

Policy 11: Land Development Guidelines

Section 13 Water Sensitive Urban Design (WSUD) Guidelines

13.8 Infiltration Measures



Infiltration System in Adelaide, showing the overflow trench

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13.8.1 Introduction

Stormwater infiltration systems capture stormwater runoff and encourage infiltration into surrounding *in-situ* soils and underlying groundwater. This has the benefit of reducing stormwater runoff peak flows and volumes, reducing downstream flooding, managing the hydrologic regime entering downstream aquatic ecosystems and improving groundwater recharge.

The purpose of infiltration systems in a stormwater management strategy is as a conveyance measure (to capture and infiltrate flows), NOT as a stormwater treatment system. Appropriate pretreatment of stormwater entering infiltration systems is required to avoid clogging and to protect groundwater quality.

Infiltration systems generally consist of a 'detention volume' and an 'infiltration area' (or infiltration surface):

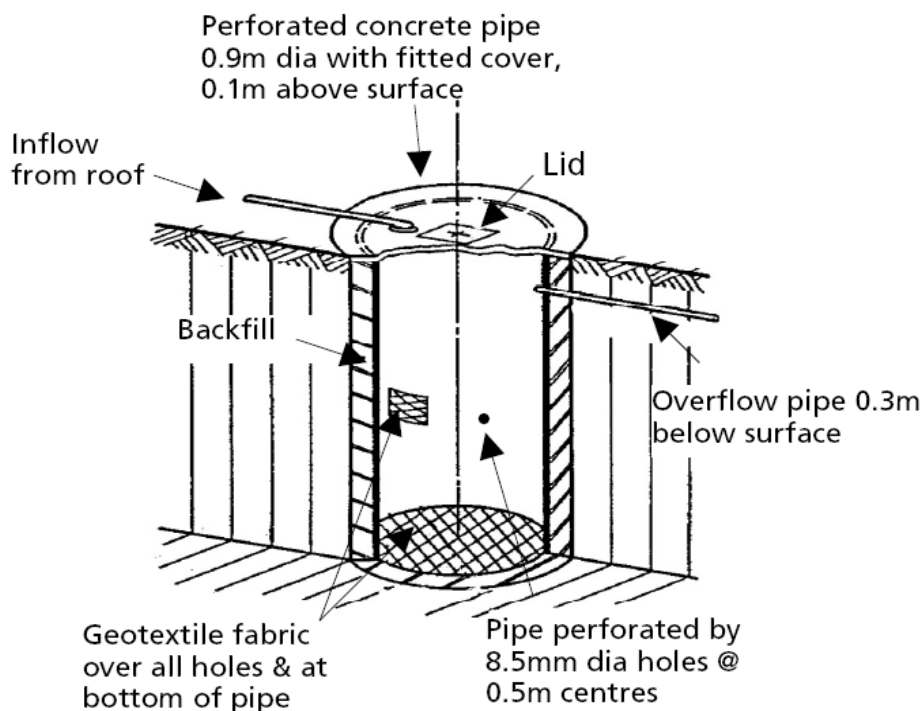
- the 'detention volume' can be located above or below ground and is designed to detain a certain volume of runoff and make it available for infiltration. When the 'detention volume' is exceeded, the system is designed to overflow to the downstream drainage systems and the receiving environment;
- the 'infiltration area' is the surface or interface between the detention volume and the *in-situ* soils through which the collected water is infiltrated.

The application of infiltration systems is best suited to moderately to highly permeable *in-situ* soils (ie. sandy loam to sandy soils); however, infiltration systems can still be applied in locations with less permeable soils by providing larger detention volumes and infiltration areas.

As outlined in **Australian Runoff Quality (Engineers Australia 2006)** and **Practice Note 5: Infiltration Devices (LHCCREMS 2002)** there are four basic types of infiltration systems:

Leaky Well

A leaky well is typically used in small scale residential applications and consists of a vertical perforated pipe (concrete or PVC) and an open base (**Figure 13.8-A**). Pretreated stormwater enters via an inlet pipe at the top of the well and when the detention volume is full, an overflow pipe delivers excess waters to the downstream drainage system. The perforations in the open pipe and the base are covered with a geotextile (non-woven) and the pipe is surrounded by a ring of clean gravel (5 – 10 mm particle size diameter).

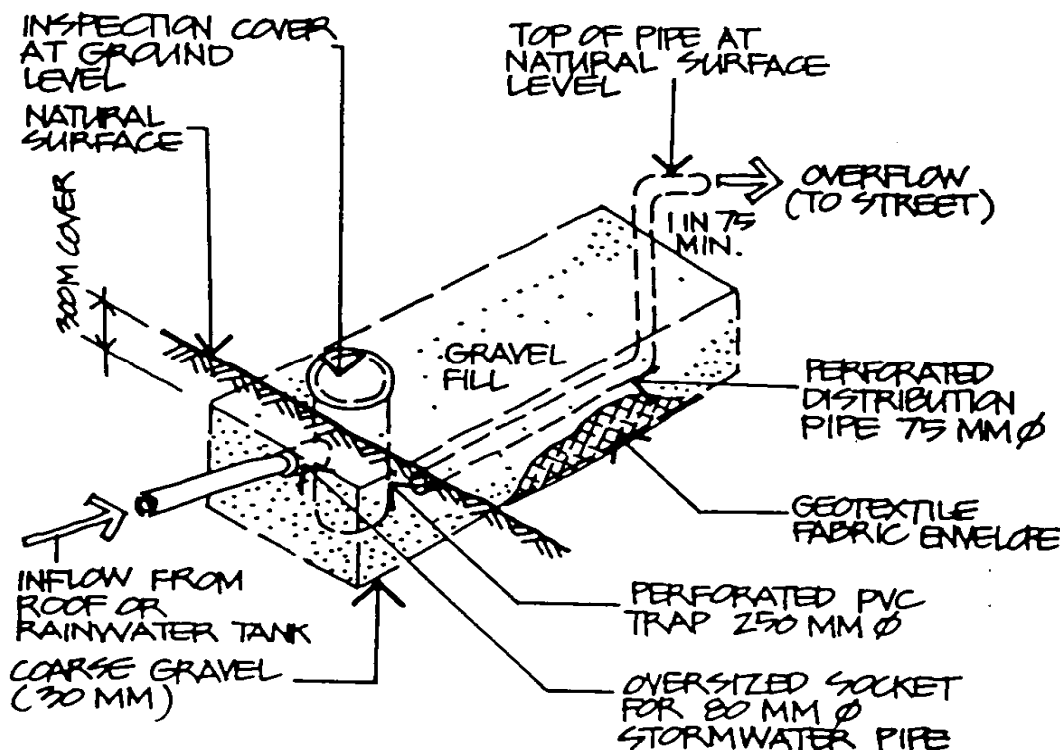


Source: Engineers Australia 2006 and LHCCREMS 2002

Figure 13.8-A: 'Leaky Well' Infiltration System

Infiltration Trench

Infiltration trenches can be applied across a range of scales and consist of a trench, typically 0.5-1.5m deep, filled with gravel or modular plastic cells lined with geotextile (non-woven) and placed under 300 mm of backfill (topsoil or sandy loam). Pretreated runoff enters the trench (detention volume) either directly or via an inlet control pit, with excess waters delivered downstream via an overflow pipe. If the trench contains gravel fill then a perforated distribution pipe is incorporated into the system to ensure effective distribution of stormwater into the detention volume. A typical configuration of an infiltration trench is shown in **Figure 13.8-B**.



Source: Engineers Australia 2006

Figure 13.8-B: Infiltration Trench

Infiltration 'Soak-away'

Soak-aways are similar to trenches in operation but have a larger plan area, being typically rectangular, and of shallower depth (**Figure 13.8-C**). Infiltration soak-aways can be applied across a range of scales from residential allotments through to open space or parklands.

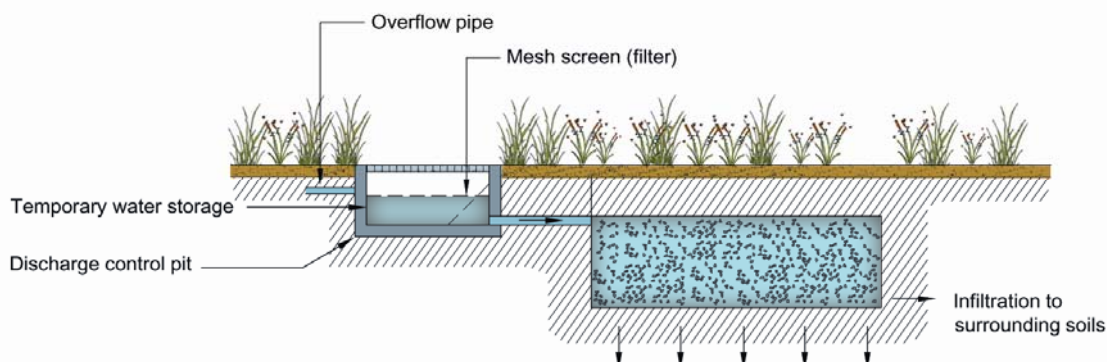


Figure 13.8-C: Operation of a Gravel Filled 'Trench' or Soak-away' Type Infiltration System

Infiltration Basin

Infiltration basins are typically used in larger scale applications where space is not a constraint (eg. parklands). They consist of natural or constructed depressions designed to capture and store stormwater runoff on the surface (ie. detention volume located above ground) prior to infiltration into the *in-situ* soils. A typical section through an infiltration basin is provided in **Figure 13.8-D**. Infiltration basins are best suited to sand or sandy-clay *in-situ* soils and can be planted out with a range of vegetation to blend into the local landscape. Pretreatment of stormwater entering infiltration basins is required with the level of pretreatment varying depending on *in-situ* soil type and basin vegetation. Further guidance in this regard is provided in **Section 13.8.2.4**.



Plate 13.8-A: Infiltration Basin

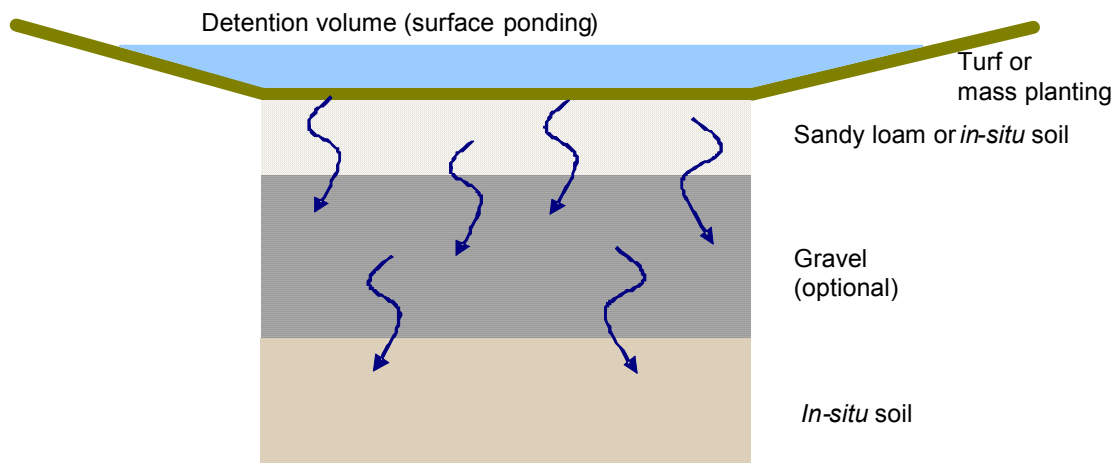


Figure 13.8-D: Infiltration Basin Typical Section

13.8.2 Design Considerations

13.8.2.1 Design Objectives

Infiltration systems can be designed to achieve a range of objectives, including:

1. Minimising the volume of stormwater runoff from a development.
2. Preserving predevelopment hydrology.
3. Capturing and infiltrating flows up to a particular design flow.
4. Enhancing groundwater recharge or preserving predevelopment groundwater recharge.

The design objective will vary from one location to another and will depend on site characteristics, development form and the requirements of the receiving ecosystems. It is essential that these objectives are established as part of the conceptual design process and approved by GCCC prior to commencing the engineering design.

13.8.2.2 Selecting the Type of Infiltration System

Selection of the type of infiltration system for a particular application must occur as part of the conceptual design process (ie. Site Based Stormwater Management Plan) by assessing the site conditions against the relative merits of the four basic types of infiltration systems described in **Section 13.8.2**. There is a range of resources available to assist with this selection process, including **Australian Runoff Quality (Engineers Australia 2006)**, **Water Sensitive Urban Design: Basic Procedures for 'Source Control' of Stormwater (Argue 2007)** and **Water Sensitive Urban Design: Technical Guidelines for Western Sydney (UPRCT 2004)**.

In general, selection of the type of infiltration system is determined by the size of the contributing catchment. **Table 13.8-A** provides guidance on selection by listing the type of infiltration systems against typical scales of application.

Table 13.8-A: Infiltration Types and Associated Application Scales

Infiltration Type	Allotment Scale (< 0.1 ha)*	Medium Scale (0.1 – 10 ha)*	Large Scale (> 10 ha)*
Leaky Wells	✓		
Infiltration Trenches	✓	✓	
Infiltration Soak-aways		✓	
Infiltration Basins		✓	✓

Note: * Catchment area directing flow to the infiltration system

13.8.2.3 Design (Sizing) Methods

Establishing the size of an infiltration system requires consideration of the volume and frequency of runoff discharged into the infiltration system, the available 'detention volume' and the infiltration rate (product of 'infiltration area' and hydraulic conductivity of *in-situ* soils). The approach for establishing these design elements depends on the design objectives as outlined in **Section 13.8.2.1**. For the purposes of these guidelines, the infiltration system design objectives can be addressed by two design methods: the hydrologic effectiveness method and the design storm method. These methods are summarised in **Table 13.8-B** and discussed in the following sections.

Table 13.8-B: Design (Sizing) Methods to Deliver Infiltration System Design Objectives

Infiltration Design objective	*Hydrologic Effectiveness Method	*Design Storm Method
Minimise the volume of stormwater runoff from a development	✓	
Preserve pre-development hydrology	✓	
Capture and infiltrate flows up to a particular design flow		✓
Enhance groundwater recharge or preserve pre-development groundwater recharge	✓	

Note: * Unless otherwise approved by GCCC, the hydrologic effectiveness method must be used when designing infiltration systems.

a) Hydrologic Effectiveness Method

The hydrologic effectiveness of an infiltration system defines the proportion of the mean annual runoff volume that infiltrates. For a given catchment area and meteorological conditions, the hydrologic effectiveness of an infiltration system is determined by the combined effect of the nature/ quantity of runoff, the 'detention volume', *in-situ* soil hydraulic conductivity and 'infiltration area'.

The hydrologic effectiveness of an infiltration system requires long term continuous simulation, which can be undertaken using the **Model for Urban Stormwater Improvement Conceptualisation (MUSIC)**(CRCCH 2005).

b) Design Storm Method

Where the design objective for a particular infiltration system is peak discharge attenuation or the capture and infiltration of a particular design storm event (eg. 3 month ARI event), then the design storm approach can be adopted for sizing the infiltration system.

This method involves defining the required 'detention volume' by relating the volume of inflow and outflow for a particular design storm, and then deriving the 'infiltration area' to ensure the system empties prior to the commencement of the next storm event. Details of the approach for defining the detention volume and infiltration area are presented in **Section 13.8.3.6**. However, unless otherwise approved by GCCC, the Hydrologic Effectiveness Method described in **Section 13.8.3.2** must be used.

13.8.2.4 Pretreatment of Stormwater

Pretreatment of stormwater entering an infiltration system is primarily required to minimise the potential for clogging of the infiltration media and to protect groundwater quality. In line with these requirements, there are two levels of stormwater pretreatment required:

Level 1 Pretreatment Stormwater should be treated to remove coarse and medium sized sediments and litter to prevent blockage of the infiltration system. Level 1 Treatment applies to all four types of infiltration system.

Level 2 Pretreatment To protect groundwater quality, pretreatment is required to remove fine particulates and associated pollutants, such as nutrients and metals. This second level of treatment is the most stringent as any stormwater infiltrated must be of equal, or preferably superior, quality to that of the receiving groundwater to ensure the groundwater quality and values are protected. To determine an appropriate level of pretreatment, assessment of the groundwater aquifer quality, values, possible uses and suitability for recharge is required to the satisfaction of GCCC.

Level 2 pretreatment applies to leaky wells, infiltration trenches and infiltration soak-aways. It also applies to most infiltration basin applications, however, there are situations where pretreatment is not required. For example, where basins are located on sandy clay to clay soils (hydraulic conductivity <180 mm/hr) and the depth to groundwater is greater than 1.0 m, the system can be planted out with rush and reed species and allowed to function in a similar manner to a bioretention system prior to waters entering the underlying groundwater. A summary of pretreatment requirements for each of the infiltration system types is presented in **Table 13.8-C**.

Table 13.8-C: Pretreatment Requirements for Each Type of Infiltration System

Infiltration Type	Level 1 Pretreatment	Level 2 Pretreatment
Leaky Well	✓	✓
Infiltration Trench	✓	✓
Infiltration Soak-away	✓	✓
Infiltration Basin		
<ul style="list-style-type: none"> ▪ Sandy clay to clay soils ($K_{sat} < 180$ mm/hr) + dense ground cover 	✓	
<ul style="list-style-type: none"> ▪ Sandy clay to clay soils ($K_{sat} < 180$ mm/hr) + turf ground cover 	✓	✓
<ul style="list-style-type: none"> ▪ Sandy soils ($K_{sat} > 180$ mm/hr) 	✓	✓

Note: K_{sat} = saturated hydraulic conductivity (mm/hr) of in-situ soil (see Section 13.8.2.6)

13.8.2.5 Site Terrain

Infiltration into steep terrain can result in stormwater re-emerging onto the surface at some point downslope. The likelihood of this pathway for infiltrated water is dependent on the soil structure. Duplex soils and shallow soil over rock create situations where re-emergence of infiltrated water to the surface is most likely to occur. These soil conditions do not necessarily preclude infiltrating stormwater, unless leaching of soil salt is associated with this process. The provision for managing this pathway will need to be taken into consideration at the design stage to ensure hazards or nuisance to downstream sites are avoided.

Additionally, the introduction of infiltration systems on steep terrain can increase the risk of slope instability. Installation of infiltration systems on slopes greater than 10% will not be approved by GCCC unless a detailed engineering assessment has been undertaken.

13.8.2.6 *In-Situ* Soils

a) Hydraulic Conductivity

Hydraulic conductivity of the *in-situ* soil, being the rate at which water passes through a water-soil interface, influences both the suitability of infiltration systems and the size of the infiltration area. Therefore, it is essential that field measurement of hydraulic conductivity be undertaken to confirm assumptions of soil hydraulic conductivity adopted during the concept design stage (ie. site based Stormwater Management Plan). The determination of hydraulic conductivity must be undertaken in accordance with procedures outlined in **Appendix 4.1F** of **AS/NZS1547:2000**, which provides an estimate of saturated hydraulic conductivity (K_{sat}) (ie. the hydraulic conductivity of a soil when it is fully saturated with water). The typical ranges of saturated hydraulic conductivities for homogeneous soils are provided in **Table 13.8-D**.

Table 13.8-D: Typical Soil Types and Associated Saturate Hydraulic Conductivity

Soil Type	Saturated Hydraulic Conductivity	
	m/s	mm/hr
Coarse Sand	>1 x 10 ⁻⁴	>360
Sand	>5 x 10 ⁻⁵ to 1-10 ⁻⁴	180 to 360
Sandy Loam	1 x 10 ⁻⁵ to 5 x 10 ⁻⁵	36 to 180
Sandy Clay	1 x 10 ⁻⁶ to 1 x 10 ⁻⁵	3.6 to 36
Medium Clay	1 x 10 ⁻⁷ to 1 x 10 ⁻⁶	0.36 to 3.6
Heavy Clay	1 x 10 ⁻⁷	0.0036 to 0.36

Engineers Australia 2006

When assessing the appropriateness of infiltration systems and the type of *in-situ* soils, the following issues must be considered:

1. Soils with a saturated hydraulic conductivity of 3.6 mm/hr to 180 mm/hr are preferred for infiltration application.
2. Infiltration systems will not be accepted by GCCC where the *in-situ* soils are very heavy clays (ie. < 0.36 mm/hr) or wind blown sand (ie. > 360 mm/hr).
3. Soils with a low hydraulic conductivity (0.36 – 3.6 mm/hr) do not necessarily preclude the use of infiltration systems even though the required infiltration/ storage area may become prohibitively large. However, soils with lower hydraulic conductivities will be more susceptible to clogging and will therefore require enhanced pretreatment.

b) Soil Salinity

Infiltration systems must be avoided in areas with poor soil conditions, in particular sodic/ saline and dispersive soils, and shallow saline groundwater. If the 'Site and Soil Evaluation' (refer to **Section 13.8.3.1**) identifies poor soil conditions, then GCCC will not approve the use of infiltration systems.

c) Impermeable Subsoil, Rock and Shale

Infiltration systems must not be placed in locations where soils are underlain by rock or a soil layer with little or no permeability (ie. K_{sat} < 0.36 mm/hr). In locations where fractured or weathered rock prevail, the use of infiltration systems may be approved by GCCC provided detailed engineering testing has been carried out to ensure the rock will accept infiltration.

13.8.2.7 Groundwater

a) Groundwater Quality

As outlined in **Section 13.8.2.4**, the suitability of infiltrating stormwater and the necessary pretreatment requires assessment of the groundwater quality. The principle legislation governing the management of groundwater quality is the **Environmental Protection (Water) Policy 1997** and the overriding consideration is that there should be no deterioration in groundwater quality. This means the stormwater being infiltrated must be of equal or preferably superior quality to that of the receiving groundwater in order to ensure the groundwater quality and values are protected. To determine an appropriate level of pretreatment for stormwater, assessment of the groundwater aquifer quality, values, possible uses and suitability for recharge is required and must be approved by GCCC.

b) Groundwater Table

A second groundwater related design consideration is to ensure that the base of an infiltration system is always above the groundwater table. It is generally recommended that the base of the infiltration system be a minimum of 1.0m above the seasonal high water table.

If a shallow groundwater table is likely to be encountered, investigation of the seasonal variation of groundwater levels is essential. This should include an assessment of potential groundwater mounding (ie. localised raising of the water table in the immediate vicinity of the infiltration system) that in shallow groundwater areas could cause problems with nearby structures.

13.8.2.8 Building Setbacks (Clearances)

Infiltration systems should not be placed near building footings to avoid the influence of continually wet sub-surface or greatly varying soil moisture content on the structural integrity. **Australian Runoff Quality (Engineers Australia 2006)** recommends minimum distances from structures and property boundaries (to protect possible future buildings in neighbouring properties) for different soil types. These values are shown in **Table 13.8-E**.

Table 13.8-E: Minimum Setback Distances

Soil Type	Saturated Hydraulic Conductivity (mm/hr)	Minimum Distance from Structures and Property Boundaries
Sand	>180	1.0 m
Sandy Clay	36 to 180	2.0 m
Medium Clay	3.6 to 36	4.0 m
Heavy Clay	0.0036 to 3.6	5.0 m

Adapted from Engineers Australia 2006

13.8.2.9 Flow Management

The following issues should be considered when designing the flow control structures within infiltration systems:

- for large scale systems (ie. infiltration basins), the surface of the 'infiltration area' must be flat or as close to this as possible to ensure uniform distribution of flow and to prevent hydraulic overloading on a small portion of the 'infiltration area';
- for gravel filled infiltration systems, flow should be delivered to the 'detention volume' via a perforated pipe(s) network that is located and sized to convey the design flow into the infiltration systems and allow distribution of flows across the entire infiltration area;
- where possible, 'above design' flows will bypass the infiltration systems. This can be achieved in a number of ways. For smaller applications, an overflow pipe or pit, which is connected to the downstream drainage system, can be used. For larger applications, a discharge control pit can be located upstream of the infiltration system. This will function much like the inlet zone of a constructed wetland to regulate flows (1 year ARI) into the infiltration systems and bypass above design flows (> 1 year ARI).

13.8.2.10 Service Location

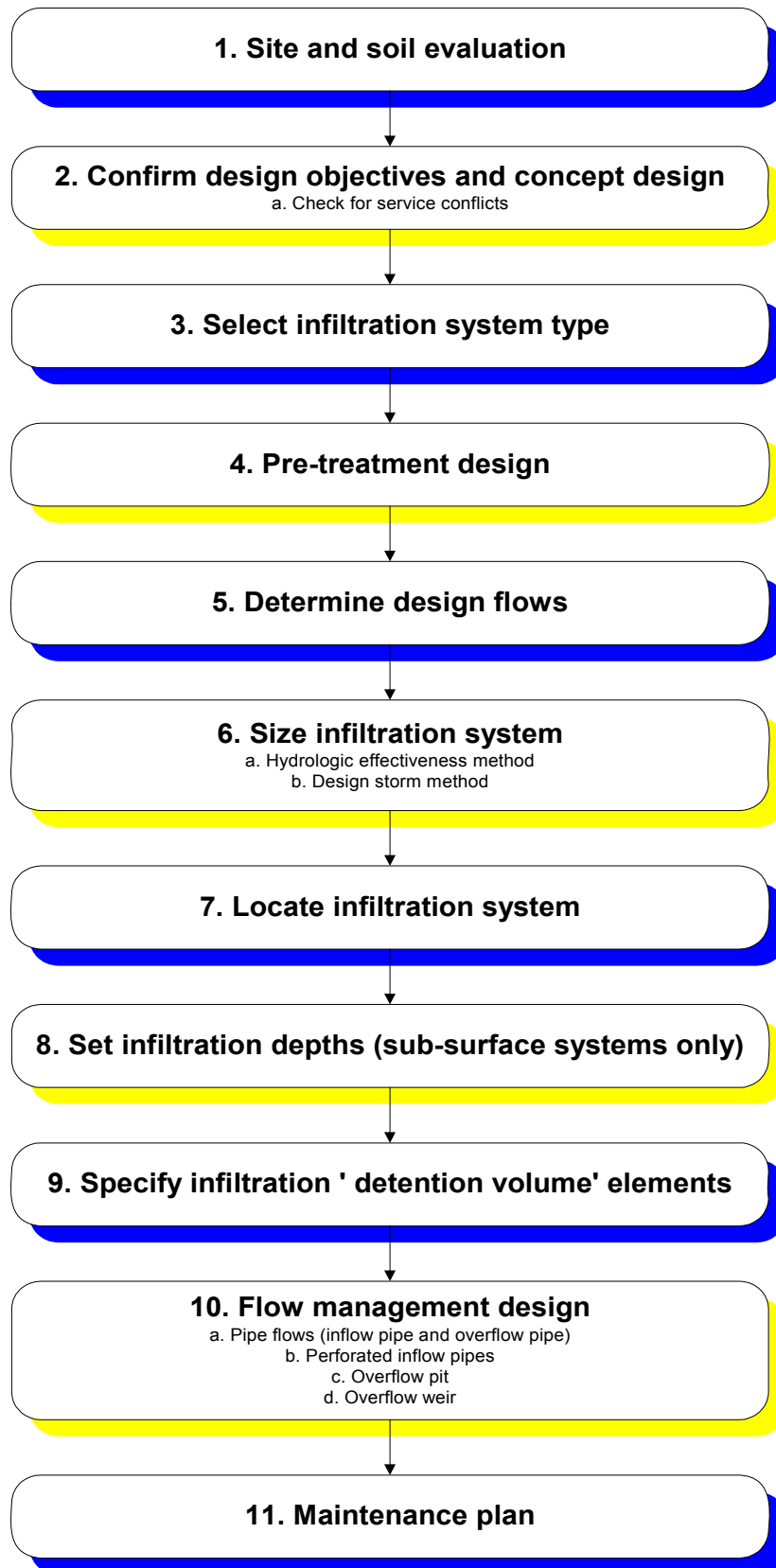
As with the requirement for building setbacks, designers must also consider the location of existing and future services including power, telecommunications, gas, water and sewerage.

The location of an infiltration system with respect to these services must ensure:

- no damage to services created through wetting of soil;
- maintenance access is not inhibited (including through wetting of soil).

13.8.3 Design Process

The following sections detail the design steps required for infiltration measures. Key design steps are:



13.8.3.1 Step 1: Site and Soil Evaluation

As outlined in **Section 13.8.2**, there are a range of site and soil conditions which influence infiltration system design. To define the site's capability to infiltrate stormwater, a 'Site and Soil Evaluation' must be undertaken in accordance with **AS/NZS1547:2000 Clause 4.1.3**. The evaluation should provide the following:

- soil type;
- hydraulic conductivity (must be measured in accordance with **AS/NZS1547:2000 Appendix 4.1F**);
- presence of soil salinity (where applicable);
- presence of rock shale;
- slope of terrain (%);
- groundwater details (depth, quality and values).

13.8.3.2 Step 2: Confirm Design Objectives and Concept Design

This step involves confirming the design objectives, defined as part of the conceptual design, to ensure the correct infiltration system design method is selected (refer to **Table 13.8-B**).

13.8.3.3 Step 3: Select Infiltration System Type

This step involves selecting the type of infiltration system by assessing the site conditions against the relative merits of the four infiltration systems described in **Section 13.8.1**. In general, the scale of application dictates selection of the infiltration system. **Table 13.8-A** provides guidance in this regard.

For further guidance in selecting infiltration systems, designer should refer to **Australian Runoff Quality (Engineers Australia 2006)**, **Water Sensitive Urban Design: Basic Procedures for 'Source Control' of Stormwater (Argue 2007)** and the **Water Sensitive Urban Design: Technical Guidelines for Western Sydney (UPRCT 2004)**.

a) Service Location Check

As part of the confirmation of objectives and review of the conceptual design, the designer must check that there are no existing or proposed services in the infiltration system site or within the setback distances provided in **Table 13.8-E**.

The designer should liaise with civil designers and GCCC officers to ensure:

- infiltration measures will not result in water damage to existing services or structures;
- access for maintenance to existing services is maintained;
- no conflicts arise between the location of services and WSUD devices.

13.8.3.4 Step 4: Pretreatment Design

As outlined in **Section 13.8.2.4** and **Table 13.8-C**, both Level 1 Pretreatment (minimising risk of clogging) and Level 2 Pretreatment (groundwater protection) are required for all infiltration systems except for specific infiltration basin applications. To determine Level 2 requirements, an assessment of the groundwater must be undertaken to define existing water quality, potential uses (current and future) and suitability for recharge.

Pretreatment measures include the provision of leaf and roof litter guards along the roof gutter, sediment basins, vegetated swales, bioretention systems or constructed wetland as outlined in the other chapters of this guideline.

13.8.3.5 Step 5: Determine Design Flows

a) Design Flows

To configure the inflow system and high flow bypass elements of the infiltration system the following design flows generally apply:

'Design Operation Flow' for sizing the inlet to the infiltration system. This may vary depending on the particular situation but will typically correspond to one of the following:

- 1 year ARI – for situations where a discharge control pit is used to regulate flows into the infiltration system and bypass larger flows;
- 2 or 10 year ARI (minor design flow) – for situations where the minor drainage system is directed to the infiltration system.

'Above Design Flow' for design of the high flow bypass around the infiltration system. The discharge capacity for the bypass system may vary depending on the particular situation but will typically correspond to one of the following:

- 2 or 10 year ARI (minor design flow) – for situations where only the minor drainage system is directed to the infiltration system. **Table 3.5B** of the Land Development Guidelines should be referred to for the required design event for the minor design flow.
- 100 year ARI (major design flow) – for situations where both the minor and major drainage system discharge to the infiltration system.

b) Design Flow Estimation

A range of hydrologic methods can be applied to estimate design flows. If typical catchment areas are relatively small, the Rational Method design procedure is considered suitable. However, if the infiltration system is to form part of a detention basin or if the catchment area to the system is large (> 50 ha) then a full flood routing computation method should be used to estimate design flows.

13.8.3.6 Step 6: Size Infiltration System

As outlined in **Section 13.8.2.3**, there are two design methods available for establishing the size of the detention volume and infiltration area of infiltration systems: the hydrologic effectiveness method and the design storm method. Unless otherwise approved by GCCC, the hydrologic effectiveness method must be used when designing infiltration systems.

a) Hydrologic Effectiveness Method

A **MUSIC** model of the surrounding catchment and 'treatment train' should be developed to provide an estimate of the size of infiltration system required to achieve a given hydrologic effectiveness.

It should be noted that any infiltration system should form part of the stormwater 'treatment train'. As described in **Sections 13.8.2.4** and **13.8.3.4**, pretreatment of stormwater flows will be required prior to discharge into any proposed infiltration systems. Therefore, other stormwater quality best management practices will need to be incorporated into the surrounding catchment to augment the performance of any proposed infiltration system.

b) Design Storm Approach

Where the design objective for a particular infiltration system is peak discharge attenuation or the capture and infiltration of a particular design storm event, then the design storm approach may be adopted for sizing the infiltration system. Use of the design storm approach must be approved by GCCC for sizing infiltration systems.

Design Storm Selection (Q_{des})

The first step in the design storm approach to sizing the infiltration system is selecting the design storm for capture and infiltration. This must occur in consultation with GCCC and will generally relate to 3 month ARI and 1 year ARI design storms.

Detention Volume

The required 'detention volume' of an infiltration system is defined by the difference in inflow and outflow (or infiltrated) volumes for the duration of a storm.

The inflow volume (V_i) is determined, in accordance with **Section 6 – Detention Basins** of **QUDM (DPI, IMEA & BCC 1992)**, as the product of the design storm flow and the storm duration:

$$V_i = Q_{des} \cdot D$$

Where:

V_i	=	inflow volume (for storm duration D) (m^3)
Q_{des}	=	design storm flow for sizing as outlined in Section 13.8.3.5 (Rational Method, $Q = CIA/360$ (m^3/s))
D	=	storm duration (hrs x 3600 s/hr)

Equation 13.8.1

As outlined in **Section 13.8.3.5**, if the infiltration system is to form part of a detention basin or if the catchment area to the system is large (> 50 ha) then a full flood routing computation method should be used to estimate design flows.

Outflow from the infiltration system is via the base and sides of the infiltration media and is dependent on the area and depth of the structure. In computing the infiltration from the walls of an infiltration system, **Australian Runoff Quality (Engineers Australia 2006)** suggests that pressure is hydrostatically distributed and thus equal to half the depth of water over the bed of the infiltration system:

$$V_o = \left[A_{inf} + \left(P \cdot \frac{d}{2} \right) \right] \cdot \frac{U \cdot K_{sat} \cdot D}{1000}$$

Where:

- V_o = outflow volume (for storm duration D) (m^3)
- K_{sat} = saturated hydraulic conductivity (mm/hr) as provided in **Step 1**
- A_{inf} = infiltration area (m^2)
- P = perimeter length of the infiltration area (m)
- d = depth of the infiltration system (m)
- U = soil hydraulic conductivity moderating factor (see **Table 13.8-F**)
- D = storm duration (hrs)

Equation 13.8.2

Thus, the required detention volume (V_d) of an infiltration system can be computed as follows:

$$V_d = \frac{V_i - V_o}{p}$$

Where:

- V_d = required detention volume (m^3)
- V_i = inflow volume (m^3)
- V_o = outflow volume (m^3)
- P = porosity (void = 1, gravel = 0.35)

Equation 13.8.3

Computation of the required storage will need to be carried out for the full range of probabilistic storm durations, ranging from 6 minutes to 72 hours. The critical storm event is that which results in the highest required storage. A spreadsheet application (using **Equations 13.8.1 to 13.8.3**) is the most convenient way of doing this. It is important to note that some storm events result in double peaks in the hyetograph for the particular storm and these may affect the size of detention storage required.

Soil Hydraulic Conductivity Moderating Factor

Soil is inherently non-homogeneous and field tests can often misrepresent the real hydraulic conductivity of a soil into which stormwater is to be infiltrated. Field experience suggests that field tests of 'point' soil hydraulic conductivity (as defined by **Step 1**) can often under estimate the areal hydraulic conductivity of clay soils and over estimate in sandy soils. As a result, **Australian Runoff Quality (Engineers Australia 2006)** recommends that moderation factors for hydraulic conductivities determined from field test be applied as shown in **Table 13.8-F**.

Table 13.8-F: Moderation Factors to Convert Point to Areal Conductivities

Soil Type	Moderation Factor (U) (To Convert 'Point' K_{sat} to Areal K_{sat})
Sandy soil	0.5
Sandy clay	1.0
Medium and Heavy Clay	2.0

After Engineers Australia 2006

Emptying Time

Emptying time is defined as the time taken to fully empty a detention volume associated with an infiltration system following the cessation of rainfall. This is an important design consideration as the computation procedure associated with **Equation 13.8.3** assumes that the storage is empty prior to the commencement of the design storm event. **Australian Runoff Quality (Engineers Australia 2006)** suggests an emptying time of the detention storage of infiltration systems to vary from 12 hours to 84 hours. For detention basins (surface systems) the emptying time must be limited to 72 hours to reduce the risk of mosquito breeding.

Emptying time is computed simply as the ratio of the volume of water in temporary storage (dimension of storage x porosity) to the infiltration rate (hydraulic conductivity x infiltration area):

$$t_e = \frac{1000 \cdot V_d \cdot P \cdot \rho}{A_{inf} \cdot K_{sat}}$$

Where:

t_e	=	emptying time (hours)
V_d	=	detention volume (m ³)
P	=	perimeter length of the infiltration area (m)
A_{inf}	=	infiltration area (m ²)
K_{sat}	=	saturated hydraulic conductivity (mm/hr) as provided in Step 1 .
ρ	=	porosity (void = 1, gravel = 0.35)

Equation 13.8.4

13.8.3.7 Step 7: Locate Infiltration System

This step involves locating the infiltration system in accordance with the requirement set out in **Section 13.8.2.8** and **Table 13.8-E** to minimise the risk of damage to structures from wetting and drying of soils (ie. swelling and shrinking of soils and slope stability).

13.8.3.8 Step 8: Set Infiltration Depths (Sub-surface Systems Only)

For sub-surface infiltration systems, selection of the optimum depth requires consideration of the seasonal high water table and the appropriate cover to the surface.

Seasonal Groundwater Table

As outlined in **Section 13.8.2.6**, it is generally recommended that the base of the infiltration system be a minimum of 1m above the seasonal high water table.

Cover

(ie. depth of soil above top of infiltration system)

Minimum cover of 0.3m. For systems created using modular plastic cell storage units, an engineering assessment is required.

13.8.3.9 Step 9: Specify Infiltration 'Detention Volume' Elements

The following design and specification requirements must be documented as part of the design process for 'leaky wells', infiltration trenches and 'soak-aways'.

a) Gravel

Where the infiltration 'detention volume' is created through the use of a gravel-filled trench then the gravel must be clean (free of fines) stone/ gravel with a uniform size of between 25-100 mm diameter.

b) Modular Plastic Cells

Where the infiltration detention volume is created through the use of modular plastic cells (similar to a milk crate), the design must be accompanied by an engineering assessment of the plastic cells and their appropriateness considering the loading above the infiltration system. A minimum 150 mm thick layer of coarse sand or fine gravel must underlie the base of the plastic cells.

c) Geofabric

Geofabric must be installed along the side walls and through the base of the infiltration detention volume to prevent the migration of *in-situ* soils into the system. For infiltration system application, Council will only accept the use of non-woven geofabric with a minimum perforation or mesh of 0.25 mm.

d) Inspection Wells

It is good design practice to install inspection wells at numerous locations in an infiltration system. This allows water levels to be monitored during and after storm events and for infiltration rates to be confirmed over time.

13.8.3.10 Step 10: Flow Management Design

The design of the hydraulic control for infiltration systems varies for the different types of systems. For smaller applications, all pretreated flows will directly enter the infiltration system and an overflow pipe or pit will be used to convey excess flow to the downstream drainage system. For larger applications, a discharge control pit will be located upstream of the infiltration systems to function similar to the inlet zone of a constructed wetland to regulate flows (1 year ARI) into the infiltration systems and bypass above design flows (> 1 year ARI). **Table 13.8-G** summarises the typical hydraulic control requirements for the different types of infiltration system.

Table 13.8-G: Typical Hydraulic Control Requirements for Infiltration Systems

Infiltration Type	Inflow		Overflow/ Bypass	
	Direct Inflow	Discharge Control Pit	Overflow Pipe/ Pit	Discharge Control Pit
Leaky Wells	✓		✓	
Infiltration Trenches	✓		✓	
Infiltration Soak-aways		✓		✓
Infiltration Basins	✓	✓	✓	✓

Note: For gravel filled infiltration systems, flow should be delivered to the 'detention volume' via a perforated pipe network.

The hydraulic control measures described in **Table 13.8-G** are designed using the following techniques.

a) Pipe Flows (Inflow Pipe and Overflow Pipe)

Pipe flows are to be calculated in accordance with **Section 3.5** and **QUDM (DPI, IMEA & BCC 1992)** which use standard pipe equations that account for energy losses associated with inlet and outlet conditions and friction losses within the pipe. For most applications, the pipe or culvert will operate under outlet control with the inlet and outlet of the pipe/ culvert being fully submerged. With relatively short pipe connections, friction losses are typically small and can be computed using Manning's equation. The total energy (head) loss (ΔH) of the connection is largely determined by the inlet and outlet conditions and the total losses can be computed using the expression as provided in **QUDM (DPI, IMEA & BCC 1992)**:

$$\Delta H = h_f + h_s$$

Where:

- h_f = $S_f \cdot L$ = head loss in pipe due to friction (m)
- h_s = $(K_{in} + K_{out}) \cdot V^2 / 2g$ = head loss at entry and exit (m)
- S_f = friction slope which is computed from Manning's Equation (m/m)
- L = is the length pipe (m)
- $K_{in} + K_{out}$ = the head loss coefficients for the inlet and outlet conditions (typically, and conservatively, assumed to be 0.5 and 1.0 respectively)
- V = velocity on flow in pipe (m/s)
- g = gravity (9.79 m/s²)

Equation 13.8.5

b) Perforated Inflow Pipes

To ensure the perforated inflow pipes to gravel filled infiltration systems have sufficient capacity to convey the 'design operation flow' (**Section 13.8.3.5**) and distribute this flow into the infiltration system, there are two design checks required:

- ensure the pipe itself has capacity to convey the 'design operation flow';
- ensure the perforations are adequate to pass the 'design operation flow'.

It is recommended that the maximum spacing of the perforated pipes is 3m (centres) and that the minimum grade is 0.5% from the inflow point. The inflow pipes should be extended to the surface of the infiltration system to allow inspection and maintenance when required. The base of the infiltration system must remain flat.

Perforated Pipe Conveyance

To confirm the capacity of the perforated pipes to convey the 'design operation flow', Manning's equation can be used (which assumes pipe full flow but not under pressure). When completing this calculation it should be noted that installing multiple perforated pipes in parallel is a means of increasing the capacity of the perforated pipe system.

Perforate Pipe Slot Conveyance

The capacity of the slots in the perforated pipe needs to be greater than the maximum infiltration rate to ensure the slots does not become the hydraulic 'control' in the infiltration system (ie. to ensure the *in-situ* soils and 'detention volume' set the hydraulic behaviour rather than the slots in the perforated pipe). To do this, orifice flow can be assumed to occur through the slots and the sharp edged orifice equation used to calculate the flow through the slots for the full length of perforated pipe. Firstly, the number and size of perforations needs to be determined (typically from manufacturer's specifications) and used to estimate the flow rate out of the pipes, with the driving head being the difference between the overflow level and the invert of the perforated pipe. It is conservative, but reasonable, to use a blockage factor to account for partial blockage of the perforations. A 50% blockage should be used.

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

Where:

Q_{perf}	=	flow through perforations (m ³ /s)
B	=	blockage factor (0.5)
C_d	=	orifice discharge coefficient (assume 0.61 for sharp edge orifice)
A	=	total area of the perforations (m ²)
g	=	gravity (9.79 m/s ²)
h	=	head above the centroid of the perforated pipe (m)

Equation 13.8.6

If the capacity of the perforated pipe system is unable to convey the 'design operation flow' then additional perforated pipes will be required.

c) Overflow Pit

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

For free overfall conditions (weir equation):

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

Where:

Q_{weir}	=	flow into pit (weir) under free overfall conditions (m ³ /s)
B	=	blockage factor (0.5)
C_w	=	weir coefficient (1.66)
L	=	Length of weir (perimeter of pit) (m)
h	=	flow depth above the weir (pit) (m)

Equation 13.8.7

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

For drowned outlet conditions (orifice equation):

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

Where:

B	=	blockage factor (0.5)
g	=	gravity (9.79 m/s ²)
h	=	head above the centroid of the perforated pipe (m)
Q_{orifice}	=	flow rate into pit under drowned conditions (m ³ /s)
C_d	=	discharge coefficient (drowned conditions = 0.6)
A	=	area of orifice (perforations in inlet grate) (m ²)

Equation 13.8.8

When designing grated field inlet pits, reference is to be made to the procedure described in **QUDM Section 5.10.4 (DPI, IMEA & BCC 1992)** and **Section 3.5** of these Guidelines.

d) Overflow Weir

In applications where infiltration systems require a discharge control pit, a 'spillway' outlet weir will form part of the high flow bypass system to convey the 'above design flow'. The 'spillway' outlet weir level will be set at the top of the 'detention storage' to ensure catchment flows bypass the infiltration system once the 'detention volume' is full. The length of the 'spillway' outlet weir is to be sized to safely pass the maximum flow discharged to the discharge control pit (as defined the 'above design flow' in **Section 13.8.3.5**).

The required length of the 'spillway' outlet weir can be computed using the weir flow equation (**Equation 13.8.7**) and the 'above design flow' (**Section 13.8.3.5**).

13.8.3.11 Design Calculation Summary

Following is a design calculation summary sheet for the key design elements of an infiltration system to aid the design process.

Infiltration Systems		Calculation Summary	
Calculation Task		Outcome	Check
Catchment Characteristics			
	Catchment Area	ha	<input type="checkbox"/>
	Catchment Land Use (ie. Residential, Commercial, etc)		
	Storm Event Entering Infiltration System (Minor or Major)	year ARI	
1	Site and Soil Evaluation		
	Site and Soil Evaluation undertaken in accordance with AS1547-2000 Clause 4.1.3		
	Soil Type		<input type="checkbox"/>
	Hydraulic Conductivity (K_{sat})	mm/hr	
	Presence of Soil Salinity		
	Presence of Rock/ Shale		
	Infiltration Site Terrain (% Slope)		
	Groundwater Level	m AHD m below surface	
	Groundwater Quality		
	Groundwater Uses		
2	Confirm Design Objectives		
	Confirm design objective as defined by conceptual design		<input type="checkbox"/>
3	Select Infiltration System Type		
	Leaky Well		<input type="checkbox"/>
	Infiltration Trench		
	Infiltration 'Soak-away'		
	Infiltration Basin		
4	Pretreatment Design		
	Level 1 Pretreatment (avoid clogging)		<input type="checkbox"/>
	Level 2 Pretreatment (groundwater protection)		
5	Determine Design Flows		
	'Design Operation Flow' – 1 year ARI	year ARI	<input type="checkbox"/>
	'Above Design Flow' – either 2 or 50 year ARI	year ARI	
	Time of Concentration		
	Refer to Section 3.5 and QUDM	minutes	<input type="checkbox"/>
	Identify Rainfall Intensities		
	'Design Operation Flow' – $I_{1 \text{ year ARI}}$	mm/hr	<input type="checkbox"/>
	'Above Design Flow' – $I_{2 \text{ year ARI}}$ or $I_{10 \text{ year}}$ or $I_{100 \text{ year ARI}}$	mm/hr	
	Design Runoff Coefficient		
	'Design Operation Flow' – $C_{1 \text{ year ARI}}$		<input type="checkbox"/>
	'Above Design Flow' – $C_{2 \text{ year ARI}}$ or $C_{10 \text{ year}}$ or $C_{100 \text{ year ARI}}$		
	Peak Design Flows		
	'Design Operation Flow' – 1 year ARI	m^3/s	<input type="checkbox"/>
	'Above Design Flow' – either 2, 10 or 100 year ARI	m^3/s	
6	Size Infiltration System		
	Hydrologic Effectiveness Approach		
	Hydrologic Effectiveness Objective	%	<input type="checkbox"/>
	Depth	m	
	Porosity (void = 1.0, gravel filled = 0.35)		
	'Infiltration Area'	m^2	<input type="checkbox"/>
	'Detention Volume'	m^3	

Infiltration Systems		Calculation Summary		
Calculation Task		Outcome	Check	
Design Storm Approach				
	Design Storm Flow	m ³ /s	<input type="checkbox"/>	
	Inflow Volume	m ³		
	Outflow Volume	m ³		
	Depth	m		
	'Infiltration Area'	m ²		
	'Detention Volume'	m ³		
7	Locate Infiltration System			
	Minimum distance from boundary (Table 13.8-E)	m	<input type="checkbox"/>	
	Width	m		
	Length	m		
8	Set Infiltration Depths (Sub-Surface Systems Only)			
	Ground Surface Level	m AHD	<input type="checkbox"/>	
	Groundwater Level	m AHD		
		m below surface		
	Infiltration System Depth	m		
	Top of Infiltration System	m AHD		
	Base of Infiltration System	m AHD		
	Cover	m		
	Depth to Water Table	m		
9	Specify Infiltration 'Detention Volume' Elements			
	Gravel Size	mm diam.		<input type="checkbox"/>
	Modular Plastic Cells			
	Geofabric			
10	Flow Management Design			
	Inflow/ Overflow Structures			
	Direct Inflow		<input type="checkbox"/>	
	Overflow Pit/ Pipe			
	Discharge Control Pit			
	Discharge Pipe			
	Pipe Capacity	m ³ /s	<input type="checkbox"/>	
	Pipe Size	mm diam.		
	Inflow Pipe			
	Pipe Capacity	m ³ /s	<input type="checkbox"/>	
	Pipe Size	mm diam.		
	Overflow Pipe			
	Pipe Capacity	m ³ /s	<input type="checkbox"/>	
	Pipe Size	mm diam.		
	Overflow Pit			
	Pit Capacity	m ³ /s	<input type="checkbox"/>	
	Pit Size	mm x mm		
	Perforated Inflow Pipes			
	No. of Pipes		<input type="checkbox"/>	
	Pipe Size	mm		
	Discharge Control Pit			
	Pit Size	mm x mm	<input type="checkbox"/>	
	Weir Length	m		

13.8.4 Construction and Establishment

It is important to note in the context of a development site and associated construction/ building works, delivering infiltration measures can be a challenging task. A careful construction and establishment approach to ensure the system is delivered in accordance with its design intent. The following sections outline a recommended staged construction and establishment methodology for infiltration measures based on the guidance provided in **Leinster (2006)**.

13.8.4.1 Construction and Establishment Challenges

There exist a number of challenges that must be appropriately considered to ensure successful construction and establishment of infiltration measures. These challenges are best described in the context of the typical phases in the development of a Greenfield or Infill development, namely the Subdivision Construction Phase and the Building Phase (see **Figure 13.8-E**).

a) Subdivision Construction Phase

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

- construction activities which can generate large sediment loads in runoff which can clog infiltration measures;
- construction traffic and other works can result in damage to the infiltration measures.

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

b) Building Phase

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

13.8.4.2 Staged Construction and Establishment Method

To overcome the challenges associated within delivering infiltration measures a Staged Construction and Establishment Method should be adopted (see **Figure 13.8-E**):

Stage 1: Functional Installation	Construction of the functional elements of the infiltration measure at the end of Subdivision Construction (ie. during landscape works) and the installation of temporary protective measures (ie. stormwater bypass system).
Stage 2: Sediment and Erosion Control	During the Building Phase the temporary protective measures preserve the functional infrastructure of the infiltration measure against damage.
Stage 3: Operational Establishment	At the completion of the Building Phase, the temporary measures protecting the functional elements of the infiltration measure can be removed and the system allowed to operation in accordance with the design intent.

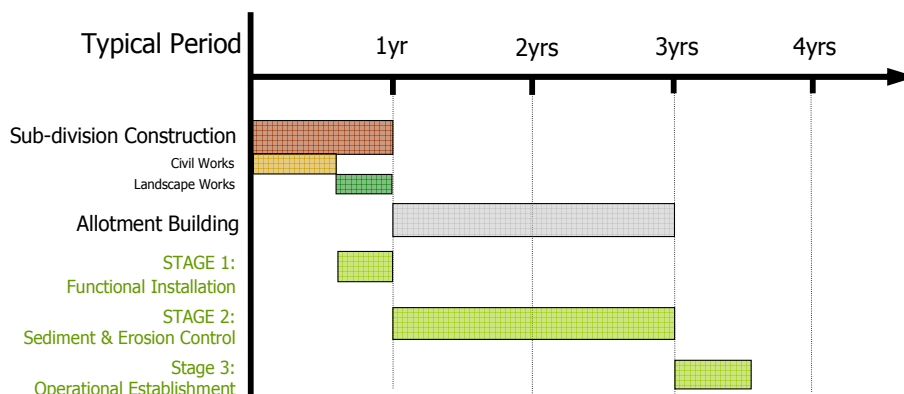


Figure 13.8-E: Staged Construction and Establishment Method

a) Functional Installation

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

- bulking out and trimming;
- installation of the control and pipe structures;
- placement of non-woven geofabric to sides and base;
- placement of gravel (if part of design);
- where infiltration system is located underground, the inlet should be blocked to ensure sediment laden stormwater flows 'bypass' the system;
- where the system is an infiltration basin, placement of a temporary protective layer – Covering the surface of filtration media with geofabric and placement of 25 mm topsoil and turf over geofabric. This temporary geofabric and turf layer will protect the infiltration measure during construction (Subdivision and Building Phases) ensuring sediment/ litter laden waters do not cause clogging;
- place silt fences around the boundary of the infiltration measure to exclude silt and restrict access.

b) Sediment and Erosion Control

The temporary protective measures are left in place through the allotment building phase to ensure sediment laden waters do not enter and clog the infiltration measure.

c) Operational Establishment

At the completion of the Allotment Building Phase the temporary measures (ie. stormwater bypass) can be removed and the infiltration measure allowed to operate. It is critical to ensure that the pretreatment system for an infiltration measure is fully operational before flows are introduced.

13.8.5 Maintenance Requirements

Maintenance for infiltration systems aims at ensuring the system does not clog with sediments and that an appropriate infiltration rate is maintained. The most important consideration during maintenance is to ensure the pretreatment elements are operating as designed to avoid blockage of the infiltration measure and to prevent groundwater contamination.

To ensure the system is operating as designed, the infiltration zone should be inspected every 1 – 6 months (or after each major rainfall event) depending on the size and complexity of the system. Typical maintenance of infiltration systems will involve:

- routine inspection to identify any surface ponding after the design infiltration period, which would indicate clogging/ blockage of the underlying aggregate or the base of the trench;
- routine inspection of inlet points to identify any areas of scour, litter build up, sediment accumulation or blockages;
- removal of accumulated sediment and clearing of blockages to inlets;
- tilling of the infiltration surface, or removing the surface layer, if there is evidence of clogging;
- maintaining the surface vegetation (if present).

13.8.6 Checking Tools

This section provides a number of checking aids for designers and Council development assessment officers. In addition, **Section 13.8.4** provides general advice on the construction and establishment of infiltration measures and key issues to be considered to ensure their successful establishment and operation based on observations from construction projects around Australia.

The following checking tools are provided:

- Design Assessment Checklist;
- Construction Inspection Checklist (during and post);
- Operation and Maintenance Inspection Form;
- Asset Transfer Checklist (following 'on-maintenance' period).

Figure 13.8-F below shows the stages of the development approval, construction and establishment, and asset transfer process and which checklists should be used at each stage.

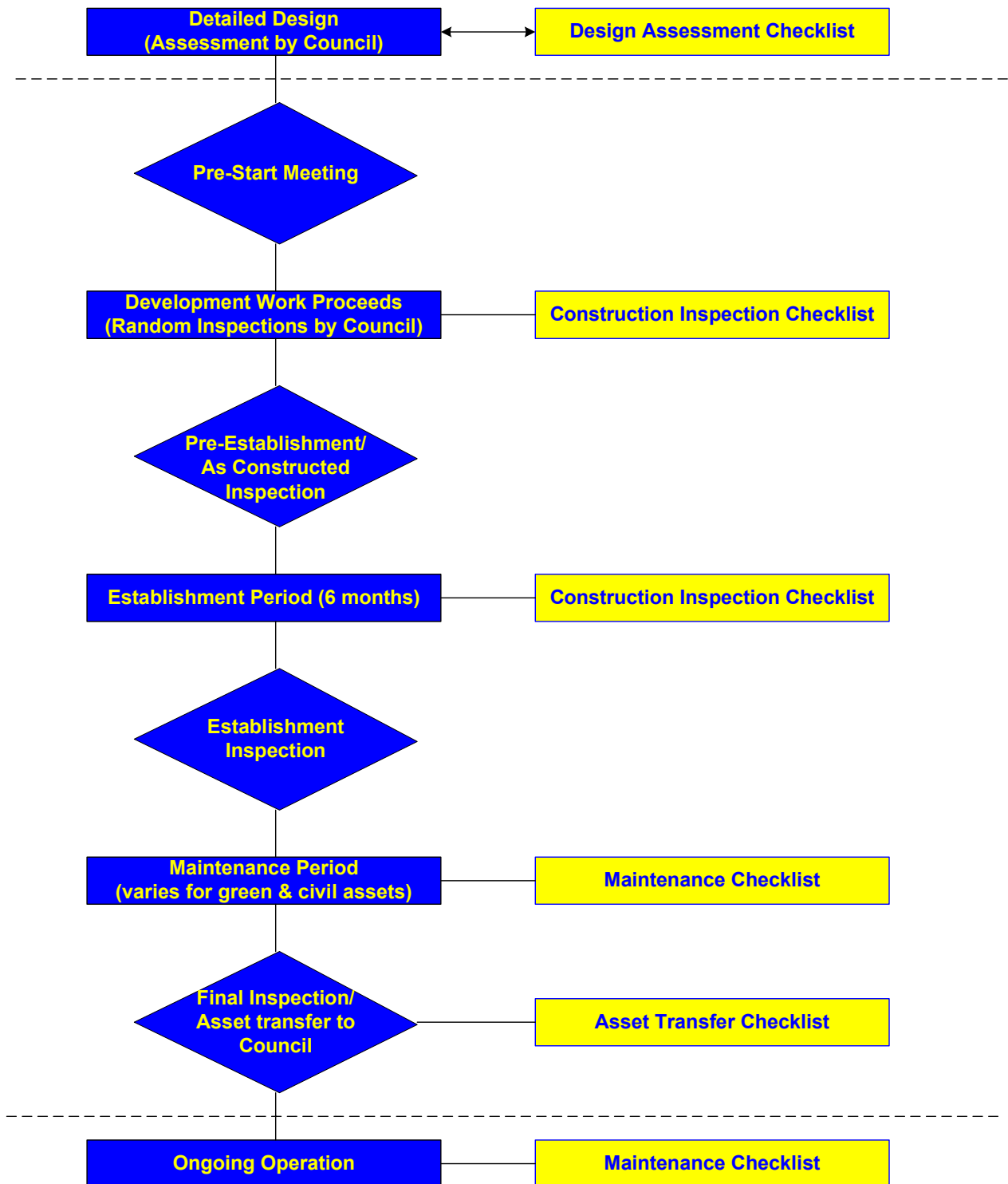


Figure 13.8-F: Development Approval and Handover Stages – Appropriate Checklists

13.8.6.1 Design Assessment Checklist

The design assessment checklist presents the key design features that are to be reviewed when assessing the design of an infiltration system. These considerations include configuration, safety, maintenance and operational issues that need to be addressed during the design phase. If an item receives an 'N' when reviewing the design, referral is to be made back to the design procedure to determine the impact of the omission or error.

In addition to the checklist, a proposed design should have all necessary permits for its installation. Council development assessment officers will require that all relevant permits are in place prior to accepting a design.

13.8.6.2 Construction Checklist

This checklist presents the key items to be reviewed when inspecting the infiltration measure during and at the completion of construction. The checklist is to be used by Construction Site Supervisors and local authority Compliance Inspectors to ensure all the elements of the infiltration measure have been constructed in accordance with the design. If an item receives an 'N' in Satisfactory criteria then appropriate actions must be specified and delivered to rectify the construction issue before final inspection sign-off is given.

13.8.6.3 Maintenance Checklist

In addition to checking and maintaining the function of pretreatment elements, the maintenance checklist can be used during routine maintenance inspections of the infiltration measure and kept as a record on the asset condition and quantity of removed pollutants over time. Inspections should occur every 1 – 6 months depending on the size and complexity of the system. More detailed site specific maintenance schedules should be developed for major infiltration systems and include a brief overview of the operation of the system and key aspects to be checked during each inspection.

13.8.6.4 Asset Transfer Checklist

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. The asset transfer checklist provides an indicative asset transfer checklist.

Infiltration Measures Design Assessment Checklist					
Asset I.D.					
Infiltration Measure Location:					
Hydraulics:	Design Operational Flow (m ³ /s):		Above Design Flow (m ³ /s):		
Area:	Catchment Area (ha):	Infiltration Area (m ²):	Detention Volume (m ³):		
Concept Design				Y	N
Design objectives established?					
Services located and no conflicts?					
Site and Soil Evaluation				Y	N
Site and Soil Evaluation undertaken in accordance with AS1547-2000					
Soil types appropriate for infiltration ($K_{sat} > 0.36\text{mm/hr}$, no salinity problems, no rock/ shale)? Refer to Section 13.8.2.6					
Pretreatment				Y	N
Groundwater conditions assessed and objectives established? Refer to Section 13.8.2.7					
Level 1 Pre-Treatment provided? Refer to Section 13.8.2.4					
Level 2 Pre-Treatment provided? Refer to Section 13.8.2.4					
Infiltration System				Y	N
Has the appropriate design approach been adopted? Refer to Sections 13.8.2.2 and 13.8.2.3					
Infiltration system setbacks appropriate? Refer to Section 13.8.2.8 . Ranges from 1m for sandy soils to 5m for clay soils.					
Base of infiltration system >1m above seasonal high groundwater table? Refer to Section 13.8.3.8					
Has appropriate cover (soil depth above infiltration system) been provided? Refer to Section 13.8.3.8					
If placed on >10% terrain (ground slope), has engineering assessment been undertaken? Refer to Section 13.8.2.5					
Flow Management (Refer to Section 13.8.3.10)				Y	N
Overall flow conveyance system sufficient for design flood event?					
Are the inflow systems designed to convey design flows?					
Bypass/ overflow sufficient for conveyance of design flood event?					
Comments					

Infiltration Measures Construction Inspection Checklist										
Asset I.D.:					Inspected by:					
Site:					Date:					
					Time:					
Constructed By:					Weather:					
					Contact During Visit:					
Items Inspected	Checked		Satisfactory		Items Inspected	Checked		Satisfactory		
	Y	N	Y	N		Y	N	Y	N	
During Construction										
A. Functional Installation					Structural Components					
Preliminary Works					10. Location and levels of infiltration system and overflow points as designed					
1. Erosion and sediment control plan adopted					11. Pipe joints and connections as designed					
2. Traffic control measures					12. Concrete and reinforcement as designed					
3. Location same as plans					13. Inlets appropriately installed					
4. Site protection from existing flows					14. Provision of geofabric to sides and base					
Earthworks					15. Correct fill media/ modular system used					
5. Excavation as designed					B. Sediment & Erosion Control (if required)					
6. Side slopes are stable					16. Stabilisation immediately following earthworks					
Pretreatment					17. Silt fences and traffic control in place					
7. Maintenance access provided					18. Temporary protection layers in place					
8. Invert levels as designed					C. Operational Establishment					
9. Ability to freely drain					19. Temporary protection layers and associated silt removed					
Final Inspection										
1. Confirm levels of inlets and outlets					6. Check for uneven settling of surface					
2. Traffic control in place					7. No surface clogging					
3. Confirm structural element sizes					8. Maintenance access provided					
4. Gravel as specified					9. Construction generated sediment and debris removed					
5. Confirm pretreatment is working										
Comments on Inspection										
Actions Required										
1.										
2.										
3.										
4.										
5.										
Inspection officer signature:										

Infiltration Measures Maintenance Checklist			
Asset I.D.:			
Inspection Frequency:	1 to 6 monthly	Date of Visit:	
Location:			
Description:			
Site Visit by:			
Inspection Items	Y	N	Action Required (Details)
Sediment accumulation in pretreatment zone?			
Erosion at inlet or other key structures?			
Evidence of dumping (eg building waste)?			
Evidence of extended ponding times (eg. algal growth)?			
Evidence of silt and clogging within 'detention volume'?			
Clogging of flow management systems (sediment or debris)?			
Damage/ vandalism to structures present?			
Drainage system inspected?			
Resetting of system required?			
Comments			

Infiltration Measures Asset Transfer Checklist			
Asset Description:			
Asset I.D.:			
Asset Location:			
Construction by:			
'On-Maintenance' Period:			
Treatment	Y	N	
System appears to be working as designed visually?			
No obvious signs of under-performance?			
Maintenance	Y	N	
Maintenance plans and indicative maintenance costs provided for each asset?			
Inspection and maintenance undertaken as per maintenance plan?			
Inspection and maintenance forms provided?			
Asset Inspected for Defects and/or Maintenance Issues at Time of Asset Transfer	Y	N	
Sediment accumulation at inflow points?			
Litter present?			
Erosion at inlet or other key structures?			
Traffic damage present?			
Evidence of dumping (eg. building waste)?			
Evidence of ponding?			
Surface clogging visible?			
Damage/ vandalism to structures present?			
Comments			

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?			

13.8.7 Infiltration Measure Worked Example

An infiltration system is to be installed to infiltrate stormwater runoff from an industrial allotment in Pimpama on the Gold Coast. The allotment is 0.8 ha in area on a rectangular site (100m x 80 m) with an overall impervious surface area of 0.45 ha (45% impervious). All stormwater runoff is to be pretreated through swale bioretention systems prior to entering the infiltration system to ensure sustainable operation of the infiltration system and protection of groundwater. An illustration of the proposed allotment and associated stormwater management scheme is shown in **Figure 13.8-G**.

Treated flows from the swale bioretention systems are to be delivered to the infiltration system via traditional pipe drainage sized to convey the minor storm event (2 year ARI).

The allotment is located within a catchment that drains to a natural wetland that has been defined by GCCC as being hydrologically sensitive to increases in catchment flow. Therefore, GCCC require that there be no increase in mean annual runoff as a result of the development.

This worked example focuses on the design of an infiltration 'soak-away' system for the allotment based on the site characteristics and design objectives listed below.

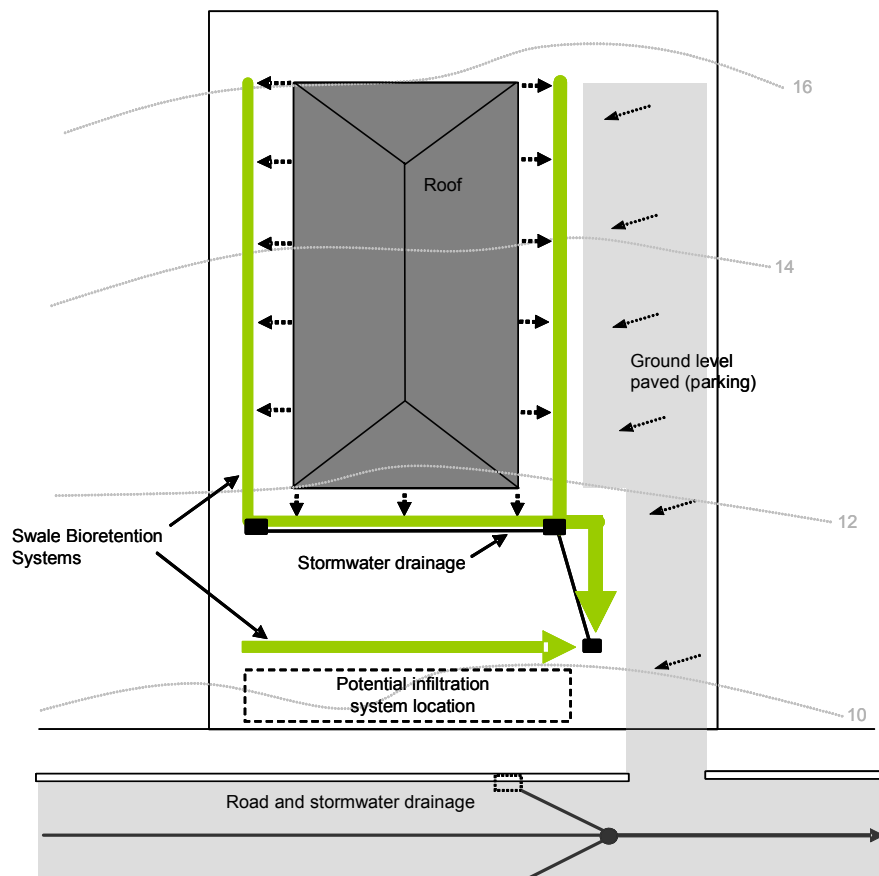


Figure 13.8-G: Site Layout

Site Characteristics

The site characteristics are summarised as follows:

- catchment area:
 - 2,000 m² (roof)
 - 1,600 m² (ground level paved)
 - 4,400 m² (pervious)
 - 8,000 m² (total)
- predevelopment mean annual runoff = 4.1 ML/yr
- post development mean annual runoff = 7.0 ML/yr
- soil type – sandy clay
- saturated hydraulic conductivity (K_{sat}) = 80 mm/hr
- topography – flat to moderate grades towards the road (2 – 4%).

MUSIC models of the pre- and post-developed scenarios were used to estimate the mean annual runoff volumes.

Design Objectives

As outlined in **Section 13.8.7**, the allotment is located within a catchment that drains to a natural wetland that has been defined by GCCC as being hydrologically sensitive to increases in catchment flow and GCCC require that there be no increase in mean annual runoff as a result of the development. Considering the predevelopment mean annual runoff is 3.3 ML/yr and the post-development mean annual runoff is 5.5 ML/yr, the design objective of the infiltration system is the capture and infiltration of 2.2 ML/yr (equal to 40% hydrologic effectiveness).

13.8.7.1 Step 1: Site and Soil Evaluation

To define the site's suitability for infiltration of stormwater a 'Site and Soil Evaluation' was undertaken in accordance with **AS1547-2000 Clause 4.1.3**. The key information from the evaluation is presented below:

- soil type = sandy clay
- hydraulic conductivity = 80 mm/hr
- presence of soil salinity = no problems discovered
- presence of rock or shale = no rock or shale discovered
- slope/ terrain (%) = 2 – 4%, ground level 10m AHD in infiltration location
- groundwater details (depth, quality and values) = water table 5m below surface (5m AHD), moderate water quality with local bores used for irrigation.

Field tests found the soil to be suitable for infiltration, consisting of sandy clay with a saturated hydraulic conductivity of 80 mm/hr.

13.8.7.2 Step 2: Confirm Design Objectives

The design objective for the infiltration system is no increase in mean annual runoff as a result of the development, which requires the system to achieve 40% hydrologic effectiveness. The hydrologic effectiveness approach will be used to establish the size of the infiltration system.

Design objective = no increase in mean annual runoff post- development (ie. 40% hydrologic effectiveness).

13.8.7.3 Step 3: Select Infiltration System Type

Based on the site attributes, the scale of the infiltration application (ie. 1.0 ha) and **Table 13.8-A**, an infiltration 'soak-away' system is selected for the industrial allotment.

13.8.7.4 Step 4: Pretreatment Design

As an infiltration 'soak-away' has been selected for the site, reference to **Section 13.8.2.4** and **Table 13.8-C** indicates both Level 1 and 2 Pretreatment is required. Considering the groundwater is of moderate quality and is currently used for irrigation purposes, best practice treatment (80% reduction in TSS and 45% reduction in TP and TN) was proposed and approved by GCCC based on meeting the GCCC water quality objectives. This is being achieved through the use of swale bioretention systems strategically located through the allotment to capture runoff before it enters the traditional drainage systems (see **Figure 13.8-G**).

13.8.7.5 Step 5: Determine Design Flows

As described in **Section 13.8.3.5**, the 'design operation flow' is required to size the inlet to the infiltration system, which may vary depending on the particular situation. In this case, flows into the infiltration system are to be regulated through a discharge control pit, which will deliver flows up to the 1 year ARI into the infiltration system. Flows greater than 1 year ARI, or when the infiltration system is full, will bypass the infiltration system by overtopping the overflow weir in the discharge control pit. Considering only traditional drainage will enter the discharge control pit, the 'above design flow' is the 2 year ARI event. Therefore:

'Design operation flow' = 1 year ARI

'Above design flow' = 2 year ARI

Design flows are established using the Rational Method and the procedures provided in **Section 3.5** of this guideline and **QUDM (DPI, IMEA & BCC 1992)**. The site has one contributing catchment being 0.8 ha in area and drained by swale bioretention systems and stormwater pipes.

Time of Concentration (t_c)

Time of Concentration $t_c = 10$ mins

Design Runoff Coefficient

Runoff Coefficients

$$C_{10} = 0.95 \text{ (Table 3.5A)}$$

ARI	C Runoff		
	1	2	10
QUDM Factor	0.8	0.85	1.0
C_{ARI}	0.76	0.81	0.95

Catchment Area,

$$A = 10,000 \text{ m}^2 \text{ (1.0 ha)}$$

Rainfall Intensities (Pimpama)

$$t_c = 10 \text{ mins}$$

$$I_1 = 100 \text{ mm/hr}$$

$$I_2 = 125.4 \text{ mm/hr}$$

Rational Method $Q = CIA/360$

$$Q_{1yr \text{ ARI}} = 0.169 \text{ m}^3/\text{s}$$

$$Q_{2yr \text{ ARI}} = 0.226 \text{ m}^3/\text{s}$$

$$\text{'Design Operation Flow'} = 0.169 \text{ m}^3/\text{s}$$

$$\text{'Above Design Flow'} = 0.226 \text{ m}^3/\text{s}$$

13.8.7.6 Step 6: Size Infiltration System

The design objective for the infiltration basin is to achieve a hydrologic effectiveness of 40%. This objective is to be delivered through use of an infiltration 'soak-away' created using gravel and being 1.0m in depth.

The **MUSIC** model of the stormwater treatment train was used to determine the size of the infiltration system required to achieve the target hydrologic effectiveness.

Gravel filled infiltration 'soak-away':

$$\text{'Infiltration Area'} = 29 \text{ m}^2$$

$$\text{'Detention Volume'} = 29 \text{ m}^3$$

13.8.7.7 Step 7: Locate Infiltration System

With a sandy clay soil profile, the minimum distance of the infiltration system from structures and property boundary is 2m (**Table 13.8-E**). As the general fall of the site is to the front of the property, it is proposed that the infiltration system be sited near the front.

The infiltration 'soak-away' is to be rectangular in shape, being 6.5m long by 4.5m wide and located 2m from the front boundary as shown in **Figure 13.8-H**. The 6.5 x 4.5m infiltration system is to be located near the front of the property set back by at least 2m from the property boundary.

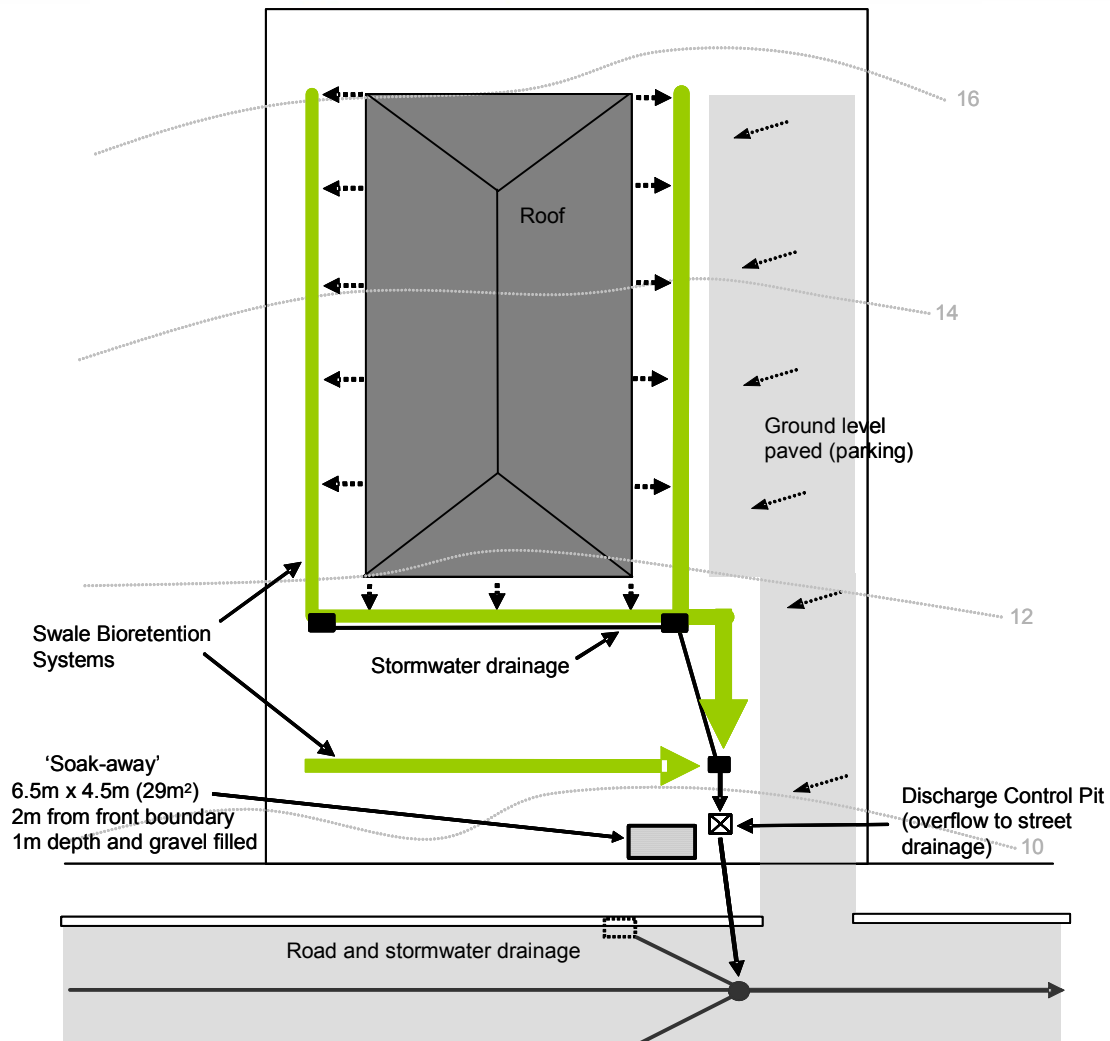


Figure 13.8-H: Location of Infiltration System

13.8.7.8 Step 8: Set Infiltration Depths (Sub-surface Systems Only)

The depth of the infiltration systems must be set to ensure the base is a minimum of 1.0m above the seasonal high water table and there is a minimum of 0.3m cover. Considering the water table sits 5m below surface (5m AHD), an infiltration depth of 1.0m is adopted with a cover of 0.5 m. This means the base of the infiltration system sits at 8.5m AHD which is 3.5m above the water table.

Infiltration depth	= 1.0m
Cover	= 0.5m
Top of infiltration system	= 9.5m AHD
Base of infiltration system	= 8.5m AHD
Depth to water table	= 3.5m

13.8.7.9 Step 9: Specify Infiltration 'Detention Volume' Elements

The following design specification applies to the infiltration 'soak-away':

- gravel – clean (fines free) stone/ gravel with a uniform size of 50 mm diameter;
- geofabric – Geofabric must to be installed along the side walls and through the base of the infiltration detention volume to prevent the migration of *in-situ* soils into the system. Geofabric must be non-woven type with a minimum perforation or mesh size of 0.25 mm.

13.8.7.10 Step 10: Hydraulic Control Design

Flow into the infiltration 'soak-away' will be regulated through a discharge control pit with overflow or bypass flows being directed into the piped drainage system located in the road reserve. As depicted in **Figure 13.8-1** (over page), the discharge control pit consists of the following:

- discharge pipe – discharge 'above design flow' (2 year ARI) into the pit;
- inflow pipe – connection between the pit and the infiltration basin sized to convey 'design operation flow' (1 year ARI);
- perforated inflow pipes – to distribute 'design operation flow' (1 year ARI) into the gravel filled 'detention volume';
- overflow weir – to bypass 'above design flow' (2 year ARI).

a) Discharge Pipe

The discharge pipe into the control pit is sized to convey the 'above design flow' (2 year ARI = 0.226 m³/s) into the discharge control pit using **Equation 13.8.5** in accordance with **QUDM (DPI, IMEA & BCC 1992)**. The resulting pipe size is a 375 mm diameter reinforced concrete pipe (RCP) at 2% grade (calculation not presented). The pipe will enter the pit at 9.2m AHD. Therefore the invert of the discharge control pit is set at 9.0m AHD.

Discharge Pipe = 375 mm diameter RCP at 2% grade
 Invert Level at Pit = 9.0m AHD

b) Inflow Pipe (Connection to Infiltration System)

The size of the inflow pipe connecting the discharge pit to the infiltration system is calculated by estimating the velocity in the connection pipe using a simplified version of **Equation 13.8.5**:

$$h = \frac{2 \cdot V^2}{2 \cdot g}$$

Where:

h	=	head level driving flow through the pipe (defined as the overflow weir crest level minus the invert level of the inflow pipe)
	=	9.5m AHD – 9.0m AHD = 0.5m
V	=	pipe velocity (m/s)
g	=	gravity (9.79 m/s ²)

Note: *The coefficient of 2 in the equation is a conservative estimate of the sum of entry and exit loss coefficients ($K_{in} + K_{out}$).*

Hence,

$$V = \sqrt{\frac{h \cdot g}{2}} = \sqrt{\frac{0.5 \cdot 9.79}{2}} = 2.21 \text{ m/s}$$

The area of pipe required to convey the 'design operation flow' (1 year ARI) is then calculated by dividing the above 'design operation flow' by the velocity:

$$A = \frac{Q}{V} = \frac{0.169}{2.21} = 0.076 \text{ m}^2$$

This area is equivalent to ~ 300 mm RCP. The invert of the pipe within the discharge pit is to be set at 9.0m AHD.

Inflow pipe = 300 mm diameter RCP
 Invert Level at Pit = 9.0m AHD

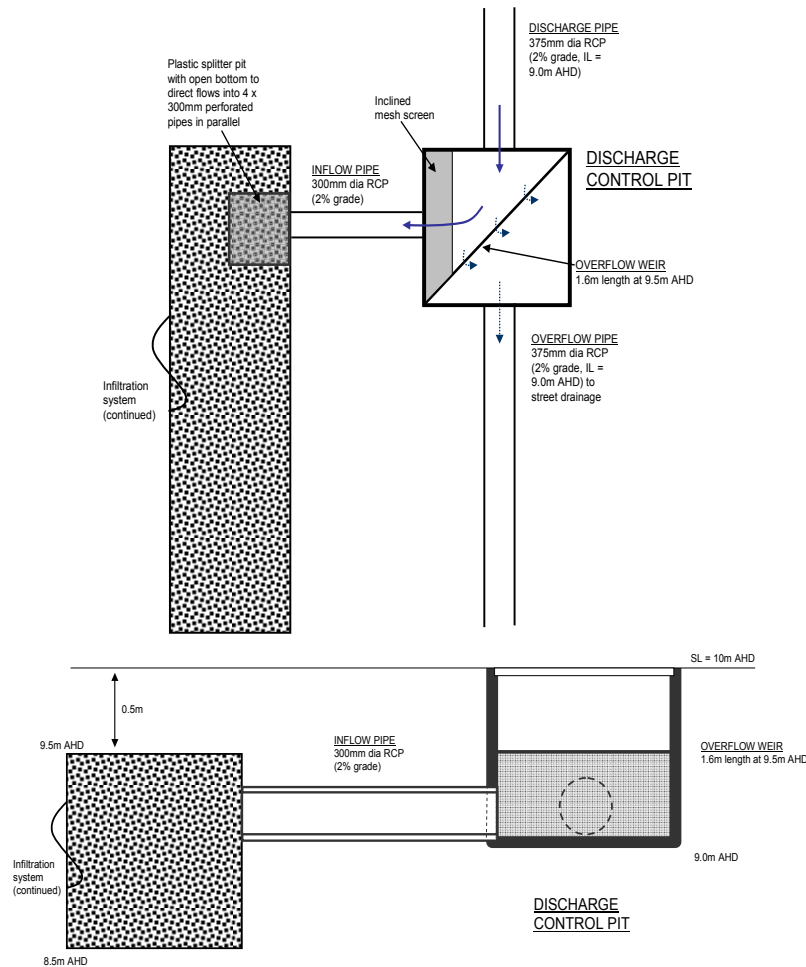


Figure 13.8-1: Discharge Control Pit Configuration

c) Perforated Inflow Pipes

To ensure appropriate distribution of flows into the gravel filled ‘detention volume’, nine 150 mm diameter perforated pipes laid in parallel (0.45m apart) are to accept flows from the 300 mm diameter RCP. The pipes have a slot clear opening of 3150 mm²/m with the slots being 1.5 mm wide and are to be placed at 2% grade. The upstream and downstream invert levels of the perforated pipes are 8.85m and 8.75m AHD respectively.

Two design checks are required:

- ensure the pipe has capacity to convey the ‘design operation flow’ (0.169 m³/s);
- ensure the perforations are adequate to pass the ‘design operation flow’.

Perforated Pipe Conveyance

Manning’s equation is applied to estimate the flow rate in the perforated pipes and confirm the capacity of the pipes is sufficient to convey the ‘design operation flow’ (0.169 m³/s). The nine 150 mm diameter perforated pipes are to be laid in parallel at a grade of 2%.

Applying the Manning’s Equation assuming a Manning’s *n* of 0.015 finds:

$$Q \text{ (flow per pipe)} = 0.019 \text{ m}^3/\text{s}$$

$$Q_{\text{Total}} = 0.172 \text{ m}^3/\text{s} \text{ (for nine pipes)} > 0.169 \text{ m}^3/\text{s}, \text{ and hence OK.}$$

Perforated Pipe Slot Conveyance

To ensure the perforated pipe slots are not a hydraulic choke in the system, the flow capacity of perforated pipe slots is estimated and compared with the ‘design operation flow’ (0.169 m³/s). To estimate the flow rate, an orifice equation (**Equation 13.8.6**) is applied as follows:

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

Where:

Head (h) = 0.625m (Average centroid level of perforated pipe is 8.875m; Spillway weir 9.5m; $0.625 = 9.5 - 8.875\text{m}$)

Blockage (B) = 0.5 (50% blocked)

Area (A) = $3150 \text{ mm}^2/\text{m}$ perforations

Slot Width = 1.5 mm

Slot Length = 7.5 mm

Pipe diameter = 375 mm

Coefficient (C_d) = 0.61 (assume slot width acts as a sharp edged orifice).

Number of slots per metre = $(3150)/(1.5 \times 7.5) = 280$

Inlet capacity/m of pipe = $0.5 \times 0.61 \times 0.00315 \times \sqrt{2 \times 9.81 \times 0.625}$
 = $0.0034 \text{ m}^3/\text{s}$

Inlet capacity/m x total length (9 lengths of 5m) = $0.0034 \times (9 \times 6.5)$
 = $0.19 \text{ m}^3/\text{s} > 0.169$, hence OK.

Perforated pipes = 9 x 150 mm diameter perforated pipe laid in parallel, 0.45m apart and at 2% grade.

d) Overflow Weir

An overflow weir (internal weir) located within the discharge control pit separates the inflow pipe to the infiltration system from the overflow pipe connecting to the street drainage. The overflow weir is to be sized to convey the 'above design flow' of $0.242 \text{ m}^3/\text{s}$ and surcharge 0.2m above the weir.

The weir flow equation (**Equation 13.8.7**) is used to determine the required weir length:

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

So

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

Using:

above 'Design Operation Flow' = $0.226 \text{ m}^3/\text{s}$

B = 1.0 (no blockage for internal weir)

C_w = 1.66

H = 0.2m

Gives:

L = 1.52m

If the weir is located diagonally across the discharge control pit, a 1200 x 1200 mm pit can be used. The crest of the weir must be set at the top of the 'detention volume' of the infiltration system (ie. 9.5m AHD).

Overflow weir = 1.52m length at 9.5m AHD

Discharge control pit = 1200 x 1200 mm

13.8.7.11 Design Calculation Summary

The sheet below summarises the results of the design calculations.

Drawing 13.8.1 demonstrates the principles of this worked example.

Infiltration Systems		Calculation Summary	
Calculation Task		Outcome	Check
Catchment Characteristics			
	Catchment Area	0.8 ha	✓
	Catchment Land Use (ie. Residential, Commercial, etc)	Industrial	
	Storm Event Entering Infiltration System (Minor or Major)	2 year ARI	
1	Site and Soil Evaluation		
	Site and Soil Evaluation undertaken in accordance with AS1547-2000 Clause 4.1.3		
	Soil Type	Sandy Clay	✓
	Hydraulic Conductivity (K_{sat})	80 mm/hr	
	Presence of Soil Salinity	No	
	Presence of Rock/ Shale	No	
	Infiltration Site Terrain (% Slope)	2-4%	
	Groundwater Level	5 m AHD 5 m below surface	
	Groundwater Quality	Moderate	
	Groundwater Uses	Irrigation	
2	Confirm Design Objectives		
	Confirm design objective as defined by conceptual design	No increase in mean annual runoff. 40% hydrologic effectiveness	✓
3	Select Infiltration System Type		
	Leaky Well		✓
	Infiltration Trench		
	Infiltration 'Soak-away'	✓	
	Infiltration Basin		
4	Pretreatment Design		
	Level 1 Pretreatment (avoid clogging)	✓	✓
	Level 2 Pretreatment (groundwater protection)	✓	
5	Determine Design Flows		
	'Design Operation Flow' – 1 year ARI	1 year ARI	✓
	'Above Design Flow' – either 2 or 50 year ARI	2 year ARI	
	Time of Concentration		
	Refer to Section 3.5 and QUDM	10 minutes	✓
	Identify Rainfall Intensities		
	'Design Operation Flow' – $I_{1 \text{ year ARI}}$	100 mm/hr	✓
	'Above Design Flow' – $I_{2 \text{ year ARI}}$ OR $I_{10 \text{ year}}$ OR $I_{100 \text{ year ARI}}$	125.4 mm/hr	
	Design Runoff Coefficient		
	'Design Operation Flow' – $C_{1 \text{ year ARI}}$	0.76	✓
	'Above Design Flow' – $C_{2 \text{ year ARI}}$ OR $C_{10 \text{ year}}$ OR $C_{100 \text{ year ARI}}$	0.81	
	Peak Design Flows		
	'Design Operation Flow' – 1 year ARI	0.169 m ³ /s	✓
	'Above Design Flow' – either 2, 10 or 100 year ARI	0.226 m ³ /s	
6	Size Infiltration System		
	Hydrologic Effectiveness Approach		
	Hydrologic Effectiveness Objective	40 %	✓
	Depth	1 m	
	Porosity (void = 1.0, gravel filled = 0.35)	0.35	
	'Infiltration Area'	29 m ²	
	'Detention Volume'	29 m ³	

Infiltration Systems		Calculation Summary	
Calculation Task		Outcome	Check
Design Storm Approach			
	Design Storm Flow	- m ³ /s	✓
	Inflow Volume	- m ³	
	Outflow Volume	- m ³	
	Depth	- m	
	'Infiltration Area'	- m ²	
	'Detention Volume'	- m ³	
7	Locate Infiltration System		
	Minimum distance from boundary (Table 13.8-E)	2 m	✓
	Width	4.5 m	
	Length	6.5 m	
8	Set Infiltration Depths (Sub-Surface Systems Only)		
	Ground Surface Level	10 m AHD	✓
	Groundwater Level	5 m AHD	
		5 m below surface	
	Infiltration System Depth	1 m	
	Top of Infiltration System	9.5 m AHD	
	Base of Infiltration System	8.5 m AHD	
	Cover	0.56 m	
	Depth to Water Table	3.5 m	
9	Specify Infiltration 'Detention Volume' Elements		
	Gravel Size	50 mm diam.	✓
	Modular Plastic Cells		
	Geofabric	✓	
10	Flow Management Design		
	Inflow/ Overflow Structures		
	Direct Inflow		✓
	Overflow Pit/ Pipe		
	Discharge Control Pit	✓	
	Discharge Pipe		
	Pipe Capacity	0.226 m ³ /s	✓
	Pipe Size	375 mm diam.	
	Inflow Pipe		
	Pipe Capacity	0.169 m ³ /s	✓
	Pipe Size	300 mm diam.	
	Overflow Pipe		
	Pipe Capacity	0.226 m ³ /s	✓
	Pipe Size	375 mm diam.	
	Overflow Pit		
	Pit Capacity	- m ³ /s	
	Pit Size	- mm x mm	
	Perforated Inflow Pipes		
	No. of Pipes	9	✓
	Pipe Size	150 mm	
	Discharge Control Pit		
	Pit Size	1200 x 1200 mm x mm	✓
	Weir Length	1.52 m	

13.8.8 References

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