# Chapter 10 Infiltration Measures

**Definition:**

A sub-surface water filtration system designed to allow water to infiltrate into surrounding soils.

**Purpose:**

- To encourage stormwater to infiltrate into surrounding soils.
- To reduce runoff as well as provide pollutant retention on site.
- To provide some detention and retention functionality

**Implementation considerations:**

- They are highly dependant on local soil characteristics and are best suited to sandy soils with deep groundwater.
- All infiltration measures require significant pretreatment of stormwater before infiltration to avoid clogging of the surrounding soils and to protect groundwater quality.
- Generally these measures are well suited to highly permeable soils, so that water can infiltrate at a sufficient rate. Areas with lower permeability soils may still be applicable, but larger areas for infiltration and detention storage volumes are required.
- Infiltration measures are required to have sufficient set-back distances from structures to avoid any structural damage, these distances depend on local soil conditions.

Infiltration measures can also be vegetated and provide some landscape amenity to an area. These systems provide improved pollutant removal through active plant growth improving filtration and ensuring the soil does not become 'clogged' with fine sediments.

*Infiltration systems are best suited to sandy soils with deep groundwater*

# 10.1 Introduction

Stormwater infiltration systems are designed to encourage stormwater to infiltrate into surrounding soils via a controlled system and are particularly suited to reducing the magnitude of peak storm discharges from impervious areas (Figure 10.1 illustrates an infiltration system during operation).

This chapter outlines the engineering design of such systems following the selection of a required detention storage volume associated with infiltration. Australian Run-off Quality (Engineers Australia, 2003) provides a detailed discussion of procedures for sizing stormwater infiltration systems.

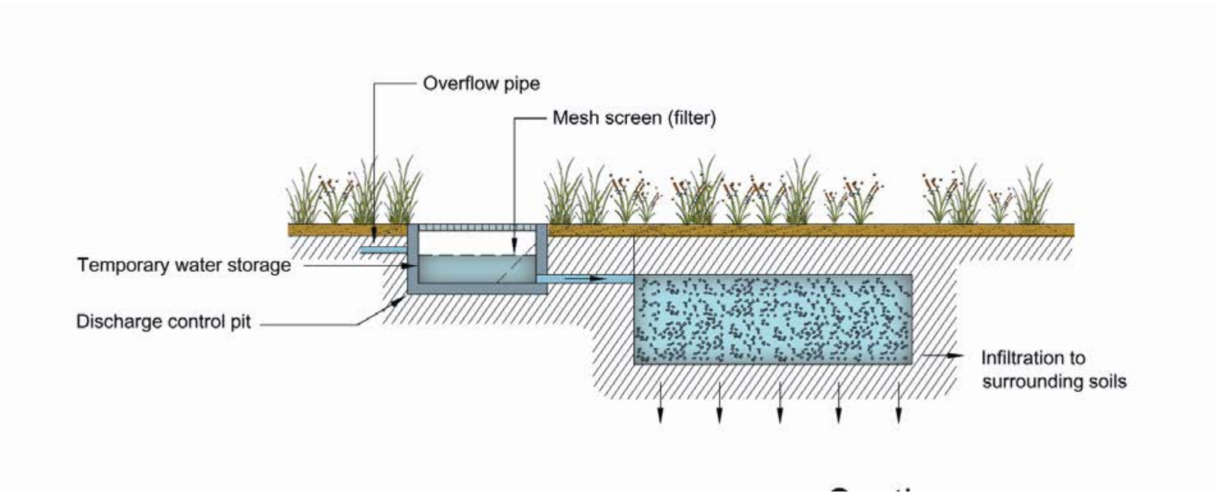



Figure 10.1 Operation of a gravel filled 'soak-away' pit style infiltration system

Not all areas are suited to infiltration systems and the following criteria should be taken into consideration when designing these systems.

- These systems are highly dependent on local soil characteristics and are best suited to sandy soils with deep groundwater.
- All infiltration measures require significant pretreatment of stormwater before infiltration to avoid clogging of the surrounding soils and to protect groundwater quality. Pre-treatment to remove sediments is a vital component in the treatment train and infiltration systems should be positioned as the final element of a treatment train, with its primary function being the discharge of treated stormwater into the surrounding soils and groundwater system.
- Careful consideration of the type of runoff source area from which the runoff originates is important to ensure the continued effective operation of these schemes. Poor consideration of catchment pollutant types and characteristics and site conditions is often the main cause for deteriorating infiltration effectiveness over time because of clogging and lack of appropriate maintenance.

Soils with low hydraulic conductivities do not necessarily preclude the use of infiltration systems even though the required infiltration/storage area may become unfeasible.

Additionally, these soils are likely to render them more susceptible to clogging and require enhanced pretreatment.

Low infiltration rates also lead to the detention of water for long periods of time, which may also promote algal growth that increases the risk of clogging of the infiltration media. It is therefore recommended that soil saturated hydraulic conductivities exceeding $1 \times 10^{-5}$ m/s (36 mm/hr) are most suited for infiltration systems.

Other key factors influencing the operation of an infiltration system are the relationship between infiltration rate, the volume of runoff discharged into the infiltration system, depth to groundwater or bedrock and the available detention storage, i.e.

- The infiltration rate is a product of the infiltration area and the hydraulic conductivity of the in-situ soil, i.e. $Q_{inf} = A \times K_h$ ($m^3/s$). It follows that different combinations of infiltration area and hydraulic conductivity can produce the same infiltration rate.
- The volume of runoff discharged into an infiltration system is a reflection of the catchment area of the system and the meteorological characteristics of the catchment.
- The detention storage provides temporary storage of inflow to optimise the volume of runoff that can be infiltrated.

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 condition, the hydrologic effectiveness of an infiltration system is determined by the combined effect of the soil hydraulic conductivity, infiltration area and available detention storage.

As outlined in Australian Runoff Quality (Engineers Australia, 2006), there are four basic types of detention storages used for promoting infiltration, these being:

- Single size gravel or crushed concrete trenches
- Upstand slotted pipes forming “leaky wells”
- “milk-crate” type trenches or “soakaways”
- Infiltration basins.

# 10.2 Verifying size for treatment

Figure 10.2 shows relationships between the hydrologic effectiveness, infiltration area and detention storage for a range of soil hydraulic conductivities using Hobart meteorological conditions. These charts can be used to verify the selected size of a proposed infiltration system.

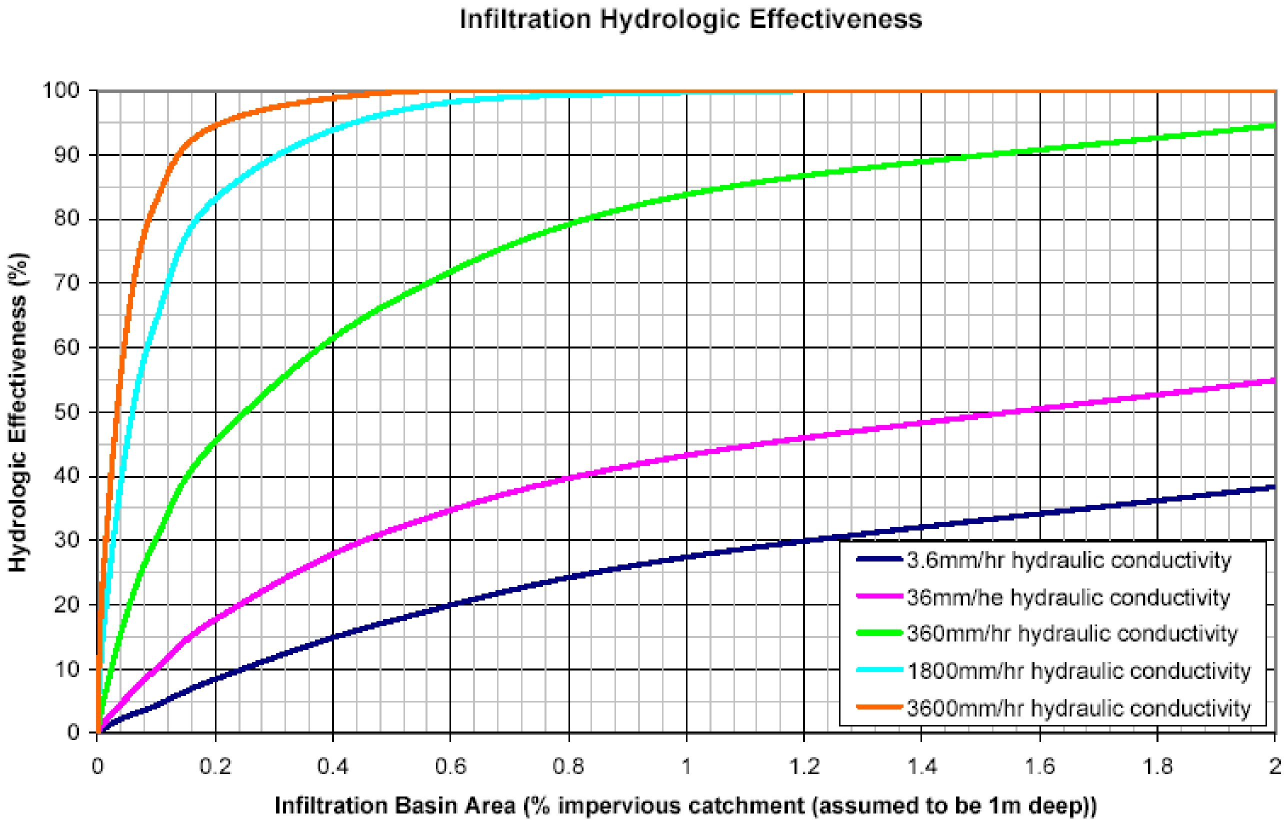



Figure 10.2 Hydrologic Effectiveness of Detention Storages for Infiltration Systems at the reference site

# 10.3 Design procedure: infiltration measures

## 10.3.1 Checking Field Conditions

Key factors influencing a site's capability to infiltrate stormwater are the soil permeability, soil reactivity to frequent wetting, presence of groundwater and its environmental values and site terrain.

### *10.3.1.1 Site terrain and soil salinity*

A combination of poor soil conditions (e.g. sodic and dispersive soils), steep terrain and shallow saline groundwater can render the use of infiltration systems inappropriate. Dryland salinity is caused by a combination of factors, including leaching of infiltrated water and salt at "break-of-slope" terrain and the tunnel erosion of dispersive soils. Soil with high sodicity is generally not considered to be suited for infiltration as a means of managing urban stormwater.

Infiltration into steep terrain can result in the stormwater re-emerging onto the surface at some point downstream. The likelihood of this pathway for infiltrated water is dependent on the soil structure, with duplex soils and shallow soil over rock being situations where re-emergence of infiltrated water to the surface is most likely to occur. This occurrence does 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.

*10.3.1.2 Hydraulic Conductivity*

It is essential that field hydraulic conductivity tests be undertaken to confirm assumptions of soil hydraulic conductivity adopted during the concept design stage. Field soil hydraulic conductivity can be determined using the falling head augerhole method of Jonasson (1984). The range of soil hydraulic conductivities typically determined from a 60-minute falling head period is as follows:

Sandy soil: $K_{60}$ = $5 \times 10^{-5}$ m/s (180 mm/hr)

Sandy clay: $K_{60}$ = between $1 \times 10^{-5}$ and $5 \times 10^{-5}$ m/s (36 to 180 mm/hr)

Medium clay: $K_{60}$ = between $1 \times 10^{-6}$ and $1 \times 10^{-5}$ m/s (3.6 to 36 mm/hr)

Heavy clay: $K_{60}$ = between $1 \times 10^{-8}$ and $1 \times 10^{-6}$ m/s (0.036 to 3.6 mm/hr)

where $k_{60}$ is the 60-minute value of hydraulic conductivity.

Saturated hydraulic conductivity ($K_{sat}$) is the hydraulic conductivity of a soil when it is fully saturated. $K_{60}$ is considered to be a reasonable estimate of $K_{sat}$ for design purposes and can be measured in the field.

Soil is inherently non-homogeneous and field tests can often misrepresent the areal hydraulic conductivity of a soil into which stormwater is to be infiltrated. Field experience has suggested that field tests of "point" soil hydraulic conductivity can often under-estimate the areal hydraulic conductivity of clay soils and over-estimate in sandy soils. To this end, Australian Runoff Quality (Engineers Australia, 2006) recommends that moderation factors for hydraulic conductivities determined from field test be applied as shown in Table 11.1.

**Table 10-1 Moderation factors to convert point to areal conductivities (after Engineers Australia, 2003)**

| Soil Type | Moderation Factor (U) (to convert "point" $K_h$ to areal $K_h$) |
|---|---|
| Sandy soil | 0.5 |
| Sandy clay | 1.0 |
| Medium and Heavy Clay | 2.0 |

*10.3.1.3 Groundwater*

Two groundwater issues need to be considered when implementing an infiltration system. The first relates to the environmental values of the groundwater (i.e. the receiving water) and it may be necessary to achieve a prescribed water quality level before stormwater can be discharged into them. A second design consideration is to ensure that the base of an infiltration system is always above the groundwater table and consideration of the seasonal variation of groundwater levels is essential if a shallow groundwater table is likely to be encountered. This investigation should include groundwater mounding (i.e. higher levels in the immediate vicinity of the infiltration system) that in shallow groundwater areas could cause problems with nearby structures.

## 10.3.2 Estimating design flows

### *10.3.2.1 Design Discharges*

Two design flows are required for infiltration systems:

- Peak inflow to the infiltration system for design of an inlet structure.
- Major flood rates for design of a by-pass system.

Infiltration systems can be subjected to a range of performance criteria including that of peak discharge attenuation and volumetric runoff reduction.

Design discharge for the by-pass system is often set at the 100-year ARI event or the discharge capacity of the stormwater conveyance system directing stormwater runoff to the infiltration system. Consultation with the relevant local authority is important to determine their criteria or requirements for the discharge design rainfall ARI.

### *10.3.2.2 Minor and major flood estimation*

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

Figure 10.3 shows an assumed shape of an inflow hydrograph that can be used to estimate the temporary storage volume for an infiltration system. The flow rate shown on the diagram represents a linear increase in flow from the commencement of runoff to the time of concentration, then this peak flow rate is maintained for the storm duration. Following the storm duration the flow rate decreases linearly over the time of concentration. This is a simplification of an urban hydrograph for the purposes of design.

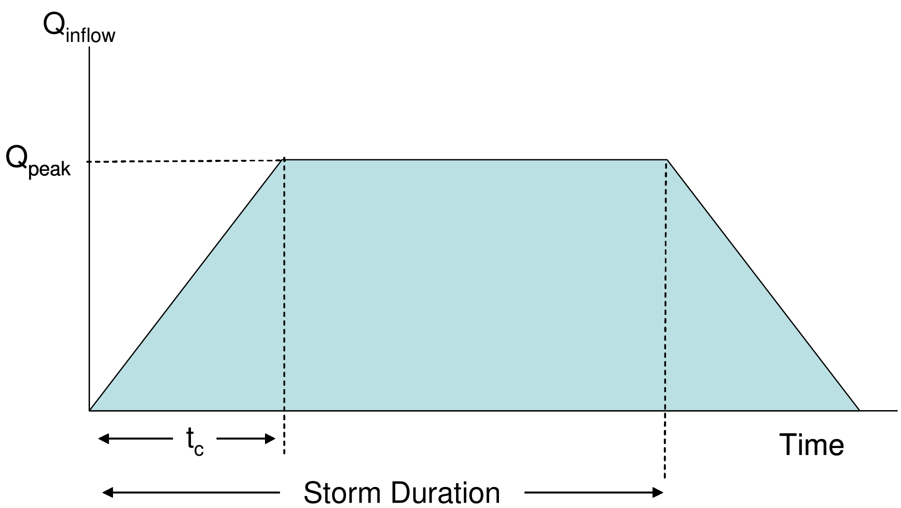



**Figure 10.3 Generalised shape of inflow hydrograph**

### 10.3.3 Location of Infiltration Systems

Infiltration systems should not be placed near building footings to remove the influence of continually wet subsurface or greatly varying soil moisture contents on the structural integrity of these structures. Australian Runoff Quality (Engineers Australia, 2006) recommends minimum distances from structures in Table 10.2 (and property boundaries to protect possible future buildings in neighbouring properties) for different soil types.

**Table 10-2 Minimum set-back distances (adapted from Engineers Australia, 2006)**

| Soil Type | Saturated Hydraulic Conductivity | Minimum distance from structures and property boundaries |
|---|---|---|
| Sand | > $5 \times 10^{-5}$ m/s (180 mm/hr) | 1.0 m |
| Sandy Clay | $1 \times 10^{-5}$ to $5 \times 10^{-5}$ m/s (36 to 180 mm/hr) | 2.0 m |
| Weathered or Fractured Rock | $1 \times 10^{-6}$ to $1 \times 10^{-5}$ m/s (3.6 to 36 mm/hr) | 2.0 m |
| Medium Clay | $1 \times 10^{-6}$ to $1 \times 10^{-5}$ m/s (3.6 to 36 mm/hr) | 4.0 m |
| Heavy Clay | $1 \times 10^{-8}$ to $1 \times 10^{-6}$ m/s (0.036 to 3.6 mm/hr) | 5.0 m |

Identifying suitable sites for infiltration systems should also include avoidance of steep terrain and areas of shallow soils overlying largely impervious rock (non-sedimentary rock and some sedimentary rock such as shale). An understanding of the seasonal variation of the groundwater table is also an essential element in the design of these systems.

### 10.3.4 Source Treatment

Treatment of source water for the removal of debris and sediment is essential and storm runoff should never be conveyed directly into an infiltration system. Pre-treatment measures include the provision of leaf and roof litter guards along the roof gutter, sediment sumps, vegetated swales, bioretention systems or sand filters.

### 10.3.5 Sizing the detention storage

#### *10.3.5.1 Storage Volume*

The required storage volume of an infiltration system is defined by the difference in inflow and outflow volumes for the duration of a storm. The inflow volume is a product of rainfall, contributing area and the runoff coefficient connected to the infiltration system, i.e.

$$\text{Inflow volume (for storm duration D, m}^3\text{)} = C \times I \times A \times D/1000$$

**Equation 10.1**

where C is the runoff coefficient as defined in ARR Book VIII

I is the probabilistic rainfall intensity (mm/hr)

A is the contributing area connected to the infiltration system ($m^2$)

D is the storm duration (hours)

Outflow from the infiltration system is via the base and sides of the infiltration system and depends on the area and depth of the infiltration system. 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, i.e.

$$\text{Outflow volume (for storm duration D, } m^3) = [(A_{inf}) + (P \times d/2)] \times U \times K_h \times D/1000$$

where $K_h$ is the "point" saturated hydraulic conductivity (mm/hr)

$A_{inf}$ is the infiltration area ($m^2$)

P is the perimeter length of the infiltration area (m)

d is the depth of the infiltration system (m)

U is the "point" soil hydraulic conductivity moderating factor (see Table 11.1)

D is the storm duration (hours)

Approximations of the required storage volumes of an infiltration system can be computed as follows:

$$\text{Required Storage } (m^3) = \{(C \times I \times A) - [(A_{inf}) + (P \times d/2)] \times U \times K_h\} D/1000$$

**Equation 10.2**

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 the one which results in the highest required storage. A spreadsheet application is the most convenient way of doing this.

*10.3.5.2 Emptying Time*

Emptying time is defined as the time taken to fully empty a detention storage associated with an infiltration system following the cessation of rainfall. This is an important design consideration as the computation procedure associated with Figure 10.3. 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, depending on the average recurrence interval of the design event with the former being more appropriate for frequent events (1 in 3 month ARI) and the latter to less frequent events of 50 years or longer ARI.

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).

### 10.3.6 Hydraulic Structures

Two checks of details of the inlet hydraulic structure are required for infiltration systems, i.e. provision of energy dissipation and by-pass of above design discharges. By-pass can be achieved in a number of ways, most commonly a surcharge pit, an overflow pit or discharge into an overflow pipe connected to a drainage system. Details of designing a surcharge pit are described in Chapter 4, 5 and 7.

### 10.3.7 Design calculation summary

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

## Infiltration System — CALCULATION SUMMARY

| | CALCULATION TASK | OUTCOME | | CHECK |
|---|---|---|---|---|
| 1 | **Identify design criteria** | | | ☐ |
| | Design ARI event to be infiltrated (in its entirety) | | year | |
| | OR | | | |
| | Design Hydrologic Effectiveness | | % | |
| | ARI of Bypass Discharge | | year | |
| 2 | **Site characteristics** | | | ☐ |
| | Catchment Area connected to infiltration system | | $m^2$ | |
| | Impervious Area connected to infiltration system | | $m^2$ | |
| | Site hydraulic conductivity | | mm/hr | |
| | Areal hydraulic conductivity moderating factor | | | |
| 3 | **Estimate design flow rates** | | | |
| | **Time of concentration** | | | |
| | estimate from flow path length and velocities | | minutes | ☐ |
| | **Identify rainfall intensities** | | | |
| | station used for IFD data: | | | |
| | Design Rainfall Intensity for inlet structure(s) | | mm/hr | |
| | Design Rainfall Intensity for overflow structure(s) | | mm/hr | ☐ |
| | **Design runoff coefficient** | | | |
| | inlet structure(s) | | | ☐ |
| | **Peak design flows** | | | ☐ |
| | Inlet structure(s) | | $m^3/s$ | |
| | Bypass structure(s) | | $m^3/s$ | |
| 4 | **Detention Storage** | | | ☐ |
| | Volume of detention storage | | m3 | |
| | Dimensions | | L:W | |
| | Depth | | m | |
| | Emptying Time | | hrs | |
| 5 | **Provision of Pre-treatment** | | | ☐ |
| | Receiving groundwater quality determined | | | |
| | Upstream pre-treatment provision | | | |
| 6 | **Hydrualic Structures** | | | |
| | **Inlet Structure** | | | ☐ |
| | Provision of energy dissipation | | | |
| | **Bypass Structure** | | | ☐ |
| | Weir length | | m | |
| | Afflux at design discharge | | m | |
| | Provision of scour protection | | | |
| | **Discharge Pipe** | | | ☐ |
| | Capacity of Discharge Pipe | | $m^3/s$ | |

# 10.4 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 infiltration systems are provided.

Checklists are provided for:

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

## 10.4.1 Design assessment checklist

The checklist below presents the key design features that should be reviewed when assessing the design of an infiltration system. 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 installation. 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.

| Infiltration Design Assessment Checklist | | | | | |
|---|---|---|---|---|---|
| *Bioretention location:* | | | | | |
| *Hydraulics* | Minor Flood: $(m^3/s)$ | | Major Flood: $(m^3/s)$ | | |
| *Area* | Catchment Area (ha): | | Infiltration Area (ha) | | |
| Treatment | | | | Y | N |
| Pretreatment system sufficient to protect groundwater? | | | | | |
| Infiltration storage volume verified from curves? | | | | | |
| | | | | | |
| Inlet zone/hydraulics | | | | Y | N |
| Station selected for IFD appropriate for location? | | | | | |
| Overall flow conveyance system sufficient for design flood event? | | | | | |
| Velocities at inlet and within infiltration system will not cause scour? | | | | | |
| Bypass sufficient for conveyance of design flood event? | | | | | |
| | | | | | |
| Basin | | | | Y | N |
| Maximum ponding depth will not impact on public safety? | | | | | |
| Maintenance access provided to base of infiltration (where reach to any part of a basin >6m)? | | | | | |
| | | | | | |

## 10.4.2 Construction advice

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

Building phase damage

Protection of infiltration media and vegetation is critical during building phase, uncontrolled building site runoff is likely to cause excessive sedimentation, introduce litter and require replacement of media.

Traffic and deliveries

Ensure traffic and deliveries do not access infiltration areas during construction. Traffic can compact the filter media, cause preferential flow paths and clogging of the surface, deliveries and wash down material can also clog filtration media. Infiltration areas should be fenced off during building phase and controls implemented to avoid washdown wastes.

Timing for engagement

It is critical to ensure that the pretreatment system for an infiltration device is fully operational before flows are introduced into the infiltration media. This will prolong the life of the infiltration system and reduce the risk of clogging.

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 infiltration rates can be confirmed over time.

Clean drainage media

Ensure drainage media is washed prior to placement to remove fines and prevent clogging.

## 10.4.3 Construction checklist

**CONSTRUCTION INSPECTION CHECKLIST**

Infiltration measures

| |
|---|
| 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 | | | | | 10. Location and levels of overflow points as designed | | | | |
| 2. Traffic control measures | | | | | 11. Pipe joints and connections as designed | | | | |
| 3. Location same as plans | | | | | 12. Concrete and reinforcement as designed | | | | |
| 4. Site protection from existing flows | | | | | 13. Inlets appropriately installed | | | | |
| **Earthworks** | | | | | 14. Observation wells appropriately installed | | | | |
| 5. Excavation as designed | | | | | **Infiltration system** | | | | |
| 6. Side slopes are stable | | | | | 15. Correct filter media used | | | | |
| **Pre-treatment** | | | | | 16. Fines removed from filter media | | | | |
| 7. Maintenance access provided | | | | | 17. Inlet and outlet as designed | | | | |
| 8. Invert levels as designed | | | | | | | | | |
| 9. Ability to freely drain | | | | | | | | | |
| **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. Filter media as specified | | | | | 9. Construction generated sediment and debris removed | | | | |
| 5. Confirm pre-treatment is working | | | | | | | | | |

**COMMENTS ON INSPECTION**

| |
|---|
| |
| |
| |
| |
| |
| |

**ACTIONS REQUIRED**

| |
|---|
| 1. |
| 2. |
| 3. |
| 4. |
| 5. |
| 6. |

Inspection officer signature: ______________________

### 10.4.4 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? | | |
| | | |

## 10.5 Maintenance requirements

Maintenance for infiltration systems is focused on 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 is operating as designed.

In addition to checking and maintaining the pretreatment, the form below can be used during routine maintenance inspections:

| Infiltration Maintenance Checklist | | | |
|---|---|---|---|
| Inspection Frequency: 3 monthly | Date of Visit: | | |
| *Location:* | | | |
| *Description:* | | | |
| *Site Visit by:* | | | |
| **Inspection Items** | **Y** | **N** | **Action Required (details)** |
| Sediment accumulation in pretreatment zone requires removal? | | | |
| Erosion at inlet or other key structures? | | | |
| Evidence of dumping (eg building waste)? | | | |
| Evidence of extended ponding times (eg. algal growth)? | | | |
| Weeds present within device? | | | |
| Clogging of drainage points (sediment or debris)? | | | |
| Damage/vandalism to structures present? | | | |
| Surface clogging visible? | | | |
| Drainage system inspected? | | | |
| Resetting of system required? | | | |
| Comments: | | | |

# 10.6 Infiltration system worked example

## 10.6.1 Introduction

An infiltration system is to be installed to treat stormwater runoff from a residential allotment in Venus Bay. As discussed in Australian Runoff Quality (Engineers Australia, 2003), pre-treatment of stormwater prior to discharge into the ground via infiltration is essential to ensure sustainable operation of the infiltration system and protection of groundwater. Suspended solids and sediment are the key water quality constituents requiring pre-treatment prior to infiltration.

Roof run-off is directed into a rainwater tank for storage and to be used as an alternative source of water. Overflow from the rainwater tank can be discharged directly into the gravel trench for infiltration into the surrounding sandy soil without further “pre-treatment”. Stormwater runoff from paved areas will be directed to a pre-treatment vegetated swale and then into a gravel trench for temporary storage and infiltration. An illustration of the proposed allotment stormwater management scheme is shown in Figure 10.4.

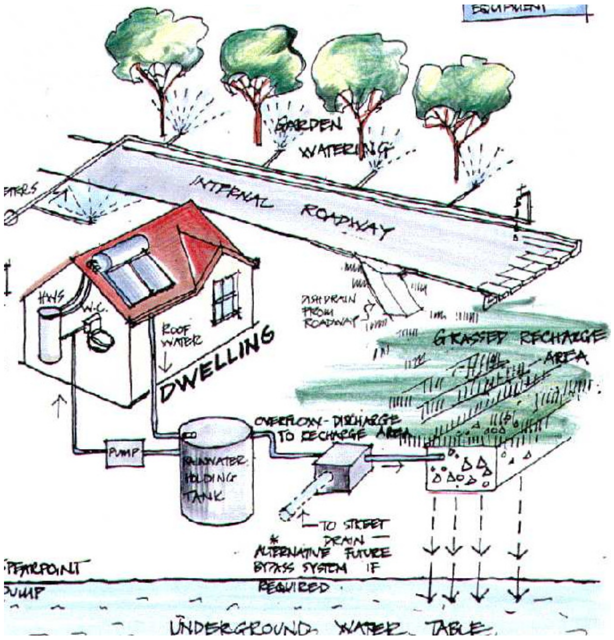



**Figure 10.4 Illustration of Allotment Stormwater Management Scheme**

[source: Urban Water Resource Centre, University of South Australia; http://www.unisa.edu.au/uwrc/ham.htm ]

The allotment in question in this worked example is 1000 $m^2$ in area on a rectangular site with an overall impervious surface area of 500 $m^2$. The site layout is shown in Figure 10.5.

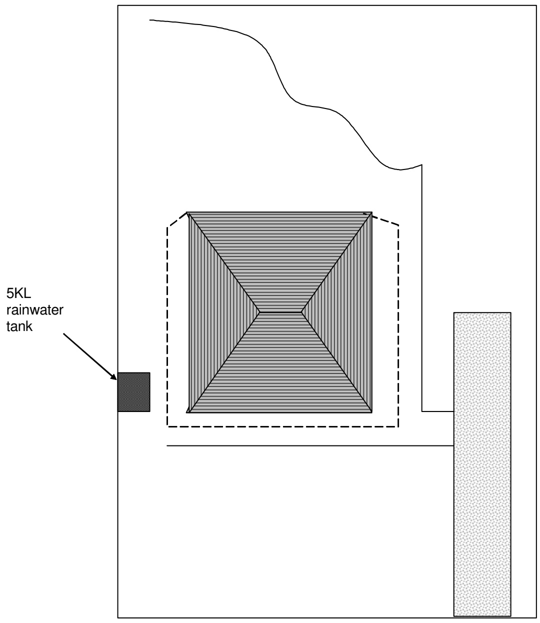



Figure 10.5 Site Layout

Of the impervious surfaces, roof areas make up a total of 210 $m^2$, while on-ground impervious surfaces make up the remaining 290 $m^2$. There is no formal stormwater drainage system, with stormwater runoff discharging into a small table drain in the front of the property.

The design objective of the infiltration system is retention of stormwater runoff from the allotment for events up to, and including, the 2-year ARI event. Stormwater flows in excess of the 2-year ARI peak discharges are directed towards the road table drain at the front of the property.

Roof runoff is directed to a 5kL rainwater tank. In this worked example, the design of the infiltration system involves an assumption that the 5kL tank will be full in the event of a 2-year storm event.

The design criteria for the infiltration system are to:

- Provide pre-treatment of stormwater runoff.
- Determine an appropriate size of infiltration system.
- Ensure that the inlet configuration to the infiltration system includes provision for by-pass of stormwater when the infiltration system is operating at its full capacity.

This worked example focuses on the design of the infiltration system and associated hydraulic structures. Analyses to be undertaken during the detailed design phase of the infiltration trench will be based on the procedure outlined in Australian Runoff Quality (Chapter 10 – Infiltration Systems).

*10.6.1.1 Design Objectives*

The design objectives are summarised as follows:

- Size infiltration trench to retain the entire runoff volume from the critical (volume) 2 year ARI storm event.
- Design the inlet and outlet structures to convey the peak 2-year ARI flow from the critical (flow rate) storm event. Ensure the inlet configuration includes provision for stormwater bypass when the infiltration system is full.
- Configure the layout of the infiltration trench and associated inlet/bypass structures.
- Pre-treat stormwater runoff.
- Design appropriate ground cover and terrestrial vegetation over the infiltration trench.

*10.6.1.2 Site Characteristics*

The property is frequently uninhabited and the 5kL tank will be full for a more significant proportion of time than typical installations. It is assumed that the 5kL tank will be full at the commencement of the design event.

The site characteristics are summarised as follows:

- Catchment area 210m² (roof)
  290 m² (ground level paved)
  500 m² (pervious)
  1000 m² (Total)
- Landuse/surface type pervious area is grassed or landscaped with garden beds.
- Overland flow slope Lot is 25m wide, 40m deep, slope = 3%
- Soil type sandy clay
- saturated hydraulic conductivity ($K_h$) = 360mm/hr

## 10.6.2 Checking Field Conditions

Boreholes were drilled at 2 locations within the site and the results are as follows:

- ❒ Field tests found the soil to be suitable for infiltration, consisting of fine sand with a saturated hydraulic conductivity of between 360 mm/hr to 1800 mm/hr.
- ❒ The moderating factor to convert this to the representative areal hydraulic loading is 0.5.

### 10.6.3 Estimating design flows

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

**Step 1 – Calculate the time of concentration.**

The catchment area is $1000m^2$

Min $t_c$ = 6 minutes

Rainfall Intensities for the area of study (for the 2 and 100 year average recurrence intervals) are estimated using ARR (1998) with a time of concentration of = 6 minutes and are:

$I_2$ = 56.4 mm/hr*

$I_{100}$ = 155 mm/hr*

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

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

Where – Fraction impervious ($f$) = 0.5

Rainfall intensity ($^{10}I_1$) = 25.6mm/hr (from the relevant IFD chart)

Calculate $C^1_{10}$ (pervious runoff coefficient)

$C^1_{10} = 0.1 + (0.7-0.1) \times (^{10}I_1 - 25)/(70 - 25) = 0.11$

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

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

$C_{10} = 0.50$

**Step 3 – Convert $C_{10}$ to values for $C_2$ and $C_{100}$**

Where – $C_y = F_y \times C_{10}$

Runoff coefficients as per Table 1.6 Book VIII ARR 1998

| ARI (years) | Runoff Coefficient, *Cy* |
|---|---|
| 2 | 0.43 |
| 100 | 0.60 |

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

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

| | | |
|---|---|---|
| Where – | C | is the runoff coefficient ($C_1$, $C_{10}$ and $C_{100}$) |
| | I | is the design rainfall intensity mm/hr ($I_1$ , $I_{10}$ and $I_{100}$) |
| | A | is the catchment area (Ha) |

Q2 = 0.007$m^3/s$

$Q_{100}$ = 0.026 $m^3/s$

| | | |
|---|---|---|
| Design Discharges | $Q_2$ | = 0.007 $m^3/s$ |
| | $Q_{100}$ | = 0.026 $m^3/s$ |

## 10.6.4 Location of Infiltration Systems

With a sandy soil profile, the minimum distance of the infiltration system from structures and property boundary is 1 m. 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 of the property with paved area runoff directed to grassed buffers and a feature vegetated landscaped area adjacent to the infiltration system. Overflow from the infiltration system will be directed to the table drain of the street in front of the property.

> The infiltration system is to be located near the front of the property set back by at least 1 m from the property boundary.

## 10.6.5 Source Treatment

Roof runoff is directed to a rainwater tank. Although the tank may often be full, it nevertheless serves a useful function as a sedimentation basin. This configuration is considered sufficient to provide the required sediment pretreatment for roof runoff.

Stormwater runoff from paved areas is directed to a combination of grass buffer areas and a landscape vegetated area which is slightly depressed to provide for trapping of suspended solids conveyed by stormwater. Stormwater overflow from the landscaped area into a grated sump pit and then into the infiltration system.

> Pre-treatment for sediment removal is provided by the following:
>
> - connection of roof runoff into a rainwater tank;
>
> - paved area runoff is conveyed to a combination of grassed buffer areas and a landscaped vegetated depression.

## 10.6.6 Sizing the detention storage

Estimating the required storage volume of the infiltration system involves the computation of the difference in the volumes of stormwater inflow and infiltration outflow according to Figure 10.6. A gravel-filled trench will be used, with a depth of 1 m proposed.

Figure 10.6 shows the spreadsheet developed to undertake the calculations to determine the required dimension of a gravel-filled soakaway trench for the range of probabilistic 2-year ARI storm durations. By varying the size (and perimeter) of the infiltration system, at least 100% of required storage is provided for all storm durations.

**Calculation of Dimensions of Soakaways**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Location** | **Venus Bay** | | | | | |
| Catchment Area | 1000 | $m^2$ | Infiltration Area | 16 | $m^2$ | |
| Volumetric Runoff Coefficient | 0.55 | | Perimeter of Infiltration Area | 20 | m | |
| Soil $K_h$ | 360 | mm/hr | Emptying Time | 1 | hours | OK |
| Moderating Factor | 0.5 | | | | | |
| Width of Infiltration Area | 2 | m | | | | |
| Length of Infiltration Area | 8 | m | | | | |
| Depth of Storage | 1 | m | | | | |
| Porosity | 0.35 | | | | | |

| Storm Duration | Storm Mean Intensity | Volume in | Volume out | Storage Volume Required | Percentage of Storage provided | |
|---|---|---|---|---|---|---|
| (minutes) | (mm/hr) | ($m^3$) | ($m^3$) | ($m^3$) | % | |
| 6 | 56.39 | 3.101 | 0.468 | 2.633 | 213% | OK |
| 12 | 42.29 | 4.652 | 0.936 | 3.716 | 151% | OK |
| 18 | 34.87 | 5.754 | 1.404 | 4.350 | 129% | OK |
| 30 | 26.71 | 7.345 | 2.340 | 5.005 | 112% | OK |
| 45 | 21.27 | 8.774 | 3.510 | 5.264 | 106% | OK |
| 60 | 17.97 | 9.884 | 4.680 | 5.204 | 108% | OK |
| 90 | 14.11 | 11.641 | 7.020 | 4.621 | 121% | OK |
| 120 | 11.84 | 13.024 | 9.360 | 3.664 | 153% | OK |
| 180 | 9.22 | 15.213 | 14.040 | 1.173 | 477% | OK |
| 240 | 7.72 | 16.984 | 18.720 | 0.000 | | OK |
| 300 | 6.72 | 18.480 | 23.400 | 0.000 | | OK |
| 360 | 6.01 | 19.833 | 28.080 | 0.000 | | OK |
| 480 | 5.03 | 22.132 | 37.440 | 0.000 | | OK |
| 600 | 4.39 | 24.145 | 46.800 | 0.000 | | OK |
| 720 | 3.92 | 25.872 | 56.160 | 0.000 | | OK |
| 840 | 3.53 | 27.181 | 65.520 | 0.000 | | OK |
| 960 | 3.22 | 28.336 | 74.880 | 0.000 | | OK |
| 1080 | 2.98 | 29.502 | 84.240 | 0.000 | | OK |
| 1200 | 2.77 | 30.470 | 93.600 | 0.000 | | OK |
| 1320 | 2.59 | 31.339 | 102.960 | 0.000 | | OK |
| 1440 | 2.44 | 32.208 | 112.320 | 0.000 | | OK |
| 2160 | 1.83 | 36.234 | 168.480 | 0.000 | | OK |
| 2880 | 1.48 | 39.072 | 224.640 | 0.000 | | OK |
| 3600 | 1.24 | 40.920 | 280.800 | 0.000 | | OK |
| 4320 | 1.07 | 42.372 | 336.960 | 0.000 | | OK |

**Figure 10.6 Spreadsheet for calculating required storage volume of infiltration system**

As shown above, the storm duration that provides the lowest percentage of required storage (above 100%) is a storm duration of 45 minutes (the dimensions of the infiltration device in the spreadsheet have been altered until the storage is greater than 100% for each storm duration). The critical storm duration is 45 minutes and the storage volume requirement 5.3 $m^3$. With a porosity of a gravel-filled trench estimated to be 0.35, the required dimension of the soakaway is 2 m (w) by 8 m (L) by 1m (d). The proposed layout of the infiltration system is shown below.

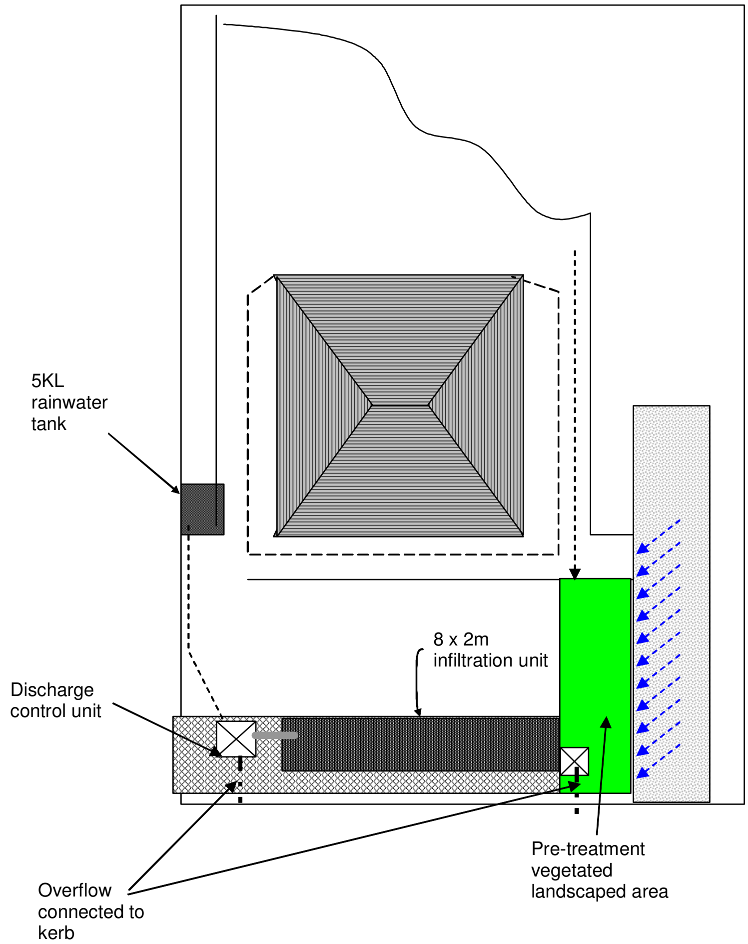


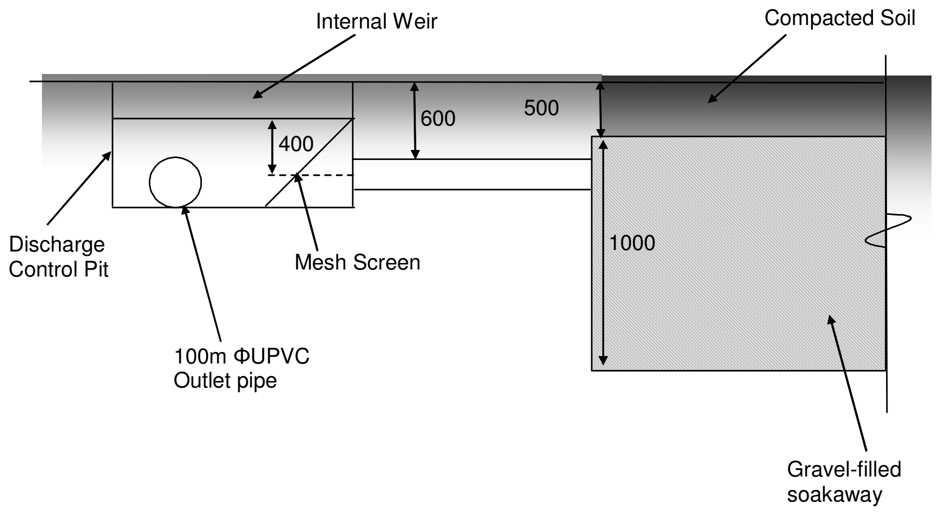

Figure 10.7 Layout of Stormwater Infiltration System

## 10.6.7 Hydraulic Structures

*10.6.7.1 Inlet design*

- Peak 2yr ARI design flow = 0.007 $m^3/s$ (calculated previously) with approximately 0.003 $m^3/s$ discharging from the rainwater tank overflow and 0.004 $m^3/s$ from other paved areas
- There are two inlets to the infiltration system, i.e. one from the rainwater tank and the second from the driveway (see Figure 10.7). These inlets are to be designed to discharge flows up to 0.004 $m^3/s$ each into the infiltration trench with overflows directed to the table drain on the street in front of the property.

Pipe connections from the inlet pits to the infiltration system and street table drain are computed using the orifice flow equation



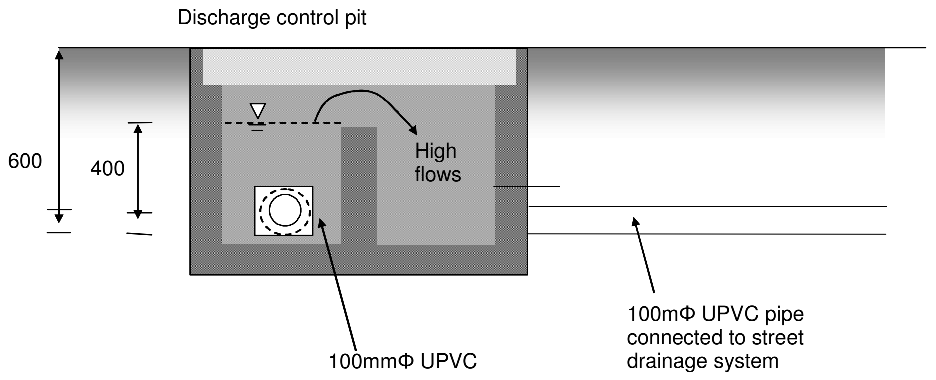

$$A_o = \frac{Q}{C_d\sqrt{2gh}}$$

**Equation 10.3**

| | | |
|---|---|---|
| $C_d$ | = | Orifice Discharge Coefficient (0.6) |
| H | = | Depth of water above the centroid of the orifice (m) |
| $A_o$ | = | Orifice area ($m^2$) |

- For pipe connections to the infiltration system, adopt h = 0.40 m; Q = 0.004$m^3$/s

  This gives an orifice area of 0.002 $m^2$, equivalent to a 55 mm diameter pipe ➔adopt 100 mm diameter uPVC pipe.




*10.6.7.2 Bypass Design*

An overflow weir (internal weir) separates two chambers in the inlet pits; one connecting to the infiltration system and the second to convey overflows (in excess of the 2 year ARI event) to the street table drain. The overflow internal weirs in discharge control pits are to be sized to convey the peak 100 yr ARI flow, i.e.

$Q_{100}$ = 0.5 x 0.026 $m^3$/s (two inlet pits) = 0.013$m^3$/s

- The weir flow equation is used to determine the required weir length:-

$$L = \frac{Q}{C_w \Delta H^{1.5}}$$

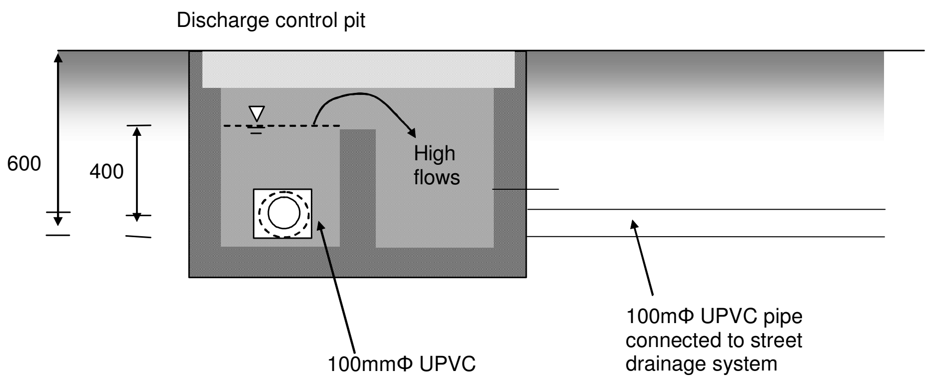
**Equation 10.4**

Adopting C =1.7 and H = 0.05 gives L = 0.7

Overflow weir will provide at least 150m freeboard during the peak 100 yr ARI flow

- For pipe connection to the street table drain, adopt h=0.40 m; Q = 0.013 $m^3/s$

  This gives an orifice area of 0.008 $m^2$, equivalent to a 100 mm diameter pipe ➔ adopt 100 mm diameter uPVC pipe.



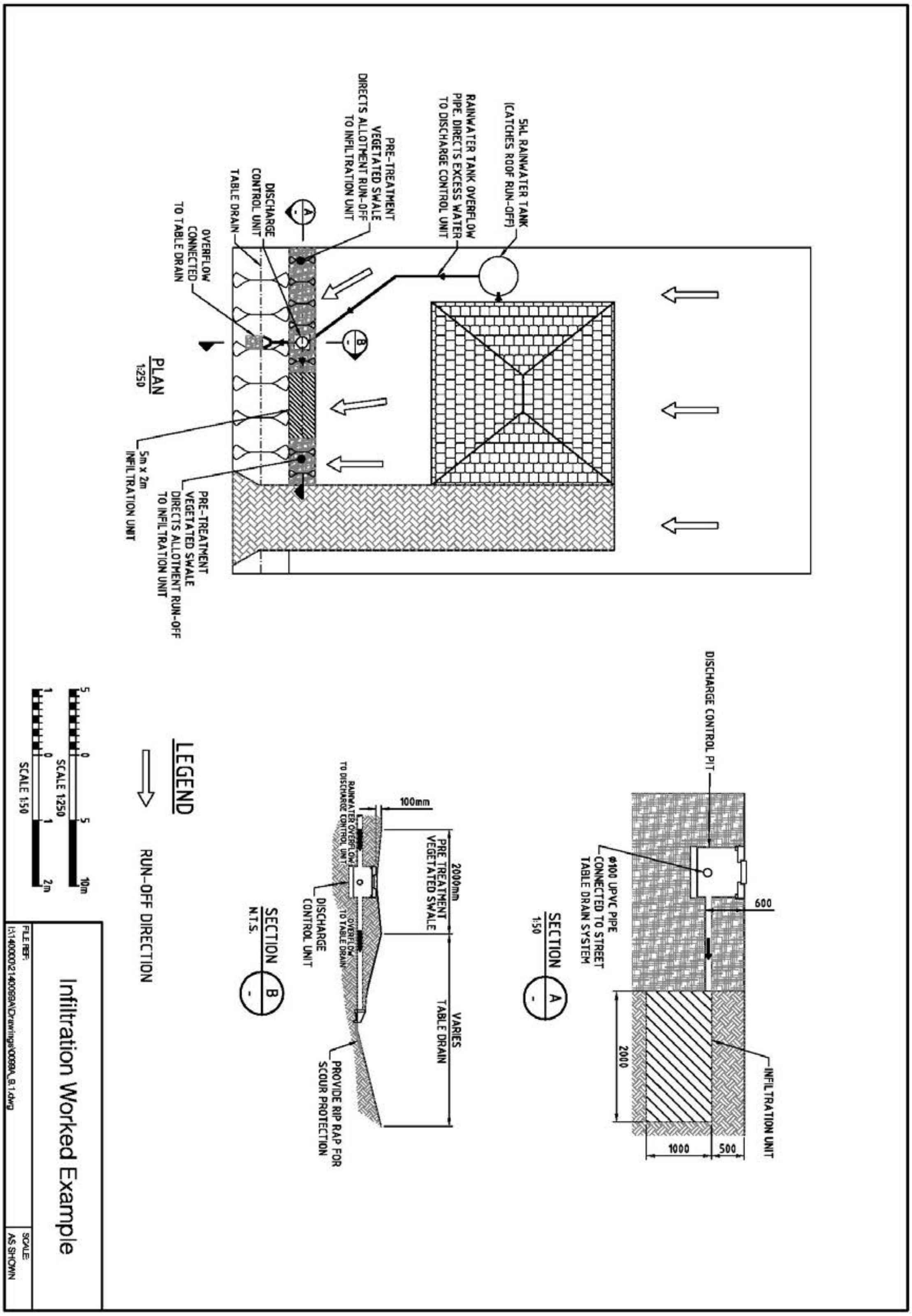

## 10.6.8 Design Calculation Summary

## Infiltration System

## CALCULATION SUMMARY

| | CALCULATION TASK | OUTCOME | | CHECK |
|---|---|---|---|---|
| 1 | **Identify design criteria** | | | ✓ |
| | Design ARI event to be infiltrated (in its entirety) | 2 | year | |
| | OR | | | |
| | Design Hydrologic Effectiveness | N/A | % | |
| | ARI of Bypass Discharge | 100 | year | |
| 2 | **Site characteristics** | | | ✓ |
| | Catchment Area connected to infiltration system | 1000 | $m^2$ | |
| | Impervious Area connected to infiltration system | 500 | $m^2$ | |
| | Site hydraulic conductivity | 360 | mm/hr | |
| | Areal hydraulic conductivity moderating factor | 0.5 | | |
| 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 | | |
| | Design Rainfall Intensity for inlet structure(s) | 56.4 | mm/hr | |
| | Design Rainfall Intensity for overflow structure(s) | 155 | mm/hr | ✓ |
| | **Design runoff coefficient** | | | |
| | inlet structure(s) | 0.43 to 0.60 | | ✓ |
| | **Peak design flows** | | | ✓ |
| | Inlet structure(s) | 0.007 | $m^3/s$ | |
| | Bypass structure(s) | 0.026 | $m^3/s$ | |
| 4 | **Detention Storage** | | | ✓ |
| | Volume of detention storage | 5.3 | m3 | |
| | Dimensions | 8 m x 2 m | L:W | |
| | Depth | 1 | m | |
| | Emptying Time | 1 | hrs | |
| 5 | **Provision of Pre-treatment** | | | ✓ |
| | Receiving groundwater quality determined | Y | | |
| | Upstream pre-treatment provision | Y | | |
| 6 | **Hydrualic Structures** | | | |
| | **Inlet Structure** | | | ✓ |
| | Provision of energy dissipation | Y | | |
| | **Bypass Structure** | | | ✓ |
| | Weir length | 0.70 | m | |
| | Afflux at design discharge | 0.05 | m | |
| | Provision of scour protection | Y | | |
| | **Discharge Pipe** | | | ✓ |
| | Capacity of Discharge Pipe | 0.013 | $m^3/s$ | |

## 10.6.9 Construction drawings



## 10.7 References

Engineers Australia, 2006, *Australian Runoff Quality Australian Runoff Quality: A guide to Water Sensitive Urban Design, Editor-in-Chief, Wong, T.H.F.*

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Institution of Engineers Australia, 1997, *Australian Rainfall and Runoff – A guide to flood estimation*, Editor in Chief – Pilgram, D.H.