Chapter 4 Bioretention Swales

Definition:

A bioretention swale (or biofiltration trench) is a bioretention system that is located within the base of a swale.

Purpose:

- To provide a conveyance function.
- Removal of fine and coarse sediments.
- Efficient removal of hydrocarbons and other soluble or fine particulate contaminants from biological uptake.
- To provide a low levels of extended detention.
- Provide flow retardation for frequent (low ARI) rainfall events.

Implementation considerations:

- Bioretention swales can form attractive streetscapes and provide landscape features in an urban development.
- Bioretention systems are well suited to a wide range of soil conditions including areas affected by soil salinity and saline groundwater as their operation is generally designed to minimise or eliminate the likelihood of stormwater exfiltration from the filtration trench to surrounding soils.
- Vegetation that grows in the filter media enhances its function by preventing erosion of the filter medium, continuously breaking up the soil through plant growth to prevent clogging of the system and providing biofilms on plant roots that pollutants can adsorb to. The type of vegetation varies depending on landscape requirements and climatic conditions.

Bioretention swales are commonly located in median strips of roads and carparks

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4.1 Introduction

Bioretention swales provide both stormwater treatment and conveyance functions where a bioretention system is installed in the base of a swale that is designed to convey minor floods. The swale component provides pretreatment of stormwater to remove coarse to medium sediments while the bioretention system removes finer particulates and associated contaminants. Figure 4.1 shows the layout of a bioretention swale.

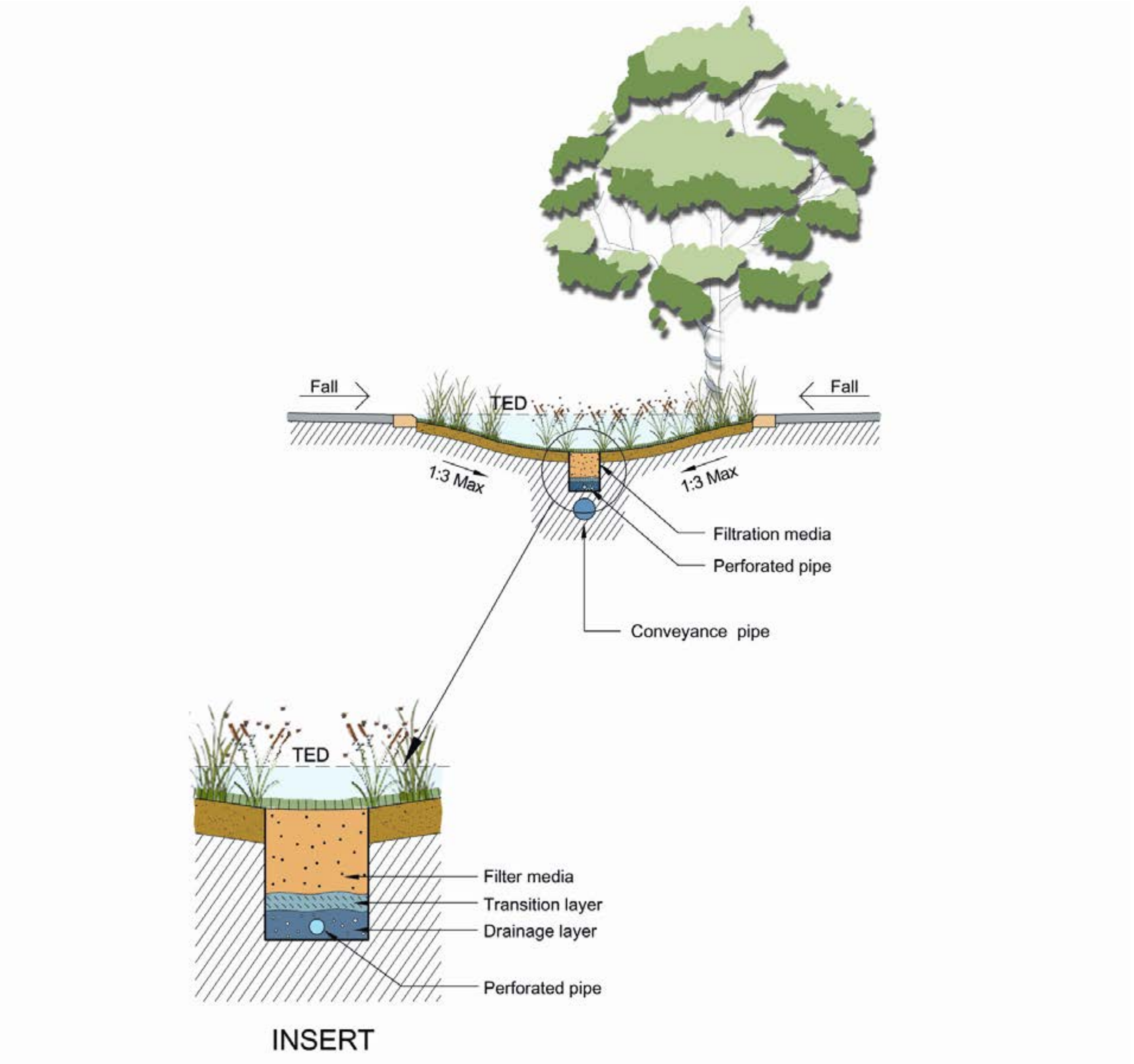


Figure 4.1. Bioretention swale as a centre road median

A bioretention system can be installed in part of a swale, or along the full length of a swale, depending on treatment requirements. Typically, these systems should be installed with slopes of between 1 and 4 %. Depending on the length of the swale and steepness of the terrain, check dams can be used to manage steep slopes and also to provide ponding over a bioretention surface. In this way increased volumes of runoff can be treated through a bioretention system prior to bypass.

Runoff can be directed into bioretention swales either through direct surface runoff (e.g. with flush kerbs) or from an outlet of a pipe system. In either case it is important to keep traffic away from the filter media as compaction can change the filter media functions substantially.

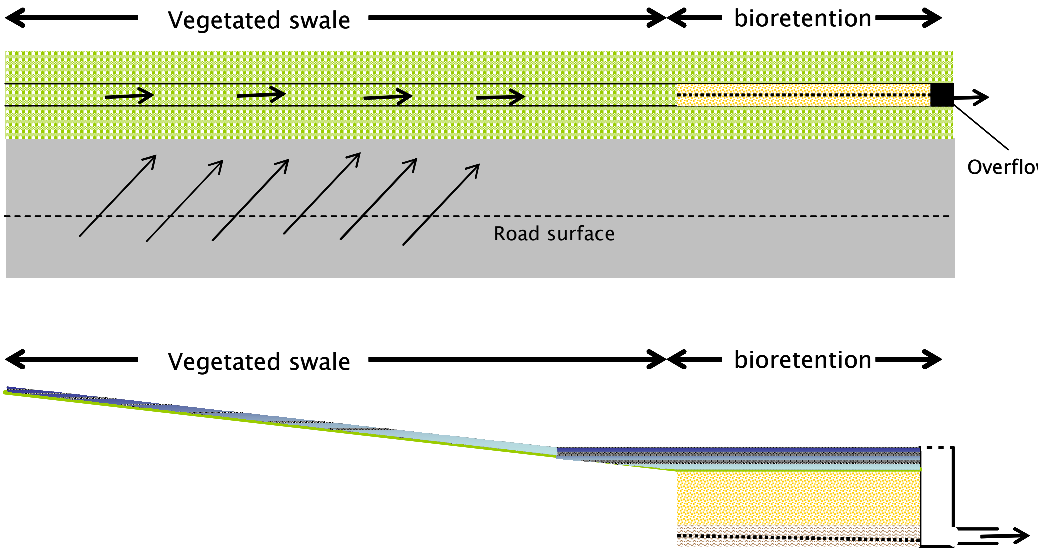


Figure 4.2. Bioretention swale example layout

When designing a system, separate calculations are performed to design the swale and the bioretention system, with iterations to ensure appropriate criteria are met in each section.

In many urban situations, the width available for a swale system will be fixed (as well as the longitudinal slope), therefore the length of the swale to safely convey a minor storm will also be fixed.

A common way to design these systems is as a series of discrete 'cells'. Each cell has an overflow pit that discharges flow to an underground pipe system (Figure 4.2 is an example of a 'cell'). Bioretention systems can then be installed directly upstream of the overflow pits. This also allows an area for ponding over the filtration media and the overflow pit provides a point of connection from the bioretention system's underdrain to the piped stormwater network.

With flood flows being conveyed along the bioretention surface, it is important to ensure that velocities are kept low to avoid scouring of collected pollutants and vegetation.

The treatment system operates by firstly filtering surface flows through surface vegetation and then percolating runoff through prescribed filtration media that provides treatment through fine filtration, extended detention and some biological uptake. They also provide flow retardation for frequent storm events and are particularly efficient at removing nutrients.

The bioretention systems can be designed to either encourage infiltration (where reducing volumes of stormwater runoff is important) or as conveyance systems that do not allow infiltration (where soils are not suitable for infiltration or in close proximity to surrounding structures).

Where bioretention systems are not intended to encourage infiltration they convey collected water to downstream waters (or collection systems for reuse) with any loss in runoff mainly attributed to maintaining soil moisture of the filter media itself (which is also the growing media for the vegetation).

Where bioretention systems perform pretreatment for infiltration, they are designed to facilitate infiltration by removing the collection system at the base of the filtration media allowing contact with surrounding soils.

Figure 4.3 shows a typical section of a swale bioretention combination.

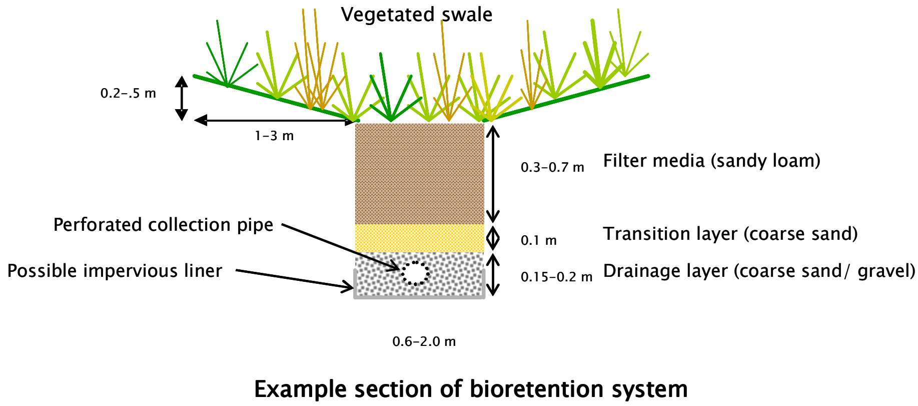


Figure 4.3. Typical section of a bioretention swale

Vegetation that grows in the filter media enhances its function by preventing erosion of the filter medium, continuously breaking up the soil through plant growth to prevent clogging of the system or caking at the soil surface and providing biofilms on plant roots that pollutants can adsorb to. The type of vegetation varies depending on landscaping requirements. Generally, the denser and higher the vegetation the better the filtration process.

Vegetation is critical to maintaining porosity of the filtration layer. Selection of an appropriate filtration media is a key issue that involves balancing sufficient hydraulic conductivity (ie. passing water through the filtration media as quickly as possible), stormwater detention for treatment and providing a suitable growing media to support vegetation growth (ie. retaining sufficient soil moisture and organic content). Typically a sandy loam type material is suitable, however soils can be tailored to a vegetation type.

As shown in Figure 4.3, a bioretention trench could consist of three layers. In addition to the filtration media, a drainage layer is required to convey treated water into the perforated underdrains. This material surrounds the perforated underdrainage pipes and can be either coarse sand (1 mm) or fine gravel (2–5 mm). Should fine gravel be 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 any filtration media being washed into the perforated pipes.

Keeping traffic off bioretention swales is an important consideration in the design phase of such a system. Traffic can ruin the vegetation, create ruts that cause preferential flow paths that do not offer filtration and compact the filter media. Traffic control can be achieved by selecting vegetation that discourages the movement of traffic or by providing physical barriers to traffic movement. For example, barrier kerbs with breaks in them (to allow distributed water entry, albeit with reduced uniformity of flows compared with flush kerbs) or bollards along flush kerbs can be used to prevent vehicle movement onto swales.

The design process for a bioretention swale involves firstly designing the system for treatment and secondly ensuring the system can convey a minor flood.

Key design issues to be considered are:

Verifying size and configuration for treatment

Determine design capacity and treatment flows

Dimension the swale

Specify details of the filtration media

Above ground components:

- check velocities
- design of inlet zone and overflow pits
- check above design flow operation

Below ground components:

- prescribe soil media layer characteristics (filter, transition and drainage layers)
- underdrain design and capacity check
- check requirement for bioretention lining

Recommended plant species and planting densities

Provision for maintenance.

4.2 Verifying size for treatment

The curves below show pollutant removal performance expected for bioretention systems (either swales or basins) at varying depths of ponding. Average ponding depth should be used in design as average depth is likely to be less than the maximum depth.

These curves are based on the performance of a system in Hobart, the reference site and were derived using the Model for Urban Stormwater improvement Conceptualisation (MUSIC, eWater, 2009). To estimate the size of a bioretention swale anywhere in Tasmania, the required area for a system in Hobart, the reference site should be multiplied by the appropriate adjustment factor listed in Chapter 2. In preference to using the curves, local data should be used to model the specific treatment performance of the system.

The curves were derived assuming the systems receive direct runoff (i.e. no pretreatment) and have the following characteristics:

- Hydraulic conductivity of 36mm/hr

- Filtration media depth of 600 mm
- Filter media particle size (D_{50}) of 0.45 mm

These curves can be used to check the expected performance of the bioretention system for removal of TSS, TP and TN. The x-axis is the area of bioretention expressed as a percentage of the bioretention area of the *impervious* contributing catchment area.

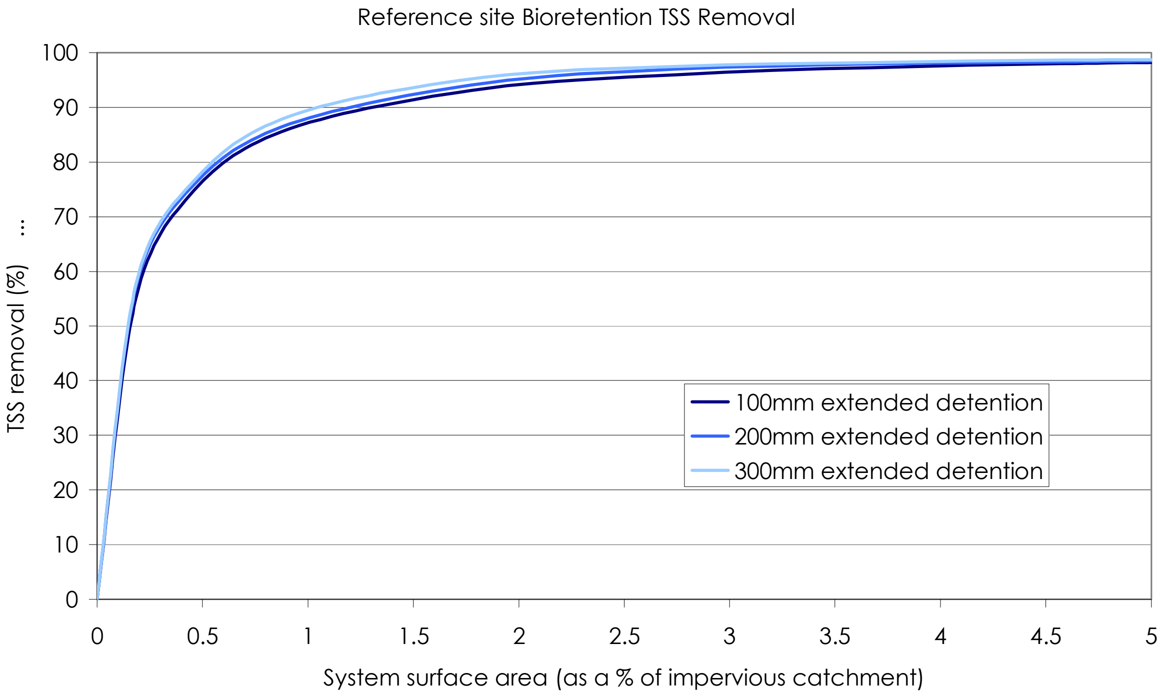


Figure 4.4. TSS removal in bioretention systems with varying extended detention

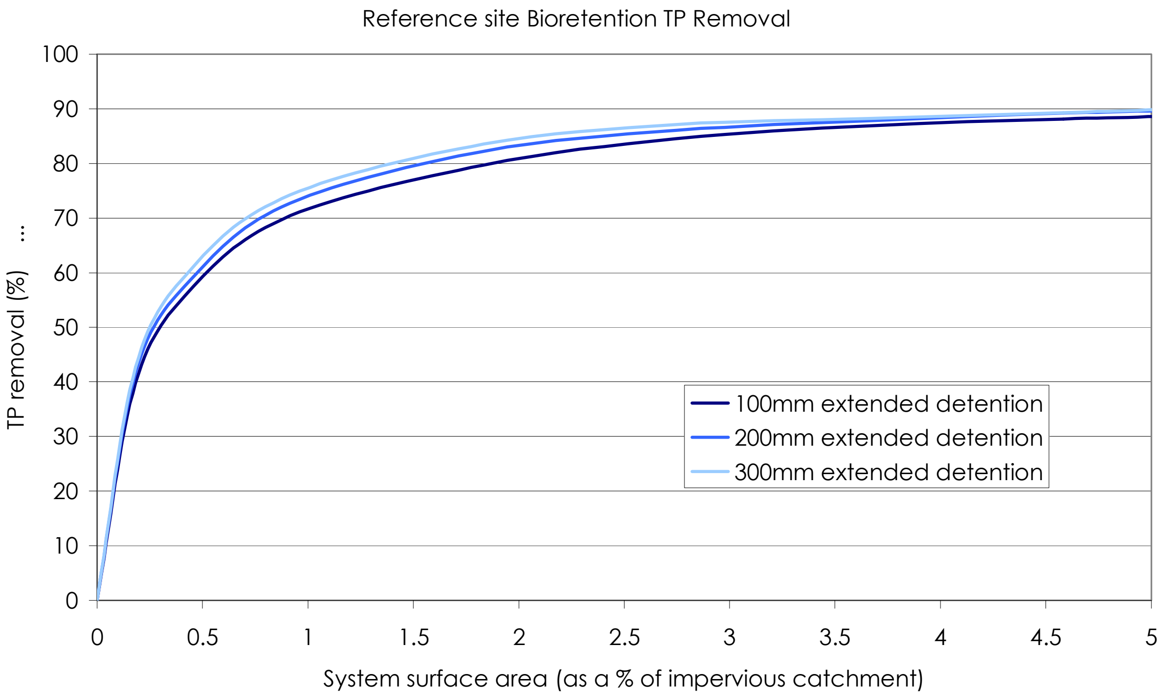


Figure 4.5. TP removal in bioretention systems with varying extended detention

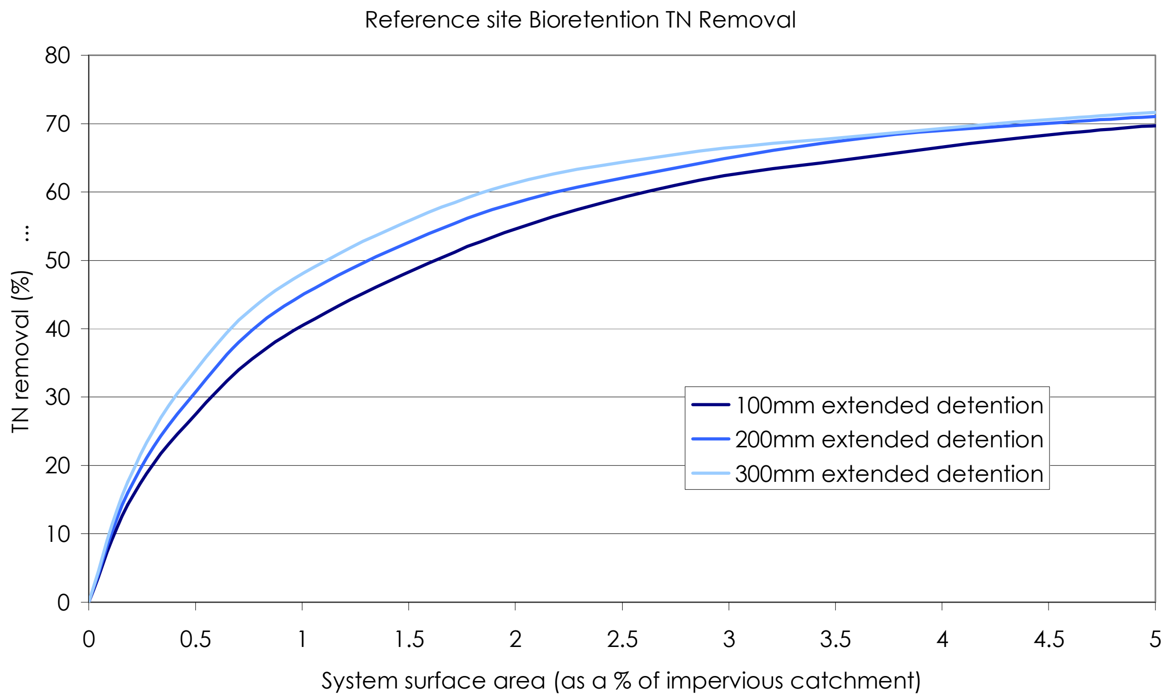


Figure 4.6. TN removal in bioretention systems with varying extended detention

4.3 Design procedure for bioretention swales

The following sections detail the design steps required for bioretention swales.

4.3.1 Estimating design flows

Three design flows are required for bioretention swales:

- Minor flood rates (typically 5-year ARI) to size the overflows to allow minor floods to be safely conveyed and not increase any flooding risk compared to conventional stormwater systems
- Major flood rates (typically 100 year ARI) to check that flow velocities are not too large in the bioretention system, which could potentially scour pollutants or damage vegetation
- Maximum infiltration rate through the filtration media to allow for the underdrainage to be sized, such that the underdrains will allow filter media to drain freely.

4.3.1.1 Minor and major flood estimation

A range of hydrologic methods can be applied to estimate design flows. With typical catchment areas being relatively small, the Rational Method Design Procedure is considered to be a suitable method for estimating design flows.

4.3.1.2 Maximum infiltration rate

The maximum infiltration rate represents the design flow for the underdrainage system (i.e. the slotted pipes at the base of the filter media). The capacity of the underdrains needs to be greater than the maximum infiltration rate to ensure the filter media drains freely and doesn't become a 'choke' in the system.

A maximum infiltration rate (Q_{max}) can be estimated by applying Darcy's equation:

$$Q_{\max} = k \cdot L \cdot W_{base} \cdot \frac{h_{\max} + d}{d}$$

Equation 4.1

where k is the hydraulic conductivity of the soil filter (m/s)

W_{base} is the base width of the ponded cross section above the soil filter (m)

L is the length of the bioretention zone (m)

h_{max} is the depth of pondage above the soil filter (m)

d is the depth of filter media

4.3.2 Swale design

The swale component of a bioretention swale needs to be determined first to set the broad dimensions of the system. Typically the swale will be trapezoidal in shape with side slopes ranging from 1:9 to 1:3 depending on local council regulations and any requirements for driveway crossings. The base of the swale is where a bioretention system can be installed. A minimum base width of 300mm is suggested, however this would more typically be 600-1,000mm.

The swale design involves either:

i. Determining the width of swale required to pass the design flow for the minor drainage system (if the catchment areas are known) or

ii. Determining the maximum length of swale prior to discharge into an overflow pit (i.e. maximum length of each cell) for a given width of swale.

Manning's equation is used to size the swale given the site conditions. Selection of an appropriate Manning's 'n' is a critical consideration (see 4.3.2.2) and this will vary depending on the vegetation type. Consideration of landscape and maintenance elements of vegetation will need to be made before selecting a vegetation type.

4.3.2.1 Slope considerations

Two considerations for slope are required for the swale component of a bioretention swale, namely side slopes and longitudinal slopes.

Selection of an appropriate side slope is dependent on local council regulations and will relate to traffic access and the provision of driveway crossings (if required). The provision of driveway crossings can significantly impact on the required width of the swale/ bioretention system with driveway crossings either being 'elevated' or 'at-grade'. Elevated crossings provide a culvert along the swale to allow flows to continue downstream, whereas at-grade crossings act as small fords and flows pass over the crossings.

The slope of at-grade crossings (and therefore the swale) is governed by the trafficability of the change in slope across the base of the swale. Typically 1:9 side slopes, with a small flat base, will provide sufficient transitions to allow for suitable traffic movement.

Where narrower swales are required, elevated crossings can be used (with side slopes typically of 1 in 5) which will require provision for drainage under the crossings with a culvert or similar.

Crossings can provide good locations for promoting extended detention within the bioretention swale and also for providing overflow points in the bioretention swale that can also be used to achieve ponding over a bioretention system (e.g. Figure 4.2). The distance between crossings will determine how feasible having overflow points at each one is.

Selection of an appropriate crossing type should be made in consultation with urban and landscape designers.

4.3.2.2 Selection of Mannings "n"

Manning's '*n*' is a critical variable in the Manning's equation relating to roughness of the channel. It varies with flow depth, channel dimensions and the vegetation type. For constructed swale systems, the 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 (e.g. 0.03) for flows with greater depth than the vegetation. It is considered reasonable for Manning's 'n' to have a maximum at the vegetation height and then sharply reduce as depths increase. Figure 4.7 shows a plot of varying Manning's *n* with flow depth for a grass swale. 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 4.7) 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.

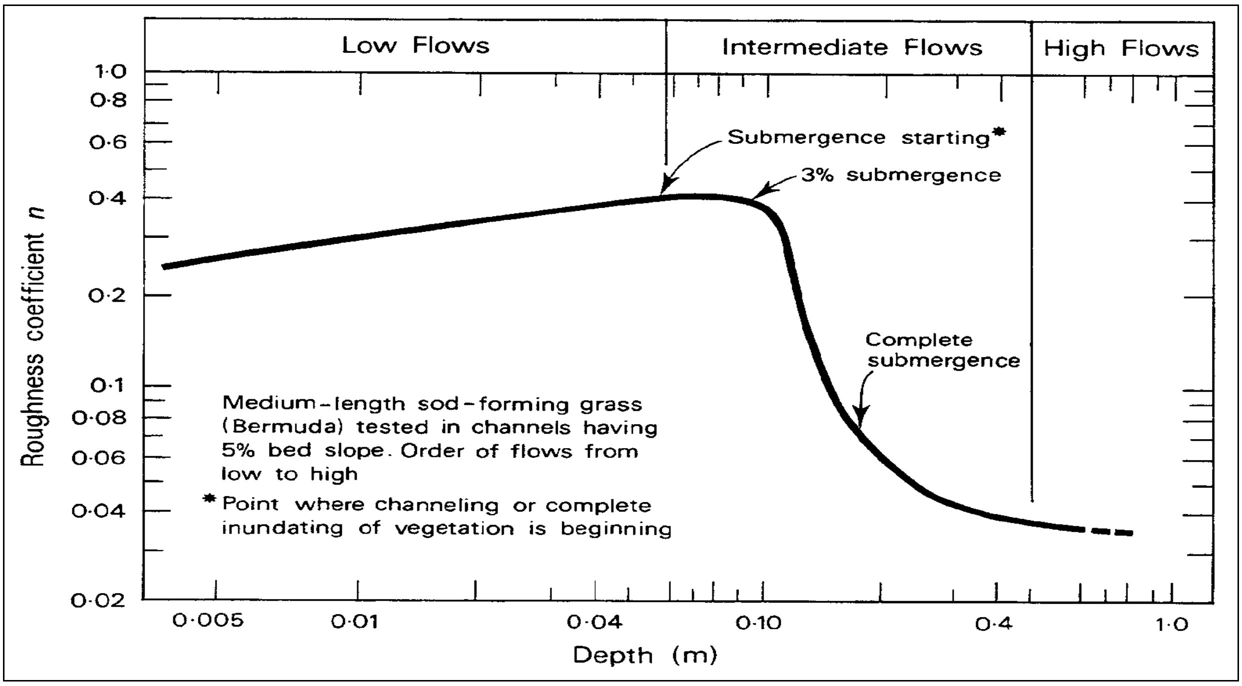


Figure 4.7. Impact of flow depth on hydraulic roughness adapted from Barling and Moore (1993)

Further discussion on selecting an appropriate Manning's 'n' for swales is provided in Appendix F of the MUSIC modelling manual (eWater, 2009).

4.3.3 Inlet details

Stormwater inflow to bioretention swales can be uniformly distributed (e.g. from flush kerbs along a road) or directly from pipe outlets. Combinations of these two entrance pathways can be used.

4.3.3.1 Distributed inflows

An advantage of flows entering a swale system in a distributed manner (ie. entering perpendicular to the direction of the swale) is that inflows are distributed and inflow depths are shallow which maximises contact with vegetation. This provides good pretreatment prior to flows entering the bioretention system. Creating distributed inflows can be achieved either by having flush kerbs or by using kerbs with regular breaks (Figure 4.9).

For distributed inflows, it is important to provide an area for coarse sediments to accumulate off the road surface. The photograph in Figure 4.8 shows sediment accumulating on a street surface where the vegetation is at the same level as the road. To avoid this accumulation, a tapered flush kerb can be used that sets the top of the vegetation between 40-50mm lower than the road surface (Figure 4.8). This requires the top of the ground surface (before turf is placed) to be between 80-100 mm below the road surface. This allows sediments to accumulate off any trafficable surface.

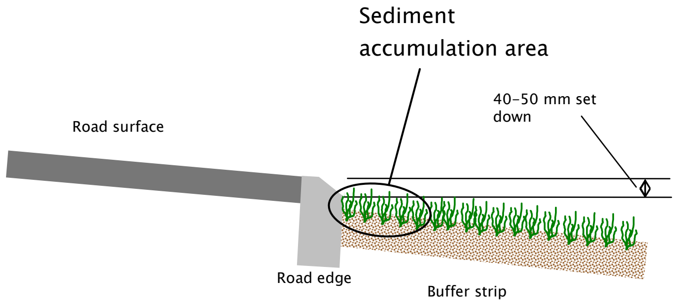


Figure 4.8. Photograph of flush kerb without setdown, edge detail showing setdown

Figure 4.9. Photograph of kerbs with breaks to distribute inflows

4.3.4 Direct entry points

Direct entry of flows can either be through a break in a kerb or from a pipe system. Entrances through kerb breaks may cause some level of water ponding around the entry points. The width of the flow inundation on the road prior to entry will need to be checked and the width of the required opening determined to meet Council requirements. These issues are discussed further in Chapter 5, Bioretention basins.

For piped entrances into bioretention swales, energy dissipation at the pipe outlet point is an important consideration to minimise any erosion potential. This can usually be achieved with a rock mattress and dense vegetation or pipe outlet structures with specific provision for energy dissipation.

The most common constraint on this system is bringing the pipe to the surface of the bioretention swale within the available width. Generally the maximum width of the system will be fixed, as will maximum batter slopes along the swale (1:5 is typical, however 1:3 may be possible for shallow systems with bollards). Further constraints are the cover required for a pipe that crosses underneath a road, as well as the required grade of the pipe. These constraints need to be considered carefully.

In situations where geometry doesn't permit the pipe to reach the surface, a surcharge pit can be used to bring flows to the surface. This is considered preferable to discharging flows below the surface directly into the bioretention filter media because of the potential for blockage and the inability to monitor operation.

Surcharge pits should be designed so that they are as shallow as possible and they should also have pervious bases to avoid long term ponding in the pits and to allow flows from within the pits to drain through the bioretention media and receive treatment. The pits need to be accessible so that any build up of coarse sediment and debris can be monitored and removed if necessary.

These systems are most frequently used when allotment runoff is required to cross a road into a swale on the opposite side. Several allotments can generally be combined prior to crossing the road to minimise the number of road crossings. Figure 4.10 shows an example of a surcharge pit discharging into a bioretention swale.

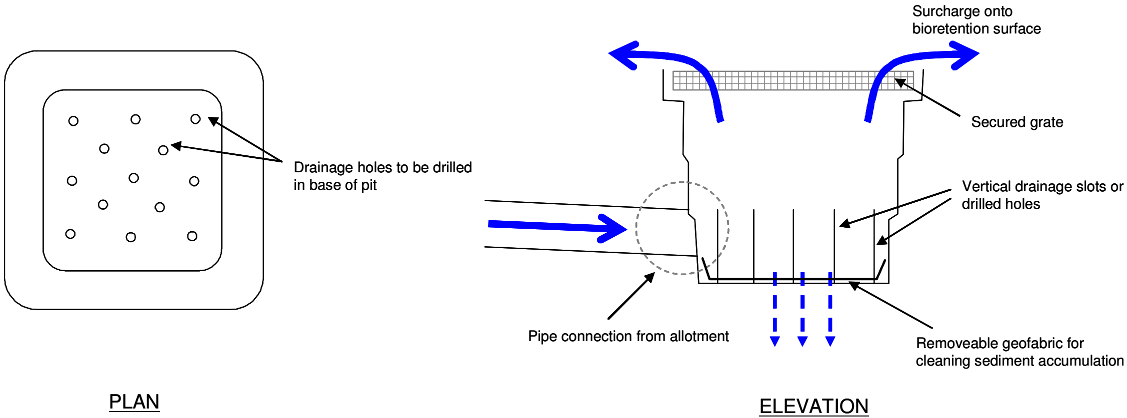


Figure 4.10. Example of surcharge pit for discharging allotment runoff into a bioretention swale

4.3.5 Vegetation scour velocity check

Scour velocities over the vegetation along the swale need to be checked. Manning's equation is used to estimate the mean velocity in the swale. An important consideration is the selection of an appropriate Manning's 'n' that suits the vegetation height. The selection of an appropriate 'n' is discussed in 4.3.2.2.

Manning's equation should be used to estimate flow velocities and ensure the following criteria are met:

- Less than 0.5 m/s for flows up to the design discharge for the minor drainage system (e.g.5-year ARI)
- Less than 1.0 m/s for flows up to the 100-year ARI

4.3.5.1 Velocity check – safety

As swales are generally accessible by the public, it is important to check that the combined depth and velocities product is acceptable from a public risk perspective. To avoid people being swept away by flows along swales, a velocity-depth product check should be performed for design flow rates, as in ARR BkVIII Section 1.10.4.

Velocity (m/s) x depth (m) < 0.4 m^2/s

4.3.6 Size perforated collection pipes

Perforated or slotted collection pipes at the base of bioretention systems collect treated water for conveyance downstream. The collection pipes (there may need to be multiple pipes) should be sized so that the filtration media are freely drained and the collection system does not become a 'choke' in the system.

If gravel is used around the perforated pipes and the filtration media is finer than sand, it is recommended to install an additional 'transition' layer to prevent the fine filtration media being washed into the perforated pipes. Typically this is sand to coarse sand (0.7 – 1.0 mm). Alternatively, a geotextile fabric could be used above the drainage layer to prevent finer material from reaching the perforated pipes, however, caution should be taken to ensure this material is not too fine as if it becomes blocked the whole system will require resetting.

Considerations for the selection of a drainage layer include the slot widths in the perforated pipes as well as construction techniques. In addition, where the bioretention system can only have limited depth (e.g. max depth to perforated pipe <0.5m) it will be preferable to install just one drainage layer with a geotextile fabric providing the function of the transition layer.

Installing parallel pipes is a means to increase the capacity of the perforated pipe system. 100 mm diameter is recommended as the maximum size for the perforated pipes to minimise the 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 should also be a consideration when specifying the drainage layer media.

DESIGN NOTE – The use of slotted uPVC over the more traditional choice of flexible agricultural pipe (Agriflex) has numerous advantages:

- Increased structural strength resulting in greater filter media depths without failure.
- Consistent grades to maintain self cleansing velocities are more easily maintained.
- Larger drainage slots allow for faster drainage and less risk of blockage thus increasing service life of the filter bed.
- Higher flow capacities therefore requiring lower numbers of pipes.

The maximum spacing of the perforated pipes should be 1.5m (centre to centre) so that the distance water needs to travel through the drainage layer does not hinder drainage of the filtration media.

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

- Ensure the perforations are adequate to pass the maximum infiltration rate
- Ensure the pipe itself has capacity
- Ensure that the material in the drainage layer will not be washed into the perforated pipes (consider a transition layer).

These checks can be performed using the equations outlined in the following sections, or alternatively manufacturers' design charts can be adopted to select appropriately sized pipes.

4.3.6.1 Perforations inflow check

To estimate the capacity of flows through the perforations, orifice flow conditions are assumed and a 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 a head of the filtration media depth plus the ponding depth. Secondly, it is conservative but reasonable to use a blockage factor (e.g. 50% blocked) to account for partial blockage of the perforations by the drainage layer media.

$$Q_{perforation} = B \cdot C \cdot A_{perforation} \sqrt{2gh}$$

Equation 4.2

where	B	is the blockage factor (0.5-0.75)
	C	is the orifice coefficient (~0.6)
	A	is the area of the perforation
	h	is depth of water over the collection pipe

The combined discharge capacity of the perforations in the collection pipe should exceed the design discharge of the sand filter unless the specific intention is to increase detention time in the sand filter by limiting the discharge through the collection pipe.

4.3.6.2 Perforated pipe capacity

One form of the Colebrook-White equation can be applied to estimate the velocity and hence flow rate in the perforated pipe. The capacity of this pipe needs to exceed the maximum infiltration rate.

V = -2(2gDSf) 0.5 x log [(k/3.7D) + (2.51v/D(2gDSf)0.5)]

V = Q / A

Therefore

Q = -2(2gDSf) 0.5 x log [(k/3.7D) + (2.51v/D(2gDSf)0.5)] x A

Equation 4.3

Where D = pipe diameter

A = area of the pipe

S_f = pipe slope

k = wall roughness

ν = viscosity

g = gravity constant

4.3.6.3 Drainage layer hydraulic conductivity

The composition of the drainage layer should be considered when selecting the perforated pipe system, as the slot sizes in the pipes may determine a minimum size of drainage layer particle size. Coarser material (e.g. fine gravel) should be used if the slot sizes are large enough that sand will be washed into the slots.

The material size differential should be an order of magnitude between layers to avoid fine material being washed through the voids of a lower layer. Therefore, if fine gravels are used, then a transition layer is recommended to prevent the filtration media from washing into the perforated pipes. The addition of a transition layer increases the overall depth of the bioretention system and may be an important consideration for some sites (therefore pipes with smaller perforations may be preferable where depth of the system is limited by site constraints).

4.3.6.4 Impervious liner requirement

Should surrounding soils be very sensitive to any exfiltration from the bioretention system (e.g. sodic soils, shallow groundwater or close proximity to significant structures), an impervious liner can be used to contain all water within the bioretention system. The liner could be a flexible membrane or a concrete casing.

The intention of the lining is to eliminate the risk of exfiltration from the bioretention trench. The greatest risk of exfiltration is through the base of a bioretention trench. Gravity and the difference in hydraulic conductivity between the filtration media and the surrounding native soil would act to minimise exfiltration through the walls of the trench. It is recommended that if lining is required, only the base and the sides of the *drainage layer* be lined. Furthermore, it is recommended that the base of the bioretention trench be shaped to promote a more defined flow path of treated water towards the perforated pipe.

The amount of water lost to surrounding soils is highly dependant on local soils and the hydraulic conductivity of the filtration media in the bioretention system. Typically the hydraulic conductivity of filtration media should be selected such that it is 1-2 orders of magnitude greater than the native surrounding soil profile to ensure that the preferred flow path is into the perforated underdrainage system.

4.3.7 High-flow route and overflow design

The design for high flows must safely convey flows up to the design storm for the minor drainage system (e.g. 5-year ARI flows) to the same level of protection that a conventional stormwater system provides. Flows are to be contained within the bioretention swale. Where the capacity of the swale system is exceeded at a certain point along its length, an overflow pit is required. This discharges excess flows into an underground drainage system for conveyance downstream. The frequency of overflow pits is determined in the swale design (4.3.2). This section suggests a method to dimension the overflow pits.

Locations of overflow pits are variable, but it is desirable to locate them at the downstream end of the bioretention system and to have their inverts higher than the filter media to allow ponding and therefore more treatment of flow before bypass occurs.

Typically grated pits are used and the allowable head for discharges is the difference in level between the invert and the nearby road surface. This should be at least 100 mm, but preferably more.

To size a grated overflow pit, two checks should be made to check for either drowned or free flowing conditions. A broad crested weir equation can be used to determine the length of weir required (assuming free flowing conditions) and an orifice equation used to estimate the area between opening required (assumed drowned outlet conditions). The larger of the two pit configurations should be adopted. In addition, a blockage factor is be to used that assumes the orifice is 50% blocked.

3. **Weir flow condition** – *when free overall conditions occur over the pit (usually when the extended detention storage of the retarding basin is not fully engaged),* ie.

$$P = \frac{Q_{des}}{B \cdot C_w \cdot H^{1.5}}$$

Equation 4.4

P = Perimeter of the outlet pit

B = Blockage factor (0.5)

H = Depth of water above the crest of the outlet pit

Q_{des} = Design discharge (m^3/s)

C_w = weir coefficient (1.7)

4. **Orifice flow conditions** – *when the inlet pit is completely submerged (corresponding to conditions associated with larger flood events*), ie.

$$A_o = \frac{Q_{des}}{B \cdot C_d \sqrt{2gH}}$$

Equation 4.5

C_d = Orifice Discharge Coefficient (0.6)

B = Blockage factor (0.5)

H = Depth of water above the centroid of the orifice (m)

A_o = Orifice area (m^2)

Q_{des} = Design discharge (m^3/s)

It is important that an outlet pit is prevented from blockage by debris. Design consideration needs to include means of preventing blockage of the outlet structure.

4.3.8 Soil media specification

At least two and possibly three types of soil media are required for the bioretention component of the system.

A filter media layer provides the majority of the treatment function, through fine filtration and also by supporting vegetation that enhances filtration, keeps the filter media porous and provides some uptake of nutrients and other contaminants. It is required to have sufficient depth to support vegetation, this usually is between 300-1,000 mm.

A drainage layer is used to convey treated flows into the perforated underdrainage pipes. Either coarse sand or fine gravel can be used. The layer should surround the perforated pipes and be 150 or 200 mm thick. Should fine gravel be used, a 100 mm transition layer is recommended that will prevent finer filter media being washed into the perforated pipes.

Materials similar to that given in the sections below should provide adequate substrate for vegetation to grow in and sufficient conveyance of stormwater through the bioretention system.

4.3.8.1 Filter media specifications

The material can be of siliceous or calcareous origin. The material will be placed and lightly compacted. Compaction is only required to avoid subsidence and uneven drainage. The material will periodically be completely saturated and completely drained. The bioretention system will operate so that water will infiltrate into the filter media and move vertically down through the profile. Maintaining the prescribed hydraulic conductivity is crucial.

The material shall meet the geotechnical requirements set out below:

Material - Sandy loam or equivalent material (ie similar hydraulic conductivity, 36-180 mm/hr) free of rubbish and deleterious material.

Particle Size- Soils with infiltration rates in the appropriate range typically vary from sandy loams to loamy sands. Soils with the following composition are likely to have an infiltration rate in the appropriate range - clay 5 - 15 %, silt <30 %, sand 50 - 70 %, assuming the following particle size ranges (clay < 0.002 mm, silt 0.002 - 0.05 mm, sand 0.05 - 2.0 mm).

Soils with the majority of particles in this range would be suitable. Variation in large particle size is flexible (ie. an approved material does not have to be screened). Substratum materials should avoid the lower particle size ranges unless hydraulic conductivity tests can demonstrate an adequate hydraulic conductivity (36-180 mm/hr).

Organic Content - between 5% and 10%, measured in accordance with AS1289 4.1.1.

pH - is variable, but preferably neutral, nominal pH 6.0 to pH 7.5 range. Optimum pH for denitrification, which is a target process in this system, is pH 7-8. It is recognised that siliceous materials may have lower pH values.

Any component or soil found to contain high levels of salt, high levels of clay or silt particles (exceeding the particle size limits set above), extremely low levels of organic carbon or any other extremes which may be considered a retardant to plant growth and denitrification should be rejected.

4.3.8.2 Transition layer specifications

Transition layer material shall be sand/ coarse sand material. A typical particle size distribution is provided below:

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

This grading is based on a Unimin 16/30 FG sand grading.

The transition layer is recommended to be a minimum of 100mm thick. Table 4.1 presents hydraulic conductivities for a range of media sizes (based on D_{50} sizes) that can be applied in either the transition or drainage layers.

Table 4.1. Hydraulic conductivity for a range of media particle sizes (d_{50}), Engineers Australia (2003)

Soil type	Particle Size (mm)	Saturated Hydraulic Conductivity (mm/hr)	Saturated Hydraulic Conductivity (m/s)
Gravel	2	36000	1×10^{-2}
Coarse Sand	1	3600	1×10^{-3}
Sand	0.7	360	1×10^{-4}
Sandy Loam	0.45	180	5×10^{-5}
Sandy Clay	0.01	36	1×10^{-5}

4.3.8.3 Drainage layer specifications

The drainage layer specification can be either coarse sand (similar to the transition layer) or fine gravel, such as a 2mm or 5 mm screenings. Alternative material can also be used (such as recycled glass screenings) provided it is inert and free draining.

This layer should be a minimum of 150mm, and preferably 200mm, thick.

4.3.9 Vegetation specification

Appendix B Plant Lists provides lists of plants that are suitable for bioretention swales. Consultation with landscape architects is recommended when selecting vegetation, to ensure the treatment system compliments the landscape of the area.

4.3.9.1 Design calculation summary

Bioretention Swales — **CALCULATION SUMMARY**

	CALCULATION TASK		OUTCOME		CHECK
1	**Identify design criteria**				☐
	conveyance flow standard (ARI)			year	
	area of bioretention			m^2	
	maximum ponding depth			mm	
	Filter media type			mm/hr	
2	**Catchment characteristics**				☐
				m^2	
				m^2	
		slope		%	
	Fraction impervious				☐
3	**Estimate design flow rates**				
	Time of concentration				
	estimate from flow path length and velocities			minutes	☐
	Identify rainfall intensities				
		station used for IFD data:			
		major flood - 100 year ARI		mm/hr	
		minor flood - 5 year ARI		mm/hr	
	Peak design flows				
		Q_{minor}		m^3/s	
		Q_{100}		m^3/s	
		Q_{infil}		m^3/s	☐
3	**Swale design**				
		appropriate Manning's n used?			☐
4	**Inlet details**				
		adequate erosion and scour protection?			☐
5	**Velocities over vegetation**				
		Velocity for 5 year flow (<0.5m/s)		m/s	
		Velocity for 100 year flow (<1.0m/s)		m/s	
		Safety: Vel x Depth (<0.4)		m/s	☐
6	**Slotted collection pipe capacity**				
		pipe diameter		mm	
		number of pipes			
		pipe capacity		m^3/s	
		capacity of perforations		m^3/s	
		soil media infiltration capacity		m^3/s	☐
8	**Overflow system**				
		system to convey minor floods			☐
9	**Surrounding soil check**				
		Soil hydraulic conductivity		mm/hr	
		Filter media		mm/hr	
		MORE THAN 10 TIMES HIGHER THAN SOILS?			☐
10	**Filter media specification**				
		filtration media			
		transition layer			
		drainage layer			☐
11	**Plant selection**				☐

4.4 Checking tools

This section provides a number of checking aids for designers and referral authorities. In addition, advice on construction techniques and lessons learnt from building bioretention systems are provided.

Checklists are provided for:

- Design assessments
- Construction (during and post)
- Operation and maintenance inspections
- Asset transfer (following defects period).

4.4.1 Design assessment checklist

The checklist below presents the key design features that should be reviewed when assessing a design of a bioretention basin. These considerations include configuration, safety, maintenance and operational issues that should be addressed during the design phase.

Where an item results in an "N" when reviewing the design, referral should be made back to the design procedure to determine the impact of the omission or error.

In addition to the checklist, a proposed design should have all necessary permits for its installations. The referral agency should 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.

Land ownership and asset ownership are key considerations prior to construction of a stormwater treatment device. A proposed design should clearly identify the asset owner and who is responsible for its maintenance. The proposed owner should be responsible for performing the asset transfer checklist (see 4.4.4).

Bioretention Swale Design Assessment Checklist					
Bioretention location:					
Hydraulics	Minor Flood: (m^3/s)		Major Flood: (m^3/s)		
Area	Catchment Area (ha):		Bioretention Area (ha)		
Treatment				Y	N
Treatment performance verified from curves?					
Inlet zone/hydraulics				Y	N
Station selected for IFD appropriate for location?					
Longitundinal slope of invert >1% and <4%?					
Mannings 'n' selected appropriate for proposed vegetation type?					
Overall flow conveyance system sufficient for design flood event?					
Maximum flood conveyance width does not impact on traffic amenity?					
Overflow pits provided where flow capacity exceeded?					
Inlet flows appropriately distributed?					
Energy dissipation provided at inlet?					
Velocities within bioretention cells will not cause scour?					
Set down of at least 50mm below kerb invert incorporated?					
Collection System				Y	N
Slotted pipe capacity > infiltration capacity of filter media?					
Transition layer/geofabric barrier provided to prevent clogging of drainage layer?					
Cells				Y	N
Maximum ponding depth and velocity will not impact on public safety (v x d <0.4)?					
Selected filter media hydraulic conductivity > 10x hydraulic conductivity of surrounding soil?					
Maintenance access provided to invert of conveyance channel?					
Protection from gross pollutants provided (for larger systems)?					
Vegetation				Y	N
Plant species selected can tolerate periodic inundation and design velocites?					
Plant species selected integrate with surrounding landscape design?					
Detailed soil specification included in design?					

4.4.2 Construction advice

This section provides general advice for the construction of bioretention basins. It is based on observations from construction projects around Australia.

Building phase damage

Protection of filtration media and vegetation is important during building phase, uncontrolled building site runoff is likely to cause excessive sedimentation, introduce weeds and litter and require replanting following the building phase. Can use a staged implementation – i.e. during building use geofabric and some soil and instant turf (laid perpendicular to flow path) to provide erosion control and sediment trapping. Following building, remove and revegetate possibly reusing turf at subsequent stages. Also divert flows around swales during building (divert to sediment controls).

Traffic and deliveries

Ensure traffic and deliveries do not access bioretention swales during construction. Traffic can compact the filter media and cause preferential flow paths, deliveries (such as sand or gravel) can block filtration media. Washdown wastes (e.g. concrete) can also cause blockage of filtration media and damage vegetation. Bioretention areas should be fenced off during building phase and controls implemented to avoid washdown wastes.

Management of traffic during the building phase is particularly important and poses significant risks to the health f the vegetation and functionality of the bioretention system. Measures such as those proposed above (e.g. staged implementation of final landscape) should be considered.

Inlet erosion checks

It is good practice to check the operation of inlet erosion protection measures following the first few rainfall events. It is important to check for these early in the systems life, to avoid continuing problems. Should problems occur in these events the erosion protection should be enhanced.

Sediment build-up on roads

Where flush kerbs are to be used, a set-down from the pavement surface to the vegetation should be adopted. This allows a location for sediments to accumulate that is off the pavement surface. Generally a set down from kerb of 50mm to the top of vegetation (if turf) is adequate. Therefore, total set down to the base soil is approximately 100 mm (with 50mm turf on top of base soil).

Tolerances

It is importance to stress the importance of tolerances in the construction of bioretention swales (eg base, longitudinal and batters) – having flat surfaces is particularly important for a well distributed flow paths and even ponding over the surfaces. Generally plus or minus 50mm is acceptable.

Erosion control

Immediately following earthworks it is good practice to revegetate all exposed surfaces with sterile grasses (e.g. hydroseed). These will stabilise soils, prevent weed invasion yet not prevent future planting from establishing.

Timing for planting

Timing of vegetation is dependent on a suitable time of year (and potential irrigation requirements) as well as timing in relation to the phases of development. For example temporary planting during construction for sediment control (e.g. with turf) then removal and planting with long term vegetation. Alternatively temporary (e.g. turf or sterile grass) can used until a suitable season for long term vegetation.

Planting strategy

A planting strategy for a development will depend on the timing of building phases was well as marketing pressure. For example, it may be desirable to plant out several entrance bioretention systems to demonstrate long term landscape values, and use the remainder of bioretention systems as building phase sediment control facilities (to be planted out following building). Other important considerations include the time of year and whether irrigation will be required during establishment.

Perforated pipes

Perforated pipes can be either a PVC pipe with slots cut into the length of it or a flexible ribbed pipe with smaller holes distributed across its surface (an AG pipe). Both can be suitable. PVC pipes have the advantage of being stiffer with less surface roughness therefore greater flow capacity, however the slots are generally larger than for flexible pipes and this may cause problems with filter or drainage layer particle ingress into the pipe. Stiff PVC pipes however can be cleaned out easily using simple plumbing equipment. Flexible perforated pipes have the disadvantage of roughness (therefore flow capacity) however have smaller holes and are flexible which can make installation easier. Blockages within the flexible pipes can be harder to dislodge with standard plumbing tools.

Clean filter media

Ensure drainage media is washed prior to placement to remove fines.

4.4.3 Construction checklist

CONSTRUCTION INSPECTION CHECKLIST

Bioretention swales

INSPECTED BY:
DATE:
TIME:
WEATHER:
CONTACT DURING VISIT:

SITE: ____________________

CONSTRUCTED BY: ____________________

DURING CONSTRUCTION									
Items inspected	Checked		Satisfactory	Unsatisfactory		Checked		Satisfactory	Unsatisfactory
Preliminary works	Y	N			**Structural components**	Y	N		
1. Erosion and sediment control plan adopted					16. Location and levels of pits as designed				
					17. Safety protection provided				
2. Traffic control measures					18. Location of check dams as designed				
3. Location same as plans					19. Swale crossings located and built as designed				
4. Site protection from existing flows									
Earthworks					20. Pipe joints and connections as designed				
5. Level bed of swale					21. Concrete and reinforcement as designed				
6. Batter slopes as plans					22. Inlets appropriately installed				
7. Dimensions of bioretention area as plans					23. Inlet erosion protection installed				
8. Confirm surrounding soil type with design					24. Set down to correct level for flush kerbs				
9. Provision of liner					**Vegetation**				
10. Perforated pipe installed as designed					25. Stablisation immediately following earthworks				
11. Drainage layer media as designed									
12. Transition layer media as designed					26. Planting as designed (species and densities)				
13. Filter media specifications checked									
14. Compaction process as designed					27. Weed removal before stabilisation				
15. Appropriate topsoil on swale									
FINAL INSPECTION									
1. Confirm levels of inlets and outlets					6. Check for uneven settling of soil				
2. Traffic control in place					7. Inlet erosion protection working				
3. Confirm structural element sizes					8. Maintenance access provided				
4. Check batter slopes					9. Construction generated sediment removed				
5. Vegetation as designed									

COMMENTS ON INSPECTION

ACTIONS REQUIRED

1.
2.
3.
4.
5.
6.

4.4.4 Asset transfer checklist

Asset Handover Checklist		
Asset Location:		
Construction by:		
Defects and Liability Period		
Treatment	**Y**	**N**
System appears to be working as designed visually?		
No obvious signs of under-performance?		
Maintenance	**Y**	**N**
Maintenance plans provided for each asset?		
Inspection and maintenance undertaken as per maintenance plan?		
Inspection and maintenance forms provided?		
Asset inspected for defects?		
Asset Information	**Y**	**N**
Design Assessment Checklist provided?		
As constructed plans provided?		
Copies of all required permits (both construction and operational) submitted?		
Proprietary information provided (if applicable)?		
Digital files (eg drawings, survey, models) provided?		
Asset listed on asset register or database?		

4.5 Maintenance requirements

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 potential for rilling and erosion down the swale component of the system needs to be carefully monitored during establishment stages of the system.

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 poor building controls.

Other components of the system that will require careful consideration are the inlet points (if the system does not have distributed inflows). These inlets can be prone to scour and build up of litter and surcharge pits in particular will require routine inspections. Occasional litter removal and potential replanting may be required.

Maintenance is primarily concerned with:

- Maintenance of flow to and through the system
- Maintaining vegetation
- Preventing undesired vegetation from taking over the desirable vegetation
- Removal of accumulated sediments
- Litter and debris removal

Vegetation maintenance will include:

- Removal of noxious plants or weeds
- Re-establishment of plants that die

Sediment accumulation at the inlet points needs to be monitored. Depending on the catchment activities (e.g. building phase) the deposition of sediment can tend to smother plants and reduce the available ponding volume. Should excessive sediment build up occur, it will impact on plant health and require removal before it impacts on plants, leading to a reduction in their capacity to maintain the infiltration rate of the filter media.

Similar to other types of stormwater practices, debris removal is an ongoing maintenance function. Debris, if not removed, can block inlets or outlets, and can be unsightly if located in a visible location. Inspection and removal of debris should be done regularly, but debris should be removed whenever it is observed on the site.

Inspections are also recommended following large storm events to check for scour.

4.5.1 Operation & maintenance inspection form

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

Bioretention Swale Maintenance Checklist			
Inspection Frequency: 3 monthly		Date of Visit:	
Location:			
Description:			
Site Visit by:			
Inspection Items	**Y**	**N**	**Action Required (details)**
Sediment accumulation at inflow points?			
Litter within swale?			
Erosion at inlet or other key structures (eg crossovers)?			
Traffic damage present?			
Evidence of dumping (eg building waste)?			
Vegetation condition satisfactory (density, weeds etc)?			
Replanting required?			
Mowing required?			
Clogging of drainage points (sediment or debris)?			
Evidence of ponding?			
Set down from kerb still present?			
Damage/vandalism to structures present?			
Surface clogging visible?			
Drainage system inspected?			
Resetting of system required?			
Comments:			

4.6 Bioretention swale worked example

4.6.1 Worked example introduction

This worked example describes the detailed design of a grass 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 4.11. A photograph of a similar bioretention swale in a median strip is shown in Figure 4.12 (although the case study is all turf).

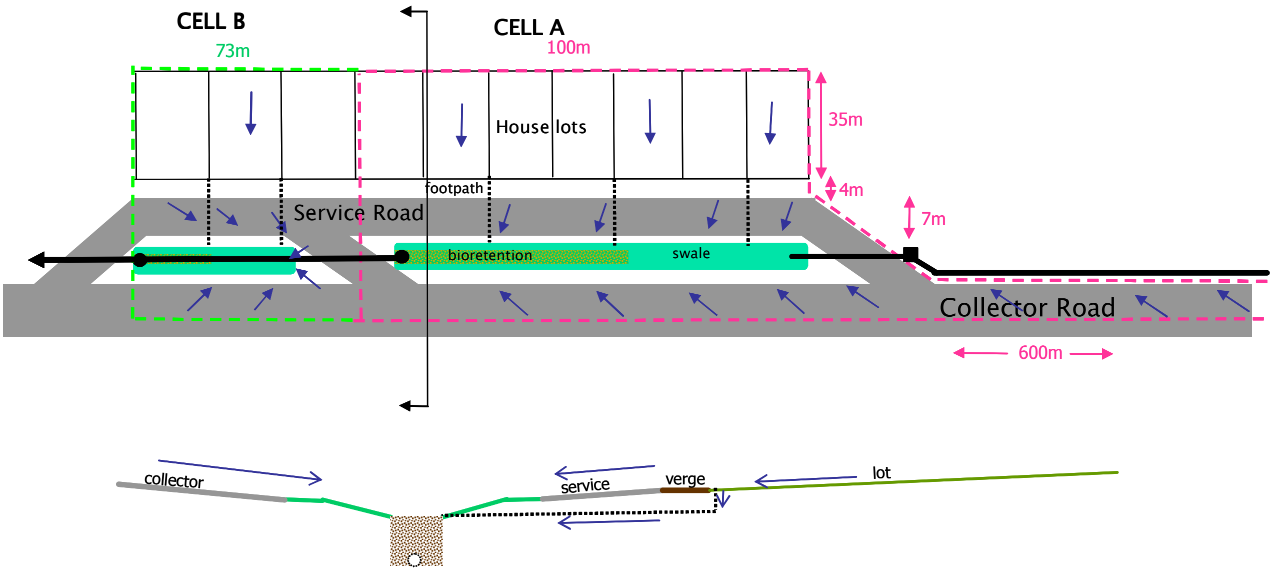


Figure 4.11. Catchment area layout and section for worked example

Figure 4.12. Photograph of bioretention swale

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

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 at the downstream end of each bioretention cell.

Simulation using MUSIC found that the required area of bioretention system to meet current best practice of 80% reduction in TSS and 45% reduction in TP and TN from values typically generated from urban catchments is approximately 110 m^2 and 42 m^2 for Cell A and B respectively. The filtration medium used is sandy loam with a notional saturated hydraulic conductivity of 180 mm/hr. The required area of the filtration zone is distributed to the two cells according to their catchment area.

4.6.1.1 Design Objectives

- Treatment to meet current best practice objectives of 80%, 45% and 45% reductions of TSS, TP and TN respectively
- Sub-soil drainage pipe to be designed to ensure that the capacity of the pipe exceeds the saturated infiltration capacity of the filtration media (both inlet and flow capacity)
- Design flows within up to 10-year ARI range are to be safely conveyed into a piped drainage system without any inundation of the adjacent road.
- The hydraulics for the swale need to be checked to confirm flow capacity for the 10 year ARI peak flow.
- Acceptable safety and scouring behaviour for 100 year ARI peak flow.

4.6.1.2 Constraints and Concept Design Criteria

- Depth of the bioretention filter layer shall be a maximum of 600mm
- Maximum ponding depth allowable is 200mm
- Width of median available for siting the system is 6m
- The filtration media available is a sandy loam with a saturated hydraulic conductivity of 180mm/hour.

4.6.1.3 Site Characteristics

- Land use Urban, low density residential
- Overland flow slopes Cell A and B=1.3%
- Soil Clay
- Catchment areas:

	Allotments	Collector road	Local road	Footpath	Swale
Cell A	100m x 35m	600m x 7m	100m x 7m	100m x 4m	103m x 7.5m
Cell B	73m x 35m	73m x 7m	73m x 7m	73m x 4m	44m x 7.5m

- Fraction impervious 0.60 (lots); 0.90 (roads); 0.50 (footpaths); 0.0 (Swale)

4.6.2 Confirm size for treatment

Interpretation of 4.2Verifying size for treatment with the input parameters below is used to estimate the reduction performance of the bioretention system to ensure the design will achieve target pollutant reductions.

- Hobart location
- 200mm extended detention
- treatment area to impervious area ratio:

Cell A 110m^2/ 6710 m^2 = 1.61%

Cell B 42m^2/ 2599 m^2 = 1.6%

From the graphs, the expected pollutant reductions are 85%, 70% and 45% for TSS, TP and TN respectively and exceed the design requirements of 80%, 45% and 45%.

DESIGN NOTE – The values derived from 4.2Verifying size for treatment will only be valid if the design criteria for the proposed installation are similar to those used to create the Figures. Site specific modelling using programs such as MUSIC may yield a more accurate result.

4.6.3 Estimating design flows

With a small catchment the Rational Method is considered an appropriate approach to estimate the 10 and 100 year ARI peak flow rates. The steps in these calculations follow below.

4.6.3.1 Major and minor design flows

The procedures in Australian Rainfall and Runoff (ARR) are used to estimate the design flows.

See Appendix E Design Flows – tc for a discussion on methodology for calculation of time of concentration.

Step 1 – Calculate the time of concentration.

Cell A and Cell B are effectively separate elements for the purpose of sizing the swales for flow capacity and inlets to the piped drainage system for a 10 year ARI peak flow event. Therefore, the t_c are estimated separately for each cell.

- Cell A– the t_c calculations include consideration of runoff from the allotments as well as from gutter flow along the collector road. Comparision of these travel times concluded the flow along the collector road 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 ARR, the following t_c values are estimated:

t_c Cell A : 10 mins

t_c Cell B: 8 mins

Rainfall Intensities for the area of study (for the 10 and 100 year average recurrence intervals) are estimated using ARR (1998) with a time of concentration of 10 minutes and 8 minutes respectively are:

	t_c	100yr	10yr
Cell A	10 min	135*	77*
Cell B	8 min	149*	85*

* These figures are for the worked example only. The appropriate region and corresponding rainfall intensities must be selected for each individual project.

Step 2 – Calculate design runoff coefficients (using the method outlined in Australian Rainfall and Runoff Book VIII (Engineers Australia, 2003)).

Apply method outlined in Section1.5.5 (iii) ARR 2001 Bk VIII

$C_{10} = 0.9f + C^1{}_{10}\,(1-f)$

Fraction impervious

Roads – adopt f = 0.90

Footpaths – adopt f = 0.50

Swales – adopt f = 0.00

Lots – adopt f = 0.60

- For Cell A (area weighted) f = 0.70
- For Cell B (area weighted) f = 0.61

Calculate C_{10} (10 year ARI runoff coefficient)

$C_{10} = 0.9f + C^1{}_{10}\ (1\text{–}f)$

- C_{10} for Cell A = 0.67
- C_{10} for Cell B = 0.61

Step 3 – Convert C_{10} to values for C_1 and C_{100}

Where – $C_y = F_y \times C_{10}$

Runoff coefficients as per Table 1.6 Book VIII ARR 1998

ARI (years)	Frequency Factor, *Fy*	Runoff Coefficient, *Cy (cell A)*	Runoff Coefficient, *Cy (cell B)*
10	1.0	0.67	0.61
100	1.2	0.80	0.73

Step 4 – Calculate peak design flow (calculated using the Rational Method).

$$Q = \frac{CIA}{360}$$

Where – C is the runoff coefficient (C_{10} and C_{100})

I is the design rainfall intensity mm/hr (I_{10} and I_{100})

A is the catchment area (Ha)

	Q_{10}	Q_{100}
Cell A	0.14	0.29
Cell B	0.06	0.11

4.6.3.2 Maximum infiltration rate

The maximum infiltration rate reaching the perforated pipe at the base of the soil media is estimated by using the hydraulic conductivity of the media and the head above the pipes and applying Darcy's equation.

Saturated permeability = 180 mm/hr

Flow capacity of the infiltration media:

$$Q_{\max} = k \cdot L \cdot W_{base} \cdot \frac{h_{\max} + d}{d}$$

$$Q_{\max} = 5E10^{-5} \cdot L \cdot W_{base} \left(\frac{0.2 + 0.6}{0.6} \right)$$

where k is the hydraulic conductivity of the soil filter (m/s)

W_{base} is the base width of the ponded cross section above the soil filter (m)

L is the length of the bioretention zone (m)

h_{max} is the depth of pondage above the soil filter (m)

d is the depth of filter media

Maximum infiltration rate Cell A = 0.004 m^3/s

Maximum infiltration rate Cell B = 0.001 m^3/s

4.6.4 Swale design

The swales need to be sized such that they can convey 10 year ARI flows into the underground pipe network without water encroaching on the road. Manning's equation is used with the following parameters. Note the depth of the swale (and hence the side slopes) were determined by the requirement of discharging allotment runoff onto the surface of the bioretention system. Given the cover requirements of the allotment drainage pipes as they flow under the service road (550 mm minimum cover), it set the base of the bioretention systems at 0.76m below road surface.

- Base width of 1m with 1:3 side slopes, max depth of 0.76m
- Grass vegetation (assume *n* = 0.045 for 10 year ARI with flows above grass height)
- 1.3% slope

The approach taken is to size the swale to accommodate flows in Cell A and then adopt the same dimension for Cell B for Aesthetic reasons (Cell B has lower flow rates).

The maximum capacity of the swale is estimated adopting a 150mm freeboard (i.e. maximum depth is 0.61m).

Q_{cap} = 2.1 m^3/s > 0.14 m^3/s

Therefore, there is adequate capacity given the relatively large dimensions of the swale to accommodate allotment runoff connection.

4.6.5 Inlet details

There are two mechanisms for flows to enter the system, firstly underground pipes (either from the upstream collector road into Cell 1 or from allotment runoff) and secondly direct runoff from road and footpaths.

Flush kerbs with a 50 mm set down are intended to be used to allow for sediment accumulation from 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.

4.6.6 Vegetation scour velocity check

Assume Q_{10} and Q_{100} will be conveyed through the swale/bioretention system. Check for scouring of the vegetation by checking that velocities are below 0.5m/s during Q_{10} and 1.0 m/s for Q_{100}.

Using Manning's equation to solve for depth for Q_{10} and Q_{100} gives the following results:

Q_{10} = 0.14 m^3/s, depth = 0.15m (with n = 0.3), velocity = 0.09m/s < 0.5m/s – therefore, OK

Q_{100} = 0.29 m^3/s, depth = 0.32m (with n = 0.05), velocity = 0.49m/s < 1.0m/s – therefore, OK

Hence, the swale and bioretention system can satisfactorily convey the peak 10 and 100-year ARI flood, with minimal risk of vegetation scour.

4.6.6.1 Safety velocity check

Check velocity – depth product in Cell A during peak 100-year ARI flow for pedestrian safety criteria.

V = 0.49m/s (calculated previously)

D = 0.32m

v.d = 0.49 x 0.32 = 0.16<0.4m^2/s (ARR 2001 Bk VIII Section1.10.4)

Therefore, velocities and depths are OK.

4.6.7 Sizing of perforated collection pipes

4.6.7.1 Perforations inflow check

Estimate the inlet capacity of sub-surface drainage system (perforated pipe) to ensure it is not a choke in the system. To build in conservatism, 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 is applied using the following parameters:

Head = 0.85 m [0.6 m (filter depth) + 0.2 m (max. pond level) + 0.05 (half of pipe diameter)]

The following are the characteristics of the selected slotted pipe

- Clear openings = 2100 mm^2/m
- Slot width = 1.5mm
- Slot length = 7.5mm
- No. rows = 6
- Diameter of pipe = 100mm

For a pipe length of 1.0 m, the total number of slots = 2100/(1.5 x 7.5) = 187.

Discharge capacity of each slot can be calculated using the orifice flow equation

$$Q_{perforation} = C \cdot A_{perforation}\sqrt{2gh} \; = 2.75 \times 10^{-5}\ m^3/s$$

where h is the head above the slotted pipe, calculated to be 0.85 m.

C is the orifice coefficient (~0.6)

The inflow capacity of the slotted pipe is thus 2.75 x 10^{-5} x 187 = 5.1 x 10^{-3} m^3/s/m-length

Adopt a blockage factor of 0.5 gives the inlet capacity of each slotted pipe to be 2.57 x 10^{-3} m^3/s/m-length.

Inlet capacity/m x total length =

Cell A = 0.0025 x 61 = 0.15 m^3/s > 0.003 (max infiltration rate), hence 1 pipe has sufficient perforation capacity to pass flows into the perforated pipe.

Cell B = 0.0025 x 22 = 0.05 m^3/s > 0.001 (max infiltration rate), hence 1 pipe is sufficient.

4.6.7.2 Perforated pipe capacity

The **Colebrook-White equation** is applied to estimate the flow rate in the perforated pipe. A slope of 0.5% is assumed and a 100mm perforated pipe (as above) 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 the Colebrook-White Equation

$$\mathbf{Q = -2(2gDS_f)^{0.5} \times \log\left[(k/3.7D) + (2.51\nu/D(2gDS_f)^{0.5})\right] \times A}$$

Adopt D = 0.10m

S_f = 0.005m/m

g = 9.81m^2/s

k = 0.007m

v = 1.007 x 10^{-6}

Q_{cap} = 0.004 m^3/s (for one pipe) > 0.003 m^3/s (Cell 1) 0.001 m^3/s (Cell 2), and hence 1 pipe is sufficient to convey maximum infiltration rate for both Cell A and B.

Adopt 1 x ϕ 100 mm perforated pipe for the underdrainage system in both Cell A and Cell B.

4.6.7.3 Drainage layer hydraulic conductivity

Typically flexible perforated pipes are installed using fine gravel media to surround them. In this case study, 5mm 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 100 mm of coarse sand.

4.6.7.4 Impervious liner requirement

In this catchment the surrounding soils are clay to silty clays with a saturate 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 > 10 times the conductivity of the surrounding soils and an impervious liner is not required.

4.6.8 Overflow design

The overflow pits are required to convey 10 year ARI flows safely from above the bioretention systems and into an underground pipe network. Grated pits are to be used at the downstream end of each bioretention system.

The size of the pits are calculated using a broad crested weir equation with the height above the maximum ponding depth and below the road surface, less freeboard (i.e. 0.76 – (.2 + .15)= 0.41m).

First check using a broad crested weir equation

$$P = \frac{Q_{des}}{B \cdot C_w \cdot H^{1.5}}$$

P = Perimeter of the outlet pit

B = Blockage factor (0.5)

H = 0.41Depth of water above the crest of the outlet pit

Q_{des} = Design discharge (m^3/s)

C_w = weir coefficient (1.7)

Gives P = .62m of weir length required (equivalent to 155 x 155mm pit)

Now check for drowned conditions:

$$A_o = \frac{Q_{des}}{B \cdot C_d \sqrt{2gH}}$$

C_d = Orifice Discharge Coefficient (0.6)

B = Blockage factor (0.5)

H = Depth of water above the centroid of the orifice (m)

A_o = Orifice area (m^2)

Q_{des} = Design discharge (m^3/s)

gives A = 0.16 m^2 (equivalent to 400 x 400 pit)

Hence, drowned outlet flow conditions dominate, adopt pit sizes of 450 x 450 mm for both Cell A and Cell B as this is minimum pit size to accommodate underground pipe connections.

4.6.9 Soil media specification

Three layer of soil media are to be used. A sandy loam filtration media (600mm) to support the vegetation, a coarse transition layer (100mm) and a fine gravel drainage layer (200mm). specifications for these are below.

4.6.9.1 *Filter media specifications*

The filter media is to be a sandy loam with the following criteria:

The material shall meet the geotechnical requirements set out below:

- hydraulic conductivity between 50-200 mm/hr
- particle sizes of between: clay 5 – 15 %, silt <30 %, sand 50 – 70 %
- between 5% and 10% organic content, measured in accordance with AS1289 4.1.1.
- pH neutral

4.6.9.2 *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:

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

4.6.9.3 *Drainage layer specifications*

The drainage layer is to be 5 mm screenings.

4.6.9.4 *Vegetation specification*

To compliment the landscape design of the area a grass species is to be used. For this application a turf with maximum height of 100 mm has been assumed. The actual species will be selected by the landscape designer.

4.6.9.5 *Calculation summary*

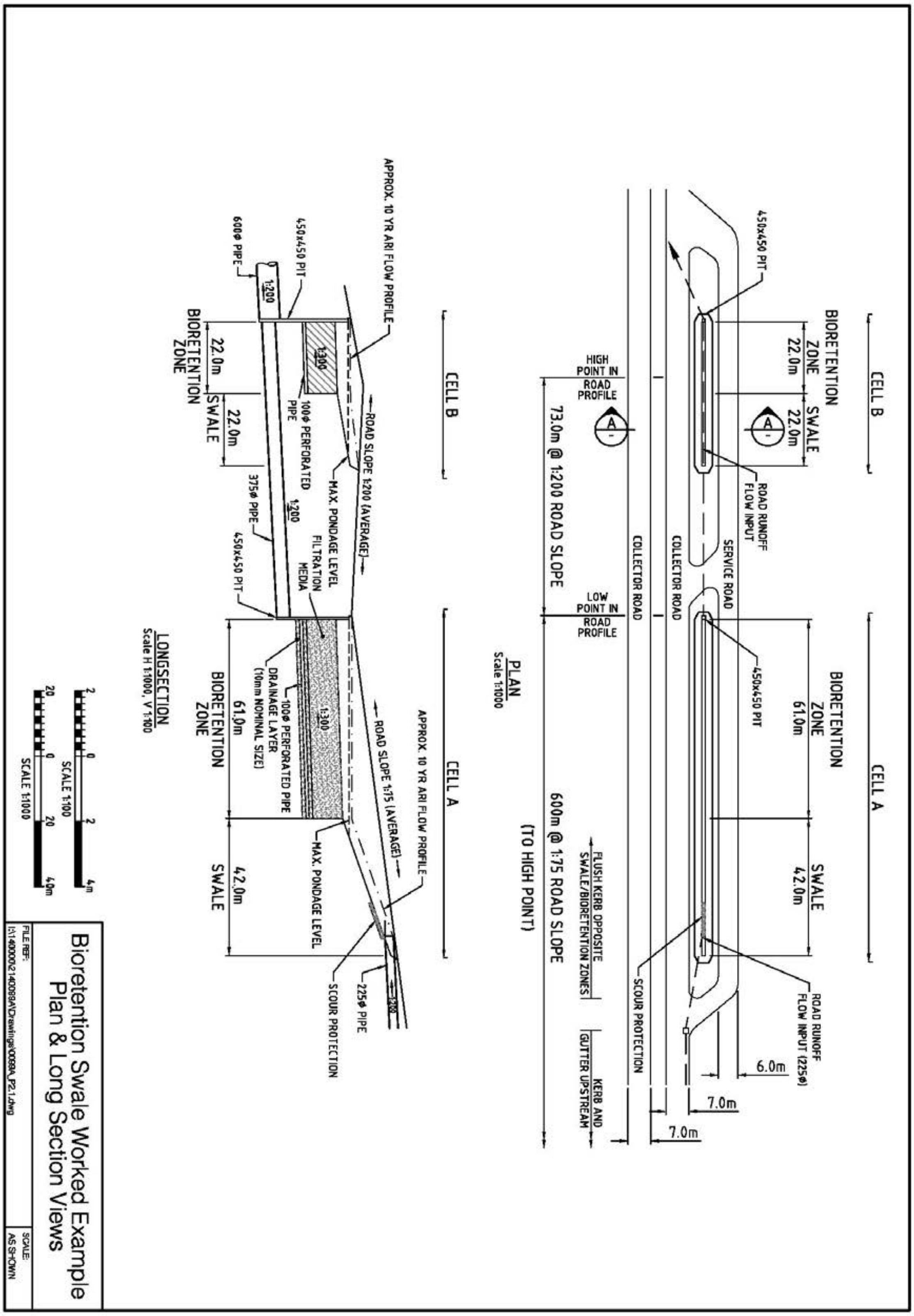
The sheet below shows the results of the design calculations.

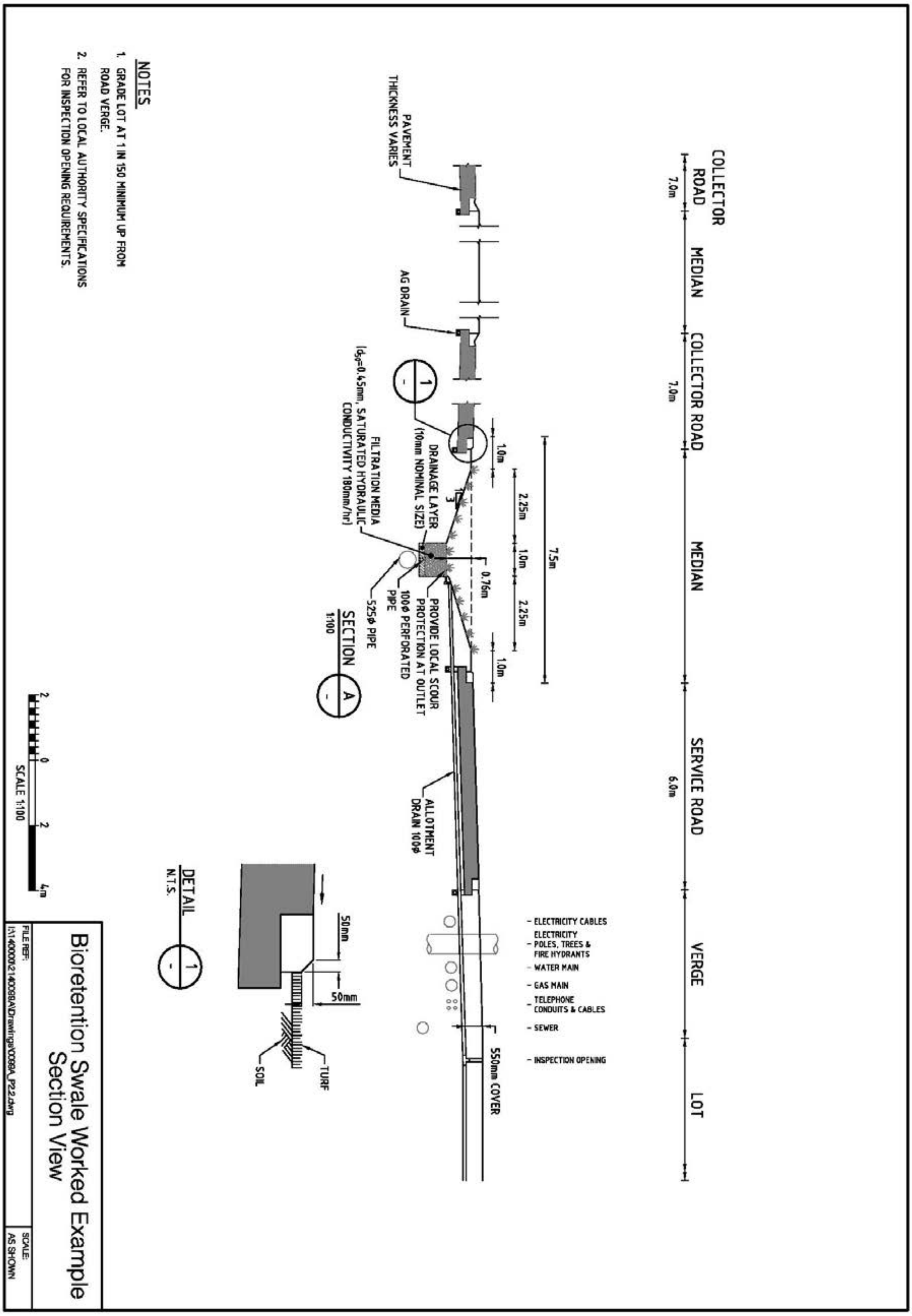
Bioretention Swales

CALCULATION SUMMARY

	CALCULATION TASK		OUTCOME		CHECK
1	**Identify design criteria**				
	conveyance flow standard (ARI)		10	year	
	area of bioretention		110 and 42	m^2	
	maximum ponding depth		200	mm	
	Filter media type		180	mm/hr	✓
2	**Catchment characteristics**				
		Cell A	9600	m^2	
		Cell B	4200	m^2	
		slope	1.3	%	
	Fraction impervious				
		Cell A	70		
		Cell B	0.61		✓
3	**Estimate design flow rates**				
	Time of concentration				
	estimate from flow path length and velocities		Cell A - 10	minutes	✓
			Cell B - 8		
	Identify rainfall intensities				
		station used for IFD data:			
		major flood - 100 year ARI		mm/hr	
		minor flood - 10 year ARI		mm/hr	
	Peak design flows		Cell A, Cell B		
		Q_{minor}	0.14, 0.06	m^3/s	
		Q_{100}	0.29, 0.11	m^3/s	
		Q_{infil}	0.004, 0.001	m^3/s	✓
3	**Swale design**				
		appropriate Manning's n used?	yes		✓
4	**Inlet details**				
		adequate erosion and scour protection?	rock pitching		✓
5	**Velocities over vegetation**				
		Velocity for 10 year flow (<0.5m/s)	0.09	m/s	
		Velocity for 100 year flow (<1.0m/s)	0.49	m/s	
		Safety: Vel x Depth (<0.4)	0.16	m/s	✓
6	**Slotted collection pipe capacity**				
		pipe diameter	100	mm	
		number of pipes	1		
		pipe capacity	0.004	m^3/s	
		capacity of perforations	0.15	m^3/s	
		soil media infiltration capacity	0.003	m^3/s	✓
8	**Overflow system**				
		system to convey minor floods	grated pits 450 x 450		✓
9	**Surrounding soil check**				
		Soil hydraulic conductivity	3.6	mm/hr	
		Filter media	180	mm/hr	
		MORE THAN 10 TIMES HIGHER THAN SOILS?	YES		✓
10	**Filter media specification**				
		filtration media	sandy loam		
		transition layer	sand		
		drainage layer	gravel		✓
11	**Plant selection**		*turf*		

4.6.10 Construction drawings




COLLECTOR ROAD
7.0m
MEDIAN
COLLECTOR ROAD
7.0m
MEDIAN
SERVICE ROAD
6.0m
VERGE
LOT
NOTES
1. GRADE LOT AT 1 IN 150 MINIMUM UP FROM ROAD VERGE.
2. REFER TO LOCAL AUTHORITY SPECIFICATIONS FOR INSPECTION OPENING REQUIREMENTS.
PAVEMENT THICKNESS VARIES
AG DRAIN
1.0m
2.25m
1.0m
2.25m
1.0m
7.5m
0.76m
3
DRAINAGE LAYER (10mm NOMINAL SIZE)
FILTRATION MEDIA (d_{50}=0.45mm, SATURATED HYDRAULIC CONDUCTIVITY 180mm/hr)
PROVIDE LOCAL SCOUR PROTECTION AT OUTLET
100ϕ PERFORATED PIPE
525ϕ PIPE
SECTION
1:100
A
ALLOTMENT DRAIN 100ϕ
- ELECTRICITY CABLES
- ELECTRICITY POLES, TREES & FIRE HYDRANTS
- WATER MAIN
- GAS MAIN
- TELEPHONE CONDUITS & CABLES
- SEWER
- INSPECTION OPENING
550mm COVER
DETAIL
N.T.S.
1
50mm
50mm
TURF
SOIL
SCALE 1:100
2
0
2
4m
Bioretention Swale Worked Example
Section View
FILE REF:
SCALE:
AS SHOWN

4.7 References

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