On-Site Stormwater Management Guideline

October 2004

NZWERF
Tumu Maru Wai o Aoteroa

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Manatū Mō Te Taiao

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Foreword

The impact of stormwater on the environment is becoming an increasingly important issue. Impacts include both *quantity* effects such as flooding, erosion and effects on the water table and also *quality* effects such as sedimentation, litter, suspended solids and dissolved contaminants. Stormwater in our urban, semi-urban and rural environments needs to be managed differently and one part of the New Zealand Water Environment Research Foundation's research portfolio has been to identify how to manage stormwater across these three very different land environments.

We are all responsible for ensuring that we protect stormwater quality and managing our own stormwater. However, with the growing interest in sustainable urban design and improvements in water quality, the *On-Site Stormwater Management Guideline* will allow local government, private sector designers and homeowners to design stormwater systems which will reduce stormwater pollution and flooding incidents.

The purpose of the Ministry for the Environment's Sustainable Management Fund is to support the community, industry, iwi, and local government in practical environmental initiatives. I am pleased that the fund has been able to support the development of these guidelines to assist in the on-site management of stormwater in New Zealand.

Hon Marian L Hobbs
MINISTER FOR THE ENVIRONMENT

Disclaimer

This Guideline aims to provide design professionals with the information they need to select the appropriate on-site stormwater management device for any given application. It gives step-by-step design procedures for the most common devices and as far as practical states key assumptions relevant to some of the devices and design methodologies. The aim is to help professionals tailor any measure to meet the needs of their general geographical area and the particular site.

The Guideline also provides a useful consolidated summary of information about on-site stormwater management in the New Zealand context, as well as highlighting areas where perhaps more work can usefully be done.

It should be noted, however, that the professional end user is responsible for applying the Guideline to particular sites and making the decisions about which on-site system to adopt. While this Guideline can help with this process, NZWERF and its consultants are not responsible for any consequences or effects of any system that may be installed solely on the Guideline's basis. NZWERF encourages users to obtain more specific advice where risks such as slope instability or flooding or other community concerns are present, in order to confirm that the proposed on-site system is efficient and adequate for the particular site and that it is installed correctly.

The Guideline does not supersede local and regional, manuals, standards or statutory plans.

Provision of information on suppliers and types of proprietary stormwater treatment devices does not imply any endorsement, approval or recommendation for their use. The lists of suppliers or types of proprietary treatment devices in this guideline may not be complete as at the time of writing, and will become out of date as the field progresses, so further information should be sought on these when using this guideline.

While every effort has been made to ensure the accuracy of the information included in this guideline, the Minister for the Environment and NZWERF accept no responsibility for any errors or omissions in the information supplied.

Work in progress

This guideline is very much a work in progress, reflecting best practice in a fast-moving field as at 2004. Any comments and additional information that could help other stormwater practitioners in New Zealand are most welcome and can be directed to:

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- Wellington City Council

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This guideline has drawn heavily on the work of the Auckland Regional Council (TP 10 and TP 124) and the Auckland City Council (*On-site Stormwater Management Manual*). The project team gratefully acknowledges this work by Earl Shaver and Greg Paterson of those councils and their input to this guideline.

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The guideline has been prepared with extensive consultation, including launch of the proposal at the NZWWA Stormwater Conference in Rotorua in June 2004 and a three-phase input process inviting email comments from a growing number of New Zealand-wide practitioners on drafts made available on the NZWERF website (www.nzwerf.org.nz).

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Contents at a glance

Concepts

Device selection and design

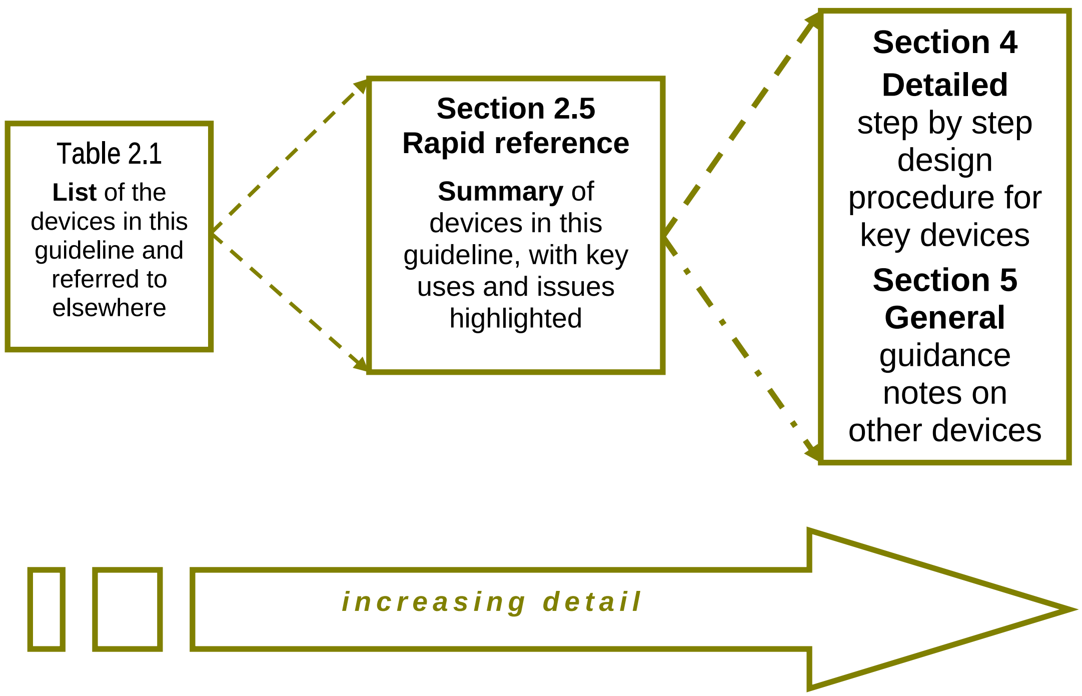
Detailed resources and technical appendices

How to use this guideline

We recommend that all users, but especially entry-level device designers, review the entire document in order to become familiar with the concepts and resources available both within the guideline and referenced as useful companion documents.

As designers become more familiar with on-site devices, they may refer directly to Section 4 for the step-by-step procedures for the particular device they are about to design.

To gain an overview of the devices and how they can be used together in a treatment train, the guideline takes an expanding view:



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Abbreviations

Note: asterisked terms are defined in the glossary overleaf.

AEP	Annual exceedance probability *
ARC	Auckland Regional Council
ARI	Average recurrence interval
BMP	Best management practice *
CMP	Catchment management plan (or planning) *
GIS	Geographic information system
HIRDS	High intensity rainfall design system (NIWA, 2002)
LGA	Local Government Act
LID	Low impact design or low impact development *
LIM	Land information memorandum
MfE	Ministry for the Environment
MPD	Maximum probable development
NZWERF	New Zealand Water Environment Research Foundation
NZWWA	New Zealand Water and Wastes Association
PAH	Polyaromatic hydrocarbon
O&M	Operation and maintenance
RMA	Resource Management Act, 1991
Tc	Time of concentration *
TLA	Territorial local authority
TPH	Total petroleum hydrocarbons
WSUD	Water sensitive urban design (or development) *

Glossary

Notes:

1. Definitions apply to the context in which they are used in this Guideline
2. Definitions exclude those of the specific on-site devices described in s2.2

Aquifer	Underground water body
Annual exceedance probability	The probability, expressed as a percentage, that a flood of a given magnitude will be equalled or exceeded in any one year. For example, the 10% AEP is a flood expected to occur on average once in a 10 year period
ARI (average recurrence interval)	The average period between exceedances of a given rainfall or flow rate
Best management practice	For stormwater, a method of control that meets sustainable water quantity and quality objectives
Body corporate	Legal entity responsible for the operation and maintenance of a multi-unit dwelling complex
Brownfields site	Brownfields are generally defined as abandoned or underused industrial or commercial properties where redevelopment is complicated by actual or perceived environmental contamination. They vary in size, location, age and past use, and can range from a small, abandoned corner gas station to a large, multi-acre former manufacturing plant that has been closed for years. They generally have lower levels of contamination that can be successfully addressed using standard environmental cleanup practices, but may be stigmatised by their past use (http://stlcin.missouri.org/cerp/brownfields/definition.cfm) With certain legal exclusions and additions, the USEPA defines the term `brownfield site' to mean real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant. (http://www.epa.gov/brownfields/glossary.htm)
Catchment	Area contributing flow to a point on a drainage system
Catchment management plan	Plan for dealing with the runoff generated in a catchment (normally to meet specified water quantity and quality objectives)
Catchpit	Small chamber incorporating a sediment trap that runoff flows through before entering a reticulated stormwater system (also termed cesspit)
Cluster housing	Multi-unit development on one or more lots, normally with some communal facilities and amenities

Combined sewer	Piped reticulated system that conveys both stormwater and sewage
Detention of stormwater	Temporarily detaining runoff on a site before discharging it to reticulated or natural system (refer also ‘retention’)
Erosion	In this guideline, means the process of detachment and transport of soil or sediment by water from the ground surface
Four waters	Comprises all forms of natural water, plus the stormwater, drinking water and wastewater systems that interact with these (see three waters)
Flood frequency	The probability that a flood discharge rate will be equalled or exceeded in any year (refer also ‘annual exceedance probability’ above)
Greenfield site	Land on which no urban development has previously taken place; usually understood to be on the periphery, of an existing built-up area Slough Borough Council, UK, http://www.slough.gov.uk)
Groundwater	Water under the ground surface that is stored and/or moving below the soil layer
Hydrologic neutrality	Neutralising the effect of increased impervious surfaces on the urban hydrograph to pre-development levels, typically by on-site and multi-site stormwater management measures, with respect to one or more of: reduction in the peak flows of selected design storms; enhancement of stream baseflows; or average annual discharge
Impervious/ impermeable surface	Surface through which water cannot pass, that sheds water, such as roofs, roads, paths
Infiltration	The passage of water through soil to reach groundwater
Low impact design	Design approach for site development that protects and incorporates natural site features into erosion and sediment control and stormwater management plans
Mana whenua	Customary authority exercised by an iwi or hapu in an identified area
On-line device	All the runoff from a contributing catchment area flows through a stormwater device
Off-line device	Only run-off up to a nominated maximum flow rate passes through a stormwater device. Flows in excess of the nominated maximum flow rate bypass the device
On-site stormwater management	The use, detention and/or retention of runoff on a site (refer also ‘detention’ and retention’)

Orifice	A hole of a specified size designed to discharge flow at a pre-determined rate (it is normally machine-drilled in a plate and attached at the entry to a pipe)
On-site device	An on-site stormwater management system that is designed to meet water quantity and/or quality goals, which utilises detention and/or retention of runoff
Overland flow path	Route taken by flood runoff not able to be contained in the reticulated or natural stormwater conveyance system
Pathogen	Disease-causing organism
Permeable (pervious) surface	Surface through which water passes by infiltration
Retention	A system that temporarily retains runoff and then disposes of it on site by infiltration
Rohe	Territory, area
Runoff	The flow of rainwater across the ground or an artificial surface generated by rain falling on it
Site	For the purposes of this guideline, a 'site' is defined as one lot, though it may include a number of separate buildings (refer section 1.2)
Source control	The control of runoff and/or contaminants at or near the point where it was or they were generated
Tangata whenua	Iwi or hapu that holds mana whenua over a particular area
Three waters	Comprises the three water systems; stormwater, drinking water and wastewater (see also four waters)
Time of concentration	Time taken for rain falling at the head of the catchment to reach a designated point as runoff
Watercourse	Natural or artificial channel which conveys runoff
Water sensitive urban design	Low impact development as defined above, with an added emphasis on sustainable vegetation practices and low-level of water usage

1. Background, scope and aims of this guideline

In this section:

1.1 Background

In 2001 the New Zealand Water and Wastes Association (NZWWA) carried out a stormwater scoping survey and needs analysis to which 41 people from city, district, regional councils and consultancies responded (the full report is on the NZWWA website, www.nzwwa.org.nz). A key finding was that not enough people responsible for stormwater management in New Zealand were aware of the seriousness of stormwater impacts – a situation that has changed to a remarkable degree in the intervening period. A growing range of relevant professions – engineers, planners, ecologists, architects, developers and the like are now becoming interested in sustainable urban design, rather than just sustainable stormwater management. Stormwater cannot be managed in isolation from water supply, wastewater and natural water assets, nor from land and habitat values that in the words of one respondent are 'part of a larger natural system that has many values important to our living environment'.

Many respondents made unprompted suggestions that a guideline was needed for better stormwater management throughout New Zealand, while more than two-thirds of respondents agreed with the proposition that a New Zealand guideline on comprehensive stormwater management was necessary. Plans were laid for NZWERF to carry out the project in 2003, funding was sought from a range of organisations during the year, and work on the project began in January 2004. Through the Minister for the Environment's Sustainable Management Fund and the other funding contributors listed earlier, NZWERF has produced this guideline to meet the needs – and concerns – identified in that 2001 survey.

This guideline is part of a stormwater management resources programme being carried out by NZWERF. The programme is made up of two components, the other one being the Stormwater directory of New Zealand. The Stormwater directory of New Zealand comprises an internet based, searchable database of stormwater information resources, such as guidelines and design manuals. Resources are listed in four main categories; regulations and legislation, catchment analysis, stormwater design and construction and asset management. A stormwater links page includes an education and research links section and an online form for adding and updating resources. The *Stormwater Directory of New Zealand* is available here: www.stormwaterdirectory.org.nz.

Interestingly, those who agreed a guideline was needed expressed the same reservations as the nay-sayers. Those who did not think a guideline was needed said:

- ‘guidelines become rules very easily [but] local conditions mean local solutions; that is, what is appropriate for a stormwater discharge from a steel plant into a mangrove estuary may not be appropriate for a stormwater discharge onto an open coastline’
- there is ‘too much variability between regions – the issues on which different stormwater strategies are based are quite different region to region’
- ‘if written they are likely to then become mandatory and they could not recognise all the differences that occur within New Zealand’

Those who said a guideline is needed or ‘highly desirable’ right now reasoned that:

- ‘urban stormwater discharges require consenting before October 2001’
- ‘a common approach may be useful. Case studies can also be useful’
- ‘we need firm guidelines to avoid confrontation based on individual personal opinions’

Again, their qualifying provisos were that any guidelines:

- ‘may need to be regional rather than national to reflect ecological differences’ and ‘must recognise different environments’
- would ‘need to carefully consider all current statutory and regulatory requirements and provisions, and the different agency roles and responsibilities [that] pertain to stormwater management and related initiatives’
- by themselves ‘will not deal with inconsistent implementation by Councils and consultants… clearer definition and application of outcomes to be achieved is needed’
- ‘must be practical with good balance between cost and effectiveness if [they are] to gain widespread acceptance’

The aims of this guideline as outlined in section 1.5 overleaf are intended to address all the needs and concerns expressed by:

- balancing consistency with flexibility for on-site stormwater management
- using information already available so practitioners can use their own judgement
- providing for geographic, policy and regulatory variability

1.2 What is a ‘site’?

For the purposes of this guideline, the term ‘site’ covers a range of land areas, including:

- individual residential household sites
- multi-unit residential developments on individual sites
- individual commercial or industrial sites, which may sometimes be large

It does not cover sites clustered together in neighbourhoods that would be served by sub-catchment or catchment scale stormwater devices.

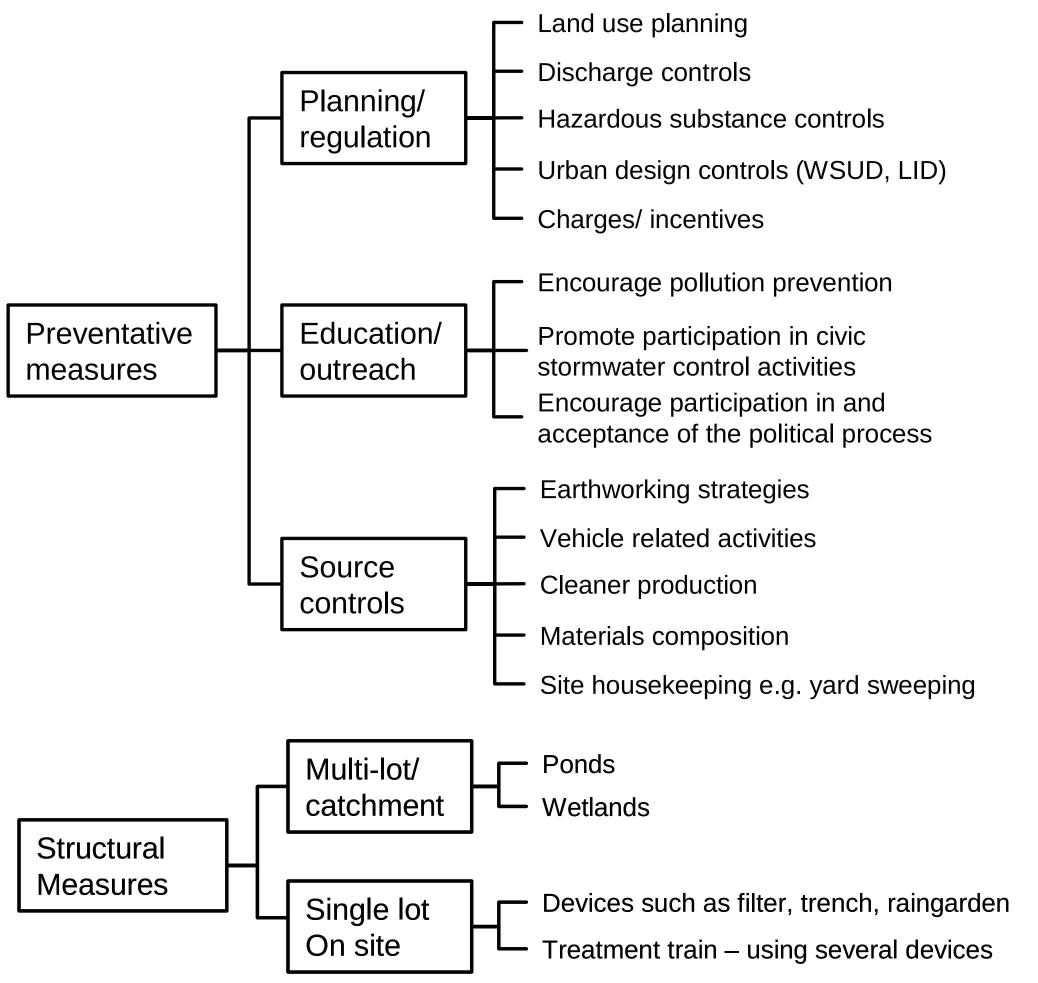
1.3 The place of on-site stormwater management devices within the full range of stormwater management tools

The range of potential stormwater management tools is shown in Figure 1.1. This guideline only addresses single lot on-site stormwater structural measures (devices).

Figure 1.1 somewhat artificially separates on-site devices from planning and regulatory measures. In practice, on-site stormwater management devices may be used to achieve or help achieve some planning and regulatory controls such as:

- discharge controls – for example, limiting peak flow discharges
- urban design controls – in conjunction with low impact design or water sensitive design, such as grass swales or using rain tanks for water re-use

Figure 1.1 Potential stormwater management tools



Source: Adapted from Natural Resources Defense Council; 1998 Auckland Urban Stormwater Project in ARC & IA, 2004

1.4 Scope

1.4.1 What this guideline does and does not cover

This guideline covers on-site stormwater devices that are suitable for use on residential, commercial and industrial sites in urban, suburban (low density) and rural areas. It does not attempt to give a history of the evolution of stormwater management practices in the New Zealand statutory environment.

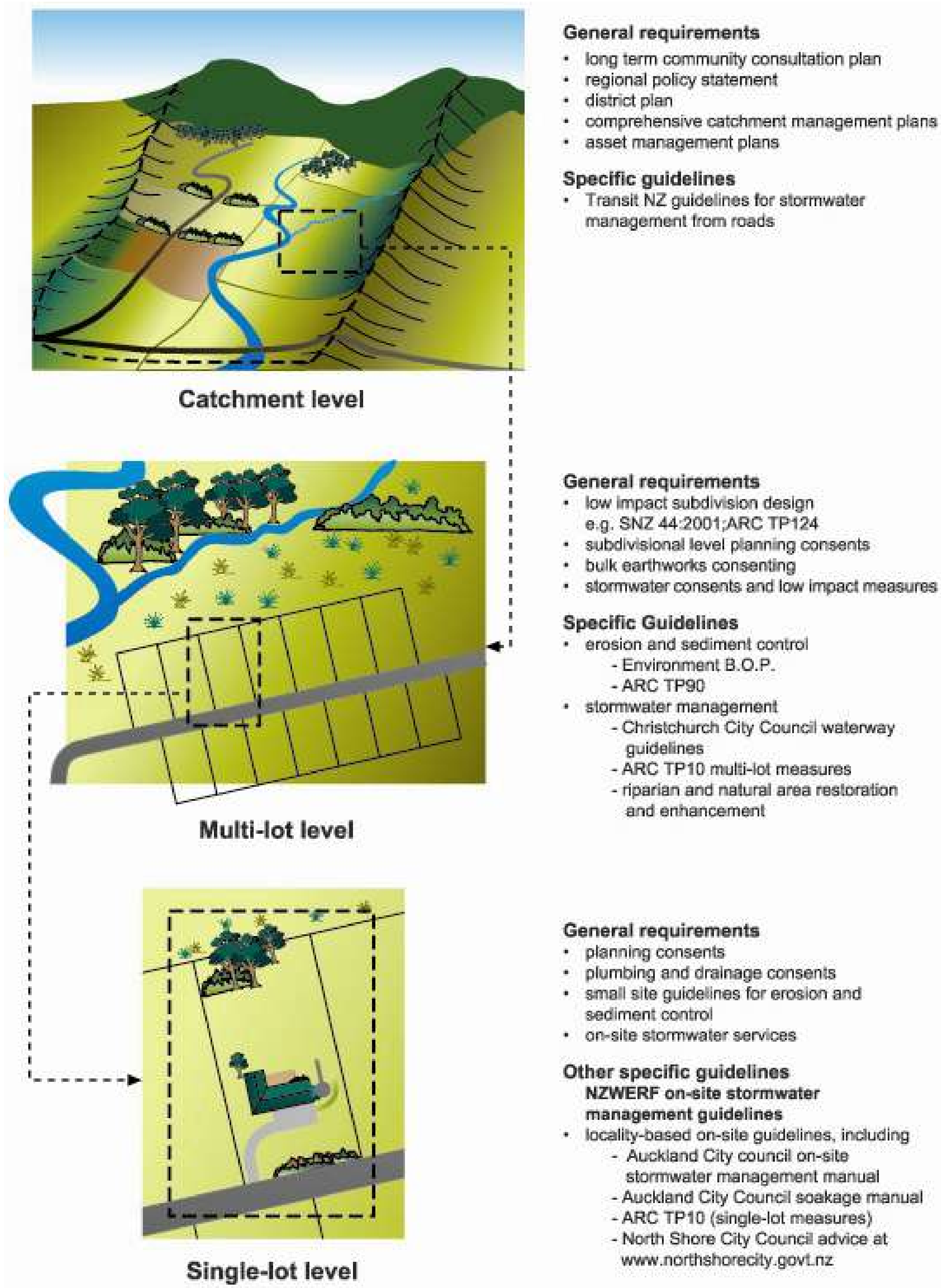
Neither does it cover matters well traversed in other New Zealand documentation, such as:

- non-structural and some structural at-source management and maintenance practices such as bunds and diversion valves or lawn maintenance and street and yard sweeping. Many documents cover this, including the ARC's EOP (Auckland Regional Council, 2000, *Environmental Operations Plan* (henceforth referred to as the 'ARC EOP')
- detailed assessment and engineering design of stormwater disposal mechanisms, in particular to avoid local scour or erosion
- forestry, farming and related rural activities, as well as wider rural drainage and flooding
- specific stream management methods such as daylighting, erosion protection or channel design
- erosion and sediment control during earthworks - this is covered in guidelines by Environment Bay of Plenty and in the Auckland Regional Council's TP90 (Auckland Regional Council, 1999, Erosion and Sediment Control: *Guidelines for Land Disturbing Activities in the Auckland Region*, ARC Technical Publication No. 90 (henceforth referred to as ARC TP90)

The guideline does not cover runoff from roads in any detail, especially public roads with high traffic volumes. The devices described in the guideline and design methodologies will, however in some cases, be suitable for managing road runoff.

Figure 1.2 indicates how this guideline relates to other guiding documents for stormwater management.

Figure 1.2 How this guideline relates to other documents



1.4.2 Limitations of this guideline and the need for further work

The primary focus of these guidelines is on stormwater management devices that provide:

- water quality treatment with final disposal to surface water or to ground soakage
- peak flow and quantity reduction for sites where final disposal is to surface water

These devices will enable developments to go some way towards hydrologic neutrality, without necessarily achieving it in all respects. For example, many devices will achieve a measure of success in reducing the peak flows in certain storms, but few will achieve enough soil or groundwater recharge to maintain base flows in urban streams. This may be a constraint to sustainable urban development in many areas.

Moreover, the work done to produce this guideline indicates that the different capabilities of on-site measures with respect to hydrologic neutrality – an important resource management goal – are not always clearly specified. This guideline aims to clarify these capabilities, but a lot is yet to be learned about the actual effectiveness of many devices for managing the urban hydrograph.

This guideline is a first base for New Zealand stormwater practitioners. However, the rapid pace of theory and implementation means it will need regular review. The recommendations made below aim to focus the attention of practitioners on monitoring and information needs that can further refine future editions. Recommendations for ongoing work are:

- developing improved definitions of hydrologic neutrality and monitoring the performance of on-site stormwater devices with respect to achieving it
- arrangement by territorial local authorities, unitary councils and regional councils to analyse local rainfall records and other aspects of treatment devices in order to arrive at accurate local or regional quality design storms
- developing a management and monitoring framework for on-site stormwater devices, in order to encourage the gathering and sharing of monitoring data in a way that is sufficiently robust and detailed to be useful to stormwater practitioners for comparing costs and performance for different sites and devices
- developing design guidelines for stormwater management devices, where current guidelines do not exist or are deficient or need refining
- preparing RMA section 32 and 36 analyses, to determine whether on-site stormwater management devices are justified in terms of quadruple bottom lines (social, environmental, cultural and economic)
- developing sound procedures relating to ownership, operation and maintenance issues, including maintenance costs
- assessing the need for further capacity-building and training for building inspectors who may need to inspect and sign off on stormwater devices
- ongoing research work to foster the use of new or under-used technologies/devices

1.5 Aims of this guideline

This guideline aims to provide design professionals with the information they need or appropriate sources to select and design appropriate on-site stormwater management devices for any given application in New Zealand. It overviews on-site stormwater management concepts in order to provide a sound basis for selecting and designing specific devices, based on a review of New Zealand and overseas precedents and use or adaptation of these to reflect New Zealand wide needs. The guideline recommends step-by-step design procedures for a range of commonly used devices where it was thought most useful to consolidate and clarify the design issues. Where this information is already well known and/or available elsewhere, such as for oil and water separators or proprietary devices, it refers to the relevant sources.

Regional variations in natural and institutional conditions mean that the individual designer needs to make an informed choice of device, based on the guidance given, in order to meet the needs of his or her general geographical area and the particular site. Wherever possible, the guideline spells out what background assumptions are known and not known about various devices and design methodologies in order to enable users to use different assumptions if desired. The guideline also provides a useful consolidated summary of information about on-site stormwater management in the New Zealand context, as well as highlighting areas where perhaps more work can usefully be done.

The format of this guideline was based on a review of the guidelines and manuals listed in Appendix A. This guideline aims to:

- focus on New Zealand applications for rural as well as small and large urban areas while drawing closely on relevant precedents from overseas
- compile information from many sources into one place where this is needed, but with an annotated bibliography, including websites, to point users to more detailed sources
- provide sound guidance on how to choose the most appropriate on-site device
- explain each of the technical issues involved in setting the design approach; design objectives, performance standards, matching site physical characteristics and so on
- as far as practicable, provide for the wide variety of site conditions and device applications that may be encountered throughout New Zealand
- put design guidelines for each on-site device in a consistent, easy-to-follow format which meets the needs of both the first-time user and the experienced professional
- give worked examples of a range of applications
- show working examples of on-site devices, with photos, narrative and performance data

The guideline also aims to promote sustainable stormwater management through wider adoption of appropriate onsite practices by:

- increasing the understanding, awareness and appropriate use of on-site practices
- encouraging the incorporation of on-site stormwater management into the development and implementation of policy, regulation, management, technical design and operations
- promoting best on-site stormwater management practice

Although reference material is cited for users to develop further skills, the guideline assumes users are broadly familiar with stormwater management technology and practice, especially:

- storm hydrology – hydrograph generation and routing: Gribbin, J.E. 1996. *Hydraulics and Hydrology for Stormwater Management.* Delmar Learning
- basic hydraulic analysis:
    - Brater, King, Lindell & Wei, 1996. *Handbook of Hydraulics.* McGraw Hill 7th Edition
    - Streeter, 1985. *Fluid Mechanics.* McGraw Hill 8th Edition
- stormwater quality: Auckland Regional Council. 2003. *Stormwater Treatment Devices Design Guidelines Manual.* ARC Technical Publication No.10 (henceforth referred to as ARC TP10)

1.6 The contribution of on-site stormwater management to sustainability

On-site devices are increasingly being used to help meet the objectives of ecologically sustainable development, or ‘development that uses, conserves and enhances the community’s resources so that ecological processes, on which life depends, are maintained and the total quality of life now and in the future can be increased’ (NSESD, 1992).

Sustainability objectives for stormwater management include:

- avoiding or minimising the discharge of contaminated stormwater to sensitive fresh or marine receiving waters
- reducing the frequency and duration of stormwater flows where necessary to reduce the potential to cause erosion or scour
- reducing flood peaks that exceed natural and built infrastructure capacity, cause hazards or cause property and other damage
- promoting cost-effective infrastructure asset management by utilising natural and privately owned assets, for example overland flow paths and depression storage, as key components of the built stormwater system (‘greening’ the ‘grey’ infrastructure) and integrating the management of all four waters (see glossary)
- promoting terrestrial and aquatic biodiversity with appropriate planting and reduction of adverse environmental effects on streams and saline receiving environments
- engaging greater general public awareness of stormwater and its interaction with the natural environment, encouraging them to take steps to protect their local environment and perhaps re-use stormwater where appropriate (in turn, this increased awareness can be tapped into to facilitate proper maintenance of on-site devices)
- meeting the concerns of tangata whenua about waters in their rohe

On-site stormwater measures promote sustainability by making some contribution towards hydrologic neutrality; that is, reducing the effect of increased impervious surfaces on the urban hydrograph towards pre-development levels. Different measures contribute to reducing peak flows from selected design storms, enhancing groundwater recharge and stream baseflows and maintaining average annual stream discharges. On-site stormwater management devices will not generally achieve pre-development runoff conditions with respect to all aspects of stormwater runoff, especially runoff volume. Sustainable development requires designers and regulators to consider a range of stormwater management measures, which may include on-site stormwater management devices.

Sustainable stormwater management is best implemented through integrated stormwater catchment management plans or other planning mechanisms that incorporate the principles of low impact development, low impact urban design and development and water sensitive urban design. On-site, multi-site and catchment-wide devices need to be planned together to form an integrated treatment train to aid progress towards the goal of sustainability.

Developers and their consultants often have limited resources to investigate the sensitivity and limiting factors for the receiving environment of an individual site and need guidance from the relevant regional and territorial councils on the most appropriate measures to help address catchment level stormwater issues: on-site stormwater management may not always be the best option at catchment level. For example, proliferation of treatment devices throughout a catchment may increase the overall lifecycle cost of stormwater management, while detention devices at the bottom third of the catchment may potentially increase the peak discharge by increasing the recession limb of the hydrograph for the lower catchment.

Again, if stormwater runoff from an individual site does not discharge into an open water body, and centralised stormwater quality and quantity management devices can be accommodated at the bottom of the catchment before discharging to the receiving water, then at-source control may not be advantageous: some sort of cost/benefit analysis should then be undertaken within the framework of a catchment wide study, in order to assess the potential for such impacts and to identify the best practical (and most affordable) management options to achieve the desired environmental outcomes.

1.7 Statutory and policy framework for on-site stormwater management

The core legislation relevant to stormwater discharges from sites is the Resource Management Act 1991 (RMA), the Local Government Act 2002 (LGA) and the Building Act 1991. Several current government initiatives also affect stormwater and are summarised below.

1.7.1 Resource Management Act 1991

The framework of the RMA relevant to site stormwater diversions and discharges is shown in Figure 1.3. Regional, district and city councils, and unitary authorities, all have functions under the RMA to control stormwater:

- under district plans, by specific rules; for example rules on maximum impermeable surfaces as a percentage of the net site area, related to site zoning
- under regional plans, by specific rules limiting:
  - the total impermeable area for a site or total contributing catchment area
  - concentrations of contaminants in site stormwater discharges or rules relating to particular land uses. Rules are increasingly being set to achieve water quality standards specified for particular receiving environments

If site parameters or stormwater diversion or discharge parameters do not comply with the permitted activities or performance standards of the relevant rules in the District Plan or Regional Plan, then a resource consent or consents could be required. Specific restrictions in the RMA controlled by regional councils and unitary authorities that may apply to stormwater infrastructure, diversions and discharges are:

- s9 for uses of land that may affect water or soil conservation such as earthworks (some existing uses are allowed)
- s12 for activities, for example structures, in the coastal marine area. All structures, such as stormwater outlets, in the coastal marine area require a resource consent unless allowed by a rule in a regional plan or regulations (some existing uses are allowed)
- s13 for activities in the beds of rivers and lakes. All structures in lakes and rivers, such as stormwater outlets, culverts or pipes, require a resource consent unless allowed by a rule in a regional plan or regulations (some existing uses are allowed)
- s14 for taking, using, damming or diverting (storm)water. Any damming of water, such as by blocking a drain, requires a resource consent unless allowed by a rule in a regional plan or regulations
- s15 for discharging water to water, or discharging contaminants to land, air or water. All stormwater discharges to land and water, including coastal water, require a resource consent unless allowed by a rule in a regional plan or regulations

Specific restrictions in the RMA that are controlled by district and city councils and unitary authorities, and may apply to stormwater infrastructure, diversions and discharges, are:

- s9 for restrictions relating to earthworks, or other uses of land that may have effects on the environment including water, for example, site coverage, impermeable surface areas, set back distances from streams and whether the land is used for residential, rural or industrial purposes (some existing uses are allowed)

- s220 for activities associated with subdivision. Subdivision consents are authorised by district councils. Subdivision conditions can cover matters such as the intensity of developments and stormwater infrastructure requirements

Regional planning documents can recommend that comprehensive catchment management plans or integrated catchment management plans be completed by territorial local authorities (TLAs) for urban or urbanising catchments. These allow stormwater discharges to a council controlled drainage system provided they comply with conditions of the comprehensive consent.

1.7.2 Local Government Act 2002

This statute provides a new purpose for all local authorities based on sustainability principles. The purpose of local government includes democratically promoting the social, economic, environmental and cultural well being of communities now and in the future.

Documents prepared by TLAs that should always be consulted when considering on-site stormwater management issues include:

- stormwater bylaws, for example to manage overland flow paths (the Local Government Act, 2002 requires local authorities to review all their bylaws by 1July 2007)
- asset management plans
- engineering codes of practice
- water and sanitary assessments: levels of service for community stormwater systems may change as a result of community consultation and risk analysis

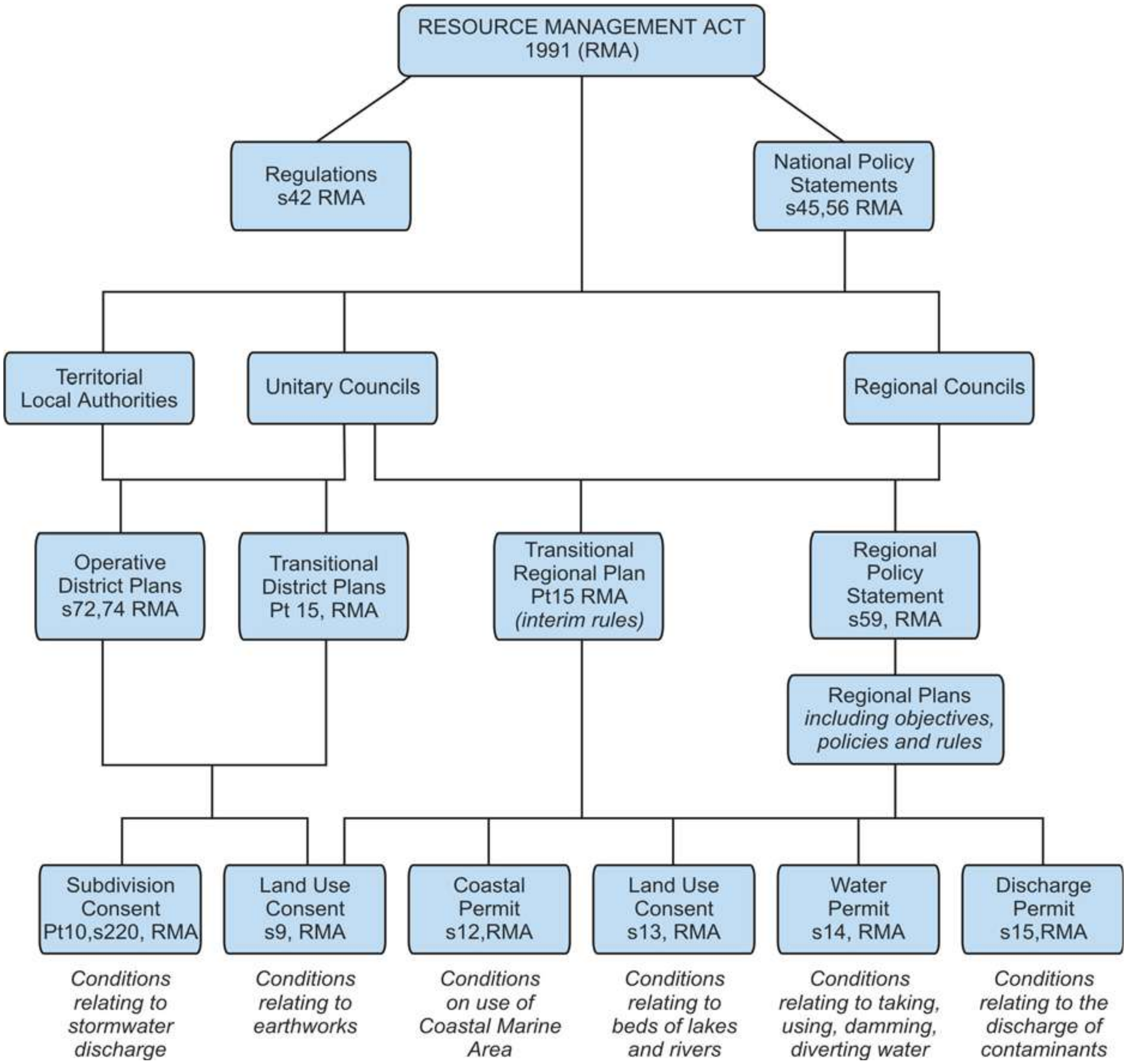
1.7.3 Building Act 1991 and Building Code

S 36 of the current Building Act (www.legislation.govt.nz) requires that all building work is adequately protected from flooding and that the results of the development do not make flooding worse. Clause E1 (surface water) of the approved New Zealand Building Code (http://www.bia.govt.nz/e/publish/legislation/building_code.shtml) addresses:

- estimation of runoff
- sizing surface water systems
- secondary flow
- disposal to soak pit
- minimum acceptable floor level

Proposed amendments to the Building Act and Code aim to promote sustainable development by the development of building standards in relation to among other things, water efficiency, and water conservation and the need to facilitate the efficient use of water and water conservation in buildings. On-site stormwater management measures may assist these goals to be met as well as meeting stormwater management goals.

Figure 1.3 Regulation of on-site stormwater management



1.7.4 Government initiatives

There are several government initiatives relevant to stormwater management, including:

- the Department of Prime Minister and Cabinet's January 2003 Sustainable development programme of action, supported by the Ministry for the Environment's sustainable cities group
- the Ministry for the Environment's Water programme of action, which initially consists of a number of projects covering water allocation and use and water quality
- the Oceans policy, which aims to ensure integrated and consistent management of the oceans within New Zealand's jurisdiction by way of a cross-government exercise, covering all aspects of oceans management including effects from land
- the proposed National environmental standards for Raw drinking water sources. In development at time of writing, this may require risk gradings to be placed on drinking water catchments, some of which may be affected by stormwater discharges
- the Government's infrastructure stocktake (www.med.govt.nz), which also raises issues about the capacity and condition of water-related infrastructure

The Sustainable development programme of action addresses (among other things) the quality and allocation of fresh water to ensure that freshwater quality is maintained to meet all appropriate needs. Relevant to stormwater discharges are the goals of:

- preserving/improving current water quality and identifying and mitigating sources of freshwater contamination
- establishing industry and other sector partnerships to improve freshwater quality

Provisions relating to sustainable cities that are relevant to on site stormwater management include:

- working collaboratively with local authorities to improve the legislative arrangements and statutory controls on planning, development and service delivery for urban areas, especially Auckland, focusing in particular on removing legislative impediments to sustainable medium and high density housing and infrastructure investment planning
- working collaboratively with local government, design professionals, and cultural, heritage and environmental interests to develop an urban design charter which aims to:
  - incorporate collaborative urban design in project planning and delivery
  - consider natural systems
- developing environmental standards, for air quality, water quality, noise and waste, and a timetable for their implementation, in consultation with urban authorities
- with urban authorities, developing a methodology and committing to collecting data and indicators to record the state of social and environmental well-being of urban areas

The Ministry for the Environment (MfE) has formed a pilot group of government agencies that are seeking to take practical steps towards sustainability. The MfE website advises that Government will facilitate initiatives by government agencies to:

- assess the main impacts of their operations on the environment
- get started with eco-efficient procurement
- report on their operational environmental performance

In the international context, Agenda 21 is a comprehensive plan for management of all forms of human impact on the environment, developed principally by the United Nations and Governmental groups. This plan of action was adopted by 178 countries (including New Zealand) in 1992. The full implementation of Agenda 21 was strongly reaffirmed at the World Summit on Sustainable Development in Johannesburg, South Africa, in 2002.

1.8 What does using this guideline mean for your council or consultancy?

This guideline outlines a decision-making and design process that enables practitioners to use onsite stormwater management devices that are appropriate to different land uses, receiving environments, soils and climates around New Zealand. It is not a standard.

Councils that want to promote or require the use of this guideline in their area will need to work out how this is best done, depending on their own approach to policy, regulation, education and other stormwater management tools. Time and other resources will be needed to go through processes such as:

- detailed critique of the design assumptions, in order to ensure that the most appropriate rainfall and other relevant criteria are used for the locality
- consultation with local stormwater practitioners
- analyses under sections 32, 35 and 36 of the Resource Management Act, to justify the expense of recommended measures by considering alternatives (for example, neighbourhood or catchment-based measures), benefits and costs; the requirement to gather information, monitor and keep records; and the possible need to fix charges to recover the reasonable costs incurred to manage the systems they wish to put in place
- recording on-site devices on the LIM (land information memorandum), GIS (geographic information system) and other relevant databases
- linking with asset management plans and rating procedures (refer to the need for further work identified in section 1.4.2 of this guideline and the operation and maintenance issues raised in Appendix D2)
- internal change management processes such as those described in Paterson and Menzies (2003), especially capacity-building for consenting and compliance monitoring of devices, as well as appropriate legal and funding arrangements and administrative systems

Consultants wanting to use the guideline to design onsite measures for use in any council's area are advised to approach the council to work out whether or not devices designed according to this guideline are acceptable.

1.9 References

Notes:

1. Internet references are accurate at the time of publication
2. Short references are given in brackets at the end of key documents that are used throughout the text for ease of use, for example (ARC TP10, or CCC, 2003)

Auckland Regional Council. (2003). *Stormwater treatment devices: design guideline manual*. ARC Technical Publication No. 10 (ARC TP10). From http://www.arc.govt.nz/arc/index.cfm?34C9C2A8-1BCF-4AA1-91AF-CC49CFE4A80C.

Auckland Regional Council. (2000). *Environmental operations plan*. (ARC EOP).

Auckland Regional Council. (2000). *Low impact design manual for the Auckland Region*. ARC Technical Publication No. 124 (ARC TP124).

Auckland Regional Council. (1999). *Erosion and sediment control: guidelines for land disturbing activities in the Auckland Region*. ARC Technical Publication No. 90 (ARC TP90).

BIA (Building Industry Authority). (2003). *Building Code Clause E1– Verification method E1/VM1: Surface water*. (BIA, 2003).

Brater, E.F., King, H.W., Lindell J.E., & Wei, C.Y. (1986). *Handbook of hydraulics*. New York: McGraw Hill.

Department of Environment and Natural Heritage. (1992). *National strategy for ecologically sustainable development*. Department of Environment and Natural Heritage, ACT, Australia. (NSESD 1992). From http://www.deh.gov.au/esd/national/nsesd/index.html.

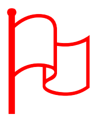
Gribbin, J. (1996). *Hydraulics and hydrology for stormwater management*. Delmar Learning.

Standards New Zealand. (2001). *New Zealand handbook: Subdivision for people and the environment*. (SNZ HB 44:2001).

2. About on-site stormwater management devices

In this section:
2.1 On-site devices defined in brief
2.2 Evolution of on-site stormwater technologies
2.3 On-site devices described and devices covered by this guideline
2.4 Other useful resources
2.5 Rapid reference: a quick guide to the devices in this guideline
2.6 References

Where particular caution needs to be exercised, the following format is used:



Cautionary advice is given in a box next to a red flag.

2.1 On-site devices defined in brief

On-site stormwater management devices typically:

- receive stormwater runoff from small-scale impervious areas such as individual lots
- aim to temporarily detain runoff and meet one or more of the following objectives:
  - flow control, for example by throttling the peak discharge
  - water quality control, for example by filtering out sediment that may contain contaminants
  - volume control by water re-use
  - provide disposal, for example infiltration trench

In contrast with the conventional approach of discharging stormwater direct to large-scale piped systems, on-site devices reflect modern practice for at-source controls that better reflect the sustainability outcomes summarised in section 1. Section 2.2 backgrounds the evolution of on-site devices.

In the context of sustainability, on-site devices are an integral part of water sensitive urban design/development (WSUD) or low impact design (LID), that protects and incorporates natural site features into erosion and sediment control and stormwater management plans. On-site devices should, where practicable, be used with water sensitive urban design/development and low impact design and, as outlined in section 1, within the context of integrated catchment and asset management plans to:

- protect or enhance water quality and preserve natural habitat and ecosystems
- mimic natural drainage regimes (including groundwater recharge where appropriate)
- adopt more sustainable forms of development
- reduce the amount and form of hard infrastructure and impervious surfaces
- improve visual and physical amenity values

On-site devices can be used:

- in small-scale developments on individual lots, where the assignment of operation and maintenance obligations to individual owners and occupiers normally dictates their applicability
- in multi-unit developments, where body corporates offer a potentially feasible operation and maintenance arrangement
- in new (greenfield) developments
- in infill or redevelopment (brownfield) developments
- where the protection or enhancement of natural features is required to be maximised
- where peak flow reduction is sought, for example to avoid overtaxing built or natural stormwater infrastructure that is undersized to cope with additional impervious areas
- where the at-source removal of contaminants in stormwater is desirable, for example where:
  - larger-scale catchment water quality control devices are not feasible, and/or where
  - there is an impetus to protect the natural values of the receiving waters

A key issue with on-site devices is the ownership and responsibility for operation and maintenance. Continuing maintenance of on-site devices may become a major issue, as many owners or subsequent owners of the development may have only very limited knowledge of them. Resolution of this issue is crucial for the successful implementation of on-site devices and their ongoing effectiveness. See Appendix D.

2.2 Evolution of on-site stormwater technologies

Built-up areas need to be drained to remove surface water. Traditionally, this was done using underground pipes designed on a quantity imperative, to prevent flooding by conveying water away as quickly as possible. However, this approach concentrates the flow and can lead to problems such as erosion and flooding elsewhere in the catchment, while current trends of intensifying urban development are generating runoff that exceeds the pipes' design capacity.

More recently, emphasis has been devoted to reducing both the concentration of flow and the discharging of the pollutants in stormwater from urban areas into watercourses or groundwater. These goals can be partly met through source-control, or on-site stormwater management, which involves detaining the runoff so as to trap contaminants at source and/or reduce flooding.

Over the past 20 years on-site stormwater management has evolved to now become the norm in many big cities throughout North America and Europe. In the USA it developed in the mid-1980s and was mainly concerned with water quality control. In other countries, its focus from the outset was more on water quantity control, although most quantity-oriented on-site methods will also provide a degree of water quality benefit.

Probably the best known examples of on-site devices are rain tanks (although these are not common in North American practice), rain gardens, wetlands and swales.

In practice, the rate of evolution of new on-site devices is quite slow, although proprietary on-site stormwater treatment devices continue to come onto the market. Current evolutionary trends are more in the application than the design of on-site practices. In the USA in particular, choices tend to be dictated by local climatic conditions.

For water quantity control, it is increasingly common to set performance targets that match the greenfield standard, even in infill applications where public stormwater assets have been designed to meet the developed urban impervious area standard.

In the USA, pipelines are also being daylighted by removing the pipe and restoring the former natural watercourse. The greenfield standard is even applied to central city commercial area in some cases, such as Calgary City in Alberta, Canada, where buildings meet the standard by storing rainfall on their flat roofs and releasing it at the greenfield rate. The State of Maryland in the USA has bad experiences with roof storage and abandoned it (E. Shaver, pers. comm).

New trends in on-site applications include:

- on-site devices, originally focused on domestic applications, are being re-engineered for industrial sites, with device selection targeted to particular industrial hazards
- detention tanks, particularly below-ground tanks, are falling from favour because of the difficulty of ensuring proper maintenance. In their place, rain tanks incorporating both stormwater detention and re-use are becoming popular, though there are potential public health issues with using water from them, especially in densely urbanised areas
- use of on-site devices to manage road runoff by means including street rain gardens (for example as sunken roundabouts) and pervious paving is growing in the USA
- roof gardens or green roofs are increasingly used, especially in commercial areas where their aesthetic merits can come to the fore, though their uptake is slow, perhaps due to waterproofing issues and the expense of the load-bearing construction
- in areas with soakage, on-site infiltration devices sometimes combined with detention devices are increasingly used, and can help to recharge aquifers as well as take pressure off the piped stormwater system. The use of on-site devices to treat runoff before discharge to ground is beneficial, as it helps prevent soakage systems failing by clogging as a result of sedimentation of the surface of the infiltration medium
- the initial enthusiasm for proprietary mechanical on-site devices has ebbed somewhat, due to the relatively high operating and maintenance costs, together with lack of understanding and data on their performance

Effective operation and maintenance is crucial for long-term satisfactory performance of on-site devices. Various models promote this, such as:

- traditional: voluntary regime, with guidance given and backed by random inspections
- obligatory (manual): owners are required to have their on-site device serviced at designated intervals, with servicing certification submitted to the controlling authority
- obligatory (high-tech): in installing an on-site device, the owner agrees to contract out maintenance to the controlling authority, which equips the serviceperson with a notebook computer that has the site and device details; on completing the service, details are logged in and downloaded to the controlling authority's database

There is more on O&M in Table 3.11, Section 4 and Appendix D.

Comparable trends in on-site design standards and guidelines include:

- traditionally, on-site devices have been designed to meet the required performance standard in the design storm condition through hydrograph analysis. New trends include:
  - continuous simulation of long pluviographic sequences, through which the performance in the full range of storm temporal patterns can be assessed
  - simulating the performance of multiple on-site devices distributed throughout a catchment (the traditional approach does not account for this or for the effects of different times of concentration in different parts of the downstream receiving network)
- similarly, design for water quality has traditionally used empirical methods such as a water quality volume, as in ARC TP10, but modelling is increasingly able to quantify the treatment process, including selective treatment of site-specific contaminants
- the trend in on-site guidance documentation is away from the 'text-book' approach of compiling all known information, because it can be easily accessed through the Internet. Instead, step-by-step design processes are often put in place to ensure appropriate use of devices

2.3 On-site devices described

On-site devices typically incorporate the following general features:

- an inlet that receives stormwater from the roof and/or impervious areas of the site
- a detention zone that temporarily stores runoff, thereby attenuating the peak flow
- a treatment zone that may comprise sand or soil that is designed to filter out contaminants (it is important to also provide detention storage for these, as the filtration rate is typically slow)
- a disposal facility, which may be by way of:
  - connection to the public stormwater system – road kerb/channel, pipe, watercourse
  - dispersal over the ground surface
  - discharge to ground by soakage, applicable in areas with good soakage characteristics such as gravels, sandy loams or fractured volcanic rocks [1]

In hydrologic terms, on-site devices flatten the runoff hydrograph in much the same way as reservoir routing. This is shown in Figure 2.1, which shows the first flush of a storm being stored and released on the tail of the hydrograph.

Table 2.1 lists the on-site devices covered by this guideline. In the absence of a universally-accepted naming convention, the generic names in common usage in New Zealand have been adopted. However, alternative names are also listed to facilitate overseas literature searches.

Section 3 provides guidance on selecting the appropriate on-site device or devices for a particular application.

In summary, criteria for selecting any particular device include:

- objectives: treatment and/or flow attenuation
- source of stormwater to be fed to device: roof and/or site runoff
- site characteristics: topography, soils, building layout, etc

[1] This guideline addresses disposal to ground by soakage by way of describing where this disposal method may be applicable, the range of disposal options and references covering the design of soakage disposal systems

- physical device requirements: space, landscaping, landscaping and aesthetics
- technical availability: for example in remote areas it may be difficult to access to those with the necessary skills and abilities to install and/or maintain particular systems, making their use less technically feasible
- number, ownership and operation/maintenance of devices
- costs and other implementation issues including permits and consents

Figure 2.1 First flush storage and release on the tail of the hydrograph

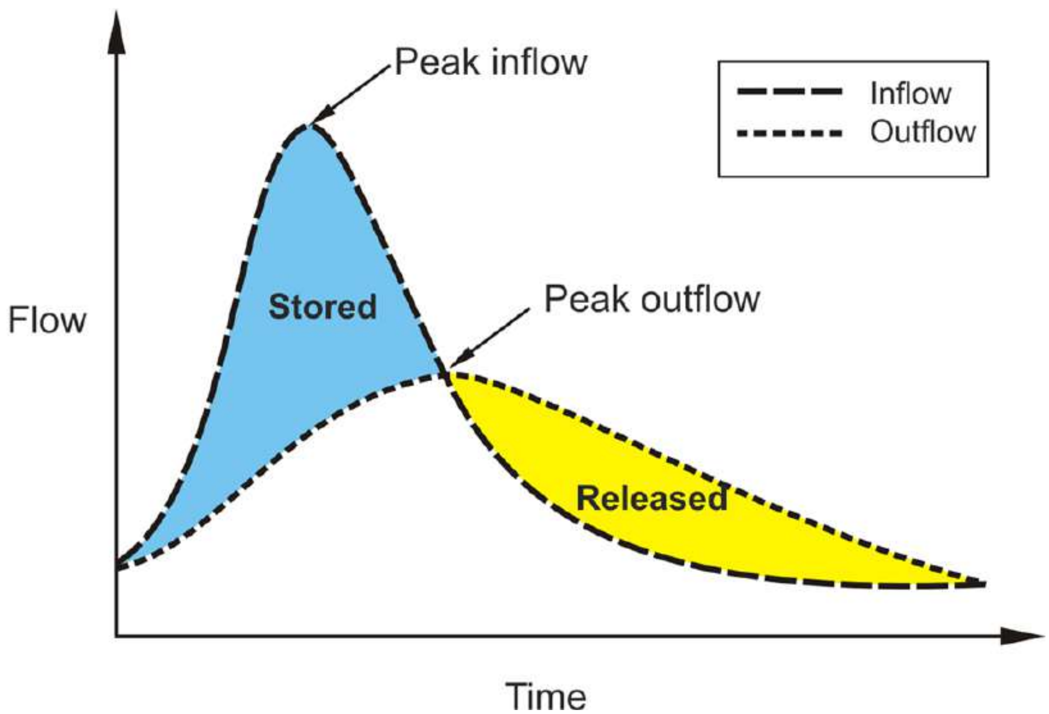


Table 2.1 On-site devices covered by this guideline

Device name	Alternative name(s)	Section	Description
Step-by-step design procedure			
Filter	Treatment wall	4.1	Device to store and treat stormwater by filtration. The sand filter is the best known example, but the genre also includes custom-designed/proprietary filters and the use of a variety of filtration media
Infiltration trench	Bio-filtration system, infiltra-tion gallery	4.2	Gravel-filled trench (can be constructed underneath a swale)
Rain garden	Bio-retention system	4.3	Device constructed within in-situ soil where treatment is achieved by flow through a sand/soil medium
Stormwater planter		4.4	Rain garden-type device, but specifically for collection of roof water only and to provide flow detention for peak flow reduction
Rain tank	Dual-use tank	4.5	Above ground tanks catching roof runoff only and incorporating stormwater detention and re-use zones
Swale / filter strip	Grass filter	4.6	Devices where treatment is achieved via shallow surface flow channels achieving treatment by surface flow
Wetland	Marsh	4.7	Constructed shallow pond with intensive plantings
Guidance notes			
Detention tank	OSD or on-site detention tank	5.1	Constructed tanks used for flow control and /or treatment, including custom built and proprietary devices
Pond	Retarding basin	5.2	Includes ponds dug or created by a dam and used for flow detention and treatment
Roof garden	Green roof or eco-roof	5.3	A planted and drained soil medium constructed on the roof of a building
Roof gutters		5.4	Use of enlarged roof gutters and similar devices to detain stormwater or peak flow control on roofs
Depression storage	Retarding basin	5.5	Ponding on specially-designed source areas to detain stormwater for peak flow control (where applicable, can dispose of stormwater to ground)
Permeable pavement	Permeable or pervious paving	5.6	Pavement systems that allow significant infiltration of runoff and percolation into underlying strata
Treatment trench/ Rock filter	Often associated with permeable pavement	5.7	An excavated trench backfilled with stone or scoria media providing treatment before disposal to a piped reticulation system or to surface water
Catchpit insert	Catchpit filter	5.8	A filter insert used to remove gross pollutants and particulate bound contaminants
Gross pollutant traps, litter traps, hydrodynamic separator		5.9	Includes devices that intercept some combination of the following: rubbish, grit, coarse sediment, oil and litter. Includes custom built gross pollutant traps, sediment traps, oil and grit traps, rubbish traps and proprietary units
Oil and water separator		5.10	Used only for removal of hydrocarbons

2.4 Other useful resources

- Auckland City Council. (2002). *On-site stormwater management manual* (henceforth referred to as ACC 2002)
- Auckland Regional Council. (2000). *Low impact design manual for the Auckland Region*. ARC Technical Publication No. 124 (henceforth referred to as ARC TP124)
- Auckland Regional Council. (2003). *Stormwater treatment devices: design guideline manual*. ARC Technical Publication No. 10 (henceforth referred to as ARC TP10)
- Christchurch City Council. (2003). *Waterways, wetlands and drainage guide* (henceforth referred to as CCC, 2003)
- Rodney District Council and the Auckland Regional Council. (2000). *DRAFT Management of stormwater in countryside living zones (rural and town): a toolbox of methods*
- Standards New Zealand. (2001). *New Zealand handbook: Subdivision for people and the environment*. (SNZ HB 44:2001)
- Waitakere City Council. (2002). *Countryside and foothills stormwater management code of practice*

2.4.2 Selected electronic reference material

New Zealand sources include:

- *Stormwater directory of New Zealand*. (2004) www.stormwaterdirectory.org.nz
- Auckland Regional Council. (2000) *Low impact design manual for the Auckland Region*. Technical Publication No. 124 (ARC TP124) www.arc.govt.nz/arc/environment/water/low-impact-design.cfm
- Auckland Regional Council. (2003) *Stormwater treatment devices – design guideline manual*. ARC TP10. http://www.arc.govt.nz/arc/index.cfm?34C9C2A8-1BCF-4AA1-91AF-CC49CFE4A80C
- Auckland City Council. (2002). *On-site stormwater management manual.* www.aucklandcity.govt.nz

International sources include:

- *International stormwater BMP database*: http://www.bmpdatabase.org/ .This contains an extensive compilation of the latest international best management practice for on-site stormwater management devices, as summarised in Table 2.2
- City of Portland: *Stormwater management manual* www.cleanrivers-pdx.org
- Maryland (USA): *Stormwater design manual, volumes* I & II (Effective October 2000). http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp
- Western Australia: A major review of the *Manual for managing urban stormwater quality in Western Australia* (Water and Rivers Commission, 1998) is under way. The Interim Position Statement: Urban Stormwater Management in WA - Principles and Objectives was released in February 2003 to provide the Department's policy on urban stormwater management while the Stormwater Management Manual for Western Australia (2004) is being produced. Once completed, the *Stormwater management manual for Western Australia* (2004) will replace the Manual for Managing Urban Stormwater Quality in WA and the Interim Position Statement: Urban Stormwater Management in WA - Principles and Objectives as the key guiding document for stormwater management in Western Australia. http://www.wrc.wa.gov.au/protect/stormwater/smm.htm

- Washington State Dept of Ecology: *Stormwater management manual for Western Washington* www.ecy.wa.gov
- Upper Parramatta River Catchment Trust: *On-site detention handbook* www.upperpararriver.nsw.gov.au
- Drainage & Irrigation Dept, Malaysia: *Draft stormwater management manual* http://agrolink.moa.my/did/river/stormwater/toc.htm

Appendix B contains a list of all the references used in this document, including Internet URLs wherever possible.

2.4.3 International stormwater BMPs

The International Stormwater BMP Database at http://www.bmpdatabase.org/, an extensive compilation of the latest international best management practices (BMPs). Devices listed are summarised in Table 2.2 (note, however, that these include practices applying to larger areas than are normally considered under the on-site category).

Table 2.2 International stormwater BMPs

Source: http://www.bmpdatabase.org/ (accessed May, 2004)

BMP category	Number of BMPs listed
Bio-filter	32
Detention	24
Hydrodynamic devices	17
Media filter	30
Percolation trench/well	1
Porous (permeable) pavement	5
Retention pond	33
Wetland basin	15
Wetland channel	14

2.5 Rapid reference: a quick guide to the devices in this guideline

The following devices are briefly overviewed in this subsection:

- filter
- infiltration trench
- rain garden
- stormwater planter
- rain tank (dual-use tank)
- swale/ filter strip
- wetland
- detention tank
- pond
- roof garden (eco-roof)
- roof gutters
- depression storage
- permeable pavement
- treatment trench/ rock filter
- catchpit insert
- gross pollutant traps
- oil and water separator

Key to symbols:

Primary function/s

● good effectiveness of device for primary function listed

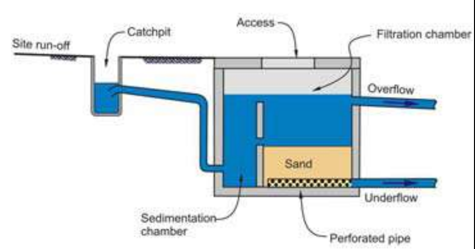
O not effective, or partial effectiveness of device for primary function listed

Applications, attributes, do's and don'ts

- positive attributes
- things to pay particular attention to if using this device
- don'ts: things not to do or use the device for

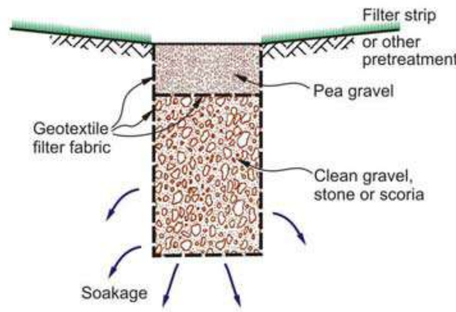
Filter

Primary function(s)	Flow attenuation	Treatment
	O	●
Receives water from	paved areas such as car parks	
Description		
The device is a custom designed or proprietary structural device that uses filtering media such as sand, soil, peat or compost to filter out contaminants. It is usually a subsurface installation and has the following components: • regulation of inflow flow rate • pre-treatment by sedimentation • filter media • outflow mechanism		
Applications, attributes, do's and don'ts		
• well suited for industrial and other sites with contaminants attached to particulates • regular maintenance including removal of accumulated fine material on filter surface is essential		
Covered in this guideline in section	**4.1**	



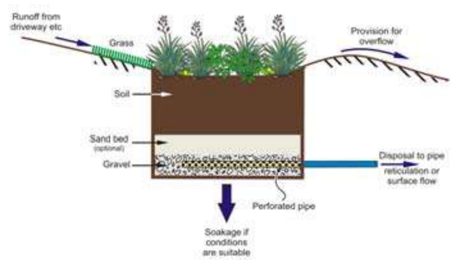
Infiltration trench

Primary function(s)	Disposal	Treatment ●
Receives water from	paved areas such as car parks	
Description The device is a trench containing gravel and provides treatment and disposal of stormwater. Some treatment is provided by gravel in the trench but most treatment is provided by adjoining soil		
Applications, attributes, do's and don'ts • requires permeable soils and appropriate topography to avoid slope instability • care need to avoid contamination of groundwater • requires pretreatment to reduce sediment loads and avoid blockage ▪ well suited for commercial, some industrial and other sites ▪ requires a small footprint		
Covered in this guideline in section	**4.2**	



Rain garden

Primary function(s)	Flow attenuation **O**	Treatment ●
Receives water from	paved areas such as driveways, car parks	
Description: This device, also known as bioretention area, is an in-ground filter with the upper surface of the filter medium exposed to allow infiltration of collected stormwater ponded on it. The filter medium is a specially selected soil/sand mix with a surface mulch or organic layer. Small, shallow-rooting plants protect this medium (the 'soil medium' and provide some evapotranspiration.		
Applications, attributes, do's and don'ts ▪ can be incorporated within domestic or commercial landscaped areas ▪ can serve as an attractive landscaping feature		
Covered in this guideline in section	**4.3**	



Stormwater planter

Primary function(s)	Flow attenuation ●	Treatment O
Receives water from	Roof only	

Description

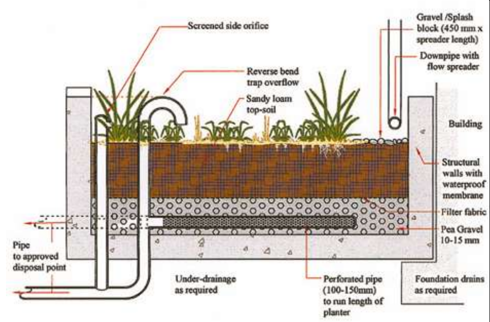
The device is essentially a box (e.g. an above-ground pre-cast concrete unit), partially filled with soil in which plants are grown. It operates as follows:

- roof water is discharged into it from the downpipe
- the first-flush infiltrates through the soil layer where it is collected in a drainage layer and fed to the discharge point
- when the inflow rate exceeds the infiltration rate, ponding occurs up to the top-of-wall level. This storage serves to attenuate flows
- a half siphon comes into operation when the ponding capacity is full

Applications, attributes, do's and don'ts

- well-suited to providing flow attenuation in urban infill situations
- can serve as an attractive landscaping feature

Covered in this guideline in section **4.4**



Rain tank (dual-use tank)

Primary function(s)	Flow attenuation ●	Treatment O
Receives water from	Roof / other impervious area	

Description

Tank (concrete, plastic or steel), receiving and storing roof runoff. Features include:

- an upper temporary storage zone, sized to detain runoff to meet the flow attenuation target. The outflow rate is controlled by an orifice at the bottom of the temporary storage zone
- below this is a permanent storage or re-use zone, from which water is drawn for household uses (e.g. non-potable uses such as outdoor watering, toilet flushing and laundry)
- tanks are normally located above-ground (or partially buried to allow gravity inflow)
- provision is generally made for topping-up the tank in dry periods from the mains supply; a backflow preventer is required to avoid cross-contamination
- a first flush diverter is typically provided to limit the contaminants reaching the tank

Applications, attributes, do's and don'ts

- where buried, concrete tanks must be crack-proof to avoid the ingress of contaminants
- close attention must be paid to ensuring that the plumbing from the tank meets NZS 3500:5:2000
- the local water and/or wastewater utility may have regulations affecting the avoidance of charges arising from water re-use
- re-use is often very cost-effective, especially where a tank is required in any event for flow control purposes
- the re-use benefit, in parallel with the public health imperative, is seen as encouraging sound maintenance practices

Covered in this guideline in section **4.5**

Swale / filter strip

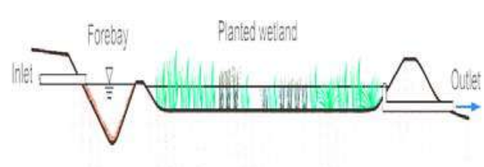
Primary function(s)	Flow attenuation O	Treatment ●
Receives water from	paved areas such as driveways, car parks	
Description These devices use vegetation in conjunction with slow and shallow depth of flow. Contaminants are removed by a combination of filtration, adsorption and biological uptake. Vegetation also decreases flow velocity and allows settlement of particulates.		
Applications, attributes, do's and don'ts ▪ can be incorporated within car parks or within road median strips ▪ can serve as an attractive landscaping feature		
Covered in this guideline in section	**4.6**	

Swale at car park at North Harbour Stadium

Wetland

Primary function(s)	Flow attenuation ●	Treatment ●
Receives water from	paved areas such as driveways, car parks, industrial yards, multi-lot developments	
Description Shallow ponds that incorporate dense vegetation. Purposes and befits are: • flood protection • extended detention for stream channel protection • water quality improvement • landscape benefit • provision of wildlife habitat		
Applications, attributes, do's and don'ts • appropriate for larger sites –generally over 1 ha ▪ provides multi-purpose quality and peak flow reduction ▪ can provide aesthetic benefit		
Covered in this guideline in section	**4.7**	

Wetland at Unitec campus Auckland



Detention tank

Primary function(s)	Flow attenuation	Treatment
	●	O

Receives water from: Roof / other impervious area

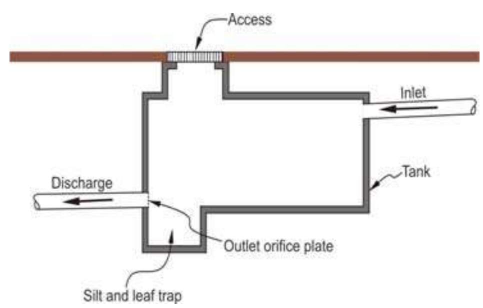
Description

- tank, typically located below ground, to store runoff for release at a slower rate to receiving system or environment
- tanks fed by site runoff will generally include a catchpit before the tank to intercept debris and coarse sediments in order to avoid blockage of the tank outlet orifice and reduce the frequency of tank clean-out

Applications, attributes, do's and don'ts

- underground concrete tanks must be crack-proof
- needs adequate fall between the tank outlet and the receiving system (e.g. street gutter or pipe)
- a forerunner to the rain tank (see above), but has fallen out of favour to a degree, due to the potential for re-use to be cost-effective with a rain tank, and the maintenance needs, especially where the tank receives site runoff (e.g. contaminants may be toxic in a confined space, requiring special maintenance safety practices)

Covered in this guideline in section 5.1



Pond

Primary function(s)	Flow attenuation	Treatment
	●	●

Receives water from: Paved areas such as driveways, car parks, industrial yards, multi-lot developments

Description

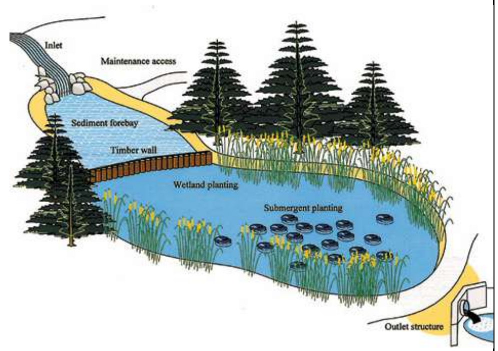
Includes ponds formed from damming watercourses and ponds constructed by excavation.
Purposes and befits are:

- flood protection
- extended detention for stream channel protection
- water quality improvement (predominantly particulate)
- landscape benefit
- provision of wildlife habitat

Applications, attributes, do's and don'ts

- usually appropriate for very large sites or multi lot developments
- can provide an attractive landscaping feature

Covered in this guideline in section 5.2



Roof garden (eco-roof)

Primary function(s)	Flow attenuation ●	Treatment ●
Receives water from	Roof only	
Description		

Used in place of a conventional roof to achieve quantity and quality control. Features include:

- roof structure overlain by a waterproof membrane
- soil, with underlying drainage system (proprietary)
- supports vegetation
- flow attenuation is achieved by evapotranspiration and soil capture
- contaminants are removed by filtration through the soil

Applications, attributes, do's and don'ts

- careful structural and waterproofing detailing is needed to avoid leakage into building
- appropriate plant selection to withstand a range of climatic conditions is vital; plants may require irrigation in dry periods
- garden requires regular maintenance
- can serve as an attractive and novel landscaping feature, for example where it is visible from an adjacent deck or roof

Covered in this guideline in section **5.3**

Example of roof garden, USA

Roof gutters

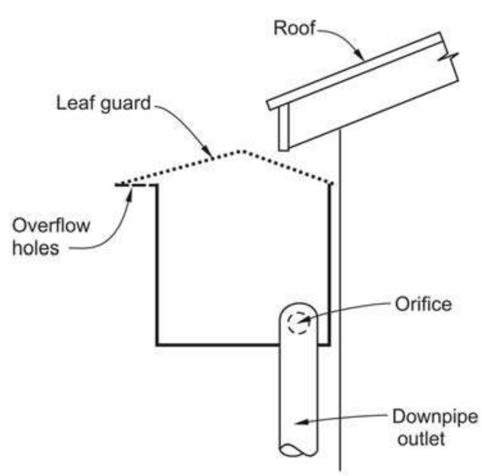
Primary function(s)	Flow attenuation ●	Treatment O
Receives water from	Roof only	
Description		

- over-sized gutters/spouting
- outlet flow throttling by orifices provides flow attenuation

Applications, attributes, do's and don'ts

- significant storage needs to be provided in the gutters to achieve anything more than minor flow attenuation
- careful structural and waterproofing detailing is needed to avoid leakage into building
- correct sizing of outlet orifices and maintenance to avoid blocking is critical

Covered in this guideline in section **5.4**



Depression storage

Primary function(s)	Flow attenuation ●	Treatment O?
Receives water from	Roof / general impervious areas	

Description

- natural or artificial permeable area capable of detaining runoff, such as a depression in the lawn or a low lying car park area
- provides temporary storage to attenuate runoff
- can provide some treatment, particularly for grasses areas
- stormwater disposal can be by soakage for vegetated areas in permeable soils or via a low level piped outlet

Applications, attributes, do's and don'ts

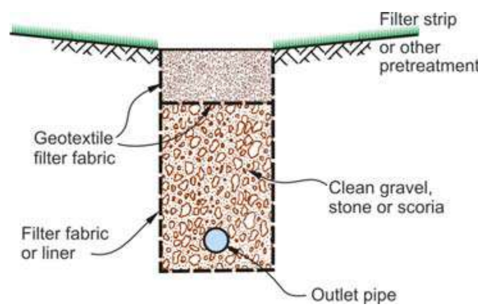
- a simple device, but may require a sizeable area which will retain water for some time after a storm
- do not site where it creates a flood risk to adjacent buildings/properties

Covered in this guideline in section	**5.5**

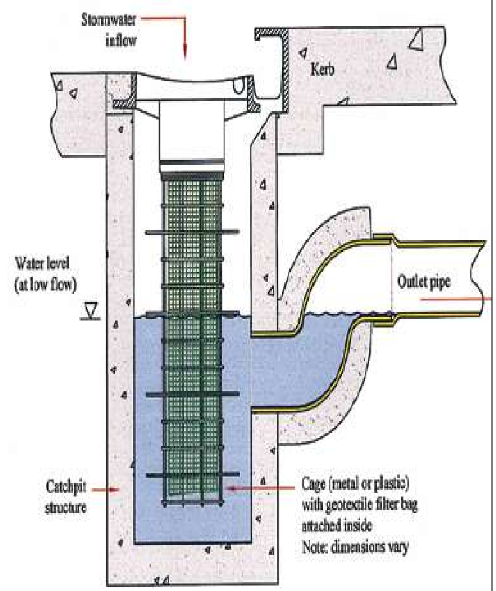
Permeable pavement

<table>
<tr><td>Primary function(s)</td><td>Flow attenuation
●</td><td>Treatment
●</td><td rowspan="5">
Car park at Parr’s Park, Auckland</td></tr>
<tr><td>Receives water from</td><td colspan="2">Car park or yard areas</td></tr>
<tr><td colspan="3">Description
• a pavement that is specifically designed to facilitate and maximise infiltration of rainfall through the pavement for stormwater benefit.
• final disposal generally is by infiltration to underlying ground but they can be used where final disposal is via a piped reticulation or to surface water.
• includes
o porous concrete and porous asphalt
o plastic modular systems
o interlocking concrete paving blocks (including modular blocks and lattice blocks)</td></tr>
<tr><td colspan="3">Applications, attributes, do’s and don’ts
• primarily parking areas, low volume roadways or driveways
• particular care is need in the design of the pavement foundations with respect to effects of infiltration, traffic loads, the nature of the subgrade and pavement durability
• there are potentially significant issues with respect to blinding of the surfaces of permeable pavements with fine material. This may in some situations be able to be prevented or minimised by ongoing maintenance, for example using suction devices. May require removal and replacement of pavers for renovation</td></tr>
<tr><td colspan="2">Covered in this guideline in section</td><td>5.6</td></tr>
</table>

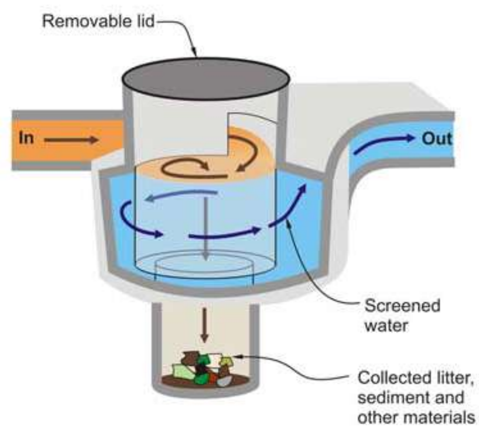
Treatment trench / rock filter

<table>
<tr><td>Primary function(s)</td><td>Flow attenuation
●</td><td>Treatment
●</td><td rowspan="5">
</td></tr>
<tr><td>Receives water from</td><td colspan="2">Car park or yard areas</td></tr>
<tr><td colspan="3">Description
• a trench or gravel bed that is specifically designed to treat runoff from hard stand areas
• comprises clean gravel and has a piped outlet where final disposal is by a pipe to piped reticulation or to surface water.
• can be used for peak flow attenuation and extended detention
• no published guidelines on design and performance
• monitoring of installations has shown reduction in metals and hydrocarbons</td></tr>
<tr><td colspan="3">Applications, attributes, do’s and don’ts
• applicable for driveways, parking areas, can be use in conjunction with permeable paving
• care is needed with respect to effects of infiltration, on adjacent pavement or building foundations – may require a liner
• requires provision for flushing to remove accumulated sediment, slime
• do not site where large sediment loads may occur
• care needed with filter fabric selection</td></tr>
<tr><td colspan="2">Covered in this guideline in section</td><td>5.7</td></tr>
</table>

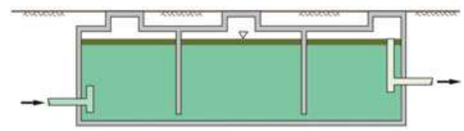
Catchpit insert

<table>
<tr><td>Primary function(s)</td><td>Flow attenuation
O</td><td>Treatment
●</td><td rowspan="6">
</td></tr>
<tr><td>Receives water from</td><td colspan="2">Roads, parking areas, commercial/industrial sites</td></tr>
<tr><td colspan="3">Description
A proprietary device in the form of a fine-mesh filter bag which hangs inside a standard catchpit to intercept sediments in the incoming stormwater. Key features include:
• units are generally made-to-measure
• includes a high-flow bypass to avoid surcharging
• mesh bag (typical size 200 µ) fits within a steel or plastic frame, to avoid the bag being sucked into the outlet pipe
• the bag must be emptied every 3 – 6 months and replaced with a laundered bag with the bag contents disposed to landfill</td></tr>
<tr><td colspan="3">New Zealand manufacturers/suppliers
Ecosol, Ingal (Enviropod), Hynds</td></tr>
<tr><td colspan="3">Applications, attributes, do's and don'ts
• the frequent maintenance requirement is a key consideration
▪ well-suited to medium-large impervious areas such as car parks and roads
▪ units are reputed to capture 70 - 90% of the incoming sediment of sizes 100 µm and larger</td></tr>
<tr><td colspan="2">Covered in this guideline in section</td><td>5.8</td></tr>
</table>

Gross pollutant traps

<table>
<tr><td>Primary function(s)</td><td>Flow attenuation
O</td><td>Treatment
●</td><td rowspan="6">
</td></tr>
<tr><td>Receives water from</td><td colspan="2">Roads, yards</td></tr>
<tr><td colspan="3">Description
Key features include:
• remove coarse sediment, litter and debris, sometimes oil
• include specifically designed proprietary devices
• includes litter traps, hydrodynamic devices</td></tr>
<tr><td colspan="3">New Zealand manufacturers/suppliers
• Ecosol New Zealand Ltd www.ecosol.com.au
• Hynds Environmental www.hynds.co.nz
• Ingal Environmental Services www.ingalenviro.com
• Bisleys Environmental Ltd www.bisleys.net</td></tr>
<tr><td colspan="3">Applications, attributes, do’s and don’ts
▪ Often used at the head of a treatment train, for example to prevent coarse sediment entering a wetland or other stormwater treatment device
• intended to remove only coarse sediment, litter and debris, unlikely to remove fine sediments or soluble contaminants
• can be retrofitted into existing development sites
• ongoing operation and maintenance, including sediment removal can be expensive</td></tr>
<tr><td colspan="2">Covered in this guideline in section</td><td>5.9</td></tr>
</table>

Oil and water separator

Primary function(s)	Flow attenuation O	Treatment ●	 API Oil and Water separator
Receives water from	Paved areas prone to hydrocarbon contamination, for example service stations		
Description Primarily aimed at removing oil from stormwater at sites where hydrocarbon products are handled and small spills regularly occur on paved surfaces. Can include specifically designed devices as well as proprietary devices.			
New Zealand manufacturers/suppliers • Alpha Environmental (Nelson) • Ecosol www.ecosol.com.au • Hynds Environmental Systems Ltd www.hynds.co.nz • Maskell Productions www.maskell.co.nz • Westfalia Separator NZ Ltd www.westfalia-separator.com			
Covered in this guideline in section	**5.10**		

2.6 References

Publications

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Auckland Regional Council. 2003. *Stormwater treatment devices design guidelines manual.* ARC Technical Publication No.10 (ARC TP10). http://www.arc.govt.nz/arc/index.cfm?34C9C2A8-1BCF-4AA1-91AF-CC49CFE4A80C.

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Western Australia: *Manual for managing urban stormwater quality in Western Australia* (Water and Rivers Commission, 1998) (currently under review) http://www.wrc.wa.gov.au/protect/stormwater/smm.htm

3. Selection and design of stormwater devices

In this section:

Where this guideline recommends a procedure, the following format is used:

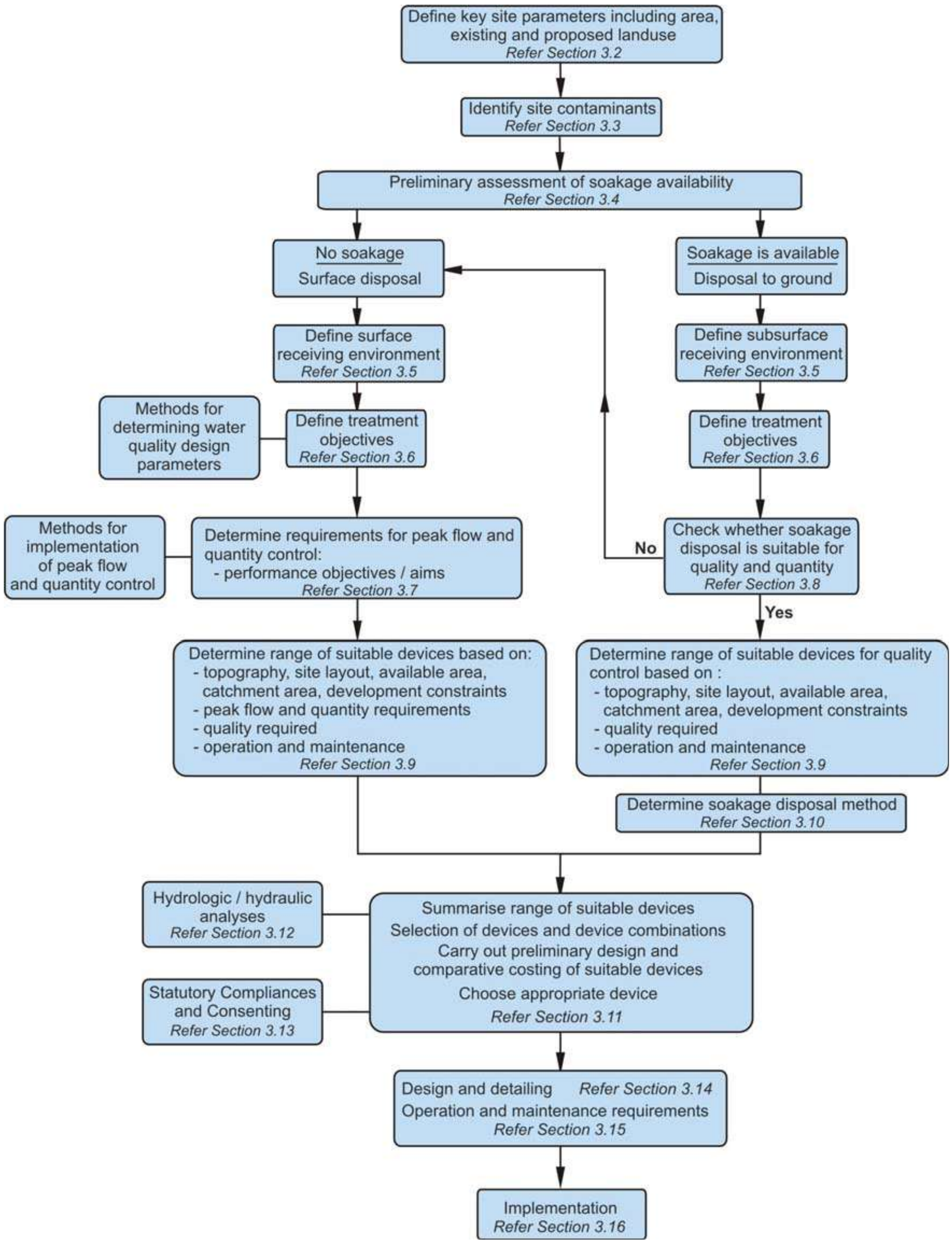
RECOMMENDATIONS

Relevant steps in bold font

Where particular caution needs to be exercised, the following format is used:

Cautionary advice is given in a box next to a red flag.

Figure 3.1 Selecting and designing on-site stormwater management devices



3.1 Overview of this section

The primary focus of these guidelines is on stormwater management devices to provide:

- water quality treatment with final disposal to surface water or to ground soakage or infiltration
- peak flow and quantity reduction for sites where final disposal is to surface water

There will be some situations where primary disposal is to ground soakage and secondary or larger flows disposed to surface water.

The structure of this section reflects the separate ground or ground soakage disposal options by:

- describing the treatment performance of stormwater quality treatment devices where final disposal may be to surface water or ground soakage, depending on the site conditions, as addressed in this section
- a separate discussion of devices that dispose stormwater to ground soakage

Before or during the processes in this section, it is necessary to assess whether on-site stormwater management is appropriate for a particular site, in comparison, for example, with catchment or neighbourhood based management approaches or devices (refer Sections 1.6 and 1.8).

The generic process for selection and design of on-site stormwater treatment devices is shown in Figure 3.1, on the previous page. The process follows a logical progression:

- site description: defining key parameters
- identifying site contaminants
- preliminary assessment of soakage availability
- defining the receiving environment
- determining stormwater quality objectives
- confirming the suitability of soakage and describing soakage disposal methods
- determining requirements for peak flow and/or quantity control
- identifying a range of suitable devices
- developing options using a variety of devices
- preliminary design of and comparative costing of suitable devices
- selecting appropriate devices
- detailed design of devices and operation and maintenance (O&M) requirements

> The selection process includes a decision step early in the process to address whether or not on-site soakage is a viable disposal option. This is important because although ground disposal can potentially avoid the many design steps needed to prevent adverse effects of stormwater on surface receiving environments, ground disposal systems do not suit many soils, geological and topographical conditions.

The detailed procedures in each step in the decision process are described next.

3.2 Define key site parameters

In this subsection:

- site area
- land use
- slopes
- soil type
- natural site features
  - streams
  - bush
  - heritage

3.2.1 Area and land use

Site parameters that determine the stormwater characteristics of stormwater runoff from the site include:

- total site area
- impervious site area (roof and on-ground)
- pervious area and cover type (for use in later run-off calculations)
- land use

Land use categories with impervious areas include:

- urban (high density) residential, commercial and industrial sites
- suburban (low density) residential, commercial and industrial sites
- rural residential, commercial and industrial sites
- subsections of the above including:
  - car parks
  - access drives
  - roads
  - storage or loading areas – specify the type of operation and types of materials handled or stored, e.g. fuel dispensing facilities, above-ground storage of liquid materials, solid waste storage areas, containers, compactors, storage of compost or fertiliser, storage of treated timber. This information will indicate expected contaminants in stormwater

3.2.2 Site slopes

Determine the slope of the catchment areas that contribute to proposed on-site devices. This is used to calculate the time of concentration used in calculation of runoff flow rates.

Determine the slope of land at the likely device location. This may affect the types of devices that can be used or to slope stability issues that might affect the disposal method.

3.2.3 Soil type

Determine the type of soil in the catchment areas that contribute to proposed on-site devices. This is used to assess appropriate factors used in calculation of runoff flow rates. Soil type generally will not have major relevance to assessment of treatment requirements, as this guideline assumes site stabilisation has been completed and sediment from bare soil will not provide major inputs to treatment devices.

Determine the type of soil at the likely device location. This may be relevant to the types of devices that can be used or to slope stability issues that might affect the disposal method and to assist with assessment of soakage availability for disposal.

The type and design of the mechanism for final disposal of site stormwater to surface water should take into account soil type and prevention of erosion. This aspect is beyond the scope of this guideline.

3.2.4 Natural site features

Important natural site features should be noted and marked on a site plan. These will include but not necessarily be limited to:

- streams
- bush areas
- heritage such as areas of archaeological significance

The development of stormwater management options for a site should include consideration of the natural site features and protection and enhancement of them if practicable.

3.3 Identify contaminants in stormwater from the site

In this subsection:

- a general guide to contaminants in stormwater from various site land uses
- a guide to contaminants in stormwater from specific industry types

The nature and form of contaminants in stormwater runoff from urbanised or developed sites is complex. These guidelines do not provide a detailed description of contaminants. The user is referred to other references for a detailed description, including:

- Williamson, 1986, *Urban Runoff Data Book: a Manual for the Preliminary Evaluation of Urban Stormwater impacts on Water Quality*, NIWA Water Quality Centre Publication No. 20
- Auckland Regional Council, 2003, *Stormwater Treatment Devices: Design Guideline Manual*, ARC Technical Publication No. 10 (ARC TP10)
- Auckland Regional Council, 1995, *The Environmental Impacts of Stormwater Runoff*, ARC Technical Publication No. 53 (ARC TP53)
- Christchurch City Council, 2003, *Waterways, Wetlands and Drainage Guide*, (CCC 2003)
- Transfund New Zealand Research Report No. 228 (2002), *see references*

Table 3.1 is a general guide to contaminants in stormwater from various site land uses.

Table 3.2 is a guide to contaminants in stormwater from specific industry types. It lists industries where typical practices include activities on uncovered areas that can lead to contaminants being entrained in stormwater. The list is not exhaustive and may not include some industries where stormwater contamination may regularly occur. On some industrial sites potential accidental spillage of product could lead to stormwater contamination. The list contains some activities for which the water discharges are more properly described as wastewater, for example car washing, steam cleaning and water blasting. Such discharges may require appropriate separate treatment or discharge to a sewer, subject to the appropriate approvals.

At this stage of the site stormwater management selection process it is important to investigate possible **source control** measures that can be carried out to reduce or prevent contaminants entering stormwater. If this can be achieved it removes the need to provide treatment for those contaminants.

Common examples where source control is likely to be a more appropriate option than providing treatment of stormwater practice are:

- painting galvanised iron roofs to prevent zinc entering stormwater
- avoiding the use of copper roofing and guttering materials and those incorporating permanently exposed zinc coated surfaces
- covering stockpiles of soil or waste products on industrial sites
- directing wash water to the sanitary sewer
- covering dirty work areas such as truck washes

Table 3.1 General guide to contaminants in stormwater

Source: ARC TP10

Land use	Contaminant (refer key below for abbreviations)								
	pH	SS	HC	ME	OD	NU	PA	TO	LI
Residential roofs	✓	?		✓?	✓?	✓?	?		
Residential: paved, parking driveways		✓	✓	✓	✓?	✓	✓		✓
Residential grassed areas		✓?			✓	✓	✓		✓
Roads and road berms		✓	✓	✓	✓	✓	✓		✓
Commercial: roofs	✓	?		✓?	?	?	?		
Commercial: paved, parking, driveways, yards		✓	✓	✓	✓?	?	✓	?	✓
Commercial landscaped, grassed areas		✓?			✓?	✓	✓		✓
Industrial: roofs	✓			✓?	?	?	?		
Industrial: paved, parking driveways, yards	?	✓	✓	✓	✓?	?	?	?	✓
Water blasting		✓		✓?	✓?				
House painting		✓			✓?				

Key to abbreviations of contaminants:

- pH power of hydrogen
- SS suspended solids
- HC hydrocarbons, including TPH and PAHs
- ME heavy metals (lead, zinc and copper)
- OD oxygen demanding substances (generally particulate organic matter)
- NU nutrients (nitrogen and phosphorus)
- PA pathogens including bacteria
- TO toxic organics, including for example antisapstain chemicals on timber treatment sites, chlorinated hydrocarbons and other toxic chemicals used on industrial sites
- LI litter
- ? uncertain, dependant on land use activities, e.g. type of industrial activities and material e.g. type of roof material

Note that for residential roofs the contaminants of concern can generally be addressed by source control measures, for example avoiding bare zinc or copper surfaces and regular cleaning of gutters to prevent accumulation of organic material. Such source control practices can avoid the need for treatment. Similar source control measures may be appropriate for roofs in or near industrial and commercial sites. However accumulation of atmospheric emissions from industry need to be considered when addressing potential contaminants in roof water.

It is important to determine whether the following contaminants in stormwater are attached to sediment, i.e. are in particulate or soluble form, as this will influence the selection of the appropriate treatment device and / or treatment media:

- hydrocarbons
- metals
- toxic organics

Table 3.2 Industry activity and associated contaminants

Sources: ARC TP10; Environment Waikato Proposed Regional Plan, Appeals version 2002

Industry / activity	Contaminant (refer key below for abbreviations)								
	pH	SS	HC	ME	OD	NU	PA	TO	LI
Mechanical workshops, service stations, refuelling areas		✓	✓	✓				?	
Spray painting facilities spray drift								✓	
Wood preserving outside storage of timber		✓	✓	✓	✓			?	
Agricultural chemicals, fertilisers-outside storage		✓		✓	✓	✓		?	
Asphalt, paving and roofing materials		✓	✓	✓	✓			?	
Concrete products yard activities	✓	✓		✓	✓				
Iron steel lead foundries yard areas	✓	✓		✓	✓				
Waste management sites transfer stations, landfills, composting		✓	✓	✓	✓	✓	✓		✓
Automobile dismantler yards-yard		✓	✓	✓				?	✓
Scrap recycling yards		✓		✓	✓			?	✓
Bakeries with outside washing of trays etc.				✓	✓	✓	✓		
Furniture / wood manufacturing and refinishing – outside activities sawdust	✓	✓			✓				
Car wash and valet		✓	✓	✓	✓				
Steam cleaning		✓	✓		✓				
Stock sale yards		✓			✓	✓	✓	✓	

Key to abbreviations of contaminants:

pH power of hydrogen
SS suspended solids
HC hydrocarbons, including TPH and PAHs
ME heavy metals (lead, zinc and copper)
OD oxygen demanding substances (generally particulate organic matter)
NU nutrients (nitrogen and phosphorus)
PA pathogens including bacteria
TO toxic organics, including for example antisapstain chemicals on timber treatment sites, chlorinated hydrocarbons and other toxic chemicals used on industrial sites
LI litter
? uncertain, dependant on land use activities, e.g. type of industrial activities and material e.g. type of roof material

3.4 Preliminary assessment of soakage availability

In this subsection:

- assessing geological conditions
- identifying suitable subsurface materials
- preliminary assessment of slope stability considerations

A preliminary assessment determines whether disposal of stormwater by soakage is likely to be possible. This procedure is relevant for sites where preliminary analysis indicates that all or a significant proportion of site stormwater can be disposed to ground soakage via specially designed devices. It does not assess the viability of utilising existing vegetation or the potential for planting additional vegetation to counteract the effects of increased impervious areas on other parts of a site (low impact development principles). Soakage disposal via on-site devices can be used in conjunction with vegetation retention or augmentation if conditions are suitable.

3.4.1 Assess hydrogeological conditions

A depth of at least 3 metres of permeable subsurface material is required for good long term soakage. Suitable permeable material may be at some depth below shallow impermeable material. This assessment can be based on the following sources:

- local knowledge of subsurface conditions and performance of existing stormwater soakage systems, for example from adjacent landowners, drainage contractors, builders, well drillers
- geological maps
- information held by territorial councils and available from LIMs
- information held by regional or unitary councils
- land use capability information held by other organisations such as Landcare Research
- preliminary field investigation such as boreholes or excavated pits

Suitable subsurface material for ground disposal of stormwater by soakage is likely to be one or a mix of the following:

- sand (some clay, silt or loam content may be acceptable)
- gravel
- fractured rock for example basalt
- scoriaceous material
- pumice
- limestone - sink holes, karst terrain (care needed to use these for disposal, consult with the regional council)

The base of soakage devices should be a minimum of 600 mm above the seasonal high water table (Georgia Stormwater, 2001).

- soakage disposal may be viable in permeable soils that are overlain by surface soils that are of low permeability
- soakage disposal should not be used at sites that are known or suspected to be contaminated and there is a risk of such contamination entering stormwater or leaching to groundwater
- soakage disposal should not be to areas of fill material unless sufficient investigation has been carried out to determine that long term disposal by soakage is viable and effects on land stability have been addressed
- valley floors or other areas that may have significant groundwater inflows should not be used for soakage disposal
- the presence of a water supply or high quality underlying aquifer may affect suitability , or influence the design details, particularly for industrial sites (see below)

3.4.2 Preliminary assessment of site stability

Slopes and soils are the key indicators of likely stability:

- ARC TP10 recommends that infiltration practices shall not be constructed on slopes exceeding 15%
- University of Technology Sydney SWITCH design (2001) states:
  - stormwater infiltration is a type of on-site retention (OSR)
  - British practice places a limit of 5% on the land-slope where water retention is recommended. This is less slope-dependant and more related to the soil/rock conditions likely to be encountered in steep terrain
  - a simple guideline is that a depth of suitable soil of at least 3m should be available throughout a downslope developed hillside before on-site retention should be contemplated

RECOMMENDATION

This guideline recommends that infiltration or soakage practices should not be considered on or adjacent to slopes steeper than 5%, without detailed geotechnical investigations that establish their viability.

3.4.3 Summary of preliminary assessment of soakage availability

The main preliminary assessment criteria are:

- local experience - is it successfully carried out nearby and under similar conditions?
- subsurface soils of sufficient permeability
- sufficient depth to water table
- no risk of slope instability due to infiltration of stormwater
- risk of subsurface contamination: for commercial or industrial sites where soakage disposal would be to an aquifer of high quality groundwater, soakage disposal may not be desirable due to risks of contamination from contaminated runoff or spills of toxic substances

Stormwater soakage disposal has been used in various areas of New Zealand in silt or clay subsoils, despite the fact that their limited permeability generally allows only partial disposal of site stormwater. Although such disposal may be of limited environmental benefit for groundwater recharge, for the purposes of this guideline stormwater disposal to silt or clay soils is not considered viable for long term disposal of site stormwater.

3.5 Define receiving environment and determine sensitivity to contaminants

In this subsection:

- assessing receiving environment sensitivity to contaminants in stormwater:
    - contaminants of concern for surface water
    - sensitivity of types of groundwater to contaminants
- determining the water quality objectives for stormwater quality management (or the degree of treatment required for site stormwater)

The first step in assessing the sensitivity of the receiving environment to contaminants is to clearly define the receiving environment, including:

- surface waters:
    - immediate receiving environment: watercourse, channel or stream immediately below the site
    - ultimate receiving environment: estuary, lake or coastal marine area the site discharges will eventually enter
- reticulated outfall point: where site stormwater discharges to a reticulated system, the receiving environment will be:
    - where the pipe reticulation discharges and
    - downstream of that point
- ground soakage: the aquifer or subsurface material

Check the site land use and site areas determined in section 3.1 against the following documents for any specific comments about the sensitivity of the receiving environment in relation to physical location and land use:

- regional policy statement
- regional plan
- district plan
- any relevant catchment management plans or structure plans
- relevant reports on the receiving environment (ARC TP10 and TP53 are good references on the environmental effects of urban stormwater runoff)
- national or other strategies for example the low impact urban design guidelines

Also check with appropriate regional council staff, unitary council staff or territorial authority staff and pipe network utility operator where relevant, about the particular aspects of the receiving environment and any requirements for stormwater quality control.

3.5.1 Surface water sensitivity

It is important to identify the key contaminant/s of concern so as to ensure use of the appropriate devices. These vary widely, for example (Greg Paterson, pers. comm. May 2004):

- nutrients affecting eelgrass beds off the Florida coast
- hypodermic syringes on Sydney beaches
- zinc in Auckland

The contaminants of concern in stormwater for surface water receiving environments are listed in Table 3.3.

Table 3.3 Indicative stormwater contaminants of concern for surface water

Description of receiving environment / values					
Stream, river, or lake used for water supply	**Stream, river or lake used for fishing**	**Stream, river, lake: potential nutrient enrichment concern**	**Estuary: Sediment accumulation and shellfish**	**Used for contact recreation**	**Visual and other amenity values**
pH	pH		pH		
SS	SS	SS	SS	SS	SS
HC	HC	HC	HC	HC	HC
ME	ME	ME	ME	ME	
OD	OD			OD	OD
NU		NU			
PA	PA		PA	PA	
TO	TO	TO	TO	TO	
				LI	LI

Key to abbreviations of contaminants:

pH power of hydrogen
SS suspended solids
HC hydrocarbons, including TPH and PAHs
ME heavy metals (lead, zinc and copper)
OD oxygen demanding substances (generally particulate organic matter)
NU nutrients (nitrogen and phosphorus)
PA pathogens including bacteria
TO toxic organics, including for example antisapstain chemicals on timber treatment sites, chlorinated hydrocarbons and other toxic chemicals used on industrial sites
LI litter

3.5.2 Sensitivity of types of groundwater to contaminants

For the purposes of these guidelines the following categories of groundwater are considered to be sensitive to contamination from stormwater (others may also do so, depending on the local situation):

- currently or potentially used for water supply
- shallow groundwater discharging to a surface water body used for water supply
- shallow groundwater discharging to a river, lake or stream where there is concern about nutrient enrichment

Table 3.4 Indicative stormwater contaminants of concern for groundwater

Note: it is assumed that all stormwater discharged to groundwater has been treated to reduce suspended solids to low levels to avoid clogging of the disposal system. The suspended solid constituent in itself is thus not a contaminant of concern to the receiving environment.

Identification of the contaminants of concern has been made from general literature reviews and these sources have not been specifically referenced (see list of references).

Description of groundwater			
Currently or potentially used for water supply	**Shallow groundwater discharging to a surface water body used for water supply**	**Shallow groundwater discharging to a river, lake or stream where there is concern about aquatic health**	**Shallow groundwater discharging to a river, lake or stream where there is concern about nutrient enrichment**
pH	pH	pH	
HC	HC	HC	
ME	ME	ME	
OD?		OD	
		NU	NU
PA	PA	PA	
TO	TO	TO	

Key to abbreviations of contaminants:

pH	power of hydrogen
SS	suspended solids
HC	hydrocarbons, including TPH and PAHs
ME	heavy metals (lead, zinc and copper)
OD	oxygen demanding substances (generally particulate organic matter)
NU	nutrients (nitrogen and phosphorus)
PA	pathogens including bacteria
TO	toxic organics, including for example antisapstain chemicals on timber treatment sites, chlorinated hydrocarbons and other toxic chemicals used on industrial sites
LI	litter

3.6 Determine water quality objectives for stormwater quality management

In this subsection:

- setting allowable discharge concentrations
- best practical option (BPO) or best management practice (BMP)
- BPO design approaches
  - description of stormwater quality volume
  - removal of a specific proportion of the total suspended solids on a long-term basis
  - calculation of water quality design storm and water quality volume
  - capture and treatment of the first flush
  - recommendations for using a water quality volume approach
- recommended procedure to determine stormwater quality design flows
  - device assessment and sizing for water quality treatment
  - summary of recommended BPO / BMP approach for water quality design parameters for these guidelines

Water quality objectives determine the degree of stormwater treatment required. There are two alternative generic approaches to determining the water quality objectives for stormwater quality management:

- setting allowable discharge concentrations
- best practical option (BPO) or best management practice (BMP)

In stormwater management the instantaneous discharge quality can be important, together with the cumulative effects of discharges of contaminants where contaminants accumulate at particular locations.

3.6.1 Setting allowable discharge concentrations

Allowable concentrations in stormwater of contaminants of concern are typically based on:

- available water quality guidelines
- regional plan rules
- detailed site specific assessment
- resource consent conditions

Setting discharge concentrations for stormwater is often not appropriate because of:

- lack of information on allowable concentrations
- the difficulty of setting appropriate allowable concentrations due to variations in receiving environments and the need to address cumulative effects
- the difficulty of representative sampling of runoff events to ensure compliance with concentration limits

Environmental exposure limits (EELs) have been established under the Hazardous Substances and New Organisms Act 1996 (HSNO) for a number of hazardous substances. They establish a conservative environmental guideline for the receiving environment after mixing and are available from http://www.ermanz.govt.nz/hs/hs-comp-eels.asp .

The use and adoption of EELs under the RMA is currently under review by the Environmental Risk Management Authority (ERMA) and the Ministry for the Environment. For industrial and commercial sites where toxic organic or other substances for which EELs have been established under HSNO may enter stormwater, setting of an allowable discharge concentrations in stormwater discharges may be appropriate.

3.6.2 Best practical option or best management practice

The definition of best practical option (BPO) in the RMA for discharge of contaminants is the best method for preventing or minimising the adverse effects on the environment having regard, among other things, to:

- the nature of the discharge and the sensitivity of the receiving environment to adverse effects; and
- the financial implications, and the effects on the environment, of that option when compared with other options; and
- the current state of technical knowledge and the likelihood that the option can be successfully applied

The BPO approach is generally considered appropriate for treatment of stormwater discharges because of the:

- impracticality and expense of carrying out detailed site specific assessments to set allowable concentrations for site stormwater discharges
- difficulty of representative sampling of runoff events to ensure compliance with concentration limits
- it provides greater certainty of treatment requirements for consent applications and of outcomes for environmental regulators

3.6.2.1 BPO approach for water quality

The BPO approach can be either regional or site specific:

- regional or city-wide
    - a region wide study is carried out to determine appropriate sizing of various devices relative to performance, rainfall characteristics, soils etc. and the regulator then sets regional standards and requires these to be met. For example water quality volume (WQV)
    - the stormwater practitioner/designer uses regional standards to calculate water quality volume and size and design the device
- site specific (where there is no regional or city-wide guideline)

The stormwater practitioner / designer:

- assesses a range of device sizes using local rainfall data and soil / contaminant characteristics
- selects a suitable size of device based on balancing cost versus performance
- the ideal analysis method is continuous series analysis and accumulated volumes of contaminants removed and discharged

3.6.2.2 Auckland Regional Council approach

The ARC approach is to capture 75% of total suspended sediment on a long term average basis. This is the water quality objective of ARC TP 10 and is also the treatment objective of a number of overseas agencies (Seyb, 2001, *A revised stormwater treatment design methodology for the new TP10*, 2nd South Pacific Stormwater Conference 2001**).**

The water quality design storm for the ARC method has been developed from detailed analysis of long term rainfall records at one rain gauge, which yielded a water quality design storm depth of 25 mm, equivalent to one third of the 2 year ARI daily rainfall at this location. The ARC method provides for the water quality design storm to be calculated for any location in the region by dividing the 2 year ARI daily rainfall at that location by a factor of 3. For the Auckland region the water quality design storm depths are:

- range over the Auckland region: from 16.7mm to 43.3 mm
- most of the urbanised area: 26.7 mm

The ARC method provides for using the water quality design storm together with catchment physical characteristics to calculate a 'water quality volume' for the catchment area contributing to a device. This method is calculated in TP108 (Auckland Regional Council, 1999, *Guidelines for stormwater runoff modelling in the Auckland region*, ARC Technical Publication No. 108) using the US Soil Conservation Service rainfall-runoff model, based largely on its Technical Release No. 55 (SCS 1986). The model takes into account rainfall losses based on ground cover and soil type. It also allows calculation of peak flows taking into account rainfall temporal pattern. Peak flows associated with the water quality design storm can be calculated for use in design of devices such as swales.

ARC TP10 then stipulates in its design methodology for different devices:

- the proportion of the WQV to be captured for ponds, wetlands, filters, rain gardens
- a nominated hydraulic retention time for the water quality flow rate for swales

3.6.2.3 Christchurch City Council approach

CCC (2003) states that:

- the principle of first flush capture should be used to treat stormwater from hard standing areas
- care should be exercised in considering stormwater runoff that has high concentrations of dissolved metals
- any dissolved contaminants that have particulate forms (e.g. metals), don't always show a first flush effect because their concentrations usually depend simply on the presence, not the amount, of their particulate forms
- for particulate contaminants in small stormwater catchments, the first flush effect will usually be pronounced
- if a treatment system can be constructed close to a stormwater source , only the first flush need be captured and treated
- the critical component of the first flush system is the bypass for stormwater in excess of the first flush volume

Environment Canterbury consent CR C000315 (granted to the Christchurch City Council for green fields development in the Upper Heathcote / Wigram area) requires capture and treatment of the first 12.5 mm of all rainfall events prior to discharge to ground. This first flush interception will achieve treatment of 58% of the Christchurch average annual rainfall depth falling on the recipient catchment.
A suggested requirement within Environment Canterbury's Draft Canterbury Natural Resources Regional Plan (2002) is for first flush to be considered as the first 15 mm of all rainfall events

followed by 72 hours detention prior to discharge to surface water. Christchurch City Council recommends as best practice the capture of runoff from the first 25 mm of storm rainfall depth, but not less than 15 mm. average detention time prior to discharge to surface waters should be at least 24 hours. To be effective in treating dissolved pollutants, detention time in wetlands and wet ponds should be longer.

The CCC (2003) method uses average effective impervious area percentages based on land use zonings to calculate first flush volumes. The CCC (2003) first flush method is limited to the design of ponds and wetlands. For design of swales it refers to ARC TP10.

3.6.2.4 Review of water quality volume and first flush approaches and applicability New Zealand wide

The ARC and Christchurch City Council (CCC 2003) approaches of water quality design storm and first flush rainfall are similar to each other and comparable with many overseas stormwater quality best management approaches.

As detailed modeling to assess water quality rainfalls and appropriate proportions of the water quality volume to be captured for various devices has not been carried out regionally in all areas of New Zealand a simplistic approach has been taken to determine approximate water quality rainfalls throughout New Zealand.

This has comprised a review of the 2 year ARI daily rainfalls for representative areas throughout New Zealand using HIRDS.

The results are in Table 3.5 and show that for the locations listed in Table 3.5, the New Zealand-wide range is reasonably similar to the range within the Auckland area. The Christchurch City value of 18.8 mm for the one third of the 2 year daily rainfall depth is above the minimum depth of 15 mm, but less than the best practice value of 25 mm of the Christchurch City Council’s recommended method for runoff capture (CCC, 2003).

Table 3.5 Summary of one third of 2 year 24 hour rainfalls at selected locations

Location	One third of 2 year 24 hour rainfall (Calculated from HIRDS) (mm)
Kaitaia	28.9
Whangarei	37.4
Auckland region	Range: 16.7mm to 43.3 mm Most of urbanised area: 26.7
Hamilton	20.8
Tauranga	33.4
Taupo	24.3
Gisborne	32.6
Napier	25.3
New Plymouth	30.8
Palmerston North	17.2
Wellington	24.4
Nelson City	23.8
Westport	33.7
Blenheim township	20.3
Hokitika	42.1
Christchurch City	18.8
Queenstown	19.3
Dunedin	20.7
Invercargill	15.0

These values are indicative only, for the purposes of a general review of variation throughout New Zealand. There can be considerable local variation in rainfall. Use of HIRDS or equivalent or other relevant locally derived data is recommended to establish site specific values.

3.6.3 Recommendations for using a BPO approach for determining water quality volume

Water quality volume determination requires assessment of a water quality design storm followed by determination of the water quality volume.

RECOMMENDATIONS

For these guidelines it is recommended that in the absence of detailed local or regional analyses to determine water quality design storms the approximate water quality design storm be assessed by dividing the 2 year ARI 24 hour rainfall by a factor of 3. The 2 year ARI 24 hour rainfall data can be derived from analysis of local rainfall data or using HIRDS. This approach is relatively simplistic and must be used with caution. In particular:

- **it should be used only for devices serving small catchments so that any inaccuracies in rainfall depths and associated water quality volumes does not have a significant impact on sizing and device cost**
- **for larger catchments or for individual devices with significant capital cost, more detailed analyses of rainfall records and device performance are likely to be appropriate**

It is recommended that territorial local authorities, unitary councils and regional councils arrange for analysis of local rainfall records and other aspects of treatment devices to arrive at accurate local or regional quality design storms. Local rainfall data may be available from a regional council, the Meteorological Service or NIWA.

The methods currently recommended in other New Zealand guidelines for determining the water quality volume, i.e. runoff to a device from a water quality rainstorm, are:

- ARC TP10: rainfall-runoff curves, with curve numbers determined by soil types. This is based on the US Department of Agriculture, Soil Conservation Service publication, Urban hydrology for small watersheds, Technical Release No.55 (SCS 1986). This method is described for use in the Auckland region in ARC TP 108, Guidelines for stormwater runoff modeling in the Auckland region
- a simplified method such as in Christchurch City Council (CCC 2003) in which catchment percent effective impervious areas are estimated from land use and runoff is assumed to be generated only from impervious areas

RECOMMENDATIONS

For this guideline, for areas outside the Auckland Regional Council and Christchurch City areas, the following method is recommended:

1. **Determine impervious and pervious contributing areas draining to a device. Note that for device water quality design purposes, the amount of pervious area contributing to the device often is relatively small or zero. This will not be the case where there are specific concerns about the effect of contaminants from pervious areas e.g. nutrients and treatment of runoff from pervious areas is required.**
2. **For impervious areas: runoff depth = water quality design storm depth less an allowance for depression storage: an allowance of 2 mm is recommended, unless site conditions give reason to allow a different amount.**
3. **For pervious areas: runoff depth = water quality design storm depth less an allowance for depression storage and infiltration into the ground:**
    - **the allowance for depression storage and infiltration into the ground will depend mainly on the subsoil drainage**
    - **for poorly drained subsoils: for example sandstone, siltstone, other fine grained slowly draining soils: an allowance for depression storage and infiltration into the**

ground of 15 mm is recommended unless site conditions and / or local knowledge give reason to allow a different amount

- **for well drained soils, for example pervious volcanic ash soils, the user is advised to carefully evaluate likely depression storage and infiltration based on the site conditions (topography and soil infiltration) as well as the amount of pervious area contributing to a device and whether all the design rainfall could be stored or would infiltrate. The allowance for depression storage and infiltration is recommended to be between 15 mm and the water quality design depth, based on the site assessment. Note that for sites where there are small amounts of contributing pervious area compared with impervious areas, the accuracy of the allowance for likely depression storage and infiltration will not be important**

3.6.4 Recommendations for using a BPO approach for determining stormwater quality design flows

Some devices such as swales and filter strips require calculation of a water quality design flow. ARC TP10 recommends that water quality design flows are calculated using the method of ARC TP108. For Christchurch City, CCC (2003) recommends the method of ARC TP10 also. This method uses rainfall data and other hydrological relationships and can be used anywhere, subject to parameter calibration for that region. For the Auckland region, swale and filter strip design assumes the time of concentration is 10 minutes. The design rainfall intensity is obtained by multiplying the water quality storm depth (mm) by a factor of 0.675 to obtain the relevant rainfall intensity (for a time of concentration of 10 minutes) in mm per hour.

RECOMMENDATIONS

For this guideline it is recommended that, for areas outside Auckland where the method of ARC TP108 has not been calibrated for local conditions, water quality design flows be calculated using standard hydrological methods such as the rational method, using the local rainfall intensity for one third of the 2 year 10 minute rainfall.

3.6.5 Summary of recommended procedure to determine water quality treatment objectives and water quality design parameters

RECOMMENDATIONS

1. **Identify site contaminants from Section 3.3, noting that this assessment should include incorporation of source control where appropriate**
2. **Define receiving environment and contaminants of concern, refer section 3.5**
3. **Compare contaminants of concern with the contaminants from the site and determine list of contaminants that require treatment**
4. **Decide on appropriate water quality objective procedure for each contaminant of concern. This could be one or more or a combination of the following:**
    - **determine allowable concentrations, if feasible and practical. This is generally unlikely to be practical for small sites or for general urban areas but may be appropriate for large (over 1 ha) commercial sites or for industrial sites that discharge to a sensitive environment**
    - **BPO / BMP approach. This is likely to be the preferred approach at present for most situations in New Zealand**
5. **Tabulate the contaminants that require treatment and the treatment aim, taking into account potential upper limit treatment efficiencies to be achieved by BPO/BMP devices (refer Table 3.6)**

6. Calculate water quality volumes using section 3.6.3

7. Calculate water quality peak flows using Section 3.6.4

Table 3.6 Potential upper limit treatment efficiencies

Source: ARC TP10; Christchurch City Council (2003)

Note: These are likely upper limit efficiencies that can be provided by treatment devices assuming a BPO water quality approach. Detailed discussions of the contaminant removal efficiency of treatment devices are in ARC TP10 and CCC (2003)

Contaminant		**Removal efficiency**	**Comment**
pH		Not applicable	
SS	suspended solids	max 80%	
HC	hydrocarbons, totals	max 80%	most reported data is for removal achieved where the contaminant is predominantly in the particulate form
HC	hydrocarbons, soluble		little data
ME	trace metals, totals	max 80%	most reported data is for removal achieved where the contaminant is predominantly in the particulate form
ME	trace metals, soluble		little data
OD	oxygen demanding	max 60%	
NU	nutrients (nitrogen)	max 60%	
NU	phosphorus	max 80%	
PA	pathogens including bacteria	max 100%	For bacteria, little data on other pathogens
TC	toxic chemicals		extremely variable, depending on the contaminant, little data available
LI	litter	not applicable	

At this stage, if contaminants of concern cannot be reduced to concentrations to be acceptable for the receiving environment, a BMP may not be suitable and other practices may be required.

Example: an industrial site with organic toxics from stockpiles of raw materials or product. If final discharge is to a groundwater system used nearby for drinking water or stock water use care needs to be taken. A management option would be to cover stockpiles to prevent contaminants reaching stormwater (source control). If the stockpile is not covered, treatment devices based on a BPO approach may not provide enough treatment. A concentration based water quality objective may then be needed, or it may be decided that final disposal to groundwater is not appropriate.

For sites where there may be spillage of toxic organic substances that could reach the stormwater disposal system, disposal to groundwater may not be appropriate.

For hydrocarbons, trace metals and toxic chemicals, it is necessary to determine whether they are in the particulate or dissolved form, as this will affect the choice of an appropriate device for treatment. Particulates mean that contaminants are attached to suspended solids and can be removed by devices that remove suspended solids, while dissolved means that contaminants are in the soluble form and require specific treatment such as bioretention.

3.6.6 Device assessment and sizing for water quality treatment

The assessment of suitable devices for achievement of water quality objectives is presented in section 3.9. Procedures for designing and sizing a range of commonly devices to meet water quality objectives are presented in section 4 on a device by device basis. Guideline notes with references to suitable design methods for devices not covered in detail in Section 4 are presented in section 5.

3.7 Requirements for peak flow and quantity control and performance requirements / aims

In this subsection:

- flood protection
- stream channel protection
- recommended procedure for determining the need for and type of stream channel protection measures

3.7.1 General

For the purposes of this guideline, flow and quantity control by devices may be required where either flood control or stream channel protection is needed downstream.

This section does not address disposal of stormwater by infiltration, which is covered in sections 3.8 and 3.10. It also does not address low stream flow augmentation in detail although some devices used for quantity control will provide this.

Two terms for flood probability are used in this guideline; average recurrence interval (ARI) and annual exceedence probability (AEP). ARI is the average period between exceedences of a given discharge and is generally used in this guideline for discussion of larger flood events such as 10 or 100 year events. AEP is the probability of exceedence of a given discharge within a period of one year and is generally used in this guideline as a percentage. The relationship between AEP and ARI is illustrated by the following examples:

- 1 % AEP = 100 year ARI
- 10% AEP = 10 year ARI
- 50% AEP = 2 year ARI

3.7.2 Flood protection

Flood protection is needed where the increase in peak flood flows and levels downstream of the site that have arisen or can be expected to arise from increases in impermeable areas on the site are reduced or controlled by an on-site device. The usual average flood recurrence intervals are:

- 2 year - relatively frequent
- 10 year – this is the flood for which stormwater reticulation is usually sized
- 50 or 100 year - this is the flood relevant for assessment of flood hazard and protection of habitable floor levels against flooding. The Building Act uses a 50 year recurrence interval, while most TLAs adopt a 100 year interval)

The ARC requirement for control of peak flows for flood protection purposes is that post-development peak discharges for the 2 and 10 year storm events shall not exceed pre-development peaks for these discharges. If there are existing flooding problems downstream, the 100 year post development peak discharge must be be limited to the pre-development peak. This approach appears to be generally applicable with the proviso that control of the 2 and 10 year flows would not be required in the following situations:

- where site stormwater discharges directly to the marine environment where no adverse effects, including scour or erosion, can be shown to result from the stormwater discharge
- other situations where no adverse effects on channels would occur

3.7.3 Stream channel protection

Site development that results in an increase in impermeable areas within a catchment has the effect of increasing the frequency and magnitude of floods, particularly during frequent storm events. The total volume of stormwater runoff also increases significantly. As a consequence streams can suffer an increase in erosion, as they enlarge to cope with larger flows and more prolonged flood flows. North American research has demonstrated that impairment of the quality of streams and lakes due to impervious cover occurs at levels as low as 5 to 15 % impervious cover (Schueler et al., 1999, *Better site design as a stormwater management practice*, Comprehensive stormwater and aquatic ecosystem management: First South Pacific Conference 1999).

The objectives for stream channel protection are to:

- maintain or improve the in-stream channel stability to protect ecological values of the stream and reduce sedimentation downstream
- prevent or minimise erosion of stream bed and banks to minimise requirements and costs for engineering solutions for stream erosion

The on-site stormwater management objectives to achieve the above stream channel protection objectives when site development is considered are to:

- not increase total volumes of stormwater runoff from the existing or greenfield conditions
- control the peak flows for frequent runoff events such that they are not more than existing or greenfield conditions (where total volumes of runoff increase significantly, peak flows will need to be significantly lower than existing to compensate for increased frequency and duration of runoff)

For sites with significant impervious cover and no significant disposal by soakage, achieving no increase in total volumes of runoff is not achievable.

For this reason selecting appropriate on-site stormwater management measures for stream channel protection usually requires consideration of a range of management measures and selection of those that can be implemented on the site.

Stormwater management options available for preventing stream channel erosion due to increases in stormwater volumes arising from site development include:

- limiting total impervious catchment area contributing to a stream to less than a nominated fraction of the stream catchment area. This fraction may range from 5% to 15%, depending on rainfall, stream morphology and other factors. This approach generally also requires implementation of other catchment wide practices to limit the effect of discharges from impermeable areas, such as for example limiting the use of piped discharges of stormwater to streams. Rigorous use of this option for stormwater management for individual sites would thus require investigation of the whole catchment contributing to a stream and use of appropriate catchment-wide criteria.
- on-site reduction of effects of increased runoff volumes by some or a combination of:
  - limiting impervious area
  - bush planting to counteract the effects of impervious areas
  - re-use of stormwater from roof storage tanks
  - discharge of stormwater to ground by soakage/infiltration. For the purposes of this guideline for areas where disposal by soakage is not considered viable, this will not be an option. Where disposal to soakage is viable, runoff to streams is unlikely or infrequent
  - controlling peak flows for more frequent flows, up to 2 year ARI
  - extended detention, that is, temporarily storing runoff on-site and discharging it slowly over a long period (at least 24 hours)

A generic guideline for stream channel protection needs to address:

- whether stream channel protection measures are needed
- if they are needed, what practices are appropriate and how are they designed and implemented

Note that stream channel protection measures referred to in this section of the guideline are for mitigating the effects of stormwater runoff from the site for the stream including the full length of stream downstream of the discharge. They do not apply to any erosion protection measures at any outfall to protect against local erosion due to the velocity of the stormwater discharge from the outlet itself.

3.7.3.1 Recommended procedure for determining whether stream channel protection measures are required

RECOMMENDATIONS

In order to assess whether stream channel protection measures are needed:

1. **Determine whether stormwater runoff from the site discharges to a stream – note that this discharge may not be within or immediately downstream of the site, but at the point where any piped or other reticulation serving the site discharges to surface water**
2. **If stormwater does discharge to a stream, contact the TLA, unitary council (UC) or regional council to determine whether stream channel protection measure are required to mitigate stormwater runoff effects for sites where new development is proposed. This would include review of any relevant catchment management or structure plans**
3. **If the TLA, UC or regional council is uncertain or requires individual site owners to make their own assessment, an assessment can be carried out as follows:**
   - **if the discharge location is to a stream or other natural channel that is within the coastal marine area or is within an area that has significant tidal influence, and the site area is small in comparison with the stream catchment area, stream channel protection measures are unlikely to be required**
   - **if the discharge is from a site near the lower end of a stream and the site area is small in comparison with the stream catchment area, stream channel protection measures are unlikely to be required**
   - **assess the future percentage impervious area within the contributing catchment permitted by the district plan, or likely to occur within say 20 years. This can be assessed assuming maximum impermeable areas as permitted by district plan rules or assessed from typical maximum impermeable areas for the permitted or expected land use. This can be carried out using GIS data bases, air photos or 1:50,000 scale topographical maps and district plan maps. For small sites in rural areas, this exercise may be straight forward. For sites in urban or urbanising areas it may be onerous.**
   - **if the assessed future percentage impervious area within the contributing catchment is less than 5%, stream channel protection measures are unlikely to be required**
   - **if the assessed future percentage impervious area within the contributing catchment is greater than 5%, stream channel protection measures are likely to be required**

3.7.3.2 Recommended procedures for selecting and designing stream channel protection measures

Some methodologies that are currently used for selecting and designing on-site devices or practices for stream channel protection are described below.

Waitakere City Council's *Countryside and foothills stormwater management code of practice* (2002) is suitable for use for lots of area greater than or equal to 1 ha. It provides design methodology for selection of on-site management options to provide stream channel protection including the use of bush planting, rain tanks, rain gardens, permeable pavements. It aims to protect stream channels by mitigating the effects of additional impermeable area by maintaining the existing hydrologic regime for flows up to the 50% AEP event and not piping discharges to streams.

Waitakere City Council's *Countryside and foothills stormwater management code of practice* (2002) gives the following detailed methodology:

- table relating area of bush required in relation to impermeable area to be mitigated
- table relating required detention storage and outlet orifice diameters in relation to impermeable area to be mitigated.
- design method for sizing rain gardens based on catchment area and per cent impervious
- a chart providing a reduction factor to apply to pervious paving depending on the percentage pervious area of the pavement - this allows calculation of the remaining equivalent pervious area of the permeable pavement which will need to be mitigated by other methods

The Code of Practice does not spell out the assumptions or approaches used to develop the detailed design methodology. It can thus not be easily adapted or used for areas outside Waitakere City.

Kettle and Heijs (2003) have developed a suggested methodology based on incorporating a limit of 15% effective imperviousness to protect stream health for Long Bay in North Shore City. This is recommended for suburban and urban lots of 200 to 1000 m^2 in area. The paper provides an example calculation in which a rain tank together with permeable pavement is used to reduce the effective site imperviousness to 15%. The paper does not describe how to size a tank for mitigation and appears to assume that areas of permeable paving provide full mitigation for the area of permeable paving installed. This is different from Waitakere City Council's (2002) approach, which allows only a portion of the permeable paving for mitigation. The Kettle and Heijs (2003) method also refers to the use of green roofs and revegetation to reduce the effective impermeable area.

The Auckland Regional Council in ARC TP10 requires that where discharges enter a perennial natural stream, its channel will need to be protected and the runoff from a rainfall event of 34.5 mm shall be stored and released over 24 hour period (extended detention). This has been developed for the Auckland area where most of the streams are suffering from some degree of frittering of banks, landslides, bank collapse or stream bed undermining. Similar approaches and rainfall detention requirements are used in some areas in the USA (McCuen et al, 1987, *Policy guidelines for controlling stream channel erosion with detention basins*, Department of Civil Engineering, University of Maryland).

The ARC also allows for mitigation of runoff from impervious areas by bush planting. This mitigation can be assessed by calculating average annual runoff for pre-development and post development conditions using the method in Chapter 2 of *Urban hydrology for small watersheds*, Technical Release No. 55, US Department of Agriculture, Soil Conservation Service, 1986. (SCS, 1986).

Using this method an area-weighted curve number (CN) for a contributing catchment based on cover type, hydrologic condition and hydrologic soil group is determined. Average annual runoff can then be estimated using rainfall data. The additional runoff due to development can then be calculated.

If site area is available for bush planting, the effect of this on runoff can be calculated. If the site is large enough, it may be possible to achieve sufficient reduction in runoff through bush planting to counteract the effect of impervious area from proposed low intensity development.

RECOMMENDATIONS

1. Where stream channel protection measures are needed, consider the following options:

- **minimising impervious areas**
- **planting bush to counteract the effects of impervious areas**
- **re-using stormwater from roof storage tanks (note that in some situations this may reduce stream base flows with adverse ecological effects)**
- **discharging stormwater to ground by infiltration**
- **controlling peak flows for more frequent flows, say up to year ARI**
- **temporarily storing runoff onsite and discharging it slowly over a long period (at least 24 hours)**

2. Assess how bush planting, if practical, can reduce total runoff using the method of SCS (1986)

3. Assess any reduction of runoff due to re-use of water from roof tanks.

4. Assess the amount of disposal by soakage/infiltration devices, if they are practical on the site (refer to sections 3.8 and 3.10)

5. Use the method of SCS (1986) to determine the net area of the site that requires mitigation after implementation of any bush planting, water re-use and infiltration disposal

6. Provide for mitigation of remaining site areas by:

- **controlling peak flows for more frequent flows, say up to 2 year ARI**
- **providing extended detention storage by temporarily storing runoff from half the 2 year 24 hour storm on-site and discharging it slowly over at least 24 hours**
- **controlling peak flows and providing extended detention can potentially be achieved by devices such as:**
  - **rainwater tanks**
  - **wetlands**
  - **ponds**
  - **detention tanks**
  - **rain gardens, roof gutters**
  - **depression storage**
  - **stormwater planters**
  - **permeable paving in conjunction with underlying storage within the pavement foundation**
  - **treatment trench/rock filter**

7. Size the devices for peak flow reduction and extended detention as per the methodology described in Appendix C

8. Choose an appropriate device, depending on the device size required to achieve the stream channel protection objective, the associated cost and treatment train considerations; for example, based on whether the device meet water quality requirements

3.8 Procedure to confirm that stormwater disposal by soakage is suitable - site characteristics and quantity

In this subsection:

- physical location criteria for groundwater soakage devices
- groundwater system characterization
- allowable infiltration rates for stormwater soakage systems

If the preliminary assessment of section 3.3 indicates suitable subsurface material of sufficient depth and extent, and the assessment of the receiving environment and definition of treatment objectives in sections 3.5 and 3.6 shows soakage to ground to be viable, then the following need to be determined:

- physical location criteria for groundwater soakage devices
- groundwater system characterisation

3.8.1 Physical location criteria for groundwater soakage devices

When locating devices:

- avoid former landfill sites or other sites which may be contaminated
- avoid the 10 year ARI flood area
- avoid valley floors or other areas that may have groundwater inflows
- allow ongoing access for maintenance
- allow clearance from existing or proposed buildings: minimum of between 1 and 3 metres, depending on type of soakage device used
- allow clearance from sewers and other services: minimum 2 metres
- slope stability considerations;
  - not on the uphill side of retaining walls unless there is appropriate clearance as per design guidelines
  - for slopes less than 5% (3°) slope stability is very unlikely to be an issue
  - for slopes between 5% and 15% (3° and 8.5°), obtain specialist geotechnical input to determine whether disposal of stormwater to ground is acceptable in terms of slope stability
  - for slopes over 15% (8.5°), disposal by soakage is not recommended unless approved by and subject to specific geotechnical investigation and reporting

3.8.2 Groundwater system characterisation

To characterise the groundwater system:

- perform permeability testing or assess permeability from knowledge of subsurface material properties to confirm that subsurface conditions are suitable for disposal of stormwater by soakage; permeability values are also required for soakage disposal device sizing. Other guidelines specify minimum and sometimes maximum allowable infiltration rates and these are summarised in Table 3.7 from four other guidelines

- determine likely depth of permeable materials and presence and extent of any impervious materials (e.g. lenses) and depth to any impervious layer
- determine the winter water table level. This must be at least 1 m deep and preferably more than 3 metres deep; the seasonally high water table must be at least 600 mm below the base of the disposal device (Georgia Stormwater, 2001)
- assess likely water table rise, both short term and long term, resulting from the proposed disposal of stormwater (both on the site and uphill of it) and check that this will not have an adverse effect on the stormwater treatment and soakage disposal devices or on adjacent structures or facilities (this may require hydrogeological analysis)

If this characterisation indicates that the groundwater system is suitable for disposal of stormwater from capacity and hydrogeological and groundwater level considerations, then further steps in designing disposal systems should be carried out.

Note
In good soakage conditions, soakage disposal capacity may be high enough to cater for the 10 year storm. However, soakage may be an appropriate solution even if this capacity is not able to be met, if a suitable secondary flow path can be provided.

Table 3.7 Allowable infiltration rates for stormwater soakage systems

Guideline	Minimum infiltration / percolation rate (mm/hr)	Maximum infiltration / percolation rate (mm/hr)	Comment
ARC TP 10	3		Guideline covers shallow disposal only, not in fractured rock
Christchurch City Council (2003)	1	50 (for infiltration basins for protection of groundwater quality)	Relevant for Christchurch conditions, i.e. free draining alluvial soils.
Auckland City Council *Soakage Design Manual* (2003)	30		Relevant for areas of fractured basalt and associated highly permeable soils
University of Technology, Sydney (2001)	Generally greater than 3.6 mm/hour, can be as low as 0.8 to 1.3		

3.9 Determine range of suitable devices for treatment, peak flow and quantity objectives

In this subsection:

- screening information to allow identification of the range of devices that meet the treatment, peak flow and quantity objectives that have been determined for the site
- a series of tables for selection of suitable devices based on various site and treatment/flow objectives and operation and maintenance requirements
- examples of how a number of devices could be used on-site in a treatment train

The type of device or devices that are suitable will depend on:

- site constraints
  - topography
  - site layout, including building location
  - available area
  - soil type, geology
  - catchment area
  - development constraints
  - benefits such as water re-use
  - natural features
- treatment objectives
- peak flow / quantity objectives
- operation and maintenance requirements

For any site a range of separate devices may be required to meet the quality, peak flow/ volume objectives. This may include a number of different devices in series, referred to as a treatment train, or separate devices in parallel.

The suitability of different devices in relation to the following site constraints is in Table 3.8. Site constraints include topography, site layout, available area, catchment area, development constraints and benefits such as water re-use. Potential constraints additional to those in Table 3.8 include soils and geology, for example:

- shallow water table which may preclude devices requiring excavation
- permeable soils which may preclude wetlands or ponds unless liners are used

This subsection includes the two generic options for final disposal of stormwater, to:

- surface water
- soakage

The range of separate devices suitable for meeting quality objectives is in Table 3.9.

The range of separate devices that meet the peak flow/ volume objectives for sites (where final discharge is to surface water, not to the subsurface) is in Table 3.10.

Operation and maintenance (O&M) considerations for selecting devices are in Table 3.11. There is more detail on (O&M) for each device in sections 4 and 5 and Appendix D.

Table 3.8 Suitability of devices in relation to site constraints

Source: ARC TP10 and others

Device	Land use [1]	*Slope*					*Catchment area* Min. (m²)	Max. (m²)	Development Constraints / Benefits
		Moderately steep >20%	Rolling 15-20%	Moderate 10-15%	Gentle 5-10%	Flat <5%			
Filter	C, I [2]	✓	✓	✓	✓	✓	100	40000	
Infiltration trench	C, IR, GR I [2]	x	? (3)	✓	✓	✓	100	2500?	small footprint
Rain garden	All	✓?	✓	✓	✓	✓	100	1000	aesthetic benefit
Stormwater planter	Roof only	✓	✓	✓	✓	✓	100	1000	aesthetic benefit
Rain tank	All	✓	✓	✓	✓	✓	NA	500?	water re-use benefit
Swale/ grass filter	All				✓?	✓	300	40,000	min length 30m required aesthetic benefit
Wetland	GR, C, I			?	✓	✓	10,000 [4]	NA	aesthetic benefit
Detention tank	All		✓	✓	✓	✓	NA	2500	small footprint
Pond	GR, C, I			?	✓	✓	20,000[4]	NA	aesthetic benefit
Roof garden	All	✓	✓	✓	✓	✓	not applicable		dependent on house/building design
Roof gutters	All	✓	✓	✓	✓	✓	not applicable		dependent on house/building design
Depression storage	All			?	✓	✓	NA	5000	possible constraint on use of area
Permeable pavement	IR, C			?	✓	✓	not applicable		
Catchpit insert	C, I	✓	✓	✓	✓	✓	NA	1000	
Treatment trench/ rock filter	I,IR,GR, C				✓	✓	100	20000?	
Gross pollutant trap	C, I	✓	✓	✓	✓	✓	dependant on device		
Oil and water separators	C, I		✓	✓	✓	✓			

Notes

1 IR Individual residential; I Industrial; GR Group residential; C Commercial; ? Uncertain; NA not applicable

2 Generally for hardstand only – industrial/commercial/roads

3 Subject to geotech evaluation of slope stability

4 For little or no summer baseflow

Table 3.9 Range of devices and their ability to remove contaminants from stormwater

Source: ARC TP10

Device	Contaminant							
	SS	HC	ME	OD	NU	PA	TO	LI
Filter	✓	✓	✓?	✓				✓
Trench	✓	✓		✓				
Rain garden	✓	✓	✓	✓				✓
Stormwater planter								
Rain tank								
Swale/filter strip	✓		✓	✓				
Wetland	✓	✓	✓	✓	✓	✓	✓	✓
Detention tank	✓							
Pond	✓	✓	✓	✓				?
Roof garden								
Roof gutters								
Depression storage	✓							
Permeable pavement	✓	✓	✓	?✓				
Catchpit insert	✓	✓	✓?	✓?				✓
Gross pollutant trap	✓			✓				✓
Litter trap								✓
Hydrodynamic separator	✓	?		✓				✓
Separators		✓						

Key to abbreviations of contaminants:

pH power of hydrogen
NU nutrients (nitrogen and phosphorus)
ME metals (lead, zinc and copper)
HC hydrocarbons, including TPH and PAHs
OD oxygen demanding substances (generally particulate organic matter)
TO toxic organics, including for example antisapstain chemicals on timber treatment sites, chlorinated hydrocarbons and other toxic chemicals used on industrial sites
? uncertain, depends on design of device or nature of contaminants
SS suspended solids
PA pathogens including bacteria
LI litter

Table 3.10 Range of separate devices that meet the peak flow / volume objectives

Source: ARC TP10, various

Device	Peak discharge control ARI (years)			Volume control Includes reduction of runoff due to re-use (RU) and the use of extended detention (ED) for stream channel protection
	Up to 2	**5-10**	**50-100**	
Filter	✓?			
Rain garden	✓			ED
Rain tanks	✓	✓		ED,RU
Swales/grass filter [1]	?			
Wetland	✓	✓	✓	ED
Detention tank	✓	✓	✓	
Pond	✓	✓	✓	ED
Roof garden	✓	?	?	?
Roof gutters	✓	?		
Depression storage	✓	✓?		
Permeable pavement	✓?	?		?
Treatment trench / rock filter	✓?			ED
Gross pollutant trap				
Oil and water separators				

Notes
(1) some guidelines refer to use of swales for detention
? uncertain

Table 3.11 Indicative operation and maintenance considerations for devices

Device	Summary of operation and maintenance issues
Filter	Requires regular maintenance, preferably by contractor
Infiltration trench	May require removal of gravel media, need to ensure suspended solids loads will not result in rapid clogging
Rain garden	Maintenance can be done by home owner
Stormwater planter	Maintenance can be done by home owner
Rain tank	Maintenance can be done by home owner
Swale / filter strip	Maintenance can be done by home owner
Wetland	Ongoing specialist maintenance required
Detention tank	Ongoing specialist maintenance required, concern about maintaining long term integrity/performance
Pond	Maintenance needs to be done by contractor, relatively onerous due to potentially large amount of potentially contaminated material requiring removal and appropriate disposal
Roof garden	Ongoing maintenance, cutting and removal vegetation
Roof gutters	Maintenance can be done by homeowner
Depression storage	Need to allow for removal of deposited sediment
Permeable pavement	Ongoing cleaning of pavement is required to avoid clogging. This may preclude their use as a robust system. Some regulators express reservations about their long term viability.
Treatment trench / rock filter	May require flushing to remove sediment and slime, may be onerous, need to ensure suspended solids loads will not result in rapid clogging
Catchpit insert	Maintenance preferably done by contractor, relatively onerous due to large amount of material collected
Gross pollutant trap	Specialist maintenance required; can be onerous
Oil and water separators	Ongoing specialist maintenance required

3.10 Selection and design of soakage disposal devices

In this subsection:

- the types of devices and mechanisms used for disposal of stormwater to ground soakage
  - mechanisms incorporated within treatment devices
  - stand alone disposal devices
- references for design methods

Some guidelines refer to disposal to ground soakage as infiltration practices. For the purposes of this guideline the terms soakage and infiltration refer to the same thing, namely the final disposal of stormwater to ground including by soakage and/or infiltration.

In this guideline, for the purposes of facilitating device selection and design, soakage methods or categories fall into two main categories:

- those that use infiltration into the soil directly from a treatment device
- stand alone disposal devices

3.10.1 Infiltration into soil directly from treatment devices

Devices such as those below can provide treatment via a constructed medium associated with the device. In some cases additional treatment is provided by insitu soils below the device:

- infiltration trenches
- rain gardens
- swales and filter strips
- permeable paving
- soakage basins

3.10.2 Stand alone devices

Stand alone disposal devices provide disposal only (any treatment of stormwater is provided beforehand). Examples include:

- trenches (where trenches used only for disposal, not treatment), chambers and pits
- infiltration galleries
- dry wells
- disposal bores, including rock bore soakholes

3.10.3 Interaction between design of treatment devices and ground disposal

For treatment devices that dispose stormwater directly to groundwater, the disposal rate of soakage or infiltration from the base and possibly the sides of the device can have a significant effect on the design size of the device. It is thus necessary to establish appropriate design soakage or infiltration rates before designing such treatment devices. If the insitu soil is relied upon to provide treatment of contaminants, then careful assessment of the receiving environment and the potential effect on it from discharge of stormwater is required. Refer to sections 3.5 and 3.8.

3.10.4 Design methodologies for soakage or infiltration disposal

This guideline does not provide detailed methods for design of stormwater soakage or infiltration practices or devices. There a number of design methodologies in other guidelines. Comment on four such guidelines with respect to their detailed stormwater soakage or design methods is in Table 3.12.

Table 3.12 Comments on guidelines that provide design methodologies for stormwater soakage disposal

Guideline	Comment
ARC TP10	Design procedure is for disposal of the water quality storm; presumably this procedure would be relevant for larger storms, ie. to provide full disposal
Christchurch City Council (2003)	This provides for water quality aspects and flood protection, developed for Christchurch conditions, namely free draining alluvial soils. Expected to be relevant for other locations with free draining soils.
Auckland City Council (ACC 2002)	Relevant for areas of fractured basalt and associated highly permeable soils. Includes details on percolation testing. Uses design charts specifically prepared for Auckland city rainfall.
Approved Document for New Zealand Building code Surface Water Clause E1 (BIA, 2003)	Design procedure for disposal of stormwater from individual buildings, including procedures for field testing of soakage and soak pit design methodology
University of Technology, Sydney (2001)	Method not reviewed

RECOMMENDATIONS

It is recommended that relevant design procedures from the above guidelines or other suitable guidelines be used for:

- **development of soakage and infiltration rates for infiltration into the soil directly from a treatment device**
- **development of soakage and infiltration rates and detailed design and operation and maintenance requirements for stand alone disposal devices. Pretreatment requirements for these devices may be able to be designed in accordance with the relevant parts of this guideline**

Care needs to be taken with procedures for field testing of soakage and use of field test results for soakage design, in particular:

- test holes in sands may collapse, affecting the geometry of the test hole and interpretation of the test results
- borehole size tests are subject to local variations in ground conditions, for example if they intercept a crack, results may indicate high soakage but may not be representative of the wider area. Multiple tests over the proposed disposal area may be required for accurate result

3.11 Selecting suitable devices and device combinations, treatment train

In this subsection:

- general considerations
- process for selecting site device or devices

3.11.1 General

On site stormwater management is often best done using a treatment train or a variety of devices on one site because:

- one device may not be able to meet a range of different objectives, for example all of the needs for water quality, peak flow and quantity control
- an appropriate combination of devices can often provide the most cost-effective approach

3.11.2 Process for selecting site device or devices

To select appropriate devices for a site:

- identify the range of separate devices that are suitable based on site constraints, quality, peak and quantity requirements and consideration of operation and maintenance requirements, determined according to the methods above
- develop a range of options of a treatment train or collection of above determined suitable devices that meet the overall site stormwater management requirements
- carry out preliminary design, sizing and costing of the devices considered
- compare the costs and sizes for each option
- choose appropriate train or collection of suitable devices based on cost and any other relevant consideration such as benefits e.g. water re-use, aesthetic benefit, site area requirements, operation and maintenance requirements, the number of devices required

Examples of common treatment trains used for residential sites and commercial / industrial sites are shown in Figures 3.2 and 3.3. Note that rain tanks provide only flow control, filters swales and grass filter strip provide only treatment, while rain gardens and wetlands can provide a combination of flow control and treatment.

An example of a summary of options considered is in Table 3.13.

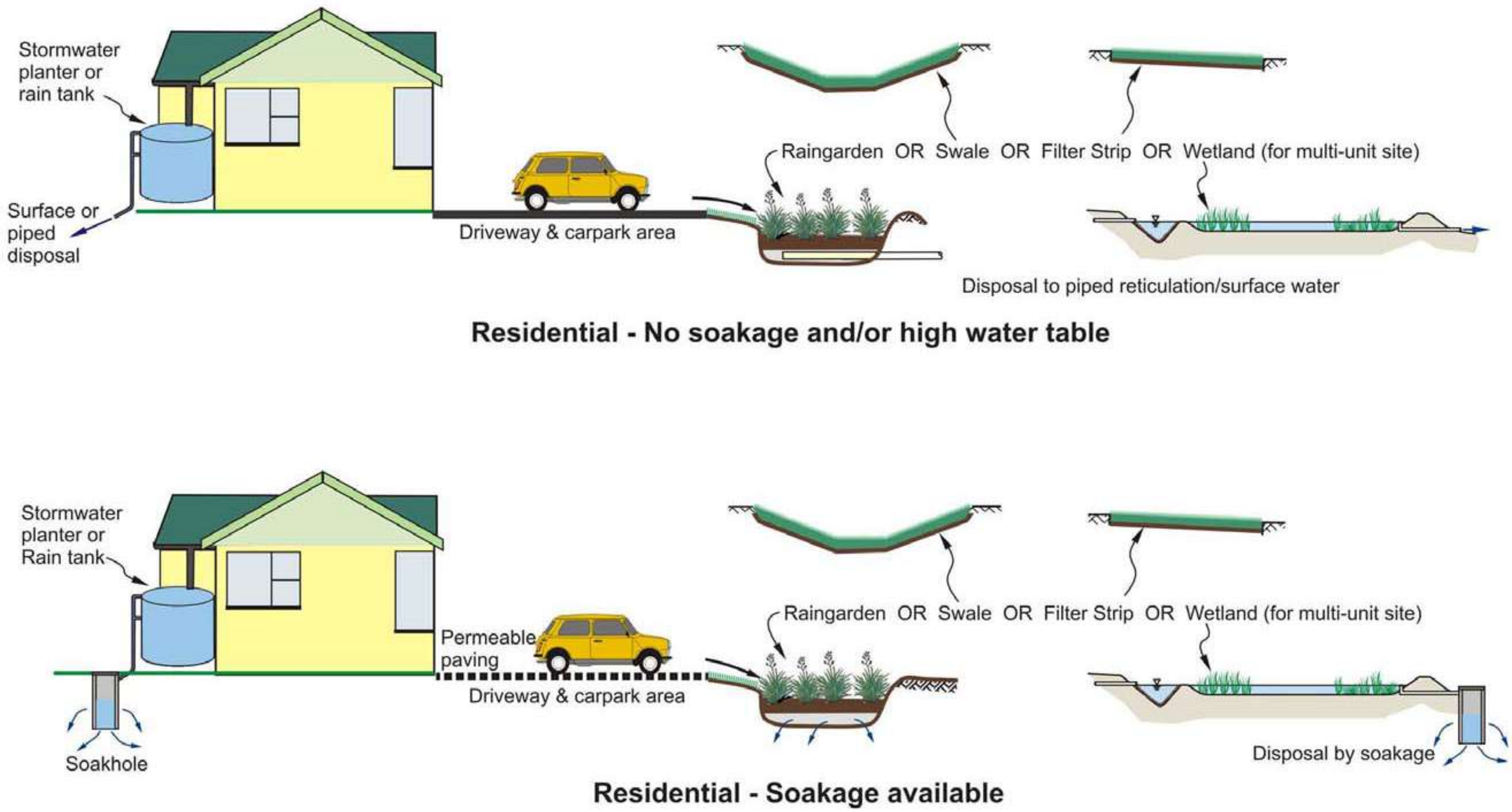


Figure 3.2 Treatment train example for typical residential site

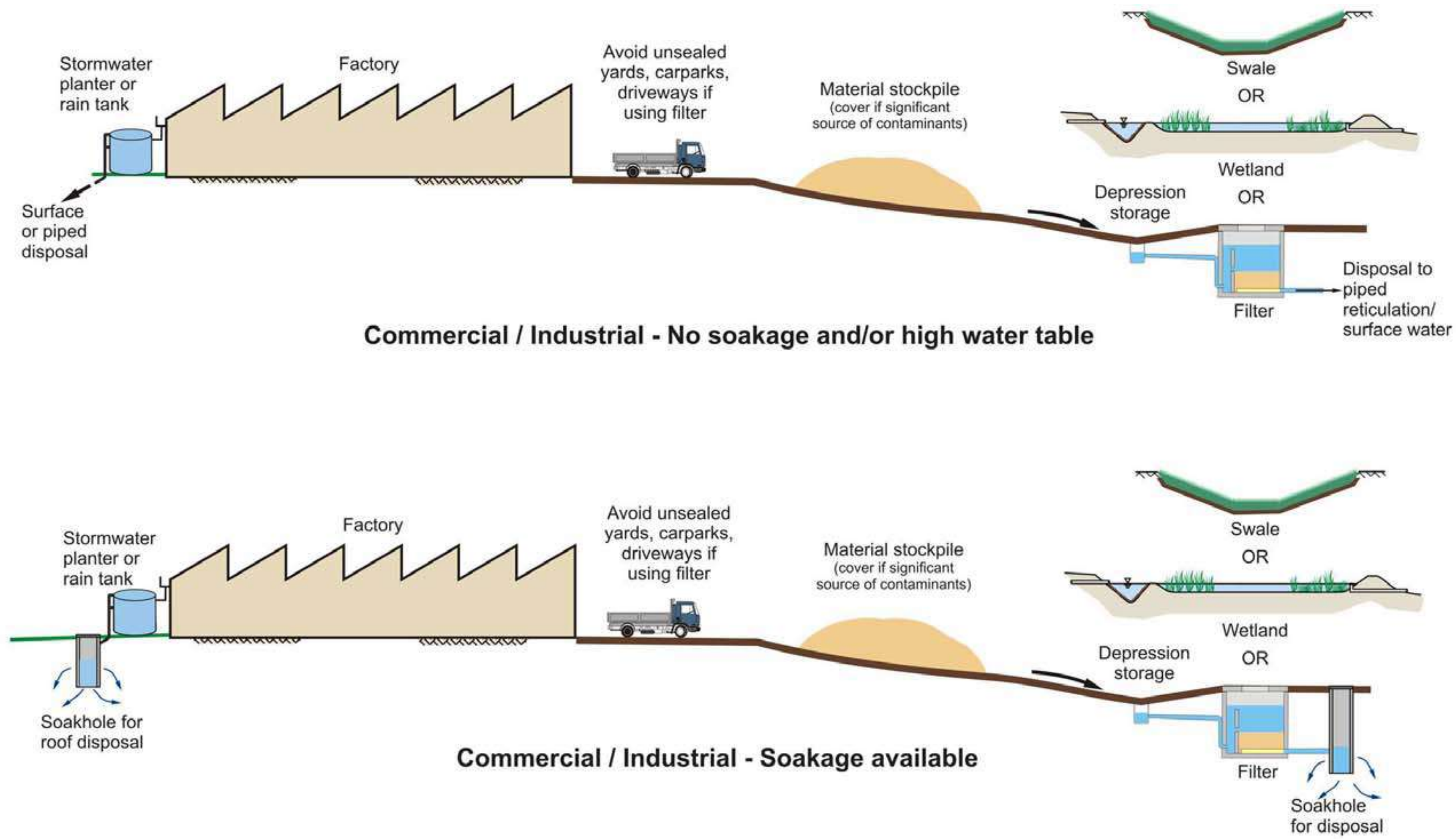


Figure 3.3 Treatment train example for typical commercial/industrial site

Table 3.13 Example of results of comparing site stormwater options

Hypothetical example for illustrative purposes

Option / Description	**Satisfies objectives of:**			**Capital cost**	**O&M**	**Comment**
	water quality	**peak flow**	**Volume**			
Example 1: Require peak flow and quality control from a 20000 m^2 (2ha) industrial site						
Option1						
Pond for peak flow control and settling coarse solids	Some	✓	✓	M	M	Would require sufficient site area for pond
and						Decision between wetland and filter will most likely depend on land availability and cost. Note that wetland can provide some peak flow control, which would require a smaller pond. Need to assess and compare efficiency of each treatment device for removal of contaminants expected in site runoff
Filter / rain garden	✓	✓	✓	H / M	H / M	
OR						
Wetland for treatment	✓	✓		M	M	
Option 2						
Depression storage using car park and /or detention tanks. May require gross pollutant trap (GPT)	Some	✓	✓	M to H	M to H	Using car park could be cost effective if depression storage is not possible, detention tanks could be used. GPT may be necessary to reduce maintenance costs for detention tank
Filter / rain garden / wetland for treatment	As for option 1	As for option 1	As for option 1	As for option 1	As for option 1	As for option 1

Example 2 Residential site: requiring quality treatment for driveways and extended detention flow control for stream channel protection, no soakage available						
Option 1						
Rain tank for flow control		✓	✓	M	L to M	Benefit for water re-use
and						
Swales for quality	✓			L	L to M	Swales require large amount of land
Option 2						
Rain garden providing flow and quality control	✓	✓	✓	L to M	L to M	Carefully designed rain garden may be able to provide flow control and water quality treatment
Option 3						
Roof gutter		✓	✓	M	L	Viability of depression storage depends on topography
Depression storage		✓		L	L	
Permeable pavement	✓**?**	✓	✓	M to H	H	Long term performance of permeable pavement is uncertain

Notes

O & M is operation and maintenance

L= low M= medium H = high

3.12 Hydrologic / hydraulic analysis

In this subsection:

- hydrograph generation
- routing computations
- hydraulic computations

Hydrologic/hydraulic analysis will often be required as part of the design of an on-site device, especially the flow attenuation component. This typically involves:

- hydrograph derivation, manually, or by modelling. For an example of a rainfall analysis to feed into such modelling, see the Auckland Regional Council's TP108
- routing computations: routing the inflow hydrograph through the device to establish the outflow hydrograph
- hydraulic computations to size pipes, orifices, weirs and other components

These are discussed below.

Appendix C provides more guidance on these topics, with the brief notes below clarifying the general approach. The following aspects also require consideration, but are covered elsewhere in the guide:

- design storm magnitude: refer section 3.7
- flow attenuation performance and extended detention requirements: refer Section 3.7
- rainfall temporal and spatial patterns (and time of concentration, Tc): refer Appendix C
- computer modelling:
    - this guide focuses on manual or spreadsheet-oriented analysis methods, but commercial models area available to simulate the performance of on-site devices and establish device sizings
    - such models typically generate hydrographs based on rainfall data from single-storm events or long-term pluviographic records
    - Appendix C comments on modelling approaches, noting that these methods are very powerful and their use is recommended for users planning to specialise in preparing on-site device designs

3.12.1 Hydrograph generation

Typical methods include:

- the rational method, for example as used in BIA (2003) typically expressed as Q = C x I x A / 360, where:

    Q = peak flow (m^3/s)
    C = runoff coefficient (refer below for details)
    I = rainfall intensity (mm/hr), for the applicable duration (Tc) and design storm magnitude
    A = catchment area (ha)

- TM61 Method for estimating design peak discharge (MWD, 1980)
- US Soil Conservation Service Method (USSCS, 1986, for example as applied in ARC TP108 (Guidelines for Stormwater Runoff Modelling in the Auckland Region)

Some considerations and sources of the data required to apply these methods include:

- location-specific rainfall depth-duration-frequency data:
  - NZ Meteorological Service ('Metservice') publications (eg Coulter & Hessell 1980)
  - NIWA's HIRDS software; URL: www.niwa.cri.nz/ncc/tools/hirds
- time of concentration: typically short for on-site devices (e.g. 5 – 15 minutes), but see Appendix C for a commentary on the broader issues to be considered in this context
- runoff coefficient 'C':
  - for impervious areas, the coefficient will be 0.9
  - however, where the device is to be designed to match, for example, the greenfield discharge standard, more attention needs to be devoted to selecting the appropriate C factor(s). For values, refer to chart in Appendix C, or the table in BIA (2003)
- hydrograph shape: the rational method or TM61 methods produce peak discharge figures, but a hydrograph is needed for use in the routing analysis. A suitable triangular hydrograph can be prepared by (refer Appendix C for further details on hydrograph derivation, including the approach applicable to longer-duration storms where the hydrograph shape is trapezoidal in form):
  - rising limb: linear rise to reach the peak at time Tc
  - falling limb: linear fall back to zero, over a time period Tc

3.12.2 Routing computations

Routing involves quantifying the way the storage provided in the on-site device modifies the inflow hydrograph. Typically, a spreadsheet will be used to perform the routing calculations, applying the following general relationships:

- outflow = inflow – change in storage
- outflow = function of the applied head on the outlet flow control device (eg orifice, weir)

The layout of a typical spreadsheet used to perform the routing calculation, is shown in section 4.5.6 and in Appendix C. It should be noted that cell arithmetic will vary depending on the device type, especially the type, number and size of outlet(s).

To size an on-site device, use a trial and error approach to using the routing computation spreadsheet as follows:

- define the device performance target, eg: site runoff peak to match the greenfield case in the 10% AEP storm
- derive the peak flows and hydrographs for the following cases (note that worked examples are given in Appendix C – Section C3.5):
  - for the target performance standard case, as above
  - inflow to the on-site device, for the post-development case
  - rest-of-site runoff, for the post-development case (ie to add to the device outflow hydrograph, to establish the post-development with-device outflow)
- select the trial device size characteristics, for example for a detention tank:
  - plan area of tank
  - top outlet pipe diameter and height above tank base
  - outlet orifice diameter and height
- run the spreadsheet (refer examples in Section 4.5.10) and:
  - identify the peak site outflow rate
  - compare this to the target peak site outflow (eg greenfield, as above)
- select new trial device sizing parameters (eg smaller/larger tank, smaller/larger orifice) and re-run the spreadsheet until the required device performance standard is met
- in practice, as explained in Appendix C - Section C2.2, spreadsheet runs will be required to cover a series of storm durations, to identify the critical case

3.12.3 Hydraulic computations

The user is referred to the following documents and standard hydraulics textbooks for the various formulae to size pipes, orifices, weirs and so on:

Building Industry Authority. *Building Code Clause E1– Verification Method E1/VM1: Surface Water.* New Zealand, Effective September 2003 (BIA, 2003)

Brater, E.F., King, H.W., Lindell J.E., & Wei, C.Y. (1986). *Handbook of hydraulics*. New York: McGraw Hill.

Streeter, V.L. (1985). *Fluid mechanics*. Tokyo: McGraw Hill.

Department of Environment and Natural Heritage. (1992). *National strategy for ecologically sustainable development*. Department of Environment and Natural Heritage, ACT, Australia. (NSESD 1992). http://www.deh.gov.au/esd/national/nsesd/index.html.

> Check that nominated coefficients in formulae apply to the metric case; especially in material of American origin, where imperial units are used. Also check units e.g. U.S. versus British gallons

3.12.4 References

Auckland Regional Council. (2003). *Stormwater treatment devices: design guideline manual*. ARC Technical Publication No. 10 (ARC TP10). From http://www.arc.govt.nz/arc/index.cfm?34C9C2A8-1BCF-4AA1-91AF-CC49CFE4A80C.

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Brater, E.F., King, H.W., Lindell J.E., & Wei, C.Y. (1986). *Handbook of hydraulics*. New York: McGraw Hill.

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3.13 Statutory compliances and consenting

When planning to use an on-site device, apply sound stormwater planning principles in the context of the relevant statutory requirements. Aspects such as those listed below will need to be drawn together and documented in a consent application (also discussed later in this sub-section). The issues discussed below should be addressed at an early stage in planning for an on-site device.

1. Identify if the site is susceptible to existing or potential future flooding by checking to see if any stormwater issues are identified in the following documents, which are available from the territorial local authority:
   - PIM (project information memorandum)
   - LIM (Land Information Memorandum)
   - any catchment management plan and/or flood hazard maps
   - if these are not available, consider the capacity of both public and private drainage
   - undertake a site visit to see that planning information matches the on-the-ground situation

2. Structures must comply with both council and central government policy on flood hazards if building consents are to be issued. In general, it is convenient to consider these polices at the same time that the stormwater system is designed, and for this reason the policies are summarised below. Relevant policy documents include, but may not be limited to:
   - Building Act (Section 36)
   - Building Code (Approved Documents E1 and E2)
   - District Plan
   - Regional and District/City Council Bylaw and Engineering Standards on Stormwater Management (if applicable)
   - Resource Management Act (Section 76)

3. For all properties, all structures (including decks, fences, etc) must be designed so there is no obstruction of overland flow paths

4. For land that may be subject to flooding, the following policies apply:
   - all building work and land on the property must be adequately protected from flooding, in accordance with s36 of the Building Act and the relevant parts of the District Plan
   - at a minimum, flood protection for building work is required to prevent floodwaters from a 2% AEP flood entering houses, communal residential buildings and communal non-residential buildings, in accordance with Approved Document E1 of the Building Code
   - note, however, that council will consider each case individually and may decline a building consent if they do not consider that s36 of the Building Act and the relevant requirements of the District Plan have been adequately complied with
   - Building consents may also be issued subject to s36(2) of the Building Act, which will mean that a note will be placed on the title of the land indicating that the land is subject to flooding
   - the development must not increase the extent of flooding on any other property, either upstream or downstream (ie as broadly required by sections 36 of the Building Act and 76 of the RMA, as amplified by provisions in Regional/District Plans)

5. Confirm with the consenting authority the precise consent application requirements so as to take account of these in developing the on-site device designs and details. Consenting processes will vary around the country, but the following general guidance may help when implementing an on-site device:
   - depending on the provisions of the relevant district plan, implementation of an on-site device may require a resource consent. If so, seek advice from the consenting authority as to what details must be included in the consent application
   - even if it does not require a resource consent, an on-site device will generally require a building consent

6. Although requirements will vary, consent applications will typically need to include:

- details of the proposed type(s) of on-site device(s), together with evidence as to the suitability of the proposed on-site device(s) to the site/development, for example, availability of a connection to a formal stormwater system such as a pipe or watercourse
- a site plan to scale showing proposed layout and key elevations, covering:
  - site development plan, including buildings, paving, etc
  - details of the proposed on-site device(s), specifically:
    - location(s) of the device(s)
    - delineation of the impervious area connected to each on-site device
    - arrangements as to the ownership of each on-site device and corresponding responsibilities for operation and maintenance (if applicable)
    - the route(s) of the connecting pipes or channels between the impervious area and the device and, if applicable, the device outlet and the receiving system
- design calculations for the on-site device(s), covering:
  - structural elements
  - analyses/sizing
  - performance in accordance with appropriate guidelines
- technical specifications, including construction materials details
- producer statements for any proprietary equipment
- as well as standard provisions, consent conditions may also cover:
  - O&M provisions (obligatory or recommended)
  - prohibition on modifying/dismantling/removing the device, except with the written permission of the local authority

3.14 Design and detailing

The step-by-step design procedures in section 4 give device-specific guidance for sizing and design detailing, so only general comment is given here. Examples of design and detailing issues to account for include:

- conservatism: be conservative at all stages in the design of on-site devices, recognising for example that O&M practices will often be less than ideal
- non-standard applications: although this guideline provides for a wide variety of site conditions and device applications, there will be instances where further guidance is required. In such cases it is suggested that the user:
  - refer to the references listed in section 4 for each device and/or to Appendix B
  - seek the advice of experienced New Zealand on-site device designers (NZWWA and any of the councils may be able to suggest suitably experienced practitioners)
- detailing principles: attention to well thought-out and accurate detailing is essential if the device is to give long-term effective service. Issues to consider include:
  - construction practicality
  - ease of O&M and adequate access for maintenance
  - building in measures which will limit damage if the device blocks or otherwise fails, such as directing spills to a defined overland flow path
- detailing practices: examples of areas where attention to detail is especially important include:
  - device siting, such as considering aesthetics, ease of maintenance
  - setting key elevations, for example to ensure adequate fall to the outlet receiving system
  - appropriate selection of materials, such as rain tank material, concrete or timber walling for stormwater planter, soil/gravel specifications
  - screening of outlets to avoid blockage and provision of inspection covers for screen cleaning

It is especially important to ensure good erosion protection of all sources draining to the inlet of devices such as surface of rain gardens and stormwater planters, to avoid clogging up the media with eroded sediment.

3.15 Operation and maintenance (O&M)

In order to meet water quantity and/or quality targets, the long-term effective operation of on-site devices depends not only on sound design and construction, but also on applying routine operation and maintenance practices. These 'O&M' practices are typically not onerous in terms of either effort or frequency. Further, the costs are modest – and are typically less than neglect causing devices to fall into disrepair and need major overhaul.

It is generally the responsibility of the on-site device owner to carry out appropriate O&M, unless the local authority agrees to take-over responsibility. Ideally, requirements should be scheduled in the appropriate consent. O&M practices will typically involve:

- frequently: check for and rectify any problems evident during/after heavy rain
- regularly, about every 2 – 3 months: check state of repair of the OSM device and remove growths, repair leaks, clear blockages, etc
- periodically (eg once or twice a year): inspect pipes, remove sediment, repair any defects

O&M requirements are specific to each on-site device, but will typically cover (refer Appendix D for full details):

- soils in stormwater planters, rain gardens, roof gardens
- vegetation management
- sediment management/pollutant control
- insect/vector control
- access and safety
- a monitoring and inspection programme detailing the above

Sediment accumulated in treatment devices may be contaminated, in particular with hydrocarbons and metals. Appropriate disposal of such sediment is essential to avoid adverse effects.

Table 3.14 is a typical O&M checklist for an on-site device.

Table 3.14 Operation and maintenance checklist - grass swale

Frequency			Action
As required	**Quarterly**	**Annually**	
	✓	✓	**General** Remove any debris accumulation / waste vegetation
		✓	**Inlets and outlets** Remove sediment
✓	✓	✓	**Grass** Mow (with catcher) to maintain the grass length at 50 – 150 mm
	✓	✓	**Grass** • remove nuisance weeds • fertilise or treat to maintain vigorous growth, as required • fill any erosion holes and re-seed
	✓	✓	**Pipework:** Check for debris/blockages/leaks & rectify

The consenting authority typically sets the O&M obligations and the corresponding enforcement regime. O&M delivery models include (see Appendix D for more detail):

- traditional: voluntary regime, with guidance given and backed by random inspections
- obligatory:
  - owner responsibility: owners are required to have their on-site device serviced at designated intervals, with certification by an independent person as to the servicing submitted to the controlling authority (eg as in Auckland City)
  - contracted out responsibility: in installing an on-site device, the owner agrees to contract-out maintenance to the controlling authority, which equips the serviceperson with a notebook computer that has the site and device details. On completing the service, details are logged in and downloaded to the controlling authority's database (for example as in the City of Orlando, Florida, USA)

3.16 Implementation

Following the receipt of the consent (refer Section 3.15), steps are:

- construction: requires close attention to ensuring that the following are met:
  - design details (refer Section 3.13)
  - materials specifications, especially the grading of the materials in the planting medium
  - specifications
- commissioning:
  - once constructed, the device will need to be commissioned and tested
  - in the event that the device is commissioned during a dry spell, in some cases it may be appropriate to test the device using a high-capacity hose (eg from hydrant or tanker, feeding water to the roof or site impervious area)
  - checks need to be made for flaws such as leaks, blockages, evidence of scour etc
- certification: once commissioned and operating satisfactorily, the device will need to be certified under the provisions of the Building and/or Resource Consent – ARC TP10 provides examples of the checklists used by certification authorities
- O&M (ongoing): the routine maintenance provisions set out in Section 3.15 will need to be undertaken, in accordance with either (as applicable):
  - the provisions of the consent (where nominated), or
  - a voluntary, non-enforced basis (albeit recognising that the local authority generally has the power, under either its bylaw or the Local Government Act, to require repairs where the device is causing flooding on a neighbouring property)

3.17 References

Notes:

1. Internet references are accurate at the time of publication
2. Short references are given in brackets at the end of key documents that are used throughout the text for ease of use, for example (ARC TP10, or CCC, 2003)

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Section 4 Detailed device description and design procedures

In this section:

Detailed descriptions and designs for:

For each device:

- description
- capability
- applicability
- design approach
- design steps
- design detailing
- implementation provisions
- operation and maintenance
- worked example

The format of the step-by-step design procedures is:

- **device description**: explains the form of the device (with variants where applicable) and how it works, with the aid of diagrams and/or photos
- **capability**: treatment performance and other capability
- **applicability**: sets out the situations where the subject device can/cannot be used, with guidance notes on some of the key technical and/or operation and maintenance issues that should be accounted for before proceeding to the site-specific design of the device
- **summary of design approach**: summarises the steps involved
- **preparatory steps**: lists the site-specific information that will be needed to prepare the design and any related information
- **step-by-step design procedure**: explains the steps in the design procedure (note that this is kept quite succinct, with cross-referencing used to direct users to explanatory material where they need further guidance)
- **design detailing**: sets out the standard details to be shown in design drawings, with attendant guidance notes on alternatives where applicable
- **implementation provisions**: summarises key issues in implementing the specific device such as consenting, construction, operation and maintenance
- **references**: lists reference material providing general guidance, precedents, worked examples
- **worked example(s)**: numerical example(s) to illustrate use of the design procedure in typical applications

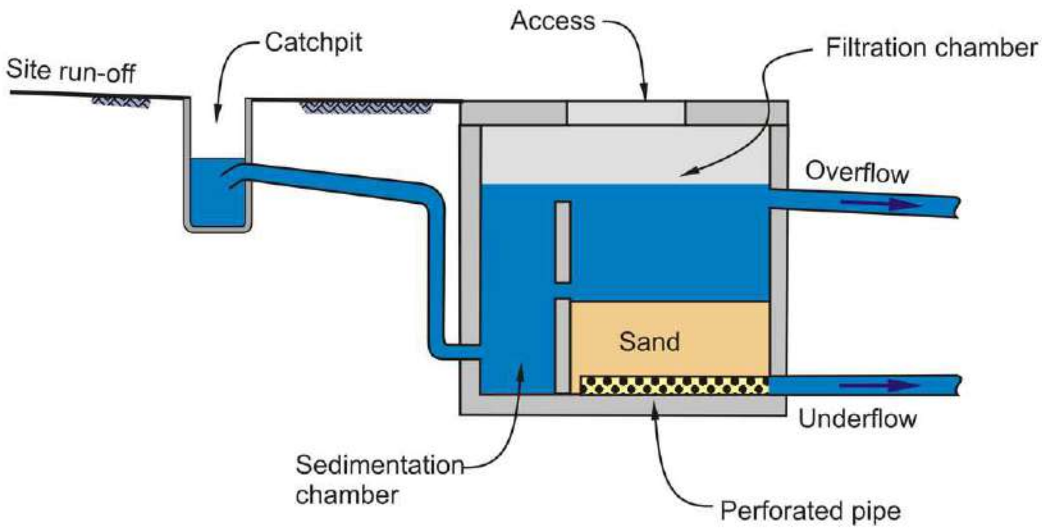
In using the design procedures, users should also note that the device selection and design should follow the steps in the flow chart in Figure 3.1.

4.1 Filter

4.1.1 Description

Filters are structures in which a bed of material such as sand traps and accumulates contaminants. Filters can include those with inert media in which only particulate pollutants are removed and those with absorptive media, which remove dissolved contaminants. Filters usually include a sedimentation unit to reduce sediment loads to the filter.

Figure 4.1.1 Filter operating principles



4.1.2 Capability

Filters are able to:

- treat runoff from impermeable hardstand ground surfaces in commercial, residential and industrial areas
- treat road or parking lot runoff

Filters are not able to:

- treat sediment-laden water from construction sites. Install after site works are complete and contributing areas have been fully stabilised in order to prevent excess sediment loading
- provide significant peak flow or volume control

The most common filter is the sand filter.

Expected contaminant removal rates for sand filters are (ARC TP10, EPA 1999a):

- suspended solids > 75%
- metals (copper, zinc, lead) (total) > 75 %
- total phosphorus 33 %
- total nitrogen 21%
- biochemical oxygen demand 70%
- hydrocarbons >75%

Filters other than sand filters include filters that use standard sand filter type hydraulic design but modify or replace the sand with other media such as:

- iron oxide coated sand
- iron wool
- polypropylene fabric
- leaf compost
- peat
- sphagnum moss
- limestone
- waste wood fibre
- bottom ash
- perlite
- zeolite
- iron oxide coated sand
- granular polymer
- iron amended resin
- proprietary filters with a variety of media, which can treat a variety of contaminants both particulate and dissolved

For other media, references are in work by Landcare Research (Reducing road runoff contaminants through low-cost treatment wall (filter) systems: Landcare Research studies (Surya Pandey pers. comm.), summarised below.

Territorial and regional authorities in New Zealand have identified stormwater management as a priority environmental issue in urban areas, with increasing attention being paid to the use of various filter systems to reduce the contaminant load in road runoff. In many cases, the effective application of such systems requires the development of improved filtration media, design and operational parameters (e.g. frequency of sediment or medium removal) to align construction, performance and maintenance to specific guidelines, such as those for stormwater interception devices as suggested by Auckland Regional Council in TP10.

Under laboratory conditions, Landcare Research examined five media that may be suitable as a medium in treatment walls through their ability to remove the heavy metals copper (Cu), lead (Pb), zinc (Zn), and also selected polyaromatic hydrocarbons (PAH) (fluoranthene and pyrene) from artificial road run-off. The media tested were commercially available *sphagnum moss*, crushed limestone, waste wood pulp, wood ash, and waste wool felt. Two media, sphagnum/lime and sphagnum/wood ash in layered (1 layer of each) and mixed configurations, containing 10% by weight of *sphagnum*, were also tested.

The individual, mixed and layered media were ranked according to their contaminant removal efficiency, 1 being the best performance (Table 1). The best-performed medium over the 5 contaminants studied; presence of PAH degrader; and hydraulic conductivity is given by the lowest total score. The best-performed media overall were lime, wood ash and the mixed *sphagnum*/wood ash combination.

Table 4.1 Ranked treatment matrix

Note: 1 is the best performing: lowest total is best performing overall

Medium	Copper	Lead	Zinc	Fluoranthene	Pyrene	PAH degraders	Hydraulic conductivity	Total
Sphagnum	1	3	1	2	2	1	5*	15
Lime	1	1	1	1	1	3	3	11
Wood Fibre	2	4	4	3	2	3	6	24
Wood Ash	1	1	1	1	1	2	2	9
Sphagnum/Ash mixed	1	2	1	1	1	1	1	8
Sphagnum/lime mixed	3	2	1	1	1	1	3	12
Sphagnum/Ash layered	1	4	3	1	1	1	4	15
Sphagnum/lime layered	1	3	2	1	1	1	4	13

Although sphagnum had the highest hydraulic conductivity, the use as filter media on its own will be limited due to very small contact time between dissolved pollutants and sphagnum, hence the higher ranking. Based on the above results, the *sphagnum*/wood ash media (1:1 by volume, 1:10 by weight) was chosen for field-testing. A treatment wall/filter was constructed at the corner of River Road and Wairere Drive in Hamilton in December 2000, to intercept the run-off from a portion of a roundabout. Subsequently, an additional wall was constructed in Cambridge on the side of State Highway 1. In contrast to the Hamilton trial, we are testing an increased ratio of *sphagnum* (20% by weight).

Comparison of input and output pollutants through the treatment walls show that both treatment walls greatly reduce the quantities of pollutants being discharged into the aquatic environment.

Landcare Research also determined the types and amounts of contaminants (Cu, Pb, Zn, fluoranthene, pyrene, and suspended solids) removed from stormwater during typical storm events from the Henderson aquatic centre car park in Waitakere City. We tested wood-ash, sand, and green-waste compost as filter media in a filtration system designed to standard TP10 filtration criteria. The results indicated that wood-ash was the most effective medium, removing more Cu and Zn than the compost, or the sand filter medium. All three media removed fluoranthene and pyrene. A ranked treatment matrix for the media tested is presented in Table 2 below. A ranking of 1 indicates the best overall performance for the removal of the contaminant indicated.

Table 4.2 Overall ranked treatment matrix for filter media

Note: 1 is the highest overall performance

Media	Cu	Pb	New Zealand	Fluoranthene	Pyrene
Wood-ash	1	1=	1	1	2=
Sand	2	1=	2	2=	1
Compost	3	2	3	2=	2=

In May 2003 a fourth treatment wall was constructed at the Hewletts Rd/Tasman Quay roundabout at the entrance to the port in Tauranga, to intercept the runoff from a portion of a roundabout. The treatment wall consists of a *sphagnum* "basket" on top of 300 mm wood ash housed in a shallow rectangular tank (0.5 m deep by 1 m wide by 4 m long). This study is continuing and initial results are similar to those found at other study sites in New Zealand.

Additional references for filter media are:

- discussion of sorptive media filtration in Minton, 2002
- discussion of sorbent materials for removal of hydrocarbons in stormwater applications (EPA 2002)

4.1.3 Applicability

- specific applications include:
    - commercial and industrial parking areas or yards
    - service stations
    - high density residential housing
- on line or off line location
- suitable for retrofits
- can be constructed completely underground with surface access lids or can be constructed using a pond or other structure that is open at the surface
- device catchment area no more than 4 ha (ARC TP10)
- New Zealand suppliers of proprietary filters include:
    - Hynds Environmental Systems
    - Ingal Environmental

Care is needed if using media other than sand for which design methodologies have been well established. In such situations assessment of long term permeabilities or allowance for reduction in permeability with time should be addressed.

The use of compost or similar materials should consider the possibility of viral or bacterial contamination from the compost.

4.1.4 Summary of design approach

1. Determine the nature of contaminants to be removed, including whether particulate or dissolved, and determine the type of filter required, i.e. sand or modified type of sand filter or proprietary filter
2. Calculate water quality volume or other parameters if required for sizing a proprietary filter
3. Size the filter per appropriate method. The design method for a sand filter is set out below. Design of proprietary filters as to the supplier's recommendation

4.1.5 Preparatory steps

1. Confirm quality objective: refer section 3.6
2. Define key site parameters and device needs that determine design details:
    - device catchment land use (this is required to be used in design calculations)
    - device catchment impervious area (roof and on-ground areas)
    - device catchment pervious area and cover type (e.g. grass, shrubs, forest). This should be minimal or zero
    - adequate hydraulic head between entry and discharge from the filter
    - location of filter:
        - clearance to services and boundaries
        - subsoil materials and costs for excavation (beware of rock)
        - water table to be below base of filter
        - access for maintenance
    - define maximum flow capacity requirements for the area to be drained and locate overland flow paths for flows in excess of the capacity of the swale/filter strip
    - check any regional, city or district council requirements for resource consent, building consent or drainage permit or compliance with other standards

4.1.6 Design steps

4.1.6.1 Sizing for water quality design

Sand filter (and similar types) design parameters:

- determine the water quality volume (refer to section 3.6)
- choose media type and sizing

For sand, ARC TP10 specifies sand size as:

Sieve size (mm)	Percentage passing
9.5	100
6.3	95-100
3.17	80-100
1.5	50-85
0.8	25-60
0.5	10-30
0.25	2-10

For sand that complies with the above or is close to compliance, a permeability (k) value of 1 m per day is used in design. If other media are used, or mixtures of sand with other media are used, the permeability should be carefully assessed and a conservative value used for filter design.

Design/sizing methodology (refer to Figure 4.1.2):

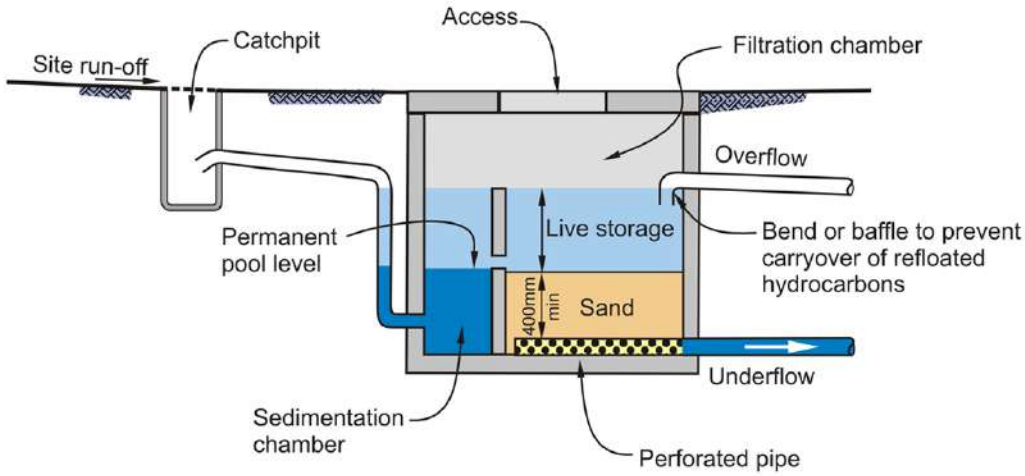
Sand filtration chamber to be sized using the equation:

$$A = WQV \times d / [k \times (h+d) \times t]$$

Where:

- A = surface area of the sand bed
- WQV= water quality volume
- d = depth of sand = 0.4 m minimum
- k = permeability of the sand or other media in m per day
- h = average depth of water during the WQV storm above the surface of the sand in metres, assume to be half the maximum depth
- t = time required for runoff to pass through the filter, in days. This relates to the inter-event period. ARC TP10 requires this to be a maximum of 2 days for the Auckland area. It is suggested that this is used as a default value throughout New Zealand, unless more specific local guidance is available

Figure 4.1.2 Filter detailed design



Provide adequate live storage. The live storage includes the water above the top of the sand in the filtration chamber together with the volume of water in the sedimentation chamber and any associated chambers or pipes that is above the permanent pool level but below the overflow level. Live storage determines the overall performance of the filter, i.e. the total amount of runoff it will treat, so should be maximised (within economical limits). Live storage can be maximised by installing additional separate chambers upstream of the filter. Pipes discharging to the filter can also be utilised to provide additional live storage, subject to suitable geometry and levels. Where peak flow control or extended detention is required, detention tanks can be incorporated before the filtration chamber to provide further live storage and possibly act as sedimentation chambers. The minimum live volume required in ARC TP10 is 37% of the WQV, based on modelling of Auckland conditions. This guideline recommends a minimum live volume of 37% of the WQV unless analysis of local rainfall records and other conditions indicate a larger live volume should be used.

Check that the area of the sedimentation chamber is at least 25% of the filtration area.

Flow velocities in the sedimentation chamber must be less than 0.25 m/s to avoid re-suspension of sediment.

The sedimentation chamber must have a permanent pool with a minimum depth of 0.4 m to reduce re-suspension of trapped sediments.

4.1.7 Design detailing and drawings

Inlet and overflow bypass

- provide flow bypass when live storage is completely utilised; it is better to pass excess flow through the filter chamber than bypassing it before the filter, providing re-suspension of sediment can be avoided
- If inlet flows drop some distance into the sediment chamber, provide energy dissipation before the sediment chamber to avoid re-suspension of sediment

Sedimentation chamber

- configure to avoid short-circuiting of the flow, by using a long narrow pool or tank, the use of baffles to lengthen the flow path and/or provide flow resistance at the inlet

Flow from sedimentation chamber to filter chamber

- design the transfer structure to avoid velocities that will scour the filter bed, using baffles and erosion protection, if necessary, where the flow enters the filter compartment

Access

- provide surface access to sedimentation chamber to allow removal of sediment;
- provide access to filter chamber to allow removal of accumulated material on filter surface

Underdrainage

The filter chamber must have an underdrainage system which can be:

- horizontal perforated pipes in a clean gravel layer or pocket covered with filter cloth
- horizontal perforated pipes covered with filter fabric
- proprietary rectangular drainage product incorporating filter fabric cover

Filter fabric to be chosen and underdrainage system sized and designed to:

- allow maximum filtered flow to pass through with negligible head loss
- pore size suitable to retain sand
- robust fixing of the edges of the filter fabric to prevent short circuiting of sand or water around the edges

Collector pipe system

- sized to pass the design filter flow at the pipe gradient
- provide for flushing of collector pipes
- slope of pipes exceeding 10 m length to be preferably 3% or more

Council requirements

Check any regional, city or district council requirements for resource consent, building consent or drainage permit or compliance with other standards.

4.1.8 Implementation provisions

Following the issuing of the consent, the steps implementing the on-site device are:

- construction: requires close attention to ensuring that the following are met:
  - design details
  - materials specifications in particular topsoil and grass
  - specifications

- commissioning:
  - once constructed, the device will need to be commissioned and tested
  - in the event that the device is commissioned during a dry spell, in some cases it may be appropriate to test the device using a high-capacity hose (e.g. from hydrant or tanker, feeding water to the roof or site impervious area)
  - checks need to be made for "flaws" such as leaks, blockages, evidence of scour, etc

- certification: once commissioned and operating satisfactorily, the device will need to be certified under the provisions of the Building and/or Resource Consent – ARC TP10 provides examples of the checklists used by certification authorities

- O&M (ongoing): the routine maintenance provisions set out below will need to be undertaken, in accordance with either (as applicable):
  - the provisions of the consent (where nominated), or
  - as per an appropriate O&M model (refer to Appendix D2.0)

Filter operation and maintenance

Item	Frequency
Check depth of and removal of accumulated sediment in the sedimentation chamber, remove if depth of accumulated sediment exceeds 25% of the permanent pool depth.	As required, at least annually
Remove excess vegetation, litter, debris from surface of filter bed	As required, at least quarterly
Maintain surface of filter bed by removing accumulated sediment from the surface of the sand.	As required, at least annually, areas with significant contaminant loading may require six monthly
Rejuvenation of the filter bed if emptying times exceed the design time by 50%. This may involve tilling the surface or removal and replacement of the upper part of the bed.	As required

4.1.9 Filter: worked example

Job name	Example			
Location	Gisborne			

design objective	water quality		5 year ARI	
catchment land use	industrial			
impervious area type	seal			
pervious area type	not applicable			
catchment impervious area	800	m^2	800	m^2
catchment pervious area	0	m^2	0	
catchment time of concentration	10	min	10	min
rain intensity source			HIRDS	
rain intensity			54	mm/hr
C impervious	0.9		0.9	
C pervious	0.18		0.18	
catchment CA			0.072	ha
Design Flow			**0.011**	**m^3/s**

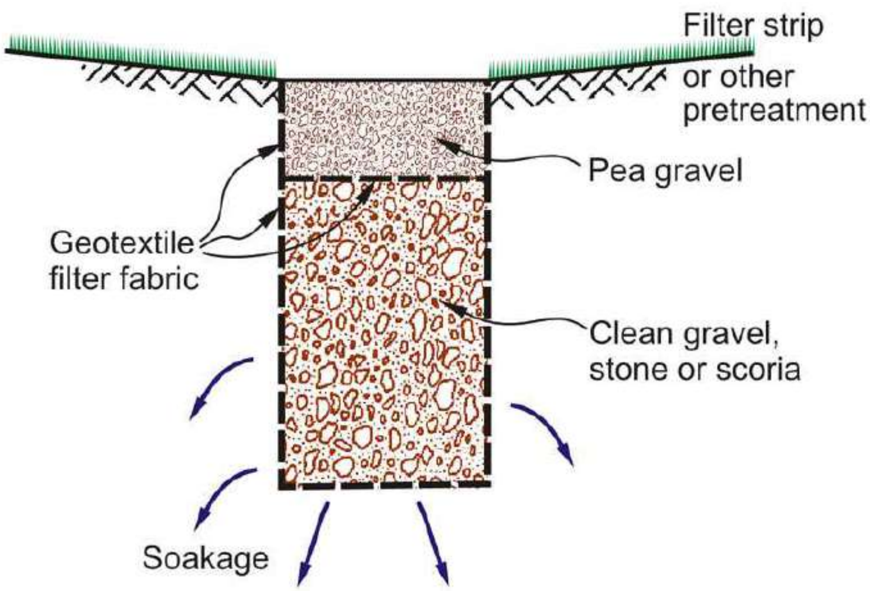
water quality design storm depth	32.6	mm	1/3 of 2 year 24 hour rainfall from HIRDS
runoff from impervious area = rainfall - 2 mm	30.6	mm	
pervious area depression storage and infiltration	na	mm	
pervious area runoff	0.0	mm	
total runoff = runoff from imp & perm area = WQV	24.5	m^3	
depth of sand , d	0.4	m	
coeff perm k	1	m/day	sand 0.25 mm to 9.5 mm
maximum height of ponded water hmax	1	m	from geometry of filter chamber
average height water h = half max height	0.5	m	half maximum height
time to pass WQV t_f	2	day	
area of filter, Af = WQV x d / k(h+d) x tf			
thus required filter area, Af =	5.4	m^2	
minimum live storage required = 37% of WQV =	9.1	m^3	
total required area of filter chamber and sed chamber = min live storage/ max height ponded water			
A_{f+S} =	9.1	m^2	
for filter chamber, nominate inside width, w of	1	m	
required filter length = Af / w	5.4	m	
for width of sed chamber same as for filter chamber, ie = w =	1	m	
total filter chamber & sed chamber length for 37% WQV =	Af+s / w		
=	9.1	m	
min. sed chamber length based on 37% WQV =	total filter & sed chamber length - filter length		
	3.6	m	
Min sed chamber area based on 37% WQV = length x width	3.6	m^2	
check that minimum sedimentation chamber area = 0.25 x A =	1.4	m^2	OK
check velocities in sed chamber for 5 year ARI event			
A rea of flow = w x h =	1	m	
vel = Q_5 / area of flow =	0.01	m/s	< 0.25 OK

4.2 Infiltration trench

4.2.1 Description

An excavated trench, backfilled with stone or scoria media. Stormwater from paved areas enters the trench and trickles through the trench media. Infiltration trenches are used where final disposal is via infiltration of stormwater into surrounding insitu soils. In these cases most of the treatment is provided by adjacent soils provided they are of suitable texture.

Figure 4.2.1 Infiltration trench operating principles



4.2.2 Capability

Infiltration trenches are able to:

- o treat runoff from impermeable hardstand ground surfaces in commercial, residential and industrial areas
- o treat road or parking lot runoff
- o be located so as to take up a small amount of space
- o may in some situations, provide peak flow detention up to the two year ARI event and thus can be used for stream channel protection

Infiltration trenches are not able to:

- treat sediment-laden water from construction sites

Expected contaminant removal rates for trenches where disposal is by infiltration to adjacent soil are listed below, from ARC TP10 and EPA, 1999b. Note that treatment is provided primarily by the insitu soil and will be dependant on its texture:

sediment	90%
metals (copper, zinc, lead) (totals)	85 to 90 %
total phosphorus	60 to 70%
total nitrogen	55 to 60%
organics	90%
bacteria	90%

4.2.3 Applicability

- care is needed to avoid groundwater contamination: refer section 3.5, 3.6 and 3.8
- for car parks and other areas with high or hydrocarbon loads, inflow should be pre-treated to reduce sediment loads, for example by using shallow flow over grass (6 to 8 m wide)
- check that adequate soakage is available and other requirements for infiltration are complied with; refer sections 3.8 and 3.10. Trench preferably horizontal along its length, maximum slope along trench less than 5% to avoid wastage of trench volume. Works best if upgradient drainage slope is less than 5%
- ensure minimum separation distance of 600 mm between bottom of the device and the seasonably high water table (Georgia Stormwater 2001)
- adequate clearance to existing utilities and to site boundaries
- provide downstream overland flow path to avoid scour damage or flood damage to assets
- can incorporate large pipes within trench to provide additional pore space to provide additional storage to help treat large volumes of stormwater
- can add organic matter to the subsoil to enhance removal of metals and nutrients
- device catchment area: no more than 4 hectares, preferably not more than 2 ha (ARC TP10)
- care is needed to prevent large amounts of sediment entering the trench

> Infiltration trenches are not suitable for sites with risk of significant sediment runoff that could block up the trench.
>
> Ensure trenches are not installed until after site works are complete and contributing areas are fully stabilised

4.2.4 Summary of design approach

Determine the size required to meet water quality objectives.

4.2.5 Preparatory steps

1. Confirm design imperatives
   - quality objective: refer section 3.6, confirm that an assessment has been made to ensure that discharge to ground will not have an adverse effect on groundwater
   - refer to ground disposal assessment requirements in Section 3.8 and 3.10 sensitivity of groundwater
2. Define key site parameters and device needs that determine design details
   - device catchment land use (this is required to be used in design calculations)
   - device catchment impervious area (roof and on-ground areas)
   - device catchment pervious area and cover type (e.g. grass, shrubs, forest)
   - check any regional, city or district council requirements for resource consent, building consent or drainage permit or compliance with other standards.
   - provision of adequate access for maintenance

4.2.6 Design steps

4.2.6.1 Sizing for water quality design

The recommended method for sizing for infiltration trenches is similar to that in ARC TP10 and other stormwater guidelines.

Design parameters:

- determine Water Quality Volume (WQV) from the appropriate method in section 3.6
- determine design percolation or soakage rate, based on the results of soakage tests or based on soil properties
- assess void ratio of trench media - for clean stone this is typically 0.35, for scoria 0.5 (ARC TP10)
- select the trench drain time in days this should be a minimum of 6 hours (EPA 1999b) and a maximum of 48 hours. ARC recommends a drain time of 48 hours be used for the Auckland region. It is recommended that a maximum drain time of 48 hours be used unless local conditions suggest a different value

4.2.6.1 Design / sizing methodology

The recommended method is a simplified version of that in ARC TP10, which allows complete infiltration within a nominated drain time:

$$A = WQV / (f \times i \times t)$$

where:

A = base area of trench
WQV = water quality volume, m^3 as per section 3.6 (include trench surface area in the calculation for WQV)
f = design infiltration rate (measured rate multiplied by a factor of safety of 0.5)
i = hydraulic gradient, assumed to =1
t = drain time, maximum 48 hours

Size the trench depth to provide storage in the trench voids equal to 37% of the water quality volume unless hydrologic analysis or local experience provide another more appropriate proportion of the WQV to be used to calculate trench storage.

Trench gross area = V = 0.37 x WQV / n
where
n = the stone void ratio, typically 0.35 for stone

Check that the trench sized to meet the storage requirements also meets the area requirements, using the formula above for trench area, resize trench as necessary.

4.2.7 Design detailing and drawings

Inlet

- provide appropriate pre-treatment to reduce sediment input, such as grassed swale, grass filter strip, permeable pavement

Trench dimensions

- typically 0.9 m wide and 0.9 to 2 m deep

Addition of organic material

provide details of amount and method of adding organic material, if required. Take care not to compromise disposal capacity

Stone or scoria media

- 25 to 75 mm , clean

Filter fabric

- use filter fabric on the side walls to prevent migration of in situ soils into the trench
- filter fabric to overlap across the top of the trench or at a depth of 300 mm to minimise entry of sediment form the surface

Observation well

use 100 mm perforated PVC pipe with a footplate and cap

Council requirements

check any regional, city or district council requirements for resource consent, building consent or drainage permit or compliance with other standards

4.2.8 Implementation provisions

Following issuing of the consent, the steps involved in implementing the on-site device are:

- construction: requires close attention to ensuring that the following are met:
    - design details
    - materials specifications in particular stone or scoria medium
    - use light equipment for trench excavation to minimise compaction of surrounding soils
    - trench base and side clear of roots etc that could damage filter fabric or impermeable liner
    - follow construction specifications

- commissioning:
    - once constructed, the device will need to be commissioned and tested
    - in the event that the device is commissioned during a dry spell, in some cases it may be appropriate to test the device using a high-capacity hose (e.g. from hydrant or tanker, feeding water to the roof or site impervious area)
    - checks need to be made for "flaws" such as leaks, blockages, evidence of scour, etc

- certification: once commissioned and operating satisfactorily, the device will need to be certified under the provisions of the Building and/or Resource Consent – ARC TP10 provides examples of the checklists used by certification authorities

- as-builts – preparation of as-built drawings for the TA and the property owner

- O&M (ongoing): the routine maintenance provisions set out below will need to be undertaken, in accordance with either (as applicable):
    - the provisions of the consent (where nominated), or
    - as per an appropriate O&M model (refer to Appendix D2.0)

Operation and maintenance

Item	Frequency
Clear debris, litter from entry and contributing areas	As required, at least quarterly
Monitor observation well to assess whether trench ids draining within the specified times	Annually
Remove small section of upper trench and inspect upper layer of filter fabric for sediment deposits. If clogged, restore to original condition	Every 2 years

Infiltration trench worked example

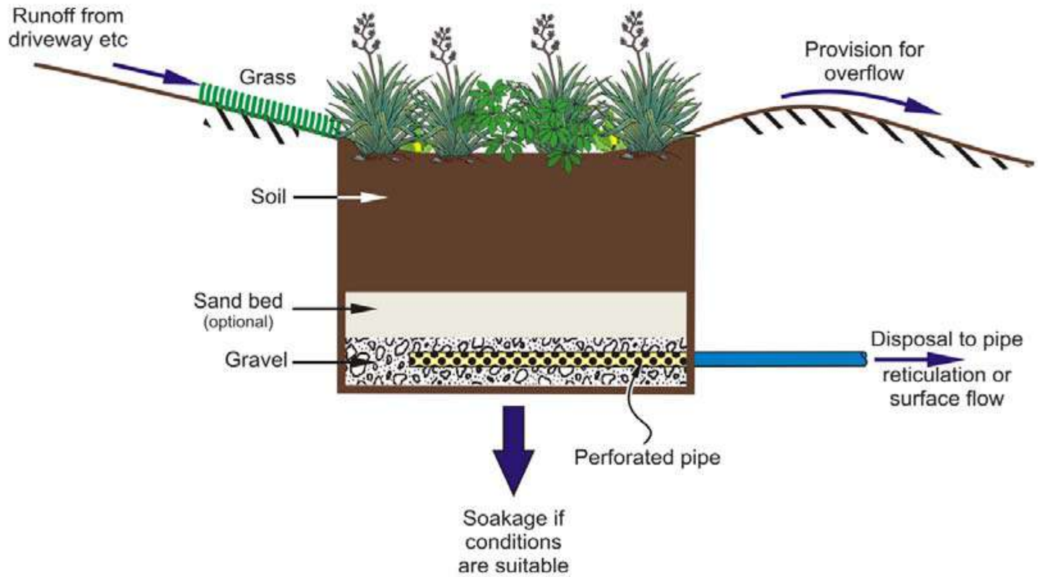
Job name	Example				
Location	Gisborne				
design objective	Water quality				
catchment land use	industrial				
impervious area type	seal				
pervious area type	not applicable				
catchment impervious area	800	m^2			
catchment pervious area	0	m^2			
catchment time of concentration	10	min			
rain intensity source					
rain intensity					
C impervious	0.9				
C pervious	0.18				
Catchment CA					
water quality design storm depth	32.6	mm	1/3 of 2 year 24 hour rainfall from HIRDS		
runoff from impervious area = rainfall - 2 mm	30.6	mm			
impervious area soil drainage	na				
pervious area depression storage and infiltration	na	mm			
pervious area runoff	0.0	mm			
total runoff = runoff from imp & perm area = **WQV**	24.5	m^3			
soil infiltration rate based on soakage test/soil type	26	mm/hr	sandy loam		
design percolation or soakage rate = half infiltration rate = f =	0.31	m/day			
media porosity, n =	0.35	gravel			
drain time, t =	2	days			
hydraulic gradient, i assumed =	1	m/m			
Required area, A = WQV / (f x i x t) =	39.5	m^2			
Required trench gross volume, V = 0.37 x WQV / n =	25.9	m^3			
if trench depth, D =	1.30	m			
choose trench width, W =	0.9	m			
Thus required trench length, based on gross volume requirement = L = V / (W x D)	22.1	m			
Check trench area, based on gross volume = L x W=	19	m^2			
Need to increase trench length and /or width to meet area requirement of 39.5 m^2					
Required trench length based on width of 0.9 m = A/L=	44	m			

4.3 Rain garden

4.3.1 Description

Also known as bioretention areas or stormwater planters, rain gardens are an in-ground filter, with the upper surface of the filter medium exposed to allow infiltration of collected stormwater ponded on it. The filter medium is a specially selected soil/sand mix with a surface mulch or organic layer. Small, shallow-rooting plants protect this medium (the ‘soil medium’) and provide some evapotranspiration.

Figure 4.3.1 Rain garden operating principles



Stormwater is conveyed by surface flow to the rain garden, ponds on the surface and slowly infiltrates through the planting medium. Treatment is provided by filtration in the soil medium together with bioretention provided by the plants and organic/mulch layer. After infiltrating through the soil medium, water is discharged either by infiltration to underlying soil, or is collected in a pipe and discharged to a reticulated service or surface disposal.

4.3.2 Capability

Rain gardens are able to:

- treat runoff from impermeable hardstand ground surfaces in commercial, residential and industrial areas, including parking lot runoff

Expected contaminant removal rates are (ARC TP10, EPA 1999c):

• sediment	90%
• metals (copper, zinc, lead)	93 to 98 %
• total phosphorus	70-83%
• total Kjeldahl nitrogen	68-80%
• organics	90%
• bacteria	90%
• hydrocarbons	> 75%

Rain gardens may be able to:

- be used for flow attenuation and extended detention thus may be used for stream channel protection
- provide aesthetic benefit

Rain gardens are not able to:

- treat sediment-laden water from construction sites. Install after site works are complete and contributing areas have been fully stabilised in order to prevent excess sediment loading

4.3.3 Applicability

- can be located in median strips and islands
- on line or off line location (refer to glossary for definition)
- maximum ground slope: 20% (11°) from considerations of construction practicality: need to check for slope stability
- avoid unstable ground
- ensure minimum separation distance of 600 mm between bottom of the device and the seasonably high water table(Georgia Stormwater 2001)
- adequate clearance to existing utilities and to site boundaries
- inflow should be via shallow flow over grass, to prevent scour of the rain garden surface
- provide overland flow downhill path to avoid scour damage or flood damage to assets
- minimum head required between inlet and outlet is 1.5 m (Georgia stormwater 2001)
- location of piped outlet to discharge to pipe reticulation or surface dispersal
- device catchment area no more than 1000 m^2 (ARC TP10)

4.3.4 Summary of design approach

Determine the size required to meet:

- water quality objectives
- peak flow control and stream channel protection objectives

Check that a device of the required size can be built on the site for all relevant objectives. A device sized to meet the most onerous objective will meet the others.

If a device of the size required to meet a water quality/peak flow/quantity objective cannot be built on the site but a smaller device will be able to meet the most onerous objective, then adopt the sizing for that less onerous objective and select a separate device to meet the more onerous objective.

4.3.5 Preparatory steps

1. Confirm design imperatives

- quality objective: refer section 3.6
- peak flow quantity and stream channel protection: refer section 3.7

2. Define key site parameters and device needs that determine design details

- device catchment land use (this is required to be used in design calculations)
- device catchment impervious area (roof and on-ground areas)
- device catchment pervious area and cover type (e.g. grass, shrubs, forest)
- for final discharge by infiltration to ground, refer to ground disposal assessment requirements in Section 3.8 and 3.10
- for final discharge to pipe reticulation or to the surface, care is needed to avoid potential slope instability from infiltration from the rain garden to adjacent in situ soil. For slopes over 5%, an impermeable liner is required, or approval from geotechnical advisor obtained if a liner is not used
- for water quality treatment only, the maximum ponding depth recommended to avoid over wetting of plants is 220 mm (ARC,2004). Where the maximum water depth will be 220 mm, select suitable plants from Chapter 7, Table 7-3 of ARC TP10
- for flow control and extended detention for stream channel protection, maximum ponding depth may need to be over 220 mm. Obtain specialist plant selection advice for depth of ponding more than 220 mm, or use mulch instead of plants
- check any regional, city or district council requirements for resource consent, building consent or drainage permit or compliance with other standards
- provision of adequate access for maintenance

4.3.6 Design steps

4.3.6.1 Sizing for water quality design

These steps follow the ARC TP10 method, unless noted otherwise.

Design parameters

- determine water quality volume (WQV) from the appropriate method in section 3.6
- minimum live storage: 40% of WQV; This is recommended to be used unless local studies suggest a different value should be used
- detention time for WQV (time to pass through soil):
  - ARC TP10 recommends 1 day for residential sites, which is based on the amenity considerations, ie homeowners may not want ponding longer than this
  - ARC TP10 recommends a detention time up to 1.5 days for commercial/industrial sites
  - the above are recommended to be used unless local studies suggest different values should be used
- planting soil depth: minimum 1 metre for good root growth
- soil permeability: adopt 0.3 m/day default for soil per description in section 4.3.7
- ponding depth:
  - initial assumption: maximum 220 mm
  - average depth during device operation: half maximum
- once area has been calculated, check that depth based on 40% WQV is satisfied by the assumed ponding depth

Design/sizing methodology

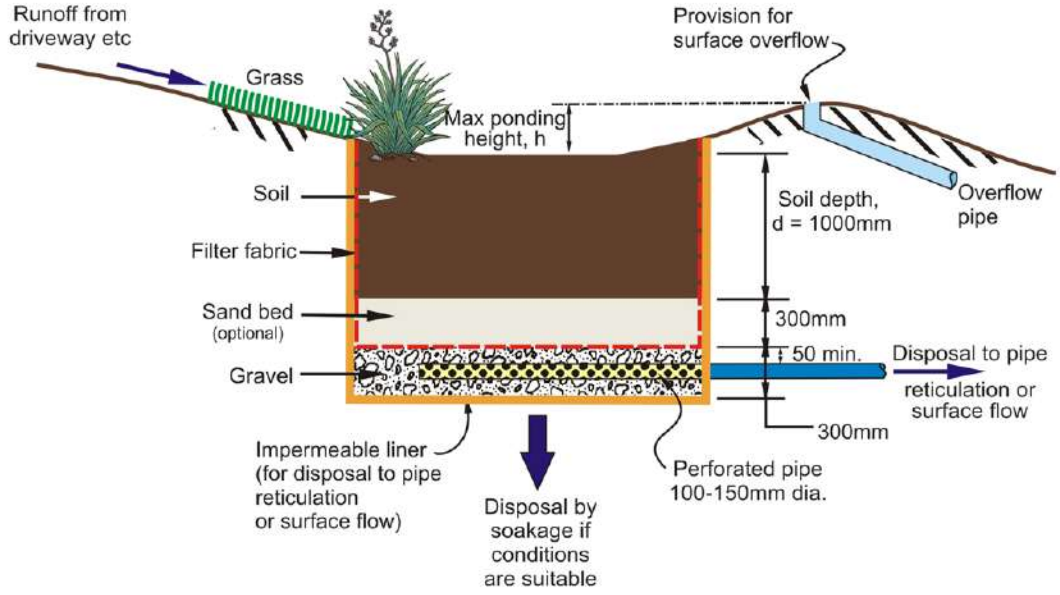
Refer to Figure 4.3.2.

$$A = WQV \times d / (k \times (h/2+d) \times t)$$

Where:

A = surface area, m^2
WQV = water quality volume, m^3
d = planting soil depth, m
k = coefficient of permeability, m/day
h = maximum depth of ponded water above surface, mm
t = time to pass WQV through soil

Figure 4.3.2 Rain garden detailed design



4.3.6.2 Sizing for peak flow / volume control

Design objectives

confirm design objectives, refer section 3.7, i.e. required peak flow control (ARI events to be considered) and extended detention requirements

Design parameters

- determine catchment rainfall losses, or land use runoff factors, refer to Appendix C
- determine rainstorm ARI and duration to be considered and associated rainfall depths
- assess a maximum ponding depth based on site topography. A maximum ponding depth of 0.6 metres is recommended, to avoid excessive inundation of plants. Obtain specialist plant selection advice for this depth of inundation
- assume average ponded depth = half maximum depth
- planting soil depth: minimum 1 metre
- soil permeability: adopt 0.3m/day for planting soil

Design/sizing methodology

- generate hydrographs for existing situation –for peak flow control ARI events under consideration
- generate inflow hydrographs for developed situation –for peak flow control ARI events and for rainfall depth for extended detention requirements
- adopt trial rain garden area

- calculate outflow characteristics (one or more of the following):
  - seepage through planting soil: Q = A x k x (h/2+d) / d
  - outflow through overflow pipe using appropriate standard equations
  - overflow via surface overflow using standard equations Mannings for gentle slope downstream of rain garden, broad crested weir for embankment
- route inflow hydrographs (developed) through the rain garden
- check whether peak flow and extended detention objectives are achieved. If they are not achieved, decide whether a larger device is practical for the site. If so, increase the surface area and maximum water height to the practical maximum and recalculate the routing calculations
- if the required peak flow and extended detention control objectives can be achieved by the revised design, confirm the device feasibility in relation to the site characteristics, especially slope and available area

Determine device size

- check that the required size can be achieved on the site for all relevant objectives. If so, the device is sized to meet the most onerous objective will meet other objectives
- if a device of the size required to meet a water quality/peak flow/extended detention objective cannot be built on the site but a smaller device will be able to meet a less onerous objective, then adopt the sizing for that less onerous objective and select a separate device to meet the more onerous objective
- if the required depth of ponding results in drainage time in excess of 1 to 1.5 days, select plants that can tolerate longer wetting times

4.3.7 Design detailing and drawings

Inlet

Provide a grass buffer between the downstream edge of paved areas and the edge of the rain garden of at least 1 m length in the direction of flow. Design inflow to be spread over as much of the full width of one side of the rain garden as possible to minimise scour of the surface. Need to address on line and off line and design implications.

Plants

Use the plant types and spacings in Section 7.5 and Tables 7-2 and 7-3 of ARC TP10.

Soil medium requirements

- loamy soil: 35 to 60% sand
- clay content: less than 25% (some clay is beneficial for treatment)
- permeability: at least 0.3 m per day
- free of stones, stumps, roots, seeds

Soil placement requirements

- place soil in lifts of 300-400 mm and loosely compact
- cover soil surface with a mulch layer
- use filter fabric on the side walls to prevent migration of in situ soils into the rain garden

Interface between soil and underdrain

There are two options for managing the potential migration of planting soil in the underlying gravel:

- option 1: do not place filter cloth between the planting soil and the gravel underdrain, to avoid potential clogging as recommended in ARC TP10.
- option 2: place a permeable filter cloth to stop planting soil migrating into the underdrainage system, recommended in Georgia Stormwater, 2001

Maintenance implications

Using filter cloth means accepting that the planting soil may need to be removed and the filter cloth cleaned or replaced at certain intervals. Not using filter cloth means potential clogging of underdrainage gravel material may occur which would be difficult to remove and clean but may need to be done infrequently.

Surface mulch

- standard landscape type shredded wood mulch or chips
- well aged, free of other materials such as weed seeds, soil, roots etc
- apply in a uniform thickness of between 50 and 75 mm deep

Impermeable liner

May be required on sites where ground soakage is not used in order to avoid raising local groundwater levels which may lead to instability or other problems. Options are an impermeable liner or a suitable impermeable container such as concrete or timber with an internal impermeable liner. For slopes over 5%, or where stability of adjacent land may be vulnerable to infiltration of water from the raingarden, an impermeable liner is required unless site-specific geotechnical advice is obtained that it is not necessary.

Underdrainage

The underdrainage system comprises gravel layer and a perforated pipe:

- gravel to be clean (no fines) with minimum thickness of 300 mm
- outlet pipe to be perforated 100 mm or 150 mm diameter
- minimum cover of gravel over the pipe to be 50 mm.

Outlet from surface of garden and overflow

A surface entry piped outlet can be used if the hydrologic design requires additional outflow. Whether or not a piped outlet for the garden surface is used, the minimum requirements for provision of overflow are:

- grassed or protected length of in situ or fully compacted soil for the full length of the downstream side of the rain garden
- use of a 50 x 150 mm horizontal timber level spreader to ensure even flow and minimise scour
- overflow directed clear of buildings or other assets or features that may cause obstructions to flow

Council requirements

Check any regional, city or district council requirements for resource consent, building consent or drainage permit or compliance with other standards.

4.3.8 Implementation provisions

Following issuing of the consent, the steps in implementing the on-site device are:

- construction: requires close attention to ensuring that the following are met:
  - design details
  - materials specifications in particular planting medium grading
  - specifications

- commissioning:
  - once constructed, the device will need to be commissioned and tested
  - in the event that the device is commissioned during a dry spell, in some cases it may be appropriate to test the device using a high-capacity hose (e.g. from hydrant or tanker, feeding water to the roof or site impervious area)
  - checks need to be made for "flaws" such as leaks, blockages, evidence of scour, etc

- certification: once commissioned and operating satisfactorily, the device will need to be certified under the provisions of the Building and/or Resource Consent – ARC TP10 provides examples of the checklists used by certification authorities

- O&M (ongoing): the routine maintenance provisions set out below will need to be undertaken, in accordance with either (as applicable):
  - the provisions of the consent (where nominated), or
  - as per an appropriate O&M model (refer to Appendix D2.0)

Operation and maintenance

Item	Frequency
Clear debris, litter from rain garden and contributing areas	As required
Remove noxious or invasive weeds and plants	As required but inspect at least quarterly
Check plant height and density, prune excessive vegetation, replace plants if necessary	As required, but at least 6 monthly
Check that the surface dewaters between storms: 220 mm of ponded water depth should empty within 1 or 1.5 days, depending on design (residential, commercial/industrial). If longer, check for surface clogging, remove sediment. Replace planting soil medium if required	6 monthly
Outlet /overflow spillway: check condition, scour, erosion, blockage	6 monthly
Sediment accumulation: remove if more than 30 mm depth, re-establish plants after sediment removal	Annually
Rain garden integrity: check device has not been blocked or filled in	Annually
Replace mulch	Every 2 to 3 years

4.3.9 Rain garden design worked example

Job name	Example		
Location	Gisborne		

Design objective	Water quality		
catchment land use	residential		
impervious area type	seal		
pervious area type	grass, shrub		
catchment impervious area	500	m^2	
catchment pervious area	300	m^2	
catchment time of concentration	10	min	
rain intensity source			
rain intensity			
C impervious	0.83		
C pervious	0.18		
Catchment CA			
water quality design storm depth	32.6	mm	1/3 of 2 year 24 hour rainfall from HIRDS
runoff from impervious area = rainfall less 2 mm	30.6	mm	
pervious area soil drainage	slow		
pervious area depr storage and infiltration	15	mm	
pervious area runoff = rain – depr stor & infiltr =	17.6	mm	
total runoff = WQV	20.6	m^3	
planting soil depth d	1	m	
coeff perm k	0.3	m/day	
maximum height of ponded water h	0.22	m	
time to pass WQV t	1	day	residential

Area, A = WQV x d / (k x (h/2+d) x t)

Thus area	=	61.8	m^2	
check min live storage	=	area x max height ponded water		
	=	13.6	m^3	
	=	66.1	% of WQV	(> 40% OK)

4.4 Stormwater planter

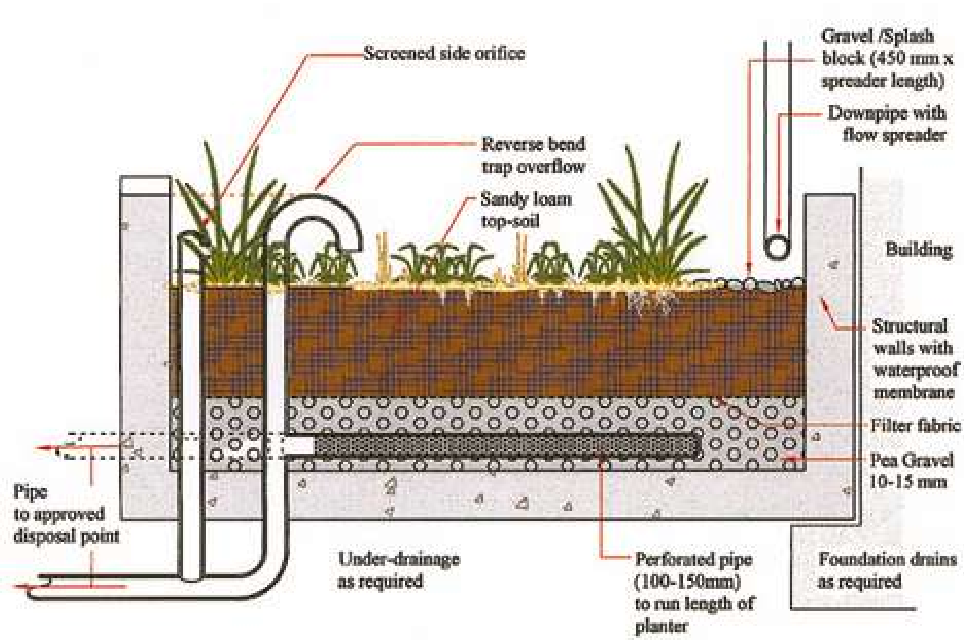
4.4.1 Description

The stormwater planter is essentially a variant of the rain garden (refer Section 4.3). The main differences are:

- it is fed from roof water only
- it is typically located above ground, or partially buried, designed to serve both stormwater and landscaping functions
- its outlet is normally connected to the public stormwater system, although it can be revamped to operate in a disposal-by-soakage mode

As documented in this guideline, the device is based on an arrangement in widespread use in Portland, Oregon, USA (CoP 2002) and adapted by Auckland City Council (ACC 2002). The stormwater planter, as illustrated in Fig. 4.4.1, functions as both a water quantity and quality control device.

Figure 4.4.1 Stormwater planter



The key components and function of the stormwater planter are:

- roof water is fed onto the surface of the stormwater planter, via a spreader device
- this water infiltrates through the top soil layer and then collects in the underlying drainage layer, from where it is piped to the public stormwater system
- when the inflow rate exceeds the soil infiltration rate, ponding occurs on top of the soil; this is contained by the wall of the stormwater planter

- two outlets[1] from the pondage, located at the end opposite the spreader inlet, feed to the public stormwater system via a standpipe, namely:
  - o an orifice [1] comes into operation when the ponding is nominally about half-full - ponding to this level is required to meet water quality requirements
  - o a half siphon which comes into operation when the ponding is nominally full[2]
- part of the wall rim is cut down to act as an emergency overflow

The stormwater planter is normally sited above-ground, rather like a planter box (Figure 4.4.2). However, the base can be below ground level, subject to suitable gradients being available to connect the outlet to the public stormwater system, and provided flooding by groundwater can be avoided. It is normally constructed in concrete (e.g. plaster-faced concrete blocks, cast-in-situ concrete or precast concrete), but can be constructed from timber, much like a retaining wall.

Figure 4.4.2 Stormwater planter example

4.4.2 Capability

The stormwater planter has the same broad capabilities as for the rain garden, but with a greater flow attenuation capacity. In summary, a stormwater planter is able to:

- provide detention to achieve peak flow attenuation of roof runoff (a stormwater planter alone can often meet the greenfield site runoff standard, by over-throttling the flow to compensate for the extra runoff from the site impervious area)
- filter-out the roof-derived sediment and allied contaminants (refer Section 4.3.2)

The stormwater planter is not able to:

- treat site runoff (refer Section 4.3 for rain gardens, which can serve this function)

4.4.3 Applicability

- receives roof runoff

[1] The plan for a second orifice-type outlet was introduced by ACC, 2002, designed to reduce the planter size over that required for a single siphon outlet arrangement (as used by City of Portland)
[2] With the orifice, the siphon is essentially superfluous, but is retained as a safety against blockage of the orifice

- performs a water quality and quantity control function (note that the former may not be as important an objective as for a rain garden which treats site runoff)
- is normally installed on the ground or partially buried, provided flooding by groundwater can be avoided
- must be sited at an elevation to allow adequate fall from outlet at the base of the planter box to the connection point with the stormwater receiving system, noting that provision may be needed for heading-up of the latter
- doubles as an attractive landscaping feature, thereby avoiding the need for a dedicated a space such as needed for say a rain tank
- allow access for maintenance

4.4.4 Summary of design approach

1. Confirm the suitability of the stormwater planter to the particular site and application
2. Establish device parameters and the applicable water quantity and quality performance standards
3. Establish the site parameters
4. Assemble the requisite hydrological data applicable to the general area in which the device to be sited
5. Size the capacity needed to meet the water quantity and quality control targets (note that the former is normally calculated first, and then the need for any incremental storage to meet the water quality target is computed)
6. Complete the attendant device sizing and hydraulic design

<u>Note</u>: *For details of the model-based approaches, refer Appendix C – Section C2.4; note that the procedure set out below used manual methods, assisted with spreadsheets*

4.4.5 Preparatory steps

4.4.5.1 General

1. Confirm the applicability of using a stormwater planter, noting that it accepts flow from roofs only
2. Confirm the water quality control performance standard (note that if water quality is a secondary objective – recognising that roof runoff is relatively clean compared to say site runoff (aside from zinc off metal roofs) - the planter can be designed as a flow control device, noting that the basic planter design achieves a degree of treatment)
3. Confirm the peak flow control performance standards, ie:
    - design storm frequency (e.g. 2% AEP, 10% AEP and/or 50% AEP, with the latter only applicable where there is a stream channel erosion protection imperative – refer Section 3.7)
    - the target peak site outflow; this is typically as existing, or greenfield – refer Section 3.7 (note that a stormwater planter alone can often meet the greenfield site runoff standard, by over-throttling the flow to compensate for the extra runoff from the site impervious area)

4. Establish applicable design time of concentration (Tc – refer Appendix C, Section C2.2 for further details), e.g.:
   - in the receiving stormwater system, at the dwelling connection point (= Tc_1 say)
   - at key points on down to the outfall (e.g. major watercourse, sea); = Tc_2 , Tc_3, etc
5. Establish key site parameters, e.g.:
   - site area
   - impervious area (roof and on-ground)
   - pervious area (and cover type)
6. Identify site/device layout constraints, e.g.:
   - device location
   - device above ground or partially buried
   - stormwater system connection points (and corresponding elevations)
   - overland flow paths (from the emergency overflow)

4.4.5.2 Hydrological data

1. Obtain rainfall depth-duration-frequency data applicable to the general area in which the planter is to be sited, for the following cases, as applicable (refer Section 3.12 for explanations/details):
   - 50%, 10% and 2% AEP
   - applicable Tc values (from 3 above)

Using the data from (1) above, establish design storm runoff peaks and hydrographs, according to the Rational Formula, or other method (refer Section 3.12 and Appendix C for details), for:

- target site outflow (only the peak flow is required)
- roof runoff
- rest-of-site runoff (ie surface impervious and pervious)

4.4.6 Design steps

(a) Summary:

1. Collate the design data/parameters from Section 4.4.5
2. Size the storage capacity required for water quality control
3. Select tentative planter dimensions and size the storage capacity required for flow control
4. Reconcile the storage volumes from (2) and (3) above
5. Size the allied hydraulic components

(b) Sizing water quality storage:

Note: *As explained in Section 4.4.5.1(2), where water quality control is a secondary objective, this computation step can be bypassed*

This should apply the water quality volume (WQV) based approach, as used for the rain garden (refer Section 4.3.6.1 – note that, because the method is the same, it is not repeated here).

From this calculation, the following will be derived:

- planter surface area, W (m^2)
- planter ponding height[3], h (mm)
- planter storage capacity, P (m^3) = W x h / 1000

(c) Sizing storage to meet flow control:

Typically, a spreadsheet is used to size the temporary storage capacity. This involves performing routing calculations to quantify the way the storage provided in the planter modifies the inflow hydrograph (refer Appendix C – Section C3.4 for details).

Because the method closely parallels that applied in sizing the temporary storage component of a rain tank - refer Section 4.5.6(b) and Section 4.5.10 for a sample of the spreadsheet – it is not repeated here. Note also the probable need for "trial and error" iterations, also accounting for the full range of applicable storm durations from the catchment Tc value up to the duration giving the maximum volume requirement [ie as set out in Section 4.4.5.1(4)], to arrive at the design sizings.

The following adjustments should be applied to the generalised spreadsheet in Appendix C (Table C3) to model the planter features:

- planter dimensions (refer Figs 4.4.3 and 4.4.4 for typical dimensions[2]):
  - o in place of the tank area, the planter area is used (<u>note</u>: *where the water quality-based design step (b) above applies, this area should match that used in (b), ie A m^2)*
  - o in place of the tank height, the heights of the orifice and siphon are used (ie both relative to the top of the planter soil surface)
- orifice:
  - o apply the orifice discharge formula to match its location in the stormwater planter (<u>note</u>: *where the water quality-based design step (b) above applies, this orifice should be located at height "h" – as derived in (b) - above the planter soil surface)*
  - o size the orifice so that when the water level in the planter reaches the siphon level, the sum of the orifice and the infiltration flows matches the required maximum device outflow rate

o add the following outlets/outflows:

  - o an infiltration component (ie based on the infiltration rate, in m/day)
  - o the half siphon outlet[4]
  - o the emergency overflow[3]

An example of the planter spreadsheet is given in Section 4.4.10. Note that:

- the spreadsheet also incorporates a trial orifice diameter calculation (ie based on the simplifying assumption that the peak flows from both the planter and "rest of site" coincide in time)
- infiltration = infiltration rate (K) x planter area
- orifice discharge – refer formula in Table C4 (Appendix C)
- overflow; not accounted for in the spreadsheet example (refer spreadsheet footnote for an explanation)

[3] For aesthetic reasons, the height of the planter wall above the soil surface should not exceed about 300 mm

[4] In the spreadsheet, the hydraulics of these two high level outlets can be adequately approximated by applying the assumption that the outflow matches the inflow

From the spreadsheet, the following will be derived:

- planter surface area, W (m^2)
- maximum water depth above the planter soil surface, M (m)
- planter storage capacity, R (m^3) = W x M
- orifice: E (mm) diameter, set N (mm) above the planter soil surface

(d) Net storage:

Use the following procedure to reconcile the storage capacities derived in (b) and (c) above:

- water quantity control only: adopt the planter sizings derived by the spreadsheet in (c) above
- water quality and quantity control (the symbols used below are as defined in (b) and (c) above):
  - o select the greater of the planter storage capacities, P and R (ie as derived in (b) and (c) respectively)
  - o check that the orifice height, N [ie as computed in (c)] is set above the depth, h, needed for water quality control [ie as computed in (b)]

(e) Sizing of hydraulic components:

1. orifice standpipe diameter, F (mm) = 1.5 x orifice diameter E (mm)
2. siphon diameter, G (mm): select the larger of:
   - o the orifice diameter, E (mm), or
   - o 50 mm
3. emergency overflow:
   - o takes the form of a “discharge slot”, namely a cut-down section of the planter wall, located to ensure flow is directed away from buildings and avoids damage to adjacent properties
   - o design the overflow to pass the full 2% AEP flood, with the pipework assumed blocked
   - o size the discharge slot by applying the sharp-crested weir formula (refer Appendix C – Section C4.0), allowing a modest freeboard
   - o an illustrative sizing (from ACC, 2002) as shown in Fig 4.4.4,. takes the form of a slot, S = 30 mm deep x T(m) in length, where T = 0.1xwall perimeter length, or 0.2 x (Y+Z)
4. planter wall height, K = M (max water depth)+G (siphon diameter)+S (emergency overflow slot depth)

Figure 4.4.3 Stormwater planter – definition sketch

Note: Dimensions are illustrative only

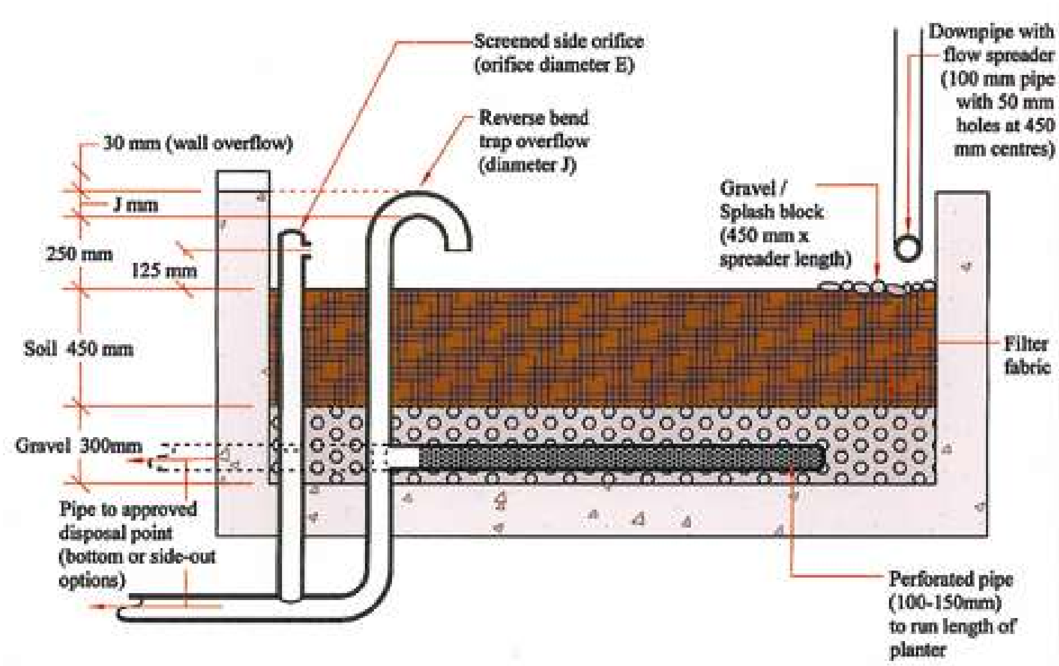
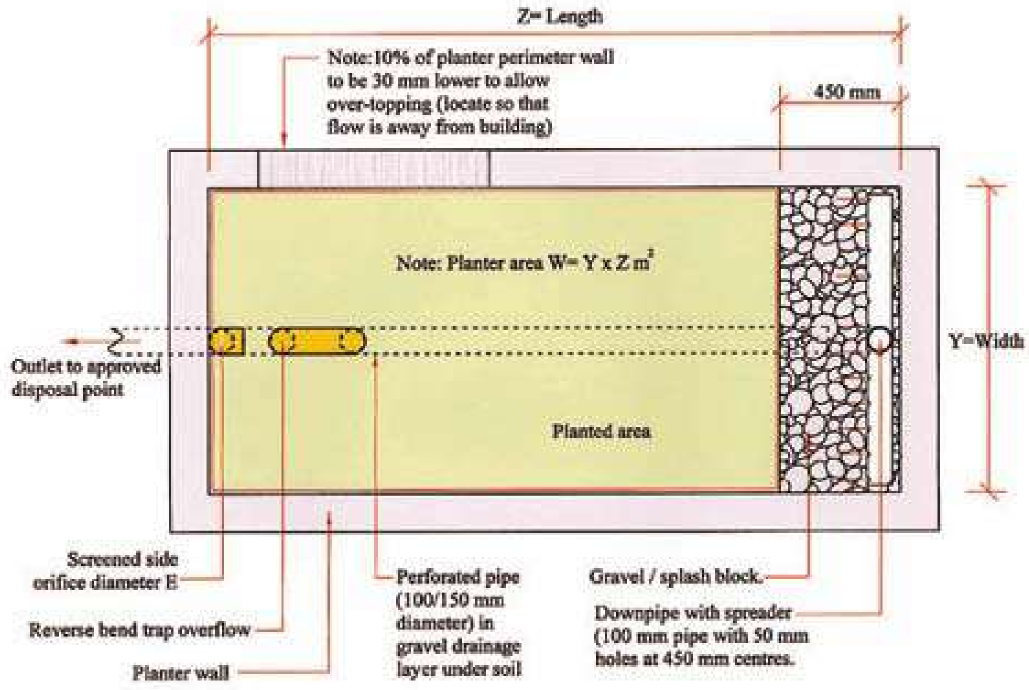


Figure 4.4.4 Stormwater planter – plan

Note: Dimensions are illustrative only



4.4.7 Design detailing and drawings

The standard design details applicable to stormwater planters, to be shown on drawings to be submitted with the consent application(s), are as listed below (adapted from ACC, 2002). These should be read in conjunction with Figs 4.4.3 and 4.4.4, noting that the dimensions on these drawings are illustrative only.

In parallel, it will be appropriate to check any regional, city or district council requirements for resource consent, building consent or drainage permit or compliance with other standards.

Stormwater planter worked example

Item:	**Requirement:**
Planter base elevation	Nominally at ground level, but can be sunk into the ground to a depth of not more than 500 mm, subject to suitable gradients being available to connect the outlet to the main/public stormwater system, and provided flooding by groundwater can be avoided by installing separate sub-surface drainage externally, at base level. In such cases, the applicant / developer is to provide full details of the proposed arrangement for: - the connection (including the reduced levels of the planter base and stormwater system connection) - the sub-surface drainage system
Key dimensions:	
- Minimum planter width	500 mm (no minimum length or prescribed planter shape)
- Gravel depth	300 mm
- Soil depth	450 mm
- Planter wall height	Approx. 300 mm maximum
Inlet: (from roof drainage)	
- Spreader	"Spreader-type" pipe inlet across the width of the shortest side (typically comprises 100 mm diameter pipe with 30 – 50 mm diameter holes at 300 - 450 mm centres)
- Erosion protection	Spreader flow to discharge onto a gravel bed (typical dimensions: spreader length x 450 mm x 75 mm depth)
Top outlets:	
- Location	At the end opposite the inlet
- Orifice	Machine drilled, to the calculated diameter; to be covered with wire mesh to protect against the ingress of debris
Emergency overflow	To discharge the full 2% AEP flood peak; overtopping to be directed away from buildings and avoid damage to adjacent properties
Bottom outlet	Perforated pipe, embedded in gravel, with the pipe length covering the full length of the planter (pipe diameter typically 100 mm)
Construction materials:	
- Concrete	Reinforced concrete, reinforced concrete blocks, or pre-cast concrete, painted on the inside face with two coats of a bitumen-based sealer
- Timber	Constructed as a retaining wall using H4 radiata; boards to be tongue and groove; the inside of the planter to be lined with 200µ grade black PVC sheeting; all joints to be sealed with approved tape
Planter media:	
- Soil	As for rain garden (refer Section 4.3.7)
- Filter cloth	As for rain garden (refer Section 4.3.7)
- Gravel	Gravel or scoria 10 – 15 mm sizes; minimum infiltration rate 4 m/day
- Plants	As for rain garden (refer Section 4.3.7); ie as specified in Section 7 of ARC TP10

4.4.8 Implementation provisions

Following the completion of the design and detailing, the steps to implementation are:

- consents:
  - apply for the appropriate consent (refer Section 3.13 for details of the type of information that will need to be included)
  - receive the consent and account for any design changes required under the consent
- construction: requires close attention to ensuring that the following are met:
  - design details
  - materials specifications in particular planting medium grading
  - specifications
- commissioning:
  - once constructed, the device will need to be commissioned and tested
  - checks need to be made for flaws such as leaks, blockages, etc.
- certification: once commissioned and operating satisfactorily, the device will need to be certified under the provisions of the Building and/or Resource Consent – ARC TP10, Chapter 7 provides examples of the checklists used by certification authorities
- O&M (ongoing): the routine maintenance provisions set out in Section 4.4.9 will need to be undertaken, in accordance with either (as applicable):
  - the provisions of the consent (where nominated), or
  - as per an appropriate O&M model (refer to Appendix D2.0)

4.4.9 Operation and maintenance

The routine maintenance activities that should be undertaken in respect to a stormwater planter are as tabulated below (note that Section 4.3.8 provides a checklist for the rain garden, which is closely comparable). It is recommended that the owner be issued with a copy of the checklist, along with a description of the rain tank, covering how it works and explaining the maintenance imperative (refer ACC, 2002 – Appendix C, pages C8 & C9 for an example of such a handout).

Stormwater planter operation and maintenance

Frequency			Action
After storm	Quarterly	Annually	
✓	✓	✓	**Spouting & downpipes:** check for problems such as debris/blockages and leaks & rectify
✓	✓	✓	**Spreader & splash pad:** check for blockage/erosion and rectify
	✓	✓	**Planter surface:** remove litter & sediment accumulation
		✓	**Vegetation:** maintain healthy plants & replace dying plants (to ensure at least 90% of the surface is covered); trim/prune
		✓	**Soil:** cultivate to a depth of 100 mm (insofar as possible without disturbing the plant root zone
		✓	**Planter box:** check for structural deficiencies. Leaks, growths & rectify
	✓	✓	**Overflow pipe & orifice:** check for blockage, damaged/leaking pipe & rectify

4.4.10 Worked example

The worked example below, including the spreadsheet for the calculation of the stormwater planting sizings, is for the following case (note that this is for a flow attenuation-only case – refer Section 4.3.9 for a comparable worked example for a water quality control situation):

Base data:

(i) Areas (m^2):

Roofs (multiple units):	250
Other impervious	110
Pervious:	90
Lot total:	450

(ii) Soil type: alluvium

(iii) Planter performance standards:

- flow: attenuate to 'as existing' in a 10% AEP storm event
- water quality: no requirement

(iv) Applicable time of concentration (Tc): 20 minutes

Hydrological data and calculations:

The methodology uses the Rational Method – refer Section C3.2 or details.

(i) Rainfall depth-duration-frequency data (for Tc = 20 mins & 10% AEP) gives I =75 mm/hr

(ii) Design hydrographs for the following cases (refer spreadsheet below for results):

- roof
- rest-of-site
- target (ie 60% impervious area equivalent)

Sizing storage to meet flow control:

Refer spreadsheet overleaf for the case where the storm duration (D) is equal to the time of concentration (Tc); a comparable example of the case where D > Tc is given for a rain tank in Section 4.5.10.2.

Planter dimensions and sizing of hydraulic components:

(i) Planter dimensions:

From the spreadsheet above, the sizings are as follows:

- planter surface area, W = 7.2m^2
- maximum water depth (above the planter soil surface), M = 0.25m
- planter storage capacity, R = W x M = 1.8m^3
- orifice diameter, E = 70 mm
- orifice height (above the planter soil surface), N = 125 mm

(ii) Sizing of hydraulic components:

- orifice standpipe diameter, F = 1.5 x orifice diameter E = 105 mm
- siphon diameter, G = E = 69 mm (say 70 mm)
- emergency overflow:
  - 2% AEP peak inflow is approximately 7 l/s (ie Q = 0.007 m^3/s)
  - select discharge slot depth, S = 30 mm (flow depth, h_1 = say 25 mm = 0.025 m)
  - computed weir length, L, by weir formula Q = 1.8 x L x $h_1^{1.5}$, is 1.0 m

(iii) Planter wall height, K = M+ G+ S = 0.35 m

Note: Eliminating the orifice (ie matching the original CoP (2002) version of the stormwater planter) has the effect of increasing appreciably the required planter area. Note that to simulate this case, the spreadsheet must be modified so that when the water level reaches the siphon, the siphon flow equals the roof inflow less the infiltration.

STORMWATER PLANTER - FLOW ROUTING ANALYSIS

(A) SITE DATA:

Soil Type	Clay		C value
Roof area	250	m2	0.9
Other impervious area	110	m2	0.86
Pervious area	90	m2	0.43
Lot area	450	m2	

(B) PLANTER DETAILS:

Target performance standard: reduce peak flow to the equivalent of that from the site with an impervious area coverage of 60 %

Planter area	7.2	m2
Storage height	0.25	m

Orifice:

height	0.125 m		*Peak orifice flow:*	*3.76 l/s*
diameter	0.069 m		*Max orifice head:*	*0.125 m*
discharge coeff	0.75		*Trial diameter:*	*0.066 m*

Trial orifice diameter calculation: (see right-hand columns above)

Infiltration rate 0.3 m/day

(C) HYDROLOGY - BY RATIONAL METHOD:

(refer comparable calculations in Appendix C - Section C3.5)

Tc	20	min
Storm duration (D)	20	min
Rainfall intensity (10% AEP)	75	mm/hr

Case		C Value	Peak discharge (l/s)
Peak runoff from roof		0.9	4.69
Peak runoff from site impervious area		0.86	1.97
Peak runoff from site pervious area		0.43	0.81
Target peak site outflow:	60 % impervious	0.70	6.56

(D) SIMULATION:

Time step 2 mins = 120 sec

Time (mins)	Planter Inflow l/s	Infiltration Flow l/s	xs Flow to Storage m3	Planter Storage m3	Planter WL m	Av orifice Head (m)	Orifice Flow l/s	SITE RUNOFF CALCULATION Planter Outflow l/s	Rest Site Flow l/s	Total Site Flow l/s
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.0	0.47	0.03	0.03	0.03	0.00	0.00	0.00	0.03	0.28	0.30
4.0	0.94	0.03	0.08	0.11	0.01	0.00	0.00	0.03	0.56	0.58
6.0	1.41	0.03	0.14	0.24	0.03	0.00	0.00	0.03	0.83	0.86
8.0	1.88	0.03	0.19	0.44	0.06	0.00	0.00	0.03	1.11	1.14
10.0	2.34	0.03	0.25	0.69	0.10	0.00	0.00	0.03	1.39	1.41
12.0	2.81	0.03	0.31	0.99	0.14	0.00	0.00	0.03	1.67	1.69
14.0	3.28	0.03	0.36	1.36	0.19	0.04	2.26	2.29	1.94	4.23
16.0	3.75	0.03	0.42	1.50	0.21	0.07	3.14	3.17	2.22	5.39
18.0	4.22	0.03	0.48	1.60	0.22	0.09	3.49	3.51	2.50	6.01
20.0	4.69	0.03	0.53	1.72	0.24	0.11	3.76	3.78	2.78	6.56
22.0	4.22	0.03	0.53	1.80	0.25	0.12	3.99	4.01	2.50	6.51
24.0	3.75	0.03	0.48	1.79	0.25	0.12	4.08	4.10	2.22	6.32
26.0	3.28	0.03	0.42	1.72	0.24	0.12	3.99	4.02	1.94	5.96
28.0	2.81	0.03	0.36	1.61	0.22	0.11	3.77	3.79	1.67	5.46
30.0	2.34	0.03	0.31	1.46	0.20	0.09	3.43	3.45	1.39	4.84

32.0	1.88	0.03	0.25	1.30	0.18	0.07	2.98	3.01	1.11	4.12
34.0	1.41	0.03	0.19	1.13	0.16	0.04	2.42	2.45	0.83	3.28
36.0	0.94	0.03	0.14	0.98	0.14	0.02	1.71	1.74	0.56	2.29
38.0	0.47	0.03	0.08	0.86	0.12	0.00	0.59	0.62	0.28	0.89
40.0	0.00	0.03	0.03	0.81	0.11	0.00	0.00	0.03	0.00	0.03

NOTE: If/ when planter WL exceeds storage height, site runoff calculation should include planter overflow
(ie overflow = inflow - orifice outflow - infiltration)

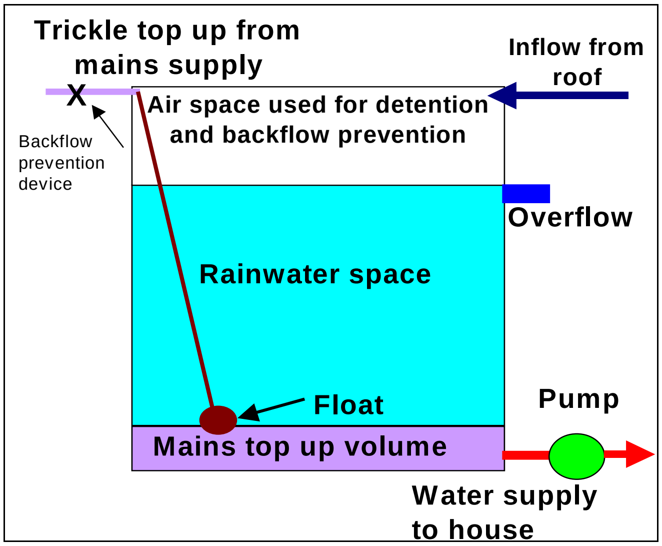
4.5 Rain tank

4.5.1 Description

A rain tank, or dual-use tank, is fed from roof runoff and serves to not only attenuate peak flow but also allow re-use of stored water. As illustrated in Fig 4.5.1, in order to do this, the rain tank has two 'zones', namely:

- temporary storage (or 'air space'):
  - the upper part of the tank, dedicated to retaining runoff in short duration, high intensity storm events
  - has an orifice outlet at the bottom (ie this defines the interface between the temporary and permanent storage zones); this serves to "throttle" the flow
  - has an overflow at the top of the tank, connected to the stormwater system
- permanent storage (or 'rainwater space'):
  - the bottom portion, dedicated to storing water for re-use
  - in areas with mains water supply, it includes a mains connection for "topping-up" the storage to ensure continuity of supply in dry periods

Figure 4.5.1 Rain tank – elevation



Tanks are generally made of concrete, plastic, steel or fibreglass and are typically fabricated off-site. Other types of specifically designed tanks can be used. Rain tanks as described in this guideline take only roof water and are typically placed above ground.

The difference between the rain tank and the detention tank (refer Section 5.2) is that the latter is designed to accomplish only the peak flow attenuation function. The rain tank is nowadays generally preferred, for the following reasons:

- the potential for re-use to be cost-effective, due to the modest extra cost of the larger tank needed to provide the permanent storage
- avoiding the potential maintenance problems of underground detention tanks (refer Section 5.1)
- the re-use benefit of a rain tank, in parallel with avoiding potential public health problems of underground detention tanks, refer to section 4.5.3.1 below, leads to the use of rain tanks being seen as encouraging sound maintenance practices

4.5.2 Capability

Rain tanks are able to:

- provide detention to achieve peak flow attenuation of roof runoff (note that a rain tank alone can often meet the “greenfield” site peak runoff standard, by over-throttling the flow to compensate for the extra runoff from the site impervious area)
- settle-out the roof-derived sediment in the tank
- allow stored water to be re-used for domestic purposes (in turn, this leads to a reduction in the volume of stormwater discharged from the site)

Rain tanks:

- are not able to treat site runoff (apart from removing roof derived sediment)

4.5.3 Applicability

4.5.3.1 General

- are normally installed on the ground or partially buried (ie as needed to ensure gravity feed from the roof gutters)
- can be installed underground, provided that they incorporate adequate structural strength to avoid cracking (note that cracking has the potential to lead not only to leakage, but also the ingress of microbiological contaminants from adjoining soil, with potential risks to public health)
- must be sited at an elevation to allow adequate fall from the orifice at the base of the temporary storage zone to the connection point with the stormwater receiving system, noting that provision may be needed for heading-up of latter (this requirement most often only poses a problem if the rain tank is located below the road and/or is partially/fully buried).
- can be used in rural areas without mains supply to meet all domestic water supply needs
- can be used in areas with mains supply, can be used as a supplemental water source
- allow access for maintenance

4.5.3.2 Re-use component

The issues below need to be considered for the re-use component.

(a) Water quality

In urban areas, airborne contaminants, including hydrocarbons, can intercepted by rainfall, either in the air or on the roof, and washed into the rain tank. Without treatment, the water cannot be considered potable and so should not be plumbed to fixtures where human consumption is likely. A study for Auckland City Council (Ogilvie, 2002) explored the public health risk and recommended that the use of water from urban rain tanks be limited to outdoor taps, toilets and cold water feed to the washing machine and shower.

In rural areas where there is no mains supply, roof tanks have long been the sole source of supply. While the risks are less than in urban areas, tests on rural tank water have found it fails the potable standards (ACE, 2003) set out in the NZ Drinking Water Standards (MoH, DWSNZ, 2000). It is believed that rural dwellers may develop a resistance to illness from E Coli and the like through persistent exposure, but vigilant adherence to maintenance practice (e.g. SDC, 1997; MoH, 2001) is nevertheless warranted. Added safety can be achieved through the implementation of first flush water diverters on tanks (RWHWWS, 2004 - refer Section 4.5.7 for details) and/or water filters on kitchen taps.

(b) Ownership of tanks

In high density urban developments in which the Local Authority requires the installation of on-site devices, there are particular issues with rain tanks in this context. This arises from the fact that on say a multi-unit development, it will be much less costly to implement a single large tank than having one tank per dwelling unit. At issue then is the maintenance obligations and the rights to the re-use water. Although this will be an issue for the controlling local authority, as an example, Auckland City Council has the following policies on the use of rain tanks in multi-dwelling developments (ACC 2002):

- options for ownership, connection and maintenance of tanks (any one of the following to apply):
  - multiple tanks, one connected to each dwelling, with each owner responsible for operation & maintenance
  - one tank fed by multiple roofs, with one particular dwelling having legal responsibility for owning and operating/maintaining the tank; in such a case the owner may choose to plumb water from the tank to other dwellings
  - in the case of a Body Corporate having legal responsibility for owning and operating/maintaining the tank, at least 50% of the dwellings must be plumbed to a tank(s)
- connection of roofs: provision must be made to connect the entire roof area of the development to rainwater tank(s)

4.5.4 Summary of design approach

Note: ***items (1) – (4) are covered in Section 4.5.5 and the remainder in Section 4.5.6***

1. Confirm the suitability of the rain tank to the particular site and application
2. Establish device parameters and the applicable performance standard
3. Establish the water re-use targets
4. Establish the site parameters
5. Assemble the requisite hydrological data applicable to the general area in which the rain tank is to be sited
6. Size temporary storage capacity
7. Size the permanent storage capacity
8. Complete the attendant tank sizing and hydraulic design

Note 1: *There is in practice an interaction between the two storage zones (e.g. at the start of a summer storm, the water level may be drawn down into the permanent storage zone), meaning that steps 6 & 7 should ideally be computed by a "whole of tank" simulation approach, as is possible through modelling[5] (refer note 2). In practice, most practitioners will find it more convenient to use the two-stage approach presented in Section 4.5.6: studies show that this approach produces more conservative (ie slightly larger) temporary storage capacities than the modelling-based approach (ACC, 2002).*

Note 2: *Computer based models can be used in place of or to augment the detailed approach set out in this guideline. For details of the model-based approaches, refer Appendix C – Section C2.4. The procedure set out below uses manual methods, assisted with spreadsheets.*

[5] For further information on this topic, refer Coombes & Kuczera, 2001

4.5.5 Preparatory steps

4.5.5.1 General

1. Confirm the applicability of using a rain tank, noting that it accepts flow from roofs only
2. Confirm the peak flow control performance standards, ie:
   - o design storm frequency (e.g. 10% AEP and/or 50% AEP, with the latter only applicable where there is a stream channel erosion protection imperative – refer Section 3.7)
   - o the target peak site outflow; this is typically as existing, or greenfield – refer Section 3.7 (note that a rain tank alone can often meet the greenfield site runoff standard, by over-throttling the flow to compensate for the extra runoff from the site impervious area)
3. Establish applicable design time of concentration (Tc – refer Appendix C, Section C2.2 for further details), e.g.:
   - o in the receiving stormwater system, at the dwelling connection point (= Tc_1 say)
   - o at key points on down to the outfall (e.g. major watercourse, sea); = Tc_2 , Tc_3, etc
4. Define water re-use targets:
   - o define appropriate uses [refer Section 4.5.3.2(a)]
   - o set target percentage of domestic use to be met (e.g. typically 100% for rural and up to 50% in urban areas with mains supply)
   - o establish the drought frequency condition to be met (applicable in rural areas only where the tank is the sole supply source[6])
5. Establish the water re-use demand, in turn a function of:
   - o the number of persons (it is wise to account for the number usually resident in summer, since this is the critical season)
   - o the per capita demand: this can vary from 100 l/h/d (ie where tanks are the sole source of supply and the users are conservation-minded) to 200 - 250 l/h/d (this figure is representative of an urban situation with unrestricted supply and high water-use facilities, e.g. dishwasher, wastemaster)
   - o where garden/lawn watering and the like is to be met from the tank, this should be catered for by allowing a higher demand in summer
6. Establish key site parameters, e.g.:
   - o site area
   - o impervious area (roof and on-ground)
   - o pervious area (and cover type)
7. For multiple dwelling units case – refer Section 4.5.3.2(b)
8. Identify site/device layout constraints, e.g.:
   - o tank location
   - o tank above ground or underground (note that special structural requirements apply in respect to the latter)
   - o stormwater system connection points (and corresponding elevations)
   - o overland flow paths (from tank outlet)

4.5.5.2 Hydrological data

1. Obtain rainfall depth-duration-frequency data applicable to the general area in which the rain tank is to be sited, for the following cases, as applicable (refer Section 3.12):
   - o 50%, 10% and 1%/2% AEP

[6] It will normally be prudent to size tanks to enable the demand to be met over a dry summer: the severity of the drought to be catered for will depend on factors such as:
- the householders willingness to curb demand in a dry period
- the cost of supplementary supply, if available (eg tanker-delivered)

- o applicable Tc values (from 3 above)

2. Using the data from (1) above, establish design storm runoff peaks and hydrographs, according to the rational formula or other method (refer Section 3.12 and Appendix C for details), for:
   - o target site outflow (only the peak flow is required)
   - o roof runoff
   - o rest-of-site runoff (ie surface impervious and pervious)
3. Obtain monthly rainfall sequence applicable to the general area in which the rain tank is to be sited (e.g. from NZMS 1983); options are:
   - o mean monthly totals where security against droughts is not an issue (for example for the urban case)
   - o mean monthly totals for a representative dry year (ie selected from a review of a long-term record, to meet the required severity
   - o the dry year case can be approximated by applying a factor to the mean monthly totals; this is the "dry period factor" (factor values can be found by analysing long-term local records, but are typically in the range 0.9 - 0.85 for the 2 – 5 year return period drought)

4.5.6 Design steps

(a) Summary:

1. collate the design data/parameters from Section 4.5.5
2. size the temporary storage capacity – refer (b) below
3. size permanent storage capacity – refer (c) below
4. add results from 2 & 3 to establish the total storage (ie tank capacity) and size the allied hydraulic components – refer (d) below

<u>Note</u>: it should be appreciated that the design process\set out below is quite long and involved, due to the need to size both the temporary and permanent storages, in turn involving collation and analysis of the requisite hydrological data. The process can be streamlined appreciably through the use of spreadsheets (see examples below and in Section 4.5.10). Note also that some local authorities have undertaken analyses with local data to prepare design charts or tables, and/or spreadsheets developed by others are available, for example:

- for temporary storage:
  - o ARC TP10 (Chapter 11) has charts enabling the reading-off of the tank storage volume for a range of roof area and paved area combinations (applies to meeting the greenfield flow attenuation target, on clay soils)
  - o North Shore City Council has a spreadsheet available to compute the temporary storage (NSCCWS 2002), where the user input the various site and development parameters (note that the January 2002 version current at the time of writing this Guide is understood to be under review)
- for permanent storage:
  - o ARC TP10 (Chapter 11) includes tables of roof area versus demand and relates these to the percentage of the demand that can be met by a tank of a given size
  - o Ashworth, 2002 includes a spreadsheet on CD to size the permanent storage

(b) Temporary storage:

Typically, a spreadsheet is used to size the temporary storage capacity. This involves performing routing calculations to quantify the way the storage provided in the tank modifies the inflow hydrograph (refer Appendix C – Section C3.4 for details); in turn it applies the following general relationships:

Device outflow =	function of the applied head on the outlet flow control device (e.g. orifice, weir)
Change in storage =	device inflow – device outflow
Site outflow =	device outflow + rest-of-site runoff (ie from pervious plus other impervious area)

Table 4.5.1 illustrates the layout of a typical spreadsheet used to perform the tank routing calculation, together with generalised explanations of the cell arithmetic (the worked example in Section 4.5.10 presents the full spreadsheet). The box below that is below Table 4.5.1 discusses points arising from the analysis.

Table 4.5.1 Illustration of spreadsheet-type routing computation

Time (min)	<u>*Roof runoff*</u>		Tank Storage (C, m)	Tank water level (E, m)	Tank orifice outflow (F, l/s)	Net Tank Storage (G, m³)	SITE RUNOFF CALC	
	Hydrograph (A, l/s) *Note 1*	Volume (B, m³)					Rest of Site [3] H (l/s)	Total Site I (l/s)
Go to 2-3 x Tc in about 0.1 x Tc increments	*Design hydrograph (contributing area)*	*= A(l/s) [averaged] x time*	*= volume G at prior time step + inflow B*	*= volume C / tank area*	*Function of head, E refer note 1*	*= volume C – F x time*	*= design hydro-graph for rest of site*	*= tank outflow F + rest of site runoff H*
0	0	0	0	0	0	0	0	0
2.5	1.05	0.16	0.16	0.05	0.31	0.11	1.12	1.42
5.0	2.1	0.32	0.43	0.14	0.59	0.34	2.23	2.83
7.5	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…

<u>**Notes**</u>**:**

1: It is usual to use the average head over the prior and current time steps; note also that once the tank is full, the outflow is set to match the inflow

2: Hydrograph from the pervious plus other impervious area (e.g. as in Section C3.5 – Case 2B below)

The routing computation spreadsheet is used as follows to size the on-site device, involving applying a trial and error approach:

(1) Set storm duration D = Tc_1 (refer Section 4.5.5.1(3) for details)

(2) Compute the corresponding design hydrographs, for the following refer Section 4.5.5.2(2) for details):
  - roof runoff
  - rest-of-site runoff (ie surface impervious and pervious)

(3) Select the trial tank sizing parameters:
  - plan area of tank
  - top outlet pipe diameter and height above the permanent/temporary storage interface
  - outlet orifice diameter (ie located at the permanent/temporary storage interface)

(4) Run the spreadsheet and:
  - identify the peak site outflow rate (also, it is useful to check if/when device overflow occurs)
  - compare this to the target peak site outflow (e.g. greenfield)

(5) Select new trial device sizing parameters (e.g. smaller/larger tank, smaller/larger orifice) and re-run the spreadsheet: continue until the required device performance standard is met

(6) Re-run steps (2) – (5) with storm duration D = Tc_2, then again for Tc_3, etc (refer Section 4.5.5.1(3) for details)

(7) Select the largest tank capacity arising from the above runs; noting:
  - this is the "temporary storage" volume, V (m^3)
  - the corresponding orifice diameter, E (mm), applies

Allied issues for sizing temporary storage

Dual orifice arrangement to meet stream channel erosion protection requirement:

The normal requirement is to size the tank and orifice to meet the required performance standard (e.g. greenfield, or as existing) in a 20% or 10% AEP storm (ie matching the sizing basis for the piped stormwater receiving system. However, where the tank discharges to a watercourse where channel erosion protection is an issue, it may be necessary to attenuate the 50% AEP flood event, over and above that for the 20% or 10% AEP storm and provide extended detention(refer Section 3.7 for details). Often a single orifice cannot easily meet the dual performance requirement, with the result that the tank will have the following (note that the North Shore City Council 2002 rain tank spreadsheet incorporates this provision):

- a small diameter orifice at the permanent/temporary storage interface to meet the 50% AEP requirement
- a larger diameter orifice, located higher up in the tank, to meet the 20% or 10% AEP requirement

Case where the tank cannot meet the flow attenuation performance target:

There may be cases where the spreadsheet identifies that no tank/orifice combination can meet the meet the required flow attenuation performance target; this will be evident when even very large tanks with small orifices cannot meet the required flow target. This situation occurs in cases where the site impervious area is large in comparison to the roof area, because even fully absorbing the tank inflow and throttling the tank outflow is not enough to compensate for the extra runoff from the site impervious area. In such cases the potential solutions are:

- reduce the site impervious area, or
- in conjunction with the tank, use a separate on site device (e.g. rain garden) to attenuate the site impervious area runoff

(c) Permanent storage

Typically, a spreadsheet will be used to perform the permanent storage calculations, applying the following general relationships:

Change in tank storage = inflow (from roof) – outflow (ie demand)
Inflow from roof = rainfall x roof area x loss/drought factor

Note on data sources and assumptions used in the computation:

- security against droughts: refer Section 4.5.5.1(4)
- rainfall: refer Section 4.5.5.2(3)
- losses: not all of the rainfall measured at a rain gauge will reach the tank; correspondingly, a loss factor of 0.05 – 0.10 is typically applied to the rainfall to account for:
  - losses due to wind currents (e.g. on the lee side of a steep-pitched roof, the rainfall settling on the roof will be lower)
  - evaporation losses (e.g. in summer, in light showers especially, the first millimetre or so will evaporate off a hot roof)
- demand: refer Section 4.5.5.1(5)

Table 4.5.2 illustrates the layout of a typical spreadsheet used to perform the permanent storage calculation, together with generalised explanations of the cell arithmetic, accounting for the above factors (the worked example in Section 4.5.10 presents the full spreadsheet). The computation should start in winter with the tank nominally full and continue over successive months until the minimum storage is found (this is typically in late summer, e.g. Feb, March or April) - the required permanent storage (S, m^3) is then equal to the nominal starting/full storage minus the minimum storage. The box below discusses points arising from the analysis.

Points arising from the permanent storage analysis example in Table 4.5.2
In rural cases where the demand is relatively high in comparison to the roof area, large increments in tank capacity will be required to get from a target supply percentage of about 90% to the full 100%: in this case, an "economic" supply percentage can be calculated if required by running different tank sizes and comparing: - the cost of providing the extra tank capacity, versus the alternative of: - buying water – in turn, there is a frequency question
Similarly, in the urban case, especially where dwellings are 2/3-storeyed, it may be uneconomic to meet more than a modest fraction of the demand (e.g. calculations referenced in Auckland City, 2002 show that, in targeting to meet 50% of the total water demand, this cannot be met where the roof area per person is less than 25 m^2 – in such cases, a storage capacity of 1.5 m^3 per person is recommended)

Table 4.5.2 Illustration of tank permanent storage spreadsheet computation

Month	Mean Monthly Rainfall (A, mm)	Inflow (B, m3) [note 1]	Demand (C, m3) [note 2]	Storage Change (D, m3)	Net Storage (E, m3) [note 3]
Start in mid-winter when tank will be full		*Rainfall A (mm) x loss factor(s) x roof area (m2) / 1000*	*Litres/day x days in the month / 1000*	*D = C - B*	*= volume E at prior time step + D (but not greater than full)*
Aug		-	-	-	100.0 (nominal)
Sep	91	15.6	15	0.6	100
Oct	76	13	15.5	-2.5	97.5
Nov	83	14.2	15	-0.8	96.7
Dec	79	13.5	18.6	-5.1	91.6
Jan	67	11.5	18.6	-7.1	84.5
Feb	78	13.3	16.8	-3.5	81
Mar	84	14.4	18.6	-4.2	**76.8**
Apr	94	16.1	15	1.1	77.9
…	**..**	**…**	**…**	**…**	**…**

<u>Notes</u>:

1: Figures in example are with:

- roof area 200 m^2
- dry period factor 0.9
- rainfall loss factor 0.05 (ie runoff = 0.95 x rainfall)

2: Demand basis in this example: 4 persons @ 125 l/h/d = 500 l/d, plus extra 100 l/d in summer (December – March)

3: Continue computation over successive months until minimum storage is found; then required storage = nominal starting/full storage – minimum storage (ie in this case, 100.0 – 76.8 = 23.2 m^3)

(d) Tank sizing:
Note*:: the symbols E, F, etc used below are as defined in Fig 4.5.2*

(1) The required total storage, T (m^3), is the sum of:
- temporary storage, V, is as determined in (b) as above
- permanent storage, S, is as determined in (c) as above
- dead storage allowance = 0.1 x (V + S)

(2) Tank size details:
- volume T (m^3, from 1 above)
  (select next largest available tank size)
- base area, R (m^2), is as determined in (b) as above
- diameter K (m) = $1.128 \times R^{0.5}$
- height G (m) = T / R

(3) Orifice at permanent/temporary storage interface:
- Diameter, E (mm), is as determined in (b) as above
- height above tank base = H (m) = S / R + 0.1 m (dead storage)

(4) Compute the top overflow pipe diameter (F, mm) as follows:

(i) Compute the design discharge Q (l/s) to allow the overflow to discharge the 2% AEP storm without the gutters overflowing:
- identify the 2% AEP rainfall intensity for the 10 minute storm = I_2 mm/hr
- for roof area A (m^2), Q (l/s) = $0.00028 \times A \times I_2$

(ii) Use the orifice discharge formula (refer Appendix C – Section C4.0) to compute the orifice diameter, F, ie:

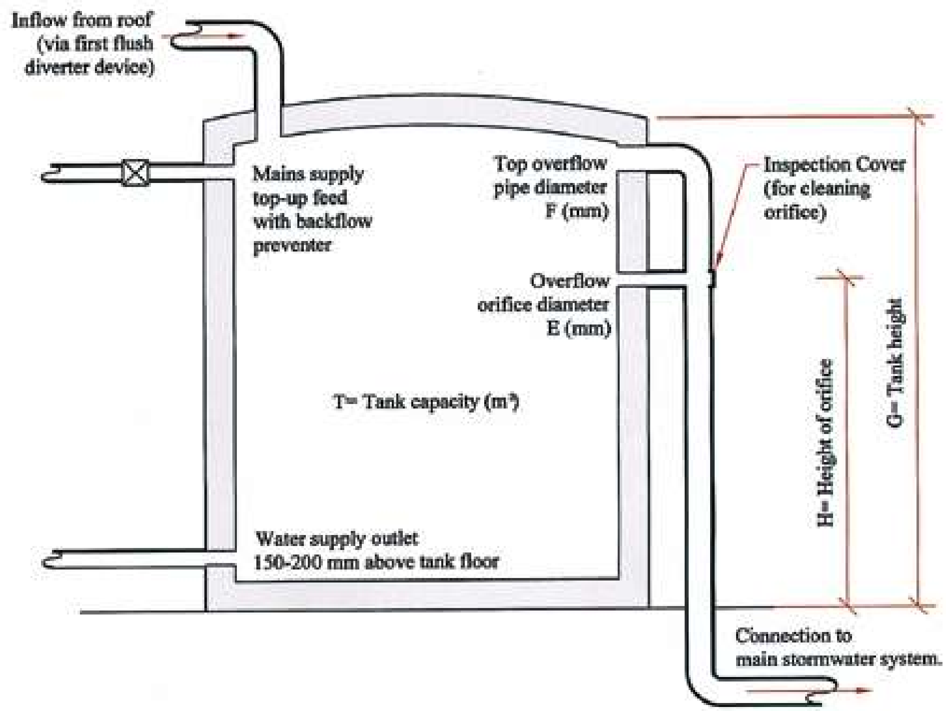
$$Q = 3470 \times Cd \times d^2 \times h^{0.5}$$

where:
Q = discharge (l/s)
Cd = orifice discharge coefficient (typically 0.6 – 0.7)
d = orifice diameter (m)
h = head on orifice (m)

Assuming h = 0.1 m and Cd = 0.6, this can be simplified to:
$F = 39 \times Q^{0.5}$, where Q is in l/s and F in mm
(choose the next largest available pipe size)

As a guide, a 100 mm diameter overflow is sufficient to cater for a roof area of about 200 m^2 in Auckland.

Figure 4.5.2 Rain tank – definition sketch



4.5.7 Design detailing and drawings

The standard design details applicable to rain tanks, to be shown on drawings to be submitted with the consent application(s), are as listed below. In parallel, it will be appropriate to check any regional, city or district council requirements for resource consent, building consent or drainage permit or compliance with other standards.

Rain tank worked example

Note: items shown with an asterisk are only applicable to tanks with a mains water feed.

Item	**Requirement**
Inlet	To enter through the roof of the tank, via an appropriate first-flush diverter device (e.g. Rain Water Harvesting & Waste Water System P/L's First-flush water diverter, Australian Patent #692835[7], or similar[8]); this device to be sized and installed according to the manufacturer' instructions
*** Mains water feed**	At top of tank, 25 mm minimum above the top outlet and controlled by a float-operated shut-off (minimum level 100 mm above water supply outlet)
*** Backflow preventer**	To be installed to NZS 3500.5 (2000) to avoid cross-contamination
Tank construction:	
- Materials	Concrete, steel, plastic or fibreglass
- Siting/Foundation	Level, on a sand or scoria base (minimum 100 mm depth; where weak sub-soil conditions exists, the foundation to be designed and certified by a geotechnical engineer)
Stormwater outlets:	(refer Fig 4.5.2 for definitions of the parameters referred to below)
- Lower orifice	Diameter E (machine drilled) at height H above base of tank; connect to pipe from top overflow (the orifice is to be accessible for maintenance by an inspection cover)
- Top overflow	Pipe diameter F; connect to main/public stormwater sstem
Water supply outlet:	
- Location	150 – 200 mm above the tank base (ie allow 100 mm dead storage for sediment accumulation)
- Feed to	Plumbing fixtures in dwelling - note that in urban situations, it is recommended that connection is limited to non-potable uses, e.g.: - outdoor watering - toilets - cold water feed to clothes washing machine - cold water feed to shower(s)
Pump	Size to meet the required household duty; plumb so that in the event of pump or power failure, mains water can be used directly
Plumbing	To NZS 3500.5 (2000) and by a certified/registered Plumber. Refer also to Building Industry Authority approved document G12/AS1: Water supply for signage and plumbing identification.

[7] RWHWWS, 2004

[8] The cited product is illustrative of the type of equipment available: note that neither the authors and publishers of this Guide nor NZWERF endorses this or any other proprietary product

4.5.8 Implementation provisions

Following the completion of the design and detailing, the steps to implementation are:

- apply for the appropriate consent (refer Section 3.13 for details of the type of information that will need to be included)
- receive the consent and account for any design changes required under the consent
- construction: requires close attention to ensuring that the following are met:
  - design details
  - specifications, including materials specifications
- commissioning:
  - once constructed, the device will need to be commissioned and tested
  - checks need to be made for flaws such as leaks, blockages, etc
- certification: once commissioned and operating satisfactorily, the device will need to be certified under the provisions of the Building and/or Resource Consent – ARC TP10, Chapter 11 provides examples of the checklists used by certification authorities
- O&M (ongoing): the routine maintenance provisions set out in Section 4.5.9 will need to be undertaken, in accordance with either (as applicable):
  - the provisions of the consent (where nominated), or
  - as per an appropriate O&M model (refer to Appendix D2.0)

4.5.9 Operation and maintenance

The routine maintenance activities that should be undertaken in respect to a rain tank are as tabulated below (note that ARC TP10 – Chapter 11 provides an alternative checklist). It is recommended that the owner be issued with a copy of the checklist, along with a description of the rain tank, covering how it works and explaining the maintenance imperative (refer ACC 2002 – Appendix C, pages C6 and C7 for an example handout).

Frequency				**Action**
After storm	**Quarterly**	**Annually**	**2-Yearly**	
✓	✓	✓	✓	**Spouting & downpipes:** check for problems such as debris /blockages and leaks and rectify
✓	✓	✓	✓	**First-flush diverter device:** check for blockages; empty debris/sediment
	✓	✓	✓	**Tank water quality:** check for clarity and odour
	✓	✓	✓	**Tank inlet/outlet pipework, orifice, float valve & backflow preventer:** perform visual check for problems e.g. debris/blockages/leaks and rectify
		✓	✓	**Tank structure:** check for leaks and rectify
		✓	✓	**Pump & electrical system:** check and carry out any necessary maintenance
			✓	**Float valve, backflow preventer and first-flush device:** test for correct functioning; repair/replace where faulty or badly worn
			✓	**Tank water quality:** collect water sample (before emptying tank, as below), submit for testing & results to check compliance with DWSNZ, 2000; if exceedances are found, review maintenance practices to identify the cause of the problem(s) and rectify
			✓	**Tank cleaning:** empty the tank and clean out any sediment accumulations and growths
			✓	**Plumbing:** examine plumbing from the tank to the dwelling and rectify any faults

4.5.10 Worked example

4.5.10.1 Case A - Temporary and permanent storage

The worked example below, including spreadsheets for the calculation of the temporary and permanent storage capacities are for the following example case:

Example case A

Base data:

(i) Areas (m^2):

Roof:	250
Other impervious:	100
Pervious:	350
Lot total:	700

(ii) Soil type: clay

(iii) Tank performance standard: attenuate to “greenfield” in 10% AEP storm event

(iv) Applicable time of concentration (Tc): 15 minutes

(v) Storm duration D = Tc (refer Section 4.5.10.2 for an example with D > Tc)

(vi) Water re-use demand: refer input data to the second spreadsheet below

Hydrological data and calculations:

The methodology is the rational method – refer Section C3.2 for details.

(i) Rainfall depth-duration-frequency data (for Tc = 15 mins & 10% AEP) gives I = 100 mm/hr (ie as worked example case 1 in Appendix C – Section C3.5)

(ii) Design hydrographs for the following cases (refer first spreadsheet below for results):

- o greenfield: refer worked example case 1 in Appendix C – Section C3.5
- o roof: refer worked example case 2A in Appendix C – Section C3.5
- o rest-of-site: refer worked example case 2B in Appendix C – Section C3.5

(iii) Mean monthly rainfalls: refer the second spreadsheet below (data is for Albert Park, Auckland)

RAIN TANK - FLOW ROUTING ANALYSIS

(A) SITE DATA:

Soil Type: Clay

AREAS:			C value
Roof area	250	m2	0.9
Other impervious area	100	m2	0.86
Pervious area	350	m2	0.43
Lot area	700	m2	

(B) TANK DETAILS:

Tank area	3.0 m2	(ie	1.9 m dia)	
Tank height	1.2 m			
Orifice dia	0.03 m	D^2=	0.0009	
Orifice discharge coefficient			0.69	

Trial orifice diameter calculation:

Peak orifice flow:	*1.79 l/s*
Max orifice head:	*1.2 m*
Trial diameter:	*0.026 m*

(C) HYDROLOGY - BY RATIONAL METHOD:

(refer comparable calculations in Appendix C - Section C3.5)

Tc 15 min

Storm duration (D) 15 min

Rainfall intensity (10% AEP) 100 mm/hr

	C value	Peak discharge (l/s)
Peak roof discharge:	0.90	6.25
Peak rest-of-site discharge:	0.53	6.57
Permissible site discharge	0.43	8.36

(D) SIMULATION:

Time step 2.5 min

Time	TANK INFLOW		Tank Storage	Tank WL	Adjusted Av WL	Tank Outflow	Net Device Storage	SITE RUNOFF CALC Rest of Site	Total Site
(mins)	l/s	m3	m3	m	m	l/s	m3	l/s	l/s
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5	1.04	0.08	0.08	0.03	0.01	0.25	0.04	1.09	1.34
5.0	2.08	0.23	0.28	0.09	0.06	0.53	0.20	2.19	2.72
7.5	3.13	0.39	0.59	0.20	0.15	0.82	0.46	3.28	4.11
10.0	4.17	0.55	1.01	0.34	0.27	1.12	0.84	4.38	5.50
12.5	5.21	0.70	1.54	0.52	0.43	1.42	1.33	5.47	6.89
15.0	6.25	0.86	2.19	0.74	0.63	1.72	1.93	6.57	8.29
17.5	5.21	0.86	2.79	0.94	0.84	1.98	2.50	5.47	7.46
20.0	4.17	0.70	3.20	1.08	1.01	2.17	2.87	4.38	6.55
22.5	3.13	0.55	3.42	1.16	1.12	2.28	3.08	3.28	5.57
25.0	2.08	0.39	3.47	1.17	1.16	2.33	3.12	2.19	4.52
27.5	1.04	0.23	3.35	1.13	1.15	2.32	3.01	1.09	3.41
30.0	0.00	0.08	3.08	1.04	1.09	2.25	2.75	0.00	2.25
32.5	0.00	0.00	2.75	0.93	0.98	2.14	2.42	0.00	2.14
35.0	0.00	0.00	2.42	0.82	0.87	2.02	2.12	0.00	2.02

NOTE: If/when tank WL exceeds tank height, site runoff calculation should include tank overflow (ie overflow = inflow - orifice outflow)

RESULT:

Tank area:	3.0	m2
Tank height:	1.2	m
Orifice diameter:	30	mm
Tank capacity (V)	**3.6**	**m3**

Permanent storage calculation – refer spreadsheet below
(note that for illustrative purposes, a “dry period” factor” of 0.9 is applied: in practice, in urban situations with mains water supply, the factor is normally set at 1.0)

RAIN TANK - REUSE COMPONENT
SIZING OF PERMANENT STORAGE

Nom Tank: 100	m^3			
Roof Area: 250	m^2			
Demand Calculation:	No. persons	5		
	Per capita use	200	l/h/d	
	Non-summer	1000	l/d	
	Summer xs (Dec - Mar)	100	l/d	
	Total summer	1100	l/d	
Target % of total demand to be met from tank:		50	%	
Rainfall loss factor:	0.05	(ie runoff = 0.95 x rainfall)		
Dry period factor:	0.9			

Month	Average Rainfall (mm)	INFLOW (m^3)	DEMAND (m^3)	Storage Change (m^3)	Net Storage (m^3)	
Jul	118	25.22	15.50	9.72	100.00	(= start full)
Aug	118	25.22	15.50	9.72	100.00	
Sep	91	19.45	15.00	4.45	100.00	
Oct	76	16.25	15.50	0.75	100.00	
Nov	83	17.74	15.00	2.74	100.00	
Dec	79	16.89	17.05	-0.16	99.84	
Jan	67	14.32	17.05	-2.73	97.11	
Feb	78	16.67	15.40	1.27	98.38	
Mar	84	17.96	17.05	0.90	99.29	
Apr	94	20.09	15.00	5.09	100.00	
May	100	21.38	15.50	5.88	100.00	
Jun	124	26.51	15.00	11.51	100.00	
Ann. Total:	1112			Minimum	97.11	m^3
			Required Storage		2.89	m^3

Tank sizing:

(1) total storage, T:
- temporary storage, V (from first spreadsheet above): = 3.6 m^3
- permanent storage, S, (from second spreadsheet above): = 2.9 m^3
- dead storage allowance, D = 0.1 x (V + S) = 0.7 m^3
- total storage, T = V + S + D = 7.2 m^3

(2) Tank size details:
- volume, T (from 1 above) = 7.2 m^3
  (select next largest available tank size)
- base area, R (from first spreadsheet above, to match sizes/diameters available from manufacturers), = 3 m^2
- height, G = T / R + 0.1m (dead storage) = 2.5 m

Orifice at permanent/temporary storage interface:

- diameter, E (from first spreadsheet above) = 30 mm
- height above tank base H = S / R + 0.1 m (dead storage) = 1.1 m

(3) Top overflow pipe diameter (F):

Compute according to the formulae set out in Section 4.5.6 d (4), ie:

Design discharge Q = 0.00028 x A X I_2, where:

A = roof area = 250 m^2

I_2 = 2% AEP rainfall intensity for the 15 minute storm = 140 mm/hr

Whence Q = 9.8 l/s

Top outlet diameter, F = 39 x $Q^{0.5}$ = 122 mm (choose next largest available pipe size)

4.5.10.2 Case B - Temporary storage with longer duration storms

A spreadsheet is set out below for the calculation of the temporary storage for the same case as in Section 4.5.10.1, but for the situation where storm duration (D) exceeds the time of concentration (Tc). Section C2.2 provides an explanation as to where this will apply; in essence this is where the rain tank needs to meet a flow control target in the downstream receiving system rather than at the outlet to the dwelling site (refer also Section 4.5.5.1(3) for application details). Fig 4.5.3 shows a plot of the relevant hydrographs.

Specifically:

(i) Tc = 15 minutes (ie as in Section 4.5.10.1)

(ii) Storm duration (D) = 30 minutes

(iii) Rainfall depth-duration-frequency data (for 30 mins & 10% AEP) gives I = 70 mm/hr

(iv) Design hydrograph derivation: refer Section C3.3 and Fig. C2b for an illustration of the corresponding hydrograph shape

Note that the tank size derived for this case (ie 4.8 m^2 x 1.2 m) is 60% larger than for the Section 5.4.10.1 example (ie 3.0 m^2 x 1.2 m).

RAIN TANK - FLOW ROUTING ANALYSIS

(A) SITE DATA:

Soil Type:	Clay		
AREAS:			C value
Roof area	250	m2	0.9
Other impervious area	100	m2	0.86
Pervious area	350	m2	0.43
Lot area	700	m2	

(B) TANK DETAILS:

Tank area	4.8	m2	(ie	2.5	m dia)	*Trial orifice diameter calculation:*		
Tank height	1.2	M				*Peak orifice flow:*	*1.25*	*l/s*
Orifice dia	0.023	M	d^2	0.000529		*Max orifice head:*	*1.2*	*m*
Orifice discharge coefficient				0.69		*Trial diameter:*	*0.022*	*m*

(C) HYDROLOGY - BY RATIONAL METHOD:

(refer comparable calculations in Appendix C - Section C3.5)

Tc	15	min		
Storm duration (D)	30	min		
Rainfall intensity (10% AEP)			70	mm/hr
		C value	Peak discharge (l/s)	

Peak roof discharge:	0.90	4.38
Peak rest-of-site discharge:	0.53	4.60
Permissible site discharge	0.43	5.85

(D) SIMULATION:

Time step 2.5 Min

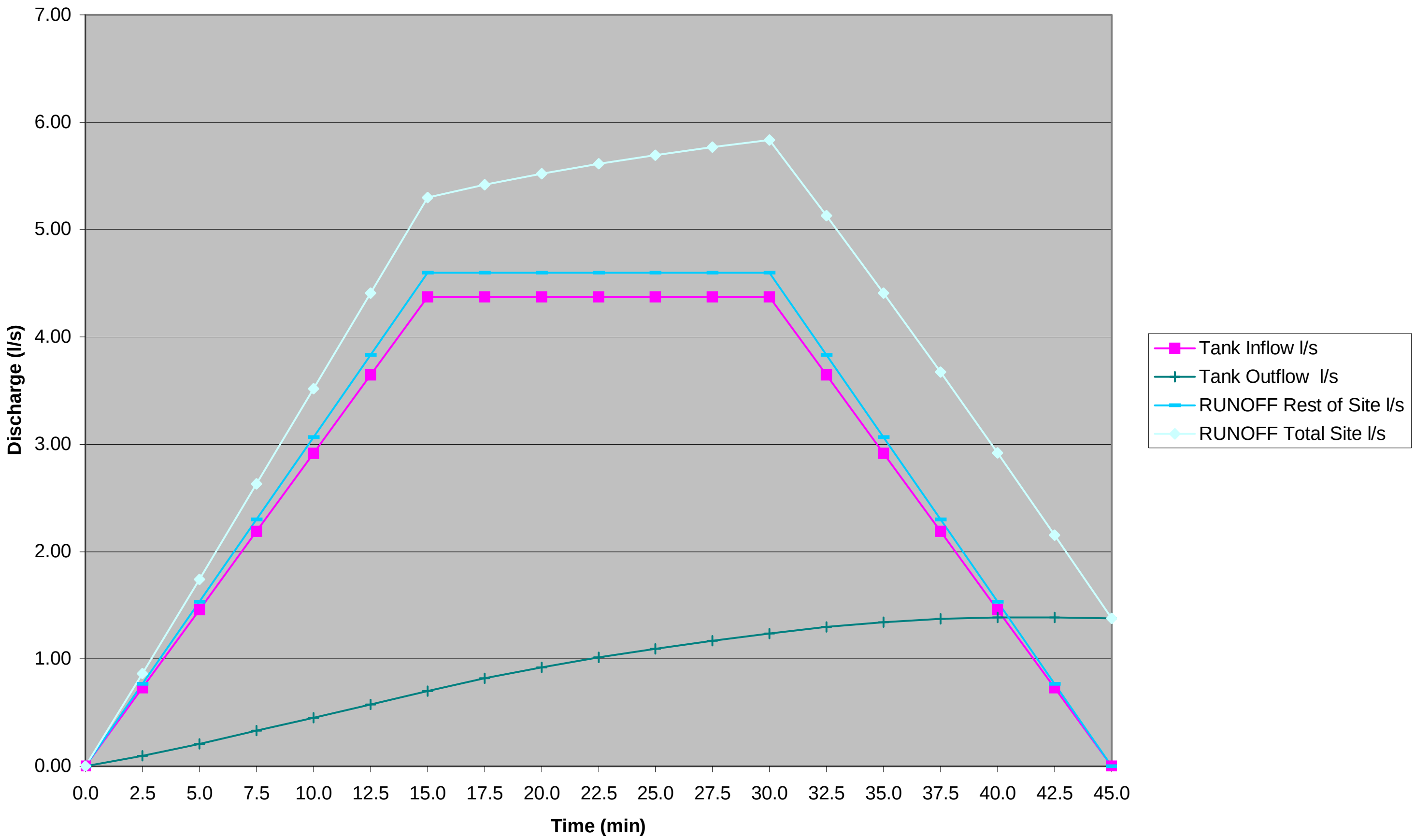
Time	TANK INFLOW		Tank Storage	Tank WL	Adjusted Av WL	Tank Outflow	Net Device Storage	SITE RUNOFF CALC Rest of Site	Total Site
(mins)	l/s	m3	m3	m	m	l/s	m3	l/s	l/s
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5	0.73	0.05	0.05	0.01	0.01	0.10	0.04	0.77	0.86
5.0	1.46	0.16	0.20	0.04	0.03	0.21	0.17	1.53	1.74
7.5	2.19	0.27	0.45	0.09	0.07	0.33	0.40	2.30	2.63
10.0	2.92	0.38	0.78	0.16	0.13	0.45	0.71	3.07	3.52
12.5	3.65	0.49	1.20	0.25	0.21	0.58	1.12	3.83	4.41
15.0	4.38	0.60	1.72	0.36	0.30	0.70	1.61	4.60	5.30
17.5	4.38	0.66	2.27	0.47	0.42	0.82	2.15	4.60	5.42
20.0	4.38	0.66	2.80	0.58	0.53	0.92	2.67	4.60	5.52
22.5	4.38	0.66	3.32	0.69	0.64	1.01	3.17	4.60	5.61
25.0	4.38	0.66	3.83	0.80	0.74	1.10	3.66	4.60	5.69
27.5	4.38	0.66	4.32	0.90	0.85	1.17	4.14	4.60	5.77
30.0	4.38	0.66	4.80	1.00	0.95	1.24	4.61	4.60	5.84
32.5	3.65	0.60	5.21	1.09	1.04	1.30	5.02	3.83	5.13
35.0	2.92	0.49	5.51	1.15	1.12	1.34	5.31	3.07	4.41
37.5	2.19	0.38	5.69	1.19	1.17	1.37	5.49	2.30	3.67
40.0	1.46	0.27	5.76	1.20	1.19	1.39	5.55	1.53	2.92
42.5	0.73	0.16	5.72	1.19	1.20	1.39	5.51	0.77	2.15
45.0	0.00	0.05	5.56	1.16	1.18	1.38	5.36	0.00	1.38

NOTE: If/when tank WL exceeds tank height, site runoff calculation should include tank overflow (ie overflow = inflow - orifice outflow)

RESULT:

Tank area:	4.8	m2
Tank height:	1.2	m
Orifice diameter:	23	mm
Tank capacity (V)	**5.8**	**m3**

Figure 4.5.3 Hydrograph plots for Case B

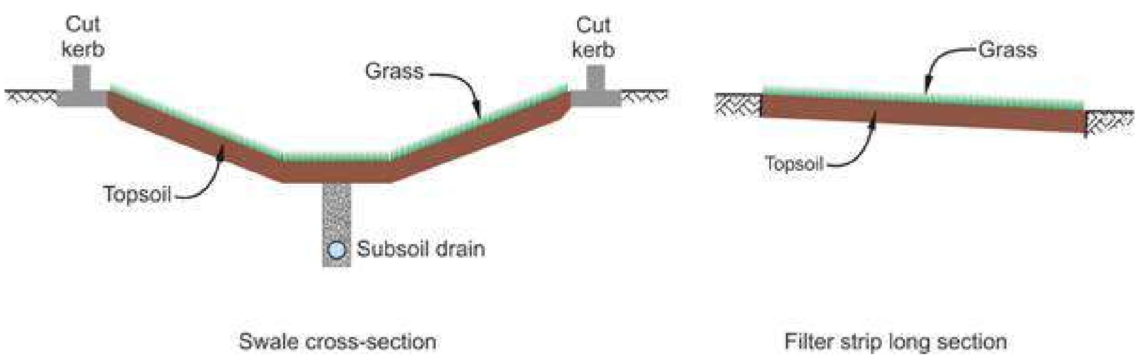


4.6 Swale / filter strip

4.6.1 Description

These devices use vegetation in conjunction with slow and shallow depth of flow to achieve treatment of stormwater. Removal of contaminants is achieved by a combination of filtration, adsorption and biological uptake. Vegetation also decreases flow velocity and allows settlement of particulates. The principal difference between swales and filter strips is that swales accept concentrated flow while filter strips accept distributed or sheet flow

Figure 4.6.1 Swale / filter strip operating principles



4.6.2 Capability

Swales and filter strips are able to:

- treat runoff from impermeable hardstand ground surfaces in commercial, residential and industrial areas
- treat road or parking lot runoff
- provide aesthetic benefit

Swales and filter strips are not able to:

- treat sediment-laden water from construction sites. Install after site works are complete and contributing areas have been fully stabilised in order to prevent excess sediment loading
- provide significant peak flow or volume control

Expected contaminant removal rates for swales / filter strips are (ARC 2003, EPA 1999d):

- suspended solids 81%
- metals (cadmium, copper, zinc, lead) 50 to 90 %
- total phosphorus 9 %
- nitrate 38%
- oxygen demanding substances 67%
- hydrocarbons 62%

4.6.3 Applicability

- can be located in;
  - median strips in car parks or substitute for kerb and gutter at the side of roads, with kerb cuts to allow entry of runoff
  - adjacent to site boundaries
- on line or off line location
- for impermeable subsoils, minimum longitudinal slope of 0.5% to avoid pugging of soil
- maximum longitudinal slope: 5% without erosion protection or check dams
- swales require minimum length of 30 m
- maximum drainage flow path to a filter strip is 50 m
- maximum longitudinal slope of contributing slope to a filter strip is 5% unless energy dissipation is provided
- maximum lateral slope of a filter strip is 2%
- require area open to sun, avoid or minimise shading (to encourage vegetation growth)
- device catchment area no more than 4 ha (ARC TP10)
- time of concentration not to exceed 10 minutes
- take care to ensure adequate subsoil drainage is provided in situations where additional infiltration into the subsurface may cause problems, for example adjacent to parking areas or roads, where infiltrating water may weaken the pavement
- use cut kerbs or other measures to prevent vehicles driving on swales

4.6.4 Summary of design approach

Note: This is consistent with ARC TP10

1. Determine the water quality flow rate , refer to section 3.6
2. Adopt trial swale/filter strip cross-section and slope
3. Calculate water quality depth and velocity for water quality flow rate
4. Check that flow depth and velocities are less than allowed maxima and check the hydraulic residence time is at least 9 minutes - this hydraulic residence time is recommended in ARC TP10 and in Minton (2002)

4.6.5 Preparatory steps

1. Confirm quality objective: refer section 3.6
2. Define key site parameters and device needs that determine design details
   - device catchment land use (this is required to be used in design calculations)
   - device catchment impervious area (roof and on-ground areas)
   - device catchment pervious area and cover type (e.g. grass, shrubs, forest)
   - ground slope at location of swale/filter strip
     - if slope is under 2%, a subsoil drain is required under the base of the swale
     - if slope is over 5% filter strip is not appropriate
     - for slopes between 5% and approximately 8%, check dams are required to reduce effective grade to 5% or less

- for slopes over 8% swales are unlikely to be appropriate as large check dams will be required

- define maximum flow capacity requirements for the area to be drained and locate overland flow paths for flows in excess of the capacity of the swale/filter strip
- check any regional, city or district council requirements for resource consent, building consent or drainage permit or compliance with other standards.
- provision of adequate access for maintenance

4.6.6 Design steps

4.6.6.1 Sizing for water quality design

Design parameters

- determine the water quality flow rate, refer to section 3.6
- swale cross-section; bottom width between 0.6 and 2m, maximum side slope 1 vertical on 3 horizontal
- longitudinal ground slope and slope. for situations where check dams are required for swales, the effective slope is the slope between the downhill base of one check dam and the crest of next downslope check dam
- swale length (minimum 30m)
- grass height, choose either 50 mm or 150 mm

Design/sizing methodology

Note: This method is generally consistent with design methods per ARC TP 10

1. Adopt trial swale/filter strip cross-section and slope
2. Calculate effective slope
3. Calculate flow depth and velocity for the water quality flow using Mannings equation. Note that this method, including formulae for calculating Mannings n values, is described in ARC TP10
4. Check flow depth is less than
   - 100 mm for swales
   - 25 mm for filter strips
5. Check velocity is less than:
   - 0.8 m/s for swale
   - 0.4 m/s for filter strip
6. If flow depth and velocity criteria are satisfied, proceed to next step, otherwise consider the following options:
   - adopt new trial swale/filter strip cross-section and / or slope. Swale longitudinal slope can be reduced by using check dams.
   - divide the site drainage to flow to multiple swales to reduce the size of the flow per swale/filter
7. Calculate residence time in swale/filter strip. The minimum hydraulic residence time for the water quality flow is at least 9 minutes to achieve the nominated contaminant reductions. If the residence time is less than 9 minutes, revise swale/filter strip cross-section, slope and/or length and recalculate. If the minimum residence time cannot be achieved, use another treatment device or use swale/filter strip in conjunction with another device.
8. Calculate peak flow for the 10 year ARI storm.

9. Calculate 10 year ARI flow velocities using Mannings equation for the 10 year flow. If velocity is greater than 1.5 m/sec, enlarge swale/filter strip size and recalculate. If swale/filter strip size is as large as practical and the 10 year ARI flow velocity is >1.5 m/s, provide erosion protection.
10. Safety check: calculate the mean annual food flow. Calculate flow depth, D and velocity, V using Mannings equation. V x D should not exceed the following:
    - for children: not greater than 0.2 m^2/s
    - for adults not greater than 0.4 m^2/s

4.6.7 Design detailing and drawings

Inlet

- care needed for concentrated inflows to reduce velocity quickly to minimise erosion potential; riprap pads or level spreaders should be used

Cut kerbs

- use cut kerbs or similar to prevent vehicles driving on swales

Swale base

- base width to be no less than 600 mm to facilitate mowing and no greater than 2 m to prevent concentration of flow
- base to be flat , level spreader boards at 15 m centres are useful to prevent concentration of flow, especially for wide bases

Swale depth

overall swale depth to take into account overall drainage requirements for the area served. A common approach is to size the swale and associated depth for the 10 year ARI flow

Filter strip crossfall

crossfall not to exceed 2%

Check dams

o to be used at 15 m centres along swale or filter strip if slope is greater than 5%

Topsoil and vegetation

- minimum topsoil depth of 150 mm
- topsoil to be of good quality and appropriate to support dense grass
- vegetation to be a dense stand of uniform grass or other fine stemmed plants that can tolerate soil saturation and the climatological and pest conditions of the location
- grass length to be maintained at between 50mm and 150mm

Filter fabric

- used to prevent migration of topsoil to underlying subsoil drain

Subsoil drain

- required under base of swale/filter strip if longitudinal grade is less than 2%
- required to protect adjacent pavement subgrades from saturation

ARC TP10 requirements

- check ARC TP10 requirements for detailed requirements for check dams, level spreader boards etc

Check council requirements

- check any regional, city or district council requirements for resource consent, building consent or drainage permit or compliance with other standards

4.6.8 Implementation provisions

Following issuing of the consent, construction will requires close attention to ensuring that the design details and materials specifications in particular topsoil and grass.

Once constructed, the device will need to be commissioned and tested if practical. In the event that the device is commissioned during a dry spell, in some cases it may be appropriate to test the device using a high-capacity hose (e.g. from hydrant or tanker, feeding water to the roof or site impervious area).

Checks need to be made for flaws such as evidence of scour, etc.

Certification: once commissioned and operating satisfactorily, the device will need to be certified under the provisions of the Building and/or Resource Consent – ARC TP10 provides examples of the checklists used by certification authorities.

O&M (ongoing): the routine maintenance provisions set out below will need to be undertaken, in accordance with either (as applicable):

- the provisions of the consent (where nominated), or
- as per an appropriate O&M model (refer to Appendix D2.0)

Operation and maintenance

Item	Frequency
Clear debris, litter from entry and contributing areas	As required, at least quarterly
Mow grass to keep height between 50 mm and 150 mm	As required, at least quarterly
Check that there is a thick growth of grass or other approved thin stemmed vegetation. Reinstate vegetation as necessary, remove undesirable vegetation,	As required, at least quarterly
Check that flow is evenly dispersed, remedy concentrated flow or erosion damage by revegetation, earthworks or installation of level spreaders or additional check dams	As required, at least quarterly
Removal of accumulated sediments, restore vegetation as required	As required, at least annually

4.6.9 Worked example

Design of swale

Job name example
Location somewhere

design objective	Water quality		100 year ARI	
catchment land use	residential			
impervious area type	seal			
pervious area type	grass, shrub			
catchment imperv area	0.7	ha	0.7	ha
catchment perv area	0.2	ha	0.2	ha
time of concentration	10	min	10	min
rain intensity source	HIRDS I/3 2 yr 10 min		HIRDS	
rain intensity	18	mm/hr	132	mm/hr
C impervious	0.9		0.9	
C pervious	0.18		0.18	
Catchment CA	0.666		0.666	98
Design Flow	**0.033**	**m^3/s**	**0.244**	**m^3/s**

Swale longitudinal slope S .02
Swale grass height 50 –150 mm
Mannings n = 0.013 $d^{-1.2}$ / (0.75+25s) For d > 60 mm, 150 mm grass ref ARC TP10
Mannings n = 0.009 $d^{-1.2}$ / (0.75+25s) For d > 75 mm, 50 mm grass
Swale shape Trapezoid

Trial calculation using Mannings equation, for water quality flow: select depth to provide calculated flow to match design flow, determine length required for water quality (to provide hydraulic residence time of 9 minutes)

depth, d	bott width	side batter	top width	area	wet. perim p	$r^{2/3}$	slope s	grass length	n	vel. V	flow Q	minimum swale length
m	**m**	**1 on -**	**m**	**m^2**	**m**			**mm**		**m/s**	**m^3/s**	**m**
0.095	2	3	2.57	0.22	2.60	0.19	0.02	150	0.175	0.15	0.033	83
0.084	2	3	2.50	0.19	2.53	0.18	0.02	50	0.141	0.18	0.033	95

Thus flow depth is less than 100 mm; OK. Required swale length is between 83 m and 95 m depending on grass length. Note velocity is well below maximum allowed (0.8 m/s).

Trial calculation for checking swale depth, velocity and safety for 100 year ARI flow: select depth to provide calculated flow to match design flow.

depth, d	bott width	side batter	top width	area	wet. perim p	$r^{2/3}$	slope S	grass length	n	vel V	Q	
m	**m**	**1 on -**	**m**	**m^2**	**m**			**mm**		**m/s**	**m^3/s**	
0.19	2	3	3.14	0.49	3.2	0.28	0.02	150	0.076	0.53	0.257	
0.165	2	3	2.99	0.41	3.04	0.26	0.02	50	0.063	0.59	0.244	

Thus required swale depth for 100 year ARI is 0.19 m, velocity is OK as less than max allowed of 1.5 m/s.
Safety: v x d= 0.04 < 0.2 m^2/s OK

4.7 Wetlands

4.7.1 Description

There are two general types of constructed wetlands, surface flow and subsurface flow. Surface flow wetlands mimic natural wetlands and are shallow open ponds with permanent water and submerged and emergent plants. Subsurface flow wetlands include a gravel substrate, which acts as a filter. They are prone to blockage and have high maintenance requirements. The following detailed discussion refers to surface flow wetlands.

Figure 4.7.12 Wetland operating principles

Stormwater flowing through a wetland provides treatment by a variety of mechanisms including settling, filtration, biological degradation, microbial uptake, adsorption, volatilisation and plant uptake. Wetlands can also provide peak flow attenuation and extended detention and landscape and wildlife habitat benefit. Wetlands have a permanent pool ponding volume and an associated permanent pool water level. When stormwater inflows occur, the wetland water level rises above the permanent pool level and the additional storage associated with this rise in water level achieves peak flow attenuation and if the wetland is appropriately designed, provides extended detention.

4.7.2 Capability

Wetlands are able to:

- treat runoff from impermeable hardstand ground surfaces in commercial, residential and some industrial areas, including parking lot runoff. They are well suited for removal of sub 100 micron particulate matter and dissolved chemicals

Expected contaminant removal rates are:

• sediment	60 to 80% (CCC 2003)
• trace metals	40 to 80 % (CCC 2003)
• total phosphorus	40 to 80% (CCC 2003)
• total nitrogen	20 to 60% (CCC 2003)
• BOD	20 to 40% (CCC 2003)
• petroleum hydrocarbons	87% (EPA 1999e)
• bacteria	60 to 100% (CCC 2003)

Wetlands may be able to:

- remove organic contaminants through adsorption, volatilisation, photosynthesis and biotic/abiotic degradation (ARC TP10)
- provide significant peak flow reduction and associated flood protection
- provide extended detention and thus can be used for stream channel protection
- provide aesthetic benefit

4.7.3 Applicability

- require summer baseflow or minimum catchment size to prevent wetland drying out in summer
- minimum catchment size for Auckland area is recommended to be 1 ha. (ARC TP10)
- require impermeable soil base or liner to prevent leakage and potential groundwater contamination
- on line or off line location (refer to glossary for definition)
- require relatively flat ground, maximum ground slope: 5%
- avoid unstable ground
- adequate clearance to existing utilities and to site boundaries
- location of piped outlet to discharge to pipe reticulation or surface dispersal

4.7.4 Summary of design approach

1. Confirm catchment area sufficient, and/or base flows will be sufficient to prevent drying out of wetland in summer.
2. Determine the size required to meet:
   - water quality objectives
   - flood protection peak flow control objectives and extended detention for stream channel protection objectives
3. Check that a device of the required size can be built on the site for all relevant objectives. A device sized to meet the most onerous objective will meet the others
4. If a device of the size required to meet a water quality/peak flow/quantity objective cannot be built on the site but a smaller device will be able to meet a less onerous objective, then adopt the sizing for that less onerous objective and select a separate device to meet the more onerous objective

4.7.5 Preparatory steps

1. Confirm design imperatives
   - quality objective: refer section 3.6
   - peak flow control and stream channel protection: refer section 3.7
2. Define key site parameters and device needs that determine design details
   - device catchment land use (this is required to be used in design calculations)
   - device catchment impervious area (roof and on-ground areas)
   - device catchment pervious area and cover type (e.g. grass, shrubs)
   - for final discharge by infiltration to ground, refer to ground disposal assessment requirements in Section 3.8 and 3.10
   - check any regional, city or district council requirements for resource consent, building consent or drainage permit or compliance with other standards.
   - provision of adequate access for maintenance

4.7.6 Design steps

4.7.6.1 Sizing for water quality design

The ARC method provides a permanent pool equal to the water quality volume with no allowance for porosity of the wetland permanent pool associated with wetland plants. It also allows for water quality benefit in addition to the permanent pool if extended detention is provided. The Christchurch City Council method recommended procedure is to provide a hydraulic residence time of 2 days for at least the first flush and use an assumed vegetation porosity of 0.75.

The recommended approach for this guideline for areas outside the Auckland region and Christchurch City is as follows:

- for typical urban areas, including car parks, low to medium trafficked roads, to provide treatment of sediment, metals and hydrocarbons: provide for at least 1 day hydraulic residence time for the water quality volume using an assumed porosity of the permanent pool of 0.75
- for areas with high contaminant loadings such as busy roads or industrial sites with particular contaminants of concern or for sites where nutrient removal is required: hydraulic residence times of 2 days or more may be required and specialist advice is recommended

Design parameters

- determine water quality volume (WQV) from the appropriate method in section 3.6
- design water level depth: ARC recommendations are:
  - 40% of the wet pool area to be between 0.5 and 1m depth
  - 60% of the wet pool area to be 0 to 0.5 m depth
  - provide banding so there are open areas and vegetated areas and water passes through both sequentially
  - consider safety – use shallow fringe areas
  - care with planting and bed levels to avoid short circuiting
  - need to consider mosquitos if close to residential areas; mosquitos can best be controlled by the establishment of dense vegetation in shallow water and adjacent to the wetland to provide habitat for mosquito predators
- include forebay or separate pond before wetland to capture coarse sediments
- forebay:
  - volume to be 15% of the water quality volume
  - maximum depth of 2 m
  - length to width ratio of between 2:1 and 3:1
  - provide for energy dissipation and even distribution of flow into the wetland
  - minimum length to width ratio for wetland is 2:1 (EPA1999e).

Design/sizing methodology

The required wetland treatment volume, V = WQV x HRT / n

Where:

WQV = water quality volume, m^3

HRT = hydraulic residence time days, refer discussion above

n = wetland permanent pool porosity assume 0.75

The required volume V will be:

- where extended detention is not provided, V = the permanent pool ponding volume
- where extended detention is provided, V = the permanent pool volume plus the temporary storage volume above the permanent pool level provided by extended detention

Determine pond dimensions using the permanent wet pool volume, site topography, available area for the wetland and preliminary construction details such as embankment batters. Obtain specialist geotechnical advice as necessary regarding maximum embankment heights, batters and crest widths

4.7.6.2 Sizing for peak flow control and extended detention

Peak flow control and extended detention are achieved by temporary ponding of water above the wetland permanent water level during a rainfall event. The amount and duration of ponding is dependant on the inflow hydrograph, the characteristics of wetland storage above the permanent water level and the outlet flow characteristics.

Design parameters

- determine catchment parameters, including time of concentration, C values, refer to Appendix C
- determine rainstorm ARI and duration to be considered and associated rainfall depth

Design/sizing methodology

- assess a maximum ponding depth, above the permanent pool water level based on site topography, available area for the wetland and preliminary construction details such as embankment batters and fill or cut soil properties. Obtain specialist geotechnical advice as necessary regarding maximum embankment heights, batters and crest widths
- refer to ARC TP10 section 5 for description of suitable outlet design and Appendix C hydrology for routing methodology
- adopt trial wetland dimensions
- generate hydrograph for existing situation
- generate inflow hydrograph for developed situation
- adopt a trial outlet design, calculate outflow characteristics and route inflow hydrograph (developed) through the wetland
- if objectives are not achieved, decide whether a larger device is practical for the site. If so, increase the surface area and maximum water height to the practical maximum and recalculate the routing calculations
- if the required peak flow control and extended detention objectives can be achieved by the revised design, confirm the device feasibility in relation to the site characteristics, especially topography and available area

Determine device size

- check that the required size can be achieved on the site for all relevant objectives. If so, the device is sized to meet the most onerous objective will meet other objectives
- if a device of the size required to meet a water quality/peak flow/quantity objective cannot be built on the site but a smaller device will be able to meet a less onerous objective, then adopt the sizing for that less onerous objective and select a separate device to meet the more onerous objective

4.7.7 Design detailing and drawings

Inlet forebays

All principal inflow points to be provided with forebays to be designed to trap coarse sediments and be readily accessible for removal of accumulated sediment.

Embankment design

Any embankments must be appropriately designed and constructed to take account of hydrostatic pressure and minimise the risk of slope instability or piping

Permanent pond liners

Lining of the permanent pond to ensure minimal leakage must be achieved by the use of appropriate compacted soil, which may be insitu soils if appropriate or a geotextile liner.

Soil for plant establishment

Place organic soil in the base of the wetland to assist with plant establishment.

Plants

Suitable plant types for the Auckland region are presented in ARC TP10, section 6.9. For other areas of New Zealand, contract appropriately qualified landscape gardeners/architects or regional council staff/publications for advice.

Outlets

- forebay outlet weir to have a length at least 50% of the forebay width
- excess flow by pass to be provided around both he forebay and the wetland
- flow velocities in wetland during the 5 year ARI storm to be less than 0.25 m/s to avoid re-suspension of sediment

Council requirements

Check any regional, city or district council requirements for resource consent, building consent or drainage permit or compliance with other standards.

4.7.8 Implementation provisions

Following the issuing of the consent, the steps in implementing the on-site device are:

- construction: requires close attention to ensuring that the following are met:
    - o design details
    - o materials specifications in particular soil liner or geotextile
    - o protection from sediment entry if catchment is unstabilised during construction
    - o specifications

- commissioning:
  - once constructed, the device will need to be commissioned and tested
  - in the event that the device is commissioned during a dry spell, in some cases it may be appropriate to test the device using a high-capacity hose (e.g. from hydrant or tanker, feeding water to the roof or site impervious area) or wait until significant rain occurs
  - checks need to be made for "flaws" such as leaks, blockages, evidence of scour, etc

- certification: once commissioned and operating satisfactorily, the device will need to be certified under the provisions of the Building and/or Resource Consent – ARC TP10 provides examples of the checklists used by certification authorities

- O&M (ongoing): the routine maintenance provisions set out below will need to be undertaken, in accordance with either (as applicable):
  - the provisions of the consent (where nominated), or
  - as per an appropriate O&M model (refer to Appendix D2.0)

4.7.9 Operation and maintenance

Item	**Frequency**
Clear debris, litter from forebay, planted wetland and outlet	As required
Remove noxious weeds and plants	As required but inspect at least quarterly
Check plant species presence, abundance and condition, prune excessive vegetation, replace plants if necessary plants may require watering or replanting during the first three years	As required, but at least 6 monthly
Check that that water is retained in the base of the wetland during dry weather.	6 monthly
Outlet /overflow spillway: check condition, scour, erosion, blockage	6 monthly
Check for mosquito breeding, augment planting as required	6 monthly
Sediment accumulation in forebay: remove if more than 50% of its design volume is occupied with sediment	Annually

4.7.10 Wetland worked example

Job name	Example		
Location	Gisborne		
design objective	Water quality		
catchment land use	residential		
impervious area type	seal		
pervious area type	grass, shrub		
catchment impervious area	8000	m^2	
catchment pervious area	2000	m^2	
catchment time of concentration	10	min	
C impervious	0.83		
C pervious	0.18		
Water quality design storm depth	32.6	mm	1/3 of 2 year 24 hour rainfall from HIRDS
runoff from impervious area = rain - 2 mm	30.6	mm	
pervious area soil drainage	slow		
pervious area depr storage and infiltration	15	mm	
pervious area runoff = rain - depr. stor. & infiltr.	17.60	mm	
total runoff =WQV	280.0	m^3	
assume porosity of wetland water/vegetation, n	0.75		
hydraulic residence time, HRT	1	day-	
required permanent wet pool volume =	WQV x HRT / n		
required permanent wet pool volume =	373.3	m^3	
no extended detention			
trial wetland total surface area	660	m^2	
volume of 0.5 -1.0 m depth (60% area, assume average depth 0.75m)	297	m^3	
volume of 0-0.5 m depth (40% area, assume average depth 0.3m)	79.2	m^3	
trial volume total	376.2	m^3	matches reqd OK

4.8 References

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Section 5 Device description and guidance notes

In this section

Device description and general guidance notes for:

5.1 Detention tank

5.2 Pond

5.3 Roof garden

5.4 Roof gutters

5.5 Depression storage

5.6 Permeable pavement

5.7 Treatment trench / rock filter

5.8 Catchpit insert

5.9 Gross pollutant trap, litter trap, hydrodynamic separator

5.10 Oil and water separator

For each device:

- description of device
- applicability
- maintenance
- references

5.1 Detention tank

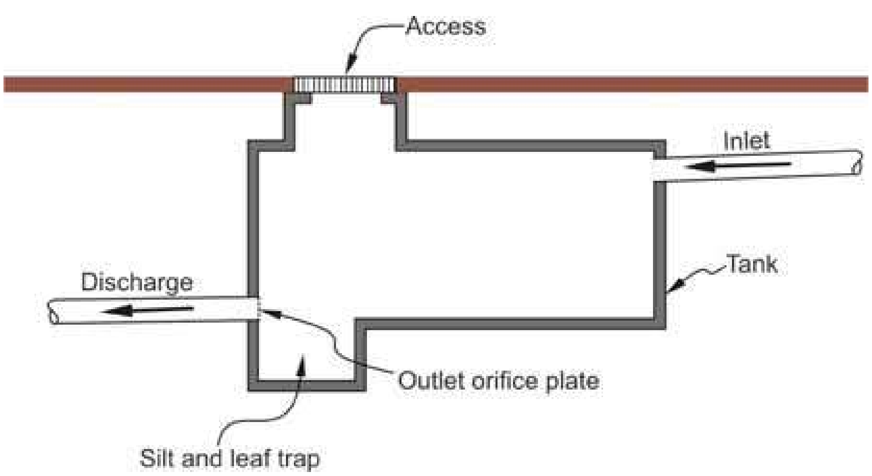
Description

A tank intended to temporarily store runoff and release it at a slower rate. Differs from the rain tank (refer Section 4.5) in that it works solely as a detention device, for peak floe reduction, with no water re-use function. Also known as OSD tank, where OSD is an acronym for on- site detention).

Key features are:

- may be located below ground or above ground
- may be fed by roof and/or site runoff: if the latter, it generally includes a catchpit before the tank to intercept debris and coarse sediments (i.e. to avoid blockage of the tank outlet orifice, and reduce the frequency of tank clean-out)
- water is fed into the top of the tank
- incorporates the following outlets, connected to the public stormwater system:
  - o an orifice, located just above the base, sized to meet the required peak outflow rate
  - o a top overflow outlet

Figure 5.1 Detention tank schematic



Applicability

***Caution**: refer red flag box below regarding the acceptance of detention tanks by NZ local authorities*

The detention tank is used only for peak flow reduction i.e., flood attenuation. They can be used in a wide range of applications and, aside from the maintenance issue (refer below), can be cost-effective.

Precedents

The Upper Paramatta River Catchment Trust (UPRCT 1999) in Sydney is a major proponent of OSD tanks and publishes a very detailed manual on the topic (refer References).

Although the tank sizing basis is unique to the locality (i.e. the requirement is for a storage capacity of 470 m^3/ha), the coverage on detailing and case studies is noteworthy. Of interest also is the requirement for a separate discharge control pit (DCP) rather than an orifice in the tank, and the preference for off-line systems where the DCP feeds water into and out of the tank.

Design and detailing issues

- tank sizing: the tank can be sized in the same manner as for the temporary storage component of a rain tank (refer Section 4.5)
- catchpit: where the tank receives site runoff, a catchpit should be installed upstream of the tank
- levels: As well as locating the tank so that water can be fed into it (also accounting for the need for a catchpit, if applicable), there is a need for adequate fall between the tank outlet and the receiving system (e.g. street gutter or pipe)
- tank materials: can be plastic, concrete or steel: especially where the tank is to partially or fully underground, account needs to be taken of:
  - structural integrity and water-tightness (e.g. cracking can result in leakage to/from groundwater which is both undesirable and not visible)
  - corrosion (e.g. without a special surface coating, steel is generally not suitable for undergrounding)

Maintenance

Where the detention tank receives roof runoff only, maintenance needs are basically as for a rain tank (refer Section 4.5).

However, where the detention tank receives site runoff containing contaminants, such as hydrocarbons which are not intercepted by the catchpit, such contaminants may be toxic in a confined space, requiring special maintenance safety practices

As an example of the potential maintenance issues, Auckland City Council used to require such tanks with new infill housing in areas served by combined sewers. However, experience showed that, due to inadequate provisions for debris capture (e.g. as would occur in a catchpit), the outlet orifice would block. To resolve the problem, the often-applied solution was to disconnect the tank and feed flow direct to the combined sewer.

An advantage of the rain tank (refer Section 4.5) over the detention tank in respect to maintenance is that the former provides the benefit of a useful water supply source. In areas of reticulated water supply, this can offer a potentially worthwhile cost savings on mains water charges. In order to secure this benefit, owners are more likely to engage in sound maintenance practices for a rain tank than for a detention tank.

Note that the detention tank is a forerunner to the rain tank (refer Section 4.5), but has fallen out of favour to a degree, due to the potential for re-use to be cost-effective with a rain tank, and the maintenance issues (refer immediately above). For these reasons, some New Zealand local authorities will not accept detention tanks.

Reference

Upper Parramatta River Catchment Trust (1999). *On-site detention handbook*. (UPRCT 1999). From www.upperpárariver.nsw.gov.au

5.2 Ponds

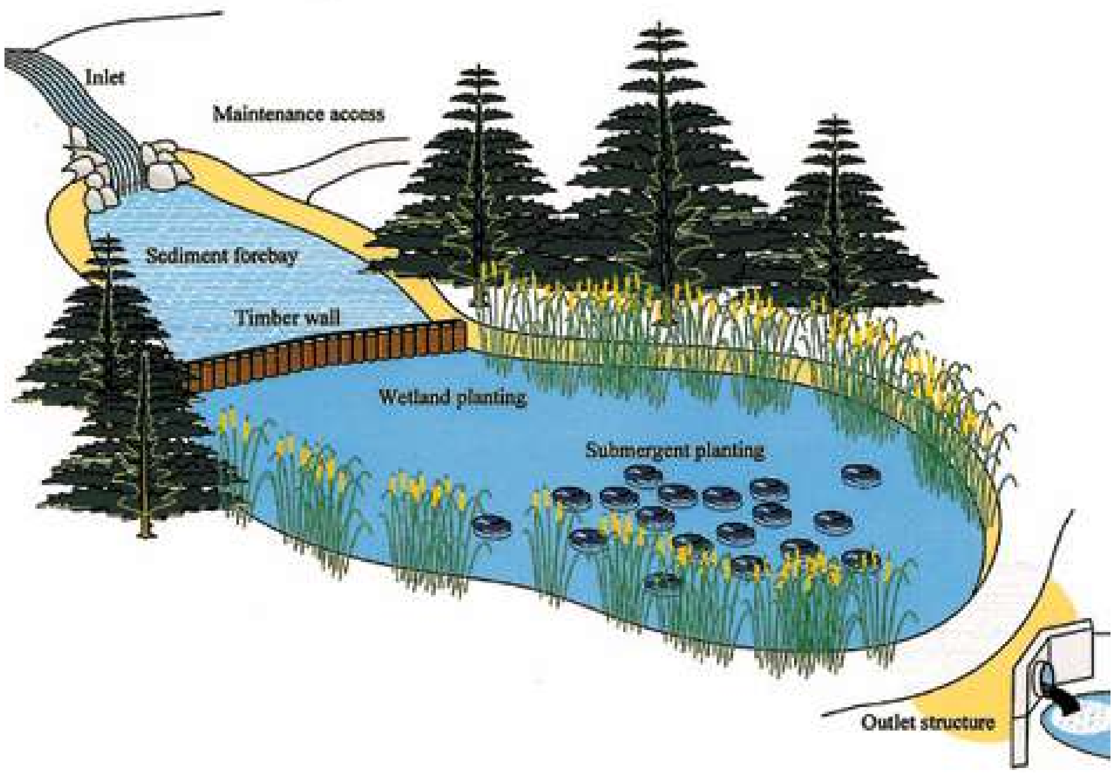
Description

Also includes wet detention basins. Ponds can be of two types:

- dry ponds which 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
- wet ponds, which have a permanent standing pool of water. They provide water quality treatment through the permanent pond and 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

Ponds can provide aesthetic benefit.

Figure 5.2 Pond schematic



Applicability

- ARC TP10 states that dry ponds are not normally recommended for stormwater management systems, due to lower water quality performance than wet ponds, ongoing maintenance problems and less aesthetic appeal than wet ponds
- dry ponds are used as a detention basin in Christchurch, (CCC 2003) with extensive vegetation which is aesthetically pleasing
- primarily for large lots, including some industrial sites, or to serve several lots
- can be used upstream of wetlands to provide removal of coarse material
- require a significant contributing catchment area (2 to 3 hectares in the Auckland region) or continuous base flow to maintain a permanent pool of water
- not suitable on steep sites or on fill unless approved through geotechnical assessment
- may require liner in porous soils to maintain permanent water pool
- require civil and geotechnical engineering expertise for design, construction and maintenance
- may not be suitable if receiving water is temperature sensitive due to warming of pond surface area
- need to address potential mosquito breeding both in design and operation and maintenance
- safety issues need to be addressed
- can have adverse effects if constructed on perennial streams due to impedance of fish passage and temperature effects on downstream receiving water

Maintenance

- require regular removal of accumulated sediment, which may be contaminated and require appropriate off-site disposal
- require monitoring for mosquito breeding and appropriate action if a problem

References

Auckland Regional Council. (2003). *Stormwater treatment devices: design guideline manual*. ARC Technical Publication No. 10 (ARC TP10). From http://www.arc.govt.nz/arc/index.cfm?34C9C2A8-1BCF-4AA1-91AF-CC49CFE4A80C

Christchurch City Council. (2003). *Waterways, wetlands and drainage guide*. (CCC 2003)

5.3 Roof garden

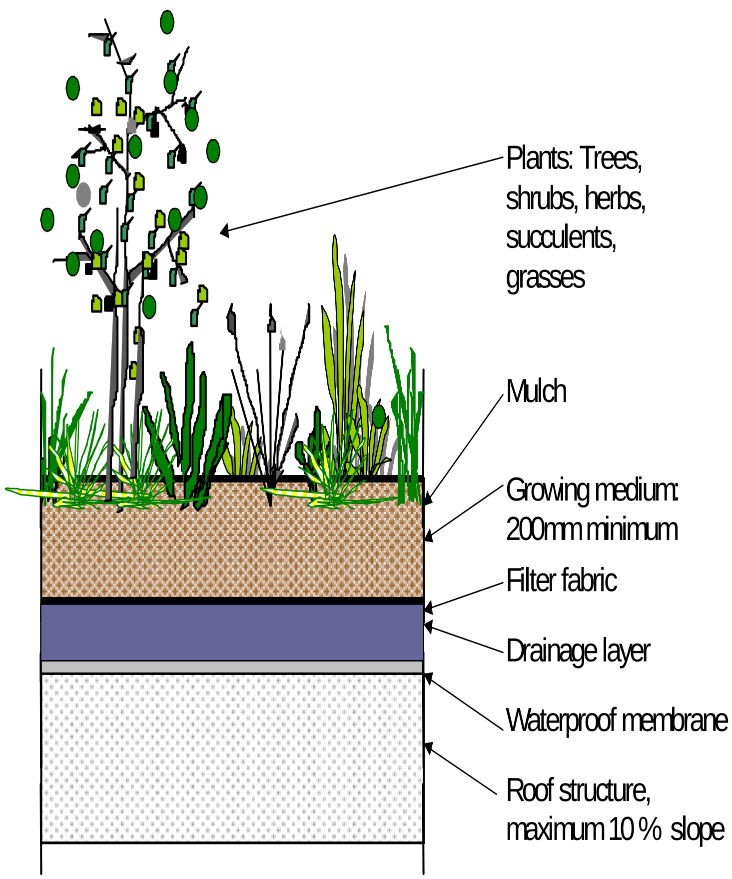
Description

A roof with a soil and vegetation cover, used in place of a conventional roof to achieve quantity and quality control. In many ways, it is similar to a rain garden (refer Section 4.3), but with negligible water storage capacity. It can also be known by the terms green roof and eco-roof.

Key features are:

- the roof structure is overlain by a waterproof membrane
- soil, with an underlying drainage system (proprietary), supports vegetation
- flow attenuation is achieved by evapotranspiration and soil capture
- contaminants are removed by filtration through the soil

Figure 5.3 Roof garden cross-section



Applicability

***Caution**: refer red flag box below regarding roof structural requirements*

Although quite novel in its concept, the roof garden is not only effective, but can also serve as an attractive landscaping feature when it can be seen from nearby decks or roofs.

Precedents

The City of Portland, Oregon, USA, is a leading proponent of roof gardens, and eco-roofs, a lighter-weight derivative. These are covered in its Stormwater Management Manual (CoP 2002). Both this and ARC TP10 provide both an overview and include details as to:

- waterproof membrane specification
- drainage layer specification
- filter fabric specification
- topsoil specification
- planting recommendation (but note should be taken of climatic differences)
- operation and maintenance provisions

Performance

Roof gardens act like pervious areas, although there is no net loss of water to soil infiltration. They can replicate the greenfield regime with respect to peak flows but not flow volume. Correspondingly, there is not generally a need to analyse their peak flow control performance.

Given that a roof garden only controls the roof runoff, there may be a need to use it in conjunction with another on-site device (e.g. controlling site runoff) to meet the overall performance standard.

Design and detailing issues

- roof gardens should not be used with roof slopes greater than 10% (roof gardens), or up to 25% with lighter weight eco-roofs
- careful structural and waterproofing detailing is needed to avoid leakage into the building
- the required soil depth will depend on the local climatic conditions and applicable plant species (note: appropriate plant selection is vital, to both ensure that they can survive the conditions and will maximise the evapotranspiration potential; plants may require irrigation in dry periods)
- soil of adequate fertility and drainage needs to be applied

Maintenance

The Portland Manual (CoP 2002) presents a sound example of the maintenance provisions for a roof garden. In summary, the main provisions cover:

- irrigation (if required)
- vegetation management (note that the use of fertilizers is discouraged, as nutrients will be leached out)
- soil substrate erosion
- structural components and drains
- debris and litter control
- access and safety

A key issue with roof gardens is the need for an adequate roof structure, to support the extra weight and ensure deflection is controlled to stay within the performance limits of the waterproofing material. Correspondingly, the costs of the roof structure and proprietary waterproofing systems should be checked before committing to a roof garden.

References

Auckland Regional Council. (2003). *Stormwater treatment devices: design guideline manual*. ARC Technical Publication No. 10 (ARC TP10). From http://www.arc.govt.nz/arc/index.cfm?34C9C2A8-1BCF-4AA1-91AF-CC49CFE4A80C

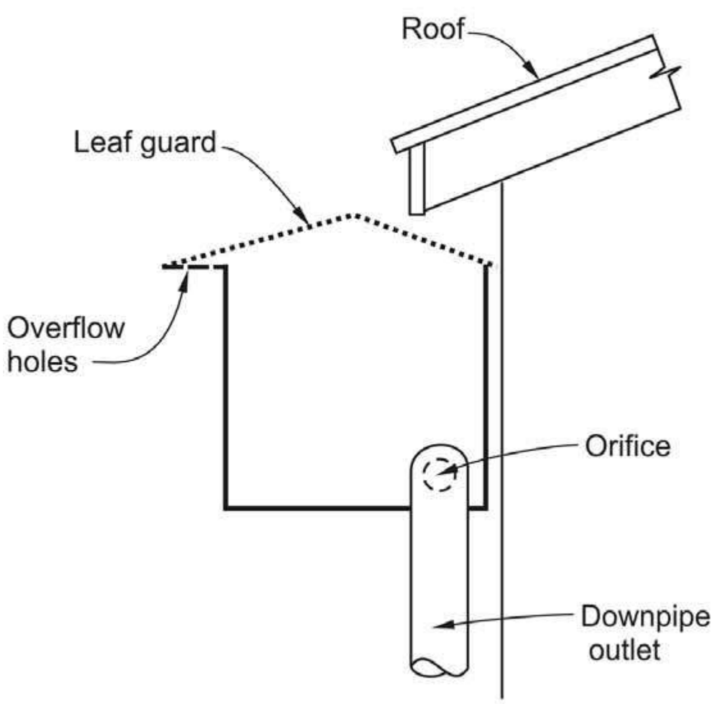
City of Portland. (2002). *Stormwater management manual*. Bureau of Environmental Services, City Of Portland, Oregon, USA, (CoP 2002). From http://www.cleanrivers-pdx.org/tech_resources/index.htm

5.4 Roof gutters

Description

Like tanks, over-sized gutters/spouting, with outlet flow throttling by orifices, can be used to provide flow attenuation. A variant, applicable to buildings with flat roofs, involves temporarily storing water on the roof for later release at a lower rate.

Figure 5.4 Roof gutter schematic



Applicability

Gutters will generally need to be quite large to meet typical flow attenuation targets, so will take the form of internal gutters. In turn, internal gutters can pose watertightness issues.

The sizing is illustrated by the following example (for Auckland – but note that actual capacities are dependent on the design storm frequency, the flow attenuation target, whether the gutters attenuate the roof or roof + site runoff, etc.):

- required storage: 1.5 – 2.0 m^3 per 100 m^2 of roof area in Auckland
- internal gutter size for a 100 m^2 roof: 40 m long (i.e. roof perimeter) x 0.4 m wide x 0.10 – 0.125 m deep

Design and detailing issues

The sizing of gutter detention will follow the same procedure as that for the temporary storage component of a rain tank (refer Section 4.5).

Points to note in designing/detailing roof gutters (or roof storage) include:

- careful structural and waterproofing detailing is needed to avoid leakage into building
- correct sizing of outlet orifices, and maintenance to avoid blocking, is critical
- care is needed with calculations for multi-level roofs where a down pipe stub-connection would normally be used to feed water from the upper roof to the lower one (in practice, it is simpler if each roof section is direct-connected to a down pipe)

Maintenance

The main maintenance needs are:

- regular cleaning and checking for blockage of the outlet orifice
- periodic checking gutters for water-tightness

Key issues to consider when contemplating the installation of gutter (or roof) detention include:

- is this approach acceptable to the local authority?
- can the potential for leakage into the building be adequately safeguarded against?

Reference

Auckland Regional Council. (2003). *Stormwater treatment devices: design guideline manual*. ARC Technical Publication No. 10 (ARC TP10). From http://www.arc.govt.nz/arc/index.cfm?34C9C2A8-1BCF-4AA1-91AF-CC49CFE4A80C

5.5 Depression storage

Description

Depression storage takes the form of a natural or man-made surface depression capable of temporarily detaining runoff and will normally dry outside storm times. Examples include:

- depression in a lawn
- sunken garden
- low area in a car-park

Larger-scale and more sophisticated versions may be called retarding basins.

These types of devices work by providing temporary storage to attenuate runoff peak flows.

Stormwater disposal can be by:

- a combination of soakage and piped discharge for vegetated areas
- or by piped discharge for paved areas.

Treatment will be provided by sedimentation, bioretention and filtration in vegetated areas and by sedimentation for paved areas.

Figure 5.5 Depression storage

Applicability

On-site depression storage has the attribute of being simple and cost effective. If used in vegetated areas of low permeability, without a low level piped outlet, water may be for retained for a significant time after a storm. Siting must avoid the risk of flooding adjacent buildings/properties.

It will typically be applicable where the site has the following characteristics:

- topography with an existing hollow or allowing a depression to be constructed relatively easily (without significant earthworks)
- situations where ponding of stormwater will not cause a hazard or risk to buildings or other assets and will be acceptable to the site owner/occupier/local authority

Design and detailing issues

Sizing of detention storage can be done by spreadsheet based routing (refer Appendix C), similar to that applied in the case of the temporary storage component of a rain tank. For paved areas, outlets need to be sized and designed to minimise the risk of blockage from debris.

The treatment benefit can be assessed by comparing the mechanisms of the depression storage with other types of devices, for example:

- where significant disposal is achieved by soakage, treatment may be similar to an infiltration trench
- for shallow surface flow through vegetated areas at slopes not more than 5%, treatment may be similar to that of a swale or grass filter strip
- for paved areas where short duration ponding occurs, removal of coarse sediment only is likely to be achieved

Detailing should follow the guidelines for the most directly equivalent device.

Maintenance

Maintenance measures should follow the guidelines for the most directly equivalent device (i.e. as noted above)

Key issues to consider when contemplating the use of depression storage include:

- does the site have suitable topography
- will ponding on the site be acceptable to the site owner, occupier and local authority

5.6 Permeable pavement

Description

Also termed porous paving. For this guideline the term 'permeable pavement' refers to a pavement that is specifically designed to facilitate and maximise infiltration of rainfall through the pavement in order to provide any of the following:

- water quality benefit
- peak flow reduction
- volume reduction

Final disposal is typically by infiltration to underlying ground, but can be used where final disposal is via a piped reticulation or to surface water.

Permeable pavements can be divided into several types (described below):

- porous concrete and porous asphalt
- plastic modular systems
- interlocking concrete paving blocks (including modular blocks and lattice blocks)

The term permeable pavement is often used to include the underlying gravel base which may provide a stormwater management function. The gravel base, may, depending on the situation, operate as a rock filter, refer to Section 5.7.

Porous concrete and porous asphalt

- these incorporate stable air pockets encased with in them that allow water to drain uniformly to underlying ground
- are described as porous pavement in 832-F-99-023 Technology Fact Sheet (EPA,1999g)
- the porous pavement surface is typically placed over a highly permeable layer of open-graded gravel and crushed stone
- traditionally these have had high failure rates (EPA,1999g)
- used in a limited way for low traffic areas
- porous asphalt is used on some highways in New Zealand, with an impermeable liner to prevent entry of water to the subgrade, for traffic spray reduction, rather than stormwater quality or quantity

Plastic modular systems

- comprise proprietary plastic grid systems placed on a base of blended sand or gravel
- voids in the grids are filled with sand/topsoil or gravel
- can provide a high degree of permeability
- manufacturers provide guidance on selection of materials and design
- proprietary systems available in New Zealand include *Grasspave, Gravelpave and Ecoblock*

Interlocking concrete paving blocks (including modular blocks and lattice blocks)

- these are shaped to provide a nominated percentage of the surface area to be space between the paving blocks to allow drainage of water through permeable material
- some proprietary systems use pavers that themselves are permeable
- stormwater infiltrates down to an aggregate material which serves as a reservoir for temporary storage until water infiltrates into the ground or drains to a piped system
- proprietary systems available in New Zealand include *Formpave,* which has been installed by Waitakere City Council (WCC) at Parrs Park in 2000 – this installation included a 350 mm thick granular sub-base, a 50 mm thick laying course and a geotextile layer - WCC require that maintenance be carried out twice per year using a mechanical suction brush

Figure 5.6 Permeable paving 'Formpave' at Parrs Park, Waitakere City

Applicability

- primarily parking areas, low volume and low load roadways or driveways
- most successful US applications have been stated to be in coastal areas with sandy soils and flatter slopes (LID,2003)
- contributing catchment should not have a significant source of sediment or other fine material that could blind the surface of the pavement

Disposal of infiltrated water

- final disposal can be to soil infiltration or by piped discharge.
- for disposal by ground infiltration the suitability of the location for such disposal needs to be assessed, refer Sections 3.4, 3.8 and 3.10 of the guideline; it is recommended that geotechnical advice is obtained regarding subgrade and basecourse depth and construction specifications

Design issues

- particular care is need in the design of the pavement foundations with respect to effects of infiltration, traffic loads, the nature of the subgrade and pavement durability
- for use in soils that contain significant amounts of silt or clay or that are highly compressible or are expansive, detailed analysis of the soils should be conducted as part of design (LID 2003)
- for porous asphalt and concrete pavement, slopes to be less than 5%(EPA1999g)

Maintenance

- ongoing maintenance is a crucial aspect. Active street sweeping measures are required in the catchment area, ideally four times a year (LID 2003)

> There are potentially significant issues with respect to blinding of the surfaces of permeable pavements with fine material. This may in some situations be prevented or minimised by ongoing maintenance, for example using suction devices. If blinding does occur, some types of permeable pavements may not be able to be renovated or renovation may require removal and replacement of pavers.

References

Auckland Regional Council. (2003). *Stormwater treatment devices: design guideline manual*. ARC Technical Publication No. 10 (ARC TP10). From http://www.arc.govt.nz/arc/index.cfm?34C9C2A8-1BCF-4AA1-91AF-CC49CFE4A80C

Environmental Protection Agency. (1999g). Stormwater Technology Fact Sheet: *Porous pavement*. EPA 832-F-99-023. (EPA 1999g). From http://www.epa.gov/npdes/pubs/porouspa.pdf

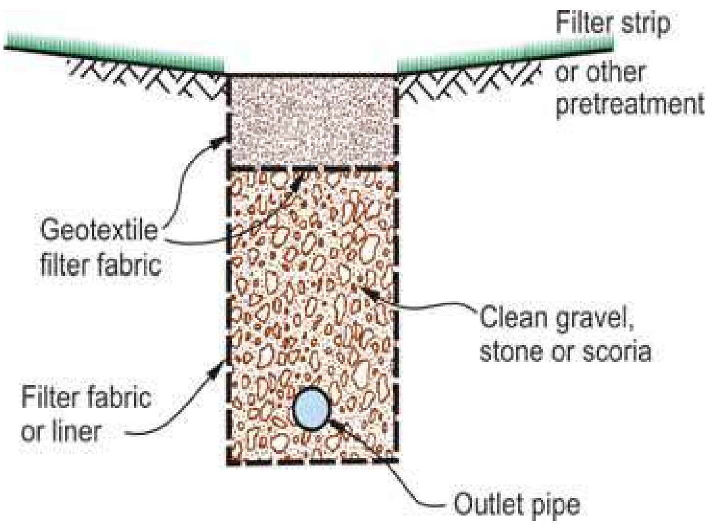
Low Impact Design Center Inc. (2003). *General permeable paver specifications*, (LID 2003). From www.lid-stormwater.net/permeable_pavers/permpaver_specs.htm

5.7 Treatment trench / rock filter

Description

An excavated trench, backfilled with stone or scoria media. Basecourse or sub-base material under permeable pavements may act as a rock filter. Stormwater from paved areas enters the trench / rock filter and trickles through the trench media. Treatment is provided within the trench, before disposal to a piped reticulation system or to surface water.

Figure 5.7 Treatment trench / rock filter



Applicability

Treatment trenches / rock filters are able to:

- treat runoff from impermeable hardstand ground surfaces in commercial, residential and industrial areas
- treat road or parking lot runoff
- be located so as to take up a small amount of space
- may in some situations, provide flow attenuation and extended detention and thus may be able to be used for flood control stream channel protection

Treatment trenches are not able to:

- treat sediment-laden water from construction sites. Install after site works are complete and contributing areas have been fully stabilised in order to prevent excess sediment loading

Little published data is available on contaminant removal rates for trenches or rock filters in impermeable soils where disposal is to piped reticulation or surface disposal. Breitenberger and Lewis (2001) reported that for a trial rock filter under a permeable pavement at Waitakere City, hydrocarbon removal and hydrocarbon biodegradation occurred.

Meyer and Singhal (2004) reported on a number of studies on the treatment performance of permeable pavement in conjunction with an underlying stone base. These data show removal of a range of contaminants by filtration and other mechanisms. Some researchers have reported removal of petroleum derived hydrocarbons by insitu microbial degradation and that experimental results indicate that appropriately constructed porous pavements can be used successfully to both trap and degrade oil which is accidentally released onto parking surfaces.

Design methodology

There do not seem to be useful available guidelines for designing such systems. Guidelines for use of permeable pavements that incorporate the treatment and flow control aspects of rock filter media under permeable pavements are currently being prepared on behalf of several local authorities in the Auckland area.

General design comments, which are similar to those for infiltration trenches are:

- for car parks and other areas with high hydrocarbon loads: inflow preferably to be via grass strip, but may not be essential if inflow is through permeable pavement and / or if flushing points provided
- trench preferably horizontal along its length, maximum slope along trench less than 5%,to avoid wastage of trench volume
- ensure minimum separation distance of 600 mm between bottom of the device and the seasonably high water table (Georgia Stormwater, 2001)
- adequate clearance to existing utilities and to site boundaries
- provide downstream overland flow path to avoid scour damage or flood damage to assets
- can incorporate large pipes within trench to provide additional pore space to assist with providing peak flow reduction
- possibly could add organic matter to the medial to enhance removal of metals and nutrients
- device catchment area probably preferably not more than 2 hectares

Maintenance

Likely to include the following:

- regular clearance of debris, litter from entry and contributing areas
- remove small section of upper trench and inspect upper layer of filter fabric for sediment deposits. If clogged, restore to original condition
- flushing to remove accumulated sediment and slime

References

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5.8 Catchpit insert

Description

A catchpit insert (also known as a catchpit filter) is a proprietary device taking the form of a fine-mesh filter bag which hangs inside a standard catchpit to intercept sediments in the incoming stormwater. It is designed to handle site runoff and has no water quantity control effect.

Key features are:

- units are generally made-to-measure by the manufacturer
- includes a high-flow bypass to avoid surcharging (different brands have different overflow arrangements)
- to ensure all incoming water is fed into the insert, a rubber seal is provided at the top to connect between the edge of the catchpit walls and the insert frame
- incorporates a nylon mesh bag (typical aperture size 200 µm) fitting within a galvanised steel or plastic frame, to avoid the bag being sucked into the catchpit outlet pipe

The bag must be emptied every 3 – 6 months and replaced with a laundered bag; the bag contents are disposed off at a landfill.

Manufacturers/suppliers in NZ include:

- Ingal (Enviropod brand) URL: www.ingalenviro.com
- Ecosol URL: www.ecosol.co.au
- Hynds URL: www.hynds.co.nz

Applicability

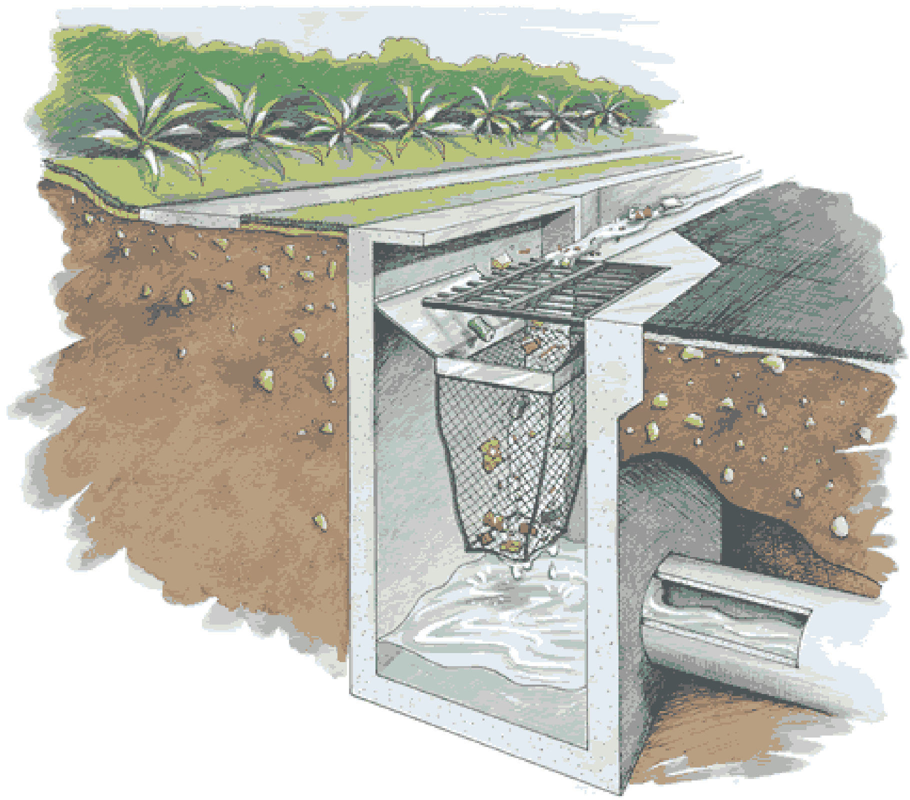
The catchpit insert is designed to intercept litter and sediment from site runoff. They are well-suited to medium-large impervious areas (e.g. car parks, roads). Because the insert is made to measure, it can be used in new or retro-fit situations.

Precedents

There are a number of large-scale applications of catchpit inserts, covering both street catchpits and commercial/industrial developments. Information on these field applications can be obtained from:

- manufacturers/suppliers
- councils (e.g. North Shore City, Waitakere City)
- Australian trials under the auspices of the Upper Paramatta River Catchment Trust (UPRCT 1999)

Figure 5.8 Catchpit insert



Performance

Available information on the sediment capture performance of catchpit inserts is quite sparse. Early field-based tests, involving sampling the inlet and outlet stormwater, proved difficult, especially in larger storm events and few reliable results were obtained.

Against this background, in 2003 Auckland City Council commissioned laboratory trials of two makes of catchpit inserts which had passed field-based reliability trials. This testing, carried out at Auckland University, sought to quantify the sediment capture performance and also determine the head loss characteristics of the filter fabric to establish its potential to limit the hydraulic capacity and cause flow to bypass the insert unit. In addition, a catchpit without the insert unit was tested. Testing was done for a range of flow rates and with different sediment concentrations. The mode of testing and the results are presented in the paper. In summary, for a composite street sweep sediment sample, the overall capture percentage for the insert units with 200 µm aperture size bags over a series of flows was found to lie in the range 78 – 98%. A Technical Paper is available on the trials (Ockleston and Butler 2004).

Design and detailing issues

These will typically be the responsibility of the manufacturer/supplier. Points to note in specifying/selecting such units include:

- the adequacy of the seal connecting between the edge of the catchpit walls and the insert frame
- the adequacy of the high flow bypass arrangement
- parts of the unit that may deteriorate and require repair/replacement (e.g. bags, galvanising on insert frame, any moving parts, etc)

Maintenance

Manufacturers/suppliers will typically provide details of the routine maintenance requirements for their units. Units are typically serviced every 3 – 6 months; with the actual frequency depending on the catchment area feeding the catchpit, and the level of sediment generated in that catchment (the frequency is typically determined by frequent inspections of the units over the first few months to see how quickly they are filling-up).

Servicing typically covers:

- emptying the bag, typically by means of by a sucker-truck
- replacing the used bag with a laundered bag (bags are typically found to last 5 years)
- inspection of the insert frame and seals to identify the need for any repairs

A key question with maintenance is who will be responsible for doing it – in some cases the supplier may offer this as part of a supply and maintain package. In looking at approving the use of such devices, local authorities will typically want to be satisfied that there is a long-term maintenance arrangement in place, by a suitably qualified operator.

Key issues to consider when contemplating the installation of catchpit inserts include:

- are they acceptable to the local authority?
- who will be responsible for their ongoing operation and maintenance?

References

Ockleston, G. & Butler, K. (2004). *Auckland City's field and laboratory testing of stormwater catchpit filters*. Paper presented to NZWWA Stormwater Conference May 2004

Stormwater Industry Association Australia. (2000). Stormwater Source Control. *Workshop proceedings*, 13 July 2000.

Upper Parramatta River Catchment Trust. (1999). *On-site detention handbook*. (UPRCT 1999). From www.upperpárariver.nsw.gov.au

5.9 Gross pollutant traps, litter traps and hydrodynamic separators

Description

These devices are described together as they are generally targeted at removing coarse sediment, litter and debris. Some of these devices can remove oil. They include specifically designed devices as well as proprietary devices.

Gross pollutant trap

Typically a sediment trap with a litter (or trash) rack, usually located at the end of the trap. Can be purpose designed or proprietary device. Similar devices include coarse sediment traps and grit traps. Some proprietary devices that are called gross pollutant traps include a filtration basket and sediment sump.

Litter Traps

A wide range of devices including:

- gross pollutant traps as describe above
- litter collection baskets
- boom diversion systems
- release nets –nets over the outlet of a pipe
- trash racks
- return flow litter baskets
- hydraulically operated trash racks
- flexible booms
- circular settling tanks
- hydrodynamic separators
- self cleaning screens
- downwardly inclined screens

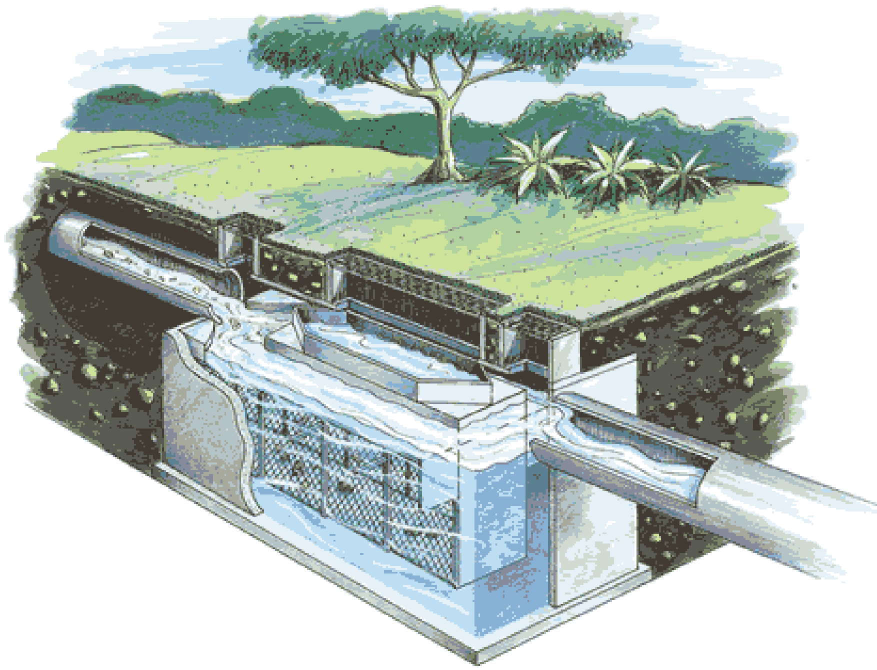
Hydrodynamic separators

These devices induce a vortex on the entering stormwater, which separates sediments. They incorporate a collection chamber at the base of the separator that is periodically cleaned or separated sediment can be piped to sewer.

Applicability

- intended to remove only coarse sediment, litter and debris, unlikely to remove fine sediments or soluble contaminants
- often used at the head of a treatment train, for example to prevent coarse sediment entering a wetland or other stormwater treatment device
- can be used for a range of contributing catchment sizes
- can be retrofitted into existing development sites
- small devices can be located underground, minimising visual impact
- potential to aggravate upstream flooding if trash rack becomes blocked by debris
- ongoing operation and maintenance, including sediment removal can be expensive

Figure 5.9 Gross pollutant trap schematic



New Zealand manufacturers/suppliers

- Ecosol New Zealand Ltd: www.ecosol.co.au
- Hynds Environmental www.hynds.co.nz
- Ingal Environmental Services www.ingalenviro.com
- Bisleys Environmental Ltd: http://www.bisleys.net

Maintenance

- require regular clearance of debris, litter and sediment
- for proprietary devices, maintenance is likely to be required to be carried out by a specialist contractor and may be expensive

References

Waters and Rivers Commission. (1997). *Stormwater quality management manual* (Draft)

Environmental Protection Agency. (1999h). Stormwater Technology Fact Sheet: *Hydrodynamic separators*. EPA 832-F-99-017. (EPA 1999h). From http://www.epa.gov/npdes/pubs/hydro.pdf

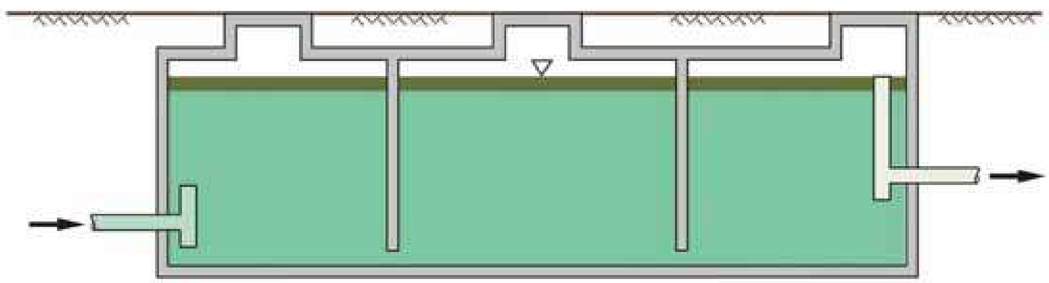
5.10 Oil and water separators

Description

These devices are primarily aimed at removing oil from stormwater at sites where hydrocarbon products are handled and small spills regularly occur on paved surfaces. Can include specifically designed devices as well as proprietary devices. Commonly used separators are API (American Petroleum Institute) and plate separators. They typically include baffles or walls within an underground concrete tank, to allow separation of oil droplets on the surface of the water within the device, which can then be removed. They usually have an initial compartment for sedimentation.

Various types of proprietary devices are available that can remove oil from stormwater (see below).

Figure 5.10 API Separator



Applicability

- intended to remove only hydrocarbons that are less dense than water
- typically used at service stations, airports, storage terminals
- should be located close to source of hydrocarbon product
- not applicable for general urban runoff
- objective to treat over 90% of the flow to an acceptable degree (15mg/l oil and grease)
- cannot treat elevated suspended solids; sites with high suspended solids loads should incorporate separate sediment removal
- require systematic, regular maintenance
- can be retrofitted into existing development sites
- small devices can be located underground, minimising visual impact

New Zealand suppliers include:

- Alpha Environmental (Nelson)
- Ecosol www.ecosol.com.au
- Hynds Environmental Systems Ltd www.hynds.co.nz
- Maskell productions: www.maskell.co.nz
- Westfalia Separator NZ Ltd: www.westfalia-separator.com

Maintenance

- regular clearance of debris, litter from entry and contributing areas
- removal of accumulated sediment from initial chamber
- removal of floating oil and appropriate disposal
- usually requires a specialist contractor

References

Auckland Regional Council. (2003). *Stormwater treatment devices: design guideline manual*. ARC Technical Publication No. 10 (ARC TP10). From http://www.arc.govt.nz/arc/index.cfm?34C9C2A8-1BCF-4AA1-91AF-CC49CFE4A80C

Ministry for the Environment. (1998). *Environmental guidelines for water discharges from petroleum industry sites in New Zealand*. From http://www.mfe.govt.nz/publications/hazardous/water_discharges_guidelines_dec98/

6. Design and costing information for existing devices

In this section:

6.1 What is known about devices in the Auckland region

6.2 Indicative life cycle costing approach

Life cycle assessment template

There is very little readily available detailed information on the design details and costings of existing on-site stormwater devices. One of the recommendations in section 1.4 of this guideline is therefore that a management and monitoring framework be developed for on-site stormwater devices, in order to encourage the gathering and sharing of monitoring data in a way that is sufficiently robust and detailed to be useful to stormwater practitioners for comparing costs and performance for different sites and devices.

This section presents available information on existing on-site stormwater devices that may be of some use to stormwater practitioners.

6.1 Devices in the Auckland region

The four major territorial councils in the Auckland region have been approached to provide information on stormwater devices used in their area and their responses are summarised below.

6.1.1 North Shore City Council (NSCC)

Devices owned by NSCC include:

34	dry flood attenuation ponds
2	dry extended detention water quality ponds
31	wet ponds
4	wetlands
5	sand filters
1	swale
1	rain garden
2	Continuous deflective separators
9	Downstream defenders
1	Ecosol
294	Enviropods
1	woolspill
1	permeable paving (under construction July 2004)

NSCC also advises that there are a number of privately owned devices including rain tanks and detention tanks.

6.1.2 Waitakere City Council

Waitakere City has a number of urban stormwater demonstration projects. Those relevant to on-site stormwater management devices are:

- permeable paving at Parrs Park reserve
- rain garden at Moselle Avenue
- rain tank – discussion of recommendations for the use of rain tanks at a subdivision in Golf Road, New Lynn
- discussion of detention ponds, stormwater quality ponds and wetlands at several sites (part of catchment wide management)

There are also a number of privately owned rain gardens and stormwater treatment filters within Waitakere City.

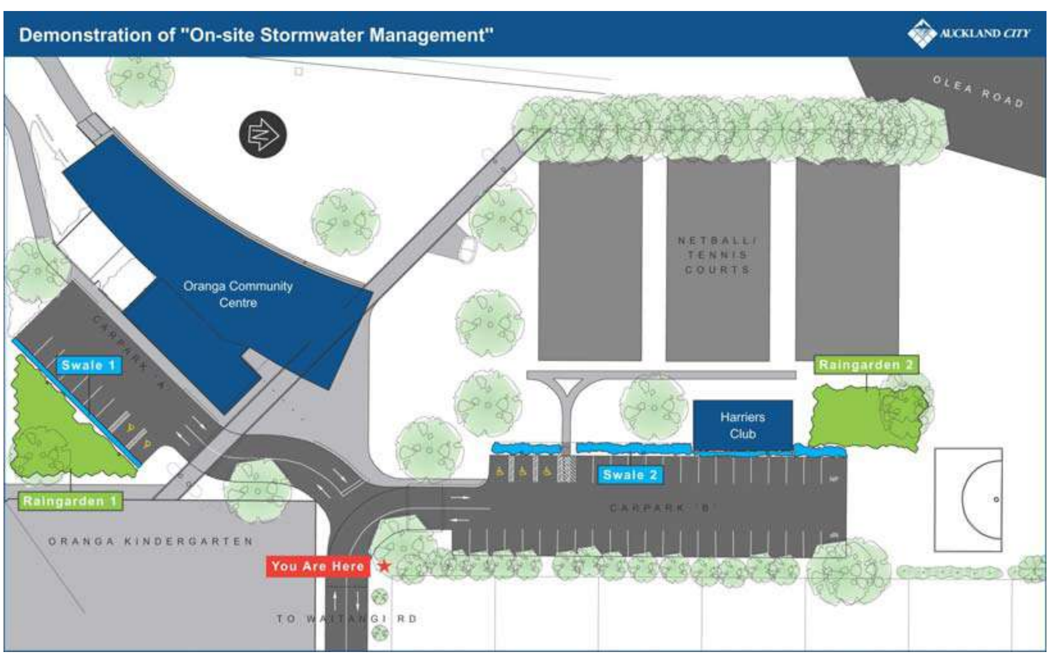
6.1.3 Auckland City Council demonstration projects

Auckland City Council demonstration projects include:

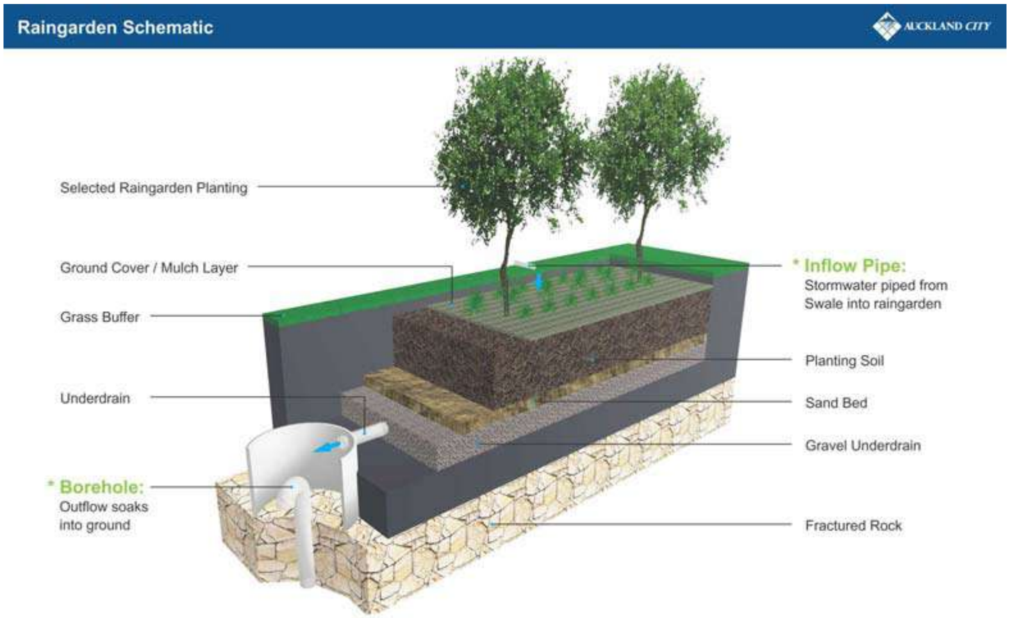
- **New Oranga Community Centre, Fergusson Park**
- **New Wesley Community Centre**

6.1.3.1 New Oranga Community Centre, Fergusson Park

The new Oranga Community Centre is off Waitangi Road, Onehunga, in an area where stormwater disposal is by soakage. The facility is a demonstration project for on-site stormwater soakage devices designed in accordance with the City's new Soakage design manual. The stormwater treatment and disposal system incorporates a series of swales, rain gardens and soakholes, with educational signs showing how they work.



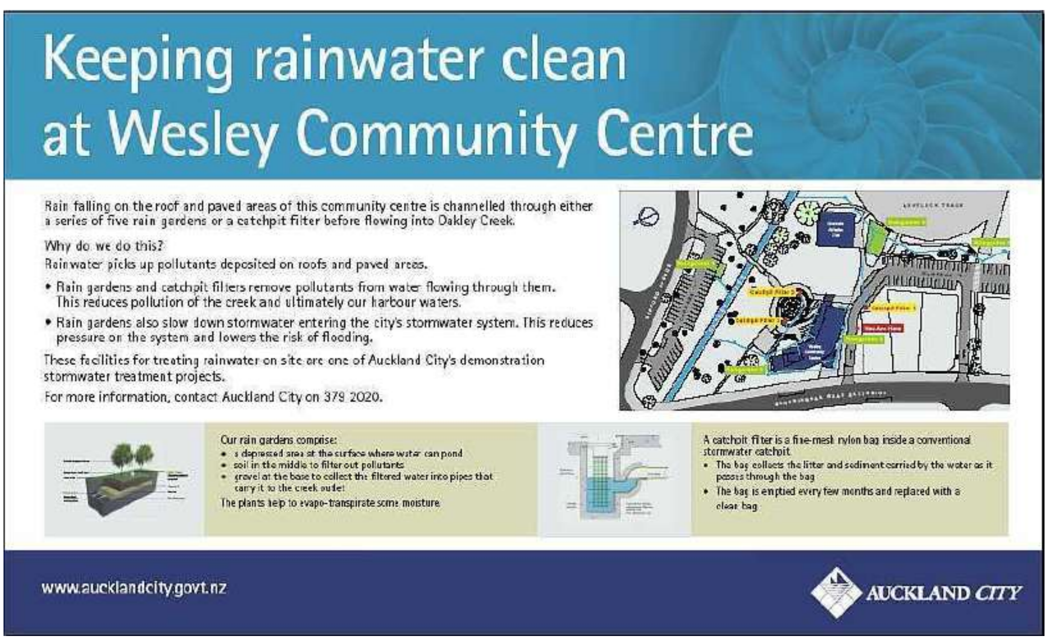
Oranga Community Centre site layout



Oranga Community Centre rain garden

6.1.3.2 New Wesley Community Centre

The new Wesley Community Centre is on the corner of Sandringham Road and Gifford Avenue, with a new building close to Sandringham Road together with car parking and outdoor space areas. The Oakley Creek is a major feature of the site and stormwater stormwater runoff from the site goes into it. The facility is a demonstration project for on-site stormwater management devices designed in accordance with the City's new On-site design manual. The chosen design incorporates a series of five rain gardens and two catchpit filters designed to treat site runoff, with educational signs showing how they work.



Signboard for Wesley Community Centre

6.1.4 Sand filter for industrial site (Auckland)

Site description: paved with building, flat <5% slope, overlying fractured basalt

Land-use / contaminants: Industrial yard with sediment and hydrocarbons from vehicle and plant (plant hire outlet) together with small polystyrene pellets spilled from storage warehouse during loading/unloading

Device purpose: the treatment aim was removal of 75% of sediment in accordance with ARC TP 10

Design methodology: as per ARC TP 10, 1993 - note this differs from the methodology in ARC TP10, 2003

Contributing catchment area: 3600 m2

Disposal: soakage to fractured basalt (previous soakhole had clogged up with sediment)

Device components:

- old soakhole (1050 mm manhole) with a concrete base, utilised as a coarse sediment trap
- sediment chamber: 3300 litre septic tank
- ponding on low lying parking area (detention storage), utilised as part of the live storage: total live storage 73 m^3
- filter chamber: 2 x 2.5m x 2.8 m x 1.5 m long precast concrete culvert units on end, with removable timber lids (located on grassed garden area adjacent to paved area)
- outflow through the sand filter is direct to underlying fractured basalt with geotextile filter cloth used to retain the sand
- overflow to manhole (1050 mm) with open base – disposal to underlying fractured basalt

Cost: construction cost in 2001 (competitive tender): $18,000 + GST

6.2 Life cycle costing approach

This subsection discusses a lifecycle costing and life cycle analysis that may help practitioners choose on-site stormwater devices. The purpose of the discussion is to help to improve the sustainability of LIUDD technologies and their application by:

- outlining the need for a lifecycle perspective when evaluating low impact urban design and development (LIUDD) technologies
- describing two useful evaluation technologies that address the lifecycle impacts of LIUDD technologies

6.2.1 Why do we need a lifecycle perspective of LIUDD technologies?

LIUDD technologies must be seen as part of a complex, dynamic urban system. The technologies are intimately linked with social and economic activity. For example, the greater the area in urban subdivision, the greater the impervious surface area and the greater the water volume that needs to be ‘treated’ by LIUDD technologies.

LIUDD technologies are also dynamic in that they are reasonably long lived, and must respond to water events over time. A lifecycle perspective captures both the complexity of the physical linkages (such as energy and material flows) through the socio-economic system, and the dynamic nature of LIUDD technologies over the life time of the technologies. A lifecycle perspective considers the whole life of a technology from its construction, through to use and decommissioning.

6.2.2 How do we know whether low impact urban design and development (LIUDD) technologies are truly low impact?

To answer this question, we need to apply suitable evaluation techniques. There are two important considerations when selecting evaluation techniques. First, we need to select a technique that measures the system wide impact of the technology over its lifecycle. Second, we also need to use an evaluation technique that informs us about the relative efficiency of resource use over time.

Two evaluation techniques can assess these elements of LIUDD technologies:

- LCA measures the physical and economic system-wide impacts over the lifecycle of a technology
- present equivalent analysis (or lifecycle costing) measures financial costs over the life of the technology and converts them to a 'present value'

6.2.3 What is lifecycle assessment?

LCA is defined as the 'compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its lifecycle' (International Organization of Standards, 1997).

LCA traces physical energy and material inputs and outputs throughout the lifecycle of a technology. Thus, in order to conduct such a study, biophysical information needs to be collected. For example, in the case of a pond, information on the energy and materials required to construct, maintain and decommission the pond needs to be collected. This energy and material input information is currently not available.

6.2.4 What is lifecycle costing?

Lifecycle costing attempts to calculate a 'present value' of the costs incurred over the life of a technology. 'Present value' is the value now of a sum, or sums, of money in the future.

The present value metric is important because money now is regarded as worth more then money in the future. This difference in value is because of uncertainty and because money can be invested how to produce a greater sum in the future.

The present value of future money is calculated by 'discounting' it at a rate of interest (or discount rate) equivalent to the rate at which it could be invested. For example, $105 in a year's time has a present value of $100 if the interest rate is 5% per annum.

The present value of a sum of money is calculated as:

$$PV = \sum_{i=1}^{n}\left(\frac{C_i}{(1+r)^i}\right) = \frac{C_1}{(1+r)^1} + \frac{C_2}{(1+r)^2} + ... \frac{C_n}{(1+r)^n}$$

Where:

PV = present value
i = year
r = discount rate
C = future cash amount
n = life of project.

Several lifecycle costings have been conducted in New Zealand on LIUDD technologies, for example to compare catchment wide treatment devices in North Shore City.

However, these results should not be used as generic present values. This is because each LIUDD technology faces unique biophysical, economic and social challenges. For this reason, it is important that a lifecycle costing is conducted for each LIUDD technology.

A template for calculating lifecycle costings is overleaf.

Benefit/cost assessment and funding options under sections 32 and 36 of the Resource Management Act are briefly reviewed in section 1.8 of this guideline.

6.2.5 Conclusions

The following points have been made in this subsection:

- a lifecycle perspective of LIUDD technologies is needed so as to understand the dynamic system impacts of the technology
- lifecycle assessment (LCA) and lifecycle costing (LCC) are two useful evaluation techniques in this context.
- LCA is the focus of future research
- LCC is relatively straightforward. A template is provided overleaf for such calculations

6.3 Reference

International Organization of Standards. (1997). *Environmental management - lifecycle assessment - principles and frameworks* (ISO 14040). Geneva: International Organization of Standards.

6.4 Life cycle costing template

Location	Street address
Coordinates	x-coord
	y-coord
Owner	
Designer	
Supplier	
Contractor	
Installation Date	
Catchment Area	m^2
Catchment Type	Forest
	Green
	Res
	Com
	Ind
	Rd
Impermeable	%
Soil	Type
Primary	
Secondary	
Design Basis	
Design Flow	L/s
Design Vol	m^3
Footprint	m^2
Sediment	%
Metals	%
Nutrients	%
	%
Monitored	Y/N

(continued overleaf)

FINANCIAL COSTS						
Year project began						
Design life						
Discount rate	10%					
ACTUAL/ESTIMATED COSTS						
Enter ACTUAL costs in the year they are expected fall						
			Year 0	1	2	3 etc
Capital Costs ($NZ)						
	Council overheads					
	Design fees					
	Land costs					
	Consent costs					
	Construction costs					
	Other capital costs					
	Total capital costs		$ -	$ -	$ -	$ -
Maintenance Costs	Council overheads					
	Maintenance costs					
	Consent fees					
	Maintenance frequency					
	Total maintenance costs		$ -	$ -	$ -	$ -
Decommissioning costs	Council overheads					
	decommissioning costs					
	Consent fees					
	Total decommissioning costs		$ -	$ -	$ -	$ -
PRESENT VALUE COSTS						
Capital costs						
Maintenance costs						
Decommissioning costs						
TOTAL PV						

On-Site Stormwater Management Guideline

Appendices

Appendix A: Comments on comparable guidelines

Organisation and Guideline	Comments
New Zealand	
Auckland Regional Council *TP10*	- sound technically (emphasis on water quality) - includes a lot of background information on the principles of stormwater management - design guideline primarily uses a design storm which has been specifically computed for the Auckland region
Auckland Regional Council *TP124*	- good descriptive background on concepts (with photos) - does not provide a detailed design guideline
Auckland City Council *On-site Stormwater Management Manual*	- applicable to a specific brownfield situation only - technical based format, with design charts and worksheets - strong emphasis on operation and maintenance
Auckland City Council *Soakage Manual*	- as above, but wider-ranging in its application
Christchurch City Council *Waterways, Wetlands and Drainage Guide*	- good description of impacts of development - uses simplified approach to stormwater quality management - large use of soakage, particularly relevant for subsurface conditions in Christchurch
USA/Canada	
City of Portland *Stormwater Management Manual*	- excellent, easy-to-follow layout - good diagrams and numerous photos - comprehensive operation and maintenance schedules
King County (Seattle) *Surface Water Design & Stormwater Pollution Control Manuals*	- very thorough treatment, albeit with unusual technical applications - software needed to perform analyses available by free download
Washington State Dept of Ecology *Stormwater Management Manual*	- very comprehensive (some useful material), but unduly long (5 Volumes)
USEPA *Urban Stormwater Best Management Practices*	- good descriptions etc. on on-site devices - good treatment of costs and benefit
Maryland DOE: *Stormwater Design Manual*	- very thorough treatment, backed by good graphics and worked examples
City of Calgary: *Stormwater Management and Design Manual*	- comprehensive and well researched - format unwieldy
Ontario Ministry of Environment: *Stormwater Management Planning & Design Manual*	- unduly long (400 pages), but short on graphics and worked examples
Other	
Upper Paramatta RCT, Australia: *On-Site Stormwater Detention Handbook*	- narrow focus (on-site detention tanks) - good worked examples and applications
CIRIA, UK: *Sustainable Urban Drainage Systems – Design Manual*	- innovative format; good introductory material - design guidelines generic only
DID, Malaysia: *Stormwater Management Manual*	- very comprehensive in terms of types of OSM devices, but requires analysis/design from first principles (no worked examples)

Appendix B: Collated references

Notes:

1. Internet references are accurate at the time of publication
2. Short references are given in brackets at the end of key documents that are used throughout the text for ease of use, for example (ARC TP10, or CCC, 2003)

Publications

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Appendix C: Hydrologic / hydraulic analysis

C1.0 Introduction

Hydrologic/hydraulic analysis will generally be required as part of the design of an on-site device, especially the flow attenuation component. In summary, this will typically involve the following, with coverage on each topic set out in this Appendix:

- preparatory considerations (e.g. methods, technical issues, key parameters, etc): refer Section C2
- peak runoff and hydrograph derivation: refer Section C3.1
- routing computations (ie routing the inflow hydrograph through the device to establish the outflow hydrograph): refer Section C3.2
- hydraulic computations (e.g. to size the likes of pipes, orifices, weirs, etc): refer Section C4

The appendix is written to guide those with a limited familiarity with hydrology and hydraulics; those with no formal training in these areas should consult the references listed in Section 1.2 of the main text for a primer in these disciplines.

C2.0 Preparatory considerations

C2.1 General

In the context of providing guidance on hydrologic/hydraulic topics, the following aspects require consideration, but are addressed only briefly here as they are covered elsewhere in the Guide:

- design storm magnitude (refer Section 3.7), e.g.:
    - 50% AEP (2 year ARI): applies to frequent flooding, often relevant where channel erosion is an issue
    - 10% AEP (10 year ARI): common standard for sizing stormwater reticulation
    - 1% or 2% AEP (100 year or 50 year ARI): the standard upper limits usually considered
- flow attenuation performance standard (refer Section 3.7), e.g.:
    - greenfield
    - as-existing

C2.2 Time of concentration and storm duration

Because an on-site device changes the response characteristics of the catchment in which it is located, an issue arises in respect to selecting the applicable storm duration (D) value to be used in generating the design hydrograph to be used in sizing an on-site device (refer Section C3). The D value should be reflective of the time of concentration (Tc) of the receiving reticulation, but this will vary between the immediate reticulation and the outfall. Building Code Clause E1 – Verification Method E1/VM1: Surface Water, Building Industry Authority, NZ, 2001 (note: referred to hereafter as BIA, 2001) sets out suggested Tc values.
As an example, actual Tc values at points along the receiving stormwater system might be:

Receiving System	Applicable Tc Value
Local street drainage	10 min
Watercourse (ie fed from pipe)	60 min

Main pipe system 30 min

The theoretical critical design case for sizing an individual on-site device, namely the storm requiring the largest storage volume, will generally be quite long, approaching that applicable at the downstream end of the receiving catchment (e.g. 60 minutes, or longer). Further, the higher the Tc/D value, the larger the on-site device orifice diameter. In practice the designer should consider the following methods (refer also Section C2.3):

i. Simplified approach:

Where there are no known major downstream flooding issues and the requirement for implementing an on-site device is more as a matter of applying the principle of mimicking the natural drainage regime, select the Tc value to match that of the immediate receiving system (e.g. typically 5 - 15 minutes)

ii. Rigorous evaluation:

Where downstream flooding is an issue, and/or the local authority requires more in-depth consideration than in (i) above, apply the following approach:

- consider the points in the receiving catchment at which the planned flow attenuation may be critical and identify the corresponding Tc values (e.g. as in the list above)
- for storm durations (D) corresponding to each of the Tc values above, compute device sizings and orifice diameters (ie using the method in Section C3)
- Compare the results, and apply judgement as to which D case is likely to be most important (e.g. if the results show only a small variation, choose the upper bound figures, namely the largest device size and smallest orifice diameter – refer computational example of a rain tank in Section 4.5.10)

C2.3 Rainfall temporal and spatial patterns

In parallel with consideration of the time of concentration issue (refer Section C2.2), the analysis of on-site devices should, in theory at least, be done on a catchment-wide basis. This would then enable assessment as to how each new device will perform, taking into consideration the following:

- catchment and stormwater system characteristics, e.g.:
    - pre-existing on-site devices (and their positions in the catchment)
    - the existing stormwater network (e.g. pipe, watercourse, etc)
- the likely variation in rainfall patterns, e.g.:
    - spatial patterns
    - temporal patterns (e.g. antecedent conditions and/or multi-peak storms may affect the expected performance of the device)

To do this, each proposed new on-site device would need to be plugged-in to an up-to-date catchment model (refer Section C2.4) and simulated. In practice, the degree of effort involved is considerable and not normally justifiable.

As an example of these factors, consider the following case of an on-site device located in the lower part of a catchment:

- say the device is designed to achieve the as existing flow attenuation target with a Tc value of 15 minutes
- in a storm event, the outflow peak will be lower and later than the as existing inflow
- when combined with flows from the upper catchment, the delay-effect may result in the device actually increasing the overall peak flow
- similar but more complex effects may occur with storms that move up or down the catchment

Instead of attempting to quantify these factors, it will generally be adequate to be aware of them and apply appropriate judgement and/or countermeasures (e.g. the problem identified in the example above could be mitigated through the application of a more stringent performance standard, such as greenfield).

C2.4 Computer modelling

The Guide focuses on manual or spreadsheet-oriented analysis methods which will be within easy reach of most users (refer Section C3 for details). However, those with a special interest in the design of on-site devices should consider the option of investing in commercially-available modelling software. Such packages are designed to simulate the performance of on-site devices whereby device sizings can be established.

In summary, such models function broadly as follows:

i. The model is set-up to describe the site to be modelled (e.g. involves the input of site data such as site area, roof area, pervious/impervious areas, soil type, etc)

ii. A rainfall data sequence is input which matches the rainfall at the site; this can be either of the following (albeit noting that the data time step should be quite short, of the order of no longer than 25% of the time of concentration; e.g. 5 minutes where Tc is 20 minutes):
   - a single-event storm (e.g. historical, or synthesised)
   - a long historic pluviographic sequence (as an example the ACC, 2002 work used a 40-year sequence from records at Albert Park, Auckland)

iii. The model is run to replicate the target performance case for the subject site (e.g. greenfield case), to establish the peak site discharge

iv. Data describing the on-site device is input to the model, normally involving <u>trial</u> device sizings (e.g. device area/depth, orifice diameters, etc)

v. The model is run with the rainfall data sequence in ii above

vi. The performance of the device is checked in the model output files, e.g. the peak site discharge is compared to the target performance case (for the pluviographic-based approach, refer to the box below)

vii. If the results in vi do not match the performance target, re-size the device and re-run (ie step v above); continue until a match is achieved and then adopt this as the design sizing

Suggested method for analysing device performance using modelling with long-term pluviographic sequences:
• establish the required design flood performance criteria (e.g. the with-device case to match the greenfield peak discharge in the 10% AEP flood) • run the model as in iii above, and tabulate the peak discharges in each storm event • undertake a frequency analysis on these peak discharges to establish the 10% AEP flood (= Qa say) • run the model for the with device case (ie as in v above) and tabulate the peak discharges in each storm event • undertake a frequency analysis on these peak discharges to establish the 10% AEP flood (= Qb say) • re-run model (ie as per vi above) until Qb = Qa

Modelling using the long-term pluviographic sequences is to be preferred over the use of design storms where practicable, because:

- pluviographic-based modelling tests out the performance of a series of rainfall temporal patterns, whereby more confidence can be placed on the ability of the device to meet the target performance
- similarly, it takes out the subjectivity of selecting representative single-event design storms
- a single pluviographic-based model run can give results applicable to a range of flood magnitudes (e.g. where say a 50 year long pluviographic sequence is used, results can be established covering all of the magnitudes normally considered, ie 50% AEP, 10% AEP and 2% AEP - albeit with some uncertainty for the latter, as the pluviographic sequence may not in practice incorporate a representative 50 year event)

As at mid-2004, there are relatively few packages available for modelling on-site devices. A brief description of the known packages is in Table C1[1].

Table C1: Software for modelling on-site devices

Software	**Description**	**Vendor/Available From**
HEC-HMS	Hydrological modelling	Freeware from US Army Corps of Engineers www.hec.usace.army.mil
PURRS	Simulates rain tanks	Urban Water Cycle Solutions 70 Howden Street, Carrington, NSW 2294 www.eng.newcastle.edu.au/~cegak/Coombes p.coombes@newcastle.edu.au
MIKE STORM	Able to simulate most types of on-site devices	DHI Water & Environment PO Box 300-705, Albany, NZ www.dhiwae.com nz@dhiwae.com
XP-SWMM and XP-RAFTS	General purpose stormwater model	XP Software Pty Ltd PO Box 3064, Belconnen, ACT, 2166 www.xpsoftware.com.au sales@xpsoftware.com.au

[1] Note, however that the fact that software is listed in Table C1should not be construed as a recommendation as to its suitability for the purpose

C3.0 Runoff estimation, hydrographs and routing

C3.1 Introduction

On-site devices which are to meet quantity-based performance standards are typically sized through the following approach, details of which are given in the following sub-sections:

- compute the applicable peak discharges (refer Section C3.2), e.g.:
  - for the target performance standard case (e.g. greenfield, as-existing)
  - inflow to the on-site device, for the post-development case
  - rest-of-site runoff, for the post-development case (ie to add to the device outflow hydrograph, to establish the post-development with-device outflow)
- derive the corresponding flow hydrographs, for the following post-development cases (refer Section C3.3):
  - inflow to the on-site device
  - rest-of-site runoff,
- route the inflow through the on-site device (refer Section C3.4): this involves a trial-and-error approach to compare the target and post-development cases and, once matched, establish the sizings for the:
  - device (e.g. area, height) and
  - oultlets (e.g. orifice, weir)

C3.2 Peak discharge computation

C3.2.1 Methods

Aside from the modelling-based approaches (refer Section C2.4) typical peak discharge computation methods used by New Zealand practitioners are listed below. Unless there are reasons to do otherwise, use of method (a), the Rational Method, is recommended (refer notes under 'suitability' below)

(a) Rational method:

i. Form of the empirical relationship:
Qp = C x I x A / 360
where:
Qp = peak discharge (m^3/s)
C = runoff coefficient (dependent on land use, soils, etc)
I = rainfall intensity (mm/hr), for the specified flood frequency (e.g. 10% AEP) and Tc value
A = site area (ha)

ii. Suitability: recommended for use for catchments under about 50 ha

iii. References:
BIA, 2001
http://agrolink.moa.my/did/river/stormwater/Chapter_14.htm
http://www.itc.nl/ilwis/applications/application11.asp
www.ct.gov/dot/lib/dot/documents/ddrainage/6.9.pdf

iv. Worked examples: refer Section C3.5

(b) TM61 'Method for estimating design peak discharge' (MWD 1980)

i. Form of the empirical relationship:

$Qp = 0.0139 \times C \times R \times S \times A^{0.75}$

where

Qp = peak discharge (m^3/s)
C = catchment coefficient
R = rainfall factor, for the specified flood frequency (e.g. 10% AEP) and Tc value
S = catchment shape factor
A = catchment area (km^2)

ii. Suitability:

- normally used for catchments 10 – 1,000 km^2, but also satisfactory for smaller catchments
- recommended for use only where the user is very familiar with this method (ie otherwise use of method (a), the Rational Method is recommended)

(c) US Soil Conservation Service Method (USCS, 1986)

i. Description:

A relatively more complex method than the Rational or TM61 methods, the USSCS method uses parameters including:

- runoff curve numbers (CN, related to the different land cover types, soil properties and antecedent moisture conditions); from these the catchment storage (S) is computed
- initial abstraction, Ia (or loss)
- the 24 hour rainfall depth (P)

From the above, a runoff index (c*) is computed. The peak flow Q is then computed through reference to a chart relating c* and Tc, where the chart is developed through reference to rainfall and runoff data from representative gauged catchments.

ii) Suitability:

The USSCS method is the basis for Auckland Regional Council's TP108 Guidelines for Stormwater Runoff Modelling in the Auckland Region, which is the standard method in the Auckland region. Consequently, designs for devices located within ARC's area of jurisdiction should use the TP108 method. Noted that TP108 also includes a method to compute hydrographs, either manually, or by use of the HEC-HMS model (refer Table C1).

iii) References:

ftp://ftp.wcc.nrcs.usda.gov/downloads/hydrology_hydraulics/tr55/tr55.pdf
http://www.alanasmith.com/theory-Calculating-Effective-Rainfall-The-SCS-Method.htm

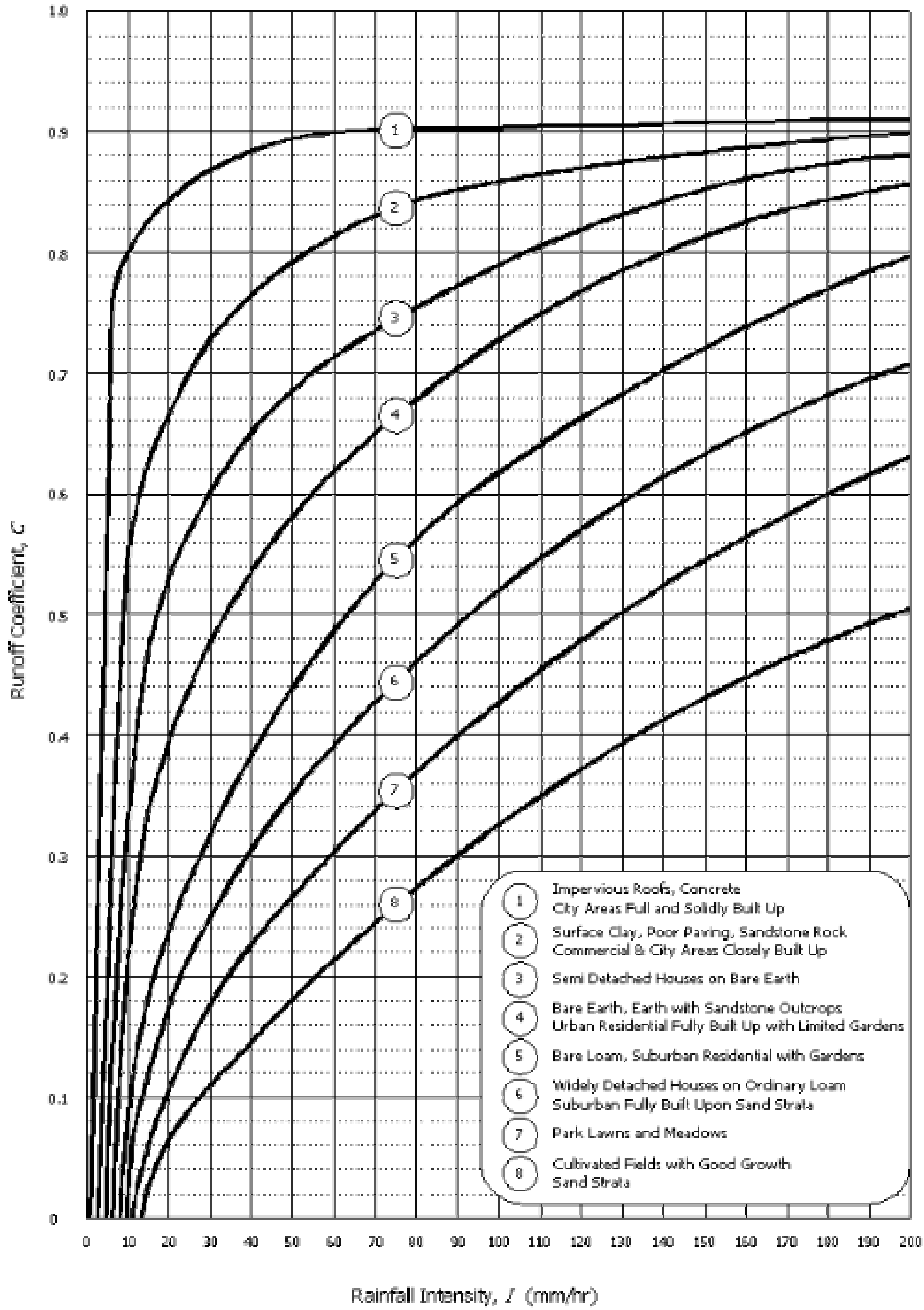
C3.2.2 Application

Notes on compiling the data required to apply the Rational and TM61 methods are:

- location-specific rainfall depth-duration-frequency data: sources of such data include:
  - NZ Meteorological Service (Metservice) publications (e.g. Coulter & Hessell, 1980)
  - NIWA's HIRDS software; URL: www.niwa.cri.nz/ncc/tools/hirds
- time of concentration (Tc): refer Section C2.2
- runoff coefficient C:
  - refer to reference material cited in Section C.2.1, e.g. BIA, 2003 (for convenience, Figure C1 presents a sample of Rational Method C values)
  - where a catchment contains a mix of land-use, the overall C value can be computed by adding the C x sub-area values for each sub-area and dividing the sum of the products by the overall area (refer Section C3.5 for a worked example, namely Case 2)

Figure C1: 'C' Values in rational method – urban catchments

(Source: ARR, 1977)


1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Runoff Coefficient, C
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
Rainfall Intensity, I (mm/hr)
1 Impervious Roofs, Concrete
City Areas Full and Solidly Built Up
2 Surface Clay, Poor Paving, Sandstone Rock
Commercial & City Areas Closely Built Up
3 Semi Detached Houses on Bare Earth
4 Bare Earth, Earth with Sandstone Outcrops
Urban Residential Fully Built Up with Limited Gardens
5 Bare Loam, Suburban Residential with Gardens
6 Widely Detached Houses on Ordinary Loam
Suburban Fully Built Upon Sand Strata
7 Park Lawns and Meadows
8 Cultivated Fields with Good Growth
Sand Strata

C3.3 Hydrograph derivation

Whereas the Rational or TM61 methods produce peak discharge figures, a hydrograph is needed for use in the routing analysis (note that the USSCS-based ARC TP108 method can produce hydrographs directly and is not covered herein). The hydrographs required will depend on the application, but typically cover:

- inflow to the on-site device (e.g. to tank, off roof), for routing according to the Section C3.4 method
- rest-of-site runoff (ie to be added to the on-site outflow hydrograph to establish the with-device total site outflow); the combined peak is then compared against the performance standard peak (e.g. greenfield)

Two cases need to be considered, addressing the time of concentration (Tc) and storm duration (D) factors discussed in Section C2.2:

i. Storm duration = Tc:

A triangular-shaped hydrograph is produced, with the following characteristics, as illustrated in Figure C2a:

- rising limb: linear rise to reach the peak at time Tc
- falling limb: linear fall back to zero, over a time period 0 - Tc.

ii. Longer storm durations (ie where D is greater than the Tc value for the immediate receiving system):

(ie matching the Tc values further down the receiving system – refer Section 2.2)

- a trapezoidal-shaped hydrograph with a longer peak is produced, as illustrated in Figure C2b, ie:rising limb: linear rise to reach the peak at time Tc
- peak: constant at the peak flow for a time (D -Tc)
- falling limb: linear fall back to zero over a time period Tc

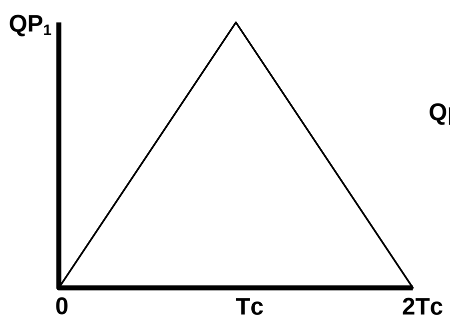


Figure C2a: Hydrograph for storm duration D = Tc (Qp_1 = peak flow for duration D = Tc)

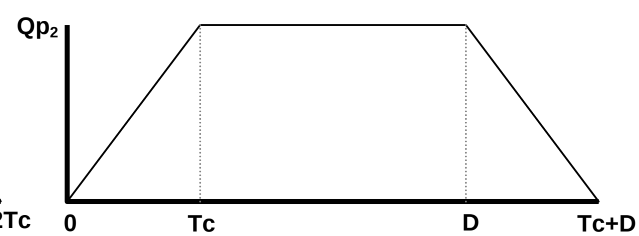


Figure C2b: Hydrograph for storm duration D (Qp_2 = peak flow for storm duration D; Tc = value for the immediate receiving system)

C3.4 On-site device routing computations

Routing involves quantifying the way the storage provided in the on-site device modifies the inflow hydrograph. Typically, a spreadsheet will be used to perform the routing calculations, applying the following general relationships:

Device outflow = function of the applied head on the outlet flow control device (e.g. orifice, weir)

Change in storage = device inflow – device outflow

Site outflow = device outflow + rest-of-site runoff (ie from pervious plus other impervious area)

Table C2 shows a typical spreadsheet used to perform the routing calculation, together with generalised explanations of the cell arithmetic (this arithmetic will vary depending on device type, in particular the type/number/size of the outlet(s), whether there is an infiltration component, etc). The example is for a detention tank with an orifice outlet at its base – the full spreadsheet is reproduced overleaf.

Table C2: Illustration of spreadsheet-type routing computation

Time (min)	*DEVICE INFLOW*		Device Storage (C, m)	Device WL (E, m)	Device Outflow (F, l/s)	Net Device Storage (G, m^3)	SITE RUNOFF CALC	
	Hydrograph (A, l/s) *Note 1*	Volume (B, m^3)					Rest of Site (note 3) H (l/s)	Total Site I (l/s)
Go to 2-3 x Tc in about 0.1 x Tc increments	*Design hydrograph (contributing area)*	*= A(l/s) [averaged] x time*	*= volume G at prior time step + inflow B*	*= volume C / device area*	*Refer note 2*	*= volume C – F x time*	*= design hydro-graph for rest of site*	*= device outflow F + rest of site runoff H*
0	0	0	0	0	0	0	0	0
2.5	1.05	0.16	0.16	0.05	0.31	0.11	1.12	1.42
5.0	2.1	0.32	0.43	0.14	0.59	0.34	2.23	2.83
7.5	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...

Notes:
1: For a tank, fed from the roof, this is the roof runoff hydrograph (e.g. as in Section C3.5 – Case 2A below)
2: The device outflow calculation:
- o requires a formula defining the outflow (e.g. orifice flow from tank outlet - refer Table C3 for orifice formula – the flow is a function of the head, ie storage in column C divided by device area – note that it is usual to use the average head over the prior and current time steps)
- o often a more complex formula is needed to also account for device overflow (e.g. out top overflow of tank, once storage height reaches the top level)

3: For a tank, fed from the roof, this is the hydrograph from the pervious plus other site impervious area (e.g. as in Section C3.5 – Case 2B below)

The routing computation spreadsheet is used as follows to size the on-site device, involving applying a trial and error approach (in practice, as in Section C2.2, spreadsheet runs may be required to cover a series of storm durations, to identify the critical case):

- define the device performance target, e.g.: site runoff peak to match the greenfield case in the 10% AEP storm
- derive the peak flows and hydrographs for the following cases:
  - o for the target performance standard case, as above
  - o inflow to the on-site device, for the post-development case
  - o rest-of-site runoff, for the post-development case (ie to add to the device outflow hydrograph, to establish the post-development with-device outflow)
  - o select the trial device size characteristics, for example for a detention tank:
  - o plan area of tank
  - o top outlet pipe diameter and height above tank base
  - o outlet orifice diameter and height
- run the spreadsheet and:
  - o identify the peak site outflow rate (also, it is useful to check if/when device overflow occurs)
  - o compare this to the target peak site outflow (e.g. greenfield, as above)
  - o select new trial device sizing parameters (e.g. smaller/larger tank, smaller/larger orifice) and re-run the spreadsheet until the required performance standard is met

C3.5 Worked examples

Note*: The following worked examples illustrate the methods explained in Sections C3.1 – C3.4, note that Cases 1 & 2 derive peak discharges and hydrographs, using the rational method, which are then used in the Case 3 on-site device routing example.*

Case 1: Compute the Peak Discharge Rate - Greenfield Site
(using the Rational Method)

Site Data:
Area (A): 700 m^2 = 0.07 ha
Soil type: Clay

Design Parameters:
Flood frequency (F): 10% AEP
Tc: 15 minutes

Calculation:

i. Rainfall intensity I: consult appropriate rainfall depth-duration (Tc)-frequency (F)curves for the location in question; whence I = 100 mm/hr
ii. C value: From Figure C1, use curve 7 & I = 100 yields C = 0.43
iii. Peak discharge: Q = C x I x A / 360
= 0.43 x 100 x 0.07 / 360
= <u>0.0084 m^3/s (8.4 l/s)</u>

Case 2: Compute Peak Discharge Rate and Hydrograph - Development Site
<u>(2A) Roof</u> (using the Rational Method):

Site Data:

Roof area:	250 m^2 = 0.025 ha
Other impervious area:	100 m^2
Pervious area:	<u>350 m^2</u>
Total site area:	700 m^2

Design Parameters:
Flood frequency (F): 10% AEP
Tc: 15 minutes

(a) Peak Discharge Calculation:

i. Rainfall intensity I: consult appropriate rainfall depth-duration (Tc) -frequency (F) curves for the location in question; whence I = 100 mm/hr
ii. C value: From Figure C1, use curve 1 & I = 100 yields C = 0.9
iii. Peak roof discharge: Qp = C x I x Aroof / 360
= 0.9 x 100 x 0.025 / 360
= <u>0.0063 m^3/s (6.3 l/s)</u>

(b) Hydrograph Calculation:

i. Hydrograph base length T = 2 x Tc
ii. Hydrograph is triangular (ie as Figure C2a),, with:
Linear rise to peak 6.3 l/s at time Tc = 15 minutes
Linear fall from peak to zero at time T = 30 minutes

<u>(2B) Rest-of-Site</u> (using the Rational Method):

(a) Peak Discharge Calculation:

i. Rainfall intensity I: as Case 2A
ii. C value: Use sub-area method: from Figure C1, with I = 100:
Pervious area (curve 7): Cp = 0.43
Other impervious area (curve 2): Co = 0.86
Net C = (350 x 0.43 + 100 x 0.86) / 450 = 0.53

iii. Peak discharge: Qp = C x I x A / 360
= 0.53 x 100 x 0.045 / 360
= 0.0067 m^3/s (6.7 l/s)

(b) Hydrograph Calculation:

i. By the approximate method, hydrograph base length T = 2 x Tc

ii. Hydrograph is triangular (ie as Figure C2a), with:
Linear rise to peak 6.7 l/s at time Tc = 15 minutes
Linear fall from peak to zero at time T = 30 minutes

Case 3: On-Site Device Routing Computation

Building on the Case 1 & 2 results, the spreadsheet overleaf illustrates a typical on-site device routing exercise. Details are:

Site data:	As Case 2 above
Device target performance:	Greenfield (ie as Case 1 above), Allowable peak discharge 8.4 l/s
Inflow hydrographs:	Roof: as Case 2A Rest of site: as Case 2B
Device type:	Detention tank (ie as described in Section 5.2), fed from roof and with orifice outlet in base of tank
Trial & error approach:	Set tank height (say 1.2 m) and tank area (ie to match sizes available from manufacturers), Compute trial orifice diameter, as shown on the spreadsheet (ie based on the simplifying assumption that the peak flows from both the tank and rest of site coincide in time), Then adjust tank area and/or orifice diameter until: o total site runoff </= 8.37 l/s target, and o tank water level </= full (ie 1.2 m) [refer also to the note at the bottom of the spreadsheet about tank overflow]
Results:	Tank area: 3 m^2 (ie 2.0 m diameter) Tank height: 1.2 m Outlet orifice diameter: 30 mm

RAIN TANK - FLOW ROUTING ANALYSIS

(A) SITE DATA:

Soil Type:		Clay						
AREAS:				C value				
Roof area		250	m2	0.9				
Other impervious area		100	m2	0.86				
Pervious area		350	m2	0.43				
Lot area		700	m2					
(B) TANK DETAILS:								
Tank area	3.0	m2	(ie 1.9	m dia)		*Trial orifice diameter calculation:*		
Tank height	1.2	m				*Peak orifice flow:*	*1.79*	*l/s*
Orifice dia	0.03	m	d^2=	0.0009		*Max orifice head:*	*1.2*	*m*
Orifice discharge coefficient			0.65			*Trial diameter:*	*0.026*	*m*

(C) HYDROLOGY - BY RATIONAL METHOD:

(refer comparable calculations in Appendix C - Section C3.5)

Tc	15	min	
Storm duration (D)	15	min	
Rainfall intensity (10% AEP)		100	mm/hr
		C value	Peak discharge (l/s)
Peak roof discharge:		0.90	6.25
Peak rest-of-site discharge:		0.53	6.57
Permissible site discharge		0.43	8.36

(D) SIMULATION:

Time step 2.5 min

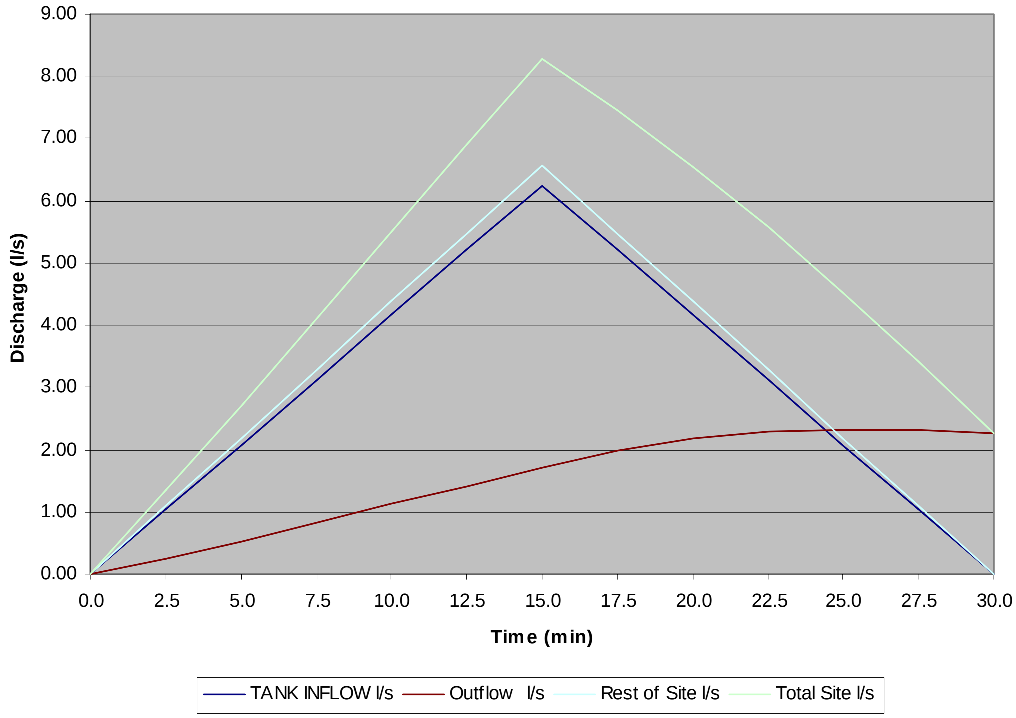
Time	**TANK INFLOW**		Tank Storage	Tank WL	Adjusted Av WL	Tank Outflow	Net Device Storage	**SITE RUNOFF CALC** Rest of Site	Total Site
(mins)	l/s	m3	m3	m	m	l/s	m3	l/s	l/s
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5	1.04	0.08	0.08	0.03	0.01	0.25	0.04	1.09	1.34
5.0	2.08	0.23	0.28	0.09	0.06	0.53	0.20	2.19	2.72
7.5	3.13	0.39	0.59	0.20	0.15	0.82	0.46	3.28	4.11
10.0	4.17	0.55	1.01	0.34	0.27	1.12	0.84	4.38	5.50
12.5	5.21	0.70	1.54	0.52	0.43	1.42	1.33	5.47	6.89
15.0	6.25	0.86	2.19	0.74	0.63	1.72	1.93	6.57	8.29
17.5	5.21	0.86	2.79	0.94	0.84	1.98	2.50	5.47	7.46
20.0	4.17	0.70	3.20	1.08	1.01	2.17	2.87	4.38	6.55
22.5	3.13	0.55	3.42	1.16	1.12	2.28	3.08	3.28	5.57
25.0	2.08	0.39	3.47	1.17	1.16	2.33	3.12	2.19	4.52
27.5	1.04	0.23	3.35	1.13	1.15	2.32	3.01	1.09	3.41
30.0	0.00	0.08	3.08	1.04	1.09	2.25	2.75	0.00	2.25
32.5	0.00	0.00	2.75	0.93	0.98	2.14	2.42	0.00	2.14
35.0	0.00	0.00	2.42	0.82	0.87	2.02	2.12	0.00	2.02

NOTE: If/when tank WL exceeds tank height, site runoff calculation should include tank overflow (ie overflow = inflow - orifice outflow)

RESULT:

Tank area:	3.0	m2
Tank height:	1.2	m
Orifice diameter:	30	mm
Tank capacity (V)	**3.6**	**m3**

Figure C4: Rain tank hydrographs



C4.0 Hydraulic computations

Users of this guideline are referred to the following standard hydraulics references for the various formulae to analyse pipes, orifices, weirs, etc (check that nominated coefficients in formulae apply to the metric/SI units case; especially in material of US-origin where imperial units are prevalent):

(a) Text books:

Building Code Clause E1– Verification Method E1/VM1: Surface Water, Building Industry Authority, NZ, 2001

Handbook of Hydraulics, Brater, King, Lindell & Wei, McGraw Hill, 7th Edition, 1996

Fluid Mechanics, Streeter, McGraw Hill, 8th Edition, 1985

Hydraulics and Hydrology for Stormwater Management, JE Gribbin, Delmar Learning, 1996

Hydraulic Structures, CD Smith, University of Saskatchewan Printing Services, Saskatoon, Canada, 1985

(b) Web Resources:
http://agrolink.moa.my/did/river/stormwater (refer Chapters 12 & 20)

Table C3 presents some of the formulae commonly used in the hydraulic design of on-site devices.

Table C3: Commonly-used hydraulic formulae

FORMULA		Coeff-icient	Typical values of Coefficient
Name	**Formula** (Q = discharge, m^3/s)		
Manning's (pipe flow)	$Q = 1/n \times (d/4)^{0.66} \times S^{0.5} \times A$ where: d = pipe diameter (m) S = friction slope or head loss (m/m) A = pipe cross-sectional area (m^2)	n	Plastic: 0.010 Concrete: 0.012
Manning's open channel flow	$V = r^{2/3} \times s^{1/2} / n$ where: r = hydraulic radius = wetted area /wetted perimeter S = friction slope or head loss (m/m)	n	Refer texts e.g ARC TP 10
Orifice discharge	$Q = 3.47 \times Cd \times d^2 \times h^{0.5}$ where: d = orifice diameter (m) h = head on orifice (m)	Cd	0.6 – 0.7 (square edged)
Weir discharge	$Q = C \times L \times h^{1.5}$ where: L = weir crest length (m) H = head on weir (m)	C	Sharp-crested: 1.8 Broad-crested: 1.7 Circular 1.5 e.g manhole riser pipe inlet (sharp-crested, L = circumference of vertical drop inlet pipe)

C5.0 References

A. Published sources

Auckland Regional Council. (1999). *Guidelines for stormwater runoff modelling in the Auckland Region*. ARC Technical Publication No. 108. (ARC TP108)

Brater, E.F., King, H.W., Lindell J.E., & Wei, C.Y. (1986). *Handbook of hydraulics*. New York: McGraw Hill.

Building Industry Authority. (2003). *Building Code Clause E1– Verification method E1/VM1: Surface water*. (BIA 2003)

Coulter, J.D., & Hessell, J.W.D. (1980). *The frequency of high intensity rainfalls in New Zealand, Part 2 - Point estimates*. Miscellaneous Publication 162, New Zealand, Meteorological Service, Wellington

Gribbin, J. (1996). *Hydraulics and hydrology for stormwater management*. Delmar Learning

Institution of Engineers Australia. (1977). *Australian rainfall and runoff - a guide to flood estimation*. (ARR 1977)

Ministry of Works and Development. (1980). *A method for estimating design peak discharge*. Technical Memorandum No 61, Planning and Technical Services, Water and Soil Division.

Smith, C.D. (1985). *Hydraulic structures*. Saskatoon: University of Saskatchewan Printing Services.

Streeter, V.L. (1985). *Fluid mechanics*. Tokyo: McGraw Hill.

US Soil Conservation Service. (1986). *Urban hydrology for small watersheds*. US Department of Agriculture, Soil Conservation Service Technical Release No. 55. (SCS 1986). From http://www.mi.nrcs.usda.gov/technical/engineering/neh.html

B. Web-based resources

(a) Hydrology/Hydraulics & General Treatise on Stormwater Management: http://agrolink.moa.my/did/river/stormwater

(b) Rational method
http://agrolink.moa.my/did/river/stormwater/Chapter_14.htm
http://www.itc.nl/ilwis/applications/application11.asp
www.ct.gov/dot/lib/dot/documents/ddrainage/6.9.pdf

(c) USCS method
ftp://ftp.wcc.nrcs.usda.gov/downloads/hydrology_hydraulics/tr55/tr55.pdf
http://www.alanasmith.com/theory-Calculating-Effective-Rainfall-The-SCS-Method.htm

(d) NIWA's HIRDS NZ Rainfall Rainfall Depth-Duration-Frequency Software: www.niwa.cri.nz/ncc/tools/hirds

Appendix D: Operation and maintenance

D1.0 Introduction

In order to meet water quantity and/or quality targets, the long-term effective operation of on-site devices depends not only on sound design and construction, but also on applying routine operation and maintenance practices. The importance of applying these 'O&M' practices, which are typically not especially onerous in terms of either effort or frequency, cannot be overstressed. Further, the costs are modest – and are typically less than neglecting O&M, leaving the device to fall into disrepair and require a major overhaul.

It will generally be the responsibility of the on-site device owner to carry out appropriate O&M, unless the local authority agrees to take-over responsibility. Ideally, requirements should be scheduled in the appropriate consent. O&M practices will typically involve:

- frequently:
  - check for and rectify any problems evident during/after heavy rain
  - regularly check state of repair of the OSM device and rectify any problems
- periodically (e.g. once or twice a year): inspect pipes, remove sediment, repair any defects

O&M requirements are specific to each on-site device, but will typically involve a monitoring and inspection programme covering the following topics:

- general maintenance (e.g. removing growths, repairing leaks, clearing blockages)
- soils in stormwater planters, rain gardens, roof gardens
- vegetation management
- sediment management/pollutant control
- access and safety

D2.0 Alternative models for delivery of O&M

Given the importance of sound O&M, a key issue is then how to educate and motivate the owner to undertake O&M, or whether to apply some form of obligatory O&M regimen. Any requirements for the latter option must lie within the powers of the controlling local authority, be it under the Local Government Act and/or a bylaw. Research shows that various models can be used to facilitate O&M:

- traditional voluntary regime:
  - guidance is given to the on-site device owner
  - random inspections are made to check compliance (whereas this is common overseas, it is not legally allowed in New Zealand, unless the controlling authority has reasonable cause to believe that the device is posing a problem to others)
- legal obligation on owner: under a bylaw provision, owners can be required to have their device serviced at designated intervals, with certification as to the servicing submitted to the controlling authority (e.g. as applied by Auckland City Council – ACC 2002)
- contracted-out: in installing an on-site device, the owner agrees to contract-out O&M to the controlling authority (in Orlando, Florida, a high-tech approach is applied, involving equipping the serviceperson with a notebook computer that has the site and device details; on completing the service, details are logged-in and downloaded to the controlling authority's database)

Whereas the legal obligation on owner model is more likely to ensure sound O&M, in most cases the traditional voluntary regime will apply. In this case, the following measures will assist with compliance:

- raise public awareness in stormwater generally and on-site devices in particular, e.g. through:
  - media coverage
  - website coverage, e.g. refer to North Shore City Council's website, URL: http://www.northshorecity.govt.nz/WaterInfo/stormwater/storm.htm
  - brochures (e.g. refer to Auckland City Council's *Rain and the City*)
  - demonstration projects incorporating on-site devices (e.g. Auckland City's Wesley Community Centre)
- provide owners with details of how their device works and what is required in respect to operation and maintenance (e.g. as set out in ACC 2002)

Where the implementation of a device requires a resource consent, such a consent may include conditions in respect to O&M (note that under Auckland City Council's legal obligation on owner O&M regime, an O&M Plan must be submitted at the consent application stage, using the standard forms in ACC 2002). Similarly, on-site devices should ideally be recorded on LIM's and PIM's, so that incoming owners are aware of their presence and with it the O&M imperatives.

D3.0 Operation and maintenance practices

D3.1 General

The following inventories indicate the general O&M practices that should ideally be applied to on-site devices:

(a) Monitoring and Inspection:

Devices should be regularly inspected, with inspection records kept to:

- determine where special maintenance conditions exist
- determine optimal frequencies for future inspection and maintenance
- establish scheduled and unscheduled maintenance provisions
- assure device operation and aesthetics

Specific requirements:

- the owner should be responsible for conducting inspections (or having then done on his/her behalf) with the device as-built plans in hand, generally at the following intervals (noting that this may vary, depending on site-specific conditions):
  - quarterly basis for the first 2 years
  - minimum of semi-annually thereafter
- the owner should keep inspection records to track the progressive development of the OSM device(s) over time, covering:
  - general condition of vegetation area(s), predominant plant species, distribution, and success rate (where applicable)
  - sediment condition and depth in forebay (or other pre-treatment structure), treatment facility, bench planting zones, and other sediment removal components
  - water elevations/observations (sheen, smell, etc.)
  - condition of the inlet, outlet, and overflow structures/devices, etc
  - unscheduled maintenance needs
  - components that do not meet performance criteria and require immediate maintenance and subsequent remedial actions
  - common problem areas, solutions, and general observations
  - aesthetic conditions

(b) Soils in stormwater planters and rain gardens:

The following guidelines apply:

- test the ph of planting bed soils in areas where vegetation has died:
  - if the ph is below 5.2, apply limestone
  - if the ph is above 7.0, add iron sulfate plus sulfur to reduce the ph
- use core aeration of unvegetated areas if the surface of the bed becomes clogged with fine sediments over time: redesign plantings to correct problems, and re-establish soil coverage

(c) Vegetation management
Vegetated stormwater facilities may require a number of control practices, especially during their 2-year establishment period. Corresponding required practices cover:

- maintain plantings for a period of 2 years after date of the building consent final inspection
- during the establishment period, remove undesired vegetation with minimal (or preferably no) use of toxic herbicides and pesticides at least three times in year 1, and once or twice in the summer of year 2; replace plants that die during this period within 3 months
- at the end of the second year, healthy plant establishment shall be achieved for at least 90% of the vegetation
- selectively irrigate if necessary during the establishment period, during times of drought, or until the vegetation becomes established: it is preferred that the facility be designed to sustain its function without a permanent irrigation system
- replenish mulch at least annually, noting also that mulching shall be done to retain topsoil, heat, and moisture, and to inhibit weed growth
- schedule maintenance outside sensitive wildlife and vegetation seasons
- minimise plant disturbance during maintenance activities
- insofar as practicable, avoid the use of fertilisers, herbicides, or pesticides for vegetation maintenance
- use replacement plants that conform with the initial planting plan

(d) Sediment management/pollutant control:
Sediment and other pollutants that degrade water quality will accumulate in on-site devices and require removal to ensure proper operational performance. Corresponding guidelines cover:

- remove sediment when accumulations reach 100 mm in depth, or 50% of the designed sediment storage depth, or if sediment accumulation inhibits facility operation
- dispose of the sediment in a safe manner, noting that sediment from trafficked and other high use areas may be contaminated
- if sediment and/or other pollutants are accumulating more rapidly than assumed when the O&M Plan was formulated, investigate and rectify the cause

(e) Access and safety
O&M programmes must provide for safe and efficient access to a facility. The following are general requirements; specific conditions may require site-specific modifications:

- secure easements necessary to provide facility and maintenance access (if applicable)
- use only suitably trained personnel to access confined spaces
- uaintain ingress/egress routes to design standards, in a manner that allows efficient maintenance of the facility
- ensure that fencing is in good repair

D3.2 Device-specific operation and maintenance guidelines

O&M guidelines are presented for each specific on-site device covered by this Guide in Section 4. These have been compiled through reference to various published guidelines including ARC TP10, ACC (2002) and CoP (2002). An example of an O&M checklist for a grass swale is in Table D1.

Table D1 O&M checklist - grass swale

Frequency			**Action**
As required	**Quarterly**	**Annually**	
	✓	✓	**General** Remove any debris accumulations and waste vegetation
		✓	**Inlets and outlets** Remove sediment
✓	✓	✓	**Grass** Mow (with catcher) to maintain the grass length at 50 – 150 mm
	✓	✓	**Grass** • remove nuisance weeds • fertilise or treat to maintain vigorous growth, as required • fill any erosion holes and re-seed
	✓	✓	**Pipework:** Check for debris/blockages/leaks & rectify

Routine O&M should be backed by inspection and record keeping by the device owner/operator, to track the progressive development and operation of the device over time [refer Section D3.1(a)]. As an example, for the grass swale, inspections cover and document the following:

- general condition of vegetation area(s), predominant plant species, distribution, and success rate (where applicable)
- condition and depth of erosion
- condition and depth of sediment accumulations
- water elevations/observations (sheen, smell, etc.)
- condition of the inlet, outlet, and overflow structures/devices, etc
- unscheduled maintenance needs
- components that do not meet performance criteria and require immediate maintenance
- common problem areas, solutions, and general observations
- aesthetic conditions

References

Auckland City Council. (2002). *On-site stormwater management manual*. (ACC 2002)

Auckland Regional Council. (2003). *Stormwater treatment devices: design guideline manual*. ARC Technical Publication No. 10 (ARC TP10). From http://www.arc.govt.nz/arc/index.cfm?34C9C2A8-1BCF-4AA1-91AF-CC49CFE4A80C

City of Portland. (2002). *Stormwater management manual.* Bureau of Environmental services, City Of Portland, Oregon, USA, (CoP 2002). From http://www.cleanrivers-pdx.org/tech_resources/index.htm