VERSION 1.0

Stormwater Solutions for Residential Sites

Prepared for

Waitakere City Council
Te Tatao o Waitakere

November 2004

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AEP	Annual Exceedance Probability- this is used to describe the potential frequency of a storm event. A 50% AEP event can also be described as a " 2 year return period event". A 20 % AEP event can also be described as a "5 year return period" event.
Overland Flow	This is runoff that does not enter the piped network and travels overland. The design target for the piped network in Waitakere City is to convey flows associated with events up to the 20 % AEP event. If an event occurs that exceeds the piped network capacity overland flow will occur. If there is no designated or formed pathway for this overland flow it can result in flooding of properties.
Impervious Area	This describes all hard surfaces constructed over natural ground. Impervious areas include roofs, driveways, carparks, roads and tennis courts. All of these surfaces impede the infiltration of stormwater back to ground and result in an acceleration of runoff.
Contaminants	Stormwater picks up many contaminants as it travels over ground and these can be later deposited in streams or coastal areas. For urban areas common contaminants include suspended solids, oils and heavy metals (zinc and copper in particular).
Outlet	In this document the term outlet is used to describe where stormwater leaving a site is discharged. Where the outlet involves connection to a trunk drainage pipeline, approval for such a connection must be sought.
ESA	Equivalent Standard Axles-design term used for paving design.
Permeable paving	Pavements designed to infiltrate stormwater through the surface of the pavement for the purpose of quality and / or quantity management. These include grass block pavements, solid block pavements with permeable gaps, and aggregate pavements
Voids ratio	Volume of voids in soil / aggregate divided by the total volume of soil / aggregate. For permeable paving, voids ratio of the basecourse plays an important role
Basecourse	Hard, durable, aggregate base- in this document applicable to permeable paving. Ideally, a basecourse needs to have a large voids volume, a controlled horizontal permeability and the required structural properties. In practice, a material is selected to provide an optimum balance.
Bedding sand	Hard, durable, permeable granular bedding material used for bedding blocks in permeable paving

Introduction

SECTION 1

1.1 Purpose

Stormwater generated from residential sites has the potential to cause a number of adverse affects. Flooding, erosion of stream channels and pollution of streams and beaches are all problems that can be associated with stormwater. These problems are often made worse by the process of in-filling and redevelopment of sites.

Traditionally, when a site located in an urban area was developed or subject to upgrades, the stormwater from roof and driveway areas would be connected directly into the existing drainage system. This can cause problems because older drainage networks often do not have capacity for more flow, nor incorporate any form of stormwater treatment.

This document promotes methodologies for on-site control of stormwater that are designed to control the effects of development in an existing urban environment. The document was developed by WCC Solutions (WCC) and is intended to provide guidance to landowners, developers, engineers and surveyors on the stormwater management methods applicable to urban residential sites located in Waitakere City. In this document "Council" refers to Waitakere City Council.

The document focuses on the management practices applicable to developments on individual residential lots. This includes new houses, house extensions, new garages and driveways. Methodologies described in the document generally apply to residential properties of 1,000 m^2 area or less.

The intent is that the document will be used by WCC engineers, and applicants for stormwater control for building permits for these types of developments.

1.2 What are the Adverse Effects

Residential development results in an increase in the area of impervious surfaces on a site (roofs, driveways, and roads). In addition, development often results in areas of earth around buildings being compacted, the removal of vegetation and changes in the natural drainage systems.

When impervious areas are added to a site the stormwater runoff from the property can potentially intensify. This can cause localised flooding problems and also contribute to any existing downstream flooding problems. In addition there is potential for an increase in contaminants associated with stormwater to be generated from a property. This can have localised adverse affects and contribute to cumulative degradation in downstream watercourses.

In summary the effects of development on stormwater flows can result in:

- Flooding as a result of the capacity of existing stormwater reticulation systems being exceeded;
- Stream bank erosion in nearby watercourses;
- Sedimentation in existing watercourses and downstream environments;

- An increased tendency for more severe flooding and increased areas of flooding;
- The increased contamination of receiving environments, both in local streams and in the marine environment where all stormwater eventually goes; and
- Adverse impacts on aquatic resources.

1.3 Design Objectives

WCC are focused on implementing stormwater management solutions that mitigate against the adverse effects of development listed above. Key design objectives applied in this document are described below:

Objective.1 **To prevent downstream flooding.** The effect of providing increased impervious surface within a property is to reduce the volume of runoff that infiltrates naturally back into the ground, causing runoff to discharge faster. Without controls in place this can result in peak flows and discharge volumes associated with storm events increasing from a property. This additional flow can cause localised flooding and contributes to wider catchment flooding problems downstream.

Objective.2 **To prevent increased erosion and change to the hydrologic regime of downstream watercourses**. Development has the potential to cause a change in the pattern of stormwater discharges to streams. In particular, an increase in impervious surface areas within a catchment can result in stormwater being transmitted faster to streams. As a result there are more occurrences in a year of short, high flow events associated with regular rainfall conditions (i.e. less than a 1 in 1 year event) than would have occurred pre-development. This change in stream response to rainfall can result in significant channel erosion and downcutting, which in turn adversely affects stream habitat.

Objective.3 **To minimise the potential for increased discharge of contaminants associated with stormwater runoff from a site following development, to streams and coastal receiving environments**. Stormwater runoff generated on impervious areas, particularly roads, tends to pick up contaminants. These contaminants have the potential to degrade streams and sensitive coastal receiving environments.

The first two objectives can be achieved through mitigating against change in the peak flow, volume and time of concentration of stormwater runoff from an area during a rainfall event after residential development has occurred.

Incorporation of stormwater treatment into the design of conveyance and storage systems provides opportunity to achieve the third objective of mitigating against increased contaminant discharge.

1.4 Stormwater Management Methods

The objectives described above can be achieved in practical terms by the application and design of suitable stormwater management methods, described in this document as follows:

Section 2	Stormwater Management Approach – this section outlines the overall approach to managing stormwater on site. This section also includes recommended conceptual layouts of stormwater management devices.
Section 3	Which option to use - this section covers how to identify appropriate stormwater management options for a planned development.
Section 4	Minimising Impervious Areas – this section outlines techniques that can be used to minimise the impervious area on a site. Minimising impervious areas is the most effective way to reduce the amount of stormwater management that is required.
Section 5	Roof tanks – this section describes the use of roof tanks to attenuate flood flows. Roof tanks can be used to provide temporary storage and attenuate stormwater flows.
Section 6	Rain Gardens –this section provides information about the use of a raingarden and basic design details. Rain gardens attenuate peak flows and provide stormwater treatment.
Section 7	Permeable Paving – this section describes how the use of permeable pavement can provide both attenuation and treatment of stormwater.
Section 8	Swales - this section describes how swales can retard flow and provide some infiltration especially when used to convey stormwater flows from larger areas of impervious surface like driveways.
Section 9	Green roofs - this section provides conceptual details for green roofs, which can retard runoff and reduce runoff volumes through evapotranspiration.
Section 10	Maintenance and Monitoring Requirements – this section outlines Councils expected requirements for monitoring and maintenance of the devices described in the document.
Appendix A	Checklists – Checklists have been provided to fill in to enable Council officers to assess applications in terms of effects on stormwater.
Appendix B	Recommended Plant Species– this appendix contains a list of the plant species recommended by WCC for Rain Gardens.

Table 1-1 illustrates devices covered in this document.

Table 1-1 - Stormwater Management Devices

Devices for Meeting Design Approach	Example
Roof tanks	
Rain gardens	

Permeable Pavement	
Swales	
Green Roofs	

1.5 Auckland Regional Council Technical Publications

The ARC has developed a series of technical publications that promote a low impact design approach to the management of stormwater. Low impact design approaches are strongly supported by WCC. Of particular relevance are the:

- Low Impact Design Manual for the Auckland Region (Technical Publication 124)
- Stormwater Treatment Devices: Design Guideline Manual (Technical Publication No 10) - (http://www.arc.govt.nz/arc/environment/water/)

For sub-divisions reference should be made to these documents as they include information on devices not covered in this document. This applies in particular to devices more suited to servicing larger catchments such as wetlands, detention ponds and sand filters.

1.6 Limitations

a) It is intended that this document be used as a guide to appropriate on-site management of stormwater. Effective stormwater management depends on correct application of systems to site constraints such as slope, vegetation, soil conditions and proposed site layout. Proper site assessment needs to be undertaken in conjunction with the use of this document to develop appropriate on-site stormwater management techniques; and

b) This document is to be used as a guide to appropriate on-site management of stormwater for **lots of 1,000 m^2 or less**. Council reserves the right in any particular case to impose more restrictive requirements than those required under this document where Council considers it necessary to ensure appropriate stormwater management, including without limitation that Council may limit the methods of stormwater mitigation that are considered appropriate on a site by site or catchment basis; and

c) As the ARC is the regulator of stormwater in the Auckland Region, this document may not in all instances meet their requirements. If for any reason the Auckland Regional Council do not accept the use of devices within this document to mitigate the effects of a development then a separate resource consent may be required from the Auckland Regional Council; and

d) Where there is any conflict between Section 1.6 above, and the wording of this document, then Section 1.6 shall prevail; and

e) Property owners are advised to use the services of a consulting engineer to assist in the development of appropriate on-site stormwater management options.

2.1 Do the Methods Described in this Document Apply ?

It is important as a first step to establish whether or not the design approaches detailed in this document apply to a given situation.

The design approaches and methods in this document primarily cover situations where there is no existing drainage system to connect into, or connection to an existing drainage system is difficult due to limitations with the capacity of an existing network or other problems (e.g. access to a connection).

Where there is no drainage network site development is generally limited to 15% impervious cover on a residential site (WCC District Plan).

Where there is an existing network the option of connecting to, or increasing the volume of stormwater discharging to this network will need to be determined from WCC.

WCC has developed models of the stormwater network throughout Waitakere City, and the outputs from these need to be referenced by WCC staff to check whether there are any limitations in the network.

The following key decision points apply:

1. *Is there an existing stormwater network either on the property or within 50 m and does it have capacity for additional flow (up to the 20 % AEP)?*
   - If the answer is yes, then stormwater from the development can be discharged to the network.
   - If connection is possible but capacity is a problem, the methods described below may apply. WCC should be consulted to confirm the correct approach.
   - If there is no possible connection point to a network then an alternative discharge point needs to be identified in conjunction with WCC.
2. *Is there a stream on or near to the property where stormwater could be discharged, or is discharge to the coast a possibility ?*
   - If the answer is yes, methods described in this document apply.
   - If the answer is no the possibility of discharging to an adjacent road should be investigated.
3. *Is the property adjacent to a road with kerb and channel and if so is there a stormwater network with catchpits?*
   - If the answer is yes the option of connection to the road drainage system should be explored with WCC. WCC will advise if direct connection is possible and if methods described in this document to attenuate flows must be applied upstream of such a connection.
   - If the answer is no, discharge options are clearly limited and the property owner will need to talk with WCC directly about possible site-specific solutions.

2.2 Design Approach

This document supports the following design approach to stormwater management defined as:

Maintain existing (pre-development) peak flows from a property for events up to the 50 % AEP (2 year return period) storm event and minimise increases in runoff volume where practicable.

This design approach is applicable to the whole of a site and not just the proposed new development.

Local drainage networks in Waitakere City are generally designed to convey flows associated with the 20 % AEP event. When a more severe event occurs drainage passes via overland flow paths that are generally designed for a 1 % AEP event.

This approach provides protection to streams immediately below sites as well as mitigating against increased flooding locally and further downstream.

Property owners are advised to confirm with Council that this design approach is applicable to their site before progressing with design of a stormwater management system based on this approach.

2.3 Design Information

The design information in this document has been developed to provide the flexibility to select the various stormwater management options and combination of options that are most appropriate for a site. Property owners may wish to develop sites using different methods that are applicable to the site conditions and the style of development. For instance it may not be feasible to fully offset the effects of development by constructing a roof tank due to architectural and landscaping concerns. Similarly rain gardens may be more applicable to "green-fingered" owners. This document provides flexibility for landowners to implement combinations of methods to be used.

Sections 4 to 9 outline various stormwater management options, and provide appropriate design detail to select combinations of stormwater management techniques.

2.4 Site Layouts

An important first step is to understand where stormwater currently flows on the site.

Obtain the relevant drainage plans from Council for the site.

It is very important to consider the location of any development in relation to existing overland flow paths. Blockage of overland flow paths by construction of new buildings or landscaping can cause stormwater to be diverted into site or neighbouring buildings. This is one of the most common causes of localised flooding.

Before progressing with any new development talk to Council about overland flow paths, to check if any run through the property and try and observe directly where water flows on the site when it rains.

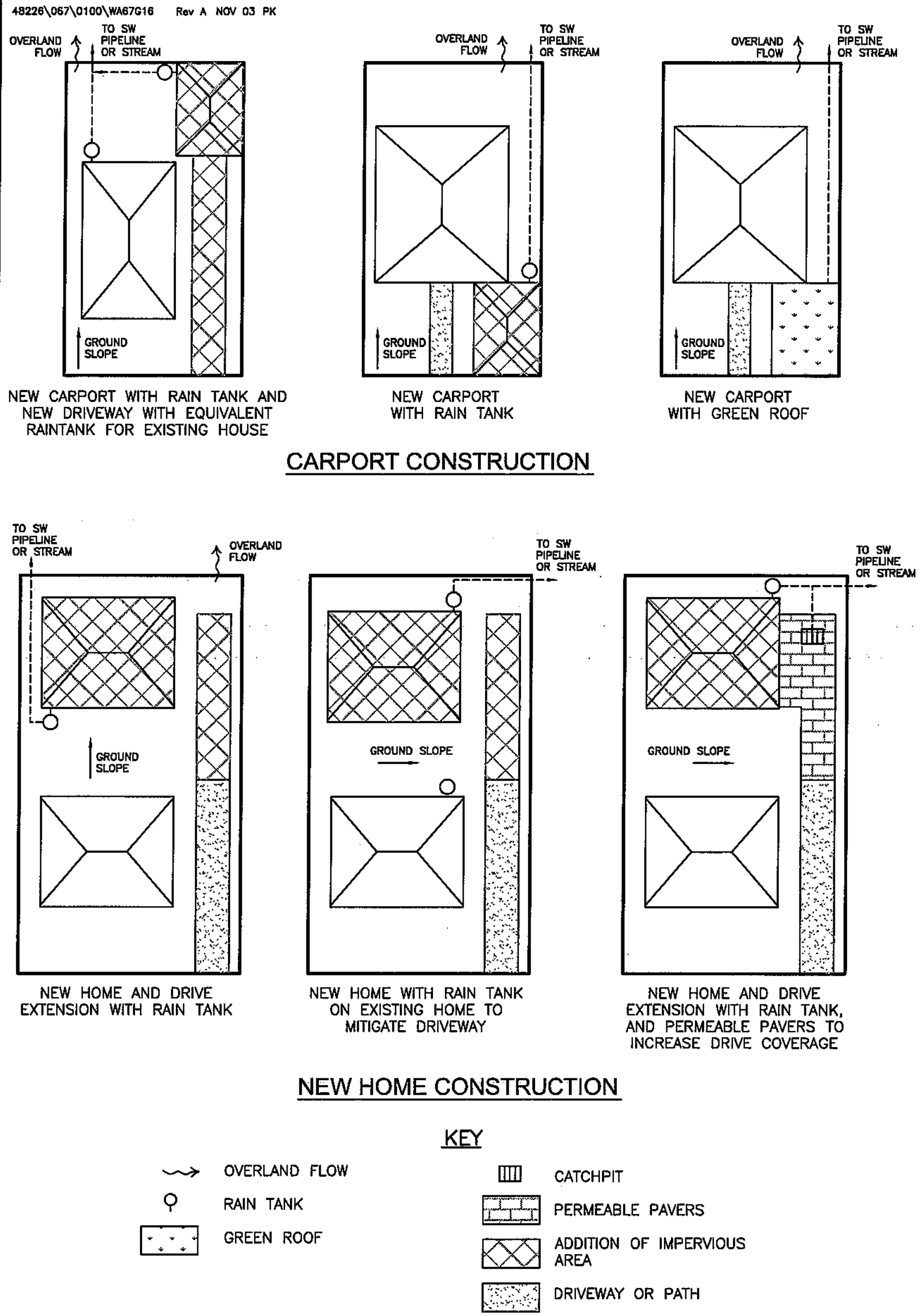
This will assist with designing the layout for a stormwater management system.

The ultimate discharge point for stormwater from the site should be determined based on application of the process outlined in Section 2-1.

When assessing the placement of stormwater detention devices, consideration of the proximity to residential dwellings needs to be made. For example if you are considering the use of a raingarden it should be located downgradient of the house and sufficient freeboard needs to be provided between the floor of the house and the stormwater detention area.

The topography and ground stability of the site must also be considered. Rain gardens are likely to be unsuitable for steep sites.

Figures 2-1 illustrates conceptual layouts of typical sites showing possible stormwater management systems that could be implemented to mitigate the effects of development on the environment and downstream infrastructure.



NOTE:

1. DISCHARGE RAIN TANK, RAIN GARDEN, GREEN ROOF AND SWALE TRENCH TO APPROVED DRAINAGE OUTLET

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CONCEPTUAL SITE STORMWATER MANAGEMENT LAYOUT

Figure No. **2-1**

2.5 Application of Methods not Listed in the Document

This document is intended to be a guide to appropriate stormwater management **on sites of 1,000 m^2 or less**. The stormwater management measures listed in the document are simple to use and aimed at providing methods that are considered most applicable for the conditions encountered. However other variations of the methods proposed in this document may be used if designed in accordance with the ARC technical publications referenced earlier (Section 1.5). Details of all methods used and the design details should be included with any application for building consent.

How to Use the Stormwater Solutions Document

3.1 Introduction

The design information provided in this document has been developed to provide the flexibility to select various stormwater management options and combination of options that are most appropriate for the site. The document provides flexibility to implement combinations of methods to be used to achieve the key objectives listed in Section 1.3.

3.2 What to do

Step 1 – Identify what amount of impervious area is being added to the site.

Step 2 – Obtain service plans for the site from Council and identify where stormwater from new impervious areas is to be discharged.

Step 3 – Confirm the location of any overland flow paths on or adjacent to the site. Assess the layout of the proposed development in relation to overland flow paths.

Step 4 – Identify the design approach applies based on Section 2-1, review the relevant Comprehensive Catchment Management Plan and discuss proposal with Council.

Step 5 – Identify what stormwater management methods are appropriate taking into account site constraints and landowner/developer preferences. Typical combinations of appropriate stormwater management options are outlined in Section 3.3.

Step 4 – Design the stormwater management devices using the appropriate techniques described in this document.

Step 5 – Fill in Checklists from Appendix A.

3.3 Combined Methods

This section outlines some possible combinations of stormwater management techniques to provide on-site stormwater management. They are listed in order of preference from higher to lower.

1. <u>Reduce Impervious Area</u>

   For new buildings consider minimising impervious surface by constructing a double-storey building, using permeable pavers or perhaps replacing concrete areas adjacent to the house with decking.

2. <u>Roof Tank and Retrofit of Paved Areas</u>

   Provide a roof tank to offset the increase in runoff from the roof area and replace hardstand areas with either open slat decking or pervious paving. The retrofitting option may be important for sites where rain gardens or planters are not practical due to site constraints. Consider a situation where additional hardstand area is required to access a new garage or provide additional parking. The removal of an existing hardstand area that is completely impervious could be replaced by a larger area of pervious paving, without increasing the extent of the effective impervious area. The roof tank would be sized based on Section 5. The pervious paving would be assessed based on Section 7.

3. Retrofitting of Permeable Paving or Roof Tanks

   A roof tank could be added to the existing house as a means to not increase the total effective impervious area in conjunction with retrofit of hardstand to a more permeable surface.

4. Multiple Devices

   Consider the construction of more than one device e.g. provide roof tanks or rain gardens for both the house and garage.

3.4 General Design Principles

General principles that should be applied include:

- Stormwater disposal should mimic, to the extent possible, the natural drainage processes of an area;
- Maintain sufficient overland flow paths capable of safely conveying the 1% AEP;
- Stormwater should not be discharged directly into streams from a piped system unless there is no other option;
- Impervious areas should not exceed 60% of the property area or 15% of the property area if there is no authorized drainage connection; and
- Appropriate methods to hold stormwater back (detention) before dispersal into waterways should be employed.
- If the site is going to be lowered below natural ground levels, then stormwater disposal must take this into account.

3.5 What to do Next?

To enable Council to assess your application in terms of effects on stormwater you must clearly and accurately provide the information set out in the checklists provided in Appendix A of this document. Your application must clearly present the existing site conditions and the proposed development and its potential effects on stormwater.

It is important that you present this information clearly, as this will assist with the assessment of your application. You are advised to use the services of a consulting engineer to assist in the preparation of your application.

4.1 Introduction

Impervious surfaces (roads, roofs, and footpaths) prevent the passage of water through the surface into the ground. Water must then be transported across the surface to the point of discharge. Minimising impervious areas is the most effective way to preserve a site's predevelopment runoff characteristics.

4.2 Description

Techniques to minimise impervious surface areas include:

- The use of permeable paving materials (refer Section 7);
- Reducing the area/extent of roof area (two stories for additional space);
- Construction of Green Roof (refer to Section 9)
- The use of pervious surfaces around buildings (e.g. open slated decks rather than concrete);
- Clustering of structures (placing the house, garage and additional structures in close proximity) to reduce the impervious hardstand areas between structures; and
- Reducing impervious surface areas of access ways and driveways by the following methods: -
  - The use of pervious paving materials such as gobi blocks, enviroblocks or gravel;
  - The use of dual strip driveways with a grassed central strip;
  - Reducing drive and access way length (locating the house closer to the road); and,
  - Providing shared access ways to serve several houses.

The design of the driveway is the responsibility of the property owner. It is important that precast paving materials are used strictly in accordance with manufacturers specifications that take into account the bedding material and basecourse requirements applicable for the site conditions.

4.3 Benefits

Reducing the amount of impervious surface reduces the amount of stormwater generated. Non-structural and alternative approaches to stormwater management are more easily applied and successful when the amount of stormwater generated is reduced.

4.4 What to do?

Consider the amount of impervious area you realistically need to meet your requirements. Apply some or all of the methods listed above to minimise the area required. The stormwater effects generated by the area that you decide on will have to be managed by application of the stormwater management techniques that you choose to apply from the following pages.

In Waitakere City **the maximum imperviousness that can be applied to a residential lot is 60% of the property area or 15% if there is no drainage connection.** The total impervious surface area allowed is calculated from private driveways, paths and all roof areas (including garages). This impervious area must not be exceeded in the stormwater management technique calculations that follow on subsequent worksheets (Appendix A).

5.1 Introduction

Roof tanks provide temporary storage and attenuation of stormwater flows generated on roof areas. Roof tanks can also be used to collect stormwater runoff for domestic use. In this regard use must be for non-potable purposes including toilet flushing and garden irrigation.

This section provides design details applicable to both attenuation and reuse.

5.2 Description

Stormwater is attenuated by holding stormwater within roof tanks during a rainfall event, and then controlling the release of stormwater through a small diameter orifice pipe. Roof tank sizes and orifice diameters given in this section are designed to control flows from roof areas to a rate similar to grass.

Stormwater discharging from the roof tank orifice must be connected into the drainage network or to an WCC approved drainage outlet.

The roof tank volume and the orifice outlet diameter depend on the area of the roof. The tank volume may also vary if it is proposed to reuse rainwater collected in the tank. In urban areas the Council does not support use of rainwater for potable water, however rainwater can be used for:

- Flushing toilets;
- Laundry cold tap;
- Laundry; and
- Garden uses.

The amount of storage provided in a tank for reuse depends on which of the above the water is to be used for.

5.3 Considerations

Consider the visual impacts of the building platform and tank for aesthetic reasons. The tanks can be supplied in a variety of colours, which will assist to blend in with the surrounding environment.

Runoff from other impervious surfaces, such as driveways or paving will need to be managed by other stormwater management methods.

Tanks should always be above ground unless approved otherwise by Council.

5.4 What to do?

In selecting a tank it is important to first establish if the tank is required for:

- Detention only; or
- Reuse and detention

Where it is intended to reuse water collected in the tank more detail is required with an application to show how the water from the tanks is to be linked into an existing water supply system. Design information covering both these situations follows.

5.5 Detention Tanks

5.5.1 What to do ?

Figure 5-1 shows a typical detail for a tank designed for detention only. Alternative fitting details must be submitted to WCC for approval. The tank is sized only to hold back stormwater during rainfall events and release all of this water stored over time.

Water is released from the tank through a small diameter orifice pipe from the base of the tank. Debris protection, such as screening mesh on the contributing spouting or a Rainwater Leafslide device on the downpipe to the tank should be installed to reduce the likelihood of blockage of the orifice pipe. If the orifice pipe becomes blocked it can be removed from the tank, cleaned and reinstalled. Flows exceeding the design rainfall event are discharged via an overflow pipe.

All roof tank overflows should discharge to a location approved by WCC.

5.5.2 Sizing Your Tank

The roof tank for the house is sized to accommodate the 20% AEP event with a maximum discharge not exceeding the discharge rate equivalent to a grass surface for this event. The orifice pipe diameter and limiting dimensions of the tanks required for roof areas up to 200 m^2 are shown in Table 5-1.

Table 5-1 - Orifice Pipe Diameter and Tank Sizing for Detention

Diameter. (mm)	897-910		1600-1785		2180		3555	
Vol. (litres)	450-1138		2499-4420		8475		25210	
Area (m^2)	d (mm)	H (mm)	d (mm)	H (mm)	d (mm)	H (mm)	d (mm)	H (mm)
<25	15	200	15	140	15	100	25	40
26-50	15	600	15	300	20	150	25	70
51-75	-	-	20	400	25	200	25	100
76-100	-	-	20	500	25	250	30	120
101-150	-	-	25	600	25	420	30	200
151-200	-	-	25	700	25	600	30	300

A typical arrangement for a detention roof tank is shown on Figure 5-1.

The orifice pipe diameters and fitting sizes identified on Figure 5-1 vary depending on the roof area served. Tank outlets in the capacities nominated are usually either 1.0 inch (25.4 mm) or 1.5 inch (32 mm) BSP. The orifice pipeline diameters and overflow diameters for these outlet diameters are listed in Table 5-2. Appropriate sized fittings should be sought for any other outlet diameters provided by tank manufacturers.

Table 5-2 - Orifice Pipe and Fitting Diameters for Detention Roof Tanks

Tank outlet diameter	Orifice Pipe Diameter	Identification on Figure 5-1	Orifice Pipe and Fitting Diameters
1 inch BSP	15 mm	A B C	25 x 15 PE reducing bush 15 mm PVC valve socket 15 mm PVC pipe
1 inch BSP	20 mm	A B C	25 x 20 PE reducing bush 20 mm PVC valve socket 20 mm PVC pipe
32 inch BSP	20 mm	A B C	32 x 20 PE reducing bush 20 mm PVC valve socket 20 mm PVC pipe
32 inch BSP	25 mm	A B C	32 x 25 PE reducing bush 25 mm PVC valve socket 25 mm PVC pipe

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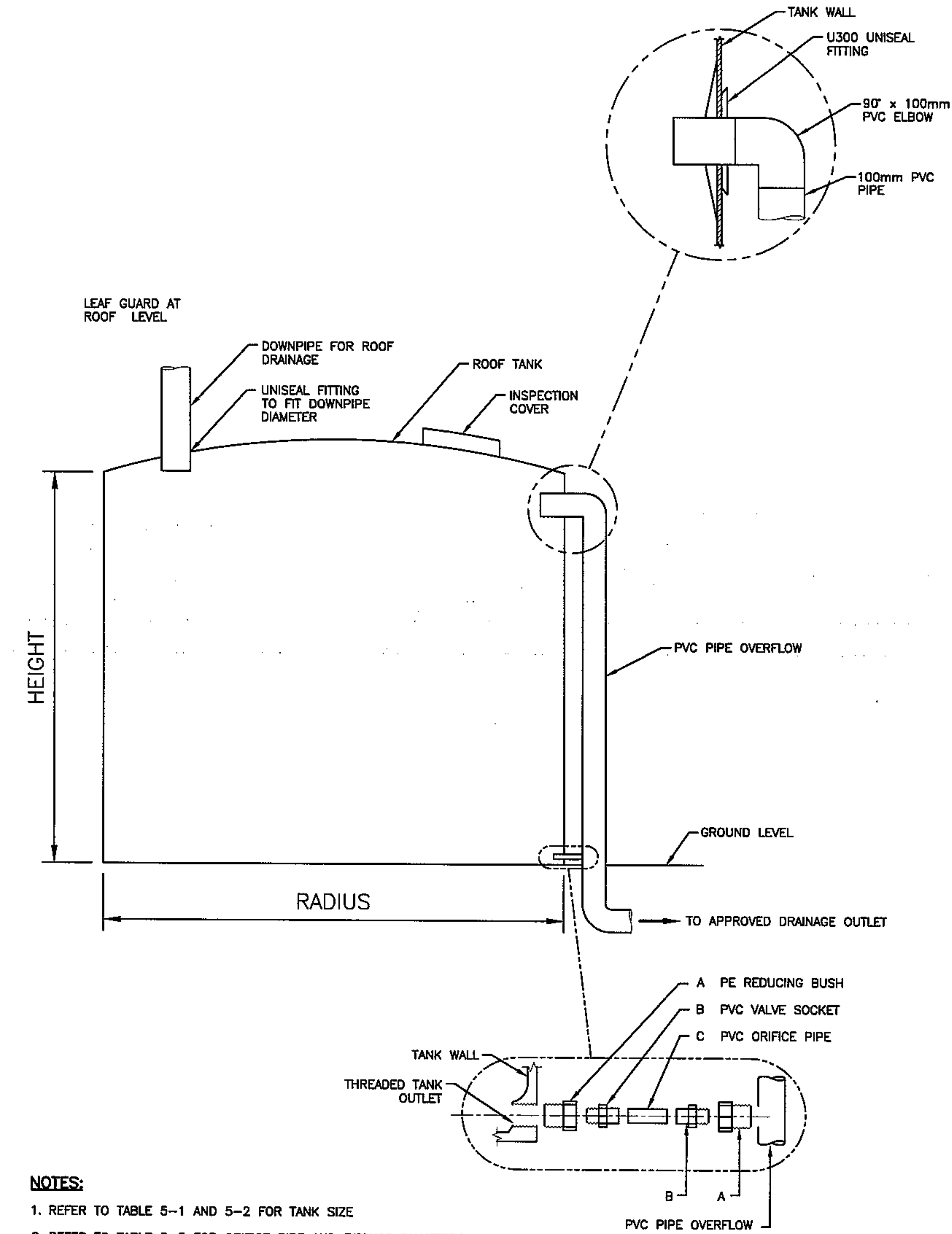

NOTES:

1. REFER TO TABLE 5–1 AND 5–2 FOR TANK SIZE
2. REFER TO TABLE 5–3 FOR ORIFICE PIPE AND FITTINGS DIAMETERS
3. ENSURE GROUND BENEATH TANK FOOTING MATCHES SUPPLIERS SPECIFICATIONS
4. FIT UNISEAL IN ACCORDANCE WITH MANUFACTURERS SPECIFICATION
5. FIT DEBRIS PROTECTION TO ROOF DRAINAGE IN ACCORDANCE WITH MANUFACTURERS SPECIFICATION
6. HOLES DRILLED THROUGH TANK WALL TO BE IN ACCORDANCE WITH MANUFACTURERS SPECIFICATION
7. TANK MUST BE ABOVE GROUND UNLESS ECOWATER APPROVE OTHERWISE

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LAYOUT OF DETENTION ROOF TANK

Figure No. **5-1**

5.6 Water Reuse

5.6.1 What to do ?

Water can be reused by installing a reuse tank that is separate from the detention tank, or by allowing for some detention at the top of the reuse tank as shown in Figure 5-2. Where a separate detention tank is used, the small bore pipe and orifice cap and associated fittings shown on Figure 5-2 can be removed and the reuse tank used for water supply only. All roof tank overflows should discharge to a location approved by WCC.

Water tanks for reuse would normally be the larger size needed to store water during dry periods i.e. typically 8 to 25 m^3 capacity. Debris protection, such as screening mesh on the contributing spouting or a Rainwater Leafslide device on the downpipe to the tank should be installed in accordance with the manufacturers specification to reduce debris into the tank. Other water quality issues to be considered when using rainwater for non-potable supply are the type of roof and spouting materials used and possibly filtration.

Should detention storage for roof runoff be incorporated into the reuse tank, the orifice diameter and detention storage head are shown in Table 5-3 for tank sizes in the range 8 to 25 m^3 capacity. These tanks have diameters of typically 2.18 to 3.55 m. As can be seen from the table the detention storage requirement is small compared to the total storage in the tank.

Table 5-3 – Orifice Diameter and Detention Storage Head incorporated with Reuse Tank

Roof Area (m2)	2.18 m Diameter Tank (8.475 m^3)		3.55 m Diameter Tank (25.2 m^3)	
	Orifice Diameter (mm)	Detention Storage (mm)	Orifice Diameter (mm)	Detention Storage (mm)
<25	20	110	25	40
26-50	25	150	25	70
51-75	25	200	25	100
76-100	30	350	30	120
101-150	30	420	30	200
151-200	30	600	30	300

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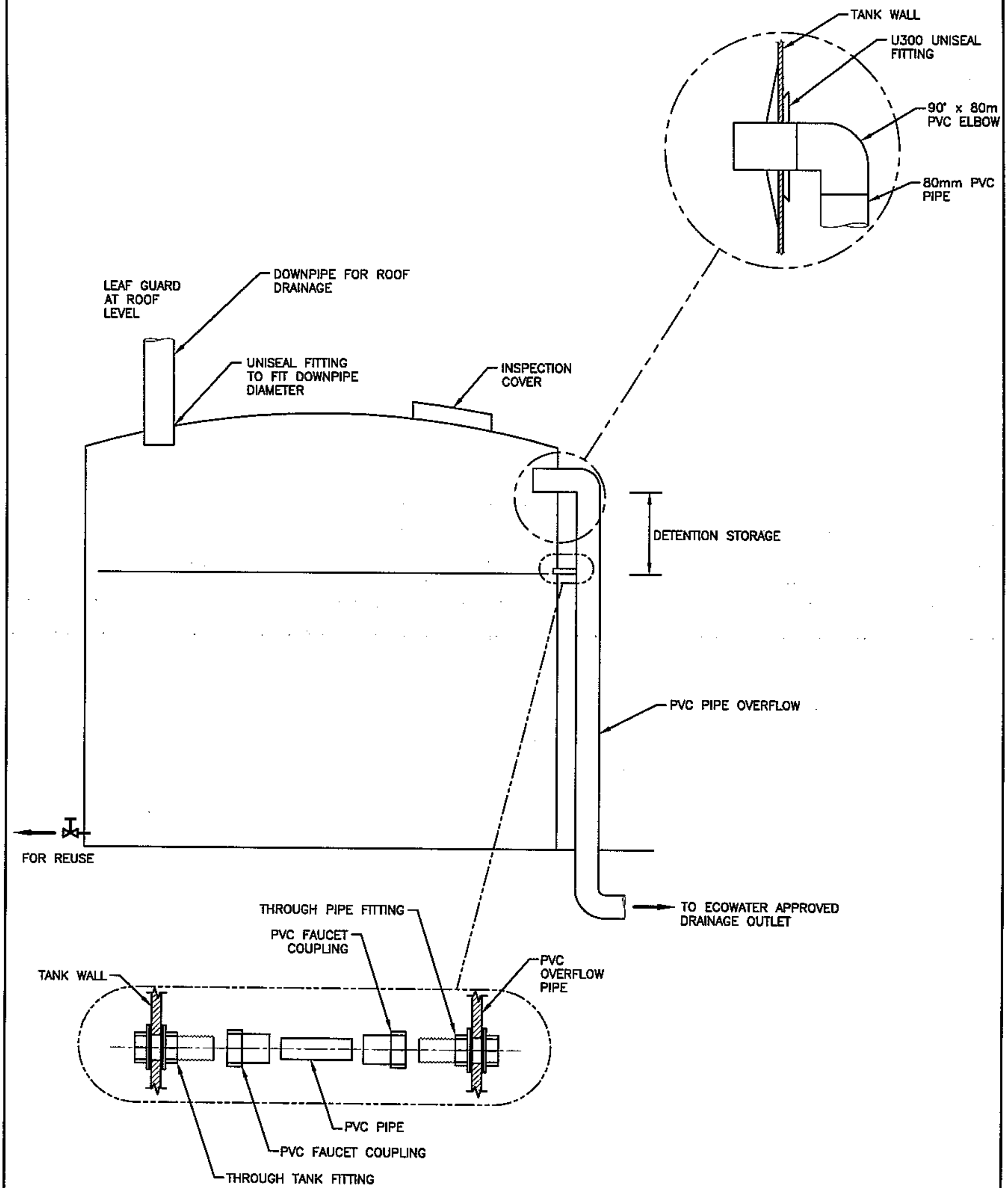

NOTES:

1. REFER TO ARC TP No. 10 FOR REUSE TANK SIZE
2. REFER TO TABLE 5-4 FOR ORIFICE PIPE AND FITTINGS DIAMETERS
3. ENSURE GROUND BENEATH TANK FOOTING MATCHES SUPPLIERS SPECIFICATIONS
4. FIT UNISEAL IN ACCORDANCE WITH MANUFACTURERS SPECIFICATION
5. FIT DEBRIS PROTECTION TO ROOF DRAINAGE IN ACCORDANCE WITH MANUFACTURERS SPECIFICATION
6. HOLES DRILLED THROUGH TANK WALL TO BE IN ACCORDANCE WITH MANUFACTURERS SPECIFICATION

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LAYOUT OF WATER REUSE AND DETENTION ROOF TANK

Figure No. **5-2**

6.1 Introduction

A rain garden is used to attenuate peak flows and to provide stormwater treatment. Rain gardens use the concept of bioretention, a water quality practice in which plants and soils remove contaminants. Rain gardens are created in low-lying areas, with specific layers of soil, sand and organic mulch. These layers naturally filter the stormwater. During the inter-event dry period, the soil absorbs and stores the rainwater and nourishes the garden's grasses, trees and shrubs.

6.2 Description

Rain gardens look and function like any other garden except they treat runoff and are specifically designed with a layer of 100 mm of mulch, 600 (minimum) to 1,000 mm of planting soil, and vegetation (grasses and shrubs). Figure 6-1 illustrates a typical layout of a rain garden. In clay soils, an underdrain should always be incorporated into the design of a rain garden to provide adequate drainage during wet weather. The underdrain must discharge to an approved stormwater outlet. To prevent the migration of adjacent soil into the planting soil and the migration of planting soil into the underdrain material, filter fabric is required.

In Waitakere City rain gardens should be designed for a water quality design storm of 25 mm over the contributing catchment area (i.e. 1/3 of the 2 year 24 hour rainfall of 75 mm as required by ARC TP No 10). Provision of a maximum ponded water depth of 200 mm above the rain garden surface (as per ARC TP No 10) provides for storm events to be caught and treated. An overflow provision should be allowed for storm events that exceed the 200 mm freeboard.

6.3 Considerations

The main issue on the long-term performance of rain gardens is adequate maintenance. Over time, the planting soil permeability may reduce which will increase surface ponding time. Another issue relates to maintenance of the rain garden vegetation. During dry periods the underdrain may cause the rain garden to dry out, which may necessitate watering of the vegetation on an as needed basis to ensure a healthy appearance.

6.4 What to do?

The size of the rain garden depends on the area that drains into the rain garden. The area may include pervious areas as well as impervious areas. The rain garden depth should be 1.0 m deep unless underdrainage is difficult in which case the depth could be reduced to 0.6 m minimum.

The rain garden area for a 1 m deep garden is sized in accordance with the procedure given in ARC TP No 10 as follows:

$$A_f = WQV*d_f / (k*(h+d_f)*(t_f))$$

Where:

A_f = surface area of rain garden (m^2)

WQV = water quality treatment volume (m^3)

d_f = planting soil depth (m) – use 0.6 to 1.0 m

k = coefficient of permeability (m/day) – use 0.3 m/day

h = average height of water (m) i.e. half the maximum depth – use 0.11 m

t_f = time to pass WQV through soil bed (use one day to be conservative)

The WQV for a contributing catchment area includes runoff from impervious area ($A_{impervious}$) and pervious area ($A_{pervious}$) due to the water quality design storm.

From ARC TP No 10, water quality design storm = 1/3*75 = 25 mm, and

$$WQV = A_{impervious}*(0.025-0.002) + 0.5*A_{pervious}*(0.025-0.015)$$

$$= A_{impervious}*0.022 + A_{pervious}*0.01$$

Hence for a 1 m deep rain garden:

$$\mathbf{Af = 3.03*(A_{impervious}*0.022 + A_{pervious}*0.01)}$$

For a 0.6 m deep rain garden the same volume of soil should be retained in the rain garden.

Hence for a 0.6 m deep rain garden:

$$\mathbf{Af = 5.05*(A_{impervious}*0.022 + A_{pervious}*0.01)}$$

The soil composition must be permeable enough to allow runoff to filter through the media. The planting soil should be a sandy loam, loamy sand, loam, or a loam/sand mix (35-60% sand). The clay content should be less than 25% and the permeability should be at least 0.3 metres per day. The soil should be free of stones, stumps, roots, or other woody material over 25 mm in diameter. Brush or seeds from noxious plants should not be present in the soils. Placement of the soil should be in lifts of 300 - 400 mm and loosely compacted (tamped lightly with a backhoe bucket). A mulch layer (standard landscape type) should be included on the surface of the rain garden.

The construction of a rain garden will require two inspections. The first inspection will be conducted after the installation of the under drainpipe and drainage layer. The trench for the pipe connecting the rain garden and dispersal device should remain open for the inspection. The final inspection will be conducted upon completion of the rain garden, including planting of vegetation. Plants suitable for use in rain gardens are listed in Appendix B.

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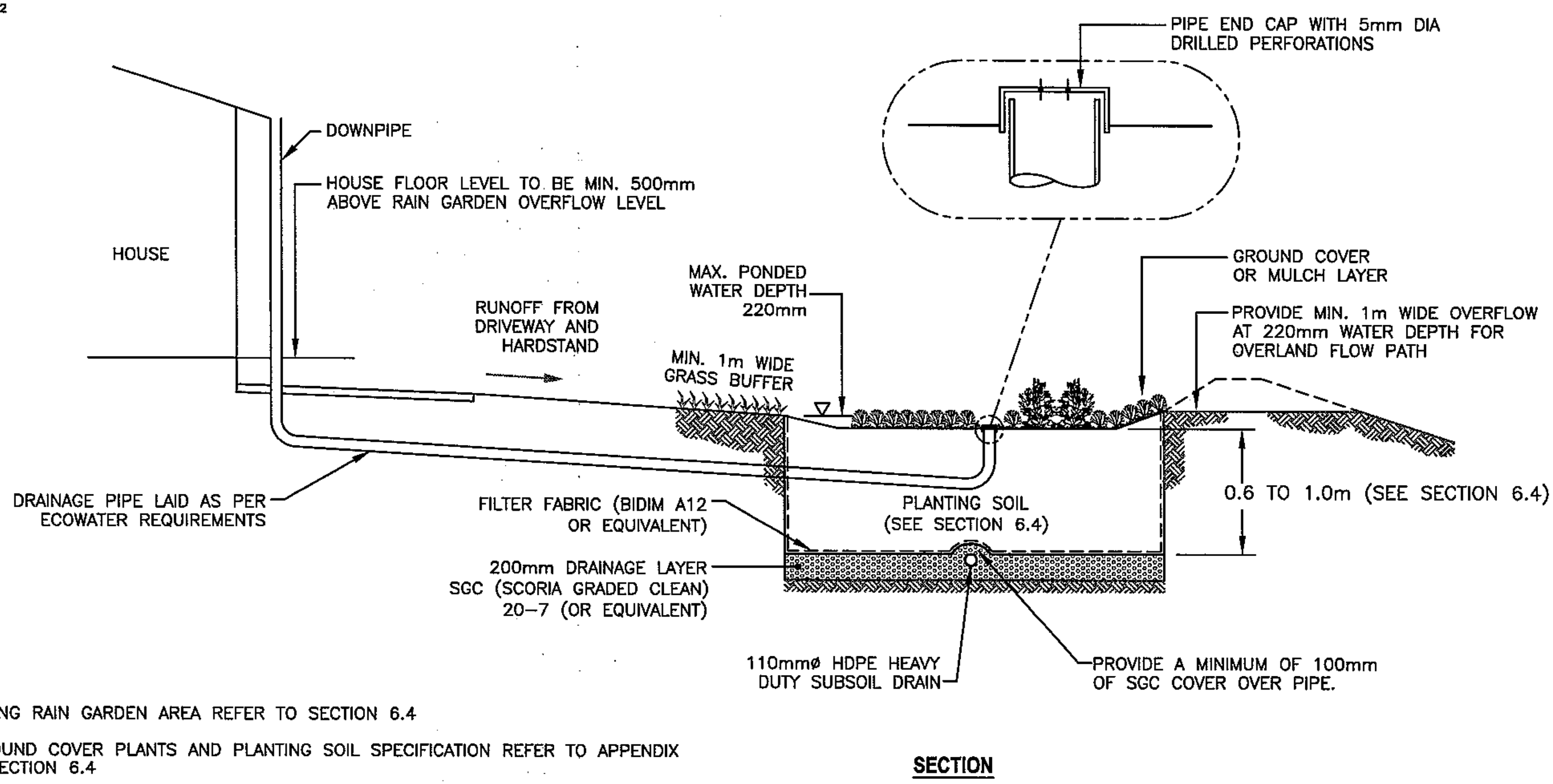

NOTES

- FOR SIZING RAIN GARDEN AREA REFER TO SECTION 6.4
- FOR GROUND COVER PLANTS AND PLANTING SOIL SPECIFICATION REFER TO APPENDIX B AND SECTION 6.4
- FOR RAIN GARDENS RECEIVING STORM WATER FROM PIPES, SPECIAL CONSIDERATION SHALL BE MADE TO DISPERSE FLOWS AND MINIMISE EROSION FROM THE CONCENTRATED FLOWS
- SELECTION OF RAIN GARDEN AND OVERFLOW LOCATION NEEDS TO CONSIDER IMPACTS TO SURROUNDING STRUCTURES AND DOWNSTREAM PROPERTIES
- SUBSOIL DRAIN TO DISCHARGE TO ECOWATER APPROVED OUTLET

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CONCEPTUAL LAYOUT OF RAIN GARDEN

Figure No. **6-1**

7.1 Introduction

Permeable paving has the potential to provide a number of beneficial functions within a stormwater management system. Potential benefits are primarily associated with stormwater treatment and lesser runoff rates and volumes being generated than conventional pavement due to infiltration and storage of stormwater within the sub-base.

The design information provided in this document has been developed to assist with both the design and review of permeable paving proposals. Permeable paving does not suit all sites and it is important that site characteristics are reviewed carefully. It is also important to define what the objectives are for using this type of system. Key considerations and design steps are outlined below.

7.2 What is Permeable Paving ?

It is important to note that these guidelines cover permeable surfacing only. The following distinction is made between permeable and porous pavements:

- "Porous surfacing is a surface that infiltrates water across the entire surface of the material forming the surface. Examples include grass and gravel surfaces, porous concrete and porous asphalt. "
- "Permeable surfacing is a surface that is formed of material that is itself impervious to water but, by virtue of voids formed through the surface, allows infiltration through the pattern of voids. An example is the concrete block paving".

Both kinds of pavements have different service and maintenance requirements as well as surface designs. The demands for porous pavements are higher, because the failure usually results in reconstruction of the surface after removing a completely section.

In general three different configurations of these permeable paving are used (Interpave, 2003) as shown in Figure 7-1. The type of system is selected based on sub-grade conditions.

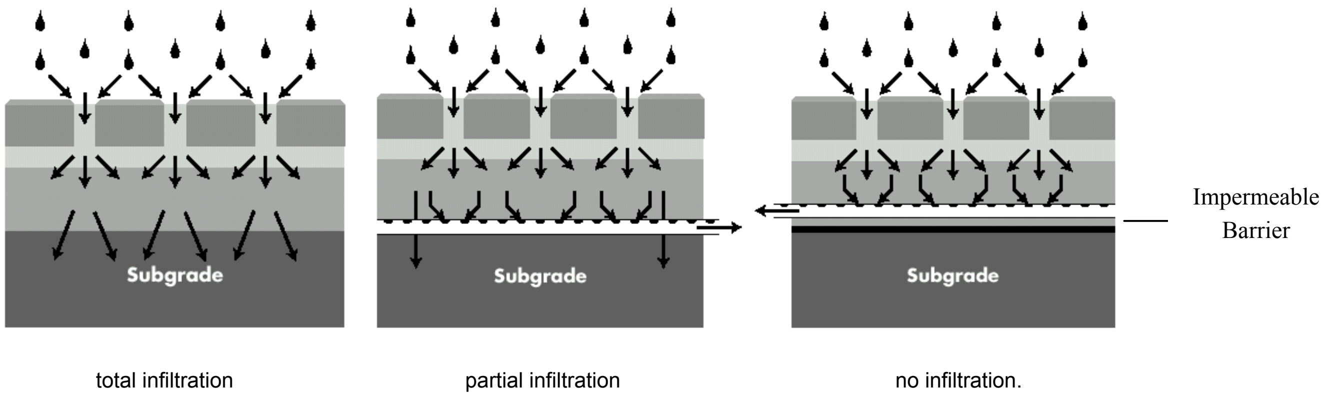


Figure 7-1 - Principal system configurations for permeable pavements (Interpave, 2003)

For Waitakere City the underlying soils in many locations are clay and have limited infiltration. The "total infiltration" system will therefore generally not apply. The benefits of using permeable paving in these areas is primarily associated with passage of stormwater through the pavement structure itself ("no infiltration" case).

Potential benefits include:

- Removal of contaminants by filtration, allowing adsorption, microbiological breakdown and settlement; and
- Attenuation of runoff.

7.3 Use

The situations where permeable paving might be used on a residential site include:

- Car parking areas;
- Walkways; and
- Residential driveways.

Some examples of these applications are shown in Table 7-1:

Table 7-1 - Permeable Paving Applications

Application	Example
Carparks	 Waitakere City Carpark  sourced from -www.petrusutr.com

Driveways and Low Traffic Residential Roads	  (sourced from www.europeanpaving.com)

7.4 Types

Permeable paving can be separated into the following broad categories:

- Grass paver /open cell paver:
- Small surfacing blocks with joints (gaps):
- Interlocking concrete blocks with voids: and
- Permeable blocks.

7.5 Limitations

Key parameters to consider for permeable paving placement include slope, traffic volumes, subgrade, land use (types of contaminant), and stability. The issues to consider with each of these parameters are outlined below:

7.5.1 Slope

The use of permeable pavement is restricted to gentle slopes up to about a 1 in 10 grade (or about 5 degrees). On steeper slopes the potential for water to seep out of the pavement surface limits use.

7.5.2 Traffic Volumes

In general only low traffic volumes up to 2,000 ESA, axle loads and speeds less than 30 mph should be considered.

7.5.3 Subgrade

The subgrade should be able to sustain traffic loading without excessive deformation. Section 4.2 discusses this in more detail.

7.5.4 Land Use

Permeable pavement may be considered for light vehicle loading including parking areas and driveways. A common cause of permeable paving failure is clogging resulting from excessive sediment discharges on to the permeable surface. For this reason, permeable paving is not suitable for use in catchments where potential for sediment generation is high. This applies equally to hard surface catchments where frequent sediment tracking is expected (e.g. access roads within construction sites). In this regard construction sequence of permeable paving is important. Preferably, all pervious areas and high-sediment hard surface areas must be excluded from the catchments treated by permeable paving.

7.5.5 Stability

Slope stability issues are exacerbated by water infiltrating and saturating the soil. In areas where there is sloping land downstream of a development, geotechnical advice is essential for the design of permeable paving. It may be necessary to use an impermeable flexible membrane liner (FML) and a protective heavy geotextile to exclude infiltrated water from the soil, or in some cases, permeable paving may not be a suitable option for sloping land. When the basecourse is tanked using an FML, a suitable sized piped outlet is necessary to drain the basecourse at the required rate.

7.5.6 Limitations Check

In order to confirm that permeable paving is suitable for a given site complete the check below.

Table 7-2 - Limitation Check

Parameter	Check	Yes	No
Slope	Slope Exceeds 1 in 10		
Traffic Volume	Traffic Volume Exceeds 2000 ESA		
Subgrade	[1]CBR is less then 3		
Land-Use	Site downstream of areas where sediment generation potential is high		
Stability	[1]Site has stability issues		

Notes 1. Permeable Paving may still be suitable - needs geotechnical investigation.

Where ‘No’ is indicated alternative systems should be considered.

7.6 What to Do

Step 1 Review site characteristics and check constraints (Table 7-2) do not apply.

Step 2 Obtain service plans for the site from Council and identify where stormwater from permeable paving is to be discharged.

Step 3 Confirm location of any overland flow paths on or adjacent to the site. Assess the layout of the proposed paving area in relation to overland flow paths.

Step 4 Design the permeable paving using the appropriate specifications described in this document.

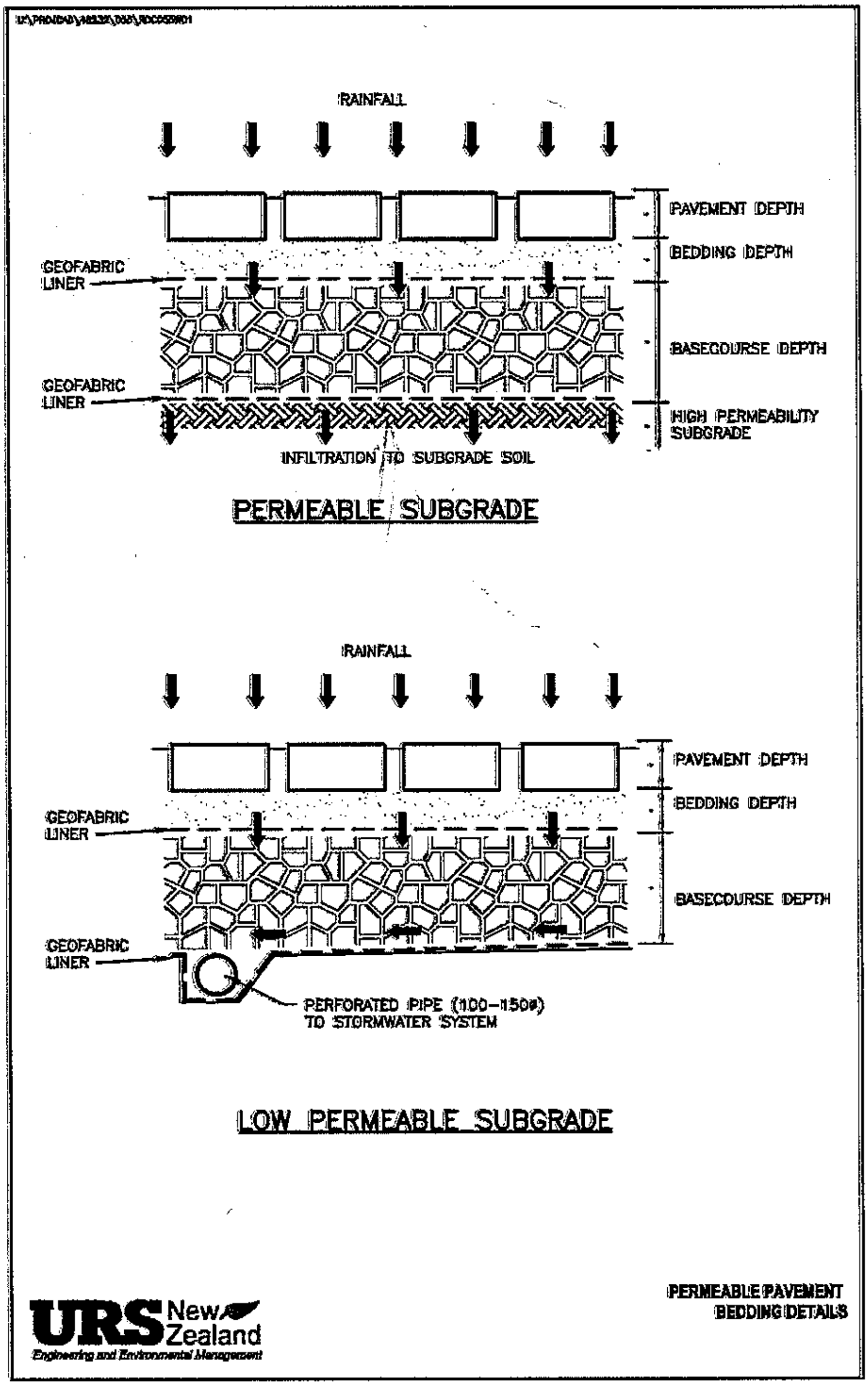
Step 5 Calculate effective impermeable area based on reduction factor from Section 7.9.

Step 6 Complete Checklists in Appendix A

7.7 Use of Permeable Pavement

Figure 7-2 shows the key structural elements of permeable paving. As identified earlier for Waitakere City the subgrade is expected to be almost impermeable and the low permeable sub-grade design will apply.

Figure 7-2 - Permeable Paving Bedding Details



7.8 Material Specifications

The permeable paving elements are to comply with the following or detail of the proposed alternative must be submitted to WCC for review.

7.8.1 Paving Surface

Grass Block

A grass block or turf paver typically consists of an open cell concrete block with typical dimensions 600 mm x 400 mm x 80 mm thick, filled with soil or porous aggregate. For structural design it is assumed that the resilient modulus of an 80 mm grass block is equivalent to that of an 80 mm concrete segmental paver.

Concrete Segmental Paving

The Concrete Masonry Association of Australia (CMAA) published the Lockpave® computer program for designing segmental pavements. In Lockpave® a resilient modulus of 2500 MPa is used for conventional concrete segmental paver of 80 mm thickness.

In the conventional pavement, the joints are typically 2 to 4 mm wide and when filled with jointing sand, a relatively stiff layer is achieved.

- The pavers must be a minimum of 80 mm thick and the quality and construction thereof must comply with the requirements of NZS 3116: 2002, Concrete Segmental Paving, unless otherwise specified.
- The paver type must comply with the requirements for residential driveways, light traffic (NZS 3116, Clause 302 Paver Selection).
- The pavers must be laid in a herringbone pattern at 90° to traffic flow, with joint widths and jointing sand to sustain a permeability of 50 mm/hour/m2 on the completed surface, provided that the joints should not be wider than the D_{95} of the jointing sand plus 3 mm.
- The bedding sand must graded between 2mm to 12mm and complying with the requirements of NZS 3116: 2002, Concrete Segmental Paving, Clause 309.1.2 Sand Properties.
- The jointing sand must be graded between 2mm and 5mm and complying with the requirements of NZS 3116: 2002, Concrete Segmental Paving, Clause 311.1.2 and 311.1.3.
- It is anticipated that the permeable segmental pavement with wider joints filled with coarser 2 to 5 mm grit, will result in a more flexible layer with lower stiffness. A resilient modulus of typically 2000 MPa is recommended.

7.8.2 Basecourse

The permeable basecourse must comply with all the requirements of TNZ M/4 AP40, except for the particle size distribution and the additional requirements specified. The particle size distribution of the aggregate must comply with the envelope limits defined below, when the aggregate is tested according to NZS 4407, Test 3.8.1 Wet Sieving Test:

Sieve Aperture	Maximum and Minimum Allowable Percentage Weight Passing
37.5 mm	100
19.0 mm	60 - 75
4.75 mm	3 - 18
2.36 mm	0 - 5

It must have a minimum permeability of 10^{-3} m/s, determined by testing in accordance with Volume 2 Section 10.6 of "The Manual of Soil Laboratory Testing" by K H Head on samples compacted to the specified density for the construction of the basecourse.

The above requirements should produce a durable basecourse with good workability properties which should not segregate during construction.

The basecourse should be a minimum of 200 mm deep.

Pavement layer compaction of at least 95 % of maximum dry density must be achieved. The maximum density of the basecourse must be determined in a laboratory by rodding and vibrating the basecourse under saturated condition

7.9 Reduction Factors

The benefits of permeable paving are associated with the increases in abstractions during the first part of a rainfall event as well as increased infiltration during the event. By using this type of paving the impervious surface being added to a site is effectively reduced.

Where permeable paving is used WCC will accept a 25% reduction in the impervious area calculation for paving.

So for example if 100 m^2 of permeable pavement is being added, this equates to 75 m^2 of equivalent impervious surface.

8.1 Description

Swales can assist in preserving a site's predevelopment runoff characteristics by retarding flow and providing some infiltration especially from larger areas of impervious surface like driveways and carpark areas. Swales also provide treatment of stormwater.

A bioretention trench is similar to a swale on the surface, but includes a low flow trench underneath the grassed surface that is filled with filter material. Runoff from driveways and carpark areas can be discharged directly to this filter media. Reference should be made to ARC TP10 publication for details on bioretention trenches.

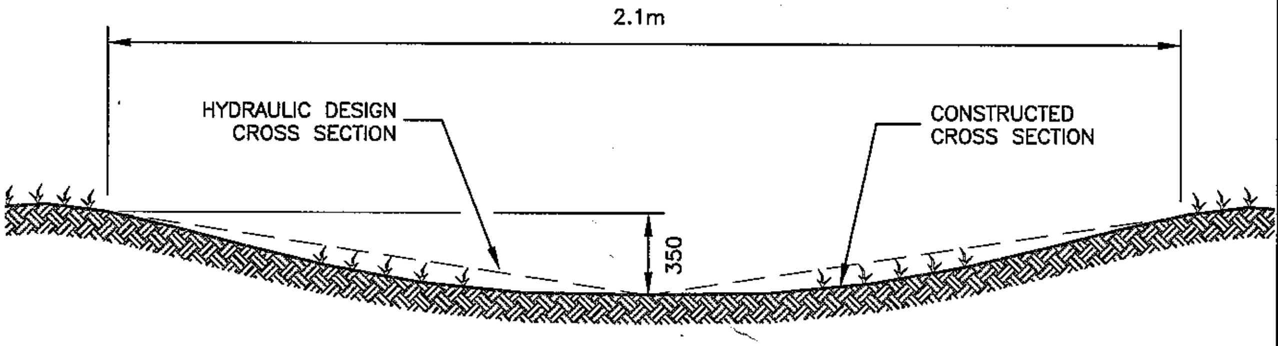
8.2 Application

Both devices can be used to convey stormwater flows within the site. They may be used to divert and convey overland flow associated with larger storm events.

8.3 Swales

8.3.1 Considerations

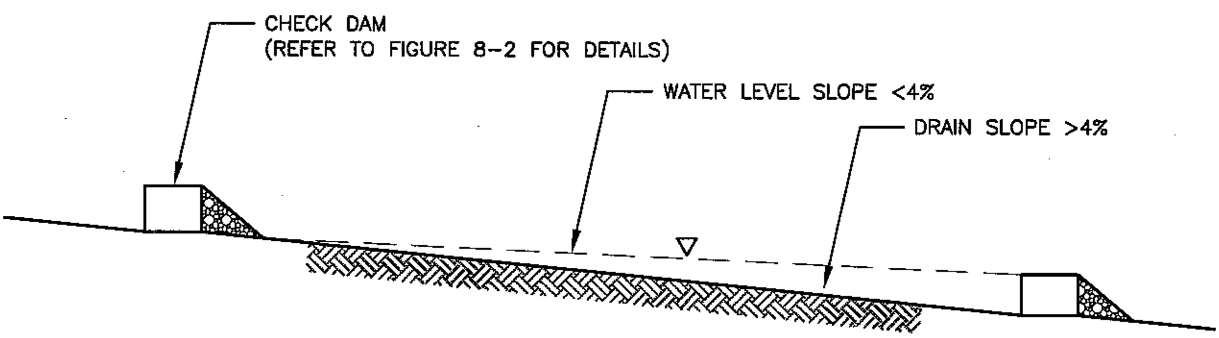
- Swales are generally suitable for gradients between 1 and 4 percent. On steeper slopes check dams may be required within the swales to prevent high velocities and subsequent erosion. A piped underdrain can also be incorporated to the design.
- Vegetative cover of swales generally consists of a dense and continuous cover of relatively long grass. The grass should be maintained at a height of not less than 35 mm and typically 150 mm. Owners must be advised of proper maintenance requirements; swales should not be mown too short, or too frequently.
- The swale size should be based on the dimensions provided on Figure 8-1. The dimensions shown are for effective catchment areas of up to 1000 m^2. The effective catchment area is equal to the impervious area plus 0.72 times the pervious area.
- Typical check dam details for the swales on Figure 8-1, are shown on Figure 8-2
- Driveways longer than 30 m should incorporate a swale with underdrain similar to the one shown in Figure 8-3.



SWALE CROSS SECTION

NOTES:

1. TO BE USED FOR ROADWAYS LESS THAN 30m AND TO CONVEY FLOWS FROM ROOF AND OTHER IMPERMEABLE SURFACES.
2. EFFECTIVE CATCHMENT AREAS UP TO 1000m2. FOR SWALE DESIGN FOR LARGER EFFECTIVE CATCHMENT AREAS REFER TO STORMWATER TREATMENT DEVICES ARC TP No. 10.
3. EFFECTIVE CATCHMENT AREA DRAINED = IMPERVIOUS AREA + 0.72 x PERVIOUS AREA.
4. MAXIMUM SWALE SLOPE UP TO 4%. STEEPER SWALES REQUIRE CHECK DAMS (REFER TO FIGURE BELOW AND TO FIGURE 8-2)
5. SWALES TO BE GRASSED.



LOCATION OF CHECK DAMS IN SWALES

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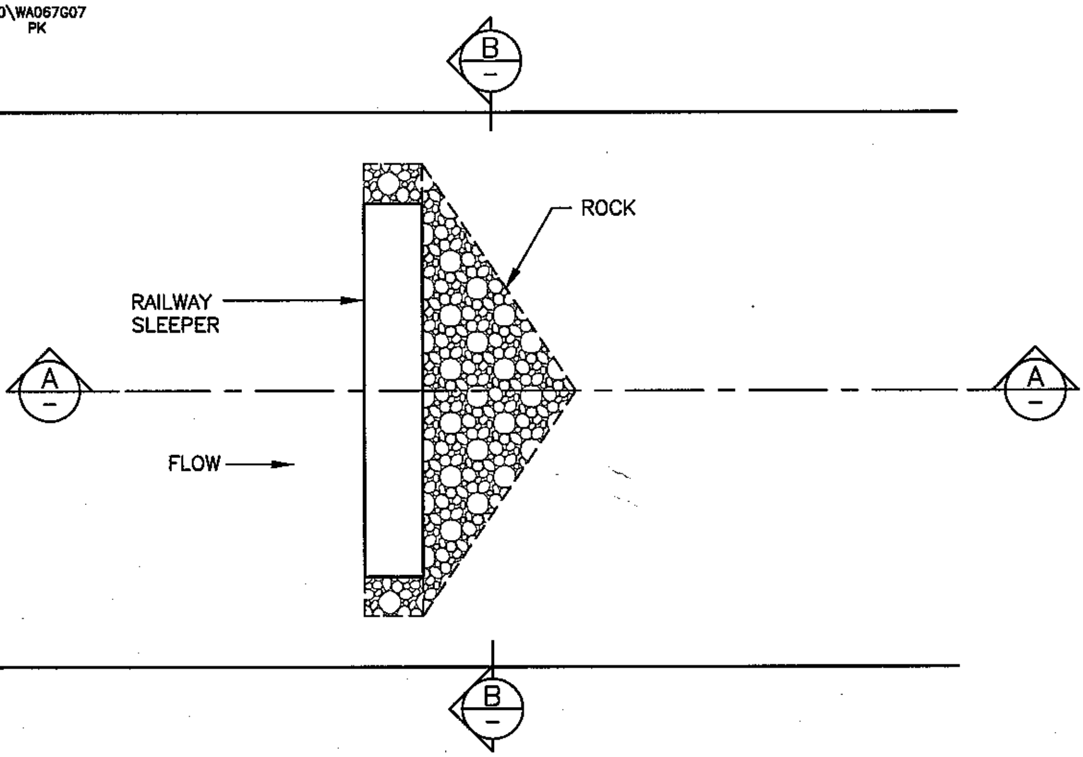
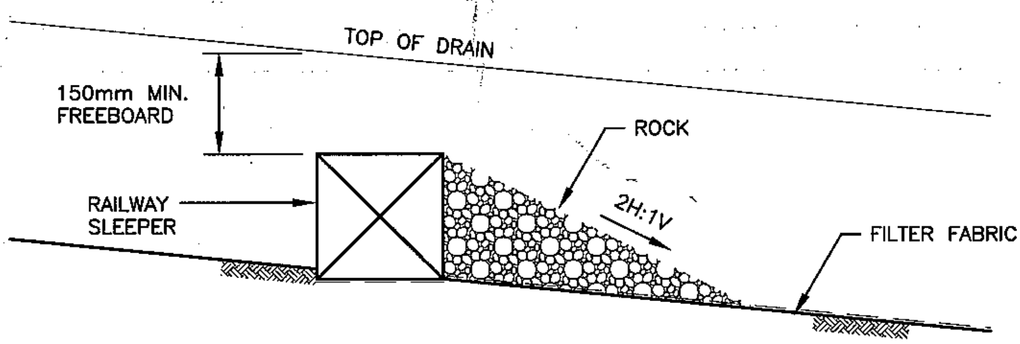
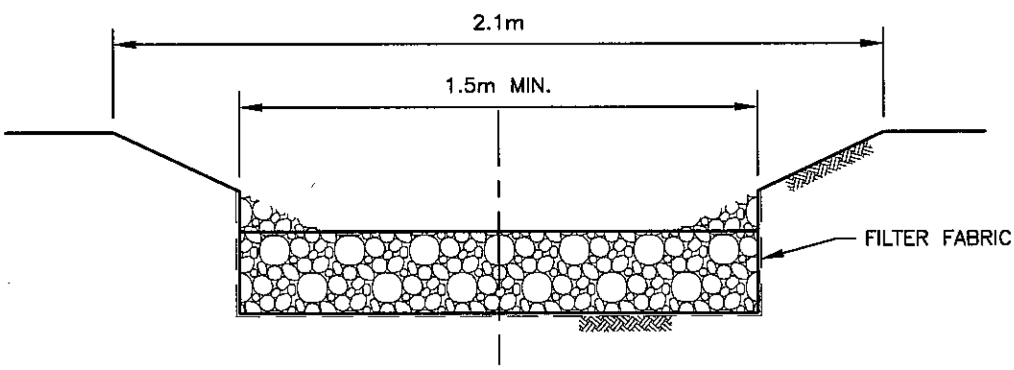


TYPICAL PLAN



ELEVATION A-A

ROCK TO BE SCORIA GRADED CLEAN (SGC) 75–70 OR EQUIVALENT.
FILTER FABRIC TO BE BIDIM A12 OR EQUIVALENT.



ELEVATION B-B

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CHECK DAM DETAILS

Figure No. **8-2**

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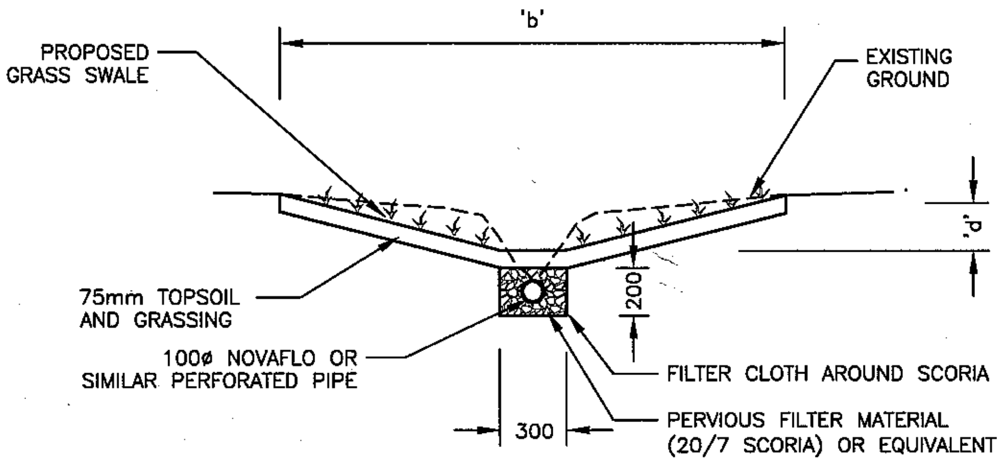

SWALE CROSS SECTION

NOTES:

1. TO BE USED FOR ROADWAYS LONGER THAN 30m.
2. DIMENSIONS 'b' & 'd' TO BE SIZED FOR CONVEYANCE OF 1% AEP EVENT.
3. EXISTING GROUND IS REGRADED, COMPACTED, TOPSOILED(75mm DEPTH) & GRASSED.
4. MINIMUM SIDE SLOPES OF 1V:3H APPLIES.

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Title
SWALE FOR DRIVEWAYS

Figure No. **8-3**

9.1 Introduction

A green roof is a roof system that incorporates soil and plants to minimise the impacts of the covered structure. The idea of the green roof is to mimic the natural environment by filtering rain through the soil while capturing some to be evapotranspired later. The infiltration and filtering of rain helps to limit the decreases in the time of concentration that normally occur when a roof structure is built.

9.2 Description

A green roof is a roof system consisting of waterproofing material covered with a thin protective layer of soil and vegetation. A green roof, also known as an “eco-roof”, can be used in place of a traditional roof. It is capable of capturing and evaporating between 10 and 100% of precipitation. The effectiveness is dependant on the soil type, soil thickness and vegetation. The season can also have an impact on the performance.

Figure 9-1 shows the conceptual design of a green roof. Green roof designs must be specific to the structure being considered. This detail is provided to illustrate the green roof option only.

9.3 Considerations

Adequate plant coverage needs to be established and maintained. Irrigation may be required during the summer months and to aid in establishment.

The additional weight of the soil and water needs to be considered in the structural design of the roof.

The slope of the roof should not exceed 25% unless additional runoff control measures are incorporated.

A registered Professional Engineer should be consulted in the design and construction of a green roof system.

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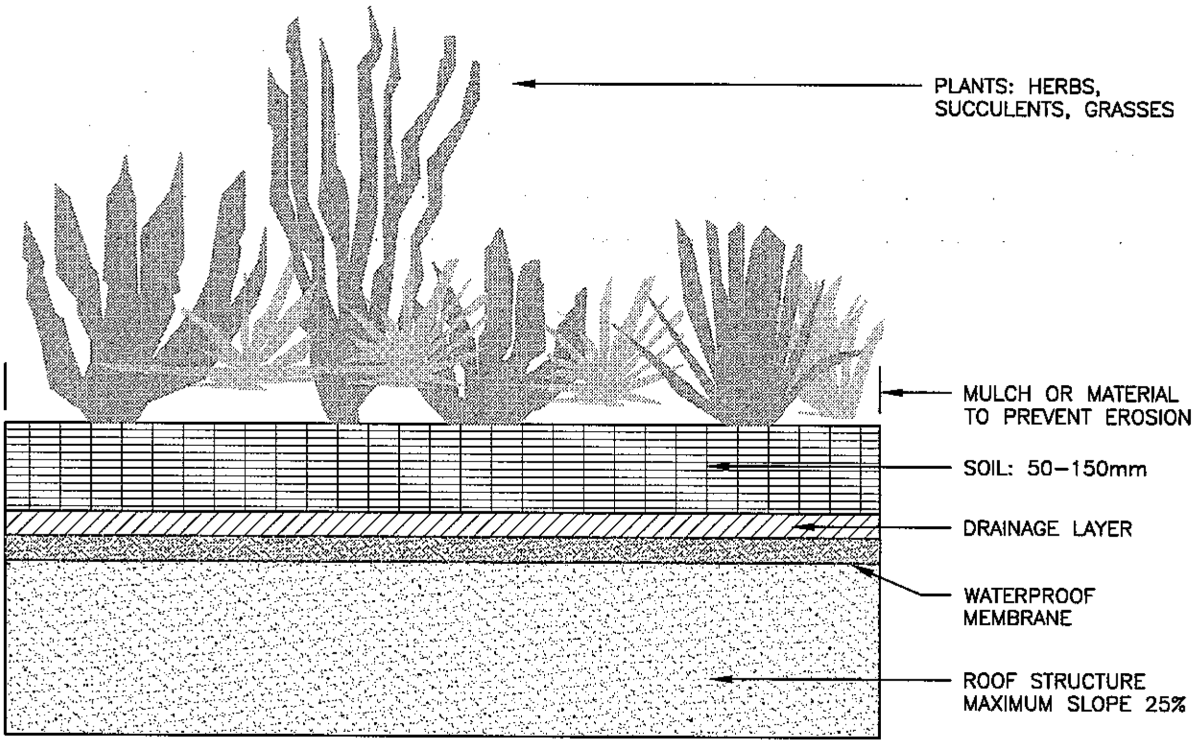

NOTE:

THIS IS A GENERAL DETAIL FOR A GREEN ROOF.

THE DETAILED DESIGN OF A GREEN ROOF SHOULD INCLUDE CONSIDERATIONS FOR ADDITIONAL LOADING ON THE STRUCTURE AND MAINTENANCE AND SUSTAINABILITY OF THE SYSTEM AFTER INSTALLATION.

DETAILED DESIGN SHOULD INCLUDE AN EVALUATION OF APPROPRIATE VEGETATION.

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Title
TYPICAL DETAIL GREEN ROOF

Figure No. **9-1**

Maintenance and Monitoring Requirements

SECTION 10

The monitoring and maintenance requirements anticipated by WCC for the devices described in this document are listed in Table 10-1. It is anticipated that property owners will carry out maintenance works. Monitoring is also the responsibility of property owners. Formal inspection requirements by WCC inspectors will be indicated in Building Consent conditions.

Table 10-1 - Summary of maintenance and monitoring requirements

Practice	Monitoring	Frequency	Maintenance	Frequency
All	Inspection by a Certified professional	5 years		
Roof Tanks	Check orifice openings for trapped or floating debris	3 months	Remove floating debris from tank	3 months
	Inspect all piping for restrictions or failures	1 year		
Rain Gardens	Check vegetation condition	6 months	Prune and clear excess vegetation. Irrigate as required	Varies depending on the type of vegetation
	Check for overflow due to clogging	6 months	Remove accumulated sediments	5 year
Swale		6 months	Remove accumulated sediments	As needed
			Clear excessive vegetation	As needed
			Repair damaged areas	As needed
Pervious Paving	Evaluate performance during a rainfall event	6 months	Remove sediments and debris that can potentially clog pores	weekly
			Repair damaged areas in paving surface	annual
Green Roof	Design Specific		Design Specific	

References

Auckland Regional Council. (2003) Stormwater Management Devices: Design Guidelines Manual, Technical Publication 10.

Bannerman R. (2003) Rain Gardens as a Stormwater Treatment Practice. *Proceedings of the Third South Pacific Conference on Stormwater and Aquatic Resource Protection*.

Cooperative Research Centre for Catchment Hydrology. (2000). Water Sensitive Road Design-Design Options for improving stormwater quality of road runoff. *Technical Report 00/1.*

Dierkes, C., Kuhlmann, L., Kandasamy, J., Angelis, G. (2002) *Pollution retention capability and maintenance of permeable pavements*

Formpave (2002) *Stormwater Source Control System*

ICPI (2000) *Permeable Interlocking Concrete Pavements*

Meyer, P., Singhal, N. (2004) *Pervious pavement: A literature review*

Appendix A
Checklists

Appendix A
Checklists

Checklist 1: Pre-Development Site Assessment

Pre-Development Site Assessment (include all parent titles)	**Please tick to indicate that the required information and detail is attached**
1. Total area of site (m^2)	
2. Contours and site boundary	
3. Assessment of the existing location, extent and material type for impervious areas on lot:	
- Roof area of all buildings including garages (m^2)	
- Driveways, accessways, turning and parking areas (m^2)	
- All paved areas, including patios, tennis courts etc. (m^2)	
4. Location of existing stormwater pipes, overland flow paths and any nearby watercourses	
5. Where the site is in relation to the upstream catchment area	

Checklist 2: Development Proposal Assessment

Development Proposal (include all site information)	**Please tick to indicate that the required information and detail is attached**
1. Locate on plan proposed addition of impervious areas: - Roof area of all buildings, garages etc (m^2) - Paved areas including driveways, accessways, patios, parking areas etc (m^2)	
2. Permeable Paving Calculation Permeable Paving Area (m^2) - Reduction Factor - Effective Impermeable area from Permeable Paving (m^2)	0.75
3. Total New Impervious Area (m^2)	

Appendix A
Checklists

Checklist 3: Balance Sheet to Assess Mitigation Measures

Item	Mitigation Measure	Design Detail		Impervious Area to be Attenuated (m^2)
1	Roof tanks	Tank Volume. (m^3): Orifice diameter (mm): Reuse storage (m^3): Roof Area mitigated (m^2)		
2	Raingarden	Effective catchment area (m^2): Surface area of raingarden (m^2):		
3	Bioretention Trench or Swale	Effective catchment area (m^2) Trench/Swale Length (m)		
5	Green Roofs	Roof Area (m^2)		

Item		Area (m^2)
6	Total increase in on-site impervious area that needs to be attenuated (from Checklist 2, point 3):	
7	Total impervious area that has been attenuated [Add up the ‘Impervious Area to be Attenuated’ for Items 1, 2, 3, 4, and 5 above]:	
8	Mitigation balance (Item 7 – Item 6):	

- ⇨ If Item 8 is positive then more than sufficient mitigation measures have been provided.
- ⇨ If Item 8 is zero then sufficient mitigation measures have been provided.
- ⇨ If Item 8 is negative then insufficient mitigation measures have been provided.

Checklist 4: Information Required

Item		Yes/No
1	Have impervious surfaces been minimised	
2	Have effects on overland flow paths been mitigated	
3	Are details on connections to existing drainage system provided	
4	Other Relevant information provided:	

Appendix B
Recommended Plant Species

Appendix B
Recommended Plant Species

Plants listed below are preferred by WCC for any activities requiring revegetation. Species listed mostly occur naturally in Ecosystem 4 of Council's Revegetation Manual 'A guide for planting and restoring the nature of Waitakere City'. Please refer to the key at the base of the table for Location and Preference Rating information.

Location	Preference Rating	Species For General Use From Waitakere Ecosystems	Common Name
B		Carex dipsaceae	NZ Sedge
B	*	C.flagellifera	NZ Sedge
B	*	C.lessoniana	NZ Sedge
B		C.maorica	NZ Sedge
B	*	C.secta	NZ Sedge
B		C.virgata	NZ Sedge
BEOS	**	Cortaderia fulvida	NZ toetoe
B		Cyperus ustulatus	giant umbrella sedge
SE		[1]Entelea arborescens	Whau
E		[1]Gahnia lacera	cutty grass
E		[1]G setifolia	cutty grass
SE	*	[1]G.xanthocarpa	cutty grass

Table Key :

[1] Not applicable for rain gardens.

* Recommended Species

** Most Recommended Species

C = Coastal margins

B = Immediate stream bank or swamp edge

E = Forest edge or gaps in bush

S = Sheltered, shady, moist

O = Open, dry, sunny