Policy 11: Land Development Guidelines

Section 13 Water Sensitive Urban Design (WSUD) Guidelines

13.4 Bioretention Swales

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Bioretention Swales incorporated into the centre median of roadways
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13.4.1 Introduction

Bioretention swales provide both stormwater treatment and conveyance functions, combining a bioretention system installed in the base of a swale that is designed to convey stormwater as part of a minor and/or major drainage system. The swale component (refer also to Section 13.3 – Swales) provides pre-treatment of stormwater to remove coarse to medium sediments while the bioretention system removes finer particulates and associated contaminants. Bioretention swales provide flow retardation for frequent storm events and are particularly efficient at removing nutrients.

The bioretention swale treatment process operates by filtering stormwater runoff through surface vegetation associated with the swale and then percolating the runoff through a prescribed filter media, forming the bioretention component which provides treatment through fine filtration, extended detention treatment and some biological uptake.

Bioretention swales also act to disconnect impervious areas from downstream waterways and provide protection to natural receiving waterways from frequent storm events by reducing flow velocities compared with piped systems. The bioretention component is typically located at the downstream end of the overlying swale ‘cell’ (i.e. immediately upstream of the swale overflow pit(s) as shown on Figure 13.4-A or along the full length of a swale as a continuous trench).

![Figure 13.4-A: Bioretention Swale Conceptual Layout](image)

The choice of bioretention location within the overlying swale will depend on a number of factors, including area available for the bioretention filter media and the maximum batter slopes for the overlying swale. Typically, when used as a continuous trench along the full length of a swale, the desirable maximum longitudinal grade of the swale is 4%. For other applications, the desirable grade of the bioretention zone is either horizontal or as close as possible to encourage uniform distribution of stormwater flows over the full surface area of bioretention filter media and allowing temporary storage of flows for treatment before bypass occurs.

Bioretention swales are not intended to be ‘infiltration’ systems in that the intent is typically not to have the stormwater exfiltrate from the bioretention filter media to the surrounding in-situ soils. Rather, the typical design intent is to recover the percolated stormwater runoff at the base of the filter media, within perforated under-drains for subsequent discharge to receiving waterways or for storage for potential reuse. In some circumstances however, where the in-situ soils allow and there is a particular design intention to recharge local groundwater, it may be desirable to permit the percolated stormwater runoff to infiltrate from the base of the filter media to the underlying in-situ soils. This should take into consideration the effects on road surfaces, etc.
### Design Considerations for Bioretention Swales

This section outlines some of the key design considerations for bioretention swales that the detailed designer should be familiar with before applying the design procedure presented later in this section. Standard design considerations for the swale component of bioretention swales are discussed in detail in Section 13.3 – Swales and are not reproduced here. However, other swale design considerations that relate specifically to the interactions between the swale and bioretention components are presented in the following sections together with design considerations relating specifically to the bioretention component.

#### 13.4.2.1 Landscape Design

Bioretention swales may be located within parkland areas, carparks or along roadway corridors within footpaths (ie. road verges) or centre medians. Council does not permit bio-retention treatment devices of any type in Council controlled easements or dedicated drainage reserves. Landscape design of bioretention swales along the road edge can assist in defining the boundary of road or street corridors as well as providing landscape character and amenity. It is therefore important that the landscape design of bioretention swales addresses stormwater quality objectives whilst also being sensitive to these other important landscape functions. Further guidance on landscape design is contained in Section 13.4.4.

#### 13.4.2.2 Hydraulic Design

A key hydraulic design consideration for bioretention swales is the delivery of stormwater runoff from the swale onto the surface of a bioretention filter media. Flow must not scour the bioretention surface and needs to be uniformly distributed over the full surface area of the filter media. In steeper areas, check dams may be required along the swale to reduce flow velocities discharged onto the bioretention filter media.

*Note: Check dams inhibit ease of mowing for Council’s maintenance equipment so approval by Council must be obtained at the concept stage in this regard.*

It is important to ensure that velocities in the bioretention swale from both minor (2-10 year ARI) and major (100 year ARI) runoff events are kept sufficiently low (preferably below 0.5 m/s and not more than 2.0 m/s for major flood) to avoid scouring. This can be achieved by ensuring the slope and hydraulic roughness of the overlying swale reduce flow velocities by creating shallow temporary ponding (ie. extended detention) over the surface of the bioretention filter media via the use of raised field inlet pits. This may also increase the overall volume of stormwater runoff that can be treated by the bioretention filter media.

#### 13.4.2.3 Ex-filtration to In-situ Soils

Bioretention swales can be designed to either preclude or promote ex-filtration of treated stormwater to the surrounding in-situ soils depending on the overall stormwater management objectives established for the given project. When considering ex-filtration to surrounding soils, the designer must consider site terrain, hydraulic conductivity of the in-situ soil, soil salinity, groundwater and building setback. Further guidance in this regard is provided in Section 13.8 – Infiltration Measures.

Where the concept design specifically aims to preclude ex-filtration of treated stormwater runoff it is necessary to consider if the bioretention swale needs to be provided with an impermeable liner. The amount of water lost from bioretention trenches to surrounding in-situ soils is largely dependant on the characteristics of the local soils and the saturated hydraulic conductivity of the bioretention filter media (see Section 13.4.2.5). Typically, if the selected saturated hydraulic conductivity of the filter media is one to two orders of magnitude (ie. 10 to 100 times) greater than that of the native surrounding soil profile, then the preferred flow path for stormwater runoff will be vertically through the bioretention filter media and into the perforated under-drains at the base of the filter media. As such, there will be little if any ex-filtration to the native surrounding soils. However, if the selected saturated hydraulic conductivity of the bioretention filter media is less than 10 times that of the native surrounding soils, it may be necessary to provide an impermeable liner. Flexible membranes or a concrete casting are commonly used to prevent excessive ex-filtration. This is particularly applicable for surrounding soils that are very sensitive to any ex-filtration (eg. sodic soils and reactive clays in close proximity to significant structures such as roads).

The greatest pathway of ex-filtration is through the base of a bioretention trench, as gravity and the difference in hydraulic conductivity between the filter media and the surrounding native soil would typically act to minimise ex-filtration through the walls of the trench. If lining is required, it is likely that only the base and the sides of the drainage layer (refer Section 13.4.2.5) will need to be lined.
Where ex-filtration of treated stormwater to the surrounding *in-situ* soils is promoted by the bioretention swale concept design, it is necessary to ensure the saturated hydraulic conductivity of the *in-situ* soils is at least equivalent to that of the bioretention filter media, thus ensuring no impedence of the desired rate of flow through the bioretention filter media. Depending on the saturated hydraulic conductivity of the *in-situ* soils it may be necessary to provide an impermeable liner to the sides of the bioretention filter media to prevent horizontal ex-filtration and subsequent short-circuiting of the treatment provided by the filter media. Bioretention trenches promoting ex-filtration do not require perforated under-drains at the base of the filter media or a drainage layer. A subsurface pipe is to be used to prevent water intrusion into a road sub-base.

### 13.4.2.4 Vegetation Types

Bioretention swales can use a variety of vegetation types including turf (swale component only), sedges and tufted grasses. Vegetation is required to cover the whole width of the swale and bioretention filter media surface, be capable of withstanding design flows and be of sufficient density to prevent preferred flow paths and scour of deposited sediments.

Grassed (turf) bioretention swales can be used in residential areas where a continuous bioretention trench approach is used. However, grassed bioretention swales need to be mown to protect the conveyance capacity of the swale component and therefore repeated mowing of the grass over a continuous bioretention trench can result in long term compaction of the filter media and reduce its treatment performance. The preferred vegetation for the bioretention component of bioretention swales is therefore sedges and tufted grasses (with potential occasional tree plantings) that do not require mowing.

The denser and taller the vegetation planted in the bioretention filter media, the better the treatment provided, especially during extended detention. Taller vegetation has better interaction with temporarily stored stormwater during ponding, which results in enhanced sedimentation of suspended sediments and associated pollutants. The vegetation that grows in the bioretention filter media also acts to continuously break up the surface of the media through plant root growth and wind induced agitation, which prevents surface clogging. Vegetation also provides a substrate for biofilm growth in the upper layer of the filter media which facilitates biological transformation of pollutants (particularly nitrogen).

Dense vegetation planted along the swale component can also offer improved sediment retention by reducing flow velocity and providing vegetation enhanced sedimentation for deeper flows. However, densely vegetated swales have higher hydraulic roughness and therefore require a larger area and/or more frequent use of swale field inlet pits to convey flows compared to grass swales. Densely vegetated bioretention swales can become features of an urban landscape and once established, require minimal maintenance and are hardy enough to withstand large flows. Section 13.13 – Plant Selection for WSUD Systems provides more specific guidance on the selection of appropriate vegetation for bioretention swales.

### 13.4.2.5 Bioretention Filter Media

Selection of an appropriate bioretention filter media is a key design step involving consideration of three inter-related factors:

1. Saturated hydraulic conductivity required to optimise the treatment performance of the bioretention component given site constraints on available filter media area.
2. Depth of extended detention provided above the filter media.
3. Suitability as a growing media to support vegetation growth (ie. retaining sufficient soil moisture and organic content).

The high rainfall intensities experienced on the Gold Coast relative to the southern capital cities means bioretention treatment areas tend to be larger in order to achieve the same level of stormwater treatment. However, the area available for bioretention swales in an urban layout is often constrained by the same factors as other capital cities (eg. the available area within the footpaths of standard road reserves). Therefore, selecting bioretention filter media for bioretention swale applications on the Gold Coast will often require careful consideration of saturated hydraulic conductivity and extended detention depth to ensure the desired minimum volume of stormwater runoff receives treatment. Contrasting this is ensuring the saturated hydraulic conductivity does not become so high that the soil can no longer sustain vegetation growth. The maximum saturated hydraulic conductivity should not exceed 500 mm/hr (and preferably be between 50 – 200 mm/hr) in order to sustain vegetation growth.

GCC usually requires hydraulic conductivity to be 180mm/hr unless specific restraints exist.
The concept design stage will have established the optimal combination of filter media saturated hydraulic conductivity and extended detention depth using a continuous simulation modelling approach (eg. MUSIC). Any adjustment of either of these two design parameters during the detailed design stage will require the continuous simulation modelling to be re-run to assess the impact on the overall treatment performance of the bioretention basin.

As shown in Figure 13.4-B a bioretention filter media can consist of three layers. In addition to the filter media required for stormwater treatment, a drainage layer is also required to convey treated water from the base of the filter media into perforated under-drains. The drainage layer surrounds perforated under-drains and can be either coarse sand (1 mm) or fine gravel (2-5 mm). If fine gravel is used, it is advisable to install a transition layer of sand or a geotextile fabric (with a mesh size equivalent to sand size) to prevent migration of the base filter media into the drainage layer and into the perforated under-drains.

**Figure 13.4-B: Typical Section of a Bioretention Swale**

13.4.2.6 Traffic Controls

Another design consideration is keeping traffic and building material deliveries off swales, particularly during the building phase of a development. If bioretention swales are used for parking, then the surface will be compacted and vegetation damaged beyond its ability to regenerate naturally. Compacting the surface of a bioretention swale will reduce the infiltration into the filter media and lead to early bypass and reduced treatment. Vehicles driving on swales can cause ruts that can create preferential flow paths that diminish the water quality treatment performance as well as creating depressions that can retain water and potentially become mosquito breeding sites.

A staged construction and establishment method (Section 13.4.5) affords protection to the subsurface elements of a bioretention swale from heavily sediment laden runoff during the subdivision construction and allotment building phases. However, to prevent vehicles driving on bioretention swales and inadvertent placement of building materials, it is necessary to consider appropriate traffic control solutions as part of the system design. These can include temporary fencing of the swale during the subdivision construction and allotment building phases with signage erected to alert builders and contractors of the purpose and function of the swales. Management of traffic onto the swales after completion of the allotment building phase can be achieved in a number of ways such as planting the interface to the road carriageway with dense vegetation that will discourage the movement of vehicles onto the swale or, if dense vegetation cannot be used, by providing physical barriers such as kerb and channel (with breaks to allow distributed water entry to the swale) or bollards and/or street tree planting.

Kerb and channel should be used at all corners, intersections, cul-de-sac heads and at traffic calming devices to ensure correct driving path is taken. For all of these applications, the kerb and channel is to extend 5 m beyond tangent points. The transition from barrier or lay back type kerb to flush kerbs and vice versa is to be done in a way that avoids creation of low points that cause ponding onto the road pavement.

Where bollards/road edge guide posts are used, consideration should be given to intermixing mature tree plantings with the bollards to break the visual monotony created by a continuous row of bollards. Bollards and any landscaping (soft or hard) must comply with Council's **Standard Drawing Nos 05-02-007** and **05-02-504**.
13.4.2.7 Roof Water Discharge

Roof runoff can contain a range of stormwater pollutants including nitrogen washed from the atmosphere during rainfall events. Rainfall is consistently the major source of nitrogen in urban stormwater runoff (Duncan 1995) and inorganic nitrogen concentrations in rainfall often exceed the threshold level for algal blooms (Weibel et al. 1966). Roof water should be discharged onto the surface of the swale for subsequent conveyance and treatment by the swale (and downstream treatment measures) before being discharged to receiving aquatic environments. Depending on the depth of the roof water drainage system and the finished levels of the bioretention swale, this may require the use of a small surcharge pit located within the invert of the swale to allow the roof water to surcharge to the swale. Any residual water left in the surcharge pit can be discharged to the underlying subsoil drainage by providing perforations in the base and sides of the surcharge pit. If a surcharge pit is used then an inspection chamber along the roof water drainage line is to be provided within the property boundary.

Roof water should only be directly connected to an underground pipe drainage system if an appropriate level of stormwater treatment is provided along (or at the outfall of) the pipe drainage system.

13.4.2.8 Services

Bioretention swales located within footpaths (ie. road verges) must consider the standard location for services within the verge and ensure access for maintenance of services. Typically it is acceptable to have water and sewer services located beneath the battens of the swale. Surface finishing from water and sewerage services shall not be located within the designated water flow area of the swale.

Designers are referred to GCCC Draft Council’s Standard Drawing No 5-02-007 for guidance on providing swales/ bioretention swales in the road verge. Essentially, the design must ensure:
- no services are located below the swale/ bioretention swale invert;
- enough space is provided to access services for maintenance without affecting the swale invert;
- there is no compromise to the width provided in the road verge for services.

13.4.2.9 Standard Drawings

Council’s Standard Drawing Nos 5-02-007, 05-02-008, 05-02-304 and 05-02-609 should be used alongside the guidelines in this section.

These standard drawings outline Council’s design preferences for:
- bioretention swales in road reserve;
- vehicular crossings of swales;
- flow management into and out of the bioretention swale.

13.4.3 Bioretention Swale Design Process

To create bioretention swales, separate calculations are performed to design the swale and the bioretention system, with iterations to ensure appropriate criteria are met in each section. The calculations and decisions required to design the swale component are presented in detail in Section 13.3 – Swales and are reproduced in this section. This is to allow designers and Council development assessment officers to consult with this section only for designing and checking bioretention swale designs.
The key design steps are:

1. Confirm concept design
   a. Check Service locations

2. Determine design flows for swale component

3. Dimension the swale component with consideration to site constraints
   a. swale width and side slopes
   b. maximum swale length (i.e. length between overflow pits)

4. Design of inflow systems to swale and bioretention components

5. Design bioretention component
   a. determine bioretention filter media saturated hydraulic conductivity and extended detention
   b. prescribe soil media layer characteristics (filter, transition and drainage layers)
   c. underdrain design and capacity check
   d. check requirement for impermeable lining

6. Verify design
   a. scour velocity checks
   b. depth x velocity check - safety
   c. confirm treatment performance

7. Size overflow pits (field inlet pits)

8. Allowances to preclude traffic

9. Specify plant species and planting densities

10. Provision for maintenance, including written maintenance plan

Each of these design steps is discussed below, followed by a worked example illustrating application of the design process on a case study site.

13.4.3.1 Step 1: Confirm Treatment Performance of Concept Design

Prior to progressing with detailed design, the designer should review the concept design developed for the site. A MUSIC model of the surrounding catchment and ‘treatment train’ should be developed at the conceptual design stage, prior to undertaking detailed design, to provide an initial estimate of the bioretention swale dimensions required to achieve the load-based water quality objectives.

The concept design should be reviewed to ensure:
- the bioretention swale(s), as part of a treatment train, provide an appropriate level of water quality treatment demonstrated through MUSIC modelling;
- bioretention swales are still appropriate for use at the site and are appropriately located within a treatment train;
- there are no additional constraints to the location and/or sizing of the bioretention swales.

The designer should refer to Council’s Standard Drawing N° 5-02-007 for integration of services with bioretention swales. The swale should not be located over services and adequate width should be provided for the swale and services to avoid conflicts.
13.4.3.2 Step 2: Estimating Design Flows for the Swale Component

a) Design Flows

Two design flows are required for the design of a swale:
- minor flood flow, determined using Table 3.5B (2-10 year ARI), to allow minor floods to be safely conveyed;
- major flood flow (100 year ARI) to check flow velocities, velocity depth criteria, conveyance within road reserve, and freeboard to adjoining property.

b) Design Flow Estimation

A range of hydrologic methods can be applied to estimate design flows. As the typical catchment area should be relatively small (<2 ha) in line with Section 3.5, the Rational Method design procedure is considered to be a suitable method for estimating design peak flows.

13.4.3.3 Step 3: Dimensioning the Swale Component

Factors to consider are:
- allowable width given the proposed road reserve and/or urban layout
- need to allow for services
- how flows are delivered into a swale (eg. cover requirements for pipes or kerb details)
- vegetation height
- longitudinal slope
- maximum side slopes and base width
- provision of crossings (elevated or at grade)
- requirements of QUDM (DPI, IMEA and BCC 1992).

Depending on which of the above factors are fixed, the other variables can be adjusted to derive the optimal swale dimensions for the given site conditions. The following sections outline some considerations in relation to dimensioning a swale.

a) Swale Width and Side Slopes

The maximum width of swale is usually determined from an urban layout and at the concept design stage. These are not intended to be prescriptive drawings which must be adhered to, rather they are intended to provide detailed examples of swales which can be incorporated into commonly used urban subdivision layouts. Where the swale width is not constrained by an urban layout (eg. when located within a large parkland area) then the width of the swale can be selected based on consideration of landscape objectives, maximum side slopes for ease of maintenance and public safety, hydraulic capacity required to convey the desired design flow, and treatment performance requirements. The maximum swale width needs to be identified early in the design process as it dictates the remaining steps in the swale design process. Selection of appropriate side slopes for swales in parks, easements or median strips is heavily dependant on site constraints, and swale side slopes are typically between 1 in 10 and 1 in 6.

For swales located adjacent to roads, the types of driveway crossing used will typically dictate batter slopes. Where there are no driveway crossings, the maximum swale side slopes will be established from ease of maintenance and public safety considerations. Council generally prefers the use of ‘at-grade’ crossings, which will require the swale to have 1:10 side slopes with a nominal 0.5 m flat base with driveway crossings at a slightly lower batter and wider driveway crossing to provide sufficient transitions to allow for traffic movement across the crossing. Flatter swale side slopes can be adopted but this will reduce the depth of the swale and its conveyance capacity. Council’s Standard Drawing Nos 5-02-007 and 05-02-008 show bioretention swale required in road reserves.

b) Maximum Length of a Swale

The maximum length of a swale is the distance along a swale before an overflow pit (or field inlet pit) is required to drain the swale to an underlying pipe drainage system.

The maximum length of a swale located within parkland areas and easements is calculated as the distance along the swale to the point where the flow in the swale from the contributing catchment (for the specific design flood frequency) exceeds the bank full capacity of the swale. For example, if the swale is to convey the minor flood flow (2-10 year ARI) without overflowing, then the maximum swale length would be determined as the distance along the swale to the point where the 2-10 year ARI flow from the contributing catchment is equivalent to the bank full flow capacity of the swale (bank full flow capacity is determined using Manning’s equation).
The maximum length of a swale located along a roadway is calculated as the distance along the swale to the point where flow on the adjoining road pavement (or road reserve) no longer complies with GCCC road design standards (for both the minor and major flood flows) as defined in the Section 3.5 and QUDM (DPI, IMEA and BCC 1992).

c) Swale Capacity – Manning’s Equation and Selection of Manning’s $n$

To calculate the flow capacity of a swale, use Manning’s equation. This allows the flow rate and flood levels to be determined for variations in swale dimensions, vegetation type and longitudinal grade.

$$Q = \frac{A \cdot R^{2/3} \cdot S^{1/2}}{n}$$

Where:

- $A$ = cross section area ($m^2$)
- $R$ = hydraulic radius (m)
- $S$ = channel slope (m/m)
- $n$ = roughness factor (Manning’s $n$)

*Equation 13.4.1*

Manning’s $n$ is a critical variable in Manning’s equation relating to roughness of the channel. It varies with flow depth, channel dimensions and vegetation type. For constructed swale systems, values are recommended to be between 0.15 and 0.4 for flow depths shallower than the vegetation height (preferable for treatment) and significantly lower for flows with greater depth than the vegetation (eg. 0.03 for flow depth more than twice the vegetation height). It is considered reasonable for Manning’s $n$ to have a maximum at the vegetation height and then to sharply reduce as depths increase. Figure 13.4-C shows a plot of Manning’s $n$ versus flow depth for a grass swale with longitudinal grade of 5%. It is reasonable to expect the shape of the Manning’s $n$ relation with flow depth to be consistent with other swale configurations, with the vegetation height at the boundary between low flows and intermediate flows (Figure 13.4-C) on the top axis of the diagram. The bottom axis of the plot has been modified from Barling and Moore (1993) to express flow depth as a percentage of vegetation height.

Further discussion on selecting an appropriate Manning’s $n$ for a swale is provided in Appendix E of the MUSIC User Guide (CRCCH 2005).

*Adapted From Barling and Moore (1993)*

*Figure 13.4-C: Impact of Flow Depth on Hydraulic Roughness*
13.4.3.4 Step 4: Design Inflow Systems to Swale and Bioretention Components

Inflows to bioretention swales can be via distributed runoff (e.g., from flush kerbs on a road) or point outlets such as pipe outfalls. Combinations of these inflow pathways can also be used.

a) Distributed Inflow

An advantage of flows entering a bioretention swale system in a distributed manner (i.e., entering perpendicular to the direction of the swale) is that flow depths are kept as shallow sheet flow, which maximises contact with the swale and bioretention vegetation, particularly on the batter receiving the distributed inflows. This swale and bioretention batter is often referred to as a buffer (see Figure 13.4-D). The requirement of the buffer is to ensure there is dense vegetation growth, flow depths are shallow (below the vegetation height) and erosion is avoided. The buffer provides good pretreatment (i.e., significant coarse sediment removal) prior to flows being conveyed along the swale.

![Figure 13.4-D: Flush Kerb with 60 mm Setdown to Allow Sediment to Flow into Vegetated Area](image)

**Figure 13.4-D: Flush Kerb with 60 mm Setdown to Allow Sediment to Flow into Vegetated Area**

Distributed inflows can be achieved either by having a flush kerb or by using kerbs with regular breaks in them to allow for even flows across the buffer surface (Plate 13.4-A).

![Plate 13.4-A: Kerb arrangements with breaks to distribute inflows on to bioretention swales and prevent vehicle access](image)

**Plate 13.4-A: Kerb arrangements with breaks to distribute inflows on to bioretention swales and prevent vehicle access**

b) Requirements of Buffers

No specific design rules exist for designing buffer systems, however there are several design guides that are to be applied to ensure buffers operate to improve water quality and provide a pre-treatment role. Key design parameters of buffer systems are:

- providing distributed flows into a buffer (potentially spreading stormwater flows to achieve this);
- avoiding rilling or channelised flows;
- maintaining flow heights lower than vegetation heights (this may require flow spreaders, or check dams);
- minimising the slope of buffer, best if slopes can be kept below 5%, however buffers can still perform well with slopes up to 20% provided flows are well distributed. The steeper the buffer the more likely flow spreaders will be required to avoid rill erosion.

Maintenance of buffers is required to remove accumulated sediment and debris therefore access is important. Most sediments will accumulate immediately downstream of the pavement surface and then progressively further downstream as sediment builds up.
It is important to ensure coarse sediments accumulate off the road surface at the start of the buffer. **Plate 13.4-B** shows sediment accumulating on a street surface where the vegetation is the same level as the road. To avoid this accumulation, a tapered flush kerb must be used that sets the top of the vegetation 60 mm (refer **Figure 13.4-D**) which requires the top of the ground surface (before turf is placed) to be approximately 100 mm below the road surface. This allows sediments to accumulate off any trafficable surface.

**c) Concentrated Inflow**

Concentrated inflows to a bioretention swale can be in the form of a concentrated overland flow or a discharge from a piped drainage system (e.g. allotment drainage line). For all concentrated inflows, energy dissipation at the inflow location is an important consideration to minimise any erosion potential. This can usually be achieved with rock benching and/or dense vegetation.

The most common constraint on pipe systems discharging to bioretention swales is bringing the pipe flows to the surface of a swale. In situations where the swale geometry does not allow the pipe to achieve ‘free’ discharge to the surface of the swale, a ‘surcharge’ pit may need to be used. Surcharge pits should be designed so that they are as shallow as possible and have pervious bases to avoid long term ponding in the pits (this may require under-drains to ensure it drains, depending on local soil conditions). The pits need to be accessible so that any build up of coarse sediment and debris can be monitored and removed if necessary. It is noted that surcharge pits generally result in additional maintenance requirements and have a mosquito breeding potential and other options to manage inflows to the swale should be considered before opting for surcharge pits.

Surcharge pit systems are most frequently used when allotment runoff is required to cross a road into a swale on the opposite side of the road or for allotment runoff discharging into shallow profile swales. Where allotment runoff needs to cross under a road to discharge to a swale, it is preferable to combine the runoff from more than one allotment to reduce the number of crossings required under the road pavement. **Figure 13.4-E** illustrates a typical surcharge pit discharging into a swale.

Another important form of concentrated inflow in a bioretention swale is the discharge from the swale component into the bioretention component, particularly where the bioretention component is located at the downstream end of the overlying swale and receives flows concentrated within the swale. Depending on the grade, its top width and batter slopes, the resultant flow velocities at the transition from the swale to the bioretention filter media may require the use of energy dissipation to prevent scour of the filter media. For most cases, this can be achieved by placing several large rocks in the flow path to reduce velocities and spread flows. Energy dissipaters located within footpaths must be designed to ensure pedestrian safety.
13.4.3.5 Step 5: Design Bioretention Component

a) Select Filter Media Saturated Hydraulic Conductivity and Extended Detention

Where design Steps 2 and 3 (Section 13.4.3.2 and 13.4.3.3) reveal that the swale geometry derived during the concept design stage does not comply with the minimum requirements of the Land Development Guidelines (GCCC 2005) (for minor flood and major flood flows on adjoining road pavements and minimum freeboard requirements to adjoining properties), it is necessary to revise the swale geometry. As such, an alternative dimension for the surface area of the bioretention component may result and this may require further MUSIC modelling to determine the ‘new’ optimal combination of filter media saturated hydraulic conductivity and extended detention depth to maximise the water quality treatment function of the bioretention component.

b) Specify the Bioretention Filter Media Characteristics

At least two and possibly three types of soil media are required for the bioretention component of the system (see Figure 13.4-B in Section 13.4.2.5).

Filter Media

The filter media layer provides the majority of the pollutant treatment function, through fine filtration and also by supporting vegetation. The vegetation enhances filtration, keeps the filter media porous and provides some uptake of nutrients and other stormwater pollutants. As a minimum, the filter media is required to have sufficient depth to support vegetation. Typical depths are usually between 400-1000 mm with a minimum depth of 400 mm for grasses and shrubs and a minimum depth of 800 mm for tree species to avoid roots interfering with the perforated under-drain system.

The saturated hydraulic conductivity of the filter media is established by optimising the treatment performance of the bioretention system given site constraints of the particular site. The filter media would have been selected during concept design and tested for water quality performance (using modelling tools such as MUSIC). Saturated hydraulic conductivity should remain between 50-200 mm/hr (saturated hydraulic conductivity should be 180 mm/hr for most cases and under no circumstances will values greater than 500 mm/hr be accepted by GCCC). Once the saturated hydraulic conductivity of the filter media has been determined for a particular bioretention swale, the following process can then be applied to derive a suitable filter media soil to match the design saturated hydraulic conductivity (from FAWB 2006):

1. Identify if local top soil is capable of supporting vegetation growth and if there is enough top soil (some top soils are very shallow) be used as a base for the filter media (may require active collection of top soil during the construction process). Any topsoil found to contain high levels of salt, extremely low levels of organic carbon (<<5%), or any other extremes which may be considered retardant to plant growth should be rejected. If the top soil is not suitable, a sandy loam soil can be purchased from a supplier for use as a base soil.

2. Conduct laboratory test to establish hydraulic conductivity, water holding capacity, particle size distribution, and AS4419-2003 parameters.

3. If the soil needs to be amended to achieve the desired design saturated hydraulic conductivity and particle size distribution either mix in a loose non-angular sand (to increase saturated hydraulic conductivity) or a loose soft clay (to reduce saturated hydraulic conductivity).

4. The required content of sand or clay (by weight) to be mixed to the base soil will need to be established in a laboratory by incrementally increasing the content of sand or clay until the desired saturated hydraulic conductivity is achieved (within reasonable bounds). The sand or clay content (by weight) that achieves the desired hydraulic conductivity should then be adopted on-site.

5. The base soil should have sufficient organic content to establish vegetation on the surface of the bio-retention system. If the proportion of base soil in the final mix is less than 50% then it may be necessary to add in additional organic material. This will be limited to 10% organic content (measured in accordance with AS1289 4.1.1).

6. The pH of the soil mixture for the filtration layer is to be amended to between 5.5 and 7.5. If the filter media mix is being prepared off-site, this amendment should be undertaken before delivery to the site before delivery to the site.

7. Ensure soil meets the specifications for:
   - hydraulic conductivity;
   - water holding capacity;
   - particle size distribution;
   - AS4419-2003 parameters.
8. The salt content of the final filter media (as measured by EC1:5) must be less than 0.63 dS/m for low clay content soils like sandy loam. (EC1:5 is the electrical conductivity of a 1:5 soil/water suspension).

9. Once the filter media is in place, the hydraulic conductivity should be tested in accordance with AS1547:2000.

Further details of these specifications can be found in Guideline Specifications for Soil Media in Bioretention Systems (FAWB 2006).

Imported soils must not contain Fire Ants. Visual assessment is required and any machinery should be free of clumped dirt. Soils must not be brought in from Fire Ant restricted areas.

**Drainage Layer**

The drainage layer is used to convey treated flows from the base of the filter media layer into the perforated under-drainage system. The composition of the drainage layer is to be considered in conjunction with the selection and design of the perforated under-drainage system (refer to Section 13.4.3.5) as the slot sizes in the perforated pipes may determine the minimum drainage layer particle size to avoid washout of the drainage layer into the perforated pipe system. Coarser material (e.g. fine gravel) is to be used for the drainage layer if the slot sizes in the perforated pipes are too large for use of a sand based drainage layer. Otherwise, sand is the preferred drainage layer media as it is likely to avoid having to provide a transition layer between the filter media and the drainage layer. The drainage layer is to be a minimum of 150 mm thick and preferably 200 mm thick.

Ensure drainage media is washed prior to placement in bioretention system to remove any fines. Drainage media must also be free from Fire Ants and visually checked to confirm this. Drainage media must not be imported from a Fire Ant restricted area.

**Transition Layer**

The particle size difference between the filter media and the underlying drainage layer should be not more than one order of magnitude to avoid the filter media being washed through the voids of the drainage layer. Therefore, if fine gravels are used for the drainage layer (which will be at least two orders of magnitude coarser than the likely average particle size of the filter media), then a transition layer is recommended to prevent the filter media from washing into the perforated pipes. If a transition layer is required then the material must be sand/coarse sand material. An example particle size distribution (% passing) is provided below (based on a Unimin specification):

- 1.4 mm 100%
- 1.0 mm 80%
- 0.7 mm 44%
- 0.5 mm 8.4%

The transition layer is recommended to be 150 mm thick.

The addition of a transition layer increases the overall depth of the bioretention system and may be an important consideration for some sites where total depth of the bioretention system may be constrained. In such cases, the use of a sand drainage layer and/or perforated pipes with smaller slot sized may need to be considered.

**c) Under-Drain Design and Capacity Checks**

The maximum spacing of the perforated pipes in wide bioretention trenches is 1.5 m (centre to centre) so that the distance water needs to travel (horizontally) through the drainage layer does not hinder drainage of the filtration media.

By installing parallel pipes, the capacity of the perforated pipe under-drain system can be increased. The recommended maximum size for the perforated pipes 100 mm to minimise the required thickness of the drainage layer. Either flexible perforated pipe (e.g. ag pipe) or slotted PVC pipes can be used, however care needs to be taken to ensure that the slots in the pipes are not so large that sediment would freely flow into the pipes from the drainage layer. This is also a consideration when specifying the drainage layer media.

To ensure the slotted pipes are of adequate size, several checks are required:

- ensure perforations are adequate to pass the maximum infiltration rate;
- ensure the pipe itself has capacity to convey the design flow/infiltration rate;
- ensure that the material in the drainage layer will not be washed into the perforated pipes (consider a transition layer).
The maximum infiltration rate represents the maximum rate of flow through the bioretention filter media and is calculated by applying Darcy’s equation (Equation 13.4.2) as follows:

\[ Q_{\text{max}} = K_{\text{sat}} \cdot L \cdot W_{\text{base}} \cdot \frac{h_{\text{max}} + d}{d} \]

Where:
- \( Q_{\text{max}} \) = maximum infiltration rate \((\text{m}^3/\text{s})\)
- \( K_{\text{sat}} \) = hydraulic conductivity of the soil filter \((\text{m/s})\)
- \( W_{\text{base}} \) = base width of the ponded cross section above the soil filter \((\text{m})\)
- \( L \) = length of the bioretention zone \((\text{m})\)
- \( h_{\text{max}} \) = depth of pondage above the soil filter \((\text{m})\)
- \( d \) = depth of filter media \((\text{m})\)

**Equation 13.4.2**

The capacity of the perforated under-drains needs to be greater than the maximum infiltration rate to ensure the filter media drains freely and the pipe(s) do not become the hydraulic ‘control’ in the bioretention system (ie. to ensure the filter media sets the travel time for flows percolating through the bioretention system rather than the perforated under-drainage system).

To ensure the perforated under-drainage system has sufficient capacity to collect and convey the maximum infiltration rate, it is necessary to determine the capacity for flows to enter the under-drainage system via perforations in the pipes. To do this, orifice flow can be assumed and the sharp edged orifice equation can be used. Firstly, the number and size of perforations needs to be determined (typically from manufacturer’s specifications) and used to estimate the flow rate into the pipes using the maximum driving head (being the depth of the filtration media if no extended detention is provided or if extended detention is provided in the design then to the top of extended detention). It is conservative but reasonable to use a blockage factor to account for partial blockage of the perforations by the drainage layer media. A 50% blockage of the perforation is recommended.

\[ Q_{\text{perf}} = B \cdot C_d \cdot A \cdot \sqrt{2 \cdot g \cdot h} \]

Where:
- \( Q_{\text{perf}} \) = flow through perforations \((\text{m}^3/\text{s})\)
- \( B \) = blockage factor \((0.5)\)
- \( C_d \) = orifice discharge coefficient (assumes 0.61 for sharp)
- \( A \) = total area of orifice \((\text{m}^2)\)
- \( g \) = gravity \((9.79 \text{ m/s}^2)\)
- \( h \) = head above the perforated pipe \((\text{m})\)

**Equation 13.4.3**

If the capacity of the drainage system is unable to collect the maximum infiltration rate then additional under-drains will be required.

After confirming the capacity of the under-drainage system to collect the maximum infiltration rate is it then necessary to confirm the conveyance capacity of the underdrainage system is sufficient to convey the collected runoff. To do this, Manning’s equation (Equation 13.4.1) can be used (which assumes pipe full flow (in place of channel flow) but not under pressure). The Manning’s roughness used will be dependent on the type of pipe used.

The under-drains should be extended vertically to the surface of the bioretention system to allow inspection and maintenance when required. The vertical section of the under-drain should be unperforated and capped to avoid short circuiting of flows directly to the drain.
d) Check Requirement for Impermeable Lining

The saturated hydraulic conductivity of the natural soil profile surrounding the bioretention system should be tested, together with the depth to groundwater, chemical composition and proximity to structures and other infrastructure, to establish if an impermeable liner is required on the base and sides (to top of drainage layer only) of the bioretention system to prevent exfiltration of stormwater runoff to the surrounding soils. If the saturated hydraulic conductivity ($K_{sat}$) of the filter media is more than one order of magnitude (10 times) greater than that of the surrounding natural soil profile then no impermeable lining is required.

13.4.3.6 Step 6: Verify Design

a) Scour Velocity Check

Potential scour velocities are checked by applying Manning’s equation (Equation 13.4.1) to the bioretention swale design to ensure the following criteria are met:

- less than 0.5 m/s for minor flood (2-10 year ARI) discharge;
- less than 2.0 m/s for major flood (100 year ARI) discharge.

b) Velocity and Depth Check – Safety

As bioretention swales are generally accessible by the public, it is important to check that depth x velocity within the bioretention swale, at any crossings and adjacent pedestrian and bicycle pathways, satisfies the following public safety criteria:

- depth x velocity < 0.4 m²/s;
- maximum depth of flow over crossing = 0.3 m.

c) Confirm Treatment Performance

If the previous two checks are satisfactory then the bioretention swale design is satisfactory from a conveyance function perspective and it is now necessary to confirm the treatment performance of the bioretention swale by reference to the performance information presented in Section 13.4.3.3.

13.4.3.7 Step 7: Size Overflow Pit (Field Inlet Pits)

In a bioretention swale system, an overflow pit can be provided flush with the invert of the swale and/or bioretention system filter media (i.e. when no extended detention is provided in the design) or it can be provided with the pit crest raised above the level of the bioretention filter media to establish the design extended detention depth (if extended detention is provided for in the design).

Grated pits are typically used and the allowable head for discharges into the pits is the difference in level between the pit crest and the maximum permissible water level to satisfy minimum freeboard requirements as defined in the Section 3.5. Depending on the location of the bioretention swale, the design flow to be used to size the overflow pit could be the maximum capacity of the swale, the minor flood flow (2-10 year ARI) or the major flood flow (100 year ARI). There should be a minimum of 100 mm head over the overflow pit crest to facilitate discharge of the design flow into the overflow pit.

To size an overflow pit, two checks should be made to test for either drowned or free flowing conditions. A broad crested weir equation can be used to determine the length of weir required (assuming free overflowing conditions) and an orifice equation used to estimate the area between openings required in the grate cover (assuming drowned outlet conditions). The larger of the two pit configurations should be adopted (as per Section 5.10 QUDM (DPI, IMEA and BCC 1992)). In addition, a blockage factor is to be used, that assumes the grate is 50% blocked.

For free overfall conditions (weir equation):

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

Where:

- $Q_{weir}$ = flow into pit (weir) under free overfall conditions (m³/s)
- B = blockage factor (0.5)
- $C_w$ = weir coefficient (1.66)
- L = length of weir (perimeter of pit) (m)
- h = flow depth above the weir (pit) (m)

Equation 13.4.4
Once the length of weir is calculated, a standard sized pit can be selected with a perimeter at least the same length of the required weir length.

For drowned outlet conditions (orifice equation):

\[
Q_{\text{orifice}} = B \cdot C_d \cdot A \cdot \sqrt{\frac{2 \cdot g \cdot h}{g}}
\]

Where:
- \(Q_{\text{orifice}}\) = flow rate into pit under drowned conditions (m³/s)
- \(B\) = blockage factor (0.5)
- \(C_d\) = discharge coefficient (drowned conditions = 0.6)
- \(A\) = area of orifice (perforations in inlet grate) (m²)
- \(g\) = gravity (9.79 m/s²)
- \(h\) = flow depth above the weir (pit) (m)

\[\text{Equation 13.4.5}\]

When designing grated field inlet pits, reference is also to be made to the procedure described in Section 3.5 QUDM Section 5.10.4 (DPI, IMEA and BCC 1992). An example of an acceptable solution for a dome top cover is provided in Council’s Standard Drawing No 5-03-009 and Council’s Draft Standard Drawings.

13.4.3.8 Step 8: Allowances to Preclude Traffic on Swales

Refer to Section 13.4.2.6 for discussion on traffic control options.

13.4.3.9 Step 9: Specify Plant Species

Refer to Sections 13.4.4 and 13.13 for advice on selecting suitable plant species for bioretention swales on the Gold Coast. Consultation with landscape architects is recommended when selecting vegetation to ensure the treatment system compliments the landscape design of the area.

13.4.3.10 Step 10: Provisions for Maintenance

Consider how maintenance is to be performed on the bioretention swale (eg. how and where access is provided, where litter and sediment will collect, etc). A specific maintenance plan and schedule should be developed for the bioretention swale in accordance with Section 13.4.6.

13.4.3.11 Design Calculation Summary

The following design calculation table can be used to summarise the design data and calculation results from the design process.
## Bioretention Swales

### Calculation Summary

<table>
<thead>
<tr>
<th>Calculation Task</th>
<th>Outcome</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Runoff Coefficient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( C_2 ) (- ) ( C_{10 \text{ year ARI}} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( C_{100 \text{ year ARI}} )</td>
<td></td>
<td></td>
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<tr>
<td>Peak Design Flows</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 – 10 year ARI ( m^3/s )</td>
<td></td>
<td></td>
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<tr>
<td>100 year ARI ( m^3/s )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Dimension the Swale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swale Width and Side Slopes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base Width ( m )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side Slopes – 1 in</td>
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<td></td>
</tr>
<tr>
<td>Longitudinal Slope ( % )</td>
<td></td>
<td></td>
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<tr>
<td>Vegetation Height ( mm )</td>
<td></td>
<td></td>
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<tr>
<td>Maximum Length of Swale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manning’s ( n )</td>
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<td></td>
</tr>
<tr>
<td>Swale Capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Length of Swale</td>
<td></td>
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</tr>
<tr>
<td>4 Design Inflow Systems to Swale &amp; Bioretention Components</td>
<td></td>
<td></td>
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<tr>
<td>Swale Kerb Type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adequate Erosion and Scour Protection (where required)</td>
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<td></td>
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<tr>
<td>5 Design Bioretention Component</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filter Media Hydraulic Conductivity ( mm/hr )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extended Detention Depth</td>
<td></td>
<td></td>
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<tr>
<td>Filter Media Depth</td>
<td></td>
<td></td>
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<tr>
<td>Drainage Layer Media (Sand or Fine Screenings)</td>
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<tr>
<td>Drainage Layer Depth</td>
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<tr>
<td>Transition Layer (Sand) Required</td>
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<tr>
<td>Transition Layer Depth</td>
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<td></td>
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<tr>
<td>Under-Drain Design and Capacity Checks</td>
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<td></td>
</tr>
<tr>
<td>Flow Capacity of Filter Media (Maximum Infiltration Rate) ( m^3/s )</td>
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<tr>
<td>Perforations Inflow Check</td>
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<tr>
<td>Pipe Diameter ( mm )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Pipes</td>
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<td></td>
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<tr>
<td>Capacity of Perforations ( m^3/s )</td>
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<td></td>
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<tr>
<td>Check PERFORATION CAPACITY &gt; FILTER MEDIA CAPACITY</td>
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<td></td>
</tr>
<tr>
<td>Perforated Pipe Capacity</td>
<td></td>
<td></td>
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<tr>
<td>Pipe Capacity ( m^3/s )</td>
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<td></td>
</tr>
<tr>
<td>Check PIPE CAPACITY &gt; FILTER MEDIA CAPACITY</td>
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<td></td>
</tr>
<tr>
<td>Check Requirement for Impermeable Lining</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil Hydraulic Conductivity ( mm/hr )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filter Media Hydraulic Conductivity ( mm/hr )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MORE THAN 10 TIMES HIGHER THAN IN-SITU SOILS?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Verify Design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Velocity for 2-10 year ARI flow (&lt; 0.5 m/s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Velocity for 100 year ARI flow (&lt; 2 m/s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Velocity x Depth for 100 year ARI (&lt; 0.4 m^2/s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment Performance consistent with <strong>Step 1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Size Overflow Pits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System to convey minor floods ( L \times W )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
13.4.3.12 Typical Design Parameters

Table 13.4-A shows typical values for a number of key bioretention swale design parameters.

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Typical Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swale longitudinal slope</td>
<td>1% to 4%</td>
</tr>
<tr>
<td>Swale side slope for trafficability (with ‘at grade’ crossover)</td>
<td>Maximum 1 in 9</td>
</tr>
<tr>
<td>Swale side slope (with elevated driveway crossover)</td>
<td>1 in 4 to 1 in 10</td>
</tr>
<tr>
<td>Manning’s $n$ (with flow depth lower than vegetation height)</td>
<td>0.15 to 0.3</td>
</tr>
<tr>
<td>Manning’s $n$ (with flow depth greater than vegetation height)</td>
<td>0.03 to 0.05</td>
</tr>
<tr>
<td>Maximum velocity for scour in minor event (eg. $Q_2$)</td>
<td>0.5 m/s</td>
</tr>
<tr>
<td>Maximum velocity for $Q_{100}$</td>
<td>2.0 m/s</td>
</tr>
<tr>
<td>Perforated pipe size</td>
<td>100 mm (maximum)</td>
</tr>
<tr>
<td>Drainage layer average material diameter (typically fine gravel or coarse sand)</td>
<td>1-5 mm diameter</td>
</tr>
<tr>
<td>Transition layer average material diameter typically sand to coarse sand</td>
<td>0.7 – 1.0 mm diameter</td>
</tr>
</tbody>
</table>

13.4.4 Landscape Design Notes

Bioretention swales are a combined solution that involves integrating a swale (Section 13.3) with the infiltration of a bioretention system (Section 13.6). These can involve an extended detention treatment and some biological uptake through the planted bioretention component. The landscaping for both the swale and bioretention parts are essentially similar to the treatments for the stand alone components, however consideration for the interface landscape between the vegetated swale and bioretention is important.

13.4.4.1 Objectives

Landscape design for bioretention swales has four key objectives:

- ensure surface treatments and planting designs address stormwater quality objectives by incorporating appropriate plant species for stormwater treatment (biologically active root zone) whilst enhancing the overall natural landscape;
- integrated planning and design of bioretention swales within the built and landscape environments;
- incorporating Crime Prevention Through Environmental Design (CPTED) principles and road, driveway and footpath visibility safety standards;
- create landscape amenity opportunities that enhance the community and environmental needs, such as visual aesthetics, shade, screening, view framing, and way finding.

13.4.4.2 Context and Site Analysis

When designing for bioretention swales as part of the WSUD strategy, the overall concept layout needs to consider:

- possible road profiles and cross-sections;
- building and lot layout;
- possible open space and recreational parks;
- existing natural landforms.

Slope and soil type will also determine if swales are appropriate to the site and which swale type and swale location will be the most effective.

Careful site analysis and integrated design with engineers, landscape architects and urban designers will ensure the bioretention swales meet functional and aesthetic outcomes. A balanced approach to alignments between roads, footpaths and lot boundaries will be required early in the concept design of new developments to ensure swales are effective in both stormwater quality objectives and built environment arrangements. This is similar to concept planning for parks and open space where a balance is required between useable recreation space and WSUD requirements.
Comprehensive site analysis should inform the landscape design as well as road layouts, civil works and maintenance requirements. Existing site factors such as roads, driveways, buildings, landforms, soils, plants, microclimates, services and views should be considered. Refer to the Landscape Works Documentation Manual (GCCC 2006). Another useful reference is Water Sensitive Urban Design in the Sydney Region: ‘Practice Note 2 – Site Planning’ (LHCCREMS 2002) for further guidance.

13.4.4.3 Streetscape Bioretention Systems

When using bioretention swales in road reserves it is important to understand how the swale landscape can be used to define the visual road space. Creative landscape treatments may be possible given that the bioretention swale element will typically be a minimum of 4 m in width. Design responses may range from informal ‘natural’ planting layouts to regimented avenues of trees along each external and internal edge of the bioretention swale element. Bioretention swales can be incorporated into a typical streetscape landscape using either a central splitter median or using one side of the road reserve.

Bioretention swale surface treatments are generally a vegetated swale that integrates into a densely planted bioretention component. The use of turf for the bioretention parts of the system is discouraged as mowing and public use of these areas will compact the upper filter media and limit the amount of filtration.

Vegetated bioretention swales can provide a relatively maintenance free finish if the planting and invert treatment are designed well. Key considerations when detailing are type and size of inorganic mulch, density and types of plantings, locations of trees and shrubs, type of garden (mowing) edges to turf areas that allows unimpeded movement of stormwater flow and overall alignment of swale invert within the streetscape.

a) Centre Median

Generally, the central median swale will provide a greater landscaped amenity, allowing planting and shade trees to enhance the streetscape more effectively, whilst verges remain constraint free. This swale configuration is however confined to roads requiring larger corridors for increased traffic. This can be seen in Plate 13.4-C.

b) Side of Road

In smaller minor roads, one side of the road can have a swale landscape to capture stormwater runoff from road pavements and house lots. To enhance the visual road space, creative landscape treatments to driveway cross-overs, general planting and invert treatments should be used. It is important in this swale arrangement that services and footpaths that are standard for road verges, have been planned and located to avoid clashes of function. This can be seen in Figure 13.4-F, Figure 13.4-G and Figure 13.4-H.
Figure 13.4-F: Landscape Treatment of Vegetated Swale on Single Side of Road

Trees and shrubs arranged informally within the swale alignment to provide an informal effect though not over water and sewer mains. Groundcovers planted densely to remove stormwater sediment.

Figure 13.4-G: Possible Avenue Planting for Residential Swales

Note: This drawing is for illustrative purposes only and should not be used as specific detailed design guidance for the Gold Coast. Landscape design is subject to the CPTED, site line safety requirements and standard service allocations detailed in GCCC Land Development Guidelines, GCCC Landscape Works Documentation Manual and Main Roads Road Landscape Manual.
Driveway

Trees and shrubs arranged informally within the swale alignment to provide an informal effect though not over water and sewer mains. Groundcovers planted densely to remove stormwater sediment.

Bioretention Swale

**Figure 13.4-H: Possible ‘Natural’ Planting Layout for Residential Swales**

*Note:* This drawing is for illustrative purposes only and should not be used as specific detailed design guidance for the Gold Coast. Landscape design is subject to the CPTED, site line safety requirements and standard service allocations detailed in GCCC Land Development Guidelines, GCCC Landscape Works Documentation Manual and Main Roads Road Landscape Manual.

13.4.4 Civic and Urban Spaces

With the increasing population growth within GCCC, gentrification of urban areas is required to create more robust spaces that meet current environmental and social needs. Often constrained by existing infrastructure, landscape treatments of swales can have a dual role of providing functional stormwater quality objectives whilst creating landscapes that enhance the communities’ perception of water sensitive design.

By creating hard useable edges to swales and using expressive planting strategies that create an almost artistic outcome, civic spaces can provide an aesthetic landscape that meets recreational uses and promotes water sensitive design to the community. Refer to **Figure 13.4-I** for illustrative example.
13.4.4.5 Open Space Bioretention Swales

Design and siting of parks/ open space swales allows for greater flexibility in sectional profile, treatments and alignments. It is important however for careful landscape planning, to ensure that spaces for particular recreational uses are not encumbered by stormwater management devices including swales. As stormwater infrastructure, swales will generally not be considered ‘creditable land’ under Planning Scheme Policy 16 - Recreation Facilities Network Developer Contributions. The requirements of Policy 16 with respect to open space contributions must also be followed with respect to flood immunity.

Bioretention strips can form convenient edges to pathway networks, frame recreational areas, create habitat adjacent to existing waterways/ vegetation and provide landscape interest. Important issues to consider as part of the open space landscape design is maintenance access and CPTED principles which are further discussed in following sections.

13.4.4.6 Appropriate Plant Species

Planting for bioretention swale elements may consist of up to four vegetation types:
- groundcovers for stormwater treatment and erosion protection (required element);
- shrubbery for screening, glare reduction, character, and other values;
- street trees for shading, character and other landscape values;
- existing vegetation.

It is important to note that deep rooted plants such as trees are to be planted towards the top of the swale bank rather than near the bioretention trench, to avoid roots interfering with the underdrain system. Where the landscape design includes canopy layers, more shade tolerant species should be selected for the groundcover layer. Trees and shrubbery should be managed so that the groundcover layer is not out-competed. If this does occur, replacement planting and possible thinning of the upper vegetation layers may be required.
a) **Groundcovers**

Groundcover vegetation is an essential functional component of bioretention swales. Section 13.13 provides guidance on selecting suitable plant (including turf) species and cultivars that meet the functional requirements of bioretention swales to deliver the desired stormwater quality objectives. Other species may be considered to aid in providing a visually aesthetic landscape. A table of recommended species is provided in Section 13.13. Generally species selection should aim to ensure:

- a high leaf surface density within the design treatment depth to aid efficient stormwater treatment;
- a dense and uniform distribution of vegetation to prevent stormwater flows from meandering between plants and to create a uniform root zone within the bioretention filter media.

b) **Shrubs**

Shrubs provide an important role in allowing for visual screening, providing interest and should compliment the design and siting of the bioretention swale. Some species are outlined in Section 13.13 that are useful in urban and residential landscapes, however it should be noted that these lists are guides only. Other species and cultivars may be appropriate given the surrounding natural and/or built environment of the bioretention swale. Designers should ensure that the proposed planting schedule is suitable for the specific site. Reference to Council’s Landscape Strategy Part 2 – Landscape Works Documentation Manual (GCCC 2003) will provide guidance on choosing suitable shrub and tree species.

c) **Street Trees**

Street Trees are not GCCC preferred option for treatment. They should only be considered on constricted sites with hydraulic grade constraints where other forms of treatment are not possible. Approval from Council at concept stage is required in this regard. Trees for systems located on road sides should conform to Section 13.13 and the Council’s Landscape Strategy Part 2 – Landscape Works Documentation Manual (GCCC 2003). Also refer to Section 13.13 for further guidance on tree species selection.

It is important when considering planting trees within the bioretention swale system that deep rooting species are planted to the top of the bioretention zone batter to reduce roots impacting upon the filter media. If planting trees in the bioretention zone is important to the overall landscape design then creating a deeper filter media zone that further separates invasive roots from the lower drainage system is critical.

Where street trees are planted adjacent to a shallower bioretention swale, designers should include provisions for preventing root intrusion into the filter media and the underdrainage. This can be achieved using root barriers located between the filter media (but not within the filter media) and the planted tree.

d) **Existing Vegetation**

Existing vegetation, such as remnant native trees, within the bioretention swale alignment may be nominated for retention. In this case, the swale will need to be diverted or piped to avoid the vegetation’s critical root zone (equivalent to 0.5 m beyond the vegetation’s drip line).

13.4.4.7 **Safety Issues**

Bioretention swales within streetscapes and parks need to be generally consistent with public safety requirements for new developments. These include reasonable batter profiles for edges, providing adequate barriers to median swales for vehicle/ pedestrian safety and safe vertical heights from driveways to intersecting swale inverts.

a) **Crime Prevention Through Environmental Design (CPTED)**

Landscape design of bioretention swales need to accommodate the standard principles of informal surveillance, exclusion of places of concealment and open visible areas. Regular clear sightlines should be provided between the roadway and footpaths/ property. Where planting may create places of concealment or hinder informal surveillance, groundcovers and shrubs should not generally exceed 1 m in height. For specific guidance on CPTED requirements the designer should refer to:

- GCCC website <www.goldcoast.qld.gov.au> ;
- GCCC Community Safety Unit (Tel: 5581 6361) for appropriate and current guidelines and standards.
b) Traffic Sightlines

The standard rules of sightline geometry apply – planting designs should allow for visibility at pedestrian crossings, intersections, rest areas, medians, driveways and roundabouts. Refer to the Road Landscape Manual (DMR 1997) for further guidance.

13.4.5 Construction and Establishment

This section provides general advice for the construction and establishment of bioretention swales and key issues to be considered to ensure their successful establishment and operation. Some of the issues raised have been discussed in other sections of this section and are reiterated here to emphasise their importance based on observations from construction projects around Australia.

It is important to note that bioretention swale systems, like most WSUD elements that employ soil and vegetation based treatment processes, require approximately two growing seasons (ie. two years) before the vegetation in the systems has reached its design condition (ie. height and density). In the context of a large development site and associated construction and building works, delivering bioretention swales and establishing vegetation can be a challenging task. Therefore, bioretention swales require a careful construction and establishment approach to ensure the basin establishes in accordance with its design intent. The following sections outline a recommended staged construction and establishment methodology for bioretention swales (Leinster, 2006).

13.4.5.1 Construction and Establishment Challenges

There exist a number of challenges that must be appropriately considered to ensure successful construction and establishment of bioretention swales. These challenges are best described in the context of the typical phases in the development of a greenfield or infill development, namely the Subdivision Construction Phase and the Building Phase (see Figure 13.4-J).

a) Subdivision Construction Phase

Involves the civil works required to create the landforms associated with a development and install the related services (roads, water, sewerage, power, etc.) followed by the landscape works to create the softscape, streetscape and parkscape features. The risks to successful construction and establishment of the WSUD systems during this phase of work have generally related to the following:

- construction activities which can generate large sediment loads in runoff which can smother vegetation and clog bioretention filter media;
- construction traffic and other works can result in damage to the bioretention swales.

Importantly, all works undertaken during Subdivision Construction are normally ‘controlled’ through the principle contractor and site manager. This means the risks described above can be readily managed through appropriate guidance and supervision.

b) Building Phase

Once the Subdivision Construction works are complete and the development plans are sealed then the Building Phase can commence (ie. construction of the houses or built form). This phase of development is effectively ‘uncontrolled’ due to the number of building contractors and sub-contractors present on any given allotment. For this reason the Allotment Building Phase represents the greatest risk to the successful establishment of bioretention swales.

13.4.5.2 Staged Construction and Establishment Method

To overcome the challenges associated within delivering bioretention swales a Staged Construction and Establishment Method should be adopted (see Figure 13.4-J):

Stage 1: Functional Installation

Construction of the functional elements of the bioretention swale at the end of Subdivision Construction (ie. during landscape works) and the installation of temporary protective measures. For example, temporary protection of bioretention swales can be achieved by using a temporary arrangement of a suitable geofabric covered with shallow topsoil (eg. 25mm) and instant turf, *in lieu* of the final swale planting.
Stage 2: Sediment and Erosion Control

During the Building Phase the temporary protective measures preserve the functional infrastructure of the bioretention swales against damage whilst also providing a temporary erosion and sediment control facility throughout the building phase to protect downstream aquatic ecosystems.

Stage 3: Operational Establishment

At the completion of the Building Phase, the temporary measures protecting the functional elements of the bioretention swales can be removed along with all accumulated sediment and the system planted in accordance with the design planting schedule.

Typical Period

<table>
<thead>
<tr>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
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<tr>
<td>Sub-division Construction</td>
<td>Sediment &amp; Erosion Control</td>
</tr>
<tr>
<td>Allotment Building</td>
<td>Operational Establishment</td>
</tr>
</tbody>
</table>

Figure 13.4-J: Staged Construction and Establishment Method

a) Functional Installation

Functional installation of bioretention swales occurs at the end of Subdivision Construction as part of landscape works and involves:

- bulking out and trimming;
- installation of the outlet structures;
- placement of liner and installation of drainage layer (ie. under-drains and drainage layer);
- placement of filter media;
- placement of a temporary protective layer – Covering the surface of filtration media with geofabric and placement of 25mm topsoil and turf over geofabric. This temporary geofabric and turf layer will protect the bioretention basin during construction (Subdivision and Building Phases) ensuring sediment/ litter laden waters do not enter the filter media causing clogging;
- place silt fences around the boundary of the bioretention swale to exclude silt and restrict access.

Plate 13.4-E: Bioretention swale functional installation
b) Sediment and Erosion Control

The temporary protective layers are left in place through the allotment building phase to ensure sediment laden waters do not clog the filtration media and allotment building traffic does not enter the bioretention swale. Importantly the configuration of the bioretention swale and the turf vegetation allow the system to function effectively as a shallow sedimentation basin reducing the load of coarse sediment discharging to the receiving environment. Using this approach WSUD systems can operate effectively to protect downstream ecosystems immediately after construction.

Plate 13.4-F: Bioretention swale sediment and erosion control

c) Operational Establishment

At the completion of the Allotment Building Phase the temporary measures (ie. geofabric and turf) are removed with all accumulated sediment and the bioretention swale re-profiled and planted in accordance with the proposed landscape design. Establishment of the vegetation to design condition can require more than two growing seasons, depending on the vegetation types, during which regular watering and removal of weeds will be required.

13.4.5.3 Construction Tolerances

It is important to emphasise the significance of tolerances in the construction of bioretention swales (eg. profiling of swale and bioretention trench base and surface grades). Ensuring the base of the filtration trench and surface of the bioretention filter media is free from localised depressions resulting from construction is particularly important to achieve even distribution of stormwater flows across the surface and to prevent localised ponding on the surface, which may cause mosquito problems. In addition, to enable the perforated sub-surface drainage pipes to drain freely, the base of the trench should be sloped towards the outlet pit (min 0.5% longitudinal grade). Generally an earthworks tolerance of plus or minus 50 mm is considered acceptable.

13.4.5.4 Sourcing Bioretention Vegetation

Notifying nurseries early for contract growing is essential to ensure the specified species are available in the required numbers and of adequate maturity in time for bioretention swale planting. When this is not done and the planting specification is compromised, poor vegetation establishment and increased initial maintenance costs may occur. The species listed in Section 13.13 are generally available commercially from local native plant nurseries. Availability is, however, dependent upon many factors including demand, season and seed availability. To ensure planting specification can be accommodated, the minimum recommended lead time for ordering is 3-6 months. This usually allows enough time for plants to be grown to the required size. The following pot sizes are recommended as the minimum:

- Viro Tubes 50 mm wide x 85 mm deep
- 50 mm Tubes 50 mm wide x 75 mm deep
- Native Tubes 50 mm wide x 125 mm deep

13.4.5.5 Vegetation Establishment

The following weed control measures and watering schedule are recommended to ensure successful plant establishment. Regular general maintenance as outlined in Section 13.4.6 will also be required.

a) Weed Control

Conventional surface mulching of bioretention swales with organic material like tanbark, should not be undertaken. Most organic mulch floats and runoff typically causes this material to be washed away with the risk of blockage of drains occurring. Weed management will need to be done manually until such time that the design vegetation is established with sufficient density to effectively prevent weed propagation.
b) Watering

Regular watering of bioretention swale vegetation is essential for successful establishment and healthy growth. The frequency of watering to achieve successful plant establishment is dependent upon rainfall, maturity of planting stock and the water holding capacity of the soil. The following watering program is generally adequate but should be adjusted (increased) to suit the site conditions:

- **Week 1-2**: 3 visits/week
- **Week 3-6**: 2 visits/week
- **Week 7-12**: 1 visit/week

After this initial three month period, watering may still be required, particularly during the first winter (dry period). Watering requirements to sustain healthy vegetation should be determined during ongoing maintenance site visits.

13.4.6 Maintenance Requirements

Bioretention swales have a flood conveyance role that needs to be maintained to ensure adequate flood protection for local properties. Vegetation plays a key role in maintaining the porosity of the soil media of the bioretention system and a strong healthy growth of vegetation is critical to its performance.

The most intensive period of maintenance is during the plant establishment period (first two years) when weed removal and replanting may be required. It is also the time when large loads of sediments could impact on plant growth, particularly in developing catchments with an inadequate level of erosion and sediment control.

The potential for rilling and erosion down the swale component of the system needs to be carefully monitored during establishment stages of the system. Other components of the system that will require careful consideration are the inlet points (if the system does not have distributed inflows) and surcharge pits, as these inlets can be prone to scour and the build up of litter and sediment. Bioretention swale field inlet pits also require routine inspections to ensure structural integrity and that they are free of blockages with debris. Debris removal is an ongoing maintenance requirement. Debris can block inlets or outlets and can be unsightly, particularly in high visibility areas. Inspection and removal of debris should be done regularly.

Typical maintenance of bioretention swale elements will involve:

- routine inspection of the swale profile to identify any areas of obvious increased sediment deposition, scouring of the swale invert from storm flows, rill erosion of the swale batters from lateral inflows, damage to the swale profile from vehicles and clogging of the bioretention trench (evident by a ‘boggy’ swale invert);
- routine inspection of inlet points (if the swale does not have distributed inflows), surcharge pits and field inlet pits to identify any areas of scour, litter build up and blockages;
- removal of sediment where it is impeding the conveyance of the swale and/or smothering the swale vegetation, and if necessary, reprofiling of the swale and revegetating to original design specification;
- repairing any damage to the swale profile resulting from scour, rill erosion or vehicle damage;
- tilling of the bioretention trench surface if there is evidence of clogging;
- clearing of blockages to inlet or outlets;
- regular watering/irrigation of vegetation until plants are established and actively growing (for the swale component);
- mowing of turf or slashing of vegetation (if required) to preserve the optimal design height for the vegetation (note: heavy machinery for mowing/slashing should be avoided);
- removal and management of invasive weeds;
- removal of plants that have died and replacement with plants of equivalent size and species as detailed in the plant schedule;
- pruning to remove dead or diseased vegetation material and to stimulate new growth;
- litter and debris removal;
- vegetation pest monitoring and control.
Resetting (ie. complete reconstruction) of bioretention elements will be required if the available flow area of the overlying swale is reduced by 25% (due to accumulation of sediment) or if the bioretention trench fails to drain adequately after tilling of the surface and other maintenance/ corrective actions are taken. Inspections are also recommended following large storm events to check for scour.

All maintenance activities must be specified in a maintenance plan (and associated maintenance inspection forms) to be developed as part of the design procedure. Maintenance personnel and asset managers will use this plan to ensure the bioretention swales continue to function as designed. The maintenance plans and forms must address the following:

- inspection frequency;
- maintenance frequency;
- data collection/ storage requirements (ie. during inspections);
- detailed cleanout procedures (main element of the plans) including:
  - equipment needs;
  - maintenance techniques;
  - occupational health and safety;
  - public safety;
  - environmental management considerations;
  - disposal requirements (of material removed);
  - access issues;
  - stakeholder notification requirements;
  - data collection requirements (if any);
- design details.

An example operation and maintenance inspection form is included in the checking tools provided in Section 13.4.7.

13.4.7 Checking Tools

The following sections provide a number of checking aids for designers and Council development assessment officers. In addition, advice on construction techniques and lessons learnt from building bioretention swale systems are provided. Checklists are provided for:

- Design Assessment;
- Construction (during and post);
- Operation and Maintenance Inspections;
- Asset Transfer (following defects period).
Figure 13.4-K below shows the stages of the development approval, construction and establishment and asset transfer process and which checklists should be used at each stage.

**Figure 13.4-K: Development Approval and Handover Stages – Appropriate Checklists**
13.4.7.1 Design Assessment Checklist

The design assessment checklist presents the key design features to be reviewed when assessing design of a bioretention swale. These considerations include configuration, safety, maintenance and operational issues that need to be addressed during the design phase. Where an item results in an ‘N’ when reviewing the design, referral is to be made back to the design procedure to determine the impact of the omission or error.

In addition to the checklist, a proposed design is to have all necessary permits for its installations. Council development assessment officers need to ensure that all relevant permits are in place. These can include permits to clear vegetation, to dredge, create a waterbody, divert flows or disturb fish or platypus habitat.

13.4.7.2 Construction Inspection Checklist

This checklist presents the key items to be reviewed when inspecting the bioretention swale during and at the completion of construction. The checklist is to be used by construction site supervisors and compliance inspectors to ensure all the elements of the bioretention basin have been constructed in accordance with the design. If an item receives an ‘N’ in Satisfactory criteria then appropriate actions must be specified and delivered to rectify the construction issue before final inspection sign-off is given.

13.4.7.3 Maintenance Checklist

The maintenance checklist is to be used whenever an inspection is conducted and kept as a record on the asset condition and quantity of removed pollutants over time.

13.4.7.4 Asset Transfer Checklist

Land ownership and asset ownership are key considerations prior to construction of a stormwater treatment device. A proposed design is to clearly identify the ultimate asset owner and who is responsible for its maintenance. GCCC will use the asset transfer checklist when the asset is to be transferred to Council.
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<thead>
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<td><strong>Hydraulics:</strong></td>
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<td>Service location checked or appropriate allocation provided?</td>
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<th><strong>Swale Component</strong></th>
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<td>Longitudinal slope of invert &gt; 1% and &lt; 4%? Refer Section 13.3.2.2</td>
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<td>Manning’s n selected appropriate for proposed vegetation type? Refer Section 13.4.3.3</td>
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<td>Overall flow conveyance system sufficient for design flood event? Refer Section 13.4.3.3</td>
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<tr>
<td>Maximum flood conveyance width does not impact on traffic requirements? Refer Section 13.4.3.3</td>
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<tr>
<td>Overflow pits provided where flow capacity exceeded? Refer Section 13.4.3.7</td>
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<tr>
<td>Energy dissipation provided at inlet points to the swale?</td>
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<tr>
<td>Velocities within bioretention cells will not cause scour? Refer Section 13.4.3.6</td>
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<tr>
<td>Set down of at least 60mm below kerb invert to top of vegetation incorporated?</td>
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<th><strong>Bioretention Component</strong></th>
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<td>Design documents bioretention area and extended detention depth as defined by treatment performance requirements? Refer concept design. Area approximately 1-3% of catchment. Extended detention depth up to 0.3m.</td>
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<td>Overflow pit crest set at top of extended detention?</td>
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<td>Maximum ponding depth and velocity will not impact on public safety (v x d &lt; 0.4)</td>
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<td>Bioretention media specification includes details of filter media, drainage layer and transition layer (if required)? Refer Section 13.4.3.6</td>
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<td>Design saturated hydraulic conductivity included in specification? Refer Section 13.4.3.5</td>
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<td>Transition layer provided where drainage layer consists of gravel (rather than coarse sand)? Refer Section 13.4.3.5</td>
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<td>Perforated pipe capacity &gt; infiltration capacity of filter media?</td>
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<td>Selected filter media hydraulic conductivity &gt; 10 x hydraulic conductivity of surrounding soil?</td>
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<tr>
<td>Maximum spacing of collection pipes &lt; 1.5m?</td>
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<td>Collection pipes extended to surface to allow inspection and flushing?</td>
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<td>Liner provided if selected filter media hydraulic conductivity &gt; 10 x hydraulic conductivity of surrounding soil?</td>
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<td>Maintenance access provided to invert of conveyance channel?</td>
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<tr>
<td>Plant species selected can tolerate periodic inundation and design velocities?</td>
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<tr>
<td>Bioretention swale landscape design integrates with surrounding natural and/or built environment?</td>
<td></td>
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<tr>
<td>Planting design conforms with acceptable sight line and safety requirements?</td>
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<tr>
<td>Top soils are a minimum depth of 300 mm for plants and 100 mm for turf?</td>
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<td>Existing trees in good condition are investigated for retention?</td>
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<td>Detailed soil specification included in design?</td>
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# Bioretention Swale Construction Inspection Checklist

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<td>N</td>
<td></td>
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</table>

## During Construction and Establishment

### A. Functional Installation

#### Preliminary Works

1. Erosion and sediment control plan adopted
2. Temporary traffic/ safety control measures
3. Location same as plans
4. Site protection from existing flows

#### Earthworks and Filter Media

5. Bed of swale correct shape and slope
6. Batter slopes as plans
7. Dimensions of bioretention area as plans
8. Confirm surrounding soil type with design
9. Confirm filter media specification in accordance with Step 4
10. Provision of liner (if required)
11. Under-drainage installed as designed
12. Drainage layer media as designed
13. Transition layer media as designed (if required)
14. Extended detention depth as designed

#### Structural Components

15. Location and configuration of inflow systems as designed
16. Location and levels of overflow pits as designed
17. Under-drainage connected to overflow pits as designed
18. Concrete and reinforcement as designed
19. Set down to correct level for flush kerbs (streetscape applications only)
20. Kerb opening width as designed

#### Vegetation

21. Stabilisation immediately following earthworks and planting of terrestrial landscape around basin
22. Silt fences and traffic control in place
23. Temporary protection layers in place
24. Temporary protection layers and associated silt removed
25. Planting as designed (species and densities)
26. Weed removal and watering as required

### Final Inspection

1. Confirm levels of inlets and outlets
2. Confirm structural element sizes
3. Check batter slopes
4. Vegetation as designed
5. Bioretention filter media surface flat and free of clogging
6. Check for uneven settling of banks
7. Under-drainage working
8. Inflow systems working
9. Maintenance access provided

### Comments on Inspection

### Actions Required

1.
2.
3.

Inspection officer signature:
## Bioretention Swale Maintenance Checklist

<table>
<thead>
<tr>
<th>Asset I.D.:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection Frequency:</td>
<td>1 to 6 monthly</td>
</tr>
<tr>
<td>Date of Visit:</td>
<td></td>
</tr>
<tr>
<td>Location:</td>
<td></td>
</tr>
<tr>
<td>Description:</td>
<td></td>
</tr>
<tr>
<td>Site Visit by:</td>
<td></td>
</tr>
</tbody>
</table>

### Inspection Items

<table>
<thead>
<tr>
<th>Inspection Items</th>
<th>Y</th>
<th>N</th>
<th>Action Required (Details)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment accumulation at inflow points?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Litter within swale?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erosion at inlet or other key structures (eg. crossovers)?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic damage present?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evidence of dumping (eg. building waste)?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation condition satisfactory (density, weeds, etc)?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Replanting required?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mowing required?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clogging of drainage points (sediment or debris)?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evidence of ponding?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set down from kerb still present?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damage/ vandalism to structures present?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface clogging visible?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drainage system inspected?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remulching of trees and shrubs required?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil additives or amendments required?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pruning and/or removal of dead or diseased vegetation required?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resetting of system required?</td>
<td></td>
<td></td>
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</tbody>
</table>

### Comments
## Bioretention Swale Asset Transfer Checklist

**Asset I.D.:**

**Asset Location:**

**Construction by:**

**Defects and Liability Period:**

### Treatment

<table>
<thead>
<tr>
<th></th>
<th>Y</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>System appears to be working as designed visually?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No obvious signs of under-performance?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Maintenance

<table>
<thead>
<tr>
<th></th>
<th>Y</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance plans and indicative maintenance costs provided for each asset?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation establishment period completed (2 years)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspection and maintenance undertaken as per maintenance plan?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspection and maintenance forms provided?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Asset Inspected for Defects and/or Maintenance Issues at Time of Asset Transfer

<table>
<thead>
<tr>
<th></th>
<th>Y</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment accumulation at inflow points?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Litter within swale?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erosion at inlet or other key structures?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic damage present?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evidence of dumping (eg. building waste)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation condition satisfactory (density, weeds)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Watering of vegetation required?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Replanting required?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mowing/ slashing required?</td>
<td></td>
<td></td>
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<tr>
<td>Clogging of drainage points (sediment or debris)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evidence of ponding?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damage/ vandalism to structures present?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface clogging visible?</td>
<td></td>
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</tr>
<tr>
<td>Drainage system inspected?</td>
<td></td>
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</tbody>
</table>

### Asset Information

<table>
<thead>
<tr>
<th></th>
<th>Y</th>
<th>N</th>
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</thead>
<tbody>
<tr>
<td>Design Assessment Checklist provided?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘As constructed’ plans provided?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copies of all required permits (both construction and operational) submitted?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proprietary information provided (if applicable)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digital files (eg. drawings, survey, models) provided?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asset listed on asset register or database?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
13.4.8 Bioretention Swale Worked Example

Modelling using MUSIC was undertaken to develop a stormwater quality treatment system for the concept design stage of a new greenfield residential estate in Pimpama. This worked example describes the detailed design of a vegetated swale and bioretention system located in a median separating an arterial road and a local road within the residential estate. The layout of the catchment and bioretention swale is shown in Figure 13.4-L. A photograph of a similar bioretention swale in a median strip is shown in Plate 13.4-C.

The site is comprised of the arterial road and a service road separated by a median approximately 6 m wide. The median area offers the opportunity for a local stormwater treatment measure. The area available is relatively large in relation to the catchment; however, it is elongated in shape. The catchment area for the swale and bioretention area includes the road reserve and the adjoining low density residential allotment (approximately 35 m in depth and with a fraction impervious of 0.6).

![Figure 13.4-L: Catchment Area Layout and Section for Worked Example](image)

Three crossings of the median are required and the raised access crossings can be designed as the separation mounds between the swale and bioretention treatment system, thus resulting in a two-cell system. Each bioretention swale cell will treat its individual catchment area. Runoff from the arterial road is conveyed by the conventional kerb and gutter system into a stormwater pipe and discharged into the surface of the swale at the upstream end of each cell. Runoff from the local street can enter the swale as distributed inflow (sheet flow) along the length of the swale.

As runoff flows over the surface of the swale, it receives some pretreatment and coarse to medium sized particles are trapped by vegetation on the swale surface. During runoff events, flow is temporarily impounded in the bioretention zone at the downstream end of each cell. Filtered runoff is collected via a perforated pipe in the base of the bioretention zone. Flows in excess of the capacity of the filtration medium pass through the swale as surface flow and overflow into the piped drainage system (via inlet pits) at the downstream end of each bioretention cell with a 2 year ARI capacity.

![Plate 13.4-G: Bioretention swale located between a main road and local road](image)
MUSIC modelling undertaken during the concept design stage found that the area of bioretention to meet the required water quality objectives is approximately 135 m$^2$ and 65 m$^2$ for Cell A and B, respectively. The filter media saturated hydraulic conductivity derived from the MUSIC modelling was 180 mm/hr based on 300 mm of extended detention and dense plantings of sedges and tufted grasses in the bioretention filter media.

**Design Objectives**

1. Treatment to achieve 80%, 60% and 45% reductions of mean annual loads of TSS, TP and TN respectively, with these reductions having been defined by earlier MUSIC modelling that indicated such standards were required in order for the stormwater treatment train proposed for the site to comply with the GCCC water quality objectives for the site.

2. Perforated under-drainage to be designed to ensure that the capacity of the perforated pipes exceeds the saturated hydraulic conductivity of the filter media.

3. Design flows up to the minor year ARI range are to be safely conveyed into a piped drainage system with acceptable inundation of the adjacent road (according to Section 3.5).

4. The hydraulics for the swale and road system need to be checked to confirm flow capacity for the 2 year and 100 year ARI peak flows, in accordance with the road drainage standards defined in Section 3.5.

5. Acceptable safety and scouring behaviour for 2 year and 100 year ARI peak flows.

6. Integration of the bioretention swale landscape design with the surrounding natural and built environment.

**Constraints and Concept Design Criteria**

1. Depth of the bioretention filter layer shall be a maximum of 600 mm.

2. Maximum extended depth allowable is 300 mm.

3. Width of median available for siting the system is 6 m.

4. The filter media available is a sandy loam top soil stripped from the site and amended by mixing in a loose non-angular sand to achieve the design saturated hydraulic conductivity of 180 mm/hr determined to be the optimal saturated hydraulic conductivity by the MUSIC modelling undertaken at the concept design stage.

**Site Characteristics**

| Land use: | urban, low density residential |
| Overland flow slopes: | Cell A and B = 1.3% |
| Soil: | clay |

<table>
<thead>
<tr>
<th>Catchment areas:</th>
<th>Allotments</th>
<th>Collector Road</th>
<th>Local Road</th>
<th>Footpath</th>
<th>Swale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell A</td>
<td>100 m x 35 m</td>
<td>600 m x 7 m</td>
<td>100 m x 7 m</td>
<td>100 m x 4 m</td>
<td>103 m x 6 m</td>
</tr>
<tr>
<td>Cell B</td>
<td>73 m x 35 m</td>
<td>73 m x 7 m</td>
<td>73 m x 7 m</td>
<td>73 m x 4 m</td>
<td>44 m x 6 m</td>
</tr>
</tbody>
</table>

Fraction impervious: lots $f_i$ = 0.60  
roads $f_i$ = 0.90  
footpaths $f_i$ = 0.50  
swale $f_i$ = 0.0

**13.4.8.1 Step 1: Confirm Concept Design**

It is assumed that earlier conceptual design of the stormwater treatment system required of this project will have undertaken appropriate modelling using MUSIC or alternative techniques to ensure that stormwater discharges from the site comply with GCCC WQOs, a prerequisite of development approval. It is noted that these objectives will change dependent on their specific location on the Gold Coast. Results for the conceptual MUSIC model undertaken in this case study indicated the following treatment:
13.4.8.2 Step 2: Determine Design Flows for Swale Component

With a small catchment, the Rational Method is considered an appropriate approach to estimate peak flow rates. The steps in these calculations follow below.

a) Major and Minor Design Flows

Time of concentration \( (t_c) \)

Approach:

Cell A and Cell B are effectively separate elements for the purpose of sizing the swales. Therefore, \( t_c \) values are estimated separately for each cell.

- **Cell A** – the \( t_c \) calculations include consideration of runoff from the allotments as well as from gutter and pipe flow along the collector road. Comparison of these travel times concluded the flow along the allotments was the longest and was adopted for \( t_c \).

- **Cell B** – the \( t_c \) calculations include overland flow across the lots and road and swale/bioretention flow time.

Following procedures in Section 3.5, the overland sheet flow component should be limited to 50m in length and determined using the Kinematic Wave Equation:

\[
t = 6.94 \left( L \cdot n^* \right)^{0.6} \cdot I^{0.4} \cdot S^{0.3}
\]

Where:

- \( t \) = overland sheet flow travel time (mins)
- \( L \) = overland sheet flow path length (m)
- \( n^* \) = surface roughness/retardance coefficient
- \( I \) = rainfall intensity (mm/hr)
- \( S \) = slope of surface (m/m)

When calculating overland channel flow travel times, it is recommended that stream velocities in Table 5.05.4 of QUDM be used.

**Cell A:**

Assuming:
- Predominant slope = 1.3%
- Overland sheet flow component through allotments = 35m
- Overland channel flow component through swale = 100m
- Sheet flow path is predominately lawn, with a typical \( n^* = 0.25 \) (QUDM)

2 year ARI:

\[
t_{\text{sheet flow}} = 6.94 \left( 35 \times 0.25 \right)^{0.6} / (104.2^{0.4} \times 0.013^{0.3})
\]

\[
= 15 \text{ mins}
\]

Iterations will need to be repeated until \( t_{\text{sheet flow}} \) matches the 2 year ARI rainfall intensity on the IFD chart for that duration, as shown in the above calculation.

**Note:** IFD data will need to be determined in line with Section 3.5.7.6.

\[
t_{\text{channel flow}} = (100m / 0.3m/s) / 60s/min
\]

\[
= 5 \text{ mins}
\]

\[
t_c = t_{\text{sheet flow}} + t_{\text{channel flow}}
\]

\[
= 20 \text{ mins}
\]
100 year ARI:
\[ t_{\text{sheet flow}} = 6.94 (35 \times 0.25)^{0.6} / (216.9^{0.4} \times 0.013^{0.3}) \]
\[ = 11 \text{ mins} \]

Iterations will need to be repeated until \( t_{\text{sheet flow}} \) matches the 100 year ARI rainfall intensity on the IFD chart for that duration, as shown in the above calculation.

**Note:** *IFD data will need to be determined in line with Section 3.5.7.6.*

\[ t_{\text{channel flow}} = (100m / 0.3m/s) / 60s/min \]
\[ = 5 \text{ mins} \]

\[ t_c = t_{\text{sheet flow}} + t_{\text{channel flow}} \]
\[ = 16 \text{ mins} \]

**Cell B:**

Assuming: Predominant slope = 1.3%
Overland sheet flow component through allotments = 35m
Overland channel flow component through swale = 73m
Sheet flow path is predominately lawn, with a typical \( n^* = 0.25 \) (QUDM)

2 year ARI:
\[ t_{\text{sheet flow}} = 6.94 (35 \times 0.25)^{0.6} / (104.2^{0.4} \times 0.013^{0.3}) \]
\[ = 15 \text{ mins} \]

Iterations will need to be repeated until \( t_{\text{sheet flow}} \) matches the 2 year ARI rainfall intensity on the IFD chart for that duration, as shown in the above calculation.

**Note:** *IFD data will need to be determined in line with Section 3.5.7.6.*

\[ t_{\text{channel flow}} = (73m / 0.3m/s) / 60s/min \]
\[ = 4 \text{ mins} \]

\[ t_c = t_{\text{sheet flow}} + t_{\text{channel flow}} \]
\[ = 19 \text{ mins} \]

100 year ARI:
\[ t_{\text{sheet flow}} = 6.94 (35 \times 0.25)^{0.6} / (216.9^{0.4} \times 0.013^{0.3}) \]
\[ = 11 \text{ mins} \]

Iterations will need to be repeated until \( t_{\text{sheet flow}} \) matches the 100 year ARI rainfall intensity on the IFD chart for that duration, as shown in the above calculation.

**Note:** *IFD data will need to be determined in line with Section 3.5.7.6.*

\[ t_{\text{channel flow}} = (73m / 0.3m/s) / 60s/min \]
\[ = 4 \text{ mins} \]

\[ t_c = t_{\text{sheet flow}} + t_{\text{channel flow}} \]
\[ = 15 \text{ mins} \]

**Design Rainfall Intensities (from Pimpama IFD Chart)**

<table>
<thead>
<tr>
<th>Bioretention Swale</th>
<th>2 yr ARI</th>
<th>100 yr ARI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( t_c )</td>
<td>Rainfall Intensity</td>
</tr>
<tr>
<td>Cell A</td>
<td>20 mins</td>
<td>119.4 mm/hr</td>
</tr>
<tr>
<td>Cell B</td>
<td>19 mins</td>
<td>122.5 mm/hr</td>
</tr>
</tbody>
</table>
Design Runoff Coefficient

Calculate runoff coefficients using Table 3.5A and as per QUDE (DPI, IMEA and BCC 1992).

Assuming: The development is Low Density Residential

- An average lot size < 600m²
- A slope of 1.3%, C₁₀ = 0.85

Hence, using QUDE Table 5.04.3:

- \( C₂ = 0.85 \times 0.85 = 0.72 \)
- \( C_{100} = 1.20 \times 0.85 = 1.02 = 1.00 \)

<table>
<thead>
<tr>
<th>Design ARI</th>
<th>Cell A</th>
<th>Cell B</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.72</td>
<td>0.72</td>
</tr>
<tr>
<td>100</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Peak Design Flows

Rational Method:

\[ Q = CIA/360 \text{ (m}^3/\text{s)} \]

<table>
<thead>
<tr>
<th>Design ARI</th>
<th>Cell A (m³/s)</th>
<th>Cell B (m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.27</td>
<td>0.12</td>
</tr>
<tr>
<td>100</td>
<td>0.48</td>
<td>0.22</td>
</tr>
</tbody>
</table>

13.4.8.3 Step 3: Dimension the Swale Component

a) Swale Width and Side Slopes

The swale component of Cell A and B need to be sized such that they can convey the 2 year and 50 year ARI flows with acceptable amount of water encroaching on the road. Manning’s equation (Equation 13.4.1) is used with the following parameters. Note the depth of the swale (and hence the side slopes) was determined by the requirement of discharging allotment runoff onto the surface of the bioretention system. The cover requirements of the allotment drainage pipes as they flow under the service road set the surface of the bioretention system. In this example, a Class 4 pipe is adopted and as such requires 300 mm cover. Allowing for this cover, a 100 mm diameter pipe and 100 mm fall with passage across the service road, the surface level of the bioretention systems must be 0.5 m below the edge of road pavement surface level.

The adopted swale dimensions for both Cell A and Cell B were:
- swale base width of 1 m with 1:5 side slopes, max depth of 0.5 m
- moderate vegetation height 300 mm (assume Manning’s \( n = 0.04 \) for flows above vegetation height)
- 1.3% slope

b) Maximum Length of Swale

The approach taken is to first determine the maximum length of the swale component of Cell A and then assume this same maximum length also applies to the swale component of Cell B (which has lower flow rates than Cell A).

To determine the maximum length of swale for the swale component of Cell A, it is necessary to calculate the maximum capacity of the swale using Manning’s equation (Equation 13.4.1) and the design parameters presented above. This equates to:

\[ Q_{\text{cap}} = 2.17 \text{ m}^3/\text{s} >> 0.48 \text{ m}^3/\text{s} (Q_{100}) \text{ and } 0.23 \text{ m}^3/\text{s} (Q₂) \]
Therefore, there is adequate capacity in the swale to convey all flows up to and well in excess of the $Q_{100}$ with no flow required to be conveyed on the adjacent road pavement. This result indicates that the maximum length of swale for the swale component of Cell A (and therefore Cell B) is much longer than the 'actual' length of the swale components of Cell A and B. As such, no additional calculations are required to check flow widths and depths on the adjacent road pavements to confirm compliance with the minor flood and major flood criteria outlined in Section 3.54 of this guideline and Section 5.09 of QUDM (DPI, IMEA and BCC 1992).

Freeboard to adjoining property must also be checked and comply with the requirements of the Land Development Guidelines (GCC 2005) and Section 5.09 of QUDM (DPI, IMEA and BCC 1992). Given, in this instance, that $Q_{100}$ is contained within the swale, the freeboard requirements are satisfied.

13.4.8.4 Step 4: Design Inflow Systems to Swale and Bioretention Components

There are two mechanisms for flows to enter the bioretention swale systems Cell A and Cell B. Firstly, underground pipes (either from the upstream road into Cell A or from allotment runoff) and secondly, direct runoff from road and footpaths.

Flush kerbs with a 60 mm set down are intended to be used to allow for sediment accumulation off the road surfaces.

Grouted rock is to be used for scour protection for the pipe outlets into the system. The intention of these is to reduce localised flow velocities to avoid erosion.

13.4.8.5 Step 5: Design Bioretention Component

a) Select Filter Media Saturated Hydraulic Conductivity and Extended Detention

The calculations undertaken for Steps 2 and 3 show that the dimensions of the swale component are sufficient to satisfy flow conveyance criteria and therefore there is no requirement for the bioretention component's saturated hydraulic conductivity or extended detention depth to be altered from what was determined by the MUSIC modelling undertaken at the concept design stage and presented in Section 13.4.7.1.

Had Steps 2 and 3 indicated that the swale geometry did not comply with the minimum requirements of Section 3.5 for minor flood and major flood flows on adjoining road pavements and minimum freeboard requirements to adjoining property, it would have been necessary to revise the swale geometry. As such, an alternative dimension for the surface area of the bioretention component may have resulted which may then have required further MUSIC modelling to determine the 'new' optimal combination of filter media saturated hydraulic conductivity and extended detention depth to maximise the water quality treatment function.

b) Specify the Bioretention Filter Media Characteristics (Filter, Transition and Drainage Layers)

The specification of the filter media and drainage layers requires consideration of the perforated under-drainage system. In this case, a perforated pipe with a slot width of 1.5 mm has been selected, meaning there is a risk that sand (typically 1 mm diameter and less) could wash into the pipe. Therefore, in this case, three layers are to be used, an amended sandy loam as the filter media (600 mm), a coarse sand transition layer (150 mm) and a fine gravel drainage layer (150 mm).

Filter Media Specifications

The filter media is to be a sandy loam, formed through the procedure documented in Section 13.4.3.5. The filter media will have a saturated hydraulic conductivity of 180 mm/hr and generally meet the following geotechnical requirements:

- particle sizes of between: clay 5 – 15%, silt < 30%, sand 50 – 70% determined from appropriate laboratory testing (see Section 3.3.5.2);
- between 5% and 10% organic content, measured in accordance with AS1289.4.1.1-1997;
- pH neutral.

Transition Layer Specifications

Transition layer material shall be coarse sand material such as Unimin 16/30 FG sand grading or equivalent. A typical particle size distribution is provided below:

<table>
<thead>
<tr>
<th>% passing</th>
<th>1.4 mm</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.0 mm</td>
<td>80%</td>
</tr>
<tr>
<td></td>
<td>0.7 mm</td>
<td>44%</td>
</tr>
<tr>
<td></td>
<td>0.5 mm</td>
<td>8.4%</td>
</tr>
</tbody>
</table>
Drainage Layer Specifications
The drainage layer is to be 5 mm screenings.

c) Under Drainage Design and Capacity Checks

Maximum Infiltration Rate

The maximum infiltration rate reaching the perforated pipe system at the base of the bioretention filter media is estimated by using the hydraulic conductivity of the media and the head above the pipes and applying Darcy’s equation (Equation 13.4.2).

\[
Q_{\text{max}} = K_{\text{sat}} \cdot L \cdot W_{\text{base}} \cdot \frac{h_{\text{max}} + d}{d}
\]

Saturated hydraulic conductivity = 180 mm/hr

\[
Q_{\text{max}} = 5 \times 10^{-5} \cdot L \cdot W_{\text{base}} \cdot \frac{0.3 + 0.6}{0.6}
\]

Where:
- \(Q_{\text{max}}\) = maximum infiltration rate (m³/s)
- \(K_{\text{sat}}\) = hydraulic conductivity of the soil filter (m/s)
- \(W_{\text{base}}\) = base width of ponded cross section above the soil filter (m)
- \(L\) = length of the bioretention zone (m)
- \(h_{\text{max}}\) = depth of pondage above the soil filter (m)
- \(d\) = depth of filter media

Maximum infiltration rate:
- Cell A = 0.010 m³/s
- Cell B = 0.005 m³/s

Perforations Inflow Check

Estimate the inlet capacity of sub-surface drainage system to ensure it is not a choke in the system. As a conservative approach, it is assumed that 50% of the holes are blocked. A standard perforated pipe was selected that is widely available. To estimate the flow rate, an orifice equation (Equation 13.4.3) is applied using the following parameters:

Head above pipe (h) = 0.95 m [0.6 m (filter depth) + 0.3 m (max. pond level) + 0.05 (half of pipe diameter)]

Assume sub-surface drains with half of all pipes blocked:
- Clear Opening = 2100 mm²/m, hence blocked openings
- = 1050 mm²/m (50%)
- Slot Width = 1.5 mm
- Slot Length = 7.5 mm
- Number of Row = 6
- Diameter = 100 mm

Number of slots per metre = \(\frac{1050}{1.5 \times 7.5}\) = 93.3

Assume orifice flow conditions:

\[
Q_{\text{perf}} = B \cdot C_d \cdot A \sqrt{2 \cdot g \cdot h}
\]

Where:
- \(C_d\) = 0.61 (Assume slot width acts as a sharp edged orifice)

Note: Blockage Factor \(B\) (= 0.5) has already been accounted for in the ‘Clear Opening’ calculation above.
Inlet capacity/m of pipe:

\[ Q_{\text{perf}} = [0.61 \times (0.0015 \times 0.0075 \times 93.3) \sqrt{2 \times 9.81 \times 0.95}] \]

\[ = 0.0028 \text{ m}^3/\text{s} \]

Inlet capacity/m x total length:

- **Cell A**: 0.0028 x 61 = 0.17 m$^3$/s > 0.010 m$^3$/s (max infiltration rate)
  
  Hence, one pipe has sufficient perforation capacity to pass flows into the perforated pipe.

- **Cell B**: 0.0028 x 22 = 0.06 m$^3$/s > 0.005 m$^3$/s (max infiltration rate)
  
  Hence, one pipe is sufficient.

**Check Perforated Pipe Capacity**

Manning’s equation is applied to estimate the flow rate in the perforated pipe. A slope of 1.5% is assumed and a 100 mm perforated pipe (as above) with Manning’s $n$ of 0.02 was used. Should the capacity not be sufficient, either a second pipe could be used or a steeper slope. The capacity of this pipe needs to exceed the maximum infiltration rate.

Estimate applying Manning’s Equation:

\[ Q = 0.0041 \text{ m}^3/\text{s} \]

Therefore, will need three pipes for Cell A (0.01 m$^3$/s max. infiltration rate) and two pipes for Cell B (0.005 m$^3$/s max. infiltration rate).

**Check Drainage Layer Hydraulic Conductivity**

Typically, flexible perforated pipes are installed using fine gravel media to surround them. In this worked example, 5 mm gravel is specified for the drainage layer. This media is much coarser than the filtration media (sandy loam) therefore, to reduce the risk of washing the filtration layer into the perforated pipe, a transition layer is to be used. This is to be 150 mm of coarse sand as specified in Section 13.4.3.5.

d) **Impervious Liner Requirement**

In this catchment, the surrounding soils are clay to silty clays with a saturated hydraulic conductivity of approximately 3.6 mm/hr. The sandy loam media that is proposed as the filter media has a hydraulic conductivity of 50-200 mm/hr. Therefore, the conductivity of the filter media is greater than 10 times the conductivity of the surrounding soils and an impervious liner is not required.

**13.4.8.6 Step 6: Verify Design**

a) **Vegetation Scour Velocity Check**

Potential scour velocities within the swale and on the bioretention surface are checked by applying Manning’s equation (Equation 13.4.1) to the bioretention swale design to ensure the following criteria is met:

- less than 0.5 m/s for minor flood (2 year ARI) discharge;
- less than 2.0 m/s for major flood (100 year ARI) discharge.

Using Manning’s equation to solve for depth for $Q_2$ and $Q_{100}$ in Cell A gives the following results.

**Note:** Manning’s $n$ used for $Q_2 = 0.3$ (flow below vegetation height) and for $Q_{50} = 0.04$ (flow above vegetation height).

\[ Q_2 = 0.23 \text{ m}^3/\text{s}, \text{ velocity } \approx 0.3 \text{ m/s} < 0.5 \text{ m/s} – \text{ therefore OK} \]

\[ Q_{100} = 0.481 \text{ m}^3/\text{s}, \text{ velocity } < 0.9 \text{ m/s} < 2.0 \text{ m/s} – \text{ therefore OK} \]

Hence, the swale can satisfactorily convey the peak 2 year and 100 year ARI flood flows with minimal risk of vegetation scour.

b) **Safety Velocity Check**

Check velocity $(V)$ x depth $(d)$ product in Cell A during peak 100 year ARI flow for pedestrian safety criteria.

\[ V = 0.9 \text{ m/s}, \text{ } d = 0.34 \text{ m}; \text{ therefore } V \times d = 0.9 \times 0.34 = 0.3 < 0.4 \text{ m}^2/\text{s} \]

Therefore, velocities and depths are OK.
13.4.8.7 Step 7: Overflow Pit Design

The overflow pits are required to convey 2 year ARI flows safely from the bioretention systems and into an underground pipe network. Grated pits are to be used at the downstream end of each bioretention system.

The sizes of the pits are calculated using a broad crested weir equation (Equation 13.4.4) with the height above the maximum ponding depth and below the road surface, less freeboard (ie. 0.76 – (0.3 + 0.15) = 0.31 m).

First check using a broad crested weir equation (refer Section 5.10.4 from QUDM (DPI, IMEA and BCC 1992) and Equation 13.4.5):

\[ Q_{\text{weir}} = B \cdot C_w \cdot L \cdot h^{3/2} \]

Where:
- \( B \) = Blockage factor (= 0.5)
- \( C_w \) = Weir coefficient (= 1.66)
- \( L \) = required length of weir (pit perimeter) (m)
- \( h \) = Flow depth above the weir (0.31 m)

\( L = 1.6 \) m of weir length required
Therefore, equivalent to a 400 x 400 mm pit.

Now check for drowned conditions (Equation 13.4.5):

\[ Q_{\text{orifice}} = B \cdot C_d \cdot A \sqrt{2 \cdot g \cdot h} \]

With \( C_d = 0.6 \) and \( h = 0.31 \) m, we have:

\[ 0.23 = 0.6 \times A \sqrt{2 \times 9.81 \times 0.31} \]

\[ A = 0.16 \text{ m}^2 \]

Therefore, equivalent to a 400 x 400 mm pit.
Hence, a minimum pit size of 400 x 400 mm is required for both Cell A and Cell B.

13.4.8.8 Step 8: Allowances to Preclude Traffic on Swales

Traffic control is achieved by using traffic bollards.

13.4.8.9 Step 9: Vegetation Specification

To compliment the landscape design of the area a mix of tufted grass and sedges is to be used. For this application, species with the average height of 300 mm have been proposed. The actual species to be planted will be selected by the landscape designer.

13.4.8.10 Calculation Summary

The sheet below summarises the results of the design calculations for Cell A.
<table>
<thead>
<tr>
<th>Calculation Task</th>
<th>Outcome</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Catchment Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catchment Area</td>
<td>0.942 Ha</td>
<td>✓</td>
</tr>
<tr>
<td>Catchment Land Use (ie. Residential, Commercial, etc)</td>
<td>Low Density Res</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Conceptual Design</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bioretention Area</td>
<td>135 m²</td>
<td>✓</td>
</tr>
<tr>
<td>Filter Media Saturated Hydraulic Conductivity</td>
<td>180 mm/hr</td>
<td>✓</td>
</tr>
<tr>
<td>Extended Detention Depth</td>
<td>300 mm</td>
<td>✓</td>
</tr>
<tr>
<td>1 <strong>Confirm Concept Design</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bioretention Area to Achieve Water Quality Objectives</td>
<td>135 m²</td>
<td>✓</td>
</tr>
<tr>
<td>TSS Removal</td>
<td>95 %</td>
<td>✓</td>
</tr>
<tr>
<td>TP Removal</td>
<td>82 %</td>
<td>✓</td>
</tr>
<tr>
<td>TN Removal</td>
<td>45 %</td>
<td>✓</td>
</tr>
<tr>
<td>2 <strong>Determine Design Flows for Swale Component</strong></td>
<td>Q₂ = 20 minutes</td>
<td>✓</td>
</tr>
<tr>
<td>Time of concentration – refer to Section 3.5 and QUDM</td>
<td>Q₁₀₀ = 16 minutes</td>
<td>✓</td>
</tr>
<tr>
<td>Identify Rainfall Intensities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I₂ year ARI</td>
<td>119.4 mm/hr</td>
<td>✓</td>
</tr>
<tr>
<td>I₁₀₀ year ARI</td>
<td>183.9 mm/hr</td>
<td>✓</td>
</tr>
<tr>
<td>Design Runoff Coefficient</td>
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<td></td>
</tr>
<tr>
<td>C₂ year ARI</td>
<td>0.72</td>
<td>✓</td>
</tr>
<tr>
<td>C₁₀₀ year ARI</td>
<td>1.00</td>
<td>✓</td>
</tr>
<tr>
<td>Peak Design Flows</td>
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<td></td>
</tr>
<tr>
<td>2 year ARI</td>
<td>0.23 m³/s</td>
<td>✓</td>
</tr>
<tr>
<td>100 year ARI</td>
<td>0.48 m³/s</td>
<td>✓</td>
</tr>
<tr>
<td>3 <strong>Dimension the Swale Component</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swale Width and Side Slopes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base Width</td>
<td>1 m</td>
<td>✓</td>
</tr>
<tr>
<td>Side Slopes – 1 in 5</td>
<td>5</td>
<td>✓</td>
</tr>
<tr>
<td>Longitudinal Slope</td>
<td>1.2 %</td>
<td>✓</td>
</tr>
<tr>
<td>Vegetation Height</td>
<td>300 mm</td>
<td>✓</td>
</tr>
<tr>
<td>Maximum Length of Swale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manning’s n</td>
<td>0.04</td>
<td>✓</td>
</tr>
<tr>
<td>Swale Capacity</td>
<td>2.17</td>
<td>✓</td>
</tr>
<tr>
<td>Maximum Length of Swale</td>
<td>Yes</td>
<td>✓</td>
</tr>
<tr>
<td>4 <strong>Design Inflow Systems to Swale and Bioretention Components</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swale Kerb Type</td>
<td>Flush</td>
<td>✓</td>
</tr>
<tr>
<td>Adequate Erosion and Scour Protection (where required)</td>
<td>N/A</td>
<td>✓</td>
</tr>
<tr>
<td>5 <strong>Design Bioretention Component</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filter Media Hydraulic Conductivity</td>
<td>180 mm/hr</td>
<td>✓</td>
</tr>
<tr>
<td>Extended Detention Depth</td>
<td>300 mm</td>
<td>✓</td>
</tr>
<tr>
<td>Filter media depth</td>
<td>600 mm</td>
<td>✓</td>
</tr>
<tr>
<td>Drainage layer media (sand or fine screenings)</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Drainage layer depth</td>
<td>150 mm</td>
<td>✓</td>
</tr>
<tr>
<td>Transition layer (sand) required</td>
<td>Yes</td>
<td>✓</td>
</tr>
<tr>
<td>Transition layer depth</td>
<td>150 mm</td>
<td>✓</td>
</tr>
<tr>
<td>Calculation Task</td>
<td>Calculation Summary</td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Under-Drain Design and Capacity Checks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow capacity of filter media (maximum infiltration rate)</td>
<td>0.010 m³/s ✓</td>
<td></td>
</tr>
<tr>
<td><strong>Perforations Inflow Check</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipe diameter</td>
<td>180 mm ✓</td>
<td></td>
</tr>
<tr>
<td>Number of pipes</td>
<td>3 ✓</td>
<td></td>
</tr>
<tr>
<td>Capacity of perforations</td>
<td>0.15 m³/s</td>
<td></td>
</tr>
<tr>
<td>Check PERFORATION CAPACITY &gt; FILTER MEDIA CAPACITY</td>
<td>Yes ✓</td>
<td></td>
</tr>
<tr>
<td><strong>Perforated Pipe Capacity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipe Capacity</td>
<td>0.0024 x 2 m³/s ✓</td>
<td></td>
</tr>
<tr>
<td>Check PIPE CAPACITY &gt; FILTER MEDIA CAPACITY</td>
<td>Yes ✓</td>
<td></td>
</tr>
<tr>
<td><strong>Check Requirement for Impermeable Lining</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil Hydraulic Conductivity</td>
<td>180 mm/hr ✓</td>
<td></td>
</tr>
<tr>
<td>Filter Media Hydraulic Conductivity</td>
<td>3.6 (clay) mm/hr ✓</td>
<td></td>
</tr>
<tr>
<td>MORE THAN 10 TIMES HIGHER THAN IN-SITU SOILS?</td>
<td>Yes ✓</td>
<td></td>
</tr>
</tbody>
</table>

6 Verify Design

- Velocity for 2 year ARI flow (< 0.5 m/s) | 0.3 m/s |
- Velocity for 100 year ARI flow (< 2 m/s) | < 0.9 m/s ✓ |
- Velocity x Depth for 100 year ARI (< 0.4 m²/s) | 0.34 m²/s |
- Treatment Performance consistent with Step 1 | Yes |

7 Size Overflow Pit Design

- System to convey minor floods | 400 x 400 L x W ✓ |
13.4.9 References

Barling RD & Moore ID 1993, The Role of Buffer Strips in the Management of Waterway Pollution, in Woodfull J et al. (eds), The Role of Buffer Strips in the Management of Waterway Pollution from Diffuse Urban and Rural Sources, LWRDRC Occasional Paper No. 01/ 93, Canberra.


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