GUIDELINE

water by design

an initiative of Healthy land & water

Guidelines for the **construction and establishment of bioretention systems and wetlands**

Version history

#	Date	Title	Contributors
1.0	April 2010	*Construction and establishment guidelines: swales, bioretention systems, and wetlands*	Technical content and reviews provided by Robin Allison and Shaun Leinster, with significant input provided by Damian McCann. Images provided by Alan Hoban, Dr Andrew O'Neill, Geoff Hunter, Dr Peter Breen, Robin Allison, Sally Boer and Shaun Leinster.
2.0	September 2022	*Guidelines for the construction and establishment of bioretention systems and wetlands*	Technical content and reviews provided by Ben Penhallurick, Brad Dalrymple, Glenn Browning, Adrian Crocetti and Paul Dubowski, with significant input provided by Alex Le Royer and Michael Jacques. Images provided by Ben Penhallurick, Brad Dalrymple, Glenn Browning and Paul Dubowski.

Citation

Water by Design (2022) *Guidelines for the construction and establishment of bioretention systems and wetlands*, Brisbane, Queensland, Healthy Land & Water.

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Purpose

These guidelines provide general and technical guidance to support the successful implementation of bioretention systems and constructed wetlands in Queensland.

About Water by Design

Healthy Land & Water's Water by Design initiative works with individuals and organisations to identify and fill knowledge gaps and facilitate the uptake of improved practices in sustainable water management. For more information visit www.waterbydesign.com.au.

About Healthy Land & Water

Healthy Land & Water is the peak environmental group for South East Queensland. For over 20 years it has been dedicated to investing in and leading initiatives to build the prosperity, liveability, and sustainability of our future region. Healthy Land & Water is focused on delivering an environment for future generations to thrive.

We are experts in research, monitoring, evaluation, and project management. Our team has led many thousands of projects to restore receiving waters and landscapes, improve native habitats, manage weeds, protect native species, inform policy, and educate communities on the best ways to improve and protect the environment.

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 lead and connect through science 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 Nations' 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.

Funding acknowledgement

The preparation of these guidelines was funded by the Queensland Government's Investing in Our Environment for the Future Program and delivered by the Department of Environment and Science (DES). The guidelines were co-funded through contributions from Healthy Land & Water's partners, including local governments across the South East Queensland region.

Queensland Government

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TABLE OF
CONTENTS

List of tables

List of figures

List of abbreviations and acronyms

AG	Agricultural
CEC	Cation exchange capacity
DAF	Department of Agriculture and Fisheries
DES	Department of Environment and Science
ESC	Erosion and sediment control
HES	High efficiency sediment
HDPE	High-density polyethylene
IECA	International Erosion Control Association
IPWEA	Institute of Public Works Engineering Australasia
NATA	National Association of Testing Authorities
RPEQ	Registered professional engineer Queensland
SEQ	South East Queensland
SMDOs	Stormwater management design objectives
TOC	Total organic carbon
WSUD	Water sensitive urban design

1 INTRODUCTION

1.1 Background of the guidelines

Water sensitive urban design (WSUD) is an approach to the planning and design of urban areas that aims to minimise the impacts of urban development on receiving waters while maximising economically, environmentally, and socially beneficial outcomes for communities.

The approach espouses that the management of water in the urban environment must be integrated and considered at the earliest stages of the urban planning and design process. Beneficial outcomes of a WSUD approach can include cooling urban areas, conserving potable water, improving the recreational and visual amenity of urban landscapes, improving property values, and protecting receiving waters from the impacts of unmitigated stormwater (Water by Design 2009).

A WSUD approach is often needed to comply with local and state government requirements for stormwater management, including achieving post-construction phase stormwater management design objectives (SMDOs) outlined in the *State Planning Policy 2017 State interest – water quality*. This can involve using bioretention systems and constructed wetlands to improve the quality and reduce the quantity of stormwater generated by urban development and released to receiving waters or stormwater networks.

Water by Design and others have developed tools and guidelines to assist practitioners in applying a WSUD approach in Queensland, including using bioretention systems, constructed wetlands, and other vegetated stormwater assets to achieve post-construction phase SMDOs.

Figure 1.1 illustrates these tools and guidelines and when they can be used over the life cycle of a typical vegetated stormwater asset.

<table>
<tr><th>Planning</th><th>Concept design</th><th>Detailed design</th><th>Construction</th><th>Establishment</th><th>Operation & maintenance</th></tr>
<tr><td>Strategic waterways
Water by Design (2019)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Living waterways
Water by Design (2019)</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Concept design guidelines for water sensitive urban design
Water by Design (2009)</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="2">MUSIC modelling guidelines
Water by Design (2018)</td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Bioretention technical design guidelines
Water by Design (2014)</td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Wetland technical design guidelines
Water by Design (2017)</td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Deemed to comply solutions
Water by Design (2010)</td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Drainage and water quality standard drawings
Institute of Public Works Engineering Australasia (IPWEA) (2017)</td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Stormwater harvesting guidelines
Water by Design (2009)</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Best practice erosion and sediment control International Erosion Control Association (IECA) (2008)</td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Erosion and sediment control fact sheets
Water by Design (2021)</td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Guidelines for improving the biology of bioretention systems
Water by Design (2022)</td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Guidelines for the construction and establishment of bioretention systems and wetlands
Water by Design (2022)</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Transferring ownership of vegetated stormwater assets
Water by Design (2012)</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>Maintaining vegetated stormwater assets
Water by Design (2012)</td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Rectifying vegetated stormwater assets
Water by Design (2012)</td><td></td></tr>
</table>

Figure 1.1 WSUD tools and guidelines.

Go to www.waterbydesign.com.au to access these tools and guidelines.

Construction and establishment are critical stages in the life cycle of bioretention systems and constructed wetlands. Construction refers to all civil works involved in building or constructing an asset, including earthworks and the installation of hydraulic, functional, and other components. Establishment refers to all landscape works involved in bringing an asset to an operational and resilient state, including mulching, planting, watering, and weeding. The timing and approach to these stages must be carefully considered to ensure the implementation of healthy, resilient assets that perform as intended in the long term.

Industry stakeholders have highlighted that a major barrier to the successful implementation of bioretention systems and constructed wetlands is a lack of appropriate guidance for construction and establishment. These guidelines focus on overcoming that barrier. They have been prepared to assist those involved in the construction and establishment of bioretention systems and constructed wetlands in Queensland.

1.2 Scope of the guidelines

These guidelines provide general and technical guidance to support the successful implementation of vegetated stormwater assets over their construction and establishment. They specifically address bioretention systems and constructed wetlands as they are two of the most commonly implemented vegetated stormwater assets in Queensland.

1.2.1 Bioretention systems

Bioretention systems are densely vegetated ephemeral water bodies (Figure 1.2). They improve the quality of stormwater through adsorption, filtration, and biological uptake of pollutants. They reduce the quantity of stormwater through infiltration, exfiltration, and evapotranspiration. Bioretention systems have flexible designs and can be applied at many scales, taking forms such as basins, street trees, and swales.

Figure 1.2 Bioretention system in Queensland.

Bioretention systems are the most common vegetated stormwater asset in Queensland. Their successful implementation requires sufficient time and maintenance to establish biological components and processes, including a living soil and vegetation community.

1.2.2 Constructed wetlands

Constructed wetlands are shallow, vegetated permanent water bodies (Figure 1.3). They improve the quality of stormwater through enhanced sedimentation, filtration, and biological uptake of pollutants.

Figure 1.3 Constructed wetland in Queensland.

Constructed wetlands are less commonly used than bioretention systems, but often form part of a WSUD stormwater management approach (Water by Design 2009). Like bioretention systems, their successful implementation requires sufficient time and maintenance to establish biological components and processes.

The content of these guidelines was developed for Queensland but can be easily applied more broadly. The guidelines do not cover the design, transfer, and ongoing management of vegetated stormwater assets. Water by Design have developed other guidelines to address these life cycle stages including the *Bioretention technical design guidelines, Wetland technical design guidelines, Transferring ownership of vegetated stormwater assets, Maintaining vegetated stormwater assets, and Rectifying vegetated stormwater assets guidelines* (Figure 1.1).

These guidelines also do not cover the construction and establishment of sediment basins and swales. Please refer to the *Construction and establishment guidelines: swales, bioretention systems, and wetlands* (2010) for guidance on the construction and establishment of swales.

Although these guidelines have been developed primarily to support the construction and establishment of bioretention systems and constructed wetlands that will ultimately be owned by local authorities, they can also be used to support the implementation of assets that will be privately owned and managed.

1.3 Structure of the guidelines

Each section of these guidelines has a similar structure to help users find the guidance they need. Table 1.1 describes the contents of each section.

Table 1.1 Structure of the guidelines.

Section	Description
Overview	Provides an overview of the components and functions of bioretention systems and constructed wetlands.
Construction considerations and specifications	Provides guidance for undertaking the more challenging works involved in civil construction.
Establishment considerations and specifications	Provides guidance for undertaking the more challenging works involved in landscaping and establishment.
Compliance requirements	Provides an overview of what's needed to comply with these guidelines.
Risks affecting construction and establishment	Identifies and describes risks affecting construction and establishment associated with the construction and building phases of development.
Approaches to construction and establishment	Identifies and describes approaches to construction and establishment that control for the risks identified in the previous section.
Step-by-step guidance	Provides step-by-step construction and establishment guidance for the approaches described in the previous section.

Sign-off forms for inspection hold points are provided in the appendix to these guidelines.

1.4 Audience of the guidelines

These guidelines are intended for professionals responsible for the on-ground implementation of bioretention systems and constructed wetlands, including:

- Asset designers.
- Local government compliance officers.
- Landscape architects.
- Civil engineers.
- Site superintendents.
- Geotechnical engineers.
- Civil contractors.
- Landscape contractors.
- Materials suppliers.

1.5 How to use the guidelines

These guidelines provide a single point of reference for those involved in the construction and establishment of bioretention systems and constructed wetlands in Queensland.

The considerations and specifications sections provide guidance for undertaking the more challenging civil construction, landscaping, and establishment works involved in construction and establishment. These sections can be referred to for specifications for civil and landscape design drawings rather than generating specification documents.

The sections outlining compliance requirements can be used to guide civil construction, landscaping, and establishment works to comply with these guidelines and achieve good outcomes for all stakeholders.

The sections identifying and describing risks, as well as approaches to construction and establishment that control them, can be used to inform decisions on the best approach to implementing bioretention systems and constructed wetlands for specific sites. The step-by-step guidance sections can be laminated and used as on-site references for civil construction, landscaping, and establishment works.

The sign-off forms (appendices to the guidelines) are the basis for compliance and sign-off. They should be used within contracts to guide day-to-day construction and establishment works and to inform sign-off.

Users of these guidelines are encouraged to provide feedback to **info@hlw.org.au**. Feedback will be considered in future updates of these guidelines.

1.6 How to enforce the guidelines

Local authorities have two ways of mandating adherence to these guidelines for development in their jurisdictions.

Firstly, local government planning schemes can be amended to specify adherence to these guidelines.

The second approach is to condition that guidance be adhered to in the decision notice of a development approval. Ideally, conditions may refer to:

- Construction and establishment considerations and specifications.
- Compliance requirements.
- The required construction and establishment approach.
- The use of sign-off forms as a means to ensure compliance with these guidelines.

Water by Design is assisting local authorities to develop a set of development approval conditions that can be used to support adherence to these guidelines and other relevant tools (Figure 1.1).

1.7 Roles and responsibilities

The successful implementation of bioretention systems and constructed wetlands requires a close working relationship between the various professionals involved in civil and landscape works. Table 1.2 summarises the professionals involved and how they should work together.

Table 1.2 Roles and responsibilities for construction and establishment.

Role	Responsibility	Description
Asset designer	Asset design, civil construction, landscaping, and establishment works supervision, troubleshooting and sign-off	The asset designer designs the asset in collaboration with the civil engineer and landscape architect. They should also support the site superintendent by supervising civil construction, landscaping and establishment works, providing troubleshooting advice and signing off on works as per the sign-off forms. Sign-off by the asset designer provides the basis for the site superintendent's overall sign-off of the site. The designer should be suitably qualified and have a minimum 5 years' experience designing bioretention systems and constructed wetlands.
Landscape architect	Design of landscape components	The landscape architect develops landscape design drawings and plans in collaboration with the asset designer. They also develop planting lists, often with input from an ecologist or horticulturalist.
Civil engineer	Design of civil components	The civil engineer developers the civil design drawings and plans. A registered professional engineer Queensland (RPEQ) is required to sign-off on civil components.
Site superintendent	Supervision of civil construction works	The site superintendent is responsible for all civil construction works. The site superintendent coordinates the civil construction and issues the overall sign-off of the site.
Civil contractor	Implementation of civil construction works	The civil contractor is responsible for all civil construction works, including earthworks and the installation of structural, functional and other components. The civil contractor is also required to ensure the asset is protected from sediment until the landscape contractor starts work.
Material supplier	Supply of bioretention filter materials	The supplier of bioretention filter materials is responsible for ensuring filter media, transition layer, drainage layer, and other materials comply with the specifications in the *Guidelines for improving the biology of bioretention systems* (Water by Design 2022). The supplier will coordinate with the civil contractor and site superintendent to ensure compliant materials are delivered to site.
Landscape contractor	Implementation of landscaping and establishment works	The landscape contractor is responsible for all landscaping and establishment works, including the installation of mulch and plants and watering and weeding. In some cases, the landscape contractor may also install the bioretention filter materials and protective measures.
Local authority compliance officer	Compliance inspections	The local authority's compliance officer represents the interests of the local authority. They are often responsible for ensuring assets are constructed, established and transferred to the local authority according to approved civil and landscape design drawings and the local authority's requirements.
Geotechnical engineer	Geotechnical investigations and sign-off	Depending on the contract, a geotechnical engineer may be engaged by the civil engineer to undertake geotechnical investigations of the site, as well as inspection, testing and sign-off of any impermeable liner materials (i.e. where a clay liner is used). The geotechnical engineer may also be engaged to test groundwater levels where there is a risk of a high water table or backwater.

The order in which each of these roles are involved in the construction and establishment of a bioretention system or constructed wetland is illustrated in Figure 1.4.

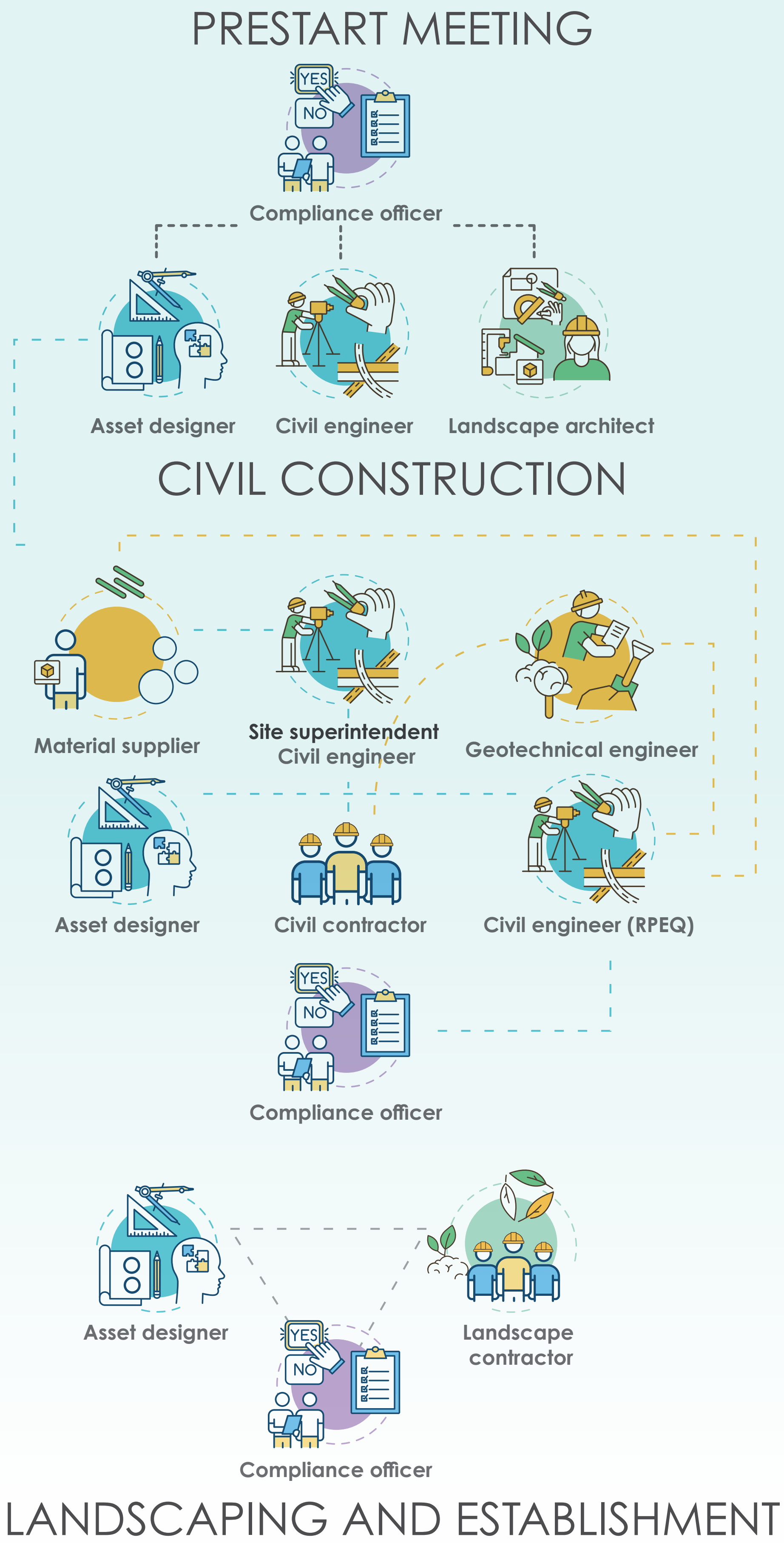


Figure 1.4 Roles and responsibilities for construction and establishment.

1.8 Success factors

A number of factors contribute to the successful implementation of bioretention systems and constructed wetlands. Factors that aren't described in these guidelines are presented in Table 1.3, alongside supporting references and helpful tips.

We also refer to Water by Design's guidelines *Transferring ownership of vegetated stormwater assets and Maintaining vegetated stormwater assets (2012)* which are helpful in ensuring the successful implementation of vegetated stormwater assets.

Table 1.3 Factors that contribute to construction and establishment success.

Factor	Reference	Tips
Preparing civil and landscape design drawings that reflect best practice guidance and standards	***Drainage and water quality standard drawings*** IPWEA (2017)	The Standard notes in the IPWEA's drawings for bioretention systems and constructed wetlands summarise a lot of the information presented in these guidelines in a simplified format. It is recommended that these notes are included in civil and landscape design drawings with appropriate site-specific amendments.
Preparing contracts for civil construction, landscaping and establishment works which require best practice approaches	***Guidelines for the construction and establishment of bioretention systems and wetlands*** Water by Design (2022)	Contracts should include clauses which require adherence to these guidelines, including its considerations and specifications, compliance requirements, best practice construction and establishment approaches and sign-off forms. In situations where civil and landscape design drawings do not include the IPWEA's Standard notes, it is recommended that contracts require adherence to them and that they are included in the contract document.
Ordering materials ahead of time	***Guidelines for the construction and establishment of bioretention systems and wetlands*** Water by Design (2022) ***Guidelines for improving the biology of bioretention systems*** Water by Design (2022)	To ensure civil construction, landscaping and establishment works are efficient, it is recommended that all materials are ordered and delivered to site before works start. For bioretention systems, filter materials require the greatest lead time due to laboratory testing and compliance requirements. The lead time for these materials may be further increased if there are no local suppliers with materials that comply with relevant specifications including those outlined in the *Guidelines for improving the biology of bioretention systems* (Water by Design 2022). Materials should be ordered within a week of the contract being awarded and delivered to site and at least 10 working days before works are due to commence. It should be noted that supply times can vary widely depending on the capacity of local industry suppliers, with increased times generally expected in regional areas or even in capital cities in times of high urban development and growth.
Protecting assets from surrounding development works		Before the civil construction works begin, ensure the surrounding development site is stabilised and appropriate erosion and sediment control (ESC) is present in the catchment. ESC measures must be implemented in accordance with local authority requirements and a recognised guideline, such as *Best practice erosion and sediment control* (IECA 2008).

Factor	Reference	Tips
Timing civil construction, landscaping and establishment works to avoid or make use of wet weather	***Guidelines for the construction and establishment of bioretention systems and wetlands*** Water by Design (2022)	When construction and building works begin in the development, stormwater inflows into bioretention systems and constructed wetlands can cause irreparable damage. Therefore, it is recommended that the timing of civil works be planned to protect assets from stormwater inflows during construction. Where possible, the civil contractor and site superintendent should target a suitably dry period for civil construction works or have a diversion system in place to isolate the site. Conversely, the timing of landscaping and establishment works should ideally be during a wetter period to take advantage of rain and reduce watering requirements.
Timing civil construction and landscaping works to minimise time between them	***Guidelines for the construction and establishment of bioretention systems and wetlands*** Water by Design (2022)	Landscaping works should start as soon as possible after the civil construction works are complete. This limits the risk of erosion and sediment-laden runoff entering assets. Close coordination between the civil contractor and the landscape contractor is required. The responsibility during handover between the civil construction and landscaping works must be clear. Responsibility for any rectification works if assets are damaged should be explicit.
Using compliant filter materials in bioretention systems	***Guidelines for improving the biology of bioretention systems*** Water by Design (2022)	Low total organic carbon (TOC) in filter media has been identified as a key risk factor affecting plant establishment and survival in bioretention systems (Skorobogatov *et al*. 2020). This and other risk factors have been addressed in the filter materials specifications included in the *Guidelines for improving the biology of bioretention systems* (Water by Design 2022), released with these guidelines. Sourcing and using filter materials that comply with the specifications is critical to ensuring the establishment and survival of healthy plants in bioretention systems.
Involving asset designers in the construction and establishment process	***Guidelines for the construction and establishment of bioretention systems and wetlands*** Water by Design (2022)	It is common for the civil engineer and landscape architect to prepare design drawings without input from an asset designer and/or for the asset designer to be excluded from inspections and sign-off in the construction and establishment process. Consequently, common issues affecting the construction and establishment of assets can be missed. It is recommended the asset designer remains involved throughout construction and establishment process, including providing troubleshooting advice and signing off on works as per the sign-off forms. It is acknowledged that on smaller projects, the asset designer and civil engineer may be one and the same.
Undertaking regular inspection and maintenance works throughout the establishment period	***Maintaining vegetated stormwater assets*** Water by Design (2012)	It is imperative that regular inspection and maintenance works are undertaken throughout the establishment period. Frequent and regular inspections minimise the extent of maintenance and rectification works required. Conversely, infrequent and irregular inspections typically result in more significant maintenance and rectification requirements. For example, it is well recognised that managing weeds early and frequently is significantly more cost-effective than attempting to manage large outbreaks once they are established. Similarly, minor erosion can result in large scouring if left unrectified. Developers are encouraged to include regular inspection and maintenance during the establishment period, ideally by commissioning a separate inspection and maintenance contract from the landscaping works contract.

BIORETENTION SYSTEMS

2.1 Overview

Figure 2.1 presents a typical cross-section of a bioretention system and identifies its components.

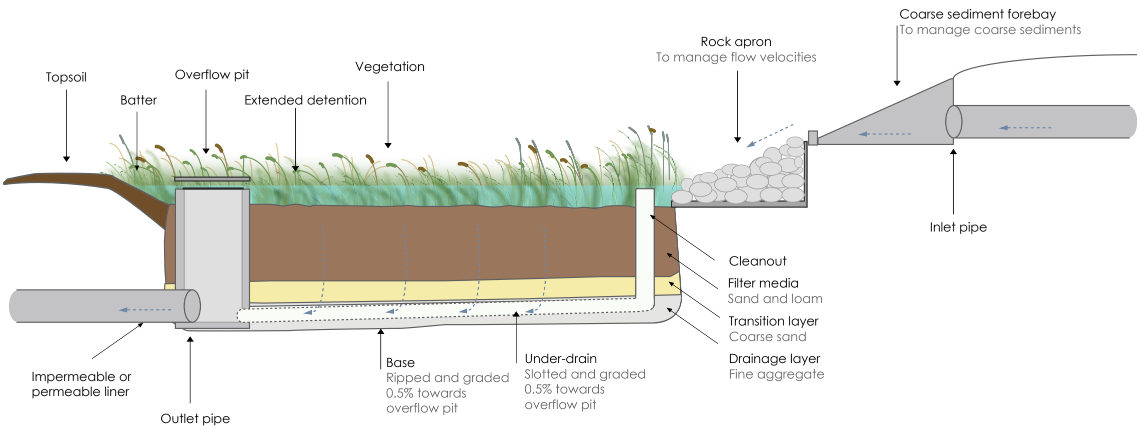


Figure 2.1 Typical cross-section of a bioretention system.

Please note the proportions of depicted components are not to scale.

Each of the components identified in Figure 2.1 are described below. Further information can be found in the *Bioretention technical design guidelines* (Water by Design 2014).

2.1.1 Filter media

A layer of sand and loam soil that treats the bulk of pollutants entering the bioretention system through adsorption and filtration. The filter media is also the growth substrate for vegetation. Typically, stormwater inflows are discharged onto the surface of the filter media from an inlet pipe or channel. The inlet often incorporates a coarse sediment forebay that captures and stores coarse sediment and slows and distributes flows evenly across the bioretention system.

2.1.2 Transition layer

A layer of coarse sand under the filter media that prevents filter media moving into the drainage layer and under-drains.

2.1.3 Drainage layer

A layer of fine aggregate that secures the under-drain pipes and drains treated stormwater into the base of the bioretention system.

2.1.4 Under-drainage

A network of perforated pipes in the drainage layer that collect treated stormwater from the base of the bioretention system and convey it to the overflow pits.

2.1.5 Cleanout riser pipes

Unperforated pipes connected to each under-drain pipe that allow for inspection and cleaning of the under-drains.

2.1.6 Liner

An impermeable or permeable layer lining the base and/or surroundings of a bioretention system, preventing or slowing the infiltration of treated water into the below lying earth.

2.1.7 Overflow pits

Pits that collect treated stormwater from the under-drains and convey it to the receiving water or stormwater network. Overflow pits also convey excessive and high velocity inflows (or above design flows), away from the bioretention system, preventing erosion and scouring, preferential flow paths, and the resuspension of sediments and other pollutants.

2.1.8 Extended detention

When stormwater enters a bioretention system, it temporarily ponds over the surface of the filter media. The depth of the ponding, or the extended detention, is set by the crest of the overflow pit, as presented in Figure 2.1. Extended detention helps to manage flows over the surface of the filter media and increases the overall volume of stormwater that can be treated by the bioretention system.

2.1.9 High flow bypass

An optional weir that releases inflows that exceed the capacity of the bioretention system to the receiving water or stormwater network. These flows are often caused by major storms.

2.1.10 Batters

Batters that integrate the bioretention system with the surrounding site.

2.1.11 Bunds and embankments

Bunds and embankments that hold stormwater in the bioretention system.

2.1.12 Vegetation

Vegetation improves stormwater infiltration, provides a substrate for biofilm to form, maintains the porosity of the filter media, and takes up nutrients and other pollutants.

2.1.13 Saturated zone

A zone at the base of a bioretention system that holds water. A saturated zone improves stormwater treatment and sustains vegetation through periods without rainfall or stormwater inflow. Figure 2.2 shows that saturated zones are a simple modification to the standard bioretention system design and can be achieved by:

- Incorporating an impermeable liner to ensure the bioretention system holds water.
- Amending the hydraulic structures in the overflow pit to allow ponding in the base.
- Using coarse gravel (10 – 20 mm) mixed with a source of carbon (e.g. straw and hardwood chips) to improve biological stormwater treatment.
- Ensuring the base of the bioretention system is flat.

In many instances, it is desirable to increase water loss from the base of a bioretention system into surrounding soils. This helps to maximise groundwater recharge and improves the stormwater treatment performance of the bioretention system. To achieve this, the bioretention system may feature a temporary saturated zone without an impermeable liner.

This approach is acceptable in wetter climate zones where the storage of water in a saturated zone is not necessary to maintain vegetation through prolonged dry periods or where enhanced filter media with increased water holding capacity is used. If the site superintendent or civil contractor has any doubt about the use of an impermeable liner in a bioretention system with a saturated zone, the asset designer should be consulted.

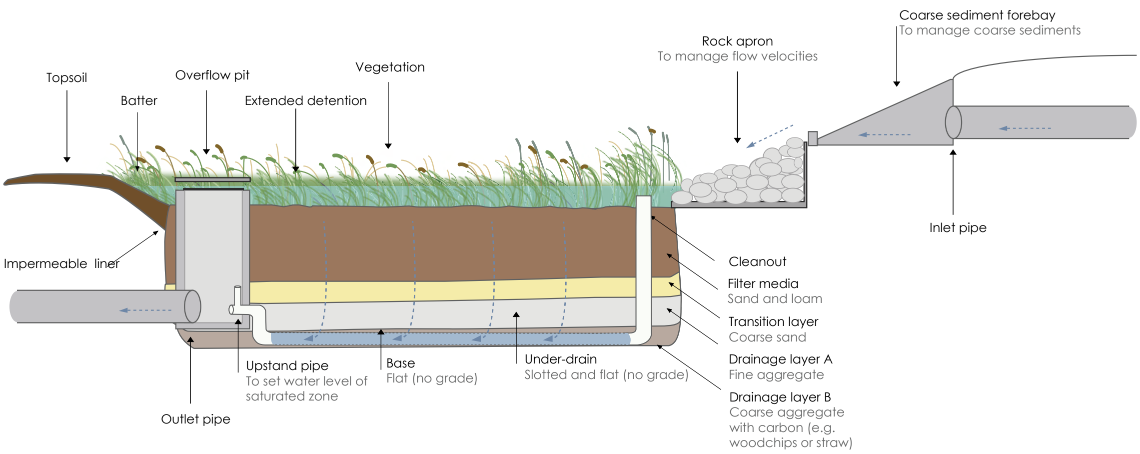


Figure 2.2 Typical cross-section of a bioretention system with a saturated zone.

2.2 Construction considerations and specifications

Guidance is provided for civil construction works associated with the following:

- Installing hydraulic structures.
- Installing the liner.
- Ripping the base.
- Installing under-drainage pipes.
- Sourcing filter materials.
- Installing filter materials.
- Installing the coarse sediment forebay.
- Managing flow velocities.
- Managing flow distribution.
- Providing maintenance access.
- Avoiding services.

This section can be referred to for specifications for civil design drawings rather than generating specification documents.

2.2.1 Installing hydraulic structures

Correct hydraulic function is critical for successful bioretention systems. Most hydraulic structures in bioretention systems are relatively simple. However, constructing components within the fine tolerances required can be easily overlooked and this can have a dramatic effect on the overall function of bioretention systems. All structures must be constructed in accordance with the civil design drawings and any potential changes must be confirmed in writing with the asset designer before civil construction works start. Once constructed, hydraulic structures should be surveyed by a licenced surveyor and reviewed by the asset designer before further works are undertaken.

Even very large bioretention systems require very fine tolerances (e.g. <25 mm) for their hydraulic structures. Table 2.1 summarises hydraulic structures and their preferred construction specifications. These specifications should be considered part of the civil design. However, if there are concerns about hydraulic structures during civil construction, the bioretention system may need to be redesigned.

If the proposed civil design is missing any of the hydraulic structures presented in Table 2.1, or if they vary from the descriptions provided in Section 2.1, the asset designer should be consulted for guidance.

Table 2.1 Construction specifications for hydraulic structures in bioretention systems.

Structure	Specifications
Under-drainage	To prevent backwater and ensure free drainage, the under-drainage levels are to be above the level of the overflow pit and outlet pipe for conventional bioretention systems without saturated zones.
Overflow pit	To prevent backwater and ensure free drainage, the overflow pit level is to be above the receiving water or stormwater network. The overflow pit should also: • Be concrete in construction. • Be a letter box or dome grate (not a flush grate). • Have a crest level typically 100 – 300 mm above the surface of the filter media and 300 mm+ below the bypass weir level or surcharge point. • Have under-drainage pipes that are sealed into the overflow pit. • Have a filter cloth fixed to the perimeter of overflow pits to avoid funnelling of water between the overflow pit and filter media, to prevent erosion. Refer to standard drawings for bioretention systems in IPWEA's *Drainage and water quality standard drawings* (IPWEA 2017).
Outlet pipes	To prevent backwater and ensure free drainage, the outlet pipe invert levels must be above the receiving water or stormwater network. If the outlet pipe contains water or has backwater during construction, consult with the asset designer. The outlet pipes must also be free draining and include a seepage collar. Rock protection may be required at the outfall of the pipe.
High flow bypass weir	High flow bypass weirs need to operate under high flow conditions requiring: • A mass concrete weir crest, typically 500 mm deep with reinforcing. • Grouted rock protection on both sides of the crest to at least the base of the batters. • Concrete and rock protection extending up the batters into bunds/ embankments at the ends of the weir to avoid scouring.

2.2.2 Installing the liner

2.2.2.1 Permeable liners for conventional bioretention systems

Unless a bioretention system features an impermeable liner, it should be lined with a permeable filter cloth. The filter cloth defines the edge and reinforces the base of the bioretention system. The filter cloth is keyed into the batters of the bioretention system. It is laid underneath the topsoil on the batter slope to a distance of at least 500 mm beyond the perimeter of the bioretention system (i.e. beyond the filter media). The filter cloth is pinned to the in-situ soil. Topsoil should be placed over the filter cloth to a depth of 200 – 300 mm (Figure 2.1and Figure 2.2). Where the bioretention system is bounded by a bund/embankment, the filter cloth should extend over the bund/embankment (Figure 2.3). This provides additional reinforcement to the bund/ embankment as well as the bioretention system base.

Figure 2.3 Filter cloth liner in a bioretention system.

2.2.2.2 Impermeable liner

An impermeable liner will be required if:

- In-situ soils are unconsolidated, sodic, saline, dispersive, or contaminated, or there is shallow groundwater.
- The bioretention system includes a saturated zone in the base.
- The bioretention system is close to structures or buildings.

A site and geotechnical investigation undertaken as part of the civil design process will establish the requirements for impermeable liners, with details provided in the civil design drawings. Liner options include geosynthetic bentonite clay liners or high-density polyethylene (HDPE) liners. The liners must be sealed in accordance with product specifications and keyed into the batters and bunds/embankments to ensure the bioretention system is watertight. Consideration must be given to protrusions through the liners such as outlet pipes. Testing and sign-off of liners by a geotechnical engineer must be obtained stating that the liner has been installed in accordance with the product specifications and is watertight.

2.2.2.3 No liners (open base)

Treated water at the base of the bioretention system may be allowed to infiltrate to in-situ soils. In these cases, filter cloths should only line the sides and batters of the bioretention system to define its edge.

2.2.3 Ripping the base

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 under-drainage 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 under-drainage pipes (i.e. so that they can be laid flat without sinking in places). If the base of the bioretention systems is graded towards the outlet pit to ensure under-drainage 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.

2.2.4 Installing under-drainage pipes

The civil design drawings should identify and specify the under-drainage. Table 2.2 provides specifications to consider for the under-drainage.

Table 2.2 Construction specifications for under-drainage.

Property	Specifications
Material	100 mm slotted rigid PVC is the preferred type of rigid pipe. Flexible agricultural (AG) pipe can be used in exceptional circumstances.
Slot size	The slots in the pipes should not allow the drainage layer aggregate to freely enter the pipes. This specification is consistent with the requirements of Part 1 of AS2439.1-2007. This issue should be discussed with the supplier when sourcing the under-drainage pipes. To ensure the correct size, test the slot using a 20 cent coin. If the coin falls through the slot easily, the slot is too large.
Slot orientation	When laying the under-drainage pipe, consideration should be given to the slot orientation. Slots directly on the top and the bottom of the pipe are not preferred.
Spacing	The maximum spacing of under-drains for bioretention systems <100 m^2 is 1.5 m from centre to centre. Small bioretention systems are used in streetscapes and small open space areas. The maximum spacing of under-drains for bioretention systems >100 m^2 can be increased to 2.0 – 2.5 m. Larger bioretention systems are used in local parks and large open space areas. These specified distances ensure that flows towards the under-drainage pipes through the drainage layer do not hinder drainage of the filter media.
Length	The maximum length of 100 mm slotted PVC pipes is 25 m before the flow conveyance of the pipe is reached. For longer lengths, the pipe size must be increased or duplicated to increase conveyance.
Grading	For effective drainage, under-drainage pipes should grade at a minimum of 0.5% towards the overflow pit. This is best achieved by grading the base of the bioretention system towards the pit and placing the under-drainage pipes and the drainage layer on this grade.
Connections	All under-drainage pipe junctions and connections to the overflow pit must be sealed to prevent soil entering the pit, receiving water or stormwater network.
Inspection and maintenance	Under-drains should be extended vertically beyond the surface of the bioretention system by a minimum of 50 mm, and preferably by 150 mm, to allow inspection and maintenance. The vertical section of the under-drain must be unperforated and capped to avoid short-circuiting flows directly to the pipes. The caps should be screwed down with one screw through either the side or top of the lid to reduce the risk of vandalism.

Under-drainage pipes must not use a filter cloth wrapping or sock. Filter cloths cause blockages that require a complete resetting of the bioretention system. Remove any filter cloth wrapping before installation.

Figure 2.4 Under-drainage pipes in a bioretention system.

2.2.5 Sourcing filter materials

A number of materials make up the filter and growth substrate of a bioretention system:

- Mulch.
- Organic material.
- Filter media (loamy sand).
- Transition layer material (coarse sand).
- Drainage layer material (fine aggregate).
- Saturated zone material (where required).

2.2.5.1 Filter media

Filter media is a fundamental component of bioretention systems. It filters pollutants from stormwater while also supporting the establishment and survival of healthy vegetation. The vegetation in turn plays a secondary stormwater treatment role through, among other things, the biological uptake of pollutants.

Filter media should be a blend of loamy sand and organic material. It should comply with the specifications in the *Guidelines for improving the biology of bioretention systems* (Water by Design 2022) and be tested at the frequencies provided in Section 2.4.2. Guidance on compliance requirements for filter media, including testing and chain of custody, is provided in Sections 2.4.2 and 2.4.3.

2.2.5.2 Sourcing filter media in regional or remote areas

In areas where a local supplier of filter media is not available, it will be the responsibility of the civil contractor or site superintendent to source a filter media which complies with the specifications. Table 2.3 outlines the steps involved in sourcing a compliant filter media when one is not immediately available in your area, including some helpful tips.

Table 2.3 Steps for finding a compliant filter media.

<table>
<tr><th>Step</th><th>Description</th><th>Tips</th></tr>
<tr><td>1</td><td>Visit bulk soils suppliers or local quarries in the region to collect samples from stockpiles which look like compliant filter media (Figure 2.5).</td><td>Having a sample of known compliant media can be useful when visiting suppliers to help identify potential filter media. Samples can often be sourced from regular filter media suppliers in capital cities. If a sample of compliant filter media is not available, look for any filter media which looks like sandy loam.

Filter media sourced from marine origins is often high in calcium and salts and will be non-compliant if it has not been washed by the supplier, and filter media sourced from quarries often has incorrect particle size gradings. It is useful to ask the supplier the source of the filter media, how it has been processed, and what equipment they have on site to determine if they are capable of ameliorating materials (e.g. washing/grading/mixing equipment). This may save the civil contractor from having to ameliorate the filter media themselves, reducing civil construction costs.</td></tr>
<tr><td>2</td><td>Send samples away for laboratory analysis</td><td>Prior to sending samples, it is recommended that the civil contractor or site superintendent contact the laboratory to check:
• That it is National Association of Testing Authorities (NATA) accredited for testing the soil properties outlined in the specifications.
• That it will provide advice on amelioration along with their test results.
• The quantity of samples that the laboratory requires to undertake testing in accordance with the specifications.
• The turnaround time for providing testing results and amelioration advice.
• That the laboratory is familiar with the specifications, soil properties to be tested, and the test methods and standards.

Many small local laboratories do not meet these requirements which can limit the quality of testing and reliability of results. This can cause delays in civil construction and increase costs as samples need to be retested by other, more qualified laboratories. To avoid this, samples are often sent for testing to more qualified laboratories located in capital cities. Sending samples interstate is common.

While visiting material suppliers to collect samples, mulch, organic material, and transition and drainage layer material samples should also be collected (i.e. if they supply them). Again, it is useful to have samples of compliant materials to help identify if the materials they supply will be compliant.</td></tr>
<tr><td>3</td><td>Ameliorate materials to comply with the specifications</td><td>Amelioration may include grading, mixing in additives recommended by the laboratory and washing. This may be done by some material suppliers subject to their capacity to undertake what is required to ameliorate the material.
If amelioration by the material supplier is not an option, the civil contractor will need to undertake the amelioration.</td></tr>
<tr><td>4</td><td>Retest the ameliorated material prior to installation</td><td>The material must be retested to determine if the amelioration was successful (i.e. if the filter media complies with the specifications) or if further amelioration is required. Amelioration costs can vary widely between the types of material and many materials will simply be unsuitable. As a result, it is recommended that at least two to three samples of filter media are collected from at least two different material suppliers. Although more samples will result in a higher cost for laboratory testing, it is typically the case that the greater the number of samples which are collected, the greater the likelihood of finding a compliant filter media. Finding a compliant filter media will also minimise costs associated with amelioration, which greatly outweigh the costs of laboratory testing.</td></tr>
</table>

Figure 2.5 Finding compliant filter media for a bioretention system.

In any regional area where sourcing filter media in this manner is expected, the civil contractor should increase the expected lead times to account for:

- Collecting samples: 1 day.
- Posting/couriering of samples: 2 days.
- Testing by laboratory: 1 – 2 weeks, depending on laboratory.
- Amelioration: dependent on volumes and what is required, but typically 1 – 2 weeks.
- Retesting by laboratory: 1 – 2 weeks, depending on laboratory.
- Further amelioration, if required: dependent on volumes and what is required, but typically 1 – 2 weeks.

2.2.5.3 Transition and drainage layer

Like the filter media, the transition and drainage layer materials must comply with the specifications in the *Guidelines for improving the biology of bioretention systems* (Water by Design 2022) and be tested at the frequencies provided in Section 2.4.2. The drainage layer must ensure at least 50 mm of cover above the under-drainage pipes, and preferably 100 mm, meaning the typical drainage layer depth is about 200 mm.

2.2.5.4 Saturated zone

The saturated zone consists of a few different types of materials which should be mixed by a material supplier prior to delivery. If this is not feasible, it can be undertaken by the civil contractor on site. Specifications for saturated zones can be found in the *Guidelines for improving the biology of bioretention systems* (Water by Design 2022).

2.2.6 Installing filter media

To function successfully, bioretention systems require a living soil that can support a vegetation community. The installation of filter media must be undertaken carefully to ensure the correct depth, slope, compaction and finished surface. Table 2.4 provides specifications to consider for the installation of filter media.

Table 2.4 Installation specifications for filter media.

Property	Specifications
Depth	Filter media should be installed and very lightly compacted in two lifts for depths of over 500 mm. For example, for 800 mm of filter media, installation should be in two lifts of 400 mm.
Slope	The top surface of the drainage layer, transition layer, and filter media should be flat. A spreader bar should be used to level the surface of each layer.
Compaction	The filter media can be lightly compacted during installation to prevent the migration of fine particles and subsidence. Watering in filter media can assist to lightly compact layers. Where significant subsidence has occurred, the top up of filter media to design levels may be necessary. Where filter media has been over-compacted, a tyne cultivator can be used to loosen the material prior to planting.
Finished surface	The finished surface of the filter media should be completely flat to ensure even distribution of stormwater flows.

2.2.6.1 Installing filter materials in large bioretention systems

Large bioretention systems can be difficult to construct. Construction plant may need to work from within the bioretention system, which risks damaging the under-drainage and compacting the filter media. It can also be difficult to create a level surface across a large area while minimising traffic across the bioretention system.

Large bioretention systems should be built as separate cells. Each cell should be no wider than twice the reach of an excavator arm. This allows for building with the excavator operating from either side of the bioretention system without entering it, as shown in Figure 2.6. For example, for an excavator arm with a reach of 10 m, the maximum width of each bioretention system cell should be 20 m. Dividing larger bioretention systems into discrete cells makes, the overall design more resilient and enables parts of the bioretention system to be reset if necessary.

If it is not possible to split a bioretention system into separate cells, it can be bulked out using an excavator. However, light compaction should be undertaken by watering in the media as noted in Table 2.4. Conveyor belts can be used to place material in bioretention systems up to 40 m from their edges, preventing the need to drive heavy machinery over the surface (Figure 2.7).

Scenario 1: Divide large bioretention systems into smaller cells so they can be built without heavy machinery entering them. Long-arm excavators can reach 10 m, so each cell can be 20 m wide.

Scenario 2: Where bioretention systems cannot be split into 20 m cells, bioretention filter materials can be installed using a conveyor system, allowing for much wider cells.

Figure 2.6 Approaches to installing filter media in a bioretention system.

Figure 2.7 Approaches to constructing a bioretention system.

2.2.7 Installing the coarse sediment forebay

Where stormwater runoff is delivered directly to a bioretention system without pre-treatment through a gross pollutant trap, vegetated swale, or other asset, coarse sediment may accumulate near the bioretention system inlet. This sediment may smother vegetation and block the surface of the filter media.

The design and civil construction of bioretention systems must allow for coarse sediment to be captured in a way that allows for easy and infrequent maintenance. This can be achieved through the following:

- Coarse sediment forebays should have a solid base to provide support for maintenance plant such as excavators and bobcats. The base should be concrete in construction.
- Coarse sediment forebays should be placed on in-situ soils to avoid the short-circuiting of incoming flows due to scouring.
- If coarse sediment forebays are constructed in the filter media, the base should sit on at least 400 mm of filter media.
- The top of the coarse sediment forebay should be set above the filter media to allow free drainage.

Design and civil construction of coarse sediment forebays should also account for potential scour. This which is addressed in the following section.

2.2.8 Managing flow velocities

Energy dissipation may be required to prevent filter media scouring. Larger rocks and boulders can be used directly downstream of the inlet pipe for velocity control. However, rocks should not be used to line the base of the coarse sediment forebay as sediments can settle, encourage the growth of weeds, and trap gross pollutants and other debris, making the coarse sediment forebay difficult to maintain.

One of the most common problems with newly established bioretention systems is the scouring of filter media immediately downstream of coarse sediment forebays. This is because high energy water transfers from a hard surface (i.e. concrete) to a soft surface (i.e. filter media). Some asset designers have attempted to manage this with small rock-lined concrete aprons, but this simply shifts the erosion to occur around the aprons (Figure 2.8).

A rock apron around the entire coarse sediment forebay perimeter provides a simple and effective solution in managing the effects of scouring to the bioretention system surface (Figure 2.9). Placing a large rock or boulder in front of the nib wall slots prevents direct flow onto the surface, forcing stormwater into the surrounding rock. This has proven to be highly effective, especially in high flow situations.

It is important for the site superintendent to ensure that there is step down between the top of the rock and coarse sediment forebay apron to maintain free drainage. Blockage can occur if sediment builds up too high, which leads to algal growth (Figure 2.10). This highlights the need for sediment removal during the civil construction, landscaping, and establishment phases.

Another option is to use coir netting and extra dense planting (e.g. >8 plants/m^2) for a few metres downstream of the coarse sediment forebay. However, this option may incur a higher risk of scouring if planting is occurring in the wet season, so the timing of landscaping works needs to be considered.

A combination of a rock apron with extra dense planting immediately downstream is usually the most effective solution to prevent scouring, especially during establishment. The civil and landscape design drawings do not always specify this level of detail, so these are important considerations for the site superintendent to monitor during both the civil construction and landscaping works phases.

Figure 2.8 Rock lined concrete aprons downstream of a coarse sediment forebay.

Figure 2.9 Rock apron downstream of a coarse sediment forebay.

Figure 2.10 Build up of algae and sediment downstream of a coarse sediment forebay.

Design drawings for rock aprons are available in the *Drainage and water quality standard drawings* (IPWEA 2017). Where the bioretention system design does not incorporate coarse sediment management or the coarse sediment forebay is not consistent with these guidelines, the asset designer should be consulted.

2.2.9 Managing flow distribution

Maintaining an even distribution of flow across filter media during small events is a challenge for large bioretention systems and this can cause plant dieback in drier zones (i.e. those areas furthest from the inlet). In the first instance, bioretention systems greater than 400 m^2 should be broken into smaller basins to avoid plant dieback from poor flow distribution. Where larger basins are used, they should have flow distribution comprised of the following:

- Multiple inlet pipes (e.g., one per 100 m^2 of filter media).
- A distribution channel leading from the coarse sediment forebay to the furthest extents of the filter media.
- A mix of wet zone and dry zone plants.

There are a number of options for flow distribution channels:

- Option 1: Inverted box culvert with weir cut-outs at 5 m spacing.
- Option 2: A half PVC pipe filled with gravel.
- Option 3: Stone pavers or concrete spoon drain.

Whatever option is used, the civil contractor and site superintendent should ensure no ponding of water in the channel to avoid creating mosquito breeding habitat.
Flow distribution channels can also help to disperse persistent baseflows and distribute erosive forces around the bioretention system inlet.

2.2.10 Providing maintenance access

Maintenance access (Figure 2.11) is required to remove coarse sediments from the coarse sediment forebay or a sediment basin for larger bioretention systems. Maintenance will occur at least once a year and typically involve the use of small-scale plant such as excavators, bobcats, trucks, tippers or utes.

Maintenance access pathways are typically concrete although reinforced turf or gravel may also be an option depending on local authority requirements. The pathways must provide access to both the coarse sediment forebay and the filter media surface.

The civil contractor and site superintendent will need to ensure that maintenance access paths join neatly to coarse sediment forebays, footpaths and roads if required.

Figure 2.11 Maintenance access for a bioretention system.

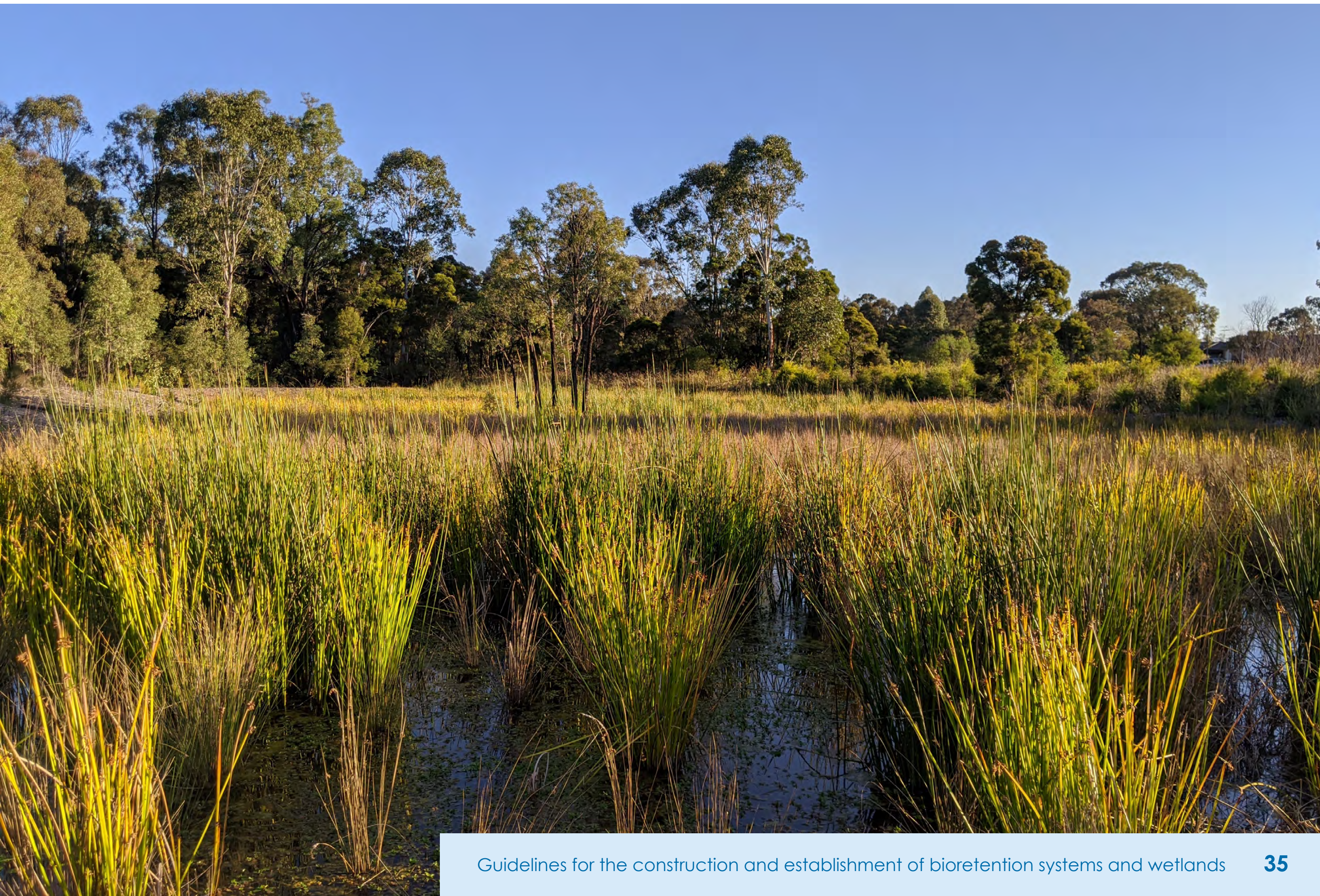
2.2.11 Avoiding services

In general, services should not pass through bioretention systems. However, this is not always possible, particularly where bioretention systems are implemented in streetscapes or in retrofit situations.

Locating services should be part of the civil design process. However, services that do not appear on civil design drawings or plans are often discovered during civil construction, particularly in older areas. The civil contractor should contact the asset designer and civil engineer to discuss the redesign of the bioretention system to accommodate any additional services that are found in the civil construction process. Proactive collaboration between the site superintendent, civil contractor, asset designer, and civil engineer is important.

Services should preferably be installed below or around a bioretention system with an impervious barrier if it is exposed to the services trench. The profile of a bioretention system can be modified in conjunction with the asset designer and civil engineer to suit local services rather than relocating them.

Where services cannot be located around a bioretention system, conduits with pits at either end of the bioretention system should be used. The interface of the conduits and the edge of the bioretention system must be sealed to prevent flows from migrating along the services trench. Detection tape must be placed above the conduits to clearly mark their location.



2.3 Establishment considerations and specifications

Guidance is provided for landscape establishment works associated with the following:

- Selecting plants.
- Sourcing plants.
- Installing plants.
- Installing mulch and netting.
- Identifying establishment success.

This section can be referred to for specifications for landscape design drawings rather than generating specification documents.

2.3.1 Selecting plants

There is ongoing research to determine species that are best suited for use in bioretention systems. Species need to be reliable through both wet and dry periods, while also providing good root structure and landscape amenity.

These guidelines do not advise specific plants. Where advice is required, the asset designer or landscape architect may refer to the Water by Design's water sensitive urban design (WSUD) plant database, *Bioretention technical design guidelines* (Water by Design 2014) or the local authority.

It is important to use a relatively high density and diversity of species. This ensures a higher likelihood of successful establishment and quickly delivers a dense, mature planting, managing any potential weed issues. Local authorities should be consulted for planting density requirements. The following is recommended as a minimum:

- A planting density of 6 – 10 plants per m^2.
- A minimum of three species per bioretention system including appropriate tree species with a spacing of 1 tree per 6 m^2.

If the landscape design does not allow for these specifications, consult the asset designer. In the past, some practitioners believed that planting trees in bioretention systems was inappropriate due to the potential issue of roots blocking under-drainage pipes.

A number of studies of existing bioretention systems with trees planted in the filter media have demonstrated that root ingress into under-drainage pipes is very limited, and the roots that do enter pipes are very fine (Lim *et al*. 2021). It is thought that the reason for limited root ingress is that under-drainage pipes do not hold water if constructed correctly.

The civil contractor and site superintendent should therefore ensure under-drainage pipes are correctly laid and will not pond water, which may attract tree roots. Suitable tree species are encouraged in bioretention systems due to the wide range of benefits they provide. Trees and shrubs are particularly good at shading out weeds and are therefore encouraged.

2.3.2 Sourcing plants

Tubestock available from wholesale nurseries are typically used in bioretention systems. Specialist nurseries are familiar with supplying plants for bioretention systems, constructed wetlands and other vegetated stormwater assets. Purchasing from specialist suppliers increases the chances of obtaining the right plants in the correct condition.

Availability varies between nurseries and is influenced by the time of year. Substituting species when some are unavailable can be problematic. If a change in species is necessary, confirm any changes with the asset designer and document it in the as-constructed drawings. Ideally, plant availability should be discussed at the pre-start meeting.

For large orders, it is recommended that periodic inspection of the plant stock at the nursery is undertaken to ensure the plants will be ready when required.
Consider:

- Making it explicit at the time of ordering that periodic inspections of plants will be required.
- Checking that plants are being grown in clean, weed and pest-free conditions.
- Checking the plants for fresh white roots.
- Ensuring that plants have a hardening off phase before delivery and that they are not taken directly from a shade house to the construction site. This ensures plants are resilient to the shock of being planted and will establish and survive in the long term.

2.3.2.1 Timing

Plant availability varies considerably in different regions and at different times of year. Sufficient time must be allowed to order plants. Up to six months lead time may be required to ensure appropriate species are available. If provenance plant stock is required, up to 18 months may be required to collect seeds and propagate plants.

Certain species are very difficult or slow to propagate, with some species only producing one batch of seedlings per year. Check these issues with a knowledgeable nursery to avoid last minute substitutions due to species not being available at the time of delivery.

2.3.2.2 Maturity

Plant stock must be mature, sun-hardened, and contain a fully established root ball that does not crumble when removed from its container. Ideally, the plants will be on average 300 – 500 mm high and not less than 200 mm high (Figure 2.12). Height is important to enable plants to cope with inundation and not be buried in mulch.

Both immature plants and plants that are too old can struggle to establish. While some species benefit from additional growing time, permitting further root development, many species of sedges and other common bioretention system plants will struggle to develop if they are old and root-bound. These plants will not establish well and may remain stunted, be susceptible to predators and disease, and fail to provide the cover required for optimal filtration.

Key things to look for in plant stock include:

- Pests and disease.
- Nutrient deficiency.
- New growth and general vigour.
- Weeds.
- Clear labelling.

Tubestock plants are usually supplied in a plastic container with dimensions of 70 – 150 mm high and 50 – 70 mm wide. However, there is a large variation in tubestock container size and price. A container with dimensions of at least 90 x 50 x 50 mm is recommended.
These containers can come in a number of forms:

- Viro tubes – 50 x 90 mm with a minimum plant height of 300 mm.
- 50 mm tubes – 50 x 75 – 90 mm with a minimum plant height of 300 mm.
- Native tubes – 50 x 125 mm with a minimum plant height of 300 mm.

Seedling pots of 20 mm should be avoided for bioretention systems. These seedlings are relatively immature and may result in high plant loss rates and patchy growth.

Figure 2.12 Suitable mature tubestock for a bioretention system.

2.3.3 Installing plants

2.3.3.1 Preparing filter media

Filter media in bioretention systems is typically low in nutrients and has a low cation exchange capacity (CEC). Consequently, tubestock may struggle to establish in the short term without additional nutrients. If laboratory testing of filter media demonstrates that soil properties are inadequate for plant establishment and survival, it is recommended that each plant receives at least 5 – 10 g of slow-release native fertiliser in granular or tablet form. While this should be sufficient to help establishment, monitoring may show that certain species require an additional treatment after several months. If laboratory testing shows adequate nutrients and CEC, additional fertiliser is not required.

Tip: Be careful to avoid over application of fertilisers
Typically, fertilisers that are used in landscaping works contain slow-release nutrients such as nitrates and phosphates. When overused in bioretention systems, these nutrients can promote algal blooms in receiving waters which are highly detrimental to native wildlife.

Plant stress and watering requirements can be reduced by wetting the filter media prior to planting to a depth of at least 90 mm and using a wetting agent at a rate of 2 – 3 g per plant. Organic wetting agents are preferred, but water crystals can be used if they are already hydrated (to limit the potential of plants being pushed out of their holes as the crystals swell). Timing planting immediately after watering in filter media avoids the need to wet the filter media a second time prior to planting.

2.3.3.2 Setting out plants

Plant set out is a critical part of landscaping works and must be confirmed with the asset designer or landscape architect before works start. It is essential to confirm the placement of species, particularly for trees or shrubs within the bioretention system or if attempting to mimic a representative vegetation community.

Planting areas should be measured from landscape design drawings and marked with stakes for ease of planting and to reduce the risk of incorrect set out.

2.3.3.3 Installing plants

Plants in bioretention systems are usually installed using either hand tools or light machinery such as augers/post hole borers. Heavier equipment is not necessary as the filter media will be mostly uncompacted. Planting 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. The top of the root ball should be slightly lower than the surface level after the filter media is placed in the planting hole and around the plant. Using the soil to create an in-situ reservoir around the plant to temporarily pond water is also recommended.

2.3.3.4 Establishing plants

Given the importance of establishing plant cover as quickly as possible, a proactive and adaptive approach should be taken, responding to any issues related to plant health. Responses can include watering or fertilising to deal with plant stress, and removing weeds. Spreading seed can improve the seed bank and increase plant cover in bare areas. Trees and shrubs are particularly good at shading out weeds and are therefore encouraged. More than 90% of plants must survive, otherwise replanting should occur.

2.3.3.5 Watering plants

Time of year and the climate will determine the frequency of watering. However, during establishment, regular watering is essential for plants. Successfully establishing plants is dependent on the frequency of watering (which is dependent on rainfall), the maturity of the plant stock and the water holding capacity of the soil. A good watering program will result in deeper roots and a faster plant establishment rate. Watering should always be adjusted to suit site conditions. However, the general recommendations are:

- Prior to planting: Water entire surface of filter media immediately.
- 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:

- Prior to planting, the entire surface of the filter media is thoroughly wetted to at least 90 mm of the filter media depth. This will both help decrease the temperature of the filter media and provide an immediate source of water for the new plants, greatly assisting with initial establishment. As noted above, the timing of planting immediately after watering in filter media will avoid the need to water the filter media a second time before planting. The site superintendent will need to coordinate the civil and landscape contractors accordingly.
- Each plant receives 2.5 – 5.0 litres of water per week during the first six weeks (i.e. 40 mm of watering per week during establishment).

After the first four months, watering may still be required, particularly during the first winter or dry period. Watering requirements for healthy vegetation can be determined by ongoing inspections.

In dry regions, establishment of irrigation, either temporary (e.g. during establishment) or permanent is likely to be required (Figure 2.13). This should be specified on the landscape design drawings, however local authorities may also require irrigation during landscaping works regardless of whether irrigation is shown on the landscape design drawings. Both the asset designer and contractors should regularly check with their local authority for current irrigation requirements, which may change in times of water restrictions.

Figure 2.13 Temporary irrigation in a bioretention system.

2.3.3.6 Using temporary saturated zones

Temporary saturated zones within standard bioretention systems have also been used to help the bioretention systems during the initial plant establishment phase. A temporary saturated zone can be created by installing a temporary and removable upstand pipe or weir within an overflow pit. The hydraulic impacts of this approach on the upstream stormwater network must be investigated if this option is pursued.

2.3.4 Installing mulch and netting

Filter media drains well, which can make it difficult to establish plants, particularly in hot, dry conditions. A good mulch helps to retain moisture around plants and provides a source of organic matter to help them establish. A bad mulch can cause mass planting failure and result in widespread disease and/or weeds.

There are several preferred mulches for the surface of bioretention systems. While organic friable mulches are typically recommended, the form of carbon in these mulches is highly labile, which results in rapid nutrient leaching. They break down very quickly, minimising the benefits of application beyond approximately six months. Friable mulches also typically require netting to hold down the mulch, which can add to the costs of landscaping works.

The type and depth of mulch should be specified in the civil or landscape design drawings. If not, the asset designer, civil engineer, or landscape architect should be consulted. Mulching options for the surface of bioretention systems are described below.

2.3.4.1 Hardwood – Organic, composted, double tub ground or coarse mulch

In general, the use of uncomposted mulches is not preferred, as microorganisms, fungi, and bacteria lock up nutrients as they progressively compost the mulch. This process, known as nitrogen drawdown, locks up nutrients essential for plant growth. In bioretention systems, however, nitrogen is readily delivered to plants by stormwater, and locking up nitrogen via nitrogen drawdown is desirable from a stormwater treatment perspective. Such mulches can also feature fine material that prolongs water holding capacity, which in regular landscaping works can promote rot diseases in plants. However, the sandy nature of filter media minimises waterlogging and in Queensland climates, prolonging moist conditions in bioretention systems is desirable to help establish and maintain plants.

Mulch should be chunks of wood (not bark) typically 15 – 40 mm in size, mixed in with some fine material, which helps bond the mulch and minimise the risk of 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, thereby reducing risks of mould, fungus and rot.

When the correct hardwood mulch is used, there is limited risk of it floating. However, it should be thoroughly wetted during installation to improve binding, which further minimises the risk of floating. A well-wetted hardwood mulch is denser than water, which means it should not float.

Some material will likely still float in the first few storms. However, the loss of mulch is expected to be very low, and it should easily be removed from in and around outlet pits as part of regular maintenance during establishment works. Installing a permanent or temporary gully or pit basket in the overflow pit has worked successfully in some bioretention systems to help reduce loss of mulch. If there are still concerns about mulch floating, it should be pinned down with an organic weed mat.

2.3.4.2 Organic friable mulches

These are mulches which degrade quickly (e.g. within six months). Fine sugar cane or tea tree mulch are examples of organic friable mulches.

Where organic hardwood or friable mulch is used, the thickness should be limited to 75 – 100 mm to ensure new vegetation shoots are not hindered. The mulch should be kept clear of plant stems by approximately 50 mm. Like hardwood mulch, wetting the mulch once laid will also help to bind it and reduce its capacity to float.

2.3.4.3 Jute netting

To avoid the mulch being washed away during storms, it should be pinned down with an organic weed mat, such as loose-weave jute, pinned at no more than 500 mm centres with u-shaped, biodegradable pins (Figure 2.14). Installation is more effective when the pins are installed at a 45 – 60° angle. Pins should be at least 300 mm in length.

Figure 2.14 Jute netting in a bioretention system.

2.3.4.4 No mulch

This option may appear to be counterintuitive, as plant mortality in bioretention systems is perceived as a common issue. However, some contractors in South East Queensland (SEQ) have questioned the value of mulching bioretention systems when organic friable mulches degrade within six months, a period during which plants should still be watered. It has been sugggested that the added cost of the mulch, netting and pinning could be better spent on increased watering, reducing overall costs. However, this situation may be unique to SEQ, where a local filter media supplier is producing a filter media that is achieving good plant establishment. Longer term effects on plants are also not well documented.

As numerous bioretention systems in SEQ have been established using this methodology (including in the driest parts of the region), it is a valid option and has therefore been included in these guidelines. However, this option does carry some risk of plant dieback once watering stops. The asset designer, landscape architect, and landscape contractor need to be aware of this risk and know how to manage it if bioretention systems are to be successfully established (which remains the responsibility of the landscape contractor). It is important to note that this option has also generally been used in combination with the selection of hardier plant species that are known to do well in bioretention systems in SEQ.

2.3.4.5 Turf

This option has been used successfully in other landscaping works (e.g. bank stabilisation) in place of mulch and can also be used in bioretention systems (Figure 2.15). Turf has many advantages in bioretention systems, including:

- It can completely cover the surface of the filter media, greatly limiting the opportunity for weeds and therefore decreasing plant establishment and maintenance costs.
- Tubestock can be planted directly into the turf without the need for any specialised tools or equipment.
- It can help to regulate the temperature of the filter media and help retain moisture which assists other plants to grow.
- It can help to trap sediments thereby protecting the filter media from clogging.
- There are many turf species readily available from commercial growers/nurseries with limited lead time for ordering. This includes species which are drought tolerant and capable of withstanding the low organic content of traditional filter media. Some species such as saltcouch (*Sporobolus virginicus*), and to a lesser extent green couch (*Cynodon dactylon*), are salt tolerant, which may be useful in rectifying bioretention systems with salt intrusion or where incorrect filter media has been used. Townsville City Council has also shown that zoysia (*Zoysia matrella*) is very slow growing and therefore may also be suitable when planting with tubestock as it does not outcompete the tubestock, unlike most typical turf species.
- If the correct turf species are selected, they do not require mowing when planted in filter media as the mature grasses are shorter than most typical plant species.

One Australian study also showed turf provides excellent stormwater nutrient reduction (e.g. comparable to macrophytes) (Fowdar *et al*. 2018).

Turf provides a range of benefits and should ideally be planted as part of a diverse planting palette. Until more research is available on the nutrient reduction associated with turf, its use in bioretention systems does not decrease the required density of other plants. Instead, turf should be considered a complementary plant.

Ideally, turf which is used in bioretention systems as a permanent species would be seeded to reduce the amount of soil (and therefore nutrients) imported with the roots. However, this may not always be practical and roll-on turf may need to be laid, especially if planting during the dry season or in a particularly dry climate zone. Additional topsoil should not be imported to the top of the filter media when seeding or laying turf.

The main downside of turf is that creeping species might spread onto batters if there is no planting edge or batters have inadequate mulch. This does not affect the performance of the bioretention system, but might be undesirable from a landscape amenity perspective, especially in high profile sites. The landscape architect should be consulted on the best planting edge to avoid this outcome, if it is expected to be an issue. Planting edges should not be installed in the filter media but rather at the base of the batters.

Figure 2.15 Turf in a bioretention system.

2.3.4.6 Mulches to avoid

Mulches to avoid on the surface of bioretention systems are described below:

- Gravel or stone are not preferred as they inhibit the growth of tubestock and prevent new plant recruitment. During summer, gravel and stones can heat up to the point where they kill tubestock and microorganisms essential to the bioretention system. They also provide limited, if any, benefit in terms of moisture retention and organic matter content. River stone is also sourced from natural receiving waters and is an unsustainable option. Maintenance, especially removal of accumulated sediment, is particularly difficult with gravel or stone mulches, so they should only be considered for use in high profile sites and locations where a high maintenance regime is assured.
- Except as specified above, be wary of any mulch with ≥20% hardwood chip or bark. These mulches do not mat or weave very well, meaning they float easily and cannot be readily pinned down due to the small size of the chip or bark.
- Organic mulch that is likely to contain weed seeds.
- Inorganic matting such as filter cloth.
- Organic matting is generally not preferred as it has a very low water holding capacity and does not help build good soil microbe populations. Light organic matting may be suitable for use on batters in some instances. It should never be used beneath mulch as it can lead to prolonged damp conditions, increasing the incidence of disease, particularly root rot, even in plants considered tough and resistant to disease. Heavy-duty matting such as 800 gsm jute mat is unsuitable.

2.3.5 Identifying establishment success

Bioretention systems are considered to be established when they are robust and self-sustaining. The growth and maturity of plants should be recorded through three-monthly photo logs every 500 m^2.

Indicators to help identify when bioretention systems are successfully established include:

- Greater than 90% plant survival.
- Greater than 80% coverage.
- Preferably more than one species.
- At least 5 plants/m^2, but preferably 6 – 10 plants/m^2.
- An increase in plant height of at least 50% through the establishment phase[1].
- Propagation is occurring with more than 2 – 3 stems and seeding.
- No weeds.

[1] This can be measured by marker stakes in the bioretention system at a rate of one stake for every 500 m^2.

2.4 Compliance requirements

The bioretention system construction and establishment sign-off forms and the requirements outlined in this section provide the basis for complying with these guidelines. For the civil construction and landscaping and establishment sign-off forms, if an item receives an 'N' in the 'Satisfactory criteria' column (i.e. indicating that an element is 'not satisfactory'), appropriate actions must be specified to rectify the issue before final sign-off is given by the site superintendent and asset designer.

2.4.1 Undertaking surveys

Constructing bioretention systems within accepted tolerances is a critical part of their successful implementation. Table 2.5 and Figure 2.16 summarise the construction considerations and tolerances for relevant components of a bioretention system. The as-constructed survey must be undertaken as described in Table 2.5, with relevant information included on as-constructed drawings to assess compliance and support the sign-off process. Surveys should be completed by a qualified surveyor.

Table 2.5 Construction considerations and tolerances for bioretention systems.

Component	Considerations	Tolerance	Survey method
Hydraulic structures	The construction of hydraulic structures must ensure design levels are achieved. The tolerances given apply to: • Inlet pipes. • Overflow pit crest level. • Under-drainage. connections to overflow pit. • Outlet pipe invert levels (upstream and downstream). • High flow bypass weirs.	±25 mm or ±15 mm when installed in streetscape	Survey
Under-drainage pipes	To freely drain the base of bioretention systems, the under-drainage pipes must be sloped towards the overflow pit at a grade of 0.5% in most cases. Installation of the under-drainage pipes should meet the recommended tolerance to ensure this grade is achieved.	±25 mm	Dumpy level or laser
Earthworks (base of bioretention system)	To enable the perforated under-drainage pipes to drain freely, the base should be sloped towards the outlet pit at a minimum of 0.5% longitudinal grade. It is also important to ensure the base is free from localised depressions. This means earthworks bulking and trimming needs to be carefully undertaken.	±50 mm	Survey

Component	Considerations	Tolerance	Survey method
Saturated zone (where required)	The depth of the saturated zone should ensure at least 400 – 500 mm of ponding in the base. The material used is coarse gravel (10 – 20 mm) with a mix of carbon sources.	±25 mm	Dumpy level or laser
Drainage and transition layers	The depth of the drainage layer should ensure at least 50 mm of aggregate cover over the under-drainage pipes. The depth of the transition layer should ensure that 100 mm of coarse sand covers the aggregate.	±25 mm	Dumpy level or laser
Surface level (filter media)	The surface of the filter media must be free from localised depressions to ensure even distribution of stormwater flows and to prevent localised ponding. Compaction should be light and even across the surface.	±25 mm, though achieving a flat surface on large bioretention systems can be challenging so a separate tolerance is provided. ±40 mm for bioretention systems greater than 300 m², provided the average extended detention depth is within 25 mm of the design.	Survey (for as-constructed)
Embankments and bunds	Embankments or bunds around bioretention systems hold stormwater within the extended detention during rainfall. If required, they force runoff from larger rainfall into the hydraulic structures. Therefore, the crest level on embankments or bunds is important.	-25 mm +50 mm It is preferable for the bund to be higher than lower.	Survey (for as-constructed)

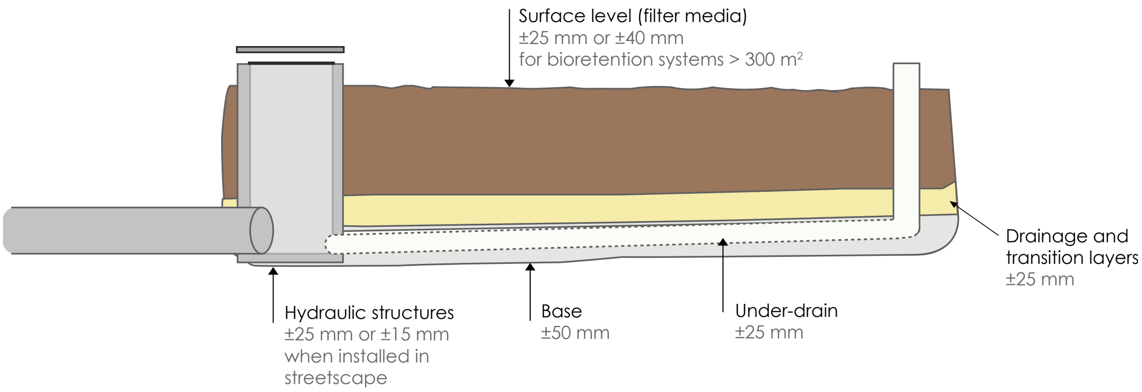


Figure 2.16 Construction tolerances and survey methods in bioretention systems.

The asset designer and site superintendent will require digital copies of as-constructed surveys for review before sign-off of civil construction works. Adequate time for review of these plans needs to be factored in when arranging inspections and hold points so as not to delay civil construction works.

Table 2.6 provides the spacing requirements for surveys. Survey plans are to indicate the degree of compliance with construction tolerances noted in Table 2.5, for example:

- Blue levels compliant.
- Black levels on tolerance level.
- Red levels exceed compliance.

The survey plans are also required to be accompanied by:

- A table which lists all levels and degree of compliance as per the above.
- Photos of all the surveyed bioretention system components listed in the sign-off forms.

Table 2.6 Survey spacing requirements for bioretention systems.

Component	Survey spacing requirements			
	Street trees	Streetscape biopods	Small bioretention systems up to 100 m²	Large bioretention systems >100 m²
Earthworks (base of bioretention system)	Each corner and one central point.	Every two lineal metres maximum spacing along central length of biopod.	5 m x 5 m maximum spacing.	5 m x 5 m maximum spacing.
Impermeable liner (if present)	For clay liners: Surface of clay liner at each corner. For proprietary liners: Perimeter at each corner (simply to indicate presence).	For clay liners: Perimeter and along central length of biopod at every two lineal metres maximum spacing. For proprietary liners: Perimeter every five lineal metres (simply to indicate presence).	For clay liners: Perimeter every five lineal metres and surface of clay liner with 5m x 5m maximum spacing. For proprietary liners: Perimeter every five lineal metres (simply to indicate presence).	For clay liners: Perimeter every five lineal metres and surface of clay liner with 5m x 5m maximum spacing. For proprietary liners: Perimeter every five lineal metres (simply to indicate presence).
Inlet and outlet pipes	If present, upstream and downstream invert levels.	If present, upstream and downstream invert levels.	Upstream and downstream invert levels.	Upstream and downstream invert levels.
Overflow pit	Crest level, invert of pit, and invert and size of all joining pipes.	Crest level, invert of pit, and invert and size of all joining pipes. Also indicate presence of filter cloth wrapped around pit.	Crest level, invert of pit, and invert and size of all joining pipes. Also indicate presence of filter cloth wrapped around pit.	Crest level, invert of pit, and invert and size of all joining pipes. Also indicate presence of filter cloth wrapped around pit.
Under-drainage pipes	Location, invert at each end of each pipe, and invert of all inlet/outlet connections. Clearly state whether pipes have a sock or no sock.	Location, invert at each end of each pipe, and invert of all inlet/outlet connections. Clearly state whether pipes have a sock or no sock.	Location, invert at each end of each pipe, and invert of all inlet/outlet connections. Clearly state whether pipes have a sock or no sock.	Location, invert at each end of each pipe, and invert of all inlet/outlet connections. Also survey every ten lineal metres along pipes. Clearly state whether pipes have a sock or no sock.
Clean-out pipes	Location, top and bottom of pipes. Clearly state if pipes are slotted or unslotted.	Location, top and bottom of pipes. Clearly state if pipes are slotted or unslotted.	Location, top and bottom of pipes. Clearly state if pipes are slotted or unslotted.	Location, top and bottom of pipes. Clearly state if pipes are slotted or unslotted.
High flow bypass weirs	Top of weir and crest of weir at each end.	Top of weir and crest of weir at each end.	Top of weir at each end and crest of weir every one lineal metre.	Top of weir at each end and crest of weir every one lineal metre.
Surface of saturated zone layer, drainage layer, transition layer, and filter media layer	Each corner and one central point.	Every two lineal metres maximum spacing along central length of biopod.	5 m x 5 m maximum spacing.	5 m x 5 m maximum spacing.
Embankments and bunds	Typically not present although inlet point should be surveyed and surface levels at each corner.	Every two lineal metres along top and bottom of embankment or bund around full perimeter of biopod as well as any low points.	Every five lineal metres along top and bottom of embankment or bund around full perimeter of bioretention system as well as any low points.	Every five lineal metres along top and bottom of embankment or bund around full perimeter of bioretention system as well as any low points.

2.4.2 Testing filter materials

2.4.2.1 Ex-situ testing

Bioretention filter materials should comply with the specifications in the *Guidelines for improving the biology of bioretention systems* (Water by Design 2022) and be tested at the following frequencies:

- Mulch: One sample per 1,000 m^3 of material.
- Organic material (prior to mixing with filter media): One sample per 1,000 m^3 of material.
- Filter media: One sample per 1,000 m^3 of material.
- Transition and drainage layer materials: One sample per 2,000 m^3 of material.

Where the amount of material to be used is less than the rates above, a minimum of one sample per bioretention system is required.

Testing must be undertaken on the materials to be installed in the bioretention system (Figure 2.17). The supplier and contractor are responsible for ensuring the materials comply with the specifications and compliant materials are installed. This includes retesting ameliorated materials to ensure compliance.

Figure 2.17 Filter materials for bioretention systems.

2.4.2.2 In-situ testing

It is recommended that in-situ testing of hydraulic conductivity is completed before both entering the establishment period and transferring the bioretention system to the local authority or asset owner. This should be undertaken in accordance with *Practice note 1: In-situ measurement of hydraulic conductivity* (Hatt & Le Coustumer 2008) at the following frequencies:

- One set of in-situ tests prior to establishment works.
- One set of in-situ tests completed within three months of final completion inspection (i.e. before transfer to the local authority or asset owner).

Further advice can be found in *Transferring ownership of vegetated stormwater assets* (Water by Design 2021).

2.4.2.3 Considerations for hydraulic conductivity

It is important to note that in-situ hydraulic conductivity may decrease in bioretention systems following civil construction and then recover over the years (Figure 2.18, adapted from Facility for Advancing Water Biofiltration 2009).

If the hydraulic conductivity test fails, consideration should be given to:

- The in-situ hydraulic conductivity test taken prior to establishment works.
- The particle size distribution.
- Construction age and likely recovery of the hydraulic conductivity as per Figure 2.18.
- What has occurred on the site during civil construction, landscaping and establishment works.
- Whether inappropriate filter media has been installed and structural collapse has occurred.
- Whether construction and building works in the surrounding development has blocked the filter media with sediment.

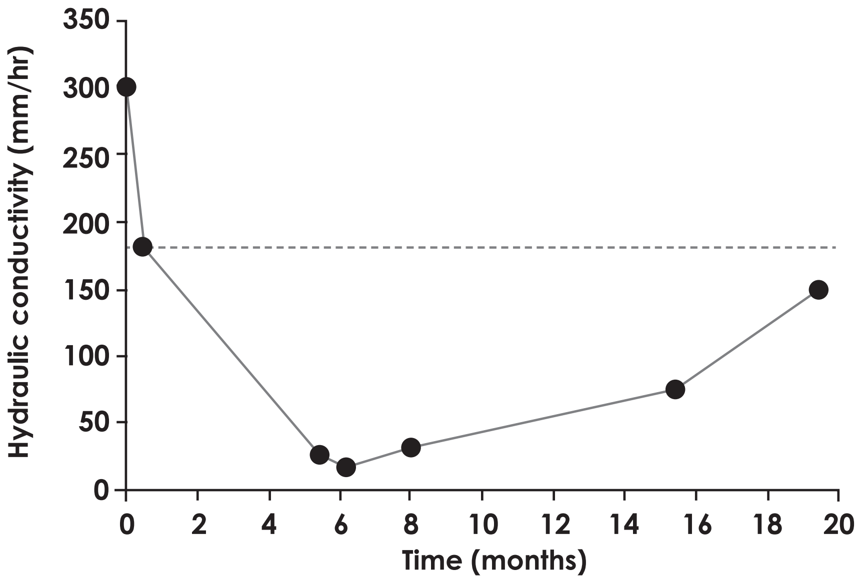


Figure 2.18 Hydraulic conductivity in a bioretention system.

2.4.3 Following the chain of custody

The following chain of custody applies to bioretention filter materials:

- The civil contractor or site superintendent must arrange for testing of the filter media by an independent NATA-accredited soil laboratory.
- Testing must be undertaken in accordance with the *Guidelines for improving the biology of bioretention systems* (Water by Design 2022), ensuring all soil properties are tested as per the prescribed test methods and standards.
- Based on the testing, the soil laboratory must provide a test report that indicates if the material complies with the specifications.
- The supplier must provide the test report and material supply docket to the contractor which confirms the materials to be installed in the bioretention system come from compliant stockpiles. For this to happen, the test report and supply docket must identify the supplier, stockpile location, stockpile number, and batch number.
- The contractor must provide a copy of the report and supply docket to the site superintendent and asset designer for review.
- Following review of the test report and supply docket and, if the materials are demonstrated to be compliant, the site superintendent and asset designer will approve the materials for installation in the bioretention system.
- The relevant sections of the bioretention system construction sign-off form must be completed and signed. The completion of these sections is required for the overall sign-off of the civil construction works.

2.4.4 Common compliance issues

There are a few common issues that affect the civil construction of bioretention systems that warrant further testing of the filter media and other materials:

- There has been over-compaction of filter media by vehicle or other construction plant.
- There has been construction/building sediment discharged directly onto the filter media.
- Non-compliant filter media has been installed.
- Non-approved filter media has been installed, or filter media that has not followed the chain of custody requirements identified above has been installed.
- Other circumstances as identified by the asset designer, civil engineer, or landscape architect.

Approaches to rectifying these issues are described below. Further information can be found in *Rectifying vegetated stormwater assets* (Water by Design 2012).

2.4.4.1 Over-compaction of filter media

Over-compaction of the filter media can be a significant problem if it restricts plant establishment or hydraulic conductivity.

If there is suspicion of over-compaction, there is a simple test to determine if rectification is necessary. This should occur prior to planting, whether the bioretention system has had a sacrificial turf layer or is being planted immediately following civil construction.

Using a post hole shovel, dig down through the filter media and transition layer in several places over the bioretention system surface until the drainage layer is reached. Where significant resistance is felt or the filter media is difficult to dig through, it is advisable to decompact the filter media to ensure sufficient hydraulic conductivity is reinstated. Decompaction of the filter media can be achieved with a mechanical tyne cultivator.

Care should be taken to ensure the filter media is decompacted all the way down to the transition layer. Do not leave a section of compacted filter media above the transition layer as this will cause stratification of the sand where water is likely to hold for extended periods in the filter media above. In-situ hydraulic conductivity testing will be required to confirm acceptable hydraulic conductivity.

2.4.4.2 Sediment contamination of filter materials

Sediments entering bioretention systems from construction or building activities in the surrounding development site can block the filter media or significantly reduce its hydraulic conductivity. If this occurs, it is generally advisable to remove and replace 150 – 200 mm of filter media from the bioretention system surface.

In-situ hydraulic conductivity testing will be required to confirm acceptable hydraulic conductivity. It is also advisable to reassess for compaction prior to planting.

2.4.4.3 Non-compliant filter materials installed

If the materials did not originate from a supplier of compliant materials, in-situ testing should be undertaken to assess compliance with the specifications. Where non-compliant materials are found to have been installed by the contractor, then they need to either be ameliorated until they comply or removed and replaced with a compliant filter media.

Tip: Implementing 150% bonds for the construction of bioretention systems will often be a significant incentive for developers to ensure they engage contractors that will construct assets as per the approved civil and landscape designs. It also provides local authorities with sufficient funds to undertake the work themselves, if that becomes necessary.

2.5 Risks affecting construction and establishment

The construction and establishment of bioretention systems can occur concurrently with the construction and building phases of a development site (Figure 2.19).

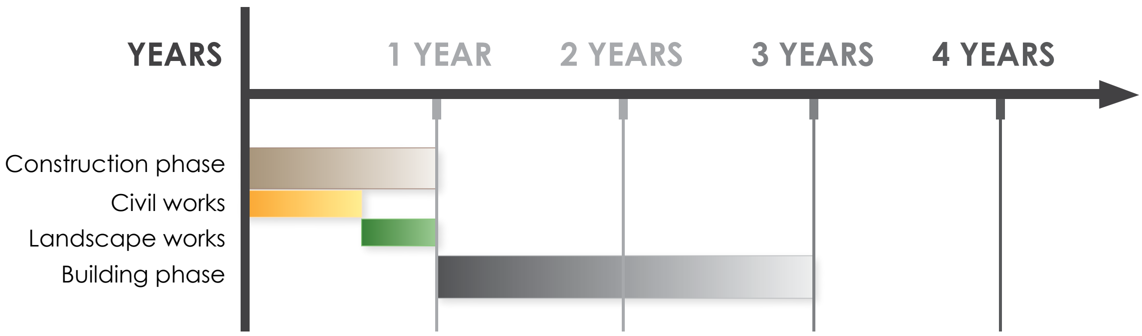


Figure 2.19 Typical phases of a development site.

The construction or subdivision phase typically involves clearing land and installing major infrastructure to service buildings and homes (e.g. drains and roads). The building phase typically involves constructing the buildings and homes. The activities associated with these phases can present significant risks to bioretention systems, as outlined below.

2.5.1 Construction phase

Construction activities generate large sediment loads in stormwater which can enter bioretention systems, smother their vegetation, and block their surface, filter media and under-drainage pipes (Figure 2.20). In some bioretention systems, inflow of sediment has required reconstruction at significant cost. Construction traffic and other activities can also cause physical damage to bioretention system components including bunds/ embankments and vegetation.

Figure 2.20 Sediment from construction phase activities in a bioretention system.

All activities during the construction phase should be coordinated by the principal contractor and/or site manager, so that risks can be controlled through appropriate contractor instruction and supervision, including instructing contractors to implement appropriate erosion and sediment control (ESC) measures.

2.5.2 Building phase

Building activities also generate large sediment loads which can enter bioretention systems, smother their vegetation, and block the surface, filter media and under-drainage pipes (Figure 2.21).

Figure 2.21 Sediment from building phase activities in a bioretention system.

Unlike the construction phase, the risks posed by the building phase cannot be easily controlled due to the large number of contractors and sub contractors undertaking activities independently and without a consistent source of instruction or supervision. For example, although site-based ESC is required, it is often not executed properly or at all (Water by Design 2022). Therefore, the building phase represents the greatest risk to the successful construction and establishment of bioretention systems.

These risks can be managed through:

- Implementing ESC within the catchments of bioretention systems in accordance with local authority requirements and a recognised guideline, for example the *Best practice erosion and sediment control* (IECA 2008).
- Implementing protective measures for bioretention system including, for example, the use of turf until the majority of the catchment is built (Figure 2.22).
- Undertaking a staged approach to transitioning the bioretention system from the bulk earthworks to the operational stage.

Figure 2.22 Temporary turf protecting a bioretention system.

2.6 Approaches to construction and establishment

To control the risks associated with the building phase of development site, two approaches to the construction and establishment of bioretention systems are recommended:

- High efficiency sediment basin.
- Temporary surface protection.

These approaches are described below. Both approaches are based on a threshold of 90% buildout of the upstream catchment, defined as 90% of houses and surrounding landscapes and surfaces being built.

2.6.1 High efficiency sediment basin

This approach is preferred and involves bulking out, installing hydraulic structures and allowing the bioretention system to operate as a high efficiency sediment (HES) basin (Type A or B) during the building phase (Figure 2.23). For guidance on the above, refer to a recognised guideline, for example the *Best practice erosion and sediment control* (IECA 2008).

When building in the catchment is 90% complete, the bioretention system can be cleaned and profiled, the under-drainage, filter materials, and plants installed, and the plants established.

This approach provides a high level of protection to the bioretention system, receiving water, and stormwater network.

Figure 2.23 Use of a bioretention system as a HES basin during the building phase.

2.6.2 Temporary surface protection

This approach involves the installation of all civil components including hydraulic structures, under-drainage and filter materials for the bioretention system. However, instead of installing selected plants, a protective layer is installed over the filter media surface, allowing the bioretention system to operate as a shallow sediment basin during the building phase. The surface protection typically involves the use of filter cloth, topsoil and turf (Figure 2.22). When 90% of building in the catchment is complete, the protective layers are removed, filter media topped up, and plants installed and established.

This approach protects the filter media and provides some protection to the receiving water and stormwater network during the building phase. It also typically has a higher level of amenity than the first approach.

Figure 2.24 Use of temporary measures to protect a bioretention system during the building phase.

2.7 Step-by-step guidance for construction

The recommended civil construction process for bioretention systems is outlined below. The process should be read with the sign-off forms.

2.7.1 Undertake earthworks and install hydraulic structures

Step 1: Hold pre-start meeting

Hold a pre-start meeting (Figure 2.25) with the asset designer, civil engineer, landscape architect, site superintendent, civil contractor, landscape contractor and, where required, the local authority's compliance officer to:

- Provide an overview of the bioretention system.
- Highlight risks affecting construction and establishment.
- Talk through the construction and establishment approach.
- Explain the compliance requirements, including as-constructed surveys and the testing and supply of compliant filter materials.
- Explain the inspection and sign-off process.

Relevant sections of these guidelines can be used to guide the pre-start meeting.

Figure 2.25 Pre-start meeting for the construction and establishment of a bioretention system.

Step 2: Prepare for civil construction works

Prepare for civil construction works at least ten days before starting them. Preparation includes organising the correct plant and equipment to achieve required construction tolerances (Section 2.4.1), sourcing compliant filter materials (Section 2.2.5), ordering construction materials, and timing construction activities to avoid rain and other issues (Section 1.8).

Tip: Have you checked the following?

☑ ***The local authority and site superintendent has approved works.***

☑ ***There is a reliable source of compliant filter materials nearby (Form B).***

☑ ***There is no significant rain forecast during civil construction works.***

Step 3: Set out basin

Survey the bioretention system layout in accordance with the set out plans.

Step 4: Bulk out basin

Undertake bulk earthworks, including the construction of bunds and batters (Figure 2.26). The bunds and batters of the bioretention system should have 200 mm of topsoil applied following earthworks. Design levels for the top of the bund are inclusive of this 200 mm layer of topsoil, so bulk earthworks should leave the top of the bund 200 mm below the design level.

Excavate the surrounding landform to design subsoil levels. If excavating in rocky areas, some over-excavation and backfill may be necessary.

Figure 2.26 Bulking out a bioretention system.

APPROACH 1 ONLY (skip Steps 5 to 7 for Approach 2)

Step 5: Install HES basin

The various flow controls for the HES basin should be installed in accordance with the civil design drawings. Refer to a recognised guideline, for example the *Best practice erosion and sediment control* (IECA 2008).

The base of the HES basin should be stabilised to avoid scour and resuspension of sediment. This may involve the installation of turf or filter cloth in the base of the basin.

Step 6: Operate HES basin

During the building phase, which may be up to 2 – 4 years, operate the bioretention system as a HES basin (Figure 2.27). When 90% of the building in the catchment is complete, the next steps can proceed.

Step 7: Clean out HES basin

Remove sediment appropriately and remove unnecessary sediment basin flow controls.

Figure 2.27 Use of a bioretention system as a HES basin during the building phase.

Step 8: Install hydraulic structures

Install the overflow pit and ensure the crest of the pit is at design level. The crest of the pit can be used as a reference point from which other levels within the bioretention system are measured. The overflow pit requires holes for under-drainage pipe connections. These holes should be drilled at this stage, or plastic stubs should be installed at the time of casting the pit. Where the bioretention system features a saturated zone, the holes in the overflow pit should allow 400 – 500 mm ponding in the base. Construct outflow headwalls and install the outlet pipe.

Note: If the outlet pipe is below the receiving water's level, consult the site superintendent and asset designer to resolve a change in the design. Design levels and tolerances (±25 mm) must be achieved (Section 2.4.1).

Where a high flow bypass weir is part of the bioretention system design, it should be constructed at this stage and appropriately keyed into the bunds. This will avoid potential scour at the edges of the high flow bypass weir. Design levels and tolerances (±25 mm) must be achieved (Section 2.4.1).

Step 9: Trim and profile

Undertake detailed excavation, trimming, and profiling of bunds, embankments, batters, and the base of the bioretention system, ensuring the base has a minimum 0.5% grade towards the overflow pit unless the design specifies a flat base (i.e. saturated zone bioretention systems). Ensure the base of the bioretention system is free from debris and meets the tolerances (Section 2.4.1).

Figure 2.28 Trimming and profiling of a bioretention system.

Step 10: Undertake as-constructed survey

Undertake an as-constructed survey of the bioretention system to confirm construction is in accordance with the civil design drawings and tolerances (Section 2.4.1). Provide the as-constructed survey to the site superintendent and asset designer.

Step 11: HOLD POINT – Inspection and sign-off (☑ *Form A*)

The site superintendent and asset designer will inspect the bioretention system with the civil contractor, review the as-constructed survey and take photos. If the construction meets the tolerances (Section 2.4.1) and conforms to the civil design drawings, sign-off *Form A* will be completed and, along with photos, attached to the as-constructed survey.

2.7.2 Install liner and under-drainage

Step 12: Install the liner

Line the bioretention system with either filter cloth or an impermeable liner, ensuring that it extends a minimum of 500 mm beyond the top of the bioretention system side walls. Where an impermeable liner is required, this must be installed in accordance with Section 2.2.2, ensuring that the liner is watertight, sealed in accordance with product specifications, and signed off by a geotechnical engineer.

Step 13: Install under-drainage and saturated zone

Install slotted rigid under-drainage pipes and rigid collector pipes in accordance with the civil design drawings and Section 2.2.4 (Figure 2.29). Ensure all pipes are laid at a minimum 0.5% slope with no localised depressions, verified using levels or string lines. Ensure levels are achieved within the required tolerance (i.e. ±25 mm). Seal junctions and connections using sufficient sealant to prevent sand, gravel, or soil passing into the under-drainage pipe network. Consideration must be given to protrusions through any impermeable liner to ensure the liner remains watertight.

At this stage, a saturated zone (where required) should also be installed (Section 2.1.13). Ensure levels are achieved within the required tolerance (i.e. ±25 mm).

Figure 2.29 Under-drainage pipes in a bioretention system.

Step 14: Install cleanouts

Connect cleanouts, ensuring top of cleanout points will ultimately sit at least 50 mm, but preferably 150 mm, above the bioretention system surface (Figure 2.30). The caps on the cleanout points should be screwed in place to protect against vandalism. Ensure cleanout pipes are not slotted.

Step 15: HOLD POINT – Inspection and sign-off (☑ *Form B*)

Following installation of the liner and under-drainage, the site superintendent and/or asset designer will inspect the bioretention system with the civil contractor and take photos. If the liner and under-drainage complies with the civil design drawings, sign-off *Form B* will be completed and, along with photos, stored with relevant civil construction documentation.

Figure 2.30 Cleanouts in a bioretention system.

2.7.3 Install filter materials and coarse sediment forebay

Step 16: Deliver filter materials to site

Testing and sourcing of the mulch, organic material, filter media, transition layer and drainage layer materials should have commenced as part of Step 2. By Step 16, the materials can be delivered and stockpiled on site, ready for installation.
Supply dockets should be collected to allow for sign-off.

Step 17: Install drainage layer

Install a 200 – 250 mm deep drainage layer to cover the slotted under-drainage pipe network. The preferred approach is to use an excavator or conveyor belt positioned on the edge of the bioretention system to place material into it. Contractors can then spread and flatten the gravel to the specified depth using spreader bars (Figure 2.1). The exact procedure for constructing the drainage layer is determined through consultation with the civil contractor.

Step 18: Inspect drainage layer

The site superintendent and/or asset designer should inspect the drainage layer to ensure the correct depth (200 – 250 mm) and grade (typically 0.5%) have been achieved and the surface is flat. The relevant sections of sign-off *Form C* must be completed and photos taken to allow for sign-off. There is no need to stop civil construction works for this inspection unless specifically required. The site superintendent or asset designer should undertake the inspection as works occur.

Figure 2.31 Installation of drainage layer materials in a bioretention system.

Step 19: Install transition layer

Install a 100 mm deep transition layer on top of the gravel drainage layer ensuring the correct tolerances are achieved (±25 mm). Ensure that the surface has been appropriately flattened using spreader bars. The relevant sections of sign-off *Form C* must be completed and photos taken to allow for sign-off.

Step 20: Inspect transition layer

The site superintendent or asset designer should inspect the transition layer to ensure the correct depth (100 mm) and grade (typically 0.5%) have been achieved and that the surface is flat. The relevant sections of sign-off *Form C* should be completed and photos taken to allow for sign-off. The site superintendent or asset designer should undertake the inspection as works occur.

Step 21: Install filter media

Place the filter media in the bioretention system in two separate lifts, where required. Once placed and compacted (Figure 2.32), use a spreader bar to flatten the surface of the filter media. The surface of the filter media must be at the design level and free from local depressions.

Figure 2.32 Installation of the filter media in a bioretention system.

Step 22: Install coarse sediment forebay

Construct the coarse sediment forebay in accordance with the guidance provided in Section 2.2.7. Concrete is preferred, with surface treatment as directed by the civil design drawings.

Step 23: Install sediment fences

Immediately after installing the filter media, install sediment control fencing around the filter media and at the bottom of the batter to prevent sediment from entering the bioretention system and to keep construction vehicles out.

Step 24: Undertake as-constructed survey

Undertake an as-constructed survey of the bioretention system surface and surrounding bunds in accordance with Section 2.4. Provide the as-constructed survey to the site superintendent and asset designer.

Step 25: HOLD POINT for practical completion – Inspection and sign-off (☑ *Form C, D and E*)

The site superintendent and asset designer will inspect the bioretention system with the civil contractor, review the as-constructed survey, and take photos. If the construction meets the tolerances (Section 2.4.1) and complies with the civil design drawings, sign-off *Forms C, D* and *E* will be completed and, along with photos, attached to the as-constructed survey. This is the practical completion inspection for civil construction works and is the basis for proceeding to the establishment phase.

2.7.4 Install protective measures

APPROACH 2 ONLY (skip Steps 26 to 28 for Approach 1)

Step 26: Install protective measures

Cover the surface of filter media with filter cloth and place 2 mm of topsoil and turf over the filter cloth.

Step 27: HOLD POINT – Inspection and sign-off (☑ *Form F*)

Following installation of protective layers, the site superintendent and asset designer will inspect the bioretention system with the civil contractor. If approved, sign-off *Form F* will be completed and, along with photos, stored with relevant civil construction documentation.

Step 28: Operate bioretention system

During the building phase, which may be as long as 2 – 4 years, the bioretention system will operate as a shallow sediment basin and protect the filter media from sediment and clogging.

When 90% of the building in the catchment is complete, the next steps can proceed.

Figure 2.33 Use of temporary measures to protect a bioretention system during the building phase.

2.8 Step-by-step guidance for establishment

The recommended process for landscaping and establishing bioretention systems is outlined below. The process should be read with the sign-off forms.

2.8.1 Landscape bioretention system

Step 29: Hold pre-start and plant set out meeting

Before starting landscaping works, hold a pre-start and plant set out meeting with the asset designer, an ecologist or horticulturalist, landscape architect, site superintendent and landscape contractor. The meeting should confirm the landscape design and plant set out to ensure the correct plants are installed in the correct locations.

Step 30: Prepare for establishment works

Prepare for the landscape works up to six months before starting, including ordering and inspecting plants at the nursery, ordering and receiving mulch and matting, and organising a supply of water for irrigation.

Tip: Have you checked the following?

☑ ***The local authority has approved works.***

☑ ***The plant selection is approved.***

APPROACH 2 ONLY (skip this step for Approach 1)

Step 31: Remove protective measures

Remove the building phase protective measures and any accumulated sediment. Care should be taken to avoid damaging the cleanouts for the under-drainage. The under-drainage can be flushed out with potable water to remove any accumulated sediment (where required).

Step 32: Flatten surface

After the protective measures are removed, flatten the surface of the filter media using a spreader bar. Additional filter media may be required to fill in any over-excavated zones. Care should be taken to not over-compact the filter media. The use of a tyne may be required where sections are over compacted.

Step 33: Install mulch and netting

Mulch the filter media surface and secure with netting. Create holes in the mulch for planting. Ensure the holes have 50 mm separation from the stem of the plant to the mulch.

Step 34: Prepare for installing the plants

Dig planting holes and apply the prescribed amount of slow-release native fertiliser detailed in 2.3.3.3. Pre-soaked wetting agents are recommended in this step.

Step 35: Install plants

Pre-wet the entire surface of the filter media immediately prior to planting to at least 90 mm of the filter media depth. Plant tubestock, ensuring the root ball is covered with filter media and the stem is sitting above the filter media. Clear away any mulch from the stem to 50 mm.

Step 36: HOLD POINT for practical completion – Inspection and sign-off (☑ *Form G*)

After installing the mulch and plants, the site superintendent and asset designer will inspect the bioretention system, take photos, and complete sign-off *Form G*. This is the practical completion inspection for landscaping works and is the basis for proceeding to the next steps.

2.8.2 Establish bioretention system

Step 37: Water plants

Water the plants according to Section 2.3.3 Where appropriate, this may include watering according to the following schedule:

- Week 1 – 6: Five waterings per week.
- Week 6 – 10: Three waterings per week.
- Week 11 – 15: Two waterings per week.

If there is no rain, each plant should receive 2.5 – 5.0 litres of water per week during establishment in the first six weeks (40 mm per week). Additional watering can be undertaken in response to plant health.

Step 38: Remove weeds

Inspect plants fortnightly during establishment, removing any weeds, including seedheads, by hand. Herbicides must not be used in bioretention systems and brush cutters should also be avoided as they disperse weed seeds and damage desirable plants. Trees and shrubs are particularly good at shading out weeds and are therefore encouraged.

Step 39: Undertake routine inspection and maintenance works

Monitor the establishment of plants fortnightly until they are robust and self-sustaining, removing any weeds by hand. Measures of established plants include:

- Greater than 90% plant survival.
- Greater than 80% coverage.
- Preferably more than one species.
- At least 5 plants/m^2, but preferably 6 – 10 plants/m^2.
- An increase in plant height of at least 50% through the establishment phase[1].
- Propagation is occurring with more than 2 – 3 stems and seeding.
- No weeds.

[1] *This can be measured by marker stakes in the bioretention system at a rate of one stake for every 500 m^2.*

Step 40: HOLD POINT for final completion – Inspection and sign-off (☑ *Form H*)

After plants are established (Figure 2.34), the site superintendent and asset designer will inspect the bioretention system, take photos, and complete sign-off *Form H*. This is the final completion inspection for landscape establishment works and is the basis for transfer to the asset owner (typically the local authority).

Figure 2.34 Established plants in a bioretention system.

CONSTRUCTED WETLANDS

3.1 Overview

Figure 3.1 presents a typical cross-section and plan of a constructed wetland and identifies its components.

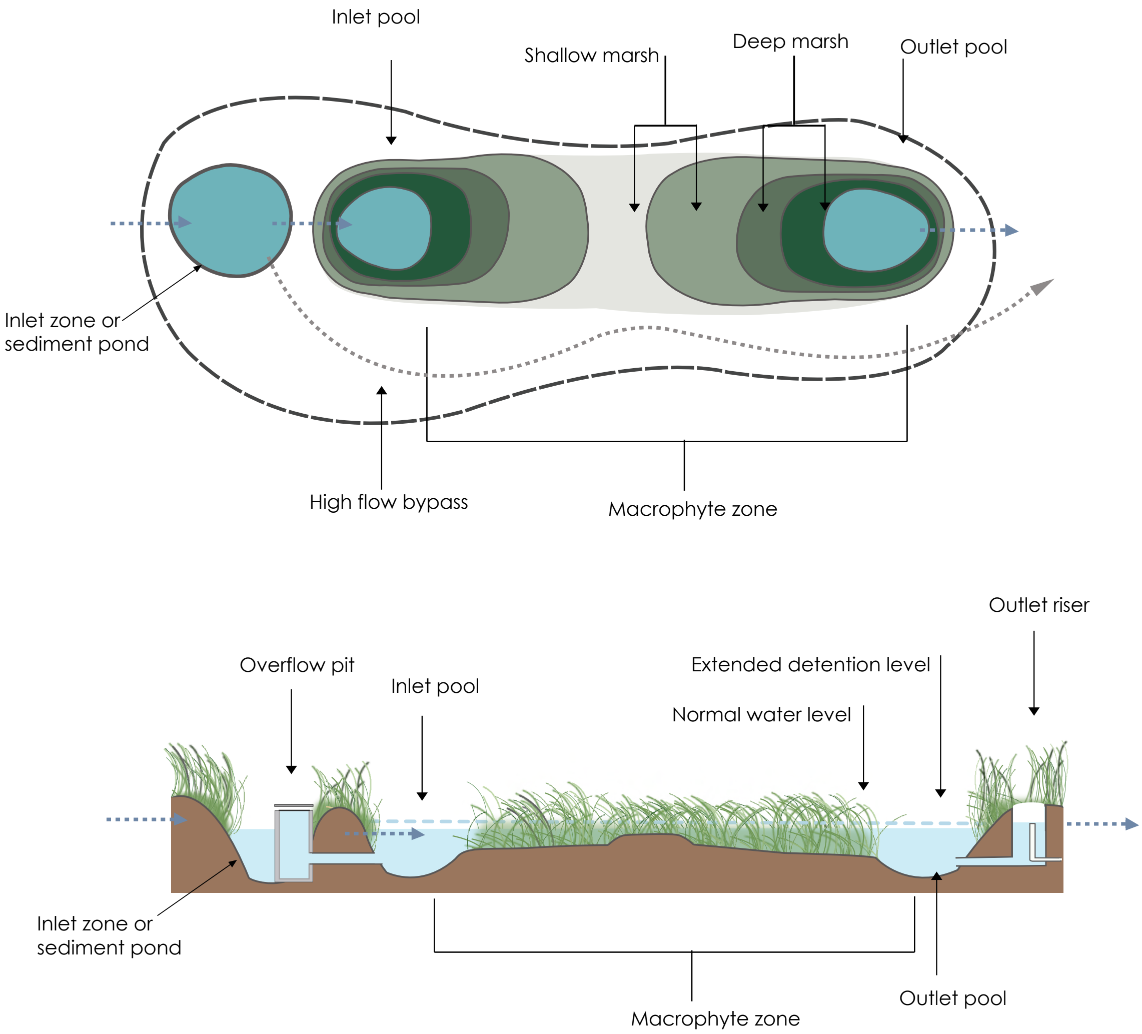


Figure 3.1 Typical cross-section and plan of a constructed wetland.

Each of the components identified in Figure 3.1 are described below. Further information can be found in the *Wetland technical design guidelines* (Water by Design 2017).

3.1.1 Sediment pond

A pond that receives stormwater inflows from the catchment. The sediment pond captures and stores sediments, preventing them from entering and damaging the downstream macrophyte zone.

3.1.2 Inlet pool

A pool that receives stormwater inflows from the sediment pond. The inlet pool helps to protect the macrophyte zone by promoting the settlement of fine sediments.

3.1.3 Inlet zone

After the building phase of a development, the sediment pond is converted into the inlet zone by reconnecting it to the macrophyte zone and installing and establishing plants.

3.1.4 Macrophyte zone

A predominantly wet marsh zone which may include areas of open water. Physical, chemical and biological processes intercept and remove fine sediments, heavy metals, particulate and soluble nutrients, and other pollutants from stormwater.

3.1.5 Outlet pool

A pool that receives treated stormwater from the macrophyte zone. Outlet pipes drain treated stormwater from the macrophyte zone to the receiving water or stormwater network.

3.1.6 Liner

A material used to retain water in the macrophyte zone to sustain its biological components and processes.

3.1.7 Overflow pits

A pit that transfers flows from the sediment pond or inlet zone to the macrophyte zone. It controls the water levels in the sediment pond or inlet zone and the maximum flow rate that can reach the macrophyte zone.

3.1.8 Extended detention

When stormwater enters a constructed wetland, it fills to the extended detention level (i.e. above the plants) and then drains when rainfall stops. The extended detention is a balance between the amount of stormwater that can be captured and the depth of inundation that constructed wetland plants can tolerate.

3.1.9 Overflow pits

A pit that transfers flows from the sediment pond or inlet zone to the macrophyte zone. It controls the water levels in the sediment pond or inlet zone and the maximum flow rate that can reach the macrophyte zone.

3.1.10 Extended detention

When stormwater enters a constructed wetland, it fills to the extended detention level (i.e. above the plants) and then drains when rainfall stops. The extended detention is a balance between the amount of stormwater that can be captured and the depth of inundation that constructed wetland plants can tolerate.

3.1.11 High flow bypass

A channel that conveys large, infrequent flows away from the macrophyte zone to prevent scouring and the resuspension of pollutants. During the building phase, the sediment pond may be configured to discharge all flows to the high flow bypass channel, diverting them away from the macrophyte zone to protect it from sediment.

3.1.12 Batters

Batters that integrate the constructed wetland with the surrounding site.

3.1.13 Bunds and embankments

Bunds and embankments that hold stormwater in the sediment pond, inlet pool, macrophyte zone and outlet pool.

3.1.14 Vegetation

Vegetation provides a substrate for biofilm to form, encourages the establishment of microbial communities, and takes up nutrients and other pollutants.

3.1.15 Outlet riser

An upstand perforated pipe or plate in the outlet control pit. The outlet riser provides a uniform detention time for water passing through the macrophyte zone of the constructed wetland. The outlet control pit drains treated stormwater from the macrophyte zone to the receiving water or stormwater network.

3.2 Construction considerations and specifications

Guidance is provided for civil construction works associated with the following:

- Installing hydraulic structures.
- Installing the liner.
- Undertaking earthworks.
- Providing maintenance access.

This section can be referred to for specifications for civil design drawings rather than generating specification documents.

3.2.1 Installing hydraulic structures

Correct hydraulic function is critical for successful constructed wetlands. Most hydraulic structures in constructed wetlands are relatively simple. However, constructing components within the fine tolerances required can be easily overlooked and this can have a dramatic effect on the overall function of constructed wetlands. All structures must be constructed in accordance with the civil design drawings and any potential changes must be confirmed in writing with the asset designer before civil construction works start. Once constructed, hydraulic structures should be surveyed by a licenced surveyor and reviewed by the asset designer before further works are undertaken.

Even very large constructed wetlands require very fine tolerances (e.g. <25 mm) for their hydraulic structures. Table 3.1 summarises hydraulic structures and their preferred construction specifications. These specifications should be considered part of the civil design. However, if there are concerns about hydraulic structures during civil construction, the constructed wetland may need to be redesigned.

If the proposed civil design is missing any of the hydraulic structures presented in Table 3.1, or if they vary from the descriptions provided in Section 3.1, the asset designer should be consulted for guidance.

Table 3.1 Construction specifications for hydraulic structures in constructed wetlands.

Structure	Specifications
Overflow pit and pipe (sediment pond or inlet zone)	The overflow pit should: • Be concrete in construction. • Be a letter box or dome grate (not flush grate). • Have a crest level typically 100 – 300 mm above the macrophyte zone water level and 300 mm+ below the high flow bypass weir level. Pipe connection requirements include scour protection at the outlet to the macrophyte zone (refer to the civil design for details).
High flow bypass weir	High flow bypass weirs need to operate under high flow conditions. This requires: • A mass concrete weir crest typically 500 mm deep with reinforcing. • Grouted rock protection (at least on the downstream face of the crest to the toe of the batters). • Concrete and rock protection extending up batters to avoid scour at the edges of the weir.
High flow bypass channel	The bypass channel typically consists of turf, but can be formed be a number of landscapes. Where turf is used, it should be laid perpendicular to the flow direction and pinned in place.
Macrophyte zone outlet (outlet riser)	The outlet riser should be located in a pit on the embankment or bund of the constructed wetland. This allows access for inspection and maintenance. A submerged connection minimises the risk of litter accumulation. The riser can be formed through either an upstand pipe with holes or a plate with holes (Figure 3.2).
Macrophyte zone outlet (maintenance drain)	The maintenance drain (where present) consists of a pipe connected to the low points or deep-water zones of the constructed wetland. The pipe passes through the macrophyte zone's outlet control pit. A valve is installed on the pipe to allow the macrophyte zone to drain.
Macrophyte zone outlet pipes	If the outlet pipe is drowned during construction, consult with the asset designer. The outlet pipe should incorporate a seepage collar.

Figure 3.2 Outlet riser in a constructed wetland.

3.2.2 Installing the liner

In most situations, constructed wetlands are designed to hold water permanently. If the constructed wetland is designed as a permanent waterbody, any leakage through the base may affect the vegetation and consequently the treatment function. The in-situ soils require a geotechnical investigation to define their water holding capacity. If permeability is greater than 1×10^{-9} m/s, an impervious liner will be required for the constructed wetland. The geotechnical investigation should preferably occur as part of the design process to define liner requirements.

Liners can either be constructed with in-situ clay, imported clay, or an imported impervious liner. The design of the constructed wetland will specify the liner type. It must extend up the walls and batters to the operating water level as a minimum, and preferably to the top of the extended detention.

When in-situ or imported clays are to be used, a geotechnical engineer must sample, test, and sign-off on the liner, providing it complies with permeability requirements (i.e. less than 1×10^{-9} m/s) and that the constructed wetland will hold water.

The liner is installed as part of the bulk earthworks. Using onsite clays is preferred, with a minimum depth of 300 mm compacted in two 150 mm layers. The geotechnical engineer must then complete in-situ permeability and compaction tests and, if the constructed wetland holds water, sign-off on the liner.

If artificial liners are used (e.g. geosynthetic bentonite clay or a HDPE liner), a geotechnical engineer must sign-off on the requirements and specifications of the product. The liner must be installed in accordance with the supplier's instructions and appropriate tests undertaken to demonstrate that the liner is watertight. Following installation of the liner, hydraulic structures including pipe connections are constructed, often through the impervious liner. It is critical that the liner is intact at these connection points and adequate attention is paid to establishing a waterproof seal.

3.2.3 Undertaking earthworks

Earthworks levels are critical for establishing constructed wetlands because they define the hydrologic regime the plants experience. Allow for a minimum of 300 mm of lightly compacted sand or topsoil above the impervious liner.

In addition to the fine tolerances for the base of constructed wetlands, local depressions must be minimised so that small puddles do not develop when water levels vary, as they can become mosquito breeding habitat. This is particularly important on the edges of batters between the normal water level and the top of the extended detention. Variations in finished earthworks and topsoil levels must be limited to 50 mm within the different constructed wetland zones.

3.2.4 Providing maintenance access

Access to the constructed wetland is important for maintenance. In particular, the sediment pond requires a track that is suitable for heavy machinery to remove sediment, as well as an area for dewatering desilted sediment. If sediment removal requires earthmoving equipment to enter the constructed wetland, a stable ramp suitable for heavy plant will be required into the base of the sediment pond. The width of the access into the sediment pond should be a minimum of 3 m, with the following preferred surface finishes:

- For slopes greater than 1 in 4, access should be a reinforced concrete design (in accordance with local authority's requirements) to support heavy plant. Surface finishes can be applied for landscape purposes.
- For slopes less than 1 in 4, access should be reinforced concrete from the base of the sediment pond to 0.5 m above the standing water level. From 0.5 m above the water level and upward, the access can be formed with gravel or reinforced turf.
- Where maintenance access to the sediment pond cannot be provided, suitable access and space should be allowed for a sucker truck to remove sediment. This option is subject to approval by the local authority.

It is recommended that the sediment pond is constructed with a hard bottom to assist with maintenance (i.e. concrete or rock). This allows excavator operators to detect when they have reached the base during desilting.

Macrophyte zones require access for weeding and replanting, as well as regular inspections of the overflow pit. Commonly, these access tracks can be incorporated with walking paths around the constructed wetland.

Typically, access to constructed wetlands is specified in the civil design stage. Where larger bodies of water are present, maintenance access, dewatering zones and turn around points are needed, especially where aquatic harvesters and associated equipment may be required to remove aquatic weeds.

3.3 Establishment considerations and specifications

Guidance is provided for landscape establishment works associated with the following:

- Installing topsoil.
- Selecting plants.
- Sourcing plants.
- Installing plants.
- Controlling the water level.
- Fighting off pests.
- Stocking fish.
- Identifying establishment success.

This section can be referred to for specifications for landscape design drawings rather than generating specification documents.

3.3.1 Placing topsoil

The correct topsoil is crucial to successful macrophyte establishment and to the long-term functioning of the constructed wetland. Macrophytes prefer medium-textured silty to sandy loams that allow for easy rhizome and root penetration. Although there are a few plants that can grow in in-situ heavy clays (e.g. *Phragmites australis*), growth is slow and the resulting constructed wetland will have a low species richness.

3.3.1.1 Topsoil specifications

Within the macrophyte zone, topsoil should be placed to a depth of 300 mm. As design levels of constructed wetlands are inclusive of topsoil, when earthworks are occurring, allowance for 300 mm of topsoil is required. If the constructed wetland sits on in-situ clay, the base should be ripped before placing topsoil to avoid a distinct soil horizon.

Topsoil must be tested by a NATA-accredited laboratory in accordance with *AS 4419:2018 Soils for landscaping and garden use*. If the proposed topsoil has high salt levels, extremely low levels of carbon (<5%), or any other extreme that may inhibit plant growth, it should be rejected. Laboratory testing will identify any amelioration requirements. The results of the topsoil test must be given to the site superintendent and asset designer for review before the topsoil is installed.

Topsoil for constructed wetlands can be sourced from the in-situ topsoil or from soil suppliers. During the civil construction process, topsoil will be stripped and stockpiled. Most terrestrial topsoils provide a good substrate for constructed wetlands, but laboratory testing in accordance with *AS 4419:2018* is always necessary to ensure the topsoil will support plant growth. If stockpiled topsoil is used, it must be approved by the laboratory and asset designer and will need to be screened to remove any coarse organic matter.

Avoid excessively weed-infested in-situ soils, particularly those containing aggressive pasture grasses tolerant of wetland conditions such as setaria (*Setaria sphacelata*) and barnyard grass (*Echinochloa* spp.). If these species are present, and no other sources of topsoil exist, a minimum of 50 mm should be scraped from the soil and discarded. If the in-situ topsoil is not suitable and amending it is not practical or cost effective, appropriate topsoil should be purchased from a soil supplier.

3.3.1.2 Ameliorating topsoil

Ameliorating the topsoil to meet specifications will be guided by a laboratory and may involve adding ameliorants, fertiliser, or organics to the soil.

The topsoil covering the bed of the constructed wetland should be treated with gypsum or lime, which is standard on most construction sites. The gypsum or lime facilitates flocculation, reducing the turbidity of the water column. With lower turbidity, higher levels of light are able to reach the plants, helping their establishment. The gypsum should be applied at a rate of 0.4 kg/m², preferably immediately prior to the initial inundation of the constructed wetland. Further application may be required at intervals depending on the condition of the constructed wetland and the amount of exchangeable sodium.

The application of lime may be required where the soil testing identifies a potential soil pH problem (i.e. $pH < 5$) or where acid sulphate soils exist. The rate of application should be guided by soil test results, an acid sulphate soils management plan, and water quality monitoring of the constructed wetland and stormwater inflow.

3.3.2 Selecting plants

The planting selection should be considered as part of the landscape design and documented on the landscape design drawings. Planting selection should be undertaken in collaboration with a aquatic ecologist and consider:

- Water depth.
- Hydrology.
- Potential drying periods.
- Location within the macrophyte zone.

It is important to use a relatively high density and diversity of species. This ensures a higher likelihood of successful establishment and quickly delivers a dense, mature planting, managing any potential weed issues. Local authorities should be consulted for planting density requirements.

The *Wetland technical design guidelines* (Water by Design 2017) and the local authority should be consulted for more information, including recommended species and planting densities. It is recommended at least two species be used per macrophyte zone. If the design does not allow for these specifications, consult the asset designer.

3.3.3 Sourcing plants

Tubestock available from wholesale nurseries are typically used in constructed wetlands. Specialist nurseries are familiar with supplying plants for bioretention systems, constructed wetlands, and other vegetated stormwater assets. Purchasing from specialist suppliers increases the chances of obtaining the right plants in the correct condition.

Availability varies between nurseries and is influenced by the time of year. Substituting species when some are unavailable can be problematic. If a change in species is necessary, confirm any changes with the asset designer and document it in the as-constructed drawings. Ideally, plant availability should be discussed at the pre-start meeting.

For large orders, it is recommended that periodic inspection of the plant stock at the nursery is undertaken to ensure the plants will be ready when required. Consider:

- Making it explicit at the time of ordering that periodic inspections of plants will be required.
- Checking that plants are being grown in clean, weed and pest-free conditions.
- Checking the plants for fresh white roots.
- Ensuring that plants have a hardening off phase before delivery and that they are not taken directly from a shade house to the construction site. This ensures plants are resilient to the shock of being planted and will establish and survive in the long term.

3.3.3.1 Timing

Plant availability varies considerably in different regions and at different times of year. Sufficient time must be allowed to order plants. Up to six months lead time may be required to ensure appropriate species are available. If provenance plant stock is required, up to 18 months may be required to collect seeds and propagate plants.

Certain species are very difficult or slow to propagate, with some species only producing one batch of seedlings per year. Check these issues with a knowledgeable nursery to avoid last minute substitutions due to species not being available at the time of delivery.

3.3.3.2 Maturity

Plant stock must be mature, sun-hardened, and contain a fully established root ball that does not crumble when removed from its container. Ideally, the plants will be on average 300 – 500 mm high and not less than 200 mm high (Figure 3.3). Height is important to enable plants to cope with inundation and not be buried in mulch.

Figure 3.3 Suitable mature tubestock for a constructed wetland.

Both immature plants and plants that are too old can struggle to establish. While some species benefit from additional growing time, permitting further root development, many species of sedges and other common constructed wetland plants will struggle to develop if they are old and root-bound. These plants will not establish well and may remain stunted, be susceptible to predators and disease, and fail to provide the cover required for optimal filtration.

Key things to look for in plant stock include:

- Pests and disease.
- Nutrient deficiency.
- New growth and general vigour.
- Weeds.
- Clear labelling.

Tubestock plants are usually supplied in a plastic container with dimensions of 70 – 150 mm high and 50 – 70 mm wide. However, there is a large variation in tubestock container size and price. A container with dimensions of at least 90 x 50 x 50 mm is recommended.

These containers can come in a number of forms:

- Viro tubes: 50 x 90 mm with a minimum plant height of 300 mm.
- 50 mm tubes: 50 x 75 – 90 mm with a minimum plant height of 300 mm.
- Native tubes: 50 x 125 mm with a minimum plant height of 300 mm.

Seedling pots of 20 mm should be avoided for bioretention systems. These seedlings are relatively immature and may result in high plant loss rates and patchy growth.

3.3.4 Installing plants

Timing of planting is dependent on time of year, irrigation requirements, and the construction and building phases of the development. In Queensland, October and November are considered ideal times to plant in constructed wetlands. Macrophytes are more tolerant of inundation in warmer waters and this timing allows for adequate establishment and root growth before the heavy summer rainfall period. Planting late in the year also avoids the dry winter months in Queensland, reducing maintenance costs associated with watering. Landscape planning and phasing should try to correspond with suitable planting months wherever possible. Planting should be avoided during periods of extreme weather conditions such as very hot days or during frost or heavy rainfall.

3.3.4.1 Setting out plants

While many constructed wetland plants may look the same, there can be substantial differences in growing requirements, particularly due to differences in water depth. Species planted too deep or in a location that is too dry will struggle to establish. This makes plant set out an important hold point in the landscaping process. If the site superintendent lacks specialist plant knowledge, an appropriately qualified ecologist or horticulturalist should be consulted to confirm the set out and that any proposed adjustments are appropriate.

It is important to get an even cover of vegetation perpendicular to the dominant flow path. Plant densities must be checked to ensure there is no excessive clumping of plants at the expense of other areas that are bare. Uneven distribution of plants increases the establishment time, promotes short-circuiting, and can compromise stormwater treatment performance.

3.3.4.2 Installing plants

Plants in constructed wetlands are usually installed using either hand tools or machinery. In very large constructed wetlands, tractors are sometimes required. 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. The top of the root ball should be slightly lower than the surface level around the plant. Using the soil to create an in-situ reservoir around the plant to temporarily pond water is also recommended. Water crystals and fertiliser may also be used to assist with establishment but fertiliser should not be necessary in ameliorated soils.

3.3.4.3 Establishing plants

Ideally, constructed wetland plants, except true aquatic species, should be established in a mudflat environment. Constructed wetland plants require 2.5 – 5.0 litres of water per plant per week. Watering should be responsive to prevailing conditions to preserve the muddy substrate. A mudflat environment reduces the risk of plants drowning and makes the freshly planted site less attractive for problem birds such as swamp hen and ibis (Section 3.3.6.2).

It is very important to ensure plants are established correctly in the early stages of the constructed wetland's life because increasing plant cover in a constructed wetland that has been flooded or has an established bird population is very difficult, time consuming and expensive.

If plants must be established in a flooded constructed wetland, water levels should be established at half the height of the plants. It must not exceed two-thirds of the height of the plants to avoid stress and drowning, particularly in winter. Planting in water will be 2 – 3 times slower than in dry conditions.

Given the critical importance of successfully establishing plant cover within the constructed wetland as quickly as possible, a proactive and adaptive approach should be taken, responding to any issues relating to the health of the plants. Responses can include adjusting water levels (3.3.5), eliminating weeds, or spreading seed to improve the constructed wetland's seed bank and increase plant cover in bare areas.

More than 90% of plants must survive with 80% coverage of the constructed wetland. If this is not achieved, investigate the issue, rectify, and replant where necessary.

3.3.4.4 Watering plants

Regular watering during plant establishment is essential to retain a muddy substrate in the shallow marsh section of the constructed wetland. The frequency of watering is dependent on rainfall, the maturity of plant stock and the water holding capacity of the soil. A watering program should be established to suit the site conditions.

The following guidance provides a starting point for the watering program:

- 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 – 5.0 litres per week during the first six weeks to retain a muddy substrate (i.e. 40 mm of watering per week during establishment).

After an initial four-month period, watering may still be required within the shallow zones of the constructed wetland, particularly during the first winter or dry period. Importantly, a suitable source and quantity of irrigation water must be identified before plants are delivered to site. Recycled water may be appropriate for use, but this should be confirmed with the site superintendent.

3.3.5 Controlling the water level

To maximise the chances of successful establishment of plants, the water level of the constructed wetland should be manipulated in the early stages of growth.

Before planting macrophytes, the constructed wetland can be fully inundated for a period of 1 – 2 weeks. This allows sufficient time for sedimentation, assisted by added gypsum if necessary, to ensure that the water is relatively clear. It will also give time for nutrient cycling within the water body to reach an acceptable level of equilibrium. The installation of plants must start immediately after this inundation period as conditions will be favourable for algal growth, increasing the threat of an algal bloom.

The water depth must be controlled in the establishment period for constructed wetland plants. Closing off the connection between the sediment pond and the macrophyte zone and opening the maintenance valve in the outlet riser will help to control the depth. The deep marsh zones should be approximately 150 – 200 mm for at least the first 6 – 8 weeks. This will ensure these areas are inundated to a shallow depth and that the shallow marsh zone remains moist, providing suitable conditions for plant establishment.

When first planted, vegetation in the deep marsh and pool zones may be too small for their prescribed water depths. Seedlings intended for inundated sections should ideally have half their stem height above water level and must not have any less than one-third of their stem above the water level. This may not be possible if planting stock is immature and initially planted at the intended depth. If planted too deeply, young submerged plants will not be able to access sufficient light in the open water zones. Without competition from submerged plants, algae may start to proliferate.

Seedlings planted in the shallow marsh and littoral zones of the constructed wetland will require ongoing watering. When plants are establishing well and growing actively, they should be of sufficient height to endure deeper water. The connection between the sediment pond and the macrophyte zone can be temporarily opened to allow the constructed wetland to fill slowly. The designed operating water level can be established when it is clear plants have matured to the point where at least half of the stem is above the operating water level.

3.3.6 Controlling pests

3.3.6.1 Weeds

Weed control in constructed wetlands is important to ensure that weeds do not compete with the planted species. Most weed seeds will find it difficult to establish due to the permanently wet nature of constructed wetlands. However, it is important to control native aquatic species like bulrush (*Typha orientalis*) or common reed (*Phragmites australis*) that can naturally appear in constructed wetlands and compete with planted species.

The most effective method of controlling weeds during establishment is by fortnightly inspection and removing weeds by hand. Regular inspections will minimise the work and ensure weeds are not able to establish in large populations and start to propagate.

High planting densities also help desired plants establish rapidly and propagate quickly to the point where weeds find it difficult to establish.

If a constructed wetland becomes weed-infested, any herbicides used must be carefully selected to avoid potential impact on downstream ecosystems. Herbicides should be applied via painting onto the weeds rather than spraying. It should be done during autumn when the weeds may be senescing. Weed spraying and any use of chemicals should be undertaken by staff with relevant qualifications and experience.

Mulching of the batter, embankments and littoral banks can help manage weeds, however the risk of conventional surface mulches (e.g. tanbark) floating must be considered. Adopting high planting density rates and, if necessary, a suitable biodegradable erosion control matting to the batters will help to combat weed invasion (Figure 3.4). The use of biodegradable matting is essential as it allows the plants to grow through it as it degrades (Figure 3.5).

If mulch is used on the littoral zones, it should be secured in place with appropriate organic mesh or netting. Note that local authority approval may be required to use netting.

Figure 3.4 Erosion control matting in a constructed wetland.

Figure 3.5 Desired plants growing in a constructed wetland.

3.3.6.2 Birds

During the early stages of establishment, water birds can be a major problem as they may pull out recent plantings. Interlocking planting systems, where several plants are grown together in a single container (e.g. floral edges) can be an effective solution. Water birds find it difficult to lift the interlocking plants out of the substrate, unlike single plants grown in tubes.

Other measures include:

- Installing protective fencing such as para-webbing on the open water side of a planting to discourage birds.
- Reflective bird deterrents.
- Ultrasonic bird deterrents.

Different measures work for different bird species and often a combination is required. In many cases, the best measure or combination of measures is identified through trial and error. There may also be other factors which need to be considered, such as food source supply, especially if the food source is rubbish which can be controlled. Generally, the sooner that bird control measures are implemented, the more likely that control measures will be effective, as birds become more difficult to move on once they have started nesting.

When establishing a new constructed wetland, there is a small window of opportunity before a water bird population establishes. Failure to take advantage of this window can make it difficult to establish desired plants.

In situations where birds have already damaged desired plants and replanting is necessary, there is an option to plant with larger stock. Many water birds, including swamp hens, tend to uproot plants to access the fresh white shoots. They can easily uproot tubestock but generally cannot uproot 300 mm sized pots. Many nurseries will quote high costs for constructed wetland plants of this size. However costs should be reflective of establishment duration and there may be net savings in the long term.

Constructed wetland plants grow much quicker than terrestrial plants. Where it may take three months to produce a terrestrial plant at 300 mm size, a constructed wetland plant of this size should be able to be produced in 6 – 8 weeks, reducing the production cost compared to terrestrial plants. The costs and benefits need to be weighed up against other options and will be dependent on the area which needs to be replanted.

3.3.6.3 Toads

Toads are another species which commonly invade newly constructed wetlands. Although they don't affect the functioning of the constructed wetland, a single egg clutch can contain up to 35,000 eggs, each with the potential to kill native wildlife at all stages of its life cycle. They can have a devastating effect on local ecology and should be controlled during the construction and establishment phase.

The cane toad is not a prohibited or restricted invasive animal under the *Biosecurity Act 2014*. However, by law everyone has a general biosecurity obligation to take reasonable and practical steps to minimise the risks associated with invasive plants and animals under their control.

Identifying cane toad eggs is easy because they are the only amphibian species in Australia to lay eggs in long, gelatinous strings, with the developing tadpoles appearing as a row of small black dots along the length (Figure 3.6, courtesy of the Department of Agriculture and Fisheries (DAF)). These strings are normally located beneath the water surface. Australian native frogs typically produce egg clusters as mounds of foam floating on the water surface.

Figure 3.6 Cane toad egg strings.

Figure 3.7 Cane toad tadpoles.

Similarly, identifying cane toad tadpoles is easy as they are the only species in Australia which are completely black, although they may turn lighter depending on lighting conditions (Figure 3.7, courtesy of Queensland Frog Society). They usually congregate in vast, slow-moving schools or shoals (Figure 3.8, courtesy of Queensland Frog Society), which is uncharacteristic of native species, and they don't break the water surface to take a breath.

Figure 3.8 Cane toad tadpoles schooling.

Figure 3.9 Sediment control fence around a constructed wetland.

Controlling cane toad eggs and tadpoles can be achieved quickly and cheaply by removing them with a pool scoop and allowing them to dry out in the sun. Adult cane toads can also be prevented from entering a constructed wetland by installing sediment control fencing at the top and/or bottom of the batters (Figure 3.9). This fencing is typically already required in most cases and only slightly more (if any), additional fencing is needed to ensure there are no gaps.

The use of pesticides for cane toad control is expensive, unnecessary and discouraged. Visit the Royal Society for the Prevention of Cruelty to Animals website for the most up-to-date information on the humane euthanasia of adult cane toads.

Further information on identification and control of cane toads is available through the Queensland Frog Society and DAF websites.

3.3.6.4 Mosquitoes

Mosquito control in constructed wetlands is not typically required. A well designed, constructed and established constructed wetland will naturally attract mosquito predators (e.g. dragonfly nymphs) very early during establishment, although it may take a little while for populations to become established.

Although mosquito larvae will still be present, natural predation means that very few larvae mature to adult stage. Thus, seeing mosquito larvae in a constructed wetland should not be used as a reason to justify chemical control, which can also kill mosquito predators.

3.3.7 Stocking fish

While the primary function of constructed wetlands is stormwater quality improvement, increasing pressure on developable land is driving interest in maximising value from assets. Constructed wetlands provide a range of co-benefits including improved visual amenity and ecology, and may play a role in enhancing local fish populations, as they are ideal nurseries for many fish species. Although not essential for mosquito control (Section 3.3.6.4), many native fish prey on mosquito larvae, which can be particularly beneficial in regions where mosquitoes are a known problem. Examples of native fish which are very effective at controlling mosquito populations include glassfish, dudgeons, rainbowfish and blue-eyes.

Privately and local authority-owned receiving waters have very different legal requirements for fish stocking. Most constructed wetlands will ultimately be local authority-owned and therefore a general fisheries permit will be required for any fish stocking to comply with Sections 90 and 91 of the *Fisheries Act 1994*. This permit must also be accompanied by a fish stocking management plan. Unless a general fisheries permit has been attained and a fish stocking management plan has been approved, the civil or landscape contractors should not undertake any fish stocking in the constructed wetland.

Restrictions on the species of fish which can be stocked will be detailed in the general fisheries permit, but generally should be species indigenous to the receiving water. The mosquitofish (*Gambusia affinis*) (Figure 3.10, courtesy of DAF) is an exotic, noxious pest which was introduced to Australia for mosquito control. Unfortunately, in many parts of Australia, it has exacerbated the problem by outcompeting native invertebrate predators of mosquito larvae, while impacting local native fish and frog populations.

Tilapia and carp are other examples of exotic fish which have caused widespread environmental damage and negatively impacted commercially and recreationally important fish species. These examples demonstrate how good intentions without proper knowledge can lead to perverse outcomes and why species which are not native to the receiving water should not be stocked.

The sourcing of fish used in stocking also needs to be carefully considered as it is not generally acceptable to source fish from aquarium retailers or to translocate fish from local receiving waters. General fisheries permit conditions require all fish to be sourced from a licensed hatchery approved under the *Planning Act 2016* or an appropriate quality assurance program.

Figure 3.10 Female (top) and male (bottom) mosquito fish.

Fisheries Queensland, within DAF, is responsible for ensuring public fisheries are managed and used sustainably. Further information on fish stocking is available through Fisheries Queensland and in the Queensland Government's *Policy for fish stocking in Queensland 2020* available on the DAF website.

3.3.8 Identifying establishment success

Constructed wetlands are considered to be established when plants are robust and self-sustaining. The growth and maturity of plants should be recorded through three-monthly photo logs every 500 m^2. Indicators to help identify when constructed wetlands are successfully established include:

- Greater than 90% plant survival.
- Greater than 80% coverage.
- Preferably more than one species per macrophyte zone.
- An increase in plant height of at least 50% through the establishment phase[1].
- Propagation is occurring with more than 2 – 3 stems and seeding.
- No weeds.
- Limited pest fauna (i.e. if present, they are not affecting wetland health or present in large numbers).

[1] *This can be measured by marker stakes in the bioretention system at a rate of one stake for every 500 m^2.*

3.4 Compliance requirements

The constructed wetland construction and establishment sign-off forms and the requirements outlined in this section provide the basis for complying with these guidelines. For the civil construction and landscaping and establishment sign-off forms, if an item receives an 'N' in the 'Satisfactory criteria' column (i.e. indicating that an element is 'not satisfactory'), appropriate actions must be specified to rectify the issue before final sign-off is given by the site superintendent and asset designer.

3.4.1 Undertaking surveys

It is important to emphasise the significance of tolerances when constructing wetlands. Table 3.1 summarises the construction considerations and tolerances for relevant components of a constructed wetland. It provides construction tolerances that should be adopted to ensure the successful construction of a wetland. The as-constructed survey must be undertaken as described in Table 3.1, with relevant information included on as-constructed drawings to assess compliance and support the sign-off process. Surveys should be completed by a qualified surveyor.

Table 3.2 Construction considerations and tolerances for constructed wetlands.

Component	Considerations	Tolerance	Survey method
Hydraulic structures	The construction of hydraulic structures must ensure design levels are achieved. The tolerance given applies to: • Inlet pipes. • Sediment pond connections (pit and pipe). • Outlet riser. • Outlet pipe (upstream and downstream). • High flow bypass weir. • Maintenance pipe and valves.	±25 mm	Survey
Earthworks (base of constructed wetland)	The bathymetry or final earthworks through all components of the constructed wetland is critical. The establishment of vegetation relies on correct water depths. The tolerance provided relates to all earthworks through the constructed wetland and must be measured at the surface of the topsoil.	±50 mm	Survey
Embankments or bunds	Embankment or bunds around constructed wetlands hold stormwater within the extended detention during rainfall. If required, they force larger rainfall into the hydraulic structures. Therefore, the crest level on the embankments or bunds is important.	±50 mm	Survey

The asset designer and site superintendent will require digital copies of as-constructed surveys for review before sign-off of civil construction works. Adequate time for review of these plans needs to be factored in when arranging inspections and hold points so as not to delay civil construction works.

Table 3.3 provides the spacing requirements for surveys. Survey plans are to indicate the degree of compliance with construction tolerances noted in Table 3.1, for example:

- Blue levels compliant.
- Black levels on tolerance level.
- Red levels exceed compliance.

The survey plans are also required to be accompanied by:

- A table which lists all levels and degree of compliance as per the above.
- Photos of all the surveyed constructed wetland components listed in the sign-off forms.

Table 3.3 Survey spacing requirements for constructed wetlands.

Component	Survey spacing requirements
Hydraulic structures	5 x 5 m maximum spacing.
Impermeable liner	For clay liners: Perimeter every five lineal metres and surface of clay liner with 5 x 5 m maximum spacing. For proprietary liners: Perimeter every five lineal metres (simply to indicate presence).
Inlet and outlet pipes	If present, upstream and downstream invert levels.
Overflow pit	Crest level, invert of pit and invert and size of all joining pipes.
High flow bypass weir	Top of weir at each end and crest of weir every one lineal metre.
High flow bypass channel	Invert of channel: Perimeter every five lineal metres with 5 x 5 m maximum spacing. Tops of bunds: Every five lineal metres.
Macrophyte zone outlet (outlet riser)	Survey should be crosschecked against civil design drawings to confirm any variations.
Macrophyte zone outlet (maintenance drain)	Location and invert at each end of pipe.
Embankments and bunds	Typically not present, although inlet point and surface levels at each corner should be surveyed.

3.5 Risks affecting construction and establishment

The construction and establishment of constructed wetlands can occur concurrently with the construction and building phases of a development site (Figure 3.12).

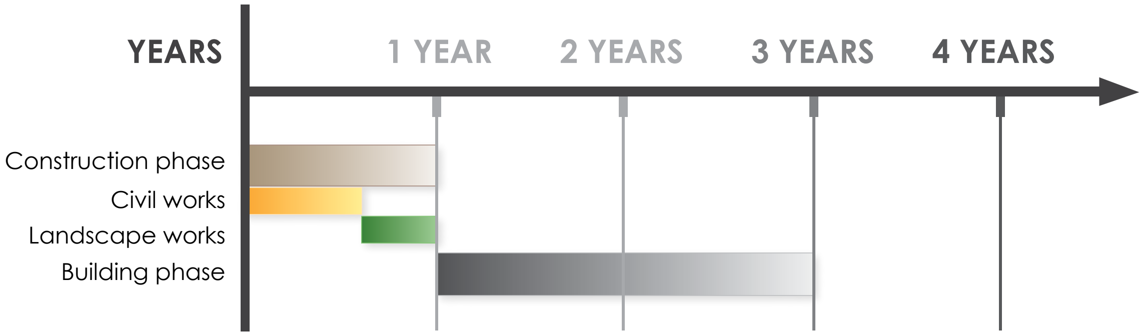


Figure 3.12 Typical phases of a development site.

The construction or subdivision phase typically involves clearing land and installing major infrastructure to service buildings and homes (e.g. drains and roads). The building phase typically involves constructing the buildings and homes. The activities associated with these phases can present significant risks to constructed wetlands, as outlined below.

3.5.1 Construction phase

Construction phase activities generate large sediment loads in stormwater which can enter constructed wetlands and smother their vegetation. Construction traffic and other activities can also cause physical damage to constructed wetland components including bunds/embankments and vegetation.

All activities during the construction phase should be coordinated by the principal contractor and/or site manager, so that risks can be controlled through appropriate contractor instruction and supervision, including instructing contractors to implement appropriate ESC measures.

3.5.2 Building phase

Building phase activities can also generate large sediment loads which can enter constructed wetlands. Sediment can smother vegetation, change water depths in the macrophyte zone and muddy the water, obstructing plant photosynthesis (i.e. drowning plants). In some constructed wetlands, the accumulation of sediment has required a complete reconstruction at significant cost.

Unlike the construction phase, the risks posed by the building phase cannot be easily controlled due to the large number of contractors and sub contractors undertaking activities independently and without a consistent source of instruction or supervision. For example, although site-based ESC is required, it is often not executed properly or at all (Water by Design 2022). Therefore, the building phase represents the greatest risk to the successful construction and establishment of constructed wetlands.

These risks can be managed through:

- Implementing ESC within the catchments of constructed wetlands in accordance with the local authority's requirements and a recognised guideline, for example the *Best practice erosion and sediment contro*l (IECA 2008).
- Protecting the macrophyte zone from sediment-laden runoff while plants are establishing.
- Undertaking a staged approach to transitioning the constructed wetland from the bulk earthworks to operational stages.

3.6 Approaches to construction and establishment

To control the risks associated with the building phase of a development site, two approaches to the construction and establishment of constructed wetlands are recommended:

- High efficiency sediment basin.
- Macrophyte zone disconnection.

These approaches are described below. Both approaches are based on a threshold of 90% buildout of the upstream catchment, defined as 90% of houses and surrounding landscapes and surfaces being built.

3.6.1 High efficiency sediment basin

This approach is preferred. It involves using the constructed wetland as a high efficiency sediment (HES) basin (Type A or B) during the building phase (Figure 3.13).

When building in the upstream catchment is 90% complete, the HES basin can be transitioned into the constructed wetland.

This approach provides a high level of protection to the constructed wetland, receiving water and stormwater network.

Figure 3.13 Use of a constructed wetland as a HES basin during the building phase.

3.6.2 Macrophyte zone disconnection

This approach involves disconnecting the macrophyte zone from the sediment pond and allowing all flows to divert into the high flow bypass channel (Figure 3.14). This can be achieved by creating and stabilising the sediment pond and the high flow bypass channel to receive and convey incoming flows around the macrophyte zone. When building in the upstream catchment is 90% complete, the sediment pond is converted into the inlet zone and connected to the macrophyte zone.

This approach protects the macrophyte zone and allows it to establish over a longer period of time (relative to using a HES basin) over the building phase. It also typically has a high level of amenity than the first approach.

Figure 3.14 Macrophyte zone disconnection in a constructed wetland.

3.7 Step-by-step guidance for construction

The recommended civil construction process for constructed wetlands is outlined below. The process should be read with the sign-off forms.

3.7.1 Undertake earthworks and profiling

Step 1: Hold pre-start meeting

Hold a pre-start meeting (Figure 2.25) with the asset designer, civil engineer, landscape architect, site superintendent, civil contractor, landscape contractor and, where required, the local authority's compliance officer to:

- Provide an overview of the constructed wetland.
- Highlight risks affecting construction and establishment.
- Talk through the construction and establishment approach.
- Explain the compliance requirements, including as-constructed surveys.
- Explain the inspection and sign-off process.

Relevant sections of these guidelines can be used to guide the pre-start meeting.

Step 2: Prepare for civil construction works

Prepare for construction at least ten days before starting works. Preparation includes organising for the hydraulic structures to be fabricated or supplied, organising the correct plant and equipment to achieve required tolerances (Section 3.4.1), ensuring the topsoil is tested (Section 3.3.1), and timing construction activities to avoid rain and other issues (Section 1.8).

Tip: Have you checked the following?

☑ ***The local authority and site superintendent has approved works.***

☑ ***The topsoil and liner material are approved (Form B).***

Step 3: Set out basin

Survey the constructed wetland layout in accordance with the set out plans.

Step 4: Strip and stockpile topsoil

Remove groundcover and strip topsoil (Figure 3.15). If the topsoil is to be used in the constructed wetland, on the bunds, or in the high flow bypass, it must be tested (Section 3.3.1) and screened to remove coarse material and weed seeds.

Figure 3.15 Excavator stripping back topsoil in a constructed wetland.

Step 5: Bulk out basin

Undertake bulk earthworks, including the sediment pond, high flow bypass, inlet pool, macrophyte zone, outlet pool, bunds and embankments, and surrounds.

Step 6: Trim and profile

Trimming and profiling of earthworks must allow for 300 mm of topsoil to form the final design levels within the constructed wetland and on batters or bunds. The design levels for the constructed wetland are inclusive of topsoil, so an additional 300 mm of excavation below the design levels is required during bulk earthworks (Section 3.3.1).

If an impervious liner is specified in the design, the excavation must allow for this as well (Section 3.2.2). For example, if a clay liner of 300 mm is specified, excavation of an additional 300 mm will need to occur within the constructed wetland (for a total of 600 mm including topsoil).

Step 7: Undertake as-constructed survey

Undertake an as-constructed survey of the constructed wetland to confirm construction is in accordance with the civil design drawings and tolerances (Section 3.4.1). Provide the as-constructed survey to the site superintendent and asset designer.

Step 8: HOLD POINT – Inspection and sign-off (☑ *Form A*)

The site superintendent and asset designer will inspect the constructed wetland with the civil contractor, review the as-constructed survey, and take photos. If the construction meets the tolerances (Section 3.4.1) and conforms with the civil design drawings, sign-off *Form A* will be completed and, along with photos, attached to the as-constructed survey. The as-constructed survey of the final topsoil levels is critical. Special attention should be paid to batter grades and safety benches.

3.7.2 Install bunds and liner

Step 9: Install bunds

Construct the bunds between the sediment pond and macrophyte zone of the constructed wetland and between the constructed wetland and receiving environment, including a clay core within the bunds. Compact the bunds, including the top of the bund, to ensure it retains water in the constructed wetland. Geotechnical sign-off of the liner must be obtained to confirm that the bunds will hold water (Section 3.2.2). Ensure batter grades are correct and safety benches are in place.

Step 10: Install impervious liner

Install the impervious liner to design and supplier specifications (Section 3.2.2) (Figure 3.16). It is critical that the liner is sealed and geotechnical sign-off of the liner is obtained.

Figure 3.16 Installation of clay liner in a constructed wetland.

Step 11: HOLD POINT – Inspection and sign-off (☑ *Form B*)

Following installation of the liner and the bunds, the site superintendent and/or asset designer will inspect the constructed wetland with the civil contractor and take photos. Where required, the geotechnical engineer will also attend the inspection. As a minimum, geotechnical sign-off must be obtained as part of the inspection.

If the construction meets the geotechnical and suppliers' specifications, sign-off *Form B* will be completed and, along with photos, stored with relevant civil construction documentation.

3.7.3 Install hydraulic structures

Step 12: Install hydraulic and functional structures

Construct and install all hydraulic, functional and structural components of the constructed wetland (Figure 3.17). This includes, but is not limited to:

- Inlet pipes and headwalls.
- Sediment pond connections (pit and pipe).
- Outlet riser.
- Outlet pipe (upstream and downstream) and headwalls.
- High flow bypass weir.
- Rock protection.
- Maintenance pipe and valves.
- Rock or concrete base of sediment pond.
- Maintenance access.

Any pipework through bunds or embankments must have seepage collars. Construction of the hydraulic, functional and structural components of the constructed wetland should meet the tolerances outlined in Section 3.4.1. An as-constructed survey is required at this stage for each of the components.

Figure 3.17 Hydraulic structures of a constructed wetland.

Step 13: Undertake as-constructed survey

Undertake an as-constructed survey of the constructed wetland to confirm construction is in accordance with the civil design drawings and tolerances (Section 3.4.1). Provide the as-constructed survey to the site superintendent and asset designer.

Step 14: HOLD POINT – Inspection and sign-off (☑ *Form C*)

The site superintendent and asset designer will inspect works with the civil contractor, review the as-constructed survey, and take photos. If the construction meets the tolerances (Section 3.4.1) and conforms to the civil design drawings, sign-off *Form C* will be completed and, along with photos, attached to the as-constructed survey.

APPROACH 1 ONLY (skip Steps 15 to 17 for Approach 2)

Step 15: Install HES basin

The various flow controls for the HES basin should be installed in accordance with the civil design drawings. Refer to a recognised guideline, for example the *Best practice erosion and sediment control* (IECA 2008)

The base of the HES basin should be stabilised to avoid scour and resuspension of sediment. This may involve the installation of turf or filter cloth in the base of the basin.

Step 16: Operate HES basin

During the building phase, which may be up to 2 – 4 years, operate the constructed wetland as a HES basin (Figure 3.18). Operation and maintenance of the HES basin is the responsibility of the developer. It is recommended that an inspection and maintenance contract is established with the landscape contractor to inspect the HES basin and undertake maintenance and rectification as required. If necessary, add gypsum to promote sedimentation.

When 90% of the building in the catchment is complete, the next steps can proceed.

Step 17: Clean out the macrophyte zone and sediment pond

Remove sediment and gross pollutants from the sediment pond and the macrophyte zone, as well as any unnecessary sediment basin flow controls.

Step 18: Check liner and hydraulic structures

The impervious liner should be reassessed or installed if installation was delayed until this step, to ensure it conforms with the requirements of Section 3.2.2. The hydraulic structures should also be inspected for damage or movement.

Figure 3.18 Use of a constructed wetland as a HES basin during the building phase.

Figure 3.19 Finished surfaced level of a constructed wetland.

3.7.4 Place topsoil and profile to final levels

Step 19: Place topsoil and profile to final levels

Install suitable topsoil (as identified in Step 2 and tested in accordance with Section 3.3.1) to a minimum depth of 300 m (Figure 3.19).

Profile the topsoil using a Posi-Track bobcat with a spreader bar to achieve the final constructed wetland design levels in accordance with the tolerances in Section 3.4.1. The design levels through the macrophyte zone must be achieved to within 50 mm and will often require a number of profiling steps to achieve the required levels.

An as-constructed survey of the final topsoil levels through the entire constructed wetland, particularly the macrophyte zone, will be required. Superimpose this survey on the original design for the site superintendent and asset designer.

Step 20: HOLD POINT – Inspection and sign-off (☑ *Form D*)

The site superintendent and asset designer will inspect works with the civil contractor, review the as-constructed survey, and take photos. If the construction meets the tolerances (Section 3.4.1) and conforms to the civil design drawings, sign-off *Form D* will be completed and, along with photos, attached to the as-constructed survey.

3.7.5 Disconnect macrophyte zone

Step 21: Stabilise the high flow bypass channel

Stabilise the high flow bypass channel as it will receive flows while vegetation is establishing in the macrophyte zone. The high flow bypass channel can be stabilised with turf or reinforced turf placed perpendicular to the flow and pinned down.

Step 22: Install sediment fences

Install sediment control fencing around the perimeter of the constructed wetland to prevent sediment entering from the batters and to keep construction vehicles out (Figure 3.20). Also install temporary safety fencing during the plant establishment phase to prevent public access to deep water zones.

Figure 3.20 Temporary sediment fencing around a constructed wetland.

Step 23: Disconnect sediment pond from the macrophyte zone

To help vegetation establish within the macrophyte zone, disconnect the sediment pond from the macrophyte zone. This excludes sediment-laden runoff from the macrophyte zone and allows for manipulation of the water level. This is only a temporary measure achieved by blocking the connection between the sediment pond and the macrophyte zone. Include a mechanism to open this connection for short periods to slowly fill or flush the constructed wetland when required. Place moveable steel plates on the overflow pit in the sediment pond.

During this establishment period, all flows from minor and major storms will be directed over the sediment pond bypass weir and into the high flow bypass channel. The sediment pond may require desilting several times before establishment. When building in the upstream catchment is 90% complete, the sediment pond is converted into the inlet zone and connected to the macrophyte zone.

Step 24: HOLD POINT for practical completion – Inspection and sign-off (☑ *Form E*)

Following the macrophyte zone disconnection, the site superintendent and/or asset designer will inspect the constructed wetland with the civil contractor and take photos. If the works conform with the civil design drawings, sign-off *Form E* will be completed and, along with photos, stored with relevant construction documentation. This is the practical completion inspection for civil construction works and is the basis for proceeding to the establishment phase.

3.8 Step-by-step guidance for establishment

The recommended process for landscaping and establishing constructed wetlands is outlined below. The process should be read with the sign-off forms.

3.8.1 Landscape macrophyte zone

Step 25: Hold pre-start and plant set out meeting

Before starting landscaping works, hold a pre-start and plant set out meeting with the asset designer, an ecologist or horticulturalist, landscape architect, site superintendent and landscape contractor. The meeting should confirm the landscape design and plant set out to ensure the correct plants are installed in the correct locations.

Step 26: Prepare for establishment works

Prepare for landscape establishment up to six months before starting, including ordering and inspecting plants at the nursery (Figure 3.21), ordering and receiving mulch, and organising a supply of water for irrigation.

Tip: Have you checked the following?

- ☑ ***The local authority has approved works.***
- ☑ ***The plant selection is approved.***

Figure 3.21 Inspecting plants for installation in a constructed wetland.

If any plants have been replaced with a species other than those specified in the landscape design drawings, confirm with the asset designer prior to ordering. Any changes to plant species or numbers of plants must be recorded in the as-constructed drawings.

Step 27: Install hardscapes

If not completed as part of the civil construction of the constructed wetland, install pathways and boardwalks according to the civil and/or landscape design drawings.

Step 28: Install mulch

Mulch the areas of the batters of the constructed wetland that are above the extended detention. Install a sediment control fence on the downslope side of the mulch for batters that are steeper than 1 in 4. Mulch should be suitably secured with organic netting or other measures to avoid it floating into the constructed wetland.

Step 29: Install plants

Ideally, constructed wetland plants should be established in a mudflat environment (Figure 3.22). Therefore, commence planting immediately after the initial inundation period. Plant the tubestock in accordance with the plant selection, densities, and set out, ensuring the root ball is covered with topsoil and the stem is sitting above the topsoil.

Figure 3.22 Plants installed in the mudflat environment of a constructed wetland.

Step 30: Control water level

Manipulate the water level in the macrophyte zone in the early stages of vegetation growth. The maximum water level should be half the height of the plants and must not exceed two-thirds of their height to avoid stress and drowning, particularly in winter. The deep marsh species will dictate the depth. Lower the water level by at least 300 mm during establishment and water the dryer planting zones regularly to sustain a mudflat environment during establishment. If lowering of the macrophyte zone water level via a valve is not possible, pump out will be required.

A temporary cover over the overflow pit in the sediment pond can be used to control water levels. Partially open the disconnection between the sediment pond and macrophyte zone to allow the macrophyte zone to fill with stormwater.

Fully inundate the constructed wetland for around 1 – 2 weeks. This allows sufficient time for sedimentation, assisted by the gypsum, to ensure that the water is relatively clear and that nutrient cycling within the constructed wetland reaches an acceptable equilibrium.

Step 31: HOLD POINT for practical completion – Inspection and sign-off (☑ *Form F*)

After installing the mulch and plants, the site superintendent and asset designer will inspect the constructed wetland with the landscape contractor, take photos, and complete sign-off *Form F*. This is the practical completion inspection for landscaping works for all constructed wetland components, except the sediment pond, which is converted to the inlet zone in Step 38. This inspection is the basis for proceeding to the next steps.

3.8.2 Establish macrophyte zone

Step 32: Water plants

Constructed wetland plants should be established in a mudflat environment. Water the dryer parts of the constructed wetland (i.e. shallow marsh, ephemeral and littoral zones) while the water level is low. Water the plants in accordance with Section 3.3.4.4. Where appropriate, this may include watering according to the following schedule:

- Week 1 – 6: Five waterings per week.
- Week 6 – 10: Three waterings per week.
- Week 11 – 15: Two waterings per week.

If there is no rain, each plant should receive 2.5 – 5.0 litres of water per week during establishment in the first six weeks (40 mm per week). Additional watering can be undertaken in response to plant health.

Step 33: Remove weeds

Inspect plants fortnightly during establishment, removing any weeds (including seedheads), by hand (Figure 3.23). Herbicides must not be used in constructed wetlands and brush cutters should also be avoided as they disperse weed seeds and damage desirable plants.

Figure 3.23 Bulrush (*Typha orientalis*) in a constructed wetland.

APPROACH 1 ONLY (skip Steps 34 and 35 for Approach 2)

Step 34: Establish normal water level

When the plants are mature and tall enough to endure deeper water, fill the constructed wetland to its normal operating water level. It typically takes 3 – 4 months (depending on the season) for plants to reach this level of maturity.

Temporarily open the connection between the sediment pond and the macrophyte zone to fill the constructed wetland to normal operating water levels. Once filled, close off the connection between the sediment pond and the macrophyte zone to allow for a further period of plant establishment with limited water level variation.

Step 35: Reconnect the macrophyte zone

Reconnect sediment pond to macrophyte zone after plant establishment and proceed to Steps 37 to 43.

Step 36: Undertake routine inspection and maintenance works

Monitor the establishment of plants fortnightly until they are robust and self-sustaining (Figure 3.24), removing any weeds by hand. Measures of an established constructed wetland include:

- Greater than 90% plant survival.
- Greater than 80% coverage.
- Preferably more than one species per macrophyte zone.
- An increase in plant height of at least 50% through the establishment phase[1].
- Propagation is occurring with more than 2 – 3 stems and seeding.
- No weeds.
- Limited pest fauna (i.e. if present, they are not affecting wetland health or present in large numbers).

[1] This can be measured by marker stakes in the bioretention system at a rate of one stake for every 500 m^2.

Step 37: HOLD POINT – Inspection and sign-off (☑ *Form G*)

Following the establishment of plants and normal water level in the macrophyte zone, the site superintendent and asset designer will inspect the constructed wetland, take photos, and complete sign-off *Form G*. The constructed wetland will continue to establish during the building phase, during which time most stormwater events pass through the sediment pond and bypass the constructed wetland macrophyte zone.

Figure 3.24 Established macrophyte zone of a constructed wetland.

3.8.3 Landscape and establish inlet zone

When 90% of the building phase is complete, the macrophyte zone in the constructed wetland will likely be ready for operation and have fully established mature vegetation. The only thing left to do is convert the sediment pond into the inlet zone. This involves desilting and landscaping the sediment pond and removing the disconnection between the sediment pond and macrophyte zone, allowing the constructed wetland to operate in accordance with its civil and landscape design.

Step 38: Hold pre-start and plant set out meeting

Hold a pre-start and plant set out meeting with the asset designer, an ecologist or horticulturalist, landscape architect, site superintendent, landscape contractor and, where required, the local authority's compliance officer. The meeting will confirm the sediment pond clean out and plant set out to ensure the correct plants are installed in the correct locations.

Step 39: Prepare for establishment works

Similar to the macrophyte zone, landscape works should be planned for up to six months before starting, including ordering and inspecting plants at the nursery, and organising a supply of water for irrigation.

Tip: Have you checked the following?
- ☑ ***The local authority has approved works.***
- ☑ ***The plant selection is approved.***

If any plants have been replaced with a species other than those specified on the design, confirm with the asset designer prior to ordering. Any changes to plant species or numbers of plants must be recorded in the as-constructed drawings.

Step 40: Clean out the sediment pond

Remove accumulated sediment and gross pollutants from the sediment pond down to the concrete or rock base. Dispose of accumulated sediment appropriately.

Step 41: Place topsoil

Place topsoil to a depth of 300 mm in the inlet zone from the batters to a depth of 500 mm below the water level for planting.

Step 42: Install and maintain plants

Install and maintain plants on the inlet zone batters in accordance with Steps 29, 32, 33 and 36.

Step 43: HOLD POINT for final completion – Inspection and sign-off (☑ *Form H*)

After plants are established (Figure 3.25), the site superintendent and asset designer will inspect the constructed wetland, take photos and complete sign-off *Form H*. This is the final completion inspection for landscape establishment works and is the basis for transfer to the asset owner (typically the local authority).

Figure 3 24 Established macrophyte zone of a constructed wetland.

4 REFERENCES

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5 SIGN-OFF FORMS

5.1 Construction and establishment sign-off forms for bioretention systems

CONSTRUCTION & ESTABLISHMENT SIGN-OFF FORMS FOR BIORETENTION SYSTEMS			
Asset location:			
Asset ID:		Development approval #:	
Catchment area (ha):		Bioretention area (ha):	
Civil design drawing #:		Landscape design drawing #:	
SIGN-OFF FORMS			
FORM	DATE COMPLETED	NAME & ROLE (E.G. SUPERINTENDENT)	SIGNATURE
Pre-start meeting			
Form A: Undertake earthworks and install hydraulic structures			
Form B: Install liner and under-drainage			
Form C: Install filter materials			
Form D: Undertake as-constructed survey			
Form E: Install coarse sediment forebay			
Form F: Install protective measures			
Form G: Landscape bioretention system			
Form H: Establish bioretention system			

<table>
<tr><th colspan="6">PRE-START MEETING</th></tr>
<tr><td colspan="6">Purpose: To ensure everyone involved in construction works understands the processes and requirements.</td></tr>
<tr><td colspan="5">Meeting location:</td><td>Date:</td></tr>
<tr><td>ROLE/STAKEHOLDER</td><td colspan="2">COMPANY</td><td colspan="2">CONTACT NAME</td><td>SIGNATURE</td></tr>
<tr><td>Asset designer</td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td>Landscape architect</td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td>Civil engineer</td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td>Site superintendent (construction)</td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td>Civil contractor</td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td>Local authority compliance officer</td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td>Other</td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
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<tr><td>BEFORE YOU START</td><td>CHECKED</td><td colspan="4">ACTION</td></tr>
<tr><td>Has the local authority approved works?</td><td></td><td colspan="4"></td></tr>
<tr><td>Is there a reliable source of compliant filter materials nearby?</td><td></td><td colspan="4"></td></tr>
<tr><td>Is there no significant rain forecast during works?</td><td></td><td colspan="4"></td></tr>
<tr><td colspan="6">Comments (attach and refer to additional pages if necessary)</td></tr>
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FORM A: UNDERTAKE EARTHWORKS AND INSTALL HYDRAULIC STRUCTURES				BIORETENTION SYSTEMS
Purpose: To ensure earthworks and hydraulic structures are installed correctly and in accordance with the civil design.				
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
As-constructed survey completed and attached to this form.				
Photos taken and attached to this form.				
Set out of bioretention system is correct.				
Base at correct level (±50 mm).				
Base at correct grading (0.5%).				
Overflow pit holes punched out and at correct size.				
Overflow pit at correct size.				
Overflow pit crest and invert at correct level (±25 mm).				
Outlet pipe invert (up and downstream) at correct level (±25 mm).				
Outlet pipe is free draining.				
High flow bypass weir (if present) is correct length and at correct level (±25 mm).				
High flow bypass weir (if present) is keyed into bund.				
Bunds/embankments at correct levels (-25 mm to +50 mm).				
HOLD POINT: Superintendent and asset designer inspection and sign-off before proceeding.				

COMMENTS:

Attach as-constructed survey and photos

Add pages if necessary

Signed by superintendent:		Signed by asset designer:	
Print name:		Print name:	
Date:		Date:	

FORM B: INSTALL LINER AND UNDER-DRAINAGE				BIORETENTION SYSTEMS
Purpose: To ensure under-drainage is installed correctly and in accordance with the civil design.				
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
Base of system free from debris.				
Liner correctly installed.				
No socks in or around under-drainage pipes.				
Correct under-drainage has been supplied.				
Under-drainage pipes laid at correct spacing (small system 1.5 m; large system 2 m).				
Under-drainage pipes at correct level (±25 mm).				
Under-drainage pipes at correct grade (0.5% grade).				
All junctions and connections are appropriately sealed.				
Top of clean out points at design level (50 – 150 mm above filter media surface).				
HOLD POINT: Superintendent and asset designer inspection and sign-off before proceeding.				
COMMENTS:				
Attach as-constructed survey and photos				
Add pages if necessary				

Signed by superintendent:		Signed by asset designer:	
Print name:		Print name:	
Date:		Date:	

FORM C: INSTALL FILTER MATERIALS				BIORETENTION SYSTEMS
Purpose: To ensure filter materials are installed correctly and in accordance with the civil design and relevant specifications.				
DRAINAGE LAYER				
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
Complies with specifications.				
Follows testing and chain of custody requirements (see Section 2.4).				
TRANSITION LAYER				
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
Complies with specifications.				
Follows testing and chain of custody requirements (see Section 2.4).				
FILTER MEDIA				
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
Complies with specifications.				
Follows testing and chain of custody requirements (see Section 2.4).				
HOLD POINT: Superintendent or asset designer inspection and review of test reports and supply dockets before proceeding.				
COMMENTS:				
				Attach test results and supply dockets
				Add pages if necessary

FORM C: INSTALL FILTER MATERIALS				BIORETENTION SYSTEMS
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
Base of system free from debris.				
Drainage layer installed to correct depth (± 25 mm).				
Transition layer installed to correct depth (± 25 mm).				
Filter media installed to correct depth (± 25 mm).				
Filter media installed in two lifts.				
Filter media installed to avoid compaction.				
Ultralight, even compaction applied to remove air gaps.				
Spreader bar used to flatten surface of filter media.				
Sediment control fencing erected.				
HOLD POINT: Superintendent and asset designer inspection and sign-off to occur during installation of filter materials. Photos must be taken by the superintendent, the asset designer, or the civil contractor.				
COMMENTS:				
				Attach as-constructed survey and photos
				Add pages if necessary

Signed by superintendent:		Signed by asset designer:	
Print name:		Print name:	
Date:		Date:	

FORM D: UNDERTAKE AS-CONSTRUCTED SURVEY				BIORETENTION SYSTEMS
Purpose: To ensure the finished levels of the bioretention system's surfaces and bunds comply with the civil design.				
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
Landscaping topsoil applied to comply with civil design.				
As-constructed survey of surfaces and surrounding bunds completed.				
Final constructed levels are consistent with civil design.				
Under-drainage clean-outs extended 50 – 150 mm above filter media.				
Under-drainage pipes flushed to remove construction materials, if any.				
HOLD POINT: Superintendent and asset designer inspection and sign-off before proceeding.				
COMMENTS:				
				Attach as-constructed survey and photos
				Add pages if necessary

Signed by superintendent:		Signed by asset designer:	
Print name:		Print name:	
Date:		Date:	

FORM E: INSTALL COARSE SEDIMENT FOREBAY				BIORETENTION SYSTEMS
Purpose: To ensure the coarse sediment forebay is installed correctly and in accordance with the civil design.				
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
Coarse sediment forebay set out correct.				
Base of coarse sediment forebay at correct level.				
Base of coarse sediment forebay drains.				
Coarse sediment forebay can be accessed for inspection and maintenance.				
Energy dissipation installed at correct location.				
Energy dissipation (e.g. rocks or concrete blocks) at correct size.				
Interface between coarse sediment forebay and filter media is structurally sound and not prone to collapse or scour.				
HOLD POINT: Superintendent or asset designer inspection and sign-off before proceeding.				
COMMENTS:				
				Attach as-constructed survey and photos
				Add pages if necessary

Signed by superintendent:		Signed by asset designer:	
Print name:		Print name:	
Date:		Date:	

FORM F: INSTALL PROTECTIVE MEASURES				BIORETENTION SYSTEMS
Purpose: To ensure protective measures are installed correctly to protect the bioretention system while building is occurring in the catchment.				
OPTION 1 – HIGH EFFICIENCY SEDIMENT BASIN				
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
Continuous sediment control fencing installed around perimeter of filter media and top of batter.				
High efficiency sediment (HES) basin installed in accordance with *Best Practice Erosion and Sediment Control* (IECA 2008).				
Suitable access provided to HES basin for inspection and maintenance.				
OPTION 2 – TEMPORARY SURFACE PROTECTION				
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
Continuous sediment control fencing installed around perimeter of filter media and top of batter.				
Where landscaping works are not to commence immediately, cover batters with filter cloth.				
Protective covering (e.g. filter cloth + 25 mm topsoil + turf) installed across entire filter media area.				
HOLD POINT: Superintendent or asset designer inspection and sign-off before proceeding.				
COMMENTS:				
				Attach as-constructed survey and photos
				Add pages if necessary

Signed by superintendent:		Signed by asset designer:	
Print name:		Print name:	
Date:		Date:	

FORM G: LANDSCAPE BIORETENTION SYSTEM				BIORETENTION SYSTEMS
Purpose: To ensure the plants are supplied, installed, and established correctly and in accordance with the landscape design.				
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
Mulch complies with specifications.				
Mulch applied to correct depth.				
Mulch secured.				
Supplied plants are correct species.				
Supplied plants are in correct pot sizes.				
Supplied plants at correct maturity and hardened.				
Supplied plants are healthy.				
Plants have been installed at correct planting density (minimum 6 plants/m^2).				
As-constructed drawings marked up with final plant species and densities.				
Mulch is clear of plant stems by approximately 50 mm.				
HOLD POINT: Superintendent and asset designer inspection and sign-off before proceeding.				
COMMENTS:				
				Attach as-constructed survey and photos
				Add pages if necessary

Signed by superintendent:		Signed by asset designer:	
Print name:		Print name:	
Date:		Date:	

FORM H: ESTABLISH BIORETENTION SYSTEM				BIORETENTION SYSTEMS
Purpose: To ensure plants establish correctly and in accordance with the landscape design.				
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
Weeds removed.				
Watering undertaken as required.				
Replanting occurred as required to replace failed vegetation.				
Plants successfully established.				
Propagation/recruitment is occurring.				
Measure of successful establishment:				
1. Greater than 90% plant survival.				
2. Greater than 80% coverage.				
3. Preferably more than one species.				
4. At least 5 plants/m^2 (preferably 6 – 10 plants/m^2).				
5. Increase in plant height of at least 50%. This can be measured by marker stakes at a rate of one stake per 500 m^2 every three months.				
6. Propagation is occurring with more than 2 – 3 stems and seeding.				
7. No weeds.				
Remove any temporary upstream stormwater diversions once minimum 90% catchment buildout is achieved.				
HOLD POINT: Superintendent and asset designer inspection and sign-off.				

COMMENTS:

Attach as-constructed survey and photos

Add pages if necessary

Signed by superintendent:		Signed by asset designer:	
Print name:		Print name:	
Date:		Date:	

5.2 Construction and establishment sign-off forms for constructed wetlands

CONSTRUCTION & ESTABLISHMENT SIGN-OFF FORMS FOR CONSTRUCTED WETLANDS			
Asset location:			
Asset ID:		Development approval #:	
Catchment area (ha):		Macrophyte zone area (ha):	
Civil design drawing #:		Landscape design drawing #:	
SIGN-OFF FORMS			
FORM	DATE COMPLETED	NAME & ROLE (E.G. SUPERINTENDENT)	SIGNATURE
Pre-start meeting			
Form A: Undertake earthworks and profiling			
Form B: Install bunds and liner			
Form C: Install hydraulic structures			
Form D: Place topsoil and profile to final levels			
Form E: Disconnect macrophyte zone			
Form F: Landscape macrophyte zone			
Form G: Establish macrophyte zone			
Form H: Landscape and establish inlet zone			

PRE-START MEETING	CONSTRUCTED WETLANDS
Purpose: To ensure everyone involved in establishment works understands the processes and requirements.	
Meeting location:	Date:

ROLE/STAKEHOLDER	COMPANY	CONTACT NAME	SIGNATURE
Asset designer			
Landscape architect			
Site superintendent (establishment)			
Landscape contractor			
Local authority compliance officer			
Other			
Other			
Other			
Other			

BEFORE YOU START	CHECKED	ACTION
Has the local authority approved works?		
Are the topsoil and liner material approved?		
Is there no significant rain forecast during works?		

Comments (attach and refer to additional pages if necessary)

Actions (attach and refer to additional pages if necessary)
Add pages if necessary

FORM A: UNDERTAKE EARTHWORKS AND PROFILING				CONSTRUCTED WETLANDS
Purpose: To ensure earthworks and profiling are undertaken correctly and in accordance with the civil design.				
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
As-constructed survey completed and attached to this form.				
Photos taken and attached to this form.				
Set out of constructed wetlands is correct, including inlet zone/sediment pond, inlet pool, macrophyte zone, and outlet pool.				
Levels are correct (±50 mm) allowing for 300 mm of topsoil and 300 mm impervious liner where required.				
HOLD POINT: Superintendent and asset designer inspection and sign-off before proceeding.				
COMMENTS:				
				Attach as-constructed survey and photos
				Add pages if necessary

Signed by superintendent:		Signed by asset designer:	
Print name:		Print name:	
Date:		Date:	

FORM B: INSTALL BUNDS AND LINER				CONSTRUCTED WETLANDS
Purpose: To ensure the bunds and liner are installed correctly and in accordance with the civil design and relevant specifications.				
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
As-constructed survey complete for top of bunds and liner and attached to this form.				
Liner complies with specifications.				
Follows testing and chain of custody requirements (see Section 2.4).				
Liner material installed and sealed in accordance with the civil design and relevant specification.				
Geotechnical engineer sign-off of in-situ compaction or liner placement.				
Geotechnical sign-off of bunds.				
HOLD POINT: Superintendent or asset designer inspection and review of test reports and supply dockets before proceeding.				
COMMENTS:				
				Attach test reports, supply dockets, as-constructed survey and photos
				Add pages if necessary

Signed by superintendent:		Signed by asset designer:	
Print name:		Print name:	
Date:		Date:	

FORM C : INSTALL HYDRAULIC STRUCTURES				CONSTRUCTED WETLANDS
Purpose: To ensure hydraulic structures are installed correctly and in accordance with the civil design.				
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
As-constructed survey completed and attached to this form.				
Photos taken and attached to this form.				
Inlet pipe and headwall at correct locations and levels (±25 mm).				
Inlet zone connection pit or pipe at correct location, size and level (±25 mm).				
Outlet riser connection at correct location, size and level (±25 mm).				
Outlet pipe and headwall at correct locations and levels (±25 mm).				
Bypass weir at correct width and level (±25 mm).				
Maintenance pipe and valve at correct location and level (±25 mm).				
Maintenance access installed to inlet zone/sediment pond.				
Rock or concrete base constructed to inlet zone/sediment pond.				
Rock protection provided at correct locations.				
Rock protection at correct size.				
Seepage collars installed to all pipe outlets from wetland.				
HOLD POINT: Superintendent and asset designer inspection and sign-off before proceeding.				
COMMENTS:				
				Attach as-constructed survey and photos
				Add pages if necessary

Signed by superintendent:		Signed by asset designer:	
Print name:		Print name:	
Date:		Date:	

FORM D: PLACE TOPSOIL AND PROFILE TO FINAL LEVELS				CONSTRUCTED WETLANDS
Purpose: To ensure topsoil is installed correctly and finished levels are in accordance with the civil design.				
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
Topsoil complies with specifications.				
Topsoil has been screened and is free of large debris.				
Follows testing and chain of custody requirements (see Section 2.4).				
Topsoil applied to wetland to a minimum 300 mm depth.				
As-constructed survey of wetland surface and surrounding bunds completed.				
Final topsoil levels are consistent with design levels (±50 mm), especially in the macrophyte zone.				
Surface is smooth and free of local depressions and debris.				
HOLD POINT: Superintendent and asset designer inspection and sign-off before proceeding.				
COMMENTS:				
				Attach test reports, supply dockets, as-constructed survey and photos
				Add pages if necessary

Signed by superintendent:		Signed by asset designer:	
Print name:		Print name:	
Date:		Date:	

FORM E: DISCONNECT MACROPHYTE ZONE				CONSTRUCTED WETLANDS
Purpose: To ensure protective measures are correctly installed to protect the macrophyte zone during establishment and while building is occurring in the catchment.				
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
Sediment control fencing installed around all components of constructed wetland.				
High flow bypass channel protective measures in place (e.g. turf installed and reinforced where required).				
Inlet zone disconnected from macrophyte zone (i.e. plates placed on overflow pit and secured).				
HOLD POINT: Superintendent or asset designer inspection and sign-off before proceeding.				
COMMENTS:				
				Attach photos
				Add pages if necessary

Signed by superintendent:		Signed by asset designer:	
Print name:		Print name:	
Date:		Date:	

FORM F: LANDSCAPE MACROPHYTE ZONE				CONSTRUCTED WETLANDS
Purpose: To ensure the plants are supplied, installed, and established correctly and in accordance with the landscape design.				
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
Supplied plants are correct species. Changes must be approved by asset designer or ecologist and marked on as-constructed drawings.				
Supplied plants are in correct pot sizes.				
Supplied plants at correct maturity and hardened.				
Supplied plants are healthy.				
Plants have been installed at correct planting density.				
As-constructed drawings marked up with final plant species and densities.				
Water level control is operating appropriately.				
Correct mulch has been supplied and installed to batters and bunds above the extended detention and secured in place.				
HOLD POINT: Superintendent and asset designer inspection and sign-off.				
COMMENTS:				
				Attach as-constructed survey and photos
				Add pages if necessary

Signed by superintendent:		Signed by asset designer:	
Print name:		Print name:	
Date:		Date:	

FORM G: ESTABLISH MACROPHYTE ZONE				CONSTRUCTED WETLANDS
Purpose: To ensure plants establish correctly and in accordance with the landscape design.				
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
Weeds removed.				
Watering undertaken as required.				
Macrophyte zone plants established (500 mm above normal water level).				
Propogation/recruitment is occuring.				
Measure of successful establishment:				
1. Greater than 90% plant survival.				
2. Preferably more than one species per macrophyte zone.				
3. Increase in plant height of at least 50%. This can be measured by marker stakes at a rate of one stake per 500 m^2 every three months.				
4. Propagation is occurring with more than 2 – 3 stems and seeding.				
5. No weeds.				
Remove any temporary upstream stormwater diversions once minimum 90% catchment buildout is achieved.				
HOLD POINT: Superintendent and asset designer inspection and sign-off before proceeding.				

COMMENTS:

Attach as-constructed survey and photos

Add pages if necessary

Signed by superintendent:		Signed by asset designer:	
Print name:		Print name:	
Date:		Date:	

FORM H: LANDSCAPE AND ESTABLISH INLET ZONE				CONSTRUCTED WETLANDS
Purpose: To ensure the correct plants are supplied, installed and established.				
ITEMS	CHECKED	SATISFACTORY	ACTION (IF UNSATISFACTORY)	INITIAL
Supplied plants are correct species. Changes must be approved by asset designer or ecologist and marked on as-constructed drawings.				
Supplied plants are in correct pot sizes.				
Supplied plants at correct maturity and hardened.				
Supplied plants are healthy.				
Plants have been installed at correct planting density.				
As-constructed drawings marked up with final plant species and densities.				
Weeds removed.				
Watering undertaken as required.				
All measures of plant establishment are observed (see *Form G*).				
HOLD POINT: Superintendent and asset designer inspection and signoff before proceeding.				
COMMENTS:				
				Attach as-constructed survey and photos
				Add pages if necessary

Signed by superintendent:		Signed by asset designer:	
Print name:		Print name:	
Date:		Date:	

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