Chapter 5 Bioretention Basins

Definition:

A bioretention basin is a bioretention system that provides efficient treatment of stormwater through fine filtration, extended detention and some biological uptake.

Purpose:

- 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 basins operate with the same treatment processes as bioretention swales except do not have a conveyance function. High flows are either diverted away from a basin or are discharged into an overflow structure.
- Bioretention basins have an advantage of being applicable at a range of scales and shapes and can therefore have flexibility for locations within a development. They can be located along streets at regular intervals and treat runoff prior to entry into an underground drainage system, or be located at outfalls of a drainage system to provide treatment for much larger areas (e.g. in the base of retarding basins).

A wide range of vegetation can be used within a bioretention basin, allowing them to be well integrated into a landscape theme of an area. Smaller systems can be integrated with traffic calming measures or parking bays, reducing their requirement for space. They are equally applicable to redevelopment as well as greenfield sites.

Bioretention basins are applicable at a range of scales and can be integrated with an urban landscape

5.1 Introduction

Bioretention basins use ponding to maximise the volume of runoff treated through the filtration media. Their operation is the same as bioretention swales, but typically they convey above design flows through overflow pits or bypass paths, and are not required to convey flood flows over the filtration surface. This has the advantage of not subjecting the filter surface to high velocities that can dislodge collected pollutants or scour vegetation.

These devices can be installed at various scales, for example, in planter boxes, in retarding basins or in streetscapes integrated with traffic calming measures. In larger applications, it is considered good practice to have pretreatment measures upstream of the basin to reduce the maintenance frequency of the bioretention basin. For small systems this is not required.

Figure 5.1 shows an example of a basin integrated into a local streetscape and a car park.

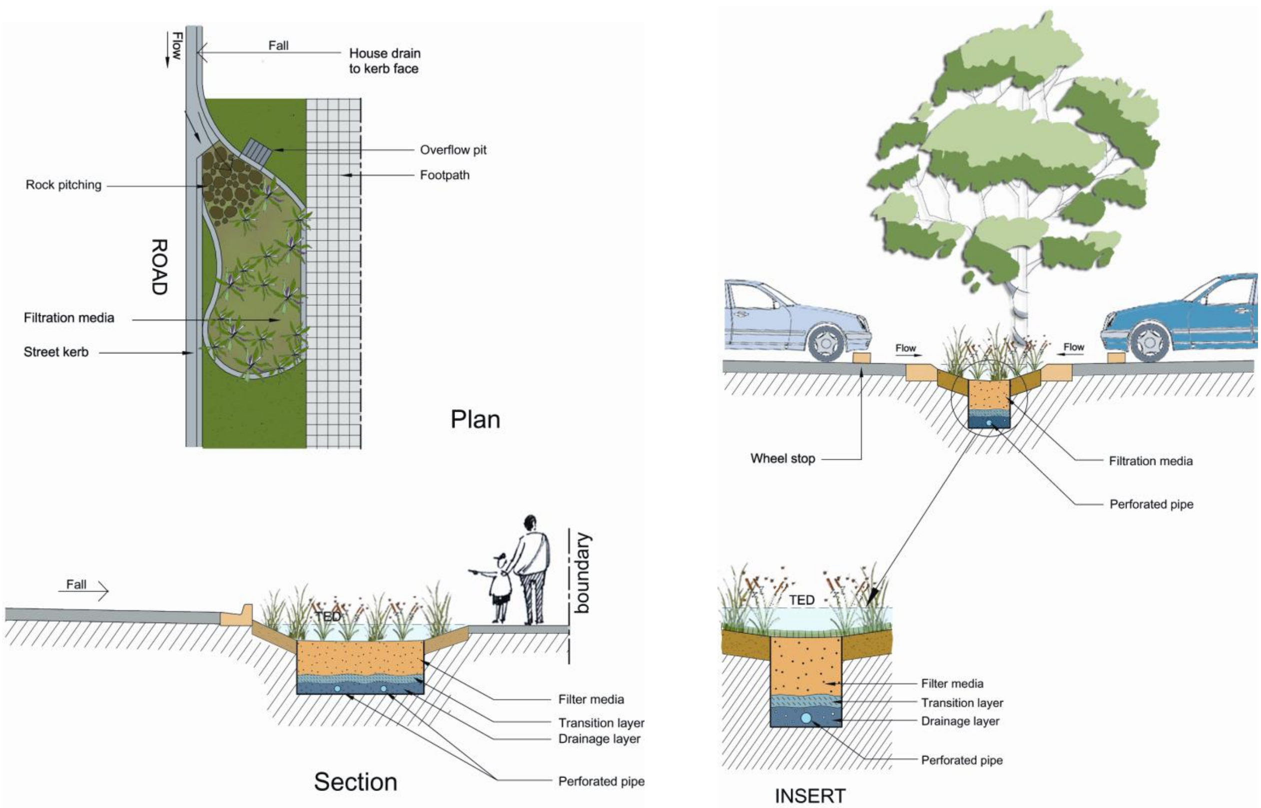


Figure 5.1. Bioretention basin integrated into a local streetscape (L) and a car park (R)

They 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 perform a 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.

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 absorb 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 a trade-off between providing sufficient hydraulic conductivity (ie. passing water through the filtration media as quickly as possible) and providing sufficient water retention to support vegetation growth (i.e. retaining sufficient moisture by having low hydraulic conductivities). Typically a sandy loam type material is suitable, however the soils can be tailored to a vegetation type.

A drainage layer is required. 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 to prevent any filtration media being washed into the perforated pipes.

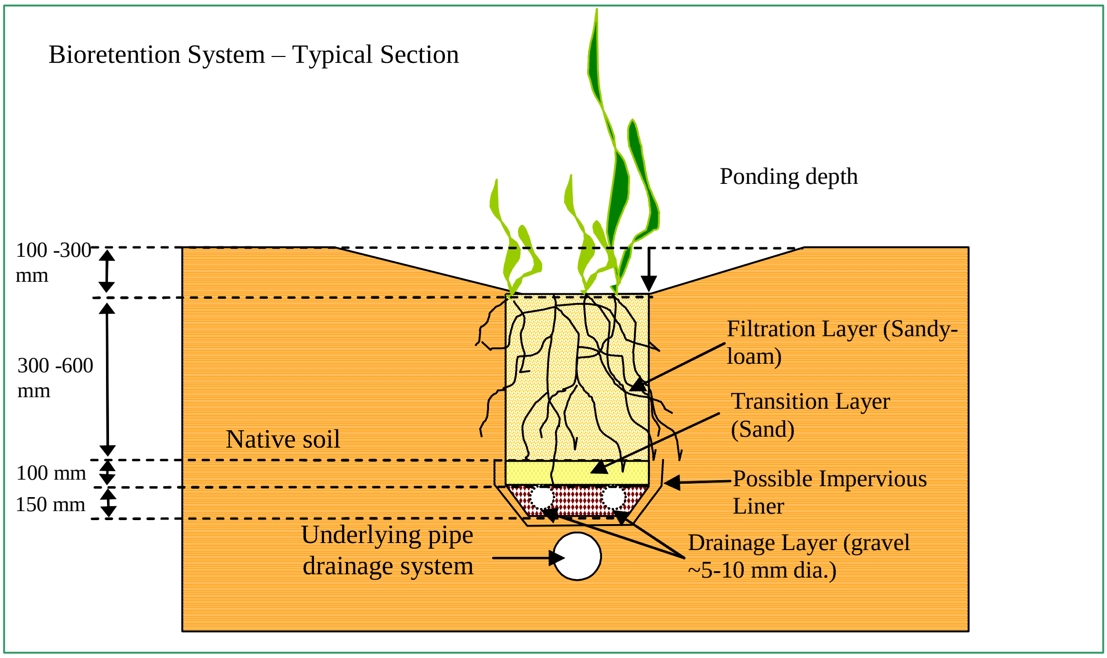


Figure 5.2. Typical section of an bioretention basin

The design process for a bioretention basin is slightly different to bioretention swales, as they do not need to be capable of conveying large floods (e.g. 5-year flows) over their surface and an alternative route for flood flows is required.

Key design issues to be considered are:

- Verifying size and configuration for treatment
- Determine design capacity and treatment flows
- Specify details of the filtration media
- Above ground design:
  - check velocities
  - design of inlet zone and overflow pits
  - check above design flow operation
- Below ground design:

  - 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

5.2 Verifying size for treatment

The curves below show the pollutant removal performance expected for bioretention basins with varying depths of ponding. The curves are based on the performance of the system at the reference site and were derived using the Model for Urban Stormwater improvement Conceptualisation (MUSIC). To estimate an equivalent performance at other locations in Tasmania, the hydrologic design region relationships should be used, refer to 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
- Particle size 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.

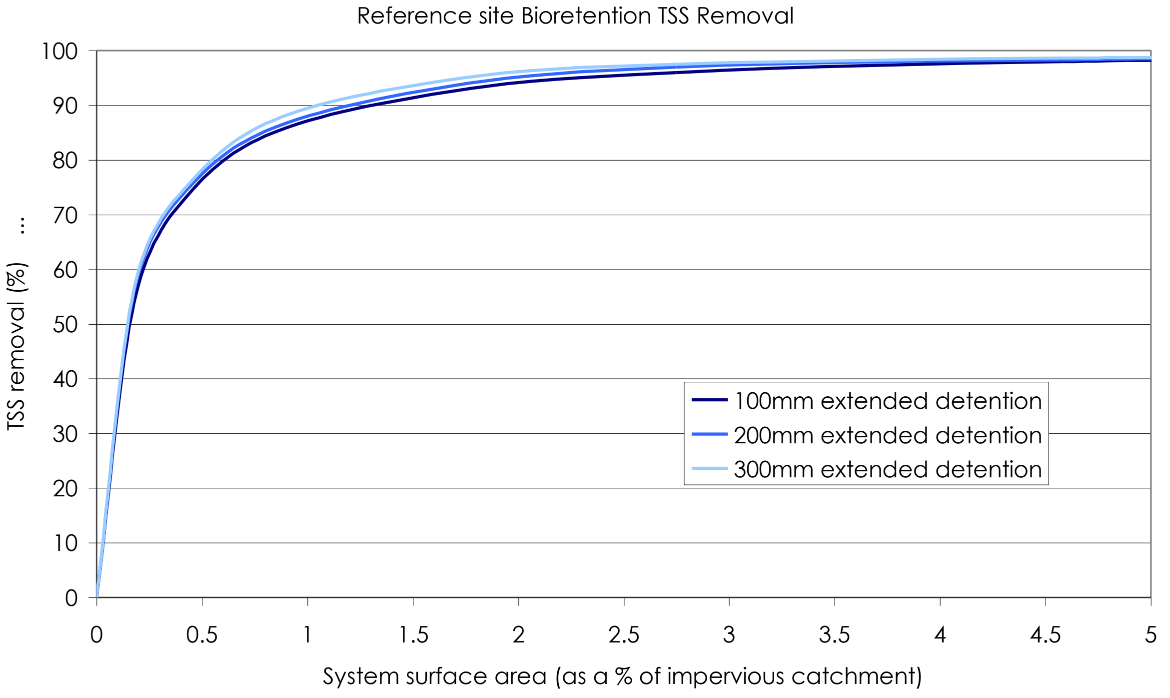


Figure 5.3. TSS removal in bioretention systems with varying extended detention

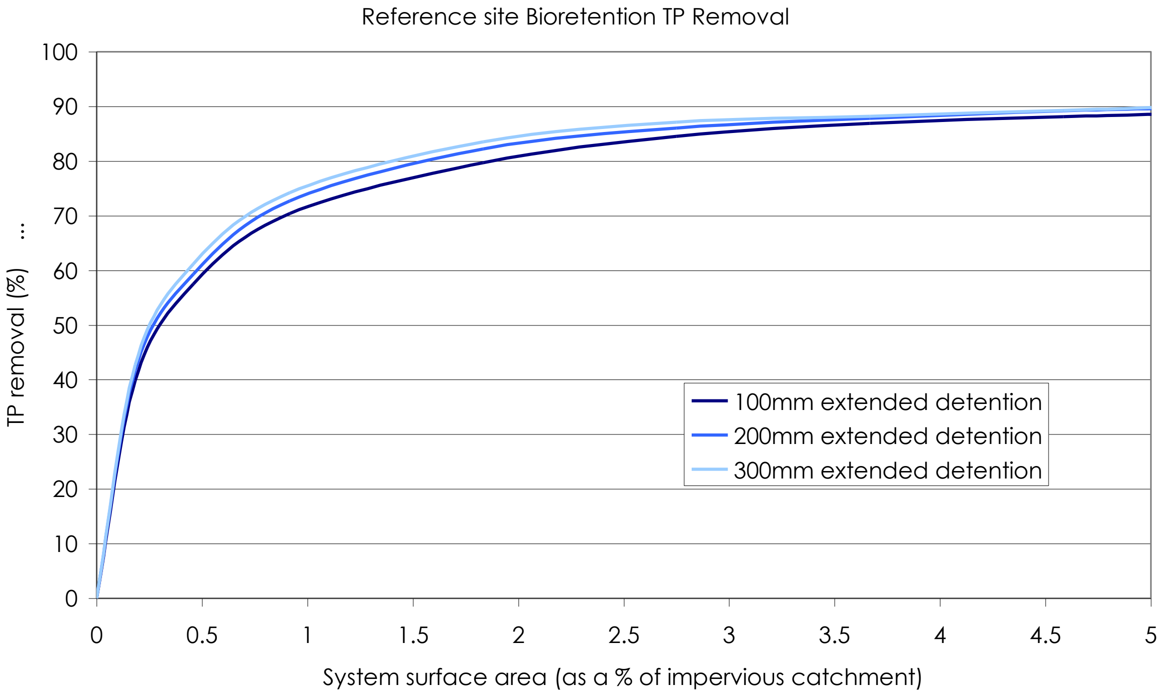


Figure 5.4. TP removal in bioretention systems with varying extended detention

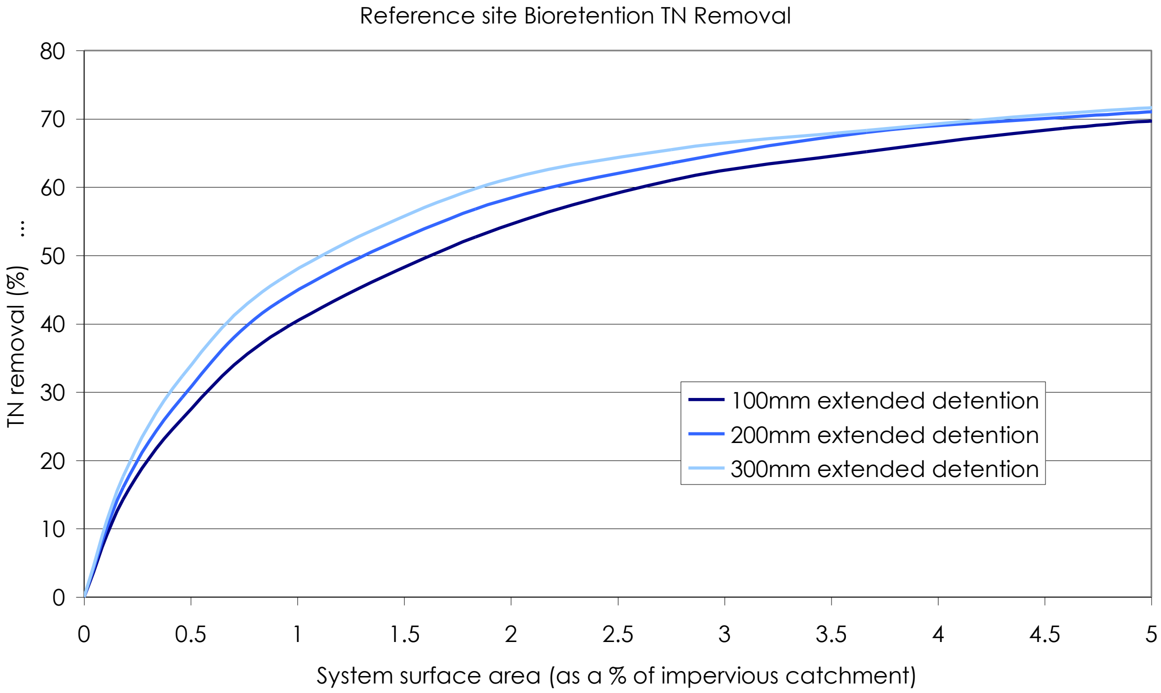


Figure 5.5. TN removal in bioretention systems with varying extended detention

5.3 Design procedure: bioretention basins

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

5.3.1 Estimating design flows

Three design flows are required for bioretention basins:

- 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 the filter media to freely drain.

5.3.1.1 *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. More detailed flow analysis is required for larger catchment-scale systems.

5.3.1.2 *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 5.1

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

W is the average width of the ponded cross section above the sand filter (m)

L is the length of the bioretention zone (m)

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

5.3.2 Inlet details

Two checks of inlet details are required for bioretention basins, checking the width of flow in the gutter at the inlet (so traffic is not affected) and checking velocities to ensure scour doesn't occur at the entry for both minor and major storm events.

5.3.2.1 Flow widths at entry

The width of flow at the entry during a minor storm event (typically 5 year ARI) needs to be checked. This can be done by applying Manning's equation and ensuring that flows do not exceed local council regulations (e.g. maintaining at least one trafficable lane during a 5-year ARI storm).

5.3.2.2 Kerb opening width at entry

To determine the width of the inlet slot in the kerb into the bioretention basin, Manning's equation can be used with the kerb, gutter and road profile to estimate flow depths at the entry point. Once the flow depths for the minor storm (e.g. 5-year ARI) is estimated, this can be used to calculate the required width of opening in the kerb by applying a broad crested weir equation. This ensures free draining flows into the bioretention basin. The opening width is estimated by applying the flow depth in the gutter (as H) and solving for L (opening width).

$$Q = C.L.H^{3/2} \quad \text{with } C=1.7$$

Equation 5.2

5.3.2.3 Inlet scour protection

It is considered good practice to provide erosion protection for flows as they enter a bioretention basin. Typically velocities will increase as flows drop from the kerb invert into the top of the bioretention soil media. Rock beaching is a simple method for managing these velocities.

5.3.3 Vegetation scour velocity check

Scour velocities over the vegetation are checked through the bioretention basin by assuming the system flows at a depth equal to the ponding depth across the full with of the system. Then by dividing the design flow rate by the cross sectional area, an estimate of flow velocity can be made. It is a conservative approach to assume that all flows pass through the bioretention basin (particularly for a 100 year ARI) however this will ensure the integrity of the vegetation.

Velocities should be kept below:

- 0.5 m/s for 5-year ARI discharges
- 1.0 m/s for 100-year ARI discharges

5.3.4 Size slotted 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.

Treated water that has passed through the filtration media is directed into slotted pipes via a ‘drainage layer’ (typically fine gravel or coarse sand, 1-5 mm diameter). To convey water from the filtration media and into the perforated pipe, flows must pass through the drainage layer. The purpose of the drainage layer is to efficiently convey treated flows into the perforated pipes while preventing any of the filtration media from being washed downstream.

If gravel is used around the perforated pipes an additional ‘transition’ layer is recommended 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.

<u>DESIGN NOTE</u> – 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. Product information may be available from suppliers (for example Vinidex, www.vinidex.com.au; or Iplex, www.iplex.com.au/).

5.3.4.1 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 5.3

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.

5.3.4.2 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

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

Equation 5.4

Where D = pipe diameter

A = area of the pipe

S_f = pipe slope

k = wall roughness

ν = viscosity

g = gravity constant

5.3.4.3 *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).

5.3.4.4 *Impervious liner requirement*

When infiltration is not to be encouraged, stormwater is treated via filtration through a specified soil media with the filtrate collected via a sub-surface drainage system to be either discharge as treated surface flow or collected for reuse. The amount of water lost to surrounding soils is highly dependent on local soils and the hydraulic conductivity of the filtration media in the bioretention system. Typically the hydraulic conductivity of filtration media (sandy loam) is 1-2 orders of magnitude greater than the native surrounding soil profile therefore the preferred flow path is into the perforated underdrainage system.

Where bioretention basins are installed near to significant structures care should be taken to minimise any leakage from the bioretention system. Soil tests of the surrounding soils should be made and the expected hydraulic conductivity estimated (this can be measured with practices described in Chapter 11 Australian Runoff Quality [Engineers Australia, 2006]).

During a detailed design it is considered good practice to provide an impervious liner where the saturated hydraulic conductivity of the surrounding soils is under one order of magnitude less than the filtration media. This is only expected to be required in sandy loam to sandy soils and where infiltration is expected to create problems.

In many roadside applications, a drainage trench runs parallel with the road and will collect any seepage from a bioretention system.

If surrounding soils are very sensitive to exfiltration from the bioretention basin (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 a bioretention system. It is considered that the lining of the whole bioretention system in some terrain can be problematic. Fully lined bioretention systems could create sub-surface barriers to shallow groundwater movements. In areas of shallow groundwater any interruption to groundwater movements could increase groundwater levels.

It is considered the greatest risk of exfiltration was through the floor of the 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. To minimise the likelihood of exfiltration from the floor of the bioretention it was concluded the floor of the bioretention should be lined and shaped to ensure the most efficient drainage of the floor of the bioretention basin.

5.3.5 High-flow route and by-pass design

The intention of the high flow design is to convey safely the minor floods (e.g. 5-year ARI flows) to the same level of protection that a conventional stormwater system provides. Bioretention basins are typically served with either grated overflow pits or conventional side entry pits (located downstream of an inlet) to transfer flows into an underground pipe network (the same pipe network that collects treated flows).

The location of the overflow pit is variable but it is desirable to ensure that flows do not pass through extended length of vegetation. Grated pits can be located near the inlet to minimize the flow path length for above design flows. A level of conservatism is built into the design of grated overflow pits by placing their inverts at least 100 mm below the invert of the street gutter (and therefore the maximum ponding depth). This allows the overflow to convey a minor flood prior to any afflux effects in the street gutter. The overflow pit should be sized to pass a five year ARI storm with the available head below the gutter invert (i.e. 100 mm).

Overflow pits can also be located external to bioretention basins, potentially in the kerb and gutter immediately downstream of the inlet to the basin. In this way the overflow pit can operate in the same was as a conventional side entry pit, with flows entering the pit only when the bioretention system is at maximum ponding depth.

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.

1. **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 5.5

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)

2. **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 5.6

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.

5.3.6 Soil media specification

At least two and possibly three types of soil media are required for bioretention basins.

A filter media layer provides the majority of the treatment function and supports vegetation. It is required to have sufficient depth to support the vegetation, usually between 300–1000 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.

5.3.6.1 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 subsistence 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 sediment 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, 50–200 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 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 tests can demonstrate an adequate hydraulic conductivity ($1–5 \times 10^{-5}$ m/s).

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, 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 retardant to plant growth and denitrification should be rejected.

5.3.6.2 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 5.1 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 5-1. Hydraulic conductivity for a range of media particle sizes (d_{50}).

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}

5.3.6.3 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.

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

5.3.7 Vegetation specification

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

5.3.8 Design calculation summary

Bioretention basins **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:		
		100 year ARI	mm/hr	
		5 year ARI	mm/hr	
	Peak design flows			
		Q_5	m^3/s	
		Q_{100}	m^3/s	
		Q_{infil}	m^3/s	☐
4	**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	
		CHECK PIPE CAPACITY > SOIL CAPACITY		☐
5	**Check flow widths in upstream gutter**			
		Q_5 flow width	m	
		CHECK ADEQUATE LANES TRAFFICABLE		☐
6	**Kerb opening width**			
		width of brak in kerb for inflows	m	☐
7	**Velocities over vegetation**			
		Velocity for 5 year flow (<0.5m/s)	m/s	
		Velocity for 100 year flow (<1.0m/s)	m/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**			☐

5.4 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).

5.4.1 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 5.4.4).

Bioretention Basin 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?		
Overall flow conveyance system sufficient for design flood event?		
Maximum upstream flood conveyance width does not impact on traffic amenity?		
Velocities at inlet and within bioretention system will not cause scour?		
Bypass sufficient for conveyance of design flood event?		
Bypass has set down of at least 100mm below kerb invert?		
Collection System	**Y**	**N**
Slotted pipe capacity > infiltration capacity of filter media?		
Maximum spacing of collection pipes <1.5m?		
Transition layer/geofabric barrier provided to prevent clogging of drainage layer?		
Basin	**Y**	**N**
Maximum ponding depth will not impact on public safety?		
Selected filter media hydraulic conductivity > 10x hydraulic conductivity of surrounding soil?		
Maintenance access provided to base of bioretention (where reach to any part of a basin >6m)?		
Protection from gross pollutants provided (for larger systems)?		
Vegetation	**Y**	**N**
Plant species selected can tolerate periodic inundation?		
Plant species selected integrate with surrounding landscape design?		
Detailed soil specification included in design?		

5.4.2 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. Staged implementation may be used – i.e. during building use geofabric, soil (e.g. 50mm) 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.

Traffic and deliveries

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

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).

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 remove and plant out with long term vegetation.

Planting strategy

A planting strategy for a development will depend on the timing of 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).

Perforated pipes

Perforated pipes can be either 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 reduced 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.

Inspection openings

It is good design practice to have inspection openings at the end of the perforated pipes. The pipes should be brought to the surface and have a sealed capping. This allows inspection of sediment buildup and water level fluctuations when required and easy access for maintenance. The vertical component of the pipe should not be perforated otherwise short circuiting can occur.

Clean filter media

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

5.4.3 Construction checklist

CONSTRUCTION INSPECTION CHECKLIST

Bioretention basins

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					15. Location and levels of pits as designed				
					16. Safety protection provided				
2. Traffic control measures					17. Pipe joints and connections as designed				
3. Location same as plans					18. Concrete and reinforcement as designed				
4. Site protection from existing flows					19. Inlets appropriately installed				
Earthworks					20. Inlet erosion protection installed				
5. Bed of basin correct shape					21. Set down to correct level for flush kerbs				
6. Batter slopes as plans					**Vegetation**				
7. Dimensions of bioretention area as plans					22. Stablisation immediately following earthworks				
8. Confirm surrounding soil type with design									
9. Provision of liner					23. Planting as designed (species and densities)				
10. Perforated pipe installed as designed									
11. Drainage layer media as designed					24. Weed removal before stabilisation				
12. Transition layer media as designed									
13. Filter media specifications checked									
14. Compaction process as designed									
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.

5.4.4 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?		

5.5 Maintenance requirements

Bioretention basins treat runoff by filtering it through vegetation and then passing the runoff vertically through a filtration media which filters the runoff. Besides vegetative filtration, treatment relies upon infiltration of runoff into an underdrain. Vegetation plays a key role in maintaining the porosity of the surface of the filter media 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 poor building controls.

Maintenance is primarily concerned with:

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

Vegetation maintenance will include:

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

Sediment accumulation at the inlets needs to be monitored. Depending on the catchment activities (e.g. building phase) the deposition of sediment can smother plants and reduce the ponding depth available. Excessive sediment build up will impact on plant health and require removal before it reduces the infiltration rate of the filter media.

Similar to other types of 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.

5.5.1 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 Basin 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 basin?			
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?			
Damage/vandalism to structures present?			
Surface clogging visible?			
Drainage system inspected?			
Resetting of system required?			
Comments:			

5.6 Bioretention basin worked example

5.6.1 Worked example introduction

A series of bioretention basins, designed as street traffic parking "out-stands" is to be retrofitted into a local street to treat road runoff. The local street is in inner Hobart. A proposed layout of the bioretention system is shown in Figure 5.6 and an image of a similar system to that proposed is shown in Figure 5.7.

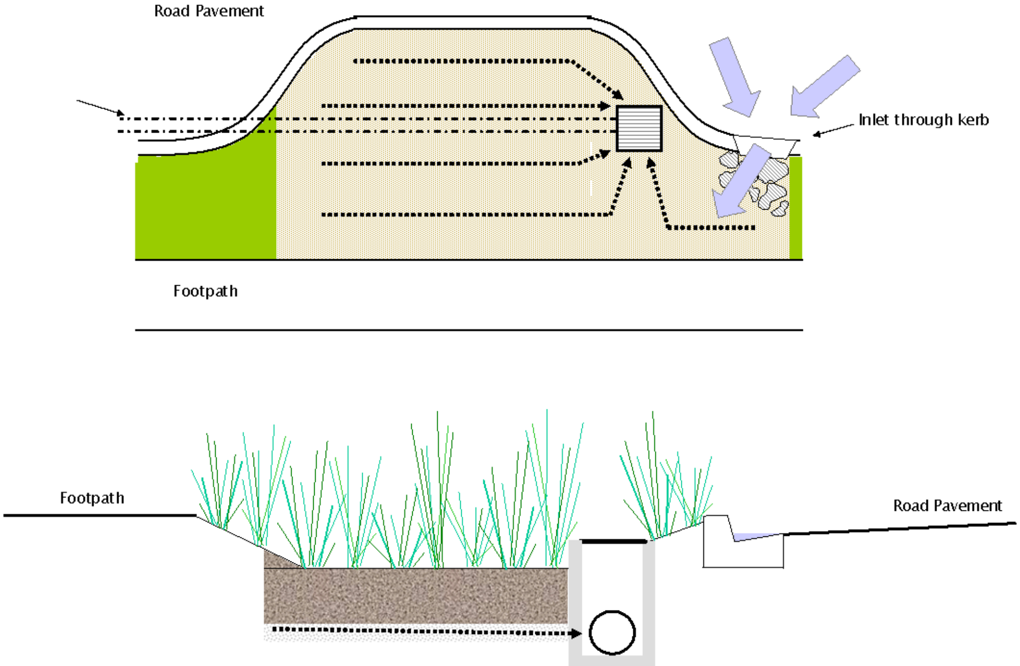


Figure 5.6General Layout and Cross Section of Proposed Bioretention System

Figure 5.7. Retrofitted Bioretention System in a street

The contributing catchment areas to each of the individual bioretention basins consist of 300 m^2 of road and footpath pavement and 600 m^2 of adjoining properties. Runoff from adjoining properties (approx. 60% impervious) is discharged into the road gutter and, together with road runoff, is conveyed along a conventional roadside gutter to the bioretention cell.

The aim of the design is to facilitate effective treatment of stormwater runoff while maintaining a 5-year ARI level of flood protection for the local street. The actual size of the cell may however, be increased to suit other streetscape objectives. The maximum width (measured perpendicular to the alignment of the road) of the bioretention basin is to be two metres. Analyses to detail the operation of the bioretention basin are shown below and demonstrate the design procedures. The analyses include:

- Road and gutter details to convey water into the basin
- Detailing inlet conditions to provide for erosion protection
- Configuring and designing a system for above-design operation that will provide the required 5-year ARI flood protection for the local street
- Sizing of below ground drainage system
- Specification of the soil filtration medium
- Landscape layout and details of vegetation

5.6.1.1 Design Objectives

Treatment to meet current best practice objectives of 80%, 45% and 45% reductions of TSS, TP and TN respectively whilst maintaining a 5 year ARI level of flood protection for the local street.

5.6.1.2 Constraints and Concept Design Criteria

Analyses during a concept design determined the following criteria:

- A bioretention basin area of 10 m^2 (minimum) is required to achieve the water quality objectives.
- The maximum width of the bioretention basin is to be 2m.
- The extended detention depth is 200 mm.
- Filter media shall be a sandy loam.

5.6.1.3 Site Characteristics

• Land Use	Urban, paved carpark and footpaths, lots.		
• Overland flow slope	1% typical.		
• Soil	Assumed to be clay		
• Catchment Area	Carpark	= 300 m^2
	Lots	= 600 m^2
• Fraction Impervious	Carpark	= 0.90
	Lots	= 0.60

5.6.2 Confirm size for treatment

Interpretation of Figures 5.3 to 5.5 with the input parameters below is used to estimate the reduction performance of the bioretention basin for the three pollutants.

- Hobart location

- 200mm extended detention
- treatment area to impervious area ration of:

  $10m^2 / [(0.9x300) + (0.6x600)]m^2 = 1.60\%$

From the graphs, the expected pollutant reductions are 85%, 69% and 45% for TSS, TP and TN respectively and exceed the design requirements of 80%, 45% and 45%.

DESIGN NOTE – The values derived from 5.2 Verifying 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.

5.6.3 Estimating design flows

5.6.3.1 Major and minor design flows

With a small catchment the Rational Method is considered an appropriate approach to estimate the 5 and 100 year ARI peak flow rates. The steps in these calculations follow below.

See **Error! Reference source not found.** for a discussion on methodology for calculation of time of concentration.

Step 1 – Calculate the time of concentration.

DESIGN NOTE – See Sand Filters chapter section 6.6.3 for more information on Tc.

$$Tc = \frac{91 \times 0.015}{0.063^{0.1} \times 10^{0.2}}$$

$$= 1.365 / 1.202$$

$$= 1.135 \text{ minutes}$$

- Gutter flow: adopt flow path length of 50 m to bioretention.

  Assume gutter velocity = 1m/s

  Flow time = 50/1 = 50sec

Adopt t_c = 1.135 + 0.8 = 1.95 min Assume minimum of 6 minutes

Design rainfall intensities

- Using a time of concentration of 6 minutes, the design rainfall intensities from the IFD chart relevant to the catchment location are –

	5yr	100yr
Intensity (mm/hr)	72+	150+

* 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 run-off coefficients (using the method outlined in Australian Rainfall and Runoff Book VIII (Engineers Australia, 2003)).

Where – Fraction impervious (f) = 0.9

Rainfall intensity ($^{10}I_1$) = 28.6mm/hr (from the relevant IFD chart)

Calculate C^1_{10} (pervious run-off coefficient)

$$C^1_{10} = 0.1 + 0.0133\ (^{10}I_1 - 25) = 0.15$$

Calculate C_{10} (10 year ARI run-off coefficient)

$$f = 0.06 \times 0.6 + 0.03 \times \frac{0.90}{(0.06+.03)}$$

$$= 0.70$$

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

$$C_{10} = 0.67$$

Step 3 – Convert C_{10} to values for C_5 and C_{100}

Where – $C_y = F_y \times C_{10}$

From Table 1.6 in Australian Rainfall and Runoff – Book VII;

C_5 = $0.95 \times C_{10} = 0.64$

C_{100} = $1.2 \times C_{10} = 0.81$

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

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

Where – C is the runoff coefficient (C_5 and C_{100})

I is the design rainfall intensity mm/hr (I_5 and I_{100})

A is the catchment area (Ha)

Q_5 = 0.012 m^3/s (16 L/s)

Q_{100} = 0.030 m^3/s (93 L/s)

5.6.3.2 Maximum infiltration rate

The maximum infiltration rate (Q_{max}) through the sand filter is computed using Darcy's equation, i.e.

$$Q_{max} = k \cdot A \cdot \frac{h_{max} + d}{d} = 0.0067\ m^3/s$$

where k is the hydraulic conductivity of sand = 5×10^{-5} m/s (Engineers Australia, 2003, Ch. 9)

A is the surface area of the sand filter = 10 m^2

h_{max} is the depth of pondage above the sand filter = 0.2 m

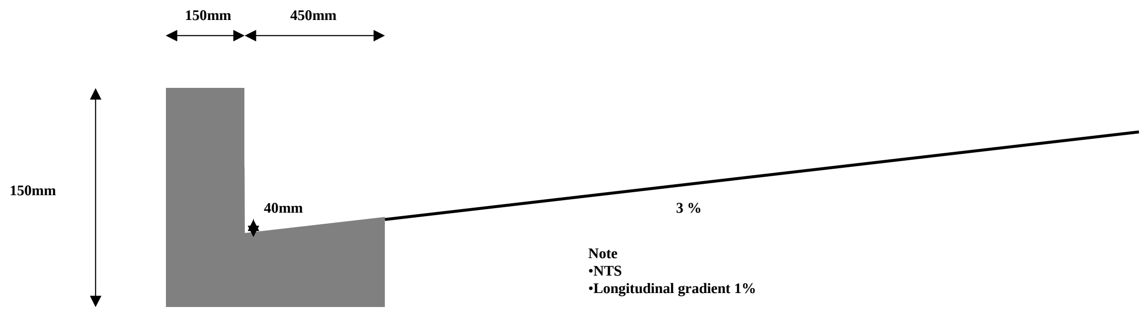
d is the depth of the sand filter = 0.6 m

5.6.3.3 Inlet details

Flow width at entry

A check of the flow capacity of the system and the width of the flow across the road needs to be performed to ensure the road is protected to council standards for a minor (5 year ARI) flood. In this case council has a criterion of having less than 2 metre wide flow in the gutter, which facilitates one trafficable lane during a minor flood.

Adopt following kerb, gutter and road profile, with a longitudinal gradient of 1% along the gutter the following flow and depth estimates can be made using the Manning's equation.



- Check flow capacity and width of flow
- Assume uniform flow conditions, estimate by applying Manning's equation

$Q_{5\ Year}$ = 0.012 m^3/s

Depth of Flow = 55 mm

Width of Flow = 900 mm (within gutter)

Velocity = 0.6 m/s (within gutter)

The estimated peak flow width during the $Q_{5\ Year}$ storm event is appropriate for the development (<2.0 m during minor storm flow).

Q_{100} = 0.030 m^3/s Depth of Flow = 70 mm

Width of Flow = 1.45 m (within gutter)

Velocity = 0.8 m/s (within gutter)

Kerb opening at entry

The flow depth in the gutter estimated above is used to determine the required width of opening in the kerb to allow for flows to freely flow into the bioretention system.

Q_5 = 0.012 m^3/s

Assume broad crested weir flow conditions through the slot

$Q_{minor} = B.C.L.H^{3/2}$

with $B = 1.0$,

$C = 1.7$ and

H (Flow depth Q_5) = 0.055 and solving for L

$\therefore$ $L = Q_5/(CH^{3/2}) = (0.012)/(1.7 \times 0.055^{3/2}) = 0.55$ m

Therefore adopt a 0.6m wide opening in the kerb at the inlet.

Inlet scour protection

Rock beaching is to be provided at the inlet to manage flow velocities from the kerb and into the bioretention system. This detail is shown on the diagrams.

5.6.4 Vegetation scour velocity check

Assume Q_5 and Q_{100} will be conveyed through the bioretention system. Check for scouring of the vegetation by checking that velocities are below 0.5m/s during Q_5 and 1.0 m/s for Q_{100}.

Width of bioretention = 2 m

Extended detention depth = 0.2 m

Area = 2 x 0.2 = 0.4 m^2

Q_5 average velocity = 0.012/0.4 = 0.03 m/s < 0.5 m/s – therefore OK

Q_{100} average velocity = 0.03/0.4 = 0.08 m/s < 1.0m/s – therefore OK

Hence, bioretention system can satisfactorily convey the peak 5 and 100-year ARI flood, minimising the potential for scour.

5.6.5 Size perforated collection pipes

5.6.5.1 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, i.e.

$$Q_{perforation} = C \cdot A_{perforation}\sqrt{2gh} = 2.67 \times 10^{-5}\ m^3/s$$

where h is the head above the slotted pipe, calculated to be 0.80 m.

C is the orifice coefficient (~0.6)

The inflow capacity of the slotted pipe is thus $2.67 \times 10^{-5} \times 187 = 5 \times 10^{-3}$ m^3/s/m-length

Adopt a blockage factor of 0.5 gives the inlet capacity of each slotted pipe to be 2.5×10^{-3} m^3/s/m-length.

Inlet capacity/m x total length = 0.0025 x 5 = 0.0125 m^3/s > 0.0067 (max infiltration rate), hence OK.

5.6.5.2 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

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

Where D = pipe diameter

A = area of the pipe

S_f = pipe slope

k = wall roughness

ν = viscosity

g = gravity constant

Total discharge capacity = 0.019 m^3/s > maximum infiltration rate of 0.0067 m^3/s ➔ OK

Adopt 1 x ϕ 100 mm perforated pipe for the underdrainage system.

5.6.5.3 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 later into the perforated pipe a transition layer is to be used. This is to be 100 mm of coarse sand.

5.6.5.4 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 > 10times the conductivity of the surrounding soils and an impervious liner is not considered to be required.

5.6.6 High flow route and by-pass design

The overflow pit is required to convey 5 year ARI flows safely from above the bioretention system into an underground pipe network. Grated pits are to be used at the upstream end of the 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, (i.e. 100mm).

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 = 0.1m Depth of water above the crest of the outlet pit

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

C_w = weir coefficient (1.7)

Gives P = .44m of weir length required (equivalent to 115 x 115mm 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 (0.1m)
A_o = Orifice area (m^2)
Q_{des} = Design discharge (m^3/s)

gives A = 0.16 m^2 (equivalent to 170 x 170 pit)

Hence, drowned outlet flow conditions dominate, adopt pit sizes of 600 x 600 mm for this systems as this is minimum pit size to accommodate underground pipe connections.

5.6.7 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.

5.6.7.1 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

5.6.7.2 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 %

5.6.7.3 Drainage layer specifications

The drainage layer is to be 5 mm screenings.

5.6.8 Vegetation specification

With such a small system it is considered to have a single species of plants within the bioretention system. For this application a Tall Sedge (*Carrex appressa*) is proposed with a planting density of 8 plants /m^2. More information on maintenance and establishment is provided in Appendix B.

5.6.9 Calculation summary

The sheet below shows the results of the design calculations.

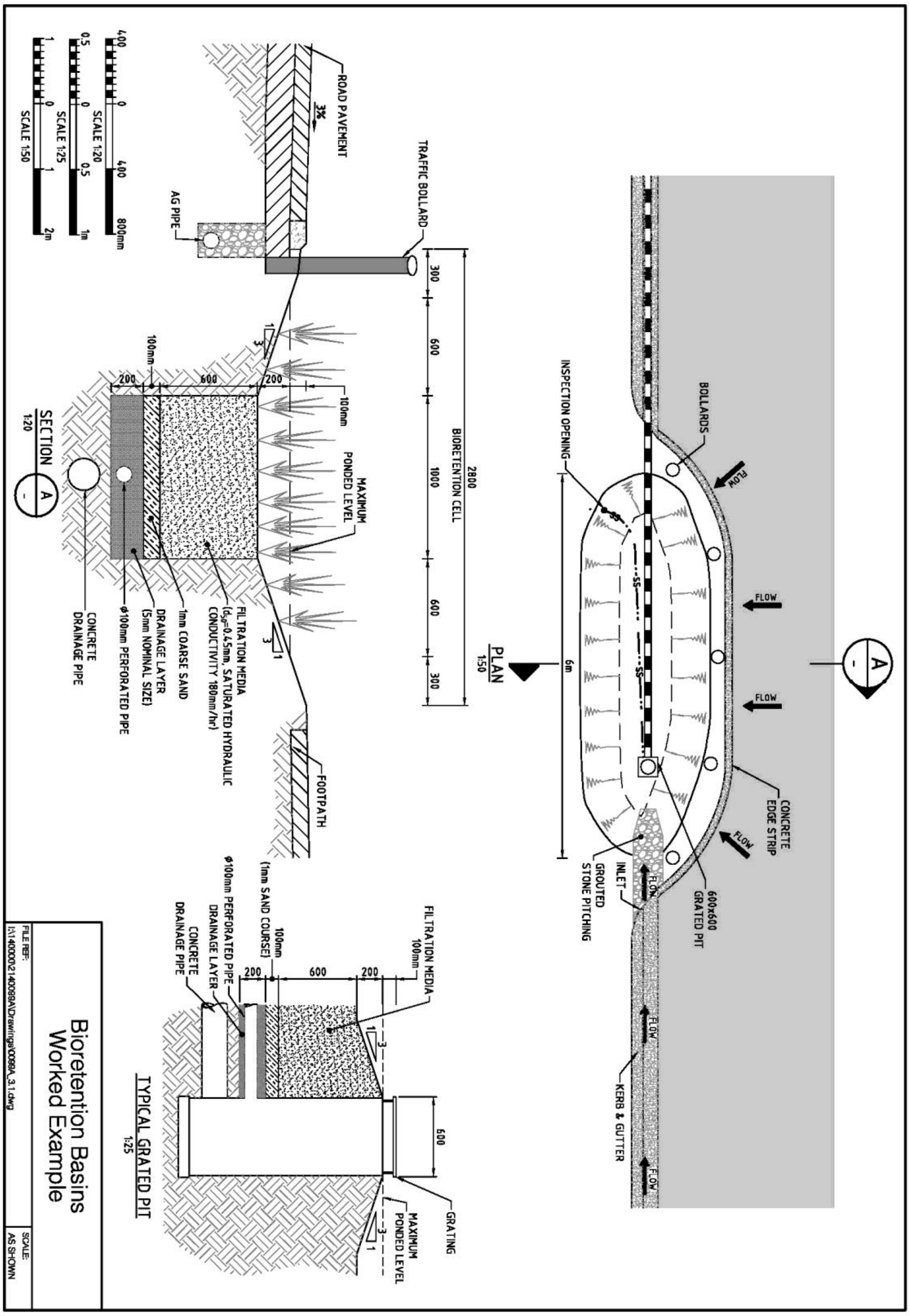
Bioretention basins

CALCULATION SUMMARY

	CALCULATION TASK		OUTCOME		CHECK
1	**Identify design criteria**				✓
	conveyance flow standard (ARI)		5	year	
	area of bioretention		10	m^2	
	maximum ponding depth		200	mm	
	Filter media type		180	mm/hr	
2	**Catchment characteristics**				✓
		car park area	300	m^2	
		allotment area	600	m^2	
		slope	1	%	
	Fraction impervious				✓
		car park	0.9		
		allotments	0.6		
3	**Estimate design flow rates**				
	Time of concentration				
	estimate from flow path length and velocities		6	minutes	✓
	Identify rainfall intensities				
		station used for IFD data:	Hobart		
		100 year ARI	150	mm/hr	
		5 year ARI	72	mm/hr	
	Peak design flows				
		Q_5	0.012	m^3/s	
		Q_{100}	0.030	m^3/s	
		Q_{infil}	0.0003	m^3/s	✓
4	**Slotted collection pipe capacity**				
		pipe diameter	100	mm	
		number of pipes	1		
		pipe capacity	0.019	m^3/s	
		capacity of perforations	0.0125	m^3/s	
		soil media infiltration capacity	0.0067	m^3/s	
		CHECK PIPE CAPACITY > SOIL CAPACITY	YES		✓
5	**Check flow widths in upstream gutter**				
		Q_5 flow width	0.9	m	
		CHECK ADEQUATE LANES TRAFFICABLE	YES		✓
6	**Kerb opening width**				
		width of brak in kerb for inflows	0.6	m	✓
7	**Velocities over vegetation**				
		Velocity for 5 year flow (<0.5m/s)	0.03	m/s	
		Velocity for 100 year flow (<1.0m/s)	0.08	m/s	✓
8	**Overflow system**				
		system to convey minor floods	grated pit 600 x 600		✓
9	**Surrounding soil check**				
		Soil hydraulic conductivity	0.36	mm/hr	
		Filter media	180	mm/hr	
		MORE THAN 10 TIMES HIGHER THAN SOILS?	YES (no liner)		✓
10	**Filter media specification**				
		filtration media	sandy loam		
		transition layer	coarse sand		
		drainage layer	fine gravel		✓

5.6.9.1 Construction drawings

The diagram below shows the construction drawing for the worked example.



5.7 References

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