Fact Sheet: Biofilter design to meet objectives and adapt to local site conditions

One of the greatest benefits of biofiltration is the adaptability and flexibility of the technology. As a result, the design process is essential. Successful systems are designed to meet various stormwater treatment and additional objectives, suit the specific application and take advantage of opportunities presented by the site (e.g. high potential for infiltration), while managing any constraints (e.g. nearby sensitive assets). Biofilter designs can vary widely as a result of different target pollutants, applications or conditions. While the basic principles are the same, the design should be adapted to suit the specific site conditions and performance objectives.

The way in which system design can be influenced by objectives and site conditions is illustrated using a flow chart in Figure 1. First of all the objectives must be clearly defined, and must reflect the purpose of the biofilter (e.g. downstream waterway protection and/or stormwater harvesting for a given re-use application). The critical pollutants should be identified and targets determined for their reduction (e.g. set concentration or load thresholds for treated water – if available, these may reflect local regulations), and flow management objectives should be defined (e.g. reduce volume, peak or frequency of flows to improve downstream waterway health or, in harvesting schemes, to maximise the volume collected for reuse).

The design also needs to consider conditions at the site and within its catchment including:

- Local climate
- Geology of surrounding soils
- Groundwater characteristics
- Catchment characteristics (size, land-use, level of development (imperviousness), hydraulic connectivity of impervious areas, degree of construction activities or other sediment sources, prevalence of deciduous trees)
- Nearby sensitive infrastructure
- Surrounding landscape and vegetation
- Safety
- Maintenance access and efficiency

Tips to adapt biofilter design to these various considerations are provided in Table 1. Importantly, these objectives, site opportunities and constraints should be identified in an initial site inspection and through consultation with all stakeholders throughout the life of the biofilter. In particular, representatives from the design, construction, establishment, maintenance and operational phases of the biofilter must be involved and communicate with each other from the outset of the project.

For full details please refer to the Adoption Guidelines for Stormwater Biofiltration, CRC for Water Sensitive Cities (2015)

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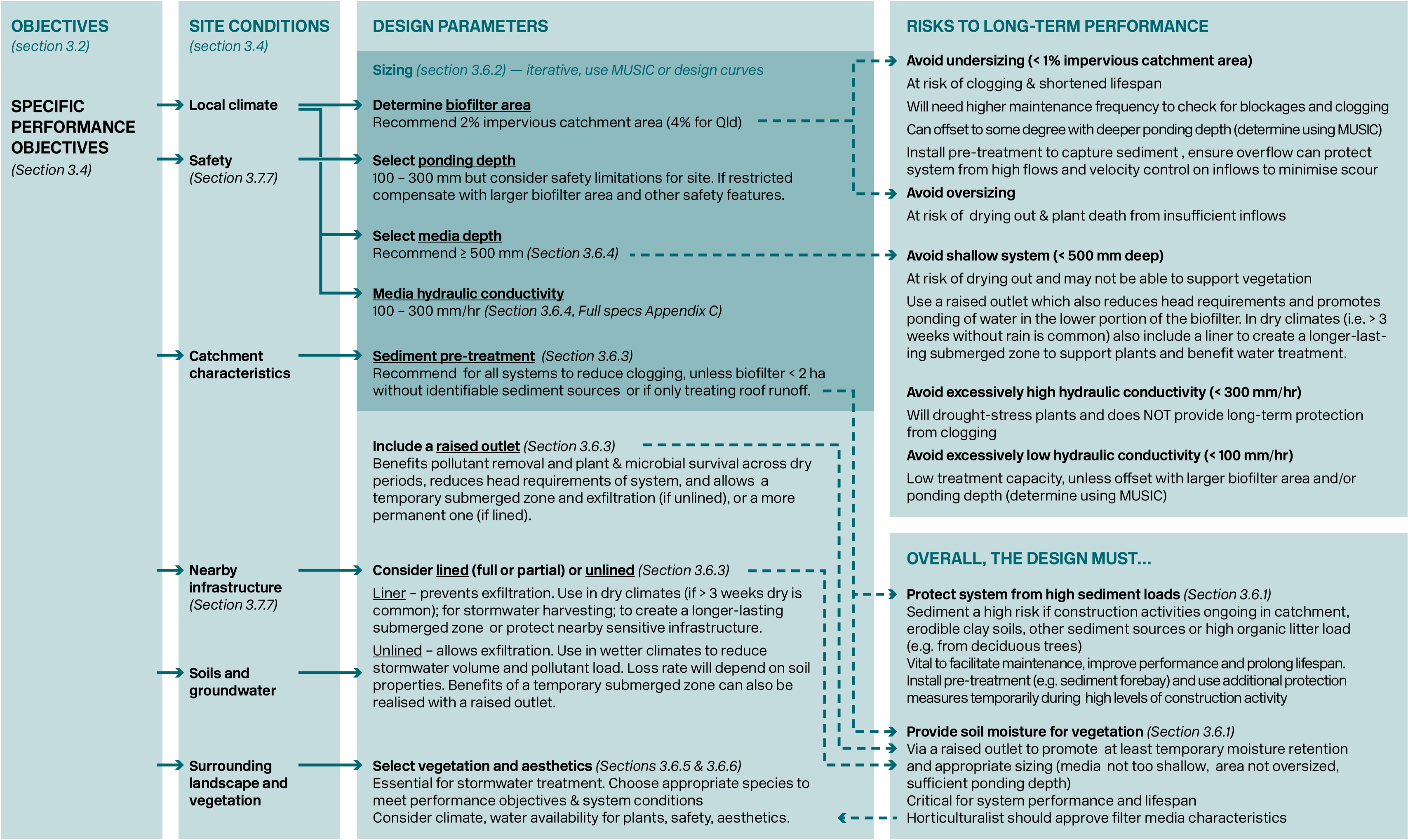

OBJECTIVES
(section 3.2)

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

Figure 1. Decision flow-chart illustrating the design process across a range of biofilter components, with references to Sections of the Biofilter Adoption Guidelines (CRC for Water Sensitive Cities, 2015) for further details .

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Table 1. Summary table relating biofilter applications and performance objectives with design tips

Waterways Protection	
Nutrients	• Plants are essential – plant densely, include a diversity of species, and select at least 50% of species with characteristics for effective removal (particularly for nitrogen – see below for further guidance) • Minimise N & P content in filter media to avoid leaching • Include a raised outlet and liner to create a submerged zone, particularly in dry climates (> 3 weeks dry is common) and if N removal is a key objective • Minimise desiccation by watering across dry periods and using species that cover or shade the surface • To enhance P retention, select media rich in iron- or aluminium-oxides
Sediment	• Primarily captured in surface layer. Remove by scraping once treatment is compromised by clogging. • Protect biofilter from high sediment loads from catchment (e.g. during construction) using temporary or permanent measures (e.g. pre-treatment) • Size the system appropriately to avoid a shortened lifespan from clogging (area – 2% of impervious catchment (Melbourne climate) or 4% (Brisbane) and sufficient ponding depth)
Heavy metals	• High fraction bound to sediment (see above)\ • Incoming load may be higher in industrial catchments. Zinc accumulation can be problematic. • Organic matter binds metals, but note high content compromises nutrient removal and infiltration • Iron removal optimal with a larger biofilter area (≥4%) and use of effective species (e.g. *Carex appressa*)
Organic micro-pollutants	• For example: hydrocarbons, pesticides, herbicides, PAHs, phthalates and phenols • Similarly as for heavy metals, organic matter assists removal but content must not be excessive • Prolonged drying benefits removal
Pathogens	• Use known effective plant species (e.g. *Leptospermum continentale, Melaleuca incana, Carex appressa*) • Include a raised outlet and liner to create a submerged zone which provides prolonged retention for die-off and adsorption to occur • Some drying is beneficial, but beyond 2 weeks drying performance is adversely affected. Successive inflow events (back-to-back) also lead to poor treatment. • Top-up the level of the submerged zone during extended dry periods • (Subject to further testing), consider use of a novel antimicrobial media (heat-treated copper-coated Zeolite) to enhance pathogen removal (see Biofilter Guidelines)
Flow Management	• Objectives may include reduction in volume, peak flow and frequency of flows • Maximise biofilter treatment capacity via increased area, media depth or hydraulic conductivity of media (but within recommended range) • Consider including a submerged zone to retain a proportion of runoff • Promote infiltration if conditions are suitable (e.g. unlined, partially lined or bioinfiltration design) • Maximise evapotranspiration loss by maximising the biofilter area and using a dense planting
Stormwater harvesting	
Pathogen, sediment, heavy metals and organic micro-pollutants may be key objectives (see above, and further below for more details) Nutrient removal may not be important if re-use for irrigation purposes	
Maximise pathogen removal & yield	• Design to co-optimise for yield and to meet ecosystem protection objectives – generally line the system but balance with stormwater storage and demand patterns to achieve desired discharge reduction. • Use good species for pathogen removal. • Use media that are good for the removal of pathogens (see Appendix D, but note that the use of
Additional	
Biodiversity	• Use a diverse mixture of local native species
Microclimate	• Include trees to provide shading and cooling via evapotranspiration • Local in urban zones lacking green spaces e.g. streets and car parks
Amenity, aesthetics & community engagement	• Use species and landscaping with compatibility with local surrounds (see below for further guidance) • Include a raised outlet to retain more moisture to support green and lush plant growth\ • Engage with the community and communicate the function of the system through the design (e.g. signage), and encourage the public to view and walk alongside the biofilter • As far as practical keep biofilter looking neat, well-kept and green – design for low-level maintenance
Habitat	• Use flowering species to promote birds and insects, and native plants from nearby habitat patches