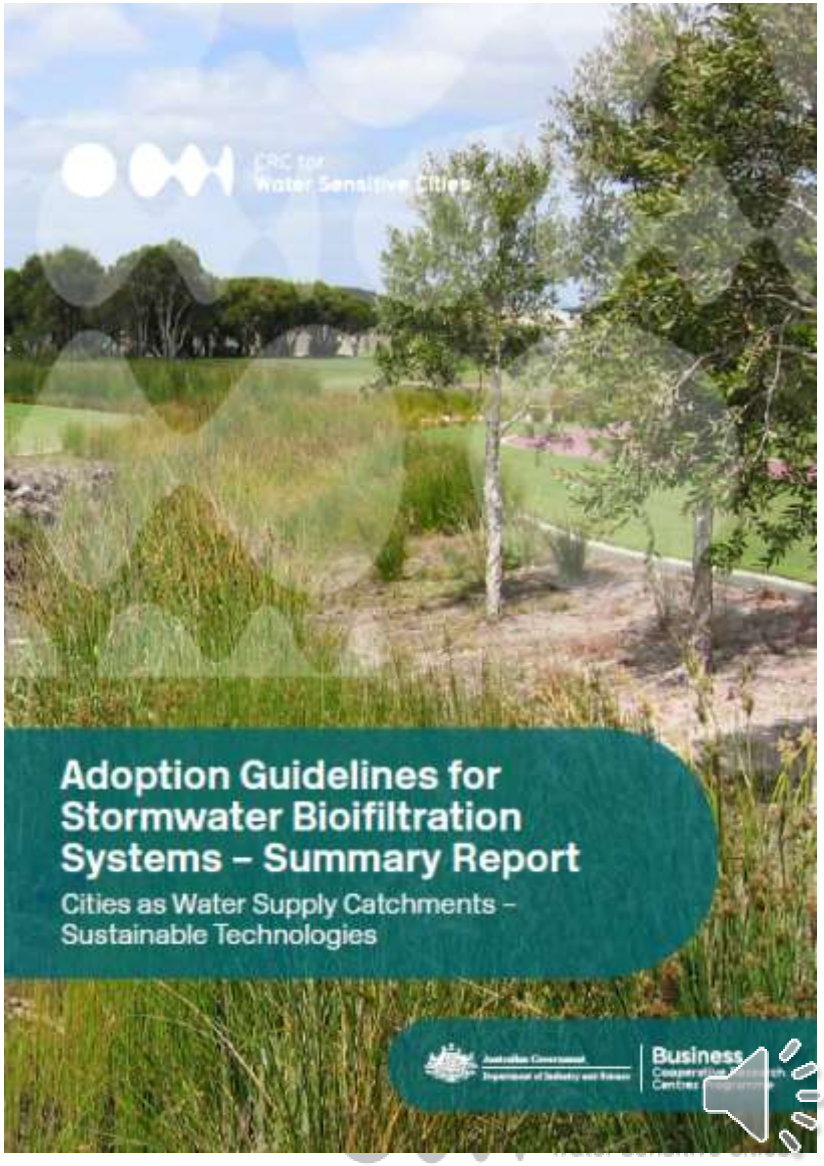
What's new in v2 of the Biofilter Adoption Guidelines?

- Summary Report
  - Overview of key design, construction & maintenance considerations
  - Navigation to particular sections of main report



What's new in v2 of the Biofilter Adoption Guidelines?

- The business case for biofiltration
  - How to justify and endorse their adoption
  - Broad economic costs and benefits

Multiple benefits & evidence

Benefit/Cost	Outcome	References
Overall	Business case analysis concluded the **benefits of best-practice WSUD do surpass the costs**	Water by Design (2010a)
	A cost-benefit analysis in Pennsylvania highlighted the **broad range of environmental and social benefits** provided by Low Impact Development and Green Infrastructure systems which are **not typically provided by traditional approaches.**	U.S. EPA (2013)
Water quality	In Victoria a Stormwater Offsets Program operates to help developers meet the legislated reduction targets. **Nitrogen** (commonly the limiting nutrient in Port Phillip Bay) reduction is currently valued at **$6,645/kg N (in terms of annual total nitrogen load), based on the cost of stormwater treatment works implemented in the past by Melbourne Water** (effective 1st August 2014).	Melbourne Water (2015)
	Value of N reduction alone estimated to be **worth more than the project life cycle cost** (based on $515/kg N – cost to reduce load using wastewater treatment).	Water by Design (2010a)
Property values	**Increase in property values** from the greater amenity of healthy waterways estimated at **~90% of the capital costs of WSUD projects.**	Water by Design (2010a)
	The **amenity value of streetscape raingardens** in Sydney is realised in residential house prices, **increasing property values by around 6% ($54,000 AUD) for houses within 50 m and 4% ($36,000 AUD) up to 100 m away.** This demonstrates that raingardens are valued by the community, and a typical raingarden installation at a street intersection can generate around $1.5 million increase in residential value.	Polyakov et al. (2015)
	A **10% increase in tree canopy coverage on the street verge adds a property price premium of about AU$14,500**	Pandit et al. (2013)

What's new in v2 of the Biofilter Adoption Guidelines?

- The business case for biofiltration
  - How to justify and endorse their adoption
  - Broad economic costs and benefits
- Expanded guidance on plant selection
  - List of 'effective' plant species
  - Desirable plant traits for nutrient removal performance
  - Use of specific plant types e.g. trees, lawn species
  - Practical considerations for selection & planting

Plant Selection

Objective	Effective	Medium or Mixed performance with different conditions	Poorer performers
Nitrogen removal	· *Baumea juncea* · *Baumea rubiginosa* · *Carex appressa* · *Carex tereticaulis* · *Ficinia nodosa* · *Goodenia ovata* · *Juncus amabilis* · *Juncus flavidus* · *Juncus pallidus* · *Juncus subsecundus* · *Melaleuca ericifolia* · *Melaleuca incana* · *Melaleuca lateritia*	**Medium** · *Poa labillardieri* · *Poa sieberiana* · *Sporobolus virginicus* **Effective in wet/ poorer in dry** · *Allocasurina littoralis* · *Cyperus gymnocaulos* · *Juncus kraussii* · *Leptospermum continentale* **Effective in dry/poorer in wet** · *Poa poiformis*	· *Acacia suaveolens* · *Astartea scoparia* · *Austrodanthonia caespitosa* · *Banksia marginata* · *Dianella revoluta* · *Dianella tasmanica* · *Gahnia trifida* · *Gahnia sieberiana* · *Hakea laurina* · *Hypocalymma angustifolium* · *Leucophyta brownii* · *Lomandra longifolia* · *Microlaena stipoides* · *Pomaderris paniculosa* · *Rytidosperma caespitosum*
Pathogen removal	· *Carex appressa* · *Leptospermum continentale* · *Melaleuca incana* · Palmetto® buffalo		· *Dianella tasmanica* · *Poa labillardieri* · *Sporobolus virginicus*
Infiltration capacity	· *Melaleuca incana* · *Melaleuca ericifolia*		
Iron removal	· *Carex appressa*		

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- Clearer communication of filter media requirements
  - Essential vs. recommended

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Essential Filter Media Requirements

	Property	Specification to be met	Why is this important to biofilter function?
Filter Media (top layer/ growing media)			
ESSENTIAL SPECIFICATIONS	**Material**	Either an engineered material – a **washed, well-graded sand** – or naturally occurring sand, possibly a mixture	Media must be sand-based (and not a loam) to ensure adequate hydraulic conductivity, low nutrient content and structural stability
	Hydraulic conductivity	**100 – 300 mm/hr** (higher in tropical regions but must be capable of supporting plant growth). Determine using ASTM F1815-11 method	Provides adequate capacity to treat a higher proportion of incoming stormwater Testing method best represents field conditions
	Clay & silt content	**< 3% (w/w)**	Above this threshold hydraulic conductivity is substantially reduced. Too many very fine particles also reduce structural stability leading to migration and leaching
	Grading of particles	**Smooth grading** – all particle size classes should be represented across sieve sizes from the 0.05mm to the 3.4mm sieve (as per ASTM F1632-03(2010)	Provides a stable media, avoiding structural collapse from downwards migration of fine particles
	Nutrient content	**Low nutrient content** Total Nitrogen **(TN) < 1000 mg/kg** Available phosphate (Colwell) **< 80 mg/kg**	Prevents leaching of nutrients from the media
	Organic matter content	**≤5%** to prevent leaching	Although some organic matter helps to retain moisture for vegetation and can benefit pollutant removal, higher levels will lead to nutrient leaching
	pH	**5.5 – 7.5** – as specified for 'natural soils and soil blends' in AS4419 – 2003 (pH 1:5 in water)	To support healthy vegetation over the long-term – without which the biofilter cannot function effectively
	Electrical conductivity	**< 1.2 dS/m** – as specified for 'natural soils and soil blends' in AS4419 – 2003	
	Horticultural suitability	Assessment by horticulturalist – **media must be capable of supporting healthy vegetation.** Note that additional nutrients are delivered with incoming stormwater	

Recommended Filter Media Properties

	Property	Specification to be met	Why is this important to biofilter function?
	Particle size distribution (PSD)	Note that it is most critical for plant survival to ensure that the fine fractions are included (% w/w) Retained **Clay & silt < 3% (< 0.05 mm)** **Very fine sand 5-30% (0.05-0.15mm)** Fine sand 10-30% (0.15-0.25 mm) Medium sand 40-60% (0.25-0.5 mm) Coarse sand < 25% (0.5-1.0 mm) Very coarse sand 0-10% (1.0-2.0mm) Fine gravel < 3% (2.0-3.4 mm)	Of secondary importance compared with hydraulic conductivity and grading of particles, but provides a starting point for selecting appropriate material with adequate water-holding capacity to support vegetation. **Filter media do not need to comply with this particle size distribution to be suitable for use in biofilters**
	Depth	400-600 mm or deeper	To provide sufficient depth to support vegetation Shallow systems are at risk of excessive drying
	Once-off nutrient amelioration	Added manually to top 100 mm **once only** Particularly important for engineered media	To facilitate plant establishment, but in the longer term incoming stormwater provides nutrients
GUIDANCE	**Submerged zone**	Strongly recommended, particularly if entirely engineered media is used, filter media has a relatively high hydraulic conductivity or a shallow depth	To provide water retention to support plants through dry periods, and greater pollutant removal

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What's new in v2 of the Biofilter Adoption Guidelines?

- Designing for stormwater harvesting
  - Removal of pathogens, organic micro-pollutants and heavy metals
- Updated design configuration guidance, e.g.
  - Inclusion of a raised outlet

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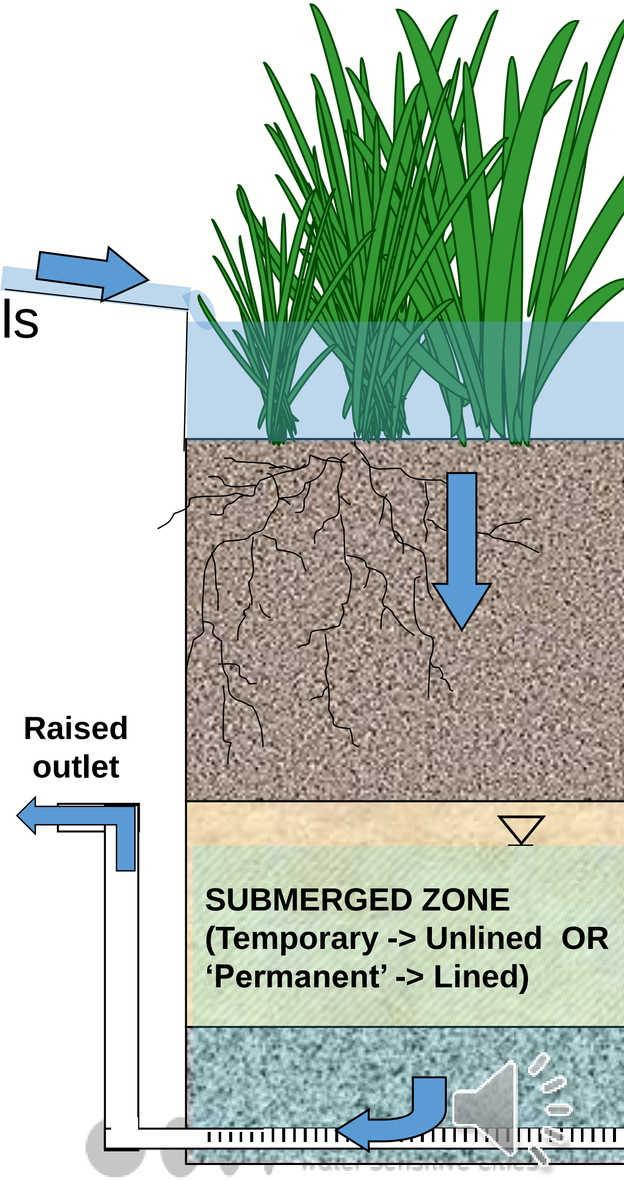
Raised outlet / Submerged zone

- **Unlined -> will be temporary**
  - Appropriate in wet climates or heavy clay soils
  - Promotes exfiltration into surrounding soils – hydrological & water quality benefits

- **Lined -> longer lasting**
  - Use in areas where >3 weeks dry weather is common

- Ideal depth is 450-500 mm



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- Tips for aesthetics and community appreciation
  - Designing biofilters that look attractive

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Landscape design

- Work by Meredith Dobbie
- Visit site
- Design to suit neighbourhood character – fit the context
- Consider
  - land use
  - architecture
  - nearby planting layout and species (including private gardens)
- Use colour & texture

Meredith Dobbie & Hamish Smilie

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  - Inclusion of a raised outlet
- Tips for aesthetics and community appreciation
  - Designing biofilters that look attractive
- Designing for successful long-term operation and low maintenance
  - Planned vs. corrective maintenance
  - Delaying clogging
  - Practical considerations

What's new in v2 of the Biofilter Adoption Guidelines?

- Tips for addressing unique and/or challenging site conditions
  - Steep sites or shallow gradients
  - Designing for drought resilience
  - Limited space
  - Shallow groundwater
  - High sediment load
  - Saline environments
- Illustration and summaries
  - How biofilters work, what components are important and why
  - Design process
  - Important construction checks
  - Key maintenance issues

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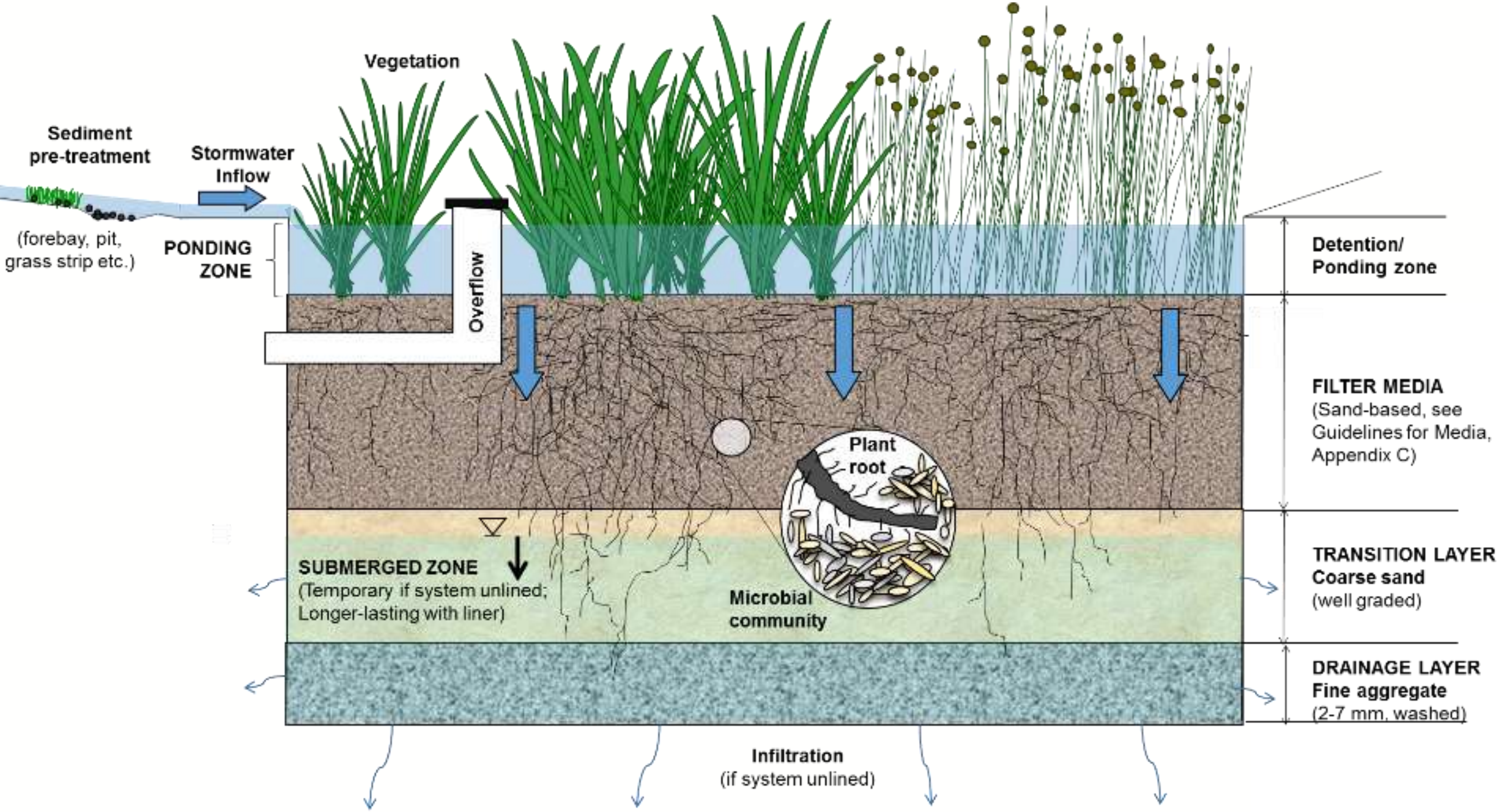
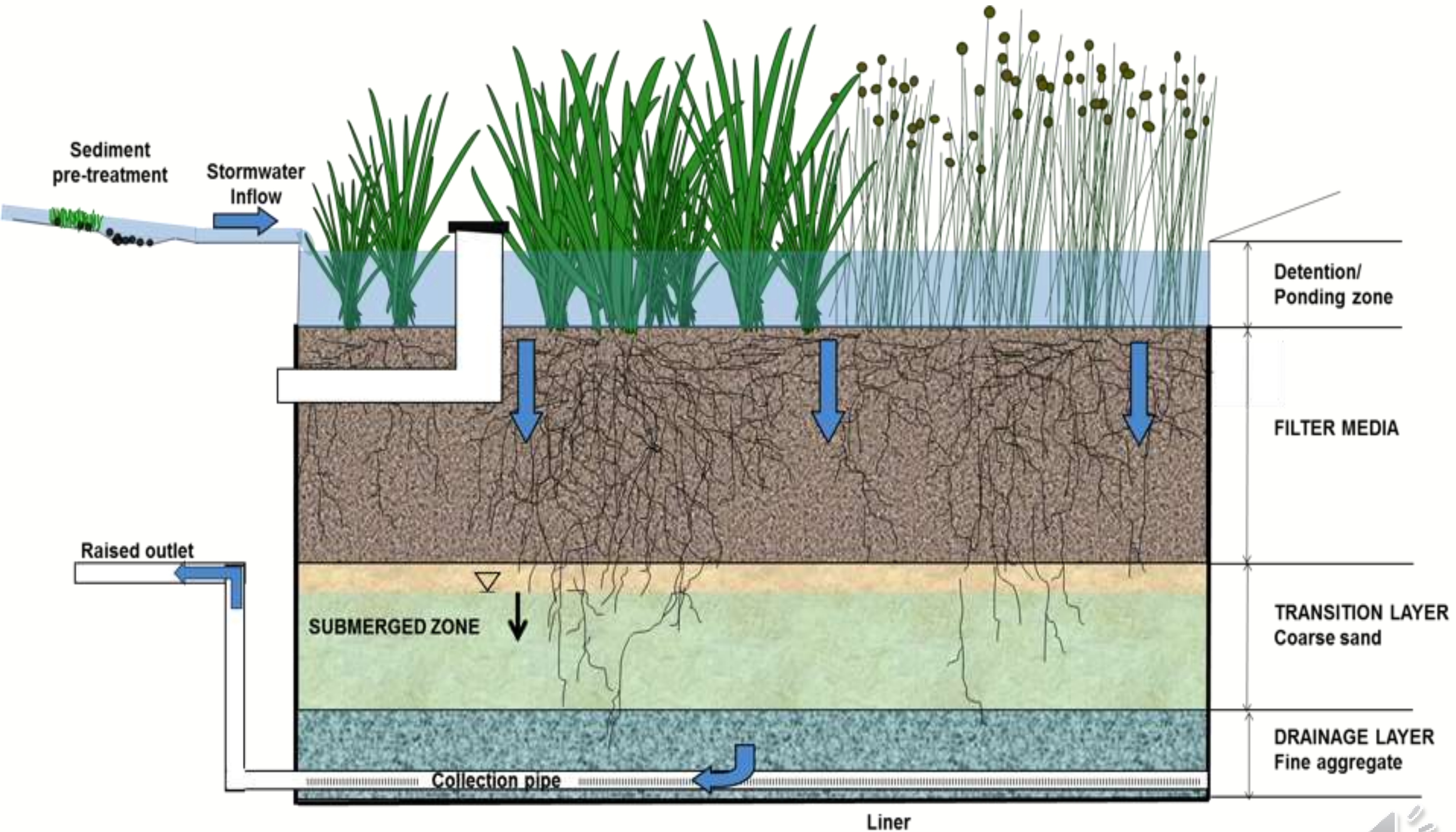
Key components of biofilters and their functional roles

Essential components and function	Key information can be found within Biofilter Adoption Guidelines v2 (CRCWSC, 2015), Section...	
Inflow	Delivers stormwater into biofilter	3.6.3
Overflow	Allows high flows to bypass to avoid damage to system	3.6.3
Ponding	(or detention zone) Increases treatment capacity by allowing stormwater to pond before infiltration	3.6.2
Vegetation	Serves multiple roles in water treatment via uptake, transformation to organic forms, carbon provision to microbes, transpiration reducing stormwater volume, stabilising media surface, helping to maintaining infiltration rates, provides cooling to surrounding environment, amenity and aesthetics. The microbial community associated with plant roots facilitates uptake, decomposition and transformation of stormwater pollutants and plant litter.	3.6.5
Filter media	Provides physical filtration of particulates, physiochemical pollutant removal processes such as adsorption, fixation, precipitation, supports vegetation growth and the infiltration of stormwater attenuates and reduces the magnitude of the outflow hydrograph (providing stream health benefits)	3.6.4
Transition layer	Coarse sand. Provides a bridging layer to prevent migration of fine particles from the upper filter media to the gravel drainage layer	3.6.4
Drainage layer	Gravel. Allows the system to drain, either into a collection pipe and outflow point or infiltration into surrounding soils, also provides higher porosity to temporarily store stormwater within the pore space	3.6.4
Unlined	Allows infiltration into surrounding soils, either for the entire or only part of the system	3.6.3
Pre-treatment	Collects coarse sediment and litter, helping to protect the biofilter itself from premature clogging and blockages, and facilitating maintenance. Recommended for all systems except those whose impervious catchment is <2ha in size without identifiable sediment sources, or systems only receiving roof runoff (Water by Design, 2014).	3.6.3

Essential Components



Additional Components



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Key design decisions and tips

OBJECTIVES
(section 3.2)

SPECIFIC PERFORMANCE OBJECTIVES
(Section 3.4)

SITE CONDITIONS
(section 3.4)

- **Local climate**
- **Safety** *(Section 3.7.7)*
- **Catchment characteristics**
- **Nearby infrastructure** *(Section 3.7.7)*
- **Soils and groundwater**
- **Surrounding landscape and vegetation**

DESIGN PARAMETERS

Sizing *(section 3.6.2) — iterative, use MUSIC or design curves*

Determine biofilter area
Recommend 2% impervious catchment area (4% for Qld)

Select ponding depth
100 – 300 mm but consider safety limitations for site. If restricted compensate with larger biofilter area and other safety features.

Select media depth
Recommend ≥ 500 mm *(Section 3.6.4)*

Media hydraulic conductivity
100 – 300 mm/hr *(Section 3.6.4, Full specs Appendix C)*

Sediment pre-treatment *(Section 3.6.3)*
Recommend for all systems to reduce clogging, unless biofilter < 2 ha without identifiable sediment sources or if only treating roof runoff.

Include a raised outlet *(Section 3.6.3)*
Benefits pollutant removal and plant & microbial survival across dry periods, reduces head requirements of system, and allows a temporary submerged zone and exfiltration (if unlined), or a more permanent one (if lined).

Consider lined (full or partial) or unlined *(Section 3.6.3)*
Liner – prevents exfiltration. Use in dry climates (if > 3 weeks dry is common); for stormwater harvesting; to create a longer-lasting submerged zone or protect nearby sensitive infrastructure.
Unlined – allows exfiltration. Use in wetter climates to reduce stormwater volume and pollutant load. Loss rate will depend on soil properties. Benefits of a temporary submerged zone can also be realised with a raised outlet.

Select vegetation and aesthetics *(Sections 3.6.5 & 3.6.6)*
Essential for stormwater treatment. Choose appropriate species to meet performance objectives & system conditions
Consider climate, water availability for plants, safety, aesthetics.

RISKS TO LONG-TERM PERFORMANCE

Avoid undersizing (< 1% impervious catchment area)
At risk of clogging & shortened lifespan
Will need higher maintenance frequency to check for blockages and clogging
Can offset to some degree with deeper ponding depth (determine using MUSIC)
Install pre-treatment to capture sediment , ensure overflow can protect system from high flows and velocity control on inflows to minimise scour

Avoid oversizing
At risk of drying out & plant death from insufficient inflows

Avoid shallow system (< 500 mm deep)
At risk of drying out and may not be able to support vegetation
Use a raised outlet which also reduces head requirements and promotes ponding of water in the lower portion of the biofilter. In dry climates (i.e. > 3 weeks without rain is common) also include a liner to create a longer-lasting submerged zone to support plants and benefit water treatment.

Avoid excessively high hydraulic conductivity (< 300 mm/hr)
Will drought-stress plants and does NOT provide long-term protection from clogging

Avoid excessively low hydraulic conductivity (< 100 mm/hr)
Low treatment capacity, unless offset with larger biofilter area and/or ponding depth (determine using MUSIC)

OVERALL, THE DESIGN MUST...

Protect system from high sediment loads *(Section 3.6.1)*
Sediment a high risk if construction activities ongoing in catchment, erodible clay soils, other sediment sources or high organic litter load (e.g. from deciduous trees)
Vital to facilitate maintenance, improve performance and prolong lifespan.
Install pre-treatment (e.g. sediment forebay) and use additional protection measures temporarily during high levels of construction activity

Provide soil moisture for vegetation *(Section 3.6.1)*
Via a raised outlet to promote at least temporary moisture retention and appropriate sizing (media not too shallow, area not oversized, sufficient ponding depth)
Critical for system performance and lifespan
Horticulturalist should approve filter media characteristics

Risks, pitfalls and tips during construction

Critical stages	Risks / common pitfalls	Useful tips
Pre-construction		
Underground services check	Damage to unexpected **underground services** during excavation can be highly expensive, dangerous and may require costly late-stage design modification.	Use the Dial-Before-You-Dig service during initial design phase (service locations may influence siting and depth). Before construction commission an underground services expert to prove service locations and depth. Mark out services at the site and map locations and depths on site plan. Inform all site personnel at pre-site meeting.
Ordering plant stock	If **plant stock** is not pre-ordered in sufficient time they may not be available at the desired planting time (especially for large projects).	Communicate well ahead of construction with the nursery, ideally during plant selection in the design phase.
Sourcing filter media	**Media composition** is critical to pollutant retention and infiltration rate. Poor media selection can lead to nutrient leaching, clogging, a system that is too dry or wet, and the washout of fine particles.	Ensure the media has been tested to comply with specifications in the Guidelines for Filter Media in Biofiltration Systems (Appendix C). Ensure fine aggregate for drainage layer material has been sufficiently washed to remove fine particles.
Sediment management	**Sediment management** is critical in catchments undergoing development and during construction of the biofilter	During construction activities the system must be protected using temporary measures such as flow diversions, use of bunding and/or geofabric, sediment traps, and planted

Common issues

t – high risk of
biofilter during

No drop down into biofilter – flow
cannot easily enter

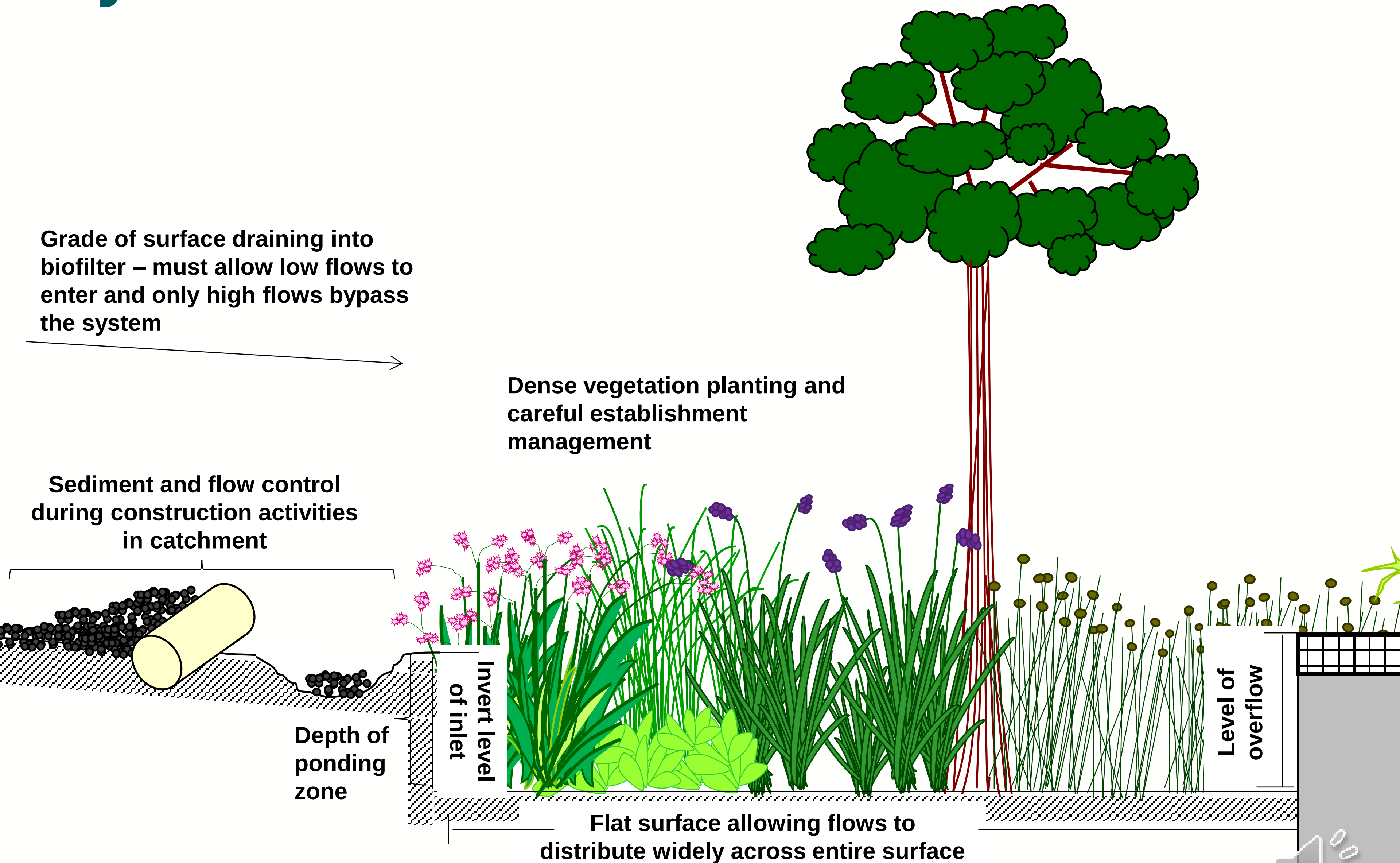
Slope follows road
Biofilter surface nc
distribution and pc
flows to top of sys

urpose for
actored into
ıe outlet level

Good hydraulic design, flow
management during construction and
establishment, and effective sealing

Outlet too close to
Outlet level too low

Key construction checks



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Maintenance & Monitoring Tasks

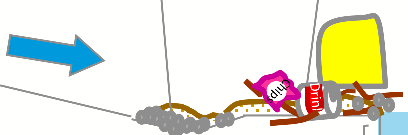
Pre-treatment zone (forebay, grass strip, pit)
- Check for sediment accumulation & clear periodically

Inlet/s
- Check for blockages & keep clear

Media surface
- Check for significant sediment or litter accumulation, signs of clogging
- Check for erosion/scour or preferential flow pathways
- Remove litter

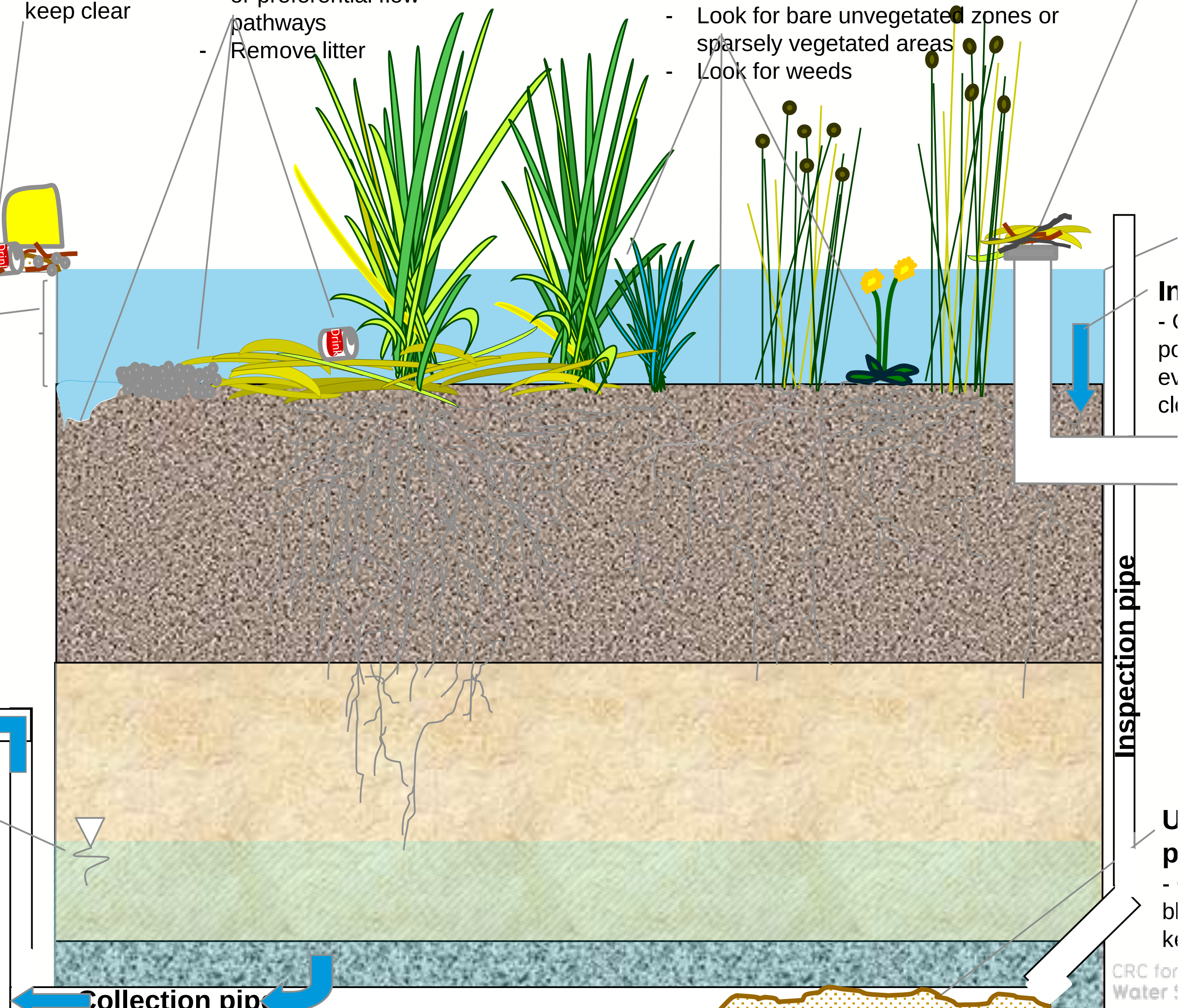
Vegetation
- Check health of vegetation
- Cause of widespread die-back or poor health must be investigated and rectified
- Re-plant as required after fixing root cause
- Look for bare unvegetated zones or sparsely vegetated areas
- Look for weeds

Overflow
- Check for blockage & keep clear



Ponding zone
- Check for significant sediment or litter accumulation, signs of clogging
- Ensure design depth of ponding maintained to provide treatment capacity

Raised outlet and submerged zone
- Check for blockages in pipe
- Check level (if inspection pipe available) to see if drawdown
- Top up level or provide irrigation to support plants through long dry periods



Appendices

- **Fact Sheets**
  - Why choose biofiltration?
  - How does stormwater biofiltration work?
  - Stormwater biofiltration – What are the ingredients for successful systems?
  - Biofilter design to meet objectives and adapt to local site conditions
  - Vegetation selection for stormwater biofilters
  - Stormwater biofilter monitoring and maintenance
  - Biofilter construction checks
- **Publications List**
- **Stand-alone guidelines for:**
  - Filter media in stormwater biofiltration systems
  - Enhancing pathogen removal using novel antimicrobial media
  - Enhancing aesthetics, community appreciation and acceptance
  - Monitoring using simulated rain events
  - Measuring filter media infiltration rates
- **Maintenance field sheet & checking tools**

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Key References

***Adoption Guidelines for Stormwater Biofilters* (2015)**

Full document & Summary document

http://watersensitivecities.org.au/new-publication-adoption-guidelines-for-stormwater-biofiltration-systems/

***Vegetation Guidelines for stormwater biofilters in the south-west of Western Australia* (2014)**

Guidelines & Practice Note:

http://www.newwaterways.org.au/files/files/381_Biofilter_vegetation_guidelines_for_southwestWA.pdf

and

http://www.newwaterways.org.au/files/files/382_Biofilter_vegetation_Practice_Note_for_southwestWA.pdf

Thanks

- Industry Advisory Panel:
  - Krish Seewraj & Antonietta Torre (Western Australia Department of Water)
  - Sam Phillips (Natural Resources Adelaide and Mt Lofty Ranges, South Australia Department of Environment, Water and Natural Resources)
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  - Jay Jonasson (Ku-ring-gai Council)
  - Dale Browne (E2 Design Lab)
  - Adrian Crocetti (Brisbane City Council)
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  - Nathan Wicker (City of Port Adelaide Enfield)
  - Katia Bratieres (Clearwater)

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