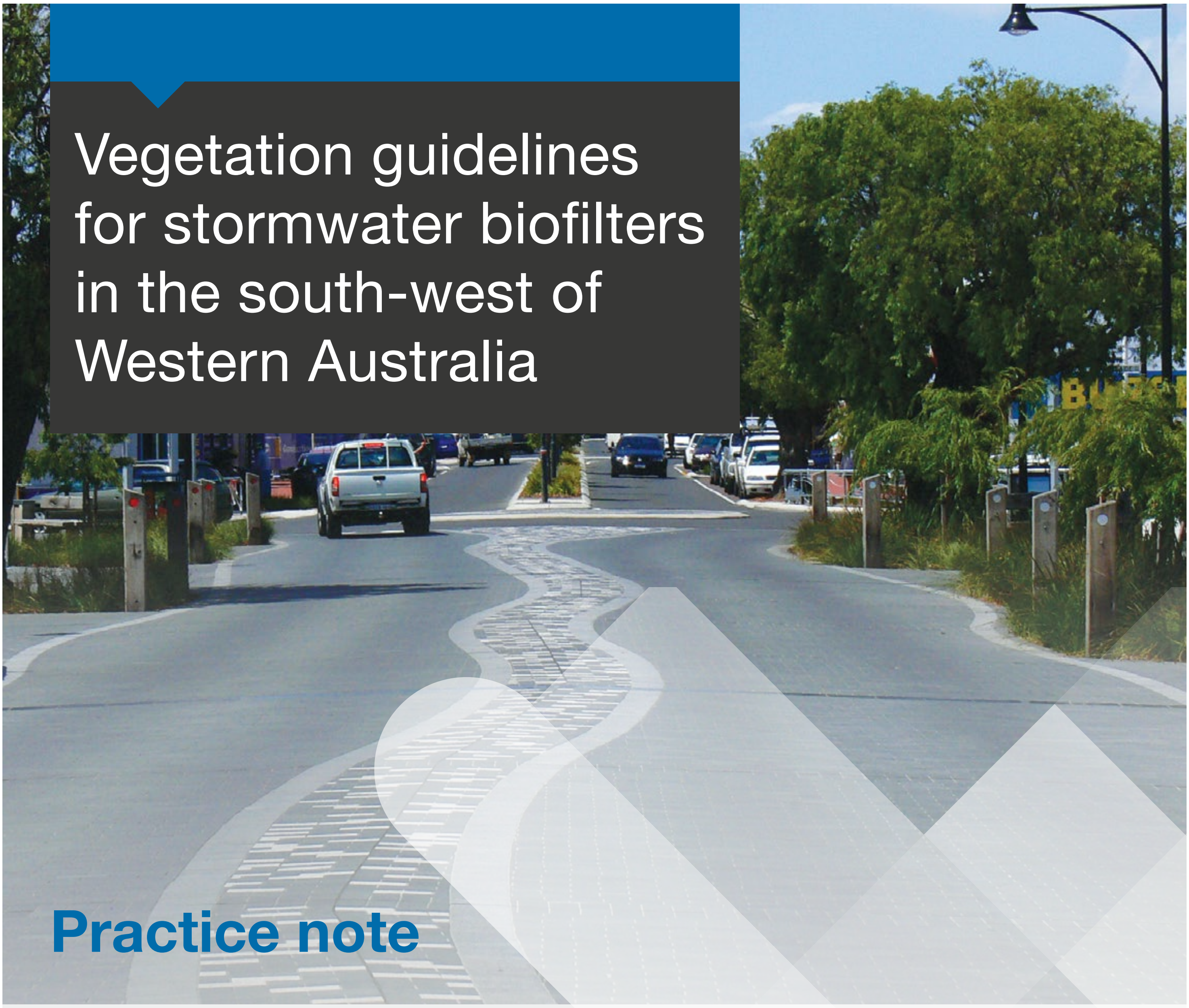
MONASH University
Water for Liveability Centre

Vegetation guidelines for stormwater biofilters in the south-west of Western Australia



Practice note

This practice note provides information on how to select the most appropriate plant species for biofilters within the south-west of Western Australia and how to establish and maintain the vegetation. This document is a summary of the *Vegetation guidelines for biofilters in the south-west of Western Australia* (Monash University 2014), which includes a review of the research that provides the basis for this practice note.

Biofilters (also known as biofiltration systems, bioretention systems and rain gardens) are excavated basins or trenches filled with porous material that acts as filter media and growing media for the planted vegetation. Biofilters are a proven method of treating stormwater from urban areas. To function well, biofilters rely on both the filtering properties of the soil media and the pollutant uptake and/or transformation capacity of their plants and the associated microbial community.

This document is not intended to be a complete design guide for biofilters. The *Adoption Guidelines for Stormwater Biofiltration Systems* (FAWB 2009) describes the biofilter design process. Please note that the FAWB Adoption Guidelines are currently being revised, and the revision is due to be completed at the end of 2014.

How to select plants for a biofilter

The attributes that make plants suitable for biofilters occur in many of the native plants found within the seasonal wetlands of the south-west of Western Australia, and on the fringes of permanent wetlands. These habitats experience inundation as well as periods of drought. In general, these seasonal wetland species can be used as a basis for plant selection in biofilters.

Table 1 Summary of principles for choosing plants

Principle	Reason
Plant a mixture of plant types and include a diversity of species.	• because species that are good at removing nitrogen in wet conditions may not perform as effectively during dry conditions, or vice-versa • provides diversity in plant morphology and physiology • to make biofilter performance more resilient against a range of climatic conditions and across seasons • to achieve a range of treatment objectives
Select plants that can withstand at least temporary inundation and waterlogging of their roots, as well as prolonged drought.	• improves plant survival and resilience to the range of conditions experienced within biofilters
Select plants that are able to grow in sandy, free draining soils.	• because plants need to be suited to the sandy loam filter media used in biofilters
Include species with extensive and fine root systems, relatively fast growth and high total plant mass.	• to optimise nitrogen removal, particularly under conditions of regular stormwater inflows • these characteristics allow effective plant uptake of nitrogen and support microbial processes
Avoid species with limited root biomass and total root length.	• these characteristics are associated with reduced nitrogen removal capacity
Include some thicker rooted species such as shrubs and trees, as well as sedges and rushes. However, avoid a high proportion of these species if nitrogen removal is a key objective. For every thick rooted plant, at least 20 plants with extensive fine roots and high growth should be used.	• to maintain the desired filter media infiltration rate • root systems dominated by thick roots are less effective for nitrogen removal
Avoid selecting plant species based upon similarity in above-ground appearance.	• above-ground characteristics do not provide a good indication of performance capability, particularly for nitrogen removal
Include species with long growing seasons and various periods of growth covering the autumn, spring and summer periods.	• to improve year-round biofilter performance
Plant with multiple layers of vegetation such as sedges, shrubs and trees.	• increases evapotranspiration and maximises leaf area • provides shading of the media and understorey layers, which may reduce the negative effects of prolonged dry periods
Select plants with high rates of transpiration when water is available, but are able to 'down-regulate' their water use during periods of drought.	• increases evapotranspiration, which reduces the volume of stormwater and the exported pollutant load • allows plants to survive dry periods • mitigates the reduction in nitrogen removal performance during dry periods
Include a range of species suited to different hydrologic zones that may exist within the biofilter.	• allows 'zonation' of species suited to drier or wetter conditions
Avoid the use of nitrogen-fixing species.	• due to the potential for nitrogen-leaching
Ensure that at least 50% of plants within the biofilter are species known to be highly effective for nutrient removal.	• provides flexibility to meet other objectives, such as amenity and biodiversity, while still providing effective nutrient removal
Note that species within the same genus may be expected to demonstrate similar nitrogen removal performance in the context of similar native environments.	• different species within the same genus in the same climatic zone do not tend to lie at opposite ends of the treatment spectrum (however more research is required)

Native plant species that are suited to biofilters in the south-west of Western Australia can be found in Table 2.

Table 2 South-west WA plants suited to biofilters

Family	Genus	Species	Common name	Habit	Root Type	Inundation	Drought tolerant	Height (m)	Nutrient removal	Growth rate	Flower colour	Salinity tolerance	pH preference
Cyperaceae	Carex	tereticaulis		Sedge - C	CF	RTD	N	1.5	H	F	white/yellow	F	AN
Cyperaceae	Carex	appressa	Tall sedge/Tussock sedge	Sedge -C	CF	RTD	Y	1.8	H	F	white/yellow	F	AN
Cyperaceae	Cyperus	gymnocaulos	Spiny flat sedge	Sedge - C	C	RT	N	1	M	M	brown	FB	AN
Cyperaceae	Baumea	articulata	Jointed twig sedge	Sedge - S	F	RT	N	2.5	H	F	white/yellow	FB	AN
Cyperaceae	Baumea	juncea	Bare twig sedge	Sedge - C	F	RTD	N	1.2	H	M	white/yellow	FB	AN
Cyperaceae	Baumea	preissii		Sedge - S	F	RT	N	1	H	M	white/yellow	FB	AN
Cyperaceae	Baumea	vaginalis	Sheath twig sedge	Sedge - S	F	RT	N	1.2	H	M	white/yellow	FB	AN
Cyperaceae	Baumea	rubiginosa	Soft twig sedge	Sedge - S	F	RT	N	1	H	M	white/yellow	FB	AN
Cyperaceae	Bolboschoenus	caldwellii	Sea Club sedge	Sedge - S		RT	N	1.2	S	F	white/yellow	FB	ANL
Cyperaceae	Carex	fascicularis	Tassel sedge	Sedge - S	F	RT	N	1	M	F		F	ANL
Cyperaceae	Carex	inversa	Knob sedge	Sedge - S	F	RT		0.5	M	F		F	ANL
Cyperaceae	Ficinia	nodosa	Knotted club sedge	Sedge - C	F	TD	Y	1	M	M	brown	FB	ANL
Cyperaceae	Lepidosperma	effusum	Spreading Sword Sedge	Sedge - S		RT	N	2.5	S	M	white/yellow	FBS	AN
Cyperaceae	Lepidosperma	gladiatum	Coast saw sedge	Sedge - S		TD	Y		S	M	white/yellow	FB	ANL
Cyperaceae	Lepidosperma	longitudinale	Pithy Sword Sedge	Sedge - S		RT	N	1	S	M	white/yellow	FB	AN
Frankeniaceae	Frankenia	pauciflora	Sea Heath	Shrub		TD	Y	0.5	U	M	white/pink	BS	ANL
Juncaceae	Juncus	pallidus	Pale Rush	Rush - C	F	TD	Y	1.5	H	F	straw	FB	AN
Juncaceae	Juncus	kraussii	Sea Rush	Rush -C	F	RT	N	1.2	M	M	brown/red	FBS	AN
Juncaceae	Juncus	pauciflorus	Loose Flower rush	Rush - C	F	RTD	Y	1	S	F	straw	FB	AN
Juncaceae	Juncus	subsecundus	Finger Rush	Rush - C	F	RTD	Y	1	H	F	straw	F	AN
Myrtaceae	Melaleuca	incana	Grey Honey Myrtle	Shrub	F	T	N	3	H	M	white	F	AN
Myrtaceae	Agonis	flexuosa	WA Peppermint	Tree		D	Y	10	U	S	white	FB	ANL
Myrtaceae	Beaufortia	elegans		Shrub		TD	Y	1	U	M	red/purple/ pink/white	F	
Myrtaceae	Callistemon	phoeniceus	Lesser Bottlebrush	shrub		TD	Y	6	U	F	red	FBS	AN
Myrtaceae	Calothamnus	hirsutus		Shrub		TD	Y	1.5	U	M	red	F	
Myrtaceae	Calothamnus	lateralis		Shrub		RTD	N	2.5	U	S	red	FB	AN
Myrtaceae	Calothamnus	quadrifidus	one sided bottlebrush	Shrub		TD	Y	1.5	U	M	red	FB	ANL
Myrtaceae	Corymbia	ficifolia	Red fowering gum	Tree		TD	N	10	U	M	red	F	AN
Myrtaceae	Eucalyptus	rudis	Flooded gum	Tree		RTD	N	20	S	F	white	FB	AN
Myrtaceae	Kunzea	ericifolia	Spearwood	Shrub		RTD	Y	4	U	S	white	F	AN
Myrtaceae	Kunzea	recurva	Pea shrub	Shrub		RTD	Y	2	U	S	purple	F	AN
Myrtaceae	Kunzea	glabrescens	Spearwood	Shrub		RT	Y	4	U	S	yellow	F	ANL
Myrtaceae	Melaleuca	cuticularis	Saltwater paperbark	Tree	F	RT	N	7	S	S	white	FBS	ANL
Myrtaceae	Melaleuca	lateritia	Robin redbreast bush	Shrub	F	RT	N	2.5	H	M	red	FB	AN
Myrtaceae	Melaleuca	pauciflora		Shrub	F	RT	Y	3	S	M	white	FBS	
Myrtaceae	Melaleuca	preissiana	Moonah	Tree	F	RT	N	9	S	M	white	F	AN
Myrtaceae	Melaleuca	rhaphiophylla	Freshwater paperbark	Tree	F	RT	N	10	S	F	white	FBS	AN

Myrtaceae	Melaleuca	thymoides			F	RTD	Y	2	S	M	yellow	FB	
Myrtaceae	Melaleuca	viminea	Mohan	Tree	F	RTD	Y	5	S	M	white	FBS	
Myrtaceae	Melaleuca	fulgens	Scarlet Honeymyrtle	Shrub	F	TD	Y	3	S	M	red	F	
Myrtaceae	Melaleuca	lanceolata	Rottnest Tea tree	Tree	F	RTD	Y	5	S	M	white	FBS	ANL
Myrtaceae	Melaleuca	pulchella	Claw Flower	Shrub	F	TD	Y	2	S	M	pink	FB	
Myrtaceae	Melaleuca	seriata		Shrub	F	RTD	Y	1	S	M	pink	F	
Myrtaceae	Melaleuca	teretifolia	Banbar	Tree	F	RTD	Y	5	S	M	white	F	
Myrtaceae	Melaleuca	scabra	Rough Honey Myrtle	Shrub		TD	Y	1.5	S	M	pink	FB	
Myrtaceae	Taxandria	linearifolia	Swamp peppermint	Tree		RTD	Y	4	U	F	white	F	AN
Poaceae	Poa	poiformis	Coastal poa	grass		TD	Y	0.9	M	M	green / yellow	F	
Poaceae	Sporobolus	virginicus	Marine Couch	Grass		TD	N	0.5	M	F	green/ purple	FBS	ANL
Poaceae	Hemarthria	uncinata	Mat grass	Grass		TD	Y	0.4	S	M			
Poaceae	Microlaena	stipoides	Weeping Grass	Grass		TD	Y	0.75	S	M	purple	F	
Restionaceae	Meeboldina	scariosa	Velvet rush	Rush - C		RT	N	1	M	F	red brown	F	AN
Restionaceae	Meeboldina	coangustatus		Rush - C		RT	N	1	U	M	red brown	F	AN

If a box is blank, the parameter is unknown and needs further investigation

Root type: C – Coarse, F – Fine

Inundation: R – Regular, T – Temporary, D – Dry

Drought tolerant: Y – Yes, N – No

Nutrient removal: H – High, M – Moderate, L – Low, U – Unknown, S – Suspected effective

Growth rate: F – Fast, M – Moderate, S – Slow, U – Unknown

Salinity tolerance: F – Fresh, B – Brackish, S – Saline

pH preference: A – Acid, N – Neutral, L – Alakaline/Limestone tolerant

Tips for improving biofilter performance

Table 3 highlights tips for improving plant performance and overall pollutant removal. For additional recommendations, refer to the *Vegetation guidelines for biofilters in the south-west of Western Australia* (Monash University 2014) and the *Adoption Guidelines for Stormwater Biofiltration Systems* (FAWB 2009).

Table 3 Tips for improving biofilter performance

Plant at high density	• provides high contact between the plant roots, biofilter media and stormwater • supports an extensive microbial community alongside the roots – this optimises the opportunity for pollutant removal processes • to maintain the desired filter media infiltration rate • maximises evapotranspiration
Include a saturated zone in climates with long dry spells in summer	• improves plant survival across dry summer periods • reduces the need for irrigation • biofilter performance for nitrogen removal benefits significantly from the presence of a saturated zone, particularly in dry conditions • helps to ‘even-out’ performance differences between different plant species for nitrogen removal • provides an opportunity for denitrification to permanently remove nitrogen from the system
Prevent severe or complete drying out of the biofilter system Irrigate to improve plant performance and to top up the saturated zone during prolonged periods without rainfall Alternatively, if groundwater is of suitable quality and within the root zone, the biofilter may be left unlined at the base to utilise this water source over dry periods	• biofilter removal of nutrients is most effective under conditions of regular water availability • drying out leads to reduced nutrient removal or even to nutrient release upon rewetting • desiccation leads to reduce microbial activity and bacterial death • affects plant growth and function and may lead to root and plant death
Use low-nutrient filter media, as specified in the *Adoption Guidelines for Stormwater Biofiltration Systems* (FAWB 2009)	• provides more consistent biofilter performance for nutrient retention between plant species • enables a relatively wide range of plant species selected from a palette of suitable plants to be used in biofilters
Use media with a relatively high sand and low clay content (i.e. a loamy sand or a sand with appropriate ameliorants added), as specified in the *Adoption Guidelines for Stormwater Biofiltration Systems* (FAWB 2009)	• provides both sufficient water quality treatment and infiltration

Establish the plants

Plant densely

A denser planting of the chosen understorey species assists with reducing erosion and precluding weed encroachment into the system. It will also achieve improved uptake of pollutants. A general rule is to plant at a density where the plants will cover the majority of the biofilter surface area within one year.

Recommended densities to achieve this rapid cover are:

- clumping sedges and rushes – 6 to 9 plants/m^2
- spreading sedges and rushes – 4 to 6 plants/m^2
- shrubs and trees (over sedges and rushes) – 1 plant/2m^2 for small shrubs and 1 plant/5m^2 for larger trees.

Planting in rows can assist with obtaining the correct density, but rows that are evenly aligned should be avoided to prevent short-circuiting and the creation of preferential flow paths along the biofilter. Plants should be planted in rows perpendicular to the flow path, with each row offset to the adjacent rows to create resistance to flows.

Creating multiple canopy levels by planting trees and shrubs over sedges and rushes will help achieve a better functioning biofilter system. The two plant types work together to remove nutrients and maintain the infiltration rate of the media. The impact of shade needs to be considered in both tree placement and chosen understorey species shade tolerance.

Plant lay-out

In the wettest areas, around the inlet and in the deepest parts of the base of the system, species that thrive on inundation and a wet root zone are appropriate. In larger systems, as distance increases up the sides of the system or away from the inlet, more drought tolerant species should be chosen.

Care should be taken around the inlet and outlet zones so that the plants do not clog these structures, reducing the design flows. Using mortared rock pitching or similar around the structures will stop the plants growing up to and within the inlet and outlet pipes.

When to plant

Generally, the best time to plant in the south-west of Western Australia is June. This provides the whole of winter and spring for the plants to establish with (generally) regular watering from rain and stormwater. Where irrigation can be utilised, the planting can be extended into spring or autumn. Plants should be ordered at least six months before needed. The timing of local site activities (e.g. subdivision works and lot development) is an important consideration in determining when to plant. See the Erosion and sediment management section below.

Plant quality

Good quality planting stock will increase the likelihood of plants establishing effectively. The tubestock should ideally be grown in root pruning cells, so that the plants are not root bound. Larger trees may also be incorporated where a more instant effect is desired. These may require staking.

Planting

The plants should be placed in their preferred zone and at the required density by an experienced operator to minimise incorrect planting. It is highly recommended that the plants are watered in well to maximise their early survival, with a follow up watering one week after planting.

Mulch

Both inorganic and organic mulch types add expense and complexity to the installation of the biofilter system. Planting at higher densities can reduce or remove the need for mulch, especially if the system is irrigated to encourage early growth. The denser rate and irrigation means that the sedge and rush layer rapidly colonises the biofilter surface, providing protection to the media. Generally, fertiliser should not be applied to the biofilter. A foliar spray (e.g. seaweed extract) may assist during the initial establishment phase (one or two applications only). There is no requirement for ongoing applications, as the plants should derive their nutrient requirements from the stormwater.

Monitoring and maintenance

For effective vegetation establishment, regular monitoring and maintenance is required in the first two years after planting, followed by a less intensive monitoring regime.

In a well-designed system, the maintenance requirements should be minimal, especially if issues such as weeds are dealt with early.

Erosion and sediment management

New biofilters constructed within a residential development will be affected by site disturbance, roadworks and service installation. These activities generate sediment and debris that can smother vegetation and clog biofilters. It is generally advisable to limit planting of the understorey until extensive roadworks or house building works are completed in the upstream catchment. In the interim, the media within the biofilter should be protected from excessive fine sediments and gross pollutants. One option is to place a geofabric or artificial lawn to cover the biofilter surface. This can be easily removed, along with the sediments, once the catchment is stable, prior to later planting. Should some vegetation be desired in the interim, larger trees can be planted through holes in the geofabric or artificial lawn. Upstream sediment and dust management should also be put in place, where possible, to reduce the loads entering the biofilter.

Check for erosion near inlets and flow paths. Repair any eroded areas and protect plants with geofabric or rocks while establishing.

Irrigation

Irrigation should be used for at least the first two years of establishment. Irrigation may also be beneficial in the longer term where there is no groundwater available for plant roots to draw upon. It is best to give plants a good soak when watering so they are not encouraged to develop shallow roots.

Weeding and pruning

Any vegetation pruned or cut within the system should be removed to assist with the general removal of nutrients and pollutants from the biofilter.

Stormwater and wind can transport large quantities of weed seed that will invade biofilters. Regular weed control and seasonal infill planting will be required until the plants cover the biofilter surface area. The incorporation of weed barriers around a biofilter can assist with reducing the initial invasion of weed species, particularly lawn grasses.

Acknowledgements

Author team:
Brendan Oversby, TME Town Planning Management Engineering Pty Ltd
Emily Payne, Monash University
Tim Fletcher, The University of Melbourne
Glen Byleveld, South East Regional Centre for Urban Landcare
Belinda Hatt, Monash University

Cover photograph:
Biofilters on Queen Street, City of Busselton, Western Australia (Source: Peter Roberts, Design Workroom)

MONASH University
Water for Liveability Centre

Further information

Water for Liveability Centre
Level 1
Building 74, Clayton Campus
Monash University, VIC 3800

Telephone: +61 3 9902 4601
Email: waterforliveability@monash.edu

www.waterforliveability.org.au