Adoption Guidelines for Stormwater Biofiltration Systems

Cities as Water Supply Catchments – Sustainable Technologies

CRC for
Water Sensitive Cities

Australian Government
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Business
Cooperative Research
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Adoption Guidelines for Stormwater Biofiltration Systems (Version 2)
Cities as Water Supply Catchments – Sustainable Technologies (Project C1.1)
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Authors

Emily Payne, Belinda Hatt, Ana Deletic, Meredith Dobbie, David McCarthy and Gayani Chandrasena (Monash University)

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Cooperative Research Centre for Water Sensitive Cities

Level 1, 8 Scenic Blvd
Monash University
Clayton VIC 3800
Australia

p. +61 3 9902 4985
e. admin@crcwsc.org.au
w. www.watersensitivecities.org.au

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Preamble

These guidelines are based on extensive testing and development of biofiltration system designs that use readily sourced soil-based filter media and mainly Australian native plants. Other biofiltration systems with alternative design specifications to those listed in these guidelines can also be considered as effective stormwater treatment systems, provided they have been demonstrated under realistic conditions to achieve an acceptable pollutant removal and operational performance.

Acknowledgements

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This second version of the guidelines was authored by Emily Payne, Belinda Hatt, Ana Deletic, Meredith Dobbie, David McCarthy and Gayani Chandrasena of the Monash Water for Liveability Centre and the Cooperative Research Centre for Water Sensitive Cities (CRCWSC). Daniel Connellan (CRCWSC) managed formatting and graphic design, while Steve Pogonowski and Fiona Chandler (CRCWSC) and Louisa John-Krol (Monash Water for Liveability Centre) provided communication advice and editing to improve the reader's experience, particularly on the accompanying summary and fact sheet documents.

Our sincere thanks to our Industry Advisory Panel members for their invaluable contribution of time, knowledge, comments and insights throughout the review; 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) and Adrian Crocetti (Brisbane City Council). The contribution of industry experts has added significant value to these guidelines.

We also greatly appreciate the input of Kerrie Burge (E2DesignLab), Sam Innes (City of Port Phillip), Greg Fitzgerald and Shane Howes (Daisy's Garden Supplies), Terry Woodcock (Sportsturf Consultants), Ruth Ward (Environmental Protection Agency, South Australia), Mellissa Bradley (Water Sensitive South Australia), Rob Allison (DesignFlow) and Nathan Wicker (City of Port Adelaide Enfield). Many thanks also to Katia Bratières (ClearWater) for her advice and assistance with the communication and distribution of these guidelines.

These guidelines would not have been possible without the research efforts of researchers and postgraduate students, past and present, working under FAWB, the Cities as Water Supply Catchments project and most recently, the CRCWSC, and affiliated projects, thus we extend our thanks to them.

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Chapter 1: Introduction

1.1 What are stormwater biofiltration systems and how do they work?

Water biofiltration is the process of improving water (stormwater and wastewater) quality by filtering water through biologically influenced media (Figure 1).

Compared with undeveloped catchments, urban areas generate stormwater runoff that is magnified in flow volume, peak and pollutant load. The poor water quality and altered hydrology are both highly detrimental to the health of receiving waters (e.g. streams, estuaries, bays). Stormwater biofiltration systems (also known as biofilters, bioretention systems and raingardens) are just one facet of a range of accepted water sensitive urban design (WSUD)[1] elements (Wong, 2006). They are a low energy treatment technology with the potential to provide both water quality and quantity benefits.

A typical biofiltration system consists of a vegetated swale or basin overlaying a porous, sand-based filter medium with a drainage pipe at the bottom (Figure 1). Stormwater is diverted from a kerb or pipe into the biofiltration system, where it flows through dense vegetation and temporarily ponds on the surface before slowly filtering down through the filter media. Depending on the design, treated flows are either infiltrated to underlying soils, or collected in the underdrain system for conveyance to downstream waterways or storages for subsequent re-use.

Biofiltration technology can be applied to various catchment sizes and landscape settings, from street trees and private backyards to street-scale applications and car parks, up to larger regional stormwater treatment systems, including those in public parks and forested reserves (Figure 2 and case studies in Appendix E). Further, biofilter design can be tailored to optimise performance for local conditions and specific treatment objectives.

Small bioretention pods are often referred to as raingardens, while linear systems are commonly referred to as biofiltration swales. Biofiltration swales provide both treatment and conveyance functions, while basins are normally built off-line to protect them from scour. Biofilters include standard features and operate using the same basic principles (Figure 2). In all designs an elevated outlet is strongly recommended. This feature provides multiple benefits for water treatment, retaining moisture for plants, increasing retentive capacity, reducing the total head requirement and promoting exfiltration loss (in unlined systems) or a longer-lasting submerged zone (in-lined systems). However, design configurations are flexible to suit different site conditions, applications and objectives.

Projects will differ in their application of standard features versus more innovative biofilter designs. Regardless, **site-specific factors and performance objectives must be considered in the design process**. This will ensure optimal performance, with the system adapted to suit the local environment and address the target pollutants or relevant hydrological objectives.

Successful design and implementation require a multidisciplinary approach. This includes the fields of civil engineering, town planning, botany, ecology, chemistry, soil science, microbiology, hydraulics, hydrology, landscape architecture and social studies to foster community support. These guidelines draw the aforementioned diverse fields together to inform the designer and facilitate effective designs.

1.1.1 Hydrologic function

Stormwater runoff from urban areas is characterised by short, sharp peak flows and substantially larger volumes in comparison to runoff from undeveloped areas. A primary goal of best-practice stormwater management is to reduce runoff peaks, volumes and frequencies. Biofiltration systems can achieve this, for two reasons:

- Depending on their size relative to the catchment, and their infiltration properties, they may reduce below 1-year Average Recurrence Interval (ARI) peak flows by around 80%. Instead of runoff being delivered directly to the local waterway via the conventional drainage network, it is collected on the surface of the biofilter and slow filters through the soil media; and

- They reduce runoff volumes: a portion of every runoff event is retained by the filter media – this will then be lost via evapotranspiration and/or exfiltration, depending on design of the system. Small runoff events might even be completely absorbed by the biofilter (i.e., there is no discharge from the underdrain). Therefore, and particularly in the case of unlined systems with an elevated underdrain or no underdrain at all, they may substantially reduce runoff frequency to receiving waters, thus protecting aquatic ecosystems from frequent disturbance.

[1] *WSUD is "…a philosophical approach to urban planning and design that aims to minimise the hydrological impacts of urban development on the surrounding environment" Lloyd, S. D., Wong, T. H. & Chesterfield, C. J. 2002. Water sensitive urban design: a stormwater management perspective..*

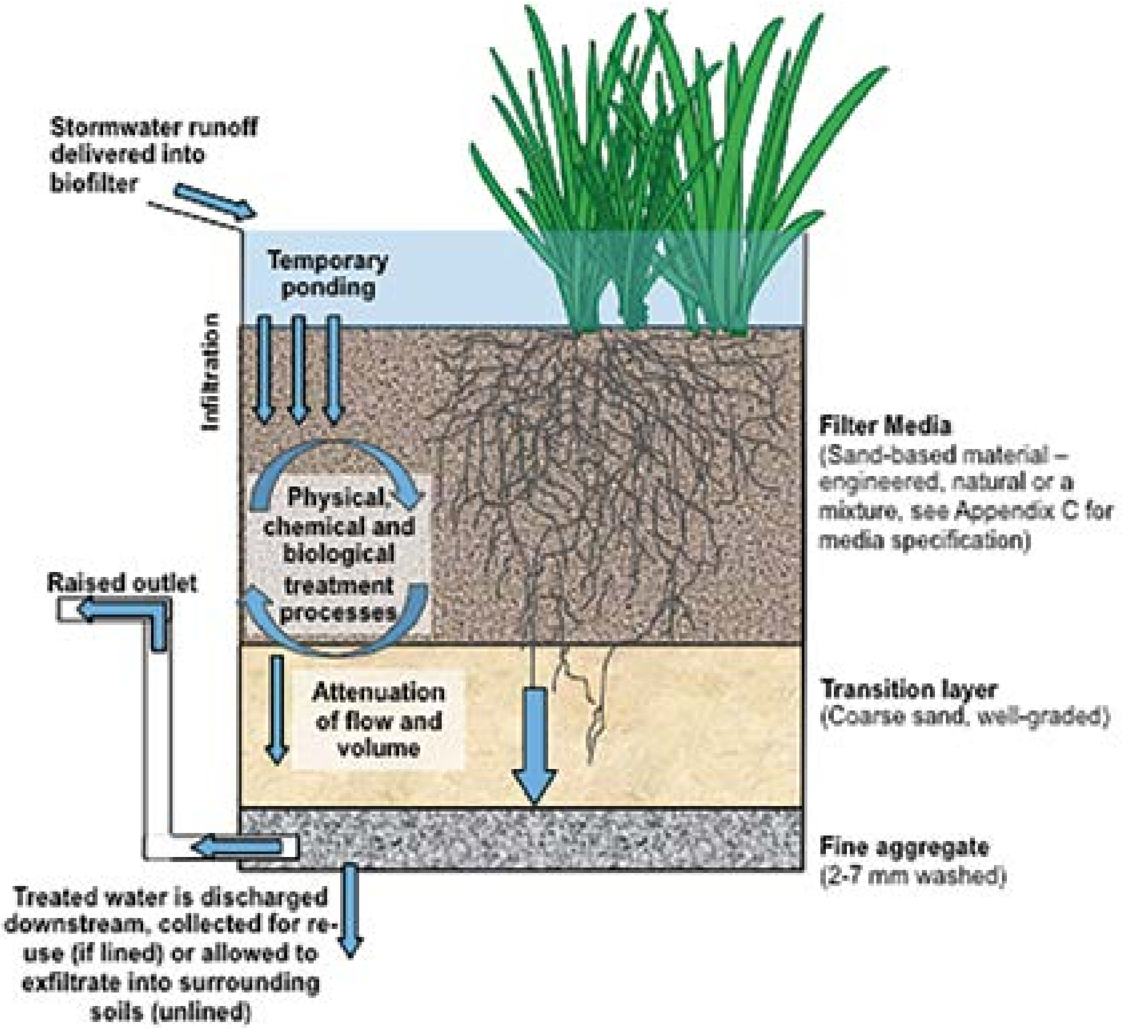

Figure 1. Key principles of stormwater biofiltration

1.1.2 Treatment processes

Stormwater runoff from urban areas contains pollutants that are detrimental to the health of receiving waters. Therefore, the other goal of stormwater management is to improve the quality of water being discharged to urban waterways. Biofiltration systems aim to replicate the following natural treatment processes:

- Physical: as stormwater enters the biofilter, the dense vegetation reduces flows, causing soil particles and particulates to settle out (sedimentation). In addition, particulates are filtered from the water as it percolates down through the soil media (mechanical straining);
- Chemical: soil filter media contains clay minerals and other chemically active compounds that bind dissolved pollutants (sorption); and
- Biological: vegetation and the associated microbial community take up nutrients and some other pollutants as growth components (e.g. plant and microbial uptake).

Further details on the range of biofilter treatment processes are provided in Section 3.3.2.


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Figure 2. Examples of stormwater biofilters, which can vary widely in their scale, appearance and design to suit treatment objectives and local site conditions. Photos supplied by Krish Seewraj and Antonietta Torre, Department of Water and Emily Payne, Monash University

1.2 Why might we choose a biofiltration system?

There have been many successful applications of biofiltration, but also some poor outcomes owing to inadequate design and construction, and poor maintenance. These guidelines seek to improve understanding of biofiltration and disseminate guidance borne out of successful applications, and research and development.

When used appropriately, biofiltration systems have been found to be viable and sustainable as a water treatment measure. The treatment performance for water quality and hydrological benefits are summarised in Section 2.4. In addition to reducing the impacts of urbanisation on catchment hydrology and improving water quality, biofiltration systems:

- Have an acceptably small footprint relative to their catchment (typically ranging from 2 - 4%, depending on climate);
- Are attractive landscape features which enhance urban amenity;
- Are flexible in their design and application;
- Are self-irrigating (and fertilising) gardens;
- Provide habitat and biodiversity values;
- Are an effective pre-treatment for stormwater harvesting applications;
- Are potentially beneficial to the local micro-climate (due to the cooling effect of evapotranspiration and shading);
- Are not restricted by scale; and
- Can be integrated with the local urban design (streetscape).

The wide-ranging benefits of stormwater biofilters are discussed in detail within Chapter 2.

1.3 Planning policy

The mechanisms for the adoption of biofiltration technology are embedded in multiple policy documents across local and state jurisdictions. Biofiltration, alongside all WSUD technologies, must be integrated into urban design, and as such a wide range of planning and other policy mechanisms can be relevant to its adoption. Key legislation and guidelines that regulate or promote WSUD have been summarised in Table 1. Additional regulations or planning instruments may be relevant to aspects of the use of biofiltration (e.g. related to road design or safety), or help to make the business case for its adoption. This section is not intended to provide a comprehensive overview of all relevant guidelines or legislation, but instead highlights some of the key policies and strategies.

Table 1. Key planning instruments addressing WSUD at the State and local scales

State	**Planning Instruments**	
	State planning legislation	**Local**
Queensland	WSUD is required in the design of developments. Stormwater management is also required for planning and development activities. State policy requires site based Stormwater Quality Management Plans for some developments and assists local governments to formulate regional plans. The Environmental Protection (Water) Policy outlines environmental values and water quality objectives to protect different waters in Queensland.	Various local council policies with ranging requirements. Local government planning schemes implement the state planning frameworks, and are authorised to develop and implement a Total Water Cycle Management Plan.
New South Wales	WSUD not prescribed in legislation and no mandated targets in regards to water quality. Obligations for management of urban waters by council directed by the Local Government Act 1993. Section 117 Direction requires stormwater discharge considerations in local environmental plans (LEPs).	WSUD initiatives primarily driven and policies developed by local councils. Various Development Control Plans (see www.wsud.org for complete list); deemed-to-comply requirements at some Councils.
Victoria	State Environment Protection Policy (SEPP) (Waters of Victoria) requires stormwater quality treatment for all activities on private and public land. The *Victoria Planning Provisions* include *State Planning Policy Framework Clauses* which allow councils to require WSUD for all residential, industrial and commercial developments. The *Best Practice Environmental Management Guidelines for Urban Stormwater* help to implement the SEPP requirements in design. Minimum water quality and quantity objectives must be met for developments.	Various WSUD guidelines, policies and action plans adopted by local councils. These promote and facilitate the implementation and maintenance of WSUD systems and may seek to achieve specific goals, such as stormwater quality and discharge targets.
Western Australia	Significant policy development in light of greatly diminished rainfall and population growth. Statement of Planning Policy 2.9 'Water Resources' promotes WSUD in new development but not mandatory. Obligation for sites to sites to protect or enhance water quality and quantity. Further guidance given in *Better Urban Water Management* (Western Australian Planning Commission 2008) and supported by *Stormwater Management Manual for Western Australia* (Department of Water 2004-2007), which outlines criteria to 'retain or detail stormwater runoff from constructed impervious surfaces generated by up to 1-year, 1-hour average recurrence interval (ARI) events on-site' (note – criteria currently under review) and encourages close-to-source treatment. Liveable Neighbourhoods (WAPC 2009) and Direction 2031 and Beyond (WAPC 2010) – further promotes sustainable development. For stormwater harvesting projects consult Guideline for the approval of non-drinking water systems in Western Australia – urban developments (Department of Water 2013) and for aquifer recharge - Operational policy 1.01 – Managed aquifer recharge in Western Australia (Department of Water 2011).	Within specific localities, local government planning policies vary; some promote the use of WSUD for stormwater treatment. Further, various Water Quality Improvement Plans and Drainage and Water Management Plans across WA support the use of biofiltration systems.
South Australia	WSUD is not mandatory but encouraged, through a range of government policies including the state's WSUD policy *Water sensitive urban design – Creating more liveable and water sensitive cities in South Australia*. It sets out the aims, objectives and guiding principles for WSUD in South Australia, and outlines the WSUD performance principles and performance targets. The state WSUD policy (2013) follows the 2011 *Stormwater Strategy – The Future of Stormwater Management*, the 2010 *30-Year Plan for Greater Adelaide*, the 2009 *Water for Good*, and the 2007 *Institutionalising WSUD in the Greater Adelaide Region*. The issues paper T*ransitioning Adelaide to a water sensitive city – Towards and Urban Water Plan for Greater Adelaide* was released in 2014 as part of the process of developing a new urban water plan intended to address all sources and uses of water. The initial draft urban water plan is expected in 2015. Water Sensitive SA is South Australia's emerging WSUD capacity-building program. Water Sensitive SA was launched in 2015 and delivers on Action7 of the state WSUD policy.	Each local government must have strategic management plans in accordance with the *Local Government Act 1999*. These plans may include policies relevant to WSUD to reflect the aspirations of the local government's constituents. A local government may prepare a stormwater management plan to meet the requirements of the Stormwater Management Authority. A stormwater management plan may consider WSUD.

Cont.

Table 1. Continued

State	Planning Instruments	
	State planning legislation	**Local**
Tasmania	Stormwater management and objectives outlined in the Tasmanian *State Policy on Water Quality Management 1997 (SPWQM)*, including Protected Environmental Values for waterways. Implementation is supported by the *State Stormwater Strategy* and requires pollutant reduction targets for nitrogen, phosphorus and suspended solids. New developments over 500 m^2 impervious surface required to incorporate best practice stormwater practices, including targets for stormwater quality.	Local planning schemes must require stormwater management strategies from development proposals, both for construction and operation. Both state and local governments are required by the SPWQM to develop strategies to reduce stormwater pollution as its source. Various local plans developed, such as the *NRM North Regional Stormwater Quality Management Strategy 2014-2017* and the Derwent Estuary Program's WSUD *Engineering Procedures: Stormwater for Southern Tasmania* (2006).
Australian Capital Territory	WSUD embodied in the *Waterways: Water Sensitive Urban Design code* in 2009. It replaces elements of the previous strategy; *Think water, act water – Strategy for sustainable water resource management in the ACT*. Targets are set for improved stormwater quality and quantity, and reduced mains water use. The stormwater targets are mandated for sites > 2,000 m^2, and further quality targets are required for sites > 5,000 m^2. A recent review, *Water Sensitive Urban Design – Review report*, investigated a range of WSUD implementation issues and identified recommendations.	N/A
Northern Territory	Environmental values and objectives stated in the *Water Act* via Beneficial Use Declarations for water bodies such as Darwin Harbour. Development proposals must adhere to these, as well as the requirements for stormwater pollution under the *Waste Management and Pollution Control Act*. The adoption of WSUD strategies are discussed in the report Water Sensitive Urban Design: The implementation of WSUD within the existing legislation and policy framework (2009). The *WSUD Strategy for Darwin Harbour* requires WSUD for new urban developments.	While local governments review and comment on development proposals, the Department of Planning and Infrastructure (and more specifically the division known as the Development Consent Authority) is responsible for approval of development applications. Stormwater is managed by both local and the Territory governments, and councils are responsible for stormwater drainage. Local government subdivision and development guidelines also set requirements for stormwater drainage.

1.4 Research underpinning the design of biofiltration systems

The first version of these guidelines was developed by the Facility for Advancing Water Biofiltration (FAWB) in 2009. FAWB was an unincorporated joint venture between the Institute for Sustainable Water Resources (ISWR), Monash University and EDAW Australia (previously Ecological Engineering). It also involved collaboration with industry partners from Adelaide and Mount Lofty Ranges Natural Resources Management Board (South Australia), Brisbane City Council (Queensland), Landcom (NSW), Manningham City Council (Victoria), Melbourne Water (VIC) and VicRoads (VIC). FAWB was primarily funded through the Victorian State Government's Science, Technology and Innovation (STI) grant, industry cash contributions and a direct cash contribution from Monash University.

This revision of the guidelines was undertaken by the Cooperative Research Centre for Water Sensitive Cities (CRCWSC). The guidelines have been revised to incorporate recent research work, much of which was undertaken under the original Cities as Water Supply Catchments Project, which later became the CRCWSC, or by associated projects funded by industry partners (Melbourne Water and the Department of Water, WA) and the Australian Research Council (ARC).

This update was undertaken in partnership with a number of industry partners who provided valuable input material, feedback and review of these guidelines. An Industry Advisory Panel had oversight and closely collaborated throughout the review process, incorporating seven industry partners from five Australian States:

- Department of Water, Western Australia (WA)
- Melbourne Water, VIC
- Ku-ring-gai Council, NSW
- Natural Resources Adelaide and Mt Loft Ranges, Department of Environment, Water and Natural Resources, SA
- Hornsby Shire Council, NSW
- Brisbane City Council, QLD
- E2DesignLab, VIC

Specific aspects of the guidelines were also developed in consultation with industry representatives, including input from:

- City of Port Phillip
- Daisy's Garden Supplies
- Sportsturf Consultants
- DesignFlow
- EPA SA
- Water Sensitive South Australia
- City of Port Adelaide, Enfield

1.5 How to use these guidelines

The purpose of this document is to provide guidance on how to apply the research findings in practice. The target audience includes planners, engineers, landscape architects, developers, constructors, and all other parties involved in urban design.

These guidelines are intended to be viewed as a reference – readers are encouraged to go to specific sections as required, and it is not expected to be read cover-to-cover. As a result, sections of the document are intended to stand alone to some extent.

The guidelines are presented as a series of chapters, each addressing a different aspect of implementation of biofiltration systems, as follows:

- Chapter 2 (*Business Case for Biofiltration*) outlines the broad suite of benefits and performance expected from stormwater biofilters. It also identifies the key stakeholders and discusses their relationships to the project. The costs and benefits of the technology are discussed and studies that have quantified aspects of the business case for biofiltration are presented.

- Chapter 3 (*Technical Considerations*) provides guidance on conceptual design and linking design outcomes to identified management objectives, a key step in biofilter design that is often overlooked. It then describes the main components of biofilters and key processes, as well as four fundamental design configurations. The key considerations in design are summarised, along with recommendations to achieve effective systems. Finally, sub-sections discuss each biofilter component in detail, from aspects of sizing, system hydraulics, media selection, vegetation, aesthetics, stormwater harvesting and other specific considerations.

- Chapter 4 (*Practical Implementation*) provides guidance on the construction, establishment, maintenance, and monitoring of biofiltration systems in Australia. The recommendations are based on the experience and observations of ecologists and engineers who have been actively involved in the design, on-site delivery and monitoring of biofilters.

Appendices provide additional information, either as summaries in the form of fact or field sheets, or more detailed information for specific reference:

- Appendix A – Fact Sheets: short summaries outlining:
  - 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
- Appendix B – Publications: research underpinning the Biofilter Adoption Guidelines
- Appendix C – Guidelines for filter media in stormwater biofiltration systems
- Appendix D – Enhancing pathogen removal using novel antimicrobial media
- Appendix E – Case studies
- Appendix F – Biofilters that look good – enhancing aesthetics, community appreciation and acceptance
- Appendix G – Detailed scientific monitoring
- Appendix H – Performance assessment of biofiltration systems using simulated rain events
- Appendix I – Measurement of hydraulic conductivity – using in situ and ex situ (laboratory) sampling methods
- Appendix J – Maintenance field sheet
- Appendix K – Maintenance requirements for biofiltration systems: Plan and checking tools

Note: Like all other WSUD elements, biofilters are most easily and successfully included in urban design when considered in an integrated manner i.e., in conjunction with all other elements of the urban layout. These guidelines should therefore be consulted **before** any detailed planning and design occurs.

1.6 Other relevant documents

These guidelines are intended to be relevant at the national scale and therefore cannot comprise a standalone document, as the final detailed design of biofilters will be influenced by local site conditions (e.g. soil type, rainfall intensity) and stormwater management requirements.

Other external documents including, but not limited to, the following should also be consulted in the design of biofiltration systems:

- Local planning policies and regulations (see Table 1 for further details)
- Local development guidelines (Table 1)
- Local stormwater management guidelines (Table 1)
- Local construction guidelines
- MUSIC modelling documentation (see www.toolkit.net.au/music)
- Australian Runoff Quality (Engineers Australia)
- ANZECC Water Quality Guidelines (see www.environment.gov.au/water/publications/quality/index.html#nwqmsguidelines)

Examples of successful and not-so-successful implementation and operation of biofilters are a valuable source of information. In some respects, ironically, the least successful examples may serve as the most useful reference points, in a cautionary sense. They can also provide creative ideas for sites that are constrained in some way. Many local water authorities and other related organisations compile this information, some of which is available from their websites. Useful websites include:

- Water Sensitive Urban Design (wsud.melbournewater.com.au)
- Water by Design (www.waterbydesign.com.au)
- Water Sensitive Urban Design in the Sydney region (www.wsud.org)
- New WAter Ways (www.newwaterways.org.au)
- urbanwater.info (www.urbanwater.info)
- CRC for Water Sensitive Cities (www.watersensitivecities.org.au)
- Water Sensitive SA (www.watersensitivesa.com)

It is also important to consult with the local water authority, particularly where design solutions are required for “problem” sites.

1.7 References

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