
21 ON SITE AND COMMUNITY RETENTION

21.1	PLANNING AND FEASIBILITY ANALYSIS	21-1
21.1.1	Introduction.....	21-1
21.1.2	General Limitations.....	21-2
21.1.3	Feasibility Analysis.....	21-3
21.2	GENERAL DESIGN CRITERIA AND PROCEDURE.....	21-4
21.2.1	Design/Sizing Methods.....	21-4
21.2.2	Design Criteria	21-5
21.2.3	Design of Trench Facilities.....	21-5
21.2.4	Design of Infiltration Basin Facilities.....	21-8
21.3	ON SITE RETENTION.....	21-9
21.3.1	Dispersion Trenches	21-9
21.3.2	Infiltration Sump	21-9
21.3.3	Design Criteria	21-9
21.4	COMMUNITY RETENTION	21-12
21.4.1	Infiltration Trench	21-12
21.4.2	Infiltration Basin.....	21-13
21.4.3	Porous/Modular Pavements	21-14
21.5	GENERAL CONSTRUCTION, OPERATION AND MAINTENANCE	21-15
21.5.1	Quality Control in Construction	21-15
21.5.2	Safeguarding Retention Facilities	21-16
21.5.3	Construction Criteria	21-16
21.5.4	Maturing of Infiltration Surface.....	21-17
21.5.5	Clogging.....	21-17
21.5.6	Slope Stability	21-17
21.5.7	Effects on Groundwater	21-17
21.5.8	Care and Maintenance	21-18
APPENDIX 21.A	SOIL INFILTRATION	21-21
21.A.1	General Notes.....	21-21
21.A.2	Initial Feasibility and Concept Design Testing	21-21
21.A.3	Documentation	21-21
21.A.4	Test Pit/Boring Requirements	21-21
21.A.5	Infiltration Testing Requirements.....	21-22
21.A.6	Laboratory Testing	21-22
APPENDIX 21.B	WORKED EXAMPLE	21-23

21.B.1	Sizing an Infiltration Trench.....	21-23
21.B.2	Sizing an Infiltration Basin	21-25

21.1 PLANNING AND FEASIBILITY ANALYSIS

21.1.1 Introduction

Retention facilities may be classified on the basis of their locations and sizes, namely;

1. *On-Site Retention* : facilities constructed on individual residential, commercial, and industrial lots (smaller than 500 m².)
2. *Community Retention* : facilities constructed in public open space areas (up to 15 ha.)

These types of BMPs retention facilities, will typically be an integral part of the primary conveyance/detention system because of their lesser efficiency for infrequent events (say 50 or 100 year ARI). In practice, retention facilities are being used as a complement to the whole system. The general types of on-site retention (OSR) and community retention (CR) techniques are dispersion trench, infiltration sump, infiltration trench, and infiltration basin. The main differences of these facilities are the sizes and their drainage contribution areas.

(a) Dispersion Trench

A dispersion trench control is a technique in which stormwater collected via a traditional storm drain system is dispersed widely on the ground and a trench with a stone-filled 'reservoir' for percolation to groundwater, constructed below the ground. Disposal of stormwater from paved surfaces requires that particular attention be paid to the pre-treatment system.

(b) Infiltration Sump

An infiltration sump or soakaway pit has been the traditional method of disposal of stormwater in many developed countries where no sewer or conveniently close watercourse existed. Often on single dwellings, the infiltration sump consisted of a roughly dug pit filled with rubble or hardcore to which the storm drain discharged. There was often no means of cleansing or access to the end of the drain and blockage around the outfall into the pit was common. Before the production of geotextiles, the infiltration sumps were subject to infilling by soil from above or from the sides as local percolation of groundwater transported material into the pits. Pre-cast concrete ring unit infiltration sumps are now in common use with the advantage that they retain access for cleansing and monitoring of performance. The access cover provides evidence of the location of the sump – a fact not always known with the rubble-filled pits.

(c) Infiltration Trench

An infiltration trench is a trench in which the permeable fill material extends to the ground surface and overland flow

discharges onto the top of the trench along its length i.e. there is no traditional pipe and gully drainage system collecting and conveying stormwater to the trench. The top of the trench must retain an infiltration rate sufficient to allow for inflows from the surface at the design rainfall intensity multiplied by the surface area ratio (i.e. ratio of the area draining to the trench to the top surface area of the trench).

(d) Infiltration Basin

An infiltration basin is an area of land surrounded by a bank or berm, which retains the stormwater until it has infiltrated through the base of the basin. The basin is frequently excavated in the ground surface, but occasions do occur where berms are used to enclose an area of land on the ground surface, or on one side where the basin is constructed on sloping ground. There are examples where combined attenuation/infiltration processes can be established: the principal mode of operation is stormwater detention to attenuate the discharge hydrograph, but ground conditions are such that some measure of infiltration occurs during storage.

Experience elsewhere has shown that infiltration can be successfully utilised if adherence to proper design, construction, and maintenance standards is followed. Where operating problems with infiltration structures have occurred, the primary causes of failure have been:

- inadequate soil investigation, resulting in poorly designed systems
- improper construction practices, especially compaction for soil
- siltation, which clogs, soils for infiltration, especially due to construction-related erosion and sedimentation. All infiltration must be preceded by a pretreatment to remove suspended solids

The standards in this chapter are intended to prevent these problems from occurring. In addition to these standards, there may be local, state and federal regulatory requirements, which must be met in the future.

Infiltration structures are not practical in all cases. The feasibility of using infiltration depends not only on the nature of the soils but also on the need to protect ground water quality. The location and depth to bedrock, the water table, or impermeable layers (such as glacial till) can preclude the use of infiltration. In addition, the proximity of infiltration to wells, foundations, septic tank, drainfields, unstable slopes, and other features can restrict its use. General limitations are described in Section 21.1.2.

An acceptance criterion requires development sites to provide runoff quantity control to limit peak flows discharged from developed sites. The level of runoff

control required is dependent on the type of retention facilities and type of development proposed.

The level of runoff control required for the different types of retention facilities are :

- On-site retention is provided to reduce the peak discharge in small storms, up to the minor system design ARI.
- Community retention should be provided to reduce peak discharges in storms up to 100 year ARI.

Runoff control requirements for the different type of development categories are defined in Section 4.5 and are summarised in Table 4.2.

For a new development, the peak flow should be smaller than the pre-development peak flow for minor and major system design storm ARI. The redevelopments are divided into two categories of scale of developments; lot and subdivision redevelopments. A lot redevelopment requires that the peak flow is smaller than pre-redevelopment peak flow for minor system design storm, and storage is greater than the Site Storage Ratio (SSR) in accordance with Chapter 19. Subdivision redevelopment requires that the peak flow is smaller than the pre-redevelopment peak flow for minor and major system design storm ARI of existing development. Refer Section 4.5 for a detail requirement.

For a site to be suitable it must meet or exceed all of the specific criteria listed under GL-1 through GL-6. Should a site investigation reveal that any one of the General Limitations could not be met, the implementation of the infiltration practice should not be pursued.

21.1.2 General Limitations

The General Limitations (GL's) are governed by the physical suitability of the site and the need to prevent pollution of ground water. They include:

- GL-1 Soil Suitability
- GL-2 Depth to Bedrock, Water Table, or Impermeable Layer, or Dissimilar soil layer
- GL-3 Proximity to Drinking Water Wells, Septic Tanks, Drainfields, Building Foundations, Structures and Property Lines
- GL-4 Land Slope
- GL-5 Drainage Area
- GL-6 Control of Siltation

GL-1 *Soil Suitability*

The suitability of soil for infiltration is to be based on evaluating the following:

- there is no limitation on soil infiltration rate but a minimum rate of 13 mm/hr is recommended

- soils with 30% or greater clay content or 40% greater silt/clay content shall not be used
- infiltration systems shall neither utilise fill material nor be placed over fill soils

Refer to Appendix 21.A for soil infiltration test procedures. In addition, it is recommended that a more detailed soils investigation be conducted if potential impacts to ground water are a concern, or if applicant is proposing to infiltrate in areas underlain by impermeable layers or till. For further investigations, consultation with soils and ground water specialists is recommended.

GL-2 *Depth to Bedrock, Water Table, or Impermeable Layers*

The base of all facilities shall be located at least 1.5 m above the seasonal high ground water mark, bedrock (or hardpan) and/or impermeable layer. Infiltration may be inhibited by the high water table, which could result in the facility not functioning as designed. Also, a high water table can indicate the potential for ground water contamination.

GL-3 *Proximity to Drinking Water Wells, Septic Tanks, Drainfields, Building Foundations, Structures and Property Lines*

The proximity of infiltration facilities to other structures and facilities must be taken into account. Otherwise the potential exists to contaminate ground water, disrupt the proper functioning of septic tank systems, damage foundations and other property. The site designer or engineer must conduct an investigation to determine the most appropriate locations of infiltration facilities; this is best done on a case-by-case basis but the following basic criteria is provided for information purposes:

- infiltration facilities on commercial and industrial sites should be placed no closer than 35 m from drinking water wells, septic tanks or drainfields and springs used for public drinking water supplies
- infiltration facilities should be situated at least 7 m downslope and 50 m from building foundations. An exception is OSR facilities which should be located a minimum of 3 m from any structure and 10 m from a water supply well, septic tank or drainfield

GL-4 *Land Slope*

Slope restrictions depend on the BMP selected. Application of infiltration practices on a steep grade increase the chance of water seepage from the subgrade to the lower areas of the site and reduces the amount of water which actually infiltrates.

Infiltration facilities can be located on slopes up to 15% as long as the slope of the base of the facility is less than 3%.

All basins should be a minimum of 20 m from any slope greater than 15%.

GL-5 *Drainage Area*

Infiltration BMPs are limited in their ability to accept flows from larger drainage areas. The following drainage area limitations will be applied:

- Dispersion trenches – maximum of 500 m²
- Infiltration sumps – maximum of 500 m²
- Infiltration trenches – maximum of 4 hectares
- Infiltration basins – maximum of 15 hectares
- Pavement - maximum of 4 hectares

GL-6 *Control of Siltation*

Siltation is one of the major reasons for failure of infiltration facilities. This often occurs during construction, thus it is most important not to excavate trenches or ponds to final grade during this phases. Even after construction, it is vital to prevent as much sediment as possible from entering by first routing the water through a pretreatment BMP. Also there may be other construction activities upstream that take place and could result in surges of sediment entering the site.

The following conditions also apply:

- Final construction of infiltration facilities shall not be done until after other site construction has finished and the site has been properly stabilised with permanent erosion control practices as outlined in Chapters on Erosion and Sediment Control.
- Infiltration facilities are not recommended for use as temporary sediment traps during the construction phase. Infiltration facilities should be constructed only after upstream drainage areas have been stabilised. If an infiltration BMP is to be used as a sediment trap it must not be excavated to final grade until after the upstream drainage area has been stabilised. Any accumulation of silt in the basin must be removed before putting it in service.
- Inflow to infiltration, other than roof downspout systems, must first pass through a pretreatment BMP in order to minimise the suspended solid load and prevent siltation of the infiltration facility.

21.1.3 Feasibility Analysis

Collection and analysis of soils, geologic and hydrologic information are a critical component of the planning and design process for infiltration BMPs. A subsurface

investigation must be conducted under the supervision of an engineer or scientist of appropriate qualifications. The investigation shall involve both a review of the available literature and any other relevant sources and a field investigation as part of the overall geotechnical site investigation.

A soils report is required for each location. A soil log should be taken at a minimum 1.5 m depth below the proposed base of the facility and an additional soil log shall be taken for every 500 m² of infiltrating surface area.

To effectively design an infiltration structure, the following information is required:

- Textural character of the soil horizons and/or strata within the subsoil profile. Based on this textural analysis the following variables are to be determined:
 - (i) Soil infiltration rate, "f_c"
 - (ii) Percent clay content in soil
- Location of the seasonal high ground water table depth to bedrock or impermeable layer, and/or depth to dissimilar soil layers (duplex soils).

The first step in determining the site capabilities should be to conduct an on-site investigation, in conjunction with consulting the available soil survey data available at Malaysian Agriculture Department. Soil types may vary dramatically within a small area. An on-site investigation is always necessary because local conditions may be different than what published soil survey data indicates. In Malaysia surface soil data are generally not available in urban areas.

For larger land development, soil information has traditionally been collected during the geotechnical site investigation in order to determine foundation conditions for structures and to design earth structures such as fills and cuts. The standard method of conducting subsurface investigation is to drill holes and collect soil sample. Solid augers are also used to collect large samples for compaction testing but do not provide an accurate picture of the soil profile. The soil final infiltration rate is obtained by identifying the soil textures by a gradation test for each of the change in soil profile.

The soil textures of the U.S. Department of Agriculture (USDA) Textural Triangle is presented and recommended in Figure 21.1 for use. The use of the soil properties established in the table for design and review procedures will offer two advantages. First, it will provide for consistency of results in the design procedures and second, it will eliminate the need for the laborious and costly process of conducting field and laboratory infiltration and permeability tests.

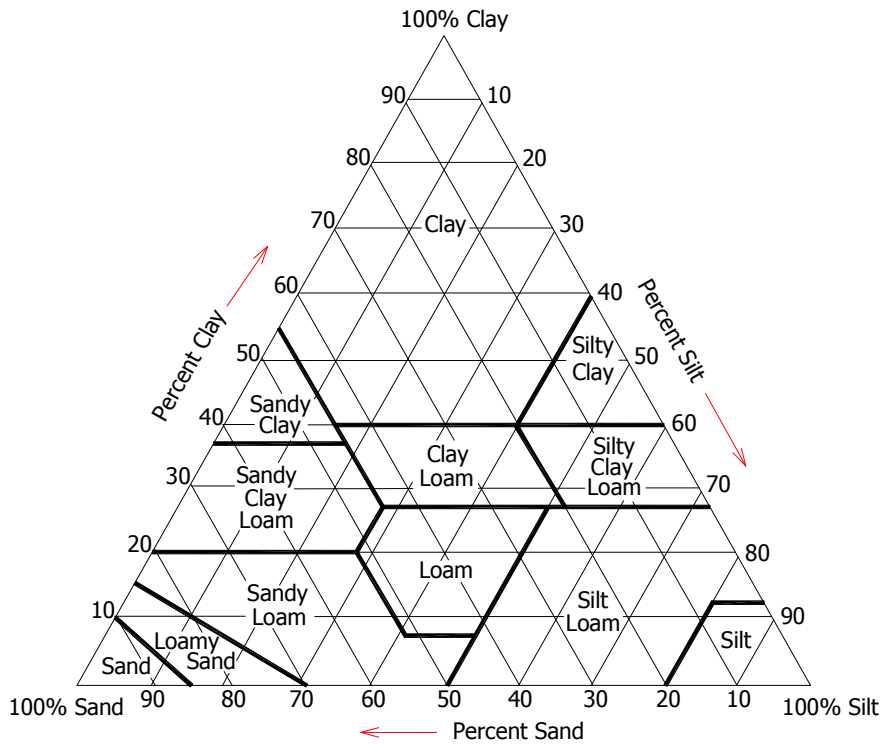


Figure 21.1 USDA Textural Triangle

The location of the seasonal high ground water table can be determined by field observation of static water elevation in borings, changes in soil moisture content, and changes in soil colour (mottling, for example). It should be noted that the ground water table elevation fluctuates not only on a seasonal basis but also on an annual basis in response to prolonged periods of wet and dry precipitation cycles. Thus, the field work should be supplemented with consultation of the local government/geological survey department to benefit from their experience with local ground water conditions.

Developments, which occur on sloping and rolling sites, may use extensive cut and fill operations. The use of infiltration systems on fill material is not permitted because of the possibility of creating an unstable subgrade. Fill areas can be very susceptible to slope failure due to slippage along the interface of the in-situ and fill material. This condition could be aggravated if the fill material is allowed to become saturated by using infiltration practices.

21.2 GENERAL DESIGN CRITERIA AND PROCEDURE

21.2.1 Design/Sizing Methods

In this chapter, design methodologies are emphasis on the two community retention facilities practices; infiltration trenches and infiltration basins; since these type of

facilities serve large drainage contribution area and they have higher tendencies to become malfunctions than OSR. The design methodology of the CR facilities can be applied in designing OSR with emphasis of smaller contribution drainage area.

There are two general types of situations where infiltration practices may be used. First, one may be interested in the dimensions of an infiltration device that is required to provide storage of the water quality volume (WQ_v), and/or downstream protection volume. Second, site conditions may dictate the layout and capacity of infiltration measures and one might be interested in determining the level of control provided by such a layout. In the latter case, control may not be sufficient and additional control, possibly using other acceptable control measures, may be required. It is important to emphasise that the same principles of design apply to both cases.

The design procedures are based on either intercepting the water quality volume from the area contributing runoff or using the hydrograph method for control of the runoff from an area for downstream protection volume. The design equations may be defined for either case of stormwater quality or quantity control because the volume of water (V_w) stored in the individual infiltration practice may be determined from the methods described in Chapter 13.

21.2.2 Design Criteria

The general design criteria discussed in this section is intended for all retention facilities. This section lists the detail description of terms that has been used in the Design Criteria of On-Site Retention and Community Retention Facilities (Refer Table 21.1 or Table 21.2).

(i) Soils Investigation

Soil log shall be required for any type of retention facilities for each proposed development location. Each soils log should extend a minimum of 1.5 m below the bottom of the facility, describe the series of the soil, the textural class of the soil horizon(s) through the depth of the log and note any evidence of high ground water level, such as mottling. In addition, the location of impermeable soil layers or dissimilar soil layers shall be determined.

(ii) Design Infiltration Rate

The design infiltration rate (f_d) will be equal to one-half (factor of safety) the infiltration rate (f_c) found from the soil textural analysis with minimum f_c of 13 mm/hr. ($f_d = 0.5f_c$)

(iii) Runoff Quality Treatment

Runoff from the 3 month ARI design storm is to be completely treated prior to discharge to these BMPs.

(iv) Drawdown Time

All retention facilities shall be designed to completely drain stored runoff within one day following the occurrence of the 10 year ARI, 4 hour design storm and within two days of the 100 year ARI, 4 hour design storm. Thus, a maximum allowable drawdown time of 48 hours is permissible.

(v) Backfill Material

The aggregate material shall consist of a clean aggregate with a minimum diameter of 30 mm and a maximum diameter of 70 mm. The aggregate should be graded such that there will be few aggregates smaller than the selected size. Void space for these aggregates is assumed to be in the range of 30 to 40%.

(vi) Overflow Route

An overflow route must be identified in the event that the retention facilities capacity is exceeded. This overflow route should be designed to meet Minimum Requirement of Preservation of Natural Drainage Systems (within erosive velocities).

(vii) Seepage Analysis and Control

An analysis shall be made to determine any possible adverse effects of seepage zones when there are nearby building foundations, basements, roads, parking lots or sloping sites. Developments on sloping sites often require the use of extensive cut and fill operations. The use of infiltration trenches on fill sites is not permitted.

(viii) Buildings

OSR facilities shall be located 3 m from building foundations and CR facilities should be a minimum of 50 m upslope and 7 m downslope from any building

(ix) Slopes

CR facilities should be minimum of 20 m from any slopes greater than 15%. A geotechnical report should address the potential impact of the basin infiltration upon the steep slope.

(x) Observation Well

An observation well shall be recommended for every OSR and shall be required for every CR. The observation well will serve two primary functions: it will indicate how quickly the trench dewateres following a storm and it will provide a method of observing how quickly the trench fills up with sediments. The observation well should consist of perforated PVC pipe, 100 to 150 mm in diameter. It should be located in the centre for the structure and be constructed flush with the ground elevation of the trench. The top of the well should be capped to discourage vandalism and tampering.

(xi) Spillways

The spillway requirement is only applied for the infiltration basin. The bottom elevation of the low-stage orifice should be designed to coincide with the one-day infiltration capacity of the basin. All other aspects of the principal spillway design and the emergency spillway shall follow the details provided for detention basins in Chapter 18.

(xii) Vegetation

The embankment, emergency spillways, spoil and borrow areas and other disturbed areas shall be stabilised and planted in accordance with Minimum Requirement of Erosion and Sediment Control .

21.2.3 Design of Trench Facilities

(a) General Considerations

The design procedure outline in this section shall be used in designing trench systems that includes dispersion trenches, infiltration sumps and infiltration trenches.

Table 21.1 Design Criteria of On-Site Retention Facilities

Design Parameters	On Site Retention	
	Dispersion Trench	Infiltration Sump
Contribution drainage area	Up to 500 m ²	Up to 500 m ²
Soil investigation requirement	1 soil log test per site with min. 1.5 m below of the trench bottom	1 soil log test per site with min. 1.5 m below of the sump bottom
Design infiltration rate (f_d)	f_d is equal to $0.5f_c$ with min f_c of 13 mm/hr	f_d is equal to $0.5f_c$ with min f_c of 13 mm/hr
Maximum drawdown time	24 hrs - 10 year ARI 48 hrs - 100 year ARI.	24 hrs - 10 year ARI 48 hrs - 100 year ARI.
Runoff quality treatment	3 month ARI	3 month ARI
Backfill material	Minimum dia. – 30 mm Maximum dia. – 70 mm	Minimum dia. – 30 mm Maximum dia. – 70 mm
Maximum depth	1.5 m above the seasonal groundwater	2 m above the seasonal groundwater
Minimum proximity to special facilities	3 m from building foundation 10 m from water supply well	3 m from building foundation 10 m from water supply well
Overflow route	need to identified	need to identified
Observation well	1 every site (recommended)	1 every site (recommended)

The design of a trench system is based on the textural class of the soils underlying the trench such that a feasible design is possible. The design of a trench system is also based on the maximum allowable depth of the trench (d_{max}). The maximum allowable depth should meet the following criteria:

$$d_{max} = \frac{f_c T_s}{n} \quad (21.1)$$

where,

- f_c = final infiltration rate (mm/hr)
- T_s = maximum allowable storage time (hrs)
- n = porosity of the stone reservoir

A trench system is sized to accept the design volume that enters the trench (V_w) plus the volume of rain that falls on the surface of the trench (PA_t) minus the exfiltration volume ($f_d TA_t$) out of the bottom of the trench (Figure 21.2). Based on the analysis, the effective filling time for most trenches (T) will generally be less than two hours. The volume of water that must be stored in the trench (V) is defined as:

$$V = V_w + PA_t - f_d TA_t \quad (21.2)$$

where,

- P = design rainfall event (mm)

- A_t = trench surface area (m²)
- V_w = design volume that enters the trench
- T = effective filling time, generally < 2 hrs
- f_d = design infiltration rate

For most design storm events, the volume of water due to rainfall on the surface area of the trench (PA_t) is small when compared to the design volume (V_w) of the trench and may be ignored with little loss in accuracy to the final design.

The volume of rainfall and runoff entering the trench can be defined in terms of trench geometry. The gross volume of the trench (V_t) is equal to the ratio of the volume of water that must be stored (V) to the porosity (n) of the stone reservoir in the trench; V_t is also equal to the product of the depth (d_t) and the surface area (A_t):

$$V_t = \frac{V}{n} = d_t A_t \quad (21.3)$$

Combining Equations 21.2 and 21.3 yields the relationship: $d_t A_t n + f_d TA_t = V_w$. Because both dimensions of the trench are unknown, this equation may be rearranged to determine the area of the trench (A_t) if the value of d_t were set based on either the location of the water table or the maximum allowable depth of the trench (d_{max}):

$$A_t = \frac{V_w}{nd_t + f_d T} \quad (21.4)$$

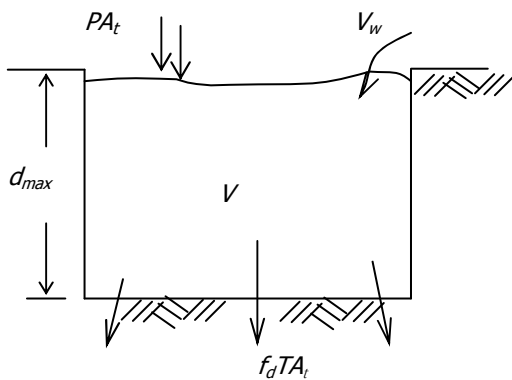


Figure 21.2 Model of Trench Hydrologic Balance

(b) Procedures for Trench System Design

1. Determine the contributed volume of water from the development for storage to meet the runoff control requirement (acceptance criteria).
2. Compute the maximum allowable trench depth (d_{max}) from the feasibility equation:

$$d_{max} = \frac{f_c T_s}{n}$$

Select the trench design depth (d_t) based on the depth that is the required depth above the seasonal groundwater table, or a depth less than or equal to d_{max} whichever results in the smaller depth.

3. Compute the trench surface area (A_t) for the particular soil type using Equation 21.4.

Table 21.2 Design Criteria of Community Retention Facilities

Design Parameters	Community Retention		
	Infiltration Trench	Infiltration Basin	Pavement
Contribution drainage area	Up to 4 ha.	Up to 15 ha	Up to 4 ha
Soil investigation requirement	1 soil log test every 15 m of trench with min 1.5 m below of the trench bottom	1 soil log test every 500 m ² of basin area with min 1.5 m below of the basin bottom	1 soil log test every 500 m ² of basin area with min 1.5 m below of the basin bottom
Design infiltration rate (f_d)	f_d is equal to $0.5f_c$ with min f_c of 13 mm/hr	f_d is equal to $0.5f_c$ with min f_c of 13 mm/hr	f_d is equal to $0.5f_c$ with min f_c of 13 mm/hr
Maximum drawdown time	24 hrs - 10 year ARI 48 hrs - 100 year ARI.	24 hrs - 10 year ARI 48 hrs - 100 year ARI.	24 hrs - 10 year ARI 48 hrs - 100 year ARI.
Runoff quality treatment	3 month ARI	3 month ARI	3 month ARI
Backfill material	Minimum dia. – 30 mm Maximum dia. – 70 mm	Minimum dia. – 30 mm Maximum dia. – 70 mm	Minimum dia. – 30 mm Maximum dia. – 70 mm
Maximum depth	3 m with min. 1.5 m above the seasonal groundwater	3 m with min. 1.5 m above the seasonal groundwater	
Minimum proximity to special facilities or building foundation	7 m (up slope) 50 m (down slope)	7 m (up slope) 50 m (down slope)	The potential impacts of infiltration on building foundations must be evaluated.
Overflow route	need to identified	need to identified	need to identified
Observation well	1 every 15 m of trench length	1 every 50 m ² of basin area	1 every 50 m ² of pavement area
Spillway and Embankment		Require and shall be stabilised and planted with vegetation	

In the event that the side walls of the trench must be sloped for stability during construction, the surface dimensions of the trench should be based on the following equation:

$$A_t = (L - Zd_t)(W - Zd_t) \quad (21.5)$$

where,

- L = the top length
- W = the top width
- Z = the trench side slope ratio

The design procedure would begin by selecting a top width (W) that is greater than $2xZd_t$ for a specified slope (Z). The side slope ratio value will depend on the soil type and the depth of the trench. The top length (L) is then determined as:

$$L = Zd_t + \frac{A}{W - Zd_t} \quad (21.6)$$

21.2.4 Design of Infiltration Basin Facilities

(a) General Considerations

The same principles can be used as general design consideration for infiltration basin, porous and modular pavements. The design of an infiltration basin facilities are based on same soil textural properties and maximum allowable depth as the infiltration trench such that a feasible design is possible. However, because the infiltration basin uses an open area or shallow depression for storage, the maximum allowable depth (d_{max}) should meet the following criteria:

$$d_{max} = f_c T_p \quad (21.7)$$

where,

- f_c = final infiltration rate of the trench area (mm/hr)
- T_p = maximum allowable ponding time (hrs)

An infiltration basin is sized to accept the design volume that enters the basin (V_w) plus the volume of rain that falls on the surface of the basin (PA_b) minus the exfiltration volume ($f_d TA_b$) out of the bottom of the basin. Based on the analysis, the effective filling time for most infiltration basins (T) will generally be less than two hours. The volume of water that must be stored in the basin (V) is defined as:

$$V = V_w + PA_b - f_d TA_b \quad (21.8)$$

where,

- P = design rainfall event (mm)
- A_b = basin surface area (m^2)

- V_w = design volume that enters the trench
- T = effective filling time, generally < 2 hrs
- f_d = design infiltration rate

For most design storm events, the volume of water due to rainfall on the surface area of the basin (PA_b) is small when compared to the design volume (V_w) of the basin and may be ignored with little loss in accuracy to the final design.

The volume of rainfall and runoff entering the basin can be defined in terms of basin geometry. The geometry of a basin will generally be in the shape of an excavated trapezoid with specified side slopes. The volume of a trapezoidal shaped basin may be approximated by:

$$V = \frac{(A_b + A_t)d_b}{2} \quad (21.9)$$

where,

- A_t = top surface area of the basin (m^2)
- A_b = bottom surface area of the basin (m^2)
- d_b = basin depth (m)

The bottom length and width of the basin may be defined in terms of the top length and width as:

$$L_b = L_t - 2Zd_b \quad (21.10a)$$

$$W_b = W_t - 2Zd_b \quad (21.10b)$$

where,

- L_b = basin bottom length (m)
- W_b = basin bottom width (m)
- L_t = basin top length (m)
- W_t = basin top width (m)
- Z = specified side slope ratio (h:v)

By setting Equations 21.8 and 21.9 equal and substituting the above relationships for L_b and W_b , the following equation is derived for the basin top length:

$$L_t = \frac{V_w + Zd_b(W_t - 2Zd_b)}{W_t d_b - Zd_b^2} \quad (21.11)$$

The infiltration basin usually adopts irregular shape in accordance with grading plan. Sizing is thus based on method described in Chapter on detention basin.

(b) Procedures for Infiltration Basin Design

- (1) Determine the contributed volume of water from the development for storage to meet the runoff control requirement (acceptance criteria).

- (2) Compute the maximum allowable basin depth (d_{max}) from the feasibility equation, $d_{max} = f_c T_p$. Select the basin design depth (d_b) based on the depth that is the required depth above the seasonal groundwater table, or a depth less than or equal to d_{max} , whichever results in the smaller depth
- (3) Compute the basin surface area dimensions for the particular soil type using Equation 21.11. The basin top length (L_t) and width (W_t) must be greater than $2Zd_b$ for a feasible solution. If L_t and W_t are not greater than $2Zd_b$ the bottom dimensions would be less than or equal to zero. In this case, the basin depth (d_b) shall be reduced for a feasible solution.

21.3 ON SITE RETENTION

This section presents the methods, criteria, and details for analysis and design of On Site Retention (OSR) or small parcel of infiltration BMPs. Any single family residential or individual lot project that is subject to the flow control requirements must implement one of the following types of OSR or combination of controls for each lot:

- Dispersion Trenches
- Infiltration Sumps

In general, OSR is an undersized or small scale of infiltration BMPs as discussed in detail in Section 21.4.

Note that use of these required system does not preclude use of other innovative flow control facilities such as rain barrels or tank detention (Chapter 19).

21.3.1 Dispersion Trenches

This facility provides some storage for runoff, promote infiltration, and spread concentrated flows so that a shorter vegetated path length can be used at the trench outlet. Where dispersion of concentrated flows through vegetation filter (refer Chapter 29) is not feasible, such as on a small or highly contained site, a dispersion trench may be used instead (Figure 21.3).

A dispersion trench can be applied for roof downspouts, steep driveways, or any situation where flows are concentrated but where dispersion through vegetation is not feasible.

Appropriate soil conditions and the protection of ground water are among the important consideration which may limit the use of this BMP. See Section 21.1 for description of General Limitations.

A dispersion trench will generally be used on relatively small drainage areas up to 500 m². Dispersion trenches

are one of the few BMPs that are relatively easy to fit into the margin, perimeter and other less-utilised areas of developed sites, making them particularly suitable for retrofitting. One main advantage of these type of trenches is that they have fewer tendencies to become clogged with sediment than other infiltration BMPs.

Dispersion trenches are assumed to have rectangular cross-sections, thus the infiltration surface area (sides and bottom) can be readily calculated from the trench geometry. The storage volume of the trench must take into account the volume of backfill material placed in the trench (i.e., void ratio).

21.3.2 Infiltration Sump

Small infiltration basin consist of an excavated sump filled with washed drain rock or a bottomless precast concrete catch basin (or equivalent structure) placed in an excavation. Stormwater infiltrates through the drain rock into the surrounding soil. This facility is intended for use with contributing surface areas of less than 500 m². If water quality treatment is required runoff from pollution-generating impervious surface must be treated before it enters the infiltration portion of the system.

Infiltration sumps are assumed to have rectangular cross-sections without/with a bottomless, precast concrete catch basin. The infiltration surface areas are sides and bottom. The bottomless precast concrete basin that provides greater live storage than backfill material void ratio, however, the infiltration surface area is only the bottom. The storage volume of the infiltration sump must take into account the volume of backfill material placed in the sump or/and the live storage volume of precast concrete basin.

This BMP will typically be located 'on-line' and be an integral part of the primary conveyance/detention system. Figure 21.4 and Figure 21.5 show typical connection of roof drainage.

The design criteria for small infiltration sumps are essentially the same as for other retention facilities except that only one infiltration rate test and soil log is required for each small infiltration sump.

Appropriate soil conditions and the protection of ground water are among the important considerations, which may limit the use of this BMP. Refer to Section 21.1.2 for a description of General Limitations.

21.3.3 Design Criteria

The procedure described in Section 21.2.2 and Table 21.1 should be used in designing dispersion trenches and infiltration sumps.

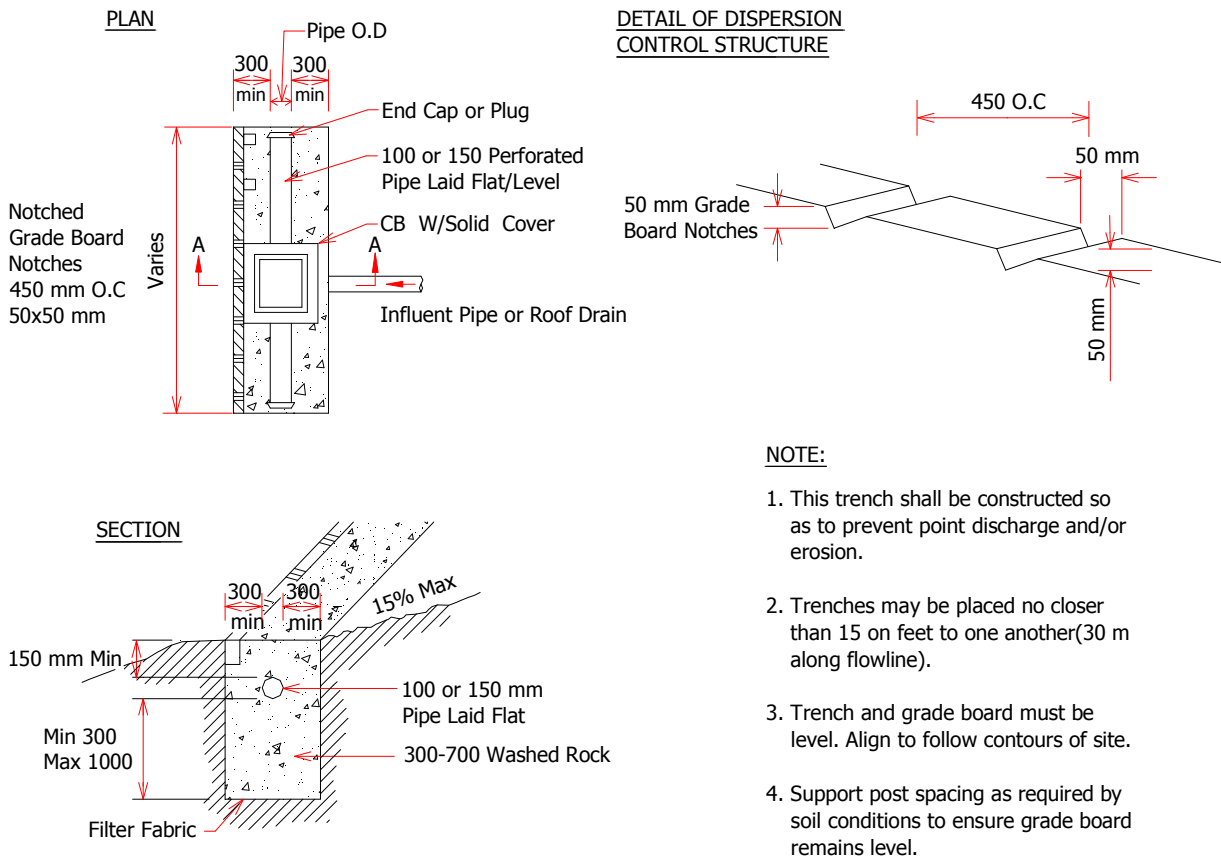


Figure 21.3 Typical Dispersion Trench

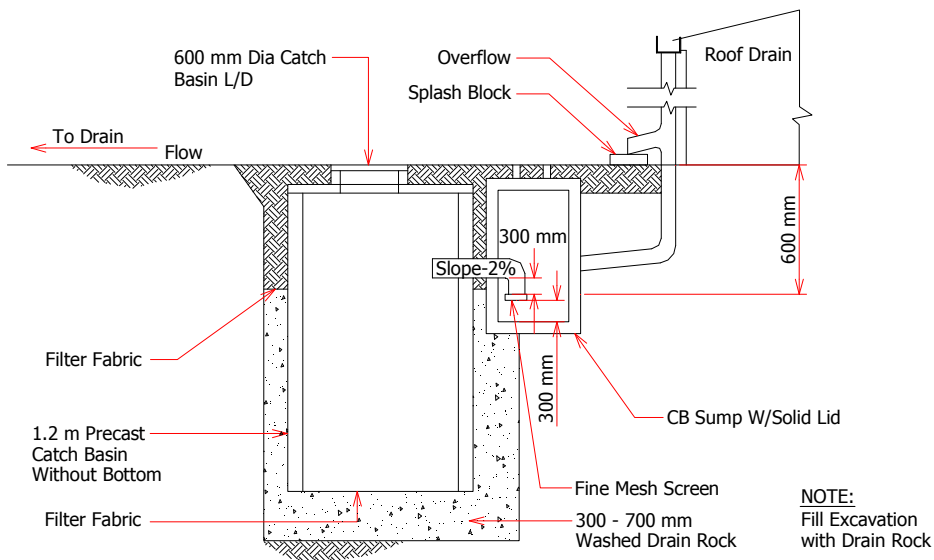


Figure 21.4 Infiltration Sump (with Typical Connection to Roof Drainage)

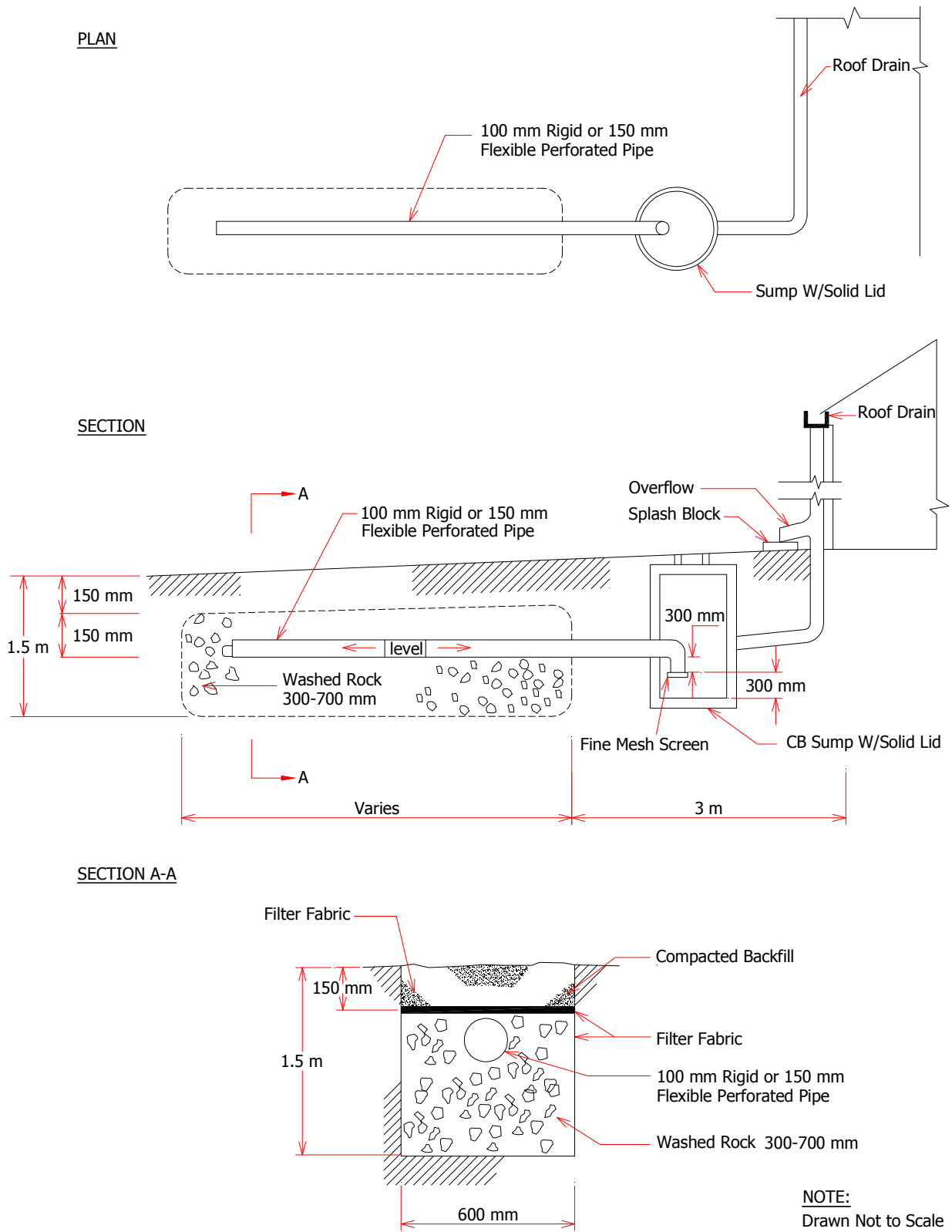


Figure 21.5 Typical Connection to Roof Drainage (Infiltration Trench)

21.4 COMMUNITY RETENTION

This section presents the methods, criteria, and details for analysis and design of Community Retention (CR) or a large parcel of infiltration BMPs. There are several types of CR include:

- Infiltration Trench
- Infiltration Basin
- Porous/Modular Pavement

CR is normally designed as integral part of or as complementary for the primary conveyance/detention system because it requires a large area to capture a major flood.

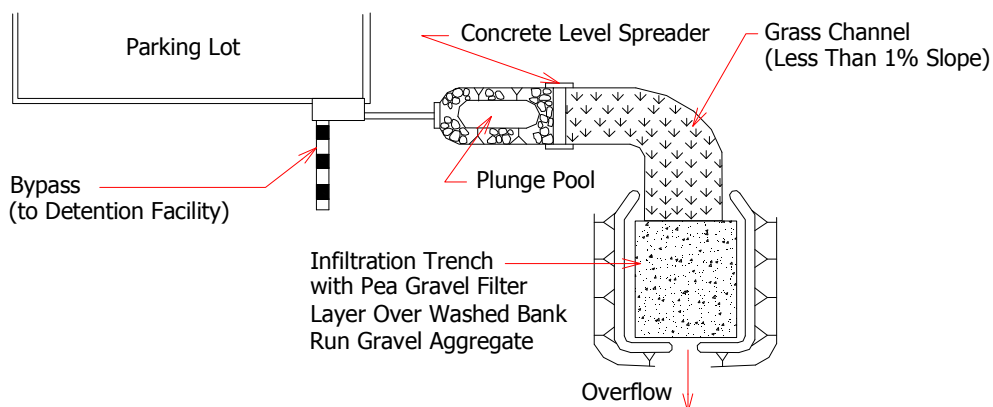
21.4.1 Infiltration Trench

This facility is a shallow excavated trench designed to provide runoff quantity control. The soils underlying this

BMP will be too coarse for pollution removal and stormwater must be treated prior to discharge to this BMP. While physically resembling the Water Quality Infiltration Trench the design criteria for this BMP more closely resembles that used for the quantity control Infiltration Basin. Infiltration trench designs and variances are provided in Chapter 18.

Appropriate soil conditions and the protection of ground water are among the important consideration which may limit the use of this BMP. Refer Section 21.1 for description of General Limitations. This BMP will typically be located on-line with the primary conveyance/detention system. The 3 month design storm must be completely treated prior to runoff being discharged to this BMP.

PLAN



SECTION

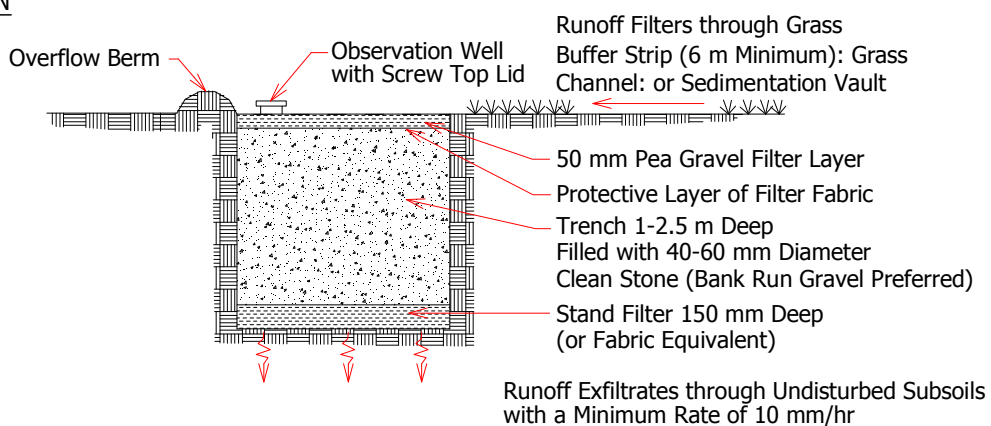


Figure 21.6 Typical Trench Design (Schueler, 1998)

An infiltration trench will generally be used on relatively small drainage areas, less than 4 ha. This practice can be used in residential lots, commercial areas, parking lots and open space areas. Trenches are one of the few BMPs that are relatively easy to fit into the margin, perimeter and other less-utilised areas of developed sites, making them particularly suitable for retrofitting. A trench may also be installed under a swale to increase the storage of the infiltration system.

The procedure described in Section 21.2 and Chapter 13 should be used to design an infiltration trench. Trenches are assumed to have rectangular cross-sections, thus the infiltration surface area (sides and bottom) can be readily calculated from the trench geometry. The storage volume

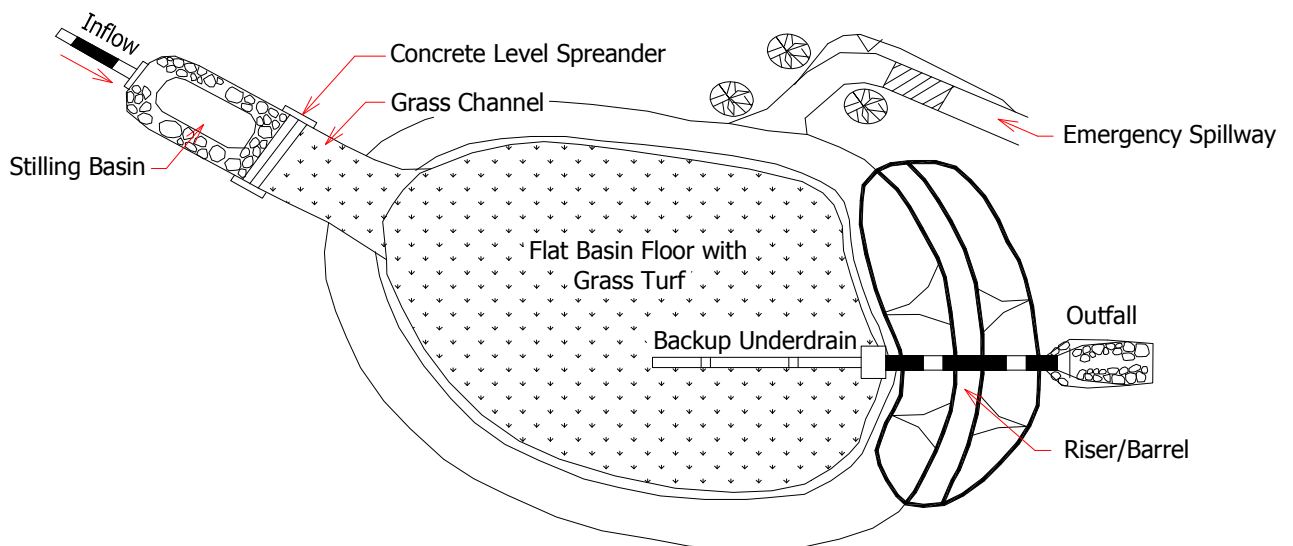
of the trench must take into account the volume of backfill material placed in the trench (i.e., void ratio).

21.4.2 Infiltration Basin

This BMP is similar in design to the Water Quality Infiltration Basin except that it is designed to provide only quantity control; the soils underlying this BMP will be too coarse for runoff treatment purposes. Stormwater must always be treated prior to discharge to this BMP. Figure 21.7 illustrates a typical infiltration basin.

Appropriate soil conditions and the protection of ground water are among the important considerations which may limit the use of the BMP. Refer section 21.1.2 for a description of General Limitations.

PLAN



SECTION

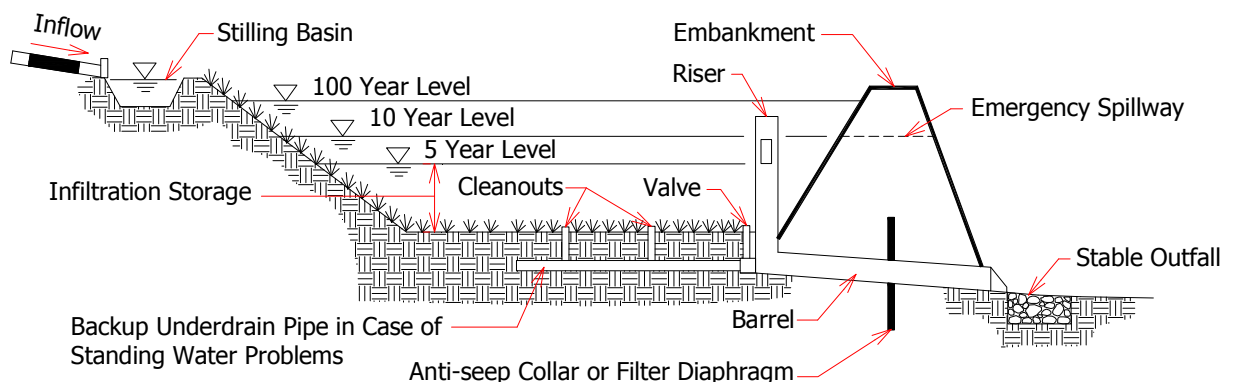


Figure 21.7 Typical Infiltration Basin (Schueler, 1998)

Unlike the Water Quality Infiltration Basin, this basin will typically be located “on-line” and be an integral component of the primary conveyance/detention system. The 3 month ARI design storm must be completely treated prior to runoff being discharged to this BMP. Drainage areas can be up to 15 hectares and basin depths are generally from 1 to 4 m.

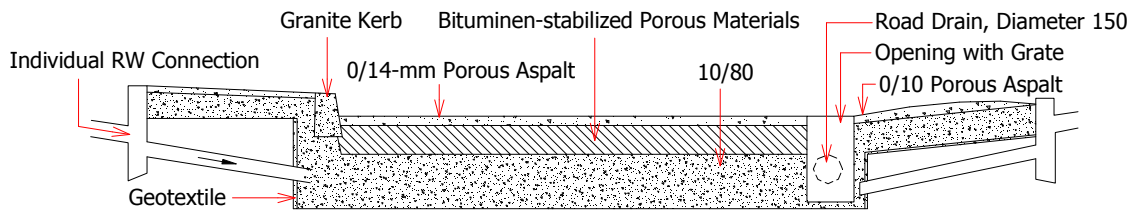
The design procedure described in Section 21.2 and Chapter 13 should be used to design an infiltration basin. The construction of structures, materials allowed, accessibility for maintenance, safety measures, easements, and hydraulics design methods shall be the same as those required for detention basins as given in Chapter 18.

21.4.3 Porous/Modular Pavements

This BMP is similar to the Water Quality Porous Pavement but is designed to provide only quantity control. Thus,

while it physically resembles Water Quality Porous Pavement, it’s function more closely resembles that of the infiltration basin. The soils underlying this BMP will be too coarse for pollution removal and stormwater must be treated prior to discharge to this BMP. There are two types of porous pavement; porous asphalt pavement and pervious concrete pavement. Figure 21.8 and Figure 21.9 show typical cross sections of porous pavement structure and porous asphalt paving drainage system variances.

Porous and modular pavements are designed to provide quantity control by infiltrating runoff into the soil. It is not to be used for runoff treatment purposes and should only be used in low-volume traffic areas. Porous and modular pavements are a pavement consisting of strong structural materials having regularly interspersed void areas which are filled with pervious materials, such as sod, gravel, or sand. Types of concrete grid and modular pavement are illustrated in Figure 21.10.



NOTE:
Drawn Not to Scale

Figure 21.8 Typical Cross section of Porous Pavement Structure (Raimbault,1997)

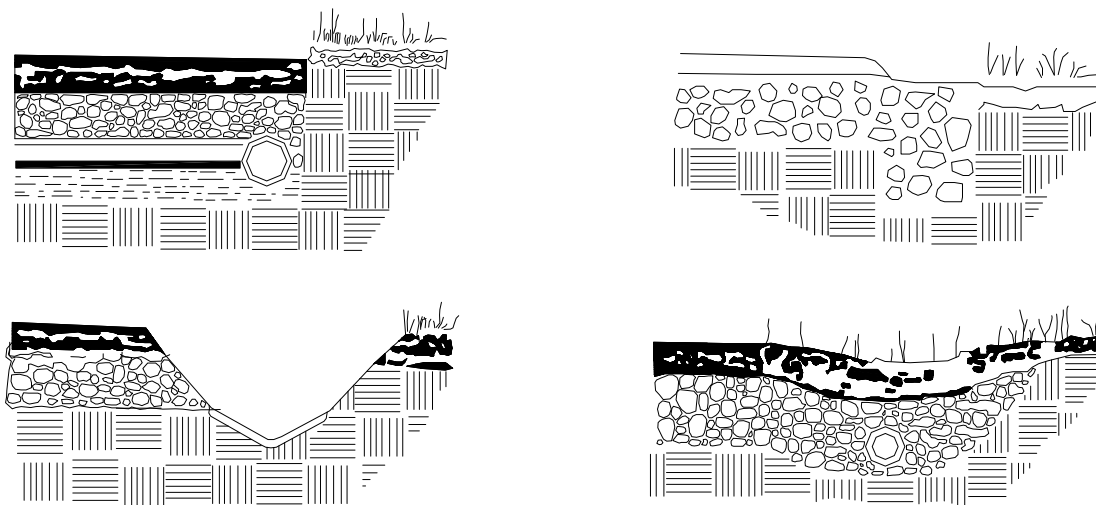
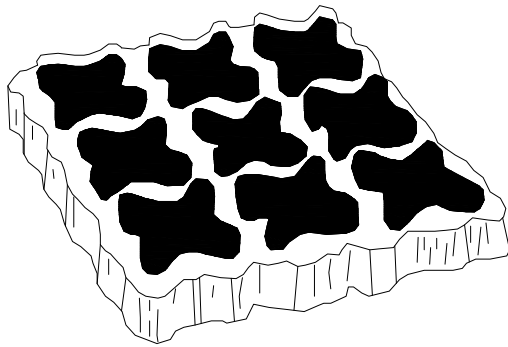


Figure 21.9 Typical Porous Asphalt Paving Drainage System Variances

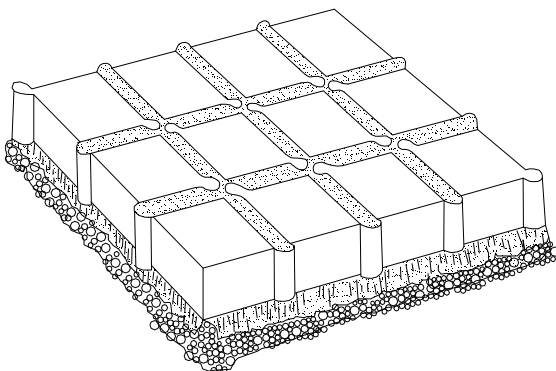
Appropriate soil conditions and the protection of ground water are among the important considerations which may limit the use of this BMP. Refer Section 21.1.2 for a description of General Limitations.

Basic design criteria are given in the previous sections of this chapter. This BMP will typically be located 'on-line' and be an integral part of the primary conveyance/detention system. The 3 month ARI design storm must be completely treated prior to being discharge to this BMP. Drainage areas up to 4 hectares can be served by this BMP.

The construction of structures, material allowed, accessibility for maintenance, safety measures, easement and hydraulic design methods shall be the same as those required for infiltration basins.



(a) Poured-in-Place Slab



(b) Modular Unit

Figure 21.10 Types of Grid and Modular Pavements

21.5 GENERAL CONSTRUCTION, OPERATION AND MAINTENANCE

The failure of infiltration facilities to function properly can often be traced back to construction and maintenance issues. By utilising appropriate construction practices and conducting systematic and rigorous maintenance, infiltration BMPs should function properly.

21.5.1 Quality Control in Construction

Obviously, satisfactory performance of infiltration facilities is very much dependent on the installation being built in accordance with the designer's plans, specifications, and/or instructions. Although this is obvious, it is very common to see improper installation of infiltration facilities even in developed countries.

Unlike the construction of large public works projects that have full-time professional inspection, infiltration facilities, because of their small size, will often not to have full-time inspection. Even if they do, according to Shaver (1986), the inspectors are often not familiar with the technology and functional relationships of such facilities. We need to recognise that a typical construction worker cannot be expected to know the special need of these type of installations.

When selecting infiltration facilities as a functioning part of a community's stormwater management system, proper installation, inspection and quality control procedures will also have to be provided by the community. Inspectors will have to be hired and trained. They will also need to be trained to call for expert help when unforeseen field conditions are encountered that may require design changes. The importance of attempting to properly deal, on a case-by-case basis, with the installation problems cannot be overemphasised. The successful performance of the entire stormwater system depends on a quality assurance program.

Regardless of the type of infiltration practice to be constructed, careful consideration must be given in advance of construction to the effects of the work sequence, techniques, and equipment employed during construction of the facility. Serious maintenance problems can be averted, or in large part mitigated by the adoption of relatively simple measures during construction.

Previous experience with infiltration practices in the developed countries has shown that these BMPs must not be put into use, or preferably even constructed, until the drainage areas that contribute runoff to the structure have been adequately stabilised. When this precaution is not taken, infiltration structures often clogged with sediment from upland construction and thus fail to operate properly from the outset. It cannot be emphasised enough how important it is to protect these from sediment deposition at all times.

Care must also be taken not to compact soils during the construction phase as this can seriously affect infiltration rates. If vehicles must be driven over the infiltration BMP during construction only those with large tracks may be used.

Specific construction methods and specifications are already provided for each infiltration type.

21.5.2 Safeguarding Retention Facilities

Infiltration facilities are usually constructed at the same time other facilities structure are constructed. The risk of damage to these facilities is the greatest at this time. To minimise these risks the following are recommended:

- Locate retention facilities away from roads or construction haul routes. Heavy vehicles travelling over these basins can cause the surrounding soil to flow into the pores of the rock media.
- Minimise the sealing of infiltration surface by keeping traffic off those areas where they are to be built. Also, locate other activities that could seal soil surfaces (e.g., cement mixing, vehicle maintenance, etc.) away from these sites.
- Since runoff from construction sites is heavily laden with fine, suspended solids, which clog infiltration facilities, keep runoff out of these facilities until construction is completed.

21.5.3 Construction Criteria

(a) Construction Timing

The retention BMPs shall not be constructed or placed into service until all of the contributing drainage area has been stabilised and approved by the responsible inspector.

(b) Trench Preparation

Excavate the retention facility to the design dimensions. Excavation materials shall be placed away from the proposed facility sides to enhance wall stability. Care should also be taken to keep this material away from slopes, neighbouring property, sidewalks and streets. It is recommended that this material be covered with plastic if it is to be left in place for more than 30 days.

(c) Fabric Laydown

The filter fabric roll must be cut to the proper width prior to installation. The cut width must include sufficient material to conform to the trench perimeter irregularities and for a 300 mm minimum top overlap.

Place the fabric roll over the facility and unroll a sufficient length to allow placement of the fabric down into the facility. Stones or other anchoring objects should be

placed on the fabric at the edge of the trench to keep the lined trench open during windy periods. When overlaps are required between rolls, the upstream roll should overlap a minimum of 0.6 m over the downstream roll in order to provide a shingled effect. The overlap insures fabric continuity and allows the fabric to conform to the excavated surface during aggregate placement and compaction.

(d) Stone Aggregate Placement and Compaction

The stone aggregate should be placed in lifts and compacted using plate compactors. As a rule of thumb, a maximum loose lift thickness of 300 mm is recommended. The compaction process ensures fabric conformity to the excavation sides, thereby reducing potential soil piping, fabric clogging and settlement problems.

(e) Overlapping and Covering

Following the stone aggregate placement, the filter fabric shall be folded over the stone aggregate to form a 300 mm minimum longitudinal overlap. The desired fill soil or stone aggregate shall be placed over the lap at sufficient intervals to maintain the lap during subsequent backfilling.

(f) Potential Contamination

Care shall be exercised to prevent natural or fill soils from intermixing with the stone aggregate. All contaminated stone aggregate shall be removed and replaced with uncontaminated stone aggregate.

(g) Voids Behind Fabric

Voids may be created between the fabric and excavation sides and shall be avoided. Removing boulders or other obstacles from the facility walls is one source of such voids. Natural soils should be placed in these voids at the most convenient time during construction to ensure fabric conformity to the excavation sides. Soil piping, fabric clogging and possible surface subsidence will be avoided by this remedial process.

(h) Unstable Excavation Sites

Vertically excavated walls may be difficult to maintain in areas where the soil moisture is high or where soft or cohesionless soils predominate. These conditions require laying back of the side slopes to maintain stability; trapezoidal rather than rectangular cross-sections may result. This is acceptable, but any change in the size or the shape of the stone reservoir needs to be taken into consideration in size calculations.

(i) Traffic Control

Heavy equipment and traffic shall be restricted from travelling over the infiltration areas to minimise compaction

of the soil. The trench should be flagged or marked to prevent drive-on.

(j) *Observation Well*

An observation well shall be provided as described in the design criteria in the previous section. The depth of the well at the time of installation will be clearly marked on the well cap.

21.5.4 **Maturing of Infiltration Surface**

Newly constructed infiltration surfaces may not have as rapid an infiltration rate as more mature surface. This is attributed to freshly compacted surfaces and immature vegetative cover.

After infiltration surface undergo thaw and the vegetation's root system loosens the soil, infiltration rates tend to increase. Use of nursery grown turf in newly installed infiltration basins can achieve the highest possible infiltration rates in the shortest amount of time after construction.

Since infiltration rates in a new facility are likely to be less than anticipated in design, the downstream stormwater conveyance system may appear to be somewhat undersized. It is wise to account for this interim period and to either slightly oversize the local disposal facility or the downstream conveyance system.

As the local disposal facilities begin to age, some of them will fail and will have to be repaired or replaced. When failures begin to occur, the downstream conveyance system will need to handle more runoff. If the conveyance system was not designed with this in mind, it will become inadequate to handle the increase in runoff.

After land development is completed, random erosion occurs at points of concentrated flow (e.g., at edge pavement, at roof downspouts, etc.). The eroded soils are carried to the infiltration facilities and the infiltration and rates are significantly reduced. Control of erosion is very important and can be accomplished through the installation of splash pads at downspouts, the use of rock or paved rundowns, and other measures. Erosion control can go a long way toward reducing the rate of deterioration of local disposal facilities.

21.5.5 **Clogging**

It is not possible entirely to prevent fine sediments from entering the infiltration facilities and eventually clogging the soil pores. How long it takes will depend on the porosity of the soil, the quality of the stormwater, and how often runoff occurs. It is possible to reduce the amount of sediment through mechanical separation, such as presettlement in a holding basin. The use of filtration

system as pretreatment of infiltration beds, mentioned earlier, is very effective in reducing clogging.

If clogging occurs shortly after installation of infiltration facilities, it can indicate excessive sediment loads. One should check for erosion in the tributary area and for any other source of excessive sediment. Frequent clogging may also indicate the blockage of filters at the inlets to the infiltration or percolation beds. If this is the case, the problem can be corrected by simply cleaning out the filter media.

Of a more serious nature is the clogging that will occur over a long period of time. This is due to the accumulation of pollutants in the pores of the soil and in the percolation media. This could take several years, unless there are unusually heavy loads of sediment from the tributary basin.

21.5.6 **Slope Stability**

Because local disposal artificially forces stormwater into the ground, the possibility of creating slope stability problems should always be considered. As the water infiltrates or percolates into soils, the intergranular friction in the soil can be reduced and previously stable slopes can become unstable. Slope failures in urban areas can be disastrous. A geotechnical expert should be consulted whenever on-site disposal is being considered, regardless of the slope of the terrain. Such expertise is especially important if slope stability may be affected.

21.5.7 **Effects on Groundwater**

The forced inflow of stormwater into the ground will affect the groundwater levels and water quality in the regions where it occurs. The impact on groundwater needs to be considered and accounted for in the design of buildings. As an example, buildings with basements may not be feasible if the groundwater levels are raised above basement floor elevations. This problem may be solved by the installation of underdrains. At any rate, retention facilities will have an impact on groundwater.

Retention facilities may also have an impact on the quality of groundwater and may be of particular concern where groundwater is used as water supply. Studies reported to date by the EPA (1983) and the others suggest that groundwater recharged by nonindustrial stormwater may not have serious water quality problems. Water quality samples taken at several sites revealed that the groundwater underneath infiltration and percolation facilities meets all of the EPA's primary drinking water standards. These findings are still considered site-specific and, as a result, are inconclusive for all conditions.

Recent findings of groundwater contamination by organic toxicants, however, leave room for concern: As our society continues to use various solvents, herbicides, pesticides, and other potentially toxic, carcinogenic, or mutagenic

chemicals, many of these chemicals will enter groundwater with infiltrated stormwater. Unfortunately, the potential of these chemicals being present in stormwater runoff is ever present. And although there is no evidence of widespread contamination, as long as these chemicals are in general use we need to consider their potential presence in the stormwater runoff.

21.5.8 Care and Maintenance

The maintenance requirements of infiltration facilities are an important aspect which is often not addressed in the planning and design of these structures. Infiltration basins can be visually inspected and easily maintained. The surface of an infiltration trench or OSR system can also be visually inspected and maintained, but the subsurface storage area cannot. It is therefore a requirement to install an observation well in practice in order to have an observation mechanism available.

Infiltration facilities must be regularly maintained. Specific maintenance specification and recommendations are provided for each infiltration BMP in earlier sections. Often, OSR facilities are constructed as apart of a new development and become the responsibility of the individual property owner. Maintenance or operational instructions provided shall be adhered to by house owners.

As these facilities begin to fail, the property owners may conclude that the site was improperly graded in the first place. This problem may be resolved by improved surface drainage through regrading the site, or by installation drainage pipes or swales. Obviously, this defeats the retention concept and results in increased loading on the downstream system. It may be possible to avoid such a scenario if local authorities mandate, by ordinance, that the new owners be notified at time of sale that they are now owners of local stormwater disposal facility. Such formal notices should contain the operation and maintenance instructions.

Infiltration facilities, to a large extent, depend on a healthy growth of vegetation to keep the infiltration surface porous. Maintenance of the infiltration areas needs to include the maintenance of the vegetation growing on the infiltration zone. As the facility ages and the surface soils become clogged the top soil layers may have to be removed, replaced, and revegetated to restore their infiltration capacity.

Maintenance of percolation facilities needs to concentrate on keeping the inlet filters from being plugged. The filter fabric and/or sand layers need to be checked frequently and cleaned when found to be excessively clogged. After a number of years it may be necessary to replace the rock media and the adjacent soils because the very fine, unfilterable particles fill the pores. Regular maintenance of the inlet filter can significantly increase the time before the percolation bed has to be replaced.

(a) Inspection Schedule

When infiltration basins are first placed into use they should be inspected on a monthly basis and more frequently if a large storm occurs in between that schedule. During the wetter months inspections shall be conducted monthly. Thereafter, once it is determined that the basin is functioning in a satisfactory manner and that there are no potential sediment problems, inspection can be reduced to a semi-annual basis with additional inspections following the occurrence of a large storm (e.g. approximately 25 mm in 4 hours). This inspection shall include investigation for potential sources of contamination.

(b) Sediment Control Effect on Vegetated Basins

The basin should be designed with maintenance in mind. Access should be provided for vehicles to easily maintain the forebay (presettling basin) area and not disturb vegetation, or resuspend sediment any more than is absolutely necessary.

Cleanout frequency of infiltration basins will depend on whether they are vegetated or non-vegetated and will be a function of their storage capacity, recharge characteristics, volume of inflow and sediment load.

Grass bottoms in infiltration basins seldom need replacement since grass serves as a good filter material. If silty water is allowed to trickle through the turf, most of the suspended material is strained out within a few yards of surface travel. Well established turf on a basin floor will grow up through sediment deposits forming a porous turf and preventing the formation of an impenetrable layer. Grass filtration works well with long, narrow, shoulder-type depressions (swales, ditches etc.) where highway runoff flows down a grassy slope between the roadway and the basin. Grass planted on basin side slopes will also prevent erosion.

(c) Sediment Removal From Non-Vegetated Basins

Sediment is most easily removed when the basin floor (or presettling basin) is completely dry and after the silt layer has mud-cracked and separated from the basin floor. It is recommended that hand raking and removal be done if possible to avoid compaction of the infiltration media by equipment. Large-tracked vehicles should not be used in order to prevent compaction of the basin floor.

(d) Tilling of the Non-Vegetated Basin Floor

All accumulated sediment must be removed prior to tilling operations. As tilling is required periodically and at least once annually, the frequency of sediment removal will be reduced to small operations on a regular basis.

Tilling may be necessary to restore the natural infiltration capacity by overcoming the effects of surface compaction and to control weed growth on the basin floor.

Rotary tillers or disc harrows will normally serve this purpose. Light tractors should be employed for these operations. In the event that heavy equipment has caused deeper than normal compaction of the surface, these operations should be preceded by deep plowing. In its final condition after tilling, the basin floor should be level, smooth and free of ridges and furrows to ease future removal of sediment and minimise the material to be removed during future cleaning operations. A levelling drag, towed behind the equipment on the last pass will accomplish this.

To enhance infiltration capacity, tilling should be done. To control vegetative growth, an additional light tillage may be necessary during the growing season. Precautions must be observed to avoid working any of the sediment accumulation into the basin floor as a part of a light cultivation for weed control. Any cultivation or tilling

operation must be preceded in all cases by careful sediment removal.

(e) Side Slope Maintenance

Maintenance of side slopes is necessary to promote dense turf with extensive root growth which enhances infiltration through the slope surface, prevents erosion and consequent sedimentation of the basin floor and prevents invasive weed growth.

Seed mixtures should be the same as those recommended in the Erosion and Sediment Control.

The use of low-growing, stoloniferous grasses will permit long intervals between mowings. Mowing twice a year is generally satisfactory. Fertilisers should be applied only as necessary and in limited amounts to avoid contributing to the pollution problems, including ground water pollution, that the infiltration basin is there to solve. Consult the local extension agency for appropriate fertiliser types and application rates.

APPENDIX 21.A SOIL INFILTRATION

21.A.1 General Notes

1. For infiltration trench and basin practices, a minimum field infiltration rate (f_c) of 13 mm/hr is required; areas yielding a lower rate preclude these practices. For surface sand filter and bioretention practices, no minimum infiltration rate is required if these facilities are designed with a "day-lighting" underdrain system; otherwise these facilities require a 13-mm/hour rate.
2. Number of required borings is based on the size of the proposed facility. Testing is done in two phases, (1) Initial Feasibility, and (2) Concept Design.
3. Testing is to be conducted by a qualified professional. This professional shall either be a registered professional engineer in Malaysia, a soils scientist or geologist licensed in Malaysia.

21.A.2 Initial Feasibility and Concept Design Testing

Feasibility testing is conducted to determine whether full-scale testing is necessary, screen unsuitable sites, and reduce testing costs. A soil boring is not required at this stage. However, a designer or landowner may opt to engage Concept Design Borings per Table 21.A1 at his or her discretion, without feasibility testing.

Initial testing involves either one-field test per facility, regardless of type or size, or previous testing data, such as the following:

- * septic percolation testing on-site, within 60 m of the proposed BMP location, and on the same contour which can establish initial rate, water table and/or depth to bedrock,

- * geotechnical report on the site prepared by a qualified geotechnical consultant, or
- * soil mapping showing an unsuitable soil group such as clay.

If the results of initial feasibility testing as determined by a qualified professional show that an infiltration rate of greater than 13 mm per hour is probable, then the number of concept design test pits shall be per the following Table 21.2. An encased soil boring may be substituted for a test pit, if desired.

21.A.3 Documentation

Infiltration testing data shall be documented, and include a description of the infiltration testing method. This is to ensure that the tester understands the procedure.

21.A.4 Test Pit/Boring Requirements

1. excavate a test pit or dig a standard soil boring to a depth of 1.5 m below the proposed facility bottom
2. determine depth to groundwater table (if within 1.5 m of proposed bottom) upon initial digging or drilling, and again 24 hours later
3. conduct Standard Penetration Testing (SPT) every 0.5 m to a depth of 1.5 m below the facility bottom
4. determine US Department of Agriculture (USDA) or Unified Soil Classification (USC) System textures at the proposed bottom and 1.5 m below the bottom of the best management practice (BMP)
5. determine depth to bedrock (if within 1.5 m of proposed bottom)
6. the soil description should include all soil horizons
7. the location of the test pit or boring shall correspond to the BMP location; test pit/soil boring stakes are to be left in the field for inspection purposes and shall be clearly labelled as such

Table 21.A1 Infiltration Testing Summary Table

Type of Facility	Initial Feasibility Testing	Concept Design Testing (initial testing yields a rate greater than 13 mm/hr)	Concept Design Testing (initial testing yields a rate lower than 13 mm/hr)
Trench	1 field infiltration test, test pit not required	1 infiltration test and 1 test pit per 15 m of trench	not acceptable practice
Basin	1 field infiltration test, test pit not required	1 infiltration test and 1 test pit per 50 m ² of basin area	not acceptable practice
Biofiltration	1 field percolation test, test pit not required	1 infiltration test and 1 test pit per 50 m ² of filter area (no underdrains required**)	underdrains required

** underdrain installation still strongly suggested

21.A.5 Infiltration Testing Requirements

1. Install casing (solid 130-mm diameter, 1-m length) to 0.7 m below proposed BMP bottom (see Figure 21.A1).
2. Remove any smeared soiled surfaces and provide a natural soil interface into which water may percolate. Remove all loose material from the casing. Upon the tester's discretion, a 50-mm layer of coarse sand or fine gravel may be placed to protect the bottom from scouring and sediment. Fill casing with *clean* water to a depth of 0.7 m and allow to pre-soak for twenty-four hours.
3. Twenty-four hours later, refill casing with another 0.7 m of clean water and monitor water level (measured drop from the top of the casing) for 1 hour. Repeat this procedure (filling the casing each time) three additional times, for a total of four observations. Upon the tester's discretion, the final field rate may either be the average of the four observations, or the value of the last observation. The final rate shall be reported in mm per hour.
4. May be done through a boring or open excavation.
5. The location of the test shall correspond to the BMP location.
6. Upon completion of the testing, the casings shall be immediately pulled, and the test pit shall be back-filled.

21.A.6 Laboratory Testing

Use grain-size sieve analysis and hydrometer tests where appropriate to determine USDA soils classification and textural analysis. Visual field inspection by a qualified professional may also be used, provided it is documented. The use of lab testing to establish infiltration rates is prohibited.

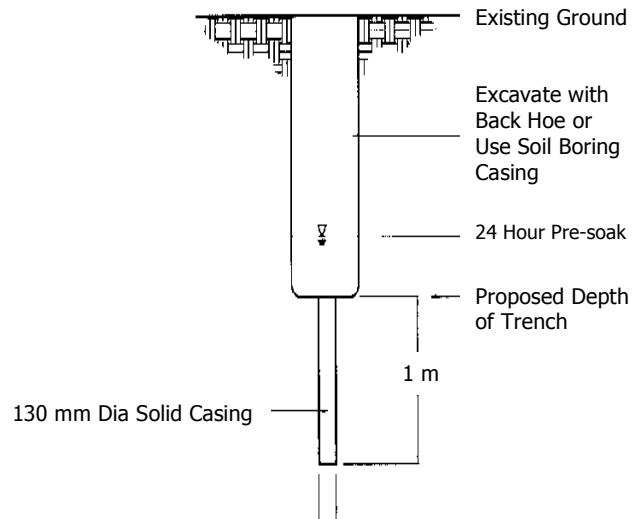


Figure 21.A1 Infiltration Testing Requirements

APPENDIX 21.B WORKED EXAMPLE

21.B.1 Sizing an Infiltration Trench

Problem: An on-site infiltration trench is proposed for a semi-detached bungalow (Figure 21.B1), Ipoh Perak. The catchment area is 171 m² (0.0171 ha). The site condition of pre-development is park lawn. From initial site investigation, the characteristics of the catchment is as follows:

Soil type: Sandy loam

Infiltration capacity (f_c): 0.035 m/hr

Ground water level: 3 m (below ground surface)

The following assumptions are made:

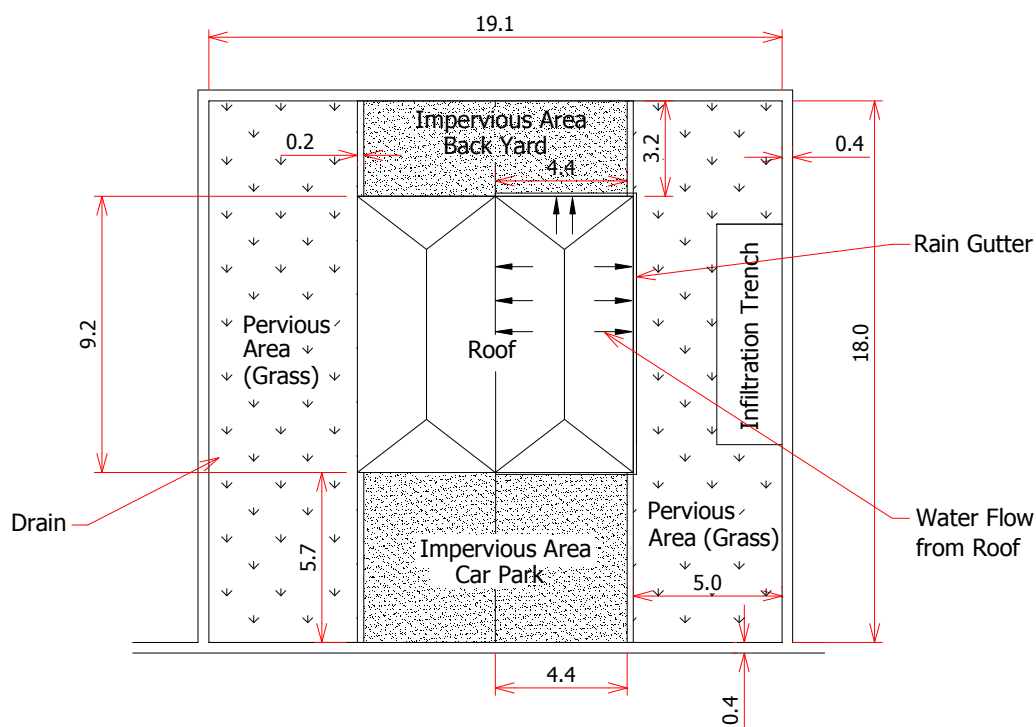
Time of concentration pre-development, $t_{cs} = 20$ minutes

Time of concentration $t_c = 10$ minutes

Porosity of fill materials, $n = 0.35$

Maximum storage time, $T_s = 24$ hrs

Effective filling time, $T_f = 2$ hrs



NOTE:

Dimensions are in metres

Drawn not to scale

Figure 21.B1 The Semi-detached House in Rapat Setia, Ipoh

Solution:

- Step (1) Determine the initial characteristic infiltration sump
 From Equation 21.1,
 Maximum allowable depth (d_{max}) = $f_c T_s / n = 2.4$ m
 Proposed depth (d_t) = 1.5 m
 Design infiltration rate (f_d): $0.5 f_c = 0.0175$ m/hr
- Step (2) Determine Q_{5-year} for the predeveloped and developed conditions

To calculate rainfall intensity (refer Table 13.A1)

$$\ln(I) = a + b \ln(t) + c [\ln(t)]^2 + d [\ln(t)]^3$$

For Ipoh, 5 year ARI and $t = 20$ minutes

t_c (min)	a	b	c	d	$\ln(I)$	I (mm/hr)
	5.0007	0.6149	-0.2406	0.0127		
	a	$b \ln(t)$	$c [\ln(t)]^2$	$d [\ln(t)]^3$		
	5.0007	1.8421	-2.1592	0.3414	5.025	152

For Ipoh, 5 year ARI and $t = 10$ minutes

t_c (min)	a	b	c	d	$\ln(I)$	I (mm/hr)
	5.0007	0.6149	-0.2406	0.0127		
	a	$b \ln(t)$	$c [\ln(t)]^2$	$d [\ln(t)]^3$		
	5.0007	1.4159	-1.2756	0.1550	5.2960	200

- Total Area, $A = 0.0171$ ha
 Predeveloped $C_{cs} = 0.48$ (category (7))
 Developed $C_t = 0.76$ (category (5))

- Step (3) Determine design volume enters the trench (V_w) that requires reducing in peak flow to pre-developed conditions

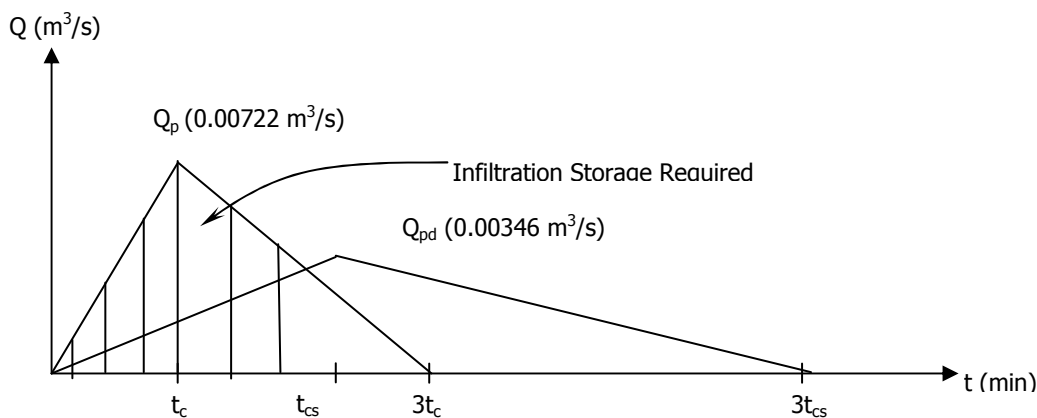


Figure 21.B2 Determination of Design Volume (V_w) for the Trench

$$Q_5 = \frac{C \cdot I_D \cdot A}{360}$$

Predeveloped $Q_5 = 0.00346 \text{ m}^3/\text{s}$

Developed $Q_5 = 0.00722 \text{ m}^3/\text{s}$

Volume enters = 5.50 m^3

Step (4) Estimate the dimension of the proposed trench using Equation 21.4, the area of the infiltration sump can be estimated

$$A_t = \frac{V_w}{nd_t + f_d T_f}$$

$$A_t = 9.83 \text{ m}^2 ;$$

Thus, the proposed infiltration trench is 2 m wide and 5.0 m length. This dimension fits the available space in the semi-detached unit compound.

21.B.2 Sizing an Infiltration Basin

Problem: A community infiltration basin is proposed for Sekolah Menengah Seri Ampang (Figure 21.B3), Ipoh Perak. The catchment area is 2.5 ha comprises of 1.26 ha of impervious area (building and parking) and 1.24 of pervious area (playing field and garden). Assume the site condition of pre-development is park lawn. From initial site investigation, the characteristic of catchment are:

Soil type : Sandy loam

Infiltration capacity (f): 0.035 m/hr

Ground water level : 2 m (below ground surface)

The following assumptions are made:

Time of concentration pre-development, $t_{cs} = 30$ minutes

Time of concentration $t_c = 20$ minutes

Porosity of fill materials, $n = 0.35$

Maximum storage time, $T_s = 24$ hrs

Effective filling time, $T_f = 2$ hrs

Solution:

Step (1) Determine the initial characteristic infiltration basin

From Equation 21.7,

Maximum allowable depth (d_{max}) = $f_c T_p = 0.84$ m

Proposed depth (d_t) = 0.5

Proposed side slope 1 : 5 (V:H)

Design infiltration rate (f_d) : $0.5 f_c = 0.0175$ m/hr

Step (2) Determine $Q_{5\text{-year}}$ for the predeveloped and developed conditions

To calculate rainfall intensity (refer Table 13.A1)

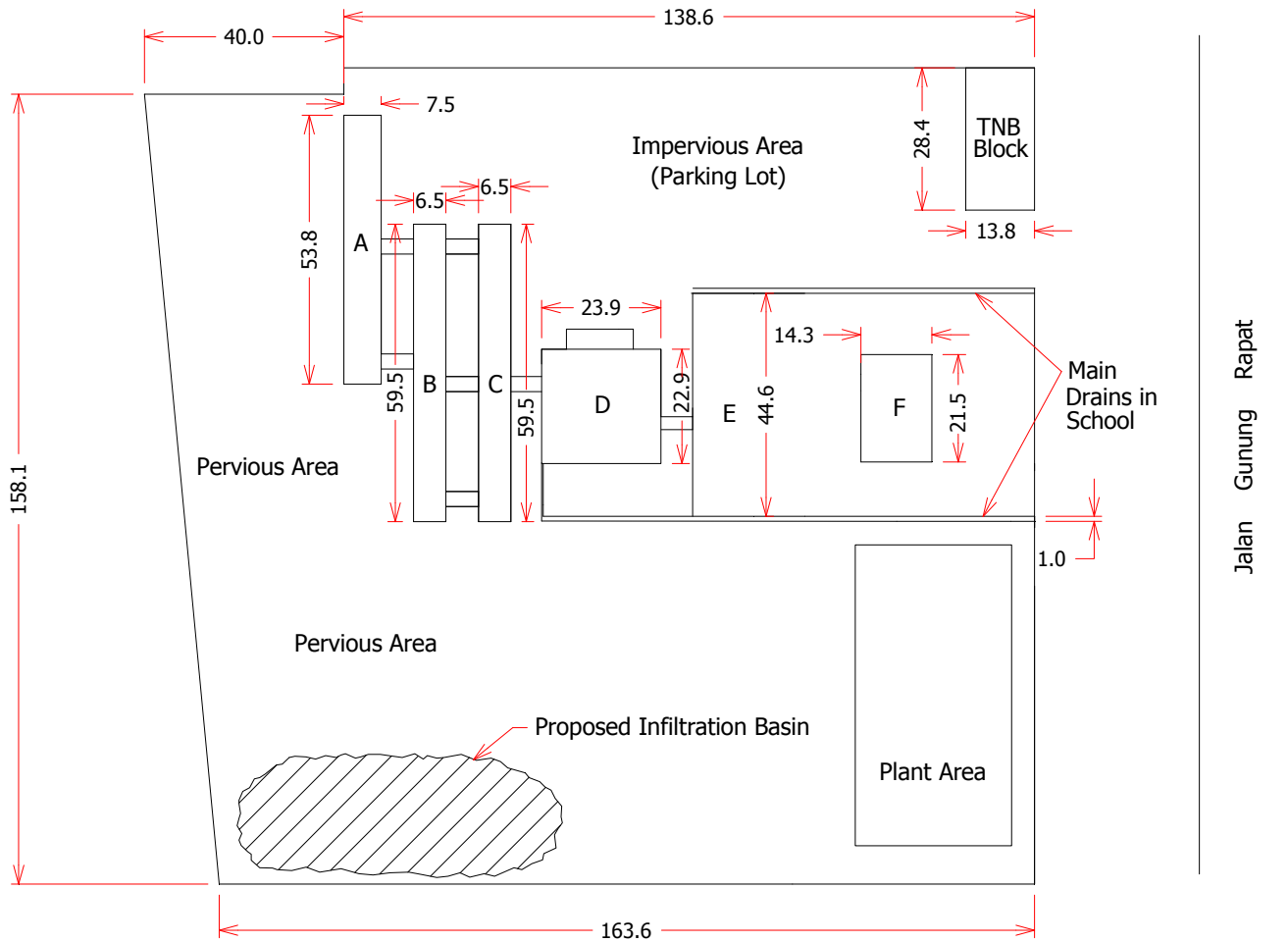
$$\ln(I) = a + b \ln(t) + c [\ln(t)]^2 + d [\ln(t)]^3$$

For Ipoh, 5 year ARI and $t = 30$ minutes

t_c (min)	a	b	c	d	Ln(I)	I (mm/hr)
	5.0007	0.6149	-0.2406	0.0127		
	a	$b \ln(t)$	$c [\ln(t)]^2$	$d [\ln(t)]^3$		
	5.0007	2.091	-2.783	0.4997	4.808	122

For Ipoh, 5 year ARI and $t = 20$ minutes

t_c (min)	a	b	c	d	Ln(I)	I (mm/hr)
	5.0007	0.6149	-0.2406	0.0127		
	a	$b \ln(t)$	$c [\ln(t)]^2$	$d [\ln(t)]^3$		
	5.0007	1.842	-2.159	0.3414	5.025	152



NOTE:

Dimensions are in Metres

Drawn Not to Scale

Figure 21.B3 Sekolah Menengah Seri Ampang at Rapat Setia, Ipoh

Total Area, $A = 2.5$ ha
 Predeveloped $C_{cs} = 0.48$ (category (7))
 Developed $C = 0.9 \times 1.26 / 2.5 + 0.63 \times 1.24 / 2.5 = 0.77$
 Impervious Area $A_I = 1.26$ ha (category (1))
 Pervious Area $A_p = 1.24$ ha (category (6))

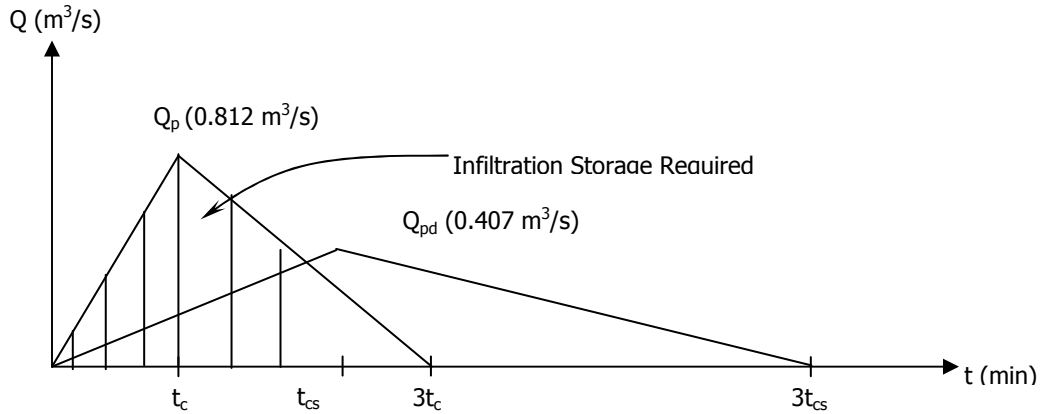


Figure 21.B4 Determination of Design Volume (V_w) for the Trench

$$Q_5 = \frac{C \cdot I_D \cdot A}{360}$$

Predeveloped $Q_5 = 0.407$ m³/s

Developed $Q_5 = 0.812$ m³/s

Volume enters (V_w) = 1170.4 m³

Step (4)

Estimate the dimension of the proposed infiltration basin. The basin top length (L_t) is determined by using Equation 21.11. The basin top width (W_t) should be predetermined by considering the available space in the compound. In this example, the available space is about 40 m wide.

$$L_t = \frac{V_w + Z d_b (W_t - 2 Z d_b)}{W_t d_b - Z d_b^2}$$

$$L_t = \frac{1170 + 5 \times 0.5 (40 - 2 \times 5 \times 0.5)}{40 \times 0.5 - 5 \times 0.5^2}$$

$L_t = 63.3$ m

Thus, the dimension of the proposed infiltration basin is 40 m x 65 m