Contents

Section 1
INTRODUCTION

1.1 Overview

This Low Impact Urban Design and Development (LIUDD) Stormwater Guideline is prepared by the Kāpiti Coast District Council for dealing with stormwater issues in subdivision and land developments in a sustainable way. Under this Guideline, the Council's LIUDD approach emphasizes the consideration of the ecology and conservation of natural systems and hydrologic functions on a site that is to be developed.

1.2 Objectives

In promoting a sustainable approach to stormwater management, the Council specifically seeks to:

1.2.1 Reduce the amount of site run-off to drains and waterways thereby reducing the risk of damage to them and other property;

1.2.2 Provide effective water capture volume and flood control detention to protect downstream areas from flooding;

1.2.3 Create stable, healthy streams by preventing pollutants from entering the stormwater system;

1.2.4 Improve biodiversity by preserving and enhancing the integrity of ecological and biological systems of the environment; and

1.2.5 Enhancing groundwater recharge for sustainable groundwater management by storing sufficient quality water underground and subsequently harvesting it for beneficial use.

1.3 Stormwater Strategies

The following defines the Council's stormwater strategies under a LIUDD approach:

1.3.1 Reduce Runoff Volume to the Maximum Extent Practicable.

Reducing runoff volume is accomplished by reducing the amount of pavement and roof area that is directly connected to inlets and storm drains, while maximizing the pervious area that receives runoff from pavements or roofs not connected to storm drains. These consist of swales, porous pavement, soaking devices, or some combination of these approaches. These receiving pervious areas should be stable and properly designed to provide stormwater treatment by dispersing the energy of the runoff, filtering the runoff through vegetation, and infiltrating flows into the soil.

1.3.2 Provide Flood Control Detention

The purpose of flood detention is to control the increase in runoff rates from developed areas during frequent storm events that cause stream degradation and overflow that may cause flooding to properties. Runoff reduction and flood detention are intended to reduce the extent and severity of degradation in watercourses downstream of developing areas.

Reducing stream degradation also helps to protect stream health and water quality.

1.3.3 Water Quality Control

There is a need to control the potential for harmful discharges from the site which degrade water quality in waterways and the marine environment. If the site has the potential for debris, trash, sediments, and other pollutants to enter the stormwater system, measures shall be provided to address the environmental issues.

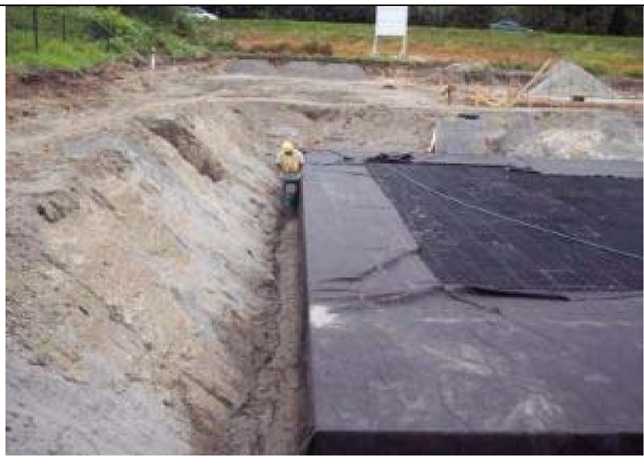
1.3.4 Hydraulic Neutrality

The Council's requirement is for post-development peak discharges from a site to be restricted to the pre-development peak discharges, unless it can be shown that there is a minimal increase in discharges which have adverse effects that are no more than minor. Hydraulic neutrality has to be achieved by compensating for loss of flood storage associated with the development, and/or by managing the difference between the pre-development and post-development peak flows.

1.4 LIUDD Stormwater Devices

The following are the devices endorsed by the Council under the LIUDD approach:

1.4.1 Rainwater tank	

1.4.2 Detention tank	
1.4.3 Soakpit	
1.4.4 Swale	

1.4.5 Filter strip	
1.4.6 Rain garden	
1.4.7 Pond	

1.4.8 Wetland	
1.4.9 Treatment Trench/ Rock Filter	
1.4.9 Permeable and Porous Pavement	

1.5 Definitions

Absorption is the adhesion of a thin layer of molecules of some substance to the surface of a solid or liquid material.

*AEP (Annual Exceedance Probability)*is the probability of exceedance of a given occurence of a storm event, within a period of one year. A 100% AEP means a "1 year return period event" or 1 in 1 year event. A 50%

AEP means a “2 year return period event” or 1 in 2 year event. A 20% AEP means a “5 year return period event” or 1 in 5 year event. A 10% AEP means a “10 year return period event” or 1 in 10 year event. A 1% AEP event means a “100 year return period event” or 1 in 100 year event.

ARI (Average Recurrence Interval) is the average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. The relationship between ARI and AEP is expressed by the equation:

$$AEP = 1 - \exp\left(\frac{-1}{ARI}\right)$$

which results in the following conversion table:

ARI (years)	**AEP**
1	0.632
2	0.393
5	0.181
10	0.095
20	0.049
50	0.020
100	0.010

ARIs that are of greater than 10 years are very closely approximated by the reciprocal of the AEP.

Bioretention is a vegetated depression on the site that is designed to collect, store and infiltrate runoff.

Contaminants are suspended soils, oils, metals and other materials and substances that stormwater picks up as it travels over ground.

Degradation is the breakdown of a chemical compound into simpler compounds.

ESA (Equivalent Standard Axle) is the unit of traffic loading that provides a measure of a damage caused to the road in terms of a standard axle. ESA serves as basis in determining the pavement life in the design. For detailed discussion of ESA, please refer to "A Guide to the Structural Design of Road Pavement (AUSTROAD, 2004)".

Eutrophication is the process by which a body of water becomes rich in dissolved nutrients from fertilizers or sewage, thereby encouraging the growth and decomposition of oxygen-depleting plant life and resulting in harm to other organisms

Impervious area refers to a hard surface constructed over natural ground such as roof, driveway, carpark, or road that impede the infiltration of stormwater back to ground and result in an acceleration of runoff.

Infiltration is the process by which stormwater passes through a substance.

Outlet is where stormwater is leaving a site for discharge.

Overland Flow is runoff that has not entered the stormwater network and travels overland.

Permeability is the infiltration or movement of stormwater through the soil.

Photosynthesis is a process by which green plants and other organisms turn carbon dioxide and water into carbohydrates and oxygen, using light energy trapped by chlorophyll.

Sedimentation is the settling of solids in a body of water by gravity.

Sub-grade is the ground on which the foundations of a road or pavement are laid.

Volatilisation is the process of changing a solid or liquid substance into a vapour.

1.6 References

Auckland Council, Operations and Maintenance Guide, Stormwater Device Information Series.

Auckland City Council, August 2003. Soakage Design Manual.

Auckland Regional Council, July 2003. Stormwater Management Devices: Design Guide Manual (TP 10).

Auckland Regional Council, April 2000. Low Impact Design Manual for the Auckland Region (TP 124).

Department of Building and Housing, 2011. Compliance Document for New Zealand Building Code Clause E1 Surface Water.

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Greater Wellington Regional Council. Erosion and Sediment Control Guidelines for the Wellington Region, reprinted June 2006.

Greater Wellington Regional Council. So You're Thinking About a Pond: A Guide to the Design, Management and Consent Requirements for Landowners.

New Zealand Water Environment Research Foundation, October 2004. On Site Stormwater Management Guideline.

National Ready Mixed Concrete Association, USA 2009. Pervious Concrete Pavement Design for Sustainable Porous and Permeable Stormwater Drainage (http://www.perviouspavement.org)

Sinclair Knight Merz Pty. Ltd. (SKM), 11 October 2011. Updated Isohyet Based Calculation of Design Peakflows, Sinclair Knight Merz Pty. Ltd (SKM) and Boffa Miskell, 21 December 2007. Northshore City Bioretention Guidelines.

URS New Zealand, Maunsell and SKM, September 2004. Draft Permeable Design Guidelines Prepared for Northshore City, Waitekere City and Rodney District.

Waitakere City Council, November 2004. Stormwater Solutions for Residential Sites Version 1.

Section 2
RAINWATER TANKS

2.1 Description

A rainwater tank is a sealed tank intended to collect and store run-off from the roof of a building. The tank serves both as a water demand management solution and as a storm water management device.

In urban areas, rainwater is used for non-potable household purposes (such as outdoor watering and toilet flushing). Where an area receives restricted or no service, rainwater is used for potable household purposes (such as drinking water) and fire fighting so must comply with the relevant standards. In areas where water supply is serviced by Council's water supply network, the storage and reuse of rainwater will reduce the demand of reticulated water supply. The Water Demand Management provisions of the District Plan requires the installation of rainwater tanks to all new or relocated dwelling units, except family flats, with one of the following:

- Rainwater storage tank(s) with a minimum capacity of 10,000 litres for the supply of non-potable water for outdoor uses and indoor toilets. Restricted top-up of a maximum 600 litres per day from the public potable water supply shall be provided when it falls below 1,000 litres storage to ensure that sufficient water to flush toilets is available.

- Rainwater storage tank(s) with a minimum capacity of 4,000 litres for the supply of non-potable water for outdoor uses and indoor toilets, and a greywater re-use system for outdoor subsurface irrigation. Restricted top-up of a maximum 600 litres per day from the public potable water supply shall be provided to the tank when it falls below 1,000 litres storage to ensure that sufficient water to flush toilets is available.

When rainwater is retained in a tank for use in human activities, it helps reduce the run-off volumes that ultimately drain to stormwater systems and devices. However, it is important to note that the need to attenuate stormwater runoff is in addition to the volumes required by the water demand management provisions in the District Plan. It is likely that when the volumes required for re-use are low, the need for attenuation will be at its highest (i.e. during winter). Where on-site disposal is not possible, rainwater tanks effectively assist in managing stormwater quantity. Both purposes can be achieved through the use of specifically designed rainwater tanks that can effectively attenuate stormwater while providing the required volumes of water for re-use.

Water tanks may be made of concrete, plastic, steel, fibreglass or other materials that are available in the market.

2.2 Features and Applications

2.2.1 Can be used in residential, commercial and industrial development where the catchment area is on a lot/allotment scale.

2.2.2 Provide non-potable water source for toilet use and outdoor irrigation. Where an area receives restricted or no water supply service, provide potable water and fire fighting water in compliance with the relevant standards.

2.2.3 May assist in stormwater management by reducing runoff volume and providing flood control detention.

2.2.4 Recommended also for retro-fitting within existing developments. However the tank size may be limited by available space.

2.2.5 May be constrained by availability of land to site the water tank.

2.3 Design Considerations and Requirements

2.3.1 Where rain tanks are installed to meet the statutory requirements of the Water Demand Management provisions of the District Plan, reference to be made to the '*Kāpiti Coast Rainwater and Greywater Code of Practice*'.

2.3.2 Where rainwater tanks are used primarily for water demand management:

2.3.2.1 Total water that can be collected in a year can be computed by the following:

Total water (litres) = Roof Area (m^2) * 0.80 * mean annual rainfall (mm)

Notes:

- The 20% reduction is due to the loss for evaporation and spillage.
- For Kāpiti Coast in general an average of 1050mm rainfall falls each year. For details on specific sites, please refer to the Rainfall Recurrence Isohyet Maps (included in Part 4, Schedule 4, Appendix 1 of the Council's Subdivision and Development Principles and Requirements) provide the quantities of rainfall intensity (in mm/day) at various average recurring intervals. A 1-in-5 year storm shall be used for tanks intended primarily for water demand management.

2.3.2.2 Water storage provided to meet the water demand management provisions of the District Plan can promote resilience in a natural disaster.

2.3.2.3 If additional storage is wanted, the tank size can be estimated using the following reference materials:

- Section 11.5.1 Design Procedure Water Quality Credit through Water Use, TP 10, Auckland Regional Council, July 2003.
- Section 4.5.6.c Design Steps Rainwater tank Permanent Storage, On-Site Stormwater Management Guideline, NZWERF, October 2004.

2.3.3 Where the rainwater tank serves both for peak flow attenuation and for re-use:

2.3.3.1 The storage volume computation shall include the calculation for the temporary storage to be provided by the tank for attenuating run-off in 10 yr ARI rainfall events for primary protection and for 100 yr ARI storm events for where a secondary flow path is not available or is through private land (refer to Appendix 3.1 for calculator).

2.3.3.2 Alternative design methods are described in the following:

- Section 11.5.3 “Design Procedure -Combined Quality and Attenuation”, TP 10, Auckland Regional Council, July 2003.
- Section 4.5.6 “Design Steps – Raintank” On-Site Stormwater Management Guideline, NZWERF, October 2004.

2.3.4 An orifice for the overflow pipe shall be provided at the storage and air space interface of the tank. The size of the orifice and overflow pipe shall meet the discharge capability of the receiving drainage system.

2.3.5 Where property is serviced by public water supply, potable water top-up when used for toilets and for fire fighting water supply.

2.3.6 In rural areas where the rainwater tank is to provide supplemental fire fighting water supply requirement complying with SNZ PAS 4509:2008, the tank shall have a suitable fire service coupling for connection.

2.3.7 Primary screening devices such as a gutter guard or a downpipe debris screen shall be installed to prevent leaves and debris entering the water tank. Mosquito screens shall also be installed.

2.3.8 The tank should be provided with first-flush diverters to capture a minimum of 20 litres of the first part of the rainfall that contains dust and other contaminants collected on the roof during dry periods. This particularly applies for rural water supplies when washing machines, toilets and hot water services are to be supplied by rainwater.

2.3.9 Where a rain water tank is supplied by Council's reticulated water supply system, a backflow prevention device to protect the reticulated water supply from any contamination from the tank, (Please refer to the Kāpiti Coast Rainwater and Greywater Code of Practice for details on the requirements for rainwater tank installation).

2.3.10 The rain water tank material must comply with one of the following specifications:

2.3.10.1 AS/NZS 4766:2006 for polyethylene storage tanks.

2.3.10.2 AS 1397:2011 Galvanized steel sheet and strip - hot-dipped zinc coated or aluminium/zinc coated.

2.3.10.3 NZS 3106:2009 Design of concrete structures for the storage of liquids.

2.3.11 The rainwater overflow shall be connected to a Council approved stormwater disposal system. Where backflow is a possibility a non-return valve on the outlet from the rainwater tank overflow shall be provided before connecting to the stormwater system.

2.4 Operations and Maintenance

2.4.1 The table1 outlines the maintenance requirements.

2.4.2 It is a best practice to inspect and clean and remove debris on the roof gutter, downspout and at the tank every after major storm.

2.4.3 Where a rainwater tank is to provide firefighting water supply, the owner is responsible for keeping the tank to the minimum volume required by the New Zealand Fire Service Firefighting Water Supplies Code of Practice (SNZ PAS 4509:2008).

Table 1: Maintenance Requirements

Frequency:			**Action:**
Every 3 months	**Annually**	**Every 2 years**	
√			Inspection/cleaning of roof gutters and downpipes, checking for any blockages, debris and leaks
√			Inspection/cleaning of first flush devices, checking for any blockages.
√			Checking water quality for clarity and odour.
	√		Inspection/repair of tank structure and checking for any water leaks.
	√		Routine maintenance of pump and electrical systems
		√	Inspection/repair of float valve and backflow preventer.
		√	Tank water quality. Testing is required to check compliance with Drinking-water Standard for New Zealand 2005 (revised 2008) if water is for potable use.
		√	Cleaning of tank by removing sediments and debris from rainwater tank floor.
		√	Inspection/repair of plumbing from the tank to the dwelling unit.

2.5 Drawings

- Drawing No. KCDC-DWG-WS-008, Rainwater Tank (Water Re-Use)
- Drawing No. KCDC-DWG-WS-009, Rainwater Tank (Water Re-Use and Stormwater Attenuation)

Section 3
DETENTION TANKS

3.1 Description

A detention tank is intended to collect and temporarily store run-off from roofs and other impervious areas for release at a slower or controlled rate to receiving stormwater system or environment. The reduction of peak flows in the receiving stormwater system will contribute significantly to protecting streams from erosion and mitigating flooding in downstream areas.

The tank may be above or below ground and is fed by site run-off, which usually includes a sump before the tank to intercept debris and coarse sediments. It generally has an inlet where water is fed into the top of the tank and restricted overflow outlet(s) connected to on-site disposal or public stormwater systems.

3.2 Features and Applications

3.2.1 Detention tanks can be used in residential, commercial and industrial developments where the catchment area may be any of the following:
- allotment scale
- subdivision scale, or
- large neighborhood scale.

3.2.2 Their primary functions are stormwater management to reduce runoff volume and to provide flood control detention.

3.2.3 May be constrained by availability of land to site the water tank.

3.3 Design Considerations and Requirements

3.3.1 Detention tanks are sized to accommodate rainfall events, using the latest KCDC rainfall data.

3.3.2 The tank size can be calculated by performing a routing calculation to quantify the temporary storage to be provided by the tank.

3.3.3 The device inflow can be calculated using the following flood frequencies:

- 10-yr ARI where the tank overflows into a reticulated stormwater system;
- 100-yr ARI where secondary flow paths not available or are through private properties on-site disposal system.

3.3.4 Design methods are described in the following:

3.3.4.1.1 KCDC Stormwater On-Site Detention Tank (OSD) Design Calculator (see Appendix 3.1). Electronic copy of the Calculator is available from the Council on request.

3.3.4.1.2 Section 11.5.2 “Design Procedure – Peak Flow Attenuation”, TP 10, Auckland Regional Council, July 2003.

3.3.4.1.3 Section 4.5.6. “Design Steps – Temporary Storage Raintank” On-Site Stormwater Management Guideline, NZWERF, October 2004.

3.3.5 Where the tanks receives site run-off, a sump shall be installed upstream of the tank to prevent debris entering the detention tank.

3.3.6 The tank shall be equipped with an overflow pipe located near the top of the tank to allow excess rainwater to drain away. The overflow pipe shall be connected to a stormwater disposal system approved by the Council.

3.3.7 There should be adequate fall between the tank outlet and the receiving system.

3.3.8 Tank materials shall be concrete, plastic or steel, complying with the same specifications as for rainwater tanks.

3.3.9 Where the tank is partially or fully underground, account needs to taken of structural integrity, water-tightness and corrosion resistance of the tank.

3.4 Operations and Maintenance

3.4.1 Where detention tanks receive runoff containing contaminants, such contaminants may be toxic in a confined space. This requires special maintenance safety practices.

3.4.2 Table 2 outlines the maintenance requirements.

3.4.3 Inspection is also required after major storm and check if cleaning is required.

Table 2: Maintenance Requirements

Frequency:			Action:
Every 6 months	**Annually**	**Every 2 years**	
√			Inspection and monitoring of the manhole for clogging and blockages caused by sediments and debris. Clean out if necessary.
	√		Inspection of outlet pipes for any blockage. Cleaning when required.
		√	Removal of sediments and debris from the tank.

3.5 Drawings

- Drawing No. KCDC-DWG-SW-009, Detention Tank (Underground Tank).
- Drawing No. KCDC-DWG-SW-0023, Detention Tank (Above Ground Tank).

Worksheet 3.1
OSD Calculator (Sample)

KAPITI COAST DISTRICT COUNCIL 22-Jun-09
STORMWATER ON-SITE DETENTION TANK (OSD) DESIGN
2 and 10 YEAR ARI STORM with ONE OUTLET

Jan 06 Version

ADDRESS		Calcs By	SJR
NAME			
PHONE		Date	22-Jun-09

NOTE:
Only fill in the blue (unprotected) cells

DATA

Depth of Tank	1.2	m
2 Year Isoheyt Value	166	mm
10 Year Isoheyt Value	166	mm
Time of Concentration	10	min. (10,15,20,30,60)

NOTE A "#DIV/0!" message appearing in a cell means that data has been entered incorrectly

	Area (m²)	'C'	CA (m²)
Site Area	600		
1. EXISTING SITE COVERAGE			
Existing Roof	0	0.9	0.0
Existing Paved	0	0.85	0.0
Existing Garden	600	0.35	210.0
TOTAL Existing Area	600		210.0
2. PROPOSED DEVELOPMENT			
Additional/Reduced Roof	250	0.9	225.0
Additional/Reduced Paved	120	0.85	102.0
Additional/Reduced Lawn/Garden	-370	0.35	-129.5
TOTAL Addition Area (should be zero)	0		197.5
3. REMAINING UNDRAINED AREA	(Not routed thru detention tank after development)		
Undrained Roof Area (Normally Zero)	0	0.9	0.0
Undrained Paved Area (Normally Zero)	120	0.85	102.0
Undrained Lawn/Garden Area	230	0.35	80.5
TOTAL Extg Not to Tank Area	350		182.5

NOTE The sum of the existing areas must equal the 'Site Area'

* NOTE If pre-development lawn areas are reduced a negative number is required to be entered.

CONTROL DATA

Existing 'C'	0.35		('CA'extg/Site Area)
Developed 'CA' to OSD tank	225	(m²)	('CA'extg+'CA'adds-'CA'undr)
Additional Area	0	(m²)	('A'add)

RUNOFF DATA

	for 2 year		for 10 year	
Intensity I	109.6	mm/hr	109.6	mm/hr
Allowable Qmax whole site	6.40		6.40	
Lost Flows	5.56		5.56	
Allowable Qmax from tanks =	0.8	l/s	0.84	l/s
Allowable Qave from tanks =	0.5	l/s	0.5	l/s (Qmax * 0.65)

Rainfall Intensities (mm)

MIN	Normalise	2 Yr(mm/hr)	10 Yr(mm/hr)
10	0.11	109.6	109.6
15	0.14	93.0	93.0
20	0.16	79.7	79.7
30	0.19	63.1	63.1
60	0.26	43.2	43.2
120	0.35	29.1	29.1
180	0.46	25.5	25.5
360	0.60	16.6	16.6
420	0.64	15.2	15.2
480	0.68	14.1	14.1
540	0.71	13.1	13.1
600	0.75	12.5	12.5
660	0.78	11.8	11.8
720	0.81	11.2	11.2

STORAGE (2 year)

time (min)	depth (mm)	inflow (l)	outflow (l)	storage (l)	
10	18.3	4109	327	3782	inflow='CA'dev'depth
15	23.2	5229	490	4739	outflow=Qave*time
20	26.6	5976	653	5323	diff=inflow-outflow
30	31.5	7097	980	6117	
60	43.2	9711	1960	7751	
120	58.1	13073	3920	9153	
180	76.4	17181	5880	11301	
240	84.7	19049	7840	11209	
300	93.0	20916	9800	11116	
360	99.6	22410	11760	10650	
420	106.2	23904	13720	10184	
480	112.9	25398	15680	9718	
540	117.9	26519	17640	8879	
600	124.5	28013	19600	8413	
660	129.5	29133	21559	7574	
720	134.5	30254	23519	6734	

STORAGE (10 year)

time (min)	depth (mm)	Inflow (l)	10 yr outflow (l)	Storage (10 yr) (l)	outflow (2 yr outlet)	Storage (2 yr outlet)
10	18.3	4109	327	3782	327	3782
15	23.2	5229	490	4739	490	4739
20	26.6	5976	653	5323	653	5323
30	31.5	7097	980	6117	980	6117
60	43.2	9711	1960	7751	1960	7751
120	58.1	13073	3920	9153	3920	9153
180	76.4	17181	5880	11301	5880	11301
240	84.7	19049	7840	11209	7840	11209
300	93.0	20916	9800	11116	9800	11116
360	99.6	22410	11760	10650	11760	10650
420	106.2	23904	13720	10184	13720	10184
480	112.9	25398	15680	9718	15680	9718
540	117.9	26519	17640	8879	17640	8879
600	124.5	28013	19600	8413	19600	8413
660	129.5	29133	21559	7574	21559	7574
720	134.5	30254	23519	6734	23519	6734

SUMMARY

Design for 2 year peak only

2 Year Tank Volume	11.3	m^3
2 Year Max Discharge	0.8	l/s
2 Year Orifice Diameter	19	mm

Design for 10 year peak only

10 Year Tank Volume	11.3	m^3
10 Year Max Discharge	0.8	l/s
10 Year Orifice Diameter	19	mm

Design for 2 and 10 year peak flows

Tank Volume	11.3	m^3
Max Discharge	0.8	l/s
Orifice Diameter	19	mm

Section 4
SOAK PITS

4.1 Description

A soakpit is an excavated trench where surface water is collected and stored before it percolates into the surrounding soil. The soakpit is either a rock filled hole, a lined chamber or a series of modular infiltration cell blocks.

The rock filled hole is a trench filled with aggregates where the water is stored in the aggregate void spaces. The aggregates, adequately wrapped by a geotextile, are typically gravel or rocks without fines but may also comprise other acceptable materials.

A lined chamber soakpit is made of a porous or perforated concrete well liner backfilled with aggregates around it.

Modular infiltration cell blocks are high strength plastic interlocking panels that allows stormwater to infiltrate through the voids when enveloped with a geotextile.

The geotextile that is wrapping around a modular infiltration cell block or a boulder soakpit, has to be adequately sealed along the edges to be effective.

4.2 Features and Applications

4.2.1 The primary function is to reduce runoff volumes (by infiltration to the sub-soils) and to delay runoff peaks by providing detention storage capacity.

4.2.2 Allows surface areas above the trench to be used for planting, gardens, temporary parking lots, etc.

4.2.3 It is not applicable for contaminated runoff because of the risk of contaminating groundwater.

4.2.4 Not suited in the following soil and terrain:
- heavy clays
- exposed bedrock or shallow soils over rock or shale
- steep terrain
- potential salinity hazard areas
- non-engineered fill, or
- contaminated land.

4.2.5 Not applicable for sites subject to 10-year flood events.

4.2.6 Not applicable for areas with high water tables.

4.3 Design Considerations and Requirements

4.3.1 The device requires permeable soils. Soakage tests shall be undertaken to determine the design percolation or soakage rate. Soakage devices are not appropriate if the percolation rate is less than 0.5 litres/min/m^2 (30mm/hr).

4.3.2 The void ratio of the media (for rock filled soakpit) shall be assessed. For clean stones this is typically 0.35 and for scoria 0.50.

4.3.3 The Building Code advises that soakage should be designed to accommodate a 60-minute storm of the size that might be expected once every 10 years. Where a secondary flow path is not available or is through private property, the soakage should be designed to accommodate the 100 year return event.

4.3.4 For consistency of all soakage procedures and calculations within the District, the soakage rate determined with the use of the on-line soakage Rate Calculator (attached Appendix 4.1).

4.3.5 Soakpit design methods are available in the following references:

4.3.5.1 Verification Method E1/VM1, Section 9.0 Disposal to Soakpit of Compliance Document for New Zealand Building Code Clause E1- Surface Water, Department of Building and Housing, December 2011.

4.3.5.2 Soakage Design Manual, Auckland City Council, August 2003.

4.3.5.3 Chapter 8, Infiltration Design, Construction and Maintenance, Technical Publication 10 (TP 10), Auckland Regional Council, July 2003.

4.3.6 Soakage devices should not be located within a stormwater secondary flow path or ponding area arising from a 10% AEP event.

4.3.7 Soakage device should be at least 3m from any building or property boundary. If this is not possible, professional site-specific design shall consider the possible effects on the building's foundations and neighbouring properties.

4.3.8 Soakage devices shall not be sited near banks of rivers or streams for stability reasons.

4.3.9 Soakage devices shall be at least 2m away from wastewater pipes or manholes.

4.3.10 The soakage device shall be above the highest elevation of water table which shall be confirmed by a soil test hole taken at the appropriate time of year.

4.3.11 The soakage device shall be positioned so that all runoff can be directed to it.

4.3.12 A sump shall be constructed before the soakpit, if it collects run-off from the ground. Discharge from the sump shall be to a chamber before dispersion into the soakage area.

4.4 Operations and Maintenance

4.4.1 Soakage devices should be inspected every two years to check that they have not become clogged up with debris.

4.4.2 Pipe work leading to the soakage device shall also be checked every two years as they may be clogged independently of the device.

4.4.3 If the soakpit is clogged by debris, debris shall be removed by vacuum pumping by a qualified contractor. Alternatively, the soakpit may need to be re-excavated and the stone material replaced.

4.4.4 Any maintenance works must be completed in accordance with occupational safety and health regulations.

4.4.5 A register of maintenance is to be kept by KCDC (for Council asset), the property owner (if non-Council asset) and/or by the contracted maintenance provider.

4.4.6 Builder of any new building shall be responsible to prevent debris and soil from site infiltrating the sumps and soakpits. On application for a Code of Compliance for the new building to the Council, the builder shall be required to lift the swales sump lids and maintenance flushing pipe lids, clean out all the debris and confirm that this had been completed before an inspection by Kāpiti Coast District Council (or other such maintenance provider).

4.4.7 The soakpit shall be maintained using the regime outlined in table 3.

Table 3: Maintenance Requirements

Frequency:				Action:
Monthly for initial six months	After major Storm	*Every* 3 months	Annually	
✓	✓	✓	✓	Surface / collection areas: check for areas of pooling, overland flows etc and clean off leaves and other debris.
✓	✓	✓	✓	Interceptor sumps: check for blockages; clean out / empty debris / sediment.
✓	✓	✓	✓	Surrounding soil: check for any settlement in surrounding soils for displacement. Indication of geotextile wrap rupture.
✓			✓	Soak pit inlet / outlet pipe work: perform visual check for possible problems such as debris / blockages / leaks & rectify.
✓			✓	Soak pit cleaning: flush water into soak pit through cleaning eye in sumps and pump out via maintenance flushing pipe.
			✓	Top geotextile condition assessment: remove surface boulders "by hand" from above soak pit and check getextile membrane for any holes or deterioration. Replace geotextile if required.

4.5 Drawings

- Drawing No. KCDC-DWG-SW-010, Soakage Device (Chamber Soak Pit)
- Drawing No. KCDC-DWG-SW-011, Soakage Device (Rock Filled Pit)
- Drawing No. KCDC-DWG-SW-012 Soakage Device (Modular Infiltration Cells)

Worksheet 4.1

Soakage Worksheet (Sample)

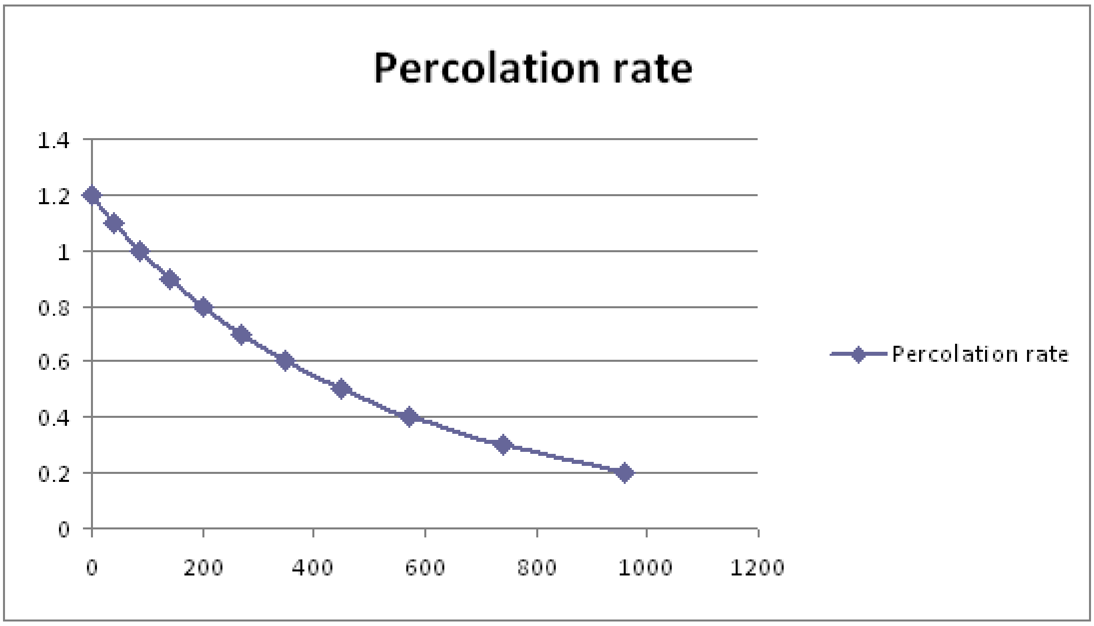
Borehole Location:	
Borehole TestNo.	
Depth of Borehole (m)	1.2
Diameter of the borehole (m)	0.15
Borehole Plan Area (m^2)	0.0176715
Circumference of borehole (m)	0.47124

Depth of Water Surface from Ground Surface	Water Depth in Borehole	Time from Start	time between readings 'dt'	Volume Soakage Between Readings 'V"	Surface Soakage Area 'SA"	Soakage Rate 'SR"
(metres)	(metres)	(seconds)	(seconds)	(litres)	(m2)	(litres/m2/min)
0	1.2	0				
0.1	1.1	40	40	1.76715	0.5595975	4.736842105
0.2	1	85	45	1.76715	0.5124735	4.597701149
0.3	0.9	140	55	1.76715	0.4653495	4.14269275
0.4	0.8	200	60	1.76715	0.4182255	4.225352113
0.5	0.7	270	70	1.76715	0.3711015	4.081632653
0.6	0.6	350	80	1.76715	0.3239775	4.090909091
0.7	0.5	450	100	1.76715	0.2768535	3.829787234
0.8	0.4	570	120	1.76715	0.2297295	3.846153846
0.9	0.3	740	170	1.76715	0.1826055	3.415559772
1	0.2	960	220	1.76715	0.1354815	3.557312253
	1.2		0	0	0	N.A.
	1.2		0	0	0	N.A.
	1.2		0	0	0	N.A.
	1.2		0	0	0	N.A.
	1.2		0	0	0	N.A.
					count	10

Average Soakage Rate (Ave SR) litres/m2/min	4.052394297
Design Soakage Rate litres/m2/min	1.215718289
Design Soakage Rate - mm/hr	72.94309734

Graph

Borehole Location:	0
Borehole TestNo.	0



Notes

1. Soakage testing shall be carried out by suitably qualified person and by an acceptable engineering laboratory.

2. Percolation tests are to be carried out in boreholes to be drilled in soil using a hand auger or post hole auger or in rock using a drilling rig.

3. The locations of boreholes should correspond within the actual location of the proposed soakage devices.

4. Boreholes of 100 mm to 150 mm diameter should be bored to at least 1.5 m below the bottom of the intended soakage device.

5. The borehole shall be protected from cave-in or erosion during the test. A perforated PVC pipe may be inserted into the hole to prevent collapse. If scouring of a test pit seems likely, about 50 mm of sand or fine gravel should be added to the pit to protect the bottom from scouring or sediment blinding.

6. There should be at least one borehole for every soakage device. Where the soakage device has a large surface area, a one borehole/ test pit for every 50 m^2 of the soakage device.

7. Equipment and resources required to carry out the test includes a suitable water supply, tape measure or water dipper, stopwatch, a copy of Worksheet and pen for recording information and a torch when necessary.

8. It is advisable that during the testing, the geological layers and soil types should be recorded or logged.

9. Water-table levels should be observed and recorded if any. It should be at least .5m above groundwater table during winter and spring or at least 1m during summer and autumn.

10. Hole must be filled to the ground level and kept full for a minimum of 4 hours prior to testing and ensure that hole in soil areas must be thoroughly pre-soaked and for any clay soils to swell. The minimum 4 hour filling may not apply where soakage is so great that the hole completely drains in a short time of less than 5 minutes, in which case, it must be filled a minimum of 5 times prior to testing.

11. Hole in rock areas must be pre-soaked to ensure that any cavities in the rock are filled before testing begins.

12. The water level at the start of the test should be no more than 500mm below the existing ground level. Record the drop in water level against time at evenly spaced intervals of no greater than 20 minutes, until the water level is around 0.20 m from the base of the hole. The maximum depth interval for recording is .200m and minimum number of recordings per test is 10.

13. Where the hole drains quickly, the borehole is refilled and the test is to be repeated for the couple of times using the same procedure. The result should be within an allowable variation of about 10% otherwise the test is failed.

Section 5
SWALES

5.1 Description

A swale is a formed depression (typically a linear, shallow, wide channel lined with either vegetation or rocks) used for the conveyance of stormwater runoff from impervious areas. They are often used as an alternative to kerb and channel along roadways, but may used to convey stormwater flows in recreation areas and car parks to watercourses, stormwater retention or disposal facilities, or Council network. Discharge flow rates generally allow filtration, absorption and biological uptake processes to improve water quality and reduce quantity before discharge.

5.2 Features and Applications

5.2.1 They are most effective in removing coarse to medium sized sediments in runoff from paved areas such as driveways and car parks.

5.2.2 Typically practical and effective when serving catchment areas up 2 hectares and not used in catchments over 4 hectares in area.

5.2.3 Often used as a pre-treatment device for other stormwater treatment devices, such as soakpit systems.

5.2.4 Can be incorporated within car parks or within road median strips.

5.2.5 Can be blended or smoothed out to resemble the natural topography of the site and to prevent the cutting-off of soil layer when mowing occurs.

5.2.6 Can serve as an attractive landscape feature when properly designed and constructed.

5.3 Design Considerations and Requirements

1.1.1. The characteristic of the catchment area has to be identified, i.e. the actual area covered, slope and the fraction of the land surface that is impervious.

1.1.2. Two design flows are required using KCDC rainfall data:

1.1.2.1. For minor flood rates (5 year ARI), size the swale so that minor floods can be safely conveyed and not increase any flood risk;

1.1.2.2. For major flood rates (100 year ARI), check that flow velocities are not so large that the swale could potentially be scoured or damaged.

1.1.3. For vegetated/grass swales, flows shall be dictated by relatively flat slopes to slow down flow velocities and increase contact time with the soil and vegetation, but not so flat as to create standing water. Velocity criteria shall be no more than 0.8m/s.

1.1.4. For rock lined swales, flow velocities will be normally above 0.8m/s, when vegetation is no longer feasible.

1.1.5. Maximum acceptable flow rate velocities for conveyance of Peak Design Flows along the swale shall not exceed the recommended maximum scour velocities for various ground covers and soil erodibility, or ideally be less than 1.5m/s, unless erosion protection is provided.

1.1.6. The dimension of swales shall be :

1.1.6.1. Designed as trapezoidal or parabolic in shape with low sloping sides, from 9H:1V to 3H:1V slope.

1.1.6.2. Swale top width to depth ratio of 6:1 or greater.

1.1.6.3. Maximum swale width of 2.5m and 30m minimum swale length, unless structural measures are incorporated to ensure uniform spread of flow and allow adequate residence time.

1.1.6.4. That the flow depth in a vegetated swale during the design treatable flow rate shall be equal to 1/3 to 1/2 the vegetative height, to a maximum of 100mm.

1.1.7. The longitudinal grades of any swale shall be:

1.1.7.1. A maximum of 5% but up to 8% if check dams are included. Check dams are used to reduce effective grade to 5%.

1.1.7.2. For less than 2% longitudinal grades, a subsoil drain may be required below the swale invert to minimise surface ponding between rain events. In high saline areas, a low permeability liner is required below the subsoil drain to minimise sub-surface infiltration.

1.1.7.3. Uniform or gradual longitudinal grade throughout its length. The floor of the swale shall have no lateral grade.

1.1.8. An optimal hydraulic residence time of 10 minutes but no less than 5 minutes.

1.1.9. The following design methodology guidelines can be used:

1.1.9.1. Section 4.6 - Swale/Filter Strip of the “On-Site Stormwater Management Guidelines” prepared by New Zealand Water Environment Research Foundation, October 2004.

1.1.9.2. Section 9.5 “Design Approach – Swales and Filter Strip”, TP 10, Auckland Regional Council, July 2003.

1.1.10. Level spreaders or energy dissipaters shall be provided at the inlet to swale channels from stormwater pipes or culverts.

1.1.11. A pavement edge treatment in the form of a concrete edger is recommended in urban areas for asphalt streets and parking areas adjacent to swales. The formed concrete provides a neat edge adjacent to the grassed area that can be constructed at a controlled grade. The concrete edger, also serve to cut off the flow of water from the filter strip or swale toward the pavement subgrade.

1.1.12. Reducing Vehicle Wheel Rut Impacts. Because standard kerb and channel is typically not used at the edge of pavement adjoining swales, inadvertent tracking of vehicles onto the grassed area can be an issue. The following options may be considered for reducing the impact of wheel rutting on swales adjacent to streets and parking areas.

1.1.12.1. Bollards. Bollards can be used in parking lots adjacent to swales to keep vehicles off the grass area.

1.1.12.2. Intermitted kerb. Kerb and channel with frequent openings in the kerb may be used to direct runoff to a swale, while still impeding inadvertent tracking off the pavement.

1.1.12.3. Cobble strip. A layer of exposed rock about a metre wide on the edges of pavements can reduce vehicle wheel rutting impacts to swales. The rock should be large enough to resist movement during the design runoff event.

1.1.13. Landscape consideration. Dense turf grass shall be used for swales, where appropriate. Where land has recreational uses or aesthetic value, an irrigation system may be needed to establish a dense stand of the grass and maintain it in periods of low precipitation. Erosion control blankets may also be used during grass establishment. The effect of any vegetation on the hydraulic capacity of a swale must be taken into account. Any mulch shall consist of rock cobbles or other material of a sufficient size and weight to stay in place during design runoff conditions.

5.4 Operations and Maintenance

5.4.1 The grass cover of the swale shall be established during the first few months of operations, otherwise, reseeding or planting is required with an alternative grass or plant species.

5.4.2 Once established the swale shall be maintained periodically. Table 4 illustrates the maintenance requirements.

Table 4: Maintenance Requirements

Frequency:				Action:
After major Storm	Monthly	Annually	Every 2 years	
✓				Check inflow points, side slopes and channel base for scouring, channeling and erosion, and repair as necessary.
	✓			Check outlet for scouring or erosion and repair.
	✓			Remove rubbish and debris on the inflow points.
	✓			If grassed, mow channel no shorter than 150mm length. Re-seed bare patches of grass and water to establish.
	✓			Remove weeds.
	✓			If planted, check plants are healthy and growth is dense. Remove dead plants and twigs. Replant gaps and water new plants until established.
		✓		Inspection of gravel diaphragm to check for clogging from excess sediments. Remove sediments and correct any associated problems.
✓		✓		The sediment that accumulates within the swale is to be removed and the vegetation / surface re-established to ensure swale performs as originally designed.
✓			✓	Remove rubbish and debris from outlet grate and catchpit.
			✓	Check for boggy patches and ponding water on the channel base.
			✓	Check soil is compacted, and aerate surface or top-up dips to repair.
✓			✓	Check stormwater is filtering through soil, by either monitoring after storm runoff or by running water across swale.

5.5 Drawings

- Drawing No. KCDC-DWG-SW-013, Typical Drawing of Swale (Plan)
- Drawing No. KCDC-DWG-SW-014, Vegetated Swales (Grass Swales)
- Drawing No. KCDC-DWG-SW-015, Rock Lined Swales

Section 6
FILTER STRIPS

6.1 Description

Filter strips are broad, gently sloped open vegetated areas that accept slow and shallow depth of flow to achieve treatment of stormwater through a distributed or sheet flow of run-off.

6.2 Features and Applications

6.2.1 They provide the following functions:

6.2.1.1 Removal of contaminants is achieved by a combination of filtration, absorption and biological intake.

6.2.1.2 Reduction of run-off volumes.

6.2.1.3 Delaying runoff peaks by reducing flow velocities.

6.2.2 They treat runoff from impervious hardstand ground surfaces in residential, commercial and industrial areas, such as driveways and carparks.

6.2.3 They provide aesthetic benefit to landscapes.

6.2.4 Effective in removing coarse to medium size sediments but not suitable to treat sediment laden water from construction sites. Filter strips should be installed after the site works are completed and the contributing areas have been fully stabilised in order to avoid excess sediment loading.

6.2.5 Typically used with other devices such as swales and rain gardens.

6.2.6 They are not suitable to provide significant peak flow or volume control.

6.2.7 Filter strips can be blended or smoothed out to resemble the natural topography of the site and to prevent scalp-in when mowing.

6.2.8 Applicable at the subdivision scale development with a maximum catchment area served of 4 hectares. However, it can also be applied in lot/allotment scale such as runoff from driveways and overflows from rainwater tanks.

6.3 Design Considerations and Requirements

6.3.1 The following design methodology guidelines can be used:

6.3.1.1 Section 4.6 "Swale/ Filter Strip" of the "On-Site Stormwater Management Guidelines" prepared by New Zealand Water Environment Research Foundation, October 2004.

6.3.1.2 Section 9.5 "Design Approach – Swale and Filter Strip", TP 10 Auckland Regional Council, July 2003..

6.3.2 The maximum runoff velocity shall be 0.4m/s.

6.3.3 The water depth above vegetation shall not exceed 25mm.

6.3.4 The longitudinal slope of the filter strip shall be between 1 to 5%. Not applicable for slopes over 5%.

6.3.5 The grass height shall be maintained at twice the depth of the flow, – i.e. about 50mm.

6.3.3 Soil type shall be organic soil of 150mm minimum depth and shall be adequately graded, but not compacted.

6.3.4 Maximum drainage flow path of the filter strip shall be 50m.

6.3.5 It requires adequate sunlight for growth of the vegetation.

6.3.6 A concrete edge is recommended in urban areas for asphalt streets and parking areas adjacent to grass filter strips. The formed concrete provides a neat edge adjacent to the grassed area that can be constructed at a controlled grade. The concrete edger, also serve to cut off the flow of water from the filter strip toward the pavement subgrade.

6.3.7 Because standard kerb and channel is typically not used at the edge of pavement adjoining grass filters, inadvertent tracking of vehicles onto the grassed area can be an issue. The following options may be considered for reducing the impact of wheel rutting on grass filter strips adjacent to streets and parking areas.

6.3.7.1 Bollards. Bollards can be used in parking lots adjacent to grass filter strips to keep vehicles off the grass area.

6.3.7.2 Intermitted kerb. Kerb and channel with frequent openings in the kerb may be used to direct runoff to grass filter strips while still impeding inadvertent tracking off the pavement.

6.3.7.3 Cobble strip. A layer of exposed rock with a metre wide on the edges of pavements can reduce vehicle wheel rutting impacts to grass filter strips. The rock shall be large enough to resist movement during the design runoff event.

6.3.8 Dense grass shall be used. Where land has recreational uses or aesthetic value, an irrigation system may be needed for large filter strips to establish a dense stand of the grass and maintain it in periods of low precipitation. Erosion control blankets may also be used during grass establishment. Shrub and tree plantings may be considered within filter strips, although their effect on capacity must be taken into account. Any mulch shall consist of rock cobbles or other material of a sufficient size and weight to stay in place during design runoff conditions.

6.4 Operations and Maintenance

6.4.1 The grass cover of the filter strip shall be established during the first few months of operations, otherwise, reseeding or planting is required with an alternative grass or plant species.

6.4.2 Trash and debris accumulated in the filter strip shall be removed.

6.4.3 Grass should to be mowed to a height of about 50mm, frequency as needed.

6.4.4 Excess silt and sediment buildup on the filter strips as evidently seen by the naked eye shall be removed by scraping it off manually, mechanically or both. The disturbed ground cover shall be re-established by grassing.

6.5 Drawing

- Drawing No. KCDC-DWG-SW-016, Filter Strip.

Section 7
RAIN GARDENS

7.1 Description

A Rain Garden is a stormwater device that uses the concept of bio-retention, a water quality practice in which plant and soils are used to remove contaminants in runoff. Rain Gardens consist of a soil filter medium, made of specially selected soil and sand mixed with mulch, where collected runoff is allowed to infiltrate through it. After infiltrating through the medium, water is discharged either through the underlying soils or is collected by a subdrain pipe to a reticulation system. Vegetation is planted to protect the medium and to provide aesthetic benefit.

7.2 Features and Application

7.2.1 Rain Gardens provide the following functions:
- 7.2.1.1 Removal of sediments and pollutants in the runoff.
- 7.2.1.2 Reduce run-off volumes.
- 7.2.1.3 Reduce flow velocities and delay runoff peaks.

7.2.2 They can be used either as a small or large scale device which can be incorporated within domestic or commercial landscape area.

7.2.3 In small scale development, they are usually in the form of residential planter boxes.

7.2.4 In large scale development, they are usually located along the streetscapes, e.g. median strips and islands of road networks, and retarding basins over large open areas or subdivisions.

7.2.5 Best suited for catchment areas of less than 5 hectares. Planting box type devices in residential areas should be restricted to catchment areas less than 1,000 m^2.

7.2.6 They are often used in conjunction with upstream filter strips or swales to provide an effective water treatment chain and conveyances of stormwater runoff.

7.2.7 They can be incorporated as a streetscape and landscape feature due to their aesthetic benefit.

7.2.8 They require sunlight for the growth of vegetation.

7.2.9 They require upstream pretreatment of litter and coarse sediments to minimize filter clogging.

7.3 Design Considerations and Requirements

7.3.1 The rainfall data shall be from the latest KCDC rainfall analysis. The 5-year ARI, minor flood rates, shall be used for sizing the overflows for minor flood to be safety conveyed without any flood risk. The 100-year ARI, major flood rates shall be used to check the flow velocities are not so large that they cause damage to the rain garden.

7.3.2 The permeability of the filter media layer to allow for the underdrainage to be sized. The capacity of the underdrain needs to be greater than the maximum infiltration rate to ensure filter media drains freely and does not choke the system.

7.3.3 If the final disposal is to be made by soakage to the underlying soil then soakage tests shall be undertaken to determine the design percolation rate. Soakage may not be appropriate if the percolation rate is less than 0.5 litres/min/m^2 (30mm/hr).

7.3.4 If final discharge is to be made to a system downstream though a collection pipe, the capacity of the pipe needs to exceed the infiltration rate. The receiving system needs to be capable of accepting the flow.

7.3.5 Design procedures are available from the following references:

7.3.5.1 Section 5 Engineering Design, Bioretention Guidelines, North Shore City, SKM - Boffa Miskell, December 2007.

7.3.5.2 Section 7.4.2 Rain Garden Design, TP 10, Auckland Regional Council, July 2003.

7.3.5.3 Section 4.3.6 Design Steps Rain Garden, On-Site Stormwater Management Guideline, NZWERF, October 2004..

7.3.6 The depression of the rain garden will need to be shallow enough to ensure that water will not stand for more than two days, but deep enough to hold the anticipated amount of water, depending on the infiltration rate of the soil. A general guideline is for a maximum depth of 220mm.

7.3.7 To capture as much stormwater as possible, a rectangular rain garden should be at least 1.5 times longer than it is wide (length is defined here as the face at a right angle to the slope). If site conditions do not allow for the optimum size, the shape can be adjusted as needed and can be of different appearances such as round edges, kidney or oval shape or any shape that suits the development.

7.3.8 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).
- less than 25% clay content
- permeability of at least 15mm per hour
- free from noxious plant seeds or weeds.

Note: it is expected that in-situ soils will not meet the above requirements.

7.3.9 Soil should be placed in 300-400 mm layers and lightly compacted.

7.3.10 A mulch layer shall cover the surface of the rain garden with a thickness of 50 to 75mm.

7.3.11 Filter fabric is required to prevent the migration of adjacent soil into the planting soil and the migration of planting soil into the under drain material.

7.3.12 The device should be above high water table level. Where the water table is high and where ground soakage is not used in order to avoid raising local groundwater levels, an impermeable liner may be required.

7.3.13 If the slope of adjacent ground below the rain garden is over 5% or where the land stability may be vulnerable to infiltration of water from the rain garden, an impermeable liner is required unless recommended otherwise from a site-specific geotechnical investigation.

7.3.14 An inspection chamber may be required to check the efficiency of the system.

7.3.15 A suitable back flushing system should be incorporated into the design to enable flushing of the perforated pipe under drain system.

7.3.16 A surface entry pipe outlet shall be installed to handle overflow. The overflow device shall flow to the underlying pipe or other stormwater disposal systems e.g. soakpits or swales.

7.4 Operations and Maintenance

7.4.1 The soil shall be keep moist until the plants are fully established. Watering the plants may be necessary on a frequency depending on the plant species, if there is no or little rain.

7.4.2 Compost may be needed to provide nutrients to the plants, once the rain garden is established. Plants that are adapted to sandy or gravelly soil tend to prefer nutrient poor conditions, so compost should be added only if it appears necessary.

7.4.3 To control insects and disease, it is best to use environmental friendly controls as far as possible. This includes but is not limited to:

- Planting strong herbs that drive pest insects away.
- Planting pest resistance varieties of plants.
- Encourage beneficial insects and wild life (those that kill or eat pest species) to inhabit the rain garden.

7.4.4 The soil has to be aerated occasionally to ensure it does not become compacted and impermeable. The presence of water standing in the bed too long indicates that the rain garden needs to improve its permeability. This may require the refurbishing of the soils and removal of accumulated sediments.

7.4.5 The rain garden shall be maintained using the following maintenance regime.

Frequency:			Action:
After major Storm	Every 3 months	Annually	
✓	✓		Remove debris, litters and organic waste.
✓	✓		Check soil and mulch level is below surrounding hard surface areas and overflow. Redistribute mulch and remove any excess soil and mulch where necessary.
✓	✓		Clear inflow points of built up sediments. Check erosion and repair where required.
	✓		Check plant health and replace dead plants as necessary. Water establishing plants. Remove weeds.
		✓	Remove any crust of fine sediment on surface of soil mix. Dispose contaminated crusted topsoil in the landfill.
		✓	Check surface of mulch for build-up of sediments, remove and replace if required.
		✓	Inspect under-drain system is working properly. Try backwashing under drain from the outlet if it is blocked, otherwise, may need to replace soil mix and replant.

7.5 Drawings

- Drawing No. KCDC-DWG-SW-017a, Rain Garden Typical Drawing A (Plan and Section)
- Drawing No. KCDC-DWG-SW-017b, Rain Garden Typical Drawing B (Plan and Section)

Section 8
PONDS

8.1 Description

A pond is a depression on land that contains water and is formed either by damming watercourses or by excavation of land, specifically in providing storage for flood management and providing ornamental landscape water features, water for plants and livestock, habitat for native fish and wildlife, or storage for fire control.

Pond can be categorized as follows:

8.1.1 Dry pond. They temporarily store stormwater runoff to control the peak rate of discharge and provide water quality treatment, primarily through the use of extended detention. These ponds are typically dry between storm events. Auckland Regional Council Technical Paper No. 10 does not normally recommend them for stormwater management systems due to their lower water quality performance and less aesthetic appeal. However, in combination with wet ponds they can be an effective stormwater management device.

8.1.2 Wet pond. These have a permanent standing pool of water. They provide water quality treatment through the permanent pond in conjunction with detention provided through the additional temporary storage provided when the pond water level rises above the permanent pond level. They can also provide peak flow attenuation for flood protection and downstream channel protection in conjunction with extended detention.

8.2 Features and Applications

8.2.1 Ponds may receive water from paved areas such as driveways, car parks, industrial yards, multi-lot development, piped stormwater systems and water courses such as streams and open channels.

8.2.2 They require significant contributing catchment areas or continuous base flow to maintain a permanent pool of water.

8.2.3 They serve and act as :

8.2.3.1 Flood protection;

8.2.3.2 Extended detention for stream channel protection;

8.2.3.3 Water quality improvement;

8.2.3.4 Landscape benefits;

8.2.3.5 Provision of wildlife habitat.

8.2.4 Usually appropriate for very large sites or multi lot developments.

8.2.5 They are not suitable on steep sites or on fill, unless found to be satisfactory through geotechnical assessment.

8.2.6 They may require a liner in porous soils to maintain a permanent water pool.

8.2.7 They require civil and geotechnical engineering expertise for design, construction and maintenance.

8.2.8 Need to address potential mosquito breeding during pond operations.

8.2.9 Safety issues need to be addressed.

Note: A stormwater attenuation pond with a water depth in excess of 400mm that is constructed on a site containing, or adjacent to any residential dwelling, may require fencing in compliance with the Fencing of Swimming Pool Act, 1987.

8.2.10 Can have adverse effects if constructed on streams due to impedance of fish passage and temperature effects on downstream receiving water.

8.2.11 Require regular removal of accumulated sediments that may be contaminated and require appropriate disposal.

8.3 Design Considerations and Requirements

8.3.1 Consideration shall be given to the Greater Wellington Regional Council's publication "*So You're Thinking about a Pond: A Guide to the Design, Management and Consent Requirements for Landowners*".

8.3.2 It shall convey stormwater inflows up to the peak 100-year ARI.

8.3.3 Ponds may be designed using the following references:

8.3.3.1 Section 5.4 Design Approach, Pond Design, TP 10, Auckland Regional Council, July 2003.

8.3.3.2 Sections 6.6 to 6.8, Part B: Design, Waterways, Wetlands and Drainage Guide, Christchurch City Council, 2003 (revised May 2012).

8.3.3.3 Section 4,7.6 Design Steps, On-Site Stormwater Management Guideline, NZWERF, October 2004.

8.3.4 The following site conditions shall be determined for the design:

8.3.4.1 Site investigations are required to determine the location and seasonal variation of the water table level.

8.3.4.2 The type of underlying soils shall also be determined to see if suitable for earthen embankments and for supporting a wet pond without a liner.

8.3.4.3 Topography to determine appropriate pond location and whether to be excavated or to be provided with embankments. Geotechnical analysis may be required for the stability analysis of the embankment.

8.3.4.4 Any embankment to be constructed shall be designed and constructed to take account of hydrostatic pressure and minimize the risk of slope instability. It shall be certified as a water retention structure by a suitably qualified person.

8.3.4.5 Catchment areas to be determined from the contour maps.

8.3.4.6 The pre-developed and developed scenarios peak discharges for 2, 10 and 100-year flood events are to be calculated based on the latest KCDC rainfall analysis.

8.3.4.7 Water quality analysis based on actual site stormwater samples.

8.3.5 The downstream conditions shall be reviewed and any potential pond hazard investigated. Any existing downstream stormwater facility shall have its capability to accept the discharge flow rate determined.

8.3.6 Ponds shall be designed to include a diversity of habitats with gently sloping irregular shorelines. The side slopes of the pond should not be steeper than 1V:3H, with some areas in the pond being at least 3 m deep (i.e. 25% of the pond area having a permanent water depth in excess of 3m to ensure sufficient volume to stop the pond heating up in summer). A planting strip (wet soil area) of 2m, with a slope of 1V:8H shall be provided around the perimeter of the pond at the designed normal water level, extending to 4m below the normal water level. An additional strip with a slope of 1:4 shall be provided to accommodate occasional floods.

8.3.7 The following pond outlets are to be provided:

8.3.7.1 Service outlet to convey the flow from the extended detention capacity, i.e. 2-year and 10-year storm.

8.3.7.2 Emergency outlet, usually a spillway, to convey flows beyond the 100-year storm and 300mm minimum freeboard as a measure for any potential embankment break. Wherever possible the emergency spillway should be located in natural ground. If placed on fill material, adequate erosion protection measures shall be included.

The outlet structures should convey a minimal outlet velocity with a consistent flow pattern to minimize any scouring and soil erosion downstream. They shall be located so they are accessible for maintenance and cleaning and shall provide for fish passage where necessary.

Outlets shall be provided with debris control device to avoid any blockages of outflow.

8.3.8 A high flow by-pass may be required to divert stormwater whenever the pond level reaches the emergency level and the pond is going to exceed its maximum design capacity.

8.4 Operations and Maintenance

8.4.1 Vegetative cover around the pond shall be maintained monthly, with some periodic fertilizing and soil conditioning, weed control and pruning to maintain healthy growth. Grass cover shall be regularly mowed and shall be re-established where damaged by erosion or stormwater flows.

8.4.2 Trash and debris shall be regularly removed at outlet structures and on other pond components to avoid clogging. Removal of trash and debris will prevent possible damage to vegetated areas and eliminate potential mosquito breeding habitats.

8.4.3 Accumulated sediments should be removed yearly or as need arises before the storage volume of the pond is threatened.

Mechanical dredging may be used provided silt control measures are installed to prevent sediment discharging from the pond into any water course, Council's network or neighbouring properties. Sediment must be disposed of in an appropriate manner. It is recommended that the work be done by a suitably qualified and experienced contractor. Resource consent may be required from Greater Wellington Regional Council.

8.4.4 Pond components such as valves, sluice gates, pumps, fences, gates, locks and access hatches should remain functional at all times. Regularly scheduled maintenance should be performed in accordance with the manufacturers' recommendations.

8.4.5 Mosquito breeding shall be controlled by allowing harmless mosquito control organisms (such as fish and birds) to survive or stay in the pond.

8.4.6 Regular water quality monitoring shall be undertaken to ensure a healthy aquatic environment in the pond. Laboratory testing of water samples shall be undertaken at least every season to provide a basis on what maintenance requirements may be needed to protect aquatic life.

8.5 Drawings

- Drawing No. KCDC-DWG-SW-018, Pond Typical Layout
- Drawing No. KCDC-DWG-SW-019, Pond Sections

Section 9
WETLANDS

9.1 Description

A wetland is a constructed stormwater device in the form of a marsh, swamp or other area of land to which runoff is drained. The surface soil is saturated or covered with water and forms habitat for wildlife.

Stormwater flowing through a wetland provides water treatment by a variety of mechanisms: sediment settling, filtration, biological degradation, absorption and microbial and plant uptake.

Wetlands have a stable pool ponding volume and an associated pool water level. When stormwater flows into the wetland, the water level rises and additional storage associated with this rise in water level achieves peak flow attenuation. If the wetland is appropriately designed, it provides extended detention.

9.2 Features and Applications

9.2.1 Wetlands are able to treat runoff from impermeable ground surfaces in commercial, residential and some industrial areas, including parking lot runoff.

9.2.2 Wetlands have the following functions:

9.2.2.1 Remove organic contaminants in runoff through adsorption, volatilisation, photosynthesis and degradation;

9.2.2.2 Provide significant peak flow reduction and associated flood protection;

9.2.2.3 Provide extended detention of runoff and thus can be used for stream channel protection; and

9.2.2.4 Provide aesthetic benefits.

9.2.3 It requires summer baseflow or minimum catchment size to prevent the wetland drying out in summer.

9.2.4 An impermeable soil base or liner may be required to prevent leakage and potential groundwater contamination.

9.2.5 It is suitable in relatively flat ground with a maximum slope of 5%.

9.2.6 It is not appropriate for unstable ground.

9.2.7 It requires adequate clearances to existing utilities and site boundaries.

9.2.8 It requires appropriate location of an outlet to discharge to a receiving environment or a piped reticulation system.

9.3 Design Considerations and Requirements

9.3.1 Wetlands ideally act as detention basins for large catchments.

9.3.2 The wetlands shall be designed to promote biodiversity and provide aesthetic benefit to the community.

9.3.3 The following are to be considered in the design:

9.3.3.1 Water. The estimate of the water inputs and outputs is a factor in sizing the system. Inputs come from rainfall, water table, and flows from other bodies of water. Outputs go to evaporation, groundwater recharge or outflow to other stormwater systems.

9.3.3.2 Landform. Wetlands require certain landforms to either hold or discharge the water from the system.

9.3.3.3 Nutrients. Substances in the water that can provide nourishment to plants. If nutrients such as nitrogen and phosphorous are excessive, then eutrophication can occur and wetlands become dysfunctional. Means to reduce nutrients could then be required.

9.3.3.4 Salinity. The type of plant species for wetlands depends on the salinity of the water in the system.

9.3.3.5 Aeration. Some wetlands have anaerobic soil conditions which can severely limit the survival of plants and animals. An oxygenation system may be required in order for organisms to survive.

9.3.3.6 Substate. Wetland soils affect plant and animal composition and growth. An analysis of existing soil conditions should be conducted before a wetland is to be created.

9.3.4 Wetlands may be designed using the following references:

9.3.4.1 Section 6.7 Design Approach, Wetland Design, TP 10, Auckland Regional Council, July 2003.

9.3.4.2 Sections 6.6 to 6.8, Part B: Design, Waterways, Wetlands and Drainage Guide, Christchurch City Council, 2003 (revised May 2012).

9.3.4.3 Section 4.7.6 Design Steps, On-Site Stormwater Management Guideline, NZWERF, October 2004.

9.3.5 A wetland shall be provided with a forebay to provide locations for debris and coarse sediment to drop out and accumulate; thus extending the functionality of the wetland as an extended detention basin. Forebays may be located upstream of the constructed wetlands basin, as long as normal runoff entering the constructed wetlands basin flows through the forebay. An excess flow bypass shall be provided around the forebay. Greater Wellington Regional Council's 'Erosion and Sediment Control Guidelines for the Wellington Region' and TP 10 provides the following guidelines:

9.3.5.1 Construct a forebay with a volume equal to 10% of the design volume. On sites with slopes less than 10% this equates to a forebay volume of 0.1% of the contributing catchment area, i.e. $10m^3$/ha of contributing catchment. On sites with slopes greater than 10% forebay volume is equivalent to 0.2% of the contributing catchment area i.e. $20m^3$/ha of contributing catchment.

9.3.5.2 Maximum water depth of 2m.

9.3.5.3 Surface length to width ratio shall be between 2:1 and 3:1.

9.3.5.4 Inlets to the forebay must be stablised

9.3.5.5 Access to the forebay is to be maintained at all times to allow easy and frequent removal of accumulated sediments by an excavator.

9.3.6 Any embankment to be constructed shall be designed and constructed to take account of hydrostatic pressure and minimize the risk of slope instability. It shall be certified as a water retention structure by a suitably qualified person.

9.3.7 The lining of the permanent pond to ensure minimal leakage may be achieved by the use of appropriate compacted soil, which may be in-situ, or formed by a geotextile liner.

9.3.8 Suitable plant types shall be provided and organic soil placed to assist plants to establish.

9.3.9 Outlets shall be provided in the following locations:

9.3.9.1 Forebay outlet weir to have at least 50% of the forebay width.

9.3.9.2 Excess flow bypass to be provided around both the forebay and the wetland with flow velocities during 20%EAP to be less than 0.25m/sec to avoid re-suspension of the sediments (TP 10).

9.3.10 Stable protection against scour at all inflow points shall be installed. This may consist of :

9.3.10.1 Appropriate type of grasses if runoff enters via sheet flow,

9.3.10.2 Rock rundowns if runoff enters at kerb cuts, or

9.3.10.3 Outlet protection if runoff enters through a pipe outfall. A sediment forebay may be incorporated into outlet protection at rundowns or pipe outfalls.

9.4 Operations and Maintenance

9.4.1 Clean the forebay, the wetland and outlet of litter and debris when the situation requires it.

9.4.2 The wetland shall be inspected for noxious weeds and plants quarterly.

9.4.3 Inspection shall be made during dry period to check that water is retained in the base of the wetland.

9.4.4 The outlet and overflow spillways shall be inspected every 6-months or after an event to check their condition, including for scour, erosion and blockages. (Event refers to a flood occurring with annual exceedance probility (AEP) of 20% or less).

9.4.5 Mosquito breeding shall be checked during the summer.

9.4.6 Sediment in the forebay should be removed annually or when sediments reach about 50% of the forebay volume.

9.5 Drawings

- Drawing No. KCDC-DWG-SW-020, Wetland Typical Layout
- Drawing No. KCDC-DWG-SW-021, Wetland Section

Section 10
TREATMENT TRENCH / ROCK FILTERS

10.1 Description

The device is an excavated trench backfilled with gravel, stone, or scoria media to provide treatment and disposal of stormwater from hardstand areas. The runoff is held on the filter media bed and the treated runoff either infiltrates into the ground or is collected by a sub drain for disposal to a reticulation system.

10.2 Features and Applications

10.2.1 They provide the following functions:

10.2.1.1 Removing sediments and pollutants;

10.2.1.2 Reduce runoff volumes; and

10.2.1.3 Delay runoff peak by providing temporary detention storage.

10.2.2 Best suited for small residential, commercial or industrial development with less than 2 hectare catchments, particularly with high percentage of impervious areas such as parking lots, high and medium density housing sites and roadways.

10.2.3 They are often used in conjunction with permeable paving as an effective runoff water treatment system.

10.2.4 Care is needed with respect to effects of infiltration to adjacent properties and structures.

10.2.5 Not applicable to where large sediment load may occur such as construction sites.

10.2.6 They need to be installed after site works are completed and contributing areas have been fully stabilized in order to prevent sediment loading.

10.2.7 Upstream pretreatment for litter and coarse sediments is essential to minimize clogging of the underlying infiltration surface.

10.3 Design Considerations and Requirements

10.3.1 They can be used as an onsite water quality facility in conjunction with other LIUDD devices or used as stand alone runoff treatment basins.

10.3.2 The design of the capacity of the treatment trench/ rock filter involves the following:

10.3.2.1 Runoff volume is determined using KCDC rainfall data.

10.3.2.2 Porosity of the gravel or rock media needs to be known.

10.3.2.3 The infiltration rate of subsoil shall be determined by soakage tests.

10.3.3 Infiltration devices may be designed using the following references:

10.3.3.1 Section 8.6 Design Procedure: Infiltration Design, Construction and Maintenance, TP 10, Auckland Regional Council, July 2003.

10.3.3.2 Section 4.2.6 Design Steps: Infiltration trench, On-Site Stormwater Management Guideline, NZWERF, October 2004.

10.3.4 Subsoil permeability shall be at least 50mm/hour to achieve efficient treatment of contaminants but a value of 20mm/hr for design purposes to allow infiltration rate over time (Christchurch 2003), unless an engineering analysis confirms the viability of less permeable subsoils. Permeability should not be greater than 1m/hr which is too rapid to allow significant water quality treatment (Auckland TP 10, 2003).

10.3.5 The facility should not be constructed on slopes greater than 15% unless an engineering analysis confirms its viability.

10.3.6 Base of facility shall be at least 1m above the highest water table, bedrock or low permeability layer.

10.3.7 The bottom of the basin shall be flat for the entire area of the filter bed.

10.3.8 Under drain piping shall be installed if treated water is directed to a piped or open drainage system.

10.3.9 Inflow points shall have a stable protection against scour. The protection may consist of stable, irrigated grasses if runoff enters via sheet flow, rock rundowns if runoff enters at kerb cuts, or outlet protection if runoff enters through a pipe outfall. A sediment forebay shall be incorporated into outlet protection at pipe outfalls.

10.3.10 No vegetation or vegetation mulch shall be provided in the treatment filter bed surface. However, vegetative treatments include grass, mulches or shrubs may be used on the sloping areas of the basin outside the limits of the treatment filter. Mulches for shrubs on the slopes of the basin shall be non-bouyant materials.

10.4 Operations and Maintenance

10.4.1 Regular clearance of debris and litter from entry and contributing areas is required.

10.4.2 A small section of upper trench should be removed for inspection of the filter fabric for sediment deposits, and restored to original condition after the inspection and maintenance work. This should be done every 2 years.

10.4.3 Regular flushing is necessary to remove accumulated sediments and slime.

10.5 Drawing

- Drawing No. KCDC-DWG-SW-022, Treatment Trench/Rock Filter (Plan and Section)

Section 11
PERMEABLE AND POROUS PAVEMENTS

11.1 Description

Permeable and porous pavements are alternatives to the traditional impervious types of hardscape paving materials. Runoff is allowed to percolate to an underlying granular sub-base until the water infiltrates into the ground or discharges to a stormwater outlet, thereby reducing runoff volumes (by infiltration to the sub-soils).

The distinctions between permeable pavement and porous pavement are as follows:

11.1.1 Permeable pavement refers to the formed 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 concrete block paving.

11.1.2 Porous pavement refers to 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.

11.2 Features and Applications

11.2.1 They are appropriate for the following scale of developments: single allotment scale, subdivision scale and in open space or large neighborhood scale.

11.2.2 They are intended to provide stormwater management for water quality benefits, peak flow reduction and volume reduction.

11.2.3 Most effective in removing coarse to medium sediments and attached pollutants such as nutrients, free oils/grease and metals, by infiltration through the underlying sand/gravel media layer.

11.2.4 Most practical and cost effective when serving catchments between 0.10 to 0.4 hectares.

11.2.5 Best suited for catchments with low sediment loads and light vehicle weight such as small carparks, low traffic streets (e.g. cul-de-sacs) and for paving within residential or commercial developments.

11.2.6 Appropriate in locations that receive runoff from upstream pavements, roofs, or fully stabilized landscape areas (e.g. irrigated grass or planting beds with stable mulch layer).

11.2.7 Used to provide a more aesthetically pleasing surface compared to conventional asphalt/concrete pavements.

11.2.8 Applicable to pavement grades of 1% or greater, with maximum grade of 5%.

11.2.9 Not suitable in the following soil, terrain or site conditions:

11.2.9.1 Loose sands or heavy clays;

11.2.9.2 Exposed bedrock or shallow soils over rock or shale;

11.2.9.3 Steep terrain (i.e. greater than 5%);

11.2.9.4 High water tables;

11.2.9.5 Non-engineered fill or contaminated land.

11.3 Design Considerations and Requirements

11.3.1 The following should be considered for the pavement design:

11.3.1.1 Subgrade soil properties. It needs to be assumed that prolonged ponding of water in the subbase is likely to occur in permeable pavements resulting in softening of the subgrade for much of its service life. Hence the pavement design should be based on a saturated CBR strength for the subgrade. If the subgrade strength is determined by scala penetrometer testing, the test to be conducted to a minimum depth of 800mm below the final road level. The water content of the soil at the time of testing to be taken into account and the penetrometer results adjusted to estimate the subgrade strength under saturated conditions.

11.3.1.2 Characteristic of pavement material. The flexural strength of a rigid pavement is very important in design as the strength of the pavement distributes loads uniformly to the subgrade. Characteristic of the material shall be determined to determine the relationships between compressive and flexural strength as well as unit weight and void contents of the material. The following are some structural surface materials available:

- Porous concrete. It consists of Portland cement, coarse aggregate, little or no fine, admixtures and water.
- Porous asphalt. Consists of standard bituminous asphalt in which fines were screened and reduced to allow water to pass through the voids.
- Permeable pavers. Are interlocking units, usually of concrete or brick materials, with openings to allow water to infiltrate through the ground.
- Reinforced turf. Consists of interlocking structural units with openings that can be filled with soil for the growth of turf grass at the same time suitable for traffic loads and/or vehicle parking.

11.3.1.3 Traffic loads. In general only low volumes up to 2000 ESA, axle loads and speeds less than 30mph should be considered (Waitakere City Council Stormwater Solutions).

11.3.1.4 Infiltration rate. The soil underneath must have sufficient permeability to infiltrate the stormwater so that no water stands within the pavement surface.

11.3.2 Permeable and porous pavement devices may be designed using the following references:

11.3.2.1 Draft Permeable Pavement Design Guidelines prepared by URS, Maunsell and SKM for Northshore City, Waitakere City and Rodney District, September 2004.

11.3.2.2 Section 7, Permeable Paving, Stormwater Solutions for Residential Sites, Waitakere City Council, November 2004.

11.3.2.3 Section 8.5 Design Approach, Infiltration Design, Construction and Maintenance, Auckland Regional Council, July 2003.

11.3.2.4 Pervious Concrete Pavement Design for Sustainable Porous and Permeable Stormwater Drainage (www.perviouspavement.org).

11.3.2.5 There are several suppliers of permeable and porous pavements that provide specific design requirements, guides and details in relation to their products.

11.3.3 Pavement shall be constructed on grades no less than 1% and no steeper than 5%. The pavement shall have a grade such that the area can drain to another downstream source control device or the street drainage system in an overflow event.

11.3.4 Where segmental concrete pavers are used, they shall comply with NZS 3116:2002 (Concrete Segmental Paving).

11.3.5 Bedding material for the pavers shall consist of fine gravel filter bedding course complying with the requirements of NZS 3116:2002 Clause 309.1.2 Sand Properties. Bedding shall have a thickness of at least 50mm.

11.3.6 The basecourse layer should comply with all the requirements of TNZ M/4 AP40 except for the particle size distribution requirement where it must comply with the limits defined below:

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 be free from silt/clay fines or other deleterious materials. It must have a minimum permeability of 10^{-3} m/s, compacted to at least 95% of maximum dry density. The basecourse shall have a minimum thickness of 200 mm.

11.3.7 Geotextile fabric may be required along the side walls and base of basecourse as a liner depending on the recommendation of a geotechnical engineer.

11.3.8 Perforated under drain piping of 100 to 150mm is to be installed for low permeable subgrades.

11.3.9 The bottom of the sub-base shall be at least 1m above the high water table level.

11.3.10 Permeable and porous pavement shall not be installed until all upstream areas are fully stabilized unless barriers or filters are set up to protect the pavement from sedimentation. Site drainage shall be considered for the period of construction prior to site stabilization and installation of the porous pavement.

11.3.11 The land surrounding and draining to the pavement shall not exceed 20% slope.

11.4 Operations and Maintenance

11.4.1 Maintenance is required to maintain the efficiency of the permeability or porosity of the pavement installed. The drainage voids in the surface of the pavement shall be kept clean and clear from all kinds of debris. Debris, if left, will clog up the drainage voids of the pavement which in turn reduce the flow capacity of the system.

11.4.2 For installed pavers with grass, undertake regular watering and mowing as for a lawn.

11.4.3 Concrete pavers and porous concrete surfaces need vacuuming and washing of the surface to maintain their effectiveness. The level of the fill material in the voids of interlocking pavers needs to be checked and re-filled when necessary, particularly after pressure cleaning.

11.4.4 Inspection and maintenance should be undertaken after heavy rain or storms as these are the times when the drainage voids can become clogged with organic debris.

11.4.5 Potholes and cracks are repaired when needed.

11.4.6 Pavement level should be maintained. Differences in pavement levels due to settlements should be rectified.

11.5 Drawings

- Drawing No. KCDC-DWG-SW-027, Permeable Pavement (Permeable Sub-grade)
- Drawing No. KCDC-DWG-SW-028, Permeable Pavement (Low Permeable Sub-grade)