



Healthy

Land & Water

Bioretention Technical Design Guidelines

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About Healthy Land & Water

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Working in partnership with Traditional Owners, government, private industry, utilities and the community, Healthy Land & Water delivers innovative and science-based solutions to challenges affecting the environment. Through a combination of scientific expertise and on-ground management works, Healthy Land & Water **leads and connects through science, big data and actions that will preserve and enhance our natural assets and support resilient regions long into the future.**

Traditional Owner acknowledgement

We acknowledge that the place we now live in has been nurtured by Australia's First Peoples for tens of thousands of years. We believe the spiritual, cultural and physical consciousness gained through this custodianship is vital to maintaining the future of our region.

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LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|-----------|---|
| AASS | Actual Acid Sulphate Soil |
| ARI | Average Recurrence Interval |
| ASS | Acid Sulphate Soil |
| CRCWSC | Cooperative Research Centre for Water Sensitive Cities |
| FAWB | Facility for Advancing Water Biofiltration |
| IPWEA-QNT | Institute of Public Works Engineering Australasia Queensland and Northern Territory |
| MUSIC | Model for Urban Stormwater Improvement Conceptualisation |
| NATA | National Association of Testing Authorities |
| PASS | Potential Acid Sulphate Soil |
| QUDM | Queensland Urban Drainage Manual |
| WSUD | Water Sensitive Urban Design |

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1 Introduction

Waterways and other aquatic environments are valued by the community for their social, cultural, economic and environmental benefits. Urban runoff, contaminated with nutrients, sediment and other pollutants, adversely impacts these valued resources.

Water Sensitive Urban Design (WSUD) is a holistic approach to the planning and design of urban landscapes that minimises these negative impacts. Using this approach, designers select the treatment technology that considers the civil, landscape and ecological aspects of the site. Owing to flexible design, space efficiency, and application at a variety of scales, bioretention systems (also called biofilters, bioretention basins, bioinfiltration systems, bioswales and raingardens) are the most commonly used treatment technology.

The key function of bioretention systems is to remove pollutants from stormwater. They achieve this by filtering the stormwater through a densely vegetated and biologically active sand and loam filter media. As the water percolates through the filter media, pollutants are captured by fine filtration, adsorption and biological processing by both soil microbes and plants. Treated water discharges to groundwater or is conveyed to downstream drainage systems such as waterways, channels or pipes. Bioretention systems also contribute to managing hydrology by slowing the rate of discharge of stormwater to the receiving environment and reducing volume through evapotranspiration.

Through careful integration and a collaborative design approach, bioretention systems must also provide multiple benefits. These benefits include:

- Conserving water through the passive irrigation of landscape features by stormwater, which reduces the demand on alternative water sources for irrigation.
- Creating or enhancing green spaces within the urban landscape.
- Providing amenity and aesthetic values for the community.
- Mitigating minor flash flooding.
- Providing urban cooling.
- Increasing habitat and supporting urban ecology.

When multiple benefits are achieved, bioretention systems help deliver important social, cultural, economic and environmental outcomes for the community and our waterways.

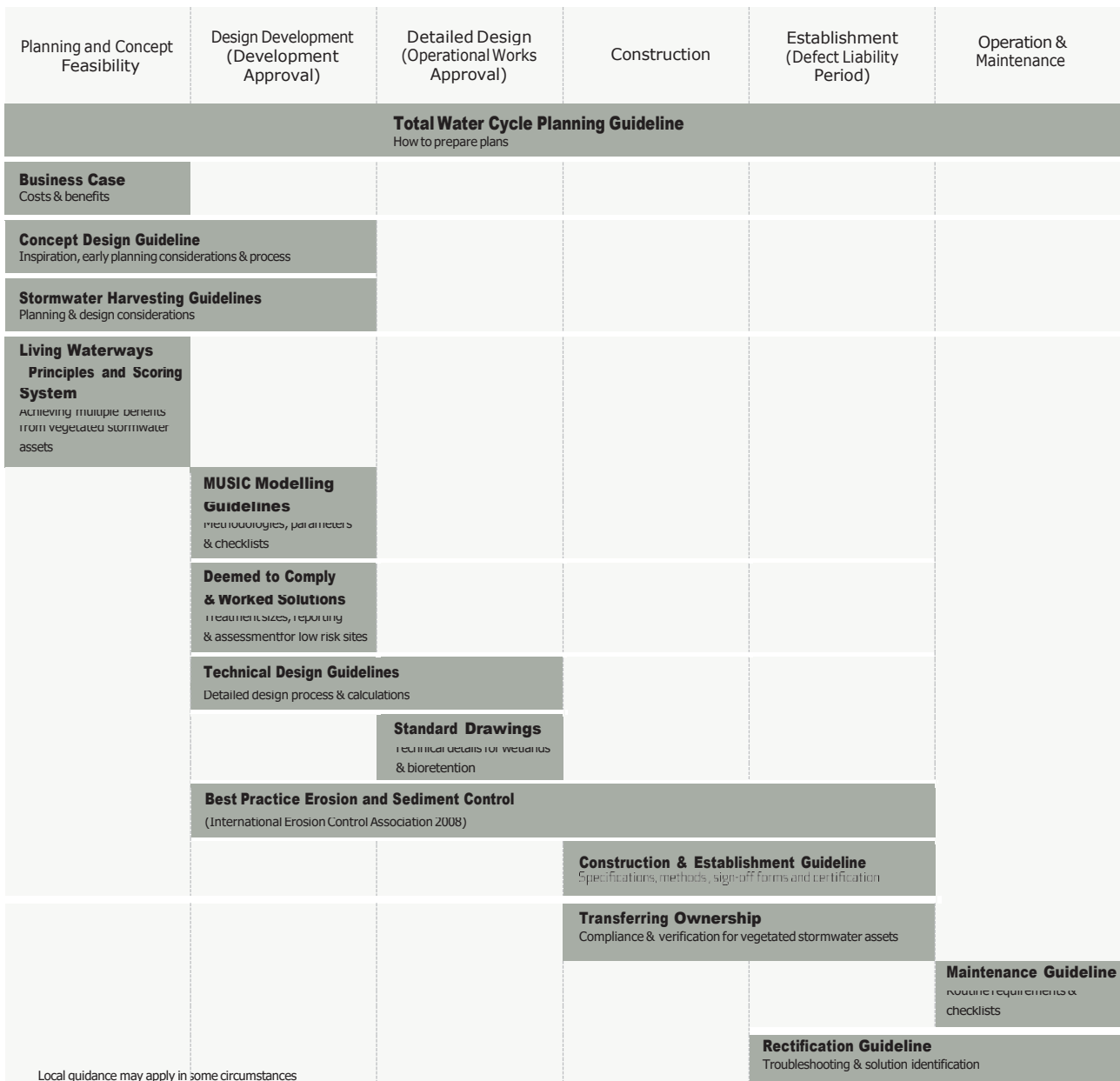


Figure 1. The WSUD timeline and supporting guidelines.

1.1 History and context of the guidelines

A comprehensive suite of tools and guidelines developed by Water by Design is available to support the planning, design and implementation of WSUD in Queensland and beyond. Figure 1 illustrates these tools and how they can be used in the context of a typical urban development process.

The *Water Sensitive Urban Design Technical Design Guidelines for South East Queensland* (Water by Design) were first released in June 2006. They provide guidance on the design, construction, establishment and maintenance of various stormwater management systems, including both bioretention swales and basins. These were addressed in several chapters throughout the guideline:

- Chapter 1 – Introduction.
- Chapter 3 – Bioretention Swales.
- Chapter 5 – Bioretention Basins.
- Appendix A – Plant Selection for WSUD Systems.

Since these guidelines were first published, the design of bioretention systems has evolved significantly.

With the release of Version 1 (2012) of the *Bioretention Technical Design Guidelines*, all bioretention references in the *Water Sensitive Urban Design Technical Design Guidelines for South East Queensland* (Water by Design) were superseded by either that document or another Water by Design publication. Version 1.1 (2014) provided further information on drought resilience and additional guidance on plant selection.

This revision (Version 1.2) brings together knowledge from an additional 10 years of bioretention implementation to provide the following updated guidance:

- Addition of a fifth drainage profile. Changes to the naming convention for several existing drainage profiles (Section 2.4).
- Increase of the minimum filter media depth from 400 mm to 600 mm. Removal of any additional depth requirements for trees (Section 2.4).
- New section on how to design bioretention for different geographic and climatic regions (Section 2.6).
- New section on functional design (Section 3.1).
- Updated guidance on filter media specifications (Section 3.3.2.1).
- Rewording to clarify the section relating to setting the maximum water level (Section 3.3.3.4).
- New guidance on how to prepare the base of bioretention systems where infiltration is a key goal (Section 3.3.4).
- Refinement of guidance on acceptable and unacceptable liner types (Section 3.3.5).
- Enhanced guidance on how to configure large bioretention systems (Section 3.4.3.1).
- Clarified that finished surface levels for batters/embankments must allow for topsoil (Section 3.4.5.3).
- Clarification of guidance regarding walls (above ground) and the interface with in-situ soils (Section 3.4.5.5 and Section 3.4.5.6).
- Enhanced guidance on maintenance access (Section 3.4.6).
- Additional guidance on the design of streetscape bioretention systems (Section 3.1.2 and Section 3.4.8).
- New guidance and clarification regarding collocation with detention basins (Section 3.4.9) and flood immunity requirements (Section 3.4.10).
- New advice regarding sediment capture in streetscape bioretention (Section 3.5.3.2)
- Further guidance on the use of energy dissipation and alignment of sediment forebays (Section 3.5.3.3).
- Additional guidance on designing inlet ponds for large bioretention systems (Section 3.5.3.4).
- New information on how to manage baseflows into bioretention (Section 3.5.6).
- Enhanced guidance on flow distribution (Section 3.5.7).
- Reduced requirements for underdrainage cleanout points (Section 3.6.1.1).
- Alterations to pit and riser configurations for saturated zone systems (Section 3.6.1.4).
- Guidance on the use of temporary upstands during plant establishment (Section 3.6.1.5).
- Change to recommended raised dome grates rather than raised flat grates (Section 3.6.2.1).
- Expanded vegetation design section with much greater focus on planting to create resilient and low-maintenance ecosystems. The use of trees is now the default in all bioretention unless there is an overriding reason not to include them (Section 3.7).

1.2 Structure of the guidelines

Each of the five chapters of this guideline describes a particular aspect of the detailed design of bioretention systems. Table 1 outlines the content of each chapter.

Table 1. Structure and content of the Bioretention Technical Design Guidelines.

| Structure | Content |
|---------------------------------|---|
| Chapter 1 – Introduction | Introduces bioretention systems and the concept of WSUD. Provides the history, context and structure of this guideline. |
| Chapter 2 – Background | Provides background information critical to designing and managing bioretention systems. Describes the key features, possible configurations and drainage profiles of bioretention systems, as well as outlining how and in what situations they can be applied. Introduces concepts and nomenclature used throughout the document. |
| Chapter 3 – Design process | Documents a design process that applies across the broad scale and range of configurations of bioretention systems available, and the contexts in which they can be applied. Each component of a bioretention system is addressed individually. Design details provided are divided into 'performance outcomes' and 'recommended approach'. The 'performance outcomes' outline the outcome to be achieved in designing each component of a bioretention system, while the 'recommended approach' is one approach that is proven to achieve the performance outcome. This delineation is to ensure that the essential aspects of bioretention design are incorporated, while also encouraging innovative approaches to design. |
| Chapter 4 – Specification guide | Provides standard specifications for typical bioretention systems to assist in ensuring they are constructed correctly. The specifications can be used as an example, or, where appropriate, copied directly into tender packages. |
| Chapter 5 – Worked example | Provides a worked example of the design of a bioretention system. The user is guided through the process of designing a bioretention system in accordance with the recommended approach outlined in Chapter 3. |

2 Background

2.1 What are bioretention systems?

Bioretention systems are shallow depressions in the urban landscape designed to collect and treat stormwater. They are implemented as standalone treatment systems or as part of a treatment train including other treatment types such as coarse sediment forebays, gross pollutant traps, swales or sediment basins. These other treatment types help to capture sediment prior to it entering the surface of the bioretention system. Figure 2 depicts the components of a typical bioretention system, while Figure 14 in Section 2.4 provides further information regarding the drainage profile, of which there are several configurations.

Stormwater conveyed to a bioretention system is treated by filtering it through a densely vegetated, biologically active sand and loam filter media. As the water percolates through the filter media, pollutants are captured by fine filtration, adsorption, and biological processing by both soil microbes and plants. Treated water discharges to groundwater or is conveyed via slotted or perforated pipes to downstream drainage systems such as waterways, channels or pipes.

As well as removing pollutants, bioretention systems also help manage changes in hydrology that occur as a result of urbanisation. For example, runoff from small rainfall events is captured in the extended detention zone above the surface and slowly percolates through the filter media. By delaying the release of stormwater, bioretention systems can mimic aspects of pre-development hydrology, such as baseflow regimes and reduce pressures on urban streams. The volume of runoff is also reduced through evapotranspiration or infiltration into the surrounding soil.

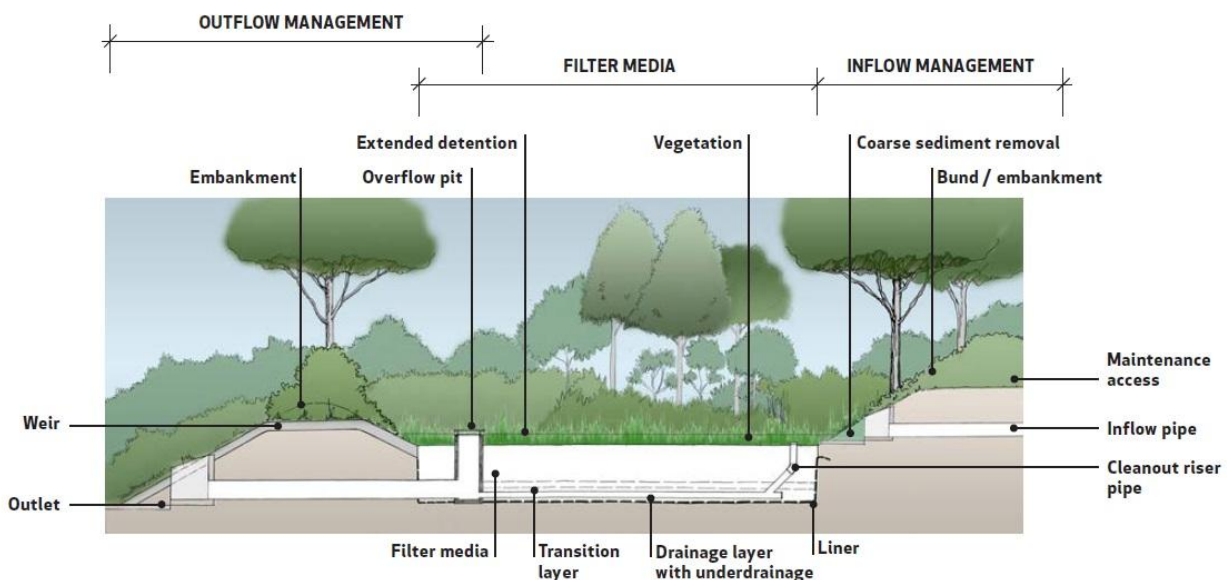


Figure 2. Components of a typical bioretention system.

The main components of a bioretention system are:

- **Filter media** – a sand and loam mix that supports vegetation and removes stormwater pollutants. Filter media is typically 600 – 1000 mm deep. The filter media surface is generally flat, except in bioretention swales.
- **Transition layer** – coarse sand located under the filter media as a 'bridging' layer to prevent finer filter media particles from migrating into the drainage layer, perforated underdrainage pipes, downstream waterway, and the surrounding soil.
- **Drainage layer** – a fine aggregate located under the transition layer as a 'bridging' layer to prevent the filter media and transition layer from washing into the underdrainage.
- **Underdrainage** – slotted or perforated underdrainage pipes that allow treated stormwater to leave the bioretention system. The exact configuration of the underdrainage depends on the type of bioretention system being designed (see Section 2.4). In large bioretention systems, bigger unslotted collector pipes are also present, which connect slotted/perforated pipes to the outlet pit.
- **Liner** – a layer surrounding either or both the base and sides of bioretention systems. Liners can be either permeable or impermeable. The need for a liner is dependent on the type of bioretention system being designed (see Section 2.4).
- **Hydraulic structures** – typically includes an inflow pipe, overflow pit, outlet and weir. Hydraulic structures convey stormwater into the bioretention system and discharge it after treatment.
- **Bunds and embankments** – earthen structures necessary to integrate bioretention systems within the surrounding topography. They vary in size and slope depending on the location, size and context of the system, and serve to detain water prior to filtration.
- **Extended detention** – a 100 – 300 mm zone above the surface of the bioretention system that temporarily stores stormwater before it infiltrates into the filter media. The extended detention is created by raised pits, weirs, or other hydraulic structures. Its purpose is to spread flows over the surface of the filter media and increase the volume of stormwater runoff that can be treated.
- **Vegetation** – in conjunction with soil biology, vegetation is the 'biological' component of bioretention systems. Critical for stormwater treatment, vegetation takes up nutrients, supports biological growth (crucial for pollutant removal), maintains and enhances the porosity of soil, and continuously breaks up the surface of the filter media to help to prevent surface clogging. Vegetation in bioretention systems (grasses, sedges, shrubs and trees) must be tolerant to extended dry periods and periodic inundation.
- **Coarse sediment removal** – a dedicated area to capture and store coarse sediment. Coarse sediment removal is typically comprised of either a coarse sediment forebay or an inlet pond, although gross pollutant traps and swales are sometimes used. Some forms of coarse sediment removal also help dissipate energy and protect against scour around inlets.
- **Maintenance access** – a dedicated access to the bioretention system, which allows for easy and cost-effective maintenance.
- **Cleanout riser pipe** – an unperforated upright pipe connected to the ends of each collector pipe and, in some instances, the underdrainage pipes, to allow inspection and cleaning of the underdrainage.

2.2 Context in the landscape

Bioretention systems are flexible in size, shape and appearance. They can be readily integrated into a range of landscapes, including individual development sites, allotments, streetscapes, civic spaces and forecourts, parklands and adjacent to riparian and bushland settings. Bioretention systems can be designed to seamlessly integrate with the local landscape, or they can be a prominent landscape feature. The following categories of bioretention systems are provided to showcase the range of applications, locations and contexts within which bioretention systems can be applied.

2.2.1 Within allotments

Bioretention systems may be located within allotments on private land. Figure 3 depicts four examples of bioretention systems located within allotments. Bioretention systems within allotments can take the form of raingardens on individual residential lots or small bioretention basins on commercial, industrial and multi-unit developments. They have shallow surfaces, usually less than 750 mm below their surroundings, and accept stormwater via surface flow and shallow, small-diameter pipes. They typically have a total filter media surface area of 5 – 200 m².



Figure 3. Examples of bioretention systems within allotments. Photo credits: top left, Shaun Leinster; top right, Jack Mullaly; bottom left, Robin Allison; bottom right, Jack Mullaly.

2.2.2 In the streetscape

The streetscape is an effective and attractive location for a bioretention system. Streetscape bioretention systems are integrated into road reserve verges or traffic calming 'buildouts' from the kerb (Figure 4 and Figure 5). They receive and treat stormwater before it enters underground drainage systems. This allows them to be implemented on flat topography where end-of-pipe treatments are often not feasible due to level constraints.

Streetscape bioretention systems are often located where conventional side-entry pits would usually go (e.g. road low points and road intersections). Bioretention layers can generally fit within the depth needed to accommodate the minor drainage pit (with appropriate cover). As such, bioretention systems in the streetscape do not dictate the depth of the minor drainage system. The layout and size of streetscape systems is however, restricted by other streetscape components such as footpaths, road pavements, and underground services corridors, which are defined by local authorities.

Streetscape bioretention systems typically have a total filter media surface area of 5 – 50 m². The filter media surface is not substantially lower than the adjacent road surface and verges (< 500 mm).

The Concept Design Guidelines for Water Sensitive Urban Design (Water by Design) provides a model streetscape bioretention layout.

DESIGN NOTE: Maintenance costs of streetscape bioretention systems

Streetscape bioretention systems are often (but not always) more expensive to maintain than a similar treatment area of systems located within and adjacent to parkland or adjacent to natural areas. Local governments may have a preference for such end-of-pipe systems over streetscape systems. Unless implementing streetscape systems due to site constraints (i.e. insufficient level to implement an end-of-pipe system), designers should check with the relevant local government prior to implementing streetscape systems.

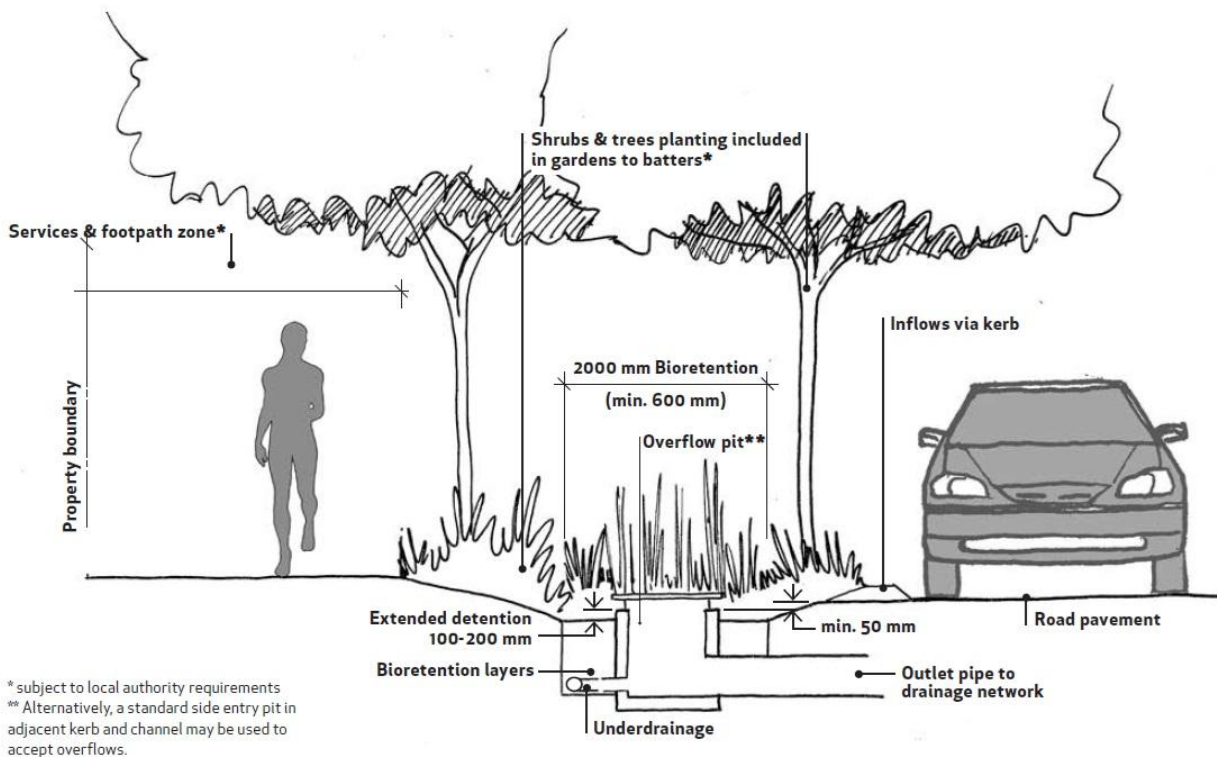


Figure 4. Streetscape bioretention cross-section.



Figure 5. Examples of bioretention systems in the streetscape. Photo credits: top left and top right, Shaun Leinster; bottom left, Jack Mullaly.

2.2.3 Within civic space

Bioretention systems can be integrated into civic spaces as an attractive feature (Figure 6). They can also be combined with stormwater harvesting for non-potable uses such as landscape irrigation, topping up water features or within buildings for flushing toilets. The plant species and planting densities chosen for civic space bioretention systems should complement the surrounding urban space. Often, this includes mass planting of a small number of plant species with low to medium vegetation height.

Civic space bioretention systems are designed with the filter media surface level close to the level of adjacent urban spaces. A difference of less than 500 mm between the two levels is recommended. Flows can be directed onto the bioretention surface through small, shallow drains (e.g. grated trenches). The total filter media surface area of civic space bioretention systems is typically 5 – 100 m².



Figure 6. Examples of bioretention systems within civic space. Photo credits: top (left and right), Jack Mullaly; bottom left, Shaun Leinster.

2.2.4 Within and adjacent parkland

Bioretention systems can be easily integrated within or adjacent to parkland (Figure 7). This has the benefits of increasing continuity of green space, engaging the community with the water cycle and providing opportunities to reuse stormwater. Planting of parkland bioretention systems should complement the surrounding landscape space and include a diverse number of understory species along with trees and shrubs. Planting should be included on the batters.

Parkland bioretention systems are typically end-of-pipe systems, receiving inflows from a piped network. However, some are designed as at-source systems to receive overland flow from hardstand areas, and some can be designed to function as both end-of-pipe and at-source systems. Parkland bioretention systems can be sited within flood detention infrastructure. The filter media area of parkland bioretention systems is typically 50 – 800 m².





Figure 7. Examples of bioretention systems within and adjacent to parkland. Photo credits: top left, Shaun Leinster; top right, Jack Mullaly; bottom (left and right), Jack Mullaly.

2.2.5 Adjacent to natural areas

Locating bioretention systems adjacent to natural areas such as bushland or riparian corridors is an easy way to achieve benefits above and beyond traditional stormwater management requirements. Bioretention systems located next to natural areas enhance the overall green space and provide for wildlife habitat and movement (Figure 8). They also have the potential to reduce maintenance costs through reducing edge effects and shading weeds.

Bioretention systems adjacent to natural areas are integrated with their surrounding landscape. This creates systems with informal shapes and gentle batter slopes, rather than hard edges. Planting in such systems should complement the surrounding landscape and involve a well-structured and diverse landscape including grasses, sedges, shrubs and trees.

Bioretention systems adjacent to natural areas are typically end-of-pipe systems, receiving inflows from a piped network. They can be sited within flood detention infrastructure. Their filter media surface area is typically 50 – 800 m².





Figure 8. Examples of bioretention systems adjacent to natural areas.

2.3 Configurations

The multiple contexts that bioretention basins are used in (see Section 2.2) require bioretention configurations that can adapt to the nature of the site in which they are located. Selecting the appropriate configuration for the site is important to ensure it integrates into the surrounding landscape, functions effectively and allows for easy and cost-effective maintenance.

There are four main configurations of bioretention system:

- Bioretention basins.
- Bioretention swales.
- Biopods.
- Bioretention street trees.

2.3.1 Bioretention basins

Bioretention basins are an end-of-pipe bioretention system. They can vary in size greatly, with typically 100 – 800 m² of filter media surface area. Bioretention basins are often located adjacent to parkland or natural areas (Figure 9) or in a dedicated drainage reserve. The vegetation used reflects the location. For example, bioretention basins located adjacent to parkland include vegetation compatible with other landscaping in the parkland, while bioretention basins adjacent to natural areas use species that reflect the ecosystem of that natural area. In all instances, shrubs and trees should be included in bioretention basins to create ecosystem-like effects that reduce long-term maintenance costs.





Figure 9. Examples of bioretention basins. Photo credits: top (left and right), Shaun Leinster; bottom left, Paul Dubowski; bottom right, Jack Mullaly.

2.3.2 Bioretention swales

Bioretention swales are a type of bioretention system that both treats and conveys stormwater. A bioretention swale comprises all the main components of a bioretention system (see Section 2.1) co-located within the base of a swale (Figure 10 and Figure 11). For bioretention swales, the surface of the filter media follows the grade of the swale's surface ($> 0.5\%$ and $< 2\%$ slope) and is generally 600 – 2000 mm wide. The swale component of a bioretention swale conveys and pre-treats stormwater to remove coarse to medium-sized sediment. The bioretention filter media removes finer particulates and contaminants.

Bioretention swales are typically located within road reserves, parklands, and drainage easements within small catchments of less than 2 ha. They can receive lateral flows across grassed or vegetated batters (1 in 4 or flatter) or directly from pipe outlets where there is adequate protection from scour. Bioretention swales are densely planted with sedges and rushes and may include trees to form a canopy.

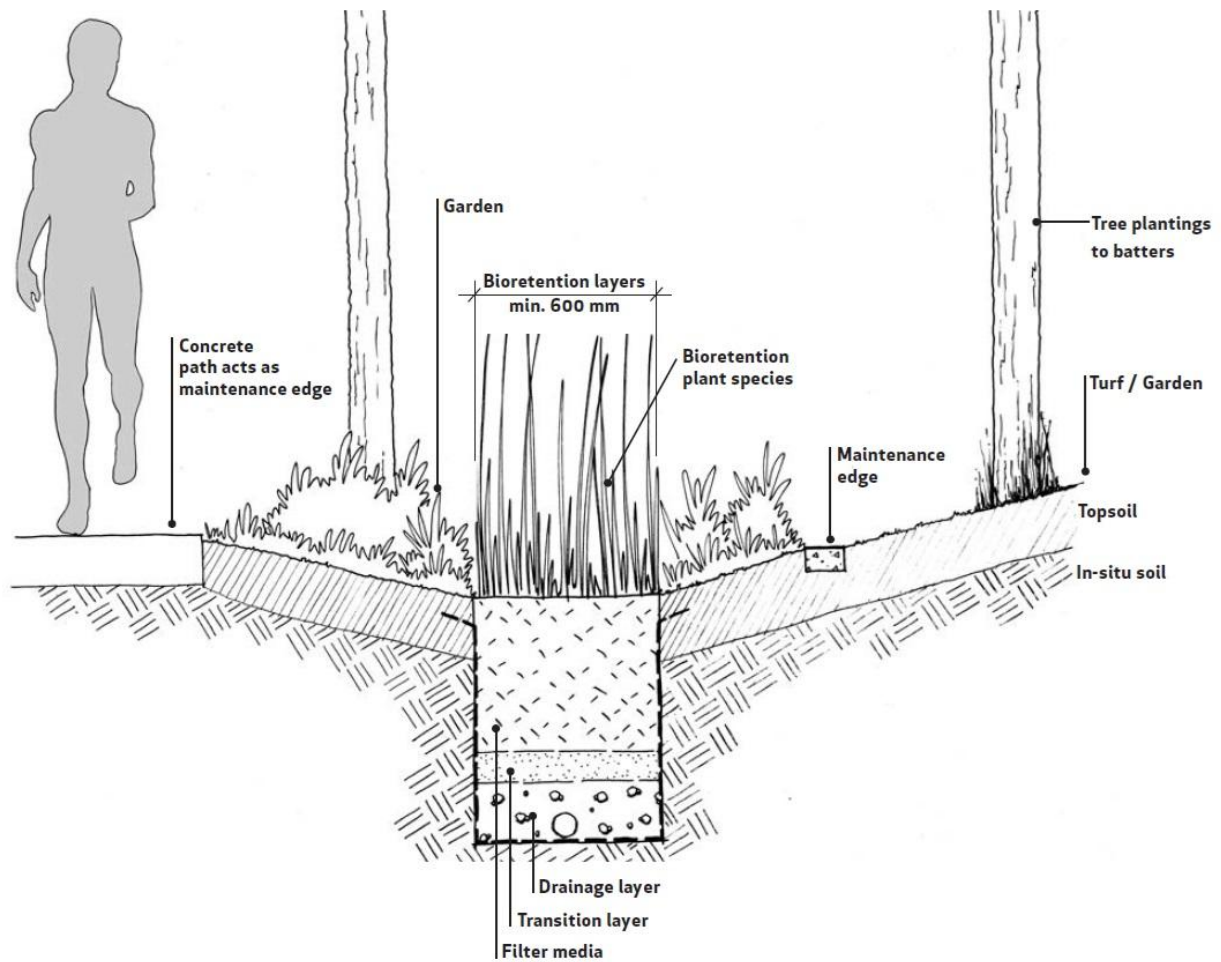


Figure 10. Bioretention swale cross-section.



Figure 11. Examples of bioretention swales. Photo credits: all photos, Jack Mullaly.

2.3.3 Biopods

Biopods are a form of at-source bioretention system. They receive stormwater runoff as overland flow from hardstand areas. Biopods are commonly used in the streetscape, but also have applications in commercial, industrial and multi-unit developments (Figure 12). They are typically less than 50 m² but can be larger. Biopods provide visual amenity to streetscapes, similar to the outcomes of traditional streetscape landscaping. An advantage of biopods compared to traditional landscaping is that biopods are passively irrigated by stormwater inflows. Shrubs, grasses and sedges are the most commonly used types of vegetation, although trees are not precluded.



Figure 12. Examples of biopods. Photo credits: top left, Robin Allison; top right, Shaun Leinster; bottom left, Brad Dalrymple.

2.3.4 Bioretention street trees

Bioretention street trees are a combination of a bioretention system and a traditional street tree (Figure 13). They are located at source and receive overland flow from adjacent hardstand areas. They are small systems, typically only a few square meters in size. The main type of vegetation used in this type is primarily street-suitable tree species, with shrubs, grasses and sedges also able to be incorporated for aesthetics and to help maintain filter media permeability. If grasses, sedges and ground covers are not used, then much of the bioretention street tree's footprint may be covered by a solid surface (Figure 13).

DESIGN NOTE: Guidance specific to bioretention street trees

This guideline provides little specific guidance for bioretention street trees. This is because the design process for bioretention street trees is the same as for streetscape bioretention systems more generally. In most instances, the only differences are the vegetation type, the possible use of a grate over the filter media surface and the possible use of a concrete planter box to house the bioretention street tree. All other aspects of design, including filter media sizing, considerations for locating them in the

streetscape, set downs and inlet and outlet design, are as per streetscape bioretention systems more generally.

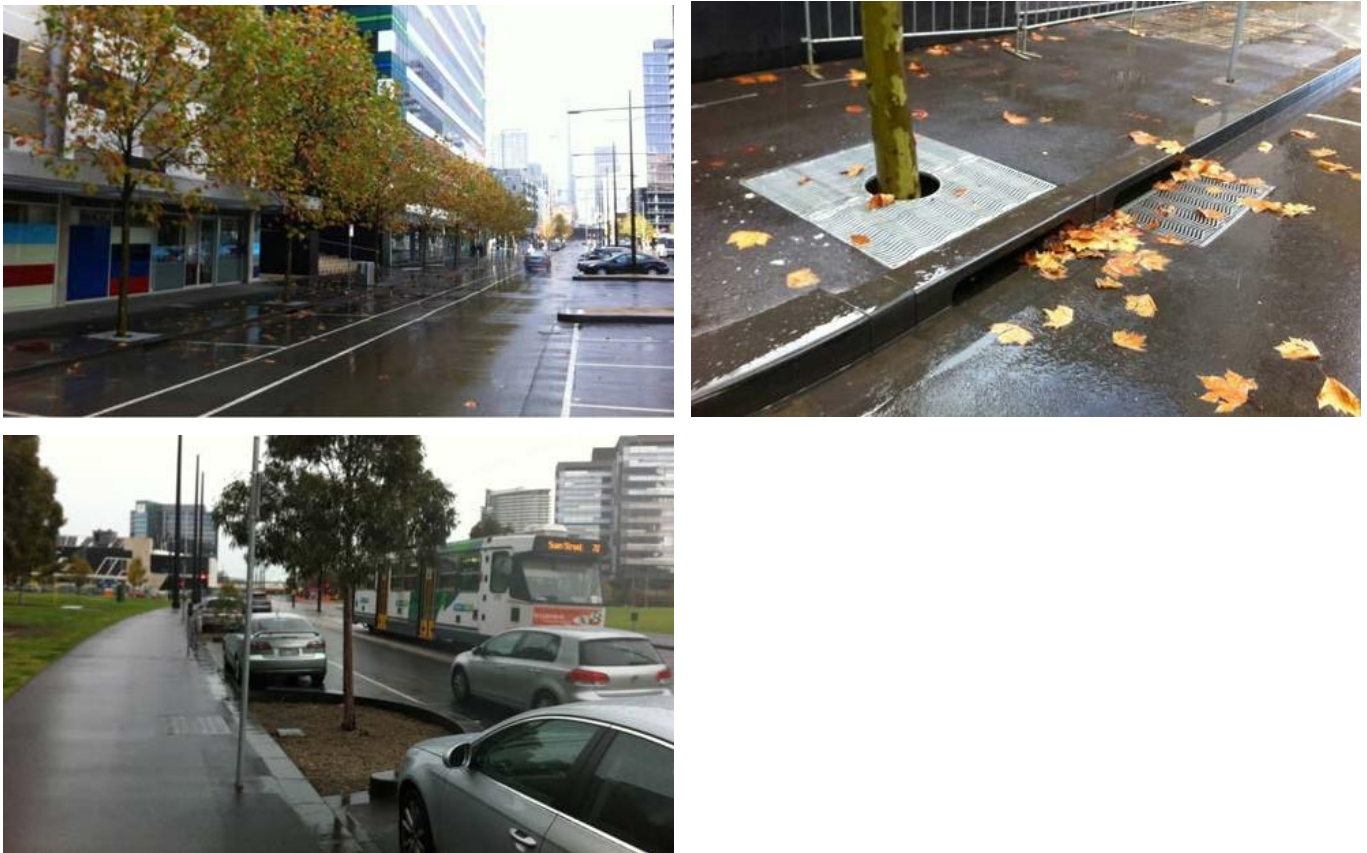


Figure 13. Examples of bioretention street trees. Photo credits: all photos, Brad Dalrymple.

2.4 Drainage profiles

The term *drainage profile* refers to the way the filter media, transition layer, drainage gravel, underdrainage and hydraulic structures are designed to discharge treated water from the system. Five drainage profiles are commonly used (Figure 14); however, the flexible nature of bioretention systems means that other drainage profiles can also be created.

The five drainage profiles in common use are:

- Type 1 saturated zone.
- Type 2A traditional sealed.
- Type 2B traditional unsealed.
- Type 3 infiltration – with pipe.
- Type 4 infiltration – pipeless.

Previous versions of this guideline identified only four drainage profiles and used a slightly different naming convention. Table 2 shows how the five current drainage profiles relate to those in previous versions.

A description of these profiles is provided in Sections 2.4.1 to 2.4.5. Section 3.3.1 details how to select the most suitable drainage profile for the application.

Table 2. Drainage profiles in this version of the guideline are compared to previous versions.

| This version of the guideline | Previous versions of the guideline | Rationale for change |
|---|------------------------------------|---|
| Type 1 saturated zone. | Type 1 saturated zone. | No change. |
| Type 2A traditional sealed. | Type 2 sealed. | Name change only to align with Type 2B naming convention. |
| Type 2B traditional unsealed. | Not previously shown. | Added to more completely show the options available. |
| Type 3 infiltration – with pipe. | Type 3 conventional. | Previous versions used the term <i>conventional</i> in an attempt to encourage this type of system. It is however, neither the conventional type nor the default. Thus, a name change was required. |
| Type 4 infiltration – pipeless. | Type 4 pipeless. | Name change to align with the new Type 3 naming convention. |

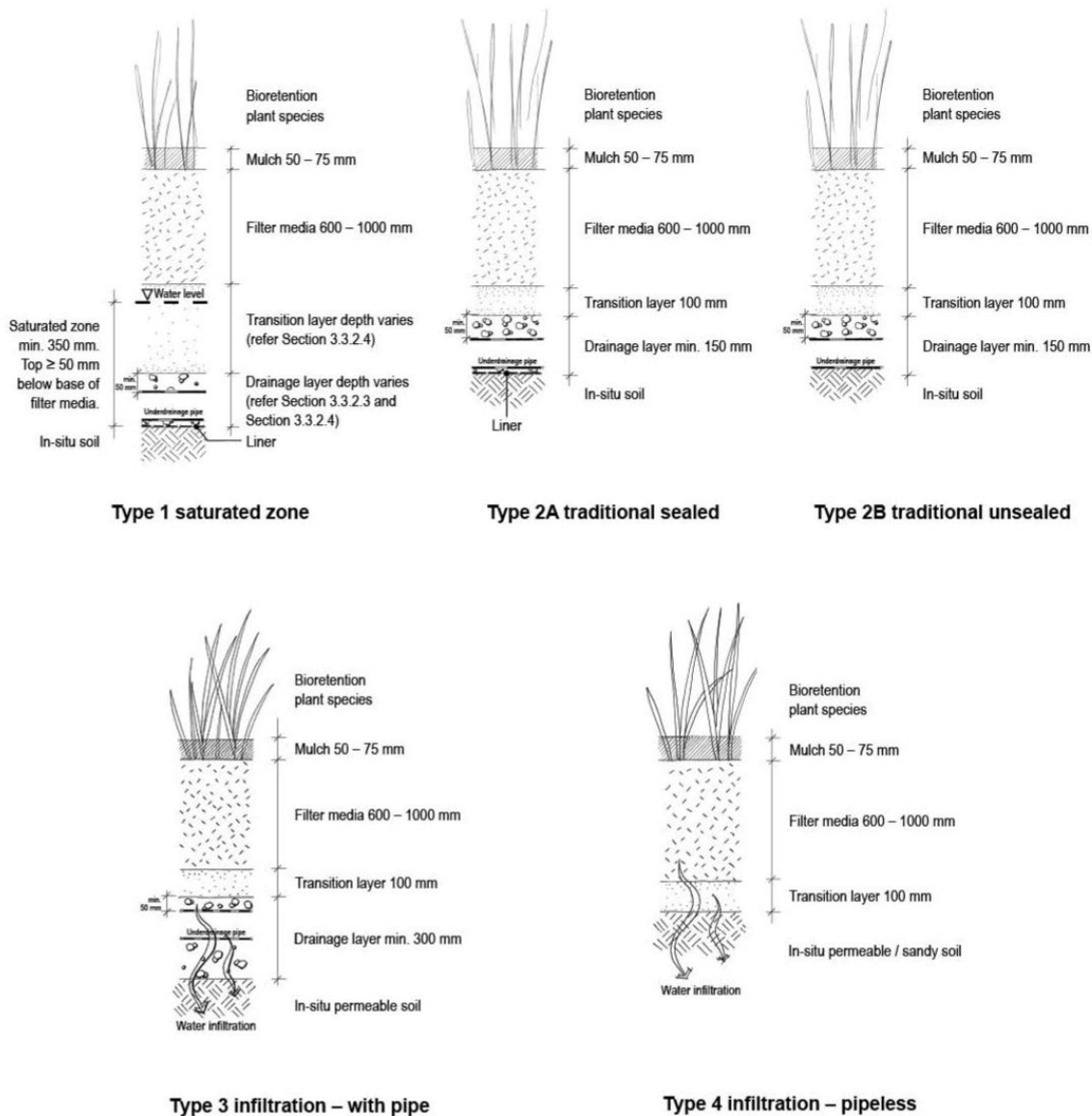


Figure 14. Bioretention drainage profiles.

2.4.1 Saturated zone bioretention systems

Type 1 saturated zone bioretention systems integrate a water storage (wet sump) in the transition and drainage layer. This water storage allows the vegetation to access water during dry periods, facilitates plant and soil biological health, and helps maintain ongoing treatment performance. Type 1 saturated zone bioretention systems have:

- an impermeable liner to ensure water is retained in the base of the system
- an outlet structure that holds water at a defined level within the transition and drainage layer, only able to be drawn down further through evapotranspiration
- a transition layer (transition layer depth varies, see Section 3.3.2.2 and Section 3.3.2.4)
- a drainage layer (drainage layer depth varies, see Section 3.3.2.3 and Section 3.3.2.4)
- a flat base beneath the drainage layer.

2.4.2 Traditional sealed bioretention systems

Type 2A traditional sealed bioretention systems drain via slotted or perforated underdrainage pipes and do not have a saturated zone.

Type 2A traditional sealed bioretention systems have:

- an impermeable liner around the base and sides
- a transition layer at least 100 mm deep
- a drainage layer at least 150 mm deep that is either flat or grades towards the outlet pit, preferably at a slope of $\geq 0.5\%$
- slotted or perforated underdrainage pipes within the drainage layer with ≥ 50 mm aggregate above them.

2.4.3 Traditional unsealed bioretention systems

Type 2B traditional unsealed bioretention systems drain via slotted or perforated underdrainage pipes and do not have a saturated zone. As the base and sides of this type of system are unsealed, some water will infiltrate into surrounding soils, but because the underdrains lie at the base of the system, capacity for infiltration is limited.

Type 2B traditional unsealed bioretention systems have:

- a permeable liner around the base and sides
- a transition layer that is at least 100 mm deep
- a drainage layer that is at least 150 mm deep, that is either flat or grades towards the outlet pit, preferably at a slope of $\geq 0.5\%$.
- slotted or perforated underdrainage pipes within the drainage layer with ≥ 50 mm aggregate above them.

2.4.4 Infiltration – with pipe bioretention systems

Type 3 infiltration – with pipe bioretention systems encourage infiltration into the surrounding soils to manage frequent stormwater flows, with slotted or perforated underdrain pipes for drainage when the infiltration capacity of the soil is exceeded.

Type 3 infiltration – with pipe bioretention systems have:

- a permeable geotextile liner around their sides (no liner along the base)
- a transition layer that is at least 100 mm deep
- a drainage layer that is at least 300 mm deep with a slotted or perforated pipe that has at least 50 mm aggregate above it and at least 150 mm aggregate below it
- a flat base under the drainage layer.

2.4.5 Infiltration – pipeless bioretention systems

Type 4 infiltration – pipeless bioretention systems allow all treated stormwater to infiltrate into the surrounding soil.

Type 4 infiltration – pipeless bioretention systems have:

- a permeable geotextile liner around their sides (no liner along the base)
- a transition layer that is at least 100 mm deep
- no drainage layer or slotted or perforated underdrainage pipes
- a flat base under the transition layer.

2.5 Site suitability

Bioretention systems are permanent. Therefore, their size and location must be appropriate for function, aesthetics, constructability, and maintenance requirements. Table 3 and Table 4 outline a range of bioretention applications and highlight important design characteristics for each application.

Table 3. When to use bioretention systems.

| Situation | Why bioretention is suitable |
|--|---|
| For managing litter, sediment, nutrients, metals and hydrocarbons transported by stormwater. | Bioretention systems are effective at removing anthropogenic and organic litter, fine sediment, phosphorus, nitrogen, metals and hydrocarbons from stormwater. Where litter or coarse sediment loads are high, pre-treatment is recommended. |
| For managing stormwater flows. | Bioretention systems can be used to manage urban hydrology, particularly frequent stormwater flows. They can also be combined with flood storage for large events, although bioretention systems are not designed specifically for this purpose. |
| For urban or civic landscapes, residential parkland and riparian and bushland landscapes. | Bioretention systems have a flexible design, and their vegetated finish allows them to be easily incorporated into a range of landscapes, from hard-edge civic spaces to more natural residential parkland, bushland, or riparian settings. |
| For small catchments or where space is constrained. | Bioretention systems are small (typically < 3% of the catchment area), allowing them to be used in small and constrained spaces. |
| For large catchments. | Bioretention systems can manage runoff from large catchments if design solutions specifically developed for large systems are used (e.g. locating systems offline, implementing a distribution system, and splitting the filter media into suitably sized cells). |
| On moderate to steep topography. | Through careful design, bioretention systems can be readily integrated into relatively steep topography. |
| On flat topography. | Bioretention systems can be located at-source or within streetscapes, directing runoff onto the surface of the bioretention system before it enters an underground drainage network. |
| For stormwater harvesting. | Bioretention systems can treat stormwater to a level suitable for some forms of reuse. It is important to account for any potential water losses through bioretention systems when estimating yields for stormwater harvesting systems. |

Table 4. When not to use bioretention systems.

| Situation | Why bioretention is not suitable |
|--|--|
| For sites with insufficient elevation. | Bioretention systems will not drain adequately if there is insufficient elevation from the surface of the system to the receiving drainage system. This will cause the filter media to remain inundated and affect both the health of plants and the functioning of the bioretention system. |
| For sites with tidal influence. | Saline water compromises the biological function of bioretention systems. |
| For sites with continuous inflow (i.e. constantly wet). | Moss or algae can form thick surface biofilms (or slimes) in continuously wetted bioretention systems, which reduce the rate of infiltration into the filter media. Periodic drying of bioretention systems is necessary to reduce the risk of blockages due to surface biofilm growth. If continuous inflows are identified post-construction, a low-flow bypass can be installed to mitigate this problem. |
| For swales with high velocities. | High flow velocities (> 1 m/s) are likely to scour the surface of bioretention systems. |
| For sites subject to toxic runoff. | When the system is likely to be exposed to toxic substances (e.g. herbicides, solvents or industrial contaminants), biological function will be compromised. Structural separation should be used to exclude contaminants from the stormwater system. |
| When the system cannot be easily accessed for maintenance. | Bioretention systems require periodic maintenance to ensure optimal function. As such, easy access for maintenance must be available. |

2.6 Geographic and climatic suitability

Bioretention systems are highly adaptable and can be implemented in a wide array of different geographic and climatic contexts. Most advice provided within this guideline is directly applicable to all geographic and climatic regions within Queensland. Nonetheless, the soils and rainfall patterns of some regions require additional consideration as outlined below.

Locations with dispersive soils

In locations with dispersive soils:

- More efficient sediment capture may be required than specified in Section 3.5.3.1. For example, high efficiency gross pollutant traps and sediment basins might be used in lieu of coarse sediment forebays.
- It is particularly important that all batters are covered with a non-dispersive topsoil (see Section 4.4.1) and dense plant coverage is established (see Section 3.7). Plants that regularly drop leaf litter are encouraged as this will provide ongoing surface coverage for the batters.
- Overland flows down batters should be avoided. Where it cannot be avoided, rock chutes or similar techniques should be applied to prevent erosion of the batters (see Section 3.5.2.1).
- Particular care must be taken when keying liners into the batters (see Section 3.3.5).

Locations with extended dry periods or generally low rainfall

In locations with extended dry periods (e.g. Townsville) or generally low rainfall (e.g. Ipswich):

- Type 1 saturated zone systems should be used to provide a water source for plants between rainfall events (see Sections 2.4.1 and 3.3.2.4).
- Temporary upstands should be used during establishment to further increase water availability to plants at this time (see Section 3.6.1.5).
- Plant species capable of surviving extended dry periods should be used.
- Plant species that regularly drop leaf litter should be used as the leaf litter will help to retain soil moisture (see Section 3.7.9.2).
- Consideration should be given to alternative filter media specifications aim at improving the hospitality of the filter for plant growth (see Section 3.3.2.1).

Locations with intense rainfall

In locations subject to intense rainfall, it is particularly important that appropriate energy dissipation and scour protection is provided at inlets, regardless of whether a sediment forebay is required (see Section 3.5.4).

2.7 Function over time

Bioretention systems provide a range of functions, including managing hydrology, removing pollutants, and enhancing amenity. Some of these functions are provided for as long as the bioretention system remains in place, while others vary over time. Most functions remain high while the porosity of the filter media is maintained and suitable plants are retained within the system. Careful selection of desirable plant species alongside appropriate maintenance practices aids in maintaining filter media porosity.

There are now many bioretention systems in Australia over 20 years old, with the oldest approaching 25 years in age. Thus, while it is currently impossible to say with accuracy what the expected lifespan of bioretention systems is, it is likely that well-designed, constructed, established and maintained systems will function well for at least 25 years, and almost certainly much longer. There is reason to believe that some bioretention functions may be retained effectively indefinitely.

Monitoring the performance of bioretention systems is an important component of their long-term management, but it can be an expensive and nuanced task. For further information on monitoring bioretention performance, refer to *Maintaining Vegetated Stormwater Assets (Water by Design)*.

Hydrologic function – While the hydraulic conductivity of the filter media remains close to the design rate, bioretention systems designed for hydrologic benefits, such as reducing stormwater volumes entering waterways, will retain their capacity to perform this function indefinitely.

Sediment removal – Sediment removal capacity is influenced by filter media grading and its porosity. While the hydraulic conductivity of the filter media remains close to the design rate, sediment removal capacity will remain constant.

Phosphorus removal – Phosphorus occurs in stormwater in particulate (attached to sediments) and soluble (dissolved) forms. Bioretention systems remove particulate sediment from stormwater via physical filtration within the filter media. Soluble phosphorus is removed by sorption onto fine particles within the filter media and to a lesser extent through biological uptake by plants.

While filter media have a finite capacity to retain dissolved phosphorus, this capacity may be replenished over time due to new sediment entering the bioretention system and uptake by plants. After a given time, when the capacity of the filter media to retain dissolved phosphorus is exhausted, phosphorus removal within the bioretention system will decrease, and be limited to filtration of particulate phosphorus and biological uptake of soluble phosphorus. The time at which this occurs is driven by the amount of filter media (surface area and depth) in the bioretention system compared to the total catchment area.

About 40% of the total phosphorus in stormwater is associated with particles greater than 50 microns (Vaze and Chiew 2004). It is reasonable to expect that this phosphorus will continue to be removed in a bioretention system even after the sorption capacity in the system has been exhausted.

Nitrogen removal – Nitrogen occurs in stormwater in particulate, organic or soluble forms. Nitrogen processing in bioretention systems occurs through a combination of mineralisation, nitrification and denitrification. These processes change the form of the nitrogen. Nitrogen is ultimately removed from stormwater by either plant uptake or by being released to the atmosphere as nitrogen gas. For this to occur, the bioretention system must contain a suitable amount of desirable plants (see Section 3.7.5). The plants in turn support microbial communities that facilitate this nitrogen processing.

Newly constructed bioretention systems may see an initial lag in nitrogen removal until plants establish during the first growing season. Once plants are established, nitrogen removal capacity in bioretention

systems should remain relatively constant over time, so long as suitable plants remain in the system and the filter media porosity is maintained.

Heavy metal removal – Heavy metals occur in stormwater in particulate (attached to sediments) and soluble (dissolved) forms. Bioretention systems remove particulate metals from stormwater via physical filtration within the filter media. Much like phosphorus, soluble metals are removed by sorption onto fine particles within the filter media and to a lesser extent through biological uptake by plants.

While filter media has a finite capacity to retain dissolved metals, this capacity may be replenished over time due to new sediment entering the bioretention system and uptake by plants. After a given time, when the capacity of the filter media to retain dissolved metals is exhausted, metals removal within the bioretention system will decrease and be limited to filtration of particulate metals and biological uptake of soluble metals. The time at which this occurs is driven by the amount of filter media (surface area and depth) in the bioretention system compared to the total catchment area.

Hydrocarbon removal – Bioretention systems remove hydrocarbons from stormwater by volatilisation and processing by microorganisms. While filter media porosity remains close to its design rate, hydrocarbon removal capacity should be retained.

Amenity – Bioretention systems provide amenity through the quality of design and plant selection. Amenity will increase as plants establish, and then remain relatively constant over time, varying seasonally, with climate and maintenance regime.

Urban heat – Bioretention systems help mitigate urban heat by providing shade and passive cooling. Their ability to do this will increase as plants establish and then remain relatively constant over time once plants have matured. Including trees in bioretention systems will further enhance their urban cooling properties.

Ecology – Bioretention systems support urban ecology by providing habitat and food for wildlife. The ecological benefits of bioretention systems increase as the plants establish and are further enhanced through the provision of layered vegetation communities with diverse plant selection.

3 Design process

Designing bioretention systems requires the civil, landscape and ecological aspects of the site to be considered to ensure systems are functional, well integrated with the urban landscape, and that they complement local ecology.

Bioretention design involves multiple stages and iterations, as illustrated in Figure 15.

Concept design involves selecting the most appropriate treatment measure, and identifying the location, size and indicative shape of the treatment system within the site. The *Concept Design Guidelines for Water Sensitive Urban Design (Water by Design)* should be used to guide the concept design phase.

Functional design involves adding detail to the conceptual design to ensure the system will work as intended. In retrofit projects, this involves setting key bioretention system levels and ensuring that all critical components (e.g. the treatment area, batters and bunds, sediment capture and maintenance access) are allocated sufficient space within the available area. The same process occurs for bioretention systems delivered through the development assessment process; however, in this case, the bioretention functional design also informs key elements of the design of the rest of the development.

For example:

- In level constrained developments, the bioretention functional design will set minimum road and pipe levels throughout the development.
- In the case of streetscape bioretention systems, the functional design will also influence lot layout, lot yield and the location of gully pits.

It is critical that for bioretention systems delivered through the development assessment process, conceptual and functional design (at a minimum) are delivered for the planning stage of development assessment. Functional design is addressed in Section 3.1 of this guideline but must occur cognisant of detailed design to follow (Sections 3.2 through 3.9).

Detailed design involves determining the remaining engineering and landscape details necessary for the system to function. The outcome of detailed design is a design report, a set of engineering and landscape drawings, and construction specifications, all of which clearly communicate the design in sufficient detail for assessment (if required) and construction. Detailed design is addressed in Section 3.2 to 3.9.

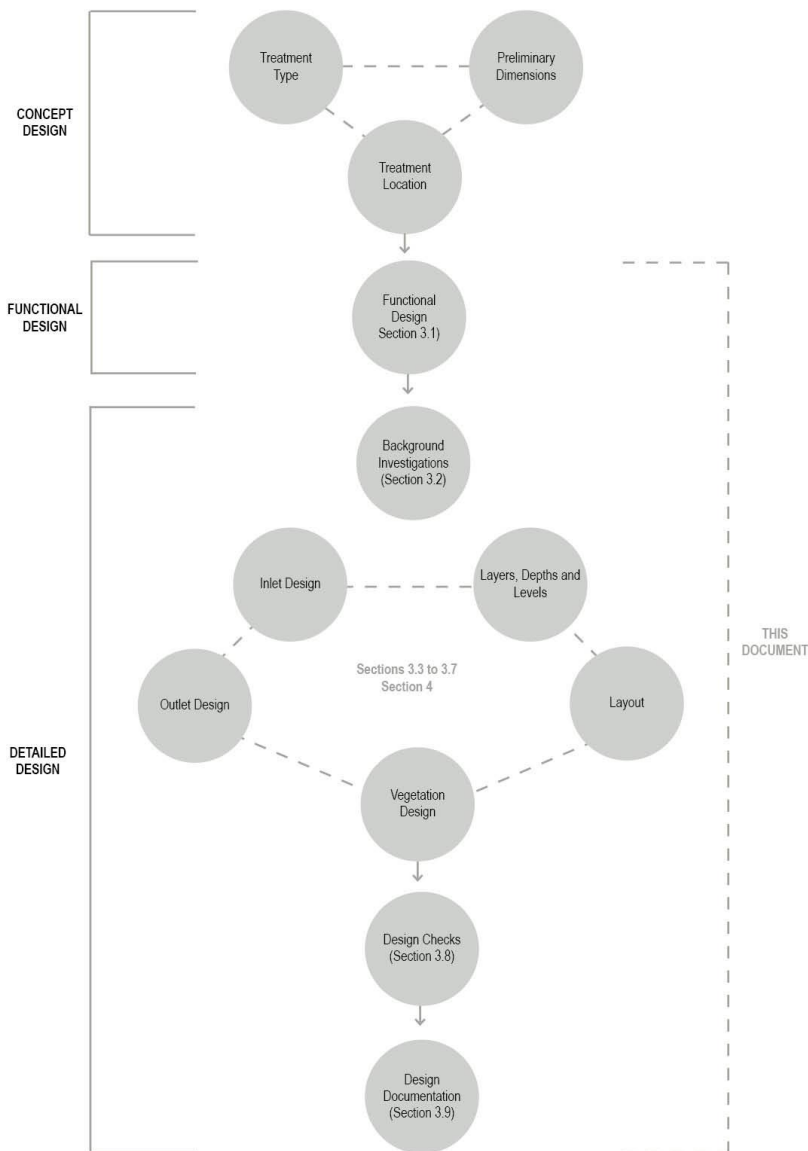


Figure 15. Bioretention design process.

The following sections describe the bioretention system's functional and detailed design processes. The design of each component of a bioretention system is addressed individually. Design details provided are divided into 'performance outcomes' and 'recommended approach'. The 'performance outcomes' outline the aim to be achieved in designing each component of a bioretention system, while the 'recommended approach' is one approach that is proven to achieve the performance outcome. This delineation is to ensure that the essential aspects of bioretention design are incorporated, while also

encouraging innovative approaches to design. In situations where the design of one element of a bioretention system is closely related to the design of another, cross-references are provided.

When reading the design process as it is laid out, it may appear that functional and detailed design are linear processes where background investigations (Section 3.2) inform the spatial location of the bioretention system via specifying layers, depths and levels (Section 3.3) and finalising the layout (Section 3.4). Inlet (Section 3.5), outlet (Section 3.6) and vegetation design (Section 3.7) are then completed, design checks undertaken (Section 3.8) and the design documented (Section 3.9). While this approach can achieve acceptable outcomes for very simple designs, it does not allow for complexity, collaboration and achieving multiple design objectives.

In almost all cases, better outcomes are achieved if bioretention systems are delivered via a highly collaborative and iterative process. The design team works together throughout the process and is cognisant of all design objectives at all times. This ensures that the optimal outcome is achieved and time-consuming repetition of design steps is avoided. It is recognised that there are perceived additional costs for collaborative design; however, this process ultimately results in significant cost savings and the delivery of assets that are integrated with the landscape and valued by the local community.

DESIGN NOTE: Bioretention design teams

The design process for bioretention systems should be:

- Collaborative between stormwater engineers, ecologists, landscape architects, and urban designers to ensure optimal functional, ecological, and aesthetic outcomes.
- Ideally, the same design team should be involved in the concept design and the detailed design to ensure continuity and avoid misinterpretations.
- Iterative to ensure the design is responsive to changes in constraints, opportunities, and urban design.

DESIGN NOTE: Local authority and service provider requirements

The design process and guidance provided in this document are based on a process that has been proven to work across many projects and locations. However, individual local authorities and service providers may have standards and requirements that differ from those provided in this document. It is important to consult with the local authority and service providers early in the design process (see Section 3.2.3) and, where specific requirements exist, defer to them.

3.1 Functional design

The functional design process outlined below is for a bioretention basin delivered through the development assessment process, where the system is located adjacent to known constraints (e.g. site boundaries, vegetation to be protected, etc.) and where the discharge location is known (pipe, channel, waterway, etc.).

Variations to the functional design process for bioretention systems delivered as retrofit projects are described in Section 3.1.1.

Additional functional design considerations for streetscape and on-lot bioretention systems are described in Section 3.1.2.

PERFORMANCE OUTCOMES

Functional design must:

- set key bioretention levels
- allocate sufficient space for all bioretention elements, including the treatment area, batters and bunds, sediment capture and maintenance access
- provide preliminary locations for all structures, such as inlets and outlets

- be completed for the planning stage of assessment (for systems delivered through development assessment).

RECOMMENDED APPROACH

The recommended functional design approach includes:

- Step 1 – Identify the treatment type, preliminary dimensions and treatment location from the concept design.
- Step 2 – Obtain the site information described in Table 5 in Section 3.2.1.
- Step 3 – Identify key levels and constraints, including the level and location of the proposed discharge point, the level and location of the proposed inlet(s), site boundaries, road reserves, services, and vegetation to be preserved.
- Step 4 – Set preliminary bioretention levels.
- Step 5 – Set available treatment footprint.
- Step 6 – Locate and size key system components (inlet(s), sediment capture, maintenance access, outlet pit and overflow weir).

Note that all six of these steps can be done easily with pen, paper and trace paper, prior to later converting to a digital format.

Step 1 – Treatment type, dimensions and location from concept design

Concept design is undertaken prior to functional design. The outputs of the concept design will be used to inform the functional design process. They should include:

- the proposed treatment type (in this instance, bioretention)
- approximate system size
- proposed system location.

Step 2 – Site information

Functional design requires a thorough understanding of the site. Table 5 and Section 3.2.1 describe all the site information required to complete the detailed design. This information is all useful at functional design, but at a minimum, obtain:

- topographical survey
- site boundaries
- catchments
- hydrology and drainage infrastructure
- services.

Step 3 – Identify key levels and constraints

Steps 4 and 5 of the functional design process require an understanding of key levels and constraints. As a minimum, the following levels and locations must be identified:

- the proposed discharge point
- the proposed inlet(s)
- site boundaries
- adjacent road reserves
- services
- vegetation to be protected.

Step 4 – Setting preliminary bioretention levels

Preliminary bioretention levels are set to not only ensure that sufficient grade is available for the system to drain, but also to directly inform the location and spatial layout of the system (Step 5).

Ideally, preliminary bioretention levels are set in conjunction with finished ground levels, the road layout and stormwater network design. This allows the requirements of the bioretention system to inform the levels throughout the development, and vice versa, and ultimately leads to the optimal outcome.

Initially, set preliminary bioretention levels using a 'bottom up' approach by identifying the level of the discharge point and then working up through the system.

Levels should be set for the (see Figure 16):

- outlet pipe at the point of discharge
- upstream end of the outlet pipe (at the outlet pit)
- base of the bioretention system
- top of the drainage layer, transition layer and filter media
- top of the extended detention depth
- crest of the overflow weir
- top of any bunds/ embankments
- invert of the inlet/ sediment forebay.

Where the bioretention system is collocated with a detention basin, the levels required for the detention basin must also be considered. This will likely include consideration of the total volume of storage required for the detention basin, the available surface area, and the acceptable depth of inundation for various storm events.

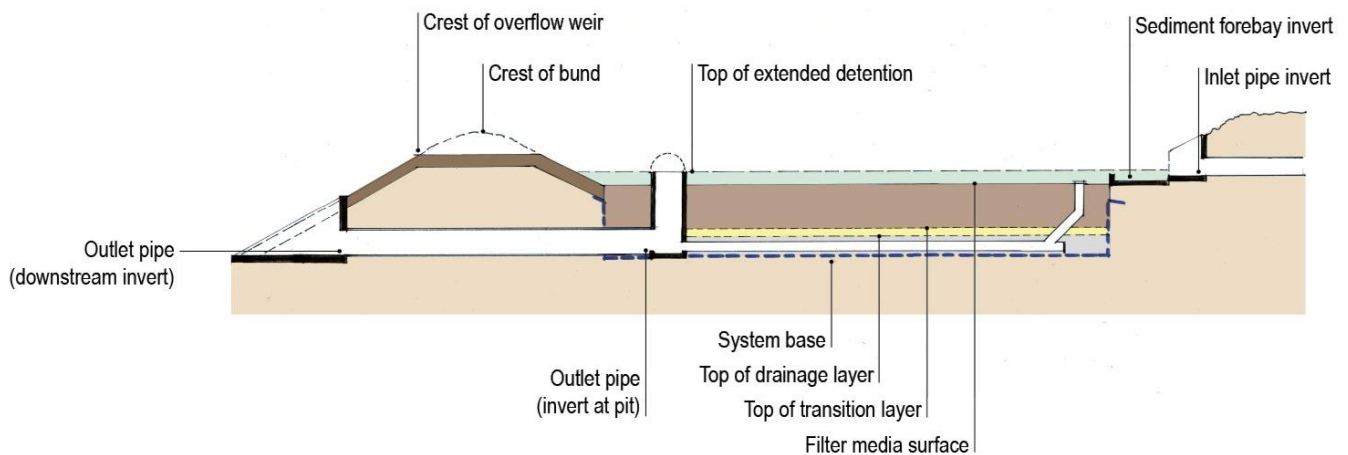
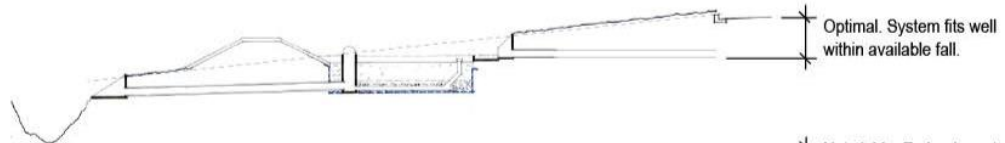


Figure 16. Key levels to set during functional design.

Once set, compare the preliminary bioretention levels to preliminary ground, road and stormwater network levels to ensure that sufficient grade is available for the system to fit within the vertical space available (Figure 17).

Scenario A - Optimal fall

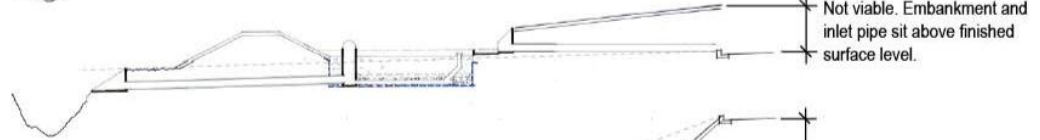
The available fall from road to discharge point allows for a well integrated bioretention basin with optimised batters and good landscape amenity.



Optimal. System fits well within available fall.

Scenario B - Insufficient fall

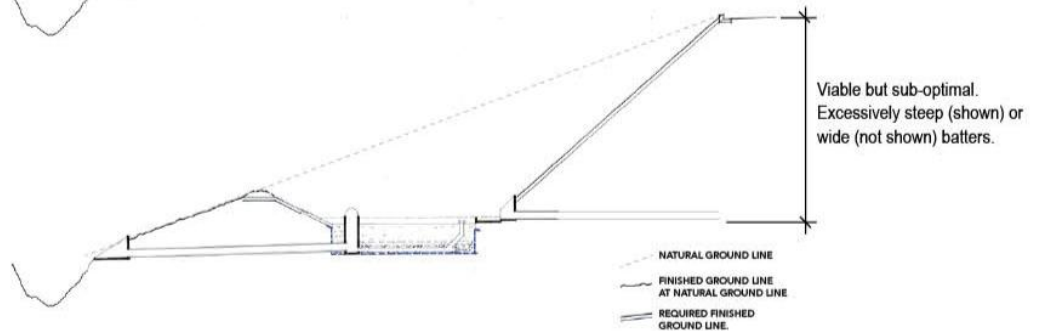
Insufficient fall is available between the road and discharge point. Bioretention will not work as shown. Alternative solution required.



Not viable. Embankment and inlet pipe sit above finished surface level.

Scenario C - Excessive fall

Bioretention designed from the 'outlet up' fits within the site but will result in excessively steep batters or unnecessarily large land take. Work with project team to reduce development levels or redesign from the top down (refer Figure 18).



Viable but sub-optimal. Excessively steep (shown) or wide (not shown) batters.

Figure 17. Preliminary levels compared to development levels.

In an ideal world, the bioretention levels and development levels will tie in neatly as shown in Figure 17 – A. If this is the case, proceed to Step 5.

In some instances, the preliminary bioretention levels may not easily fit within the available constraints (Figure 17– B). This is particularly likely to occur on flat sites, or if finished ground, road and stormwater levels have been set without consideration of stormwater treatment levels. In this instance, several options exist:

1. Collaborate with the civil engineers to increase finished ground, road and stormwater levels, being mindful that any increase may result in filling across the development site, increasing overall project costs.
2. Investigate alternative inlet arrangements. For example, using multiple box culverts or pipes rather than a single pipe may allow the inlet to enter the system at a higher level, increasing the available vertical space for the drainage profile.
3. Design a Type 1 saturated zone bioretention system with a level-constrained outlet. This drainage profile requires less vertical space than alternative drainage profiles.
4. Implement streetscape bioretention rather than end-of-pipe bioretention. Note that this will likely require a complete redesign of ground levels, road layouts and levels, and the stormwater network.
5. Implement a constructed wetland instead. Note that constructed wetlands have a larger surface area than bioretention systems for the same treatment performance and thus will require more space to implement.

The final scenario is when preliminary bioretention levels will easily fit within the available constraints (Figure 17– C). In these instances, care must be taken to ensure that an appropriate cut to fill balance and landscape outcome is achieved. For example, when designing from the 'outlet up' as described above, the bioretention will initially be set as low in the landscape as possible. For flat or level constrained sites, this is necessary, but for steeper sites that are not level constrained, this will result in excessively deep excavation, large batters and ultimately an unnecessarily large surface area.

If the preliminary bioretention levels are found to easily fit within the available constraints:

1. Consult with the project civil engineer. There may be opportunities to reduce filling within the development, lowering surface levels around the bioretention system and saving the development money on importing fill.

- Reset the preliminary bioretention levels, this time working from the inlet pipe in a 'top down' manner, with consideration of the optimal cut to fill balance. This will result in a bioretention system set higher in the landscape, with smaller batters and a smaller overall footprint (Figure 18).

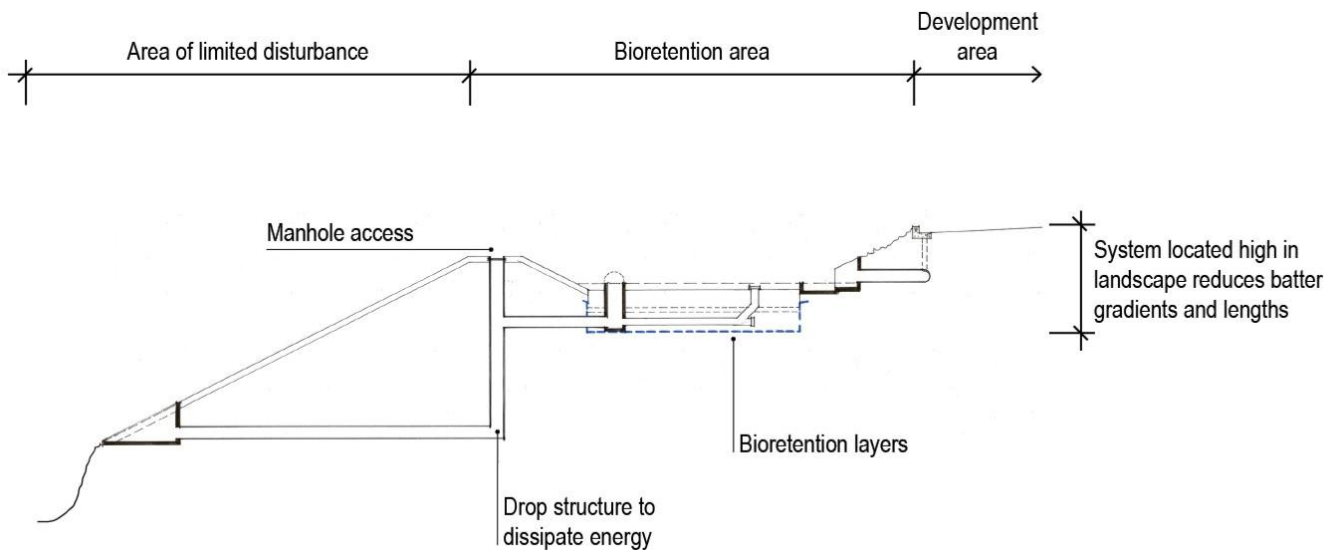


Figure 18. Bioretention designed from the top down.

Step 5 - Set available treatment footprint

Having established the bioretention levels, these can be used (alongside information on site constraints such as the location and height of the road reserve, property boundaries, and vegetation to be preserved) to identify the area available for bioretention system filter media, allowing appropriate space for batters, embankments and maintenance access.

To demonstrate this concept, consider a bioretention system located between a residential development and vegetation to be preserved. Preserving the vegetation will require not undertaking any earthworks within a tree protection zone (e.g. 500 mm outside the drip line of the tree). In this instance, comparing the surface level at the tree with the required embankment level for the bioretention system will determine the shape of the bund/ embankment required adjacent to the tree.

For example:

- Where the base of the tree is higher than the minimum bund level, then a batter from the filter media surface to the edge of the tree protection zone (allowing also for maintenance access) is required (see Figure 19).
- Where the base of the tree is lower than the minimum bund level, then a batter from the filter media surface to the top of the bund and back down to the tree protection zone (allowing also for maintenance access on top of the bund) is required (See Figure 20).

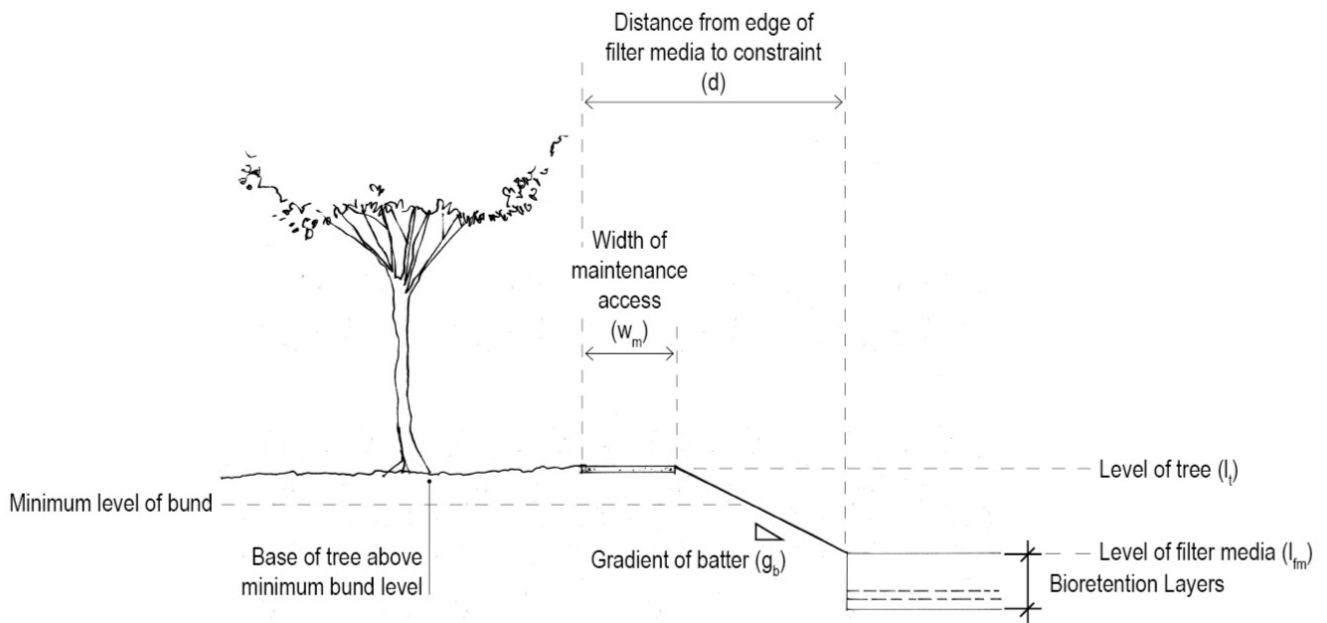


Figure 19. Batters where constraints are higher than the minimum bund level.

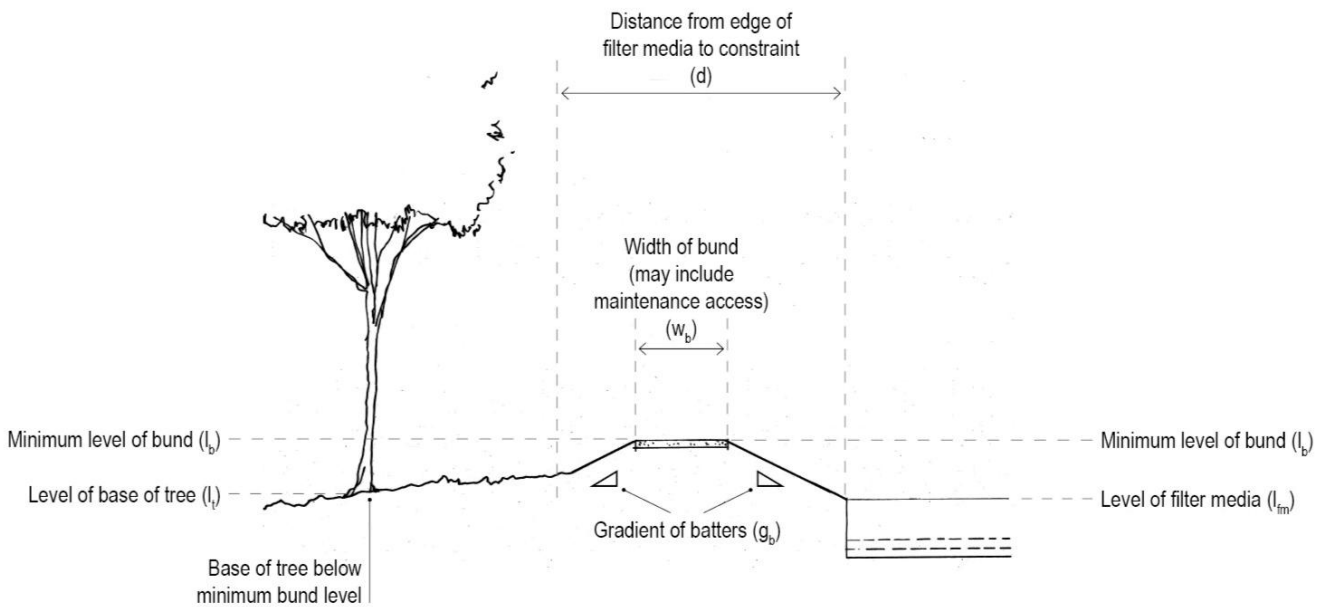


Figure 20. Batters where constraints are lower than the minimum bund level.

With this information, the distance that the filter media must be from the tree protection zone can be calculated as:

For systems where constraints are higher than the minimum bund level (Figure 19)

Equation 1

$$d = (l_t - l_{fm}) * g_b + w_m$$

Where: d = distance from edge of filter media to edge of constraint

l_t = level of the base of the tree (the constraint)

l_{fm} = level of the surface of the filter media

g_b = gradient of the batter from the filter media to the top of batter

w_m = width of the maintenance access track (if present)

For systems where constraints are lower than the minimum bund level (Figure 20)

Equation 2

$$d = (l_b - l_{fm}) * g_b + w_b + (l_b - l_t) * g_b$$

Where: d = distance from edge of filter media to edge of constraint

l_b = level of the bund

l_{fm} = level of the surface of the filter media

g_b = gradient of the batter from the filter media to the top of batter

w_b = width of the bund (may include maintenance access track)

l_t = level of the base of the tree (the constraint)

This distance can then be drawn onto plans to show the furthest extent available for the filter media, without the need for excessively steep batters or walls (Figure 21).

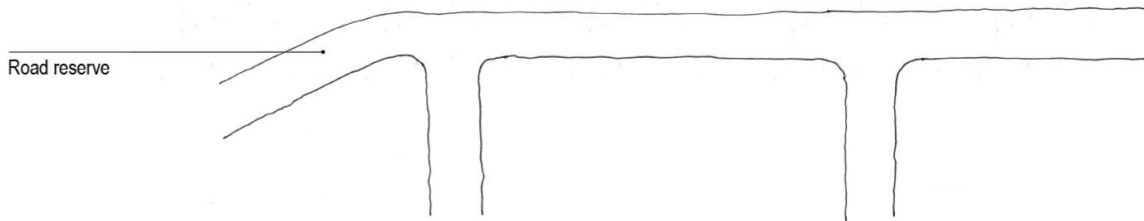
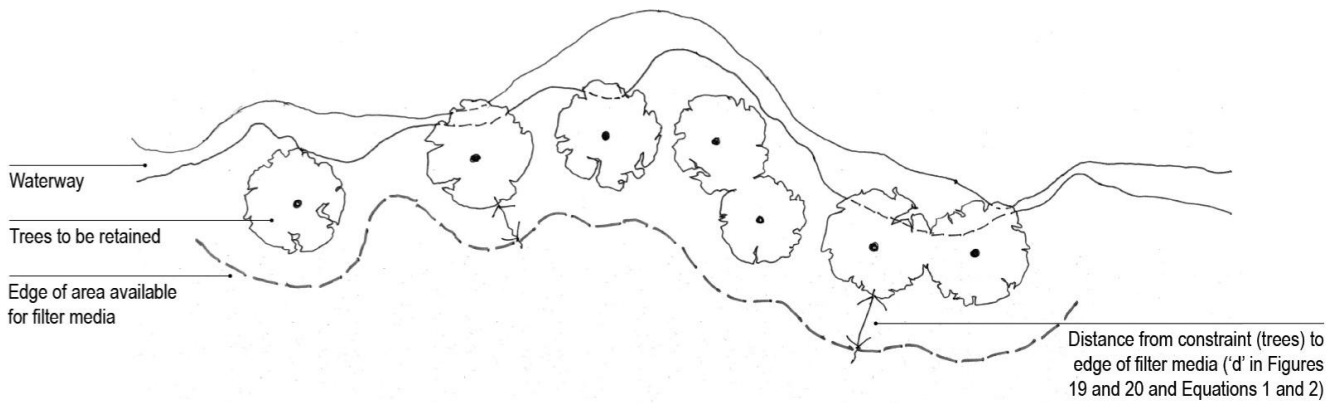


Figure 21. Available extent for filter media relative to trees.

This process can then be repeated for any other constraints, such as the location of the road reserve (Figure 22).

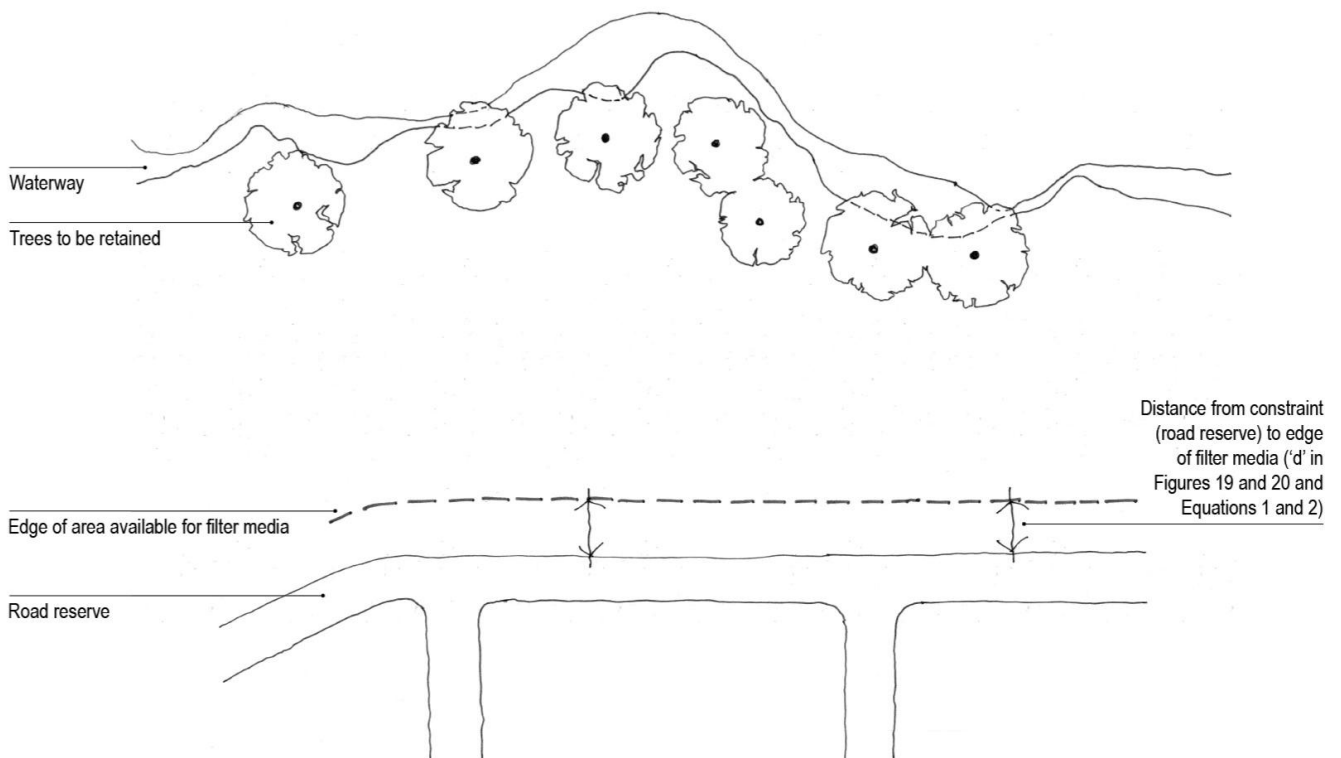


Figure 22. Available extent for filter media relevant to other constraints.

Finally, the available area for filter media is sketched in (Figure 23). This process has the advantage of creating organically shaped bioretention systems whose form relates to the surrounding landscape and topography.

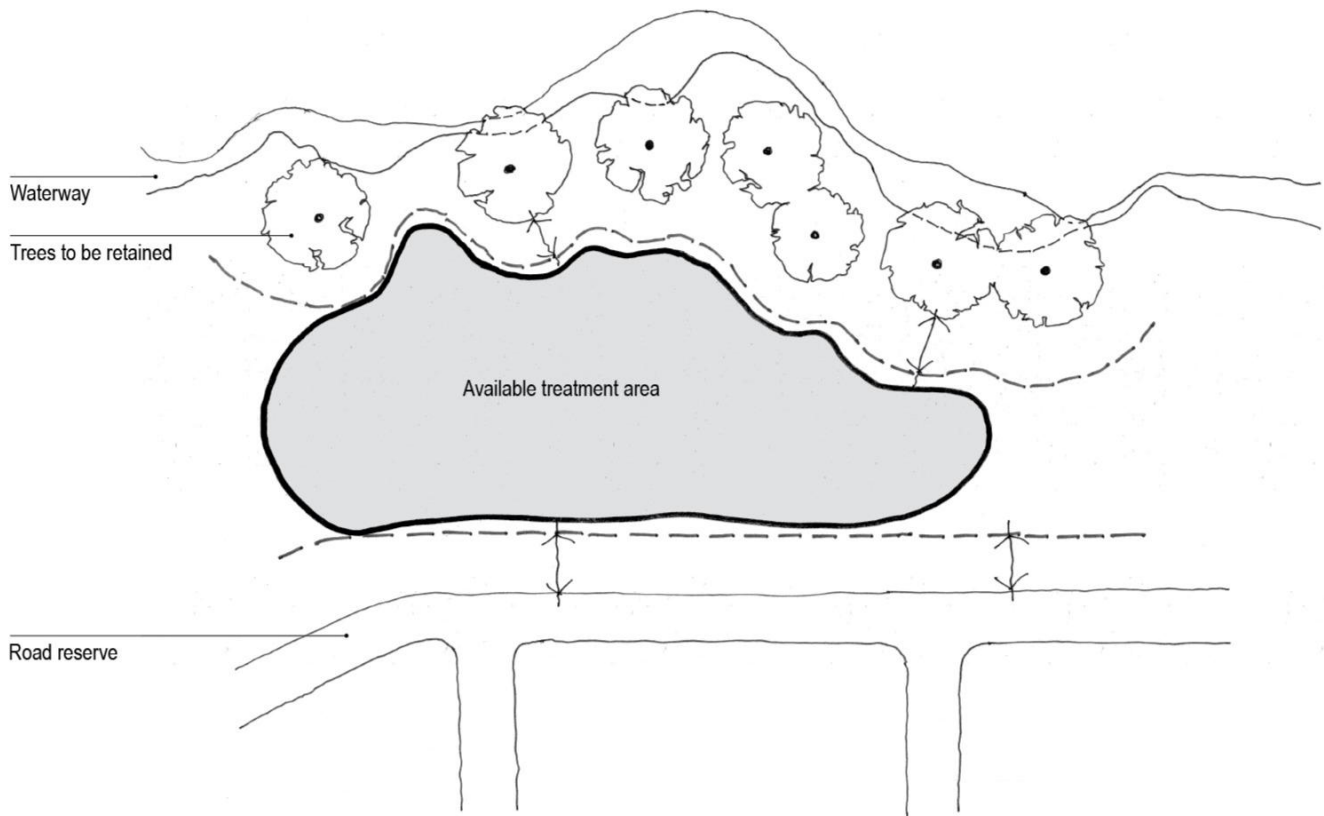


Figure 23. Sketch of the available area for filter media.

Having established the area available for the filter media, compare it to the area identified in the concept design to ensure that sufficient area is available. If sufficient area is available, proceed to Step 6. If insufficient area is available, repeat Step 5, testing different gradients of batter, and the judicious use of walls (see Sections 3.4.5.3 to 3.4.5.5 for guidance) until sufficient space is available for the filter media.

For example, if additional filter media area were required for the system shown in Figure 23, small walls could be used within the batters adjacent to each tree. This would increase the area available for filter media adjacent to the trees. As the vegetation established, the walls would be screened, making them visually unobtrusive. Consideration would need to be given to how these walls would interface with any maintenance access.

If sufficient space is still not available for the filter media, then the overall concept for the development must be reconsidered. This may include altering lot layouts and yield to create additional space for stormwater treatment.

DESIGN NOTE: Area required for detention basins

Detention basins typically require a greater area than bioretention basins. Where they are collocated, the detention basin will dictate the space required for the combined system.

Step 6 – Locate and size key system components

The final step in functional design is to provide preliminary sizing and locations for the following key structures:

- Filter media area
- Inlet(s)
- Sediment capture
- Maintenance access
- Outlet pit
- Overflow weir.

This is done in accordance with the sections listed above, and results in a layout and section as shown in Figure 24.

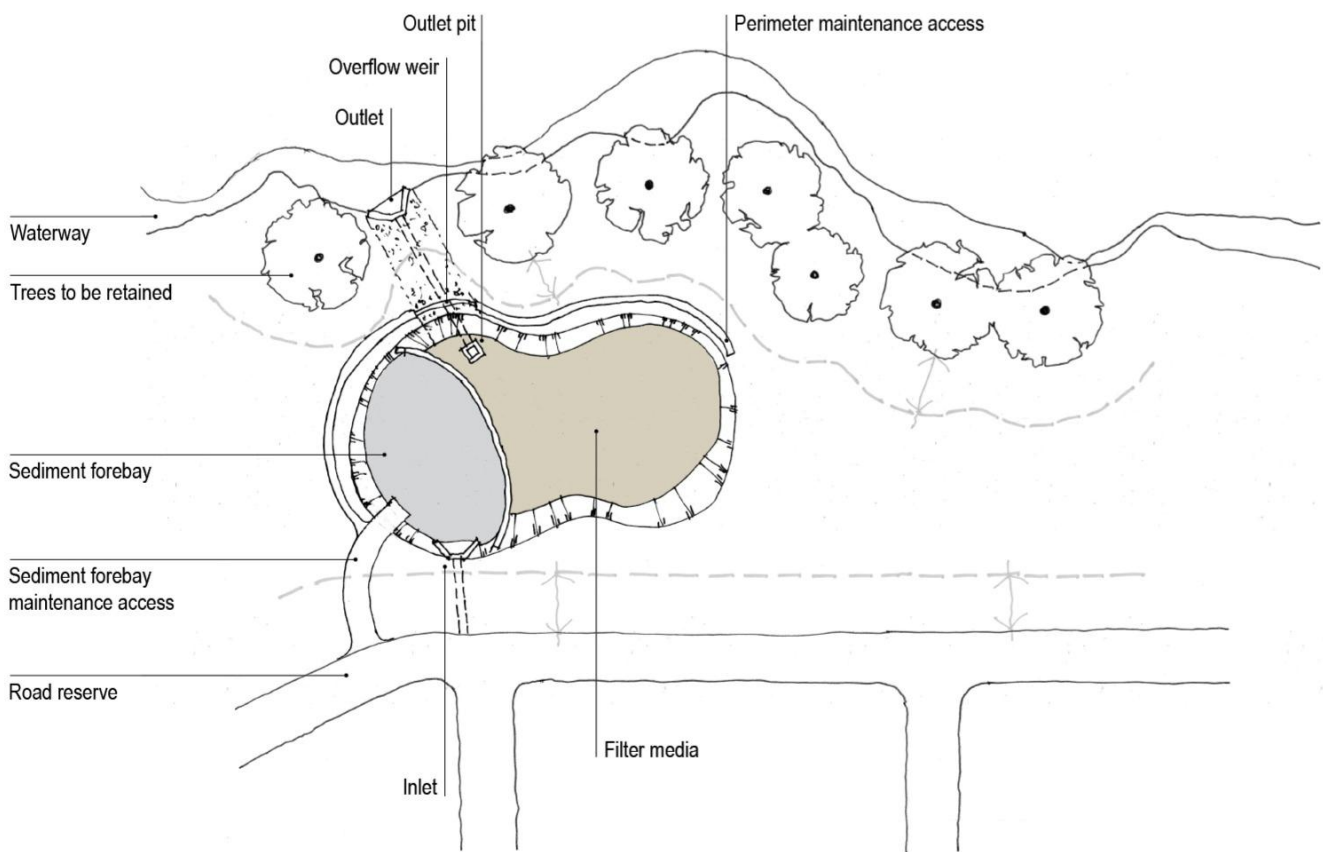


Figure 24. Typical layout and section resulting from functional design.

3.1.1 Additional consideration for retrofit projects

In many instances, the functional design process for bioretention systems delivered as retrofit projects is simpler than for those delivered as a part of new development. This is because retrofit projects generally have more fixed constraints. Very often, the inlet and outlet levels and location are fixed, with only a limited area available for the system. In these instances, bioretention design becomes a matter of fitting the system into the available space, and if sufficient space is unavailable, bioretention may not be appropriate for the site. In this instance, the designer should reassess the suitability of bioretention (see Section 2.5) before proceeding.

RECOMMENDED APPROACH

Where the site is level constrained, consider if:

- The site is suitable for a Type 4 infiltration - pipeless bioretention system (refer to Section 3.3.1 and Figure 31).
- A Type 1 saturated zone system with a level-constrained outlet (refer to Section 3.6.1.3 and Figure 78) will fit within the site constraints.

If neither of the above is suitable, bioretention is not appropriate for the site. An alternative treatment technology, such as a constructed wetland, may be considered instead.

Where the site is constrained by the available area:

- Consider if additional space for the filter media can be obtained by the judicious use of steeper batters or walls, ensuring that a safe and aesthetic outcome is still achieved. This approach is subject to the prior approval of the ultimate asset owner who, in the case of retrofit projects, is likely also the client of the project.
- Consider if it is acceptable to implement a smaller than planned bioretention system, noting that this will deliver reduced treatment performance.

If neither of the above is suitable, bioretention is not appropriate for the site.

3.1.2 Additional considerations for streetscape and on-lot bioretention systems

Streetscape and on-lot bioretention systems form important parts of the bioretention treatment palette. In the case of commercial, industrial and multi-unit developments, in many instances treatment must be located on-lot. In the case of flat development sites, streetscape bioretention systems are often the only style of bioretention that can be implemented within the available grade. However, because of the inherent constraints associated with both allotments and the streetscape (e.g. competition with services for space in the verge), bioretention functional design of these systems is inherently more complex.

RECOMMENDED APPROACH

In addition to the steps outlined in Section 3.1, functional design of streetscape and on-lot bioretention systems should take into account the substantial additional constraints and competition for space present in the streetscape.

Some examples of poor functional design of streetscape and on-lot bioretention systems include:

- Systems built excessively deep. If batters are used, this results in excessive land take. If walls are used, this results in deep, unesthetic fenced systems (Figure 25).
- Drops and trip hazards abutting footpaths, prompting the system to be fenced (Figure 26).
- Large numbers of excessively small systems implemented, increasing the batter to filter area ratio and thus overall land take and maintenance costs (Figure 27).
- Systems conflicting with driveways, resulting in problematic driveway crossovers and/ or systems being split into multiple smaller systems (Figure 27).



Figure 25. Unacceptable use of walls in a streetscape/on-lot bioretention system. Photo credits: Paul Dubowski.

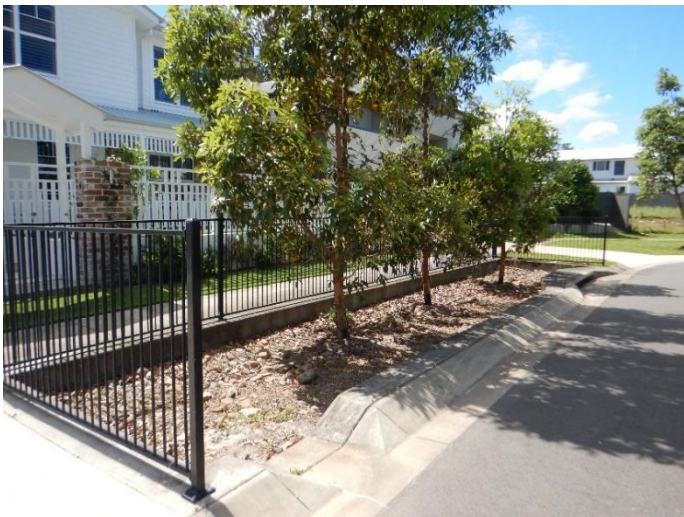


Figure 26. A system fenced because of the drop adjacent the footpath. Photo credits: Paul Dubowski.



Figure 27. Many streetscape systems in close proximity to conflicting with driveways. Photo credits: Paul Dubowski.

Functional design of streetscape and on-lot bioretention systems is most successful when it is undertaken collaboratively with the entire design team, including civil and stormwater design, prior to the road layout and stormwater network design being finalised. This allows for the functional design to inform road layout and stormwater network design.

Key design outcomes of successful functional design of streetscape and on-lot bioretention systems often include:

- on corners, lots (and thus driveways) are oriented to face collector roads, allowing bioretention systems to be located adjacent to the long edge of the lot, unencumbered by driveways (Figure 28)
- sags and high points in roads are positioned to direct appropriately sized catchments to bioretention systems
- bioretention systems receive inflows as overland flow (the minor storm is not piped prior to treatment) while preserving appropriate flow depths and widths (Figure 29)
- road reserves are locally widened (and lots narrowed) adjacent to bioretention systems to allow sufficient room for the bioretention system and services (Figure 62)
- bioretention systems are collocated with traffic calming (Figure 30).



Figure 28. Lot orientation for corner blocks. Photo credits: Brad Dalrymple.



Figure 29. Streetscape bioretention systems receive inflows as surface flow. Photo credits: Jack Mullaly



Figure 30. Collocation of bioretention with traffic calming. Photo credits: Paul Dubowski.

3.2 Background investigations

Background investigations are required to ensure that site-specific opportunities and constraints are identified early in the design process and incorporated into the final design. Undertaking the necessary background investigations streamlines the design process, reduces delays and mitigates risk during design, construction, establishment and operation.

The background investigations required are:

- analysis of the site
- defining design objectives
- consulting with the local authority.

3.2.1 Site analysis

PERFORMANCE OUTCOMES

Site analysis must:

- understand the site-specific constraints and opportunities
- test any assumptions made during concept design.

RECOMMENDED APPROACH

Site information should be obtained using desktop analysis and site inspections. All members of the design team should visit the site. Team members are likely to have visited the site during concept development; however, a site visit is recommended at the start of the detailed design phase to verify the suitability of the concept and to collect more detailed information. Ideally, the whole design team should attend an initial site inspection to develop a clear understanding of the intent of the bioretention system's design within the context of the site.

The amount and quality of information required for detailed design will vary between projects. Table 5 summarises the information typically required for detailed design. This information should be collected digitally and presented on an annotated plan.

Table 5. Site information requirements.

| Information | Requirements | Primary responsibility |
|---------------------------------------|--|---|
| Topographical site survey | Survey the site and external areas (where applicable) to assess existing flow pathways. | Surveyor |
| Boundaries | Determine boundaries of existing and proposed road reserves and allotments, and any access routes that may cross the bioretention system. Consider whether boundaries or routes are fixed or if there is scope to amend them. | Surveyor |
| Catchments | Determine the catchment area from: <ul style="list-style-type: none"> • a topographic survey for bioretention systems receiving surface flows • drainage network plans for bioretention systems receiving piped flows. | Stormwater specialist |
| Hydrology and drainage infrastructure | Inspect the site, waterways, bioretention catchment and receiving drainage during and after rainfall to verify: <ul style="list-style-type: none"> • flow direction and behaviour • presence of baseflow • ponded water zones. <p>Survey the size, location, and levels of existing drainage and waterway features upstream, within, and downstream of the site. Importantly, invert levels of drainage systems that will receive outflows from the bioretention system should be collected, as well as the levels of any existing upstream contributing drainage.</p> <p>If water is ponding in these drainage systems, survey the water level after rainfall. Confirm seasonal variation in water levels, particularly in low-lying areas.</p> <p>Where the bioretention system will connect with or abut future drainage infrastructure, the latest infrastructure design plans should be consulted in lieu of a survey.</p> | Stormwater specialist, civil engineer, surveyor |
| Services | Where the bioretention system will be retrofitted into a site, identify existing services by undertaking a 'Dial Before You Dig' search (www.byda.com.au). Include the depths of underground services on the site survey plans. Physical detection of underground services may be required. | Civil engineer |
| Flora and fauna | If a site contains individual plants or vegetation communities that are to be preserved, survey their size, location, level and drip zone. Review any flora and fauna reports for the site and receiving waterways. Identify locally occurring native plant species that are performing well in similar conditions to the conditions of the proposed bioretention system. Identify the extent and location of invasive weeds that may influence design, as well as any planting combinations that are successfully suppressing weeds. | Ecologist, surveyor |
| Soil | Identify details of the soils present on site (type, chemistry and structure) through previous investigations (concept design stage), a review of soil maps, or a soil assessment in accordance with AS/NZS 1547:2000 Clause 4.1.3. Identify the bearing capacity of the soil and any implications for system constructability. Bearing capacity may influence the design of foundations for hydraulic structures and whether a vertical sub-soil interface between the drainage layer and in-situ soils can be created. Where a permeable base or sides are proposed for the bioretention system (Type 3 or 4 drainage profile), test in-situ hydraulic conductivity and assess groundwater to confirm whether water will infiltrate into in-situ soils from the bioretention base. | Stormwater specialist and soil scientist |

| | | |
|---|--|--|
| | <p>Undertake a preliminary desktop assessment for acid sulphate soils (ASS).</p> <p>or contamination. If there is a potential risk, further geotechnical investigations are required to ensure these soils are avoided or appropriately managed. Management plans for ASS or contaminated soils should be developed by a suitably qualified professional.</p> | |
| Groundwater | <p>Determine the general characteristics of the local groundwater to:</p> <ul style="list-style-type: none"> ensure the bioretention system will not cause adverse impacts (e.g. draining local groundwater, acid sulphate impacts) determine whether infiltration of filtered flows into the surrounding soil can occur. <p>Preliminary assessment of groundwater should be undertaken at the same time as the soil assessment. Where elevated or acidic groundwater is detected, further groundwater investigations may be required to ensure the bioretention system does not interact with the groundwater (i.e. liner requirements). This work should be undertaken by a suitably qualified engineer or hydrogeologist.</p> | Stormwater/ WSUD specialist, soil scientist, hydrogeologist. |
| Landscape features and integration issues | <p>Interpret existing landscape features and, where relevant, survey these features. Features may include:</p> <ul style="list-style-type: none"> pedestrian and vehicle circulation and access points view corridors the character and nature of any adjacent development and land use. | Landscape architect |
| Other | <p>Other information may also be required, such as:</p> <ul style="list-style-type: none"> aerial photos (current and historical) site history and contamination to understand potential issues during excavation tidal information cultural and heritage information local or regional flood levels (additional flood modelling is often required as part of the overall project). | Stormwater specialist |

3.2.2 Design objectives

PERFORMANCE OUTCOMES

The design objectives for bioretention systems must:

- be clear, align with local policy, and be agreed upon by the project team
- cover landscape, engineering, and ecological considerations.

RECOMMENDED APPROACH

Design objectives should be confirmed and agreed upon by the design team, the client, and the local authority.

Each bioretention system will generally have a primary design objective and one or more secondary design objectives. Design objectives often form part of land development approval conditions.

Example bioretention system design objectives include:

- improve stormwater quality (typically the primary objective, in line with state or local government policies for the environmental protection of receiving waters)
- manage the rate and frequency of minor stormwater flows

- introduce a landscape feature into an urban setting
- enhance ecological values (e.g. increase local biodiversity)
- buffer or integrate with an existing bushland or riparian corridor to enhance degraded conditions
- facilitate passive landscape irrigation
- engage and educate the community
- provide passive cooling.

Objectives will dictate or influence particular design details. For example, if the primary objective of the bioretention system is stormwater quality and a secondary objective is linking it to an existing riparian zone, then the system will have shrubs and trees that integrate with the existing riparian vegetation communities.

3.2.3 Local authority consultation

PERFORMANCE OUTCOMES

The requirements and preferences of the local authority regarding bioretention design, construction, and maintenance must be understood and incorporated into the design process.

RECOMMENDED APPROACH

Local authorities should be consulted early in the design process to discuss the intent and purpose of the bioretention system. Local authorities are often the ultimate owners of bioretention systems, which are generally handed over to them by developers as contributed assets. Therefore, issues such as maintenance requirements must be understood from the start.

The following information should be discussed with the local authority:

- relevant standard drawings
- formal or informal policies relating to bioretention
- biodiversity issues and opportunities
- bioretention flood immunity requirements
- maintenance approach
- access requirements
- physical constraints on maintenance techniques (e.g. excavator reach length)
- level of service
- budget
- problems with existing systems.

DESIGN NOTE: Development staging and asset handover impacts on bioretention design

It is important to identify local authority requirements for accepting contributed stormwater assets as part of development. Authorities will generally not accept poorly constructed, unfinished, damaged, or unestablished vegetated stormwater assets that are still subject to significant disturbance by construction and building activities in the catchment.

Therefore, the design of bioretention systems in large developments should take into account the proposed staging and desired timing for compliance and asset handover processes. Multiple smaller bioretention systems rather than a single, larger system may avoid potential issues associated with multi-stage developments.

3.3 Layers, depths and levels

To operate effectively, adequate elevation is required for each layer of the bioretention system. The design of layers, depths and levels is dictated by site constraints (see Section 3.2.1), design objectives (see Section 3.2.2) and the preferred drainage profile of the bioretention system (see Section 3.3.1). Several iterations of a layer profile design may be needed to satisfy all engineering and landscape requirements. These iterations may occur during functional design (see Section 3.1).

When setting bioretention system layers, depths and levels, the following should be specified:

- drainage profile type
- filter media depth and level
- transition layer depth and level
- drainage layer depth and level
- saturated zone depth and level
- outlet pipe levels
- base level and liner type
- outlet pit level
- overflow weir level
- extended detention depth and level
- maximum water level
- batter and embankment levels
- inlet level(s)
- coarse sediment forebay levels.

When setting levels, the risks associated with shallow groundwater and tidal influences should be considered (refer to Section 3.3.3.2). Where possible, bioretention systems should avoid any actual acid sulphate soils (AASS) or potential acid sulphate soils (PASS). If it is not possible to avoid AASS or PASS, expert advice should be sought to manage the risks.

DESIGN NOTE: Estimating preliminary levels

It is important to carefully consider bioretention levels early in the design process and make appropriate allowances for any constraints that may be encountered as the design progresses. Constraints in bioretention levels can impact development earthwork levels.

Allow for a contingency in preliminary estimates of bioretention levels to avoid problems associated with raising development levels late in the design process. It is generally easier to convince a client to reduce development levels than increase them.

3.3.1 Drainage profile selection

PERFORMANCE OUTCOMES

The selected drainage profile must:

- provide suitable growing conditions
- ensure bioretention drainage does not adversely affect adjacent assets
- be appropriate for the design objectives.

RECOMMENDED APPROACH

The drainage profile influences bioretention depths and levels. Selecting a drainage profile is dictated by design objectives, site conditions, and climatic influences on vegetation. A decision tree for determining the most suitable drainage profile based on site conditions is shown in Figure 31.

The following attributes may assist in selecting the most appropriate drainage profile:

- Type 1 saturated zone bioretention systems are recommended for dry climates and climates with seasonal dry periods. Type 1 saturated zone systems will provide better support for vegetation between rainfall events. Testing of bioretention systems with and without saturated zones showed that the filter media moisture content was consistently higher in systems with saturated zones (Zinger et al. 2007).
- Type 1 saturated zone bioretention systems are recommended for large bioretention systems where evenly distributing flow across the filter media surface may be problematic, as the saturated zone provides a water source for all vegetation.

- Both Type 1 saturated zone and Type 2A traditional sealed bioretention are effective at managing risks posed by dispersive, sodic and acid sulphate soils, as well as risks associated with high groundwater.
- Both Type 1 saturated zone and Type 2A traditional sealed bioretention systems are appropriate for use in stormwater harvesting schemes.
- Both Type 1 saturated zone and Type 2A traditional sealed bioretention systems prevent water from infiltrating into soils, making them appropriate for use near building foundations or where infrastructure may be damaged by infiltrated water.
- Type 2A traditional sealed bioretention systems are the least effective at reducing flow volumes and meeting associated design objectives.
- Type 2B traditional unsealed bioretention systems promote some infiltration into in-situ soils without optimising for it, as is the case for Type 3 infiltration – with pipe bioretention systems.
- Type 3 infiltration – with pipe bioretention systems promote infiltration to in-situ soils and assist in re-establishing the natural water cycle where in-situ hydraulic conductivity is not high enough to allow the use of Type 4 – pipeless bioretention systems.
- Type 4 infiltration – pipeless bioretention systems have higher total losses of flow volume than the other four drainage profiles due to infiltration and evapotranspiration. Therefore, they are effective at managing frequent stormwater flows, assisting in re-establishing the natural water cycle, and reducing level constraints.

Where Type 2B, 3 or 4 bioretention systems are proposed in the vicinity of buildings, roads or other structures, certification must be obtained from a geotechnical engineer that the infiltrated water will not negatively affect the adjacent infrastructure. Where this can't be obtained, a Type 1 or 2A system should be used.

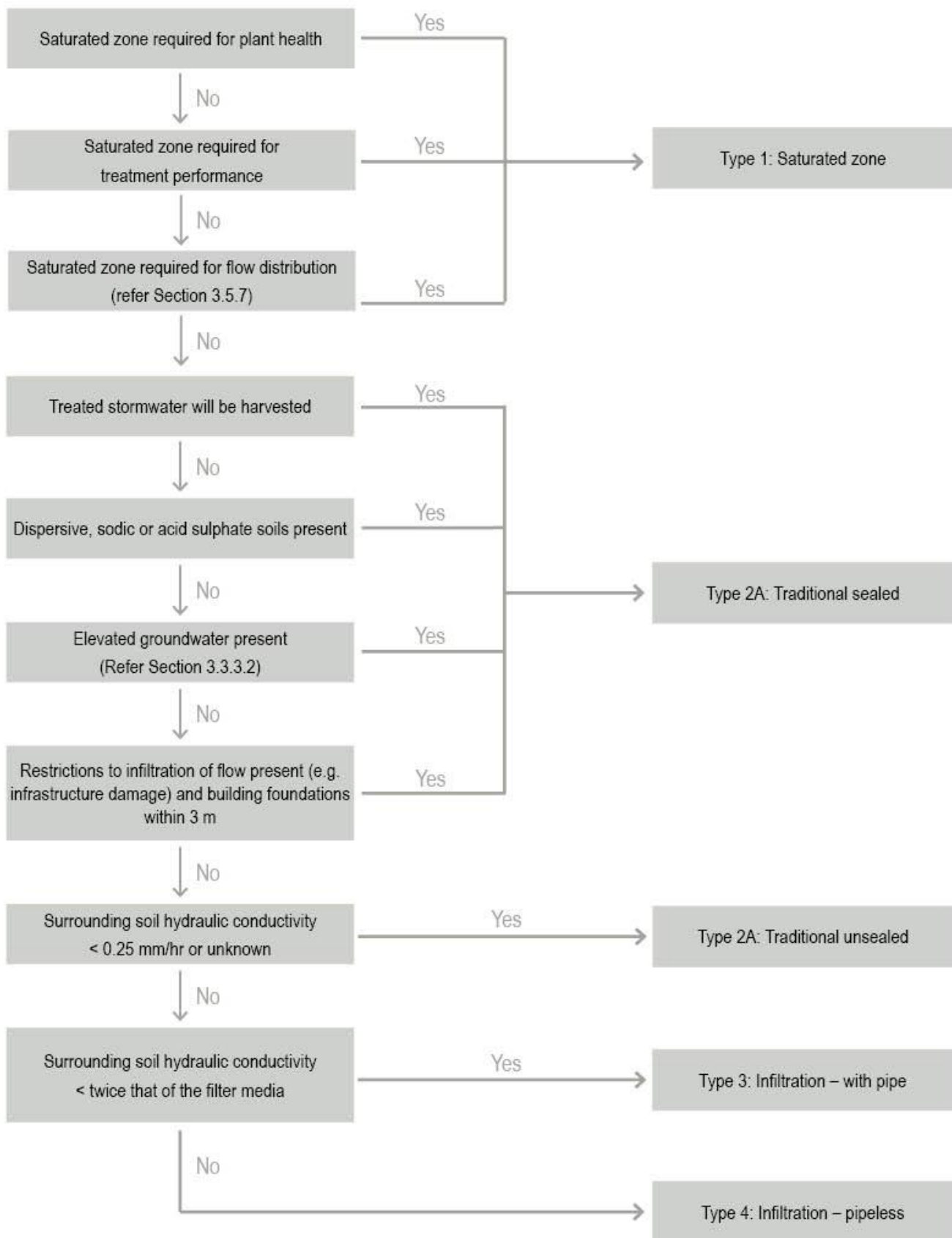


Figure 31. Drainage profile selection decision tree.

3.3.2 Media layers and depths

The functional layers and depths described in this section and shown previously in Figure 14 are used for setting key bioretention levels.

3.3.2.1 Filter media

PERFORMANCE OUTCOMES

Filter media must:

- support bioretention vegetation
- infiltrate water sufficiently to meet design objectives
- not migrate downwards through the transition layer, drainage layer, underdrainage or in-situ soil.

RECOMMENDED APPROACH

Filter media in bioretention systems is a sand and loam mix that supports vegetation and is integral to removing stormwater pollutants. Filter media is typically 600 – 1000 mm deep (see Figure 14).

The composition of filter media is critical to the function of bioretention systems. Filter media composition is a balancing act between achieving treatment performance and ensuring that the media is hospitable for plant growth, which is, in turn, essential for treatment performance.

Previous versions of this guideline required that filter media comply with the *Guidelines for Soil Filter Media in Biofiltration Systems* (2009) developed by the Facility for Advancing Water Biofiltration (FAWB). Then, in 2015, the Cooperative Research Centre for Water Sensitive Cities (CRCWSC) published the *Adoption Guidelines for Stormwater Biofiltration Systems*, which contains a filter media specification that effectively supersedes the FAWB guidelines. Since that time, it has been the default standard for bioretention filter media composition.

While systems can be successfully constructed and established using filter media consistent with the *Adoption Guidelines for Stormwater Biofiltration Systems* (CRCWSC), it is recognised that this filter media specification (and its predecessor, the FAWB specification) is relatively inhospitable for plant growth.

In 2023, Water by Design published the *Specifications for Bioretention Filter Media* and the supporting explanatory document *Improving the Biology of Bioretention Systems*. The former includes an alternative filter media specification aimed at making bioretention systems more hospitable to plant growth while retaining treatment performance. It also makes recommendations regarding the use of compost during the installation of bioretention systems.

While the Water by Design specification is generally considered a step in the right direction, few bioretention systems have since been constructed using the new specification. Thus, it is not yet appropriate to recommend that all new bioretention systems be constructed in accordance with it.

It is therefore recommended that:

1. bioretention filter media be in accordance with the *Adoption Guidelines for Stormwater Biofiltration Systems* (CRCWSC) (except as modified by the notes in Section 4.3.1); or
2. if wishing to trial a bioretention system that is more hospitable to plant growth, the designer implements either of the following, acknowledging that both approaches are still developmental:
 - specifying a filter media and compost in accordance with the *Specifications for Bioretention Filter Media* (Water by Design); or
 - specifying a filter media in accordance with the *Adoption Guidelines for Stormwater Biofiltration Systems* (CRCWSC), then ameliorating the filter media using compost in accordance with the *Specifications for Bioretention Filter Media* (Water by Design).

3.3.2.2 Transition layer

PERFORMANCE OUTCOMES

Transition layers must:

- ensure the filter media does not migrate downwards
- not migrate downwards themselves through the drainage layer, underdrainage or in-situ soil
- not restrict flow rate through the filter media.

RECOMMENDED APPROACH

Transition layers are typically included in all bioretention drainage profiles. The transition layer composition is outlined in Section 4.3.2.

For drainage profile Types 2A, 2B, 3 and 4, transition layers are typically at least 100 mm deep.

For drainage profile Type 1, the transition layer depth is strongly tied to the configuration of the saturated zone. See Section 3.3.2.4 for the design of transition layers in Type 1 saturated zone systems.

For drainage profiles Types 2A, 2B and 3 where levels are constrained, the transition layer can be omitted provided the top of the drainage layer is at least 100 mm above the top of the pipe and the specification requires the filter media and drainage layer material to comply with all parts of the specific criteria defined in the *Drainage of Subsurface Water from Roads – Technical Bulletin No. 32 (VicRoads)*:

- $D_{15}(\text{drainage layer}) \leq 5 \times D_{85}(\text{filter media})$.
- $D_{15}(\text{drainage layer}) = 5 \text{ to } 20 \times D_{15}(\text{filter media})$.
- $D_{50}(\text{drainage layer}) < 25 \times D_{50}(\text{filter media})$.
- $D_{60}(\text{drainage layer}) < 20 \times D_{10}(\text{drainage layer})$.

3.3.2.3 Drainage layer

PERFORMANCE OUTCOMES

Drainage layers must:

- ensure overlying media does not migrate downwards
- not restrict flow through the filter media.

RECOMMENDED APPROACH

The recommended drainage layer parameters for each bioretention drainage profile type are shown in Table 6, noting that the design of the drainage layer in Type 1 saturated zone bioretention systems is highly dependent on the configuration of the saturated zone (see Section 3.3.2.4). Specification details for drainage layer material are provided in Section 4.3.3.

Table 6. Recommended drainage layer parameters.

| Bioretention drainage profile | Drainage layer parameters |
|-------------------------------|--|
| Type 1 saturated zone. | <ul style="list-style-type: none"> • ≥ 50 mm of drainage layer material above all slotted or perforated underdrainage pipes. • Base does not need to slope. |
| Type 2A traditional sealed. | <ul style="list-style-type: none"> • ≥ 50 mm of drainage layer material above all slotted or perforated underdrainage pipes. • Base can either be flat or slope towards the outlet. If sloping, the recommended grade is 0.5%. |
| Type 2B traditional unsealed. | |

| | |
|----------------------------------|---|
| Type 3 infiltration – with pipe. | <ul style="list-style-type: none"> • ≥ 50 mm of drainage layer material above all slotted or perforated underdrainage pipes. • ≥ 200 mm of drainage layer material below all slotted or perforated pipes. • Base does not need to slope. |
| Type 4 infiltration – pipeless. | <ul style="list-style-type: none"> • No drainage layer required. |

3.3.2.4 Saturated zone

This section only applies to Type 1 saturated zone bioretention systems.

PERFORMANCE OUTCOME

Saturated zones must support plant health and stormwater treatment.

RECOMMENDED APPROACH

Saturated zones are a water storage integrated into the transition and drainage layers of Type 1 saturated zone bioretention systems. The water level in saturated zones is generally controlled by a piped outlet (or similar) that enables water to spill into an overflow pit when it exceeds the top of the saturated zone. During dry weather, the water level in the saturated zone is slowly drawn down by evapotranspiration.

The top of the saturated zone (i.e. the water level when the saturated zone is at capacity) must be located within the transition layer (see Figure 14), at least 50 mm below the bottom of the filter media. The top of the saturated zone should not be located within the filter media, as this may lead to leaching of nutrients, nor within the drainage layer, as this may prevent capillary action, making moisture available to plants.

The recommended minimum saturated zone depth is 350 mm (see Figure 14).

In dry climates that experience no rain for more than six continuous weeks in a typical year, the *Stormwater Biofiltration Systems Adoption Guidelines* (FAWB, 2009) recommend two options:

Increase the saturated zone depth in accordance with

- Equation 3. For example, if a bioretention is likely to experience eight weeks of dry weather, the ideal depth would be 450 mm.
- Make the saturated zone as deep as possible and allow it to be replenished at defined intervals during the dry period via surface irrigation or direct filling via inspection risers. For example, if a bioretention with a 350 mm deep saturated zone is likely to experience eight weeks of dry weather, the saturated zone would need to be filled after approximately six weeks to avoid it drying out.

Equation 3

$$D = 8 \text{ mm/day} \times t$$

Where: D = depth of saturated zone (mm)

t = average of the longest annual dry period for the last 10 years (days)

3.3.3 Design levels (outlet, surface and water levels)

Critical bioretention levels are defined relative to the level of inlet and outlet inverts, and the surrounding landscape. Setting the design levels is typically an iterative process.

DESIGN NOTE: Inlet level constrained sites

In some cases, the bioretention system surface levels.

are dictated by inflow levels, such as when sites are being retrofitted, and the inflow level is fixed. Where inflow levels are fixed and not suitably elevated above the receiving drainage system, the following options should be investigated:

- draining the bioretention to a lower downstream outlet
- designing the bioretention at a higher level and surcharging flows onto the filter surface. Due to the increased hydraulic and maintenance implications with this option, it is important to make sure that the local authority is satisfied with this solution.

3.3.3.1 Outlet pipe level

This section only applies to bioretention drainage profile Types 1, 2A, 2B and 3, as Type 4 bioretention systems do not have an outlet pipe.

PERFORMANCE OUTCOMES

Outlet pipe levels must:

- be sufficient to ensure that accumulated sediment does not block the outlet pipe connection with the receiving drainage system
- allow bioretention filter media to drain freely.

RECOMMENDED APPROACH

Bioretention system outlets should drain freely to the receiving drainage systems, as outlined in Table 7. The recommended pipe grade is at least 0.3% (preferably $\geq 0.5\%$). The outlet level is defined as the invert of the outfall pipe or channel where it discharges into the receiving drainage system.

Table 7. Outlet pipe level recommendations.

| Receiving drainage system | Minimum recommended level |
|---------------------------|--|
| Ephemeral waterway. | 300 mm above waterway invert or 100 mm above wet season water level, whichever is highest. |
| Perennial waterway. | 300 mm above the dry weather water level or 100 mm above the wet season water level, whichever is highest. |
| Natural wetland. | 100 mm above the maximum of the ground level or wet season standing water level. |
| Natural ground. | 100 mm above the maximum of the ground level or wet season standing water level. |
| Pipe drainage system. | 50 mm above the invert of the downstream pit or pipe system and above wet-season baseflow levels. |

3.3.3.2 Bioretention system levels relative to groundwater and tidal levels

PERFORMANCE OUTCOMES

With respect to groundwater and tidal levels, bioretention systems must:

- ensure bioretention biota is not harmed by water infiltrating from the surrounding soil into the bioretention system
- ensure groundwater is not drawn down by bioretention underdrainage.

RECOMMENDED APPROACH

Allowing groundwater or tidal water to enter bioretention layers can be detrimental to biota (plants, bacteria, fungi, etc.) within the system. Plants can be affected by the quality of the water (e.g. salinity) or by having saturated roots for an excessively long time. Prolonged wetting of the filter media can reduce its ability to retain stormwater pollutants. Bioretention systems may also artificially lower the local groundwater level or discharge poor-quality subsurface water if they are left open to groundwater intrusion.

The recommended bioretention system levels to ensure adequate protection for biota and groundwater are outlined in Table 8. The allowance for 300 mm above the highest astronomical tide (HAT) accounts for potential sea level rise due to climate change and is in accordance with advice in the *Queensland Urban Drainage Manual (QUDM)* (Institute of Public Works Engineering Australasia, Queensland, 2017).

Table 8. Recommended bioretention levels relative to groundwater or tidal levels.

| Drainage profile type | Level relative to wet season groundwater level (WSGL) | Level relative to the highest astronomical tide (HAT) |
|----------------------------------|--|---|
| Type 1 saturated zone. | Impermeable liner extends ≥ 300 mm above WSGL. Note that a permeable liner consistent with Section 3.3.5.2 should be applied to the remainder of the sides of the system and appropriately keyed into the batters. | Impermeable liner extends ≥ 300 mm above HAT. |
| Type 2A traditional sealed. | Typically, completely sealed (see Section 2.4), with no further requirements. Where a sealed system is implemented solely to prevent groundwater interactions, the extent of the lining of the sides of the system can be reduced so long as the liner extends a minimum of 300 mm above the WSGL. Note that where an impervious liner does not extend to the surface of the system, a permeable liner consistent with Section 3.3.5.2 should be applied to the remainder of the sides of the system and appropriately keyed into the batters. | Base of transition layer ≥ 300 mm above HAT. |
| Type 2B traditional unsealed. | Base of underdrainage pipes ≥ 300 mm above WSGL. | |
| Type 3 infiltration – with pipe. | | |
| Type 4 infiltration – pipeless. | Base of transition layer ≥ 300 mm above WSGL. | |

3.3.3.3 Extended detention

PERFORMANCE OUTCOMES

The extended detention must:

- have sufficient temporary storage to meet design objectives
- not harm vegetation through excessive inundation

- not be excessively deep so as to negatively affect integration with the surrounding landscape (streetscape systems in particular).

RECOMMENDED APPROACH

The recommended maximum extended detention depth is 300 mm (or 200 mm for constrained situations such as streetscape systems) as shown in Figure 32. Note that this is a maximum depth. Shallower depths can and should be used where doing so enhances amenity and integration.

The overflow level (typically the overflow pit crest) is set at the top of extended detention. Extended detention depths greater than 300 mm can impact plant health and potentially cause overloading of the filter media. This can reduce the operational life of the system due to surface clogging and/or release bound pollutants.

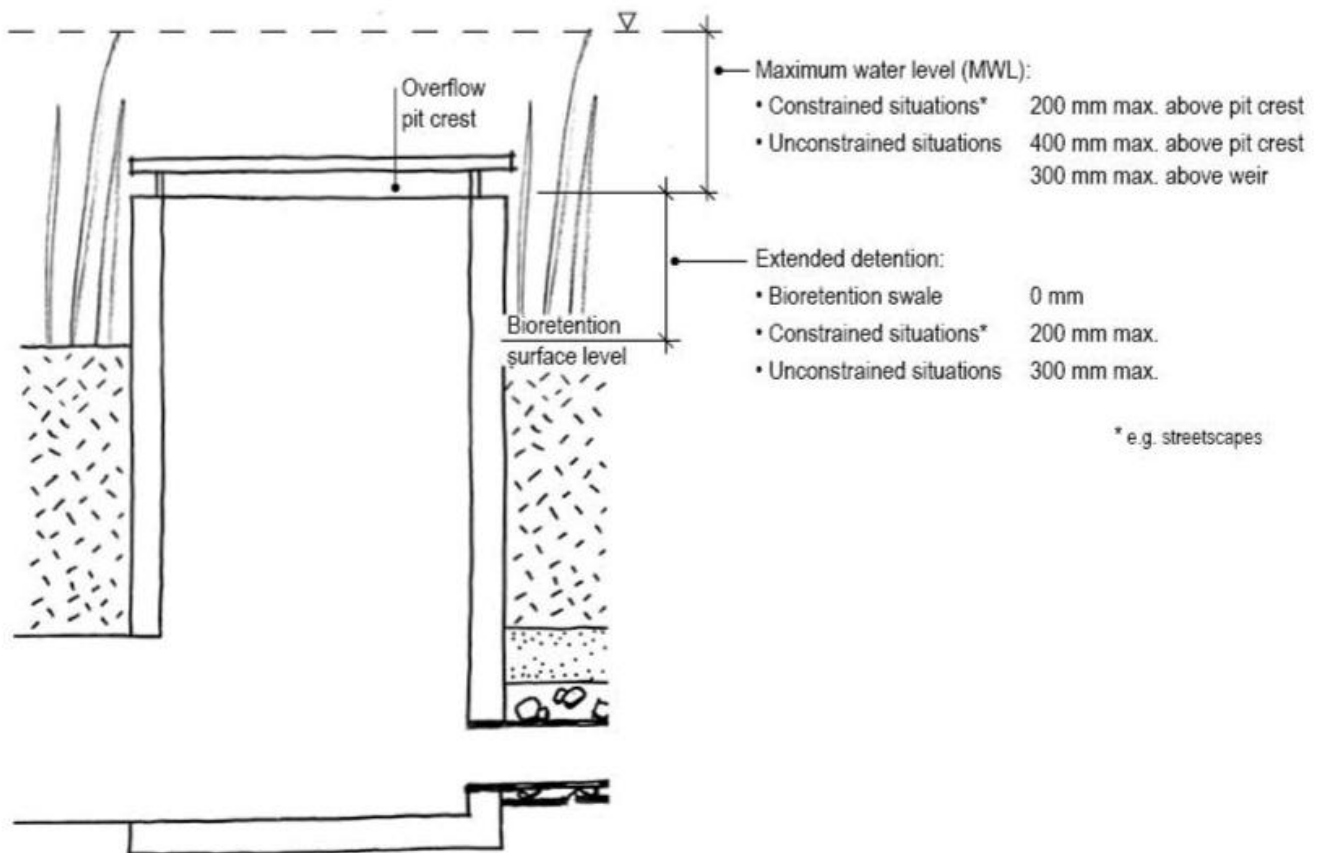


Figure 32. Extended detention depth and maximum water level requirements.

3.3.3.4 Maximum water level

The maximum water level in a bioretention system is the highest level that water will reach in the system under design conditions, considering all relevant storm events (refer to Table 14). The maximum water level above the bioretention filter media surface will be influenced by the design storm entering the system and the overflow configuration.

Consideration of the maximum water level is required at both:

- Functional design – used to set embankment heights, which in turn informs system layout, depth and the total footprint of the system.

- Detailed design – set in conjunction with outlet design and embankment heights to ensure that design storms are safely conveyed from the system and the bunds do not overtop in an uncontrolled manner.

PERFORMANCE OUTCOMES

The maximum water level must inform the minimum embankment height and flood conveyance.

RECOMMENDED APPROACH

At functional design, the maximum water level can initially be defined based on Figure 32. At detailed design, the maximum water level is refined based on outlet design (Section 3.6) and influences the minimum design levels for embankments around the bioretention perimeter.

It should be noted that the maximum water levels defined in Figure 32 is pragmatic recommendations, not hard rules. The maximum water level in a bioretention system can be deeper than shown in Figure 32, but consideration must be given to how this will affect overall system depth, the grade of batters, and integration with the landscape, along with any additional stress that this will place on the plants within the system.

Where bioretention systems lie within a flood detention basin, the maximum water level will be dictated by flood storage requirements (refer to Section 3.4.9).

DESIGN NOTE: Maximum water level for streetscape bioretention systems

In streetscape bioretention systems, the maximum allowable water level is defined by the maximum allowable flow depth in the adjacent street kerb and channel. This depth is defined by local standards such as QUDM (Institute of Public Works Engineering Australasia, Queensland, 2017) to ensure road traffic and safety standards are met.

3.3.3.5 Filter media surface level relative to surrounding surface

PERFORMANCE OUTCOMES

Relative to the surrounding landscape, the filter media surface level must:

- ensure accumulated sediment does not block the inlet pipe(s)
- provide safe and stable bioretention system edges
- ensure the bioretention system forms an attractive landscape feature.

RECOMMENDED APPROACH

It is recommended that the inflow pipe or channel inverts are at or above the surface of the bioretention system (preferably 200 mm above the surface) to prevent silt or debris from accumulating in pipes.

Bioretention system levels should be complementary to their surroundings and avoid creating significant depressions within the urban landscape. The elevation difference between the filter media and the surrounding surface is referred to as the bioretention system surface set down.

The recommended maximum bioretention surface set down is outlined in Table 9, and is shown in Figure 33.

Table 9. Recommended maximum bioretention system surface set down.

| Bioretention application | Bioretention system surface set down |
|--------------------------|--------------------------------------|
|--------------------------|--------------------------------------|

| | |
|--------------------------------------|--|
| Allotment bioretention. | ≤ 500 mm. |
| Streetscape bioretention. | ≤ 200 mm below kerb invert at bioretention inlets. |
| Civic space bioretention. | ≤ 500 mm. |
| Parkland bioretention. | ≤ 2000 mm*. |
| Bioretention adjacent natural areas. | ≤ 2000 mm*. |

*The 2000 mm surface set down for bioretention systems adjacent to parkland and natural areas assumes a large bioretention system, which requires a deep set down (e.g. because of large inlet pipes requiring cover). Smaller bioretention systems adjacent to parkland and natural areas can and should be designed with smaller surface set downs to reduce the overall footprint of the bioretention system.

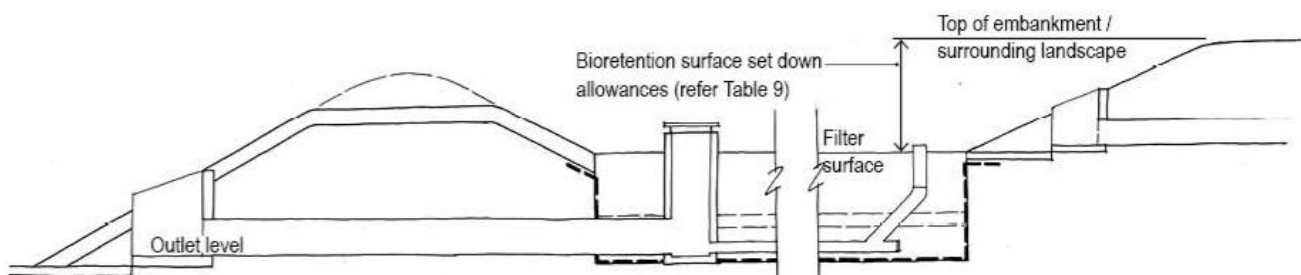


Figure 33. Bioretention system surface is set down for landscape integration.

DESIGN NOTE: Topsoil level on batters and embankments

Design levels for batters and embankments refer to the finished topsoil level. Therefore, earthworks design should account for a minimum of 200 mm of topsoil placement to meet the finished design level. Finished topsoil levels must then tie into the filter media surface level, maintenance paths, and other elements. This is an important design note to include on detailed design drawings and specifications. Refer to Section 4.4.1 for specification details.

3.3.3.6 Minimum embankment height

PERFORMANCE OUTCOMES

Bioretention system embankments must:

- contain the maximum water level with appropriate freeboard
- prevent the bioretention system from being damaged by flows from external catchments.

RECOMMENDED APPROACH

The minimum bioretention embankment height depends on the design flows entering the system and the configuration of the outlet. In practice, this means that minimum embankment height must allow the largest design flow entering the system (often the major storm) to be conveyed over the outlet pit/overflow weir without overtopping the embankment. An additional allowance should also be made for freeboard.

Some common scenarios include:

- Where the major storm enters the system, the minimum embankment height is the height of the overflow weir (or outlet pit if a weir is not present) plus both head to convey the major storm over the weir/pit and freeboard.

- Where a system is located offline and only low flows enter the system (e.g. the minor storm), the minimum embankment height is the height of the overflow weir (or outlet pit if no weir is present) plus head to convey the flow entering the system and freeboard.

It is recommended that embankment height provides for freeboard that is at least equal to the greater of:

- 20% of the elevation difference between the filter media surface and maximum water level
- 50 mm.

This freeboard recommendation aligns with a recommendation on the maximum water level around stormwater inlets described in QUDM (Institute of Public Works Engineering Australasia, Queensland, 2017).

For bioretention basins not combined with detention, the above requirements mean that the minimum embankment height is often approximately 1 m above the filter media surface.

Where bioretention basins are collocated with detention, the volume of storage required for detention will often necessitate a higher embankment. In this situation, the minimum embankment height is the greater of that required for the stormwater treatment and detention components of the system.

Where a bioretention system is located on the local or regional floodplain, minimum embankment levels must also consider immunity from flood events (refer to Section 3.4.10).

As discussed in Section 3.3.3.4, the maximum water level in streetscape bioretention systems may encroach into the road pavement. Local authority freeboard requirements for the major flow levels in streetscapes should be applied in these situations.

When proposing a new bioretention system within a sloping landscape (Figure 34), minimum bund height and freeboard requirements should be considered at the lowest point in the surrounding landscape or bund. This may require cut and fill techniques to avoid significant batters at one end of the system. Designers should ensure these types of configurations do not compromise the landscape amenity or space requirements for the system. Developing an earthworks model in conjunction with a landscape plan is useful to assist in locating bunds and achieving freeboards.

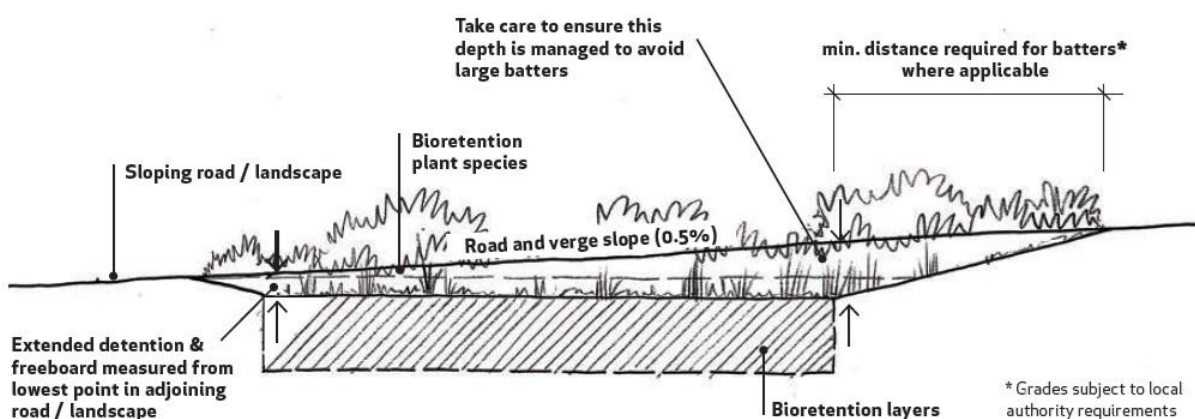


Figure 34. Typical bioretention system embankment.

3.3.3.7 Level constrained sites

PERFORMANCE OUTCOMES

Bioretention systems in level-constrained sites must:

- adapt to the constraints of the site
- be robust and resilient
- demonstrate that they are the most appropriate solution for the site.

RECOMMENDED APPROACH

In level-constrained situations, a range of design options may be feasible (subject to discussion with and approval from the local authority):

- Adopting a saturated zone that can only be drained (e.g. for maintenance) via pumping.
- Reducing the buffer between the bioretention outlet pipe invert and the receiving drainage level and ensuring the bioretention base conforms to the specifications shown previously in Table 6. Very accurate survey and seasonal water level information must be provided to local authorities to demonstrate that the bioretention will freely drain.
- Removing the transition layer by ensuring the drainage layer meets the particle size grading requirements set out in Section 3.3.2.2. This generally isn't a favoured approach as the transition layer provides resilience against structural collapse of the drainage profile.
- Using one or more other technologies that meet the design objectives more appropriately within the level constraints.

3.3.4 Base preparation

PERFORMANCE OUTCOMES

Where the base of a bioretention system does not include an impermeable liner, the base must be prepared to maximise infiltration.

RECOMMENDED APPROACH

Unless a bioretention system features an impermeable liner, it should be constructed to maximise exfiltration of stormwater to the surrounding soils. Traditionally, when bioretention systems are excavated, their base is inadvertently compacted. This compaction can prevent or limit exfiltration from the base of the bioretention system.

To overcome this issue, the base of the bioretention system should be ripped prior to the installation of the underdrainage pipes. Ripping should be to a minimum 300 mm depth and break up compacted soil layers sufficiently to allow exfiltration while leaving a relatively even surface for installation of the underdrainage pipes (so that they can be laid flat without sinking in places). If the base of the bioretention system is graded towards the outlet pit to ensure that underdrainage pipes completely drain, the site superintendent should ensure that the ripping does not affect the grading. A spreader bar should be used to level the base of the bioretention system after it has been ripped.

3.3.5 Liners

Bioretention systems often require a liner. The need for and nature of the liner required depends on the drainage profile and site conditions. Liners can be either impermeable or permeable.

3.3.5.1 Impermeable liners

PERFORMANCE OUTCOMES

Impermeable liners must:

- Ensure water cannot be exchanged between the bioretention system and the surrounding soil.
- Be durable.

RECOMMENDED APPROACH

Impermeable liners are used for Type 1 saturated zone bioretention systems and Type 2A traditional sealed bioretention systems. The liner should have a hydraulic conductivity of less than 1×10^{-9} m/s and can be made from compacted clay or a manufactured material. The liner must not be dispersive.

Impermeable liners in bioretention systems are designed to function for decades. They must be durable. Liners that exhibit seal sealing properties if punctured are highly desirable. Liners that do not self-seal should be avoided.

The full extent of the liner should be installed under the supervision of a geotechnical engineer and subsequently certified by that engineer. Requirements for certification must be included on the design drawings and in the specification.

For Type 1 saturated zone bioretention systems, the impervious liner should extend to at least the top of the saturated zone. The liner may need to be extended higher to prevent ingress of groundwater (refer Section 3.3.3.2).

For Type 2A traditional sealed bioretention systems, the impervious liner will typically extend all the way to the surface of the system. Where is used solely to prevent groundwater ingress and does not extend to the surface of the system (refer to Table 8), a permeable liner should be used for the remainder of the sides of the system and appropriately keyed into the batters.

The recommended impermeable liner is 300 mm thick compacted non-dispersive clay. Where suitable clays are available onsite, they should be used to create the liner.

Bentonite liners can also be used to create an impermeable liner. Given that bioretention systems often have a complex shape and have at least one pipe connection through the liner, the seal between liner sheets and around perforations (e.g. around pipes and structures) must be robust. HDPE and other plastic liners are not recommended as they are difficult to create a seal with.

Bentonite liners should be installed in accordance with the manufacturer's instructions. These must be included on design drawings and in the specifications package.

Proprietary liners and membranes should be 'keyed' into bioretention batters by extending them at least 500 mm beyond the edge of the filter media (i.e. up the batter), then pinned to the in-situ soil and covered with at least 200 mm of topsoil. Refer to the Institute of Public Works Engineering Australasia – Queensland and Northern Territory (IPWEA-QNT) Standard Drawings for details. Where an embankment bounds the system, the liner should extend over the embankment for reinforcement (Figure 35).



Figure 35. Bioretention system liner extended over embankments. Photo credit: Shaun Leinster.

3.3.5.2 Permeable liners

PERFORMANCE OUTCOMES

Permeable liners must prevent in-situ soils from contaminating filter media or the underdrainage network.

RECOMMENDED APPROACH

Permeable liners (e.g. geotextile) are used to line the sides but not the base of Type 2B traditional unsealed, Type 3 infiltration – with pipe and Type 4 infiltration – pipeless bioretention systems to manage in-situ soil migration into the various layers. It is recommended that liners extend at least 300 mm onto the bioretention base to allow the liner to be held in place by pins or the lowest bioretention layer.

Permeable liners should be used around the sides of Type 1 saturated zone and Type 2A sealed bioretention systems if the impermeable liner does not extend to the top of the filter media.

Permeable liners should be 'keyed' into bioretention batters by extending at least 500 mm beyond the edge of the filter media (i.e. up the batter), then pinned to in-situ soil and covered with at least 200 mm of topsoil. Refer to the IPWEA-QNT Standard Drawings for details. Where bioretention systems are bounded by an embankment, liners should extend over the embankment for reinforcement (Figure 35).

DESIGN NOTE: Options to exclude permeable liners

The advice provided in this section regarding permeable liners is somewhat conservative in nature. In many instances, permeable liners can be excluded, lowering costs and carbon footprint. If the permeable liner is to be excluded, geotechnical advice must be provided to demonstrate that the in-situ soil appropriately bridges with the bioretention layers or will not otherwise migrate into the bioretention layers. Dispersive soils, acid sulphate soils and elevated groundwater must also not be present, as these require the use of an impermeable liner.

3.4 Bioretention system layout

The layout of the bioretention system should ensure that sufficient space is allocated for all elements of the system and that the location and design of these elements do not compromise the amenity or function of the surrounding spaces and infrastructure.

The layout of the bioretention system should consider the:

- development of an earthworks model to assist in determining the optimal layout
- filter media size
- shape and location of the bioretention system
- inlet and outlet locations
- bioretention system edge and landscape interface
- maintenance access
- underground services
- road reserves
- flood storage requirements.

DESIGN NOTE: Timing of development within the catchment

During the design process, it is important to consider the timing of development within the catchment of the bioretention system. Refer to the *Guidelines for the Construction and Establishment of Bioretention Systems and Wetlands (Water by Design)* to identify options for construction staging and methods for ensuring bioretention systems are resilient while the catchment is being developed.

Key considerations include:

- location of inflow and outflow points
- protection of filter media from high sediment loads
- management of overland flow paths into or around the system
- use of the system (without filter media installed) as a sediment basin during construction
- delivery of large systems when the catchment will have building and construction activity occurring over several years or more.

If the implications of the location, construction technique, initial sediment load protection and management options for a bioretention system are not considered during design, major constraints can occur in the construction phase. Poorly designed, poorly constructed or damaged bioretention systems may not be accepted by a local authority at the asset handover stage.

3.4.1 Earthworks model

PERFORMANCE OUTCOMES

The earthworks model must demonstrate that earthworks for the bioretention system can be accommodated within vertical and horizontal constraints.

RECOMMENDED APPROACH

Developing a digital three-dimensional earthworks model of the proposed bioretention system can help to test the design layout. Having an accurate digital model of the system early in the design process can reduce the number of design iterations by identifying critical level and footprint issues. This digital model can gradually increase in detail as subsequent design elements are resolved. The final digital model can be used to produce design documents such as plans and cross-sections. For small or simpler bioretention systems, scale drawings and two-dimensional CAD designs may suffice.

3.4.2 Filter media area

PERFORMANCE OUTCOMES

The filter media area must:

- be sufficient to achieve the design objectives
- not detrimentally affect the lifespan of the bioretention system.

RECOMMENDED APPROACH

The required filter media area should be confirmed using catchment information collated in Section 3.2.

One of the following sizing options should be used:

- **Confirming concept design size** – The filter media area should have been determined during the concept design phase (e.g. using MUSIC software or a relevant deemed to comply solution). If the catchment and bioretention system properties (e.g. catchment area and land use, filter media

depth, extended detention depth) have not changed since concept design, then the filter media size should remain valid.

- **MUSIC modelling** – Where catchment or bioretention system layer properties have changed since concept design, MUSIC software can be used to confirm the filter media area needed to achieve relevant stormwater management objectives.

Where the available space for a bioretention system is constrained (i.e. less than required to meet relevant stormwater management objectives), the design team should investigate options to maximise the filter media area within the given constraints. This requires consideration of the surroundings of the bioretention system and an iterative approach to designing the layout and levels.

DESIGN NOTE: Coarse sediment removal areas

Space for a coarse sediment removal system should be included in the overall layout of the bioretention system (e.g. a coarse sediment forebay or inlet pond). The area required for these elements is in addition to the filter media area. Methods for sizing forebays and inlet ponds are provided in Section 3.5.3.

3.4.3 Shape and location

PERFORMANCE OUTCOMES

The shape and location of bioretention systems must:

- ensure the system is suitably integrated with the landscape and consider the constraints of the site
- allow the system to be easily constructed with commonly available equipment, while still meeting the design objectives.

RECOMMENDED APPROACH

Bioretention systems are permanent additions to the public landscape. Many factors influence the enjoyment of public space. Bioretention designers need to understand and respect these factors throughout the design process to ensure positive impacts on public landscapes.

For bioretention systems in road space, the factors to consider include safety, legibility and ease of movement. For systems in parks, the factors to consider include scenic views, picnic areas, passive recreation areas and open kick-around spaces. For systems in civic spaces, factors to consider include shade, seating and ease of movement for large groups of people.

Visual and land use integration issues need to be carefully considered when determining bioretention shape and location.

Visual issues include:

- aesthetics of engineering and maintenance infrastructure such as headwalls, inlets, outlets, weirs, access tracks, bunds, and batters (Figure 36 and Figure 37)
- blocking scenic views and important pedestrian and vehicle sight lines with trees and shrubs (Figure 38)
- ensuring the shape of the bioretention system is appropriate for the site, for example, an organic, curved shape is generally suitable for natural settings, while a more rigid, angular shape is better suited to built-up areas (Figure 39).

Land use issues include:

- impacts from overflows and overshadowing from tall trees
- space requirements – bunds, batters, maintenance tracks and resultant reduction in open park/grass verge area
- location of bioretention system – implications on park circulation and use patterns.

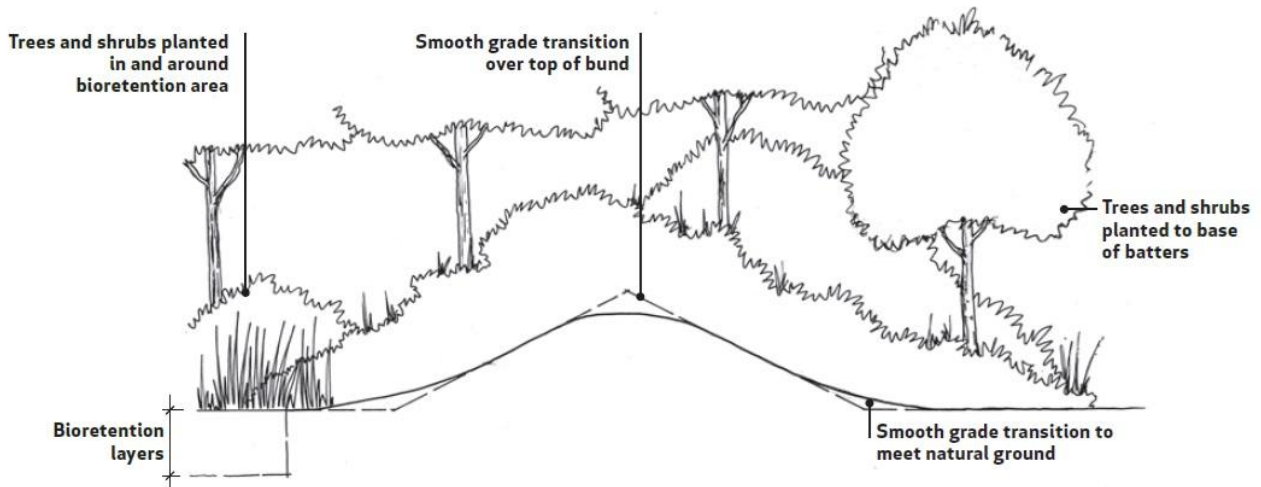


Figure 36. Visual integration of bioretention systems.

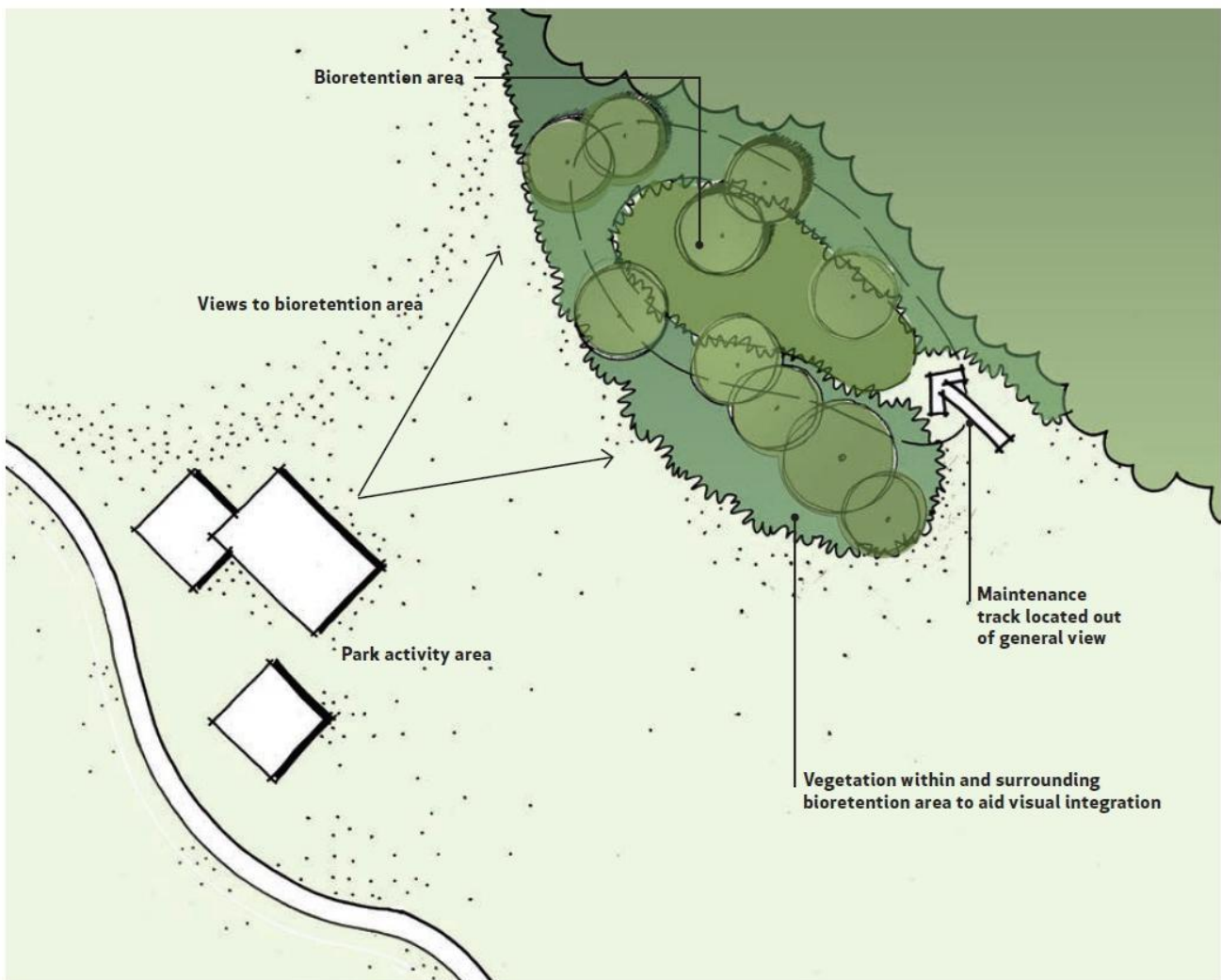


Figure 37. Visual integration of bioretention systems with existing park uses.

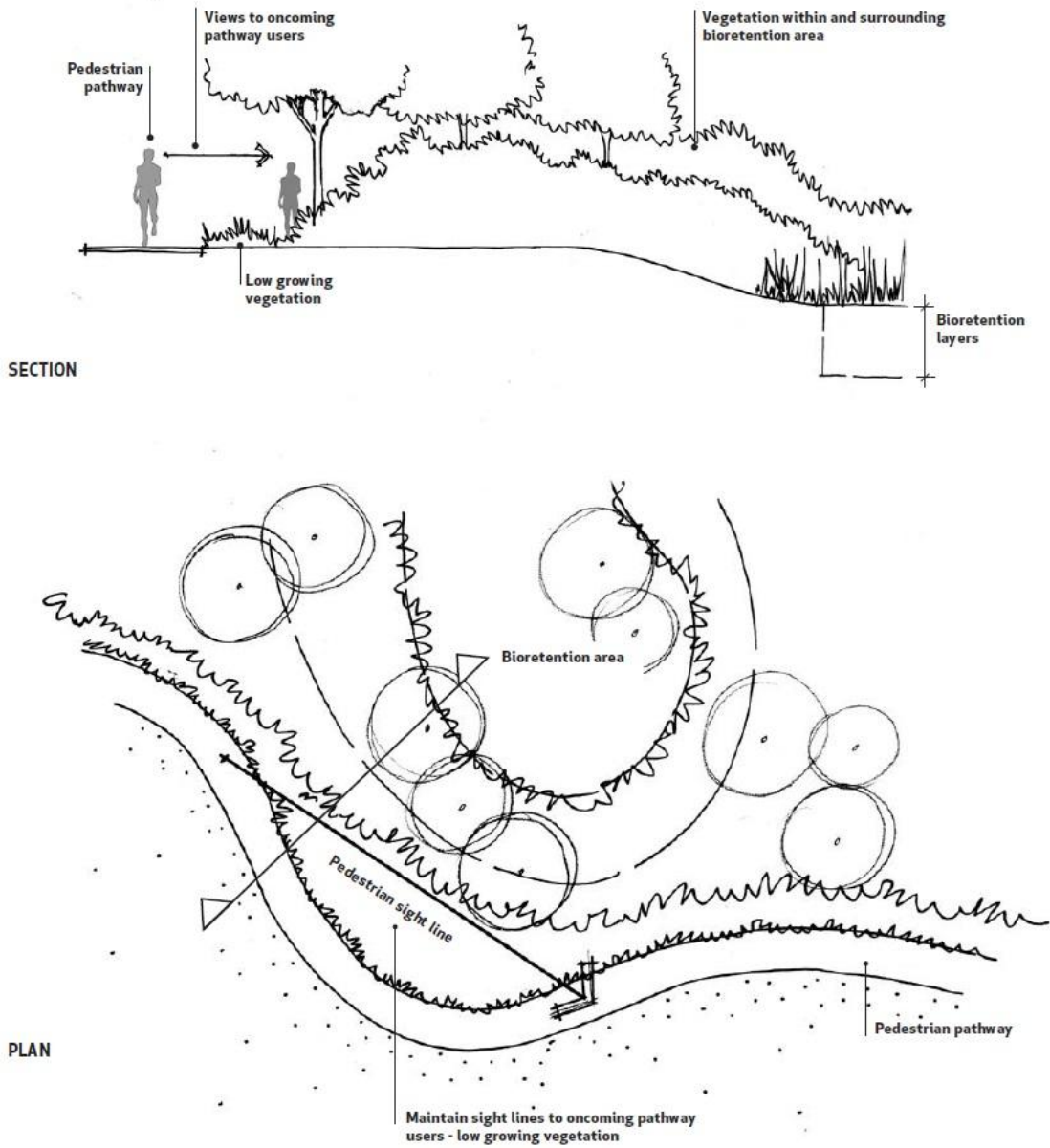


Figure 38. Integration of bioretention systems with pathways.

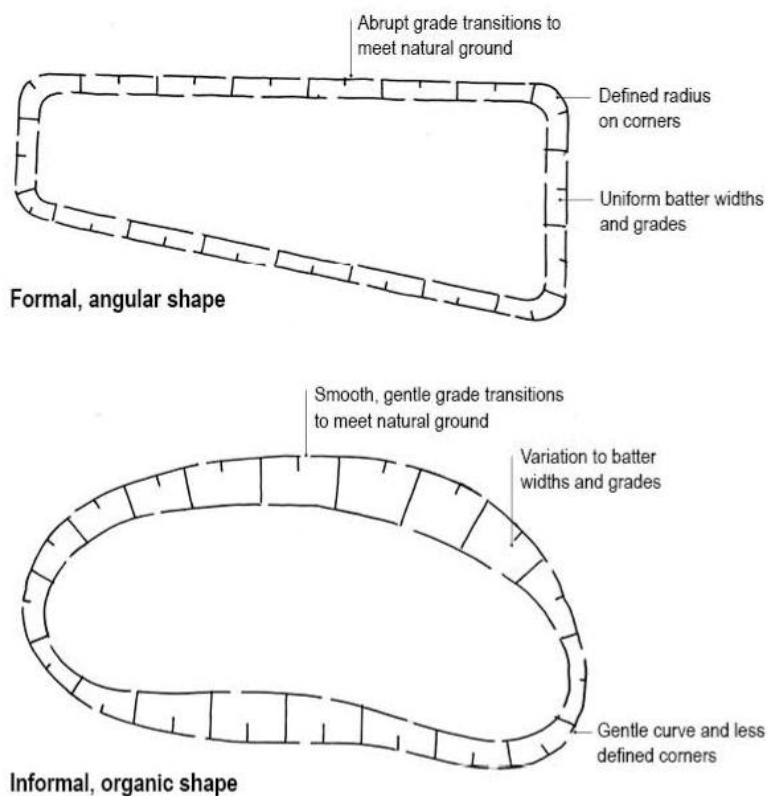


Figure 39. Bioretention system shapes.

The filter media area can be formed into almost any shape, provided the overall system can be feasibly constructed and maintained, and does not result in unacceptable hydraulic performance. The interaction of visual and land use elements should be carefully considered when determining the shape and location of bioretention systems.

To ensure the construction and maintenance of the bioretention system is feasible, filter media should:

- be a minimum width of 600 mm, as narrower bioretention systems are difficult to construct
- where construction access is available from both sides of the filter media, be a maximum width of 15 m (20 m at an absolute maximum) to ensure the system can be constructed and maintained from the edge using typical construction equipment and machinery (Figure 40)
- where construction access is available from only one side of the filter media, be a maximum width of 10 m to ensure the system can be constructed and maintained from the edge using typical construction equipment and machinery (Figure 40)
- be a maximum length of 40 m to minimise the risk of uneven distribution of stormwater over the surface and limit the length of underdrainage.

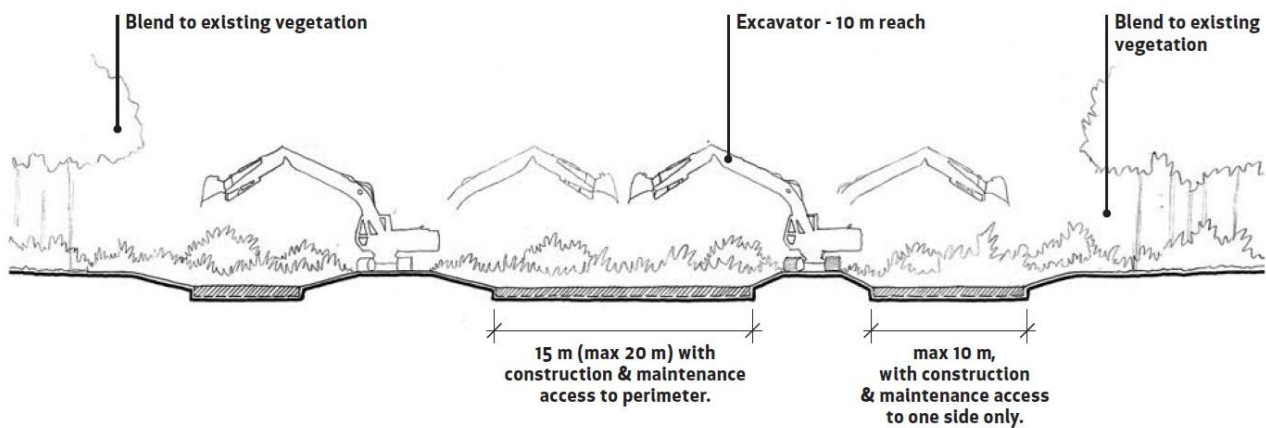


Figure 40. Bioretention width limitations.

3.4.3.1 Large system configuration

PERFORMANCE OUTCOMES

The design of large bioretention systems must:

- enable the system to be easily constructed with commonly available equipment
- ensure water is distributed evenly across the system surface (see Section 3.5.7)
- protect the filter media surface from high flows
- provide sufficient water for the growth of all plants in the filter media.

RECOMMENDED APPROACH

Large bioretention systems present unique challenges not faced by smaller systems.

Consideration must be given to how:

- the system will be constructed without compacting the filter media and crushing the underdrains
- to evenly distribute water across the filter media surface, evenly loading pollutants across the full filter media area
- to provide sufficient water to support the growth of all plants within the filter media (plants furthest from the inlet often experience drier conditions)
- to protect the filter media from high flow velocities.

To achieve this, large bioretention systems with a total filter media area greater than 800 m² should be split into cells of no larger than 800 m². This is in addition to flow distribution requirements discussed in Section 3.5.7.

As depicted in Figure 41, large systems should also incorporate:

- **an inlet pond (sediment basin)** to capture coarse sediment and dissipate energy (see Section 3.5.3.4). Note that a sediment forebay is not sufficient for bioretention systems larger than 800 m².
- **a high flow bypass** from the inlet pond to the receiving drainage to bypass high flows around the bioretention system cells
- **a low flow connection** from the inlet pond to the bioretention cells to convey design flows to the bioretention cells
- **flow distribution** to spread water evenly across the surface of the bioretention system (see Section 3.5.7)
- **construction and maintenance access** between and around bioretention cells to provide for ease of maintenance (see Section 3.4.6)

Where dimensions outside these recommendations are used, designers should provide the local authority with details and justification of the proposed design and construction method.

Note that where a bioretention system is described as being separated into 'cells', this refers to two or more entirely separate sections of filter media fed by separate inlets. Partial separation of the media fed by a single inlet, as shown in Figure 42, is not appropriate. Such designs assist with constructability but do nothing to evenly distribute flows across the filter media surface.

DESIGN NOTE: Cells greater than 800 m²

When Version 1.2 of this guideline was released in 2014, most bioretention systems were constructed using excavators, hence the need for a maximum system width of 15 m. Since that time, the use of slingers to throw filter media into bioretention systems has become more common. Where slingers are used to construct bioretention systems, system widths greater than 15 m can be used. This in turn, allows filter media areas greater than 800 m² to be designed and constructed successfully. Nonetheless, to mitigate the risks associated with very large bioretention systems, this guideline continues to recommend that the maximum size of bioretention cells be 800 m². Designers wishing to implement cells larger than this should justify their designs against the performance outcome above and in Section 3.5.7.

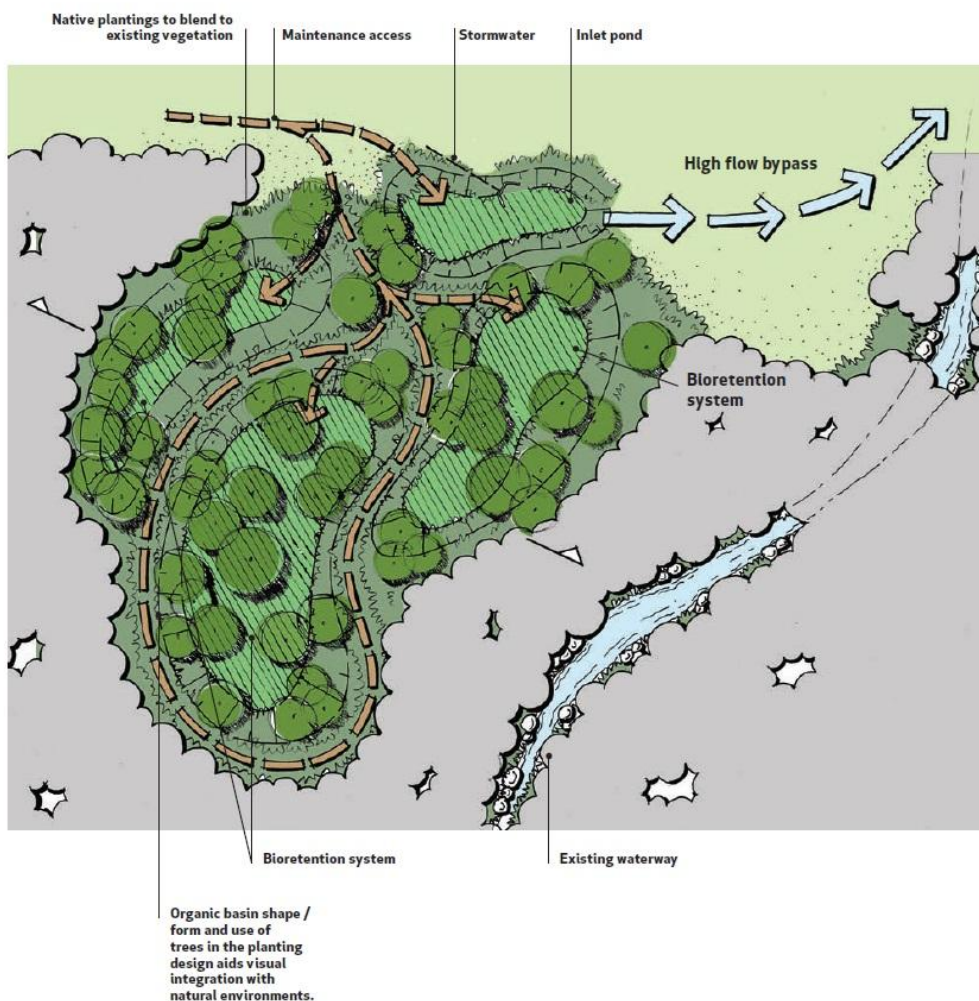


Figure 41. Example layout of a large bioretention system.

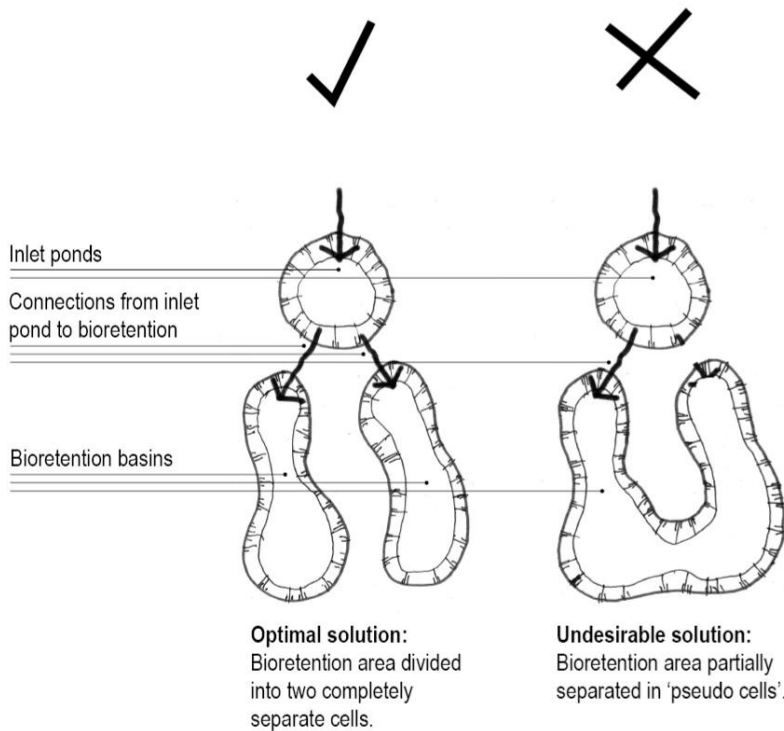


Figure 42. Separation of bioretention filter media into cells

3.4.4 Inlet and outlet locations

PERFORMANCE OUTCOMES

Inlet and outlet locations must:

- allow inflows and outflows to be efficiently managed without damaging the bioretention system or surrounding areas
- ensure hydraulic structure locations are sympathetic to landscape considerations.

RECOMMENDED APPROACH

When locating inlets and outlets, consider:

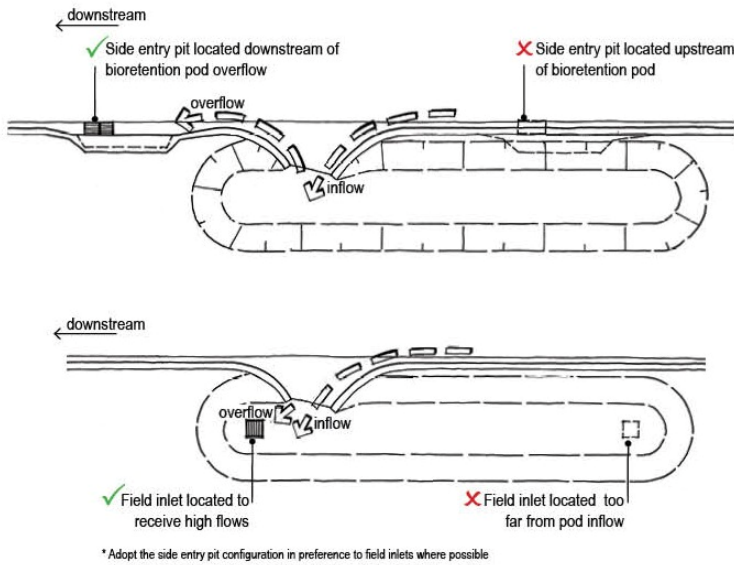
- filter media area (large bioretention systems may require inlet ponds)
- outlet structure type (overflow pit, side entry pit, weir or a combination of these)
- underdrainage design (may dictate where and how many overflow pits are required)
- landscape aesthetic of inlets and outlets (these structures can be obvious, and often dominant landscape features. Locating outlet pits out of direct or prominent view lines or planting shrubs adjacent to pits should be considered)
- local authority requirements.

Inflow and outflow structures should preferably be located close to each other (Figure 43 and Figure 44) to:

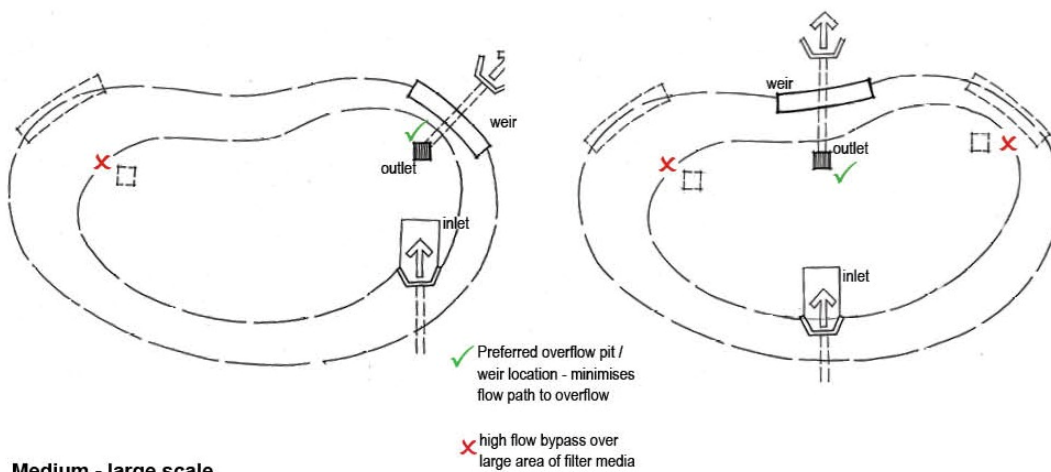
- ensure high flows can reach the outlet without scouring vegetation or filter media
- allow bioretention systems to be partitioned off and flows bypassed around the filter media while activities such as building and house construction take place within the catchment. This protects vegetation and the filter media surface, as discussed in the *Guidelines for the Construction and Establishment of Bioretention Systems and Wetlands (Water by Design)*.

When locating inlet and outlet locations close to each other, care must be taken to ensure that blockages or accumulation of debris don't result in water short-circuiting from the inlet to the outlet (see Figure 45).

Inflow and outflow system design is discussed in Sections 3.5 and 3.6.



Small scale (e.g. streetscape)



Medium - large scale

Figure 43. Bioretention inflow and outflow locations.



Figure 44. Good example of an inlet and an outlet located close to each other. Photo credit: Andrew Cook.



Figure 45. Poor example of an inlet and outlet located close to each other, where short-circuiting occurs. Photo credit: Brad Dalrymple.

3.4.5 Edge and landscape interface (batters, embankments and walls)

Designs should consider visual amenity and the safety of any transitions from a depressed bioretention system surface to the surrounding landform and landscape. Batter slopes, embankments, and walls have a significant influence on the overall footprint of bioretention systems, as well as the interaction with the adjoining landscape. This section includes important design considerations for the edges of bioretention systems.

3.4.5.1 Surrounding landscape

PERFORMANCE OUTCOMES

The layout of bioretention systems must not negatively impact surrounding landscape features.

RECOMMENDED APPROACH

Features surrounding bioretention systems have an important role in defining the overall shape and edge design of the system. Existing features often need to be preserved and are therefore an important

constraint to the layout of bioretention systems. Features in the surrounding area that will be created or modified in the future also need to be considered.

These features may include:

- vegetation or trees
- local topography
- waterway and associated riparian zone
- pedestrian paths or roads
- residential dwellings
- playgrounds and active parks.

DESIGN NOTE: Existing vegetation

Bioretention earthworks should avoid the critical root zone (typically defined as 500 mm beyond the drip line) of any retained vegetation (e.g. trees). Advice should be sought from an arborist regarding earthworks close to trees.

3.4.5.2 Public access and safety

PERFORMANCE OUTCOMES

The layout of bioretention systems must:

- integrate with adjacent public spaces
- enhance public access and safety.

RECOMMENDED APPROACH

The shape and form of bioretention systems should integrate with adjacent active and passive public spaces. Interaction with pedestrian and vehicle pathways, and Crime Prevention Through Environmental Design principles, should guide landscape design for bioretention systems in these situations.

Pathway crossings over bioretention systems allow the public to interact with and develop an appreciation of such systems but they can be expensive. Solid embankment crossings with culverts to allow water to pass underneath are generally cheaper to construct than boardwalk or bridge-style crossings. Edge safety considerations recommended for batters and walls in Sections 3.4.5.3 and 3.4.5.5 also apply to path edges.

Bioretention systems should be safe to construct, consistent with requirements of the Work Health and Safety Act 2011 (QLD).

3.4.5.3 Batters

PERFORMANCE OUTCOMES

Bioretention batters must:

- be safe and stable
- be low maintenance
- not negatively impact visual amenity
- include topsoil suitable for batter vegetation.

RECOMMENDED APPROACH

Figure 46 outlines batter design for bioretention systems. Generally, 1 in 4 batters or flatter are recommended. Batters and embankments should be densely vegetated and mulched to manage weed ingress. Groundcover coverage of 90% is recommended for all batters, which generally requires a planting density of around six plants per square metre. Lower planting densities may be acceptable for certain plant species, subject to local authority approval. Lateral flows down batters that are 1 in 3 or

steeper should be avoided by creating designated inflow points with adequate erosion protection (swales/rock-lined channel).

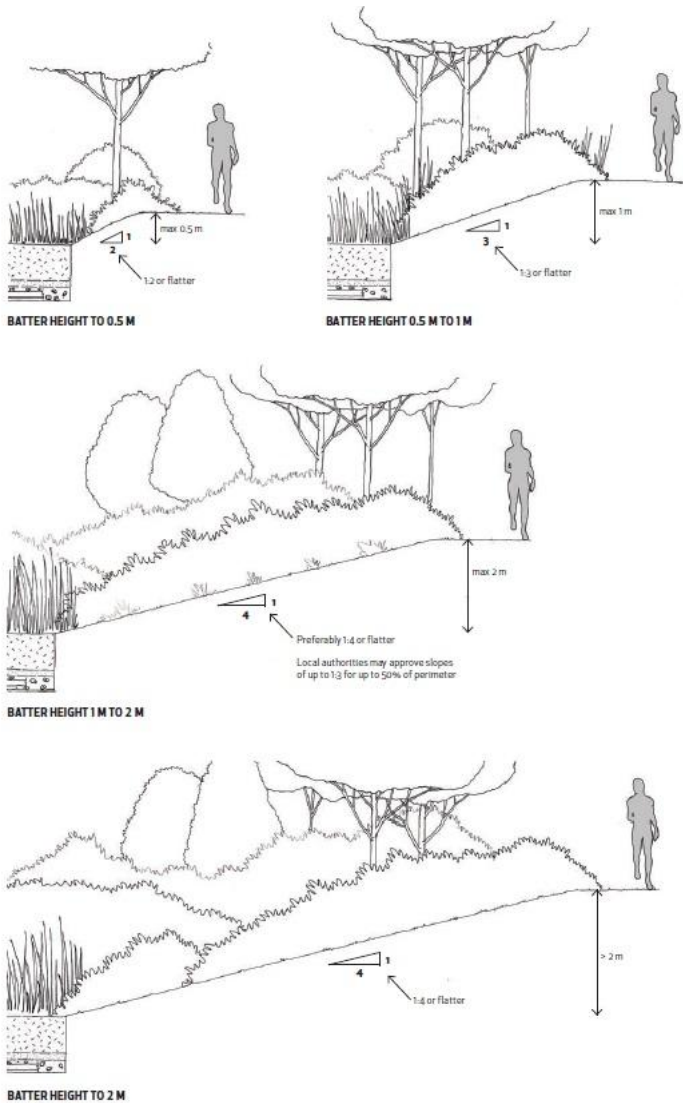


Figure 46. Batter design and guidance.

When designing bioretention systems on steep topography, care should be taken to manage the total footprint of the bioretention system, as batter slopes can extend a significant distance from the filter edge when tying into natural surfaces. Features such as retaining walls can alleviate this issue as illustrated in Figure 47. Aligning the long axis of bioretention systems to natural contours can also help minimise the total bioretention system footprint and better integrate into the landscape.

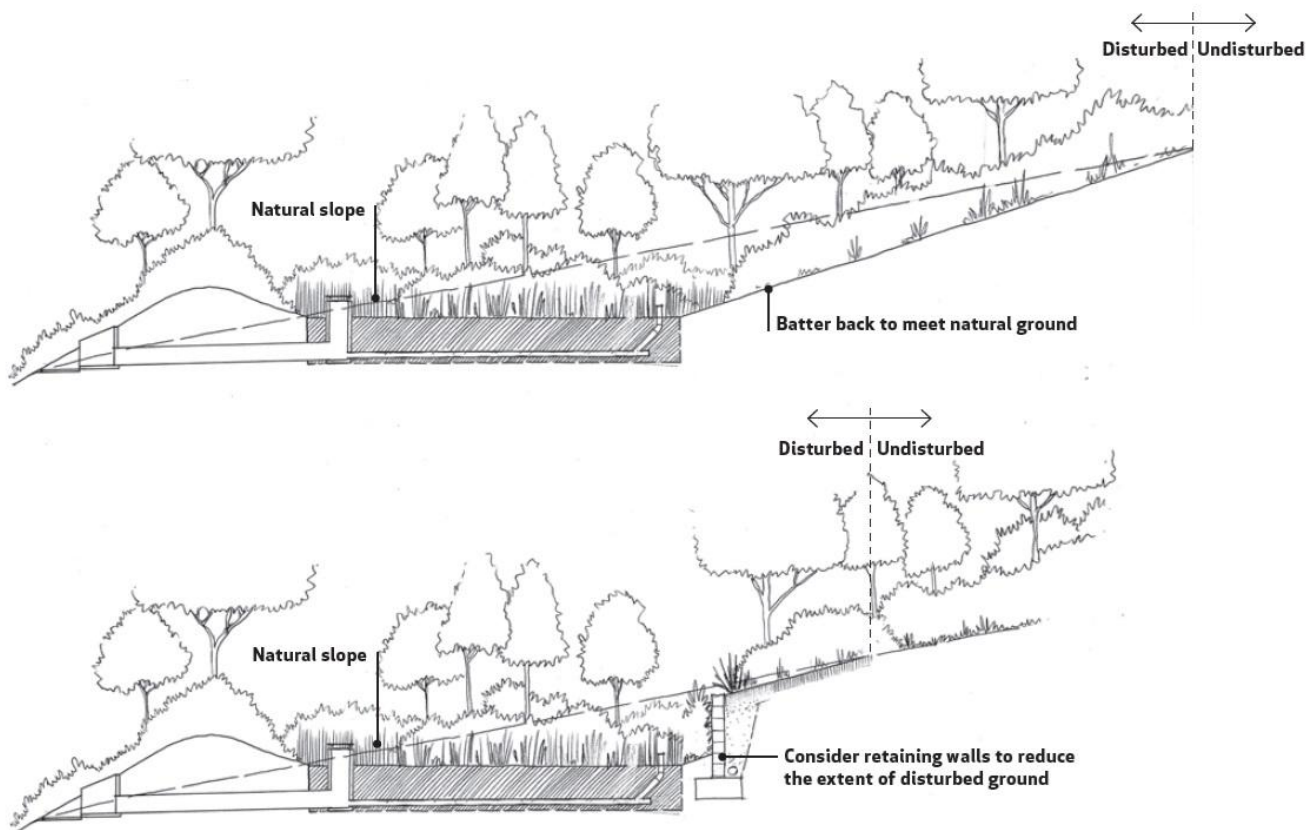


Figure 47. Bioretention system edge design on a steep slope.

Design levels for batters and embankments refer to the finished topsoil level. Therefore, earthworks design should account for a minimum of 200 mm of topsoil placement to meet the finished design level. Finished topsoil levels must then tie into the filter media surface level, maintenance paths and other elements. This is an important design note to include on detailed design drawings and specifications. Refer to Section 4.4.1 for specification details.

3.4.5.4 Embankments

PERFORMANCE OUTCOMES

Bioretention embankments must:

- be safe and stable
- be low maintenance
- not negatively impact visual amenity
- provide for the construction and maintenance of the system.

RECOMMENDED APPROACH

Bioretention embankments serve the multiple roles of retaining design stormwater flows, providing access for construction and maintenance, and providing pedestrian access. The recommended approach for designing embankments around bioretention systems is shown in Figure 48.

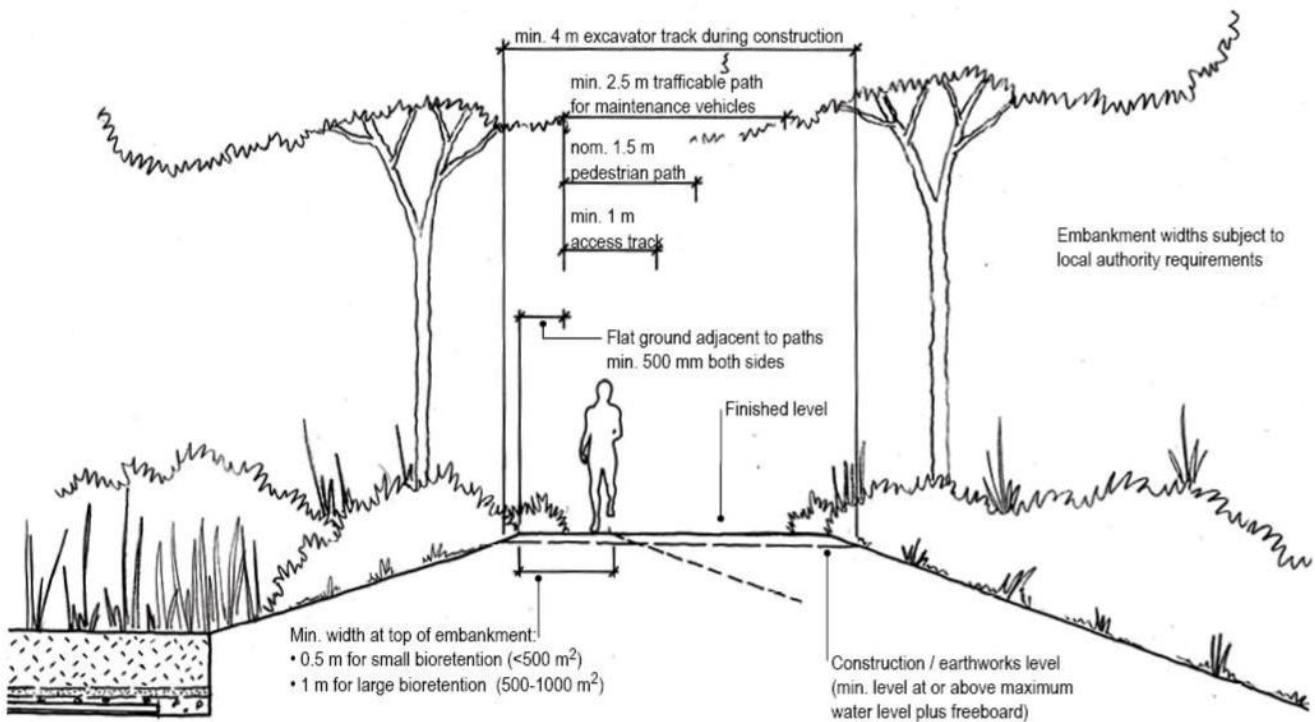


Figure 48. Embankment width requirements.

3.4.5.5 Walls – above ground

PERFORMANCE OUTCOMES

Bioretention systems should generally be constructed without walls.

Where walls are used, they must:

- be safe and stable
- not negatively impact visual amenity
- allow the bioretention system to be easily constructed and maintained.

RECOMMENDED APPROACH

Where possible, bioretention systems should be designed without walls. This is because if inappropriately designed, they present a potential safety hazard, cause maintenance difficulties and detract from the visual amenity of the surrounding landscape (Figure 49).

If designed well, walls may be appropriate for use in bioretention systems:

- in steep terrain to reduce unnecessarily large batter lengths (see Figure 47)
- to preserve existing vegetation (Figure 50)
- to create visual interest (Figure 51).

It is recommended that walls around bioretention systems be in accordance with Figure 52 and Table 10. The limits recommended will help manage the visual impact of the walls, address safety considerations and allow the wall to interact with the edge of the bioretention system. Where vertical drops are greater than 800 mm, it is recommended that more than one wall (each ≤ 800 mm high) is used.

The walls should be separated by a vegetated strip that is at least 3 m wide and planted with trees. Where a wall is only used for part of the system perimeter, batters in accordance with Section 3.4.5.3 should be used for the rest of the perimeter of the bioretention system.

Walls should not be used for streetscape bioretention systems unless the walls are integrated with seating (Figure 51). Walls are not recommended around bioretention systems within flood storage areas.

It should be noted that in steeper terrain, adhering to the recommendations in this section may result in excessively large batters. In very steep terrain, or where significant trees are to be preserved, additional use of walls may be appropriate (Figure 53), provided that a suitable landscape outcome is achieved. The onus is on the designer to demonstrate to the assessment authority that an appropriate aesthetic outcome will be achieved.

Table 10. Bioretention wall design guidance.

| Wall details | Design response |
|---------------------------------------|--|
| Vertical drop \leq 150 mm. | Wall can surround entire bioretention system. |
| 150 mm > vertical drop \leq 300 mm. | Wall around up to 75% of bioretention perimeter. |
| 300 mm > vertical drop \leq 800 mm. | Wall around up to 50% of bioretention perimeter. |



Figure 49. Unacceptable use of walls in bioretention systems. Photo credits: Paul Dubowski.



Figure 50. Well-designed walls used to protect existing trees. Photo credits: Shaun Leinster.



Figure 51. Well-designed bioretention system walls. Photo credits: left, Shaun Leinster; right, Robin Allison.

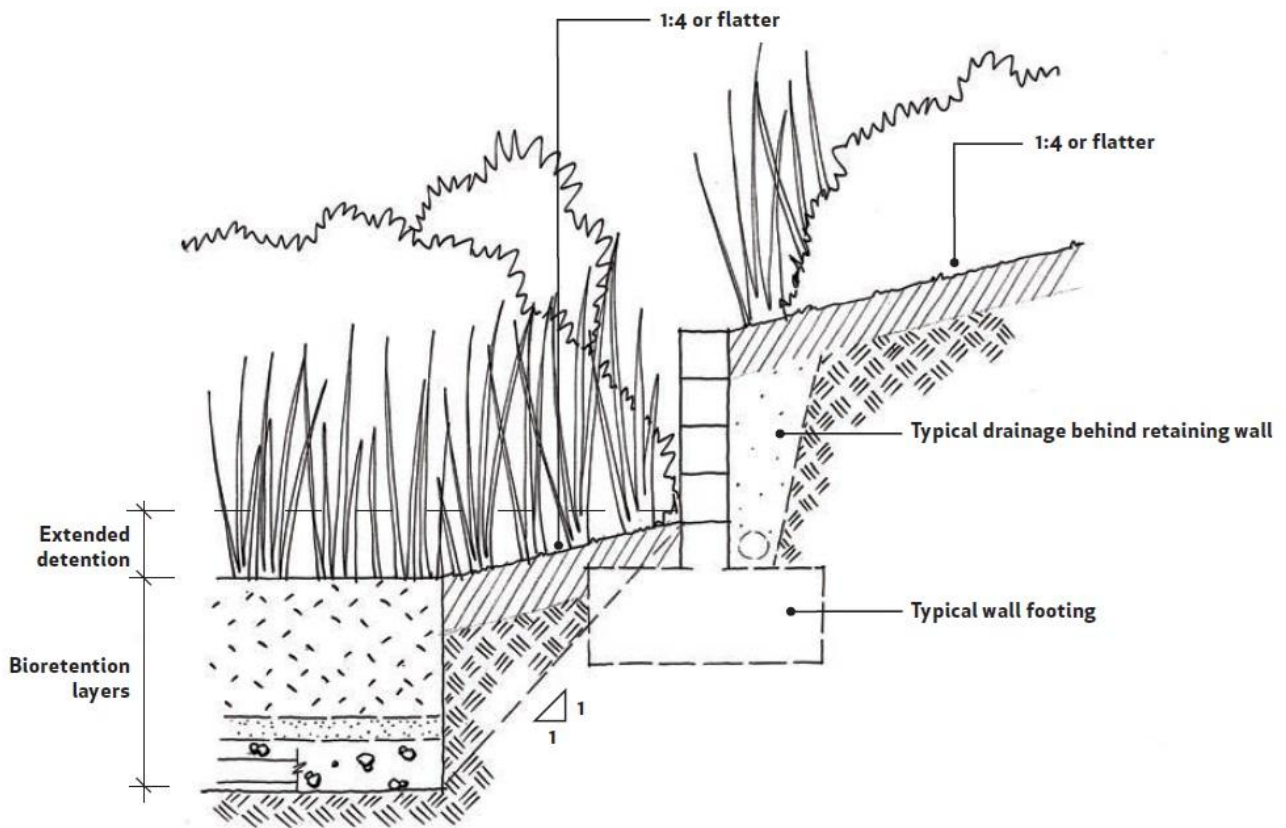


Figure 52. Preferred configurations of walls around bioretention systems.



Figure 53. Use of walls not in accordance with this guideline but still delivering a suitable landscape outcome. Photo credits: Shaun Leinster.

3.4.5.6 Subsoil interface

PERFORMANCE OUTCOME

The subsurface interface between the drainage profile (filter media, transition layer and drainage layer) and the in-situ soil must:

- be structurally sound
- allow the bioretention system to be easily constructed and maintained
- prevent short circuiting of the filter media.

The design of the interface between the drainage profile and the in-situ soil will depend on:

- the type of liner being used
- the presence of any subsoil walls
- the structural qualities of the in-situ soil.

The simplest and preferred form of subsoil interface for bioretention systems is a vertical surface excavated from in-situ soil, lined in accordance with Section 3.3.5 (see Figure 54).

In some soils (e.g. sand), it is not possible to excavate a vertical surface to form the subsoil interface, as the in-situ soil will collapse as it is excavated. In these situations, the subsoil interface should be a 1:1 slope excavated from the in-situ soil and lined in accordance with Section 3.3.5. This approach is generally suitable for systems greater than 4 m wide to allow sufficient space for construction. For narrower systems, a construction methodology should be determined during design.

It is generally not recommended to use walls as the subsurface interface between bioretention systems and the in-situ soil because water is prone to short-circuiting down the edge of the wall, reducing treatment effectiveness and increasing the chance of subsidence. However, subsurface walls can overcome the construction challenges associated with soils for which a vertical subsoil interface cannot be constructed. If using a subsurface wall, it must have a flat surface against which to compact the filter media and filter cloth installed (as shown in Figure 55) to minimise the risk of scour and short-circuiting.

Uneven rock walls should not form part of the subsoil interface. Where uneven rock retaining walls are adopted, they should be set back from the bioretention filter media, retaining at least 1 m of in-situ soil. The separation should be wide enough to ensure the base of the rock wall is well founded (i.e. it is at a 45-degree angle from the base of the filter media) (Figure 56).

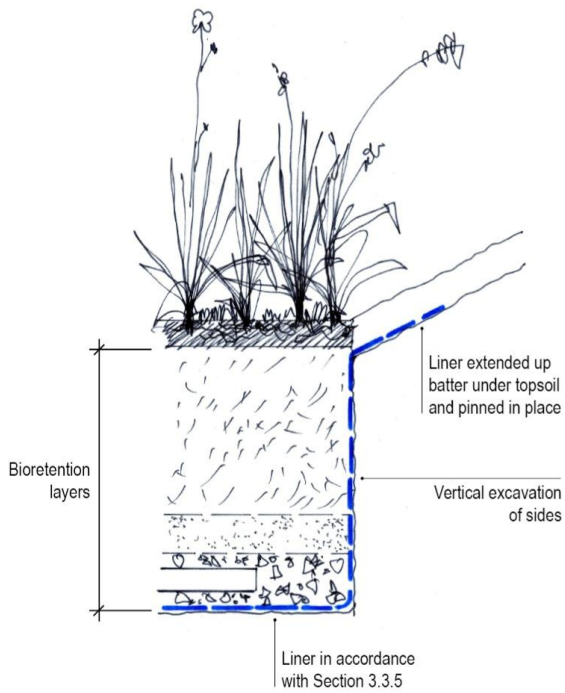
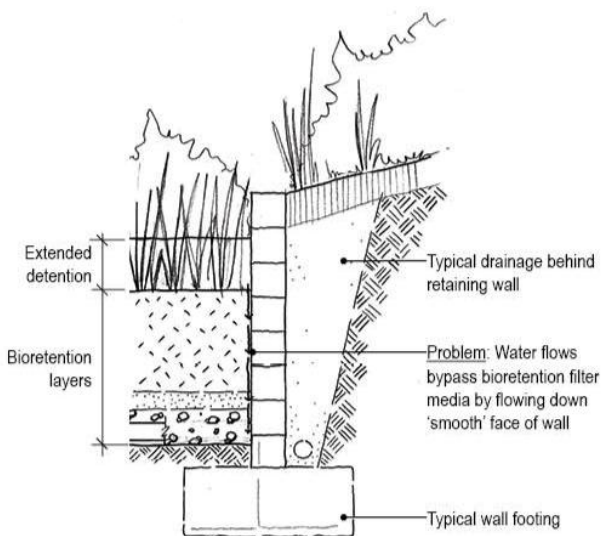
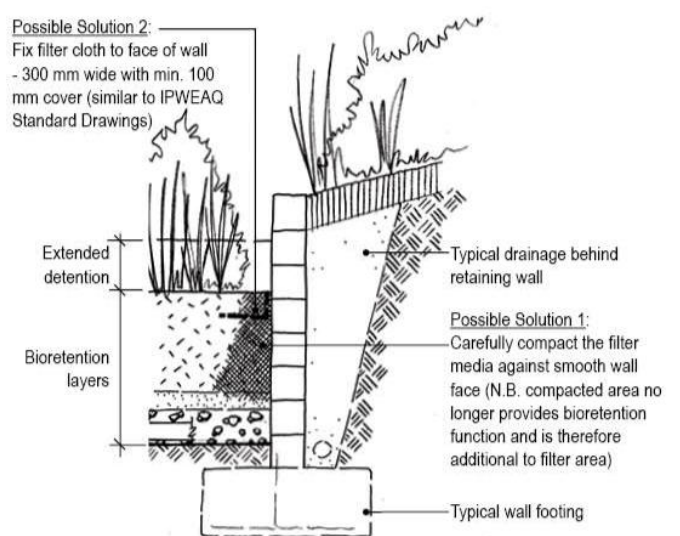


Figure 54. Basic subsoil interface.



Block Retaining Wall - typical problem



Block Retaining Wall - possible solutions

Figure 55. Design guidance for walls used as the subsoil interface.

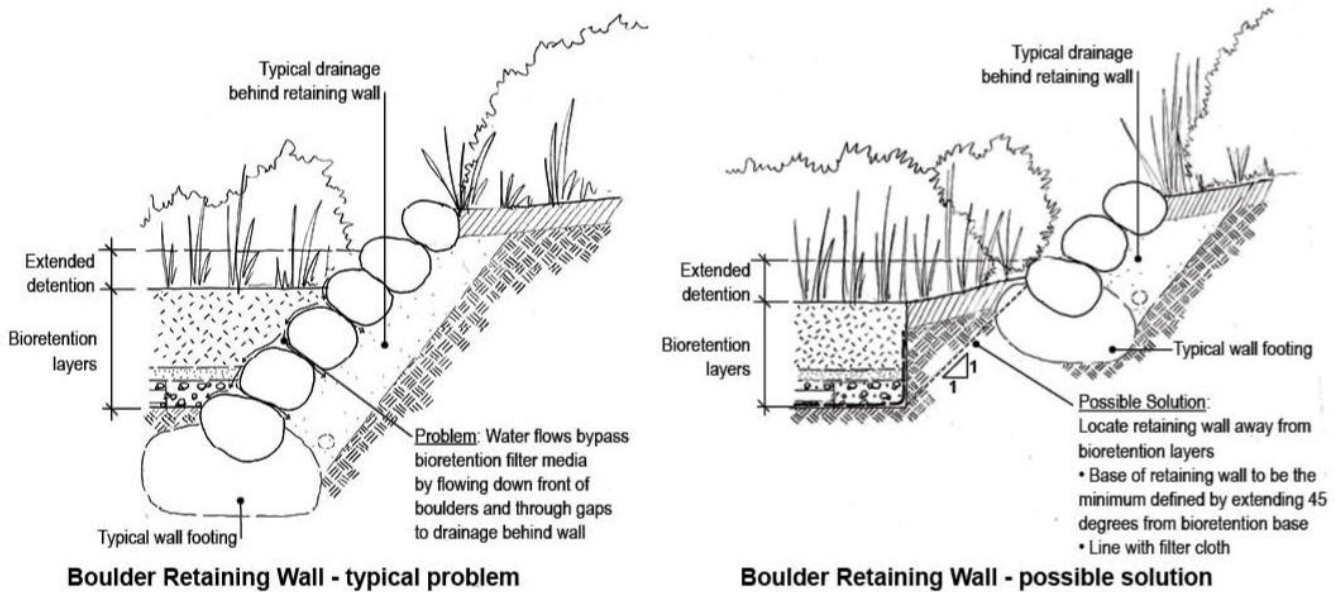


Figure 56. Uneven rock walls should not be used as the subsoil interface.

3.4.6 Maintenance access

Bioretention systems require regular, proactive but simple maintenance to ensure their effective long-term operation and minimise lifecycle costs. Typical maintenance activities involve weeding, litter collection, sediment removal, repair of localised scour and inspection of hydraulic structures.

To allow for easy maintenance, bioretention system design must:

- provide access for sediment removal
- provide access to the filter media and vegetation
- appropriately delineate the edge of the bioretention system.

3.4.6.1 Sediment cleanout access

PERFORMANCE OUTCOMES

Access for sediment cleanout must:

- ensure accumulated sediment can be easily removed using commonly available equipment
- be visually unobtrusive.

RECOMMENDED APPROACH

The way that sediment is removed from bioretention systems depends on the size and type of system. Sediment in streetscape bioretention systems and biopods is typically removed using a shovel and wheelbarrow, whereas removing sediment from larger bioretention systems typically involves machinery and vehicles such as mini excavators, bobcats, trucks, tippers or utilities. Sediment removal from such systems requires dedicated maintenance access paths.

Maintenance paths should meet an access point (road or car park) for vehicles to be able to access the bioretention system. These access points should preferably be located away from high-use pedestrian areas. Consideration should be given to preventing public vehicle access to maintenance tracks by using lockable gates or bollards.

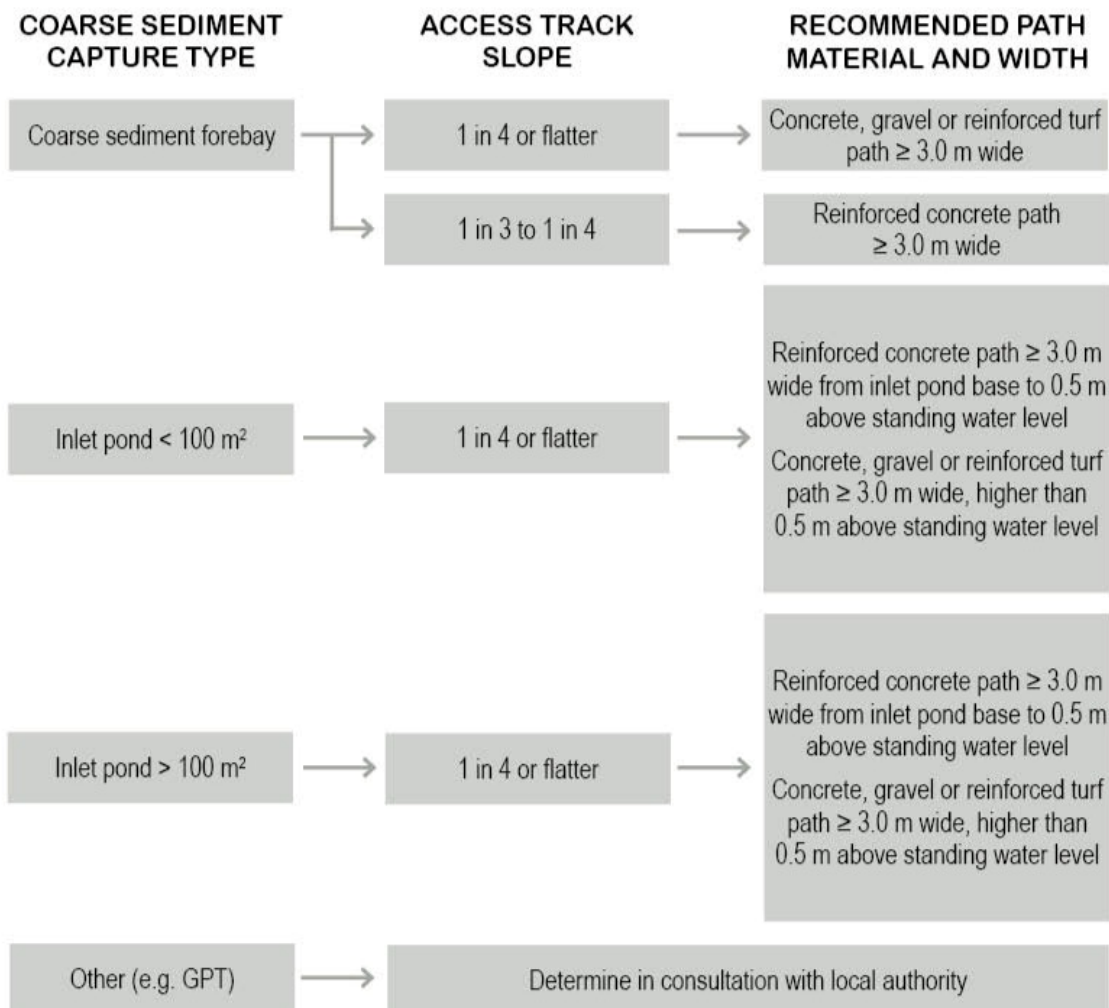
Access requirements for cleaning sediment from inlet ponds and coarse sediment forebays are outlined in Figure 57. Local authorities should be consulted to confirm their requirements as part of the design process.

Maintenance access must be provided to the invert of the coarse sediment forebay. Extending the access only to the top of the headwall or the top of the forebay wall is insufficient, as it inhibits easy maintenance. For inlet ponds, a suitable area for dewatering extracted sediments should be provided. The dewatering area should be approximately a quarter of the inlet pond area (at normal water level) and drain towards the pond.

Access paths should be curved to screen forebays behind vegetation, making them less visually obtrusive. Where maintenance access paths are curved, the curve must be gentle, and the path locally widened to facilitate vehicle turning. Tight turns on maintenance access paths are not acceptable.

Maintenance access paths must seamlessly tie into the finished levels of the sediment forebay/inlet pond, the adjacent vegetated areas, footpath crossovers and the nearest road. Maintenance access paths that do not seamlessly tie in cause trip hazards, inhibit maintenance and cause erosion of batters and thus should be avoided.

Examples of good and poor maintenance access for sediment cleanout are provided in Figure 58 and Figure 59, respectively.



*all concrete access paths steeper than 1 in 5 shall be brush finish rather than smooth finish

Figure 57. Recommended sediment maintenance access track parameters.



Figure 58. Well-designed and constructed maintenance access. Photo credits: Jack Mullaly.



Figure 59. Poorly designed maintenance access. Photo credits: Paul Dubowski.

DESIGN NOTE: Access for flow distribution channels

Where a bioretention system includes flow distribution channels, a 1-metre-wide crushed gravel access track should be provided to the entire length of the distribution channel. This access track should connect to other access tracks or the nearest road, footpath or access point.

3.4.6.2 Filter media, vegetation, outlet pit and weir maintenance access

PERFORMANCE OUTCOMES

Access for the filter media, vegetation, outlet pit and weir must allow for regular inspections and maintenance.

RECOMMENDED APPROACH

Maintenance access is required for weeding, replanting and regular inspections. All maintenance access tracks/paths should allow appropriate entry and exit connections with a road or car park. Local authority requirements for access paths and lockable gates apply. Maintenance access can be combined with pedestrian pathways in accordance with local authority requirements. Where maintenance access is for vehicles, and a turn is required, the turn must be gently curved and locally widened.

The recommended perimeter maintenance access for bioretention systems is outlined in Table 11. Examples are shown in Figure 60.

Table 11. Bioretention perimeter maintenance access.

| Filter media area | Recommended perimeter maintenance access |
|----------------------|--|
| < 500 m ² | Access path along one side of the bioretention system (≥ 40% of perimeter) and passing adjacent to all outlet structures (weir, pit, etc.) to allow easy access on foot. Turf, gravel or concrete path ≥ 1 m wide. |
| ≥ 500 m ² | Trafficable path (≥ 2.5 m wide) suitable for small utilities or tractors (e.g. reinforced turf, gravel or other) along ≥ 40% of the perimeter of each cell. Path (≥ 1 m wide) suitable for foot traffic (e.g. turf, gravel or other) around the remaining perimeter. |



Figure 60. Well-designed perimeter maintenance access paths. Photo credits: all photos, Jack Mullaly.

3.4.6.3 Outlet pipe access

PERFORMANCE OUTCOMES

Access must allow for maintenance to ensure the outlet pipe drains freely.

RECOMMENDED APPROACH

Outlet pipes discharging to low-lying, inundated areas are at risk of becoming blocked by vegetation or sediment. A maintenance access track, trafficable by small earthmoving equipment such as a dingo or small bobcat (e.g. gravel, reinforced turf or other) should be provided from an appropriate access point (e.g. road or carpark) to outlet pipes discharging to low-lying, inundated areas. Other outlet pipes (e.g. those discharging to the stormwater drainage network or parkland) should be provided with maintenance access in line with local authority requirements for similar outlets not from bioretention systems.

3.3.6.4 Maintenance edges

PERFORMANCE OUTCOMES

Maintenance edges must:

- minimise the risk of turf and weeds encroaching into the bioretention system
- provide for easy maintenance of the bioretention system
- delineate the bioretention system from surrounding land uses if required.

RECOMMENDED APPROACH

Maintenance edges minimise the risk of turf and weeds encroaching into the bioretention system. They separate different landscape types, create clean edges to the batter planting, and permit easy

maintenance of adjacent landscapes. Maintenance edges are not recommended for bioretention systems located next to bushland or riparian vegetation.

Maintenance edges (Figure 61) should be located at the perimeter of bioretention planting and consist of:

- pedestrian pathways or unvegetated maintenance access tracks
- concrete landscape maintenance edges in line with local authority standards.



Figure 61. Maintenance edges to bioretention systems. Photo credits: all photos, Shaun Leinster.

3.4.7 Underground services

PERFORMANCE OUTCOMES

Where underground services are in proximity to a bioretention system, the design of the system must:

- ensure the operation of the bioretention system does not compromise the function of the service, and vice versa
- ensure maintenance and inspection activities undertaken on the service do not compromise any component (e.g. filter media) or function of the bioretention system, and vice versa.

RECOMMENDED APPROACH

Underground services should be located outside the filter media area but may be incorporated into bioretention system batters. Where this is not possible (e.g. in retrofit or the streetscape), it is important to consider how to access services for maintenance without regularly disrupting the bioretention system.

Interactions between services and bioretention systems are detailed in Table 12. However, the requirements of local authorities and service providers take precedence over this advice.

Table 12. Bioretention system interface with underground services.

| Service | Acceptable location relative to bioretention system |
|---------------------------------|---|
| Electrical, telephone, and gas. | <p>Electrical, telephone and gas services should not be located within the filter media of the bioretention system.</p> <p>They can be installed under batters.</p> <p>In constrained situations or at service crossings within the road reserve where one or more of these services is passed through the filter media, a suitable conduit must be installed. Detection tape and kerb markers should be used to show service locations.</p> <p>Service connections (electrical pillars, etc.) in bioretention systems are not recommended.</p> |

| | |
|----------------------------------|--|
| <p>Water, sewer, stormwater.</p> | <p>Water, sewer and stormwater services should not be located within the filter media of the bioretention system. They can be installed under batters.</p> <p>In constrained situations, it may be possible to:</p> <ul style="list-style-type: none"> locate sewers or stormwater infrastructure under the filter media pass water through the filter media via a conduit. <p>Detection tape and kerb markers should be used to show service locations. Service connections (water meters, etc.) in filter media are not recommended.</p> |
|----------------------------------|--|

3.4.8 Road reserves (streetscape bioretention systems)

This section should be read in conjunction with the functional design considerations for streetscape and on-lot bioretention systems described in Section 3.1.2.

PERFORMANCE OUTCOMES

The layout of streetscape bioretention systems must:

- not compromise other streetscape functions
- integrate with the aesthetics of the streetscape.

RECOMMENDED APPROACH

Placing bioretention systems within road reserves requires careful consideration of the form and function of streetscapes, including:

- services corridors, crossings, and connections to dwellings
- road pavement and trafficable lane widths
- road base and kerb support
- pedestrian paths, access, and safety
- landscape design intent and street tree locations
- street lighting
- drainage (location of stormwater pits)
- vehicle site lines
- postal delivery services
- access to parked cars.

Road reserve cross sections need to support all these, as well as provide space for bioretention systems. Some local authorities have developed standard road reserve cross-sections for streetscape bioretention systems. Local authorities should be consulted to determine if any standards exist and if not, how one may be developed for the subject site.

Refer to the *Concept Design Guidelines for Water Sensitive Urban Design (Water by Design)* for more guidance and examples of streetscape bioretention systems and road sections.

The following design responses should be considered when locating bioretention systems within road reserves:

- Localised widening of road reserves by indenting property boundaries (e.g. 15 m wide road reserves may widen to 18 m in the vicinity of bioretention systems (Figure 62)).
- Local narrowing of lots adjacent to bioretention systems to create sufficient space for the bioretention system and services.
- Offsetting the road carriageway centreline if additional space on one side of the road is needed.
- Integrating bioretention systems within traffic calming build-outs from the kerb.
- Developing street networks with low design speeds to reduce the need for footpaths.
- Locating parking bays to accommodate bioretention (in retrofit situations).
- Ensuring bioretention systems receive inflows as overland flow to limit the depth and overall footprint of systems and discourage the use of walls.

3.4.9 Co-locating bioretention and detention

This section relates to co-locating bioretention systems within flood detention basins. For topics relating to bioretention systems located in local and regional floodplains, refer to Section 3.4.10.

PERFORMANCE OUTCOMES

Where bioretention systems are co-located with flood detention systems, they must ensure that:

- flood storage outcomes are achieved
- flood storage design does not rely on extended detention volumes
- bioretention system design objectives and functionality are not compromised during or after flood events.

RECOMMENDED APPROACH

Bioretention systems may be integrated into the base of flood detention systems, effectively reducing the overall land required for managing stormwater quality and quantity.

Where bioretention systems can be integrated into the base of detention systems, they will occasionally become inundated to greater depths than the extended detention depth. The duration of any inundation should be relatively short (i.e. hours) and is unlikely to affect the vegetation in the bioretention system if the water can drain after flood events without scouring the filter media and batters and does not deposit excessive sediment on the surface of the filter media.

The footprint to meet detention requirements is generally larger than that needed for bioretention systems. The size and configuration of the detention area should therefore be carefully defined and integrated with the broader landscape. The detention area outside the bioretention system can be flat or sloped, depending on the site characteristics and proposed vegetation. The detention size should be established using modelling and calculations in accordance with local authority standards.

The following issues should be considered when combining detention with bioretention systems:

- Extended detention volume should not be included in the detention volume used to assess the performance of flood attenuation. The extended detention is drawn down via the filter media at a slower rate than the dedicated flood storage volume. This means the extended detention volume is not available for flood storage if a flood event closely follows a smaller rainfall event.
- Where a bioretention system is sized to meet the objectives for a catchment that is smaller than the total flood storage catchment, flows from the additional flood storage catchment greater than the peak 1-year Average Recurrence Interval (ARI) event should bypass the filter media. This will avoid overloading the filter media with sediment or excessive wetting.
- To minimise the risk of scour, the spread of flows greater than the peak 1-year ARI should be controlled by the flood storage outlet (i.e. backwater).
- To manage public safety risks, the peak 20-year ARI inundation depth should be no more than 1.2 m above the surface of the filter media in accordance with *QUDM* (Institute of Public Works Engineering Australasia, Queensland, 2017).
- Walls should not be used around the perimeter of the bioretention system to avoid a vertical drop that will be hidden when the detention storage is engaged.
- Unless an overriding landscape aesthetic dictates otherwise, the entire surface of the detention storage should be vegetated with trees, shrubs and understorey species in a manner consistent with the vegetation used on the filter media surface. Turf must not be used within the surface of the flood storage that will be inundated by the peak 1-year ARI water levels. This should be vegetated with appropriate plant species other than turf, as it will be frequently wet and mowing is likely to be difficult.

3.4.10 Bioretention in local and regional floodplains

This section relates to bioretention systems located in local and regional floodplains. For topics relating to co-locating bioretention systems within flood detention basins, refer to Section 3.4.9.

PERFORMANCE OUTCOMES

Where bioretention systems are located within local or regional floodplains, they must ensure that:

- storage and conveyance capacity of the floodplain are maintained
- design objectives and functionality of the bioretention system are not compromised during or after flood events.

RECOMMENDED APPROACH

Bioretention systems can be located within local and regional floodplains, provided the following risks are managed:

- Sediment should not be deposited on the surface of the bioretention system during flood events
- Flow over the bioretention system surface or adjacent batters or embankments should not erode the filter media, batters or embankments.
- Inundation duration should not threaten plant health.
- Movement of the waterway within the floodplain over time should not risk damage to the bioretention system.

Flood immunity and protection requirements for bioretention systems located within the floodplain are provided in Table 13.

Where a bioretention system is to be located adjacent to a geomorphically active waterway, a geomorphic assessment should be undertaken to confirm the safety and stability of the proposed treatment system.

Table 13. Flood immunity and protection requirements for bioretention systems located within the floodplain.

| | |
|---|---|
| Regional flooding (backwater flood with flow velocity < 1 m/s). | Top of embankment > 2-year ARI flood level (allow 200 mm freeboard) *. Inundation period < 24 hours for > 2-year ARI. |
| Local flooding (flooding within waterways and drainage lines). | Top of embankment > 2-year ARI flood level (allow 200 mm freeboard) *. |
| Flow velocities in adjacent waterways. | Embankments (external and internal) are designed to withstand flood velocities for all events up to the 100-year ARI. Allowance to be made for appropriately sized rock armour for flows above 1 m/s. |

*Where the bioretention system is to be located within the floodplain of a regional or local waterway known to carry high sediment loads (e.g. the Bremer River), the top of embankment flood immunity should be increased to at least the 10-year ARI flood level plus 200 mm freeboard.

3.5 Inlet design

The design of the bioretention system inlet dictates the amount of water that enters the bioretention system and how this occurs. It also influences whether the system will be prone to either sediment accumulation or scour and whether flows will be evenly distributed across the filter media surface. Bioretention inlet design requires careful consideration to ensure that these elements do not compromise the long-term operation of the bioretention system.

Bioretention inlet design should consider:

- the design inflows
- the inlet type
- coarse sediment removal

- energy dissipation and scour protection
- flow distribution in large bioretention systems.

3.5.1 Design inflows

PERFORMANCE OUTCOMES

Design inflow estimates must be accurate as they inform the design of both inlet and outlet components.

RECOMMENDED APPROACH

It is recommended that a number of design inflows be used for sizing hydraulic structures and coarse sediment removal measures for bioretention systems. Table 14 defines each design inflow and sets out its uses.

For small catchment areas of ≤ 10 ha, the Rational Method as described in *QUDM* (Institute of Public Works Engineering Australasia, Queensland, 2017) is generally appropriate for determining design inflows. However, local authority requirements for rainfall-runoff assessment should be adopted where available. Where detailed hydrologic modelling is available, it should be used to estimate flows.

For large catchment areas of > 10 ha or where a bioretention system forms part of a flood detention basin, a runoff routing model should be used to estimate peak flow rates, using an appropriate method of validation against simplified methods (such as the Rational Method) as required by the local authority.

Flood modelling should be used to ensure the design criteria in Section 3.4.9 are satisfied for bioretention systems located within a flood detention basin.

DESIGN NOTE: Design flows in pipe drainage network

When designing bioretention basins at the outlet from a pipe drainage network, it is important to check if the pipe drainage has been designed to the local authority 'minor' drainage requirements or if it has been upsized to carry a portion of the major storm flow also (i.e. where surface flow depth or width is exceeded during the major storm, the underground pipe drainage may have been increased to alleviate this).

Actual drainage design capacity (and discharge velocities) should be used in the design of inlet/outlet structures and scour protection in bioretention basins.

DESIGN NOTE: Drainage network upstream of bioretention systems

When designing new or retrofit bioretention systems, consideration should be given to how the extended detention depth and maximum water level will impact the hydraulic grade line within the upstream drainage network.

DESIGN NOTE: Locating systems offline from large flows

It is generally desirable to locate bioretention systems offline from large flows, with only design treatment flows directed to the bioretention systems. This is not achievable in all situations. Where systems are located online, it is particularly important that all requirements of the following sections, including scour protection, energy dissipation and flow distribution, be met.

Table 14. Design inflows and their uses.

| Design inflow | Uses |
|--|--|
| Maximum flow that will enter the bioretention system during the peak major storm event as defined by local authority (e.g. 50-year ARI). | <ul style="list-style-type: none"> • Overflow weir design. • Setting embankment levels. • Scour velocity check. |
| Maximum flow that will enter the bioretention system during the peak minor storm event as defined by local authority (e.g. 2-year ARI). | <ul style="list-style-type: none"> • Overflow pit design. • Setting overflow weir height. • Scour velocity check. |
| Peak 1-year ARI. | <ul style="list-style-type: none"> • Inlet pond design. |
| Peak 3-month ARI. | <ul style="list-style-type: none"> • Coarse sediment forebay design. |

3.5.2 Inflow type

The site layout, levels and adjoining land use will dictate the most appropriate method for delivering stormwater to a bioretention system. Stormwater may be discharged directly from a drainage network (e.g. end-of-pipe system) or as a low-flow diversion from a nearby drainage system or kerb.

Inflows to bioretention systems mainly come from:

- pipe flow
- concentrated surface flow
- distributed surface flow.

This section provides design guidance for inflows from these inflow types. The performance outcomes below apply to all three types. The recommended approach for each inflow type is specified in Sections 3.5.2.1 to 3.5.2.3.

Stormwater may also be directed to bioretention systems via diversion or surcharge structures. Diversion or surcharge structures are often associated with retrofitting bioretention systems, where pipe or surface inflow to a bioretention system is not feasible. The design of diversion and surcharge structures should comply with local authority drainage design standards. The design should also consider upstream hydraulic impacts within existing drainage, accumulation of sediment, litter and debris, maintenance access, and dewatering following runoff events.

PERFORMANCE OUTCOMES

The inlet of bioretention systems must:

- convey a sufficient proportion of the catchment runoff onto the surface of the bioretention system to enable performance objectives to be met
- be unlikely to block with debris
- not cause inappropriate upstream inundation
- ensure the filter media does not get clogged with excessive algal growth.

3.5.2.1 Concentrated surface or pipe inflow

RECOMMENDED APPROACH

Recommended design responses for concentrated inflows are:

- a sediment forebay, inlet pond or another form of pre-treatment (e.g. gross pollutant trap) unless the bioretention system only receives roof runoff or its catchment is less than 2 ha (further design discussion on coarse sediment removal is provided in Section 3.5.3)
- energy dissipation and scour protection at the inflow point or sediment forebay designed to prevent concentrated inflows from damaging the bioretention system

- inflow pipe or channel invert at or above the surface of the bioretention system (preferably 200 mm above) to prevent siltation or debris accumulation in pipes
- where an inlet pond is used, the inflow pipe invert should ideally be at the normal water level. The local authority should be consulted if the pipe invert is submerged below or elevated above the normal water level
- where the surrounding topography dictates that the system receives lateral flows down batters, a designated inflow point should be created with adequate erosion protection (e.g. swale or rock-lined channel)
- for large bioretention systems with a filter media area $\geq 400 \text{ m}^2$ flow distribution (see Section 3.5.7).

Structural elements such as forebays and rock protection can impact the landscape amenity of the bioretention system and should be concealed where possible.

3.5.2.2 Concentrated kerb inflow (streetscape bioretention systems)

RECOMMENDED APPROACH

Concentrated inflow to streetscape bioretention systems typically occurs via kerb inlets formed as cut-outs from the kerb alignment.

The kerb opening size will be determined by the location of the stormwater outlet, which can be either:

- **Side entry pit within the kerb and channel (preferred)** – where the bioretention overflows enter a conventional side entry pit immediately downstream of the inflow point, kerb openings to the bioretention system only need to be sized to convey the treatment flow (e.g. less than 1-year ARI). When the bioretention extended detention is full to the kerb invert level, stormwater bypasses the kerb opening to the downstream side entry pit. This bypass requires kerb openings immediately upstream of side entry pits. The minimum suggested opening width is 500 mm to minimise the risk of the opening becoming blocked by debris. The side entry pit should be designed in accordance with IPWEA-QNT SEQ D-063 or equivalent. An example of a kerb inlet and a side entry pit within the kerb and channel is shown in Figure 63.
- **Overflow pit within the bioretention** – where an overflow pit is located within a streetscape bioretention system, the overflow pit will typically form part of the minor drainage for the roadway. The kerb opening will therefore need to be sufficiently sized to convey the flow from a minor storm (2 – 10-year ARI, depending on local authority standards) to the overflow pit, while meeting the flow depth and width requirements of the adjacent roadway as determined by the local authority.

To promote flow from the kerb, the slope of an apron extending from the kerb invert into the bioretention system should be between 1 in 10 and 1 in 4. The flow can be further enhanced by locally depressing the kerb invert (in longitudinal profile) at a kerb opening. This should be designed in accordance with local authority requirements and take vehicle and bicycle safety into account.

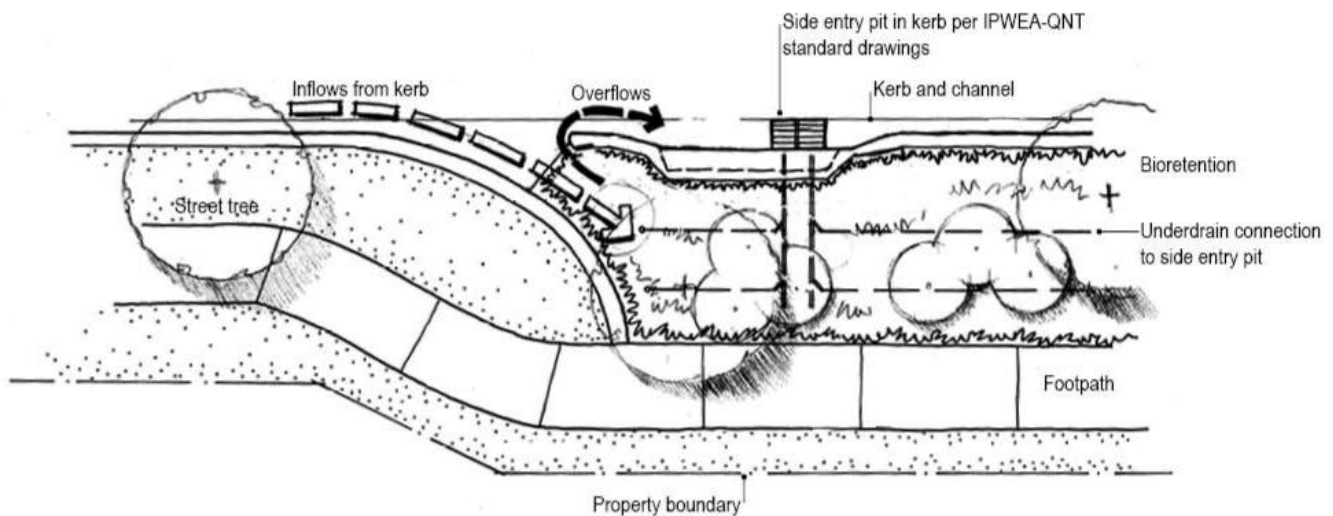


Figure 63. Kerb cut-out to streetscape bioretention system.

KERB OPENING IN SAG

To size the kerb opening width for sag locations and very low grade streets of < 1%:

- determine the depth and width of flow in the kerb at the inlet for the design flow required to enter the bioretention system using either Izzard's equation as described in *QUDM* (Institute of Public Works Engineering Australasia, Queensland, 2017) or road flow capacity charts, where available
- confirm that the flow depth and width limitations required by the local authority at the kerb opening location are met
- determine the length of kerb opening required for the flow depth in the kerb based on the broad-crested weir equation (Equation 4).

Equation 4

$$Q_{\text{weir}} = C_w \times L \times h^{3/2}$$

Where: Q_{weir} = design flow through kerb opening (m^3/s)

C_w = weir coefficient (1.66)

L = length of kerb opening (m)

h = depth of flow in kerb (m)

KERB OPENING ON-GRADE

Where the overflow pit is located within the bioretention system, and the inlet is on-grade (rather than in sag), the kerb openings should be located and sized using the same procedure for sizing on-grade minor drainage pit openings, as described in *QUDM* (Institute of Public Works Engineering Australasia, Queensland, 2017) or equivalent. Poorly designed streetscape bioretention systems can result in local flooding.

3.5.2.3 Distributed surface inflow (flush kerb or kerb breaks)

RECOMMENDED APPROACH

Flows may enter a bioretention system in a distributed manner via a flush kerb or regular kerb breaks (Figure 64). Distributed surface flows are typically associated with bioretention swales in road reserves and parkland areas where pavement runoff (from roads, paths or hardstand areas) directly enters a bioretention system as sheet flow over vegetated batters.

Standard drawings for flush kerbs are available from the IPWEA-QNT and many local authorities.

When designing streetscape bioretention systems with distributed surface inflows, it is important to:

- Promote lateral flow at the inlet to ensure that coarse sediment does not accumulate on the road or block the kerb breaks. Lateral flow should be achieved by using a minimum 1 in 6 concrete batter or a set down of 60 mm from the kerb edge to the top of the turf or mulch. This requires the finished batter topsoil surface (i.e. before turf or mulch) to be approximately 100 mm below the edge of pavement level to allow for turf or topsoil.
- Ensure an even distribution of flow. This is done by providing kerb breaks at least 500 mm wide and with a maximum spacing of 5 m. Scour protection may be required at the inflow points of kerb breaks.
- Provide suitable traffic management around flush kerbs.



Figure 64. Flush kerb to promote distributed flow into the bioretention system. Photo credits: Robin Allison.

3.5.3 Coarse sediment removal

To ensure that the deposition of coarse sediment on the filter media surface does not affect bioretention system function, bioretention systems should be designed with pre-treatment to limit the amount of coarse sediment reaching the filter media. Accumulating sediment in a dedicated area also makes maintenance simpler and more cost-effective. The following sections detail how to select the most appropriate pre-treatment method for the site, as well as methods for sizing both sediment forebays and inlet ponds.

DESIGN NOTE: The need for coarse sediment capture

The extent to which sediment capture is required for bioretention systems is a matter of debate. Some practitioners hold the view that coarse sediment isn't a risk to bioretention performance and thus coarse sediment capture prior to the filter media isn't necessary, while others maintain that bioretention systems regularly become completely blocked by sediment, and it is critical to capture it before it reaches the filter media. Clearly, these views are contradictory and cannot co-exist.

Based on the available evidence, Version 1.2 of this guideline takes the view that:

1. provided that bioretention systems are protected from construction phase sediment loads (refer to the *Water by Design Guideline for the Construction and Establishment of Bioretention Systems and Wetlands*), they are relatively resilient to ongoing sediment loads; and
2. nonetheless it is prudent to include dedicated sediment capture in most bioretention systems (refer to Table 15).

As a result, the recommendations for coarse sediment capture provided in previous versions of the guideline remain largely unchanged.

Users of this guideline are encouraged to contact Water by Design with data, observations or perspectives on this topic that may inform future direction.

3.5.3.1 Selecting the pre-treatment type

PERFORMANCE OUTCOMES

The pre-treatment type for the site and catchment must:

- ensure that deposition of coarse sediment on the filter media does not affect the performance of the bioretention system
- ensure the bioretention system integrates with the surrounding landscape
- allow for the bioretention system to be easily maintained.

RECOMMENDED APPROACH

Table 15 outlines the most appropriate coarse sediment removal methods for various catchment types and sizes. Consideration should be given to local authority requirements when specifying the coarse sediment removal method, as maintenance regimes or other requirements may prevent local authorities from accepting certain types of coarse sediment removal.

Table 15. Recommended coarse sediment removal methods.

| Catchment scenario | Coarse sediment removal methods |
|------------------------------|--|
| Roof runoff only. | None. |
| Catchment ≤ 2 ha. | Streetscape – 500 x 500 mm concrete pad (see Section 3.5.3.2). All other types – none*. |
| Catchment > 2 ha and ≤ 5 ha. | Vegetated swale, coarse sediment forebay, inlet pond or gross pollutant trap. |
| Catchment > 5 ha. | Inlet pond or gross pollutant trap. |

*Sediment accumulation at the point of inflow should be regularly assessed, and accumulated sediment should be cleared if it is blocking inlets or impeding infiltration.

3.5.3.2 Streetscape system sediment capture

PERFORMANCE OUTCOMES

Sediment capture at the inlet of streetscape systems shall allow for sediment to be easily cleaned out to avoid the inlet becoming blocked.

RECOMMENDED APPROACH

Where streetscape bioretention systems receive concentrated kerb inflows (see Section 3.5.2.2), a 500 x 500 mm concrete pad with a small slotted forebay wall shall be provided immediately adjacent the inlet to allow for easy removal of sediment, rubbish and leaf litter (see Figure 65).

Figure 65. Small sediment forebay in a streetscape bioretention system. Photo credits: Jack Mullaly

3.5.3.3 Sediment forebay design

PERFORMANCE OUTCOMES

Forebays must:

- remove 80% of particles that are 1 mm or larger in diameter from the peak 3-month ARI flow
- provide appropriate storage for coarse sediment to ensure desilting is required no more than once per year
- provide energy dissipation of incoming flows (refer to Figure 67 and Section 3.5.4).

RECOMMENDED APPROACH

Forebays should be designed in accordance with Figure 67 and by referencing local standards, such as the IPWEA-QNT Standard Drawings.

Forebays should be aligned lengthways in the direction of flow. This gives inflows additional time to dissipate energy prior to leaving the forebay and inhibits resuspension of captured sediment (see Figure 66). Achieving this may require consideration of the alignment of the inlet pipe relative to the system surface.

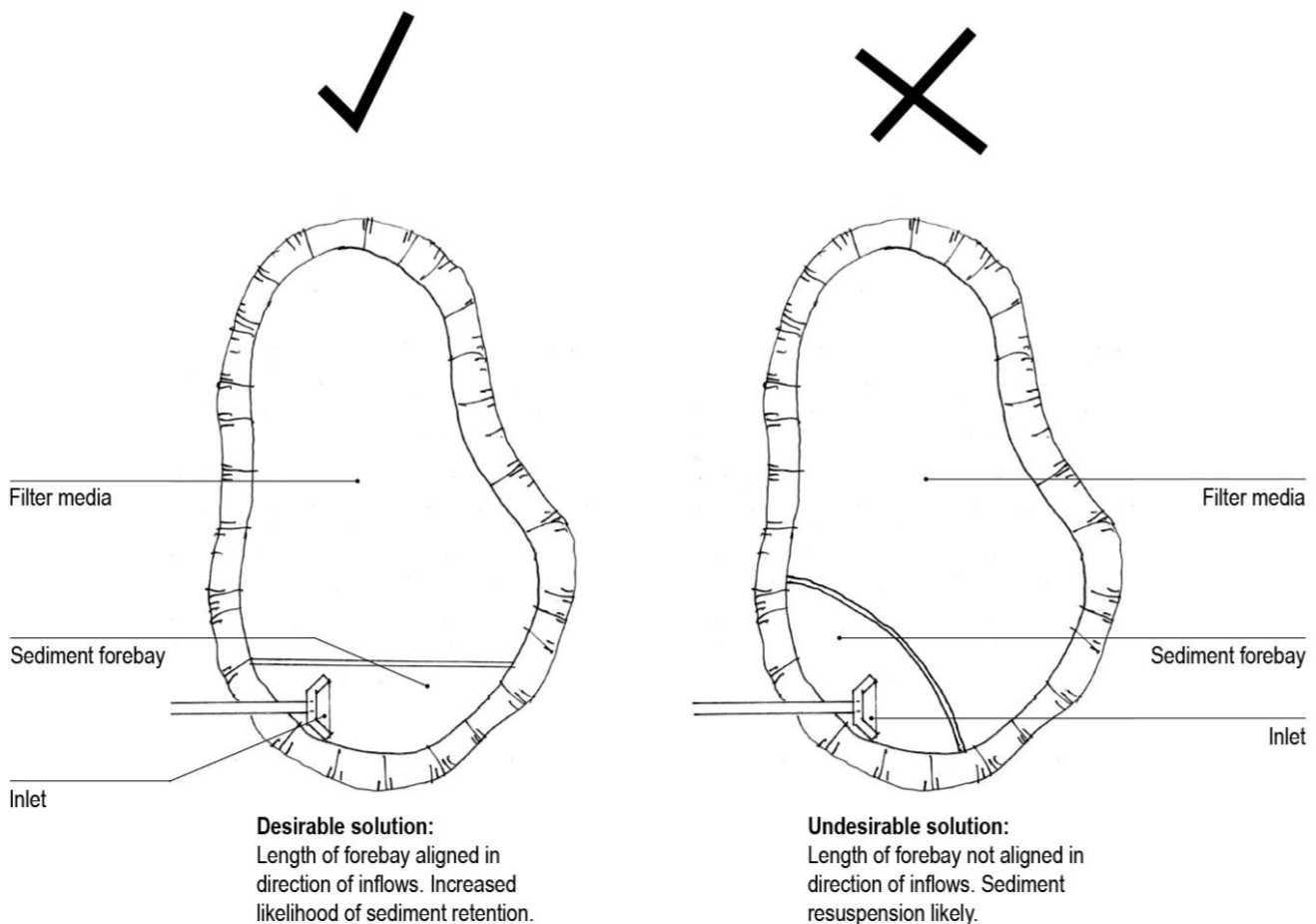


Figure 66. Forebay alignment.

Sizing of coarse sediment forebays is undertaken in three steps:

1. determine the sediment forebay volume
2. determine the sediment forebay area

3. determine the sediment forebay depth.

The minimum sediment forebay volume should be determined using Equation 5:

Equation 5

$$V_s = A_c \times R \times L_o \times F_c$$

Where: V_s = volume of forebay sediment storage required (m^3)

A_c = contributing catchment area (ha)

R = capture efficiency (0.8 recommended)

L_o = sediment loading rate ($m^3/ha/year$)

F_c = desired cleanout frequency (years)

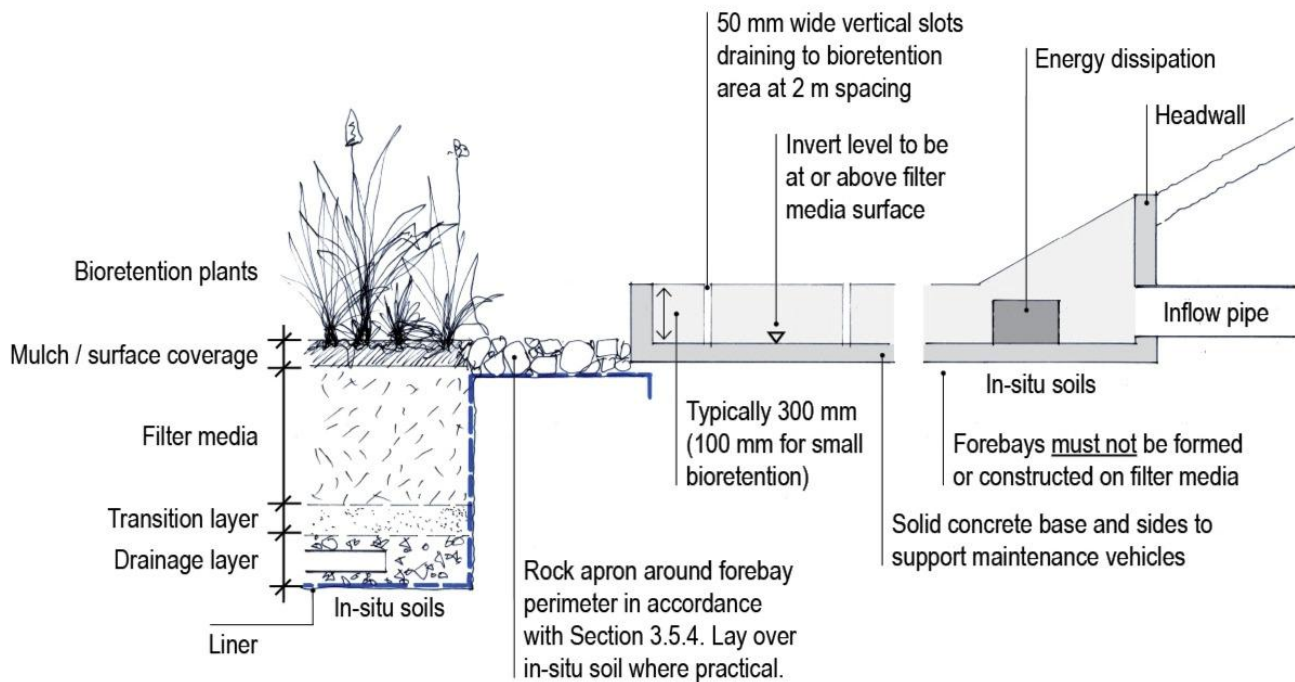


Figure 67. Coarse sediment forebay requirements.

If local data is unavailable, a catchment loading rate (L_o) of $0.6 m^3/ha/year$ is recommended. This rate is based on a review of sediment removal from gross pollutant traps (GPTs) in stable urban catchments in Brisbane. This review was commissioned by the South East Queensland Healthy Waterways Partnership in 2011.

The minimum forebay area for capturing the target sediment size (1 mm) can be determined using Equation 6 (modified from Fair and Geyer (1954)):

Equation 6

$$R = 1 - \left(1 + \frac{1}{n} \times \frac{v_s}{Q/A_f}\right)^{-n}$$

Where: R = fraction of target sediment removed (0.8 recommended)
 v_s = settling velocity of target sediment (0.1 m/s for 1 mm particle)
 Q = 3-month ARI flow rate (m³/s)
 A_f = minimum forebay area for sediment capture (m²)
 n = turbulence or short-circuiting parameter (0.5 recommended)

Preliminary depth for forebays can be established by dividing the minimum volume by the minimum area (see Equation 7). Forebays should be no more than 300 mm deep. Small forebays of <10 m² should preferably be 100 – 200 mm deep. If the minimum forebay area determined using Equation 5 results in a depth greater than these maximums, the forebay area should be increased to provide the required storage volume and an acceptable depth.

Equation 7

$$D_s = \frac{V_s}{A_f}$$

Where: V_s = minimum forebay volume for sediment storage (m³) from Equation 5
 A_f = minimum forebay area for sediment capture (m²)
 D_s = forebay depth (\leq 0.3 m)

To allow the forebay to freely drain, 50 mm wide vertical slots should be provided at 2 m spacing around the forebay wall. Where practical, slots should be located away from the primary flow path, preferably orientated at a right angle to the direction of flow, to prevent high flows from flushing sediment through slots. Circular weep holes are not recommended as they are prone to blockage.

3.5.3.4 Inlet pond design

PERFORMANCE OUTCOMES

Inlet ponds to bioretention systems must:

- remove coarse sediment by using a permanent water column to reduce flow velocities and promote settling
- regulate flows entering the bioretention filter media
- dissipate inflow energy
- allow for high flows to bypass the bioretention filter media
- provide appropriate storage for coarse sediment to ensure desilting is only required infrequently
- minimise safety risk
- provide visual amenity.

RECOMMENDED APPROACH

Inlet ponds should be used for large bioretention systems (> 800 m²) and for contributing catchments greater than 5 ha.

Inlet ponds are also recommended for systems where:

- large-diameter inlet pipes may compromise sediment capture within a forebay (pipes > 600 mm diameter)
- multiple pipes discharge to a single bioretention cell to avoid multiple forebays and access points
- improved flow distribution to multiple bioretention cells is required.

Inlet ponds should be designed in accordance with Section 3.4 of the *Wetland Technical Design Guidelines (Water by Design)* except where modified by this document.

As shown in Figure 68, inlet ponds should include:

- a high-flow bypass weir and channel
- connection from inlet pond to a bioretention system for small events only (e.g. less than 1-year ARI)
- provision to fully drain the sediment basin and/or bypass baseflows around downstream bioretention cells
- a system which ensures even distribution of flow to the bioretention system surface (refer to Section 3.5.6.1)
- maintenance access (refer to Section 3.4.6).

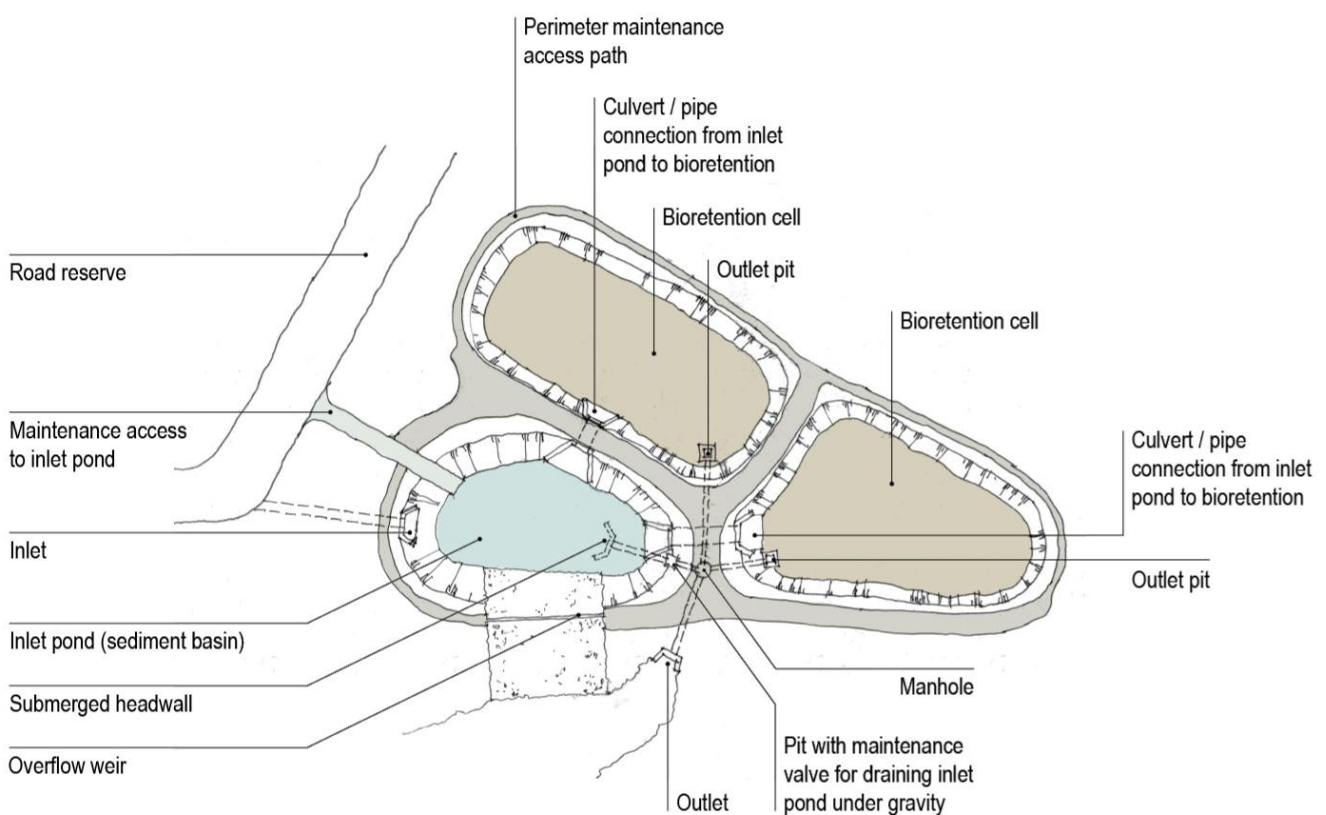


Figure 68. Key components of inlet ponds.

Inlet pond to bioretention connection – The *Wetland Technical Design Guidelines* provide options for the connection between the inlet pond and the wetland macrophyte zone. In the case of wetlands, the connection pipe/culvert discharges below the standing water level of the wetland. In the case of bioretention systems, this connection discharges onto the bioretention system surface and may be accompanied by a flow distribution system (see Figure 68 and Section 3.5.6.1).

Provision to fully drain the sediment basin – A pipe connection from at or near the base of the inlet pond to the downstream drainage via a pit in the bioretention embankment should be provided to allow the inlet pond to be drained under gravity. A valve should be provided within the pit in the embankment to allow this drain to be opened and closed (see Figure 69). In general, the valve should remain closed during normal operation and only be opened to drain the inlet pond for maintenance. Where a

baseflow into the system is identified, the valve can be partially opened to prevent baseflows from entering the downstream bioretention cells.

Inlet pond base – The base of the inlet pond must provide a hard, smooth and defined surface that cannot accidentally be damaged or over excavated during maintenance. It is recommended that the base of the system be made of cement-treated road base/rubble or unreinforced concrete. Reinforced concrete is also acceptable, but it is more expensive. Rock lining is not acceptable under any circumstances.

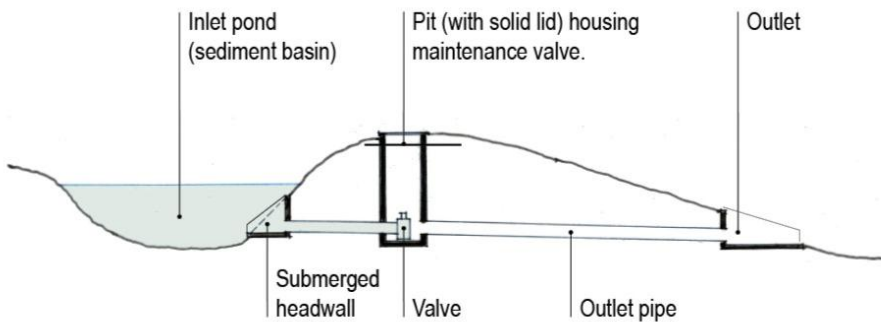


Figure 69. Sketch of the pipe connection to drain the inlet pond for maintenance.

3.5.4 Inlet energy dissipation and scour protection

Bioretention inlets require energy dissipation and scour protection to avoid damage to the filter media from inflows and to minimise the resuspension of coarse sediment collected near the inlet. The method to achieve this varies depending on whether inflow is received via a pipe, openings in the kerb or from distributed surface flow. The following performance outcomes apply to all three inlet types. The recommended approach for each inlet type is specified in Sections 3.5.4.1 to 3.5.4.3.

PERFORMANCE OUTCOMES

Energy dissipation and scour protection must:

- prevent filter media from scouring during a major storm event
- minimise resuspension of coarse sediment collected near the inlet.

3.5.4.1 Pipe inlets

RECOMMENDED APPROACH

Inflows to bioretention systems and inlet ponds usually require energy dissipation and scour protection to ensure that concentrated flow paths do not damage or destabilise vegetated batters or the filter media.

For inlet ponds, scour protection is typically limited to a rock apron at the headwall. Energy will dissipate as flows enter the deep water and velocities decrease. Incoming pipe inverts should be set as close as possible to the normal standing water level of the sediment pond to limit turbulence and resuspension of sediment and to maximise energy dissipation. Rock aprons and energy dissipaters should be designed in accordance with local authority requirements.

Where a sediment forebay is present, it will provide some protection against scour of the filter media, but energy dissipation should still be provided. A rock apron around the downstream perimeter of the forebay (see Figure 67) should help to protect further against scour. It should be designed in accordance with the advice on rock outlet pads in *QUDM* (Institute of Public Works Engineering Australasia, Queensland, 2017) or equivalent. The length of the forebay can be included in the total apron length.

Energy dissipation should be provided in accordance with *QUDM* (Institute of Public Works Engineering Australasia, Queensland, 2017).

Where no sediment forebay is present (i.e. for catchments < 2 ha as per Table 15), a rock apron and energy dissipation designed in accordance with the advice provided in *QUDM* (Institute of Public Works Engineering Australasia, Queensland, 2017) will be required.

3.5.4.2 Kerb openings

RECOMMENDED APPROACH

Kerb openings or cut-outs are typically used for streetscape bioretention systems, which have small catchments and low gradients and therefore low velocity surface drainage.

The size and length of the rock protection should be determined in accordance with the advice on rock outlet pads in *QUDM* (Institute of Public Works Engineering Australasia, Queensland, 2017) or equivalent, using the peak 1-year ARI flow depth at the entry in lieu of the inlet pipe diameter.

3.5.4.3 Distributed surface flow

RECOMMENDED APPROACH

Distributed surface flow typically has low flow velocities and therefore minimal requirements for energy dissipation or scour protection. Stabilised turf or densely vegetated zones are likely to provide sufficient protection.

Where a bioretention system primarily receives inflows from a pipe, the surrounding topography may dictate that the system receives lateral inflows down the batters. Where this occurs, a designated inflow point should be created with adequate erosion protection (e.g. swale or rock-lined channel).

3.5.5 Filter media scour velocity check

PERFORMANCE OUTCOMES

Bioretention system design must ensure that flows across the filter media surface do not cause scouring of the filter media or damage to plants.

RECOMMENDED APPROACH

In addition to scour at the interface of the inlet and the filter media (as discussed in Section 3.5.4), scour of the filter media can occur at other locations in bioretention systems.

A check of maximum velocities passing over the filter media surface should be undertaken by assuming inflows pass through the full width of the system at its narrowest point and dividing the flow rate by the area in accordance with Equation 8. Given that the outlet will generally be located near the inlet, this is a conservative approach, but it allows for a simple calculation method.

Equation 8

$$v = \frac{Q}{w \times d}$$

- Where:
- v = velocity of flow over filter media surface (m/s)
 - Q = flow rate in the design storm event (m³/s)
 - w = bioretention basin width at narrowest point (m)
 - d = depth of flow in accordance with Table 16 (m)

The bioretention system should be configured so that the maximum velocity across the filter media under minor and major storms (calculated using the flow depths in Table 16) is less than 1 m/s. This velocity limit is based on advice in Fischenich (2001) for surfaces covered in 'short native and bunch grasses'. Where more detailed information on flow depth for given design storms is available, this information can be used in lieu of the flow depths in Table 16.

Table 16. Scour velocity limits over the surface of the bioretention system.

| Design flow | Depth of flow over surface |
|----------------------------------|--|
| Minor storm (2 – 10-year ARI). | Extended detention depth ¹ + 0.1 m. |
| Major storm (50 – 100-year ARI). | Lesser of the bypass weir level ² + 0.1 m or the maximum water level ³ . |

- ¹ The extended detention depth is typically set by the crest of the outlet pit (except in the case of streetscape bioretention systems). See Section 3.6.2.
- ² The bypass weir level refers to the overflow weir. See Section 3.6.4.
- ³ For discussion of the maximum water level, refer to Section 3.3.3.4.

3.5.6 Baseflow management

Continual baseflows through either piped or surface drainage networks can lead to excessive algal biofilm growth on the filter media, which can clog the surface, preventing infiltration. This can be difficult (but not impossible) to identify prior to the design and construction of the system.

Where site analysis (see Section 3.2) finds a baseflow 10 days or more after rainfall, one of the following approaches should be used:

- bypass the baseflow around the filter media (only if the baseflow is good quality water or will be treated in another way)
- find and eliminate the source of the baseflow (e.g. fix a leaking pipe or remove a cross-connection)
- use an alternative treatment option (e.g. a constructed wetland).

The bypass method depends on whether a sediment basin is present upstream of the bioretention system:

- Sediment basin present (regardless of presence of baseflow) – refer to Section 3.5.3.4.
- Baseflow identified prior to design. No sediment basin present – refer to Section 3.5.6.1.
- Baseflow identified during or after construction – refer to *Maintaining Vegetated Stormwater Assets* (Water by Design).

3.5.6.1 Managing baseflows – no sediment basin present

PERFORMANCE OUTCOME

Where baseflows are identified prior to design, a method for bypassing baseflows around the filter media must be provided in the design.

RECOMMENDED APPROACH

Where a baseflow is identified, it should be bypassed into the underdrains as shown in Figure 70. A slotted PVC pipe must be installed adjacent and parallel to the edge of the forebay within the rock protection. It must be connected to the underdrains at the base of the system via a stop valve and unslotted PVC pipe. Where a forebay is not present, the slotted PVC pipe should be laid adjacent to the edge of the concrete apron at the inlet.

Once the filter media is installed, an iterative process can be used to open the stop valve sufficiently to bypass baseflows but not additional design flows.

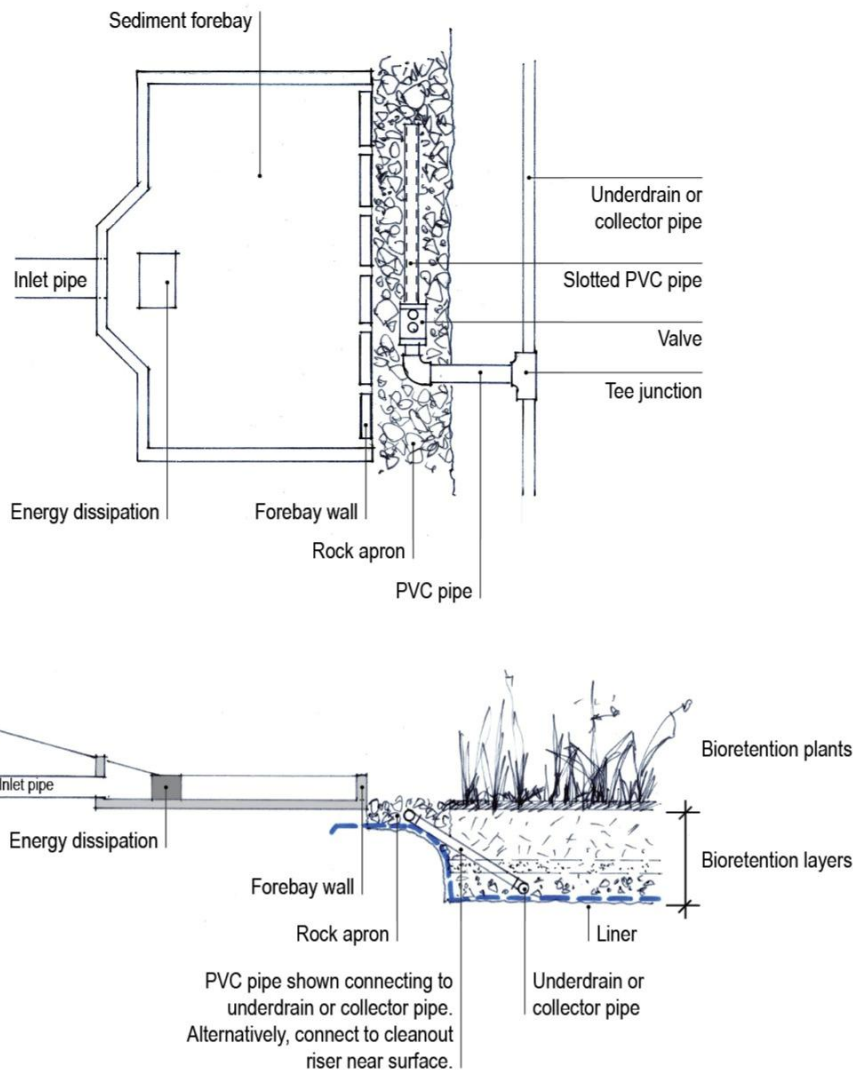


Figure 70. Bypassing baseflows to the underdrains

3.5.7 Flow distribution

Maintaining an even distribution of flow across the entire filter media area during small inflow events is a challenge for large bioretention systems. In large bioretention systems fed by a single inflow point, the area immediately downstream of the inlet will be wet more frequently than the area at the opposite end of the system, which may remain dry for extended periods.

As a result, the filter media closest to the inlet are likely to support healthy plant growth (due to frequent wetting) but will be continuously loaded with stormwater pollutants, which may result in filter media blockage or pollutant saturation. The filter media furthest from the inlet will be drier, and vegetation may die back, leading to reduced treatment performance in larger rainfall events.

To alleviate this situation, medium to large bioretention systems with a filter media area of > 400 m² should have a flow distribution system. Where a large bioretention system is split into cells (see Section 3.4.3.1), individual cells > 400 m² in size should have a flow distribution system. Refer to Table 17.

Table 17. Flow distribution requirements.

| Size of system | Flow distribution requirements |
|--|--|
| < 400 m ² | No flow distribution. |
| 400 m ² to 800 m ² | Flow distribution required. |
| > 800 m ² | System to be split into cells (see Section 3.4.3.1) with all individual cells ≥ 400 m ² to receive flow distribution. |

Flow distribution should be achieved by one of the following:

- multiple inflow points (see Section 3.5.7.1)
- distribution channels (see Section 3.5.7.2)
- level spreaders (see Section 3.5.7.3)
- where a sediment basin is located upstream of the bioretention basin, using a weir connection from the sediment basin into the bioretention system (see Section 3.5.7.4).

In all cases, flow distribution problems related to plant health are alleviated by using a Type 1 saturated zone system. In such systems, the water stored at the base of the system in the saturated zone is evenly distributed throughout the system (even when it initially infiltrated near to an inlet). This means it is evenly available to all plants and supports healthy plant growth throughout the system.

PERFORMANCE OUTCOMES

Flow must be evenly distributed across the bioretention filter media surface.

3.5.7.1 Multiple inflow points

RECOMMENDED APPROACH

Providing multiple inflow points for bioretention systems helps to distribute flows along the length of the system (provided that those inflow points are evenly spaced around the system).

To achieve flow distribution in large bioretention systems, inlets must be provided at the following frequencies:

- For Type 1 saturated zone systems – a minimum of 1 inlet per 400 m² of filter media.
- For all other types of systems – a minimum of 1 inlet per 200 m² of filter media.

Where multiple inflow points are used for flow distribution, each inflow point must deliver a similar amount of flow to the system. For example, an 800 m² saturated zone system should have a minimum of 2 inlets, each delivering roughly half of the total volume of flows to the system.

Each inflow point must adhere to the requirements of this guideline for (but not limited to) coarse sediment removal, scour protection, energy dissipation and maintenance access.

3.5.7.2 Distribution channels

RECOMMENDED APPROACH

Distribution channels (see Figure 71) can be used to evenly distribute flows throughout the length of a bioretention system. They are generally comprised of a channel and trough (e.g. an upturned box culvert) with cut-outs every 5 m to allow water to flow onto the system surface. Rock scour protection must be present at all cut-outs.

Distribution channels are located along the edge of the bioretention filter media, with maintenance access provided immediately adjacent to the channel for their entire length (see Section 3.4.6.1).

Distribution channels must be located downstream of a form of sediment capture (sediment basin, sediment forebay, gross pollutant trap, etc.) to reduce the risk of the distribution channel becoming blocked. Consideration must be given to the behaviour of flows if the distribution channel were to block.

Where a bioretention system is < 10 m wide, a distribution channel along only one edge of the system is required. Bioretention systems \geq 10 m wide require a distribution channel along both sides of the system. This allows for the entire filter media surface to be within 10 m of a distribution channel.

Maintenance access for flow distribution channels is described in Section 3.4.6.1.



Figure 71. Distribution channel. Photo credits: Shaun Leinster.

3.5.7.3 Level spreaders

RECOMMENDED APPROACH

Level spreaders (see Figure 72) distribute flows evenly across the width of a bioretention system but are less effective at distributing flows along the length of the system. If using level spreaders for flow distribution in large bioretention systems, they must be paired with a Type 1 saturated zone system to ensure sufficient water availability to plants furthest from the inlet.

Level spreaders should be located near the system inlet and span the entire width of the system. They must be keyed into the batters/bunds at either end.

Level spreaders are typically made of concrete. They should be placed on in-situ soil (not the filter media) with the concrete mass of the spreader extending into the in-situ soil. This inhibits water, undermining the level spreader. The surface of the level spreader must be completely flat.

Consideration must be given to how the invert of the level spreader will drain between rainfall events. Low permeability in-situ soils, a deep invert upstream of the level spreader or baseflow entering the system may leave this area prone to standing water between rainfall events. The level spreader should be designed to avoid this.

Level spreaders must be provided with maintenance access to their invert to the same standard provided for coarse sediment forebays (see Section 3.4.6.1).



Figure 72. Level spreader. Photo credits: Jack Mullaly.

DESIGN NOTE: Level spreaders and coarse sediment forebays

Many bioretention systems contain a coarse sediment forebay. Where a coarse sediment forebay is present, including a level spreader is undesirable as it is an unnecessary duplication of infrastructure. Coarse sediment forebays can be configured to span the width of the bioretention system and thus behave in much the same way as level spreaders. In this situation, small rainfall events leave the forebay via the cut-outs in the forebay wall, while high flows overtop the forebay wall in a distributed manner along its length.

3.5.7.4 Weir connection from sediment basin

RECOMMENDED APPROACH

Where a sediment basin is present upstream of the bioretention basin, a weir can be used to distribute flows evenly onto the bioretention system surface (see Figure 73).

Depending on the configuration of the sediment basin, weir and bioretention basin, the weir may distribute flows evenly across the entire surface of the bioretention system. However, if the bioretention basin is long and narrow, and the weir discharges to the narrow end of the bioretention system, flow distribution will not be even along the system's length. In this instance, the weir must be paired with a Type 1 saturated zone system to ensure sufficient water availability to plants furthest from the inlet.



Figure 73. Weir connection from sediment basin to bioretention. Photo credits: Shaun Leinster.

3.6 Outlet design

Bioretention system outlets serve multiple purposes, including setting the extended detention depth, discharging treated flows via the underdrainage and conveying above design flows to the receiving environment. Outlets should also ensure that the bioretention system does not exacerbate flooding nor allow stormwater to overtop bioretention system bunds and embankments. They must be able to manage a range of flow rates.

Bioretention outlet design must consider:

- bioretention outlet components
- underdrainage pipe layout, material and sizing
- overflow pit design
- overflow weir design
- outlet pipe design
- connection of the bioretention system to the receiving environment
- flood storage objectives.

Bioretention system outlet components and their associated design flows are shown in Figure 74 and detailed in Sections 3.6.1 to 3.6.6.

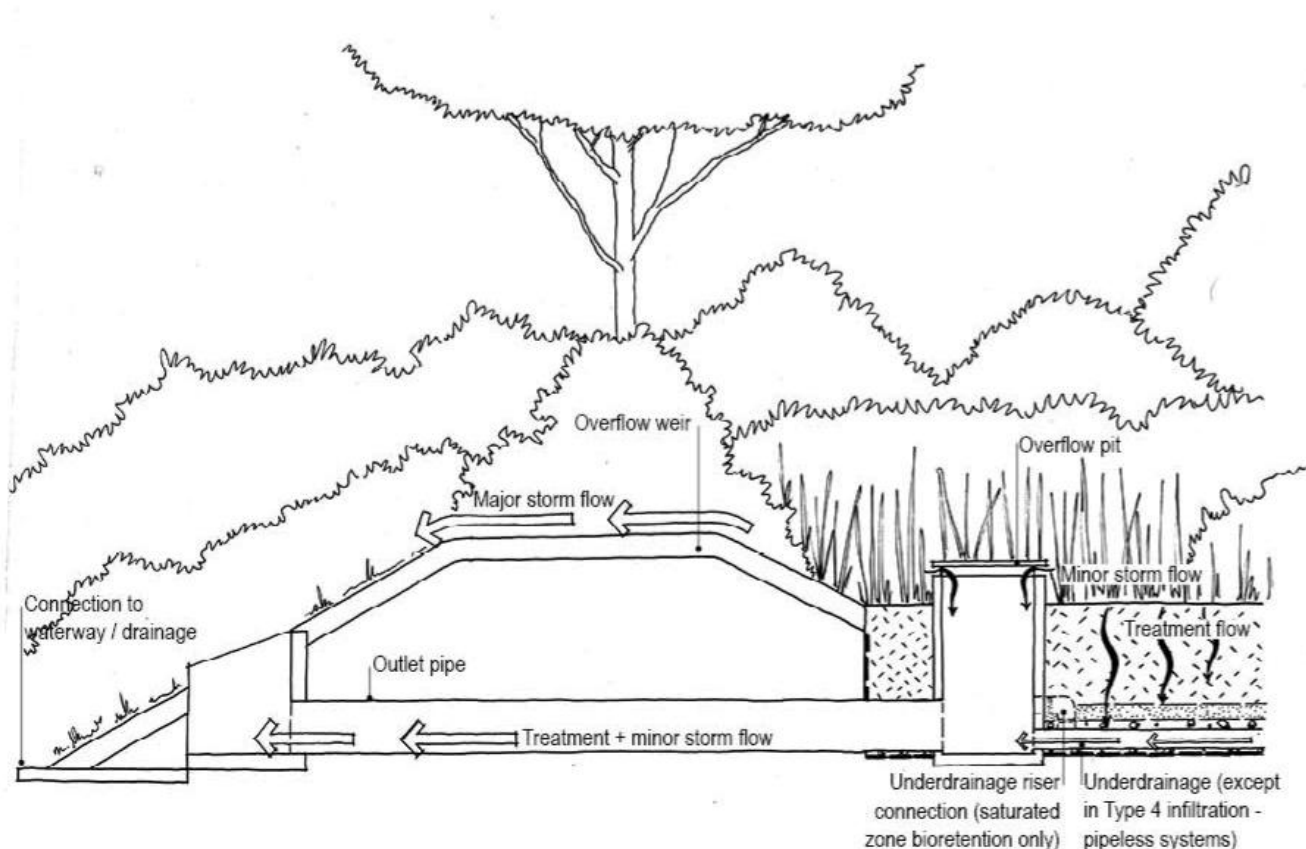


Figure 74. Bioretention outlet components and design flows.

3.6.1 Underdrainage pipes

This section outlines the methods to design bioretention system underdrainage pipes. It does not apply to Type 4 infiltration – pipeless bioretention systems, as they do not have underdrainage pipes.

The design of bioretention system underdrainage pipes involves:

- specifying the underdrainage network components and layout

- selecting the pipe material
- designing the saturated zone underdrainage riser
- sizing the underdrainage pipes.

It should be noted that two methods for sizing underdrainage pipes are provided in the following sections. The general approach to sizing underdrainage pipes (Section 3.6.1.4) can be used for Type 1, 2A, 2B and 3 bioretention systems. It sizes underdrainage pipes based on a detailed calculation of head losses through the underdrainage network. A simplified conservative approach to sizing underdrainage pipes is outlined in Section 3.6.1.7. It can be used for Type 2A traditional sealed and 2B traditional unsealed bioretention systems.

PERFORMANCE OUTCOMES

Underdrainage pipes must:

- meet local authority requirements
- not restrict flow rates through the filter media
- ensure access for inspection and cleaning
- prevent drainage layer material from entering slots
- be appropriate for the selected drainage profile
- be appropriately sealed into the outlet pit.

3.6.1.1 Underdrainage pipe network components and layout

RECOMMENDED APPROACH

Underdrainage pipes collect treated stormwater from a gravel drainage layer at the base of the bioretention system and convey it to the outlet or overflow pit. Key components of underdrainage pipe networks are illustrated in Figure 75.

The layout of underdrainage pipes must consider:

- the location of the outlet pit (refer Section 3.4.4)
- the maximum length of the slotted or perforated underdrainage pipes
- the use of collector pipes
- connections between underdrainage and collector pipes
- inspection and cleanout points.

Figure 76 illustrates various underdrainage pipe configurations. The most appropriate underdrainage pipe design for a specific site often requires multiple iterations to optimise the layout and hydraulic conveyance.

Where pipes of two different sizes are to be connected (e.g. a 225 mm collector pipe and a 100 mm slotted underdrain), consideration must be given to how the smaller pipe will sit flush to the base of the system. This is typically achieved either through the use of eccentric reducers or by digging the larger pipe into the base of the system (Figure 77).

In previous versions of this guideline, it was recommended that vertical solid pipe sections be used to create inspection or cleanout points at the end of every slotted or perforated pipe, as well as at the ends of collector pipes. This version of the guideline takes a different approach.

Underdrainage inspection and cleanout points are regularly damaged in bioretention systems, even when protected by massed concrete or similar. When they are damaged, they allow water to bypass the bioretention filter media, substantially reducing treatment performance. Damaged cleanout points are difficult to identify and repair. Simultaneously, it is rare for well-constructed bioretention systems to require their underdrainage to be flushed in a manner that could not be achieved via the outlet pit.

It is therefore now recommended that inspection and cleanout points be provided at the ends of all collector pipes, but not on the ends of slotted or perforated underdrainage pipes. Where a bioretention

system contains no collector pipe and five or fewer slotted or perforated underdrainage pipes, inspection and cleanout points should be provided at the ends of all pipes.

Cleanout and inspection points of collector pipes should be the same diameter as the pipe they connect to. They should extend at least 150 mm above the surface of the filter media to ensure they can be found when vegetation is established. A screw cap should be placed on the end of the riser pipes and secured in place with a locking mechanism. Refer to local standard such as the IPWEA-QNT Standard Drawings, when designing inspection and cleanout points.

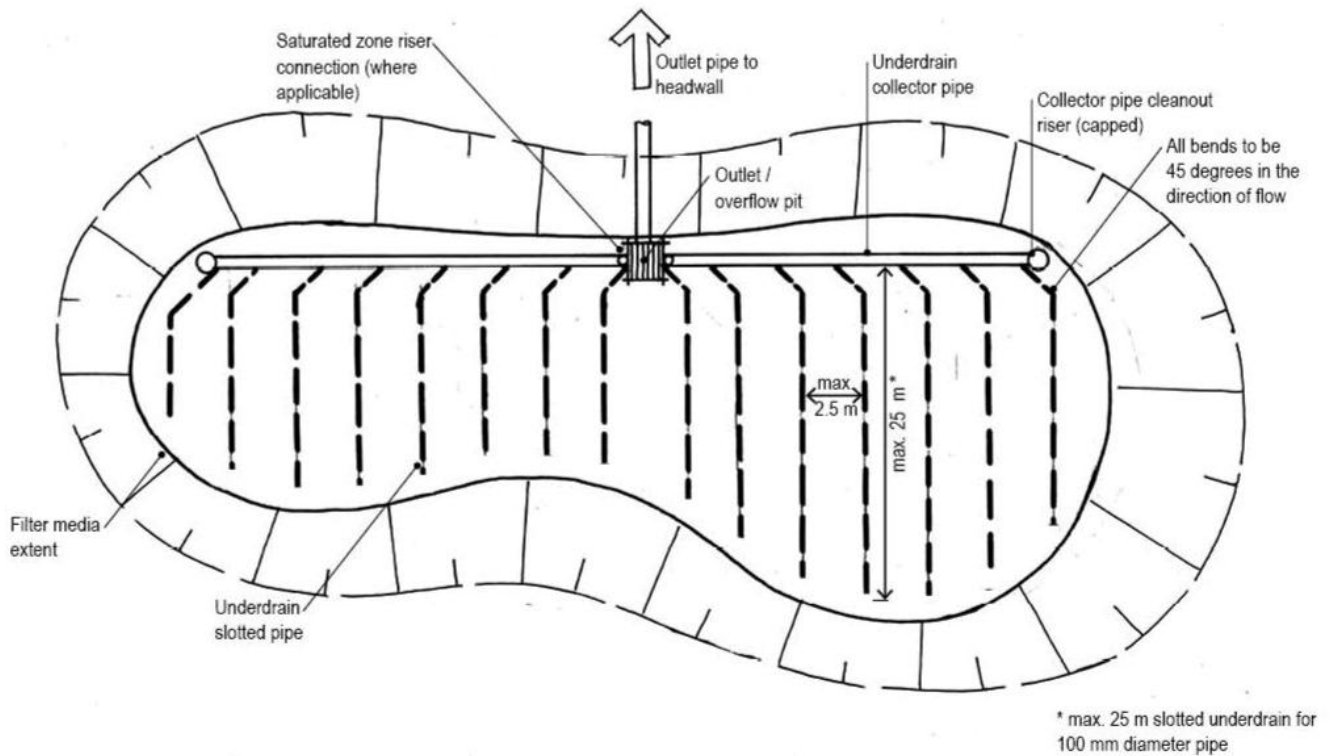
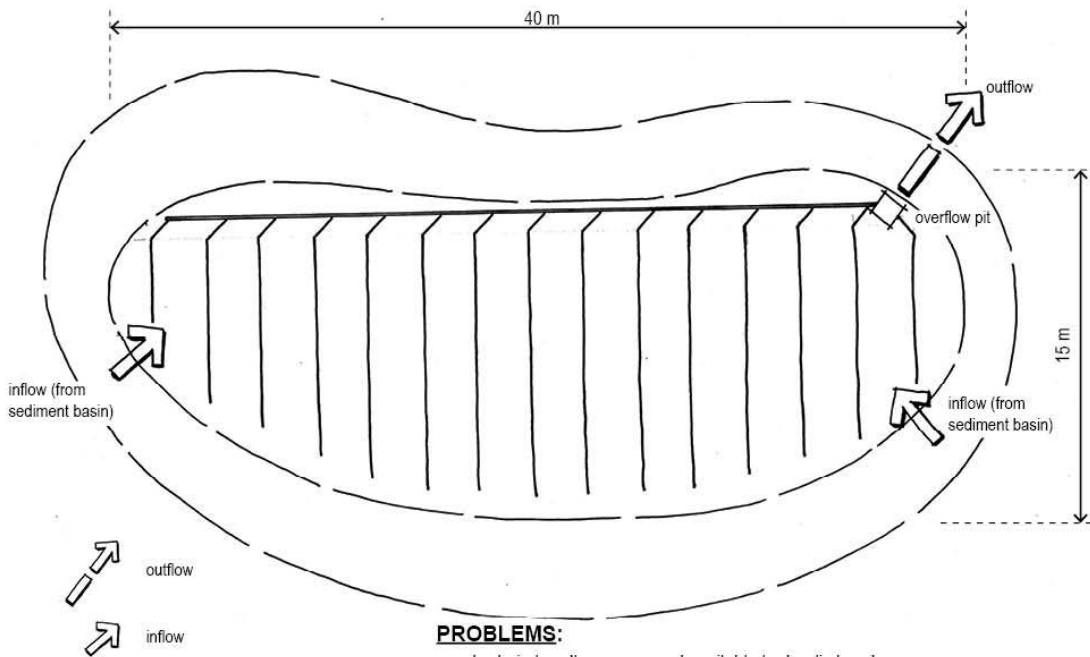
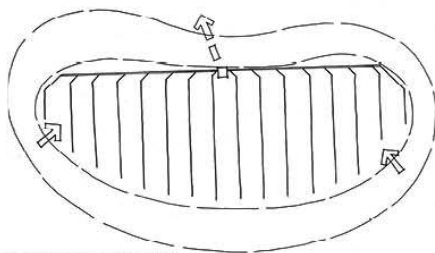


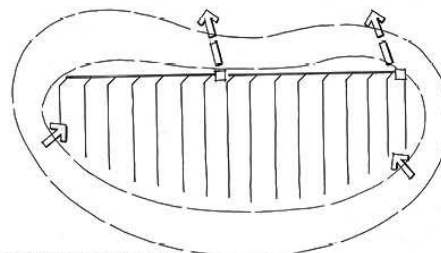
Figure 75. Underdrainage components.



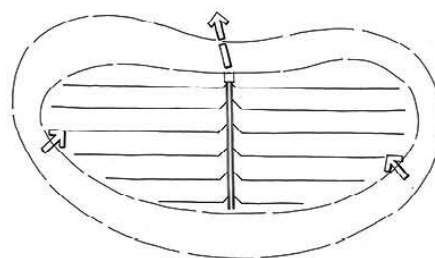
Initial Layout



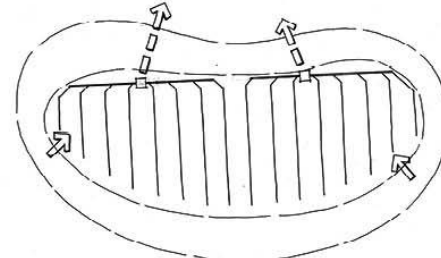
Design Solution 1



Design Solution 3



Design Solution 2

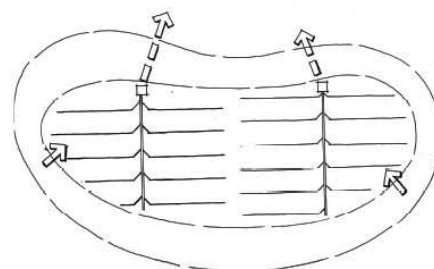


Design Solution 4

DESIGN SOLUTIONS:

- reduce pipe lengths (collector or underdrains)
- minimise pipe lengths to reduce elevation change and / or headloss
- increase number of overflow pits / connection points

The optimum arrangement can only be determined through checking design levels and hydraulic calculations.



Design Solution 5

Figure 76. Underdrainage layout variations.

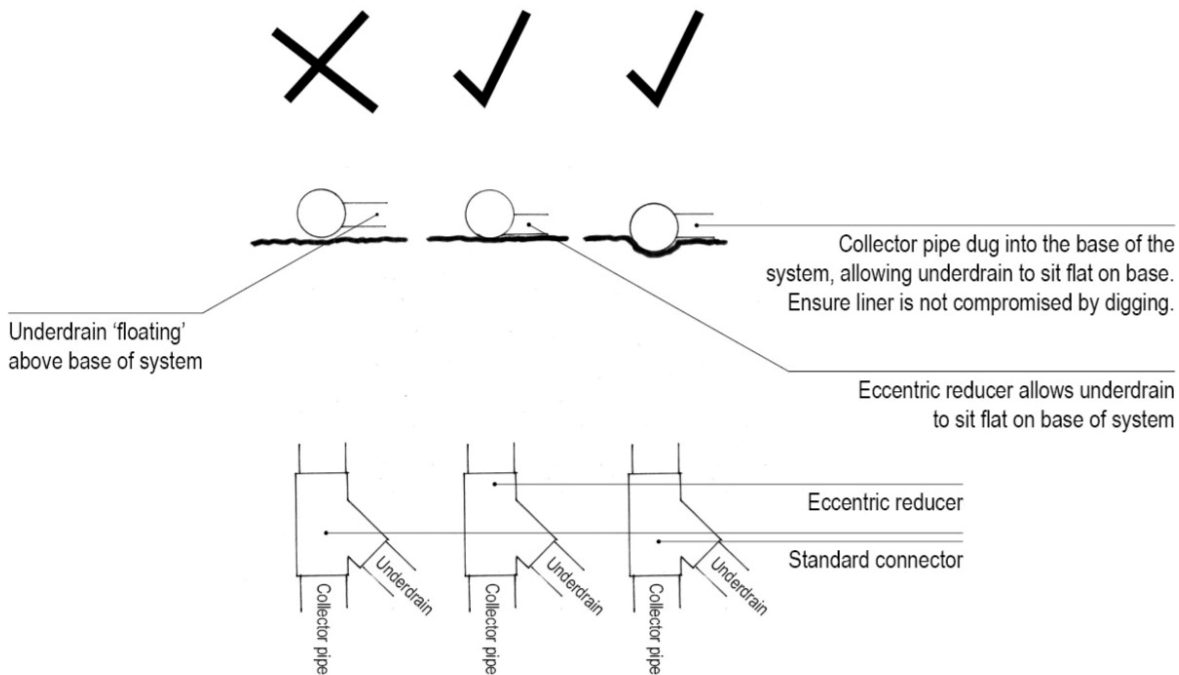


Figure 77. Connecting underdrainage pipes of different sizes.

3.6.1.2 Pipe material selection

RECOMMENDED APPROACH

Either a slotted rigid pipe or a flexible perforated corrugated pipe can be used for underdrainage. Table 18 summarises the features of slotted rigid pipes and flexible corrugated pipes. A flexible pipe may be more appropriate where the shape of the bioretention system requires the pipe to turn a number of times. Pipes should not be wrapped in a filter sock (or equivalent) because it poses a clogging risk. For example, ag-pipe is often supplied with a filter sock that should be removed. Slots and perforations must be no more than 2 mm wide.

Table 18. Underdrainage materials.

| Feature | Slotted rigid pipe | Flexible corrugated pipe |
|---------------------------------|---|---|
| Rigidity. | Pipe grade is not affected by local depressions in the bioretention base. This makes it easy to achieve a 0.5% grade towards the overflow pit if a grade is required by the design. | Pipes tend to follow the final profile of the base of the bioretention system (including local depressions), making it difficult to create a constant grade to the overflow pit. There is also a risk of local ponding within the pipe. |
| Ease of connection and sealing. | Standard plumbing for rigid pipes makes connecting and sealing pipes simple. | Connecting flexible corrugated pipe can be more difficult and may require a substantial amount of sealant. |
| Internal pipe surface. | The smooth surface is free-draining and does not hold water for a significant period after rain, minimising the potential for tree roots to enter the pipes in search of water. | The corrugated surface is more likely to retain beads of moisture inside the pipe, increasing the potential for tree roots to enter the pipes in search of water (in Type 2A, 2B or 3 bioretention systems*). |

| | | |
|--------------|---|--|
| Maintenance. | There is little resistance to flushing accumulated sediment and debris from rigid pipe. | Corrugations and the flexibility of the pipe make it harder to dislodge and flush sediment and debris. |
| Slot size. | Wider slots are less likely to block. Slots to be no more than 2 mm wide. | More slots, but narrower perforations can block easily. Perforations to be no more than 2 mm wide. |
| Resilience. | Brittle, so the damage is irreversible. | Flexible, so more resilient to rough handling. |
| Cost. | More expensive. | Cheaper and easier to handle. |

* In 2011, a video inspection of the underdrainage in an at-the-time 10-year-old bioretention system with extensive tree planting found a negligible amount of tree roots in the flexible corrugated underdrainage pipes. The base and sides of this system are lined with a permeable liner. The drainage profile operates in a similar way to a Type 2B traditional unsealed bioretention system. At the time of the release of this version of the guideline, the system is now 24-years old and continues to drain.

3.6.1.3 Pit connection – non-saturated zone systems

RECOMMENDED APPROACH

The underdrainage in Type 2A, 2B and 3 bioretention systems shall be connected to the outlet pit as shown in Figure 78.

In particular:

- a watertight seal must be achieved
- the underdrainage pipe should extend 100 mm into the outlet pit to allow a temporary upstand to be connected if needed (refer to Section 3.6.1.5)
- a downpipe protector or similar should be installed above the underdrainage connection to prevent it from being damaged (e.g. by kids throwing rocks into the outlet pit).

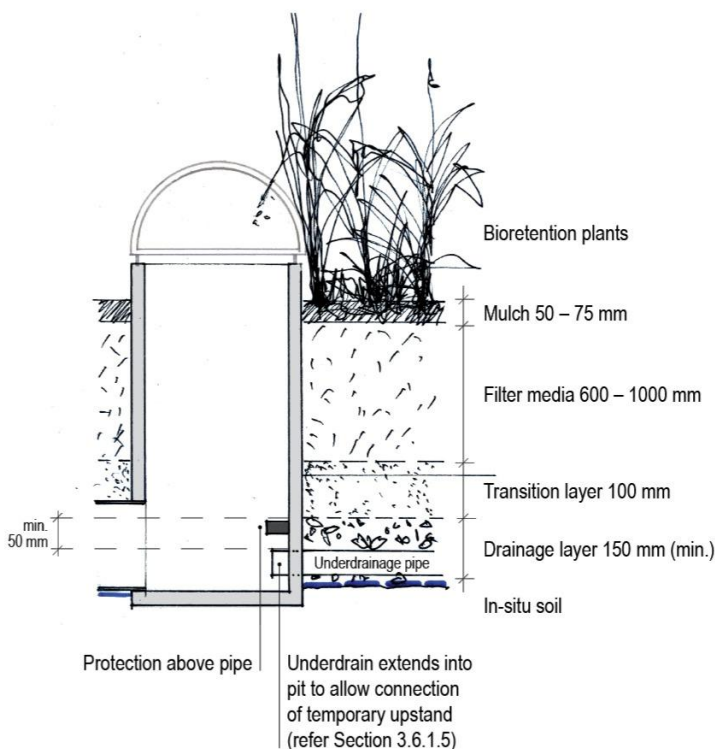


Figure 78. Non-saturated zone underdrainage connection.

3.6.1.4 Pit connection and riser – saturated zone systems

RECOMMENDED APPROACH

The method for connecting the saturated zone underdrainage pipes to the outlet pit is critical for maintaining saturated zone water levels. Three underdrainage connection options for saturated zones are shown in Figure 79. The saturated zone is created through a watertight seal at the pit and either a weir wall (option 1) or a riser (options 2 and 3).

A maintenance drain at the saturated zone base (e.g. pipe with a screw cap) will allow dewatering for maintenance. Screw caps are recommended on maintenance flushing pipes because they are significantly cheaper than sluice valves. Note that in all cases where the underdrainage connects to the outlet pit, the underdrainage should extend 100 mm into the pit to allow a temporary upstand to be attached if needed (refer to Section 3.6.1.5).

Option 1 is preferred because it allows the saturated zone to be drained under gravity if required and is also more resilient to damage (e.g. kids throwing rocks into the outlet pit to break riser pipes).

All saturated zone outlet options will have a small area of potential mosquito breeding habitat, but the potential for breeding at the outlet is insignificant compared to other habitats typically found in urban areas. Where this is of particular concern, option 2 can be used as this type of connection creates less habitat than option 1 while still allowing the saturated zone to be drained under gravity.

Option 3 should be used in space-constrained sites only to reduce the depth of the drainage profile from the filter media surface to the invert of the outlet pipe.

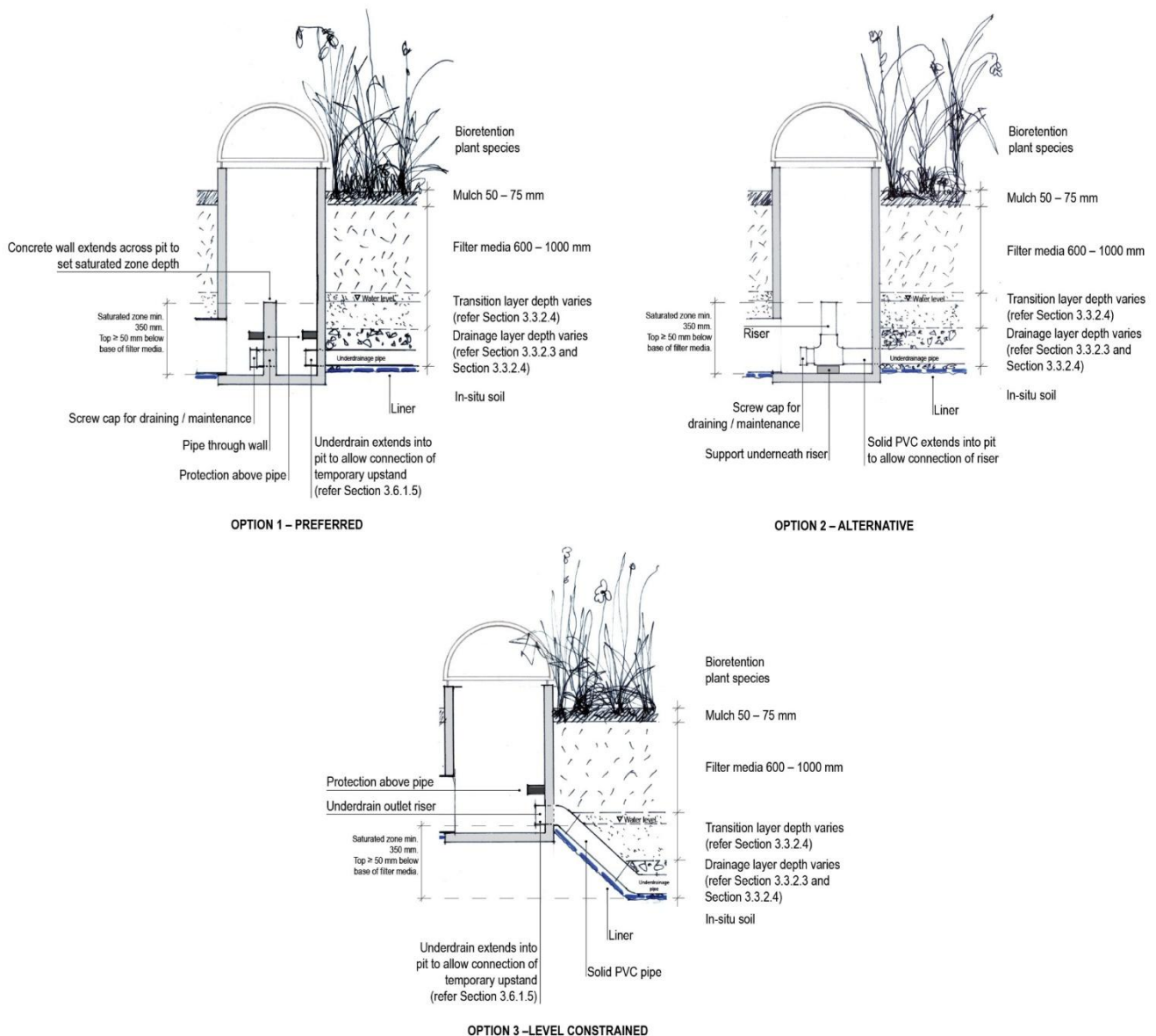


Figure 79. Saturated zone underdrainage riser connection options.

DESIGN NOTE: Saturated zone riser configurations shown in previous versions of the guideline

Previous versions of this guideline showed two additional underdrainage riser connection options for Type 1 saturated zone systems. These options were unnecessarily complex and provided no additional benefits relative to the options presented above and have thus been removed from this version of the guideline.

3.6.1.5 Temporary upstand – plant health

RECOMMENDED APPROACH

Rapid establishment of dense plant coverage in bioretention systems is important because:

- desirable species suppress weed growth

- treatment performance is closely linked to plant coverage
- plants help to maintain filter media porosity
- plants are critical to the aesthetic outcome of the system.

Plant establishment has traditionally been supported by watering, but this can be costly and intensive. A highly effective alternative is the use of a temporary upstand attached to the underdrainage pipes in the outlet pit (Figure 80).

The use of a temporary upstand varies depending on the drainage profile of the bioretention system:

- Type 1 saturated zone systems – Temporarily increases the depth of the saturated zone, making water more easily accessible to young plants.
- Type 2A traditional sealed systems – Temporarily creates a saturated zone in the system, making water more easily accessible to young plants.
- Type 2B traditional unsealed systems – Depending on the hydraulic conductivity of in-situ soils, may make additional water accessible to the plants as they establish.
- Type 3 infiltration – with pipe – Generally not used for this type of system because they are used on soils with moderate infiltration rates. Water won't be stored long in the case of these systems.
- Type 4 infiltration – pipeless systems – Not used for this type of system, as pipeless systems are only used on soils with high infiltration rates. Water cannot be stored in the base of these systems.

The use of the temporary upstand will reduce or possibly eliminate the need for watering during the plant establishment phase.

Where a temporary upstand is used, it is installed shortly before the system is planted. Initially, the top of the upstand is left 150 mm below the surface of the filter media. Over the course of 6 to 12 months, as plants establish, the upstand is gradually cut down to encourage plant roots to follow the water deeper into the filter media. Eventually, in Type 2A and 2B systems, the upstand is removed entirely. In Type 1 systems, it is reduced to the final saturated zone level (see Section 3.3.2.4).

Installing a temporary upstand requires the underdrainage to extend 100 mm into the outlet pit to provide a surface to connect the upstand to (refer to Section 3.6.1.3 and Figure 78).

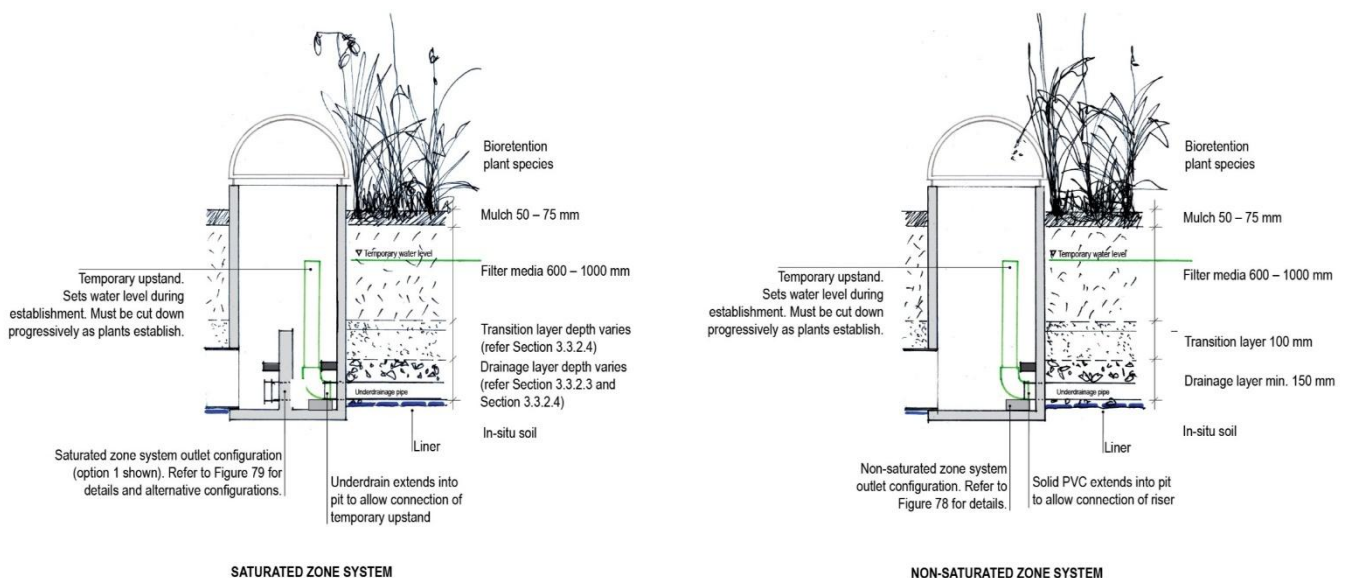


Figure 80. Temporary upstand arrangements.

3.6.1.6 General approach to sizing underdrainage pipes

RECOMMENDED APPROACH

A hydraulic head is required to drive water through underdrainage pipes.

Underdrainage pipes should be sized appropriately to:

- allow the filter media to drain at its designed hydraulic conductivity or greater
- allow the performance outcomes for the bioretention system to be met.

Poorly designed or undersized underdrainage can cause water to back up within the bioretention profile and reduce the effectiveness of the system.

Figure 81 demonstrates how, for a given outlet riser crest level, the depth (and duration) of water temporarily held above the defined level of the saturated zone is controlled by:

- the depth of water spilling from the riser
- head loss through the underdrainage.

If either of these factors is excessive (e.g. from undersized pipes), the system will not drain efficiently.

The general approach to sizing underdrainage pipes, therefore, aims to ensure that the hydraulic head required to drive water through the underdrainage (i.e. the depth of water spilling from the riser plus the head loss through the underdrainage) is less than the difference in elevation between the riser crest level and the base of the filter media (known as the allowable head loss). This approach may be used for Type 1, 2A, 2B or 3 bioretention systems. Note that underdrainage for Type 2A traditional sealed and Type 2B traditional unsealed bioretention systems may be sized using either this method or the conservative, simplified method presented in Section 3.6.1.7.

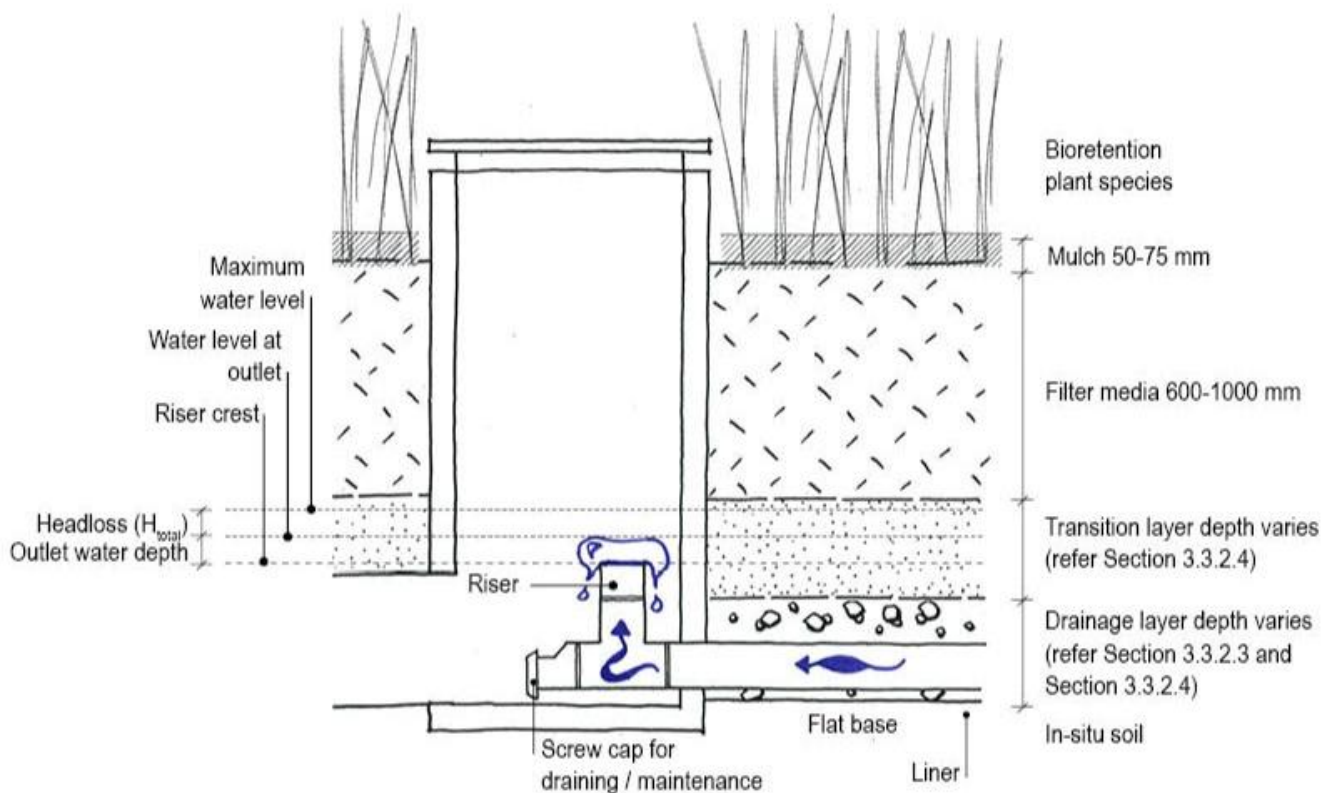


Figure 81. Hydraulics of bioretention system underdrainage.

The general approach to sizing underdrainage pipe is as follows:

1. Develop an initial underdrainage layout and pipe sizing in accordance with Section 3.6.1.1.
2. For Type 1 saturated zone bioretention systems, define the riser connection to the overflow pit. Refer to Section 3.6.1.4 for details.
3. Calculate the maximum infiltration rate through the filter media.
4. Determine the maximum water level at the outlet when it is passing the maximum infiltration rate, assuming free drainage from the outlet. Note that underdrain discharge from saturated zone risers may occur either as simple spilling from a vertical riser pipe (as weir flow) or as part-full pipe flow from a horizontal riser connection (elbow from top of vertical riser) (see Figure 79).
5. Select the longest underdrainage pipe run (slotted underdrainage plus collection pipe) from the initial underdrainage layout (Figure 82) and calculate the total hydraulic head loss. Hydraulic head losses that should be considered include:
 - a. friction losses along slotted or perforated pipes
 - b. bend losses at the transition from slotted pipes to collection pipes
 - c. friction losses along collection pipes
 - d. fitting losses from lateral inflows into collector pipes at slotted pipe connections
 - e. any bend losses (e.g. at end of collection pipe or riser connection).
6. Ensure the combined hydraulic head loss through the longest underdrainage pipe run is less than the distance between the base of the filter media and the maximum water level exiting the outlet (from step 3).
7. Where step 6 is not satisfied, revise the underdrainage layout in one or more of the following ways and repeat the hydraulic head loss assessment:
 - a. increase the slotted or collector pipe size and ensure there is at least 50 mm of drainage layer gravel above the slotted or perforated pipe
 - b. change number or type of bends and fittings
 - c. use multiple underdrainage pipe collection networks (see Figure 76)
 - d. decrease the level of the outlet relative to the base of the filter media (i.e. increase allowable head loss).

Relevant calculations for each component of the head loss assessment are provided on the following pages.

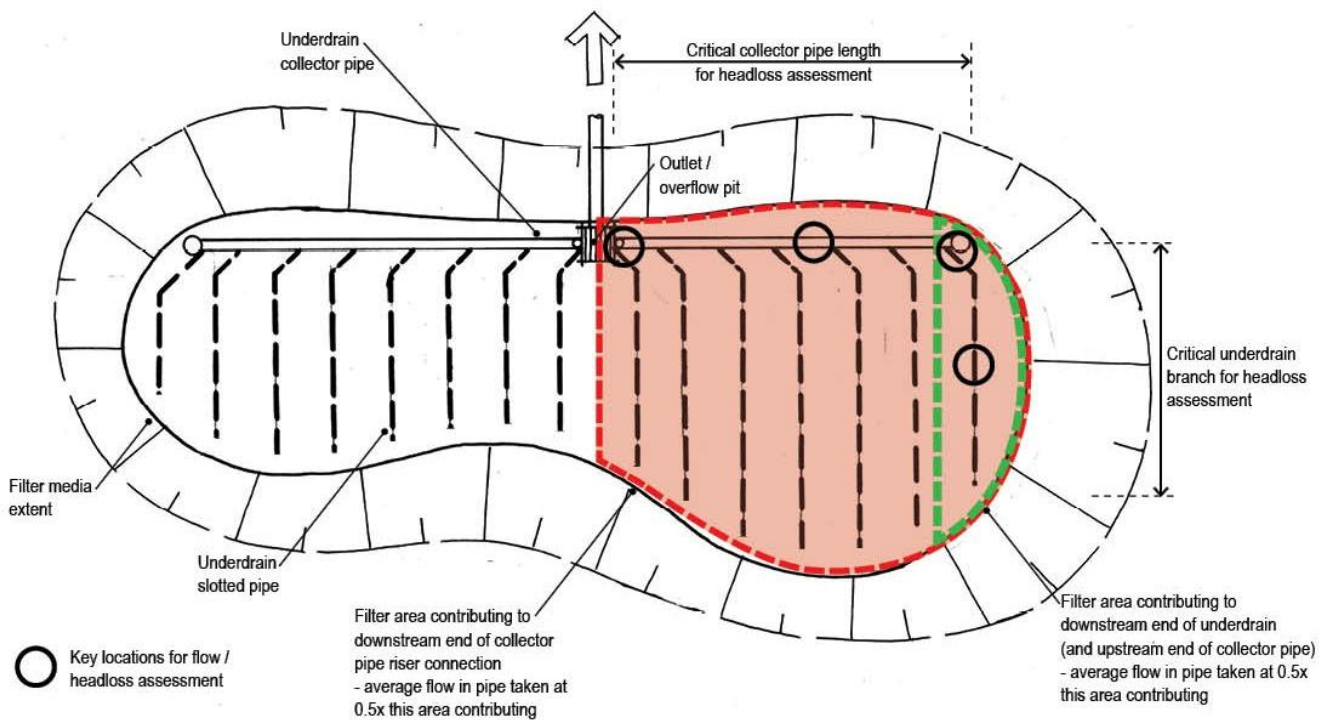


Figure 82. Underdrainage capacity assessment using head loss equations.

Maximum infiltration rate

The maximum infiltration rate for the filter media is defined by Darcy's equation (Equation 9):

Equation 9

$$Q_{max} = K_{sat} \times A \times \frac{h_{max} + d}{d}$$

Where: Q_{max} = maximum infiltration rate (m^3/s)

K_{sat} = saturated hydraulic conductivity of the soil filter (m/s). Note that hydraulic conductivity is often expressed in mm/hr and so a conversion may be required.

A = filter media area (m^2)

h_{max} = extended detention depth (above filter) (m)

d = depth of filter media (m)

Maximum water level at the outlet

The method for calculating the maximum water level at the outlet varies depending on how the underdrainage pipes connect into the outlet pit (see Section 3.6.1.3). An example of how to calculate the maximum water level at the outlet for one configuration is provided in Section 5.7.1.2. A hydraulics textbook should be consulted when using other configurations.

Friction losses (slotted and collector pipes)

The friction loss for slotted underdrainage and collector pipes is calculated separately. Average pipe flow should be used to estimate total friction loss along a pipe (see Figure 82). An estimate of the average flow rate can be derived by multiplying the area of filter media contributing to the mid-point of the

subject pipe by the maximum flow per square metre of filter media calculated previously. This flow rate should be applied over the total length of the pipe.

Pipe friction loss is determined from flow resistance charts that plot a relationship between pipe size, velocity, discharge, and head loss per length of pipe. This calculation is based on the Colebrook-White and Darcy friction factor equations. Alternatively, the rearranged Hazen-Williams equation (Equation 10) can be used:

Equation 10

$$h_f = L \left(\frac{10.67 \times Q_a^{1.85}}{C^{1.85} \times D^{4.87}} \right)$$

Where: h_f = head loss in pipe due to friction (m)
 L = total length of pipe section (m)
 Q_a = flow at mid-point of pipe length (m³/s)
 C = roughness coefficient (typically 150 for rigid plastic pipes)
 D = pipe diameter (m)

Fitting, bend and outlet losses

Head loss at each fitting, bend, and junction (structure losses) can be defined by Equation 11:

Equation 11

$$h_s = K \frac{V^2}{2g}$$

Where: h_s = head loss at structure (m)
 K = pressure change coefficient
 V = velocity in pipe section (m/s) (defined as flow/pipe area)
 g = gravity (9.81 m/s²)

Structure losses should be calculated using the maximum flow (not the average flow) at the location of the fitting, bend, or outlet (see Figure 82).

Pressure change coefficients, K (or structure loss coefficients), vary considerably between fitting types and bend angle and can often be sourced from local design standards such as *QUDM* (Institute of Public Works Engineering Australasia, Queensland, 2017), pipe manufacturers, or hydraulic textbooks.

The total head loss over the critical underdrainage or collector pipe run (typically the longest run) is therefore shown in Equation 12:

Equation 12

$$H_{total} = h_{f(slotted)} + h_{f(collector)} + \sum h_{s(slotted)} + \sum h_{s(collector)} + \sum h_{s(riser)}$$

Where:
 H_{total} = total head loss (m)
 h_f = friction losses in pipes (m)

h_s = structure losses in pipe sections (m)

3.6.1.7 Simple conservative approach for sizing underdrainage pipes for Type 2A traditional sealed and Type 2B traditional unsealed bioretention systems

RECOMMENDED APPROACH

Underdrainage pipes in Type 2A traditional sealed bioretention systems can either be flat or slope towards the outlet pit. Sloping underdrainage towards the outlet pit can be achieved by grading the bioretention system base towards the pit and placing the underdrainage and the drainage layer on this grade.

Underdrainage pipes can be sized using the following steps:

1. Develop an initial underdrainage layout and sizing in accordance with Section 3.6.1.1.
2. Calculate the maximum infiltration rate of filter media (see Section 3.6.1.4).
3. Check the flow capacity for the overall slotted underdrainage pipe system (i.e. confirm overall slotted underdrainage conveyance is greater than filter media infiltration capacity).
4. Undertake capacity checks on the collector pipes as required.
5. Where capacity issues are identified in any part of the underdrainage network, revise the layout, increase pipe size, increase pipe numbers, or undertake a combination of these.

Underdrainage capacity

Manning's equation or pipe capacity charts (see *QUDM* (Institute of Public Works Engineering Australasia, Queensland, 2017)) can be used to calculate the slotted underdrainage flow capacity (Q_{slotted}) assuming the pipe is flowing full, but not under pressure. Equation 13 should then be satisfied.

Equation 13

$$Q_{\text{slotted}} \times \text{no. pipes} > 1.2 \times Q_{\text{max}}$$

Where: Q_{slotted} = maximum conveyance of a single slotted pipe (m^3/s)

no. pipes = number of parallel slotted underdrains

Q_{max} = maximum infiltration rate (m^3/s)

1.2 = 20% blockage factor (in case pipe is partially blocked)

Collector pipe capacity

Slotted underdrains can feed into a larger diameter collector pipe (as the spine to the branched underdrainage network), which is typically unslotted. In large bioretention systems, multiple collector pipes may be required. Collector pipes need to be able to convey the maximum filter media infiltration rate, as shown in Equation 14.

Equation 14

$$Q_{\text{collector}} > 1.2 \times Q_{\text{max}}$$

Where: $Q_{\text{collector}}$ = maximum conveyance of the collector pipe (from Manning's equation) (m^3/s)

Q_{max} = maximum infiltration rate of filter media area being serviced by collector (m^3/s)

1.2 = 20% blockage factor (in case pipe is partially blocked)

3.6.2 Overflow pit

Overflow pits are the most common minor flow outlet structure used in bioretention systems. The crest of the pit is raised above the surface of the filter media to create the extended detention. The pits accept overflows when the extended detention depth is exceeded. The underdrainage discharges into the base of the overflow pit.

Field inlet pits (Section 3.6.2.1) and side entry pits (Section 3.6.2.2) are commonly used for bioretention overflows.

PERFORMANCE OUTCOMES

Overflow pits (or equivalent) must:

- pass the peak minor flow with acceptable upstream inundation
- have a low risk of being blocked with debris.

3.6.2.1 Raised field inlet

RECOMMENDED APPROACH

Overflow pits are typically used in bioretention basins and bioretention swales. They are typically not used in streetscape bioretention systems (refer to Section 3.6.2.2).

Overflow pits should be raised field inlets with raised dome grates (typically 100 mm above the pit crest) to minimise the risk of blockage (Figure 83). Flush grates should not be used as they are highly prone to blockage. Raised flat grates have been used in the past, but they are also somewhat prone to blockage. Raised dome grates are the least prone to blockage and therefore preferred.



Figure 83. Overflow pit with raised dome grate. Photo credits: Jack Mullaly.

The overflow pit should be a minimum size of 1200 x 1200 mm. This is because 1200 mm is the minimum amount of room required to easily perform construction and maintenance activities inside the pit. As a result, the size of the outlet pit will often be dictated by maintenance requirements and not the conveyance capacity of the pit. Where space is constrained, a 900 x 1200 mm pit is acceptable.

Designing streetscape bioretention systems with overflow pits sized as described will lead to poor aesthetic and operational outcomes. A side entry pit should be used instead (refer to Section 3.6.2.2).

Outlet pits should be cast in situ as pre-cast options are often flimsy and prone to damage. Furthermore, pre-cast options often have non-uniform outsides that are difficult to compact filter media against. When filter media is not suitably compacted against the pit it can lead to subsidence.

When casting in situ, both the inside and the outside of the outlet pit must be formed to ensure an even surface is provided to the outside of the pit. This allows filter media to be suitably compacted against the outside of the pit.

Sufficient hydraulic ponding depth should be provided above the pit crest to enable the design flow to enter it. The design flow will typically be for the minor design storm; however, the pit can be designed to accept higher or lower flow rates depending on site constraints, design objectives and local drainage standards.

Raised dome field inlet pits can be sized using manual hydraulic calculations. The pit capacity in free overflow conditions should be estimated using the weir equation and checked against drowned outlet conditions using the orifice equation. The lower of the two capacity estimates is adopted.

DESIGN NOTE: Bioretention basins without outlet pits

It is technically possible, but not desirable, to design bioretention basins without outlet pits. In these instances, overflows are managed solely by the overflow weir, set at the extended detention depth. The slotted underdrainage and/or collector pipes are extended through the bund to discharge into the downstream waterway, channel or pipe network. This approach is undesirable and should be avoided, as the outlet pit serves as an important access point to the underdrainage and drainage profile.

For free overfall conditions, the weir equation (Equation 15) is used:

Equation 15

$$Q_{\text{weir}} = B \times C_w \times L \times h^{3/2}$$

Where:

- Q_{weir} = flow over weir (pit perimeter) (m³/s)
- B = blockage factor (0.5 is recommended for raised grates and 0.25 for flush grates)
- C_w = weir coefficient (1.66 is recommended)
- L = length of weir (m)
- h = depth of water above weir crest (m)

For drowned outlet conditions (orifice equation), use Equation 16:

Equation 16

$$Q_{\text{orifice}} = B \times C_d \times A \times \sqrt{2 \times g \times h}$$

Where:

- Q_{orifice} = flow into drowned pit (m³/s)
- B = blockage factor (0.5 is recommended for raised grates and 0.25 for flush grates)
- C_d = discharge coefficient (0.6 recommended)
- A = total area of pit (m²)
- g = gravity (9.81 m/s²)
- h = depth of water above centre of orifice (m)

DESIGN NOTE: Replacing the overflow pit with a weir

If a weir rather than an overflow pit is being considered for minor flows, a landscape and cost assessment should be undertaken to assess the benefits of this approach. However, even if a pit is not used to convey minor flows, a dedicated underdrainage connection pit (closed) should be provided. The underdrains should be connected to this pit, with an outlet pipe conveying flows from there. The only exception is for streetscape systems, where underdrains can connect through the bunds to the nearest gully pit.

DESIGN NOTE: Designing for saturated zone outlet risers within pits

Where the saturated zone underdrainage discharges to an overflow pit, an assessment is needed to ensure that underdrainage outlet risers, control valves, maintenance drains, and access ladders can be accommodated within the pit without compromising either their function or accessibility for maintenance. The pit dimensions may

be determined by accommodating these components, rather than by the capacity to pass the design flow. Alternatively, multiple pits may be required. In general, the minimum smallest pit recommended for use is 900 x 1200 mm, with 1200 x 1200 mm preferred.

3.6.2.2 Side entry pit

RECOMMENDED APPROACH

Side entry pits within the kerb and channel can accept minor design flows in conjunction with streetscape bioretention (Figure 84). This option relies on flows entering the bioretention system through a kerb cut-out upstream of the pit (see Section 3.5.2.2), filling the extended detention, then backwatering to the kerb invert level, allowing flows to bypass the bioretention and enter the pit.

This option allows the surface of the filter media to be as high as possible relative to the adjacent road or kerb level because the surcharge depth required above the pit inlet occurs within the kerb and channel external to the bioretention system. Bioretention underdrainage can be connected to the side entry pit.

Side entry pits should be designed in accordance with local authority requirements.



Figure 84. Streetscape bioretention system with side entry pit. Photo credits: Robin Allison.

3.6.3 Outlet pipe

PERFORMANCE OUTCOMES

The outlet pipe (or equivalent) must convey the peak minor flow to the receiving drainage system, taking into account tailwater conditions.

RECOMMENDED APPROACH

Outlet pipes from overflow pits should be designed in accordance with local authority standard drainage requirements. Outlet pipes need to convey the relevant design flow from the pit, considering tailwater conditions. All pipe outlets through embankments should be appropriately backfilled, compacted, and have an anti-seepage collar, cut-off walls, or filter collars to prevent seepage paths from developing along the pipe. Failure to appropriately account for seepage can result in serious structural issues for embankment walls.

Scour protection is required at pipe outfalls and along overland flow paths in line with local authority design standards.

3.6.4 Overflow weir

PERFORMANCE OUTCOMES

Overflow weirs (or equivalent) must:

- be able to pass the peak major flow with acceptable upstream inundation
- have a low risk of being blocked with debris
- ensure the embankment does not scour during a peak major flow.

RECOMMENDED APPROACH

A safe and stable route for discharging peak major flows from the bioretention system is required. This is generally achieved by using an overflow weir (Figure 85) as well as an overflow pit.

The weir level is generally set above the overflow pit. A suitable freeboard is required between the maximum water level above the weir during the peak major flow event and the embankment level (see Section 3.3.3.6). The drop from the crest of the weir to the downstream finished surface level should be as low as possible to minimise scour and reduce costs.

Overflow weirs are generally large concrete and rock structures. Weirs should be configured in accordance with local standards such as the IPWEA-QNT Standard Drawings. They should be positioned away from highly visible areas and masked with planting. Appropriate scour protection and energy dissipation (where required) should be provided around all weirs. Rock protection on the downstream side of weirs should be designed in accordance with local authority requirements.

Weirs should not be used where they will pass flows over vegetated embankments more than once per year. Vegetated embankments are susceptible to scour from high flows if they are frequently wet.

Weir capacity can be estimated using Equation 17:

Equation 17

$$Q_{\text{weir}} = C_w \times L \times h^{3/2}$$

Where: L = weir width (m)

h = allowable hydraulic head over the weir (preferably < 0.3 m, refer to local authority requirements)

Q_{weir} = major design flow minus the overflow pit flow (m^3/s)

C_w = weir coefficient (1.74 recommended for sharp crested, 1.66 for broad crested)

DESIGN NOTE: Replacing the overflow weir with a pit

Where site constraints such as space, steep slopes, unstable soils, or retaining walls limit the use of weirs, an appropriately sized overflow pit and pipe can provide an outlet for major storm events; however, some form of overland flow or spillway will still be required for extreme flood events.

DESIGN NOTE: Climate change considerations

Climate change is likely to increase the intensity of rainfall events. To account for this (while safely maintaining the capacity to convey high flows out of bioretention systems), designers should consider increasing the capacity of overflow weirs.



Figure 85. Example overflow weir. Photo credits: Jack Mullaly.

3.6.5 Connection to waterways

PERFORMANCE OUTCOMES

The connection of the bioretention system to the receiving drainage system must prevent scour during peak major flows.

RECOMMENDED APPROACH

When discharging bioretention system outflows to waterways:

- pipes and weirs should be angled downstream
- pipes or drains should be free draining (i.e. no backwatering into the pipe from the waterway).

Scour protection (e.g. rock drop structure) should be used to transition from a bioretention outlet to a waterway. Where a transition includes a vertical drop of greater than 400 mm, major grade control and scour protection are recommended. For guidance on outlet design, energy dissipation, and stabilisation, refer to local design guidelines and standards such as *QUDM* (Institute of Public Works Engineering Australasia, Queensland, 2017).

3.6.6 Flood storage outlets

PERFORMANCE OUTCOMES

Flood storage outlets must allow both bioretention and flood attenuation design objectives to be met.

RECOMMENDED APPROACH

Where bioretention systems form part of a flood detention basin, bioretention system outflow structures (pits and weirs) may either be:

- combined with the flood discharge control outlet
- independent of and upstream of the main flood control outlet.

Where outlets are combined, hydraulic modelling required for designing the detention basin should ensure that any proposed outlet structures (pits, pipes and weirs) meet design requirements for both the bioretention and detention functions.

Section 3.4.9 provides advice on combining bioretention and flood detention basins. The design of flood detention basins and outlets needs to comply with local authority requirements.

3.7 Vegetation design

Bioretention systems should have a dense cover of healthy, actively growing plants that help to remove pollutants and maintain the long-term performance of the filter media. The function of vegetation in bioretention systems is summarised in Table 19.

The key plant attributes that influence pollutant uptake and the long-term survival of vegetation in bioretention systems include:

- **Root structure** – Plants with fibrous root systems are more effective in bioretention systems than those with tap root systems. A mix of shallow and deep-rooted plants will maximise the capacity of the bioretention system to remove pollutants at all depths.
- **Growth rate and plant size** – Both fast-growing and slow-growing plant species are required in bioretention systems. Fast-growing plants tend to be smaller with high nutrient demands, allowing rapid establishment and pollutant uptake. They also provide full coverage of the filter media, which is important to protect the filter media from scour and weeds. Their short growing cycles replenish organic material in the filter media. Slow-growing plants are typically larger with well-developed root systems and gradually increase pollutant uptake and storage capacity.
- **Tolerance to wetting and drying cycles** – To maintain year-round vegetative cover, plants must be able to tolerate prolonged dry periods as well as periodic inundation. Semi-aquatic plant species adapted to longer periods of inundation should not be used because they are generally not suited to the dry conditions between rainfall events.

Successful bioretention systems contain a variety of vegetation that:

- has the key attributes identified above
- integrates with surrounding landscapes (existing natural or created)
- suppresses weed growth to reduce maintenance costs
- maintains filter media porosity
- ameliorates the filter media to make it more hospitable to plant growth
- thrives in the local climate
- enhances biodiversity.

Suppressing weed growth is particularly important. Where vegetation is poorly specified or established, weed management will comprise the majority of maintenance activities and related expenditure. Where vegetation is appropriately specified, particularly the *medium to large scale – ecological function* planting style (refer to Table 20 and Section 3.7.3), vegetation management will decrease over time. Multiple examples of bioretention systems requiring essentially no vegetation maintenance exist throughout South East Queensland.

Designing a planting plan to meet these objectives requires consideration of vegetation types, planting style, planting structure, species diversity, planting density, planting set-out, and the type of mulch to be applied. This section contains recommendations for each of these aspects.

Table 19. The function of vegetation in bioretention system.

| Functional process | Role of vegetation |
|--------------------|---|
| Aesthetics | <ul style="list-style-type: none"> Vegetation can reduce the visual impacts of a modified landscape, such as cut batters and bund formations. Tree plantings can ensure that the existing tree canopy remains unbroken. Shrubs can screen and filter negative views to bioretention infrastructure, including maintenance tracks, headwalls, and weirs. |
| Physical | <ul style="list-style-type: none"> Vegetation reduces stormwater velocity and thereby protects the filter media surface from scour. Root growth and decay provide micro-pathways for water infiltration and oxygen movement, and limit the potential for the filter media to become clogged. |
| Chemical | <ul style="list-style-type: none"> Organic acids and sugars released from plant roots stimulate microbial activity within the root zone, which is essential for pollutant transformation. Some species of vegetation enhance soil aeration by diffusing oxygen from their roots into the surrounding filter media. |
| Biological | <ul style="list-style-type: none"> Plants uptake nutrients and, in some cases, incorporate metals into their tissue. Root decay provides a continuous source of carbon used by denitrifying bacteria. Organic material also enhances filter media moisture retention capacity. Plant roots provide a substrate for microbial growth. Soil microbes facilitate decomposition and mineralisation of organic matter, nutrient uptake, nitrogen processing and heavy metal uptake. |
| Ecological | <ul style="list-style-type: none"> Planting design and species selection can enhance local biodiversity. Bioretention planting zones can provide habitat values for fauna (e.g. shelter and food). Dense vegetation suppresses weed growth. |

DESIGN NOTE Trees and shrubs are strongly encouraged

Prior to the release of Version 1.1 of this guideline, trees and shrubs were rarely used in bioretention systems. Version 1.1 of the guideline introduced the concept of a bushland planting style for bioretention systems and encouraged the use of trees but still left it to the user's discretion as to what extent trees and shrubs were included in their designs.

Since that time, the evidence supporting the benefits of planting trees in bioretention systems has grown. It is now understood that including trees and shrubs in bioretention systems in sufficient density substantially increases system resilience and plant health while reducing maintenance costs. As a result, this version of the guideline further encourages the use of trees and shrubs in bioretention systems.

All bioretention basins within or adjacent to parkland, natural areas or drainage reserves should use the *medium to large scale – ecological function* planting style. As such, they should contain a diverse mix of trees, shrubs and understorey species. Designing such systems with only understorey species is no longer supported by this guideline unless there is an overriding reason why trees and shrubs cannot be implemented.

3.7.1 Vegetation types

3.7.1.1 Groundcovers

Groundcovers of a variety of growth habits (clumping, spreading, matting, etc.) can be used in bioretention systems. Traditionally, the most commonly used groundcovers have been sedges, tall grasses and rushes. Their use became commonplace because laboratory-scale testing showed bioretention systems planted with these species to be particularly effective at treating stormwater. Nonetheless, other types of groundcovers (e.g. herb and scrambling groundcovers) should also be used in bioretention systems (alongside traditional groundcovers, shrubs and trees) to create a layered vegetation community (see Section 3.7.3).

Turf has traditionally not been recommended for long-term use in bioretention systems because relatively few turf species are effective at stormwater treatment. This is due to their shallow root systems and short shoot length. Where there is an overriding landscape amenity objective, turf may be used in conjunction with functional tree species, avoiding a dense canopy.

3.7.1.2 Shrubs

Shrubs are commonly used in bioretention systems. Shrubs generally have medium-sized fibrous root systems, are relatively slow growing, and can take several months to establish. While shrubs may have a limited effect on nutrient uptake before they are established, their large root biomass (compared to groundcovers) has a greater capacity to take up nutrients into the plant tissues in the long term (Parke et al. 2009). Shrubs can shade the surface of the filter media, reducing weeds and surface temperature during summer. They can also enhance visual amenity, increase biodiversity, screen concrete structures, and provide dense vegetative barriers to deter public access.

3.7.1.3 Trees

Trees play a critical role within bioretention systems. While it is possible to construct successful bioretention systems using only groundcover species, systems containing trees require far less maintenance and are substantially more resilient than systems containing only understorey species. In addition, trees increase planting diversity and structure, provide habitat, and enhance amenity in bioretention systems, amongst other benefits. Trees should be used in all bioretention systems unless there is an overriding reason not to. The trees used in bioretention systems are typically small to medium in size. For example, *Melaleuca quinquenervia* is commonly used in bioretention systems in South East Queensland. In nature, it grows to 20 m, but it is often limited to 12 to 15 m in bioretention systems.

3.7.2 Planting style

PERFORMANCE OUTCOMES

The planting style of a bioretention system must:

- be suitable for the local landscape and ecology
- not interfere with sight lines
- be suitable for the available maintenance regime.

RECOMMENDED APPROACH

Planting design will be guided by the size and location of the system within the urban environment, as well as other factors such as the drainage profile type.

Table 20 outlines the characteristics of the planting styles commonly adopted for a range of landscape settings.

Examples of the planting styles described in Table 20 are shown in Figure 86 to Figure 88.

Table 20. Bioretention system planting styles.

| Planting style | Use case | Dominant planting | Characteristics |
|---|--|--|---|
| Small-scale – landscape aesthetic | Streetscape, civic spaces, urban centres and forecourts | Low-diversity groundcovers in filter media. Trees used in bioretention street trees. Shrubs often used on the perimeter of system for landscape effect. | <ul style="list-style-type: none"> Enhances or is sympathetic to the surrounding urban built form and landscape design. Low profile (plant height). Higher maintenance (weed control). |
| Medium to large scale – ecological function | Interface of urban areas with natural bushland and riparian corridors, as well as in public open space and drainage reserves. | Densely planted native vegetation community comprising groundcovers, shrubs, and trees, including locally occurring and core bioretention plant species. | <ul style="list-style-type: none"> Planting theme based on principles of bush reconstruction (Henderson and Blanch, 2009). Replicates structure and composition of existing local bushland and riparian vegetation communities. Enhances aesthetic appeal of site. Increases local biodiversity. Provides fauna habitat. Resilient to changes in local conditions. Resistant to disease and insect attack. Self-maintaining (suppresses weeds). |
| Medium to large scale – landscape aesthetic | Use in place of medium to large scale - ecological function planting style where shrubs and trees are not appropriate for use. | Diverse and structured mix of exotic or native groundcovers, shrubs, and occasionally trees (particularly in large systems). | <ul style="list-style-type: none"> Creates new landscape and amenity for surrounding areas. Low maintenance. Plants are readily available from local nurseries and are not necessarily endemic. |





Figure 86. Small-scale – landscape aesthetic planting style. Photo credits: top left, Glenn Browning; top right, Jack Mullaly; bottom left, Shaun Leinster.



Figure 87. Medium to large scale – ecological function planting style. Photo credits: all photos, Jack Mullaly



Figure 88 Medium to large scale – landscape aesthetic planting style. Photo credits: all photos, Shain Leinster.

3.7.3 Planting structure

PERFORMANCE OUTCOMES

The planting structure must:

- suppress weed growth
- reduce maintenance costs
- enhance system resilience.

RECOMMENDED APPROACH

The planting structure of a bioretention system should make use of vertical layering. Vertical layering involves specifying species of multiple different growth habits (canopy, mid-storey, understorey, etc.) to create a dense and diverse vegetation community (Figure 89). Layering a variety of plant species will suppress weeds, reduce maintenance costs and enhance system resilience. In a well-layered system, even when gaps appear in the vegetation cover at one layer, full coverage is maintained by the other layers.

In the *medium to large scale – ecological function* planting style (refer to Table 20 and Section 3.7.2), appropriate planting structure and species diversity will lead to bioretention systems exhibiting properties of ecological succession (Figure 90). Succession in bioretention systems will see species density and diversity change over time to a final, resilient state with an established canopy and thinned understorey. Leaf drop in these systems will form a mulch layer on the surface of the filter media. Over time, filter media properties will change naturally, making the filter media more hospitable for future plant growth.

The layering approach selected must respond to the planting style adopted for the system:

- **Small scale – landscape aesthetic** – Not all systems of this planting style exhibit layering. For example, some systems of this style may be planted with only understorey species to deliver a specific aesthetic outcome. In general, opportunities should be sought to include multiple layers where possible. For example, a bioretention street tree may be installed in conjunction with matting groundcovers. In this instance, the tree will facilitate treatment performance while the matting groundcovers suppress weed growth. In streetscape systems of this scale, the mid-storey is often excluded to maintain appropriate sight lines.
- **Medium to large scale – ecological function** – This style of system is specifically designed with layering in mind. At a minimum, systems of this style should be planted with canopy, mid-storey and understorey species (i.e. trees, shrubs and groundcovers).
- **Medium to large scale – landscape aesthetic** – This style of system exhibits relatively little layering because shrubs and trees are not used. For this reason, this style is typically less resilient to weed ingress and is not recommended unless there is an overriding reason that trees and shrubs cannot be installed. Limited layering should be achieved in systems of this style by mixing groundcovers of different growth habits. For example, clumping ground covers and spreading groundcovers may be used in tandem, with the spreading species filling gaps between the clumping ones.





Figure 89. Well-layered bioretention vegetation. Photo credits: all photos, Jack Mullaly.

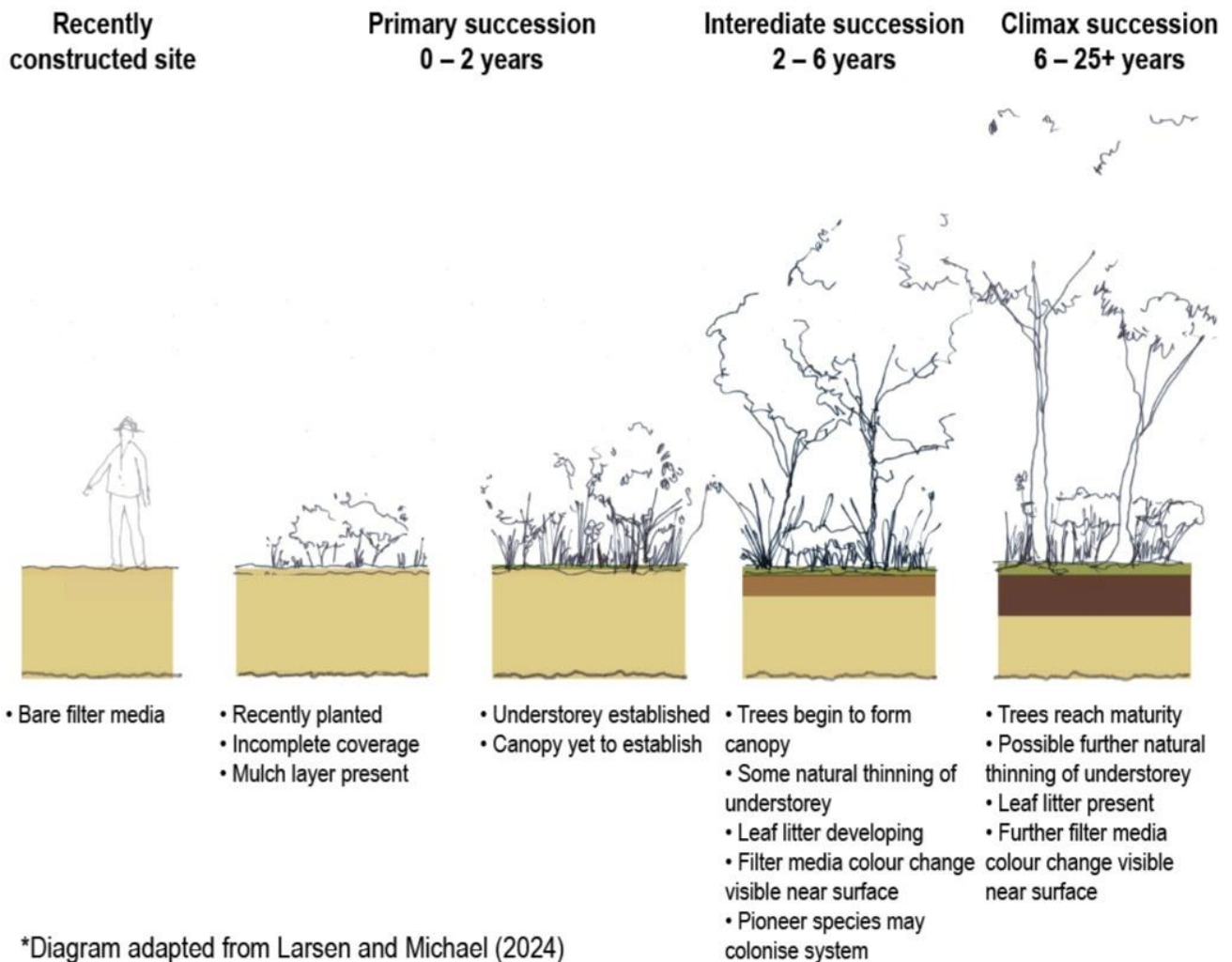


Figure 90. Succession in bioretention systems.

3.7.4 Species diversity

PERFORMANCE OUTCOMES

The diversity of selected species must:

- meet local authority requirements

- achieve 90% plant cover within two growing seasons
- enhance layering of vegetation.

RECOMMENDED APPROACH

A diverse range of plant types and species, including core plant species known to be successful in bioretention systems, will ensure a higher likelihood of successful plant establishment as well as long-term resilience to changing conditions.

The recommended minimum number of plant species for each planting style is in Table 21.

Table 21. Minimum plant species diversity in bioretention systems and batters.

| Planting style | Minimum number of plant species |
|--|--|
| Small-scale – landscape aesthetic. | <ul style="list-style-type: none"> • Two if filter area < 100 m². • Four if filter area ≥ 100 m². |
| Medium to large scale – ecological function. | Ten, comprised of at least: <ul style="list-style-type: none"> • four species of groundcover. • two species of shrub*. • two species of tree. |
| Medium to large scale – landscape aesthetic. | Six. |

* If sight lines prohibit the use of shrubs, use additional tree species instead.

3.7.5 Species selection

PERFORMANCE OUTCOMES

The plant species chosen for a bioretention system must:

- be suitable for the local landscape and ecology
- enable bioretention performance objectives to be met
- enhance layering of vegetation
- be suitable for the inherent growing constraints of filter media
- be suitable for the predicted wetting and drying regime.

RECOMMENDED APPROACH

Table 19 shows plant species that are particularly suitable for bioretention system planting. Using these core plant species ensures that a minimum level of bioretention performance will be achieved. At least 50% of the filter media area should be planted with the core plant species identified in Table 22. The remainder of the filter media area should be planted with the supplemental species shown in Table 23, or species with the attributes listed in Section 3.7. The batters should be planted with species with the attributes listed in Section 3.7.

If a lower coverage of core plant species is proposed, a suitably qualified ecologist or landscape architect should confirm that the plant species conform to the functional plant attributes outlined in Section 3.7.

Local climatic variations mean that some plant species may be more or less suited to certain locations within the regions identified in Table 22 and Table 23. The local authority should be consulted to determine if any plant species are unlikely to survive in a particular location.

Where a *Medium to large scale – ecological function* planting style is proposed, plant species should preferably be of local origin to preserve local biodiversity and ensure plants are suited to local climatic conditions. The selection of plant species that form natural associations in local bushland ecosystems also ensures that many subtle components of the ecosystem are preserved, such as food and habitat resources for insects and birds that are specific to particular plant species associations.

Regional ecosystem descriptions should be consulted for guidance on plant species selection. Local authority landscape strategies or plant selection guidelines may help with choosing suitable species. Refer to Parke et al. (2009) for examples of how to select plant species with attributes suitable for bioretention systems from a range of different vegetation communities.

In a dry climate or climates with prolonged dry periods, locally occurring drought-resistant plant species should be used to increase the resilience of the system to climatic variables and other stressors. Trees and shrubs should be installed in and around bioretention systems to produce a canopy that cools the system and reduces evapotranspiration. Plant survival in dry climates will be supported by using Type 1 saturated zone bioretention systems.

Trees with an open canopy that will not completely shade underlying plants are recommended for all climatic regions. Trees with dense canopies should only be used where suitable shade-tolerant species can be planted under them.

Selecting species for batters may be influenced by functional and landscape considerations such as providing borders (edge plantings), screening, maintaining view lines, public access, weed suppression, or facilitating maintenance access. Core plant species listed in Table 22 and supplemental plant species listed in Table 23 are also suitable for batter planting.

DESIGN NOTE: Use of other plant species

Up to 50% of the bioretention area may also include plant species that are not listed in Table 22, provided they are suitable for the site conditions. Additional species may include more commercially available varieties or amenity plant species. For example, varieties of *Melaleuca linariifolia* or other species of the *Callistemon* genus may be suitable.

DESIGN NOTE: Trialling new supplementary species

It is intended that, over time, the list of supplementary species known to perform well in bioretention systems be expanded. To do this, new species need to be trialled in bioretention systems on a regular basis. It is therefore recommended, but not mandated, that 10% of plants specified in new and rehabilitated bioretention systems be species not listed in either the core (Table 22) or supplementary (Table 23) plant lists. The performance of these species can then be observed over time, with successful species subsequently added to the supplementary plant list. Where new species are trialled, core plant species should still comprise at least 50% of the plants installed.

DESIGN NOTE: Further guidance to enhance layering and succession

Nuanced species selection can enhance layering and succession in bioretention systems.

When selecting understorey species, include a mix of growth habits. For example, combining *Lomandra longifolia* (clumping habit) with *Imperata cylindrica* (spreading habit) has been widely successful in South East Queensland. The spreading species fills any gaps left between the clumping species.

When selecting canopy species, use both pioneers (including native nitrogen-fixing species such as *Acacia* sp.) and longer-lived plants (e.g. *Melaleuca* sp.). The pioneers will form a canopy quickly, inhibit weed growth and begin to improve soil conditions. Over time, as the pioneer species die off, the longer-lived species will establish within the system.

Table 22. Core functional bioretention plant species.

| Species name ¹ | Common name | Type | Region ³ |
|--|------------------------|-------------------|---------------------|
| <i>Carex appressa</i> | Tall sedge | Groundcover sedge | ST, WT |
| <i>Ficinia nodosa</i> | Knobby club-sedge | Groundcover sedge | ST |
| <i>Imperata cylindrica</i> | Blady grass | Groundcover grass | All |
| <i>Lepidosperma laterale</i> | Variable sword-sedge | Groundcover sedge | All |
| <i>Lomandra hystrix</i> | River mat-rush | Groundcover herb | ST, DT, WT |
| <i>Lomandra longifolia</i> | Spiny-headed mat-rush | Groundcover herb | All |
| <i>Lomandra leucocephala</i> | Woolly mat-rush | Groundcover herb | DT, A |
| <i>Pennisetum alopecuroides</i> ² | Swamp foxtail grass | Groundcover grass | ST |
| <i>Poa labillardieri</i> | Common tussock grass | Groundcover grass | ST, A |
| <i>Themeda australis</i> | Kangaroo grass | Groundcover grass | All |
| <i>Callistemon sieberi</i> | River bottlebrush | Shrub | ST |
| <i>Leptospermum liversidgei</i> | Olive tea-tree | Shrub | ST |
| <i>Melaleuca thymifolia</i> | Thyme honey myrtle | Shrub | ST, DT |
| <i>Banksia robur</i> | Swamp banksia | Small tree | ST, DT, WT |
| <i>Melaleuca linariifolia</i> | Flax-leaved paperbark | Small tree | ST |
| <i>Melaleuca viridiflora</i> | Broad leaved tea-tree | Small tree | ST, WT, DT |
| <i>Casuarina glauca</i> | Swamp oak | Tree | ST, WT, DT |
| <i>Casuarina cunninghamiana</i> | River she-oak | Tree | ST |
| <i>Lophostemon suaveolens</i> | Swamp Mahogany | Tree | ST, WT, DT |
| <i>Melaleuca bracteata</i> | Black tea-tree | Tree | ST, WT, DT |
| <i>Melaleuca quinquenervia</i> | Broad-leaved paperbark | Tree | ST, WT, DT |

¹ The list of core plant species has been derived from research conducted by FAWB (<http://www.monash.edu.au/fawb>), its successors, other research organisations and observations of healthy bioretention systems.

² *Pennisetum alopecuroides* is strongly self-seeding. Local authority advice should be sought regarding its use.

³ WT = wet tropics; DT = dry tropics; ST = subtropics; A = arid zones; All = occurs in all regions.

Table 23. Supplementary bioretention plant species.

| Supplementary species | Common name | Type | Region ² |
|------------------------------------|--------------------------|-------------------|---------------------|
| <i>Cymbopogon refractus</i> | Barbed wire grass | Groundcover grass | DT, WT, ST |
| <i>Fimbristylis dichotoma</i> | Common fringe sedge | Groundcover sedge | All |
| <i>Fimbristylis ferruginea</i> | Rusty fringe sedge | Groundcover sedge | All |
| <i>Fimbristylis tristachya</i> | | Groundcover sedge | DT, WT, ST |
| <i>Fuirena umbellata</i> | | Groundcover sedge | DT, WT, ST |
| <i>Gahnia aspera</i> | Saw sedge | Groundcover sedge | ST, DT, WT |
| <i>Gahnia seiberiana</i> | Red-fruit saw-sedge | Groundcover sedge | ST, WT, DT |
| <i>Juncus polyanthemus</i> | Striated rush | Groundcover sedge | DT, WT, ST |
| <i>Juncus usitatus</i> | Common rush | Groundcover sedge | DT, WT, ST |
| <i>Lomandra confertifolia</i> | Dwarf mat-rush | Groundcover sedge | ST |
| <i>Rhynchospora corymbosa</i> | Matamat | Groundcover sedge | All |
| <i>Scleria polycarpa</i> | Many-fruited sedge grass | Groundcover sedge | DT, WT |
| <i>Aidia racemosa</i> | Archer cherry | Shrub | DT, WT |
| <i>Alphitonia excelsa</i> | Red ash | Shrub | All |
| <i>Atractocarpus fitzalanii</i> | Native gardenia | Shrub | DT, WT |
| <i>Austromyrtus dulcis</i> | Midgen berry | Shrub | ST |
| <i>Breynia oblongifolia</i> | False coffee bush | Shrub | All |
| <i>Cordyline manners-suttoniae</i> | Giant palm lily | Shrub | ST, WT |
| <i>Hibiscus heterophyllus</i> | Native rosella | Shrub | DT, WT, ST |
| <i>Leptospermum polygalifolium</i> | Wild may | Shrub | DT, WT, ST |
| <i>Melastoma malabathricum</i> | Blue tongue | Shrub | ST, WT |
| <i>Myoporum acuminatum</i> | Coastal boobialla | Shrub | All |
| <i>Xanthorrhoea fulva</i> | Swamp grass tree | Shrub | ST |
| <i>Acacia fimbriata</i> | Brisbane wattle | Tree | ST |
| <i>Acacia leiocalyx</i> | Black wattle | Tree | ST |
| <i>Albizia canescens</i> | Townsville siris | Tree | DT, WT |
| <i>Casuarina equisetifolia</i> | Coastal she-oak | Tree | DT, WT, ST |
| <i>Buckinghamia celsissima</i> | Ivory curl flower | Tree | DT, WT |
| <i>Callistemon viminalis</i> | Weeping bottlebrush | Tree | All |
| <i>Chionanthus ramiflora</i> | Native olive | Tree | DT, WT, ST |
| <i>Colubrina asiatica</i> | Latherleaf | Tree | DT, WT |
| <i>Corymbia tessellaris</i> | Moreton Bay ash | Tree | DT, WT, ST |

| | | | |
|----------------------------------|---------------------------|-------|------------|
| <i>Cupaniopsis anacardioides</i> | Beach tuckeroo | Tree | DT, WT, ST |
| <i>Eucalyptus raveretiana</i> | Black ironbox | Tree | DT |
| <i>Eucalyptus tereticornis</i> | River blue gum | Tree | DT, WT, ST |
| <i>Eugenia reinwardtiana</i> | Cedar Bay cherry | Tree | DT, WT, ST |
| <i>Ganophyllum falcatum</i> | Scaly ash | Tree | DT, WT |
| <i>Livistona decora</i> | Weeping cabbage palm | Tree | DT, ST |
| <i>Lophostemon grandiflorus</i> | Northern swamp box | Tree | DT, WT |
| <i>Melaleuca dealbata</i> | Blue-leaved paperbark | Tree | DT, WT, ST |
| <i>Melaleuca fluviatilis</i> | Weeping tea tree | Tree | DT, WT |
| <i>Melaleuca leucadendra</i> | Weeping tea tree | Tree | DT, WT |
| <i>Mimusops elengi</i> | Red Coondoo, Tanjong tree | Tree | DT, WT |
| <i>Waterhousea floribunda</i> | Weeping Lilly Pilly | Tree | ST |
| <i>Bothriochloa pertusa</i> | Indian couch | Turf1 | DT, ST |
| <i>Paspalum distichum</i> | Water couch | Turf1 | DT, ST |
| <i>Paspalum vaginatum</i> | Saltwater couch | Turf1 | DT, ST, WT |
| <i>Sporobolus virginicus</i> | Marine couch | Turf1 | DT, WT, ST |
| <i>Zoysia macrantha</i> | Zoysia | Turf1 | ST |

¹ Turf species are not as effective at stormwater treatment due to their shallower root systems and shoot length. If there is a landscape amenity objective that is driving this response, then plant with appropriate tree species (avoid dense canopies) for a deeper root distribution.

² WT = wet tropics; DT = dry tropics; ST = subtropics; A = arid zones; All = occurs in all regions.

3.7.6 Planting density

PERFORMANCE OUTCOMES

Planting densities must:

- provide rapid coverage to outcompete weeds
- have a uniform root zone throughout the filter media
- enable bioretention performance objectives to be met
- have 90% coverage in two growing seasons.

RECOMMENDED APPROACH

High plant density in bioretention systems is beneficial to:

- facilitate rapid establishment of vegetation cover
- exclude weeds
- ensure a uniform root zone throughout the filter media
- maintain filter media porosity
- maximise pollutant removal
- distribute flows evenly across the surface of the bioretention system
- prevent scour, establishment of preferred flow paths, and resuspension of deposited sediments.

A suitable planting density should be used to ensure vegetation covers at least 90% of the bioretention system surface after the establishment phase (i.e. < 10% soil or mulch visible from above). The planting density to achieve this outcome will vary depending on the species used.

Table 24 provides typical planting densities required. From a treatment performance and weed suppression perspective, achieving ≥ 90% coverage is the priority. The densities in Table 24 are recommended because they facilitate rapid achievement of this outcome. Over many years, as plants mature and expand, some plants will die, and densities will reduce. This is acceptable so long as ≥ 90% coverage is maintained. Greater than 90% coverage can be obtained with planting densities lower than those recommended; however, this requires additional maintenance during the establishment phase. Experience suggests that this is rarely achieved in an urban development context, and thus, reducing densities at planting is not recommended.

Table 24. Typical planting densities required to achieve 90% cover.

| Planting type | Vegetation type | Planting density |
|--|---|---|
| Small-scale – landscape aesthetic. | Groundcovers (including grasses, herbs and sedges). | 6 – 8 plants per m ² . |
| | Shrubs ² . | If used, in accordance with local landscape guidelines. |
| | Trees ² . | If used, in accordance with local landscape guidelines. |
| Medium to large scale – ecological function ¹ . | Groundcovers (including grasses, herbs and sedges). | 6 – 8 plants per m ² . |
| | Shrubs ² . | One plant per 5 – 10 m ² . |
| | Trees ² . | One plant per 5 – 10 m ² . |
| Medium to large scale – landscape aesthetic. | Groundcovers (including grasses, herbs and sedges). | 6 – 8 plants per m ² . |
| | Shrubs ² . | N/A. |
| | Trees ² . | N/A. |

¹ All three vegetation types (groundcovers, shrubs and trees) are to be used in each *medium to large scale – ecological function* bioretention system.

² Suitable planting densities for shrubs and trees depend on the size and form of individual plant species and the overall landscape objectives.

3.7.7 Pot size

PERFORMANCE OUTCOME

The pot size used when installing plants in bioretention systems must:

- ensure healthy plants are installed
- provide rapid coverage to outcompete weeds

RECOMMENDED APPROACH

Table 25 shows the recommended pot size for plants installed in bioretention systems. Tubestock are most commonly used. When trees and shrubs are installed in bioretention systems, there is merit in installing approximately 25% of the trees in 25 L pots, with the remainder being tubestock. This approach is useful because tubestock groundcovers will often initially outcompete tubestock shrubs and trees, slowing the development of a canopy within the system. Where 25 L pots are used for a percentage of the shrubs

and trees, those individuals can establish a partial canopy more quickly, with tubestock coming through later.

Direct seeding may also be a useful strategy, particularly in large bioretention systems where it is important to establish vegetation cover quickly to minimise weed ingress. Direct seeding is commonly used for establishing grass cover in bush reconstruction projects. It can also be used to establish shrubs and trees.

As the success rate of direct seeding cannot be guaranteed, direct seeding should only be used to complement the planting of seedlings.

Using seedlings is recommended over direct seeding because:

- Seedlings have a higher survival rate compared to direct seeding.
- Seedlings guarantee accurate selection and layout of the plants. With direct seeding, it is not possible to predict what species will germinate and in what quantities.
- Seedlings have faster growth rates, which is important where rapid growth is required for pollutant treatment and to quickly establish mature vegetation across the surface of the bioretention system.

Table 25. Recommended pot sizes for bioretention plants.

| Planting type | Vegetation type | Pot size |
|--|---|--|
| Small-scale – landscape aesthetic. | Groundcovers (including grasses, herbs and sedges). | Tubestock. |
| | Shrubs. | If used in accordance with local landscape guidelines. |
| | Trees. | If used in accordance with local landscape guidelines. |
| Medium to large scale – ecological function. | Groundcovers (including grasses, herbs and sedges). | Tubestock. |
| | Shrubs. | ≥25% in 25 L pots. Remainder as tubestock. |
| | Trees. | ≥25% in 25 L pots. Remainder as tubestock. |
| Medium to large scale – landscape aesthetic. | Groundcovers (including grasses, herbs and sedges). | Tubestock |
| | Shrubs. | N/A. |
| | Trees. | N/A. |

3.7.8 Planting set out

PERFORMANCE OUTCOMES

The planting set out must minimise the risk of bare patches developing if one species fails.

RECOMMENDED APPROACH

Groundcover species should be distributed across the surface of bioretention systems to minimise the risk of bare patches developing if one species fails. The distribution should be in small clumps of 5 to 10 plants of the same species to ensure propagation can readily occur. Where groundcovers are planted in large bands of a single species, the designer must be confident the species will survive.

Trees and shrubs should be placed to create an even distribution to provide shade cover and weed suppression. Clumping several shrubs or trees of the same species together, as would occur in nature, is acceptable.

In large bioretention systems without a saturated zone, a moisture gradient may exist. Plants nearer the inlet may receive more water than those further from the inlet. Plants should be set out such that more drought-tolerant species are located furthest from the inlet. If the inlet is constantly wet from baseflows, this should be addressed as described in Section 3.5.6.

3.7.9 Surface coverage

Bioretention systems benefit from surface coverage in the form of mulch, leaf litter, and even simply shade from dense vegetation. Mulch and leaf litter in particular cool the filter media, retain moisture within the filter media, replenish filter media organic matter, and suppress weed growth. It is therefore desirable to maintain complete surface coverage both at construction and throughout the life of the system. The optimal manner to achieve this depends on the life stage of the system.

PERFORMANCE OUTCOMES

Surface coverings must:

- ensure adequate soil moisture for plant health
- suppress weeds
- not hinder plant growth
- cool the filter media surface
- provide a source of organic matter to the filter media
- not float (or else be held in place).

3.7.9.1 Surface coverage at planting

RECOMMENDED APPROACH

Mulch should be applied to the bioretention system surface until plants have established to help insulate and retain moisture within the filter media and to suppress weeds. Mulch layers should be 50 – 75 mm deep to ensure that plants are not hindered.

The preferred and most common approach to mulching bioretention systems is to apply an organic friable mulch such as fine sugar cane or tea tree mulch 50 – 75 mm deep to the surface of the system. This should contain few stems (to reduce risk of it floating) and must be held in place using open-weave jute netting. Jute netting must be pinned in place at 500 mm centres (or closer, particularly near the inlet) using U-shaped biodegradable pins at least 300 mm in length. The pins are most effective when installed at a 45 – 60-degree angle against the direction of flow (see Figure 91). Plants are then installed in the filter media through the netting and mulch, with the mulch kept clear of the plant stems by approximately 50 mm.

Hardwood mulch (organic, composted, double tub ground or coarse mulch) may be used as an alternative in bioretention systems located offline from high flows (but not online systems where it may be washed away by high velocities). Hardwood mulch should comprise chunks of wood (not bark), typically 15 – 40 mm in size, mixed in with some fine material (which helps bind the mulch and minimise the risk of it floating). The large size of these chunks increases airflow through the mulch and into the filter media, which enables gaseous exchange and ensures the mulch does not become waterlogged for too long, reducing the risk of mould, fungus and rot.

To limit the risk of it floating, the selected mulch must have a density greater than or equal to that of water. It should also be thoroughly wetted during installation to improve binding and further minimise the risk of it floating. A well-wetted hardwood mulch is denser than water, which means it should not float.

The following surface coverage methods are not recommended and should be avoided:

- gravel or stone
- organic mulch that is likely to contain weed seeds
- heavy-duty matting such as 800 gsm jute mat

- inorganic matting such as filter cloth.

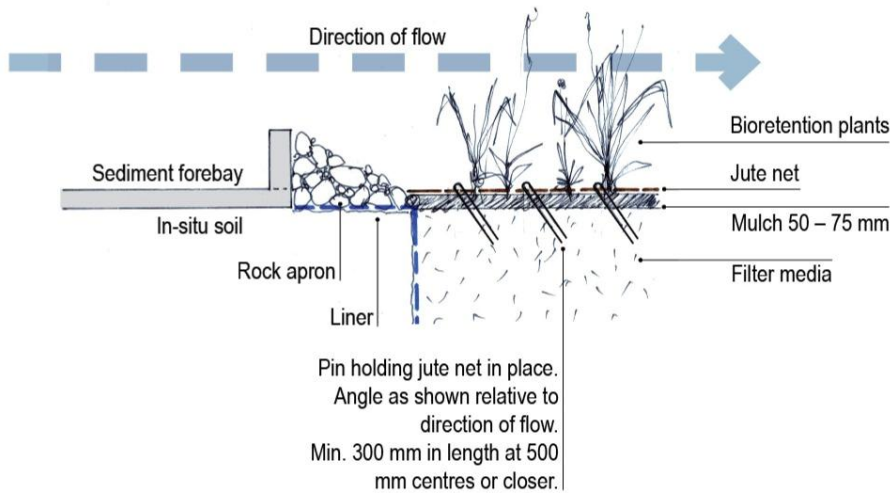


Figure 91. Placement of pins in jute netting.

3.7.9.2 Maintaining surface coverage

The optimal method of maintaining surface coverage throughout the life of a bioretention system is through specifying vegetation that drops leaf litter onto the surface of the system, as shown in Figure 92. This is a key attribute of the trees and shrubs specified in the *medium to large-scale ecological function* planting style described in Section 3.7.2.

Where systems do not include trees and shrubs, maintaining surface coverage is more difficult. Mulch can be reapplied to established systems, but the existing plants will prevent it from being pinned in place. It is therefore liable to float and be washed away. This is not desirable and should be avoided. Thus, in most instances where shrubs and trees are not present in the system, surface coverage should be maintained through dense understorey planting.



Figure 92. Leaf litter in a bioretention system. Photo credits: All photos Jack Mullaly.

3.7.10 Habitat

PERFORMANCE OUTCOME

Bioretention systems should provide habitat for native wildlife.

RECOMMENDED APPROACH

Bioretention systems (particularly those using the *medium to large scale – ecological function* planting style) present a significant opportunity to improve local habitat and biodiversity. The primary way to achieve this is through diverse plant species selection (refer to Section 3.7.5) and layering (refer to Section 3.7.3).

Habitat can be further increased by including:

- habitat logs (in systems $\geq 100 \text{ m}^2$)
- habitat boxes/ hollows (in systems $\geq 200\text{m}^2$)
- native bee hives (in systems $\geq 200\text{m}^2$)
- rock piles (in systems $\geq 200\text{m}^2$).

3.7.11 Resilience to climatic variation

PERFORMANCE OUTCOME

Bioretention systems are installed in a wide range of climatic regions. To ensure that bioretention systems function, and particularly that vegetation survives, bioretention design must be resilient and respond to local climatic conditions.

RECOMMENDED APPROACH

To ensure plant survival in dry climates or climates with extended dry periods (with low rainfall and/or high evapotranspiration), bioretention system design should include:

- Using a Type 1 saturated zone bioretention system (see Section 3.3.2.4).
- Installing locally relevant drought-tolerant plant species.

Plant survival can also be enhanced by:

- Amending filter media to increase soil moisture content (see Section 4.3.1).
- Installing trees and/or shrubs in and around the bioretention system to produce a canopy that cools the system surface and reduces evapotranspiration
- Installing plant species that regularly drop leaf litter to create a mulch layer on the system surface, which helps retain soil moisture (see Section 3.7.9.2).

During the establishment phase, plant survival can be supported through the use of a temporary upstand (see Section 3.6.1.5).

3.8 Design check and summary

Designing bioretention systems involves a number of design iterations and modifications. At the end of the design process, it is important to ensure that the iterations have delivered a successful design. Therefore, it is important to undertake a final check of the design, preferably before the design drawings are completed.

Table 26 shows key design parameters that should be checked and documented. The completed summary should then be included with any reports submitted to local authorities in conjunction with the design drawings.

Table 26. Design check and summary.

| Item | Description | Detail | Recommendation |
|--------------|--|----------------|---|
| 1. Treatment | | | |
| (a) | Catchment area. | ha | |
| (b) | Filter media area (excluding batters). | m ² | Single or multiple cells < 800 m ² each. |
| (c) | Confirm water quality performance meets the design objectives. | | |

| | | | |
|-------------------|---|-------------------|--|
| (d) | Confirm hydrologic performance meets relevant frequent flow objectives. | | |
| 2. Design inflows | | | |
| (a) | Minor design storm entering system. | ARI | |
| (b) | Minor storm peak flow rate. | m ³ /s | |
| (c) | Major design storm entering system. | ARI | |
| (d) | Major storm peak flow rate. | m ³ /s | |
| 3. Depth profile | | | |
| (a) | Bioretention drainage profile type. | Type | |
| (b) | Minimum drainage layer depth. | mm | See Section 3.3.2.3 and 3.3.2.4 for Type 1. ≥ 150 mm for Type 2A and Type 2B. ≥ 300 mm for Type 3. Not needed for Type 4. |
| (c) | Maximum drainage layer depth. | mm | Same as minimum except for Type 2. |
| (d) | Transition layer depth. | mm | See Section 3.3.2.4 for Type 1. ≥ 100 mm for Type 2A, Type 2B, Type 3 and Type 4. |
| (e) | Saturated zone depth for Type 1 bioretention systems. | mm | See Section 3.3.2.4. |
| (f) | Filter media layer depth. | mm | ≥ 600 mm. |
| (g) | Extended detention depth. | mm | ≤ 300 mm. |
| (h) | Maximum water level depth above the extended detention for major storm event. | mm | |
| (i) | Freeboard to top of the embankment. | mm | See Section 3.3.3.6. |
| (j) | Total system profile depth: [3(c)+3(d)+3(f)+3(g)+3(h)+3(i)]. | mm | = 4(j). |
| (k) | Liner type: (i) Permeable (ii) Impermeable (iii) None to base. | | Subject to drainage profile type and in-situ soils/groundwater (see Section 3.3.5). |
| (l) | AASS/PASS assessed and appropriately managed. | | |
| (m) | Presence of dispersive soils assessed and appropriately managed. | | |
| 4. Design levels | | | |
| (a) | Outlet invert level. | m AHD | |
| (b) | Overflow pit invert level. | m AHD | |
| (c) | Minimum drainage layer level. | m AHD | |
| (d) | Filter media surface level. | m AHD | |

| | | | |
|-----------------|---|----------------|--|
| (e) | Overflow pit crest level. | m AHD | |
| (f) | Overflow weir level. | m AHD | |
| (g) | Maximum design water level. | m AHD | |
| (h) | Top of embankment/batter level. | m AHD | |
| (i) | Inlet/inflow invert level. | m AHD | |
| (j) | Total level difference [4(h)-4(c)]. | m | = 3(j). |
| (k) | Highest astronomical tide (HAT) level. | m AHD | Type 1 – impermeable liner extends. ≥ 300 mm above HAT. Type 2A, Type 2B, Type 3 and Type 4 – base of transition layer ≥ 300 mm above HAT. |
| (l) | Groundwater level. | m AHD | Varies with drainage profile type (see Table 7Table 7). |
| 5. Layout | | | |
| (a) | Maximum filter media length. | m | ≤ 40 m. |
| (b) | Maximum filter media width. | m | ≤ 20 m (preferred ≤ 15 m). |
| (c) | Maximum batter slope. | V: H | |
| (d) | Maximum wall height (where applicable). | m | |
| (e) | Provision for services (water, sewer, gas, telecommunications, stormwater). | | |
| (f) | Maintenance access provided. | | |
| (g) | Flood storage volume above extended detention (where bioretention combined with flood storage). | m ³ | |
| 6. Inlet design | | | |
| (a) | Inlet/inflow type: (i) pipe (ii) channel (iii) sheet flow (iv) other. | | |
| (b) | Diversion/surcharge type (where applicable). | | |
| (c) | Coarse sediment removal: (i) forebay (ii) inlet pond (iii) swale (iv) other. | | |
| (d) | Coarse sediment removal area. | m ² | |
| (e) | Coarse sediment removal depth. | m | |
| (f) | Coarse sediment cleanout frequency. | /year | < once per year. |
| (g) | Flow distribution type. | | See Section 3.5.7. |
| (h) | Confirm scour protection at inflow locations. | | |
| (i) | Confirm energy dissipation at inflow locations. | | |

| | | | |
|------------------------------------|--|-------------------|---|
| (j) | Minor storm flow velocity over filter media. | m/s | < 1.0 m/s. |
| (k) | Major storm flow velocity over filter media. | m/s | < 1.0 m/s. |
| 7. Underdrainage (outlet design) | | | |
| (a) | Filter media saturated hydraulic conductivity. | mm/hr | 100 – 300 mm/hr. |
| (b) | Maximum filter media infiltration capacity. | m ³ /s | |
| (c) | Underdrain capacity (taking into account blockage factors). | m ³ /s | > 7 (b). |
| (d) | Confirm pit exists for underdrains to connect into. | | |
| 8. Overflow design (outlet design) | | | |
| (a) | Overflow pit type. | | |
| (b) | Overflow pit dimensions. | | Bioretention basins. Minimum 900 x 1200 mm, 1200 x 1200 mm preferred. Streetscape bioretention. Side entry pit is typical. |
| (c) | Overflow weir length. | m | |
| (d) | Overflow pit capacity (taking into account blockage factors). | m ³ /s | > 2 (b). |
| (e) | Overflow pit plus overflow weir capacity (taking into account blockage factors). | m ³ /s | > 2 (d). |
| (f) | Outlet pipe size. | mm | |
| (g) | Appropriate outlet scour protection provided. | | |
| 9. Vegetation design | | | |
| (a) | Planting style. | | (i) small scale – landscape aesthetic (ii) medium to large scale – ecological function (iii) medium to large scale – landscape aesthetic. |
| (b) | Trees and shrubs to be included. | | Yes – unless overriding reason provided to not include them. |
| (c) | Species diversity (number of species). | | Refer Table 21. |
| (d) | Species selection. | Refer to plan: | ≥ 50% coverage with plants from Table 22. |
| (e) | Planting density. | /m ² | May vary between plant species, refer to plan if required. |
| (f) | Mulch type and depth. | | See Section 3.7.9 and Section 4.4.4. |

3.9 Detailed design documentation

At the completion of detailed design, it is important to document the design both for construction and for the development approvals process if required.

Three main detailed design documents should be produced:

- design report
- detailed design drawings
- specifications.

3.9.1 Design report

A bioretention design report documenting the analysis methods and assumptions made during the design process should be submitted to the approval authority, together with the design drawings. Design reports should include a description of any unique maintenance requirements and evidence that the ultimate asset owner is satisfied with these requirements. The design report should describe the erosion and sediment control measures to be used during the construction and establishment phases (if this information is not covered elsewhere).

The report should refer to local standards for any other specific reporting requirements.

The design report should include:

- description of the design intent
- supporting calculations or modelling results
- a summary of key design parameters
- detailed design drawings
- proposed construction and establishment methodology
- design checklist.

3.9.2 Detailed design drawings

A set of engineering and landscape drawings suitable for design approval and construction tendering should be completed at the end of the design process. The drawings should clearly detail the design of the bioretention system, including all elements developed from the detailed design process.

The tendering package should also include a specification outlining construction methods, tolerances, and materials. An example of civil and landscape specifications for bioretention systems is provided in Section 4.

Final drawings should be suitably scaled and annotated, and include:

1. A plan view, showing:

- filter media, batters and embankments relative to existing features (such as roads)
- design levels and earthworks to illustrate profiles and relationships to surrounds (batters, contours, and spot heights)
- property boundaries (including road reserves)
- location and details of the inflow and outflows
- coarse sediment removal layout

- maintenance access
- road pavement and pedestrian pathways
- all services
- tree protection zones or areas of existing vegetation to be retained.

2. Cross sections of the bioretention profile and interaction with surrounding landscape, illustrating:

- filter media surface level and depths of filter media, extended detention, transition layer and drainage layer (where applicable)
- underdrainage and base profile and levels (where applicable)
- batters and embankments
- top and bottom of liner and type (where applicable)
- top and bottom of topsoil on batters
- inflow and outflow arrangements (including forebay or inlet pond)
- vegetation at mature height
- all services.

3. Details of:

- inflow
- outflow
- cleanout
- underdrainage layout, connections, and outlet riser (where applicable).

4. Relevant references to standard drawings (e.g. IPWEA-QNT)

5. A set out plan

6. A surface finishes plan, including:

- location of the bioretention system in relation to surrounding landscape (e.g. pathways, driveway crossovers, inlet and outlet structures, etc.)
- details of maintenance edges (e.g. concrete edge strip).

7. A detailed planting layout, specifying:

- location and number of plant species
- specific planting zones.

8. A planting schedule, specifying:

- planting zones that correlate with the planting layout
- a plant species list for each zone (including scientific and common names)
- plant container size
- plant density (per m²)
- mature plant size (optional)
- number of plants.

9. Notes, including:

- specifications or references to separate specification documents
- construction and establishment requirements.

3.9.3 Specifications

Design specifications (see Section 4) must be documented for assessment and construction. This is typically done by either including the specifications as notes on the detailed design drawings, providing a standalone specification document or a combination of both. The most important consideration is that

anyone either assessing or constructing the system is able to easily access the information contained within the specification. For this reason, if a standalone specification document is produced, the detailed design drawings and design report must include references to this document.

4 Specification guide

4.1 How to use this section

This section provides standard specifications for typical bioretention systems. Relevant sections of the specifications can be used as an example or copied directly into tender packages.

When using the standard specifications, designers should ensure:

- the standard specification is relevant to their particular bioretention system design
- the final specification includes any information that is not covered in this standard specification.

Most of this specification is relevant to all bioretention systems. However, there are some differences between the bioretention drainage profile types, as summarised in Table 27.

Table 27. Bioretention types and relevant specifications.

| Bioretention construction element | Specification guide reference section | | | | |
|---------------------------------------|---------------------------------------|---------------------------|------------------------------|---------------------------------|--------------------------------|
| | Type 1 saturated zone | Type 2 traditional sealed | Type 2B traditional unsealed | Type 3 infiltration – with pipe | Type 4 infiltration - pipeless |
| Tolerances | 4.2.1 | | | | |
| Hydraulic structures | 4.2.2 | | | | |
| Liner | 4.2.3.2 | 4.2.3.1 and 4.2.3.2 | 4.2.3.1 and 4.2.3.3 | 4.2.3.1 and 4.2.3.3 | 4.2.3.1 and 4.2.3.3 |
| Underdrainage | 4.2.4 | 4.2.4 | 4.2.4 | 4.2.4 | none |
| Services | 4.2.5 | | | | |
| Maintenance access | 4.2.6 | | | | |
| Filter media | 4.3.1 | | | | |
| Transition layer | 4.3.2 | | | | |
| Drainage layer | 4.3.3 | 4.3.3 | 4.3.3 | 4.3.3 | none |
| Landscape and planting considerations | 4.4 | | | | |

4.2 Civil construction

4.2.1 Tolerances

Bioretention systems must be constructed within the tolerances shown in Table 28 and Figure 93. Compliance with these requirements must be demonstrated using either the survey standard shown in Table 28 or a more accurate method agreed to by the site superintendent.

Table 28. Bioretention system tolerances.

| Bioretention element | Construction considerations | Tolerance | Minimum survey standard |
|---|--|---|--|
| Hydraulic structures (overflow pit, pipe and weirs) | <p>These structures control the movement of water through the system.</p> <p>Tolerances apply to:</p> <ul style="list-style-type: none"> inlet pipes overflow pit crest level pipe connections to overflow pit outlet pipe invert (upstream and downstream) weirs. | <p>± 15 mm for streetscape systems</p> <p>± 25 mm for other systems</p> | Survey* |
| Earthworks (base of the bioretention system) | <p>The base of Type 2A and 2B bioretention systems can either be flat or slope towards the outlet pit. The grade of the base must be in accordance with the design drawings. The base of Type 1, 3 and 4 bioretention systems must be flat.</p> <p>The base of bioretention systems must be free from localised depressions.</p> | <p>± 0.2%</p> <p>± 25 mm</p> | Survey* |
| Underdrainage | <p>The underdrainage in Type 2A and 2B bioretention systems can either be flat or slope towards the outlet pit. The grade of the underdrainage must be in accordance with the design drawings. The underdrainage in Type 1 and 3 bioretention systems must be flat. Type 4 bioretention systems do not have underdrainage.</p> | ± 0.2% | Dumpy level or laser |
| Drainage and transition layers | <p>Must be ≥ 50 mm of drainage layer material above underdrainage pipes.</p> <p>Must be ≥ 100 mm of transition layer material above the drainage layer material.</p> | + 25 mm | Dumpy level, laser or measuring tape |
| Surface level (filter media surface) | <p>Must be free from localised depressions to ensure even distribution of stormwater across the surface and prevent localised ponding.</p> <p>A separate tolerance is provided for large bioretention systems, as achieving a flat surface can be challenging.</p> | <p>± 25 mm</p> <p>± 40 mm for filter media area > 300 m² provided the 'average' extended detention depth is within 25 mm of design.</p> | <p>Dumpy level or laser for construction</p> <p>Survey for as constructed*</p> |

| | | | |
|-----------------------|---|---|----------------------------|
| Embankments and bunds | These contain water within the extended detention and, when required, force runoff to the overflow structure. | - 25 mm + 50 mm Preference for bund to be higher rather than lower. | Survey for as constructed* |
|-----------------------|---|---|----------------------------|

* Land or engineering survey by a qualified surveyor.

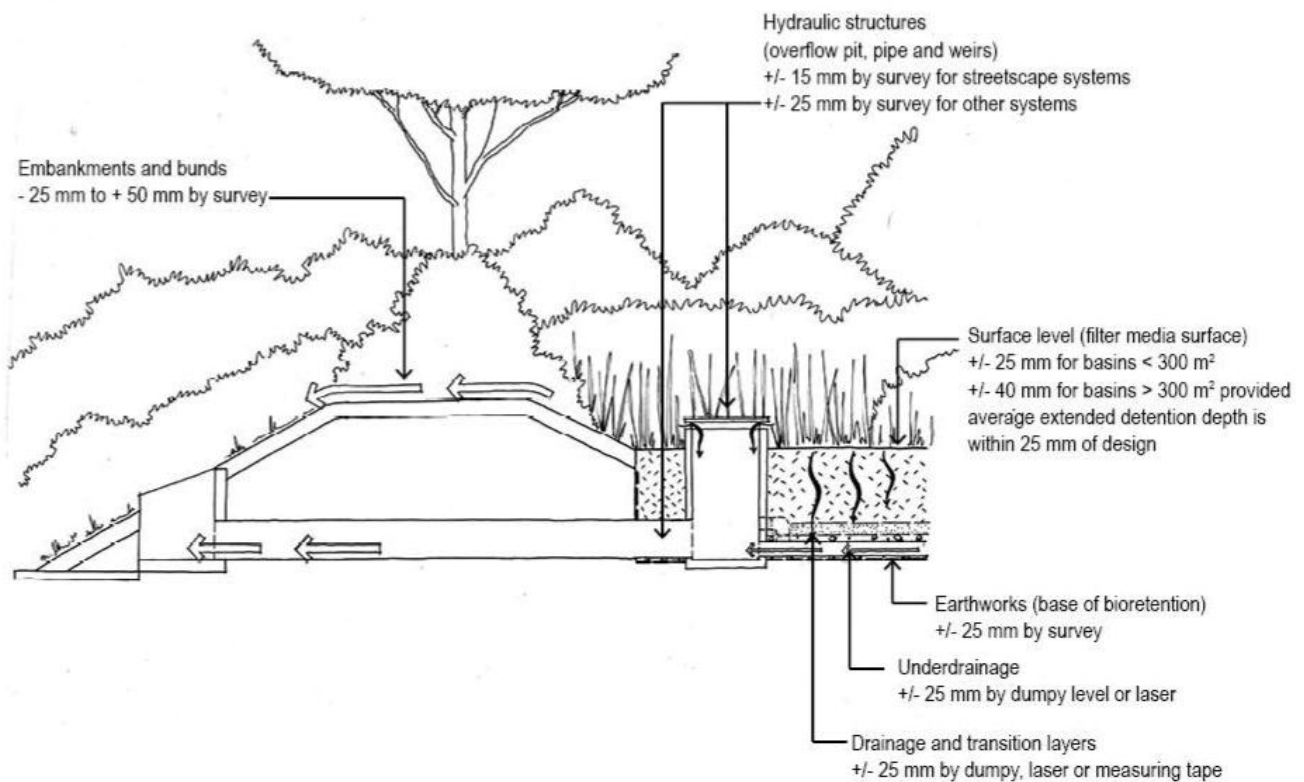


Figure 93. Typical bioretention system cross-section showing construction tolerances and survey method.

4.2.2 Hydraulic structures

A description of hydraulic structures and the corresponding construction requirements is in Table 29.

Table 29. Hydraulic structures.

| Hydraulic structure | Description | Construction requirements |
|---------------------|---|--|
| Overflow pit | Collects flows exceeding the filter media infiltration rate. Transfers collected flows to an outlet pipe that is connected to the receiving drainage system. | Concrete construction. Refer to drawings, local authority standards, or the IPWEA-QNT Standard Drawings for details. Underdrainage pipes must be sealed into the overflow pit. Note: The crest is intentionally set higher than the surface of the filter media and lower than the embankment or bund. |

| | | |
|---------------|---|---|
| Outlet pipes | Transfers flow from the overflow pit to receiving systems. Sized to convey the minor design storm. | Refer to drawings for location, size, levels, and class of pipe. Rock protection may be required at the outfall of the pipe (refer to drawings). Must be free-draining, sealed to the overflow pit and include a seepage collar. |
| Overflow weir | Transfers large flows out of the bioretention system to the receiving overland flow drainage. | Mass concrete crest, typically 500 mm deep with reinforcing. Refer to drawings, local authority standards, or the IPWEA-QNT Standard Drawings for details. Grouted rock protection required on both sides of the crest to at least the base of the batters. Concrete and rock protection must extend up batters and into bunds or batters at the ends of the weir. Refer to drawings, local authority standards, or the IPWEA-QNT Standard Drawings for details. |

4.2.3 Liner

4.2.3.1 Permeable liner

A permeable geotextile liner:

- enables treated stormwater to exfiltrate to the surrounding soils
- defines the edge of the media layers.

Permeable liners must be keyed into batters (refer to drawings or the IPWEA-QNT Standard Drawings).

The liner must:

- extend along the bioretention batter at least 500 mm beyond the top of the sides (i.e. beyond the filter media)
- extend over any embankment surrounding the system
- be pinned to the in-situ soil and covered by at least 200 mm of topsoil
- be resistant to all soil acids and alkalis and comply with the requirements of AS 3706.12
- be resistant to microorganisms (fungi and bacteria) within the soil and comply with the requirements of AS 3706.13.

4.2.3.2 Impermeable liner

Type 1 saturated zone and Type 2A traditional sealed bioretention systems require an impermeable liner. The extent of this liner must be reflected on the design drawings and should be determined in accordance with Section 2.4, Section 3.3.3.2 and Section 3.3.5.1. Care should be taken to ensure that liners create an impermeable seal around all relevant hydraulic connections. The liner must achieve a hydraulic conductivity of less than 1×10^{-9} m/s. Liners can be made of compacted clay or bentonite sheets. HDPE and plastic liners should not be used.

Clay liners can be made from suitable in-situ soil or from imported material. The material must not be dispersive. The entire extent of compacted clay liners must be installed under the supervision of a geotechnical engineer. The liner should be tested and subsequently certified by that engineer.

Where synthetic liners are used, the following conditions must be met:

- The contractor must receive written assurance from the manufacturer that the product has a permeability of no greater than 1×10^{-9} m/s.
- Specific written advice on sealing the liner around protrusions (e.g. outlet pipes) must be obtained from the manufacturer.
- Liners must be installed and sealed in accordance with manufacturer's specifications and appropriately keyed into the batters and embankments to ensure the system is watertight.

- Certification that the liner has been installed in accordance with the manufacturer's specifications and is watertight must be obtained.

4.2.3.3 No liner (open base)

For Type 2B traditional unsealed, Type 3 infiltration – with pipe and Type 4 infiltration – pipeless bioretention systems, permeable geotextile liners should only line the sides of the bioretention system (see Section 4.2.3.1).

4.2.4 Underdrainage

4.2.4.1 Slotted pipes

Underdrainage pipes collect treated stormwater from the drainage layer (aggregate) at the base of the bioretention system and convey flows to the overflow pit. Type 4 infiltration – pipeless bioretention systems do not have underdrainage pipes.

The underdrainage must comply with the following:

- Slotted rigid pipes must comply with the requirements of AS 2439.1 for Type 2 pipes.
- Ag-pipes must comply with the requirements of AS 2439.1 for Type 1 pipes.
- For filter media surfaces < 100 m², the maximum underdrainage spacing is 1.5 m from centre to centre.
- For filter media surfaces > 100 m², the maximum spacing of the underdrainage is 2.5 m from centre to centre.
- All pipe junctions and connections to the overflow pit must be sealed to prevent soil from entering the pipe network.
- Y-connections (45-degree angle) are to be used on all connections to allow easy access for cleaning devices.
- Underdrainage must not use a filter cloth wrapping or sock. Filter cloths may cause blockages that require a complete resetting of the bioretention system.
- Slots/perforations in underdrainage pipes must be no more than 2 mm wide.
- Underdrainage pipes must come supplied with slots/perforations pre-cut. Underdrain slots/perforations must not be created onsite, as it is not feasible to consistently make slots/perforations no more than 2 mm wide.
- When connecting underdrains of different sizes, ensure the smaller pipe sits flush on the base of the system by using either eccentric reducers or digging the larger pipe into the ground.

4.2.4.2 Cleanouts

Collector pipes must extend vertically beyond the surface of the filter media by at least 150 mm for inspection and maintenance. Where a system does not contain a collector pipe and has five or fewer underdrains, the underdrains must extend vertically above the surface by at least 150 mm.

The vertical section must not be perforated and must be capped to avoid short-circuiting flows. Caps should be secured with screws to reduce the risk of vandalism. Y-connections (45-degree angle) should be used on all connections to allow easy access and cleanout. Refer to the IPWEA-QNT Standard Drawings.

4.2.5 Services

In accordance with Section 3.4.7, underground services should be located outside the filter media area but may be incorporated into bioretention system batters. An impermeable barrier should separate the filter media and the service. Where there is no alternative to running services through a bioretention cell, services should be located in conduits running between pits at either end of the bioretention system

(subject to approval from the local authority and from the service providers). The interface between the conduits and the edge of the bioretention system must be sealed to prevent flows migrating along the services trench. Detection tape must be placed above the conduits to clearly mark their location.

A 'Dial Before You Dig' search must be completed before the bioretention system is constructed to determine the presence of services. If services are present, they need to be accurately located, and the site superintendent should be consulted to determine appropriate construction procedures.

4.2.6 Maintenance access

Refer to design drawings for location, width, slope, and surface finish of access tracks.

4.2.6.1 Concrete access tracks

All concrete access tracks (including where concrete is used as the base of a sediment basin) must meet the following requirements:

- Tracks must comply with local authority concrete access requirements.
- Concrete must consist of a mixture of ordinary Portland cement, coarse and fine aggregate, and water.
- Cement must comply with AS 3972.
- Aggregate must comply with AS 2758.
- Concrete must be normal class as defined by AS 1379, Class N25.
- Concrete must be sampled and tested in accordance with the provisions of AS 1012 (Method of Testing Concrete).
- Reinforcement must be deformed bars or welded wire fabric and comply with AS4671 as appropriate.
- Construction joints to be in accordance with the design drawings.

4.2.6.2 Gravel access tracks

All gravel access tracks must meet the following requirements:

- Must be comprised of well-graded crushed or rock-soil aggregate that is free from deleterious materials with no more than two-thirds of the percentage (by weight) being able to pass through a 0.425 mm sieve.
- Fill must be compacted to 98% maximum dry density using a modified compactive effort (in compliance with AS 1289-5.2.1) or 70% minimum density index (in compliance with AS 1289-1.2.1).
- Where any regular access by heavy vehicles is required, tracks should be comprised of a suitable depth (typically 200 mm) of larger ballast (75 mm diameter).

4.3 Bioretention filter media specification and certification

This section provides specifications for bioretention system filter media and guidance on the protocols for testing and certifying each type of filter media.

4.3.1 Filter media

The main role of the filter media in a bioretention system is to remove pollutants and support vegetation. The filter media must be at least 600 mm deep, with depth details provided in the design drawings.

Unless an alternative filter media specification has been adopted (refer to Section 3.3.2.1), filter media must be in accordance with the *Adoption Guidelines for Stormwater Biofiltration Systems* (Cooperative Research Centre for Water Sensitive Cities) and meet the following specifications:

- Characteristics required for plant growth should be confirmed with soil analysis in consultation with a horticulturalist, as required by the *Adoption Guidelines for Stormwater Biofiltration Systems* (Cooperative Research Centre for Water Sensitive Cities).

- The filter media should be free from AASS and PASS.
- The filter media must not be made from dispersive or erodible materials.

Design drawings should include a clause that states that the filter media (and transition layer and drainage layer) must be certified as compliant with the specification to which it has been designed.

The contractor must arrange for the delivered filter media to be tested in accordance with the *Adoption Guidelines for Stormwater Biofiltration Systems* (Cooperative Research Centre for Water Sensitive Cities) at the following frequencies:

- For small to medium bioretention systems (< 500 m²), one sample per 500 m³ must be tested to meet the specification
- For large bioretention systems (> 500 m²), one sample per 2,000 m³ must be tested for the specification, PLUS one sample per 500 m³ must be tested for hydraulic conductivity (e.g. one full test plus three hydraulic conductivity tests per 2000 m³).

Written records of the testing results, along with certification that the requirements are met, must be provided to the site superintendent for review and approval before the filter media is installed.

The surface of the filter media must be lightly compacted (e.g. using a single pass of a drum lawn roller).

The surface of the filter media must be flat and free from localised depressions. A spreader bar or equivalent should be used.

DESIGN NOTE: Clay and silt content in filter media

The *Adoption Guidelines for Stormwater Biofiltration Systems* (Cooperative Research Centre for Water Sensitive Cities) recommend that filter media has a clay and silt content of less than 3%. Industry experience has shown that filter media with a clay and silt content of less than 3% results in poor plant establishment and that filter media with an initial clay and silt content as high as 6% can function appropriately. Considering this, it is the recommendation of this guideline that the minimum clay and silt content in filter media be 2%. It is also recommended that consideration be given to filter media with a clay and silt content as high as 6%, provided that the required saturated hydraulic conductivity is achieved and the media is well graded (i.e. the particle size distribution for particles greater than 0.05 mm is in accordance with FAWB Guidelines).

DESIGN NOTE: Commercial availability of filter media

The FAWB Guidelines and the requirements of this guideline allow for flexibility in the properties of bioretention filter media. This flexibility is not always reflected in commercially available filter media. It is recommended that the bioretention designer contact filter media suppliers to ensure that the filter media specifications can be met in a commercially available product.

4.3.2 Transition layer

The transition layer prevents filter media from migrating into the drainage layer. It is not present in bioretention systems that meet the requirements outlined in Section 3.3.2.2. The transition layer surface must be flat and free from localised depressions. A spreader bar or equivalent should be used.

Where present, the transition layer must:

- meet the requirements of Section 3.3.2.4 for Type 1 saturated zone bioretention systems
- be at least 100 mm deep for Type 2A, 2B, 3 and 4 bioretention systems.

The transition layer material must be a clean, well-graded sand containing less than 2% fines.

To avoid migration of the filter media into the transition layer, the particle size distribution of the sand should be assessed to ensure it meets 'bridging criteria', that is, the smallest 15% of the sand particles of the transition layer bridge with the largest 15% of the filter media particles:

- D_{15} (transition layer) $\leq 5 \times D_{85}$ (filter media) where: D_{15} (transition layer) is the 15th percentile particle size in the transition layer material (i.e. 15% of the sand is smaller than D mm), and D_{85} (filter media) is the 85th percentile particle size in the filter media.

4.3.3 Drainage layer

The drainage layer conveys infiltrated flows horizontally across the base of the system into the slotted underdrainage pipes. It is not present in Type 4 infiltration – pipeless bioretention systems.

Drainage layers must:

- be at least 150 mm deep for Type 1 2A and 2B bioretention systems
- be at least 300 mm deep for Type 3 bioretention systems
- provide at least 50 mm of cover above the underdrainage pipes
- comprise fine gravel (2 – 5 mm) with less than 2% fines and a minimum saturated hydraulic conductivity of 4000 mm/hr. The drainage layer gravel must meet the following bridging criteria:
 - D_{15} (drainage layer) $\leq 5 \times D_{85}$ (transition layer).

The surface of the drainage layer must be flat and free from localised depressions. A spreader bar or equivalent should be used.

Geotextile fabrics are not recommended for use between layers in bioretention systems due to the risk of clogging.

4.3.4 Saturated zone

Saturated zones must be at least 350 mm deep and contain:

- a drainage layer of fine gravel (2 – 5mm) installed at the base of the saturated zone, which meets the depth requirements of Sections 3.3.2.3 and 3.3.2.4
- a transition layer of coarse double-washed sand installed on top of the drainage layer, which also meets the depth requirements of Section 3.3.2.4.

4.4 Landscape considerations and specifications

4.4.1 Topsoil (batters and embankments)

The batters and embankments around bioretention systems must be covered with at least 200 mm of topsoil.

Topsoil must be tested by a National Association of Testing Authorities (NATA) accredited laboratory in accordance with AS 4419. The proposed topsoil should be rejected if it has high salt levels, extremely low levels of carbon (< 5%), or any other extreme characteristic that may restrict plant growth. The laboratory testing will identify any amelioration requirements. The results of the topsoil test must be given to the site superintendent and bioretention system designer for review before the topsoil is installed.

Bioretention system topsoil can be sourced from the in-situ topsoil or from soil suppliers. In-situ topsoil can be used for bioretention batters; however, laboratory soil testing in accordance with AS 4419 is required to ensure the topsoil will support plant growth. If the in-situ topsoil is unsuitable, new topsoil should be purchased from a soil supplier. Purchased soils must still comply with AS 4419.

Weed-infested soils should be avoided (particularly soils containing aggressive pasture grasses tolerant of moist conditions). If weeds are present in in-situ soil and no other sources of topsoil are available, a minimum of 50 mm should be scraped from the soil surface and discarded.

4.4.2 Plants

Planting densities and species must be consistent with the detailed design drawings. No substitutions should be made unless approved by the site superintendent.

4.4.2.1 Plant procurement

For large orders, it is recommended that plant stock is periodically inspected at the nursery to ensure that suitable plants will be ready when required and to check that:

- plants are being grown in clean, weed and pest-free conditions
- roots of plants are fresh and white
- foliage is consistent with the size, colour and texture of the nominated species
- plants are exposed to direct sunlight in a 'hardening off' phase before delivery and are not taken directly from a shade house to the construction site.

Plants used in bioretention systems are typically tubestock sourced from wholesale nurseries. Plant availability varies considerably between different regions and times of the year. Sufficient time must be allowed to order plants, and up to six months lead time may be required to ensure appropriate species are available. If provenance plant stock is specified, up to 18 months may be required to collect seeds and propagate plants.

Some species are very difficult or slow to propagate. Advice should be sought from a knowledgeable nursery to avoid last-minute substitutions due to species unavailability.

4.4.2.2 Maturity

Plant stock must be well developed, sun-hardened, and contain a fully established root ball that does not crumble when removed from its container.

Immature plants and plants that are too old can be difficult to establish. Many species of sedges and other bioretention plants will struggle to develop once they are old and pot-bound. These plants may remain stunted, be susceptible to herbivory and disease and fail to provide the root cover required for optimal filtration.

All plant stock must:

- show no sign of pest and disease
- show no signs of nutrient deficiency
- show signs of new growth and general vigour
- be free from weeds
- be clearly labelled.

Tubestock must be:

- supplied in a container that is at least 90 mm high and 50 mm wide
- at least 200 mm high.

Tree stock must:

- be in accordance with AS 2303:2018 Tree stock for landscape use
- Fall within the preferred size index range for the proposed container size.

4.4.3 Preparing filter media

Before planting, the filter media should be tested at a NATA-accredited laboratory for advice on whether additional nutrients are required for successful plant establishment. This advice must be adhered to.

If a laboratory analysis is not possible, each plant must receive at least 10 g of slow-release native fertiliser in granular or tablet form. After planting, the contractor must undertake monthly assessments of plant health to determine whether any species require additional fertiliser.

Plant stress and watering requirements can be reduced by using water crystals to increase the water-holding capacity of the soil. Water crystals should be applied when they are fully hydrated (to limit the potential for plants being pushed out of their holes as the crystals swell) at a rate of 2 – 3 g per plant. Plant establishment can also be aided by using a temporary upstand (see Section 3.6.1.5)

4.4.4 Mulching

Mulching retains moisture around plants and provides a source of organic matter to help plants establish.

Mulch must be:

- applied in accordance with design drawings
- applied before planting
- 50 – 75 mm thick to ensure new vegetation shoots are not hindered
- kept clear of plant stems by at least 50 mm to avoid excessive moisture around stems.

A range of mulches are suitable for bioretention systems. These include:

- Organic friable mulches that degrade within six months, such as fine sugar cane or tea tree mulch. To avoid the mulch being washed away during storms, it should be pinned down with an organic weed mesh (e.g. loose-weave jute), pinned at no more than 500 mm centres (or closer, particularly near the inlet).
- Long-lasting organic mulches, including tanbark or other hardwood (provided the system is located offline from high flows).

The following should not be used as mulch for bioretention systems:

- Organic mulch that is likely to contain weed seeds
- Organic matting
- Inorganic matting, such as filter cloth
- Riverstone (because it is extracted from natural water courses)
- Small gravel or stone (because it restricts plant growth and transfers/reflects excessive heat onto plants).

4.4.5 Planting procedure

4.4.5.1 Plant set out

Plant set out is a critical part of landscape works and must be confirmed with the designer or landscape architect before landscape works start. It is essential to confirm the placement of species (particularly for trees or shrubs within the system) or if attempting to mimic a representative vegetation community.

Planting areas should be measured from design drawings and marked with stakes for ease of planting and to reduce the risk of incorrect placement.

Avoid creating large areas of monoculture. Contact the site superintendent if the design drawings indicate large monocultures.

4.4.5.2 Planting

Vegetation in bioretention systems is usually planted using hand tools or light machinery such as auger drills. Heavier equipment is not necessary as the filter media will be uncompacted. Planter holes should be twice the size of the tubestock. Plants should be carefully removed from the tube to ensure their stems do not break from the root ball. Plants should be placed in the filter media such that all roots are covered by at least 10 – 20 mm of soil.

4.4.5.3 Establishment

Given the importance of establishing plant cover within the bioretention system as quickly as possible, a proactive and adaptive approach must be taken to landscape establishment, responding to any issues of plant health as they arise. Responses can include watering, fertilising, the use of a temporary upstand (see Section 3.6.1.5) and manual removal of weeds. Spreading seed can improve the seed bank and increase plant cover in bare areas.

If less than 90% of plants survive, replanting must occur during the establishment phase.

4.4.6 Watering

Bioretention plants require regular water during the establishment phase. Where a temporary upstand (see Section 3.6.1.5) is not used, plants must be regularly watered. The frequency of watering will depend on the time of year and the weather.

The following watering program must be followed unless a variation is agreed to by the site superintendent:

- Week 1 – 6: Five waterings per week.
- Week 6 – 10: Three waterings per week.
- Week 11 – 15: Two waterings per week.

In the absence of rain, it is recommended that each plant receives 2.5 – 5 L of water per week during the first six weeks (40 mm of watering per week during establishment).

After an initial four-month period, watering may still be required, particularly during the first winter or dry period. Watering requirements for healthy vegetation can be determined by ongoing inspections.

Where a temporary upstand is used, water can be decreased and, in some instances, all but eliminated. Reductions in recommended watering frequencies should only occur in conjunction with plants that are healthy and growing vigorously.

4.4.7 Measures of successful establishment

Vegetation in bioretention systems is considered 'established' when the plants are robust and self-sustaining.

Growth and maturity should be recorded through three-monthly photo logs every 250 m², and the following criteria met:

- Vegetation must cover at least 90% of the bioretention system surface (< 10% soil/mulch visible from above).
- Any areas without established vegetation cover must be mulched.
- Minimum vegetation height for tubestock should be 500 mm. Height for trees and shrubs installed in larger pots will vary with the pot size and species; however, each plant must be healthy and growing vigorously.
- Plants must be healthy and free from disease.

5 Worked example

The following worked example provides a practical application of the design process presented in Section 3 of this guideline within the context of a real site. The structure of the worked example aligns closely with Section 3 to allow quick reference from the design calculations back to supporting information.

This example is intended to demonstrate concepts and calculations specific to bioretention functional design and therefore assumes that all supporting information (e.g. trunk drainage design, ecological

assessments, flood studies) has been completed in accordance with industry standards. Where applicable, such information is simply stated in the example rather than calculated or described in detail. The worked example is not intended to provide prescriptive design solutions that apply to all situations. Designers must use experience and professional judgement as well as understand local authority requirements to develop a suitable bioretention design.

DESIGN NOTE: Consistency with previous sections

This worked example is based on a real-world project that aligns with previous versions of this guideline. There are minor inconsistencies between the worked example and this version of the guideline. For example, this worked example implements more underdrainage cleanout points than are now recommended. Where inconsistencies exist, the advice in Sections 3 and 4 of this guideline should take precedence.

5.1 Project overview

As part of a retrofit stormwater treatment strategy, a bioretention basin is to be integrated into an existing park beside a small creek in Brisbane. The project aims to capture and treat stormwater prior to it entering the creek through the use of a bioretention system, which integrates with both the existing residential area and the riparian corridor.

5.2 Concept design

Concept design was undertaken for the bioretention system and is summarised in Table 26 and Figure 94.

The bioretention basin will receive piped minor flows (2-year ARI) from a 2.9-hectare catchment and overland major flows (50-year ARI) from a 1.3-hectare catchment. The filter media area and extended detention depth were established using MUSIC. The proximity to both parkland and natural areas (creek) guided the overall configuration and proposed planting outcomes for the bioretention basin. The bioretention basin will not form part of any flood detention basin nor interact with the streetscape directly, thus design considerations relating to these types of bioretention systems are not required.

The following sections present detailed design completed for the bioretention system based on the concept design parameters summarised in Table 30.

Table 30. Concept design parameters.

| Catchment parameter | Value adopted |
|---|-----------------------|
| Minor flow catchment (piped). | 2.9 ha |
| Major flow catchment. | 1.3 ha |
| Houses (with rainwater tanks supplying non-potable uses). | 8 |
| Houses (with no rainwater tank). | 21 |
| Houses (total). | 29 |
| Impervious cover. | 55% |
| Bioretention parameter. | Value adopted |
| Filter media area. | 396 m ² |
| Total footprint (3 x filter media area). | ~1,188 m ² |
| Extended detention depth. | 300 mm |

| | |
|--|----------------|
| Filter media depth. | 600 mm (min) |
| Drainage profile. | Saturated zone |
| Filter media saturated hydraulic conductivity. | 100 mm/hr |



Figure 94. Concept design.

5.3 Background investigations

5.3.1 Site analysis

The following site characteristics were confirmed based on desktop analysis, site investigation, discussions with Council and input from specialist subconsultants:

- Detailed topographical survey was completed for the entire catchment.
- Catchments for piped and overland flows were confirmed based on topography and drainage layout, including defining the location, size and invert of existing stormwater drainage infrastructure.
- All physical boundaries and constraints were identified, including the wet season water level (3.0 m AHD) in the downstream receiving waterway.
- Flood levels were provided by the Council for the bioretention location as follows:
 - 5-year ARI = 5.3 m AHD

- 50-year ARI = 5.8 m AHD.
- Dial Before You Dig search was undertaken and indicated no services in the broad bioretention area.
- Significant trees were identified along the riparian zone of the creek, and ecological assessment of the representative indigenous flora undertaken. All trees to be retained are marked on the drawings.
- Geotechnical investigations were undertaken to determine if any PASS or dispersive clays were present on site. Test pits were excavated and samples taken. PASS were found to be present and will be managed in accordance with a management plan. No dispersive soils were located.
- Groundwater monitoring was undertaken and indicated that the maximum wet season groundwater level is 3.6 m AHD.
- It was assumed that the bioretention would not receive baseflow as no flow was observed in the existing pipe during a site visit undertaken after five days without rainfall.

The above site characteristics are shown in Drawing WSUD- P01 and WSUD-P02.

5.3.2 Design objectives

The following design objectives were resolved by the design team:

- Meet best practice stormwater pollutant load reduction targets (80% reduction in total suspended solids, 60% reduction in total phosphorus and 45% reduction in total nitrogen).
- Provide integration between the existing residential area and the riparian corridor.

5.3.3 Consultation with local authority

The following design requirements were identified in consultation with Council:

- Vegetated batters to be no steeper than 1 in 4.
- The bioretention system and associated batters must be planted with groundcovers, shrubs and trees to complement the existing riparian vegetation and limit weed ingress.
- Access to the sediment forebay is required for cleaning annually at a minimum. Access must be at least 2.5 m wide and can be reinforced turf, provided the grade is 1 in 4 or flatter.
- The bioretention system embankments must be higher than the peak 5-year ARI water level from the waterway immediately south of the bioretention (i.e. 5.3 m AHD).
- Embankments and surrounding pathways require 200 mm or more freeboard above the peak water level during the major flow.

Note: In some instances, these requirements vary from the recommendations made in this guideline. These variations were agreed upon with Council.

5.4 Layers, depths and levels

5.4.1 Bioretention profile selection

A saturated zone bioretention was selected for the following reasons:

- to sustain vegetation during dry periods
- because an impermeable liner is required due to PASS, the inclusion of a saturated zone was considered an easy, beneficial change to the design.

5.4.2 Media layers and depths

The saturated zone bioretention system will be created using an outlet riser configuration sited within the outlet pit (see Option 2 in Figure 79 and Figure 95). This will ensure the saturated zone can be periodically drained for maintenance purposes. To allow trees to be planted in the bioretention basin to improve integration with the riparian zone, the filter media will be 700 mm deep. This is more than the minimum recommendation of 600 mm. The bioretention layers, depths and levels are presented in Figure 95.

5.4.2.1 Saturated zone depth

The saturated zone will be 400 mm deep. This exceeds both the minimum recommended depth of 350 mm (see Section 3.3.2.4) and the minimum requirement to sustain plants during the average annual longest expected dry period in Brisbane (see

Equation 3) as shown in Calculation 1 below.

Calculation 1

$$D_{sz} = 8 \text{ mm/day} \times t_{dp}$$

Where: D_{sz} = Ideal depth of saturated zone (mm)

t_{dp} = average of the longest annual dry period for the last 10 years = 33 days

$$D_{sz} = 8 \text{ mm/day} \times 33$$

$$D_{sz} = 264 \text{ mm}$$

The drainage layer will be 150 mm deep to allow it to extend 50 mm above the top of the perforated underdrainage (see Table 5). This will ensure that the top of the saturated zone is not located within the drainage layer (see Section 3.3.2.4). To ensure the top of the saturated zone is located within the transition layer and at least 100 mm below the base of the filter media, the transition layer will be 350 mm deep.

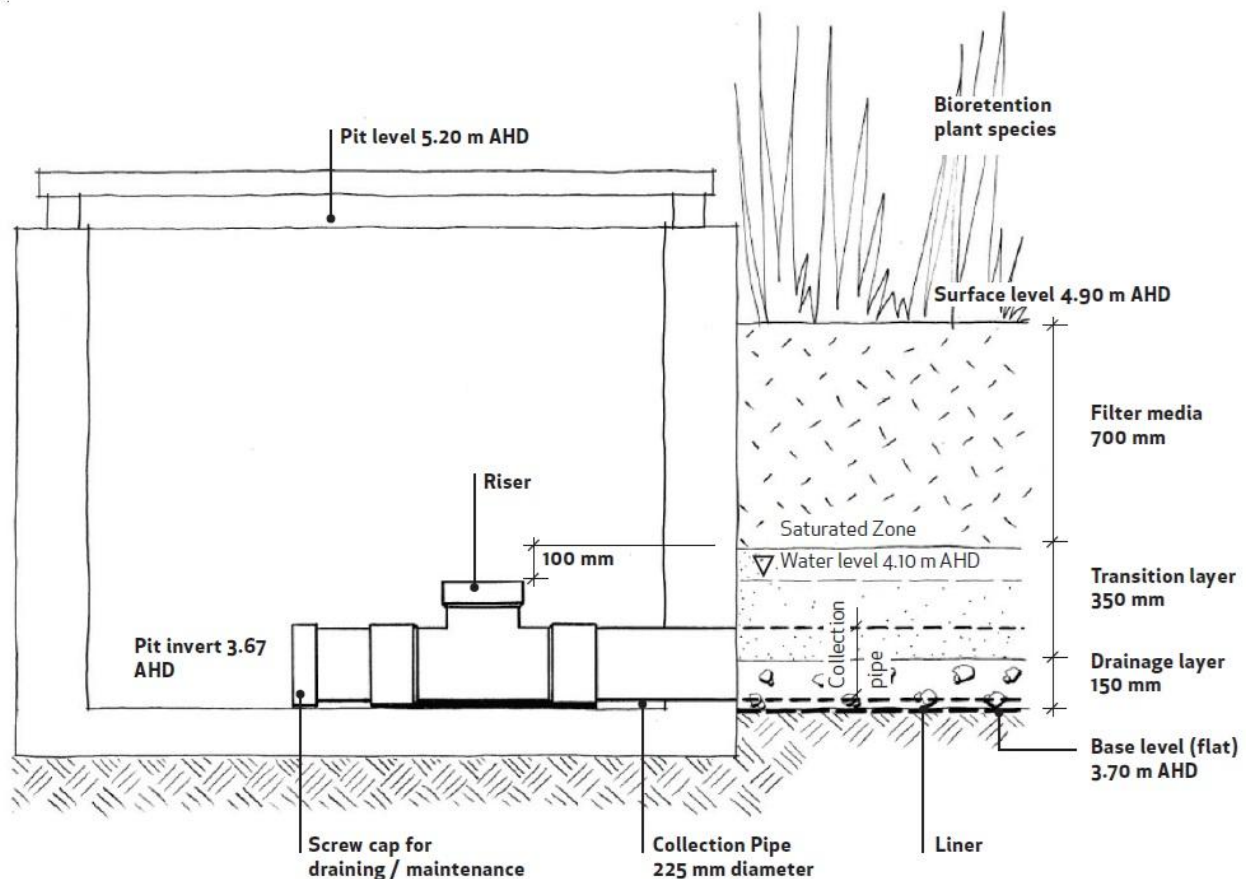


Figure 95. Bioretention media layers, depths and levels.

5.4.3 Design levels (outlet, surface and water levels)

The bioretention levels were established through an iterative design process considering layout, inlet design (existing pipes) and outlet design. In doing so, both the design objectives of this bioretention system (see Section 5.3.2) and the design requirements for layers, depths and levels specified in Section 3.3 were met. Further explanation of the method by which each level was calculated is provided in the following sections.

The design levels are:

1. Outlet invert level = 3.26 m AHD, which is 0.36 m above the standing water level and 0.16 m above the 1-month ARI flow event in the receiving waterway/drain.
2. Pipe invert levels (established based on the outlet level and pipe grade of 1.2%):
 - a. Downstream pipe invert = 3.26 m AHD
 - b. Upstream pipe invert = 3.67 m AHD.
3. Outlet pit invert level = 3.67 m AHD.
4. Bioretention base level = 3.7 m AHD. The base of the saturated zone bioretention system is flat.
5. Drainage layer, transition layer and filter media surface levels:
 - a. Drainage layer surface = 3.85 m AHD
 - b. Transition layer surface = 4.2 m AHD
 - c. Filter media surface = 4.9 m AHD.
6. Coarse sediment forebay invert is set at 5.0 m AHD (100 mm above the filter media surface) with the incoming pipe invert at 5.1 m AHD.
7. Extended detention depth = 300 mm and overflow pit level = 5.2 m AHD.

8. Maximum water level = 5.6 m AHD (based on an overflow weir level of 5.5 m AHD – refer to Calculation 24 in Section 5.7.4).
9. Minimum embankment level = 5.8 m AHD. Note this is well above the 5-year ARI requirement of 5.3 m AHD given by Council.
10. Maximum level difference from bioretention surface level to adjacent pathways will be 1.1 m.

5.4.4 Liner

A bentonite liner will be used for the bioretention base and side, as no suitable clays were found on site during geotechnical investigations.

5.5 Bioretention system layout

5.5.1 Earthworks model

A digital earthworks model was created for the site using the topographical survey. The model defines the layout and level configuration for the bioretention system. This was also used in a broader floodplain model, with the outcome showing no loss of floodplain storage or impacts on local stream hydraulics.

5.5.2 Filter media area

The bioretention filter media area of 396 m² was established during concept design using MUSIC modelling. The catchment area, land use and key bioretention parameters from the concept design remained unchanged, and hence this filter media area was retained.

5.5.3 Shape

The minimum width of the filter media will be 5 m, and the maximum length will be 40 m (refer Drawing WSUD-P03). This is in accordance with the requirements of Section 3.4.3.

5.5.4 Inlet and outlet locations

To minimise the amount of new stormwater infrastructure required, the existing pipe and headwall (refer to Drawing WSUD-P01) will be retained as the inlet to the bioretention system. The pipe invert was used as a key design level for the overall system profile. Through careful site layout and in accordance with the requirements of Section 3.4.4, the outlet pit will be located close to the inlet to ensure high flows can pass through the bioretention without engaging with the whole filter media surface. A coarse sediment forebay will be located at the inlet.

The layout and profile of the system will result in the bioretention outlet pipe discharging directly to the waterway (rather than further up the bank/floodplain). Careful design of this outlet and scour protection was therefore required to avoid adverse impacts on the local receiving waterway from concentrated outflows (see Section 5.7.5).

5.5.5 Edge and landscape interface (batters and embankments)

5.5.5.1 Surrounding landscape

The design considered the surrounding landscape by:

- retaining existing trees
- retaining existing pathways to preserve bike and pedestrian movement
- forming the bioretention system in an organic shape to ensure integration with the natural riparian setting.

5.5.5.2 Public access and safety

There will be no pedestrian access to or across the filter media. The existing pathway connection will be retained and realigned where required towards the existing road to allow passive surveillance. No pedestrian movement will be encouraged on the creek side of the bioretention system, where surveillance may not be possible.

5.5.5.3 Batters

The batters around the bioretention system will vary from 1 in 4 (maximum) to 1 in 8. The height of the batters varies from 0.9 m on the creek side of the bioretention system to 1.1 m on the road-side of the bioretention. Shrubs and trees will be planted on the batters.

5.5.5.4 Embankments

The top of the embankment (5.8 m AHD) will be 1 m wide to allow for maintenance access (see Section 5.5.6).

5.5.5.5 Walls

The bioretention system will not include any walls or fences.

5.5.6 Maintenance access

5.5.6.1 Sediment cleanout access

A reinforced turf section of the bioretention batter, with a maximum slope of 1 in 4, will serve as an access track for bobcats to enter the coarse sediment forebay for annual cleanout. The access track will be 2.5 m wide. Maintenance vehicles will be able to use the pedestrian path to get from the road to the reinforced turf access track.

5.5.6.2 Filter and vegetation maintenance

Due to the scale of the system (<500 m²), the perimeter only needed to be accessed by maintenance staff on foot (i.e. vehicle access is not required).

The 2.5 m wide pedestrian path along the northern bioretention edge will make up 41% of the perimeter and will therefore be in accordance with Table 10.

The top of the embankment along the south, east and west sides will be 1 m wide to provide an access route for maintenance staff if required. This is wider than the minimum 0.5 m requirement from Table 10.

5.5.6.3 Maintenance edges

The base of the bioretention embankment on the south, east and west edges will abut riparian vegetation, so no maintenance edge is required. The pedestrian path will form a maintenance edge along the north side.

5.5.7 Underground services

Background investigations found no known services within the bioretention vicinity.

5.6 Inlet design

5.6.1 Design inflows

Design flows were estimated using the probabilistic rational method, in accordance with *QUDM* (Institute of Public Works Engineering Australasia, Queensland, 2017) and Council standards (Table 31).

Table 31. Design inflows.

| Design flow | ARI | Flow (m ³ /s) |
|----------------------------|---------|--------------------------|
| Major | 50-year | 1.18 |
| Minor | 2-year | 0.74 |
| Coarse sediment management | 3-month | 0.22 |

5.6.2 Inflow type

Inflow to the system will be concentrated via the existing pipe and headwall (concentrated pipe inflow). Observations made during the site visit indicate that the system will not receive a constant base flow.

5.6.3 Coarse sediment removal

Due to the scale of the catchment (2.9 ha), a coarse sediment forebay is required. The base of the concrete forebay will be at 5 m AHD. This will locate it 100 mm above the filter media surface and 100 mm lower than the invert of the inlet pipe. A 200 mm high concrete rim will form the interface between the forebay and bioretention system. Vertical slots (50 mm wide) at 2 m spacing will allow the forebay to drain to the filter media.

The sediment forebay was sized in accordance with Equation 5, Equation 6 and Equation 7 (see Section 3.5.3.3), ensuring:

- adequate removal of sediment greater than 1 mm particle size
- cleanout is required no more regularly than once per year (i.e. Frequency, $F_c = 1$)
- sediment removal based on the 3-month ARI flow.

First, the minimum storage volume required was determined (Calculation 2). The contributing catchment area during the 3-month ARI flow will be 2.9 ha. A target removal efficiency of 0.8 was chosen in accordance with Section 3.5.3.3. No site-specific sediment load data were available for the site, so 0.6 m³/ha/yr was used in accordance with Section 3.5.3.3. A cleanout frequency of 1 was adopted in line with Council requirements that the forebay be designed for desilting no more than once per year.

Calculation 2

$$V_s = A_c \times R \times L_o \times F_c$$

Where: V_s = storage volume

A_c = catchment area = 2.9 ha

R = removal efficiency = 0.8

L_o = sediment loading rate = 0.6 m³/ha/yr

F_c = cleanout frequency = 1 year

$$V_s = 2.9 \times 0.8 \times 0.6 \times 1$$

$$V_s = 1.4 \text{ m}^3$$

Next, the minimum forebay area required to achieve the sediment storage volume was determined (Calculation 3). The sediment storage volume was obtained from Calculation 2. A maximum sediment storage depth of 0.1 m was a key assumption when setting the bioretention basins' depths and levels (see Section 5.4.3) and hence was adopted here.

Calculation 3

$$A_s = \frac{V_s}{D_s}$$

Where: A_s = storage area

V_s = storage volume = 1.4 m³

D_s = maximum sediment storage depth = 0.1 m

$$A_s = 1.4 / 0.1$$

$$A_s = 14 \text{ m}^2$$

Third, the minimum forebay area required to achieve the target sediment removal efficiency of 80% was calculated (Calculation 4). A settling velocity of 0.1 m/s was adopted for the target 1 mm sediment in accordance with Section 3.5.3.3. A turbulence factor of 0.5 (as recommended in Section 3.5.3.3) was adopted. The 3-month ARI design flow calculated in Section 5.6.1 (see Table 31) was used.

Calculation 4

$$R = 1 - \left(1 + \frac{1}{n} \times \frac{v_s}{Q/A_f}\right)^{-n}$$

Where: A_f = forebay area

R = target removal efficiency = 0.8

v_s = settling velocity of 1mm sediment = 0.1 m/s

Q = 3 month ARI design flow = 0.22 m³/s

n = turbulence factor = 0.5

$$0.8 = 1 - \left(1 + \frac{1}{0.5} \times \frac{0.1}{0.22/A_f}\right)^{-0.5}$$

Solving for A_f gives

$$A_f = 26.4 \text{ m}^2$$

The forebay must be large enough to achieve both the required removal efficiency and the storage volume. Therefore, the larger of these two values (26.4 m² from Calculation 4) was adopted as the forebay area. In this area, the annual sediment accumulation depth will be 53 mm. This means the coarse sediment forebay can be cleaned every 1.5 – 2 years.

5.6.4 Inlet energy dissipation and scour protection

An assessment of the inlet pipe discharge velocity was undertaken in accordance with QUDM (Institute of Public Works Engineering Australasia, Queensland, 2017) to determine the requirements for energy dissipation and scour protection. The pipe velocity dictated the need for a rock apron with a length of approximately six times the pipe diameter (600 mm). As the total forebay length will be just over 7 m, no additional energy dissipation and scour protection was designed. However, to manage localised filter media scour from flows overtopping the sediment forebay wall, a 0.6 m wide rock apron will surround the sediment forebay. This will be nominally widened (in the direction of flow) to 1.2 m between the forebay and overflow pit. The rock used will be between 100 and 150 mm nominal diameter.

5.6.5 Filter media scour velocity check

The velocity of water across the filter media surface in both the minor (Calculation 5) and major (Calculation 6) storms was calculated to check that the filter media would not be prone to scour. The flow rate previously determined for each design storm (see Table 31) was used. A width of 4 m was used as this is the width of the bioretention basin at the narrowest point in the filter media (in this case, the interface of the coarse sediment forebay rock protection and the filter media). The depth of flow was calculated in accordance with Section 3.5.5. In the minor storm calculation, the depth was 0.4 m (the extended detention depth plus 100 mm). In the major storm calculation, the depth was 0.65 m (the bypass weir level plus 100 mm).

Calculation 5

$$v = Q / (w \times d)$$

Where: v = velocity of flow over filter media surface (m/s)

Q = flow rate in the design storm event = 0.74 m³/s

w = bioretention basin width at narrowest point = 4 m

d = depth of flow in accordance with Table 16 = 0.4 m

$$v = 0.74 / (4 \times 0.4)$$

$$v = 0.46 \text{ m/s}$$

Calculation 6

$$v = Q / (w \times d)$$

Where: v = velocity of flow over filter media surface (m/s)

Q = flow rate in the design storm event = 1.18 m³/s

w = bioretention basin width at narrowest point = 4 m

d = depth of flow in accordance with Table 16 = 0.65 m

$$v = 1.18 / (4 \times 0.65)$$

$$v = 0.45 \text{ m/s}$$

The velocity in both the minor and major storms will be less than 1 m/s and will therefore be acceptable.

5.6.6 Flow distribution

A dedicated distribution system will not be required as the bioretention is not greater than 400 m². The saturated zone will ensure even soil moisture during dry weather.

5.7 Outlet design

5.7.1 Underdrainage pipes

5.7.1.1 Pipe material selection

Slotted 100 mm diameter HDPE underdrainage pipes will be used. The slotted pipes will connect to a solid 225 mm diameter HDPE collector pipe with 45-degree 'Y' junctions to permit flushing.

5.7.1.2 Saturated zone bioretention underdrainage

As the bioretention system contains a saturated zone, the underdrainage was sized in accordance with the general approach to sizing underdrainage pipes detailed in Section 3.6.1.6.

1. Underdrainage layout and pipe sizing

The proposed underdrainage arrangement is shown in Drawing WSUD-P03. The slotted pipes will be at 2 m spacing.

2. Riser connection

The riser connection will be 225 mm in diameter with a crest level 100 mm below the top of the transition layer (4.1 m AHD).

3. Maximum water level height at riser connection

a. Design flow through filter

The maximum infiltration rate (Q_{max}) per square meter of filter media was determined (Calculation 7) in accordance with Equation 9 (see Section 3.6.1.6). In accordance with the design, the filter media depth and extended detention depth used were 0.7 m and 0.3 m respectively. As the calculation was performed on a single square meter of filter media, the filter media area used was 1 m². A saturated hydraulic conductivity of 2.78×10^{-5} m/s (i.e. 100 mm/hr in accordance with Table 30) was used.

Calculation 7

$$Q_{max} = K_{sat} \times A \times \frac{h_{max} + d}{d}$$

Where: Q_{max} = maximum infiltration rate (m^3/s)
 d = depth of filter media = 0.7 m
 h_{max} = extended detention depth = 0.3 m
 A = filter media area = 1.0 m^2
 K_{sat} = saturated hydraulic conductivity of filter media = 2.78×10^{-5} m/s

$$Q_{max} = 2.78 \times 10^{-5} \times 1 \times \frac{0.3 + 0.7}{0.7}$$

$Q_{max} = 3.97 \times 10^{-5}$ m^3/s per m^2

$Q_{max} = 0.016$ m^3/s for the total filter area of 396 m^2

b. Maximum outlet riser water level

The maximum water level at the outlet from the underdrainage network (i.e. the depth of flow spilling from the vertical riser pipe) was calculated by rearranging the weir equation (Calculation 8). The weir equation was used because the outlet riser configuration chosen (see Figure 95) behaves as a weir. The length of weir used was 0.72 m as this is the circumference of the 225 mm diameter outlet pipe. A weir coefficient of 1.66 was adopted. A flow rate through the outlet of 0.016 m^3/s was adopted as determined in Calculation 7.

Calculation 8

$$Q_{weir} = C_w \times L \times h^{3/2}$$

Where: C_w = weir coefficient = 1.66
 L = length of weir = 0.72 m
 Q_{weir} = flow rate through outlet = 0.016 m^3/s
 h = depth of flow above weir crest (m)

$$0.016 = 1.66 \times 0.72 \times h^{3/2}$$

Solving for h gives

$$h = 0.056 \text{ m}$$

The maximum water level using the weir equation was found to be 0.056 m, which corresponds to 4.156 m AHD.

c. Allowable head loss

The allowable head loss through the slotted pipe network was calculated as 0.044 m; that is, the difference between the base of the filter layer (4.200 m AHD) and the maximum outlet water level (4.156 m AHD).

4. Underdrainage head loss

To check the combined head loss (H_{total}) of the underdrainage network will not exceed the allowable head loss identified above, the individual components contributing to head loss (i.e. friction (h_f) and structure (h_s) losses in the critical (typically longest) run of underdrainage network) were calculated and then summed in accordance with Equation 12 (see Section 3.6.1.6), as shown again here.

$$H_{total} = h_{f(slotted)} + h_{f(collector)} + \sum h_{s(slotted)} + \sum h_{s(collector)} + \sum h_{s(riser)}$$

The calculations for each head loss component are shown below.

a. Head loss – slotted pipe friction

The friction head loss (h_f) in the longest slotted pipe was calculated using Equation 10 (see Section 3.6.1.6).

To do this, the average flow rate for the pipe was required. This was determined as shown in Calculation 9. The contributing area for half the pipe was determined to be 10 m² (i.e. 5 m long by 2 m wide). The maximum infiltration rate per square meter of filter media determined in Calculation 7 was used.

Calculation 9

$$Q = Q_{max} \times A$$

Where: Q = flow rate for subject portion of underdrainage (m³/s)

Q_{max} = maximum infiltration rate per square meter of filter media = 3.97x10⁻⁵ m/s

A = contributing filter area = 10m²

$$Q = 3.97 \times 10^{-5} \times 10$$

$$Q = 3.97 \times 10^{-4} \text{ m}^3/\text{s}$$

This value was then used to determine the friction loss in the longest slotted pipe (Calculation 10). The length of pipe was 10 m, and the pipe diameter was 0.1 m (see Section 5.7.1.1). The coefficient of roughness used was 150 (as recommended in Section 3.6.1.6).

Calculation 10

$$h_{f(slotted)} = L \left(\frac{10.67 \times Q^{1.85}}{C^{1.85} \times D^{4.87}} \right)$$

Where: $h_{f(\text{slotted})}$ = slotted pipe friction loss (m)
 L = pipe length = 10 m
 Q = flow rate for subject portion of underdrainage = $3.97 \times 10^{-4} \text{ m}^3/\text{s}$
 C = roughness coefficient = 150
 D = pipe diameter = 0.1 m

$$h_{f(\text{slotted})} = 10 \left(\frac{10.67 \times (3.97 \times 10^{-4})^{1.85}}{150^{1.85} \times 0.1^{4.87}} \right)$$

$h_{f(\text{slotted})} < 0.001 \text{ m}$

b. Head loss – collector pipe friction

The friction loss in the collector pipe (35 m long) was also calculated using Equation 10 (see Section 3.6.1.6) based on the average pipe flow (i.e. at pipe midpoint). The contributing filter media area at the pipe midpoint will be 200 m² (approximately half the filter). The flow rate for this portion of the filter/underdrainage is therefore:

Calculation 11

$$Q = Q_{\text{max}} \times A$$

Where: Q = flow rate for subject portion of underdrainage (m³/s)
 Q_{max} = maximum infiltration rate per square meter of filter media = $3.97 \times 10^{-5} \text{ m}^3/\text{s}$
 A = contributing filter media area = 200 m²

$$Q = 3.97 \times 10^{-5} \times 200$$

$$Q = 7.94 \times 10^{-3} \text{ m}^3/\text{s}$$

The collector pipe friction loss was then determined (Calculation 12).

Calculation 12

$$h_{f(\text{collector})} = L \left(\frac{10.67 \times Q^{1.85}}{C^{1.85} \times D^{4.87}} \right)$$

Where: $h_{f(\text{collector})}$ = collector pipe friction loss (m)
 L = pipe length = 35 m
 Q = flow rate for subject portion of underdrainage = $7.94 \times 10^{-3} \text{ m}^3/\text{s}$

C = roughness coefficient = 150

D = pipe diameter = 0.225 m

$$h_{f(\text{collector})} = 35 \left(\frac{10.67 \times (7.94 \times 10^{-3})^{1.85}}{150^{1.85} \times 0.225^{4.87}} \right)$$

$$h_{f(\text{collector})} = 0.007 \text{ m}$$

c. Head loss – structural at slotted and collector pipe connection

The fitting loss where the slotted pipe connects to the collector pipe was calculated using Equation 11 (see Section 3.6.1.6). First, the flow rate in the pipe upstream of the fitting was calculated based on 20 m² of contributing filter media area.

Calculation 13

$$Q = Q_{\text{max}} \times A$$

Where: Q = flow rate in pipe at the fitting (m³/s)

Q_{max} = maximum infiltration rate per square meter of filter media = 3.97x10⁻⁵ m/s

A = contributing filter media area = 20 m²

$$Q = 3.97 \times 10^{-5} \times 20$$

$$Q = 7.94 \times 10^{-4} \text{ m}^3/\text{s}$$

Next, velocity (V) at the fitting was calculated based on the flow in the pipe from Calculation 13 and the area of the pipe (7.85 × 10⁻³ m² for a 100 mm diameter pipe).

Calculation 14

$$V = Q / A$$

Where: V = velocity at the fitting (m/s)

Q = flow rate in pipe upstream of the fitting = 7.94x10⁻⁴ m³/s

A = pipe area = 7.85x10⁻³ m²

$$V = (7.94 \times 10^{-4}) / (7.85 \times 10^{-3})$$

$$V = 0.1 \text{ m/s}$$

Finally, head loss at the fitting was calculated using Equation 11 (see Section 3.6.1.6). A K value of 1.0 was obtained from a hydraulics textbook (based conservatively on approximating the dual 45-degree elbow connection to the collector pipe as a line to branch flow in a junction).

Calculation 15

$$h_{s(\text{slotted})} = K \frac{V^2}{2g}$$

Where: h_s = head loss at the fitting (m)
 K = pressure change coefficient = 1.0
 V = velocity at the fitting = 0.1 m/s
 g = gravity = 9.81 m/s²

$$h_{s(\text{slotted})} = 1.0 \frac{0.10^2}{2 \times 9.81}$$

$$h_{s(\text{slotted})} < 0.001 \text{ m}$$

d. Head loss – structural at lateral inflow points

Head loss along the collector pipe from the lateral slotted pipe inflows was also calculated using Equation 11.

From the collector pipe friction calculation (Calculation 11), the flow rate at the midpoint is known to be $7.94 \times 10^{-3} \text{ m}^3/\text{s}$. Therefore, the velocity at this point was determined as shown in Calculation 16. The area of the 225 mm diameter collector pipe is 0.040 m^2 .

Calculation 16

$$V = \frac{Q}{A}$$

Where: V = velocity at the fitting (m/s)
 Q = flow rate in pipe upstream of the fitting = $7.94 \times 10^{-3} \text{ m}^3/\text{s}$
 A = pipe area = 0.040 m^2

$$V = \frac{7.94 \times 10^{-3}}{0.040}$$

$$V = 0.199 \text{ m/s}$$

Head loss was then determined using Equation 11 (see Section 3.6.1.6).

A K value of 0.2 was obtained from a hydraulics textbook (based on energy loss coefficients at branch lines). To estimate the gradually increasing inflows along the collector pipe, the loss from the lateral inflow at the collector pipe midpoint was calculated and multiplied by the number of lateral inflows (21 in total).

Calculation 17

$$h_{s(\text{collector})} = K \frac{V^2}{2g} \times \text{number of connections}$$

Where: h_s = head loss at the fitting (m)

K = pressure change coefficient = 0.2

V = velocity at the fitting = 0.199 m/s

g = gravity = 9.81 m/s²

number of connections = 21

$$h_{s(\text{collector})} = 0.2 \frac{0.199^2}{2 \times 9.81} \times 21$$

$h_{s(\text{collector})} = 0.008 \text{ m}$

e. Head loss – structural at bend in riser

Head loss from the bend (riser) at the end of the collector pipe was also calculated using Equation 11 (see Section 3.6.1.6). Velocity in the pipe was calculated (Calculation 18) based on the flow in the pipe. At the riser, the entire filter media contributes flow. Therefore, the flow in the pipe was 0.016 m³/s (see Calculation 7). The area of a 225 mm pipe is 0.040 m².

Calculation 18

$$V = \frac{Q}{A}$$

Where: V = velocity at the bend (m/s)

Q = flow rate in pipe at the bend = 0.016 m³/s

A = pipe area = 0.040 m²

$$V = \frac{0.016}{0.040}$$

$$V = 0.4 \text{ m/s}$$

Finally, head loss from the bend was calculated using Equation 11 (see Section 3.6.1.6). A K value of 1.0 was obtained from a hydraulics textbook (for tee junction).

Calculation 19

$$h_{s(\text{riser})} = K \frac{V^2}{2g}$$

Where: h_s = head loss at the bend (m)
 K = pressure change coefficient = 1.0
 V = velocity at the fitting = 0.4 m/s
 g = gravity = 9.81 m/s²

$$h_{s(\text{riser})} = 1.0 \frac{0.400^2}{2 \times 9.81}$$

$$h_{s(\text{riser})} = 0.008 \text{ m}$$

f. Head loss – total

The individual head loss components (Calculations 10, 12, 15, 17 and 19) were substituted into Equation 12 (see Section 3.6.1.6) to calculate the total head loss (Calculation 20).

Calculation 20

$$H_{\text{total}} = h_{f(\text{slotted})} + h_{f(\text{collector})} + \sum h_{s(\text{slotted})} + \sum h_{s(\text{collector})} + \sum h_{s(\text{riser})}$$

$$H_{\text{total}} = 0.001 + 0.007 + 0.001 + 0.008 + 0.008$$

$$H_{\text{total}} = 0.025 \text{ m}$$

The total head loss through the underdrainage at the maximum infiltration rate is therefore 0.025 m, which is less than the 0.044 m available. Thus, the underdrainage configuration adopted will operate effectively.

5.7.2 Overflow pit

Minor flows (2-year ARI) will overflow from the bioretention via a grated pit. The design intent is to manage the minor flows through the pit only (without engaging the high flow weir). A number of trial pit sizes and weir levels were assessed to determine an appropriate configuration to manage design flows and ponding depths. The pit was also checked against the underdrainage riser configuration to ensure the pipes and junctions could be adequately accommodated within the pit (225 mm riser tee

approximately 0.65 m long x 0.45 m high plus allowance for pipe and screw cap connection and access).

The hydraulic calculations for the adopted pit size of 1200 by 1800 mm are shown below.

The crest of the pit will be at 5.2 m AHD (i.e. top of extended detention at 300 mm above the filter surface). The water depth above the pit crest during the peak minor flow ($Q = 0.74 \text{ m}^3/\text{s}$ from Table 31) was tested under weir (see Equation 15) and orifice (see Equation 16) conditions.

Calculation 21 shows the results under weir flow conditions. A blockage factor of 0.5 and a weir coefficient of 1.66 were used in accordance with Section 3.6.2.1. The pit perimeter (6.0 m) was adopted as the length of the weir.

Calculation 21

$$Q_{\text{weir}} = B \times C_w \times L \times h^{3/2}$$

Where: Q_{weir} = flow rate during peak minor flow = $0.74 \text{ m}^3/\text{s}$
 B = blockage factor = 0.5
 C_w = weir coefficient = 1.66
 L = pit perimeter length = 6.0 m
 h = depth of flow over the pit (m)

$$0.74 = 0.5 \times 1.66 \times 6 \times h^{3/2}$$

$$h = 0.28\text{m}$$

Calculation 22 shows the results under orifice flow conditions. A blockage factor of 0.5 and an orifice coefficient of 0.6 were used in accordance with Section 3.6.2.1. The pit area was calculated to be 2.16 m^2 .

Calculation 22

$$Q_{\text{orifice}} = B \times C_d \times A \times \sqrt{2 \times g \times h}$$

Where: Q_{orifice} = flow rate during peak minor flow = $0.74 \text{ m}^3/\text{s}$
 B = blockage factor = 0.5
 C_d = orifice coefficient = 0.6
 A = pit area = 2.16 m^2
 g = gravity = 9.81 m/s^2
 h = depth of flow over the pit (m)

$$0.74 = 0.5 \times 0.6 \times 2.16 \times \sqrt{2 \times 9.81 \times h}$$

$$h = 0.07 \text{ m}$$

Pit overflow discharge will therefore be controlled by weir flow for the minor design event (i.e. results in lower discharge for a given depth over the pit). The maximum water level for the minor flow will therefore be 0.28 m above the pit crest (i.e. 5.48 m AHD), which satisfies the design intent of being below the adopted high flow weir level (see Section 5.7.4).

5.7.3 Outlet pipe

The outlet pipe from the pit was sized to convey the minor flow (0.74 m³/s) based on the pipe flowing full (but not under pressure) using Manning's equation. The site layout and level constraints dictate that the pipe will be approximately 34 m in length at a grade of 1.2% (1 in 80). Based on the pipe flow capacity charts in QUDM (Institute of Public Works Engineering Australasia, Queensland, 2017), the minimum standard pipe required to convey the minor event is a 675 mm diameter. The actual capacity of this pipe size will be 0.93 m³/s (based on Manning's equation).

5.7.4 Overflow weir

The overflow weir will manage the discharge of major flows entering the bioretention basin. The weir was sized (Calculation 23) to convey the balance of the major flow (see Table 31) above the capacity of the minor pit/pipe overflow (conservatively calculated in Section 5.7.3 to be 0.93 m³/s).

Calculation 23

$$Q_{\text{weir}} = Q_{\text{major}} - Q_{\text{pit/pipe}}$$

Where: Q_{weir} = flow conveyed by weir (m³/s)

Q_{major} = flow in major storm = 1.18 m³/s

$Q_{\text{pit / pipe}}$ = capacity of overflow pit and/or overflow pipe = 0.93 m³/s

$$Q_{\text{weir}} = 1.18 - 0.93$$

$$Q_{\text{weir}} = 0.25 \text{ m}^3/\text{s}$$

The crest of the overflow weir will be at 5.5 m AHD. This is just above the minor design storm water level controlled by the pit (5.48 m AHD from Section 5.7.2). Assuming a flow depth of 100 mm over the weir and the adopted minimum embankment level of 5.8 m AHD, the 200 mm freeboard required by Council will be achieved. The length of weir required to achieve the discharge (Calculation 23) at 100 mm flow depth was calculated by rearranging Equation 17 (Calculation 24).

Calculation 24

$$Q_{\text{weir}} = C_w \times L \times h^{3/2}$$

$$L = Q_{\text{weir}} / (C_w \times h^{3/2})$$

Where: L = weir length (m)
 Q_{weir} = flow conveyed by weir = 0.25 m³/s
 C_w = weir coefficient = 1.66
 h = flow depth over the weir = 0.1 m

$$L = 0.25 / (1.66 \times 0.1^{3/2})$$

$$L = 4.76 \text{ m}$$

Therefore, a 4.8 m weir will be required. The weir was also checked for the scenario where the overflow pit is completely blocked (Calculation 25) to ensure the weir can adequately convey the entire major storm flow without the bunds being overtopped, thus avoiding potential scour or failure of the bunds. This was done by rearranging the weir equation (Equation 17).

Calculation 25

$$Q_{\text{weir}} = C_w \times L \times h^{3/2}$$

$$h = (Q_{\text{weir}} / (C_w \times L))^{2/3}$$

Where: h = flow depth over the weir (m)
 Q_{weir} = flow conveyed by weir = 1.18 m³/s
 C_w = weir coefficient = 1.66
 L = weir length = 4.8 m

$$h = (1.18 / (1.66 \times 4.8))^{2/3}$$

$$h = 0.28 \text{ m (i.e. 5.78 m AHD)}$$

Therefore, under the worst-case scenario that the overflow pit is fully blocked, a 4.8 m weir can manage the discharge of the entire major storm entering the bioretention basin while maintaining the water level just below the embankment (5.8 m AHD), avoiding the potential for erosion and scour of embankments from uncontrolled overflow.

DESIGN NOTE: Sizing overflow pits, pipes and weirs

The above design method for pits, pipes and weirs represents a conservative approach to sizing hydraulic structures.

Where depth, pipe cover and/or levels are more constrained or where local authority requirements dictate, a more detailed hydraulic analysis of the outlet structures (considering hydraulic grade line and head losses) may be required to optimise conservative sizing.

5.7.5 Connection to waterway

The bioretention basin outlet pipe will discharge directly to the receiving waterway due to the levels and layout of the retrofitted bioretention basin.

To minimise the impact of discharges on the waterway and protect the stormwater infrastructure from erosion:

- the headwall and rock apron will be recessed into the bank (out of the direct flow path in the watercourse) by a minimum of 6.8 m (approximately 10 times the outlet pipe diameter) from the toe of the bank
- the discharge pipe will be angled downstream in the direction of flow
- a rock apron 4.1 m (minimum) in length with a median (D50) rock size of 200 mm (in accordance with QUDM (Institute of Public Works Engineering Australasia, Queensland, 2017)) will be constructed on the base and sides of the recessed outlet
- the outlet pipe invert will be above the minor (1-month ARI) flowing water level in the creek to allow free drainage.

5.8 Vegetation design

5.8.1 Planting style

As required by Council, the bioretention vegetation design will attempt to replicate the bushland/riparian assemblage that exists adjacent to the creek.

5.8.2 Planting structure

The system is moderately well-layered, consisting of a diverse mix of understorey plants, shrubs and trees.

5.8.3 Species diversity

The bioretention system planting will consist of 10 species of groundcovers, plus shrubs and trees. Ecological assessment of the existing vegetation was completed to inform the species selected.

5.8.4 Species selection

Five groundcover species were selected from the list of core functional bioretention plant species (Table 22).

The riparian community adjacent to the site comprises regional ecosystem (RE) 12.3.7 – Fringing Riverine Wetland. The vegetation community is comprised of a Eucalyptus dominated overstorey, with a grass and sedge-dominated understorey interspersed with medium to large shrubs.

A number of tree, shrub and groundcover species with desirable attributes were selected from the adjacent riparian community for use in the bioretention basin filter media and batters (Table 32).

Table 32. Species list for bioretention filter media and batters

| Plant species | Filter media | Batter | Vegetation Type |
|-----------------------------|--------------|--------|---------------------|
| <i>Carex appressa</i> * | √ | √ | Groundcover - sedge |
| <i>Ficinia nodosa</i> * | √ | | Groundcover - sedge |
| <i>Cymbopogon refractus</i> | | √ | Groundcover - grass |
| <i>Dianella caerulea</i> | | √ | Groundcover - herb |
| <i>Gahnia sieberiana</i> | √ | √ | Groundcover- sedge |

| | | | |
|--------------------------------|---|---|---------------------|
| <i>Imperata cylindrica</i> * # | √ | √ | Groundcover - grass |
| <i>Lomandra longifolia</i> * | √ | √ | Groundcover - herb |
| <i>Lomandra hystrix</i> | | √ | Groundcover - herb |
| <i>Poa labillardieri</i> * | √ | | Groundcover - grass |
| <i>Themeda triandra</i> | | √ | Groundcover - grass |
| <i>Callistemon viminalis</i> | √ | √ | Shrub/small tree |
| <i>Banksia robur</i> | √ | √ | Shrub/small tree |
| <i>Melaleuca nodosa</i> | √ | √ | Shrub |
| <i>Eucalyptus tereticornis</i> | | √ | Tree |
| <i>Waterhousia floribunda</i> | √ | √ | Tree |

* Denotes core functional bioretention plant species planted in filter media.

Imperata cylindrica exists in the adjacent creek riparian zone.

5.8.5 Planting density

A range of groundcover planting densities was selected to facilitate the rapid establishment of vegetation cover on both the filter media and batters (Table 33). The variation in planting densities between individual plant species reflects differences in growth rate, plant form and height.

Planting densities for shrubs and trees were guided by plant densities outlined in Table 33 and the structural composition of the adjacent riparian community.

Table 33. Total number of plants required.

| Plant species | Planting density (plants/m ²) | Filter media (396 m ²) | | Batter (500 m ²) | | Total |
|--------------------------------|---|------------------------------------|-------------|------------------------------|-------------|-------------|
| | | % Cover | Number | % Cover | Number | |
| <i>Carex appressa</i> * | 8 | 20 | 634 | 20 | 800 | 1434 |
| <i>Ficinia nodosa</i> * | 8 | 30 | 950 | 0 | | 950 |
| <i>Cymbopogon refractus</i> | 10 | 0 | | 10 | 500 | 500 |
| <i>Dianella caerulea</i> | 8 | 0 | | 5 | 200 | 200 |
| <i>Gahnia sieberiana</i> | 6 | 10 | 238 | 5 | 150 | 388 |
| <i>Imperata cylindrica</i> * | 8 | 20 | 634 | 15 | 600 | 1234 |
| <i>Lomandra longifolia</i> * | 6 | 15 | 356 | 15 | 450 | 806 |
| <i>Lomandra hystrix</i> | 6 | 0 | | 15 | 450 | 450 |
| <i>Poa labillardieri</i> * | 8 | 5 | 158 | 5 | 200 | 358 |
| <i>Themeda triandra</i> | 10 | | | 10 | 500 | 500 |
| <i>Callistemon viminalis</i> | 1/25 m ² | | 16 | | 20 | 36 |
| <i>Banksia Robur</i> | 1/25 m ² | | 16 | | 20 | 36 |
| <i>Melaleuca nodosa</i> | 1/25 m ² | | 16 | | 20 | 36 |
| <i>Eucalyptus tereticornis</i> | 1/40 m ² | | | | 12 | 12 |
| <i>Waterhousia floribunda</i> | 1/40 m ² | | 10 | | 12 | 22 |
| | Total | | 3028 | | 3934 | 6962 |

* Denotes core functional bioretention plant species planted in filter media.

5.8.6 Planting set out

The total number of plants required was calculated from the percentage cover (per plant species), the overall planting area and planting densities (see Table 33). The planting zones for the filter media and batters are shown on Drawing WSUD-P06. The planting set out for individual shrub and tree species is detailed on the planting layout, as the locations of these plants are integral to the final appearance and function of the bioretention vegetation.

5.8.7 Mulch

Sugar cane mulch will be applied to the bioretention filter media surface and 1 m up the batters. The mulch will be pinned down with open-weave jute net.

Locally sourced mulch with no fines, weeds, or soil will be used on the upper batters and embankments.

5.9 Detailed design documentation

Refer to Drawings WSUD-P01 to WSUD-P07 for detailed civil and landscape design drawings.

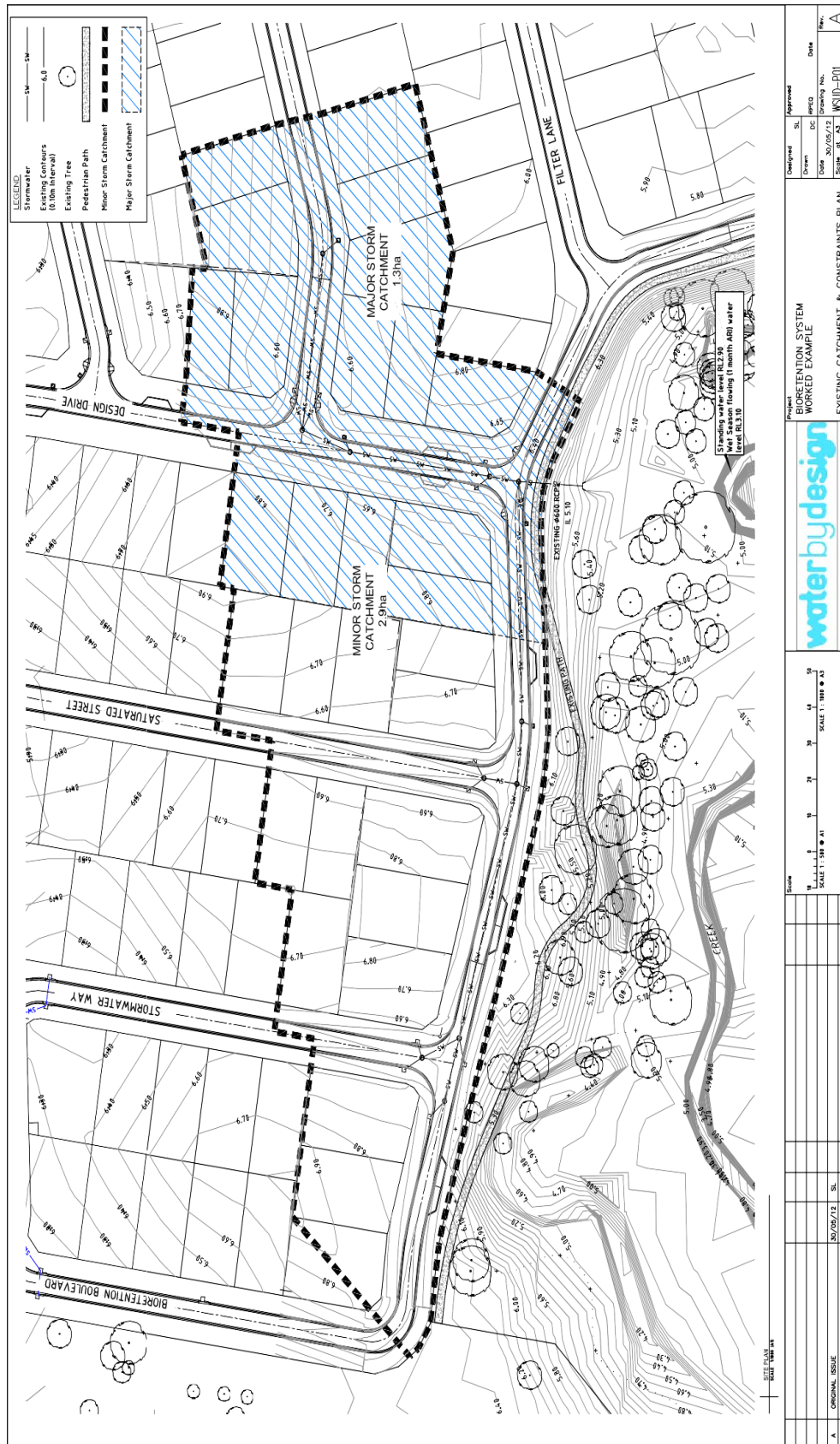


Figure 96. Drawing WSUD-P01.



Figure 97. Drawing WSUD-P02.

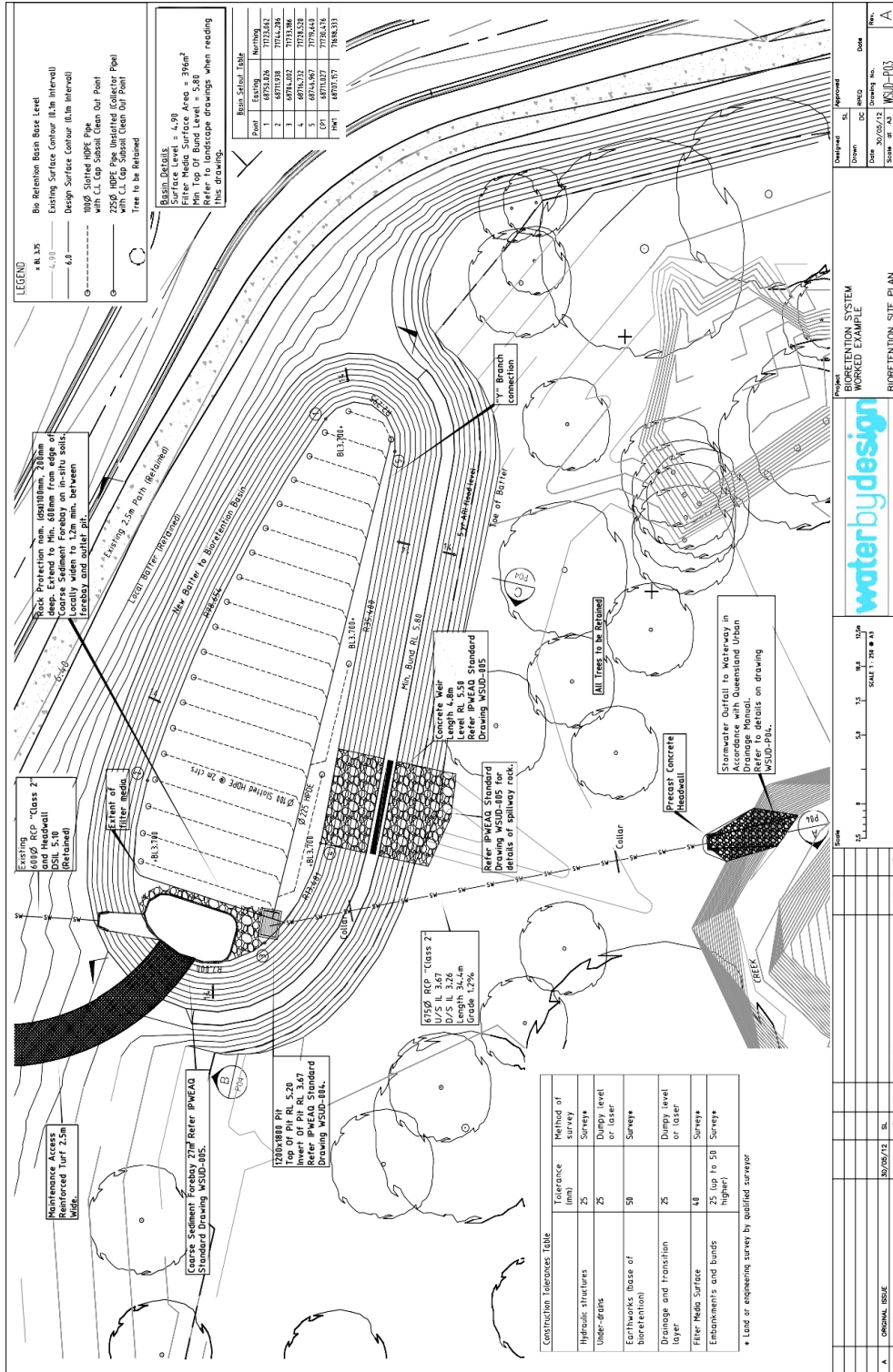


Figure 98. Drawing WSUD-P03.

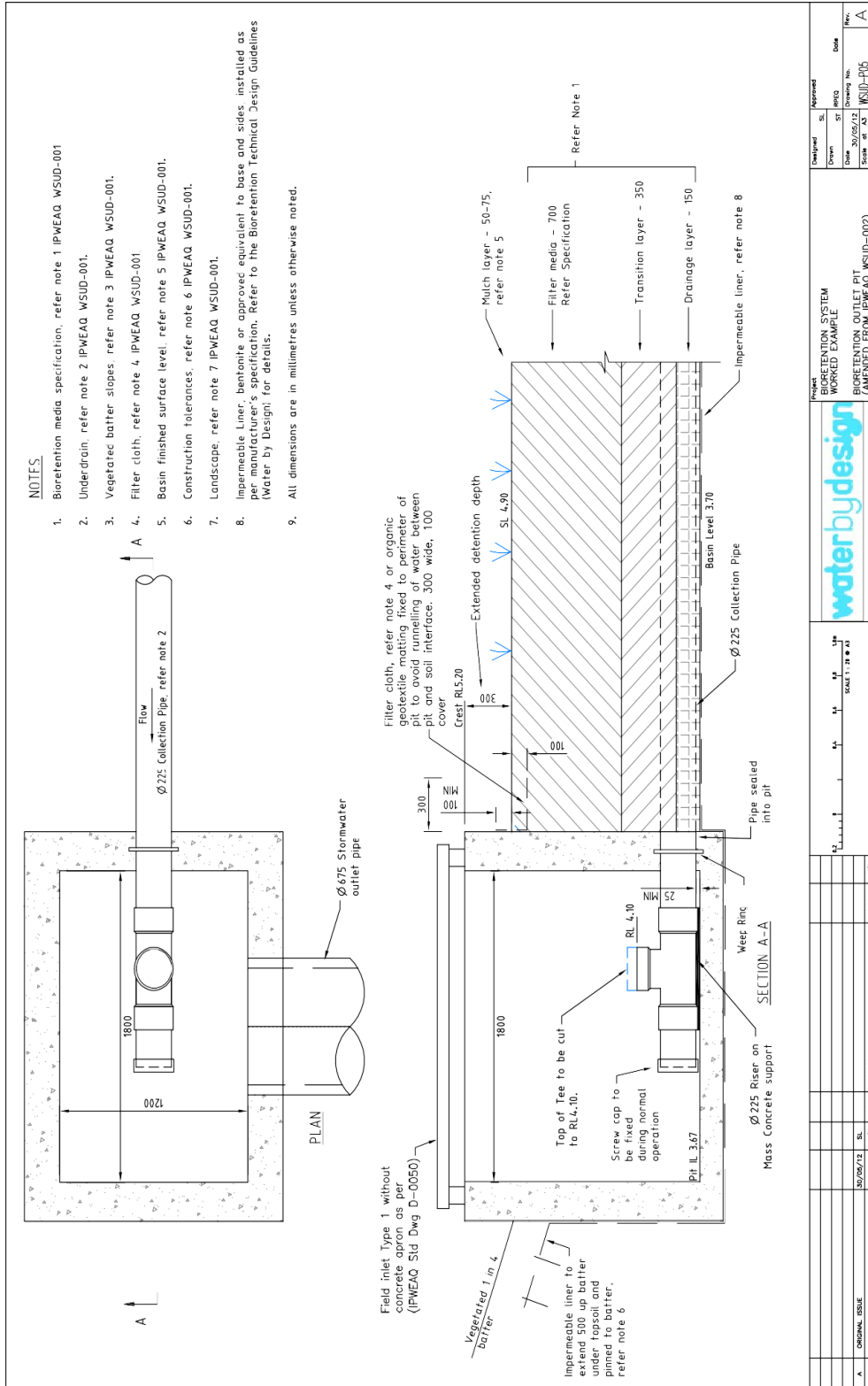


Figure 100. Drawing WSUD-P05.

5.10 Design check and summary

The key design parameters for the bioretention system are shown in Table 34.

Table 34. Worked example design check and summary.

| Item | Description | Detail | Recommendation |
|--------------------------|---|------------------------|--|
| 1. Treatment | | | |
| (a) | Catchment area. | 2.9 ha | |
| (b) | Filter media area (excluding batters). | 396 m ² | Single or multiple cells < 800 m ² each. |
| (c) | Confirm water quality performance meets the design objectives. | Yes | |
| (d) | Confirm hydrologic performance meets relevant frequent flow objectives. | Yes | |
| 2. Design inflows | | | |
| (a) | Minor design storm entering system. | 2-year ARI | |
| (b) | Minor storm peak flow rate. | 0.74 m ³ /s | |
| (c) | Major design storm entering system. | 50-year ARI | |
| (d) | Major storm peak flow rate. | 1.18 m ³ /s | |
| 3. Depth profile | | | |
| (a) | Bioretention drainage profile type. | Type 1 | |
| (b) | Minimum drainage layer depth. | 150 mm | See Section 3.3.2.3 and 3.3.2.4 for Type 1. ≥ 150 mm for Type 2A and Type 2B. ≥ 300 mm for Type 3. Not needed for Type 4. |
| (c) | Maximum drainage layer depth. | 150 mm | Same as minimum except for Type 2. |
| (d) | Transition layer depth. | 350 mm | See Section 3.3.2.4 for Type 1. ≥ 100 mm for Type 2A, Type 2B, Type 3 and Type 4. |
| (e) | Saturated zone depth for Type 1 bioretention systems. | 400 mm | See Section 3.3.2.4. |
| (f) | Filter media layer depth. | 700 mm | ≥ 600 mm. |
| (g) | Extended detention depth. | 300 mm | ≤ 300 mm. |
| (h) | Maximum water level depth above extended detention for major storm event. | 400 mm | |
| (i) | Freeboard to top of embankment. | 200 mm | See Section 3.3.3.6. |
| (j) | Total system profile depth [3(c)+3(d)+3(f)+3(g)+3(h)+3(i)]. | 2100 mm | = 4(j). |
| (k) | Liner type (i) Permeable (ii) Impermeable (iii) None to base. | Impermeable | Subject to drainage profile type and in-situ soils/groundwater (see Section 3.3.5) |
| (l) | AASS/PASS assessed and appropriately managed. | Impermeable liner used | |

| | | | |
|-------------------------|---|-------------------|--|
| (m) | Presence of dispersive soils assessed and appropriately managed. | N/A | |
| 4. Design levels | | | |
| (a) | Outlet invert level. | 3.20 m AHD | |
| (b) | Overflow pit invert level. | 3.67 m AHD | |
| (c) | Minimum drainage layer level. | 3.70 m AHD | |
| (d) | Filter media surface level. | 4.90 m AHD | |
| (e) | Overflow pit crest level. | 5.20 m AHD | |
| (f) | Overflow weir level. | 5.50 m AHD | |
| (g) | Maximum design water level. | 5.60 m AHD | |
| (h) | Top of embankment/batter level. | 5.80 m AHD | |
| (i) | Inlet/inflow invert level. | 5.10 m AHD | |
| (j) | Total level difference [4(h)-4(c)]. | 2.10 m | = 3(j). |
| (k) | Highest astronomical tide (HAT) level. | Non-tidal | Type 1 – impermeable liner extends ≥ 300 mm above HAT. Type 2A, Type 2B, Type 3 and Type 4 – base of transition layer ≥ 300 mm above HAT. |
| (l) | Groundwater level. | N/A | Varies with drainage profile type (see Table 7). |
| 5. Layout | | | |
| (a) | Maximum filter media length. | 35 m | ≤ 40 m. |
| (b) | Maximum filter media width. | 15 m | ≤ 20 m (preferred ≤ 15 m). |
| (c) | Maximum batter slope. | 1:4 | |
| (d) | Maximum wall height (where applicable). | N/A | |
| (e) | Provision for services (water, sewer, gas, telecommunications, stormwater). | N/A | |
| (f) | Maintenance access provided. | Yes | |
| (g) | Flood storage volume above extended detention (where bioretention combined with flood storage). | N/A | |
| 6. Inlet design | | | |
| (a) | Inlet/inflow type (i) pipe (ii) channel (iii) sheet flow (iv) other. | Pipe | |
| (b) | Diversion/surcharge type (where applicable). | N/A | |
| (c) | Coarse sediment removal (i) forebay (ii) inlet pond (iii) swale (iv) other. | Forebay | |
| (d) | Coarse sediment removal area. | 27 m ² | |

| | | | |
|---|--|---|---|
| (e) | Coarse sediment removal depth. | 0.2 m | |
| (f) | Coarse sediment cleanout frequency. | 0.5 /year | < once per year. |
| (g) | Flow distribution type. | N/A | See Section 3.5.7. |
| (h) | Confirm scour protection at inflow locations. | Yes | |
| (i) | Confirm energy dissipation at inflow locations. | Not required | |
| (j) | Minor storm flow velocity over filter media. | 0.46 m/s | < 1.0 m/s. |
| (k) | Major storm flow velocity over filter media. | 0.45 m/s | < 1.0 m/s. |
| 7. Underdrainage (outlet design) | | | |
| (a) | Filter media saturated hydraulic conductivity. | 100 mm/hr | 100 – 300 mm/hr. |
| (b) | Maximum filter media infiltration capacity. | 0.016 m ³ /s | |
| (c) | Underdrain capacity (taking into account blockage factors). | >0.016 m ³ /s | > 7 (b). |
| (d) | Confirm pit exists for underdrains to connect into. | Yes | |
| 8. Overflow design (outlet design) | | | |
| (a) | Overflow pit type. | Field inlet | |
| (b) | Overflow pit dimensions. | 1200 x 1800 mm | Bioretention basins. Minimum 900 x 1200 mm, 1200 x 1200 mm preferred. Streetscape bioretention. Side entry pit is typical. |
| (c) | Overflow weir length. | 4.8 m | |
| (d) | Overflow pit capacity (taking into account blockage factors). | 0.74 (at 5.48 m AHD) m ³ /s | > 2 (b). |
| (e) | Overflow pit plus overflow weir capacity (taking into account blockage factors). | 1.30 (at 5.57 m AHD) m ³ /s | > 2 (d). |
| (f) | Outlet pipe size. | 675 Ø mm | |
| (g) | Appropriate outlet scour protection provided. | Yes | |
| 9. Vegetation design | | | |
| (a) | Planting style. | Medium to large scale – ecological function | (i) small scale – landscape aesthetic (ii) medium to large scale – ecological function (iii) medium to large scale – landscape aesthetic. |
| (b) | Trees and shrubs to be included. | Yes | Yes, unless overriding reason provided to not include them. |
| (c) | Species diversity (number of species). | 15 | Refer Table 21. |
| (d) | Species selection. | Refer to plan: | ≥ 50% coverage with plants from Table 22. |

| | | | |
|-----|-----------------------|----------------------------------|--|
| | | WSUD-P08 | |
| (e) | Planting density. | 6 – 10 /m ² | May vary between plant species, refer to plan if required. |
| (f) | Mulch type and depth. | Sugar cane mulch 75 mm (min.) | See Section 3.7.9 and Section 4.4.4. |

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